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 facilities under PWA adopts the figure recommended by the authority. Average water consumption in rural area as well as sanitary districts, on the other hand, were assumed to be about 150 liter /capita/day in gross and their service ratio is to be 60% of total prospective population in the target year. Population projection in rural area was made by assessing movement of population during five years from 1984 to 1988, and it assumed that the said movement tendency will continue upto the target year of 2000.

The rate of total losses due to conveyance, leakage and operation to the gross water demand in urban area at present shows rather large values ranging from 30 to 48% in PWA systems. As the target, the ratio may be reduced to 25% if improvement of management technology and water user's moral and use of high grade pipe materials are accompanied. A reasonable ratio for the rural area, however, will be about 40% owing to scattered distribution of residential areas and poor operation techniques. The results of water demand projection including served population are summarized in Table 4-4.

4-4-2. Industrial Water Supply

The present situation of industrial water supply in the area, especially in the lower reaches of the Bang Pakong river, is not satisfactory as mentioned previously, and therefore remedial measures are urgently required. Consolidation of infrastructure by the national Government does not meet the requirement of industrial sectors and application of laws and regulations to control land uses are not being functioned well, since the progress of the development in industrial field is too fast.

The activities to develop large scale industrial complex by private sectors are privileged and supported by IEAT and the Board of Investment (BOI). On the other hand, the details are unknown for the development program of small scale factories which are also developed by private sectors.

The projection of water demand for the industrial purpose was made, taking into account the existing water supply method, categories of manufacture, water demand applied in the Eastern Seaboard Industrial Complex and the location of development. The followings are fully considered;

- The industrial water provided by the urban waterwork systems, as seen in Chonburi industrial zones, shares about 30 to 50 percent of the total supply capacity. In the local areas, those may be more or less 20%. Therefore, the figures proposed by PWA's long term development scheme are adopted for the estimates of water to be supplied for industrial purpose from the urban waterwork systems under PWA. On the other hand, about 20% of municipal water consumption for industrial use is added to estimate total requirement in the areas to be newly developed in the rural zone.

- Only Bang Pakong and Plaeng Yao areas are specified as the IEAT privileged areas for urgent water supply.

- Water supply of 10 MCM/annum for each of industrial and municipal uses in Chonburi are allocated from the Bang Pakong basin, because the water supply to most part of the district are to be covered by Bang Phra reservoir and other small reservoirs under the Eastern Seaboard Development Program.

- The scale and the extent of industrial complex development in major local areas are assumed to be 200 to 400 ha (1,250 to 2,500rai) in the target year of 2000, taking into account the number of existing factories and the existing status of infrastructural development.

- As the target year for the development plan, 2000 AD is taken, in view of project implementation period and in consideration of unforeseen factors which may be included in the sectoral development plans.

- A maximum unit water demand for light industry is estimated at 12cu.m/day/rai based on the results of surveys and discussions made with IEAT, NESDB and private sectors.

Total water demands in the target year in the respective provinces so estimated are summarized as follows. Details are given in Table 4-5.

Water Demand Projection for Industrial Sector

(Unit: MCM/year)

Province	Supply Facility				Grand Total
	Urban Waterwork	Exclusive Industrial System			
	(PWA, Other)	(IEAT)	(Private)	(Total)	
Chonburi	17.35	-	36.00	36.00	53.35
Chachoengsao	17.48	54.00	40.50	94.50	111.98
Prachinburi	13.53	-	31.50	31.50	45.03
Nakhon Nayok	4.50	-	18.00	18.00	22.50
Total	54.91	54.00	126.00	180.00	234.91

*: The figure includes 10.0 MCM of supplemental water for Chonburi area.

**: Annual unit water demand : Annual working days = 300 days
Averaged daily demand = 12cum/rai
Annual demand = 3,600 cum/yr/rai

TABLE 4-5 WATER DEMAND PROJECTION IN TARGET YEAR 2000 (OVERALL)

Province	District	Industrial Water Demand(MCM) By WWS*	IEAT	Private	Total	Urban (MCM)*	Total (MCM)
		(11.057)		(-)	(11.057)	(16.796)	(27.853)
Chonburi	M.Chonburi	12.057	-	9.000	21.057	26.796	47.853
Chonburi	Bo Thong	0.400	-	-	0.400	2.070	2.470
Chonburi	Ban Bung	1.018	-	9.000	10.018	5.383	15.401
Chonburi	Phanat Nikhom	1.280	-	9.000	10.280	5.830	16.110
Chonburi	Phan Thong	0.390	-	-	0.390	1.932	2.322
Chonburi	Others(5)	(4.260)	-	(9.000)	(13.260)	(20.868)	(34.128)
Chachoengsao	M.Chachoengsao	4.653	18.000	9.000	31.653	10.735	42.388
Chachoengsao	Bang Khra	1.217	-	9.000	10.217	2.849	13.066
Chachoengsao	Bang Pakong	7.950	18.000	9.000	34.950	4.596	39.546
Chachoengsao	Ban Pho	0.350	-	4.500	4.850	1.759	6.609
Chachoengsao	Phanom Sarakam	0.798	-	4.500	5.298	3.811	9.109
Chachoengsao	Sanamchai Khet	1.480	-	-	1.480	7.416	8.896
Chachoengsao	Plaeng Yao	0.304	18.000	-	18.304	1.518	19.822
Chachoengsao	Others (2)	0.724	-	4.500	5.224	3.622	8.846
Prachinburi	M.Prachinburi	4.543	-	9.000	13.543	8.569	22.112
Prachinburi	Kabinburi	1.256	-	4.500	5.756	6.089	11.845
Prachinburi	Khok Peep	0.150	-	-	0.150	0.725	0.875
Prachinburi	Na Dee	0.450	-	4.500	4.950	2.277	7.227
Prachinburi	Ban Srang	0.220	-	-	0.220	1.138	1.357
Prachinburi	Prachan Takan	0.410	-	4.500	4.910	2.070	6.980
Prachinburi	Wang Nam Yen	1.250	-	-	1.250	6.244	7.494
Prachinburi	Watthana Nakhon	1.259	-	-	1.259	4.294	5.553
Prachinburi	Si Ma Ha Pho	0.460	-	4.500	4.960	2.311	7.271
Prachinburi	Sra Kaeo	1.600	-	-	1.600	8.000	9.600
Prachinburi	Other (1)	(1.930)	-	(4.500)	(6.430)	(9.658)	(16.088)
Nakhon Nayok	M.Nakhon Nayok	3.313	-	9.000	12.313	6.796	19.109
Nakhon Nayok	Ban Na	0.583	-	4.500	5.083	2.993	8.076
Nakhon Nayok	Pak Pli	0.210	-	-	0.210	1.035	1.245
Nakhon Nayok	Ongkarak	0.390	-	4.500	4.890	1.932	6.822
Grand Total		54.907	54.000	126.000	234.907	163.316	398.223
Total of Within Study Area		37.658	54.000	112.500	204.158	115.994	320.152

Notes: 1) Water demands within study area are excluded the values of "others"in the provinces of Chonburi and Prachinburi and 27.853 MCM of Muang Chonburi from the Grand Total. Because the water supply values for Muang Chonburi considers only 20 MCM from Bang Pakong river basin.

2) The figures indicated in the column(*) refer to Table E-1-7.

4-4-3. Brackish Water Fishery

Shrimp culture is predominant in the Amphoes Bang Pakong and Ban Pho situated along the lower reaches of the Bang Pakong river. From the viewpoints of increasing domestic consumption of shrimp, rapid expansion of exportation and a great merit of high profitability of shrimp raising, farmers who were doing rice farming in their paddy fields are recently shifting to shrimp farming in the ponds converted from paddy fields.

As the results of the research at Chanthaburi Brackish Water Fishery Station, it is recommended that the salinity contents most suitable for shrimp raising range from 15 to 25 ppt. Salinity contents of the river water in dry season depend on the magnitude of river runoff from drainage area. The values in March and April commonly exceed this optimum content. In case that a diversion dam is constructed on the Bang Pakong river upstream of the shrimp farming zone, the river salinity would increase due to decrease of fresh water release from upstream of the dam as compared with without-diversion condition.

Fresh water demand to keep the river salinity contents at a level of 30 ppt, at a maximum, can be estimated approximately at 1,810 cum/rai/season (11,300 cum/ha/season), if the net pond area is assumed to be 65% of gross shrimp farming land. It is rather difficult to estimate an appropriate extension in area in future. However, existing extent of 4,000 rai in the vicinity of the Study area is expected to be expanded to about 8,000 rai at a maximum. The fresh water requirement is thus estimated approximately at 14.50 MCM annually. These water should be released to the shrimp ponds, if such an incremental content of salinity is observed after completion of the diversion dam across the river, and when water resources development in the river basin is achieved.

4-5. Water Resources Development Plan

4-5-1. Available Water Resources

1) Runoff Model

Where no or less data of observation of river discharges are available, a runoff model might be used to generate an adequate number of daily streamflow data. For the purposes required by the Study, a simple runoff model called "single tank model with finite height and distribution factors for surface runoff" was employed.

The model parameters such as the dimension of tank, effective rainfall and daily distribution factors were estimated by using some selected data of actual observations of discharges on the river systems included in the Study.

To determine the model parameter such as depletion coefficient, k, and a height of Tank, Ht, the correlation between the model parameter and topographic/geographic condition of drainage areas was studied for the gauging stations under the present operation.

The result shows the well correlation with the form factor (A/L/L) being expressed by the drainage area, A, and length of main stream, L.

By using the correlation equations given below, the model parameters of 54 irrigation blocks are derived from topographic parameters.

$Ht = 6.361 (A/L^2)^{1.396}$, for estimation of tank height, and

$K = 0.2119 (A/L^2)^{0.548}$, for depletion coefficient

2) Basin Rainfall

On the basis of the isohyetal map (cf. Appendix A.2.3), 20 rain gauge stations were selected to estimate areal rains to be distributed in the irrigation blocks as well as in the drainage basins of the proposed damsites.

The isohyet map shows values which widely range from the minimum of 1,100 mm distributed in the lower reaches of the Bang Pakong river to the maximum of 2,100 mm in the Hanuman river basin. The annual rainfall within the entire Bang Pakong basin is thus evaluated at 1,590 mm on an average in the recent 20 years.

3) Runoff Coefficient

The long-term average annual runoffs recorded at river-gauging stations were compared with basin rainfalls to produce runoff coefficients. Coefficients so calculated at the points of gauging station were then plotted to generate isometric lines of rate of runoff against the basin rainfall (cf. Appendix A.3.3). the coefficients vary widely from the maximum value of exceeding 70% in the high rainfall belt of the upper Maenum Nakhon Nayok to the minimum of about 15% in the lower reaches of the Bang Pakong river. The long-term runoff coefficients in irrigation blocks were thus read on the map.

4) Basin Runoff

Based on the model parameter, Thiessen rainfall and runoff coefficient, the basin runoffs were simulated for 54 irrigation blocks and summarized in eight sub-basins for recent 20 years from 1968 to 1987. Major findings are as follows;

- Annual runoffs are evaluated as the basin rainfall multiplied by runoff coefficient.

- The mean runoff coefficient for the entire basin of 17,660 km^2 is 28% with a 1,590 mm of rainfall and 7,930 MCM of runoff.

- The runoff volume of the entire basin in 20 years is varies from the maximum of 9,729 MCM in 1983 to the minimum of 6,731 MCM in 1987.

- The mean runoff coefficients for sub-basins range widely from 46% in Maenum Nakhon Nayok (MNN) to 17% in Lower Bang Pakong (LPB).

- The mean runoff coefficient exceeding 30% in northern area of Prachin river (MPP, MHM, UBP, MNN) is contrasted with that of more or less 20% in the southern area (UPP, KPS, KTL, LBP).

- The critical runoff of 10-year recurrence (6,971 MCM) is seen in 1973 for the entire basin and concurrently in every sub-basin.

- The annual maximum runoff occurred in 1981 in almost all sub basins.

Computed results in terms of annual average are then summarized as follows:

Mean Annual Runoff (1968 - 87)

Sub Basin	Catchment (km^2)	Annual Rain. (mm)	Annual Runoff (MCM)	Runoff Ratio (%)
UPP	1,628	1,760	690	24
KPS	2,643	1,580	880	21
MPP	970	1,930	560	30
MHM	2,130	1,930	1,430	35
UBP	2,757	1,640	1,480	33
MNN	1,933	1,730	1,540	46
KTL	2,493	1,340	700	21
LBP	3,106	1,240	650	17
Entire Basin	17,660	1,590	7,930	28

4-5-2. Water Balance Simulation

1) Methodology

Procedure, Computation Time Step and Standard Drought Year

All computations for water balance simulation were made with a 10 day time step for the recent 20 years from 1967 to 1986 during which a complete set of hydrological data are available. Schematic procedure of analysis employed is given in Figure 4-4. Annual maximum capacities required to meet water demands of various fields in irrigation blocks as well as in sub-basins were then put into statistical analyses to evaluate the required capacities for the standard drought years, which would occur once in 5 years,7 years and 10 years.

FIGURE 4-4 SCHEMATIC PROCEDURE OF HYDROLOGY AND WATER BALANCE STUDY

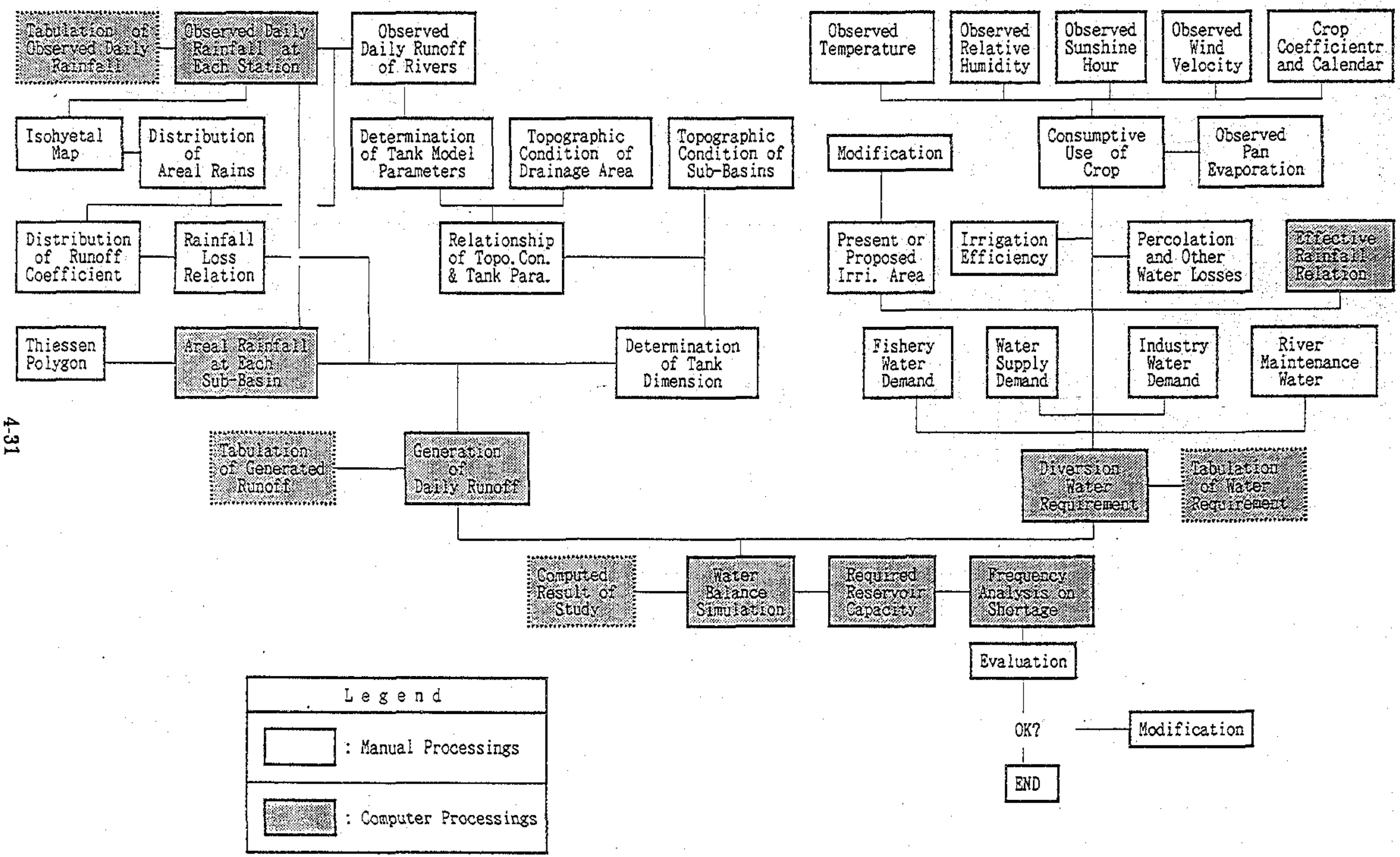
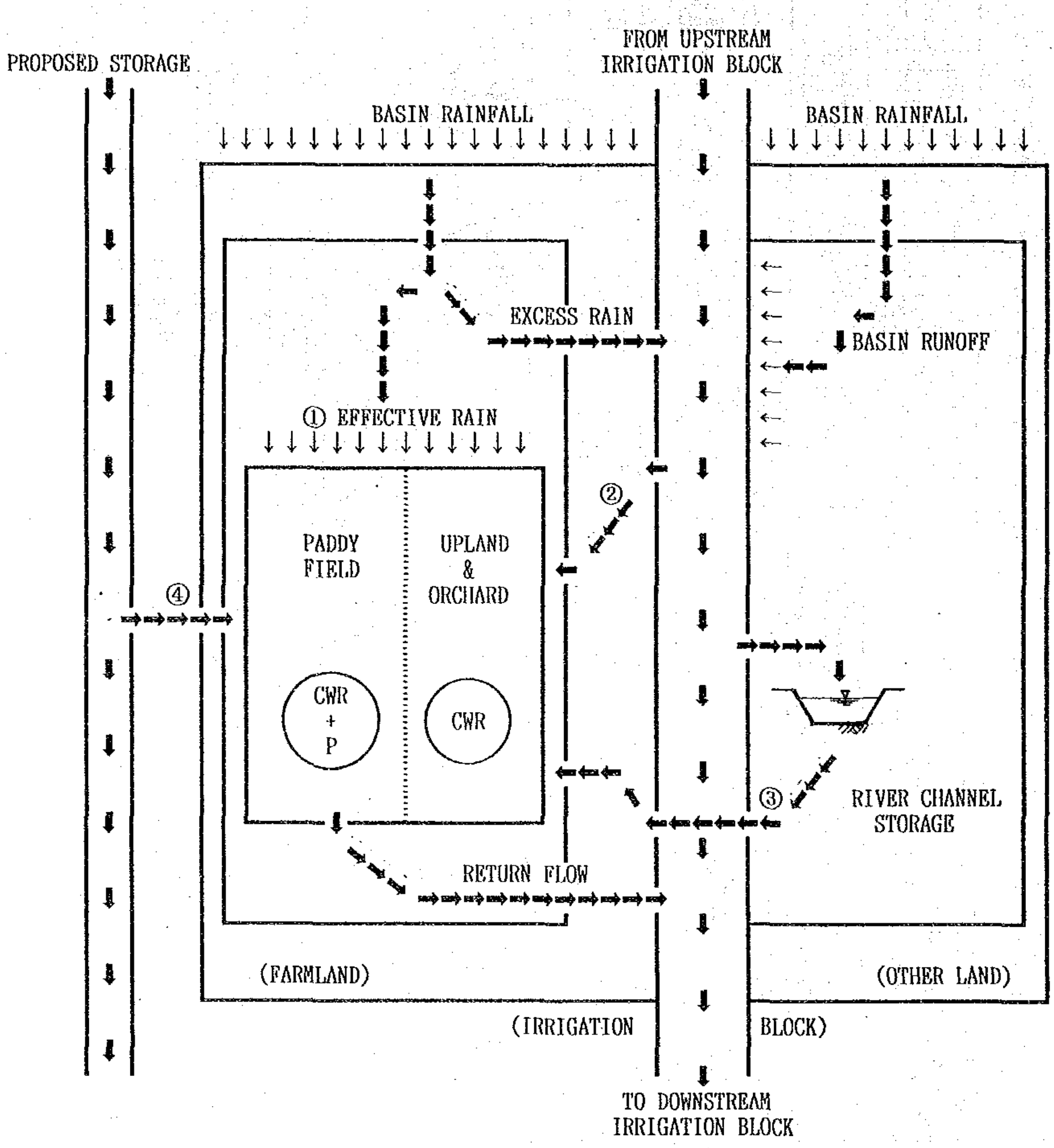


FIGURE 4-5 BASIC CONCEPT OF WATER BALANCE IN A IRRIGATION BLOCK



<u>PRIORITY ORDER OF WATER USE</u>
① EFFECTIVE RAINFALL
② RIVER FLOW INTAKE
③ RIVER CHANNEL STORAGE
④ PROPOSED STORAGE

NOTE: CWR = CROP WATER REQUIREMENT
P = PERCOLATION

Priority Order of Water Utilization

Basic assumptions employed in the preparation of computation procedures are visualized as shown in Figure 4-6, with additional explanation as follows:

- Areal rainfall by Thiessen and basin runoff generated by use of runoff model for watershed of each proposed dam as well as for irrigation block, both summarized on a 10-day basis, are given as the fundamental condition for evaluation.

- Effective rainfalls derived from RID's rating curves for paddy and upland crops may be first utilized for crop consumption. Excess rain water exceeding crop consumption requirements may return into channels of rivers, tributaries and small streams, and join with river runoff from uncultivated areas as well as from the upper reaches.

- Such river runoff joined with excess rains may be usable secondly for irrigation and other purposes by means of pumping up, constructing temporary or permanent weirs across the channel, and/or natural and artificial irrigation by gravity.

- If river runoff is adequate, excess water may be stored in river channels and existing ponds for use in drought. Storage capacities of river channel in irrigation blocks are unknown, however, an assumption of 343 cubic meter per ha obtained from experience in the Bang Pakong Right Bank area was applied for water conservation areas, while simple assumption of 3 cu.m per unit length of river channel was employed in the remaining irrigation blocks.

- When river runoff is inadequate, channel storage may be utilized taking the third priority in use of available water in the basin.

- Only when the river runoff is inadequate and channel storage is empty, supply of water to cover water shortage is dependable from the proposed storage dam(s).

- Return flow from the irrigated paddy may be usable in downstream areas. The rate of return flow was estimated at 25% of total consumption of crop on the field (evapotranspiration plus percolation).

Physical Condition of Proposed Reservoir

The physical condition of the proposed dam and reservoir was preliminarily determined on the basis of 1/50,000 scale topo-map, and may be subject for revision at the stage of more detailed study.

River Maintenance Water

River maintenance water was considered in proportion to drainage area at every portion of the river basin. As the rate of river maintenance water, 0.1 cum/sec/100sq.km was used in the study, since no guideline is available from RID. This is also subject to release of water from the proposed dam, when available water is inadequate within the irrigation block.

Compensatory Water Supply to Right Bank Area

At present, on the right bank of the Bang Pakong river, the existing Phra-ong Chaiyanuchit Irrigation Project has been receiving the river water through river intakes as well as by pumping. The amount of water diverted is accumulated at about 200 MCM throughout a year. This project area was originally excluded from the Study area, since the primary water supply for the project is expected from the Chao Phraya river. However when the proposed Project has achieved its full development, the dams are so operated to release waters just to meet water demands requested from beneficiaries, probably causing some difficulties in diverting river water together with possible increase of salt water intrusion especially in the lower reaches of the Bang Pakong river. To cope with this difficulty, the proposed Project should compensate the said project for supplemental supply of irrigation water to the amount at present achieved. A preliminary amount of 104 MCM or 580,000 cu.m/day, during dry season from December to May, was considered in the study.

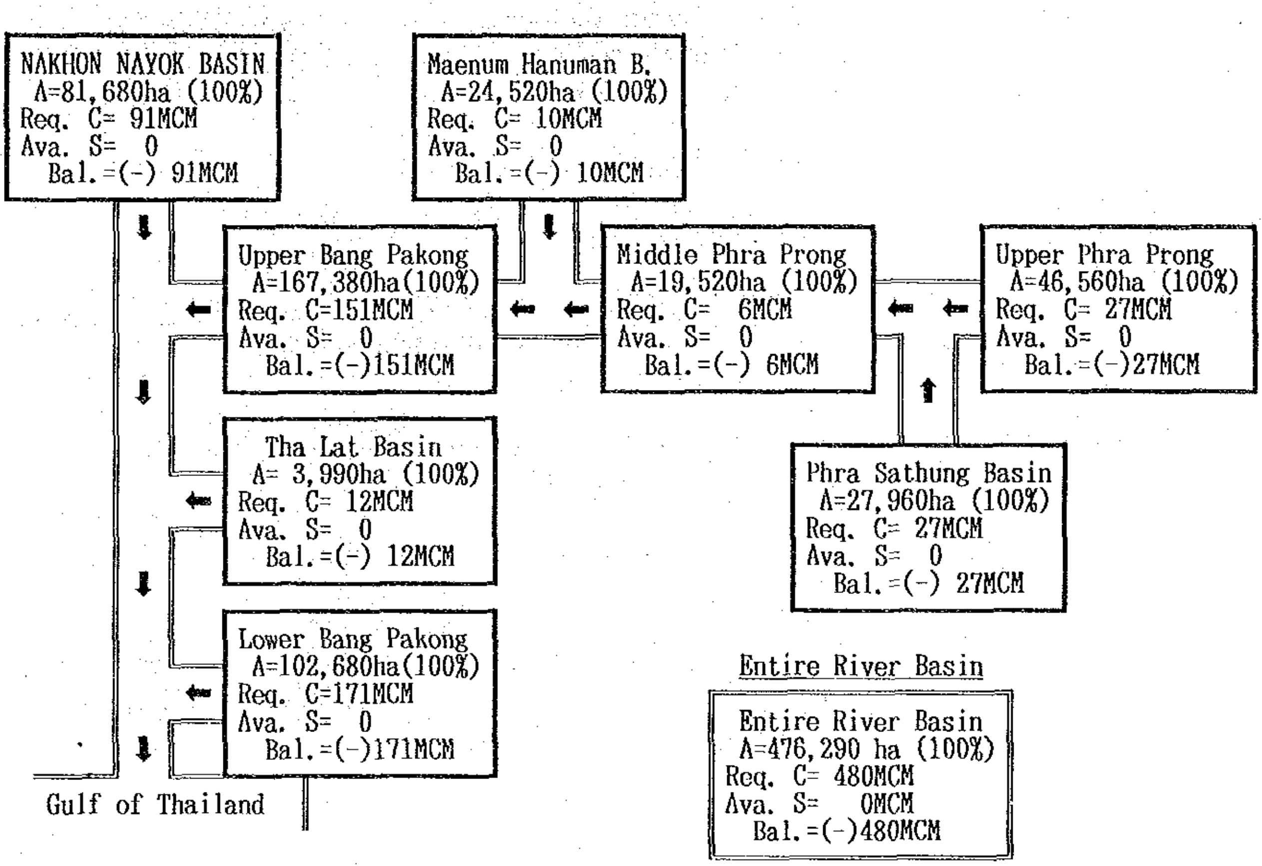
Reservoir Losses

As the evaporation and the seepage losses from the reservoir, 10% of the required storage capacity was added in the study.

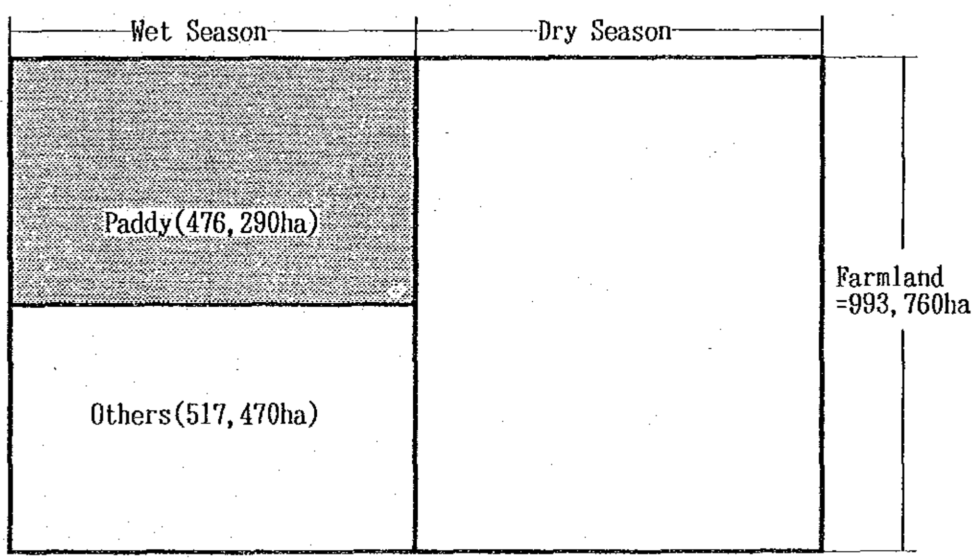
2) Present Basin Situation

About 476,000 ha of paddy are currently planted during wet season in the basin and are suffered from frequent water shortage due to the lack of basin rainfall, runoff and storage facilities. Computation was made to evaluate the existing situation of water balance in the basin. As a result of computation, about 480 MCM of water shortage, in terms of the required capacity of storage facility for the entire basin, was obtained as an average in 20 years, against the total water demand of 2,550 MCM including the supplemental water for the existing water supply systems under PWA. This means that if water resources with a capacity of 480 MCM be developed in the tributaries of the basin, the present water requirements mainly for wet paddy and the other water supply be satisfied without any shortage in an average year condition. In a critical dry year of 10-year recurrence, the required capacity would be about 735 MCM. Breakdown by sub-basin is shown in the next page.

FIGURE 4-6 DIAGRAM FOR EXISTING BASIN SITUATION



IRRIGATION PLAN FOR COMPUTATION (EXISTING SITUATION)



3) Possible Storage Dams

As the fundamental condition to be considered in the water balance simulation study, alternative studies on possible live storage capacities expected from the selected 22 damsites were made, and the results are summarized with estimated water costs as follows:

<u>Possible Alternatives of Dam Sizing</u>

Alternative Plan	Basic concept of Dam Sizing
(1) Maximum Plan	Sizes equivalent to the maximum dam inflow in the past 20 years or technically/topographically maximum sizes are considered
(2) Standard Plan	Standard sizes corresponding to the mean inflow in the past 20 years are given
(3) Reduced Plan	Intermediate between Standard Plan and Minimum Plan
(4) Minimum Plan	Minimum sizes to irrigate the existing scale of paddy during wet season as well as upland field and others in dry season are considered

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 Sub-Basin
2*	4.14 (136)	5.01 (98)	6.27 (66)	9.73 (35)	
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)	2.00 (718)	3.30 (553)	3.88 (413)	Phra Sathung Sub-Basin
8	2.14 (543)	2.56 (391)	3.34 (255)	5.63 (130)	
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 Sub-Basin
11	1.55 (136)	1.94 (93)	2.32 (67)	3.02 (46)	
12	2.25 (341)	2.35 (286)	2.49 (236)	2.70 (188)	Maenum Hanuman Sub-Basin
13	0.81 (113)	1.12 (72)	1.72 (41)	3.30 (19)	
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 Sub-Basin
22	7.24 (130)	7.68 (100)	8.24 (73)	9.12 (51)	

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

(2) Parenthesis denotes live storage volume in MCM.

4-5-3. Optimum Scale of Water Resource Development

Combining field findings in various sectors concerned, four cases of alternative irrigation plans in total were established. Basic concept employed in establishing those 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 intensity 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. This plan would correspond with the reduced plan of water resources development plan.

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

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 basin as well as in the entire Bang Pakong basin. Irrigable area by each irrigation plan is summarized as below:

Irrigable Area by Alternative Plan

	Wet Season		Dry Season				Net Irrigation Area
	Paddy	Veget.	Paddy	Upland C.	Veget.	Orchard	
Alt. Plan-1	339,600	28,000	67,000	120,000	28,000	24,200	406,800
Alt. Plan-2	339,600	28,800	38,200	120,000	28,000	24,200	406,800
Alt. Plan-3	339,600	28,000	0	120,000	28,000	24,200	406,800
Alt. Plan-4	339,600	28,000	0	15,000	28,000	24,200	406,800

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

Various parameters showing the rate of total cropping area, the rate of irrigation area and the rate of cropping on the paddy field 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: This value would be about 50% if Nakhon Nayok sub-basin is excluded.

Water shortages obtained in terms of the required capacities of the proposed storage reservoirs were thus compared with the available runoff at the proposed damsites. The diagrams prepared for each of irrigation alternative plan will explain such relations. (cf. Appendix D)

Required capacities were then allocated to each of possible damsite.

Required 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)
8	565	470	288	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, that correspond to 10% of the required capacity.

Incremental net production values (NPV) to be expected by the implementation of the proposed project were computed as follows:

Net production Value by Alternative Development Plan

(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	385
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 Phara Prong	412	390	300	338
Total	3,292	3,115	2,852	1,837

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 the agricultural and the 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 follows:

Amount of Water Resources to be Allocated to Sectors

(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%)	315 (5%)	215 (6%)	215 (8%)
Water Supply	116 (3%)	116 (3%)	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.

<u>Construction Cost (agricultural Sector) By Alternative Plan</u>

(Unit = million baht)

Item Dam No.		Alt. Plan-1	Alt. Plan-2	Alt. Plan-3	Alt. Plan-4
Dam	Total	9,957	8,902	7,839	6,212
	Agri.	92%=9,160	92%=8,190	91%=7,133	88%=5,466
Diversion Dam		595	595	595	595
Main Facilitires		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

In the above table, about 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 agricultural 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) 1,500 × 50% - 595 = 155 (Right bank).

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

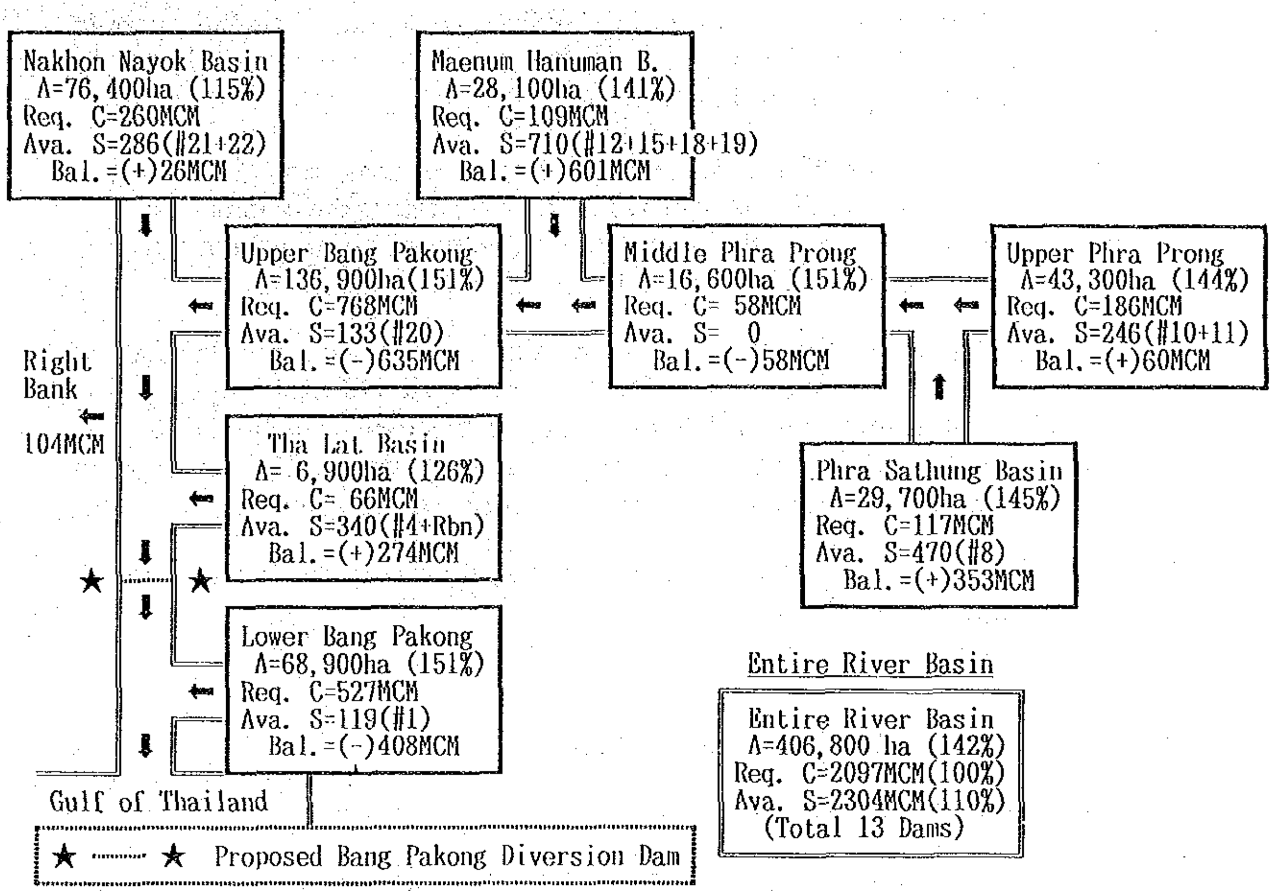
<u>B/C Ratio by Alternative Development Plan</u>

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/C Ratio	1.06	1.04	0.98	0.64

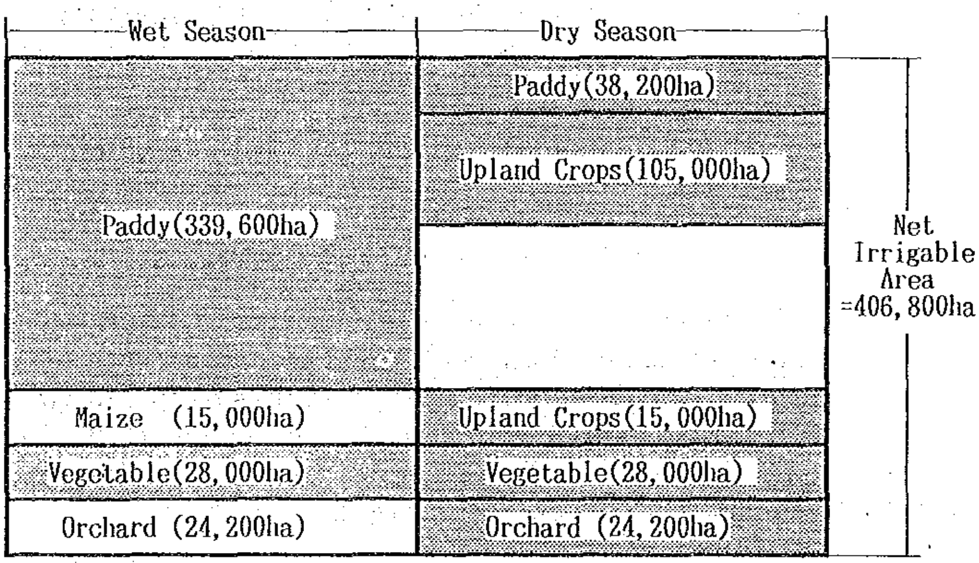
Note: Discount rate was taken at 12% and project life was considered to be 60 years as an average.

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

FIGURE 4-7 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.

- Scale of dam and reservoir mostly corresponds with the average annual runoff from the catchment, and therefore 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 intensity 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 4-7 illustrates a diagram prepared for the selected alternative plan-2 of irrigation development.

4-5-4. *Preliminary Design of Storage Dam*

1) Location of Selected Damsite

Proposed damsites for the Overall Basin Study were selected in the northern mountain area and southern undulated hilly area. Prior to the field reconnaissance survey, preliminary selection of the sites was made based on topographic maps of 1:50,000 scale, under the following criteria;

- Narrower valley with relatively steep abutments,
- Widely extended reservoir area with an optimum intake depth, and
- Favorable location of the service area

The basic idea to increase reservoir area is to select the site as far downstream as possible. However, in case that the socio-economic problems of resettlement are realized, at the sites, it must be shifted to the upper reaches. Total number of damsites selected amounts to 22, 16 of which were preliminarily studied by RID and ECI. (cf Appendix H.1.1) The location of the selected damsites are shown in Figure 4-8.

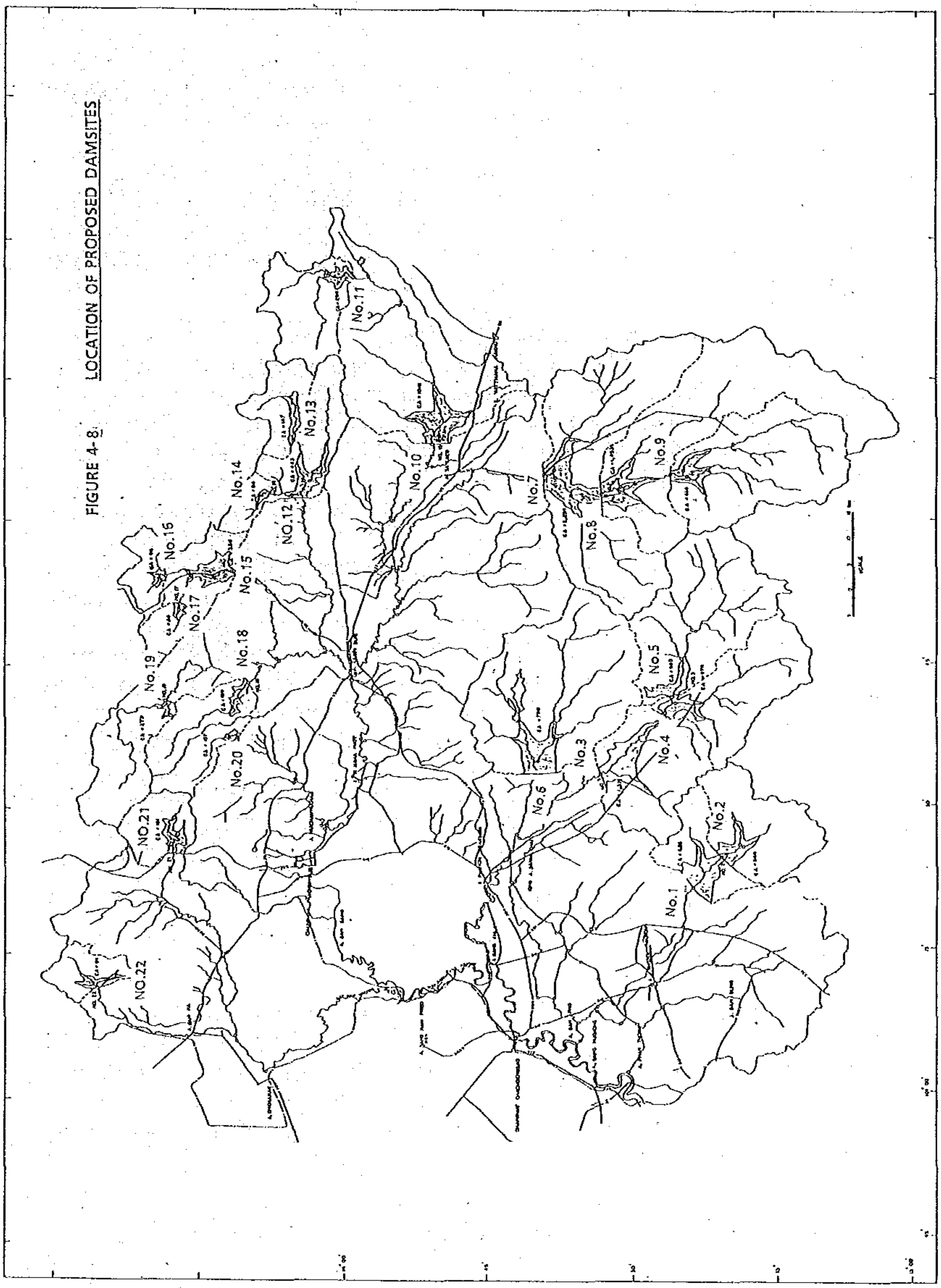


FIGURE 4-8 LOCATION OF PROPOSED DAMSITES

2) Geology at Damsite

As previously stated, reconnaissance field investigations were conducted in the selected damsites to identity a suitability of the development from view points of the facility design and engineering geology.

Unfortunately, however, the sites of Huai Sai Yai and Huai Sai Noi were not investigated due to inaccessibility in the national park. The properties of soil and rocks for respective geologic units based on the results of investigations are summarized in Table 4-6. The engineering geologic features for respective damsites are shown in Appendix C.1.2.

In general, a bearing capacity of sandstone and quartzose sandstone of the Khorat group is enough for the foundation of a gravity dam as well as an earthen dam while these rocks indicate relative high permeability due to coarse grained mineral composition. As previously indicated, the overburden was reworked from these rocks. The preliminary field investigation indicates that the proposed damsites in the Khorat Group except Khlong Tha Dan are adequate for development if seepage through the foundation is regulated by the grouting. A stability of siltstone foundation in the abutment of Khlong Tha Dan Dam is problematic because solid but fractured andesite is overlain by heavily weathered siltstone at a few meters below the riverbed where hydrostatic head and loading intensity are attained at a maximum. Sedimentary rocks of the Ratburi Group are generally suited for the foundation of an earth dam in view of bearing capacity and permeability. The Tanaosi and Thoung Song Groups are subjected to heavy weathering, the same as unconsolidated beds in appearance, according to the results of core drillings. From this, it may be inferred that deeper cut off excavation and seepage control in regard to the foundation characteristics shall be taken into consideration for the design of foundation. The property of igneous rocks in the basin generally suit to the foundation while seepage control by grouting is required in any case.

3) Design Criteria for Storage Dam

A) Design Flood

Design floods to be adopted for the design of dam structures shall be determined by taking into account such various factors as scale of reservoir, social conditions of downstream area, damsite condition, etc. In this planning, by considering the project scale and the site conditions, the design floods for dam are adopted according to the criteria for storage dams of the Project Planning Division, RID.

- Large Scale Irrigation Project (LSIP)
  ......a probable flood with a return period of 1,000 years

TABLE 4-6. SUMMARIZED ENGINEERING GEOLOGIC FEATURES FOR RESPECTIVE GEOLOGIC UNITS

Geologic Unit	Name of Dam	Lithology of Foundation	Material Avilability		Remarks
			Earth	Rock	
Khorat Group	Upper Khlong Phra Prong Huai Samong Upper Huai Samong Huai Kham Pku Lam Phraya Than Upper Lam Phraya Than Huai Si Noi Huai Sai Yai Khlong Nong Kaeo Khlong Tha Dan	-Sandstone, quarztose sandstone with interbedded siltstone and mudstone -Siltstones have large exposure in Sai Yai and Tha Dan but sand stones expose in small area -Andesite underlies in Khlong Tha Dan damsite	-H.Samong, H.Kham Pku, Phraya Than and H.Sai Noi are not available soils in sites but available within 10 km -Gravelly and/or sandy silt are available within 2 km from the other sites	-Sandstone and quartzose sandstone are available in the damsites except Sai Noi and Tha Dan -Sandstone within 5 km in H. Sai Noi -Fresh andesite in K.Tha Dan	-Depth of cutoff trench estimates wiathin 2 m except H.Samong and K.Tha Dan -Cutoff trench in H.Samong and K.Tha Dan -Dence and deep grouting requires for sand stone and andesite foundation because of high permeability -In generally, soil in sandstone areas is characterized by high permeability -Andesite and siltstone show great difference of physical properties in Tha Dan
Phon Nom Ron and Ratburi Formation	Khlong Phra Prong Upper Khlong Phra Sathung Khlong Phra Sathung	-Sandstone or chert of Phon Nom Ron Formation underlie in Upper K.Phra Sathung and Phra prong -Limestone of Ratburi in right abutment and sandstone or chert in left abutment in Phra Satung	-Clay, silt and gravelly clay in Phra Sathung -Clay, silt and sandy clay in Phra Porong	-Andesite and limestone in east of Phra Sathung -Limestone 5 km north of Up. Phra Sathung -Sandstone 15 km north of Prong	-Deep cutoff trench requires in Phra Prong because unconsolidated beds lie on the basement rocks -Limestone shows steep and cavernous in right abutment of Phra Sathung
Tanaosi Group	Khlong Si Yat No 1 Khlong Si Yat No 2	-Weathered sandstone, siltstone, limestone and conglomerate	-Clay and sandy silt in the site	-Granite locates 4 km south east of Si Yat No 2 -Rhyolite locates 8 km south of Si Yat No 2	-Layer with less than 20 blows of SPT which subject to furnish cutoff trench locates up to 6 m in maximum -Layer of high permeability(≤0.01) underlies in flood plain at right bank with 5m thick
Thung Song Group	Khlong Luang Upper Khlong Luang	-Weathered shale, phylite, schist and gneiss	-Heavily weathered basement rocks, sandy clay and sandy silt in the sites	-Metamorphic rocks in Kwang Thon Quarry 25 km far from sites	-Thickness of heavily weathered basement rocks ranges 3 to 12 m
Igneous Rocks Diorite	Huai Wang Mut	-Fresh diorite	-Gravelly and sandy silt in the site	-Diorite in the site	-Thickness of cutoff trench estimates 2 m
Granite	Khlong Si Yat No.3 Khlong Rabom	-Fresh coarse grained granite in Upper Khlong Si Yat -Weathered granite in K. Rabom	-Clay and sandy silt in the sites	-Granite in Khlong Si Yat -Sandstone 10 km east of Khlong Rabom	-Depth of cutoff trench estimates 3 m in K. Si Yat and 7 m in K. Rabom
Rhyolite	Middle K. Phra Sathung	-Fractured rhyolite	-Clay, silt and gravelly clay	-Andesite and limestone, 20 km north of the site	-Depth of cutoff estimate 3 m -Rhyolite shows permeable -Dam links on the remnants
Rholite Volcanic breccia	Khlong Ban Na	-Rhyolite, volcanic breccia and dacite	-Silt, clay and gravelly silt	-Rhyolite or dacite near the site	-Depth of cutoff estimate 3 m -Rhyolite show joint rich and cracky

° Medium Scale Irrigation Project (MSIP)
......a probable flood with a return period of 500 years

However, the discharge for the design of a capacity of spillway will be calculated by flood routing taking into account the storage effect of flood water above normal water level. (cf. Appendix H.1.4)

B) Design Seismic Intensity

Design seismic intensity of 0.05 is applied.

C) Dam Type

Dam type is mainly classified into a fill dam and a concrete dam.

The type of dam is selected according to the topographical, geologic and hydrological conditions of the damsites. From the topographical point of view, the shape of the valley is the most important factor in the selection.

On the other hand, the geological conditions such as the thickness of river deposits and weathered rock foundation, the strength and permeability of the bedrock, the distribution of construction materials are also very important factors in the selection.

The proposed damsites have a gentle topography and wide valley. A shape of valley is generally expressed by a ratio of dam height and width of valley. The ratio of proposed damsites are 11 to 340 except No. 13, 14, 21 damsites. A fill dam is more suitable than a concrete dam, taking these ratio into consideration.

In the Study area, most of the proposed dams shall be of homogeneous type earth-fill dams excepting for those of No.18 & 20 with high embankment in the mountainous area, in consideration of various local conditions. The dams of No. 18 and 20 shall be zone type rock-fill dams.

Idea of the linkage of reservoirs between No.19 dam (Huai Sai Yai) and No.18 dam (Huai Sai Noi) is more advantageous. The stored water of Huai Sai Yai can be introduced through the open channel excavated in a saddle of right bank of Huai Sai Yai, forming a transbasin project.

D) Sediment Volume

Sediment Volume; Specific sediment (cu.m/sq.km/year) × drainage area (sq.km) × 100 years

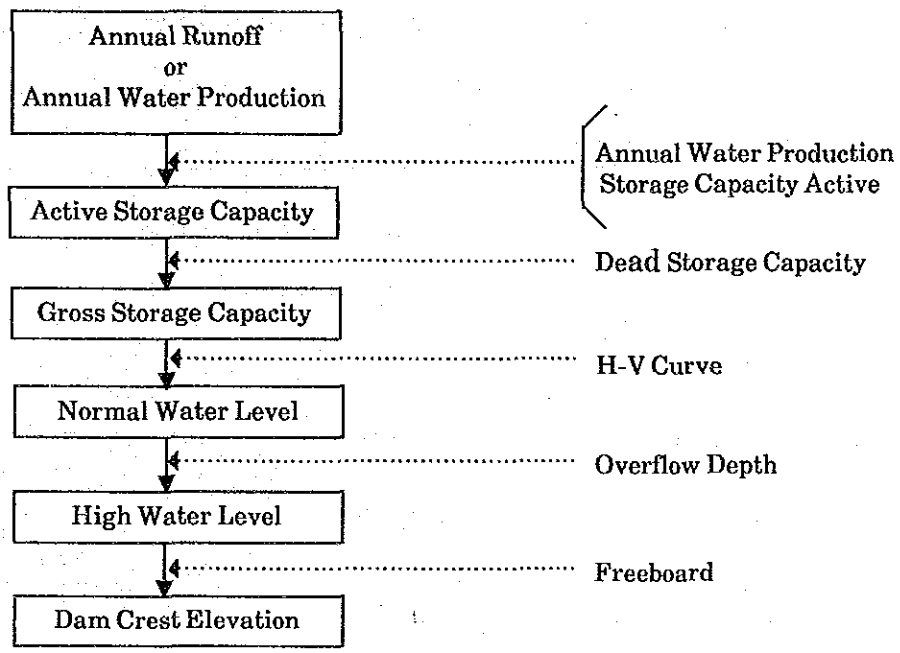
Specific sediments (qs) applied are as below;

° Southern area (No.1 ~ 9 damsite) ... qs = 250 (cu.m/sq.km/year)

° Northern area (No.10 ~ 22 damsite) ... qs = 200 (cu.m/sq.km/year)

E) Determination of Dam Crest Elevation

The following procedures and methodology are applied to determine the reservoir water levels and the dam crest elevations.



The design elevation of dam crest is determined as the higher figure between the heights calculated by the following two formulas (1) and (2).

$N.W.L + hw + he + ha$ .... (1)

if $hw + he < 2$, then $hw + he$ adapt to 2.0

$H.W.L + hw + ha$ .... (2)

if $hw < 1$, then hw adapt to 1.0

where N.W.L : Normal Water Level

H.W.L : Maximum Water Level

hw : Height of wave due to wind (given as function of the related wind velocity and fetch distance combined by Sverdrup-Munk-Bretschneider and Savilles methods)

he : Height of wave generated by earthquake by following formula

$$he = 1/2 \times K\tau / \pi \times \sqrt{gh_0}$$

where K = Horizontal seismicity (0.05)

τ = Duration of seismic waves in second (1.0 sec)

h_0 = Water depth at N.W.L. (m)

g = Acceleration due to force of gravity

ha : Allowance for fill type dams (1.0 m)

F) Slope Gradient and Width of Dam Crest

The slope gradient of dam is one of the important design parameters to govern not only stability but also quantity of filling materials. Although an optimum slope gradient of dam should be determined based on the stability analysis in consideration of topography, foundation geology, filling materials, design feature of spillway etc., following slope gradients are tentatively determined by use of experimental figures of constructed dams.

upstream slope gradient .... 1 : 3.0

downstream slope gradient .... 1 : 2.5

Experimental assumptions are used to determine the dam crest width, as;

Height of Dam (H)	Width of Dam Crest
$H \geqq 40$ m	10 m
$40 > H \geqq 20$ m	8 m
$H < 20$ m	6 m

G) Type of Spillway

The spillway would be of the type without gate. The major reasons for this are summarized as follows;

- Spillway with gate requires artificial operation and daily maintenance, while the one without gate is avoidable from any of operation and maintenance problem.
- Mismanagement of relatively sophisticated gate facilities can also be avoidable.
- Spillways of overflow type are commonly applied to the neighboring existing dams.

4) Reservoir Scale

The height-volume and height-area curves were developed combining hydrologic, topographic and geological conditions of the proposed damsites (cf. Appendix H.1.2 and H.1.3). Based on these curves, the dimension and specification of the selected dam were determined as given in Table 4-7. These figures are, however, only preliminary and may be subject for further revision, since 1 to 50,000 scale topographical maps are used to determine topographic features of the damsites, except for No.1, 4 and 5 dams.

5) Selection of Proposed Storage Damsites

A) Procedures of Damsite Selection

The following procedures and methodology were employed preliminarily in determination of suitable damsites and sizings.

TABLE 4-7 DIMENSIONS OF PROPOSED DAMSITES

Dam NO.	Drain Area	Mean Annual		Reservoir Storage		Dam Body Volume	Design Flood
		Rain	Runoff	Active	Gross		
	km²	mm	MCM	MCM	MCM	1000cu.m	CMS
NO. 1	528	1,266	136	119	135	3,340	1,073
2	344	1,268	91	91	100	2,960	756
3	1,371	1,332	396	396	431	9,200	2,492
4	976	1,334	286	300	325	3,740	2,037
5	585	1,334	171	171	186	580	1,221
6	798	1,369	232	252	272	5,100	1,647
7	2,254	1,514	715	715	772	11,500	4,666
8	1,453	1,538	470	470	507	4,270	3,190
9	614	1,566	203	203	219	4,260	1,514
10	1,041	1,547	387	160	181	2,750	2,313
11	266	1,339	86	86	92	1,060	582
12	443	2,030	289	290	299	3,450	1,417
13	147	1,836	80	80	83	450	471
14	64	1,748	31	31	33	500	214
15	338	1,417	124	98	105	260	837
16	96	1,342	32	35	37	2,450	252
17	68	1,342	23	23	25	1,280	174
18	159	2,109	150	322	326	10,800	1,296
19	273	1,571	172	-	85	480	694
20	107	1,855	133	133	136	11,150	393
21	151	1,851	188	188	191	920	498
22	114	1,602	98	98	101	6,600	380

a) Reservoir Size

Three or four alternative sizes of storage capacity were studied to find the optimum dam size in consideration of annual runoff at the damsite.

b) Dambody and Volume of Dam

The shapes of dams, including dam crest elevations, slopes and crest widths of dambodies, were determined in accordance with the design criteria.

The volume of a dambody was calculated roughly combining the values for dam height, dam crest length and river bed excavation width.

c) **Construction Costs**

The total cost of a proposed dam can be divided into the dam construction cost and the right of way cost.

The dam construction cost is estimated based on the dam embankment volume and design flood discharge for spillway, as below;

Unit rate for embankment × embankment volume + unit rate for spillway discharge × design flood discharge = Dam Construction Cost.

Unit rates are;

- 100 baht/cu.m for the dam construction excluding the spillway
- 200,000 baht/m^3/sec for spillway

Cost for right of way was estimated based on the reservoir area, as below.

Reservoir area (ha) × 1.6 × unit rate (baht/ha) = Right of way

Unit rate was taken at $30,000/ha

Right of way of damsites in the national park area was left out of consideration.

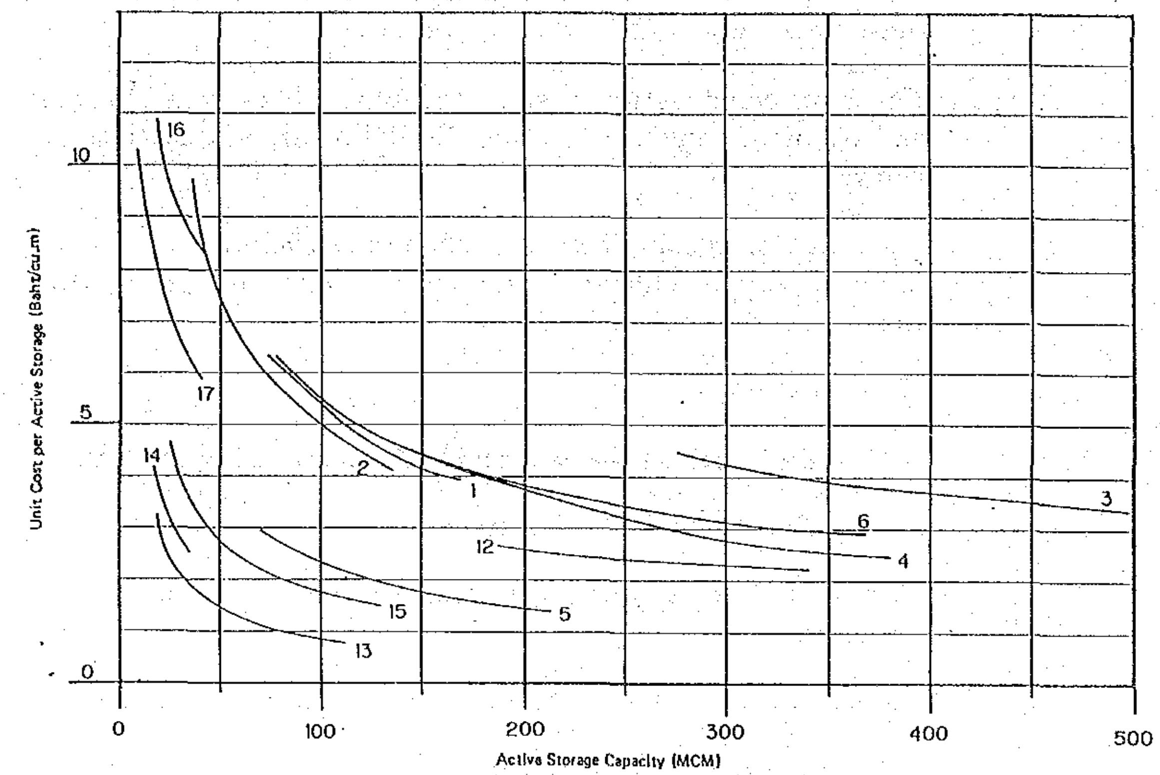
d) **Water Costs Curve**

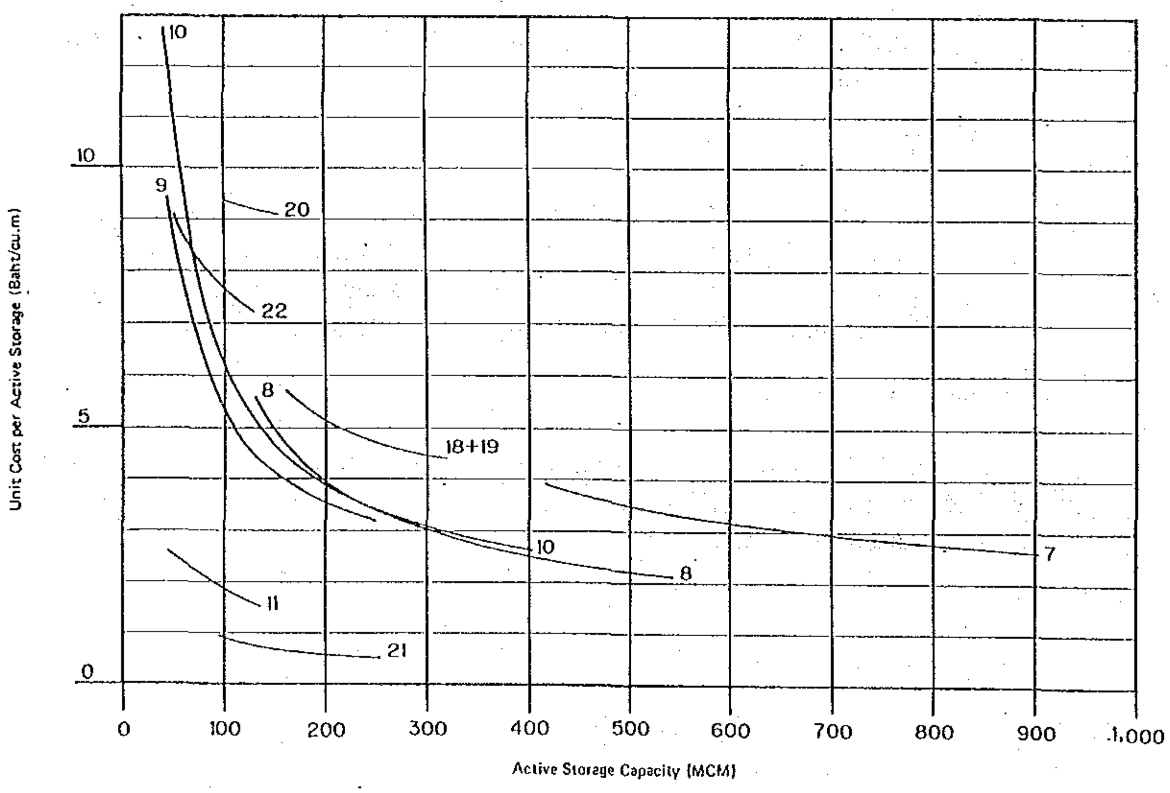
As the first stage of the study, "construction costs/effective storage capacity curves" were worked out for the comparison of proposed damsites. Figure 4-9 shows the relation between raw water costs and effective storage capacities for each damsite.

B) Selection of Damsites

In the eight tributary basins, the following damsites are selected in view of their storage capacities to meet the water requirements as well as economy in construction cost.

FIGURE 4-9 UNIT COST AND STORAGE CAPACITY





Sub-Basin	Storage Capacity Required	Proposed Damsite	Mean Annual Runoff	Active Storage Capacity
	(MCM)		(MCM)	(MCM)
LBP	527	No.1	136	119
KTL	66	No.4	286	300
KPS	117	No.8	470	470
UPP	186	No.10	387	160
		No.11	86	86
MHM	109	No.12	289	290
		No.15	124	98
		No.18	150	} 322
		No.19	172	
UBP	768	No.20	133	133
MNN	260	No.21	188	188
		No.22	98	98
Total	2,033		2,519	2,264

The proposed dam for No.10 site was planned to be much smaller than its annual runoff available, in consideration of topography, geology, and military facilities along the highway No.33.

More details about the technical matters on construction works are presented in Appendix H.1.5.

4-5-5. Water Resources Other Than Storage Dams

Due mainly to meandering channel route and topographic features, the water surface slope of the Bang Pakong river near the estuary is observed very gentle at some 1/100,000 during dry season and 1/40,000 in wet season and hence the saline water enters far upstream to Amphoe Bang Sang where is located at a distance about 150 km from the river mouth. Along this distance, several irrigation systems such as Bang Pakong Left Bank, Bang Pluang, Nakhon Nayok and Pra-ong Chaiyanuchit have been diverting river water for irrigation. This activity is, however, restricted within wet season when salinity content of river water is relatively low or negligibly small. In the belt area situated between these irrigation systems and the river channel, there extend considerable scale of orchard plantation and shrimp ponds which also utilize the river water.

Several storage dams will be constructed in the upstream basin under the proposed project. These dams will be so operated as to meet the water demand in response to the request of the beneficiaries. Some part of water so released may be conveyed directly from the water source down to the point of water use through water conduction line such as irrigation canal system, however, most part will be conducted through existing natural river channel. The proposed project envisages to extend irrigated agriculture by means of introducing as much double cropping as possible on the existing farmland. In this concern, it is very important to prevent saline water from entering into the river channel upstream.

In order to meet this demand, a diversion dam is recommended to be constructed across the Bang Pakong river. Along the banks in the lower reaches of the river, shrimp culture situated downstream of the Chachoengsao city utilizes brackish water of the river when the salinity is suitable for shrimp growth. On the contrary, orchard mostly located upstream of the Chachoengsao city requires fresh water. The proposed site of a diversion dam should also be near from the industrial complex to be located along the route 304 in consideration of industrial water supply. Possible pollution of river water due to waste water from the municipal area of Chachoengsao is to be realized in determinating the site of diversion dam.

The proposed diversion dam will be placed outside of the meandering river course by taking the convenience of construction works into consideration. After completion of the dam, the river course will be replaced. The conditions to be investigated in determining the proposed site of diversion dam are accordingly summarized as under:

- to be located upstream of the Chachoengsao city,
- to minimize replacement cost of houses and properties situated within the proposed construction site, and
- to minimize the length of diversion channel

Consequently, the proposed diversion dam site was preliminarily selected at the point 70 km from the river mouth on the basis of careful studies on the 1/10,000 scale map and the field investigations.

According to the river profile and sectional survey along the Bang Pakong river undertaken by the RID Survey Section, the bottom elevations of the river in the vicinity of proposed site varies from -7 to -9 meter above mean sea level(msl) with fluctuation of water surface elevations ranging from -1.0 m to +1.0 m, meaning that the average river depth is about 8m. The river width at the proposed site is about 200 m and this width continues almost constant on the lower stretch of the river far up to Amphoe Ban Sang. Assuming the usable layer of fresh water at 2 m, the effective storage volume of the proposed diversion dam is estimated as shown below:

- River length between the site and Ban Sang 80 km
- Average river width 200 m
- Average river depth 8 m
- Effective layer of fresh water 2 m

Estimated river channel storage = 200m×2m×80km = 32 MCM

4-5-6. Possibilities of Hydropower Generation

Table 4-8 shows the major hydraulic dimensions of the proposed dams to study possibility of hydropower generation.

TABLE 4-8 DIMENSION OF PROPOSED DAMS

No.	Annual Average Runoff	Effective Storage Capacity	N.W.L	L.W.L	Available Water Depth
	(MCM)	(MCM)	(m)	(m)	(m)
1	136	119	39.5	33.8	5.7
2	91	91	48.5	41.8	6.7
3	396	396	44.4	31.2	13.2
4	286	300	63.1	51.5	11.6
5	171	171	66.1	56.5	9.6
6	232	252	23.0	12.7	10.3
7	715	715	65.8	53.8	12.0
8	470	470	75.3	63.9	11.4
9	203	203	104.5	95.0	9.5
10	387	160	44.9	39.0	5.9
11	86	86	87.0	72.8	14.2
12	289	290	57.8	41.7	16.1
13	80	80	145.0	128.2	16.8
14	31	31	138.0	120.0	18.0
15	124	98	83.5	73.0	10.5
16	32	35	157.5	128.0	29.5
17	23	23	128.0	113.0	15.0
18	150	} 322	99.5	30.0	69.5
19	172	-	-	-	-
20	133	133	101.0	34.0	67.0
21	188	188	408.5	382.0	26.5
22	98	98	105.7	76.0	29.7

All dams except No.10 dam will have storage capacities equivalent to their annual average runoff, and have almost no overflow from their spillway in an ordinary year.

Therefore, the amount of water which can be used for power generation will be the same to be taken for irrigation, etc. The proposed operation rule of the dams is that water shall be stored during the wet season from May to November and utilized in the dry season having the storage water level minimized in April.

(1) Planned Power Output

A) Output

The following equation derives the theoretical relationship between the hydraulic condition and the power output generated at a power station.

Theoretical Power Output $P_0 = 9.8 \times Q \times H$ (Kw)

Generated Power $P = 9.8 \times \eta \times Q \times H$ (Kw)

where, Q = Discharge (m^3/s)

H = Head (m)

η = Total efficiency of turbine (0.75 ~ 0.8)

Generated Energy $E = P \times t$ (Kw)

where, t = operation time (hr)

As learned from the above, the decisive factors of the generated power are discharges, effective water head and operation time.

B) Discharge

Discharges largely fluctuate by intake amount for irrigation, which is seriously affected by meteorological conditions.

The design discharges for power generation usually adopt the maximum and most economical discharges, which are much smaller in values than the maximum irrigation requirements in many cases.

In case of the proposed dams, however, the water balance study clarifies that most of the dams will take almost 95 percent of the annual intake amount of water during four months from December to March. In the wet season, the intake amount will become very small, particularly almost zero in June.

Therefore, 60 to 80 percent of the maximum intake amount will be sufficient as the design discharge for the Project.

C) Effective Water Head

The gravity irrigation system will be introduced in the irrigation areas. Power stations will be located at the sites with possibly high elevation so as to take the water at L.W.L.

The effective water head, consequently, will be as high as 80 percent of the effective water depth even with the diameters of the penstocks largest. The effective water head will be about two thirds of the maximum effective water head in order to maximize the power generation efficiency.

D) Power Generation Period

About 100 to 120 days from December to March will be secured for power generation throughout a year in view of the discharges and effective water head.

2) Possibility of Power Generation

The power of lower cost and constant output is obtainable from discharges and water heads with fluctuation in a small range. From this point of view, introduction of power generation at the proposed damsites is, in general, judged unsuitable. Major reasons for this is summarized as follows:

- ° Power generation period is as short as about 100 to 120 days in a year.
- ° There are large fluctuations in discharge and effective water head
- ° The large scale facilities are required.

However, possibility of providing power stations at damsites No.10 and No.21 will be considerable from the following reasons;

- ° For No.10, spillage caused by excess rainfalls in wet season can be used for power generation, making the generation period longer.

- For No.21, since there is a large difference of about 400 m in elevation between damsite and irrigable area, the power output is expected to increase considerably.

It will be, however, necessary to change the cropping pattern and irrigation areas for year-round irrigation. In addition, EGAT has already made a power plan for No.21 site.

CHAPTER 5. PROJECT IMPLEMENTATION

CHAPTER 5. PROJECT IMPLEMENTATION

5-1. Selection of Priority Project

5-1-1. Items to be Evaluated

Based on the optimum basin development plan (Alternative irrigation development plan-2 as previously studied in section 4.5.3), the highest priority sub-project for implementation was selected and proposed. As the guideline to select the highest priority sub-project, the followings were investigated:

1) National Economic Feasibility

- Investment Efficiency; To evaluate the investment efficiency to be expected by development of each sub-basin, the benefit-cost ratios were calculated and compared.

2) Technical and Engineering Feasibility

- Potentiality of Water Resources Development; Availability of water resources at the proposed sites of dam and reservoir was extracted from hydrological study and compared.

- Difficulty of Dam Construction; Relative difficulty of dam construction from technical and engineering points of view, especially in view of reliability of the dam foundation, quality and quantity of embankment material and workability was evaluated and compared.

- Difficulty of Land Acquisition and Compensation; Relative difficulty of land acquisition and compensation in and around the dam/reservoir area was evaluated and compared.

3) Social Feasibility

- Needs and Request of Inhabitants; Needs and requests of the inhabitants for consolidation of irrigation facilities, domestic water supply facilities, road, and electricity were evaluated and compared.

- Urgency for Industrial Water Supply

- Urgency for Urban and Rural Water Supply

4) Farm Economic Feasibility

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

5-1-2. Integrated Evaluation

1) National Economic Feasibility

In each sub-basin, incremental benefit expected from the Project was calculated and accumulated based on the proposed plan of irrigation development. The net incremental benefit was then computed subtracting necessary costs for operation and maintenance of irrigation facilities, in order to evaluate the feasible investment cost with the assumed discount rate of 12%. In parallel with the above procedures, the project cost was also calculated on the basis of the facility development plan. The economic value of the project cost was then compared with the feasible investment cost to produce a benefit cost (B/C) ratio. The B/C ratios so obtained for each sub-basin range from the minimum of 0.23 for the Nakhon Nayok sub-basin to the maximum of 1.83 for the Upper Phra Prong sub-basin with an averaged value of 1.04.

2) Technical and Engineering Feasibility

Potentiality of water resources development or availability of water, difficulty of dam construction including evaluation of reliability of dam foundation, quality of embankment materials and workability, and difficulty of land acquisition and compensation were compared in order to evaluate the feasibility of the project implementation from technical and engineering points of view.

3) Social Feasibility

The needs and requests of inhabitants for consolidation of irrigation facilities, water supply facilities, roads, electricity networks were summarized from the interview surveys. Urgencies of water supply for both industrial and domestic purposes were also evaluated from view points of regional development.

4) Farm Economic Feasibility

The annual net incremental benefits per unit area to be achieved by the proposed irrigation development were calculated and compared. The unit area benefits range from the minimum of 1,800 baht/ha in the Nakhon Nayok sub-basin to the maximum of 11,800 baht/ha in the Tha Lat sub-basin, with a mean value of 7,700 baht/ha.

5) Overall Evaluation

Every items of evaluation were then put into the overall evaluation as presented in Table 5-1.

Summary of Overall Evaluation

Sub-basin	Total Point	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

The first priority was given to the Tha Lat sub-basin from the overall evaluation. The Upper Bang Pakong was evaluated as the second and the Lower Bang Pakong and Upper Phra Prong were the third.

However the difference in total points allocated to the second and third prioritized sub-basins is not significant. The Lower Bang Pakong sub-basin is topographically advantageous to utilize most effectively the water resources available and potential from the Khlong Rabom dam at present under construction, Khlong Luang dam whose detail design works have already been completed and Khlong Si Yat dam to be proposed by the subject study, all situated in the Tha Lat sub-basin. On the other hand, the potential sources of water are quite limited in the Upper Bang Pakong sub-basin. A combination of the Tha Lat and Lower Bang Pakong sub-basins is therefore recommendable to be developed as the highest priority sub-project. Hence the beneficial area is to be selected from the both sub-basins with available water resources just to meet water demand or requirement in the beneficial area.

5-2. Investment Cost and Project Implementation

5-2-1. Investment Costs for Respective Projects

The investment costs of water resources development as well as irrigated agricultural development in the basin were preliminarily estimated based on the following conditions and concepts. The dimensions and

TABLE 5-1 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

specifications of proposed facilities are surely at the preliminary design bases and may be subject to revision through detailed topographic and geological survey and more accurate designing.

1) Size and most suitable location of common facilities, such as storage dams and a diversion dam, were selected on the basis of the results of fields survey and detailed comparative study. Costs of dams and its appurtenant structures except a diversion dam were allocated to each sub-project or scheme in proportion to the ratio of annual water utilization. Cost allocation of the diversion dam between irrigation sector and drinking/industrial sector, however, was adopted the method of "separable cost alternative justifiable expenditure".

2) Major facilities included in the irrigation component consist of an intake, main and lateral irrigation canals and its appurtenant structures as the "direct project costs". On-farm irrigation and drainage facilities between main systems and farm land is considered as the most important functionable systems in order to use irrigation water more effectively in dry season. The cost for this, however, was estimated as "indirect project cost" due to the governmental policy.

3) Facilities to be allocated to the drinking/industrial water supply component is only storage and diversion dams. Main facilities for industrial sector leading water from Bang Pakong diversion dam site are booster pumping station, conveyance pipeline and receiving well at the industrial estate compound. Drinking water supply scheme, however, has no concrete development plan yet.

The summary of the investment cost for each project component is shown as follows (cf. Appendix-H, Table H-2-2);

Summary of Investment Cost

(Unit: Million Baht)

Item	Amount	
A. Irrigation Component		
A.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 B/ha)
A.2 Indirect Cost		
-Construction Cost (On-farm)	4,037	
-Administration./Others	1,193	
Total	5,230	(12,900 B/ha)
Grand Total	34,350	(84,500 B/ha)
B. Drinking/Industrial Component		
-Construction cost		
Storage dam	794	
Diversion dam	750	
Conveyance systems*	1,000	
Sub-Total	2,544	
-Administration./Others	616	
Total	3,160	
Grand Total (A)+(B)	37,510	

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

5-2-2. Project Implementation Schedule

Implementation of the projects shall be made based on the recommended priority. The policy and concept of development schemes were established in consideration of the results of discussion with Thai governmental officials concerned and of careful study on the technical and socio-economic aspects. The target year of development is set up by the year 2000.

As discussed in the previous section on the selection of the projects with high priority with a comprehensive evaluation, the following project priority was given to the respective sub-river basin. In order to create the more harmonious regional development and the high efficiency of the investment, staged development method is more recommendable. The schemes, therefore, were divided into following three stages.

Staged Development Scheme

Item	First	Second	Third	Total
A. Irrigation Component				
A.1 Irrigation Area (ha)	37,900 (LBP) 8,500 (KTL)	30,300 (LBP) 29,700 (KPS) 16,600 (MPP)	136,900 (UBP) 43,300 (UPP) 28,100 (MHM) 76,400 (MNN)	
Sub-Total	46,400	76,600	284,700	406,800
A.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
(Per baht/ha)	(97,600)	(91,600)	(80,100)	(84,400)
B. Drinking/Industrial Component				
B.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

5-2-3. Implementing Agency and Water Management Policy

Major beneficiaries of the project by the water resources development consist of water users for irrigation, drinking/domestic water supply, industry and brackish and freshwater fisheries. Agencies concerned in the project implementation and operation/maintenance of the systems and terminal users are scheduled as follows:

Sector/Component	Administrative Implementing Agency	Terminal Water User
A. Project Implementation Stage		
- Irrigation	Royal Irrigation Department (RID), MOAC	Farmers
- Drinking/ Domestic Water Supply	Public Work Department (PWD), Ministry of Interior and Provincial Waterwork Authority (PWA)	Inhabitant and private factory
- Industrial Water Supply	PWD and IEAT (Industrial Estate Authority of Thailand), Ministry of Industry	Private factory
- Fishery Raising	Department of Fishery (DOF), MOAC	Shrimp and fish growers

B. Operation/Maintenance Stage

- Storage Dam	RID, MOAC
- Diversion Dam	RID, MOAC
- Main Irrigation Canal	RID, MOAC
- On-farm System	Water users association or farmers
- Raw Water Conveyance	IEAT or association of industrial water users
- Fishery Raising Water	Association of shrimp/fish growers

Prior to and/or during the project implementation, "the project coordination committee" and "water management committee" should be formulated for the purposes of smooth project implementation and post project operation and maintenance. Both the committees will be managed by RID' chairmanship with the appropriate cooperation among the governmental agencies concerned and water users associations.

The members of the committees shall be the representatives of respective organizations concerned as mentioned above.

Water utilization policy and its management manner set up based on the overall water resources development plan and the regional development schemes should be reviewed periodically in order to adjust discrepancy between the water supply capacity and end users requirements. Other important points for the effective utilization of developed water resources are to control harmonious and equitable water distribution to the beneficial end users avoiding any confusion possibly be caused by illegal water users.

5-3. Environmental Impact Evaluation

Dam and reservoir projects usually cause a major alternation in the hydrologic regime of the watershed involved, they usually result in a drastic alternation of the physical and ecological setting in the immediate vicinity of the project and also these effects may continue far downstream of the area of final discharge of the stream and beyond. In addition they usually result in establishment of new access road to upstream areas in the watershed, resulting in impacts on forests, wildlife, mineral development and agricultural practices throughout the watershed. The EIS (Environmental Impact Statement) study should include effects on people involving problems of resettlement and of alteration in socio-economic patterns. Such effects as not only adverse but also essential gains may be evaluated in power and food production, flood control, water supply, aquaculture newly developed, recreation, navigation, etc. The EIS study is therefore to be undertaken during the stages of the planning and construction, and also the dam filling and stabilizing, with the recommended time schedule prepared by NEB as given in Figure 5-1. Environmental parameters to be included in the EIS report for dam/reservoir project are thus summarized as follows:

Environmental Effects common to Dam/Reservoir Project

1) Physical Resources

- Surface water hydrology: possible changes in hydrological regime by comparing the typical hydrographs for normal, drought and flood year conditions and mass water balance, both for before and after project conditions.

- Surface water quality: effect of storage on physical, biological and dissolved mineral constituents parameters, for both the reservoir and the lower reaches of the river.

- Groundwater: quality and quantity of groundwater, both in reservoir vicinity and the lower reaches of the river.

- Soils: soil erosion in the watershed as well as the irrigation aspects.

- Geology and seismology: adequacy of foundation conditions for structural stability and anticipated earthquake hazards in the region.

- Sediments and erosion: sedimentation in the reservoir.

- Climate: possible changes in microclimate in the project vicinity.

2) Ecological Resources

- Fisheries: loss in existing riverine fisheries and expected new fishery situation in the reservoir and in the altered river.

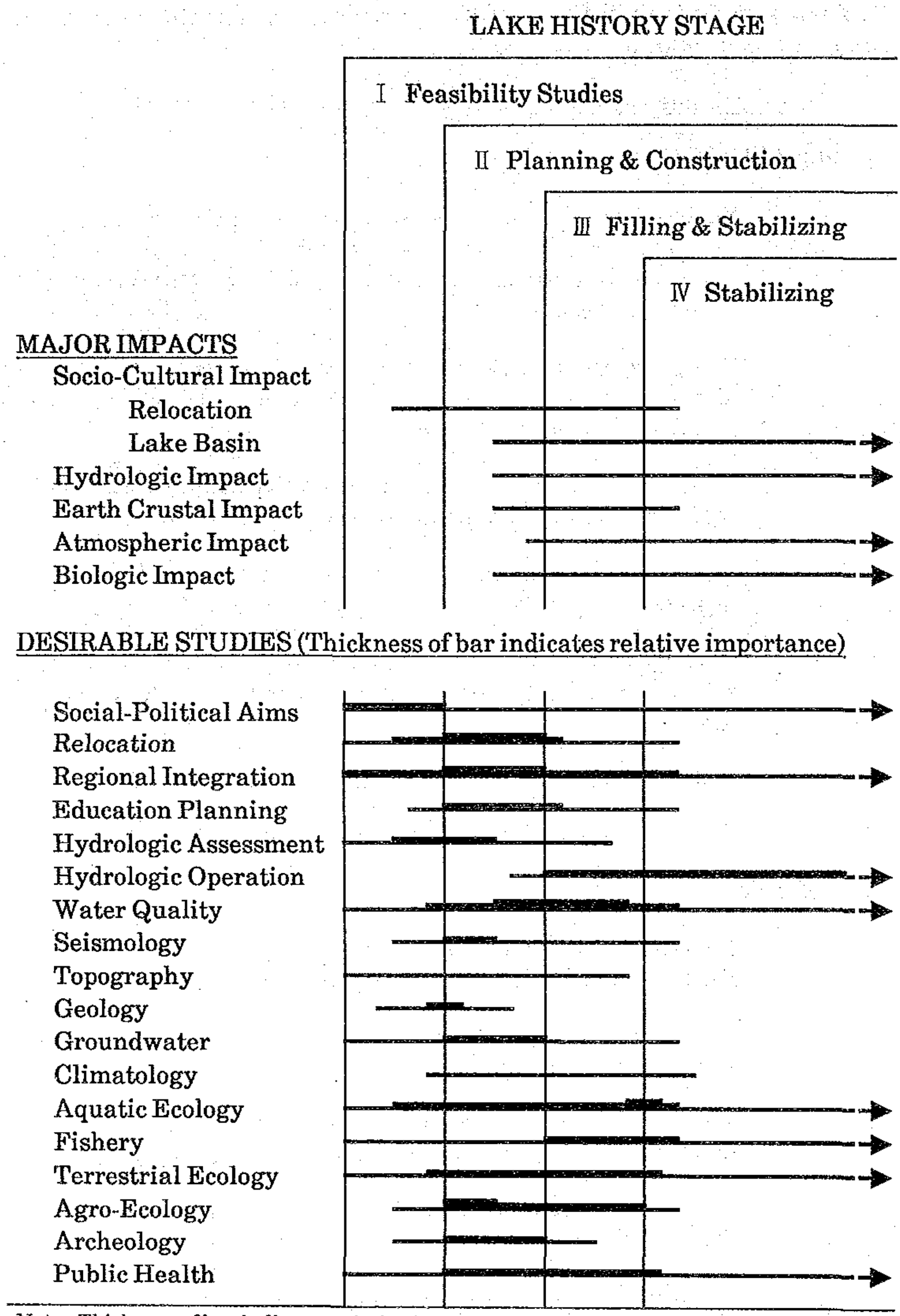
- Aquatic biology: expected new ecology in the reservoir and on the affected downstream riverine zone.

- Wildlife: impact of project on wildlife in watershed area and in downstream area, and new wildlife to be created by the project.

- Forests: impact of project in inundating forest reserves especially from the aspects in soil and water conservation.

- Reservoir ecology: anticipated environment in the new reservoir.

FIGURE 5-1. TIMING RECOMMENDABLE FOR ENVIRONMENTAL ACTIVITIES



Note: Thickness of bar indicates relative importance.

3) Human Use Values

- Water supply: availability of water for downstream communities for both domestic and rural water supply.
- Aquaculture: potentials for improved downstream aquaculture resulting from low flow augmentation, and brackish water fishery in downstream area.
- Navigation: effect of low flow augmentation caused by supply of river maintenance water, especially during dry period.
- Flood control: flood control effects to be achieved by the reservoir storage.

4) Quality of Life Values

- Socio-economics: welfare of affected rural population.
- Resettlement: problems involved in the resettlement plan of the population to be inundated.
- Public health: anticipated health/sanitation problems especially for altering hazards of water-oriented diseases in the region.
- Nutrition: probable effects on nutrition pattern due to the altered fishery production.
- Recreation: recreation and aesthetic values of the new reservoir systems.

Irrigation aspects also need to be evaluated in terms of the following:

- Crop and food production: estimated impact on types and amounts of crops to be produced, and the resulting increase in food production.
- Institutional requirement: plans for reorientation and training of the farmers to make the adjustment to irrigated farming including plans for extension services, farmers' cooperatives, and service center for furnishing training, credit, ready purchase of farm inputs, ready marketing, etc.
- Irrigation distribution: plans for distribution and use of the irrigation water.
- Soil fertility: loss of soil fertility caused by continuous irrigation.

- Return-flow: effect of return-flow on river water salinity.
- Agro-industries: potentials for agro-industrial development in the irrigation areas.
- Agricultural chemicals: effects of runoff from farming areas containing residues of fertilizers and toxic chemicals on stream ecology and effects of toxic chemicals on terrestrial wildlife.

5-4. Project Justification

5-4-1. Tangible and Intangible Benefits

Implementation of the plans proposed in each sector of the Overall Development Plan will bring in various effets to the regional development of the area. Table 5-2 shows the general effects to be expected from the Project execution. These effects can be specified into direct benefits and indirect benefits, and direct benefits are tangibly calculated by use of reasonable methods for estimation.

5-4-2. Investment Policy

1) Large-scale water resource projets have been developed without either efficient management or suitable extension projects (The Sixth National Economic and Social Development Plan 1987~ 1991, Programme 3: Development of Natural Resources and Scheduled with the Environment).

   Implementation of a large-scale water resource development project will be carried out after authorization of the overall basin development plan which deals with an effective use of water resources exploited and is scheduled with the staged development scheme.

2) The opportunity for developing water resources for agricultural purpose in the Sixth National Economic and Social Development Plan period lies under difficult situation due to the declining trend in the prices of agriculture produce (Programme 3).

   Hence, it will be necessary to consider multipurpose water resources development for irrigation, water supply, flood prevention, electricity generation, salinity control etc.

   A great emphasis will be placed on a multipurpose project in prioritizing the proposed sub-projects. Social factors will also be studied in justifying the projects, in order to avoid over-emphasis on economic factors.

3) An administrative organization and cooperation among the agencies concerned to the water resources development project should be established. Establishment of the special administrative organization capable of integrating development budget of agencies concerned is recommendable.

4) In the implementation of large scale water resources projects, occurrence of time lag among users to begin use of the exploited water has been ordinary experienced. In order to reduce this risk to the minimum, enough investigation, administrative coordination and budgeting would be necessary.

5) Water resources development is apt to be opposed to environmental conservation. Environmental assessment will be conducted during the period of feasibility study. Enough negotiation and provision of budget for compensation are necessary to resolve this compensation problem.

5-4-3. Justification of Master Plan

1) Economic Justification

A) Agriculture Sector

The alternative irrigation plan-2 was selected as the optimum scale of water resources development of the Bang Pakong river basin (refer to section 4-5-3). Economic factors involved in the optimum plan are summarized as follows:

- The beneficial area formulated through the implementation of 34.35 billion baht for irrigation component is projected at 406,800 ha, or 41 percent of the total cultivated area of 993,760 ha.

- Agricultural benefits will be generated by supply of irrigation water, increase in cropped acreage, salinity control etc. to be realized after completion of the Project. In particular, in order to strengthen profitability of farming, cassava of 23,300 ha and paddy of 2,000 ha are projected to be converted to fields for vegetable or maize and orchard or vegetable, respectively.

- Cropping intensity in future will be projected at a high degree of 146 percent.

- Incremental products of 131,000 tons of soybean, 28,000 tons of mungbeans, 47,000 tons of groundnuts, 235,000 tons of fruits represented by mango and 333,000 tons of vegetable would be marketable in extended domestic and export markets.

- Economic gross production value brought by production of paddy rice and five crops mentioned above is estimated at about 5.82 billion baht per year.

- Economic cost-benefit ratio of the optimum development plan inclusive of eight sub-projects was estimated at 1.04 with a discount rate of 12 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. The rate of marginal productivity of capital is studied by using the interests mentioned above. When the marginal productivity of capital is considered to be approximately the deposit loan rate, the cost-benefit ratio shows justifiable value from the national economic point of view.

- Financial gross income per ha is calculated at about 14,300 baht (5.82 billion baht/406,800 ha in 2000 year's financial price). According to the socio-agro-economic survey conducted in Chachoengsao and Chonburi in November, 1989, crop gross income per ha at present is about 9,400 baht (about 1,500 baht per rai). Hence, average crop gross income of farm-household with the project will be expected at about 1.5 times of that at present achieved.

B) Other Sector

- Inland Water Fishery

  Inland fishery managed in fish ponds which has been expanded in the paddy field areas in both Chonburi and Chachoengsao provinces are under shortage of water during March to May. Consequently, fish production is limited to one cycle per year. After construction of a storage dam, the fishing water will be available during this period. Two cycle per year of fish culture will be managed contributing to expansion of farm income.

- Industrial Water Supply

  Industrial water supply to the new industrial complex zone located in the lower reaches of the Bang Pakong river basin is mainly being provided from urban water work facility, irrigation canal or drain and small ponds. The status of water supply in dry season, however, does not meet the requirement of beneficiaries.

In particular, some factories are forced to purchase water with the price of 70 baht per cubic meter.

After construction of a storage dam and a diversion dam, bottle-neck mentioned above will be dissolved.

According to the optimum development plan, 215.3 MCM of industrial water will be utilized through urban waterwork, IEAT and private sector. Revenue obtained from water charge is considered as direct benefit generated from the project. Indirect effects such as extension of operation hours of factories, increase in goods shipped from factories, expansion of number of enterprise etc. are also projected in future.

- Tourism Development

Resources for tourism is exploited through construction of a dam and reservoir. Tourist facilities, such as road, transportation, electricity, water supply and hotel, will be implemented in order to attract a great deal of tourist. Consequently, revenue in rural area will be expanded.

2) Social Justification

A) Positive Effects

Social effects are projected as follows:

a) Effects to Generate Opportunity of Employment

Employment opportunity will be generated by the following key factors.

- Improvement of land use and extension of intensive technology in agricultural sector.
- Increase in opportunity of employment for skilled or unskilled labor to be created during implementation period of the project.
- Expansion and growth of industry, commerce and the agro-processing industry possibly caused by increase in agricultural production.
- Extension of operation hour in existing factories.

b) **Rise of Standard of Living**

- Improvement Effects of Public Health

  The targets of served population ratio projected in the municipal and drinking water supply plan are set up around 75 to 90 percent in urban area and 60 percent in rural area at the year of 2000. Improvement effects of public health would be expected in a wide area in future. Rise of the served population ratio will contribute to improvement of the public health through reduction of an occurrence ratio of contagious disease, improvement of nutritive conditions etc. The domestic and drinking water supply would therefore contribute to a great extent to the promotion of the Government's policy of rural development.

- Effects of Labor Saving

  Extension of the municipal and drinking water supply system will bring the saving of water-fetching labor.

c) **Security in the Thailand - Cambodia Border**

Development of water resource in the Thailand-Combadia border is the priority subject to promote social security in the border.

B) **Negative Effects**

- Social insecurity caused by inhabitants inundated in the reservoir area.
- Rise of land price influenced by expansion of establishment of manufacturing plants.
- Occurrence of environmental disruption and labor trouble caused by expansion of manufacturing industry
- Occurrence of environmental disruption caused by development of tourism

3) Adaptability of Development Contents to the Upper National Plan

Contents of the proposed development plan is considered to be adaptable as regards the following items prescribed in the Sixth National Economic Social Development Plan.

A) The proposed development plan is studied to meet the following guidelines for developing water resources prescribed in the Sixth National Plan.

   i) To encourage coordination of water resource development plans by using the river basin system.

   ii) To improve efficiency in existing large and medium-scale water resource projects.

B) The proposed development plan would contribute to promoting Chonburi and Chachoengsao as the regional urban growth centers, and to promoting the Eastern Seaboard development area through supply of industrial and domestic water.

C) The proposed development plan would contribute to development of the basic infrastructure for rural production and marketing.

TABLE 5-2. PROJECT EFFECT

Sector	Direct Effect		Indirect Effect	
	Positive Effect	Negative Effect	Positive Effect	Negative Effect
Agriculture	◦ Increase of crop products generated from improvement of drought, flood and salinity ◦ Increase of agri. income	◦ Inundation of crop field	◦ Generation of employment opportunity ◦ Enlargement of purchase market ◦ Improvement of rural road	
Fishery	◦ Increase of inland fishery products		◦ Generation of employment opportunity	◦ Influence to shrimp culture in downstream of Bang Pakong River
Forestry	◦ Irrigation of nursery	◦ Inundation of forest land		
Construction	◦ Mitigation of flood damage ◦ Increase of labor income	◦ Inundation of road and buildings	◦ Increase of construction enterprise ◦ Generation of employment opportunity	
Manufacturing industry	◦ Saving of water charge ◦ Increase of industrial production value	◦ Rise of land price	◦ Generation of employment opportunity	◦ Environmental disruption
Commerce			◦ Expansion of market ◦ Generation of employment opportunity	
Transportation		◦ Inundation of road	◦ Increase of transportation goods ◦ Improvement of road network	
Welfare	◦ Saving of water-fetching labor ◦ Improvement of living standard	◦ Increase of water charge due to convert source of water ◦ Un-stabilization of the people's liveli-hood due to dam-inundation	◦ Improvement of welfare condition ◦ Eradication of endemic disease	
Education religion		◦ Inundation of school and temple		
Sightseeing			◦ Exploitation of sightseeing resources ◦ Promotion of tourism projects	◦ Environmental disruption
Electricity			◦ Development of electric power	

CHAPTER 6. CONCLUSION AND RECOMMENDATION

CHAPTER 6. CONCLUSION AND RECOMMENDATION

6-1. Conclusion

The followings are the selected project area with priority order through comprehensive study of the overall river basin development plan. The feasibility study consists mainly of the following selection standard.

- National economy feasibility
- Technical feasibility
- Social feasibility
- Private economy feasibility

Priority order	Name of sub-river basin
1	Khlong Tha Lat (KTL)
2	Upper Bang Pakong (UBP)
3	Lower Bang Pakong (LBP)
4	Upper Phra Prong (UPP)
5	Maenum Hanuman (MHM)
6	Middle Phra Prong (MPP)
7	Khlong Phra Satung (KPS)
8	Naenum Nakhon Nayok (MNN)

The development scale and project investment are also summarized as follows ;

Sub - basin	Irrigable area	Crop intensity
	(ha)	(%)
KTL	6,900	126
UBP	136,900	151
LBP	68,900	151
UPP	43,300	144
MHM	28,100	141
MPP	16,600	151
KPS	29,700	145
MNN	76,400	115
Total or Ave.	406,800	142

2) Water demand projection

Sub - basin	Irrigable *	Industry	Drinking	Fishery	Total
KTL	64.6	3.9	8.1	-	76.6
UBP	1,350.0	28.1	17.9	-	1,396.0
LBP	779.7	137.1	52.8	19.1	988.7
UPP	310.2	2.1	10.2	-	322.5
MHM	191.7	6.4	5.1	-	203.2
MPP	119.0	2.3	2.4	-	123.7
KPS	216.7	1.7	6.7	-	225.1
MNN	575.0	22.5	12.7	-	610.2
Total	3,606.9	204.1	115.9	19.1	3,946.0

* Water requirement of irrigation was considered effective rainfall

3) Availability of water resources

Sub - basin	Storage reservoir capacity required	Proposed active storage capacity	Average runoff	Remarks (Dam S. No.)
	(MCM)	(MCM)	(MCM / yr)	
KTL	66	340	286	4. Rabom
UBP	768	133	133	20
LBP	527	119	136	1
UPP	186	246	473	10, 11
MHM	109	710	735	12,15,18,19
MPP	-	-	-	
KPS	117	470	470	8
MNN	260	286	286	21,22
Total	2,033	2,304	2,519	

4) Project implementation and investment

Phase	Sub - project name	Irrigable area	Investment cost
Phase - I	KTL, LBP (partly)	46,400 ha	6,810 (MB)
Phase - II	LBP (partly), KPS, MPP	76,600 ha	7,230 (MB)
Phase - III	UBP, UPP,MHM, MNN	284,700 ha	23,470 (MB)
Total		406,800 ha	37,510 (MB)

Note : Investment cost includes the cost for industrial and drinking

6-2. Recommendation

1) According to the estimation of the water demand variation up to the target year of 2,000 A.D. and the governmental development programs for agriculture, waterworks, industry, etc. the water resources development projects must be reviewed respectively just before the times of their being implemented.

2) Attending the diversion dam construction for preventing saline water intrusion and storing fresh water in the river course in a dry season, the control of water utilization for the fresh water to be stored just upstream of the diversion dam, the effective use of the water to be released from dam sources, etc. must be executed on the level of the government.

3) In times of the water resources development projects implementation mainly with dam construction, not only the technical and economic examinations, but also social or environmental consideration must inevitably be needed.

4) The outlines of the facilities plan and their cost estimation obtained in this overall basin study have been still roughly made. The detailed study and examination will therefore necessary at the stage of feasibility study.

5) For forming a part of the regional development programs, the rational and economical water resources development projects must be promoted by taking a long-term view and considering the plans and the needs harmonizing each industrial sector.

FEASIBILITY STUDY

CHAPTER 7. THE THA LAT RIVER BASIN

CHAPTER 7. THE THA LAT RIVER BASIN

7-1. 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-basin, 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 shrimp culture with fresh water to control the salinity; 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.

7-2. Characteristics of the Project Area

7-2-1. Population, Household and Farm Characteristics

Population

The total population of the ten Districts (Amphoe) concerning the Project area amounts to 685,532 in 1988. The population in the Project area is then estimated at 120,873, which is equivalent to 17.6% of the said total population as shown in Table 7-1.

The annual growth rate of population in the ten Districts was as low as 1.0% during the period from 1979 to 1983 and as high as 2.47% from 1983 to 1988. The expansion of the population in recent years has owed to the industrialization in the southern part of the ten District and the immigration from the North-Eastern and the other regions to Sanam Chaiket.

Household

The numbers of general households and farm households in the ten Districts are estimated at 90,213 and 63,477 respectively.

Those in the Project area are then roughly estimated at 21,130 and 14,800 respectively.

The following table shows population and farm-households by District.

TABLE 7-1. POPULATION AND FARM-HOUSEHOLD

Province	District	Population		Farm-Household	
		District (1988)	Project Area	District (1987)	Project Area
Chachoengsao	Sanam Chaiket	71,606	5,730	10,440	1,169
	Panam Sarakam	72,907	10,060	7,579	1,255
	K. Patchasam	12,233	1,315	1,576	266
	Bang Khla	60,879	9,335	7,783	1,646
	Plean Yao	29,876	5,200	3,788	792
	Muang	132,447	22,015	7,497	2,140
	Ban Pho	45,022	14,445	4,314	1,542
	Bang Pakong	73,099	6,280	4,046	413
	Sub-total	(498,069)	(74,380)	(47,023)	(9,223)
Chonburi	Phanat Nikhon	143,908	37,030	13,010	4,613
	Phanthong	43,555	9,465	3,444	964
	Sub-total	(187,463)	(46,495)	(16,454)	(5,577)
	Total	685,532	120,873	63,477	14,800
		(100%)	(17.6%)	(100%)	(23.3%)

Source: Population Statistics and Socio-economic data, NSD.

Farm Characteristics

1) Employment Structure

The employment structure in the ten Districts including the Project area is outlined with about 72% of farmers, 3% of fishermen, 21% of employee and others, based on socio-economic data, NSO, 1987. The employment situation in the Project area is characterized by the dominant rurality.

2) Farm Household Economy

Farm household economy shows different features among the Tha Lat existing irrigation area (referred to as TLEA), Bang Pakong Left Bank existing irrigation area (LBEA) and Tha Lat proposed irrigation area (TLPA).

The key factors in such differences are summarized as follows:

- Gross farm income per rai varies from 2,234 baht in LBEA and 1,800 baht in TLEA to 1,167 baht in TLPA.

- Ratio of off-farm income (employment + non-agriculture) to gross family income is 54% in LBEA, 37% in TLEA and 33% in TLPA.

- Ratio of production cost to gross farm income is 47% in LBEA, 45% in TLEA and 43% in TLPA.

- Household expenses value per person is 8,348 baht in TLEA, 8,095 baht in LBEA and 6,428 baht in TLPA.

- Net farm income value excluding family labor cost can not cover household expenses value. Hence off-farm income is an indispensable source for farm economy.

- Range of paddy land price

  TLEA : 30,000 to 400,000 baht per rai
  LBEA : 100,000 to 1,000,000 baht per rai
  TLPA : less than 100,000 baht per rai

  In this connection, the tendency of rise of land price is remarkable in Amphoes Muang Chachoengsao, Bang Pho and Bang Khla.

- To cope with increase of land price, paddy fields are being converted into fish ponds, orchard and chicken breeding farm on a relatively large scale.

TABLE 7-2. ECONOMY OF FARM-HOUSEHOLD

Item	TLEA	LBEA	TLPA
Cultivated land (rai)	31.84	22.53	36.13
Household Size (person)	4.76	5.27	5.00
Gross Family Income			
Farm Income	57,332	50,336	42,180
Off-Farm Income	33,460	59,004	20,405
Total	90,792	109,340	62,584
Gross Family Expenses			
Farm Expenses	25,808	23,537	16,163
Household Expenses	39,735	42,662	32,139
Total	65,543	66,199	48,302
Net Farm Income Excluding Family Labor	31,524	26,799	26,016
Net Family Income Excluding Family Labor	25,250	43,142	14,281

Note : Non-agriculture income is estimated as net value.
Source : Socio-agro Economic Survey, PDD, Dec., 1989

7-2-2. Climate

The climate over the Khlong Tha Lat river basin is tropical and monsoonal. Two distinct seasons recognized are: (1) dry season with northeast monsoon from November to April and (2) wet season with southwest monsoon through May to October.

Annual rainfalls range widely from the minimum of 880 mm in 1979 to the maximum of 1,660 mm in 1983, with 1,240 mm on an average. The peak of wet season generally falls in September.

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

Major climatic factors observed at the Chachoengsao station by RID are summarized as shown in Figure 7-1.

7-2-3. Topography and Geology

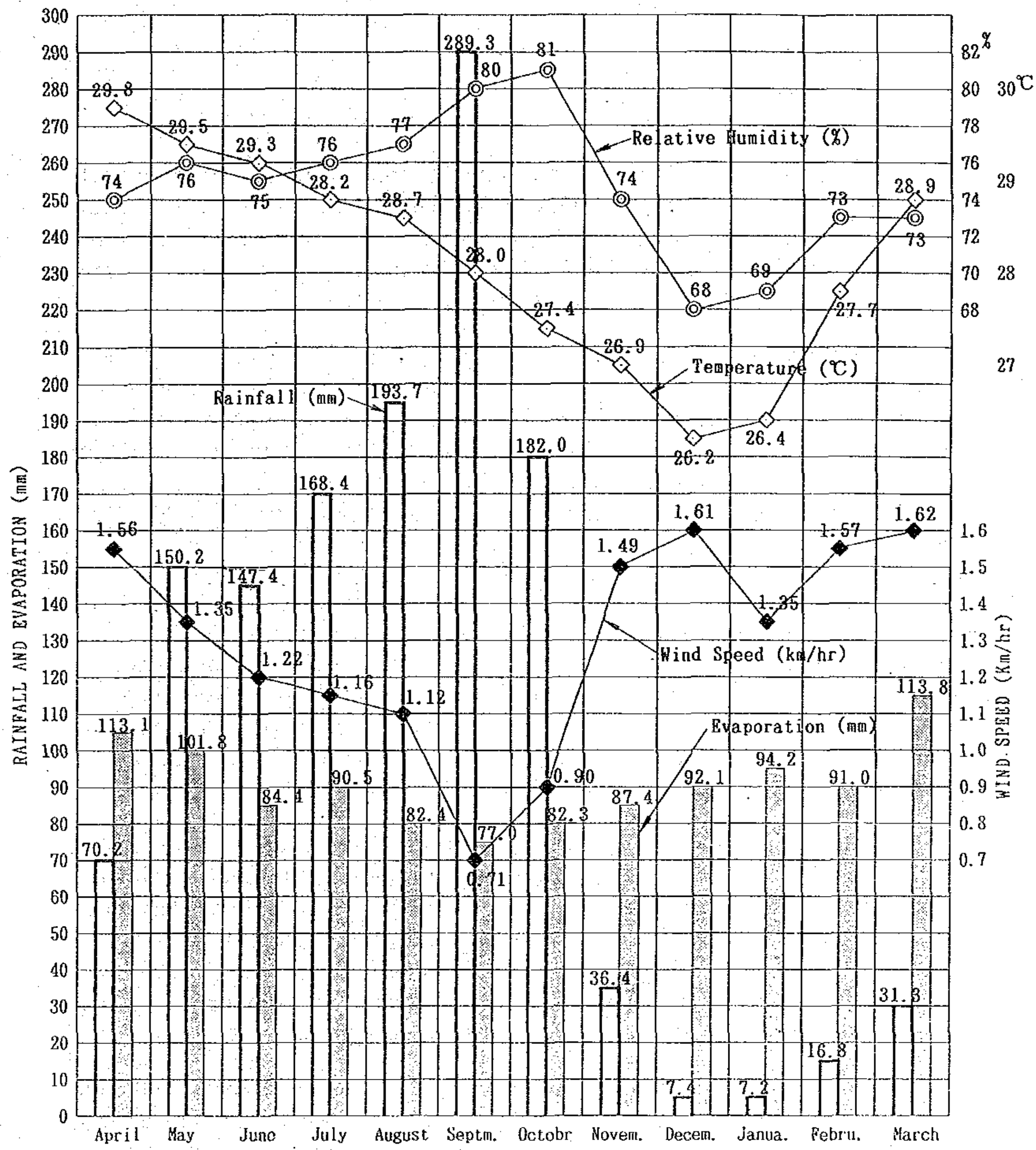
The Si Yat river running into the site of the Khlong Si Yat Dam joins with the Rabom river at 40 km downstream of the damsite and it changes the river name into the Tha Lat river. The Tha Lat river is 33 km long and flows into the Bang Pakong river. The prominent divide of the Khlong Si Yat lies on the east and south of the basin with altitude ranging from 180 to 780 m and total drainage area amount to 1,508 sq.km. Although national forest reserve area lies in the upper part of the basin, most of the basin comprises the agricultural and artificial lands.

The Project area is divided into two areas, the upstream area and the downstream area of the existing Tha Lat diversion weir by topographic and geological conditions.

The upstream area has 5 to 80 m in an altitude, and is composed of the alluvial flood plain and undulated hill. The alluvial flood plain extends to both sides of the river and is mainly underlain by consolidated clay, sand and gravel. The maximum thickness of the alluvial deposit is 18 m at the Khlong Si Yat damsite. The undulated hill is underlain by compacted sand and gravelly silt of the pleistocene terrace deposit. The sandstone and siltstone of Tanaosi Group of the carboniferous are only found on the right abutment of the Khlong Si Yat damsite.

The downstream area is flat alluvial plain with an altitude of 2 to 5 m, and the almost parts of the area is paddy field. The alluvial deposit is about 30

FIGURE 7-1 MAJOR CLIMATIC FACTORS OBSERVED AT CHACHOENGSAO



m thick at the site of the proposed Bang Pakong diversion dam and is composed of clay, sand, and gravel where saline water is occasionally intruded into the deposits.

7-2-4. Soils

1) Land Form and Soils

The Project area is a flat and formerly tidal lowland associated with low terrace in the eastern portion which is the Tha Lat Extension area. On the formerly tidal flat area along the left bank of the Bang Pakong river, soils are derived from marine and brackish water sediments. Those low terrace and granitic erosional surface are found only in a small extent.

The marine sediments are very deep clay having poor to very poor drainage, slow permeability with grey, brownish grey, olive grey or greenish grey matrix with greenish and brownish mottles. Bluish unripe marine clay occurs in deep horizon. Soil reaction is slightly acid to neutral with pH 6.0 to 7.0 on the surface becoming alkaline pH 8.0 in deep soil. The soil series are Smut Prakan, Bangkok, Phan Thong and Chachoengsao making up 12,290 ha or 20.29% of the total area.

The brackish water deposits are found inside of marine zone. They consist of very deep clayey soils. Straw yellow jarosite mottles which cause acidity are dominant. Soil reaction is very strongly to extremely acid with pH 4.5 and lower. Reduced dark grey clay occurs in very deep horizon normally below 150 cm. Soil series are Cha-am, Ongkharak, Mahapot, Rangsit, Don Muang and undifferentiated ridged acid soils covering 34,520 ha or 56.95% of the whole study area. They are under paddy.

The semi-recent and old alluvium on low terrace are found in only a small extent far away from the Bang Pakong river close to highland outside the Project area. The soils are very deep brownish grey clay loam to clay, more matured than those of tidal area. Soil reaction is strongly acid pH 5.0 - 5.5. Soil series are Hinkong, Chon Buri, Klaeng and Ko Khanun having 18,700 ha or 22.61% of the total area. Most of them are under rice growing with some upland crops, grass and fruit trees on somewhat high grounds.

The soils derived from granite are found in very small area of 60 ha or 0.1% of the total area. They are mapped as Ban Bung series, characterized by sandy texture with rather high pH. Cassava is the main upland crop growing on them.

2) Soil Suitability Classification

Most soils are suitable for paddy with the following classification.

-	Soils very well suited for paddy (P-I)	16,750 ha (27.65%)
-	Soils moderately suited for paddy (P-III)	35,210 ha (58.10%)
-	Soils poorly suited for paddy (P-IV)	3,810 ha (6.32%)
-	Soils poorly suited for upland crops	60 ha (0.10%)
-	Soils suited for fruit trees	4,740 ha (7.82%)
-	Others	30 ha (0.05%)
	Total	60,600 ha (100 %)

3) Problematic Soils and Their Improvement

Acid sulfate soils with straw yellow jarosite mottles are dominant problematic soils covering 34,520 ha or 56.95%. Soil reaction is very strongly acid to extremely acid with pH 4.5 and lower. Soil series include Cha-am, Ongkharak, Mahapot, Rangsit, Don Muang and undifferentiated ridged acid soils.

Lime application (mostly marl) at the rate of 1 - 2 ton/rai (6.25 ton - 12.5 ton/ha) with chemical fertilizer in every five years is recommended. However, irrigated water scheme and suitable crop selection should be given to expect more production from the acid sulfate soils.

7-3. Land Use and Agriculture

7-3-1. Present Land Use

The gross area covered by the Project amounts to 60,600 ha or 378,750 rai. The area comprises 34,710 ha of paddy field, 2,780 ha of upland field, 4,060 ha of orchard, 1,400 ha of fish pond, 2,000 ha of bush land and 15,650 ha of other land which is used as roads, canals, residential area, etc.

Paddy field is located in the low-elevated and flat land area, while orchard extends along the Bang Pakong river, and upland and bush land are situated in the low hilly district of Amphoe Sanam Chai Khet, Chachoengsao province. Fish ponds lie scattered around the northern part of Chonburi province.

Present land use is categorized as shown below:

Present Land Use

Irrigation Block	Paddy Field	Upland Field	Orchard	Fish Pond	Bush Land	Sub-Total	Other Land	Total
Existing Tha Lat	21,100	-	-	1,000	-	22,100	8,800	30,900
Existing Bang Pakong	10,000	190	2,110	400	-	12,700	4,700	17,400
Tha Lat Expansion	3,610	2,540	-	-	2,000	8,150	1,050	9,200
Bang Pakong Expansion	-	50	1,950	-	-	2,000	1,100	3,100
Total	34,710	2,780	4,060	1,400	2,000	44,950	15,650	60,600

Note: Others include urban area, road, river, stream, canal, tree crops, bush land etc.

7-3-2. Crop and Crop Production

Main crops of the Project area are paddy, mango, cassava and vegetables. Regarding paddy, only wet season paddy has been cultivated in almost all the Project area, excluding a part of Amphoe Phanom Sarakham where pumping facilities are installed by NEA and double cropping of paddy has been adopted. About 160 ha or 1,000 rai of paddy only are cultivated during dry season.

Although an accurate estimate of damage of paddy production due to floods during wet season is difficult due to lack of statistical data, about 353 ha per year of paddy is deemed to be damaged according to the information collected from the Agricultural Extension Offices.

The cropping patterns on upland are as follows:

Cassava .... single cropping
Vegetables .... three times per year

Cropping area and production by crop are summarized as shown in Table 7-3.

7-3-3. Agricultural Extension Service

The Project area covers two provinces and ten Amphoes each of them having the Provincial Agricultural Extension Office or the Amphoe Agricultural Extension Office. The Amphoe Extension Office is lined up by about 7 ~ 8 extension staff on an average, and renders services to farmers under its jurisdiction. The number of farm households per one extension staff is estimated at 580 ~ 1,890.

TABLE 7-3. CROPPING AREA AND PRODUCTION BY CROP

Irrigation Block	Area (ha)	Yield (kg/ha)	Production (t)	Remark
1. Existing Tha Lat Area				
Paddy Wet Season	21,100	2,141	45,183	
Paddy Dry Season	160	3,750	600	
Sub-total	21,260	-	45,783	
2. Existing Bang Pakong Area				
Paddy Wet Season	10,000	2,079	20,791	
Mango	1,930	5,221	10,076	2,110 ha planted
Vegetables	190	8,000	4,560	3 times/year
Total	12,120	-	-	
3. Tha Lat Expansion Area				
Paddy Wet Season	3,610	1,947	7,029	
Cassava	2,540	15,232	38,689	
Sub-total	6,150	-	-	
4. Bang Pakong Expansion Area				
Mango	1,810	3,761	6,807	1,950 ha planted
Vegetables	50	8,000	1,200	3 times/year
Sub-total	1,860	-	-	
5. Entire Project Area				
Paddy	34,870		73,603	
Mango	3,740		16,883	4,060 ha planted
Cassava	2,540		38,689	
Vegetables	240		5,760	
Total	41,390		-	

In recent years, supported by World Bank loan, the activities of Agricultural Extension Office have been much intensified, however, they still suffer from shortage of staff members for implementation of their services and duties. Existing situation of the Amphoe Extension Offices in the Project area is given below.

Situation of Amphoe Agricultural Extension Office

Item	Chief	Sub-Chief	Exten. Staff.	Pick-up	Motor Cycle	No. of H.H	No. of H.H / Exten Staff.
Chachoengsao Province							
A. Sanam Chai Khet	1	1	6	1	8	11,322	1,887
A. Phanom Sarakham	1	1	10	1	14	8,591	859
K.A. Ratchasarn	1	1	3	1	4	1,739	580
A. Bang Khla	1	1	8	1	8	7,087	886
A. Plean Yao	1	1	5	1	9	4,975	995
A. Muang	1	1	12	1	12	10,306	859
A. Ban Pho	1	1	7	1	8	5,491	784
A. Ban Pakong	1	1	7	1	9	5,678	811
Chonburi Province							
A. Panat Nikhom	1	1	11	1	11	14,508	1,319
A. Phan Thon	1	1	4	1	4	5,522	1,381

Source: Provincial Extension Office Data in 1988

7-3-4. Institutional Aspects

1) Agricultural Research

The Prachinburi Rice Research Center (PBRC) has been operated since 1975 in Amphoe Bansang of Prachinburi province at a distance about 150 km to the east of Bangkok. PBRC occupies a total area of 120 ha, where some 20 ha are used for experimental and research purposes, 67 ha for seed multiplication and pure seed maintenance and 33 ha mainly for buildings.

The organization of PBRC consists of activities of Varietal Improvement Unit, General Unit, Agronomy Unit, Plant Pathology Unit, Entomology Unit, Soil Research Unit, Post Harvest Technology Unit, Seed Technology and Production Unit and Specialized Project. Major PBRC are long term research on the above respective fields and have close relationship between agricultural extension and applied research.

2) Agricultural Cooperatives

One agricultural cooperative is stationed in every Amphoe and the other cooperatives are established for special purposes, such as swine raising, milking cows, water use, land reform, etc. The numbers of cooperatives are shown as below:

Province	No. of Coop.	Member
Chonburi	10	6,835
Chachoengsao	22	10,751

Farmers obtain agricultural inputs through the following channels.

(Unit: %)

Item	Seed	Fertilizer	Agro. Chemical
Agricultural Extension Office	34.8	-	15.0
State Enterprise	-	9.0	-
Financial Institute	-	23.4	-
Group/Association	-	3.6	2.5
Local Merchant/Landlord	13.1	3.6	-
in village	(8.8)	(3.6)	5.0
out village	(4.3)	-	-
Marchant/Landlord in Town	17.4	58.2	77.5
Relatives	13.0	0.9	-
Neighbours	21.7	1.3	-
Total	100.0	100.0	100.0

3) Farmers Group

Farmers groups are found in each Amphoe, supervised by DOAE. The 38 farmers groups in Chachoengsao and 21 in Chonburi are counted. The number of membership is a few less than that of cooperatives, and if the groups are bigger and stronger they will grow to the cooperatives by step and by themselves. The relation between farmers institutions and membership is shown as below;

	farmers group	cooperatives
	informal registered	
number of membership	About 20 - 200 farmers	More than 200

4) Activity of BAAC

BAAC is a semi-governmental agricultural credit organization. The service is available to farmers directly, as well as to the intermediary agricultural cooperative and farmers group. Individual client farmers in the whole kingdom occupied, at the end of march in 1989, 34% of organized farmers. Figures broken down for BAAC branches in the Study area are 41% in Chachoengsao and 34% in Chonburi.

7-3-5. Livestock

Cattle and buffalo are fed as draft animals and swine, chicken and duck are raised for foodstuff. At present, cattle and buffaloes are raised for meat animals in addition to draft animals which have been substituted gradually by the agricultural machinery.

Production of chicken and duck shares the top in the whole country, but it has been decreasing due to the unstable unit gate price. The numbers of livestock for two provinces concerned are as follows.

Numbers of Livestock

Item	Cattle	Buffalo	Swine	Duck	Chicken	Goose
Prov. Chonburi	20,978	14,665	332,848	917,756	11,830,021	2,656
A. Phanat Nikhon	4,030	4,390	173,800	97,480	540,800	240
A. Phan Thong	1,362	1,055	28,659	233,686	842,721	986
Prov. Chachoengasao	46,851	11,163	431,421	648,435	11,207,950	42,000
A. Muang	5,478	231	180,435	210,530	4,105,350	6,850
A. Bang Khla	5,480	330	75,650	36,873	695,550	1,549
A. Bang Pakong	392	62	23,900	125,500	12,300	12,300
A. Ban Pho	3,800	217	25,000	73,000	4,100,000	20,000
A. Phanom Sarakham	8,760	2,800	95,000	50.000	1,100,000	400
A. Sanam Chai Khet	2,400	3,540	1,450	5,632	24,896	163
A. Plaeng Yao	8,175	2,950	25,400	26,000	213,000	63
K.A. Ratchasaan	4,320	10	1,150	8,500	300,000	0

Source: Provincial Livestock Office in 1988

7-3-6. Fishery

1) Shrimp Culture

The production of shrimp culture has been developing nationwide with a high growth rate. In particular, the production of jumbo tiger prawn has increased from 1.3% of total shrimp production in 1983 to 44.7% in 1987.

The number of farms, cultivated area and the production of shrimp culture in Thailand during the period from 1978 to 1987 are shown in the following:

Year	Shrimp Farm	Cultivated Area		Production (tons)	
		ha	rai	Total	Jumbo Tiger Prawn
1978	3,045	21,730	135,815	6,395	12
1983	4,327	35,537	222,107	11,550	147
1984	4,519	36,792	229,949	13,007	170
1985	4,939	40,769	254,805	15,841	106
1986	5,534	45,368	283,548	17,886	897
1987	7,221	52,149	325,929	23,566	10,514

Source: Agricultural Statistics of Thailand, DOF, 1988/89

The extent of shrimp culture around the Project area along the Bang Pakong river is about 5,000 rai on the left bank and 10,000 rai on the right bank, both located outside the Project area.

According to the information obtained from a shrimp grower managing 30 rai of fish pond (5 rai × 6 places) located nearby the Provincial Irrigation Office, RID in Amphoe Ban Pho, two cycles of shrimp cultivation have usually been achieved during 6 months from January to June.

Salinity content of water stored in ponds rises from 12 - 15 ppt in January to 28 - 29 ppt in April. The content over 30 ppt is improper to growing of shrimp.

The agricultural area situated downstream is unavoidable to be suffered from high salinity of river water after construction of the proposed Bang Pakong diversion dam. In order to ensure the present condition of shrimp culture, supplemental fresh water of appropriate quantity has to be supplied from the diversion dam.

2) Fresh Water Fish Culture

In the Project area, the extent of fresh water fish pond at present has been estimated at about 8,550 rai (1,368 ha) as follows:

Fresh Water Fish Pond Culture

Amphoe	Rai	(ha)
Phanat Nikhon	4,950	(792)
Phan thong	2,600	(416)
Ban Pho	1,000	(160)
Total	8,550	(1,368)

Those fish ponds were converted from paddy lands. According to socio-agro economic survey conducted in Dec., 1989, fish culture is not succeeded during March to May due to lack of water supply from Tha Lat Irrigation canal and natural river. The following table shows the calendar of fishing culture prevailed in Amphoe Phan Thong.

Calendar of Fresh Water Fish Pond Culture

Month	At Ban Nong Fa Fast, Amphoe Phan Thong
January and February	Marketing
March to May	Lack of water
June	Release seeds fly (small size)
July	Release seeds fly (medium size)
August	Release seeds fly (large size)
September to November	Rasing
December	Marketing

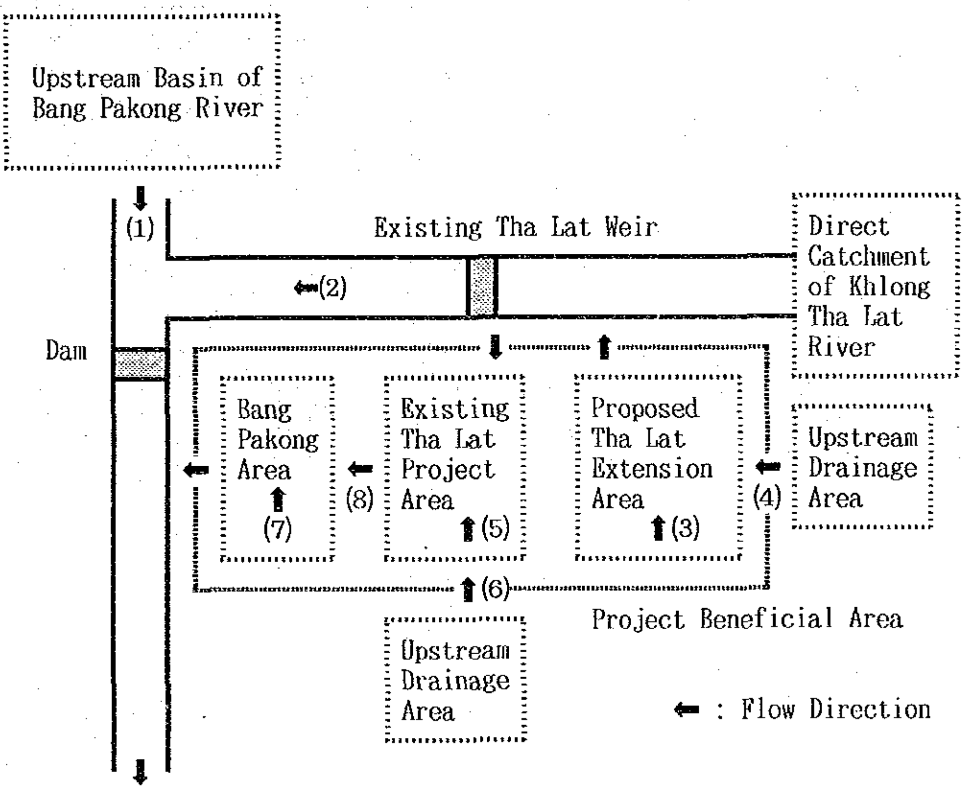
Note: Fresh water is supplied once a half month by pump during rainy season and twice a week during dry season.

If the water is available during March to May, two cycles per year of fish culture will possibly be managed to increase much more income.

7-4. Water Availability

7-4-1. Existing Water Sources

Existing water sources in the subject Project area are the excess runoff from upstream basin of the Bang Pakong river together with runoff from Khlong Tha Lat river, runoff caused by the basin areal rainfall within the Project beneficial area, and excess runoff from the direct upstream basin of the beneficial area.



Currently from the hydrological studies, available waters at the various points of the Project area as illustrated above are estimated, in terms of annual total, as follows:

Available Water at Various Points of Tha Lat River Basin

(unit: MCM)

Year	Sub-Basin (Point)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968	3,804.6	287.0	34.7	238.9	54.0	352.2	17.5	324.2
1069	5,584.1	310.7	56.5	267.2	79.3	331.4	26.3	333.1
1970	5,454.0	508.9	65.3	420.5	84.6	346.5	26.9	335.1
1971	4,782.8	316.0	60.5	267.8	88.4	396.4	27.0	389.6
1972	5,501.4	264.5	51.2	223.2	75.3	330.3	23.8	327.6
1973	4,360.6	272.3	48.5	224.1	69.4	349.0	22.1	346.8
1974	4,383.5	214.9	48.8	188.0	76.3	370.5	24.4	358.1
1975	5,263.5	331.1	61.2	278.5	75.0	327.6	20.5	319.1
1976	5,865.0	333.3	59.7	283.9	78.0	346.3	23.3	356.5
1977	4,480.8	368.4	51.2	298.3	69.6	235.9	22.6	214.2
1978	4,801.7	371.2	58.8	315.7	73.9	287.2	23.1	292.5
1979	4,155.0	373.9	39.5	300.6	46.9	211.1	13.4	166.2
1980	6,328.5	449.1	63.9	364.2	81.1	297.9	25.5	299.4
1091	5,626.1	524.3	55.4	415.9	74.4	306.3	25.2	280.7
1092	4,879.8	292.6	40.7	234.1	61.5	229.6	21.0	202.6
1983	6,847.0	427.4	88.1	364.6	122.8	445.8	37.4	486.8
1984	5,397.6	292.0	63.5	244.5	78.2	255.9	22.1	263.7
1985	5,150.1	318.9	51.4	257.2	72.7	232.2	24.2	217.7
1986	4,828.3	314.9	52.9	267.8	75.9	305.1	24.0	306.2
1987	3,693.8	272.2	39.4	223.4	55.6	326.4	16.8	274.6
Max.	6,847.0	524.3	88.1	420.5	122.8	445.8	37.4	486.8
Min.	4,155.0	214.9	34.7	223.2	46.9	211.1	13.4	166.2
Mean	5,059.4	342.2	54.6	283.9	74.7	314.2	23.4	304.8

7-4-2. Water Consumption and Shortage

The Khlong Rabom dam has been under construction on the Rabom river, one of the primary tributary of the Tha Lat river, and is expected to be completed by the end of 1990. After completion of the dam with an active storage of 40 MCM, water stored in the dam will be released to supplement irrigation and fishery water to the existing paddy land and fish ponds. Water demands required for paddy and other crops cultivation as well as for freshwater fish raising during wet season, under the existing condition, were estimated as follows:

Water Demand Estimated (MCM)

Area	Sector	Maximum	Minimum	Average
Bang Pakong	Irrigation	81.5 (1979)	39.4 (1983)	57.2
	Fishery	2.0 (1979)	1.6 (1983)	1.8
Existing Tha Lat	Irrigation	169.4 (1979)	78.1 (1983)	116.5
	Fishery	5.0 (1979)	4.0 (1983)	4.5
Tha Lat Extension	Irrigation	26.5 (1979)	12.6 (1983)	18.4
	Fishery	-	-	-
Total	Irrigation	277.4 (1979)	130.1 (1983)	192.1
	Fishery	7.0 (1979)	5.6 (1983)	6.3

Water balance made between available water supply and irrigation and other water demands for the existing extent of paddy and fish cultivation during wet months revealed water shortages as summarized below:

Water Shortage (MCM)

Area	Maximum	Minimum	Average
Bang Pakong	-	-	-
Existing Tha Lat	75.7 (1979)	6.0 (1983)	33.3
Tha Lat Extension	-	-	-
Total	75.7 (1979)	6.0 (1983)	33.3

7-5. Irrigation and Drainage

7-5-1. Existing Irrigation Systems and Practices

The subject Project involves the existing irrigation project areas of Tha Lat and Bang Pakong left Bank.

The Tha Lat irrigation project, extending over the left bank of the Bang Pakong river having a net irrigation area of 20,800 ha, was completed in 1973 by RID. The Tha Lat diversion weir with a height of 5.0 m and a length of 23.0 m is situated on the Tha Lat river, one of tributaries of the Bang Pakong river, at a distance about 34 km from the confluence of the both rivers. The main irrigation canal has a total length of 44.9 km with the design capacity of 15.9 cu.m/sec at head. In total 35 lateral canals, of which 6 were constructed by RID and 29 were supplemented by farmers themselves, have also been facilitated covering about 80% of the irrigation service area, and remaining areas are irrigated by plot-to-plot system. These canals except ones constructed by farmers were originally designed as concrete lined canals, however, were replaced by earth canals due to the budget limitation.

The Bang Pakong Left Bank irrigation project stretches along the left bank of the Bang Pakong river over the low-lying alluvial plains with a net irrigation area of 10,400 ha. The construction work was started in 1950 and completed in 1963 by RID, aiming at prevention of the Bang Pakong flood water from intruding into and inundating over the service area in wet season and of Bang Pakong saline water from intruding into the area in dry season. Polder dikes have been constructed surrounding the service area and drainage gates, which functions as flood control gates during wet season, are installed at the outlets of tributaries flowing into the Bang Pakong river. The area is mostly covered by paddy fields, the paddy cultivation is mostly carried out under rainfed condition, and there are no irrigation systems distributed in the area. The Bang Pakong water is commonly diverted into the natural drainages during wet season when salinity content is relatively low, and is used for supplemental irrigation in both wet season and transitional period between wet and dry seasons.

7-5-2. Existing Drainage Systems and Practices

Natural canals, linked each other, are used for drainage, flood mitigation and storage for dual purposes of irrigation and drainage. Beside this, there is no drainage facility in the area except some cross-drains constructed at the crossing points of irrigation canals and natural streams. These natural streams have, however, been shallowed by sedimentation and weed deposition, causing insufficient flowing capacity to drain out the inundated water over the area within an allowable limits of depth and duration for paddy cultivation.

One of the major reasons to accelerate flood damages in the area is the recent construction of road and railway systems. One to three rows of ϕ1,000 mm pipes are installed crossing the roads and railway, however, the capacities are not adequate to drain the required volume of inundated water out of the area into the Bang Pakong river.

In the existing Bang Pakong irrigation project area located adjacent downstream of the Tha Lat irrigation area, flood control gates are often operated so as to block the flood water for irrigation purposes even during a severe flood time when the upstream area is under the water. Numbers of check structures installed on the natural streams also block the water, causing serious flood damages in the Tha Lat area.

Flood damages occurred in 1983, reported as one of the biggest flood ever recorded, have been summarized as below.

1) Rainfall

	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
Rainfall (mm)	22.3	173.5	204.9	265.3	508.3	420.8	319.2	63.5	0.0
Nos. of Rainy Day	3	5	15	11	21	16	13	4	0
Flooding Period					———	———	———		

2) Inundated and damaged Area (Paddy: rai)

(unit: rai)

	Inundated Area	Damaged Area	
		50% Damaged	100% Damaged
Tha Lat Irrigation Project			
- Chachoengsao	28,000	11,000	4,000
- Chonburi	50,000	3,500	1,500
Sub-Total	78,000	14,500	5,500
Bang Pakong Left Bank Irrigation Project			
- Chachoengsao	16,500	6,730	3,770
- Chonburi	150	70	-
Sub-Total	16,650	6,800	3,770
Total	94,650	21,200	9,270

CHAPTER 8. DEVELOPMENT PLAN

CHAPTER 8. DEVELOPMENT PLAN

8-1. Project Objectives and Components

8-1-1. Project Objectives

The Tha Lat river basin development project is a multi-purpose water supply project for irrigation, industry, drinking and fishery. Improvement of land and labor productivity, provision of vegetables to the vicinity of metropolitan area, upgrading of marketing structure and other related systems to add productive value are the major benefits to be expected from implementation of the irrigated agricultural development project. On the premise of stable supply of irrigation water and improvement of drainage condition, the Project related to irrigation component envisages to upgrade living standard of the beneficial farmers with highly improved agricultural income, by means of constructing necessary irrigation systems composed of storing dams, a diversion dam, irrigation and drainage canals, and also introducing double cropping (partially triple cropping) on the existing paddy land, converting a part of cassava and shrub into mango plantation, recommending farming pattern of more productive and practically possible within the framework of existing farming technique.

In parallel with the above mentioned activities, stable and safe raw water supply for industrial sector, drinking water supply and brackish water fishery can be expected in and around the project area, especially along the lower reaches of bang Pakong river. Such comprehensive water resources development project will be one of the important roles on the consolidation and acceleration of infrastructural development in the region.

Effects of the construction of Khlong Si Yat storage dam and Bang Pakong diversion dam, especially, will be a great deal to the regional environments. Project implementation for these sectors shall be conducted based on their respective development programmes with close coordination among the authorities concerned.

8-1-2. Project Components

The project components as concerns irrigated agricultural development and other sectors and summarized as follows :

Irrigated Agricultural Development

- To construct and/or rehabilitate a storage dam, a diversion dam, irrigation and drainage canals with appurtenant structures, and other facilities for water resources development.
- To consolidate on-farm facilities such as irrigation /drainage ditches and farm roads in both the existing / newly development area in order to supply irrigation water and to manage drainage water.
- To introduce appropriate water management systems
- To increase crop yield and cropping intensity through improvements of farming technique and of providing stable irrigation water.
- To promote dry season crop cultivation especially upland crop as well as vegetables in order to increase farm income and supply them enough to newly developed industrial complex and the metropolitan area.
- To convert a part of upland where cassava has mainly been planted and shrub land left as idle land into orchard.

Industrial, Drinking Water and Fishery Sector Development

- To provide stable and safe raw water to the respective sectors, such as industrial, urban and rural water supplies and inland brackish water fishery to mitigate water shortage in the area.
- To prevent saline water intrusion into middle / upper reaches of the river in dry season.
- To improve brackish water shrimp farming productivity providing fresh water in proper time in order to control salinity contents and introducing double cropping system during December to July.

8-2. Integrated Agricultural Development Plan

8-2-1. Land Use and Crop Conversion Plan

In consideration of the result of present land use survey, irrigation water requirement, field condition, profitability of crop, etc., the following land use plan is proposed;

Item	Present (ha)	Proposed (ha)	Balance (ha)
Paddy	34,710	34,400	▲ 310 *1
Upland	2,780	940	▲ 1,840 *2
Orchard	4,060	7,160	3,100
Shrub land	2,000	450	▲ 1,550 *3
Other land	250	850	600
Total	43,800	43,800	-

Notes ; *1 : 210ha of decrease due to on farm arrangement or consolidation of irrigation facilities in Tha Lat Expansion area and 100ha of decrease due to conversion into orchard

*2 : Converted into orchard from cassava field.

*3 : Converted into orchard, road, canal ,etc.

A crop conversion plan, in terms of a comparison of the present and proposed land uses, is then summarized as given in Table 8-1.

TABLE 8-1 LAND USE COMPARISON PRESENT / PROPOSED

Unit : ha

	Proposed					
Present	Paddy	Upland	Orchard	Shrub Land	Other Land	Total
Existing Tha Lat						
Paddy	21,100	-	-	-	-	21,100
Upland	-	-	-	-	-	-
Orchard	-	-	-	-	-	-
Shrub Land	-	-	-	-	-	-
Other Land	-	-	-	-	-	-
Total	21,100	-	-	-	-	21,100
Existing Bang Pakong						
Paddy	9,900	-	100	-	-	10,000
Upland	-	190	-	-	-	190
Orchard	-	-	2,110	-	-	2,110
Shrub Land	-	-	-	-	-	-
Other Land	-	-	-	-	-	-
Total	9,900	190	2,210	-		12,300
Tha Lat Expansion						
Paddy	3,400	-	-	-	210	3,610
Upland	-	700	1,620	-	220	2,540
Orchard	-	-	-	-	-	-
Shrub Land	-	-	1,380	450	170	2,000
Other Land	-	-	-	-	250	250
Total	3,400	700	3,000	450	850	8,400
Bang Pakong Expansion						
Paddy	-	-	-	-	-	-
Upland	-	50	-	-	-	50
Orchard	-	-	1,950	-	-	1,950
Shrub Land	-	-	-	-	-	-
Other Land	-	-	-	-	-	-
Total	-	50	1,950	-	-	2,000
Grand Total	34,400	940	7,160	450	850	43,800