About 90% of local factories shown above are occupied by rice mills of small scale, cassava chip yard, sand crushing plant, concrete block maker, car and engine parts repair shop, lathe-machine-welding factory, ice maker, etc.

The second group contains new comers of modern light industry with high technology and intensive labour, composed mainly of canning packer, vegetable packing-house for export oriented crops, rubber commodity and plywood factories and tropical fruits processing etc., with modern container yard.

3-2-3. Sixth Five Year Regional Development Plan

In the Sixth Five Year Regional Development Plan, the Study area belongs to the second region in "Bangkok Metropolitan Circle Enlargement and Consolidation Program" in which the existing investment promotion area including Bangkok and five neighbouring provinces will be expanded involving the surrounding areas with 19 cities. A part of the Study area also belongs to the "Eastern Seaboard Industrial Development Region".

This area has various problems to be solved in consolidating and strengthening of traffic, transportation, flood control and water utilization.

At the same time, this area includes the wide rural zone where rural development programs to smooth earning differentials between urban and rural areas, dissolve poverty and to elevate living standard and earnings for the people under population increase are strongly requested. Especially, in the retarded developing villages, it will be very important to solve the problem of poverty by means of enlarging agricultural production, increasing farming income and decreasing unemployment in farm off-season.

According to the socio-economic surveys made by NESDB and NSO covering the whole Kingdom, the indexes of the cities and villages in the four major provinces belonging to the Study area show the following differences (cf.Appendix G-3, 4):

- In the local mountainous areas such as Sanam Chai-Khet in Chachoengsao, Sakaeo, Nadi and Watthana Nakon in Prachinburi, indexes showing the rate of farm households with land ownership, electricity utilization, television sets diffusion, and availability of drinking as well as irrigation water are generally low.

- Public hospitals or clinics managed by districts or villages can be found not far from villagers' houses. A family planning has been prevailed in the same manner as urban areas. As a result, there is little differences between urban and rural areas, and so the rate of birth will diminish successively.

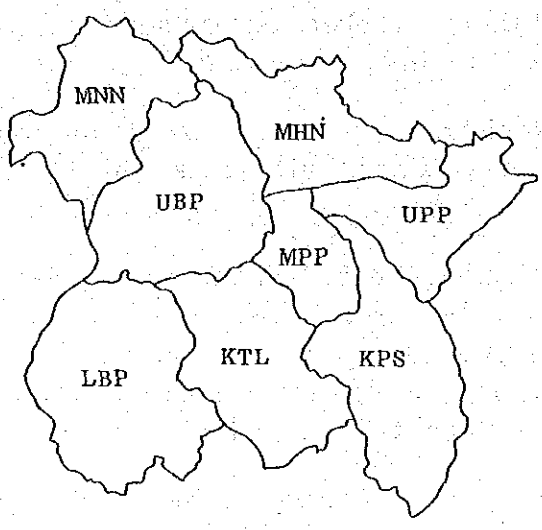
- The employment opportunity in urban areas is, as a matter of course, more than in rural areas. The rate of employment in rural areas is about a half of that in urban areas.

- The daily wages of 51 bahts in urban areas is higher than that of 42 bahts in rural areas. This tendency in Chonburi and Chachoengsao is remarkable, but in Nakhon Nayok and Prachinburi the wages in urban zones are positioned in the middle between 51 bahts and 42 bahts.

- Accordingly, the area where the rate of people gaining an annual income of more than 30,000 bahts exceeds 70% is located in the lower reaches of the Bang Pakong river basin in Chonburi and Chachoengsao, while the area less than 50% is located in mountainous areas. (cf. Appendix G-4)

- The rates of crop damage due to drought, flood, epidemic and harmful insects in rural areas are higher than those in urban areas, according to the NSO survey.

Drought, Flood, Crop Epidemics and harmful Insects Troubles reported



$$\frac{\text{Number of Sub-district damaged}}{\text{Total Sub-district}} = \%$$

Unit : Percentage

	LBP	KTL	UBP	MNN	MHN	MPP	KPS	UPP
Drought	77	100	96	56	80	85	85	100
Flood	17	10	50	19	20	19	42	25
Epedemic & Insect	64	–	70	79	100	100	100	100

The matters which were requested to the Government by many inhabitants are firstly access road construction to their villages, secondly development of irrigation water, and then drinking water security. (Table 3-2)

3-2-4. Land Use and Land Ownership

General land use of Bang Pakong basin is clearly defined by its topography. The low flat land in the west is entirely devoted to paddy cultivation with some orchards along the river banks. The upland and mountainous areas in the east are mostly under several upland crops, orchard plantation and forest. In the total basin area of approximately 1,776,000 ha, the agricultural area comprises 993,760 ha or about 56 percent. Of these farmlands, paddy, upland crop, orchard and vegetable share 467,290 ha (27%),

TABLE 3-2 REQUIREMENT TO GOVERNMENTAL SUPPORT

Unit : Number of Tambon

	Chon-buri	Chacho-engsao	Prachin-buri	Nakhon-Nayok	Total
Constructing Roads for Village	120	146	132	60	458
Finding Water Source for Agriculture	98	135	136	38	407
Arranging Drinking Water	81	46	86	17	230
Insurance of Agricultural Product Price	32	97	72	31	202
Electricity for Village	58	79	65	35	177
Providing Carriers Supporting Farmers	9	18	43	9	79
Building Bridges	15	29	17	8	69
Constructing Weir or Dam	19	16	29	3	67
Establishing Health Center	13	8	11	4	36
Land Allocation for Living	7	12	17	3	39
Investment Loan	6	6	6	3	21
Land Improvement for Production Increase	5	1	3	1	10
Establishing school	1	–	2	–	3

Source; Socio-Economic Survey, 1987 NSO

391,060 ha (22%), 102,000 ha (6%) and 24,410 ha (1%) respectively. The remaining 772,240 ha (44%) is devoted to forest, mountainous and miscellaneous areas. At present, most of agriculture in the basin is still under the rainfed condition.

Paddy cultivation in the area is largely limited only in wet season. Dry season cropping after rice is being rarely practised. Changwat Prachinburi occupies the largest extent, whereas Chonburi has the smallest. Dominant upland crop is cassava grown widespreadly in every province. Maize is largely cultivated in Amphoes Wang Nam Yen and Sa Kaeo of Prachinburi province. Orchard plantations include mainly mango, coconut and other mixed fruit trees.

According to the table of survey results by NESDB (cf. Appendix G-3) the sub-basins where the rate of farming households with land ownership is high, are the LBP, MNN, and UBP mainly in paddy field zones. On the contrary, the sub-basins where the rate of that with no land ownership is high, are the KPS, UPP, and KTL in dry field zones in Prachinburi and in Chachoengsao. The sub-basins MPP, MHM, and UBP in Kabinburi and Sa Kaeo in the Prachin river basin are in the intermediate zone. At the same time, such farmers as mentioned above, have many lots of leased lands as well as their own farming lands.

3-2-5. Transportation and Communication

The main measures of transportation in the area are road networks. Six routes of the national roads, namely, No.34, 304, 305, 315, 319 and 331 are distributed. The route No.34 runs to the border of Cambodia by way of Prachinburi.

A new railway to connect Chachoengsao with Sattahip was constructed under the Eastern Seaboard Development Program. The railway is extended 159 km long in Prachinburi, 54 km in Chachoengsao and 13 km in Nakhon Nayok.

It is 75 km in distance from the Capital of Bangkok to Chachoengsao City, 80 km to Chonburi, 102 km to Nakhon Nayok and 127 km to Prachinburi. Navigation is also active on the Bang Pakong river. In Thailand, there are 9 commercial ports where foreign ocean liners can call, and 3 harbours of which, that is, Ko Sichang, Siracha and Sattahip, are situated in Chonburi Province.

In the chain of the Eastern Seaboard Development Plan, the construction project of Lam Chambam Commercial Port has been implemented and completed in 1990, expecting container ships' calling.

The number of motor vehicles being registered in the fiscal year 1984, together with a growing rate since 1972, are shown in the following table. Remarkable figures are seen from the table in the number of vehicles in Chonburi and in the rate of growth in the Chachoengsao.

Number of Motor Vehicles Registered

Vehicle	Item	Conburi	Chachoengsao	Prachinburi	Nakhon Nayok
Passenger Car	Nos. in 1984	9,257	2,088	1,550	873
	% (1972=100)	(170)	(344)	(264)	(258)
Vans & Trucks	Nos. in 1984	20,419	6,761	4,404	902
	% (1972=100)	(143)	(713)	(524)	(130)
Motor Cycles	Nos. in 1984	42,503	8,354	10,811	10,006
	% (1972=100)	(209)	(504)	(453)	(453)

Source: Statistical Report of Region, Eastern Region, NSO

As regards communication facilities, the present status of dissemination of electricity, radio and television are as follows:

Dissemination of Electricity, Radio and Television

Item	Chonburi	Chachoengsao	Prachinburi	Nakhon Nayok
Total Household (A)	106,239	76,689	109,309	32,732
Electricity Distributed (B)	71,867	43,498	58,218	22,652
(B/A) (%)	67.6	56.7	53.3	69.2
Radio Provided (C)	99,152	67,464	88,411	28,463
(C/A) (%)	93.3	88.0	80.9	87.0
T.V. Provided (D)	54,000	34,550	22,218	14,456
(D/A) (%)	50.8	45.0	20.3	44.2

Source: Village Survey, 1987, NSO

3-3. Land Resources

3-3-1. Existing Land Use

In the total area of 1,776,000 ha, the agricultural land occupies 993,760 ha or 56 percent. The remaining 772,240 ha or 44 percent is devoted to mountains, forest and others. The agricultural land comprises paddy, upland, orchard and vegetable field with some other farmland in the serial extent of 467,290 ha or 27 percent (%), 391,060 ha (22%), 102,000 ha (6%) and 24,410 ha (1%) respectively.

Paddy is limited only in wet season without dry season crop after rice. Dominant upland crop is cassava grown widespreadly in every province in the Project area. Maize is another crop grown in some extent. Orchard is mainly mango, coconut and other mixed orchards. Vegetable is grown in the area with adequate water. The main constraints in the area are floods often occur in wet season in some area and lack of water for dry season crop cultivations. A large extent of paddy land in the western portion of Study area is under acid sulfate soils which also cause problems of use of land. These can be alleviated by construction of dams and irrigation schemes.

With the irrigation development project, the preliminary land use patterns within the irrigable areas will be as follows:

paddy land: wet season - paddy
dry season - soybean, mungbean, groundnut and second rice

upland area: wet season - maize
dry season - soybean, mungbean, groundnut

orchard: mainly mango, pomelo, durian

vegetables: grown in both wet and dry seasons where water is available

orchard extension: some paddy area should be changed to mango plantation

Land use categories are agricultural land and others. Agricultural land comprises lands planted to paddy rice, upland crops, orchard and vegetables. Statistics of land use by Amphoe and by irrigation block are summarized as given in Table 3-3 and Table 3-4.

TABLE 3-3 PRESENT LAND USE BY AMPHOE

(Area : ha)

Province/Amphoe	Project area	Agricultural Land				Other land
		Paddy	Upland	Orchard crop trees	Sub-total	
Chon Buri	206,520	48,310	103,610	25,700	177,620	28,900
A. Muang	10,400	3,340	1,910	1,550	6,800	3,600
A. Phanaat Nikhon	72,710	24,280	32,440	5,440	62,160	10,500
A. Ban Bung	58,320	7,160	36,740	7,630	51,530	6,790
A. Phan Thong	17,890	11,290	3,130	1,090	15,510	2,080
King A. Bo Thong	42,380	2,190	25,550	8,760	36,500	5,880
A. Nong Yai	5,120	50	3,840	1,230	5,120	-
Chachoengsao	444,490	91,210	75,780	19,500	186,490	258,000
A. Muang	6,760	5,110	120	780	6,010	750
A. Bang Khla	25,650	16,460	750	7,730	24,940	710
A. Ban Pho	14,770	12,550	-	950	13,500	1,270
A. Bang Pakong	5,450	2,680	30	440	3,150	2,300
A. Phanom Sarakham	112,200	21,850	23,000	1,740	46,590	65,610
A. Sanam Chai Khet	236,290	6,050	41,350	3,030	50,430	185,860
King A. Plaeng Yao	23,560	8,470	10,530	3,880	22,880	680
King A. Ratchasan	19,810	18,040	-	950	18,990	820
Prachin Buri	846,200	254,570	221,980	38,770	515,320	330,880
A. Muang	42,860	21,700	1,590	9,700	32,990	9,870
A. Bang Khla	29,440	25,710	30	840	26,580	2,860
A. Khok Pip	13,140	9,130	1,700	360	11,190	1,950
A. Si Maha Phot	31,820	16,580	6,490	3,050	26,120	5,700
A. Prachanta Kham	77,280	18,090	230	3,050	21,370	55,910
A. Kabin Buri	119,500	43,490	18,970	2,800	65,260	54,240
A. Nadi	111,180	15,010	17,360	9,700	42,070	69,110
A. Sa Kaew	206,550	67,070	66,710	4,830	138,610	67,940
A. Wang Nam Yen	69,200	4,620	56,180	1,450	62,250	6,950
A. Watthana Nakhon	104,050	30,960	16,480	2,500	49,940	54,110
King A. Khlong Hat	41,180	2,210	36,240	490	38,940	2,240
Nakhon Nayok	149,590	80,400	2,500	7,590	90,490	59,100
A. Maung	66,030	33,490	430	3,280	37,200	28,830
A. Ban Na	22,270	14,890	1,680	2,050	18,620	3,650
A. Ongkharak	15,550	13,810	310	1,060	15,180	370
A. Pak Phli	45,470	18,120	80	1,200	19,490	26,250
Other provinces	119,200	1,800	11,600	10,440	23,840	95,360
Total	1,766,000	476,290	415,470	102,000	993,760	772,240

TABLE 3-4 LAND USE BY IRRIGATION BLOCK

Sub-Basin	Project Area (ha)	Agricultural Land					Other Land Area (ha)
		Paddy (ha)	Upland (ha)	Orchard (ha)	Vege-table & etc. (ha)	Sub-total (ha)	
1. Lower Bang Pakong	310,600	102,680	144,110	17,830	8,370	272,990	37,610
2. Khlong Tha Lat	249,300	3,990	61,050	700	160	65,900	183,400
3. Upper Bang Pakong	275,700	167,380	37,130	41,880	8,560	254,950	20,750
4. Mae Num Nakhon Nayok	193,300	81,680	2,550	12,110	3,380	99,720	93,580
5. Middle Phra Prong	97,000	19,520	21,820	–	–	41,340	55,660
6. Mae Num Hanuman	213,000	24,520	24,550	15,470	80	64,620	148,380
7. Khlong Phra Sathung	264,300	29,960	69,970	8,170	2,050	110,150	154,150
8. Upper Phra Prong	162,800	46,560	29,880	5,840	1,810	84,090	78,710
Total	1,766,000	476,290	391,060	102,000	24,410	993,760	772,240

3-3-2. Soils of Farmland

1) Soil Classification

Soil in the study area are divided from four main parent materials namely marine sediments, brackish water sediments, riverine sediments and residuum/colluvium from clastic rock, granite and limestone. The low lands in the western portion are under marine brackish water sediments and recent and semi-recent riverine alluvium. Landforms are tidal flat, former tidal flat and flood plain. Soils are very deep, poorly drained and mostly clayey. Acid sulfate soils which are derived from brackish water sediments are problem soils but can be improved by irrigation and liming material application. On higher terrace found in position above paddy land, the soils are formed from old alluvium whereas those on highlands and foothill areas are derived from residuum and colluvium of mainly clastic rocks and a small extent of granite and limestone. Soils are deep well drained to moderately lateritic and fragmental soils. All of these soils can be identified based on their suitability for growing crops as shown in Table 3-5. Land suitability can be summarized as follows:

Soils Suited for Paddy and Well Suited for Irrigation

These soils occupy the flat lowland of the basin. They are derived from marine sediments, brackish water sediments and riverine sediments. Most are very deep, poorly drained, slow permeability, clayey texture. The pH of marine sediment is high. Those derived from brackish water sediments are acid having low pH. These soils are well suited for irrigated paddy. In dry season with irrigation water, upland crops such as soybean, mungbean, sesame, maize and vegetables can be grown well. These soils cover approximately 475,710 ha or about 29% of the Bang Pakong river basin.

Soils Suited for Upland Crops, Unsuited for Irrigation

These soils are derived from sandy old alluvium on middle terrace. They are very deep, excessively drained, permeable sandy soils. They are poorly suited for upland crops and not suited for irrigation due to excessive permeability. These soils cover approximately 8,250 ha or about 0.5% of the basin.

Soils Suited for Upland Crops, Tree Crops or Reforestation, Unsuited for Irrigation

These are rather shallow gravelly soils. Gravels are lateritic concretions and rock fragments. Most are derived from both old alluvium and residuum. They are poorly suited for upland crops. Tree crops and

reforestation are more favorable. Irrigation is not suitable due to gravels and high elevation. The coverage is some 380,570 ha or about 23%.

Soils Suited for Upland Crops or Tree Crops, Unsuited for Irrigation

These soils are derived from residuum and colluvium of granitic rock. They are mostly very deep sandy soils with some inclusion of loamy soils. Drainage is moderately well drained to well drained. Nutrient status is low. Existing crops are mostly cassava, sugarcane with some para-rubber. They are considered poorly suited for upland crops due to sandy texture and low nutrient status. However para-rubber and other tree crops can be grown well. Due to soil texture of permeable sand, irrigation is thus not favorable. The total area of these soils is about 117,400 ha or 7%.

Soils Suited for Orchard, Well Suited for Irrigation

These soils are derived from riverine alluvium occurring on the river levee and the area along the river course. Those found along the Bang Pakong river are very deep clayey soils already ridged to improve soil drainage for mango plantation. Some of these areas were used to be paddy lands before. Those on the levee are very deep stratified loamy textures having moderately well drained and well drained. They are physically well suited for orchard plantation and can be well irrigated. Other upland crops and vegetables can also be well cultivated. The extent is approximately 47,750 ha or 3% of the basin.

Soils Suited for Orchard and Upland Crops, Moderately Suited for Irrigation

These are derived from old alluvium on undulating topography. The soils are very deep, moderately well drained to well drained, loamy texture. Water holding capacity is medium and permeability is moderate. Soil fertility is expected to be low. They are generally well suited for orchard and moderately suited for upland crops. Thus orchard is considered to have a priority if adequate water is available. These soils are moderately suitable for irrigation development, however, a particular method may be required depending on topographic features. The extent of these soils is about 323,630 ha or 20%.

Soils to be Reserved for Forest

These include the mountainous and slope complex areas. The soils are generally very shallow. Due to many severe limitations such as very high topography, steep slope and severe erosion, these areas are not suited for crop cultivation and irrigation. They should be restricted for forest land and

wildlife. The extent of these areas is approximately 287,350 ha or about 17% of the basin.

Soils to be Reserved for Mangrove Forest

These soils are derived from marine sediments occurring on tidal flat area which are found around the mouth of the river. These are still under the influence of sea water. Soils are very deep, poorly drained, and characterized by very dark gray unripe marine clay. Fertility level is rather high. Due to the fact that these soils are flooded by sea water during high tide, they are not suited for crop cultivation and should be restricted their use for existing mangrove forest or shrimp pond. The area is approximately 6,140 ha or about 0.4%. (cf. Appendix B-2)

2) Problem Soils and Their Improvement

The term "problem soils" refers to those having certain chemical or physical characteristics which restrict agricultural development. In the study area, actual acid sulfate soils and potential acid sulfate soils are dominant. (cf. Appendix B)

A) Actual Acid Sulfate Soils

a) Their Characteristics and Effects

These soils cover some 204,800 ha or about 11.6 percent of the Study area. Nakhon Nayok has the biggest coverage of about 85,300 ha, Chachoengsao and Prachinburi have nearly equal area of 51,667 ha and 51,767 ha Chon Buri occupies the smallest extent of 16,067 ha.

The actual acid sulfate soils are formed from brackish water sediment on former tidal flat. They are under paddy cultivation with some parts which have been changed to other uses such as orchard plantations namely tangerine, mango, coconut and betelnut.

The profile shows clayey-textured throughout. The occurrence of straw yellow jarosite mottles or basic ferric sulfate or cat-clay ($KFe_3(SO_4)_2(OH_6)$) in the profiles is the main characteristics of these soils. The jarosite is formed from the oxidation of pyrite (FeS_2) in the soils. It causes very strongly acid to extremely acid reaction and occurring above the pyrite horizon which is the dark gray or bluish marine clay horizon. This pyrite horizon has pH of 7 to 8 found at the deep subsoils normally below 150 cm.

These soils directly affect the changes of elements in soils, in turn resulting in their availability level to plant. Calcium, magnesium and also potassium are deficient due to the fact that they are easily to be leached out from the soils. Iron, aluminum and manganese are excessively soluble until reaching the toxic level by which phosphorus will be fixed through precipitation and fixation processes. Soil micro organism will be less active in acid soils making organic decomposition very slow and the release of nitrogen, phosphorus and sulfur is very poor. This is why these three elements are deficient in acid soils.

The actual acid sulfate soils in the study area comprise soil units of Maka phot, Rangsit, Rangsit-very acid, Ongkharak, Don Muang undifferentiated ridged acid soils and Chan-Am series.

Based on the degree of acidity, these can be identified into normal and very strongly acid sulfate soils.

Normal acid sulfate soils are those having the surface soil pH higher than 4.5. These are not too strong acid condition. Jarosite mottles occur below 40 cm from the surface. They include the soil series of Maha Phot, Rangsit, Don Muang and undifferentiated ridged acid soils. Total extents are some 167,900 ha.

Very strongly acid sulfate soils are those having surface soil pH lower than 4.5 such as the Rangsit-very acid, Ongkharak and Cha-Am series making the total areas of about 36,880 ha.

b) Improvement Method

Hydrotechnical Method

This is to wash out the sulfate by water with good leaching and drainage system. Good quality of irrigation water, ditches and drainage canals with sufficient control of water level are required. In the rainy season, the sulfate will decrease naturally especially when they are under paddy cultivation. Pre-flooding the paddy cropping is also practical method.

Lime Application

Lime is the oxide, hydroxide and carbonate of calcium and magnesium. Those compounds are acid soil amendment materials. There are many types of liming materials such as ground lime, flue dust, white lime, burning shell and marl. It is found by DLD that marl as well as other liming materials can improve acid soils. Due to its very low price and enormous amount

which can be easily taken from the limestone areas of Nakkon Sawan, Lop Buri and Sara Buri, marl is the important agricultural lime recommended to be used for acid soil improvement. Economic return is also higher than other materials. The five-year trials of DLD summarized that optimum rate of marl application is 1 ton per rai (6.25 ton/ha) together with chemical fertilizer such as 30 kg/rai (187.5 kg/ha) of ammonium phosphate (16-20-C). Lime is applied only once in five years.

Lime application to acid soils results in changes of soil properties favorable to crop cultivation:

Improve physical properties of soils

Soil texture will become more granular and crumb structure which is more friable and good for plant growth.

Improve chemical properties of soils

pH of soils will be increased resulting in changes of chemical properties of soils.

- reducing H^+ concentration
- excessive soluble Fe, Al and Mn which are toxic to plant will be reduced.
- available phosphorus and molybdenum will be increased.
- available calcium and magnesium will be increased.

Improve biological properties of soils

Soil organism will become very active favorable to the processes of aminization, ammonification and nitrification which release many elements available to plants such as nitrogen, phosphorus etc.

Lime will help reduce or slow down the growth of some diseases in soils.

Other Methods

There are other methods to correct acid soils such as application of rock phosphate, introducing the acid tolerant crops/varieties. The acid soil areas can be cultivated to rice or other acid tolerant crops such as water melon and they also can be developed for fast growing trees such as pine and eucalyptus. Fruit orchards such as

tangerine, mango can also be adopted. However, adequate irrigation water and liming are necessary.

B) Potential Acid Sulfate Soils

a) Their Characteristics and Effects

The potential acid sulfate soils are the minor problems. They occur only 6,140 ha or about 0.4 percent of study area and occupy mostly non-agricultural area. The areas having such soils are definite in only Chon Buri and Chachoengsao on tidal flat around the month of Bang Pakong river. Existing land use is mostly mangrove forest and nipa palm with some areas adapted for shrimp ponds. These areas are still under the influence of sea water which will flood during high tide.

Soils are very deep, poorly drained having very dark gray unripen marine clay. Soil reaction is neutral to mildly alkaline with pH 7 to 8. Soil fertility is relatively high. They contain a high content of pyrite (FeS_2) under submergence and reduction. These soils are still potential acid sulfate condition with high pH. Whenever they are drained or the pyrite exposes to atmosphere, the pyrite will be oxidized becoming acid condition.

Soils of this group comprise Bang Pakong series and Tha Chin and Bang Pakong complex.

b) Improvement Method

i) Due to the fact that these soil are flooded by sea water during high tide and still being under mangrove forest, they are not suited to be developed for any kinds of crop cultivation. Existing mangrove forest should be preserved.

ii) Control groundwater level and keep it shallower than the pyrite-rich layer to prevent oxidation of the pyrites.

3-4. Water Resources

3-4-1. General Climatic Factor

The synoptic meteorological data being collected by MD and RID could offer the general climatic features in the Bang Pakong river basin. RID's meteorological stations are located at every Changwat in the basin, in which two Changwats, Chonburi and Prachinburi, are also observed by MD.

Climatic features such as temperature, precipitation, evaporation, relative humidity and winds are summarized briefly as follows;

- Temperature is the most stable meteorological feature in the entire basin throughout the year. Mean annual value is between 26 and 27°C and mean monthly fluctuation is also within a little range between 26°C in January to 30°C in April.

- Annual precipitation shows a wide range of areal difference from the lowest of 900 mm in the southwestern part of the basin to the maximum of 2,400 mm in the northern part of Prachinburi. Monthly precipitation also has a considerable difference from the average value of 200 mm in wet season to less than 50 mm in dry season with the highest value of around 300 mm in September against the lowest value of less than 10 mm in December and January.

- Evaporation range is small over the entire river basin, with an annual average of 1,700 mm. Monthly evaporation varies from the highest of 170 mm in March and April to the lowest of 120 mm in November.

- Relative humidities are recorded at 71 to 74% as the mean annual values. The highest is 80% in October and the lowest is 60% in December and January. Although the mean annual value varies within the range of only 3% between Chonburi and Prachinburi, the monthly lowest in dry season differs from 66% in Chonburi facing the Gulf of Thailand to 60% in Prachinburi, 90 km northeast inland from Chonburi.

- Wind also differs from 4.6 knots at Chonburi to 2.9 knots at Prachinburi in its mean value. As regards the prevailing wind in a year, the northeastern wind in November to December and southwestern wind in February to March are dominant.

3-4-2. Precipitation

1) Available data

The precipitation data used for the rainfall analysis is obtained from the Hydrology Division of RID that has been operating the 125 stations in the Bang Pakong river basin and its vicinity with the reliable operation of network. The precipitation data is stored in the data bank in a computer according to the station code and length of observation period. For the study analysis, the object

stations are selected in and around the Project area among stations located from 13°00' to 14°45' in latitude and from 100°45' to 102°45' in longitude.

The total number of stations in the area are counted up to 125 in six provinces consisting of 32 in Chachoengsao, 12 in Chonburi, 30 in Nakhon Nayok, 15 in Nakhon Ratchasima, 25 in Prachinburi, 9 in Pathum Thani, 1 in Chantaburi and also 1 in Bangkok. The observation period is relatively long for the stations located in Ampoe Muang of Changwat, although 75 stations (60% of the whole stations) commenced operations since 1960's.

2) Annual Rainfall

Annual precipitations collected from stations for the recent 20 years since 1968 are summarized to develop an isohyet map, which would characterize the basin precipitation as follows:

- The wide range of mean annual values from the lowest of around 900 mm to the highest of 2,400 mm.
- Considerable difference of areal rainfall ranging from 1,000 mm in the lower reach of the Bang Pakong river to the highest of 2,000 mm at the foot of the mountain range configuring the northern confines of the Project area with respect to the increase in latitude.
- Dominance of the major precipitation belt in the center of the Project area having an annual value between 1,250 mm and 1,500 mm.

3) Drought Rainfall

The areal difference of rainfall in the drought year must be in proportion to that of the mean annual rainfall. The rainfall of 10-year drought is listed in comparison of the mean value at every Ampoe Muang in the basin as follows:

Ampoe Muang	Mean	10-year	(unit: mm)
Prachinburi	1,940	1,590	
N. Nayok	1,760	1,390	
Chachoengsao	1,180	1,010	
Chonburi	1,270	990	

The result shows that the annual distribution expressed as the difference between the mean and the probable values at Chachoengsao is in small range among four stations. Moreover, the amount of the 10-year probable drought is seen in the clear difference between the north and the south of the basin.

4) Storm Rainfall

The storm rainfall occurs in the course of the rainy season from July to November. To analyze its areal distribution, magnitude and seasonal frequency, four stations containing three in Prachinburi and one in Nakhon Nayok are selected from the maximum precipitation zone of 2,000 mm.

Among four stations, the hourly records during the maximum three-day consecutive rainfall are only available from the kgt.14 station (code 44181) which is equipped with an automatic gauge. A typical pattern, or hourly distribution, of storm rainfall is determined by employing the 1972 storm that occurred in September (cf. Appendix A.2.10). This storm occurred concurrently covering the major part of the river basin and is confirmed to be equivalent to 10-year probable storm.

3-4-3. Runoff

The river runoff in the basin is recorded at the 25 RID stations, of which 18 are in the Prachin river basin and 7 are in the Nakhon Nayok river basin. Three stations out of 25 have the continuous records since 1967, and 11 stations keep the data over 15 years with some missing periods.

The drainage area covered by the reliable runoff records reaches 9,700 km^2 in total, equivalent to 55% of the whole Bang Pakong river basin of 17,660 km^2.

Based on the mean annual runoff in the recent 20 years collected from those river gauging stations and the same span of rainfall records, the runoff coefficient contour could be delineated within the river basin. The runoff coefficient decreases in proportion to the decrease of annual rainfall in general, and it varies from 70% at the highest in the upper Nakhon Nayok and Prachinburi area of 2,000 mm of annual rain amount, to 30% in 1,500 mm precipitation zone and to the lowest value of 15% in the lower reach of the Bang Pakong river where the annual rain is about 1,000 mm. The major part of the basin lies in the contour belt between 20 to 30% of runoff coefficient.

3-4-4. Flood

The Bang Pakong river, originating from the northern mountain range of more than 900 m high and joining a number of affluents such as the Khlong Phra Sathung, Maenum Hanuman, Nakhon Nayok and others, traverses the broad alluvial plains from east to west and empties into the Gulf of Thailand. The lower and middle lower reaches of the river basin are

characterized by flat bed slope, meandering channel of limited small flow capacity and low banks. Channel slopes are observed at 0.1 to 0.5 m per km. Due mainly to the insufficient channel capacity and tidal effects in the river system particularly in its lower reach, the area has frequently been suffered from floodings and inundations, posing a severe hazard to both crops and population which has inevitably been exerting a negative effect on economic growth of the area.

The middle-lower and upper reaches of the Bang Pakong river system is under the tidal effect and, therefore, flood records are available only from several stream-gauge stations installed in the middle-upper and upper reaches for relatively short periods. A preliminary flood runoff analysis was conducted in order to estimate the magnitude and distribution of flood discharge in time and space. The peak flood discharge, which would occur once in 10 years, was so obtained at the order of 4,000 to 5,000 cu.m/sec at the mouth of the bang Pakong river.

3-4-5. Groundwater

Five major aquifer systems underlie in the area, they are the large scale alluvial aquifer in the Bang Pakong river basin, small scale alluvial aquifer in the intermountain valleys, the fractured aquifer in the sandstones of the Khorat Group, the fractured aquifer in limestone and the fractured aquifer in the basement rocks of the older geologic age.

The large scale alluvial aquifer is composed largely of sand beds and estimated yield ranges from 75 to 370 lit/min with 70 meters well depth in maximum but its quality indicates brackish or saline.

The unconsolidated alluvial aquifer in the intermountain valleys is composed largely of rock fragments and sand and gravel decomposed from the basement rocks and the thickness ranges from 5 to 30 meters. Groundwater yield estimates about 75 lit/min and its quality indicates generally good for potables.

The fractured aquifer in the Khorat Group is generally developed less than 60 meters depth and yield estimates 75 to 370 lit/min.

The estimated yield of the fractured aquifer in the limestone in the upper part of the Prachin river is about 370 lit/min and it attains more than 1,500 lit/min in the limited place.

The fractured aquifer in the sedimentary rocks of older geologic age is generally developed less than 50 meters depth with yield of about 50 lit/min.

FIGURE 3-1 LOCATION OF WATER QUALITY SURVEY (NEB)

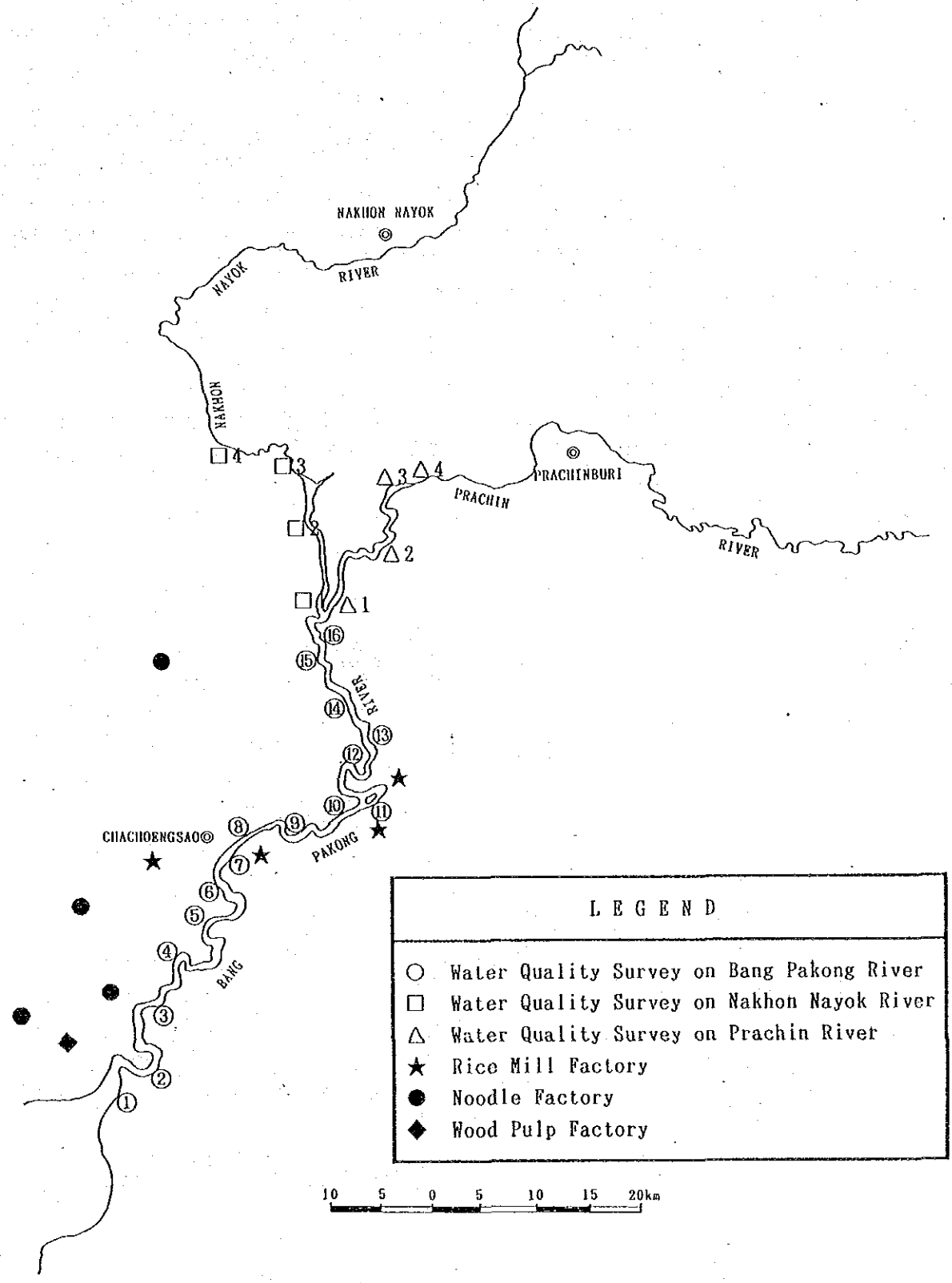


TABLE 3-5 SOIL SUITABILITY CLASSIFICATION

Soil Series	Paddy (P)	Non-flooded Annual Crop (N)	Fruit Trees (F)	Suitable Land Use according to Soil Condition
1. Tc : Tha Chin	P-Vx	N-Vfx	F-Vfx	mangrove forest.
2. Bpg : Bang Pakong	P-Vx	N-Vfx	F-Vfx	fish & shrimp pond
3. Sa : Samut Prakarn	P-I	N-Vf	F-Vf	
4. Bk : Bangkok	P-I	N-Vf	F-Vf	paddy
5. Ptg : Phan Thong	P-IIIs	N-Vf	F-Vf	
6. Ca : Cha-am	P-IVj	N-Vf	F-Vf	paddy required marl application to reduce soil acidity
7. Bp : Bang Nam Prieo	P-I	N-Vf	F-Vf	paddy
8. Cc : Chachoengsao	P-I	N-Vf	F-Vf	
9. Ha : Hahaphot	P-IIIj	N-Vf	F-Vf	
10. Rs : Rangsit	P-IIIj	N-Vf	F-Vf	paddy required marl application to reduce
11. Rs-a : Rangsit-very acid	P-IVj	N-Vf	F-Vf	soil acidity
12. Ok : Ongkharak	P-IVj	N-Vf	F-Vf	
13. Dm : Don Muang	P-IIIi	N-Vf	F-Vf	
14. NBC : Undifferentiated ridged acid soils	P-Vt	N-I	F-I	fruit orchard
15. AC-pd: Alluvial Complex, poorly drained	P-I	N-Vf	F-Vf	paddy
16. AC-wd: Alluvial Complex, well drained	P-IIIs	N-Vf	F-Vf	
17. Cm : Chiang Mai	P-Vt	N-IIn	F-IIn	fruit orchard
18. Pr : Pran Buri	P-Vt	N-IIn	F-IIn	
19. Rb : Ratchaburi	P-I	N-Vf	F-Vf	
20. Bin : Bang Pa-in	P-I	N-Vf	F-Vf	
21. Cb : Chon Buri	P-IIIs	N-Vf	F-Vf	
22. Kl : Klaeng	P-I	N-Vf	F-Vf	
23. Lgu : La-ngu	P-I	N-Vf	F-Vf	paddy
24. Hk : Hin Kong	P-I	N-Vf	F-Vf	
25. Re : Roi Et	P-IIIs	N-Vf	F-Vf	
26. Mak : Makham	P-IIIs	N-Vf	F-Vf	
27. Pn : Phen	P-IIIg	N-Vf	F-Vf	
28. Kkn : Ko Khanun	P-IIIw	N-IIId	F-IIId	fruit orchard
29. Pp : Phon Phisai	P-Vt	N-IVg	F-IVg	upland crops.
30. Bkg : Bang Khla	P-Vt	N-IVg	F-IVg	tree crop or reforestation
31. Dr : Don Rai	P-Vt	N-IIIs	F-IIn	
32. Kt : Khorat	P-Vt	N-IIIs	F-IIn	
33. Rn : Renu	P-IIIs	N-IIIsd	F-IIn	fruit orchard or upland crops
34. Suk : Satuk	P-Vt	N-IIIs	F-IIn	
35. Wn : Warin	P-Vt	N-IIIs	F-IIn	
36. Yt : Yasothorn	P-Vt	N-IIIs	F-IIn	
37. Ng : Nam Phong	P-Vt	N-IVs	F-IVs	upland crops
38. Pg : Pang Rai	P-Vt	N-IVg	F-IVg	upland crop.
39. Nkk : Nong Khok	P-Vt	N-IVg	F-IIIg	tree crop or
40. Mr : Mae Rim	P-Vt	N-IVg	F-IVg	reforestation
41. Bog : Bang Bung	P-Vt	N-IVs	F-IVs	
42. Hg : Hup Kapong	P-Vt	N-IIIs	F-IIIs	upland crop or
43. Sh : Sattahip	P-Vt	N-IVs	F-IVs	tree crop
44. Mb : Map Bon	P-Vt	N-IIIs	F-IIn	
45. Nm : Nong Mot	P-Vt	N-IIIs	F-IIn	
46. Lb : Lop Buri	P-Vt	N-I	F-I	fruit orchard or upland crop
47. Bng : Bung Chanung	P-Vt	N-IIIc	F-IVc	upland crop or tree crop
48. Tk : Takhli	P-Vt	N-I	F-IIIg	
49. Tok : Thap Phrik	P-Vt	N-IIn	F-IIn	fruit orchard or upland crop
50. Kb : Kabin Buri	P-Vt	N-IVg	F-IVg	
51. Ch : Chiang Khan	P-Vt	N-IVg	F-IVg	upland crop. tree crop or reforestation
52. Ws : Wang Saphung	P-Vt	N-IIn	F-IIIg	
53. Oc : O Luk Chaik	P-Vt	N-I	F-IIIg	
54. Ho : Huai Yot	P-Vt	N-IVg	F-IVg	
55. Tw : Thap Kwang	P-Vt	N-I	F-I	fruit orchard or upland crop
56. Ml : Muak Lek	P-Vt	N-IVgt	F-IVg	upland crop. tree crop or reforestation
57. Ty : Tha Yang	P-Vt	N-IVgt	F-IVg	
58. Ly : Lat Ya	P-Vt	N-IVgt	F-IVg	
59. SC : Slope Complex	P-Vt	N-Vt	F-Vt	forest

Notes: Soil suitability classes; I=very well suited, II=well suited, III=moderately suited, IV=poorly suited, V=not suited

Limitations; f=flooding, x=salinity, s=unfavorable soil texture, j=acid soil, n=low nutrient status, g=gravels, w=risk of water shortage, d=soil drainage, t=topography or slope, c=consolidated layer

TABLE 3-6 PROPERTIES OF WATER SAMPLES FROM BANG PAKONG RIVER

Testing Item	Unit	1986			1987		
		Maximum	Minimum	Mean	Maximum	Minimum	Mean
Temperature	℃	32.0	25.0	29.7	34.5	24.5	29.3
pH		8.00	6.80	7.25	8.20	6.57	7.20
Salinity	ppt	25.70	0.00	-	25.50	0.00	-
Conductivity	μmhos/cm	41,800	62	-	38,500	50	-
DO	mg/l	6.10	3.10	4.45	7.40	2.60	4.78
BOD	mg/l	4.60	0.01	0.99	3.40	0.10	0.86
COD	mg/l	94.60	4.40	16.29	50.00	8.20	21.02
Total Coliform	MPN/100ml	24,000	130	4,300	92,000	140	6,860
Fecal Coliform	MPN/100ml	9,200	50	1,101	24,000	20	1,486
Total P	mg/l	0.097	0.001	0.024	0.050	0.010	0.014
Alkalinity	Mg/l as $CaCO_3$	84.0	23.0	37.8	101.6	18.0	45.3
NH_3-N	mg/l	0.74	0.02	0.08	0.15	0.02	0.03
NO_2-N	mg/l	0.088	0.002	0.014	0.170	0.010	0.026
NO_3-N	mg/l	1.090	0.023	0.405	1.350	0.010	0.427
Cu	ppb	21.3	1.8	7.5	34.4	1.2	9.5
Mn	ppb	1,185	26	606			
Zn	ppb	196	5	38			
Hg	ppb	2.25	0.16	0.28	0.70	0.20	0.13
Cd	ppb	4.31	0.10	0.79	2.50	0.10	0.57
Cr	ppb	31.3	2.4	9.4	65.0	1.0	8.2
Pb	ppb	19.0	1.0	4.5	21.0	1.2	6.2
Fe	ppb	8,300	1,235	3,457			

Groundwater yield of the large scale alluvial aquifer near Chachoengsao attains 10 to 20 m^3 per hour but its quality indicates saline due to seawater encroachment during marine transgression in the early Holocene.

3-4-6. Water Quality

Water quality survey has been made on the Bang Pakong river and its main tributaries by the national Environment Board (NEB) for the recent five years. Water samples were taken four times a year from 16, four and six sampling sites situated respectively on the Bang Pakong river, Nakhon Nayok river and Prachin river. Such locations are given in Figure 3-1. Data obtained were then averaged to evaluate the properties of water as presented in Table 3-6. Besides salinity problem, as far as principal elements of water quality regarding irrigation water application are concerned, the Bang Pakong water is considered to be suitable for irrigation uses.

Date of Water Sampling

Year	Date
1986	8 November (1985), 28 February, 6 June and 8 August
1987	1 November (1986), 5 February, 21 May and 26 August

Another serious problem in these areas is the recent rapid progress of shrimp culture promotion. Many shrimp ponds, which require salt water mixed with fresh water, have been developed both right and left banks of the Bang Pakong river near the estuary. Such shrimp ponds lie scattered in the existing paddy area confronting difficulties in water control and distribution. Water drained from shrimp ponds may damage paddy crops.

3-4-7. Sediment Deposition

The observation of sediment yield has been continued by RID at four gauging stations in Prachinburi Province with regard to the suspended load. The location, observation period and catchment area at four stations are presented as follows. The observation is incorporated in rivergauging stations. In addition to those stations, RID has started observations at four other stations, namely kgt-18, 25, 27 and Ny-4, in 1988, which are located on Khlong Si Yat, Khlong Rabom, Khlong Yang and Maenum Nakhon Nayok. Those records will be available from 1990.

Suspended Sediment Observation

Station	Stream	Catchment Area Km	Observ.Period	Suspended Load ton/sq.km
Kgt.3	Prachin	7,502	1968 - 1986	65
Kgt.10	Phra Sathung	2,523	1967 - 1988	29
Kgt.12	Phra Prong	1,540	1967 - 1986	23
Kgt.14	Huai Yang	366	1967 - 1983	65

Although the measured suspended load shows rather low values in wide catchment areas, the sediment yield at the proposed damsites is to be estimated in consideration of following conditions,

- Bed load volume without having observation data.
- Vegetation and geographic conditions of watershed area.
- High sediment yield in upper river areas for dam basins.
- Employed design values for the completed and on-going projects.

The sediment yield in the Bang Pakong basin is thus evaluated in two areas, divided by Prachin river, in which 200 and 250 cu.m/sq.km/year is for the north and the south arears respectively.

3-5. Regional Agriculture

3-5-1. Agricultural Production

The basic agricultural product in the Project area is rice. In four provinces i.e., Chonburi, Chachoengsao, Prachinburi and Nakhon Nayok, 588,246 tons of rice were produced occupying only 3.2 percent(%) of the share in the whole country product. These provinces are ranked as provinces importing rice from other areas, having the following major characteristics.

- 83,390 tons of mango were produced sharing about 20% of the whole country.
- The number of chickens and ducks were ranked as the first of the whole country.
- Shrimp culture has been developing recently. The shrimp culture area was 2,376 ha or 1.1% of the whole country.
- Those four provinces have 501,976 ha of forest land without producing any agricultural benefit.

3-5-2. Crop and Cropping Pattern

The Project area extends over four provinces, namely; Chonburi, Chachoengsao, Prachinburi and Nakhon Nayok, having 24 Amphoes within the area, and covers 993,760 ha of agricultural land. Cultivated area per household is estimated at 4.8 ha which is larger than the national average of 4.2 ha. Crop intensity is 100% which is a little bit smaller than the national average because of lack of irrigation water in the dry season predominantly. Vegetables are cultivated during dry season only in small areas.

According to the 1988/89 statistics, the paddy area extends over 476,000 ha occupying about 48% of total net areas. Upland, orchard and vegetable areas are approximately 391,000 ha or 39%, 102,000 ha or 10% and 24,000 ha or 3%, respectively. Crops are mostly grown during wet season, however, the crop yield stays low and unstable due mainly to the lack of flood control of drainage facilities. Some simple facilities for irrigation are found in the orchard area, especially in mango plantations, however, irrigation water is still inadequate.

Main crops in the Project area are paddy, cassava, maize, sugarcane, soybean, groundnuts, mango, durian, pomelo and coconut. Beside these, some special crops such as bamboo-shoot and jack fruit are cultivated in Prachanburi and Chonburi provinces respectively.

3-5-3. Agricultural Product

The present average crop yields and total product of main crops in the Project area are summarized based on the "Agricultural Statistics of Thailand for the Crop Year 1987/88" and the "Provincial Agricultural Statistics" prepared by the four provincial agricultural extension offices in the past three years, 1984/85 to 1987/88, as shown below:

Agricultural Statistics of Related Amphoe

Crops	Harvested Area	Yield	Product
	ha	kg/ha	ton
Paddy	510,150	2,186	1,115,440
Paddy in the Project Area	348,800	2,186	about 762,500
Cassava	170,100	15,864	2,698,451
Maize	107,263	2,881	308,983
Soybeans	9,725	1,270	12,350
Mungbeans	3,014	779	2,349
Groundnuts	2,499	1,635	4,087
Sugarcane	28,090	41,852	1,175,629
Cotton	4,939	1,517	7,490
Kenaf	6,111	1,770	10,819
Mangos	15,539	5,567	86,509
Coconuts	11,830	4,598	54,399
Jack Fruits	589	17,971	10,585
Bananas	3,040	14,762	44,875
Durians	1,500	11,661	17,491
Oranges	858	16,058	18,949
Pomeloes	433	14,896	6,450
Bamboo	7,697	10,880	83,744

Related Amphoe: 26 Amphoes

3-5-4. Marketability of Major Crops and Its Structures

1) Export and Price of Major Agricultural Products

Thai exports of agricultural products have contributed to improving the trade and balance of payments, and kept always leading rank of export value even when international commodity price such as rice rubber, tapioka, sugar and maize hovered at low level in 1985 - 86.

The export items of which volume rose substantially were new manufactured products such as computer components, plastic products, furniture and parts, foot wear, integrated circuits and canned seafood.

Thai agricultural production is influenced firmly by economic environment arising outside countries and always supported on continuous demand, so that there is a strong character of dependency of overseas market. (cf. Appendix G-7)

International prices of major crops have risen rapidly from the bottom of prices in 1985 - 86, with high economic expansion and supported on a firm demand caused by going up of global consumption level. (cf. Appendix G-8)

In parallel with the farm gate price of paddy; oil seeds, fibre plants, fresh vegetables and live animals also increased significantly and led to substantial gain in food and feed prices.

A) Rice

The export of white rice marked 5.267 million ton in 1988, and is prospected at 5.9 million ton in 1989. On the world market, the export price of BOT (FOB Bangkok) fetched a high price of $369 in July 1989 after the bottom of $210 in 1986, in consequence both export volumes and value have been increased. However, Vietnam and Pakistan also participated in international rice market as strong competitors, the demand and the supply in the world rice market came loose, and the price is beginning decline to $300.

According to the forecasting of rice demand and supply in Thailand shown in the following, reserves for rice export in 2000 year are amounted to about 6 million ton. The rice export marketability could be expected available in considering recent rice export results, even if paddy production will be increased to some extent.

Outlook of rice demand/supply in 2000

Paddy production	26,174 million ton
in which domestic consumption	17,162 million ton
Reserve for export	9,012 million ton
	(corresponding to 5,948 million ton of rice)

Calculation basis;

a) total population: 64.389 million persons
   by NESDB: Population Projection in Thailand
b) paddy consumption per person:
   for farmers 328 kg/year (including seeds and others)
   for non farmers 225 kg/year
c) converting rate from paddy to rice: 66% (cf. Appendix G-10)

B) Maize

Thai maize exports increased annually up to a few years ago, but recently retarded at 1.65 million ton in 1987, at 1.15 million ton in 1988, and at 1.2 million ton in 1989, in spite of the recovery of maize production of 5 million ton in 1989.

Meanwhile, domestic demand for feed has been rising sharply in these 10 years, and it is forecasted to increase to 2.55 million ton in 1989, 2.9 million ton in 1990, owing to rapid expanding of livestock industry (the growth rate of livestock during 1981 to 1987 was 6.1%), and the compound feeds usually require maize of about 53%, soybean cake of about 21% as the raw materials.

C) Soybean

The annual production volume was 50,000 ton during 1960's, 100,000 ton during 1970's, and exceeded 300,000 ton in 1985/86, at last exceeding 400,000 ton in 1988/89. About 100,000 ton of the production are provided for traditional food processing such as TOFU while the rest of about 80% are destined to oil factory. In parallel soybean cakes also increase as by-product of oil industry. However those products couldn't overtake even radical expansion of feeds industry.

The Ministry of Agriculture made a program of soybean production self-sufficiency which accelerates the product to be set the goal of 850,000 ton in 3,269 million rai in 1993/94 and after that 1,150,000 ton in 3,966 million rai in 1996/97.

D) Mungbean

The current production continues a tendency of decrease or stagnation after the peak production of 350,000 ton since the price levels hang at low. The export of mungbean decreased below the level of 100,000 ton a year. The export of black matpe bean to the Japanese market, the major importer also decreased, due to losing price and quality competitiveness with China and neibouring countries such as Burma.

E) Groundnuts

Ground nuts production is almost constant amounting to around 170,000 ton a year during last several years. Their export shouldn't be expected in prospect, because of being put in strong competing articles, such as soybean and oilpalm as international plants for oil seeds.

F) Mango

The mango production annually averages about 400,000 ton, with principal growing area in Chachoengsao, Chonburi, Ratchaburi, Saraburi, and Nakhon Ratchasima. About 6,700 ton is destined for export market in 1988. Main export markets are Malaysia, Hong Kong, Singapore, EC and Japan. The export prospect of Thai mangoes is still bright, even though the Philippines is a giant competitor with Thailand, providing 4,200 ton against 48 ton only of Thailand in the Japanese market. Since the introduction of vapor heat treating system in 1988, Thailand has become a promising potential source.

G) Vegetables

In Thailand, the vegetable production is not necessarily for export different from other economic crops. However, in alignment a rapid expansion of big supermarket chain shops and family restaurant chain shops in the

advanced countries such as USA, Japan and EC from the last decade, the demand of vegetables for mass-consumption become active and the exports from Thailand are starting a little, too.

The fresh vegetables, such as onion, shallot and baby-corn for EC as well as the fresh vegetables such as okra, asparagus etc. for Japan come to be able to be transported by air-cargos or reefer container boats.

Many items and varieties of the vegetables suitable for Japanese consumption tendency e.g. green soybean (EDAMAME), green pea pods (KINUSAYA), mushroom, broccoli, lettuces and so on ... began to appear in the Bangkok market, too.

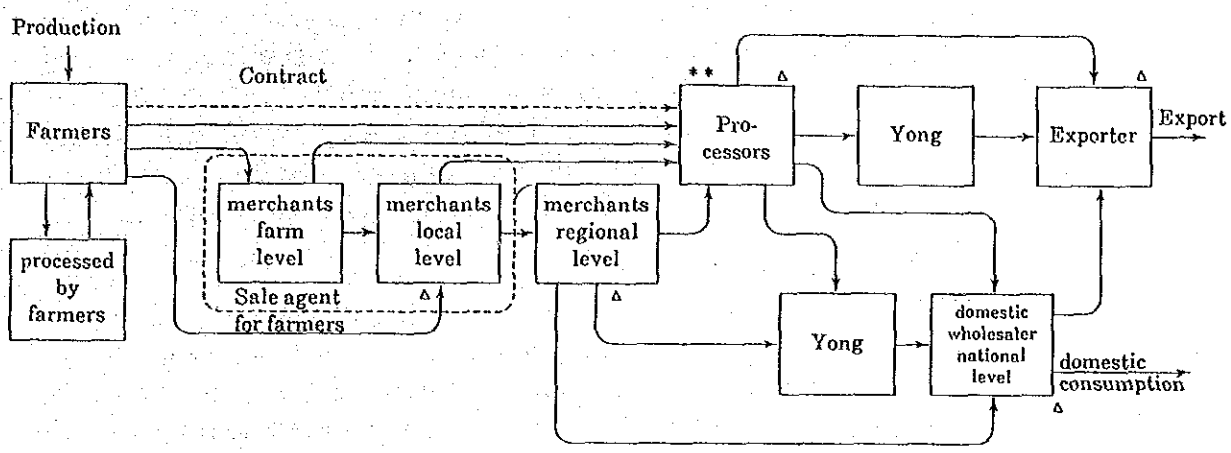
Meanwhile, the amount of the frozen vegetables in Japanese market has been increasing by 20% of growth rate annually, and marked more than 300,000 ton in 1988. Although the Japanese markets have gotten about 30% of vegetables imports from Taiwan, most of which will be shifted to Thailand due to new Taiwanese currency appreciation. Considering the Japanese markets also continue to enlarge in future, frozen vegetables exports from Thailand will increase to more than 50,000 ton on the condition that the vegetable production of consistent quality and quantity with special standard and specification is possible and also space of aircargo or reefer container boat can be insured instantly and easily, while the inland transportation network of frozen container truck is arranged.

2) Distribution and Marketing of Agricultural Products

A) In general, distribution and marketing of Thai agricultural products are traded by Chinese-Thai merchant, not farmer's own capital. As the channels of crops circuits are shown in the following charts, most products are transported to Bangkok from producing farmer through local level merchants (in village, district or province), and finally delivered to inland or overseas consumers.

There is unneglectable existence of the big brokers in Bangkok (so called Mr. Yong), who are playing an important role on distribution of agricultural products in Thailand. They are agents on distribution among local merchants (at amphoe or province), and foods processors, exporters or wholesalers in Bangkok, announce a price quotation and daily informations to the local merchants concerned, and sometimes advance payment fund to collect products. They may be likend to "Sogo-Shosha" plus middleman in the Japanese Central market.

FIGURE 3-2 MARKETING CHANNELS FOR AGRICULTURAL PRODUCE



Remarks : Processors
rice : rice miller
sugar : sugar refinery
kenaf : kenaf baling plant
coffee : roaster

* some merchandise e.g. kenaf, rubber, maize
** some do not need procession e.g. maize
△ warehouse

B) There are some examples in case of rice trading as shown below:

a) For fixing the cost of rice, Mr. Yong will look at the prices which the various exporters have quoted as a main point and will notify the local merchants and rice-mill about the daily price that he can buy.

b) After that he will wait for the reply and the price at which such rice-mill would like to sell, then notify each exporter. After both the party were satisfied with the price, Mr. Yong will collect the rice, check the quality so that it coincides with the requirement of each exporter, and control to hand over concedes the rice.

c) In operating this business, Mr. Yong will charge the broker's commission corresponding to approximately 60% of the proposed sale price. The rice-mill will have to pay the broker's commission. Mr. Yong will follow up collecting the money from the exporters. At the time when he will pay in advance to the rice-mill, the rice-mill could circulate his money in buying more paddy from the farmers or the paddy merchants, for milling more rice for distribution.

d) As regards the sale of rice to the wholesale merchants who are the middle-men (Yee Pua) in Bangkok, they will also have to pass through Mr. Yong. The price which Mr. Yong fixes each day will be higher than that fixed by each exporter, since on selling rice to the wholesale merchants, it is normally in a small volume or it may be on a credit system, even though the rice to be sold to the merchants for being forwarded to Bangkok may be of good quality (whether it is year rice or old rice) and the rice to be sold to the exporters may be an additional or transitional crop which is cheaper.

e) However, the price of wholesale rice will conform with the price of the exporters. When the price quoted by the exporter is higher, the price quoted by the wholesale merchant will become also higher and the wholesale merchant will quickly buy up more rice for fear that the price goes up. But if the wholesale merchant knows that the price goes down, he will quickly try to sell more rice.

Marketing channels and their structures of rice, cassava, maize, soybean and mango are attached in Appendix G-11, 12, 13, 14, 15.

3-5-5. Agricultural Institutions and Farmers Group

1) Agricultural Extension

Under the organization of Department of Agricultural Extension of MOAC, provincial and local agricultural extension offices are provided in each Changwat and Amphoe. Responsibility of agricultural extension offices is to extend agricultural techniques in farming practices, and to conduct surveys on crop yield and production. In recent years supported by World Bank loan, activities of agricultural extension offices have been much intensified, however, they still suffer from shortage of staff members for implementation of their services and duties. Existing situation of agricultural extension services in four major provinces in the Study area is given below:

Province	No. of Staff	Agricultural Area	Area/staff
		ha	ha
Chonburi	109	326,201	2,993
Chachoengsao	115	297,430	2,586
Prachinburi	135	599,832	4,443
Nakhon Nayok	55	133,087	2,420

2) 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. PBRC was established initially as the Prachinburi Rice Experiment Station, and was upgraded to a Research Center in 1982. Research organization and personnel engaged are as follows:

Organization		Personnel	
1)	Varietal Improvement Unit	Staff	28
2)	Genetic Unit	Worker	
3)	Agronomy Unit	- Permanent	14
4)	Plant Pathology Unit	- Temporary	42
5)	Entomology Unit	Total	84
6)	Soil Research Unit		
7)	Post Harvest Technology Unit		
8)	Seed Technology and Production Unit		
9)	Specialized Project		

3) Farmers Group

A) Agricultural Cooperatives

One agricultural cooperative is stationed at every Ampoe and the other cooperatives are stationed for special purposes, such as swine raising, milking cows, water use, land reform, etc. Besides some local settlement cooperatives supervised directly by DCP are found. The numbers of cooperatives are as shown below:

Province	Agricultural	Land Settlement
Nakhon Nayok	7	2
Chachoengsao	22	-
Prachinburi	20	12
Chonburi	10	-

B) Farmers Group

Farmers groups are found in each Ampoe, supervised by DOAE. The 37 farmers groups in Nakhon Nayok, 68 in Chachoengsao, 98 in Prachinburi and 21 in Chonburi are counted.

C) 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 69% in Nakhon Nayok, 41% in Chachoengsao, 31% in Prachinburi and 34% in Chonburi (cf. Appendix G-16). It is considered that BAAC's activities have gotten well acquainted with farmers than other institutions.

3-5-6. Livestock

Cattle and buffalo are fed as draft animals and swine, chicken and duck are raised for foodstuff. At present, cattle and buffalo 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 four provinces concerned are as follows.

Livestock in Four Provinces

Province/year	Cattle	Buffalo	Swine	Chicken	Duck
	head	head	head	1,000head	1,000head
Chonburi					
1987	16,405	20,453	231,162	1,174	14,000
1988	18,560	16,282	227,847	1,089	12,942
1989	20,978	14,282	332,847	918	11,830
Chachoengsao					
1986	37,468	15,882	573,402	1,234	10,608
1987	45,992	13,860	418,160	1,198	12,292
1988	46,851	11,163	431,421	648	11,208
Prachinburi					
1986	44,856	97,813	40,198	3,001	113
1987	53,249	100,321	108,376	2,891	165
1988	69,783	105,835	101,965	2,419	140
Nakhon Nayok					
1987	8,192	15,924	25,370	2,669	51
1988	8,245	15,847	25,184	2,412	52
1989	8,988	16,375	26,910	2,204	47

Source: Provincial Livestock Office

3-5-7. Fishery

Fishery in the Study area consists of brackish water fishery and inland water fishery. The former has been developing in the lower reaches of the Bang Paking river stretching on both banks, and the latter in the paddy field areas in both Chonburi and Chachoengsao provinces. Brackish water fishery is being farmed mostly by fishery enterprises with large ponds. On the other hand, inland fishery, which has been expanded rapidly in last five or six years, is managed by farmers who converted their rice fields into fish ponds in order to obtain higher income than that expected from rice cropping. According to the Village Survey by NSO, numbers of households with fishery career are specialized as follows:

Inland fishery farmers, who receive water for fish pond supplied from irrigation facilities controlled by RID, release fish seeds into pond in June to July and market fishes when grown up after six to seven months. Fish pond water is not available during March to May. If the water is available during this period, two cycles per year of fish culture may be managed contributing to a great deal to expansion of farm income.

Number of Households with Fishery Career

Province	Amphoes	Nos. of Households have Fishery Career
Chonburi	M. Chonburi	647
	Phan Thong	281
	Phanat Nikhom	65
	Ban Bung	n.a.
Chachoengsao	Bang Pakong	946
	Ban Pho	280
	M. Chachoengsao	67
	Bangk Khla	12

Note: Fishery in Chonburi is treated as inland fishery, while inland fishery farmers in Ban Bung were found from field survey.

Source: NSO, Village Survey, 1987.

3-5-8. Rural Area Development

1) Gross Provincial Products in Agricultural Sector

The principal crops in each province are extracted as below:

Chonburi	: rice, cassava, sugarcane and pineapple
Chachoengsao	: rice, mango, cassava, coconuts and watermelon
Nakhon Nayok	: rice, mango, orange, watermelon and bamboo-shoot
Prachinburi	: rice, maize, cassava and bamboo-shoot

GPP of agricultural sector in Chonburi and Chachoengsao is much higher than those in Prachinburi and Nakhon Nayok, showing about two times of average products per one farmer in the former provinces as compared with those in the latter.

	Agricultural Products	
	(Gross)	(per one farmer)
	million Bahts	Baht
Chonburi	3,532	30,454
Chachoengsao	3,446	33,949
Nakhon Nayok	727	18,372
Prachinburi	2,868	17,233

2) Classification of Households into Economic Groups

According to the socio-economic data in the NSO Village Survey in 1987, numbers of households by size of annual income are summarized in the following.

Percentage of Households by Size of Annual Income

- 1987 -

(unit: %)

Province	less than 6,000 Baht	6,000 to 10,000 Baht	10,000 to 20,000 Baht	Over 20,000 Baht	Total
Chonburi	16.4	25.2	31.4	27.0	100.0
Chachoengaso	22.3	28.8	27.1	21.8	100.0
Prachinburi	35.1	30.0	20.4	14.5	100.0
Nakhon Nayok	22.8	31.2	25.2	20.8	100.0

The Fifth National Economic and Social Development Plan classified the households into four economic groups, namely; the poor group with income less than 165 baht per person per month, the marginal group with 166 to 220 baht, the better off group with 221 to 330 baht and wealthy group with more than 331 baht. According to this guideline for grouping, households in the basin as categorized in the above table may be classified below:

- Households with income less than 6,000 baht and 6,000 to 10,000 baht would belong to "the Poor" and partly to "the marginal" group.
- Households with 10,000 to 20,000 baht are the constituents of "the marginal" and "the better off" groups.

- Households with 20,000 baht may be called "the wealthy" group.

In this connection, about one-third of whole households would belong to "the poor" group in Prachinburi province.

3) Rural Labour Income

According to the socio-economic data in the NSO Village Survey in 1987, the average wage rate in the rural area is still on a low level, and those in Chachoengsao and Chonburi are higher than that in Prachinburi. It is considered that the rural poverty is still so serious socio-economic constraints.

Average Wage Rate - 1987 -

Item	Chonburi	Chachoengsao	Prachinburi	Nakhon Nayok
Maximum B/Day	70.0	63.7	50.6	49.6
Minimum B/Day	36.0	35.0	31.7	46.5
Average B/Day	46.9	52.0	39.4	47.9

Note : Average figures by Amphoe
Source : NSO, Village Survey, 1987

3-5-9. Farm Economy

RID Economic Section has carried out farm economic survey in the Khlong Tha Lat area during Dec. 1989. The 10 sample farmers each were randomly selected from the 18 villages in the existing irrigation area, water conservation area, new expansion area and the dam reservoir area, couting the total selected farmers of 180 units.

The average value of farm household income of the sample farmers amounts to 66,601 bahts per year on a higher level, comparing with the socio-economic data in the NSO village survey in 1987. The size of land holding is 39.1 rai, therefore, the sample farmers might belong to "the wealthy" group classified by the NESDB's Five Years Plan.

Moreover, non-agricultural products income (41.2% of farm income) is almost equal to the agricultural products income (40.9% in share), indicating one of the important character of the survey area.

1) The existing irrigation area is near the Chachoengsao municipality, bordering on the industrial estate under construction. The farm household income is as high as 86,752bahts, making the rate of income from non-agricultural sector particularly higher.

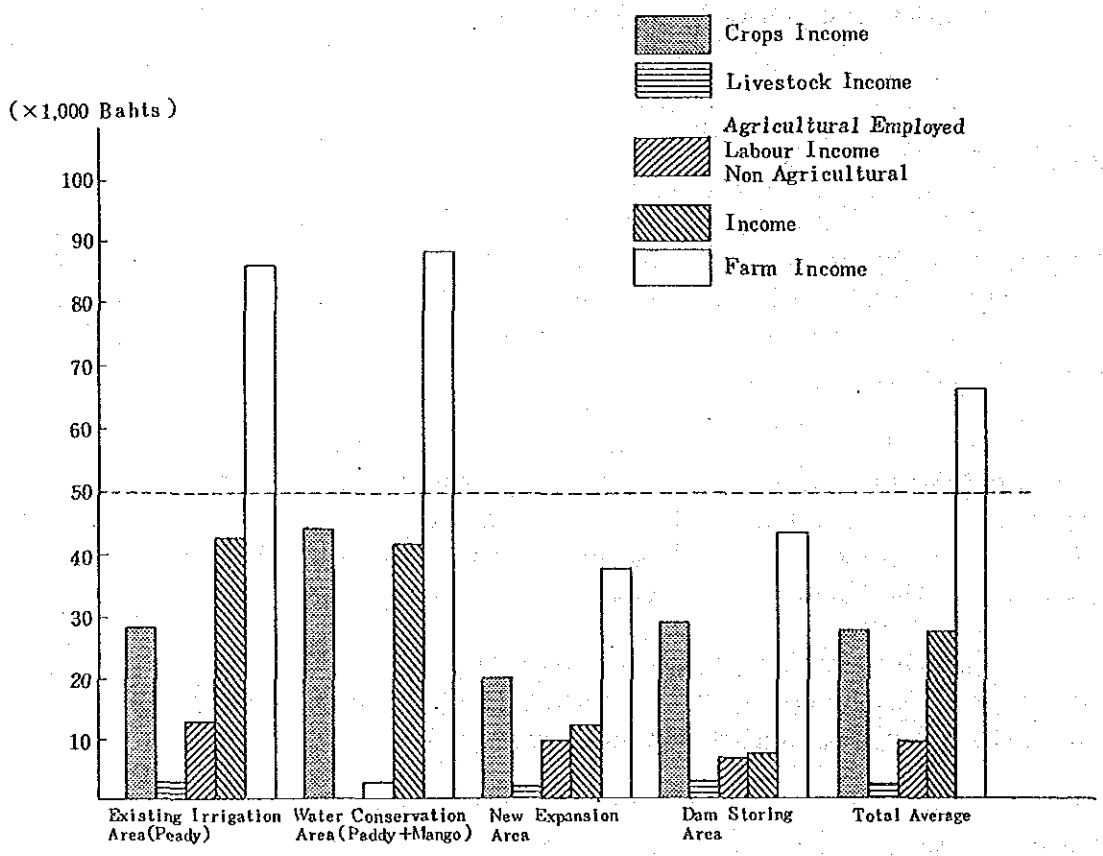
2) Water conservation area involves the diversion dam proposed where most of farmers along the Bang Pakong river draw fresh water from the river

into ditches at the end of wet season for irrigating orchard and paddy in dry season. The farm household income is as high as 89,626 bahts, despite the farming scale is as small as 17.7 rai.

3) In the Dam Storing Area placed Amphoe Sanam Chai-Khet, the income level of major crops such as cassava and sugar-cane is about not always on a low level but the total farm income is about a half of that of the irrigated area, owing to the low income from a non-agricultural sector.

4) Although the income from each sector is low, the crop products are expected to be largely increased by the implementation of a water resources development project in the expansion area.

Farm Economy Survey



3-6. Water Demand and Water Resources Development

3-6-1. Existing Irrigation Systems and Practices

There are 31 agencies and 17 committees under eight ministries responsible for various aspects of the administration of water resources development. Each agency has its own allocated budget and program to develop water resources for its own specific purposes. Government agencies involved in water resources development are as follows:

Ministry of Agriculture and Cooperatives

- Office of the Permanent Secretary
- Royal Irrigation Department
- Department of Agricultural Extension
- Department of Agriculture
- Royal Forest Department
- Department of Land Development
- Cooperatives Promotion Department
- Department of Fisheries
- Department of Livestock Development
- Agricultural Land Reform Office
- Royal Rain Making Research and Development Institute

Ministry of Interior

- Local Administration Department
- Department of Public Works
- Department of Public Welfare
- Office of Accelerated Rural Development
- Department of Community Development
- Department of Lands
- Metropolitan Water Works Authority
- Provincial Water Works Authority

Ministry of Public Health

- Department of Health

Office of the Prime Ministry

- Electricity Generating Authority of Thailand
- Rural Employment Generating Committee

Ministry of Industry

- Department of Mineral Resource
- Department of Industrial Works

Ministry of Communications

- Department of Harbor
- Meteorological Department

Ministry of Defense

- Naval Hydrographic Department
- National Security Command Headquarters

Ministry of Science, Technology and Energy

- National Energy Administration
- National Environment Board
- National Research Council of Thailand

As the roles of various government agencies in the development of a typical river basin, the electricity Generating Authority of Thailand (EGAT), the Royal Forest Department (RFD) and the Local Administration Department are all responsible for the headwater area. In the irrigated area, the Local Administration Department is responsible for People's Irrigation while the Royal Irrigation Department (RID) and the Harbor Department are responsible for Public Irrigation. The Harbor Department is also responsible for the river outlet and estuary area.

The RID is the primary agency responsible for planning, design, implementation and operation and maintenance of the major irrigation systems. The RID divides its service area covering the entire country into 12 regions with regional irrigation offices, each of which is responsible for preliminary studies for water resources development, construction of small scale water resources and operation & maintenance of irrigation and drainage projects implemented in its responsible area. The Bang Pakong basin is involved within the territory of the Regional Office IX.

There are several categories in classifying the projects. The RID divides irrigation projects into three categories of large-scale projects, medium-scale projects and small-scale project based on findings. Apart from these categories, projects are also classified into categories, such as irrigation projects, drainage projects, water storage projects, flood control projects, pumping projects, water conservation projects and hydropower projects, according to the type of project. Table 3-7 tabulates water resources development projects categorized under the large-medium scale projects and

involved in Bang Pakong basin. Numbers of small scale irrigation projects have also been constructed in the basin in accordance with the urgent needs of people of the area aiming at solving water shortage problem for crop cultivation as well as for domestic purposes, which would, in turn, raise the people's standard of living. Within the Bang Pakong basin, 111 small scale projects have already been completed over the area of about 186,000 rai or 29,820 ha with the total storage capacity of 13.67 MCM.

Among 27 irrigation projects listed in Table 3-7, 24 projects have been completed and in operation. Three projects; i.e., Khlong Yang, Khlong Rabom and Prachantakham, are at present under construction. Of 16 projects which have irrigated areas exceeding 1,000 ha and currently in operation, only four projects provide irrigation canals within their systems, and remainders utilize natural rivers and streams for the purposes of irrigation, drainage and storage. There are, however, no efficient irrigation systems as far as systematic operation of irrigation water distribution is concerned. This is due mainly to the lack of storage functions in the irrigation systems.

Cultivated areas rely principally on rainfall for crop production. Existing paddy areas adjacent to natural channels are presently irrigated by flooding when river stages are high.

Consequently, paddy cultivation is stable only during wet season. However, such wet season paddies are being suffered from frequent shortages of supplemental irrigation water. Under the existing climatic condition, wet paddy consumes about 550 mm of water for evapotranspiration of the field, of which 300 mm only is satisfied by effective rains, meaning that the supplemental irrigation of about 250 mm per growing season is still required. This supplemental irrigation has been, however, hardly made due to the lack of irrigation facilities, limited river runoff and saline water intrusion. In dry season, on the contrary, the area is almost left fallow because of absolute lack of water.

In general, farming practice for paddy cultivation is summarized as follows:

- Land preparation works or plowings are made not later than the middle of May before the monsoon rains.
- After the monsoon rains prevail the area, germinated seeds are broadcasted.
- Monsoon rain usually begins in late May or early June and lasts about five months until the end of September or the middle of October, during which paddies are mostly fed by rain.

TABLE 3-7 LARGE-MEDIUM SCALE PROJECTS IN BANG PAKONG RIVER BASIN

Province	Project Name	Type	Year	Irrigated (ha)	Storage (MCM)	Remarks
Nakhon Nayok	Tha Dan	I	1981	1,280	-	
	Wang Takhrai	I	1956	240	-	
	Nakhon Nayok	ID	1954	59,010	-	
	Nakhon Nayok River					
	- Sai Thong	SI	1983	160	2.0	
	- Khlong Bot	SI	1984	160	4.3	
	- Huai Pru	SI	1987	320	5.5	
	Ban Na	I	1981	3,200	-	
	Khlong Yang	I	1990	2,640	-	under construction
Prachinburi	Khlong Sam Sip	SI	1986	429	5.7	military supply
	Khlong Klua	SI	1988	480	5.5	
	Phan Po	SI	1988	448	0.3	
	Tha Kra-bak	SI	1981	640	6.4	
	Huai Khrai	I	1976	1,920	-	
	Takhian Thong	C	1977	1,040	-	
	Tha Hae	CF	1960	9,600	-	
	Khao I-To	S	1978	-	2.4	military supply
	Huai Krasian	FC	1977	480	-	
	Prachantakham	I	1990	2,624	-	under construction
	Bang Phluang	CF	1981	52,160	-	
	Khok Kacha	CF	1977	3,200	-	
	Khlong Saraphi	CD	1980	1,680	-	
	Huai Khao Din	SI	1988	192	1.4	
Chacheongsao	Khlong Rabom	SI	1988	24,864	40.0	under construction
	Lat Krathing	SI	1984	240	4.2	
	Tha Lat	I	1973	20,768	-	
	Bang Pakong (L)	FC	1963	10,400	-	
Chonburi	Ban Bung	SD	1958	-	1.9	domestic water
	Phan Thong	DC	1965	2,960	-	
	Phan Thong (E)	DC	1978	3,520	-	
Total				204,655	79.6	

Notes: S=storage of water, I=irrigation, D=drainage, C=conservation and F=flood control

- The monsoon rains may end before the rice crop has matured, hence, rain waters are stored in the natural drainages and controlled to keep elevations on the cultivated paddies to prevent the paddies from draining too early at a critical time in the rice plant cycle.

- After the rice crop has matured, waters are drained at the end of November, and rice crops harvested in December.

3-6-2. Present Drainages Practice and Flood Damages

In the lower reaches of the basin particularly in water conservation areas where paddy crops are grown, there are very poor surface drainage facilities. Many small natural surface drains are linked each other and function as storage facilities during irrigation period. Stored water are being utilized not only for irrigation but also for domestic purposes. These drains are often filled with weeds resulting difficulty in operating drainage as well as for navigation. There have been little countermeasures to improve this condition due to lack of fund and because of the fact that no importance on surface drainage has been recognized in rice-growing areas. The main canal in the Phan Thong Project area in Chonburi is the only structure so designed and constructed to improve drainage conditions, however, it has been functioning as an irrigation canal. Pump drainage has not been introduced in any part of irrigated areas in the basin.

Because of restricted outflow capacity of the Bang Pakong river and its tributaries, large areas are inundated annually and periodically. Basin is so flat that the gradient and limited cross-sectional area of river channels do not allow the excess rainfall to flow out into the Gulf especially during the peak flood period, which commonly occurs in the latter stages of wet season in the months September and October. Consequently areas adjacent to the Bang Pakong, Nakhon Nayok and Prachin rivers become a very shallow natural flood-retarding reservoir. Paddy fields situated in these areas are operated so as to allow an early flood flow into them. The flood storage capacity of ponded paddy areas is considerably large, and they works effective in reducing the flood peak discharges.

In many existing irrigation project areas, irrigation systems are so designed and operated to allow part of river water to enter the area in order to provide water for land preparation, planting and even for irrigation during the normal stage of rice growth. Water is controlled at an acceptable range of flooding so that it would not exceed the rate of plant growth. Even so in the peak flood period, the lowlands are flooded annually or periodically causing a considerable amount of crop damage, by combination of runoff from their

hinterlands and rising water stage in the major river systems to which drainage is to be made.

During the past decade, the most severe flood occurred extending over the whole river basin in 1983. Flooded area was reported as follows:

Flooded and Damaged Area during 1983 Flood

Amphoe	Irrigation Project	Flooded Area	Damaged Area
Prachinburi	Bang Pluang	54,150	6,770
	Left Bank	9,280	2,510
	Tha Hae	680	680
	Huai Chan	160	150
	Huai Khrai	60	60
	Out of Project Area	39,810	29,640
	Sub-Total	104,140	39,810
Nakhon Nayok	Nakhon Nayok	4,110	1,230
	Out of Project Area	6,810	4,720
	Sub-Total	10,920	5,950
Chachoengsao	Bang Pakong Left Bank	2,500	1,680
	Tha Lat	12,480	2,400
	Out of Project Area	11,630	–
	Sub-Total	26,610	4,080
Chonburi	Pan Thong	1,440	810
	Out of Project Area	720	–
	Sub-Total	2,160	810
Total		160,940	50,650

To improve this situation, RID has provided polder dikes surrounding mostly the water conservation areas along the rivers and tributaries to channel the flood flow away from the protected area with control structures across them. This activities are still going on at the present time bringing immediate results. However, this would not be perfect until the time interior drainage by gravities or by pumping is provided. Some control structures have no gates or too small capacities to drain required volume of water in time. Construction of dams and reservoirs on the river tributaries within the basin would contribute to reducing flood peaks.

3-6-3. Present Water Consumption

1) Irrigation

Favored moderately with an average annual rainfall of 1,590 mm, paddy cultivation is dominant only during wet season. Overall water balance between the paddy crop consumption and effective rainfalls under the average year condition is as follows:

Month	Rain-fall (mm)	Effective Rainfall (mm)	Paddy Crop Consumption		Water Balance	
			Wet Paddy (mm)	Dry Paddy (mm)	Wet Paddy (mm)	Dry Paddy (mm)
April	93	75	-	76	-	▲1
May	170	123	-	-	-	-
June	219	147	-	-	-	-
July	229	150	197	-	▲47	-
August	274	166	250	-	▲84	-
September	307	177	209	-	▲32	-
October	170	123	192	-	▲69	-
November	44	38	68	-	▲30	-
December	8	7	-	204	-	▲197
January	7	6	-	276	-	▲270
February	26	24	-	258	-	▲234
March	44	38	-	235	-	▲197
ANNUAL	1,591	1,074	916	1,049	▲262	▲899

As is clear in the above table, wet paddy has also been suffered from the lack of water. Supplemental irrigation is therefore required even in wet season, however, it has not been achieved yet due to lack of the stable source of irrigation water as well as of irrigation facilities. During dry season, the area is almost left fallow because of absolute lack of water.

2) Domestic Water Supply Sector

Major waterwork facilities of four provinces, namely Chonburi, Chachoengsao, Prachinburi and Nakhon Nayok consist of 12 systems under the management of Provincial Waterwork Authority (PWA) and 22 small scale facilities belong to the Sanitary District and or few numbers of local administration. The consolidation of facilities in the rural area seems to be difficult due mainly to a scattered residential situation where rainwater and groundwater are still being utilized.

Main water source of Chonburi waterwork system under PWA is the existing Bang Phra reservoir located outside of the Study area. Water supply to Chonburi from the Bang Pakong river basin, therefore, will not be necessary except for some incremental water demands. Waterwork facilities other than Chonburi system have often been suffered from water shortage in dry season,

due to unstable water sources such as rivers streams, ponds and irrigation canals.

Existing water supply capacities of the PWA systems are summarized as follows;

Project Name	Served Population (%)	Daily Water Demand (cu.m.)	Production Capacity (cu.m.)	Annual Demand (MCM)	Water Resources
M. Chonburi	149,900 (73)	57,555	48,000	22.10	Reservoir
Ban Bung	2,677 (27)	610	1,080	0.23	Reservoir
Phanat Nikhom	8,296 (61)	1,880	2,640	0.73	River
M. Chachoengsao	27,255 (67)	11,550	16,800	4.45	Canal
Bang Phra	4,060 (54)	1,206	1,440	0.48	Canal/Well
Bang Pakong	9,792 (48)	9,236	4,800	3.62	River
Phanom Sarakham	8,198 (56)	2,010	3,360	0.80	Canal
M. Prachinburi	13,398 (83)	10,560	10,560	4.05	River
Kabinburi	6,625 (50)	2,000	2,640	0.77	River
Watthana Nakhon	5,469 (74)	2,400	2,400	0.92	River
M. Nakhon Nayok	14,751 (63)	8,640	9,600	3.33	River
Ban Na	5,516 (70)	960	960	0.37	Canal
Total	260,937 (67)	108,607	104,280	41.84	

According to the PWA's information, the amount of 32,000 cu.m/ day out of 109,000 cu.m/ day in total are for industrial purposes. Amphoes Chonburi and Bang Pakong, where industrial complex has been developed rapidly, have suffered from remarkable water shortage in dry season.

Served population and averaged water consumption of small scale water supply systems are tabulated as under;

Province	No. of Facility	Population Served	Annual Water Demand (MCM)
Chonburi	5	92,566	1.287
Chachoengsao	6	24,447	0.949
Prachinburi	10	48,307	1.869
Nakhon Nayok	1	3,622	0.146
Total	22	168,942	4.497

Data source: PWD, Ministry of Interior

Major water sources of the small systems are rivers, irrigation canals, small ponds and groundwater.

The population projection and the water demand estimate in the urban area should be made taking into account the required level of infrastructure consolidation, regional development plan and investment tendency or capacity of private sector.

Most of the PWA's existing facilities supply treated water to both domestic and industrial purposes except bulk water users in the large scale industrial complex. In the future programmes of expansion and /or rehabilitation of existing facilities, from economic point of view, water supply system for drinking purpose is to be separated whenever possible from bulk water supply system for industrial purpose, since the water quality standards for the both fields are significantly different.

Unit water consumption of municipal water is fluctuated largely from 100 to 300 liter/capita/day. The projection of water consumption in the target year of 2000 tends to concentrate into 200 to 300 liter/capita/day when the improvement of living standard and the efficiency of collected amount to collectible amount are achieved. Monthly fluctuations of municipal water consumption, however, ranges from 97 to 100% of the annual average.

As for the water supply in the rural area, on the other hand, more stable and hygienic sources of drinking water will be required in future in response to the regional economic and social development.

3) Industrial Water Supply

The recent economic growth in Thailand indicates an annual rate at around 10 percent. Especially the rate in industrial sector is remarkably high. The Thai Government has designated the industrial complex around the Eastern Seaboard area as the most important industrial promotion area, investing a lot in infrastructure development including national road, deep sea port, electricity, telecommunication and water supply.

Construction of factory and its facility by private sector in parallel with the governmental investment activity for infrastructural development has been in rapid progress and, at the present time, 1,500 factories in Chonburi and 420 factories in Chachoengsao have been successfully in operation. Furthermore, more than 100 factories will be constructed and operated very soon in the said two provinces.

The area in the reaches of the Bang Pakong river basin lying between Bangkok Metropolitan area and Chonburi province is spotlighted as a suitable industrial promotion zone. Industrial water in this area is being provided mainly from urban waterwork 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 most areas. In particular, some factories are forced to purchase water from Bang Phra reservoir, located southernmost part of Muang Chonburi, by a water tank truck with the price of 70 baht per cubic meter.

Major reasons for this situation are the delay of water resources development progress in contrast with the rapid expansion of industrial

complex, difficulty of taking fresh water from the river due to saline water intrusion which reaches about 120 km upstream from the river mouth, absolutely small amount of river runoff in dry season, and poor capacities of urban water supply systems where no stable water source has been secured.

In general, most of the industrial water for existing factories is being supplied through regulating reservoirs, constructed in their compound and filled with water stored in wet season. In the modernized or large scale factories, treatment plants for drinking water are also equipped separated from the industrial purpose.

The water demand in this sector depends upon the kinds of products, the scale of factory, the number of labours and so forth. According to the results of sample survey conducted by the Team and to the information obtained from IEAT and Eastern Sea Board, averaged water demands are about 8 to 11 cum/day/rai, since the factories in this area are mostly categorized into light industry. The maximum water consumption including some allowance is, therefore, estimated to be 12 cum/day/rai.

4) Fishery Sector

There are many brackish water shrimp culture farms and fresh water fish raisers in the lower reaches of the Bang Pakong river. In general, the salinity content most suited for brackish water shrimp culture is within the range 15 to 20 ppt. The activity is predominant in the areas located along the Bang Pakong river extending from the river mouth to about 40 km upstream, where farmers can divert brackish water directly from the river during transitional periods from dry season to wet season and from wet season to dry season.

Variation of salinity contents during dry season measured by NEB in the last five years indicates that the monthly maximum values during the period from January to May vary in a range 33 to 20 ppt, while in December and June ranges are 20 to 10, showing a general tendency of higher salinity contents in the lower reaches and lower contents in the upper reaches. Brackish water is received from the river by pumping and conveyed to private ponds through natural canals or canals of common use in the area. The extent of shrimp culture in and around the Study area along the river is about 4,000 rai in the left bank and 10,000 rai in the right bank. Supplemental fresh water supply of appropriate quantity for the said area will be required after the realization of full scale water resources development.

The fresh water fish raising, on the other hand, predominantly expands in the southern part of existing Tha Lat Irrigation Project area as well as in the Nakhon Nayok Irrigation Project area mainly in wet season. Most of these fish ponds were converted from paddy lands. The beneficiaries in such

areas intend to expand fish ponds more and more on a larger scale, because the net benefit obtainable from fish raising is quite higher than that from wet season paddy and, furthermore, two cycles of the culture in a year is possibly expected if adequate supply of fresh water is achieved in dry season. The present extent of fresh water fish culture in the area is estimated approximately at 2,000 rai.

3-6-4. Saline Water Intrusion

Saline water intrusion during low-flow periods along the lower reaches of the Bang Pakong river is one of the most serious problems to irrigated agriculture in the area. The salinity extends about 120 km the gulf to the upstream confluence of the Nakhon Nayok and Prachin rivers, and has been extending further and further as the demand of water in the upstream area increases and the critical drought flow in the river from upstream decreases year by year. Most of the existing water conservation areas situated along the lower Bang Pakong river are protected from such saline water intrusions, by means of distributing polder dikes and by installing control structures across them. Water is diverted from the river into the natural drainages during high-flow periods when salinity contents of river water are negligibly small or less than the allowable limit for irrigation purpose, and is stored and used in dry season. Main drains of the area concerned have already been equipped with tail-end regulators which also control internal water level against external river stages. Many of structures running under the protection dike have been, however, equipped with no gates. In the minor areas that are too small to warrant the cost of a control facility, every possible effort has been made by farmers to prevent their land from saline water, by constructing temporary structure at the outlet of natural drain.

According to the NEB records, saline water exceeding one ppt (or 1,000 ppm), that is assumed to be unallowable limit for irrigation, reaches 10 km upstream of the estuary in November, the beginning of dry season, some 70 km in January, and about 120 km during the months from February to May. Details are given in Appendix J.

3-6-5. Navigation

Inland navigation (ship transportation) along the Bang Pakong river around Amphoe Muang Chachoengsao is being made mainly by ferryboats in a short distance, because only a few bridges are provided to connect both the banks of the river and that road network in the residential area along riverside is sparsely distributed. The most common system of ship transportation links major municipal areas by ferryboats of 5 to 20 passengers. There are few ship

transportation systems along the tributary through navigation lock in lower reaches of the Bang Pakong river.

Frequency of shipping services on the Bang Pakong river surveyed at the site of Chachoengsao bridge is summarized as follows;

Ship Category	Sunday (October 7th)		Wednesday (October 4th)	
(Destination)	(6:00-12:00)	(12:00-20:00)	(6:00-12:00)	(12:00-20:00)
Man Carrier				
- To upstream	10	13	10	14
- To downstream	13	13	12	14
Large Ship				
- To upstream	6	-	2	-
- To downstream	2	-	1	1
Other Small Ship				
- To upstream	20	8	15	14
- To downstream	43	32	61	38
Total (Upstream)	36	21	27	28
(downstream)	58	45	74	53

3-6-6. Groundwater Resources

The alluvial and the fractured aquifers are extensively developed in the upper reaches of the Bang Pakong river near Nakhon Nayok and the intermountain valleys along the Prachin river basin. The depth of wells near Nakhon Nayok ranges from 40 to 50 meters and the yield attains about 50 lit/min in a maximum.

The groundwater in the intermountain valleys is developed for a domestic use and the yield estimates 20 lit/min from the fractured aquifer of the Khorat Group north of the Prachin river and it attains more than 500 lit/min if a well drills in the potential aquifers.

The groundwater in the lower reaches of the Bang Pakong river has been developed for agricultural and industrial uses but it was contaminated with saline due to overdrafting. A large number of production wells were abandoned due to qualitative inferiority and a small desalination plant was also applied by a factory for improvement of the water quality.

CHAPTER 4. PLAN FORMULATION

CHAPTER 4. PLAN FORMULATION

4-1. Problems and Constraints Involved

4-1-1. Legal and Political Constraints

There are some laws and regulations on the implementation of land and water development project. Followings are the major legal and political issues to be discussed for formulation of the proposed Project.

1) Reserved Forest

The catchment area of 17,660 sq.km to cover the Study area consists of 9,940 sq.km of farm lands and 7,720 sq.km of forest and other lands.
There exist the preservation areas in the basin, specified for various land uses as follows:

- National Park Area: Approximately 3,100 sq.km in Khao Yai, Thap Larn and Pang Sida
- Wildlife Reserved Area: About 108 sq.km in Khao Ang Runai in the southern part of the Study area
- National Reserved Forest: Approximately 4,500 sq.km extended over the whole basin

Careful studies and investigations to assess the impact of project implementation on the ecological environment of wildlife and plants should be made in advance of the construction of storage dam(s), a diversion dam, irrigation canals and roads to be proposed. Preparation of the report on environmental assessment will be made by the third party prior to the commencement of project implementation.

2) Policy on Crop Diversification

Thailand's policy on agricultural crop production tends to change gradually from placing concentration upon paddy rice production to raising self-sufficiency ratio of crops for domestic consumption as well as promotion of stable crops for export. The share of paddy rice production in the whole agro-products of the country still remains quite high. A part of dry season paddy has therefore been converted into upland crops to avoid the risk of international price fluctuation on exporting rice and also stability of supply of Thai rice in the world market.

Cassava production of Thailand, on the other hand, takes place the first rank in the world. Since the expansion of export of tapioka and tapioka pellet has become unstable, strong promotion of more profitable upland crops should be made in the area where irrigation water can be supplied through out a year and are favored by fertile soils. High potentiality of irrigated agricultural development is investigated in the Study area. Hence, crop diversification programmes should fully be considered in view of the promising location of the Study area adjacent to the metropolitan area, including selection of suitable dry season crop for existing low-lying paddy area, and dry crops such as soybean, groundnuts and perennial orchard crops for converting cassava plantation in the proposed expansion area.

3) Industrial Development

Industrial development in the Eastern Seaboard Industrial Complex and Bangkok metropolitan area are in rapid progress funded by both governmental investment for consolidation of infrastructure and private sectors for construction of factories. In the Study area and its vicinity, the establishment of light industries that may consume less water and may produce less air pollution has been in progress supported by the Thai Government.

Under the circumstances, preparation of the master plan for multi-purpose water resources development is of vital importance in consideration of a close relationship of the Study area with the northeastern economic zone with harmonious development concepts on both water and land resources.

4-1-2. Land and Water Resources Development

The Study area is moderately favored with an annual rainfall, widely ranging from the highest of 2,400mm at the foot of the northern mountainous area to the lowest of more or less 1,000mm in the lower reaches of the Bang Pakong river. Seasonal variation of rainfall is also remarkable. The southwestern monsoon brings humid air over the basin, resulting in most rainfall concentrated during wet season from June to October. Receiving such rainfalls, paddy cultivation is dominant during wet season in the basin, especially in lowlying flat areas in the middle and lower reaches as well as along the rivers and tributaries.

From a hydrological point of view, existing paddy areas often suffer from floodings and inundations during wet season. This is due mainly to the lack of interior drainage facilities combined with absolutely limited outflow capacities of rivers and tributaries. There are about 30 irrigation projects in the Study area at present in operation or under construction by RID. The aim of these projects is to block and distribute river water for irrigation, to drain

water and to prevent flood and saline water from entering into the area protected. Even so, these irrigation systems are so designed and operated as to allow a part of flood flow into the protected paddy areas. In practical irrigation, waters are drained only when an adequate volume of water exceeding the crop demand and beyond the storage capacity of natural river channel is available. The area, however, is submerged under water when the raise of external river stage happened at this timing. Large areas around Kabinburi in Changwat Prachinburi, where the major tributaries of Khlong Phra Prong and Maenum Hanuman rivers join, are inundated frequently. Because of this risk, farmers used to plant local varieties of paddy with long stems, which grow as quick as the water rises to avoid themselves from being covered with water. Unfortunately these are low yielding varieties.

To the contrary, frequent shortage of supplemental irrigation water even during wet season is another serious problem in the basin. Having less amount of annual rainfall of around 1,000 mm in the lower reaches of the basin, wet paddy suffers from annual drought damages. In general under the climatic condition, wet paddy consumes about 550 mm of water for evapotranspiration inclusive of percolation on the field, of which only 300 mm are covered by effective rains. Supplemental irrigation of about 250 mm per growing period are required. It, however, has not been achieved due to the lack of irrigation facilities, limited river runoff and saline water intrusion.

In dry season, on the contrary, the area is almost left fallow because of lack of water.

As a result, a level of farming households' income has been kept lower, that is, about a half of them still belong to a class in poverty.

From an agronomic point of view, problematic soils as concerns the farming practice are so-called acid sulfate soils. These soils are mostly under paddy, some parts of which have already been converted into orchard. The total area of these soils is some 204,800 ha distributing wide spread in the four major provinces. Marl or lime application is recommended to improve soil acidity. Land use on these soils, however, may be quite limited. Other problems are shallow skeletal upland soils which are poorly suited for upland crops but more favorable for reforestation. Development of the potential acid sulfate soils in the limited tidal area may cause the other problem, since these soils will become acid when they are drained or ridged.

Cassava is a profitable crop and an easy crop to grow, requiring no particular technical knowledge, extensive labour and no irrigation. It also grows in a poor soil. Based on the agreement signed between Thailand and EEC, main importers of cassava; the exports to EEC may not increase any longer, although the exports to other countries have gradually increased. This will lead to limiting production of cassava, and in turn crop diversification plan

should be examined. Crop conversion plan from cassava to other upland crops may be feasible only when countermeasures to grow alternative crops are given, and it is certain that irrigation development is the basic solution to this problem.

Land rights still represent a main problem in the basin because the boundary of national forest reserve covers a rather larger area. In the encroached forest areas, land allocation projects are being operated by the Royal Forest Department (RFD) and the Agricultural Land Reform Office (ALRO). RFD issues a land use permit called "STK Certificate" for illegal settlers in the national forestal reserve. ALRO also issues a land use permit (Sor Por Kor 401). These two documents cannot be used as collateral for a loan. A change in this type of documents to Nor Sor 3 or Nor Sor 4 will have a significant economic impact to the local farmers. On the other hand, it may facilitate the transfer of ownership leading to the loss of land by poor farmers and eventually more encroachment of forest land. Deforestation will result in increase of soil erosion, often boosting the sediment load in nearby streams and rivers. Simultaneously the rate of which rainfall runs off into water courses will be accelerated, and the combination of greater volumes of water racing into rivers with sediment will often lead to floodings.

In the fisheries, there are large scale shrimp cultures on both the banks in the lower reaches of the Bang Pakong river, and an inland fishery in paddy field areas. The shrimp culture needs saline water in fairly high concentration, which is unfavorable to rice farming.

Municipal and domestic water supply in the basin have not yet been developed enough. There are only 12 waterwork facility systems under the management of Provincial Waterwork Authority (PWA) and small scale facilities belonging to Sanitary Districts and rural administrations. They have often suffered from water shortage in dry season due to unstable water sources.

The area in the lower reaches of the Bang Pakong river basin is highlighted as a suitable industrial complex zone. The industrial water supply for the purpose is mainly being provided from municipal waterwork facilities, irrigation canals or drains and small ponds. The water demand during dry season, however, does not meet the available water amount.

Many tube wells were drilled for industrial use in the plain along the river. Most of them, however, were recently abandoned due to saline water intrusion into the aquifers.

4-2. Basic Strategy for Basin Development

4-2-1. Integrated Regional Development Plan

In order to solve the problems and to release the constraints mentioned above, the integrated regional development plan for the area must be established by all means.

Since the rurality is predominant over the socio-economic environments in the area, the agricultural development must at first be taken into consideration. For the agricultural development, irrigation water supply; supplementary in rainy season and fully in dry season; must first be implemented, and the existing irrigation facilities also be rehabilitated. Next, the drainage from divided sub-basins and prevention of flooding and saline waters intrusion into the said sub-basins, are needed. On a premise of irrigation water supply, paddy farming, dry farming and pomiculture must be promoted.

The main objectives of agricultural policy set up by Thai Government are as follows:

- Elevation of agricultural productivity
- Dissolution of poverty in rural area and adjustment of earning differentials among regions
- Expansion of agricultural products export for balance of national revenue and expenditure
- Effective utilization of agricultural land, protection of forestal resources and preservation of other natural resources and environment

According to the above objectives, the development strategy of land and water resources in the area must be established.

In the area adjacent to the Eastern Seaboard Industrial Zone, there is one site proposed for industrial complex on both the banks of the river respectively, for which urgent water supply must be secured.

The tasks for both municipal and industrial waters are supplying sufficient water amount, enlarging and strengthening the facilities.

For a promotion of the fisheries in this area, the shrimp culture at the lower reaches of the river must be very important, and the saline water supply in adequate concentration for the purpose not be hindered.

As mentioned above, a development for multipurpose is inevitably needed. The concrete land and water resources development plans to be established will be stated below.

4-2-2. Land Resources Development Plan

The land resources development depends on water supply and flood exclusion. The lower reaches of the river basin forming wide flat paddy field zone are able to be subsidiary irrigation only during wet season when the river discharge is abundant. On the contrary, they are unable to be supplied with water resulting in impossible paddy farming in dry season owing to river discharge decrease and saline water intrusion.

Such cropping pattern as double paddy farmings and wet season rice-upland crop are to be introduced by securing water by dam construction from now on.

The international price of rice was once deeply dropped, but the movements of the market have recently been recovered and the new demands from Red China and Indo-Chinese countries can be expected.

In the orchard zone along the main river, coco-palms and mango trees are cultivated and irrigated by excavating deep ditches and taking and storing water during wet season. The minor domestic animal and fowl such as pigs, chicken, ducks, etc. have been raised on a fairly large scale. It must be considered that the area with the same managing form as this area is extended.

The middle and upper reaches of the river basin, on the other hand, are expected to be developed urgently from a security viewpoint, since the eastern border of the basin is located near the Cambodian boundary.

In the dry fields with no irrigation and no fertilization, cassava has been exclusively cultivated under extensive farming. The export limits to Europe, however, have been regulated. As a result, the sudden production increase more than the limits cannot be expected, and then crop diversification must be taken into account.

The farmers' intention to dry farming and/or pomiculture became stronger and the land utilization form has been gradually changed. The objective crops selected by the provincial government are pulse; soybean, peanuts, etc.; maize, sugarcane, sesame, water melon, vegetables and fruits; mango, jackfruits, etc.

In the economy of Thailand, the progress of the industry has been quite remarkable. As one of the most important areas for industrial promotion, the

Government designated the eastern marine industrial zone, and has pushed forward development and adjustment of the infrastructures positively. The investment in equipment in private sector, in response to this national investment has also been advanced at high speed. Under such circumstances, the whole lower reaches of Bang Pakong river situated between Chonburi, the northern edge of the eastern marine industrial zone and Bangkok, the capital of Thailand, have suddenly been highlighted as the areas suitable for industrial estates. One site on the right bank and another site on the left bank of the river have already been proposed for the estates.

The municipal and domestic water supply is served by 12 waterworks managed by Provincial Waterworks Authority (PWA), and some waterworks managed by Sanitary Districts and directed by Public Works Department (PWD). The rural area water supply is served mostly by simple waterworks on a small scale, using rain water and groundwater.

For industrial, municipal and domestic water supplies, the tasks are to secure water source, to extend and strengthen the conveying, distributing and purifying facilities as stated above.

4-2-3. Water Resources Development Plan

The river basin is divided into 8 sub-basins, and studied in details. And then the project areas with higher priority must be developed in order, so as to utilize water resources effectively in the whole Bang Pakong river basin, and to plan a balanced development of the areas. Firstly, multipurpose dams are constructed to supply water stably for agriculture, industry, municipal and domestic purposes, and fishery. Concurrently, a diversion dam is built on the main Bang Pakong river just upstream of Chachoengsao City to prevent saline water from intruding in dry season, and to supply water multi-purposely by storing fresh water in the river course upstream of the diversion dam.

The existing irrigation facilities are radically rehabilitated to utilize stored water effectively. Intake facilities and irrigation networks are newly built for the areas to be developed.

Industrial water supply in dry season is short at present for almost all the demanders. The Government, therefore, strongly requires to construct multi-purpose dams for industry and municipal and domestic purposes as well as agriculture.

It takes, however, 7 to 8 years at least to complete each dam. Urgent water supply must be considered by releasing water from the dam to be completed very soon by RID. And a diversion dam must be built as soon as possible, taking 3 to 4 years to complete it, for preventing saline water from

intruding in dry season, and for storing fresh water in the river course and pumping up and conveying it for the demanders.

The future plan of 11 waterworks belonging to PWA excepting Chonburi waterworks is examined. The popularization plan of the waterworks managed by Sanitary District and the waterworks for rural areas must be examined in consideration of inhabitants' demands. Presently, A.D.2000 year-plan must be established and the water source for this sector be secured.

4-3. Irrigated Agricultural Development

4-3-1. Basic Concept of Irrigated Agricultural Development

In order to meet the rapidly increasing water demand for agriculture, industrial, urban and rural development, the overall water supply plan has been worked out covering the whole Bang Pakong river basin. The basic concepts and approaches considered in formulating the plan were: 1) to utilize existing farmland most effectively, 2) to ensure possible and stable sources of water for irrigation and other purposes, and 3) to upgrade farming practices and to add values of agricultural products. As the result of such countermeasures, land and labor productivity can be extremely expanded with unit area production increase.

About 56%(993,760ha or 6,211,000rai) of the Bang Pakong river basin is intensively used for agricultural purposes. Non-product area shares remaining 44% (772,240ha = 4,826,500rai) which is mostly composed of reserved forest area. Since such unused areas are hardly expected to be converted into farmland even when consideration for environmental preservation is excluded, the most recommendable manner to maximize the benefit from the potential farmland is to introduce as much double cropping as possible during dry season in the existing paddy area and to introduce highly profitable crops with providing stable irrigation water.

At present, about 467,200 ha or 2,920,000 rai of paddy is being cultivated in the basin during wet season, relying principally on rainfall for crop production. About 89% of annual runoff is concentrated during wet season from May to October, however, only 27% of annual runoff within the entire basin is being utilized for irrigation. This is mainly for the lack of storage facility as well as unfavorable distribution of rainfall in time and space. In dry season, on the contrary, the area is almost left fallow because of absolute lack of water. An appropriate manner to utilize most efficiently the huge amount of water available in wet season is to store water in the reservoir and to release it in response to the request of the beneficiaries throughout wet and dry seasons when supplemental water supply is needed. An optimal plan of water resources development should be prepared by taking into account the proper water

demand projection, water allocation between respective water users with possible plan of project implementation and more technical and economical feasibility.

As the realistic plan to increase agricultural production, the following measures are to be carefully investigated:

Agricultural Development

- Introduction of double cropping in the existing paddy area
- Expansion of agricultural area
- Conversion of cassava plantation into other profitable upland crops
- Increase of crop yield

In order to achieve the above target, dependable supply of irrigation water and consolidation of irrigation facilities are inevitably necessary.

Irrigation System Consolidation

- Construction of storage dams, intake facilities, a diversion dam and other structures required for water resources development
- Installation of irrigation water conveyance and distribution systems
- Consolidation of on-farm irrigation facility
- Introduction of water management system

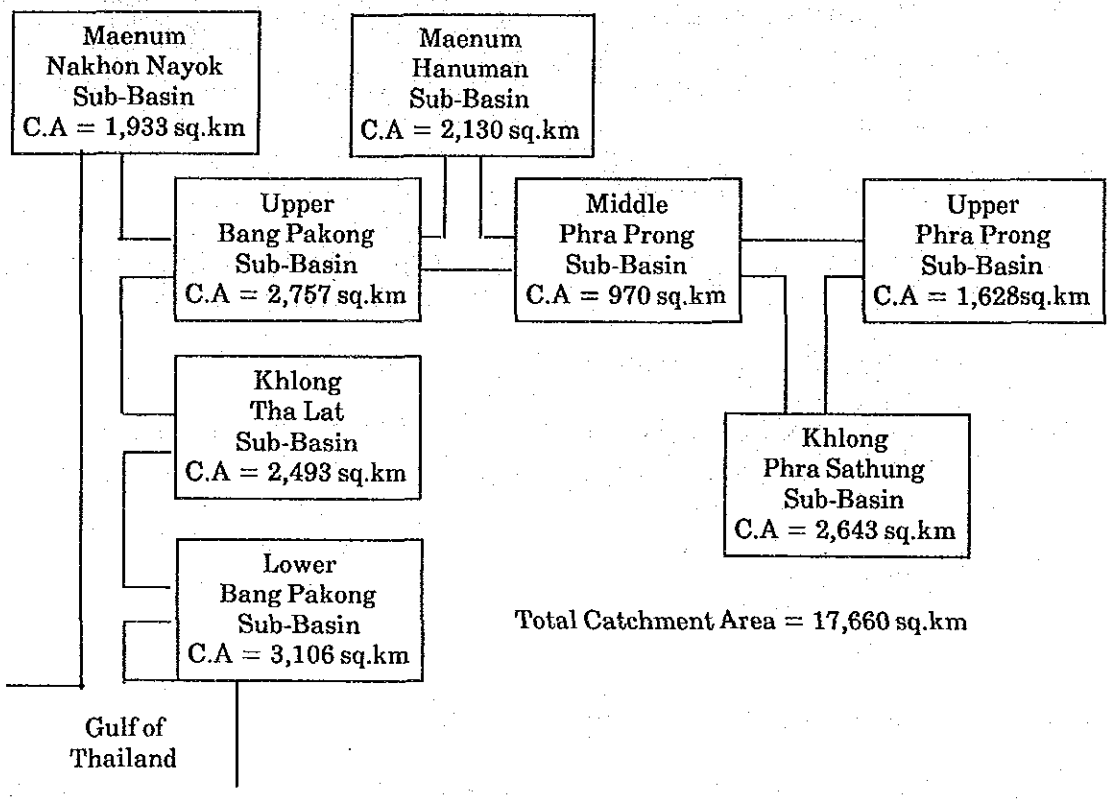
The domestic and industrial water supply together with supplemental fresh water supply for brackish water fishery forms an integral part of the land and water resources development. Water demands for such purposes are estimated at the target year 2000, which was determined in due consideration of period of the National Five-Year Development Plan and anticipated period of the Project implementation. Therefore formulation of the optimum development plan deals with three variables; extent of irrigation area, crops and cropping intensity, and availability of water or the development scale of dams.

In order to establish relationships among variables, a number of water balance studies were conducted with a 10 day time unit. Based on the relationships so established, various development alternatives were arbitrarily

selected and their cost and benefit were estimated for the economic comparison purpose.

4-3-2. Zoning of Irrigation Service Area

Based mainly on topographic conditions, alignment of river systems and distribution of possible damsites and beneficial areas, the Bang Pakong river basin was divided into eight sub-basins as shown below:



Sub-basins are further divided into 54 irrigation blocks as presented in Figure 4-1. An irrigation diagram so prepared is given in Figure 4-2.

4-3-3. Proposed Land Use

The proposed land use was determined by taking into consideration the present land use, topography, field conditions, the plan of supply and demand for agricultural production and irrigation water requirements, etc., as shown below;

FIGURE 4-1 BAOUNDARY AND COMMANDED AREAS OF IRRIGATION BLOCKS

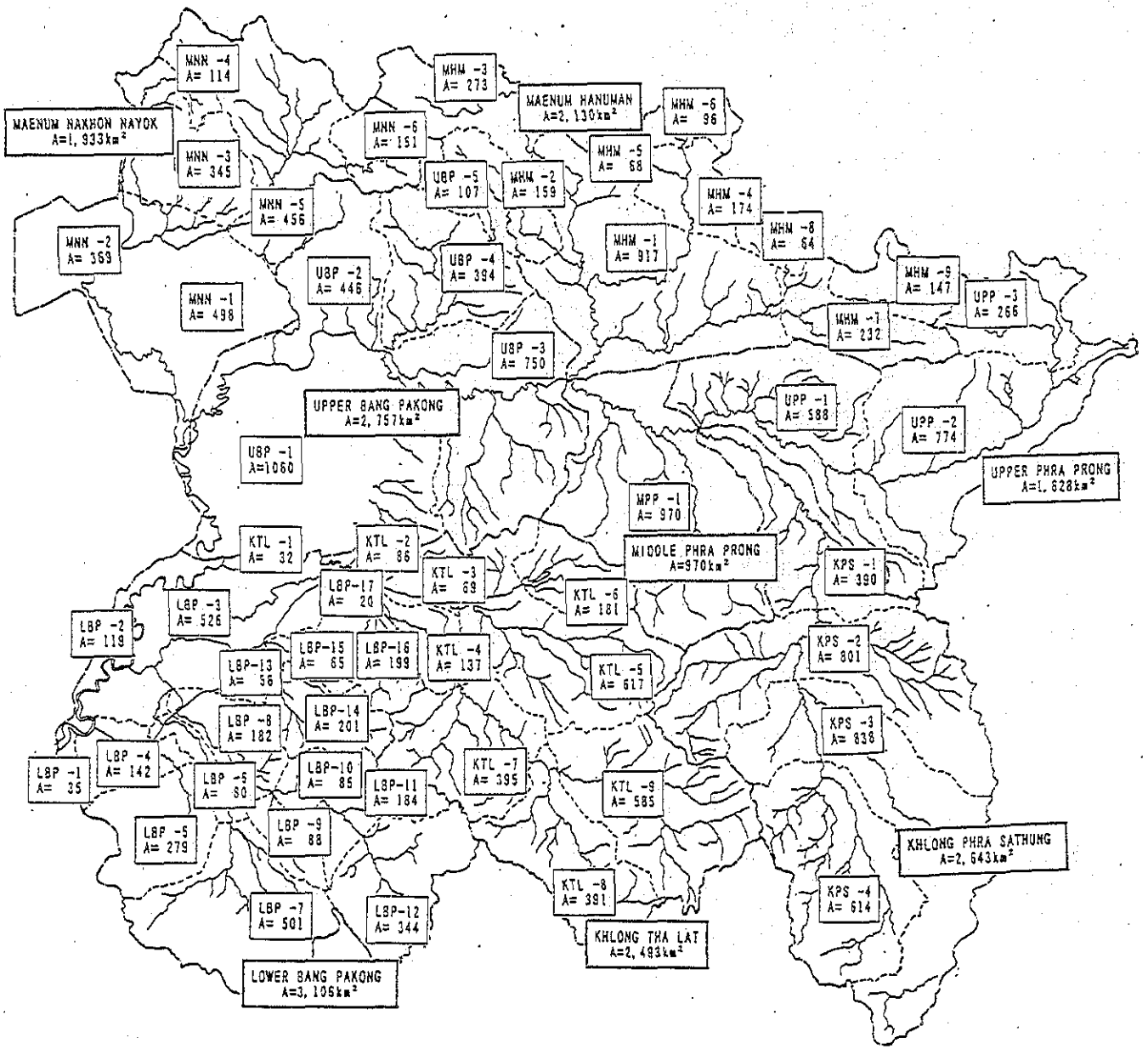
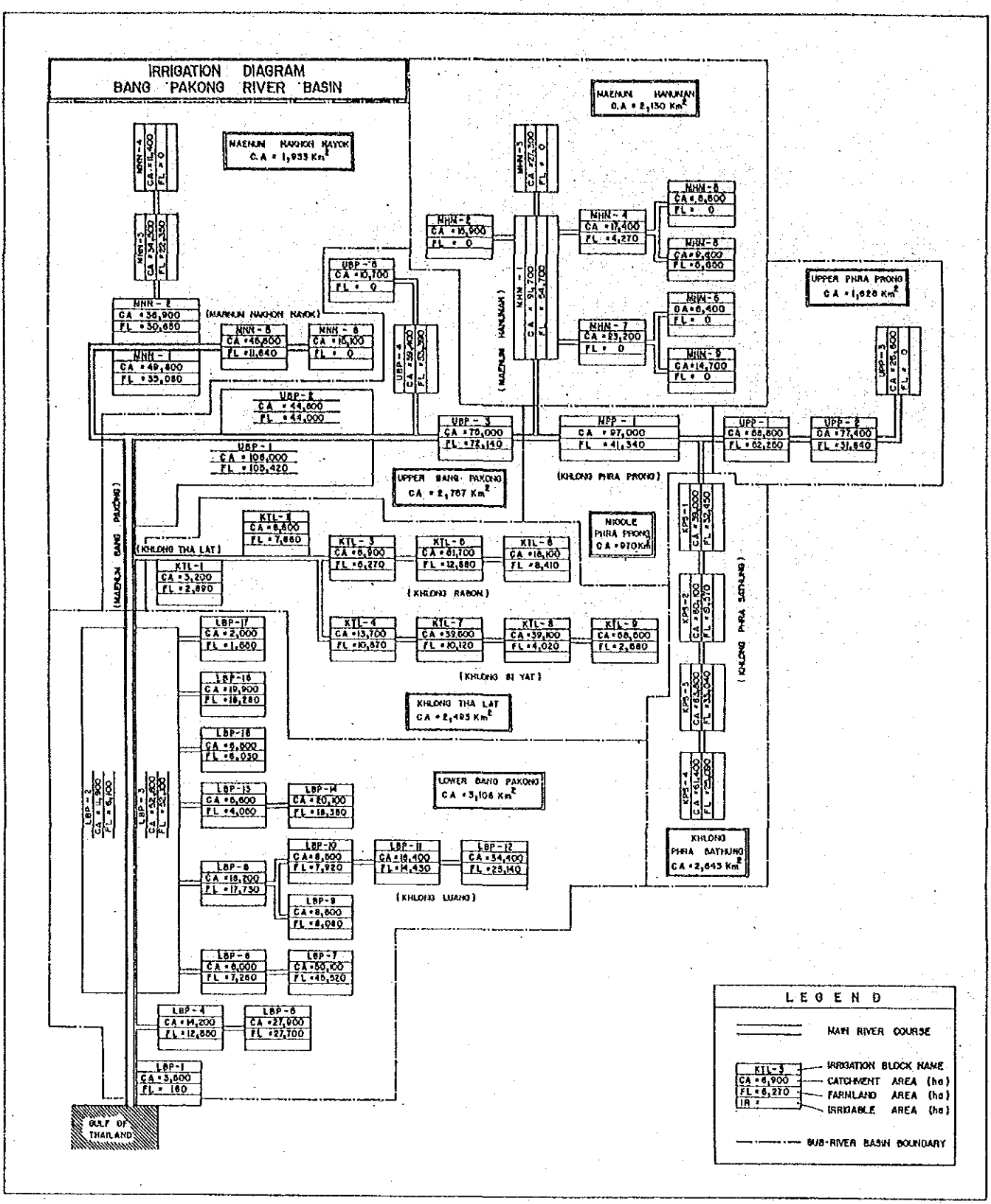


FIGURE 4-2 IRRIGATION DIAGRAM



(Unit: ha)

Present \ Plan	Paddy	Upland	Orchard	Sub Total	Non-Irrigable Area	Total
Paddy	339,600	1,200	8,000	348,800	127,490	476,290
Upland	—	41,900	700	42,600	372,870	415,470
Orchard	—	—	14,200	14,200	87,800	102,000
Others	—	—	1,300	1,300		1,300
Total	339,600	43,100	24,200	406,900	588,160	995,060

The conversion from paddy into other crops depends upon farmers' intention and recommendation of Provincial Agricultural Extension Offices etc.. Non-irrigation areas were decided based on field and topographical conditions. Table 4-1 presents the proposed land use by sub-basin.

4-3-4. Cropping Plan

1) Crop Diversification

Blessed with an advantageous economic situation, the Study area is expected to be a supply base of agricultural products for domestic consumption, processing materials and trading goods to both Bangkok metropolitan area and the Eastern Sea Board Development area. The development of land and water resources in the Bang Pakong basin would contribute to a great extent to the growth of national economy. A master plan to promote agricultural production should, therefore, comprise such crops as properly selected by taking into consideration the advantageous situation of the Study area. The Study area with 994,000 ha or 6,210,000 rai of farmland has high potentialities of economic expansion in the field of both agriculture and industry. Crop production in the area will highly expand through stable supply of irrigation water and through extension of advanced agricultural techniques under the harmonious development of infrastructures required. The basic concepts and procedures for selection of crops are summarized into two steps, as follows:

A) First Step: Basic Conception

- Assessment of the existing crop production in each Changwat and sub-river basin
- Evaluation of self-sufficiencies of the major crops for domestic consumption

TABLE 4-1 PROPOSED LAND USE BY SUB-BASIN

(Unit : ha)

Present \ Proposed	IRRIGATED AGRICULTURAL LAND					NOT IRRIGATED	TOTAL
	PADDY	UPLAND	ORCHARD	VEGETBLE	SUBTOTAL		
(1) Lower Bang Pakong Sub-Basin							
PADDY	53,400	-	-	-	53,400	49,300	102,700
UPLAND CROP	-	2,200	-	300	2,500	141,600	144,100
ORCHARD	-	-	4,900	-	4,900	12,900	17,800
VEGETABLES	-	-	-	8,300	8,300	100	8,400
TOTAL	53,400	2,200	4,900	8,600	69,100	203,900	273,000
(2) Khlon Tha Lat Sub Basin							
PADDY	3,300	-	-	-	3,300	700	4,000
UPLAND CROP	-	1,700	700	-	2,400	58,700	61,100
ORCHARD	-	-	-	-	-	700	700
VEGETABLES	-	-	-	-	-	200	200
OTHER LAND	-	-	1,300	-	1,300	3,000	4,300
TOTAL	3,300	1,700	2,000	-	7,000	63,300	70,300
(3) Upper Bang Pakong Sub Basin							
PADDY	115,100	-	-	-	115,100	52,300	167,400
UPLAND CROP	-	-	-	4,500	4,500	32,600	37,100
ORCHARD	-	-	8,800	-	8,800	33,100	41,900
VEGETABLES	-	-	-	8,500	8,500	100	8,600
TOTAL	115,100	-	8,800	13,000	136,900	118,100	255,000
(4) Mae Num Nakhon Nayok Sub Basin							
PADDY	76,400	-	-	-	76,400	5,300	81,700
UPLAND CROP	-	-	-	-	-	2,600	2,600
ORCHARD	-	-	-	-	-	12,100	12,100
VEGETABLES	-	-	-	-	-	3,400	3,400
TOTAL	76,400	-	-	-	76,400	23,400	99,800
(5) Middle Phra Prong Sub Basin							
PADDY	15,500	-	-	-	15,500	4,000	19,500
UPLAND CROP	-	-	-	-	-	21,800	21,800
ORCHARD	-	-	-	-	-	-	-
VEGETABLES	-	-	-	-	-	-	-
TOTAL	15,500	-	-	-	15,500	25,800	41,300
(6) Mae Num Hanuman Sub Basin							
PADDY	21,600	-	2,900	-	24,500	-	24,500
UPLAND CROP	-	3,400	-	500	3,900	20,700	24,600
ORCHARD	-	-	-	-	-	15,500	15,500
VEGETABLES	-	-	-	-	-	100	100
TOTAL	21,600	3,400	2,900	500	28,400	36,300	64,700
(7) Khlong Phra Sathung Sub-Basin							
PADDY	21,700	-	1,600	-	23,300	6,600	29,900
UPLAND CROP	-	3,800	-	600	4,400	65,600	70,000
ORCHARD	-	-	500	-	500	7,700	8,200
VEGETABLES	-	-	-	1,800	1,800	200	2,000
TOTAL	21,700	3,800	2,100	2,400	30,000	80,100	110,100
(8) Upper Phra Prong Sub-Basin							
PADDY	32,600	-	3,500	1,200	37,300	9,300	46,600
UPLAND CROP	-	4,600	-	-	4,600	25,300	29,900
ORCHARD	-	-	-	-	-	5,800	5,800
VEGETABLES	-	-	-	500	500	1,300	1,800
TOTAL	32,600	4,600	3,500	1,700	42,400	41,700	84,100

- Consideration of export-oriented, export promotive or export promising crops and products
- Estimation of the capability of crop expansion in the entire Study area

B) Second Step: Evaluation and Study

- Availability of irrigation water
- Policy of the local agricultural extension offices on the crop diversification plan
- Adaptability of advanced farming techniques
- Profitability of the proposed crops
- Land/labour availability and its productivity
- Trend of the consumption in the urban areas in the vicinity of the Study area

Standard for Crop Selection

Item	Paddy	Maize	Mung-bean	Soy-bean	Ground-nuts	Cassa-va	Vege-tables	Mango	Sugar-cane
1. Exportable	M2	M2	S1	S1	M2	M2	L3	L3	M2
2. Domestic Consump.	L3	L3	M2	L3	M2	S1	M2	M2	M2
3. Extension	S1	L3	S1	L3	S1	S1	L3	L3	S1
4. Cultivation Tech.	E3	E3	E3	E3	E3	E3	D1	D1	E3
5. Product. of labor	L3	M2	M2	M2	M2	L3	S1	M2	M2
6. Profita-bility	L3	M2	M2	M2	M2	M2	L3	L3	M2
7. Labour Avail-ability	S3	S3	S3	S3	W1	W1	W1	W1	W1
8. Soil fertility Ma.	M2	S1	L3	L3	L3	S1	M2	M2	S1
9. Irrigation effect	L3	L3	L3	L3	M2	S1	L3	M2	M2
Total	23	22	20	23	20	15	19	19	16

Note: L: Large 3 M: Middle 2 S: Small 1
E: Easy 3 M: Middle 2 W: Weak 1

Accordingly, paddy, maize, soybean, groundnuts, mungbean, mango and vegetables were selected for the Project, on the basis of the above criteria and standards.

2) Cropping Pattern

The basic cropping pattern can be specified into the following four categories according to kinds of the second crops to be grown .

Field Character	Wet Season	Dry Season
- Paddy field	Paddy	Paddy
	Paddy	Soybean, Groundnuts, Mungbean Maize, Vegetables (50% of acreage double cropping)
- Upland field	Maize	Soybean, Groundnuts, Mungbean
	Vegetables	Vegetables
- Orchar		

3) Cropping Area

Proposed paddy fields cover the existing paddy fields except for the area which will be converted to orchard or vegetables fields.

In dry season, paddy fields are used for the cultivation of paddy, soybean, groundnuts and mungbean. These area occupy about 43% of wet season paddy field area.

The demand of soybean has been increasing recently. According to the "Plan of Soybean Increasing for Self-Supply", the soybean cultivation area is planned to be expanded to 635,000 ha by 1997/98.

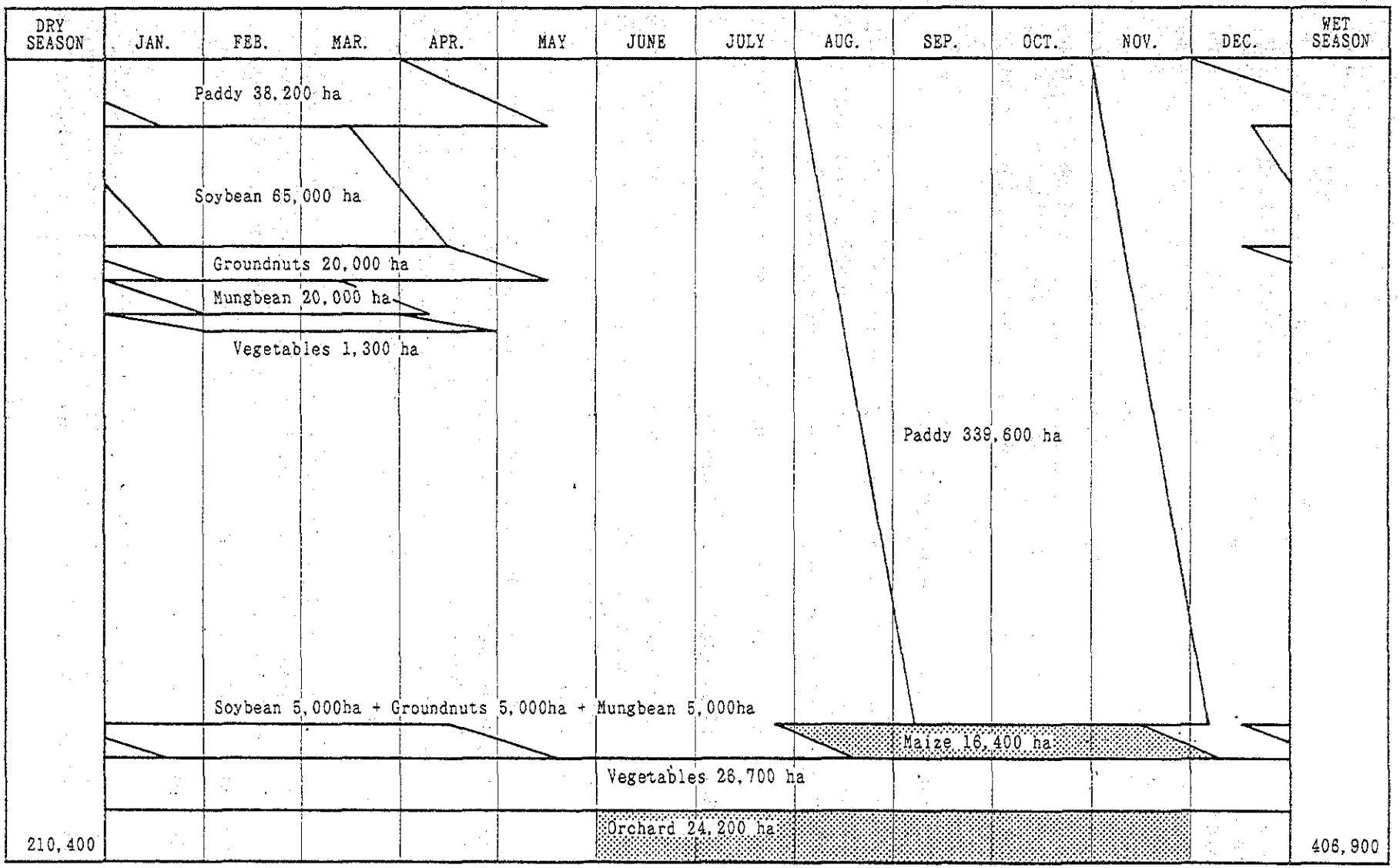
Considering this Plan, soybean is planned to be planted in 70,000 ha, sharing about 10% of the area in the Soybean Increasing Plan.

The demand of mungbean and groundnuts will also increase gradually. Therefore, mungbean and groundnuts are planned to be planted in 25,000 ha each, occupying about 30% of the area for soybean.

The vegetable consumption has been rising recently. Vegetables are planned to be planted in 26,700 ha with about 10% increase of the present cultivation area.

Mango is the representative fruit crops in the area and is planned to be planted in 10,000 ha with a new variety. Cropping areas by respective crops are then summarized as follows;

FIGURE 4-3 CROPPING PATTERN AND AREA



(unit: ha)

Crop	Paddy Field		Upland Field		Orchard	Total
	Wet S.	Dry S.	Wet S.	Dry S.		
Paddy	339,600	38,200	–	–	–	377,800
Soybean	–	65,000	–	5,000	–	70,000
Mungbean	–	20,000	–	5,000	–	25,000
Groundnuts	–	20,000	–	5,000	–	25,000
Maize	–	–	16,400	–	–	16,400
Vegetables	–	1,300	26,700	26,700	–	54,700
Mango	–	–	–	–	24,200	24,200
Total	339,600	144,500	43,100	41,700	24,200	593,100
Rai	(2,122,500)	(903,125)	(269,375)	(260,625)	(151,250)	(3,706,875)

4) Input Material and Labor Requirement

The necessary input materials for the proposed crops such as seeds, fertilizers, agro-chemicals and labor were studied making a reference to the reports prepared by the four provincial agricultural extension offices.

The Table 4-2 shows the necessary input materials and their amounts.

5) Rural Labour Market in the Target Year

It is estimated that the requirement of additional labour force population arising by introduction of proposed crops amounts to 222,326 persons in the year of 2000, taking a workable day per year at 300 days. (cf. Appendix G-20)

On the other hand, it is forecasted that the increasing population comes to 520,000 persons in 2000, by the NESDB's "Population Projections for Thailand 1980-2015", accounting a labour force population of 286,000 persons. Accordingly, it is possible to put workers into agricultural sector, even if the incremental labour force to be caused by the formation of new industrial estates is considered.

However, it might be required to adjust labour force distribution throughout a year. Vegetable cultivation is labour intensive, and harvesting periods of upland crops, such as cassava, soybean, are short and therefore they must be done at the same time.

6) Agricultural Product

The present yield fluctuates widely depending upon meteorological and other conditions. In estimating the target yields of proposed crops, as a general rule, various conditions such as seed breeding, fertilization,

TABLE 4-2 INPUT MATERIAL BY CROP PER HECTARE

Crop	Seed (kg)	Fertilizer (kg or kg/tree)			Lime (t)	Pesti -cide	Remark
		Compound	Urea	Dung			
Paddy							
- Transplant	63	280(16-20-0)	63		1.26	25kg	
- Broadcast	94	280(16-20-0)	63		1.26	2,250g	
Soybean	44	156(12-24-12)			1.26	-	
Mungbean	50	156(12-24-12)			1.26	-	
Groundnuts	75	156(12-24-12)			1.26	-	
Mango	278/ tree		0.5	10	1.26	5-6	Harvest:3yrs after plant
Vegetables							
- Green bean	25.0	220(15-15-15)	31	10,000	1.26	2.4-4.8ι	
- Tomato	0.3	220(15-15-15)	-	10,000	1.26	4.8-7.2ι	
- Baby corn	19.0	220(15-15-15)	31	10,000	1.26	4.8ι	
- Chilli	0.6	220(15-15-15)	31	10,000	1.26	-	
- Kale	3.2	220(15-15-15)	63	10,000	1.26	2.4-4.8ι	
- Sweet corn	19.0	315(15-15-15)	-	10,000	1.26	4.8ι	
- Chinese Cabbage	3.2	220(15-15-15)	31	10,000	1.26	2.4-4.8ι	
- Cucumber	7.2	220(15-15-15)	31	10,000	1.26	2.4-4.8ι	
Water Melon	9.0	220(15-15-15)	31	10,000	1.26	4.8-7.2ι	
Pumpkin	3.5	250(15-15-15)	31	10,000	1.26	-	

Note: Lime application only to acid soil, 6.3 ton/5 years.

TABLE 4-3 LABOR REQUIREMENT PER HECTARE

Crop	Human Power		Machine	
	Hour/ha	Hour/rai	Hour/ha	Hour/rai
Wet Season Paddy	1,034	166	98	16
Dry Season Paddy	887	142	97	16
Soybean	449	72	52	8
Groundnuts	560	90	35	6
Mungbean	423	68	43	7
Baby Corn	454	73	32	5
Chinese Kale	459	74	35	6
Chilli	657	105	34	6
Cucumber	478	77	37	6

availability of irrigation water and others should be taken into consideration. The target yields were estimated on the basis of the analytical results of yield data, collected from 27 Amphoes in and around the Project area. Improvement of farming techniques and the effect of the agricultural extension activities to be proposed by the Project were also taken into account. The target yields so estimated are as follows:

Target Yield by Crop

Crop	Target Yield (kg/ha)
Paddy	
Wet season	4,000
Dry season	4,500
Soybean	1,875
Groundnuts	1,875
Mungbean	1,125
Mango	13,800
Vegetable	
Kale	9,200
Chinese Cabbage	12,000
Green bean	9,300
Tomato	12,000
Cucumber	12,000
Watermelon	12,500
Sweet Corn	6,000
Baby Corn	2,000
Chilli,	3,000
Pumpkin	7,000
Vegetable average	8,500

7) Seed Supply

The seed requirements of major crops were estimated as follows.

Crops	Area ha	Seed quantity kg/ha	Seed requirement t
Paddy (wet s.)	339,600	79	26,830
Soybean	70,000	44	3,080
Groundnuts	25,000	75	1,875
Mungbean	25,000	50	1,250
Maize	16,400	100	1,640
Vegetables	54,700	9	495

It is desirable to renew the seeds of HYV for every cropping. Making seed renewal once a four year croppings, the following seed quantities would be

required. In this connection, however, the seeds of vegetables will need to be renewed every year.

Crop	Seed requirement
	ton/year
Paddy	6,700
Soybean	770
Groundnuts	470
Mungbean	315
Maize	410
Vegetables	495

Therefore, the proper seed production and distribution system should be established to meet the increasing requirement.

8) Processing and Storage of Agricultural Production

After-Project, increased production by each crop is estimated as follows;

Crops	Annual Production
	ton
Paddy wet season	655,000
dry season	172,000
Soybean	131,000
Groundnuts	47,000
Mungbean	28,000
Maize	47,000
Vegetables	333,000
Mango	243,000

Establishment of rice mill and multi-crop storage enables to increase various benefits directly to the beneficiaries. The following facilities would be required to meet the above requirements;

Facilities	Capacity	No. of Facilities	Working day
Rice mill	100 t/day	40 unit	200 day/year
Grain silo	10,000 t	4	365
Go-down	2,500 t	4	365
Cold storage	1,000 t	4	150

4-3-5. Irrigation Water Requirement

Irrigation water requirement was calculated with a 10-day time step combining estimated values of water consumption for respective crops,

percolation rate, other field water requirements for initial leaching and land preparation, on-field effective rainfall, and water losses due to conveyance and system operation. Major items for estimation are briefly described below:

Cropping Calendar

Cropping calendar is prepared in accordance with the field survey on farming practice and with recommendations from an agronomic point of view, as given in Figure 4-3.

Reference Crop Evapotranspiration and Kp/Kc Values

Modified Penman Method was employed to estimate water consumption of paddy, vegetable and fruit crops. Climatological records collected at both Prachinburi and Chonburi meteorological stations were used for the estimation. Kc values developed in Thailand for use of Penman Method were referred to in the "Report on the Consumptive Use of Paddy, RD23 at Mae Taeng Irrigation Research Station, Chiang Mai", May 1987, prepared by Irrigated Agriculture Branch, Operation and Division, RID. On the other hand, Pan-Evaporation Method was used for upland crops since experimental Kp values were fully available in the "Report of the Consumptive Use of Upland Crops, The Consumptive Use of Upland Crops Research Project" prepared in May 1988 by the above branch of RID.

Field Water Requirements

Percolation rate was estimated at 2.0 mm/day. As for the requirement for both initial leaching and land preparation for paddy cultivation, respectively 50 mm and 150 mm were used. Field water requirements so calculated are summarized as under:

Field Water Requirement by Crop

(Unit=mm/day)

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet Paddy T.P.	-	-	-	-	-	-	0.9	6.7	7.7	6.4	2.3	-
Wet Paddy B.C.	-	-	-	-	-	-	6.6	8.3	7.0	6.4	2.3	-
Dry paddy T.P.	7.0	9.2	7.9	2.5	-	-	-	-	-	-	-	0.9
Dry Paddy B.C.	9.2	8.6	7.8	2.5	-	-	-	-	-	-	-	6.8
Dry Soybeans	2.7	5.0	3.9	0.2	-	-	-	-	-	-	-	0.3
Dry Groundnuts	2.8	4.7	4.6	1.8	-	-	-	-	-	-	-	0.3
Dry Mungbeans	-	-	-	1.8	4.7	0.8	-	-	-	-	-	-

Effective Rainfall

RID's rating curve showing relationship between monthly rainfall and monthly effective rainfall was applied. In each irrigation block, areal rainfalls were estimated by use of Thiessen Method.

Irrigation Efficiency

Farm distribution losses consist mainly of percolation loss for upland field and seepage loss through dikes for paddy field, and was assumed at 0.85 and 0.70, respectively for paddy and upland fields. For the canal conveyance efficiency, a value of 0.70 is adopted in this study including efficiencies for all canals from the site of water source down to the inlet of the planted field. Overall efficiencies are thus taken as 0.85x0.70=0.595 and 0.70x0.70=0.49, respectively for paddy rice and upland crop cultivations.

Water Demand (Irrigation Diversion Requirement)

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

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

4-4. Other Water Supply Requirements

4-4-1. Domestic and Drinking Water

Supply of domestic and drinking water in the area are being conducted through waterwork facilities operated by PWA, Sanitary Districts and a few local community units. The Thai Government has made efforts continuously to provide stable and hygienic drinking water to the people in both the urban area and the rural area.

TABLE 4-4 WATER DEMAND PROJECTION IN TARGET YEAR 2000 (INDUSTRIAL AND URBAN WATER SUPPLY FROM WATER WORK FACILITY)

Province	District	Served Population			Water Demand Projection (MCM)								
					PWA			Rural Area			Total		
		PWA	Rural	Total	Indust.	Urban	Total	Indust.	Urban	Total	Indust.	Urban	Total
Chonburi	M. Chonburi	239,200	35,600	274,800	11.657	24.752	36.409	0.400	2.044	2.444	12.057	26.796	38.853
Chonburi	Bo Thong	-	36,000	36,000	-	-	-	0.400	2.070	2.470	0.400	2.070	2.470
Chonburi	Ban Bung	8,430	81,600	90,030	0.088	0.713	0.801	0.930	4.670	5.600	1.018	5.383	6.401
Chonburi	Phanat Nikhom	14,290	75,700	89,990	0.400	1.480	1.880	0.880	4.350	5.230	1.280	5.830	7.110
Chonburi	Phan Thong	-	33,600	33,600	-	-	-	0.390	1.932	2.322	0.390	1.932	2.322
Chonburi	Others(5)	-	363,000	363,000	-	-	-	4.260	20.868	25.128	4.260	20.868	25.128
Total		261,920	625,500	887,420	12.145	26.945	39.090	7.260	35.934	43.194	19.405	62.879	82.284
Chachoengsao	M. Chachoengsao	43,200	71,500	114,700	3.833	6.623	10.456	0.820	4.112	4.932	4.653	10.735	15.388
Chachoengsao	Bang Khra	7,000	38,800	45,800	0.767	0.617	1.384	0.450	2.232	2.682	1.217	2.849	4.066
Chachoengsao	Bang Pakong	24,800	35,100	59,900	7.550	2.568	10.118	0.400	2.028	2.428	7.950	4.596	12.546
Chachoengsao	Ban Pho	-	30,600	30,600	-	-	-	0.350	1.759	2.109	0.350	1.759	2.109
Chachoengsao	Phanom Sarakam	13,800	44,200	58,000	0.288	1.272	1.560	0.510	2.539	3.049	0.798	3.811	4.609
Chachoengsao	Sanamchai Khet	-	129,000	129,000	-	-	-	1.480	7.416	8.896	1.480	7.416	8.896
Chachoengsao	Plaeng Yao	-	26,400	26,400				0.304	1.518	1.822	0.304	1.518	1.822
Chachoengsao	Others (2)	-	63,000	63,000	-	-	-	0.724	3.622	4.346	0.724	3.622	4.346
Total		88,800	438,600	527,400	12.438	11.080	23.518	5.038	25.226	30.264	17.476	36.306	53.782
Prachinburi	M. Prachinburi	27,600	62,400	90,000	3.833	4.982	8.815	0.710	3.587	4.297	4.543	8.569	13.112
Prachinburi	Kabinburi	14,100	75,800	89,900	0.386	1.729	2.115	0.870	4.360	5.230	1.256	6.089	7.345
Prachinburi	Khok Peep	-	12,600	12,600	-	-	-	0.150	0.725	0.875	0.150	0.725	0.875
Prachinburi	Na Dee	-	39,600	39,600	-	-	-	0.450	2.277	2.727	0.450	2.277	2.727
Prachinburi	Ban Srang	-	19,800	19,800	-	-	-	0.220	1.138	1.358	0.220	1.138	1.358
Prachinburi	Prachan Takan	-	36,000	36,000	-	-	-	0.410	2.070	2.480	0.410	2.070	2.480
Prachinburi	Wang Nam Yen	-	108,600	108,600	-	-	-	1.250	6.244	7.494	1.250	6.244	7.494
Prachinburi	Watthana Nakhon	8,800	55,900	64,700	0.619	1.079	1.698	0.640	3.215	3.855	1.259	4.294	5.553
Prachinburi	Si Ma Ha Pho	-	40,200	40,200	-	-	-	0.460	2.311	2.771	0.460	2.311	2.771
Prachinburi	Sra Kaeo	-	139,200	139,200	-	-	-	1.600	8.000	9.600	1.600	8.000	9.600
Prachinburi	Other (1)	-	168,000	168,000	-	-	-	1.930	9.658	11.588	1.930	9.658	11.588
Total		50,500	758,100	808,600	4.838	7.790	12.628	8.690	43.585	52.275	13.528	51.375	64.903
Nakhon Nayok	M. Nakhon Nayok	27,700	51,700	79,400	2.713	3.822	6.535	0.600	2.974	3.574	3.313	6.796	10.109
Nakhon Nayok	Ban Na	8,900	40,200	49,100	0.123	0.682	0.805	0.460	2.311	2.771	0.583	2.993	3.576
Nakhon Nayok	Pak Pli	-	18,000	18,000	-	-	-	0.210	1.035	1.245	0.210	1.035	1.245
Nakhon Nayok	Ongkarak	-	33,600	33,600	-	-	-	0.390	1.932	2.322	0.390	1.932	2.322
Total		36,600	143,500	180,100	2.836	4.504	7.340	1.660	8.252	9.912	4.496	12.756	17.252
Grand Total		437,820	1,965,700	2403,520	32.257	50.319	82.576	22.650	112.997	135.647	54.907	163.316	218.223

Note: 1) The proposed served population was estimated based on populatin census during 1984 to 1988.
2) The figures of PWA' water demand are based on PWA proposal in the inventory.
3) Industrial water demands in the rural area asummed as 20 % of urban (drinking) water demands.