FIGURES

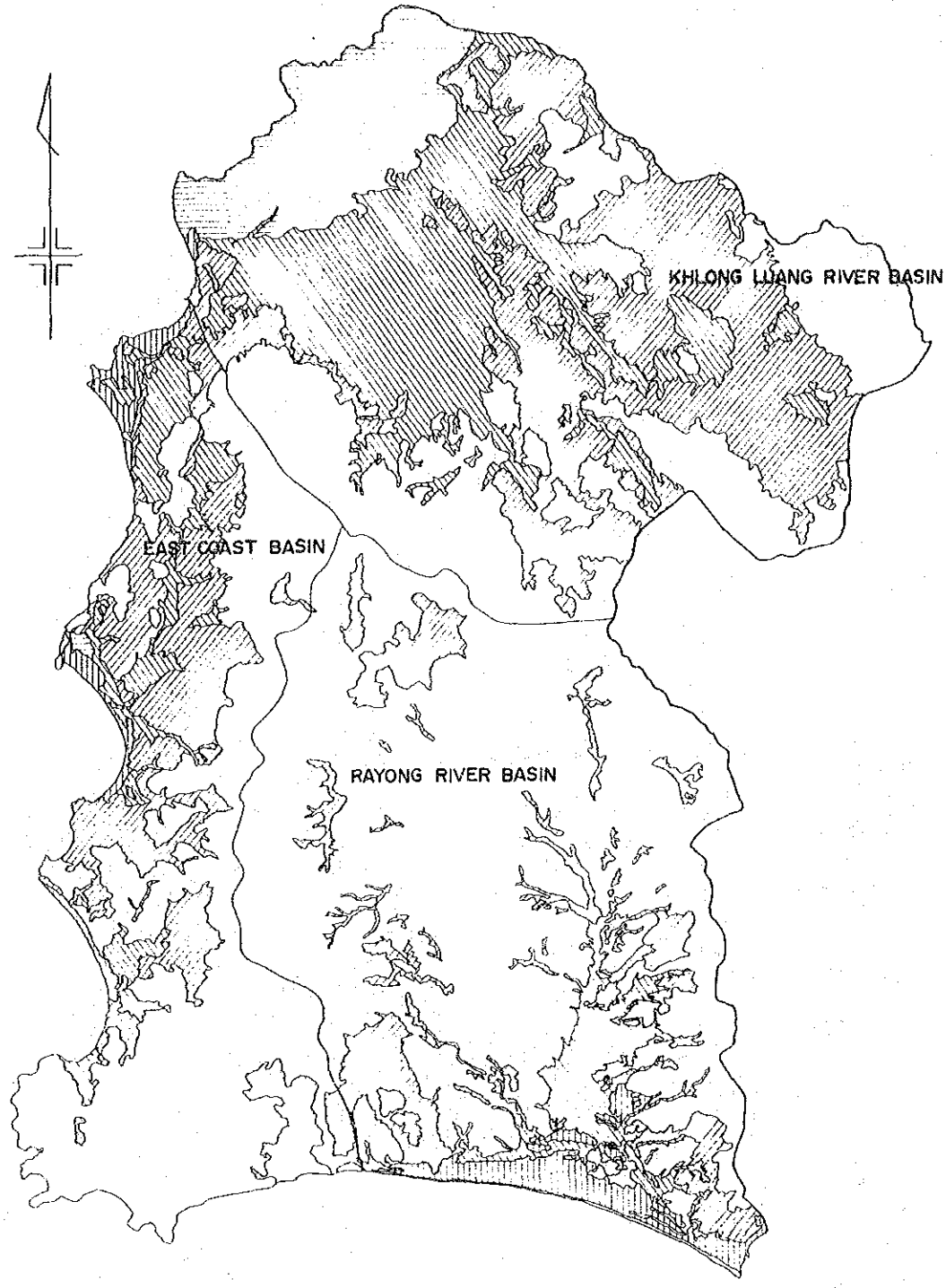

Fig. 1 Soil Group Map in the Study Area

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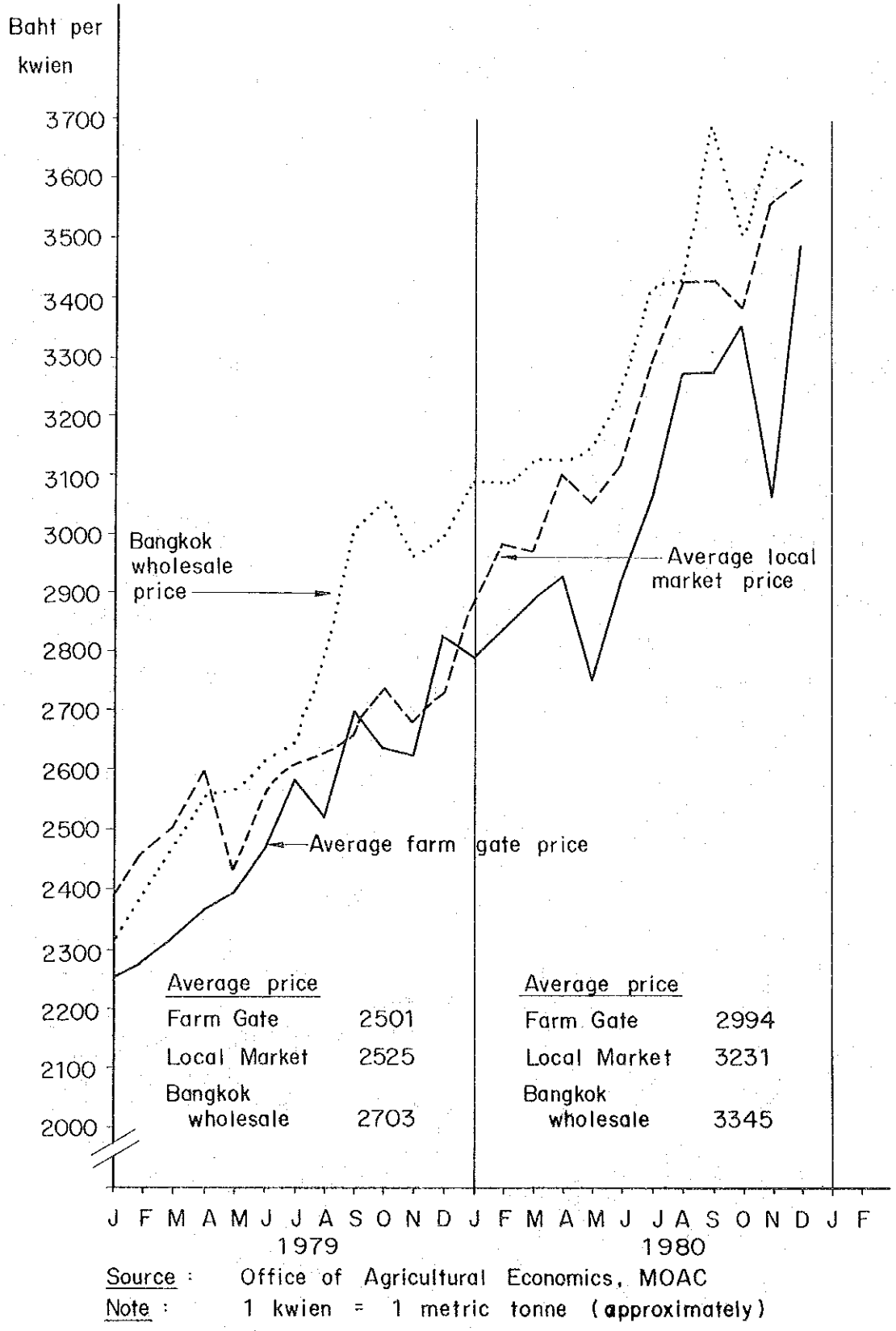

Source : Office of Agricultural Economics, MOAC

Note : 1 kwien = 1 metric tonne (approximately)

Fig. 2 Price of Paddy in Different Market

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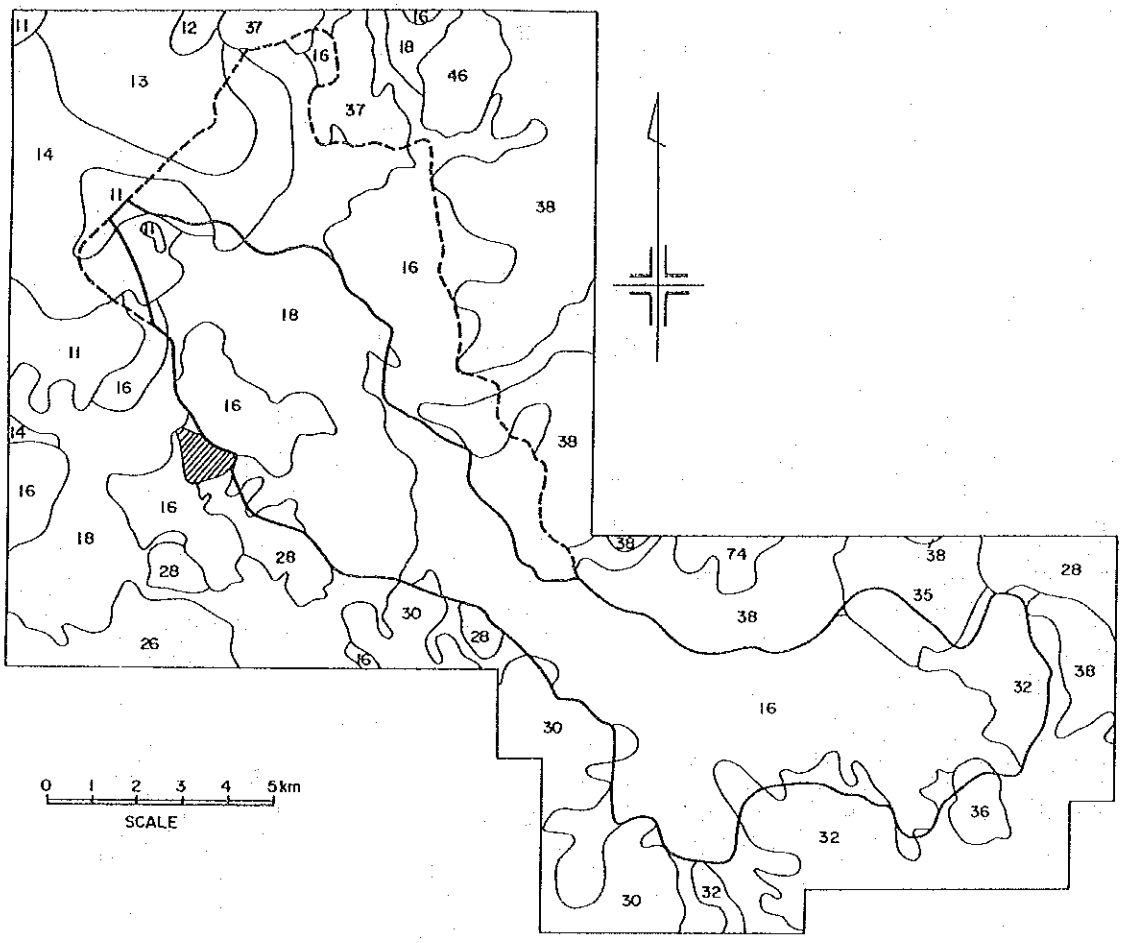

Topography	Materials	Soil Series No. Associated	Study Area (ha)	(%)	Potential Irrigable Area (ha)	(%)	Proposed Scheme Area (ha)	(%)
Former Tidal Flat	Brackish Deposits	11. 12. 13. 14	4,180	14	1,210	11	230	2
Lower Terrace	Riverine Alluvium	16. 18. 26	14,550	48	9,270	79	6,490	84
Higher Terrace	Riverine Alluvium	28. 30. 32. 35 36. 37. 38. 46	11,290	38	1,220	10	1,080	14
Residual Hill and Footslope	Granite Rocks	74	180	–	–	–	–	–
		Total	30,200	100	11,700	100	7,800	100

Fig. 3 Soil Map of the Khlong Luang Scheme Area

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Topography	Materials	Soil Series No Associated	Study Area Extent (ha)	(%)	Ban Khai Extension Area (ha)	(%)	Ban Khai Existing Area (ha)	(%)	Thap Ma Area (ha)	(%)
Beach and Sand Bars	Beach and Sand Bar Deposits	1. 2. 3. 4	7.470	18	1.550	17	420	8	640	23
Tidal Flat	Brackish Deposits	6	300	—	300	3	—	—	—	—
Alluvial Plain	Alluvium	8. 9. 12. 14	12.480	30	4.280	48	4.810	89	1.720	61
Piedmont or Low Residual Hill	Alluvium or Colluvium	19. 20. 21. 27. 34	770	2	30	—	—	—	—	—
Hill (Slighty undulating wash surface)	Transported Materials and Residuum from Granite and Gneiss	36. 37	4.680	11	1.060	12	30	—	30	1
Hill (Undulating to rolling topography)	—do—	39. 40. 41. 42. 43 44. 46. 48. 49. 50 52. 55. 59. 60	16.590	39	1.780	20	140	3	410	15
		Total	42.290	100	9.000	100	5.400	100	2.800	100

① Ban Khai Extension Area

② Ban Khai Existing Area

③ Khlong Thap Ma Area

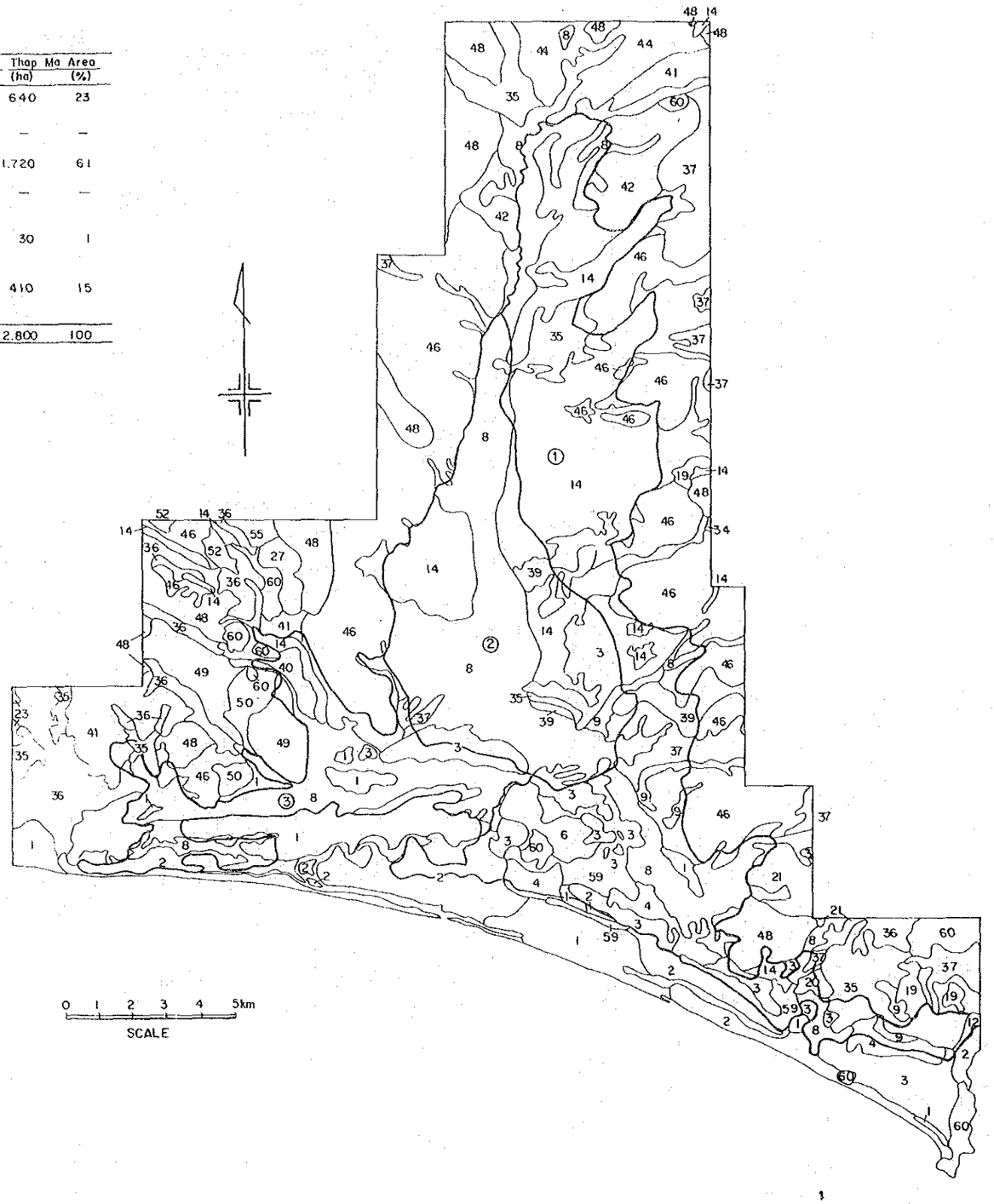

Fig. 4 Soil Map of the Rayong Area

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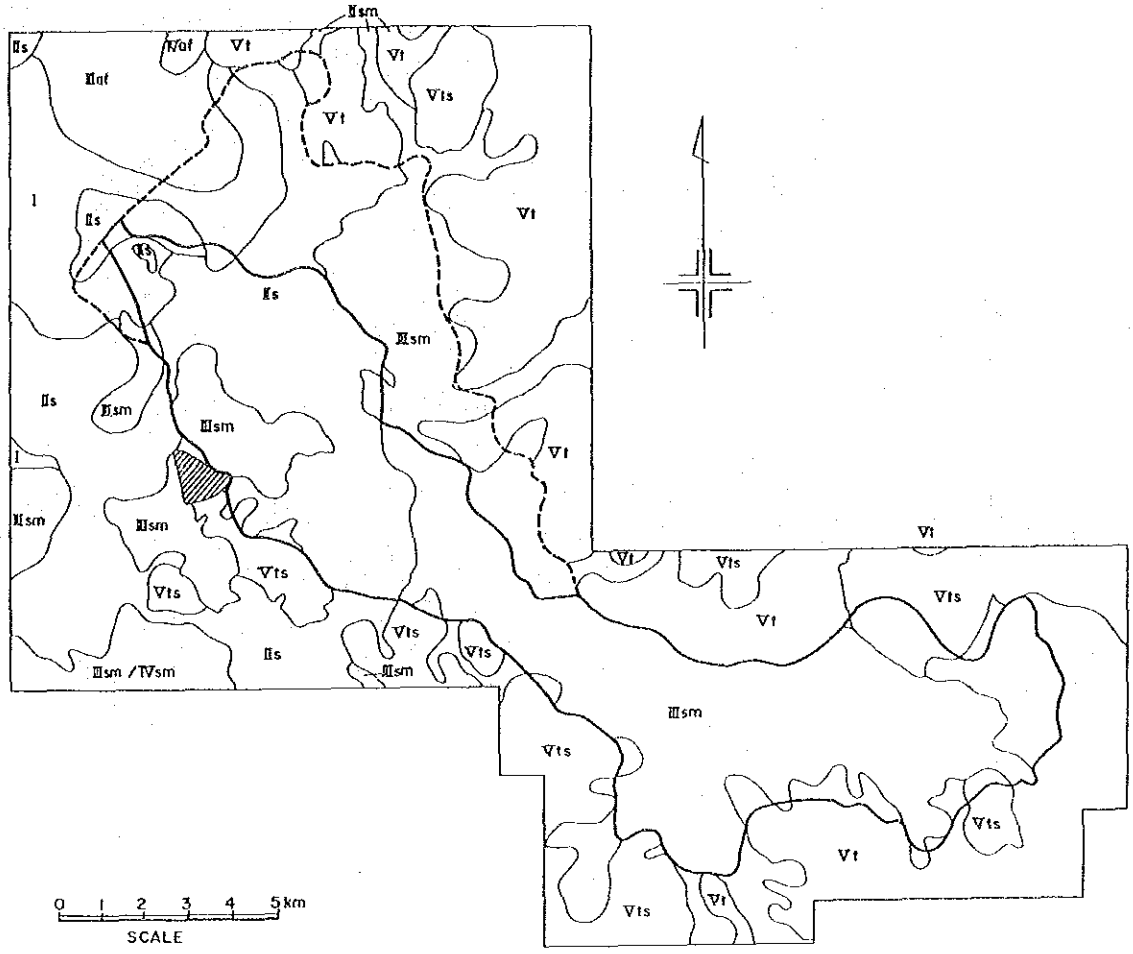

Sutability Class	Study Area	Potential Irrigable Area	Proposed Scheme Area
I	1.830	830	210
II	5.580	2.970	2.120
III	10.500	6.300	4.410
III / IV	610	—	—
IV	70	—	—
V	11.610	1.600	1.060
Total	30.200	11.700	7.800

(Unit : Ha)

Potential Irrigable Area

Proposed Scheme Area

Fig. 5 Land Capability Map for Paddy of the Khlong Luang Scheme Area

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Capability Class	Study Area	Ban Khai Extension Area (ha)	(%)	Ban Khai Existing Area (ha)	(%)	Thap Ma Area (ha)	(%)
Ⅲ	12.460	4.620	51	4.700	87	760	27
Ⅳ	580	420	5	—	—	80	3
Ⅴ	26.070	2.780	31	630	12	1.120	40
Ⅴ/Ⅲ	2.190	1.040	12	70	1	840	30
Ⅴ/Ⅳ	990	140	1	—	—	—	—
Total	42.290	9.000	100	5.400	100	2.800	100

① Ban Khai Extension Area

② Ban Khai Existing Area

③ Khlong Thap Ma Area

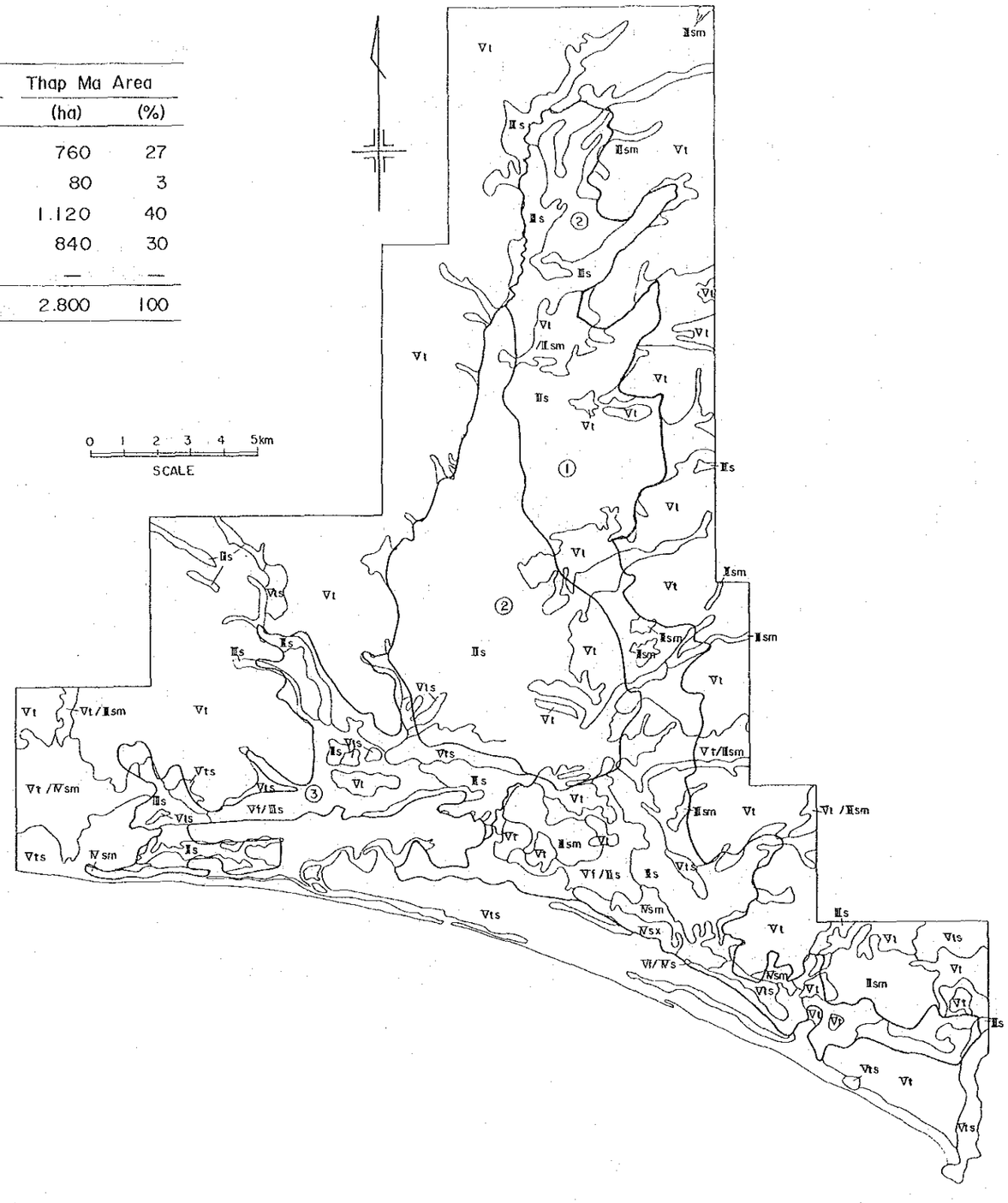

Fig. 6 Land Capability Map for Paddy of the Rayong Area

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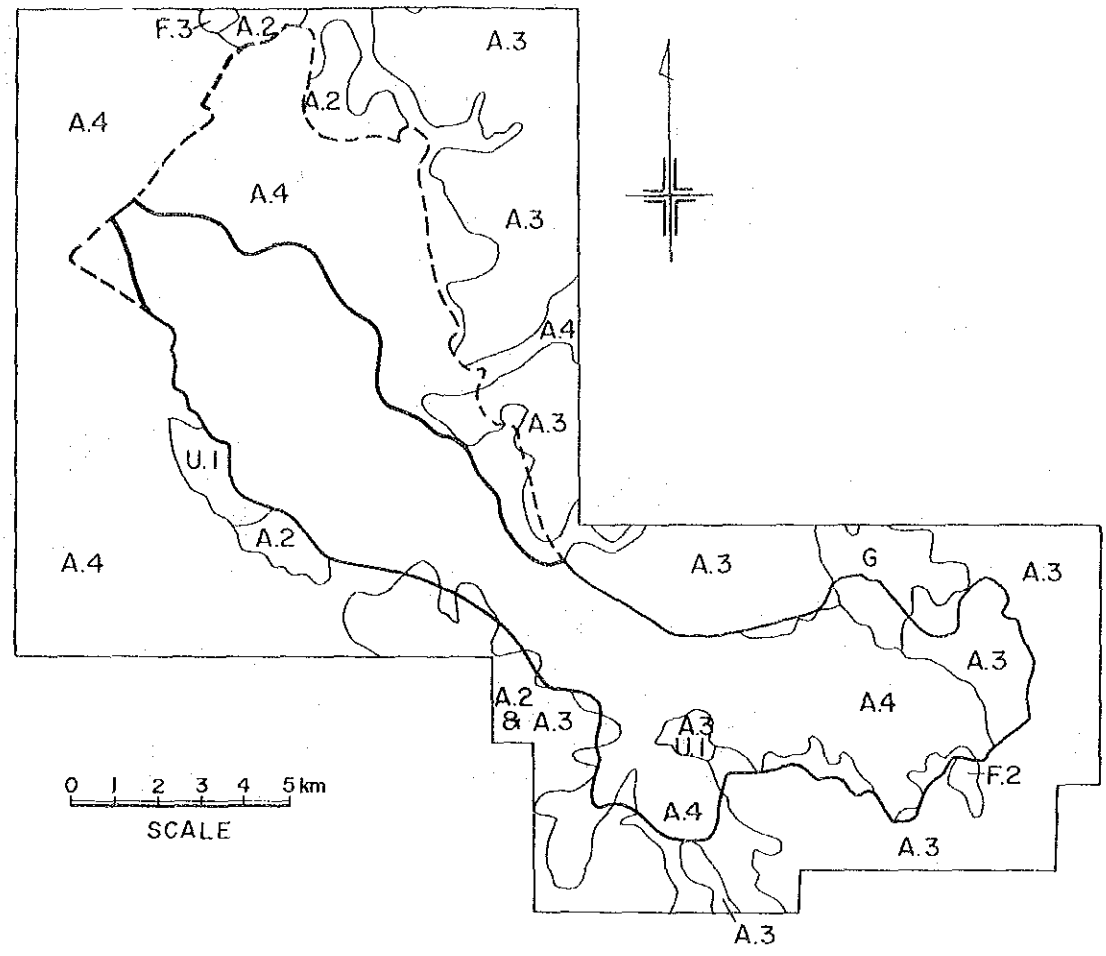

LEGEND

Land Use			Study Area		Potential Irrigable Area		Proposed Scheme Area	
Class	Subclass	Map Symbol	(ha)	(%)	(ha)	(%)	(ha)	(%)
Urban area	Residential and commercial	U.1	300	1	40	—	80	1
Agricultural land	Perennial crop	A.2	1.410	5	260	3	60	1
	Field crop	A.3	8.780	29	1.020	9	870	11
	Raddy field	A.4	19.050	63	10.210	87	6.620	85
Grassland		G	570	2	170	1	170	2
Forest	Hill and mountain forest	F.2	60	—	—	—	—	—
	Mangrove	F.3	30	—	—	—	—	—
		Total	30.200	100	11.700	100	7.800	100

Potential Irrigable Area

Proposed Scheme Area

Fig. 7 Present Land Use Map of the Khlong Luang Scheme Area

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Land Use	Ban Khai Extension Area		Ban Khai Existing Area		Thap Ma Area	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Rice Field	6.310	70.1	4.800	88.9	1.960	70.0
Upland Crop Field	1.900	21.1	100	1.9	650	23.2
Perennial Crop	580	6.4	—	—	100	3.6
Others	210	2.4	500	9.2	90	3.2
Total	9.000	100.0	5.400	100.0	2.800	100.0

① Ban Khai Extension Area

② Ban Khai Existing Area

③ Khlong Thap Ma Area

LEGEND

Land Use		
Class	Subclass	Map Symbol
Urban area	Residential and commercial	U.1
	Institutional	U.3
Agricultural land	Perennial crop	A.2
	Field crop	A.3
	Raddy field	A.4
Grassland	Unimproved grassland	G.2
Forest	Lowland and piedmont forest	F.1
	Hill and mountain	F.2
Marsh and Swamp		M

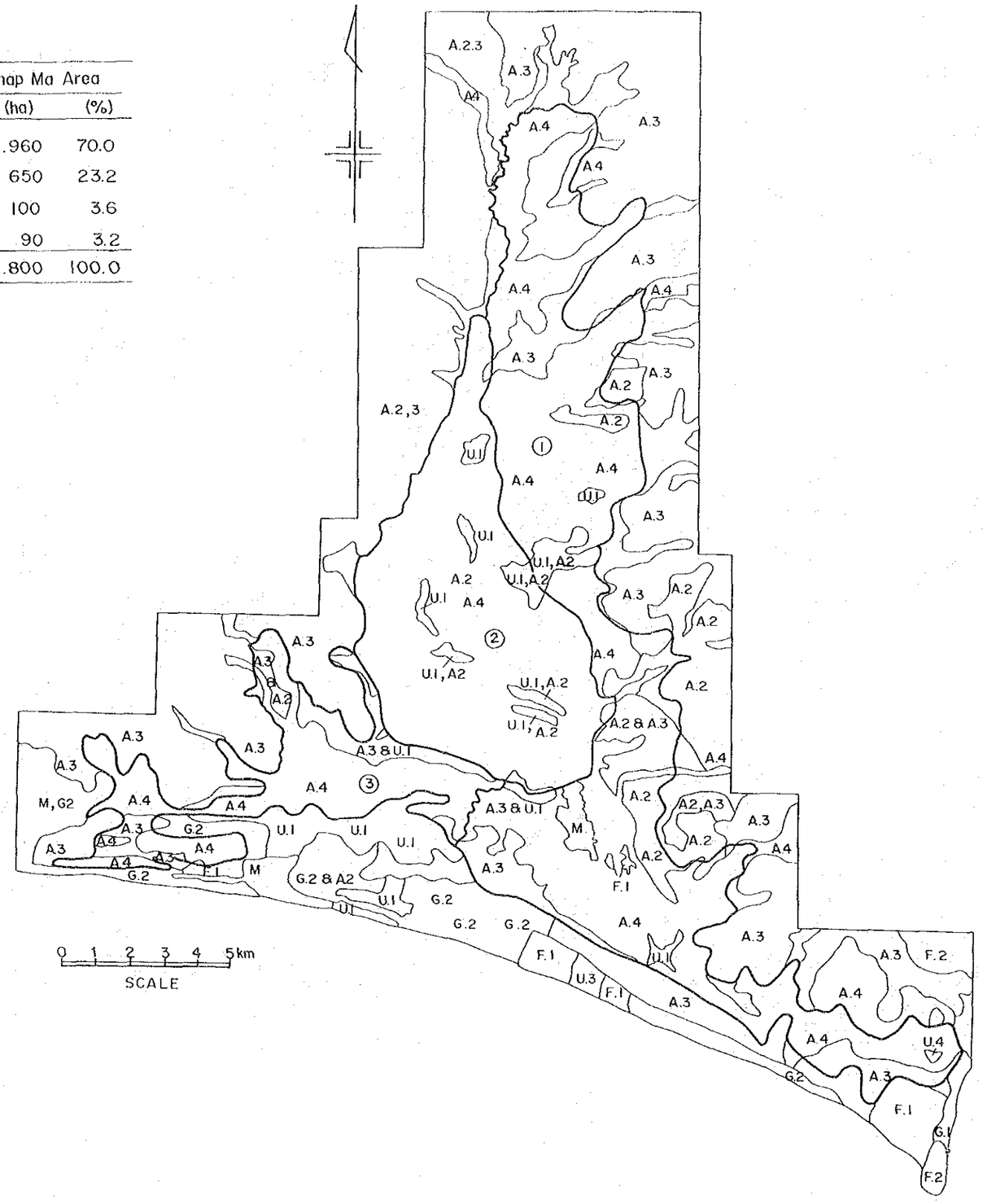

Fig. 8 Present Land Use Map of the Rayong Area

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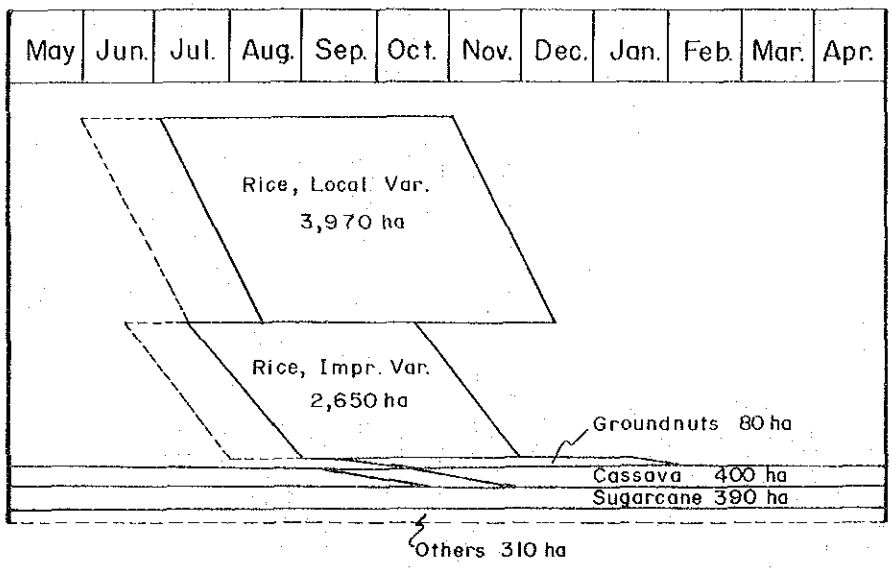
(1) Khlong Luang Irrigation Scheme



(2) Ban Khai Extension Irrigation Scheme

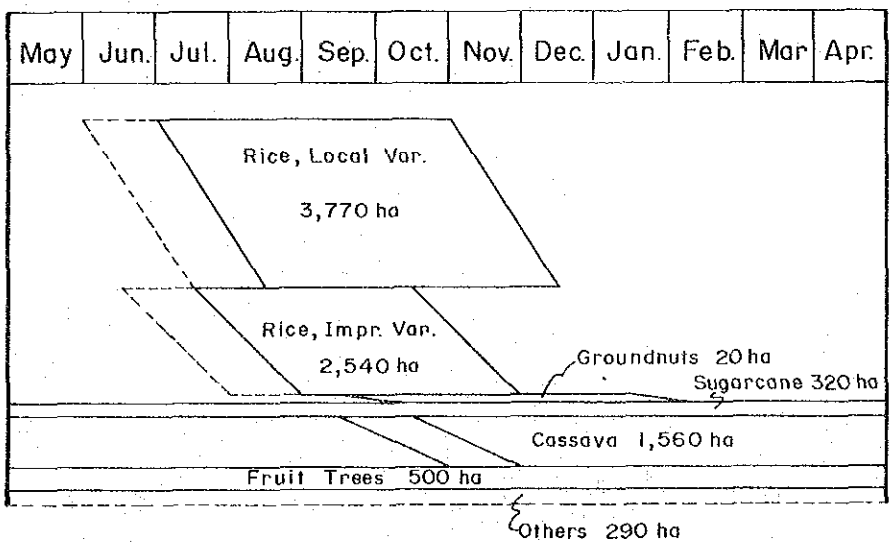


Fig. 9 (1/2) Present Cropping Pattern in the Proposed Irrigation Scheme Area

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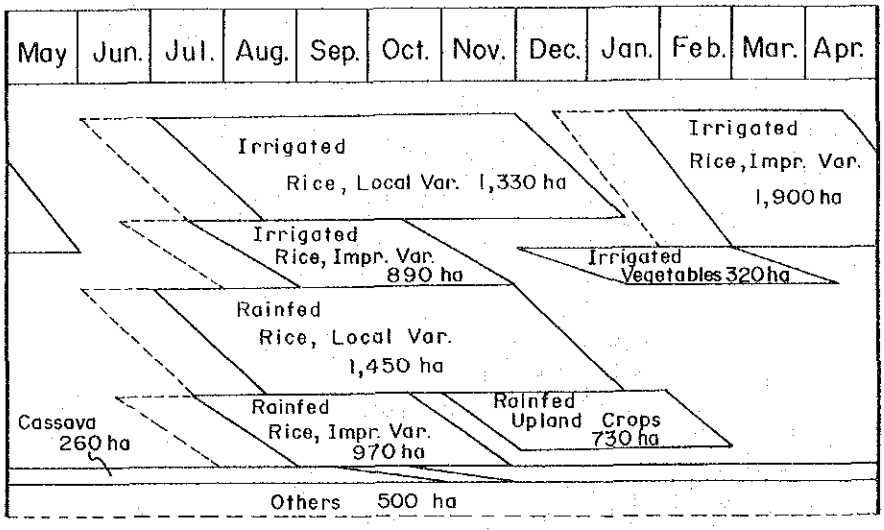
(3) Ban Khai Existing Irrigation Scheme



(4) Khlong Thap Ma Irrigation Scheme

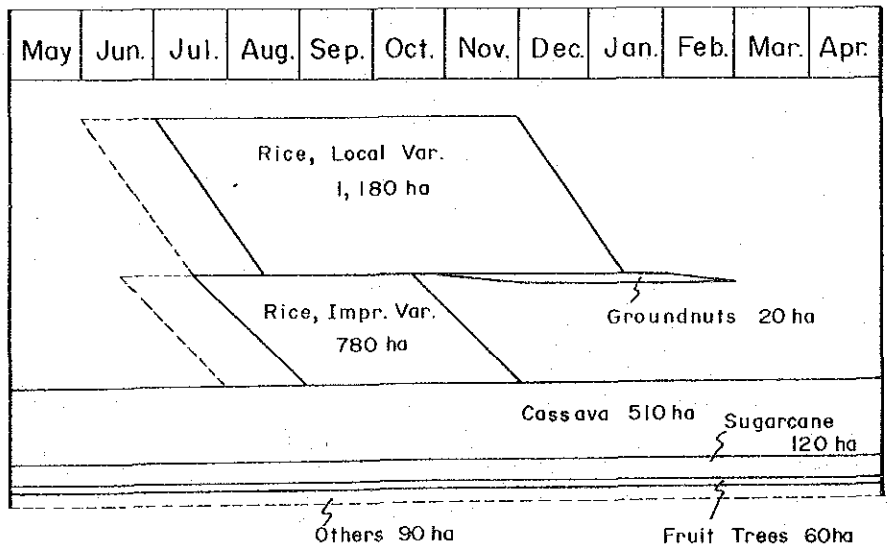


Fig. 9 (2/2) Present Cropping Pattern in the Proposed Irrigation Scheme Area

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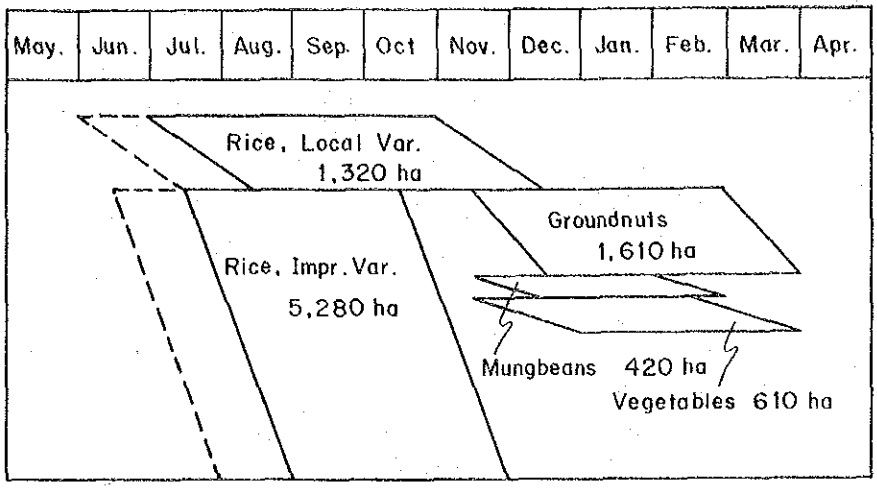
(1) Khlong Luang Irrigation Scheme

(Cropping Intensity 1.4)



(2) Ban Khai Extension Irrigation Scheme

(Cropping Intensity 1.4)

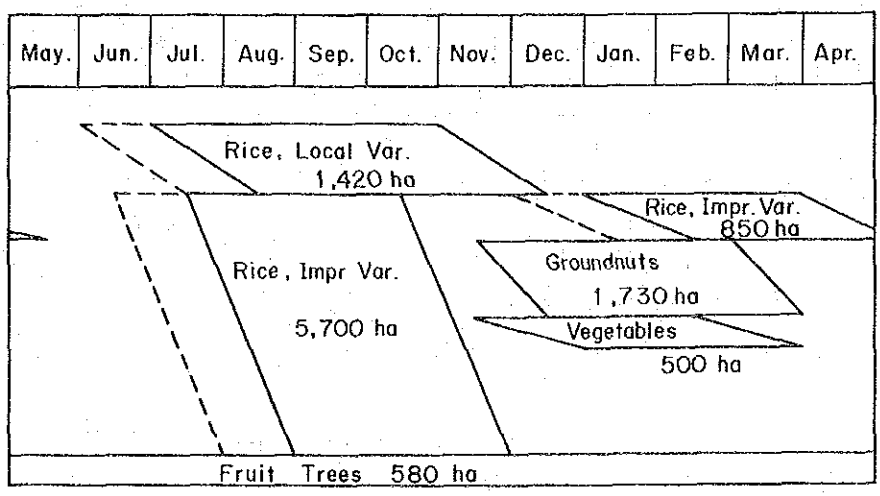


Fig. 10(1/2) Cropping Pattern for the Proposed Irrigation Scheme

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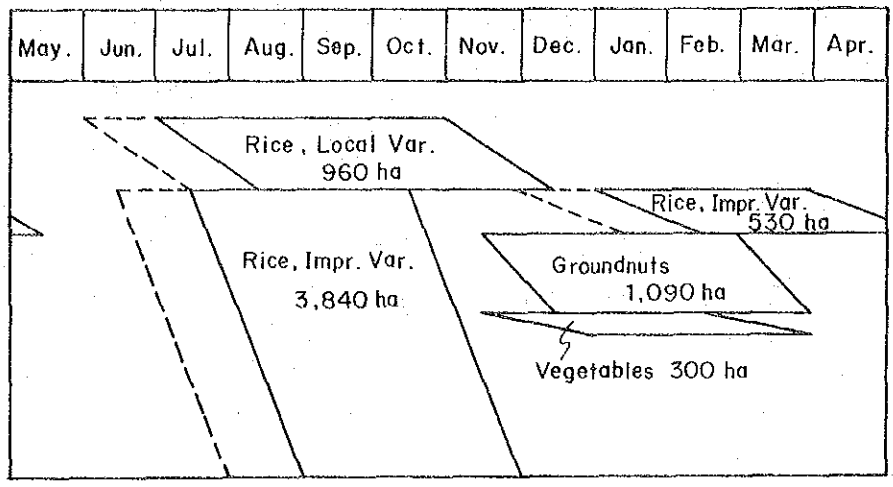
(3) Ban khai Existing Irrigation Scheme

(Cropping Intensity : 1.4)



(4) Khlong Thap Ma Irrigation Scheme

(Cropping Intensity : 1.7)

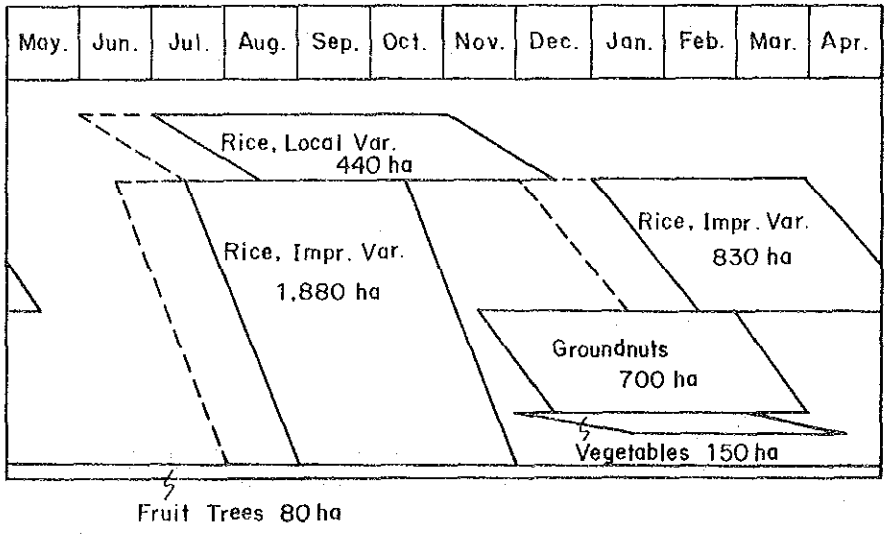


Fig. 10 (2/2) Cropping Pattern for the Proposed Irrigation Scheme

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SECTORAL REPORT III
IRRIGATION DEVELOPMENT PLAN

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1. INTRODUCTION

The irrigation development in Thailand has been promoted in order to raise productivity of agriculture, especially putting a priority on development of irrigation system and expansion of on-farm facilities as well as water resources development.

This sectoral report presents the irrigation development plan concerned with the Khlong Luang, Ban Khai Extension and Khlong Thap Ma Irrigation Schemes as well as the Ban Khai Existing Irrigation Scheme. The irrigation development plan has been formulated in harmony with development plan of the Khlong Luang, Khlong Yai and Khlong Thap Ma Dam Schemes.

Field survey and investigation were carried out in collaboration with RID during a four-month period from August to December, 1982. During the period for field survey, major effort was laid on collection of data and information, and the projection of irrigation water demand for the target year 2001. The projection of irrigation water demand comprises selection of potential irrigable area and estimation of unit irrigation diversion requirement.

The specific irrigation development plans for the respective scheme areas were established based on the results of field works and the available data during the period from January to May, 1983.

2. PRESENT IRRIGATION AND DRAINAGE CONDITIONS IN THE STUDY AREA

2.1 General

The Study Area covers Chon Buri and Rayong Provinces, excluding the Prasae river basin, and roughly corresponds to the area defined as Eastern Seaboard. The Study Area of about 5,500 km^2 is divided into coastal basin and inland basin which is further sub-divided into the Rayong river basin of about 1,800 km^2 and the Khlong Luang river basin of about 2,100 km^2. The coastal basin is dissected by a large number of small rivers and has an area of about 1,600 km^2.

The first activity for the irrigation development taken by RID in the Rayong river basin is the construction of irrigation facilities in the Ban Khai Irrigation Project area with a net irrigation area of 4,800 ha (30,000 rai). The construction was started in 1951 and completed in 1960 after spending 9 years. Following the completion of this project, RID took up the Rayong Flood Protection Project, Khlong Thap Ma Drainage Project, Khlong Yai Da Irrigation Project and Bun Ton Chan Irrigation Project.

In the Khlong Luang river basin, the Ban Bung Dam Project was implemented in 1958 for manufacturing use and to maintain irrigation water to the paddy fields of 320 ha (2,000 rai) located downstream of the dam. The Phan Thong and Phan Thong Extension Drainage and Conservation Projects were constructed by RID near the confluence of the Bang Pakong and Khlong Luang rivers. In addition to these projects, the Tha Lat Irrigation Project and the Bang Pakong Left Bank Flood Protection and Conservation Project were mainly established in Chacheongsao Province covering the low-lying area located in the left bank of the Bang Pakong river, a part of which is included in the Khlong Luang river basin.

Major activity of RID in the coatal basin is the construction of the Ban Phra Dam and Irrigation Project with a net irrigation area of 1,360 ha (8,500 rai). Its construction was initiated in 1971 and completed in 1974. Following the Ban Phra Project, the Khlong Samnak Ma-muang Irrigation Project was implemented in 1979. Besides, the construction of the

Map Prachan Dam Project was completed in 1980, and the construction of the Nong Kho Dam Project was started in 1980 and is scheduled to be completed in 1983.

Other than the above-mentioned irrigation facilities, there are village-level irrigation facilities constructed by villagers themselves, depending their water sources on small streams. Most of these systems serve only supplementary irrigation in the rainy season.

The locations of the above-mentioned RID projects are shown in Fig. 1. The main features and operation and maintenance conditions in the projects are briefed below.

2.2 Rayong River Basin

(1) Ban Khai Irrigation Project

The Ban Khai Irrigation Project with a net irrigation area of 4,800 ha was implemented by RID. Its construction was started in 1951 and completed in 1960 after spending 9 years. The Dok Krai dam was constructed in 1975 by RID for releasing water to the Ban Khai area. The dam is located on the Dok Krai river, which is the tributary of the Rayong river, about 10 km upstream from the confluence with two rivers. The active storage capacity of this reservoir is 57 MCM. A diversion weir with a crest length of 47 m is located on the Rayong river about 4 km upstream from Ban Khai. The project area broadly extends north to south along the Rayong river downstream from the diversion weir. The right main canal of 11.4 km long and the left main canal of 12.7 km long are constructed with unlined conditions in all reaches. Their design capacities are 2.95 m^3/sec for the right main canal and 2.0 m^3/sec for the left main canal respectively. The lateral canals and the farm ditches have been constructed in 50 % of the whole area. The remaining areas are irrigated by plot-to-plot system.

There is no drainage facility in the project area except some drainage ditches and crossdrains. Many tributaries of the Rayong river crisscross in this area and cross the main canals. Many cross-

drains are constructed at each crossing point. The drainage ditches, which have been constructed by farmers themselves, are connected to the tributaries. Some drainage ditches are used as the dual-purpose ditches for irrigation and drainage.

Operation and maintenance works are carried out by RID for the diversion weir, main canals and lateral canals. According to the operation records at the diversion weir site, about 68 MCM of irrigation water was diverted to the area in 1979. The annual budget allotted for these works is about ฿ 127 x 10^3. Water users' group has not been established yet in the area. No water charge is collected from the farmers.

(2) Bung Ton Chan Irrigation Project

The project area of 1,280 ha (8,000 rai) is located immediately east of the left main canal of the Ban Khai Irrigation Project. The diversion weir with a length of 8 m and a height of 1.5 m is constructed on the tributary of the Rayong river about 8 km upstream from the confluence in 1980 by RID. The main canal, however, is not constructed. Farm ditches have been constructed in some parts of the project area by farmers as the dual-purpose ditches for irrigation and drainage. The area is irrigated by plot-to-plot system. There is no drainage facility in the project area. Farm ditches are used as the drainage ditches.

(3) Khlong Yai Da Irrigation Project

The project area of 320 ha (2,000 rai) is located about 10 km east from the Rayong municipality. The diversion weir with a length of 15 m and a height of 1.8 m connects to two main canals with a length of 100 m each and were constructed in 1977 by RID. Farm ditches have been constructed to some extent in the area by farmers themselves. Any drainage facility has not been constructed. Some farm ditches are used for drainage and connected to the tributaries.

(4) Rayong Flood Protection Project

This project area is located immediately south of the Ban Khai Irrigation Project and north of the Rayong municipality, and slenderly extends east to west along Route 3. Since this area extends over the low-lying alluvial flood plains of the Rayong river, the area suffers from inundation especially in the rainy season. Three short-cut channels equipped with drainage gates was constructed in 1962 by RID. Most of this area is covered by paddy fields. These paddy fields are cultivated under the rainfed condition and by using the stagnant water in the rainy reason. The new national highway, Route 36, was constructed across this area. The construction of this new highway is causing the inundation problems even after the completion of the flood protection facilities.

(5) Khlong Thap Ma Drainage Project

The project was implemented in 1978 by RID to solve the drainage problems in the area. The area is located about 10 km west of the Rayong municipality and bounded by Route 3 in north. The drainage sluice, which is the main facility of this project, is only constructed.

2.3 Khlong Luang River Basin

(1) Ban Bung Dam Project

The Ban Bung dam is located on the Ban Bung river, which is the tributary of the Khlong Luang river, about 30 km upstream from the confluence of the both rivers. The dam with a length of 2,100 m and a height of 9.5 m was constructed for the purpose of manufacturing use in 1958 by RID. The dam has an active storage capacity of 0.4 MCM. The area located downstream of the dam is covered by the paddy fields of 320 ha (2,000 rai). The operation and maintenance schedule for the dam is planned to release water to the paddy fields as a maintenance flow, though the paddy fields are not provided with the irrigation facilities.

(2) Phan Thong and Phan Thong Extension Drainage and Conservation Projects

The Phan Thong Project area of 2,960 ha (18,500 rai) and the Phan Thong Extension Project area of 3,520 ha (22,000 rai) are located downstream reach of the Khlong Luang river basin, near the confluence of the Bang Pakong river and the Khlong Luang river. The areas extend over the low-lying alluvial plains of the Khlong Luang river. Before completion of the project works, these areas suffered from inundation in the rainy season and intrusion of sea water in the dry season. The implementation of the Phan Thong Project was started in 1956 and completed in 1965 by RID after spending 9 years. The major facilities of the project comprise the double rectangular tidal gates and 12-km long drainage channel. The drainage channel is used for the regulating pond against the flooding water. The implementation of the Phan Thong Extension Project was started in 1970 and completed in 1978 by RID. The double rectangular tidal gates and the single rectangular tidal gates were constructed as the main project facilities.

Most of these project areas are covered by paddy fields which are not irrigated through the irrigation facilities. In the rainy season, water regulated in the drainage channel is supplied to the fields through the drainage gates installed by farmers themselves. A certain area is irrigated on the same way by farmers even in the dry season.

(3) Tha Lat Irrigation Project

The Tha Lat Irrigation Project with a net irrigation area of about 20,800 ha (130,000 rai) was constructed by RID during a 23-year period from 1950 to 1973. The project area extends over the left bank of the Bang Pakong river. The irrigation area of about 13,000 ha extends over Chachoengsao Province and the area of 7,800 ha extends over Chon Buri Province. The diversion weir with a length of 23.0 m and a height of 5.0 m is located on the tributary of the Bang Pakong river, which is the Tha Lat river, about 34 km upstream from the confluence of the both rivers. The main canal having the design capacity of 16.0 m^3/sec at head runs for 45 km and reaches to

the Khlong Luang river basin area. The lateral canals and farm ditches have been constructed in about 80 % of the area, and the remaining areas are irrigated by plot-to-plot system.

There is no drainage facility in the project area except some crossdrains, which are constructed at the crossing points of canals and natural streams. The small tributaries crisscrossing in the area are used as the drainage canals.

Operation and maintenance works are carried out by RID for the diversion weir, the main canal and lateral canals. According to the operation records at the diversion weir, about 255 MCM of river flow were diverted to the area in 1980. Water users' groups have not been established yet in the project area. Water charge is not collected from the farmers.

(4) Bang Pakong Left Bank Flood Protection and Conservation Project

The project area lies on the left bank of the Bang Pakong river and extends over the low-lying alluvial plains of the Bang Pakong river. This area is mainly located in Chachoengsao Province and about 2,700 ha (16,875 rai) out of 10,400 ha (65,000 rai) is located in Chon Buri Province. The area was inundated in the rainy season and intruded by saline water in the dry season before implementation of the project works. The construction was started in 1950 and completed in 1963 by RID. The drainage gates were installed at the outlets of each tributary flowing into the Bang Pakong river. They are used as flood control gates in the rainy season and as tidal gates in the dry season. The area is covered by paddy fields. The paddy cultivation is mostly carried out under the rainfed condition.

2.4 Coastal Basin

(1) Ban Phra Dam and Irrigation Project

The project area is located about 5 km north from the Si Racha municipality slenderly extending from south to north, and bounded by the hill skirts in east and by Route 3 in west. The Ban Phra dam with a crest length of 1,800 m and a height of 24 m and the irrigation area of 1,360 ha (8,500 rai) in net were constructed by RID during a 3-year

period from 1971 to 1974. The dam has an active storage capacity of 104 MCM. The main canal with a length of 8.2 km is lined with concrete throughout all reaches. The farm ditches have been constructed by farmers themselves.

There is no drainage facility in the project area except some crossdrains. Some farm ditches are connected to small tributaries and used as the drainage ditches.

Operation and maintenance works have been carried out by RID for the dam and the main canal. The annual budget allotted for these works is about ฿ 52 x 10^3. According to the data on present land use, the planted area of paddy in the rainy season is reduced by about 200 ha from the original area of 1,360 ha due to urbanization in the vicinity of the project area.

(2) Khlong Samnak Ma-muang Irrigation Project

The project is located about 19 km west from the Rayong municipality and has an area of 100 ha (635 rai). The diversion weir with a length of 11.4 m and a height of 1.8 m was constructed in 1979 by RID. Though the construction of irrigation canals and farm ditches has been entrusted to the farmers, there is no irrigation facility in the area. Any drainage facility has not been constructed. Natural streams in the area are used for drainage canals. Operation and maintenance works of the diversion weir is executed by RID. Irrigation in the area is carried out by plot-to-plot system.

(3) Map Prachan Dam Project

The Map Prachan dam having an active storage capacity of 14 MCM is located about 8 km east from Pattaya. The 2-km long and 17-m high dam was constructed by RID mainly for water supply. Its construction was started in 1974 and completed in 1980. The paddy fields of 480 ha (3,000 rai) are located downstream of the dam. Although these paddy fields are not irrigated by the irrigation facilities, the dam operation is planned to release water to the paddy fields as maintenance flow.

(4) Nong Kho Dam Project

The Nong Kho dam is located about 15 km east from the Si Racha municipality. The construction of dam was commenced in 1980 and will be completed in 1983. The dam with a length of 2,000 m and a height of 17 m is expected to create a reservoir having active storage capacity of 18 MCM. The outlet facilities of dam for releasing water to paddy fields of 1,200 ha (7,500 rai) is under constructuion, though the irrigation project has not been realized yet.

3. POTENTIAL IRRIGABLE AREA

3.1 General

In order to select the other potential irrigable areas than the existing irrigation areas in the Study Area, various data on complex natural resources and interrelated land data have been collected and analyzed. Systematic appraisal for land, soils, topography and so on has been conducted as a basic study integrated with economics, engineering and other fields in selection of relative degree of land suitability. Lands selected as potential irrigable area should be suitable for crop production under the irrigation and drainage improvements.

The potential irrigable area for paddy cultivation is selected for every basin, i.e. the Rayong river basin, the Khlong Luang river basin and the coastal basin.

3.2 Potential Irrigable Area in the Study Area

3.2.1 Factors to be Considered in Selection

(1) Land, Soils and Topography

Land capability classfication related to the soils, topography and drainage characteristics has been carried out referring to the land capability maps in a scale of 1/100,000 prepared by the Land Development Department and revealed the grade of irrigation suitability. Typical soil characteristics involved are texture, structure, depth, stoniness, horizon arrangement and layering, EC, pH, infiltration rate, moisture characteristics and so on.

Macro and micro topographic conditions are evaluated with respect to degree and direction of slope, land capability and land development, based on the available topographic maps (1/20,000 and 1/50,000). Irrigability relating to location and topography is the main point in this context.

Land capability classification is firstly categorized into two orders, namely, Suitable Land and Not Suitable Land. The Suitable Land is sub-classified into Highly Suitable (Class I), Moderately

Suitable (II), Suitable (III) and Marginally Suitable (IV), according to suitable degree. The land capability classification in the Study Area is shown in Fig. 2.

(2) Present Land Use

Land use survey has been carried out in three basins. The present land use is classified based on the maps on a scale of 1/50,000 and the results of field check survey.

The condition of present land use is the major factor for selection of the potential irrigable area in order to minimize the investment cost. To quickly reap the economic return after implementation of the project, the cultivated land, especially existing paddy field, should be selected within the suitable range of land capability classification with provision of irrigation and drainage improvements. So far as the land capability allows, the area should be further extended over the existing upland area.

(3) Water Resources

The irrigation development depend on the water resources endowed in the upper reaches of the rivers in the Study Area. In order to use the limited water resources to the maximum extent, construction of storage dam is essentially needed. The area should be selected in the vicinity of the exploited site of water resources and developed to some extent.

Judging from the fact that a pump irrigation is costly from the aspect of operation and maintenance costs, the area to be developed under a gravity irrigation system is preferentially selected as the potential irrigable area. Locations of possible intake sites and their water stages are essential factors in this context.

3.2.2 Rayong River Basin

The Rayong river basin is located in the southeastern part of the Study Area and has a catchment area of approximately 1,800 km^2, corresponding to the western half of Rayong Province.

This river basin is encompassed by the western and eastern mountaneous ranges and bisected by the Rayong river flowing from north to south. An alluvial plain is extending over the both banks of the Rayong river only from Ban Khai to Rayong with width of 5 km to 10 km, with gentle undulation in altitude ranging from El. 30 m to El. 5 m and merging with the southern coastal plain. The Ban Khai Existing Irrigation Project area of 4,800 ha in net is located in the middle of the above alluvial plain. The remaining area of the alluvial plain is cultivated with paddy under rainfed conditions without irrigation facilities. The hilly land is covered almost with forest and upland crops excepting the narrow strips along the small stream.

The land capability of the area for paddy cultivation is classified into the Suitable of 14,000 ha, the Marginally Suitable of 700 ha and the Not Suitable of 162,900 ha. Most of the suitable lands extend over the alluvial plains along the Rayong river and the Khlong Thap Ma river. These rivers have ample perennial flows and the potential damsites are identified in the upper reaches of the rivers. Therefore, the alluvial plains extending over the both banks of the Rayong river and the Khlong Thap Ma river are considered to be potential irrigable areas.

3.2.3 Khlong Luang River Basin

The Khlong Luang river basin is situated in the northern part of the Study Area. This basin covers the northern part of Chon Buri Province and has an area of about 2,100 km^2.

The area is bounded by mountains in south and northeast, and a vast alluvial plain is extending from southeast to northeast with slight undulation in altitude ranging from El. 40 m to El. 5m. Most of lowland areas of the alluvial plains suffer from inundation during the rainy season.

The Khlong Luang river has an ample perennial flow and the water resource can be exploited in its upper reach due to topographic conditions. The paddy cultivation is carried out under the rainfed condition in most of the alluvial plains especially during the rainy seasons.

About 40 % of the total river basin area is capable for paddy caltivation, according to the land capability classification, i.e. Highly Suitable: 4,500 ha, Moderately Suitable: 18,000 ha, Suitable: 55,000 ha, Marginally Suitable: 4,000 ha and Not Suitable 130,300 ha. Taking into consideration the potential water resources, the land extending over the both banks of the Khlong Luang river is given a top priority for irrigation development and considered to be a potential irrigable area.

3.2.4 Coastal Basin

The coastal basin is located in the southwestern part of the Study Area and covers 1,600 km^2 of the southern coastal area of Chon Buri Province.

The boundaries of the area are the mountaineous ranges in east and north, and the area is facing with the Gulf of Thailand in west. Coastal plains are well developed in the western coast of the area with width of about 10 km. Numerous small rivers originating from the eastern mountains dissect the area into small patches forming low-lying alluvial plains.

The land capability for paddy cultivation classified into the Moderately Suitable of 1,000 ha, the Suitable of 10,500 ha, the Marginally Suitable of 2,500 ha and the Not Suitable of 144,500 ha respectively. The suitable lands disperse on the both banks of the small streams which has scarce of water resources to be exploited. In the area, only the existing Bang Phra Irrigation Project area of 1,360 ha is developed in the northern part with provision of the storage dam. Taking into consideration the availability of water resources and topographic conditions, the suitable lands extending along the small rivers are not attractive for newly irrigation development and not taken as a potential irrigable area.

3.3 Irrigation Development Scheme Area

3.3.1 Basic Consideration in Selection of Scheme Area

(1) Government Development Plan

Following the Fourth National Economic and Social Development Plan (hereinafter referred to as National Development Plan) which terminated in late 1981, the Fifth National Development Plan was issued by the National Economic and Social Development Board (NESDB) in late 1981.

In order to achieve the shorter-run objectives of a rapid economic recovery and a greater degree of economic stability stipulated in the Fifth Development Plan, the following overall targets and supporting policy measures were set forth in respect to agricultural sector.

(a) To attain the target of about 7 % increase in the GDP, the value in agricultural sector is projected as; overall target: annual increase by 4.5 %, a crop production: annual increase by 4.7 %.

(b) The strategy for agricultural development has to emphasize structural improvement within the sector: production increase through crop intensification and further agricultural diversification will be promoted.

(c) In order to raise productivity of agriculture, the priority is given to development of irrigation system and expansion of on-farm facilities as well as water resources development. In addition, emphasis is placed on soil improvement and strengthening agricultural support services.

(d) The investment of the Government for irrigation development will stress on improving and restoring the existing irrigation projects to increase production efficiency. The new irrigation system, however, will stress more on medium and small scale projects which could raise productivity in a short term.

(2) Relation with Industrial Development

The Government of Thailand is launching into industrialization with performance of the Fifth National Development Plan. The development of the Eastern Seaboard is the backbone of industrialization and its development plan is being as Eastern Seaboard Study (ESS) under the NESDB.

To cope with the rapidly increasing water demand owing to the development of the Eastern Seaboard, the East Coast Water Resources Development Project, Phase-I (hereinafter called Phase-I Study) was conducted during the period from July 1981 to March 1982. Though the industrial water demand projected by Phase-I Study is a little different from the projected by ESS, the Phase-I Study conducted the detailed design of water transmission system from the Dok Krai reservoir, active storage capacity of 47 MCM, to Map Ta Phut - Sattahip. The Dok Krai reservoir has been utilized to supply irrigation water to the existing Ban Khai Irrigation Project area of 4,800 ha in net. In accordance with the above water diversion from the Dok Krai reservoir, the Phase-I Study proposed the construction of the Nong Pla Lai dam, which will create a reservoir with an active storage capacity of 144 MCM, to irrigate not only the existing Ban Khai area but also its surrounding area. These plans will, thus, be treated as existing one in the present study.

There exist no definite plan for future water supply to Laem Chabang area which has the industrial and domestic water demand of 28×10^6 m^3/year in 2001. In addition, there appears an acute shortage of domestic water in communities located in the area downstream from the proposed Khlong Luang damsite. Though the Khlong Luang dam scheme has originally been planned for the purpose of irrigation and flood control, this scheme is deemed to be most prospective alternative in supplying the future industrial and domestic water in Laem Chabang area.

3.3.2 Potential Irrigable Area for Irrigation Development Scheme

Following the results of the land capability classification (refer to Sectoral Report II), present land use and other selecting factors, the potential irrigation development scheme areas are delineated in both the Rayong and the Khlong Luang river basins in the Study Area as shown in Figs. 3 and 4.

In the Rayong river basin, there exist two proposed schemes, i.e. the Ban Khai Extension Scheme and the Khlong Thap Ma Scheme. On the other hand, the Khlong Luang Scheme is proposed to be developed in the Khlong Luang river basin.

The Ban Khai Extension area lies on the left bank of the Rayong river and outside the Ban Khai Existing Scheme area. The area is located immediately to the east of Rayong municipality and slenderly extends north to south along the left main canal of the Ban Khai Existing Scheme.

The Khlong Thap Ma area lies over both banks of the Khlong Thap Ma river which is a branch of the Rayong river. The area is located immediately west from the Rayong municipality, bounded by the Rayong river in east.

The Khlong Luang area is located immediately to the east of Phanat Nikhom which is located about 30 km northeast from Chon Buri municipality. The area lies on both banks of the Khlong Luang river, is bounded by the hill skirts in north and south, and extends for 25 km from east to west with an average width of 4 km.

In selecting the potential irrigable areas for each scheme, some areas classified into class V in land capability are taken up as a potential irrigable area, taking into consideration the present land use of paddy cultivation and the irrigation and drainage improvements under the with-project conditions.

The potential irrigable areas for each scheme including the Ban Khai Existing Scheme are summarized as follows:

(Unit: ha)

Class of Land Capability	Khlong Luang		Ban Khai Extension		Thap Ma		Ban Khai Existing	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net
I	830	710	0	0	0	0	0	0
II	2,970	2,510	0	0	0	0	0	0
III	6,300	5,330	4,620	3,940	760	650	4,700	4,180
IV	0	0	420	370	80	70	0	0
V	1,600	1,350	3,960	3,390	1,960	1,750	700	620
Total	11,700	9,900	9,000	7,700	2,800	2,400	5,400	4,800

3.3.3 Irrigation Development Scheme Area

(1) Khlong Luang Irrigation Scheme

According to the result of optimization study on the Khlong Luang Dam Scheme presented in Sectoral Report XI, the exploited water resource limits the irrigation area to 6,600 ha in net with cropping intensity of 140%. The irrigation area is selected from upper to lower as far as 6,600 ha are obtained. The selected irrigation area extends from the proposed damsite to Phanat Nikhom municipality.

The selected irrigation area is almost identical with that envisaged by RID. It is located immediately downstream from the proposed damsite and divided into North sub-area (3,100 ha) and South sub-area (3,500 ha).

(2) Ban Khai Extension Irrigation Scheme

The exploited water resources of the Nong Pla Lai and Khlong Yai reservoirs can supply water to the whole potential irrigable area of 7,700 ha other than the Ban Khai Existing area of 4,800 ha with cropping intensity of 140%.

There exist two possible intake sites for the Ban Khai Extension Scheme, i.e. at the confluence of the Nong Pla Lai and the Khlong Yai rivers, and on the Khlong Yai river about 7.5 km downstream from the proposed Khlong Yai damsite. The former can topographically cover the irrigation area up to only 5,500 ha in maximum and can not cover

the highly suitable area extending over the left bank of the Khlong Yai river. Whereas, the latter can cover the whole area with provision of diversion of water from the Nong Pla Lai river to the Khlong Yai river. Taking into account the above conditions, the irrigation area is selected from the Khlong Yai diversion site down to the lower part.

The Ban Khai Extension area extends along the Left Main Canal of the Ban Khai Existing Irrigation Scheme. It integrates approximately two-third of the existing irrigation area under the Bung Ton Chan Irrigation Project (1,280 ha). The area is being irrigated by unregulated runoff of the Khlong Hin Dat river.

(3) Khlong Thap Ma Irrigation Scheme

According to the result of optimization study, the Khlong Thap Ma dam can serve irrigation water to the whole potential irrigable area of 2,400 ha in net with cropping intensity of 170%. The selected irrigation area extends from the proposed damsite to Rayong municipality. The area is mainly divided by Route 3 into two areas, i.e. the alluvial flood plain extending to the north from Route 3 and the coastal plain extending to the south from Route 3.

Distribution of land capability for each scheme area including the Ban Khai Existing Scheme area is summarized below.

(Unit: ha in net)

Class of Land Capability	Khlong Luang	Ban Khai Extension	Khlong Thap Ma	Ban Khai Existing
I	150	0	0	0
II	1,800	0	0	0
III	3,750	3,940	650	4,180
IV	0	370	70	0
V	900	3,390	1,750	620
Total	6,600	7,700	2,400	4,800

4. IRRIGATION WATER REQUIREMENTS

4.1 General

This Chapter describes the method for determining the irrigation diversion requirements for each of the irrigation schemes proposed in both the Rayong and Khlong Luang river basins. The irrigation diversion requirements for the Ban Khai Existing area of 4,800 ha are also estimated in this Chapter, since the future water diversion schedule was not confirmed during the study period. These irrigation diversion requirements are used for the water balance study in the Study Area.

Determinations of irrigation diversion requirements for each of the irrigation schemes are made on a monthly basis for a 14-year period from 1968 through 1981 utilizing the meteorological data presented in Sectoral Report VI and also on a 10-day basis for a period required for the water balance study.

Irrigation diversion requirements are estimated based on the cropping calendar shown in Fig. 5 and alternative cropping patterns with different cropping intensities for each scheme as presented in Sectoral Report II.

In estimating the requirements, the study results presented in the "Feasibility Study Report on the East Coast Water Resources Development Project, Phase-I" by JICA in March 1982, and "Reconnaissance Report for Bang Pakong River Basin Development" by RID in 1971 are fully referred to. The empirical and theoretical formulas developed in the past by various experts are also used in this study.

4.2 Crop Water Requirement

Crop water requirement is defined as amount of water needed to meet consumptive demands of a crop for optimum growth from seeding until harvesting. This requirement includes water necessary for the land preparation period, the nursery bed period for transplanted paddy and the crop growing period. This can be expressed in the following equation:

$$CWR = LP + N + FC \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

where,

CWR ; crop water requirement in mm

LP ; land preparation requirement in mm

N ; nursery requirement in mm (for paddy)

FC ; field crop requirement in mm

Parts of the above equation are derived by using the methods mentioned below. The calculated results of crop water requirement is summarized in Table 1.

(1) Field Crop Requirement

The field crop requirement consists of water consumed by crops during the period from seeding or transplanting until harvesting and percolation losses in the paddy field. It is expressed in the following equation:

$$FC = (ET \cdot kc + P) \cdot Kf \quad \ldots\ldots\ldots\ldots\ldots \quad (4.2)$$

where,

FC ; field crop requirement in mm

ET ; reference crop evapotranspiration in mm

kc ; crop coefficient

P ; percolation loss in paddy field in mm

Kf ; crop area factor determined by the cropping calendar and given in Table 2.

(a) Reference crop evapotranspiration

Reference crop evapotranspiration rates may be correlated with recorded evaporation data or derived by empirical methods. Since there is no sufficient recorded evaporation data available, empirical method based on other recorded meteorological data is utilized. Out of several empirical and theoretical methods, the modified Penman method, which is introduced in the "Crop Water Requirements" published by FAO in 1977, is selected for this study.

The meteorological data recorded at Chon Buri Station are used in the calculation of reference crop evapotranspiration for the

scheme areas proposed in both the Rayong and Khlong Luang river basins. Those data are summarized in Table 3. The following is the calculated result of reference crop evapotranspiration.

(Unit: mm)

Month	Monthly	Daily
APR	164	5.5
MAY	141	4.5
JUN	137	4.6
JUL	136	4.0
AUG	130	4.2
SEP	112	3.7
OCT	116	3.7
NOV	128	4.3
DEC	140	4.5
JAN	137	4.4
FEB	137	4.9
MAR	173	5.6
Total or average	1,651	4.5

(b) Crop coefficient

The relationship between reference crop evapotranspiration and water consumed by crops is expressed in terms of crop coefficient. The crop coefficient of each crop varies with their growing stages. It is determined based on the actual measurement data by Irrigated Agriculture Section, RID, though some modifications are made referring to the FAO standard.
The crop coefficient curves for each crop are shown in Fig. 6. The average crop coefficients are estimated taking into consideration the various growing stages and crop area factors as presented in Table 4.

(c) Percolation

Percolation is affected largely by soil textures as well as groundwater condition in paddy fields. The rate of percolation is considered to be constant throughout the year, though the slight change in groundwater condition may occur in a long range. The soil texture in the proposed scheme areas are generally sandy.

The rate of percolation is determined on the bais of the actual measurement results carried out in the Ban Khai Existing area in Phase-I Study and in the Bang Pakong river basin in the Bang Pakong River Basin Development Study. Their results show that the percolation rates range from 1.6 mm/day to 5.8 mm/day in the Ban Khai Existing area and from 1.0 mm/day to 4.0 mm/day in the Bang Pakong river basin respectively. Considering of these results, the percolation rate for the proposed scheme areas in both the Rayong and Khlong Luang river basins is assumed to be 3.0 mm/day on an average throughout the year.

(2) Land Preparation Requirement

Water required for land preparation is considered for puddling work in paddy cropping and for pre-irrigation in upland cropping.

The quantity of water required for puddling works is theoretically assessed for soil depth to be puddled and porosity, which vary relatively from place to place. In this study, the following formula and assumptions are adopted for the approximation.

(a) Formula

$$LP = (WS + E + P + DS) \cdot Kl \cdot (Di/Dp) \quad \ldots\ldots\ldots\ldots \quad (4.3)$$

where,

- LP ; land preparation requirement in mm
- WS ; amount of water required to raise soil moisture content to saturation in mm
- E ; evaporation from water surface in mm
- P ; percolation loss in mm
- DS ; required water depth above surface of paddy field after puddling in mm
- Kl ; land preparation area factor
- Di ; days of calculation basis for water requirements: monthly basis; 30 days, 10-day basis; 10 days
- Dp ; land preparation period in days.

(b) Assumptions

i) Land preparation works will be done for 10 days.
ii) Water depth above the surface of paddy field after puddling is 30 mm
iii) Porosity is 45 % in both surface soil (20 cm depth) and subsoil (10 cm depth) to be puddled
iv) Vapour phase in soils after puddling is 5 %
v) Soil moisture content before irrigation is 15 % in volume
vi) Evaporation rate is 3.5 mm/day, 80 % of evapotranspiration rate
vii) Percolation rate is 3.0 mm/day

(c) Calculated results

The calculated result of total puddling water requirement per unit area for 10 days is as follows:

$$LP = DS + WS + E + P$$
$$= 30 + 300 \times (0.45 - 0.15 - 0.05) + 3.5 \times 10 + 3.0 \times 10$$
$$= 170 \text{ mm}$$

The land preparation requirement for upland crops such as groundnuts, mung beans and vegetables are assumed to be 60 mm on an average, referring to the other similar projects in Thailand.

(3) Nursery Requirement

Water for nursery bed period is required only for transplanted paddy. The nursery requirement is calculated based on the following equation:

$$N = LP \cdot R + (ET \cdot kc + P) \cdot Kn \quad \ldots\ldots\ldots\ldots\ldots \quad (4.4)$$

where,

N ; nursery requirement for paddy field in mm
LP ; land preparation requirement of nursery bed in mm
R ; ratio of area for nursery bed to main paddy field, 1/20 of main field

ET ; reference crop evapotranspiration in mm

kc ; crop coefficient

P ; percolation loss, 3 mm/day

Kn ; nursery area factor.

4.3 Crop Irrigation Requirement

The crop irrigation requirement is defined as amount of water exclusive of effective rainfall for crop growth. This requirement is expressed in the following equation:

$$CIR = CWR - ER \cdot Kt \quad \ldots\ldots\ldots \quad (4.5)$$

where,

CIR ; crop irrigation requirement in mm

CWR ; crop water requirement in mm

ER ; effective rainfall in mm

Kt ; total crop area factor.

The daily and monthly rainfall data have been collected from the various meteorological stations in and around the scheme area as presented in Sectoral Report VII. Among them, the data at the Ban Khai station are used for the estimation of effective rainfall for the scheme areas in the Rayong river basin and the data at the Ban Mai station are used for the Khlong Luang river basin respectively.

The effective rainfall depends on several factors including amount and intensity of rainfall, permeability and water holding capacity of soils, slope of the land, and vegetative characteristics. In this study, however, the relation between the monthly rainfall and the monthly effective rainfall established by RID are adopted for the estimation of effective rainfall for both the paddy and upland crops. Their relations are presented in Fig. 7. The estimated results are shown in Table 5.

4.4 Farm Irrigation Requirement

The farm irrigation requirement is defined as a crop irrigation requirement plus an allowance for farm distribution losses within a farm unit or rotation unit which is approximately 10 ha in size. Thus the farm irrigation requirement can be expressed as:

$$FIR = CIR/Ef \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4.6)$$

where,

FIR ; farm irrigation requirement in mm

CIR ; crop irrigation requirement in mm

Ef ; farm irrigation efficiency factor.

The farm distribution losses consist of mainly percolation loss for upland crop field and seepage losses through paddy dike for paddy field on the farm level. Very little experiment data are available for evaluation of farm efficiencies for the projects in Thailand. Therefore, the average farm efficiency for paddy cultivation is assumed to be 0.85 and that for upland crops is assumed to be 0.7.

4.5 Irrigation Diversion Requirement

The irrigation diversion requirement is estimated as the unit water requirement based on the alternative cropping patterns for the respective scheme areas.

Losses and wastes inherent in the operation of water distribution systems must be added to the farm irrigation requirements to determine the diversion requirements. These losses and wastes are grouped into canal conveyance losses due to evaporation and seepage, and canal operation losses due to inproper gate operation.

The irrigation diversion requirement is estimated by the following equation:

$$IDR = \sum (FIRi \cdot Ci) \ /Et \quad \ldots\ldots\ldots\ldots\ldots \quad (4.7)$$

where,

IDR ; irrigation diversion requirement in lit/s/ha

FIRi ; farm irrigation requirement of each crop in lit/s/ha

Ci ; cropping intensity of each crop based on the cropping pattern and given in Table 6

Et ; combined irrigation efficiency factor

Combined irrigation efficiency consists of canal conveyance efficiency and canal operation efficiency. These efficiencies are assumed as follows:

(Unit: %)

	Canal Conveyance Efficiency	Canal Operation Efficiency	Combined Efficiency
Field canal duty	90	95	86
Lateral canal duty	95	95	77
Main canal duty	95	95	70

Based on the above assumptions, the combined irrigation efficiency factor of 0.7 is adopted in this study.

The calculated results of the unit irrigation diversion requirements for the respective scheme areas are shown in Table 7.

5. DRAINAGE WATER REQUIREMENT

5.1 Standard for Drainage Plan

The proposed scheme areas mainly extend over the alluvial plains of each river, i.e. the Rayong river, the Khlong Thap Ma river and the Khlong Luang river. Most of the areas suffer from mal-drainage in the rainy season. If the lands are not drained well within a feasible range, the productivity will not go up even after the provision of well-designed irrigation facilities.

From the past experiments and observations in Japan[/1] on the relation between the yield reduction rate of paddy and, depth and duration of sub-mergence at different growing stages of paddy, the following considerations could be made:

(a) The sub-mergence at the growing stage of young panicle formation gives the serious damage to the yield of paddy, on the contrary, damage due to sub-mergence at the maturing stage is insignificant.

(b) The duration of sub-mergence within 1 to 3 days is not significant, but damages of paddy remarkably increases due to sub-mergence beyond 3 days.

(c) When a part of leaves still remains above water surface, the damage to paddy is decreased as compared with that when leaves are completely sub-merged.

While, the midest rainy season in the project area occurs in the period between August and October. The growing stage of paddy between middle stage of tillering and beginning stage of panicle formation would correspond to midest rainy season.

/1: These are presented in "Hand Book on Yield Reduction Rates of Summer Crop due to Various Causes" published by the Ministry of Agriculture, Forestry and Fisheries of Japan in 1975.

Taking into account the above considerations, the following design standard would be applied for making the future drainage plans in the proposed schemes.

(1) The allowable depth of sub-mergence in the paddy fields should be 30 cm, and duration of sub-mergence should not exceed 3 days.

(2) The sub-mergence more than 30 cm in depth should not last more than 24 hours.

5.2 Drainage Requirement

In general, the criteria for the calculation of unit drainage requirement defines the rainfall intensity with certain probability and a drain period necessary for removal of excess water to an allowable extent.

In this study, the drainage requirements are estimated on the basis of the following assumptions and procedures:

(1) The daily rainfall data at Ban Khai (1968 - 1981) are used in this study for the scheme areas in the Rayong river basin and the daily rainfall data at Ban Mai (1968 - 1981) are used in the Khlong Luang river basin respectively.

(2) Design rainfalls at the both stations are estimated to be 208 mm at Ban Khai and 166 mm at Ban Mai of 3 days consecutive rainfall with a 10-year return period.

(3) Based on the average rainfall distribution pattern, the distribution percentages of the design daily rainfall are estimated as follows:

(Unit: %)

Day	Ban Khai	Ban Mai
1st day	40	43
2nd day	29	27
3rd day	31	30

(4) Relationship between cumulative rainfall and runoff coefficient is assumed as follows:

Cumulative Rainfall (mm)	Runoff Coefficient (f)
less than 10	0
10 - 30	0.1
30 - 50	0.3
50 - 100	0.5
100 - 300	0.8

(5) Relationship between rainfall and runoff distribution is assumed as follows:

Rainfall (mm)	1st Day (%)	2nd Day (%)	3rd Day (%)	4th Day (%)
less than 30	100	-	-	-
30 - 50	70	30	-	-
50 - 100	60	30	10	-
more than 100	50	30	15	5

(6) Based on the above assumptions, the drainage requirements are estimated as follows:

Design Rainfall (mm)	Cumulative Rainfall (mm)	Coef-ficient (f)	Run-off (mm) 1st Day	2nd Day	3rd Day	4th Day	5th Day
1. Ban Khai (for Rayong river basin)							
83.2	83.2	0.5	25.0	12.5	4.1	-	-
60.3	143.5	0.8	-	28.9	14.5	4.8	-
64.5	208.0	0.8	-	-	31.0	15.5	5.1
Total (mm)			25.0	41.4	49.6	20.3	5.1
Unit Drainage Req. (lit/s/ha)			2.89	4.79	5.74	2.35	0.59
2. Ban Mai (for Khlong Luang river basin)							
71.4	71.4	0.5	21.4	10.7	3.6	-	-
44.8	116.2	0.8	-	25.1	10.7	-	-
49.8	166.0	0.8	-	-	27.9	11.9	-
Total (mm)			21.4	35.8	42.2	11.9	-
Unit Drainage Req. (lit/s/ha)			2.48	4.14	4.88	1.38	-

From the above calculations, the design drainage requirements are determined to be 5.74 lit/s/ha for Rayong river basin area and 4.88 lit/s/ha for Khlong Luang river basin area, which are defined as the peak requirements in the above calculation.

6. UPGRADING OF EXISTING IRRIGATION AND DRAINAGE SYSTEMS OF THE BAN KHAI IRRIGATION PROJECT

6.1 Present Conditions and Constraint

The Ban Khai Irrigation Project with a net irrigation area of 4,800 ha was wholly completed in 1960 after a long construction period over 10 years. The area is being served by two main canal systems; Left Main Canal with a total length of 12.7 km commands 2,560 ha and the Right Main Canal with a total length of 11.4 km serves 2,240 ha. At present, lateral canal systems and farm distribution systems have been completed to only 50% of the entire area, resulting in mal-distribution and uneven distribution of irrigation water throughout the service area and ineffective use of the available water resources. Drainage systems have been provided to such extent as could be constructed by farmers' themselves.

Number of households, population and family size are estimated to be 1,840 households, 9,300 persons and 5.1 persons respectively. Number of farmer's households, population and farm size are also estimated to be 1,625 households, 5,400 persons and 3.3 ha.

The scheme area of 4,800 ha is used for 4,640 ha of paddy and 160 ha of upland crops in the wet season, and used for 1,900 ha of paddy and 1,150 ha of upland crops in the dry season. Whereas, the cropped area under the irrigated condition is 2,240 ha of paddy in the wet season, and 1,900 ha of paddy and 320 ha of vegetables in the dry season.

Yields of crops remain relatively low. For instance, yield of paddy is in the order of 1.8 t/ha to 3.2 t/ha, which vary substantially with the variety of paddy, irrigation water available, amount of farm input, etc. Such low yield is considered to be attributable to the mal- and uneven distribution of irrigation water, conventional farming practices, less application of fertilizers and chemicals, insufficient agricultural support services, etc.

6.2 Proposed Upgrading Works

The most suitable cropping pattern is determined so as to maintain a living standard of the farmers at the same level as that in the Ban Khai Extension area, through the study on the optimum development scale of the Khlong Yai Dam Scheme. The cropping intensity is proposed to be raised up to 1.4, though the present cropping intensity under the irrigated condition is about 0.9. The crop yields are projected to be 4.0 to 5.0 t/ha for paddy, 2.5 t/ha for groundnuts and 10.0 t/ha for vegetables.

According to the result of layout planning, it is proposed that the Left Main Canal covers the irrigation area of 2,420 ha and the Right Main Canal also covers the area of 2,380 ha. Furthermore, based on the proposed cropping pattern, the calculated design discharges for each canal are to be 3.8 m^3/s for the Left Main Canal and 3.7 m^3/s for the Right Main Canal respectively. In order to meet these design discharges, the existing design capacities of intake structures and canals are necessary to be expanded and the canals will be lined with a plain concrete to convey the irrigation water efficiently.

The lateral and sub-lateral canals will be newly provided in the area where the lateral and sub-lateral canals have not been provided. Even in the area provided with the lateral and sub-lateral canals, those are necessary to be upgraded. The total length of canals is to be 16 km for the upgrading works and 26 km for the new construction.

The drainage water from the irrigated lands will be evacuated to the Rayong river through the improved and newly constructed drainage canals. The total length of the drainage canals is about 52 km consisting of 32 km of improved canals and 20 km of newly constructed canals.

6.3 Economic Justification

In order to assess economic viability on the upgrading works of the Ban Khai existing irrigation facilities, the benefit-cost ratio (B/C) and surplus (B-C) are calculated based on the annual equivalent benefits and costs. The annual benefit is estimated as the remainder between the total benefits under the with-project and without-project conditions. The annual

cost is estimated as the total cost of the annual equivalent construction cost, based on economic life of 50 years and discount rate of 8%, and the annual operation, maintenance and replacement costs. In estimating the annual cost, the economic cost for on-farm development as well as the economic cost for upgrading works of the existing irrigation and drainage facilities are counted. The calculated results are as follows:

(a) Economic cost for upgrading works

	Amount (10^3 ฿)
- Preparatory works	20,360
- Main canals	70,320
- Lateral canals	33,690
- Drainage canals	6,000
- On-farm facilities	1,920
- Contractor's administration cost	4,560
- Contractor's profit	8,480
Sub-total	145,330
- Engineering services	20,740
- O&M equipment	19,470
- Administration cost of executive agency	7,100
- Physical contingency	28,900
Total	221,540

(b) Annual cost

- Annual equivalent construction cost	21,010
- Annual OMR costs	2,250
Total	23,260
(c) Annual incremental benefit	71,040
(d) Benefit-cost ratio (B/C)	3.1
(e) Surplus (B-C)	47,780

From the result of the above economic evaluation, it can be said that the upgrading works of the irrigation facilities would be feasible. These upgrading works are proposed to be implemented as soon as possible, in accordance with implementation of the Nong Pla Lai dam which is scheduled to be constructed by 1986 as the water resources for the Ban Khai Existing Irrigation Scheme.

7. PLANNING AND PRELIMINARY DESIGN OF PROJECT FACILITIES

7.1 General

Major objective of the irrigation scheme is to increase agricultural productions with provision of suitable irrigation and drainage systems. In order to supply optimum irrigation water to the service area from water resources, the facilities required include intake facilities, irrigation canals, drainage canals, inspection road and their related structures.

The basis for determining the facility requirements is that enough facilities be provided in the most effective and economical manner so that each function can be combined with and fully compatible with other farming operations. Based on these requirements, the following planning and preliminary design of facilities are prepared. The salient features of facilities required for each scheme are summarized in Tables 8 to 11

7.2 Design Irrigation Water Requirement

7.2.1 Unit Design Irrigation Water Requirement

According to the calculation results of the water requirements for water balance study, the peak irrigation water requirements concentrate in August in most years. The unit design irrigation water requirements in August are calculated on the 10-day basis through the same procedures as that mentioned in Chapter 4. In the calculation, the 10-day effective rainfall with 5-year return period of non-excess probability are estimated using 14-year rainfall records observed at Ban Mai and Ban Khai Stations. The estimated results are shown below.

(Unit: mm)

Station	August		
	1st 10-day	2nd 10-day	3rd 10-day
Ban Mai (for paddy)	3.0	5.0	25.1
Ban Khai (for paddy)	10.4	13.5	0.0

Based on the above effective rainfall, the unit design irrigation water requirements for the respective schemes are calculated taking into account

the respective cropping patterns. According to the calculation, the peak unit irrigation water requirements for 10-day period are summarized as follows:

(Unit: lit/s/ha)

Scheme	August		
	1st 10-day	2nd 10-day	3rd 10-day
Khlong Luang	1.34	1.55	1.11
Ban Khai Extension	1.20	1.29	1.44
Ban Khai Existing	1.30	1.40	1.56
Khlong Thap Ma	1.20	1.29	1.44

7.2.2 Design Diversion Requirement

The design diversion requirements are defined as the peak diversion discharge, which are obtained by multiplying the unit design water requirement by the irrigation area. The design diversion requirements thus calculated for the respective scheme areas are shown below.

Scheme	Irrigation Area (ha)	Design Diversion Requirement (m^3/s)
Khlong Luang	6,600	10.7/1
Ban Khai Extension	7,700	11.1
Ban Khai Existing	4,800	7.5
Khlong Thap Ma	2,400	3.5

/1: Including the design discharge of 0.51 m^3/s for the domestic and industrial use.

7.3 Intake Facility

7.3.1 General

The irrigation water for the Khlong Luang Irrigation Scheme area is directly diverted from the Khlong Luang dam through the intake structures. The Khlong Thap Ma Irrigation Scheme area is also supplied with irrigation water from the intake structures to be constructed at the Khlong Thap Ma dam. On the other hand, the irrigation water for the Ban Khai Extension Irrigation Scheme area is taken from the Khlong Yai headworks to be constructed on the Khlong Yai river. In addition, the irrigation water is supplementarily diverted from the Nong Pla Lai headworks to the Khlong Yai river. For the Ban Khai Existing Irrigation Scheme area, the irrigation water is supplied from the existing headworks, though the intake structure is upgraded to meet the design intake capacity.

7.3.2 Intake Structure

Intake structure comprises intake tower, outlet conduit, outlet and access bridge. The water off-taken is dissipated its energy at the bottom of the intake tower and then passes through outlet conduit with free flow condition. Each intake tower is of reinforced concrete and equipped with regulating gate respectively.

The size of each outlet conduit is mainly determined so as to pass the design intake discharge with free flow condition. The longitudinal slope of 1:1,000 is given for each conduit within the limits of permissible velocity. Outlet is installed to dissipate velocity head and regulate the flow condition. The parshall flume is equipped at the end of outlet in order to measure the intake discharge.

A bridge access to intake tower would be spanned between the dam crest or abutment and the tower to operate regulating gates. The bridge is composed of steel girders and piers.

The intake structure for the South Main Canal is the joint facility to serve domestic and industrial water as well as irrigation water, and its design discharge includes 0.51 m^3/s for the domestic and industrial use. The configurations of the intake structures are shown in Figs. 8 and 9. Their main features are summarized below.

Intake Structure	Design Intake Discharge (m^3/s)	Intake Tower Size (m)	Intake Tower Height (m)	Outlet Conduit Diameter (m)	Outlet Conduit Length (m)	Length of Bridge (m)
Khlong Luang Dam						
- North	4.81	2.0x2.0	10.2	2.0	54.0	23.0
- South	5.94	2.0x2.0	10.2	2.0	300.0	43.0
Khlong Thap Ma Dam						
- East	1.80	2.0x1.3	13.9	1.3	100.0	41.0
- West	1.63	2.0x1.3	13.9	1.3	87.0	46.0

7.3.3 Headworks

The main function of headworks is to introduce the required quantity of irrigation water from the river to the scheme area at every stage of river water. In order to fulfill this purpose, the structure should be stable against flood and other forces and should not hamper the river flow.

The Ban Khai Extension Irrigation Scheme has two headworks, i.e. the Nong Pla Lai and Khlong Yai headworks. The both headworks consist of various components such as movable weir, fixed weir, intake and dike portions. For well functioning as the headworks, each portion should be combined with and fully compatible with each other.

(1) Basic Design Condition

For the preliminary design of the headworks, the following basic design conditions are taken into consideration.

(a) Topography

The proposed site of the Nong Pla Lai headworks is located on the Nong Pla Lai river at about 3.5 km downstream from the Nong Pla Lai proposed damsite. The Khlong Yai headworks is located on the Khlong Yai river at approximately 7.5 km downstream from the Khlong Yai proposed damsite. For the both sites, there exist the narrow strip of the alluvial deposit in the both banks of the river and the skirt of the hilly region with gentle inclination. The river widths are about 40 m at the Nong Pla Lai headworks site and about 30 m at the Khlong Yai headworks site.

(b) Geology

The geological conditions of the both proposed headworks sites are broadly constituted by the sediment deposits consisting of terrace deposits and fluvial deposits. The N-value is ranging from 15 to 30. The foundations are expected to have the bearing capacity of about 20 t/m^2.

(c) Hydrology and hydraulics

Design flood discharge: The flood discharge with 50-year return period is taken as the design flood discharge. The relation between the regulated outflow and inflow at the Dok Krai dam is applied in order to assume the design flood discharge after completion of the Nong Pla Lai and Khlong Yai dams. The estimated design flood discharges are 200 m^3/s for the Nong Pla Lai headworks and 310 m^3/s for the Khlong Yai headworks.

Design flood water level: The design flood water levels at the both headworks sites are calculated to be El. 27.1 m for the Nong Pla Lai headworks and El. 26.6 m for the Khlong Yai headworks.

Design intake discharge: The design intake discharge at the Khlong Yai headworks is taken as the peak irrigation diversion requirement of 11.1 m^3/s for the Ban Khai Extension area. The design intake discharge at the Nong Pla Lai headworks is determined to be 4.9 m^3/s, in order to divert water from the Nong Pla Lai river to Khlong Yai river for the irrigation area of 3,400 ha, at the peak discharge time.

Design intake water level: Based on the ground surface elevation of irrigation area and the topographic conditions of the both headworks sites, the design intake water level at the Khlong Yai headworks site is determined to be El. 25.0 m at the head of the main canal and at the Nong Pla Lai headworks site to be El. 25.5 m.

(2) Specific Design of Headworks

(a) Type of weir

As described in the "Basic Design Condition", the design flood discharges at the both sites are large and the foundation materials are sediment deposits. In such conditions, the overflow-type concrete weir with scouring sluice is proposed at the both sites. The full width of concrete weir would be constructed on the sediment deposits as a floating type.

(b) Hydraulic calculation

Overflow discharge of water under complete overflowing condition can be calculated by;

$$Q = C \cdot B \cdot H^{3/2} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (7.1)$$

where,

Q : discharge (m^3/s)
B : width of weir (m)
H : upstream water depth above crest (m)
C : coefficient of discharge (= 1.83)

(c) Typical section

Typical section of the weir is decided considering such forces as external water pressures, uplift pressures, silt pressures, and own weight of the weir. As the foundations at the both weir sites would have enough bearing capacity for the weirs, the stability is examined on overturning and sliding. According to the study result on creep length, the both weirs would require the sheet piles. The general features of the both weirs are shown in Figs. 10 and 11.

(d) Intake

The intake structures are designed based on the intake water discharges. In order to prevent the sand intrusion from the river, a permissible intake velocity is limited to be about 1.0 m/s.

7.3.4 Diversion Channel

Between the two headworks, approximately 1.8 km long diversion channel will be constructed. A part of regulated release from the Nong Pla Lai dam will be diverted at the Nong Pla Lai headworks into the Khlong Yai river through the diversion channel. Furthermore, the water will be diverted, together with the regulated release from the Khlong Yai dam, at the Khlong Yai headworks into the Ban Khai Extension area. The diversion channel has a design capacity of 4.9 m^3/s. The channel is lined with a 7-cm thick plain concrete in its all reaches.

7.4 Irrigation Canal System

7.4.1 Function and Requirement of Canal

Irrigation canal systems in each scheme include main canals, lateral and sub-lateral canals. The layout plannings of these canals are done after understanding their respective functions and requirements mentioned below. The canal layouts of each scheme are shown in Figs. 12 to 15.

(1) Main Canal

The function of main canal is to convey irrigation water from intake site to development area in the most economical way. The khlong Luang, Khlong Thap Ma and Ban Khai Existing Schemes have two main canals respectively. The Ban Khai Extension Scheme has one main canal. The main canals have concrete lined trapezoidal sections.

(2) Lateral and Sub-lateral Canals

The functions of lateral and sub-lateral canals are to deliver irrigation water from main canals to tertiary units. The sizes of lateral units vary basically from 50 to 500 ha consisting of 2 to 20 tertiary units. The lateral and sub-lateral canals are of unlined earth canal and have trapezoidal sections.

(3) Tertiary Units

The tertiary units are demarcated so as to have the maximum area of 40 ha.

7.4.2 Layout Planning of Canal

(1) Layout Planning

Prior to the field survey, layout planning of canals is made on the map. For this work, the map on a scale of 1/20,000 prepared by RID is used. In the planning, the following matters are taken into consideration.

(a) Canal alignment should be straight and short as much as possible.

(b) The alignment should be planned so as not to pass through village yards and not to give damages to public facilities.

(c) If there are existing irrigation areas, areas are to be incorporated to the new scheme as much as possible.

(d) Embankment portion should be minimized as much as possible.

(e) Canal water level should be kept as high as possible for easy operation of canal system.

(2) Field Survey

(a) Based on the layout planning prepared on the map, the detailed field reconnaissance is made along the canal alignments to grasp micro-topography, hydrological conditions and soil conditions.

(b) The topographic survey including preparation of additional map on a scale of 1/20,000 for the Khlong Thap Ma Scheme area and the map on a scale of 1/2,000 for the diversion weir sites of the Ban Khai Extension Scheme area.

(c) The construction material survey is made for their availabilities and prices.

(d) For the layout planning, agricultural and socio-economical data are also collected.

7.4.3 Preliminary Design of Irrigation Canal

(1) Design Discharge

Based on the unit irrigation water requirements for the respective scheme areas, the design discharges for the canals over the four scheme areas are obtained as shown in Figs. 16 to 19.

(2) Velocity

The maximum and minimum permissible velocity is determined so as not to give the erosion and not to allow the sedimentation and the growth of aquaplant and moss in canals. Considering these basic requirements, the canal water velocities are determined as follows:

	Maximum Velocity (m/s)	Minimun Velocity (m/s)
- concrete-lined canal	1.2	0.6
- earth canal	0.7	0.4

(3) Roughness Coefficient

The Manning formula is used for determination of hydraulic properties of canals. The Manning's roughness coefficient "n" is determined as follows:

	Manning's "n"
- concrete-lined canal	0.015
- earth canal	0.025

(4) Freeboard and Waste Bank

The freeboard in canals is normally governed by considerations of the canal size and location, velocity, storm-water inflow, water surface fluctuations caused by checks, wind action, soil characteristics, etc. The freeboard is determined by the following formula:

$$Fb = 0.05 \times d + hv + A \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7.2)$$

where,

Fb : minimum freeboard (m)
d : water depth for maximum design discharge (m)
hv : velocity head (m)
A : allowance (0.05 to 0.15 m)

The height of waste bank is determined to be 0.2 to 0.5 m for concrete-lined canal and 0.2 to 0.3 m for earth canal, while their width is 2.0 m for concrete-lined canal and 1.0 m for earth canal.

(5) Canal Base Width/Water Depth (B/h) Ratio

The ratio of canal base width and water depth is determined as follows:

	B/h
- concrete-lined canal	1.0 - 1.5
- earth canal	1.0 - 2.0

(6) Side Slope

The side slope of 1:1.5 is adopted for the design of both concrete-lined and earth canals taking into account the soil mechanical conditions.

(7) Lining of Canal

All the main canals are lined with 7-cm thick plain concrete to check seepage from the canal banks and bottom and to protect the canal section against erosion.

(8) Canal Cross Section

Considering above mentioned items, canal types and their typical cross sections are designed as shown in Fig. 24.

7.4.4 Preliminary Design of Related Structures

A number of related structures are required in conjunction with irrigation canals for conveyance, regulation and measurement of irrigation water and protection of canal system.

The required types and their features of the major canal related structures are shown in Figs. 25 to 31. The general characteristics and design criteria of those structures are briefed as follows:

(1) Culvert

Culverts are constructed to convey canal water under roads. The culverts in the proposed canal system are classified into 14 types depending on their discharges. The two types for main canal have box barrels and the others have pipe barrels. Design water depth in the barrel is taken to be about 80% of barrel height, and design velocity is to be 110% to 130% of canal water velocity.

(2) Inverted Siphon

Inverted siphons are constructed to convey canal water under rivers and drainage channels. These structures are classified into four types depending on the canal discharge. The three types have design capacities of more than 1.0 m^3/s and are provided with box barrels. Other types have a design capacity of less than 1.0 m^3/s and provided with pipe barrel. The maximum velocity is taken to be 1.5 to 2.0 m/s.

(3) Drop Structure

The function of drop structure is to dissipate excess energy. The structures are classified into two types depending on canal water discharge, i.e. inclined type and vertical type. The inclined type is applied in case that canal discharge is more than 2.0 m^3/s and drop height is more than 1.5 m.

(4) Check Gate

A check gate is provided just downstream from turnout and spillway to maintain the required water level during the period of off-peak flow in the canal. The check gate structures are classified into two types. Type-A has two rectangular gates and installed at the site where the canal discharge is more than 5.0 m^3/s.

(5) Turnout

Turnouts are constructed to divert irrigation water from one canal to others. There are two types of turnout; (1) for diversion of water from main canal to lateral or sub-lateral canals, or lateral canal to sub-lateral canal (simply called "turnout"), (2) for diversion from main canal or lateral canal or sub-lateral canal to tertiary unit (called "farm turnout"). The turnouts are provided with one lane of pipe barrel with a diameter of 300 mm - 1,000 mm and concrete-made outlet structure. All the farm turnouts have a pipe barrel with 300 mm diameter, and the farm turnouts are protected by stone masonry against erosion upstream and downstream from these structures. Parshall flumes are equipped with turnouts and installed at the head of lateral and sub-lateral canals for the purpose of canal water measurement. The parshall flumes are classified into eight types depending on the canal discharge.

(6) Spillway

Over-flow type spillways are constructed along the canals for the purpose of flushing off all the excess water in the canals. These structures are classified into six types depending on the canal discharge. The design discharge of the spillway is taken to be 25% of the canal discharge.

(7) Crossdrain

Crossdrains are constructed across the irrigation canals at the places where the canals run across depressed lands or natural streams. Crossdrains are classified into three types depending on the design

discharge. Type-A has two lanes of box barrel and provided for the design discharge of more than 8.0 m^3/s. Type-B with a single box barrel is provided for the design discharge of more than 1.6 m^3/s. Type-C has a single pipe barrel.

(8) Over Chute

In order to take water of less than 1.6 m^3/s into the irrigation canals at the crossing point of canals and streams, over chutes are provided in case that the base elevation of stream is higher than the canal base elevation.

(9) Bridge

Concrete bridges are provided on operation and maintenance roads to cross over rivers and drainage channels at the points where the construction of siphons is planned. Concrete bridges are also provided over irrigation canals at the points where canal crossings are needed for villagers along the irrigation canals.

7.5 Drainage Canal System

7.5.1 General

The functions of drainage canals are to drain out water in fields and to lower or control the subsurface water level, and to lead the water to outlets or disposal points. The layout of the irrigation system and topography are the main factors for determining the location of the drainage canal. Existing natural streams or depressed areas are used for location of the drainage canal as much as possible.

7.5.2 Layout Planning of Drainage Canal

Through the field investigation, the following items are checked and studied.

- Field damage due to floods and mal-drainage is surveyed for its extent and magnitude.
- Present drainage mechanism is observed in its vicinal areas.

- Rainfall data is calculated for the analysis of the intensity and duration of rainfall and estimation of drainage requirements.
- Present land use in the areas is surveyed for the use of analysis on drainage requirements.

Based on the results of field investigation mentioned above, drainage canal systems are planned.

7.5.3 Preliminary Design of Drainage Canal and Its Related Structures

According to the drainage water requirement calculated in Chapter 5, the unit design discharge is determined for each scheme area. Design discharges of respective drainage canals are calculated on the basis of the unit design discharge. Existing natural streams and drainage canals are incorporated into the proposed drainage canal network as much as possible.

The related structures to the drainage canals include culverts and drops. They are planned and designed with the same principles as those of the related structures for the irrigation canals.

7.6 Inspection Road

For the proper operation and maintenance of project facilities, well arranged inspection roads are of vital importance. Since these roads will be used as village roads and farm roads after the project implementation, the arrangement of the inspection roads should be made considering the existing road networks.

(1) Main Inspection Road

The main inspection roads are required for inspection, operation and maintenance of main canals. Considering the future increase of vehicles for the inspection and operation and heavy construction equipment to be required for the canal maintenance and repair, all the main inspection roads are so designed as to have an effective width of 5 meters and to be laterite-paved. These roads are also used for the movement of agricultural products and equipment and for the day-to-day services between villages and from them to the highway.

(2) Lateral Inspection Raod

The lateral inspection road is mainly provided alongside the lateral canal. All these roads have an effective width of 3 meters and are paved with laterite. These roads are also used for the purpose of farm operation, particularly for harvesting.

8. CONSTRUCTION TIME SCHEDULE

8.1 Development Programme

8.1.1 Basic Considerations on Development Programme

In order to formulate the construction time schedules of the proposed irrigation schemes, i.e. the Khlong Luang, the Ban Khai Extension and the Khlong Thap Ma Irrigation Schemes, including the upgrading of the Ban Khai Existing Irrigation Scheme, the following basic considerations on development programme are made:

(a) The priority is given to improvement or upgrading of the existing irrigation system and expansion of on-farm facilities.

(b) The irrigation scheme, of which the water resource is already planned or proposed to be developed, will be developed in keeping pace with implementation of water resource development.

(c) Development of irrigation scheme will be well harmonized with development sequence of water resources.

(d) For financial flexibility, the implementation schedule of each scheme will not be overlapped as far as possible.

(e) The irrigation schemes will be extended in accordance with establishment of agricultural supporting systems to obtain the benefit projected.

(f) To raise a living standard of the farmers in the Study Area, the irrigation schemes will be realized alternately in both the Rayong and the Khlong Luang river basins.

8.1.2 Development Programme for Each Scheme

In accordance with the above considerations, the development programmes for each irrigation scheme are established as follows:

(1) Ban Khai Existing Irrigation Scheme

The Nong Pla Lai reservoir has been proposed to be created by the end of 1986. This reservoir was planned as the water resource mainly for irrigation of the Ban Khai area of 4,800 ha which is being supplied from the Dok Krai reservoir at present. Following this plan, the irrigation and drainage facilities in the existing area will be upgraded and extended to the whole area in keeping pace with implementation of the Nong Pla Lai dam, as mentioned in Chapter 6.

(2) Ban Khai Extension Irrigation Scheme

The Nong Pla Lai reservoir is expected to have an active storage capacity of 144 MCM. Based on the result of water balance study, the Nong Pla Lai reservoir can serve irrigation water to about 3,400 ha of the Ban Khai Extension area other than the Ban Khai Existing area, even if the domestic and industrial water for the coastal area is taken from the reservoir. The remaining area of 4,300 ha will be developed with provision of construction of the Khlong Yai reservoir. Taking into consideration the above conditions, the Ban Khai Extension area will be developed in accordance with the completion of the Khlong Yai dam.

(3) Khlong Luang Irrigation Scheme

In the Khlong Luang river basin, only the Khlong Luang Irrigation Scheme is envisaged to be developed. Considering of equal distribution of the Government's investment to the farmers in the Study Area, this scheme will be developed by the end of 1991. Based on the result of water balance study, the Khlong Luang reservoir can supply irrigation water to 6,600 ha with cropping intensity of 140%.

(4) Khlong Thap Ma Irrigation Scheme

The implementation of the Khlong Thap Ma Irrigation Scheme will be made with provision of construction of the Khlong Thap Ma reservoir which will be used only for irrigation purpose. This scheme will be implemented from 1985 to the end of 1989.

8.2 Construction Time Schedule

The construction time schedules for each scheme are prepared in accordance with the development programmes described in the preceding section 8.1 and shown in Fig. 32. The detailed descriptions are as follows:

(1) Ban Khai Existing Irrigation Scheme

Topographic map on a scale of 1:5,000 with a contour interval of 0.5 m has to be prepared for the scheme area. This work will be started from 1985 and completed within six months. The detailed design works for upgrading of the main canals, lateral canals and drainage canals will be started from 1985 and completed by the end of 1986, including the time necessary for survey and investigation and the detailed design.

The project office and quarters will be completed prior to the major construction works. This work will be started from 1986 and completed by the middle of 1987. The land aquisition for construction of project facilities will be completed six months ahead of the construction work. The necessary financial arrangement will be started at least one year ahead of commencement of construction.

The time required for the upgrading works of the Right and Left Main Canals will be around 2.5 years. The upgrading and extension works of lateral canals will be started from 1988 and completed by the end of 1989. The drainage canals will be improved and constructed for 1.5 years and completed by the end of 1989.

(2) Ban Khai Extension Irrigation Scheme

Aerial photo mapping for the scheme area and the detailed design works will be commenced from 1985 and completed by the end of 1986. The loan arrangement and necessary preparatory works will be started from 1986 and completed before the major construction works.

The construction of the Nong Pla Lai diversion weir will be carried out by dividing into two portions. The left side portion

of the weir including fixed weir, movable weir and intake will be constructed in two dry seasons of 1987 and 1988. The dike portion at the right side will be constructed in 1988. The construction of the Khlong Yai diversion weir will be also carried out on the same procedure as the Nong Pla Lai diversion weir. The construction of left side portion of the weir will be started after the completion of diversion channel and completed in the dry season of 1989. The dike portion will be constructed in 1989.

The construction of main canal including main inspection road will be carried out for three years from 1988 to 1990. Following the main canal construction, lateral canals including secondary inspection roads will be implemented during the period from the middle of 1989 to the middle of 1991. In the rainy season, the earth works will be cut down and the main effort will be paid to the construction of related structures. The excavation work of drainage canals will be started from 1990 and completed by the end of 1991.

(3) Khlong Luang Irrigation Scheme

Aerial photo mapping for the scheme area will be prepared on a scale of 1:5,000 with a contour interval of 0.5 m. This work will be carried out during the period from the beginning of 1986 to the middle of 1986. The detailed design works will be started from the beginning of 1986 and completed by the end of 1987. The loan arrangement and preparatory works such as construction of office and quarters and land acquisition will be started from the beginning of 1987 and completed by the middle of 1988.

The construction of the intake structure will be carried out in keeping pace with progress of construction of the Khlong Luang dam and started from the beginning of 1988 and completed by the middle of 1989. The North and South Main Canals including main inspection roads will be constructed during the period from 1988 to 1991. The construction of lateral canals will be started from the middle of 1989 and completed by the middle of 1991. The drainage canals will be constructed during two years of 1991 and 1992.

(4) Khlong Thap Ma Irrigation Scheme

Aerial photo mapping for the scheme area and the detailed design works will be started from 1985 and completed by the end of 1986. The loan arrangement and preparatory works will be commenced from 1986 and completed by the start of the major construction works.

The construction of intake structure, main canals, lateral canals and drainage canals will be started from the beginning of 1987 and completed by the end of 1989.

9. CONSTRUCTION COST ESTIMATE

9.1 Conditions

The unit prices for construction works are analyzed on the 1982 current price basis prior to construction cost estimate. For the construction cost estimate of each irrigation scheme, the following assumptions are made:

(1) The conversion rate between Baht and US Dollar is assumed to be US$1.00 = Baht 23.00 referring to the current exchange rate in Thailand.

(2) All of the construction works would be executed by contract basis. Machinery and equipment required for construction works would be provided by contractors themselves. Therefore, depreciation cost of construction machinery and equipment would be accounted in construction cost. The procurement cost of machinery and equipment would be out of consideration.

(3) The contractor's administration cost, profits and taxes payable to the Government for contract amount are estimated separating from the unit prices used for estimation of direct construction costs.

(4) Taxes on the construction materials, machinery and equipment to be imported from abroad are not include in the estimate.

(5) The construction costs integrated by unit costs are divided into foreign and local currency portions. The local currency portion is estimated on the basis of the current price in Chan Buri and Rayong Provinces in 1982 and the data collected from the on-going and completed irrigation projects around the project area. While, the foreign currency portion is also estimated based on the CIF prices in Bangkok referring to the FOB prices in Japan in 1982. All of the work items, materials and equipment are provisionally classified into both local and foreign currency portion as given below:

Local Currency Portion

- Labour wages,
- Sand, gravel and wooden materials,
- Fuel, oil, etc.
- Cement,
- Secondary concrete products,
- Small gates for canals,
- Reinforcement bar,
- Structural steel and steel pipe,
- Inland transportion cost,
- Construction cost of the Government's office and quarters,
- Minor and miscellaneous works,
- Land acquisition and compensation, and
- Administration cost of executive agency.

Foreign Currency Portion

- Large gates for intake structure and headworks,
- Depreciation cost of construction equipment and machinery,
- Expenses and fees of engineering services by foreign consultant,
- Foreign contractor's administration cost and profits, and
- Vehicles to be required for the construction supervision and O&M equipment for the project operation.

(6) As regards the physical contingency related to the construction quantities, commissions and changes in unit prices, around 15% equivalence of the direct construction cost is incorporated in the construction cost in view of the preliminary nature of the estimate. While, the price contingency of 8% per annum for the foreign currency portion and 10% per annum for the local currency portion are also incorporated in the construction cost to cover increase of costs due to future price escalation.

(7) Associated costs to be financed by the Government, such as the costs for strengthening the extension services, facilities of water users' association and improvement of social infrastructures are not included in the estimate.

9.2 Cost Estimate

The summary of the construction cost for each irrigation scheme is shown in Tables 12 to 15. The annual disbursement schedule of the construction cost is worked out based on the construction time schedule. The details for each irrigation scheme are stated in Tables 16 to 19. The breakdown of the direct construction cost estimate for each irrigation scheme is shown in the Bill of Quantity in separate volume.

The prices of major local materials and labour wages used in the estimate and the unit prices for major construction works are shown in Tables 20 and 21 respectively.

In addition to the cost estimate on the contract basis, the construction costs on the force account basis are estimated for reference to implementation of the schemes by the Government. They are shown in Tables 26 through 38.

9.3 Annual Operation and Maintenance Costs

The annual operation and maintenance costs include the salaries of project administration and water control staffs, the materials and labour cost for repair and maintenance of project facilities, the cost for operation, repair and maintenance of O&M Equipment, the running cost of project facilities. The annual operation and maintenance costs for each irrigation scheme are taken to be 0.5% of the direct construction costs, and summarized below.

Scheme	O&M Cost (10^3฿)
Khlong Luang	1,860
Ban Khai Extension	2,810
Ban Khai Existing	860
Khlong Thap Ma	740

9.4 Replacement Cost

Some of the facilities, especially mechanical works and O&M equipment have shorter useful life than the civil works and require replacement at a certain time within the project useful life. Table 25 shows the useful life and replacement costs of the mechanical works and O&M equipment.

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