(2) More emphasis will be placed on the conservation of forest and watershed. The forests and national park, totalling about 10.4×10^6 ha, should carefully be conserved by proper rehabilitation works and the reafforestation should be implemented at a rate of about 48,000 ha per annum. Hence, expansion of farmland will be limited over the 5-year period. In this context, the strategy of agricultural development has to emphasize structural improvement within the sector.

(3) 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. An emphasis will be placed on soil improvement and strengthening the agricultural support services.

Sectoral Report I, Socio-Economy presents in more detail the issues and policy measures of agricultural development in Thailand.

2.5 Pipe-Water Supply Services

The pipe-water supply services are mainly administerd by MWWA and PWWA. The MWWA is responsible solely for Bangkok Metropolis and the PWWA assumes a direct responsibility for 117 townships, 707 sanitary districts and 2,000 villages throughout the country.

The PWWA has been endeavouring to expand the pipe-water supply services along its two basic programmes; large scale water supply programme and rural water supply programme. The former focuses on the municipalities and sanitary districts with more than 5,000 population and is executed under full responsibility of PWWA. The latter is promoted for sanitary districts and rural communities with 1,500 - 5,000 population and is mainly implemented by the local administrative authorities under financial and technical assistance from PWWA, OARD and DMR.

According to the information obtained from PWWA, the pipe-water supply situation in 1982 are as follows.

Water Supply Programme	Nos. of Supply System (nos)	Water Supply Capacity (10^3 m^3/day)	Served Population (10^6)
Large Scale	169	849	3.7
Rural	663	378	2.1
Total	832	1,227	5.8

As is clear from the above table, the pipe-water served population is only 13 % of the national population. The water supply per capita is 210 l/day on the average.

In line with the policy measures set forth in the Fifth National Plan, the PWWA established its Five-Year Plan. It stipulates the following basic objectives;

(1) The water supply capacity in the urban area will be augmented from 849 x 10^3 m^3 per day in 1981 to 1,414 x 10^3 m^3 per day in 1986. Pipe-water supply population will be 4.4 x 10^6 m^3 in 1986.

(2) The rural water supply programme will also be emphasized in order to alleviate a gap in standard of living between the urban area and the rural area. The objective is to develop and expand the water supply system for 150 communities and to construct the new water supply system for 250 communities. These will bring about an additional water supply capacity of 35 x 10^6 m^3 per annum.

According to the Five-Year Plan of PWWA, the total investment cost is estimated at ฿ 7,665 x 10^6, comprising ฿ 1,577 x 10^6 for the rural water supply programme and ฿ 6,088 x 10^6 for the large scale water supply programme.

2.6 Long-Term Water Supply Plan

2.6.1 General

In order to meet the rapidly increasing water demand due to industrial and urban development and agricultural development, long-term water supply plan has been worked out for the Study Area as one of the objectives of the present study. The proposed development plan is reported in Study Report on Long-Term Water Supply Plan. Herein contained are the outline of the plan.

The long-term water supply plan is, in principle, formulated aiming at satisfying all the water demands in the Study Area in Target Year 2001. The Target Year is determined in due consideration of periods of the national five-year development plans and development period of Eastern Seaboard Development.

Pursuant to principle of water resources management, the Study Area is basically divided into 10 zones as shown in Fig. 2. Each zone consists of a single river basin or a couple of river basins. The water supply plan over the Study Area is formulated primarily based on the result of water demand and supply balance of the respective zone.

It should, however, be kept in mind that the water supply plan presented in this report is a little different from that originally proposed in the Study Report on Long-Term Water Supply or other relevant sectoral reports. The water diversion from New Ban Bung dam, which was an integral part of the original plan, has been cancelled in due consideration of the RID's policy amendment. In the revised plan, corresponding amount of water is supplied from the Bang Phra dam by means of reduction of a rate of river maintenance flow. The reduction of the river maintenance flow is judged allowable for the following reasons.

(1) The Bang Phra dam is located only at 2.5 km distance to estuary. There is neither intake nor water user inbetween the dam and the river mouth.

(2) The Bang Phra dam has never been releasing regularly the water to the downstream for unspecified use, according to its operation record. The unspecified release is rarely possible, since the Bang Phra reservoir is 2.4 times bigger than the average annual inflow.

(3) Under the present reservoir operation practices, any particular adverse effect on aquatic ecology has not been identified.

(4) The river maintenance flow is still sustained at a rate of 1.1×10^6 m^3 per year. The aquatic ecology and riparian lands would, therefore, be preserved at the same status as the present.

The water demand and supply balance and alignment of raw water conveyance systems have been adjusted accordingly in this report.

2.6.2 Water Demand

The water demand comprises the domestic use, industrial use and irrigation use. In addition, a concept of river maintenance flow is introduced. The projection of the water demand is discussed in detail in Sectoral Report IV, Domestic and Industrial Water Demand, and III, Irrigation Development Plan.

(1) Domestic Water Demand

In compliance with the pipe-water supply programme set forth in the Five-Year Plan of PWWA, each zone is classified into urban area and rural area. The urban area is defined as municipality/sanitary district with more than 5,000 population by Target Year 2001 and is further classified into development area and non-development area in accordance with Eastern Seaboard Development Plan.

The domestic water demand is projected based on the projected population, water consumption per capita and service factor for every 5-year period, namely, 1986, 1991, 1996 and 2001. The projected population and domestic water demand are shown in Table 3.

(2) Industrial Water Demand

The industrial water demand has been projected by ESS in line with the industrial development plan described in the preceding Section 2.3. The industrial water demand projected by ESS accrues only from the development areas.

Presently several enterprises are extracting groundwater or water from reservoirs by their own facilities. For enterprises located outside the development area, the same quantity of water as being consumed needs to be guaranteed. This water supply was carefully investigated and is added to the industrial water demand projected by ESS to produce the real industrial water demand. The estimated industrial water demand is presented in Table 4.

(3) Irrigation Water Demand

In the Study Area, there are two major existing irrigation areas at present. They are Bang Phra irrigation area with a net irrigation area of 1,120 ha in Zone 2 and Ban Khai irrigation area with 4,800 ha in Zone 10.

In addition, three irrigation development schemes are envisaged to be newly realized in association with development plan of Khlong Luang, Khlong Yai and Khlong Thap Ma dams. The irrigation area of the respective scheme is tentatively determined based on the preliminary water balance study. The development programme was set up in conjunction with water resources development requirement for the domestic and industrial water supply.

The irrigation water requirement is estimated based on the provisional cropping pattern with 150 % of cropping intensity and approximated irrigation area. The irrigation area and water requirement applied for water balance study are given below.

Irrigation Scheme	Irrigation Area (ha)	Irrigation Water Requirement (10^6 m^3/yr)			
		1986	1991	1996	2001
Khlong Luang	4,700	0	60.1	60.1	60.1
Bang Phra	1,120	15.4	15.4	15.4	15.4
Ban Khai	4,800	65.8	65.8	65.8	65.8
Ban Khai Extension	5,400	75.1	75.1	75.1	75.1
Thap Ma	2,200	0	0	30.6	30.6
Total	18,220	156.3	216.4	247.0	247.0

It should be noted that the above agricultural development plan is provisional. They will finally be determined through optimization study of the agricultural land and water resources development of the respective development shceme.

(4) River Maintenance Flow

The reduction of river flow due to intensified water use will result in adverse effect to various water users, if it exceeds a certain amount. It is therefore proposed to introduce the concept of the river maintenance flow. The river maintenance flow is the minimum discharge which is able to maintain water depth, flow velocity, water quality, channel stability, aquatic ecosystem and scenery to the extent necessary for navigation, fish catch, operation and maintenance of intakes, maintenance of river facilities, sea water repulsion, prevention of estuary clogging, conservation of groundwater, preservation of riparian land and people's amenity.

In the Study, in principle, the rate of the river maintenance flow is tentatively assessed to be equal to 90 % dependable monthly run-off at balance point. The river maintenance flow thus assessed is shown in Table 5.

(5) Overall Water Demand

The overall water demand of the respective zone is presented in Tables 6 through 9. The followings are the overall water demand expressed in terms of source water demand for the whole Study Area.

(Unit: 10^6 m^3/yr)

Water Demand	1986	1991	1996	2001
Domestic	33.1	45.4	66.7	91.5
Industrial	56.6	71.2	77.4	88.5
Irrigation	156.3	216.4	247.0	247.0
River maintenance flow	21.0	21.0	31.5	31.5
Total	267.0	354.0	422.6	458.5

2.6.3 Water Resources Development Potentials

As varified in the succeeding sub-section 2.6.4, under the present water resources development conditions, water shortage of about 57 x 10^6 m^3 is foreseen to occur in Target Year 2001. A new water resources development plan is indispensable to satisfy the whole water demand for the successful implementation of Easten Seaboard Development and agricultural development.

The water resources development potentials in the Study Area are studied primarily based on the data and information so far collected by RID as reported in detail in Sectoral Report XI, Water Resources Engineering.

As listed hereunder, there are 8 dams either existing or under construction or under planning as shown in Fig. 2 and Table 10.

Out of dams in operation, both the Phluta Luang and Khlong Bang Phai dams are used exclusively for Sattahip Naval Base. Thus they are not taken into consideration in the formulation of the long-term water supply plan.

Six dams, Bang Phra, Map Prachan, Dok Krai, Nong Kho, New Ban Bung and Nong Pla Lai dams have the active storage capacity of 339.7 x $10^6 m^3$ in total and produce the net regulated outflow of 227.5 x 10^6 m^3 per year in such drought year as 1979.

There have been identified 9 potential damsites, including Khlong Luang, Khlong Thap Ma and Khlong Yai damsites, in the Study Area. Out of these, five damsites are located on small rivers in the coastal area as shown in Fig. 2. It is foreseeable that the anticipated water shortage will be met by development of several dams among the potential damsites.

Water supply capacity of the respective potential damsite is obtained based on storage-draft relationships of Khlong Luang, Dok Krai, Nong Pla Lai and Khlong Yai damsites, where streamflow observation records are available for a 14-year period from April, 1968 to March, 1982. The said storage-draft relationships are shown in Fig. 3. A relationship between storage ratio and unit development cost of water is then developed for the respective potential damsite as shown in Fig. 4.

The relationships shown in Fig. 4 expresses two elements. Firstly, Khlong Luang, Khlong Yai and Khlong Thap Ma damsites are incomparably superior to the other potential damsites in terms of unit development cost of water. Secondly development scale is the most economical within a range of 80 - 100 % in terms of storage ratio. For the purpose of water balance study, development scale is tentatively determined to be 100 % in terms of the storage ratio for Khlong Luang, Khlong Yai and Khlong Thap Ma damsites and 80 % for the remaining 6 pontential damsites. Table 11 shows the salient features and water supply capacity of the respective potential dams at the pre-determined development scale.

2.6.4 Water Balance

The water balance study was performed in order to determine the water resources development requirement as reported in detail in Sectoral Report X, Water Balance Study.

The representative river was selected in each zone and the balance point was, in principle, set up at the lowest intake site for the water balance study. The representative river and balance point of the respective zone are as shown in Table 5.

The water demand and supply balance was calculated zone by zone at intervals of 10-day period during a 12-month period from May, 1979 to April, 1980, which is the driest year among a 14-year period from 1968 to 1981.

At first water withdrawal was computed as the water demand deducted by the available local water resources. The water withdrawal means the net reduction in river flow which is required to meet the water demand. The water deficit is then calculated as the water withdrawal less the natural run-off at the balance point under the following presumptions.

(a) The Dok Krai Pipeline Project fully supplies the water withdrawals in Zones 7 through 9.

(b) As to Zone 2, natural run-off of the representative river is negligibly small compared to the domestic and industrial water demand. Therefore the whole domestic and industrial water demand is determined to be met by inter-zone water diversion.

The water demand and supply balance was initially calculated under the present water resources development condition. The Nong Kho and Nong Pla Lai dams are treated as existing one. The result is given hereunder.

(Unit: 10^6 m^3/yr)

Year	Water Demand	Water Withdrawal	Water Deficit	Supply by Dams	Balance
1986	267.0	264.9	214.0	218.0	-4.0
1991	354.0	351.9	283.1	218.0	+65.1
1996	422.6	420.5	335.3	218.0	+117.3
2001	458.5	456.4	367.5	218.0	+149.5

As shown in the above, the water supply as a whole is short of the demand. The water demand and supply balance situation varies largely from zone to zone, depending on the magnitude of water demand and the availability of water resources. The integrated development of water resources and inter-zone water diversion system is ascertained to be most appropriate measure to overcome the shortage of water supply.

A set of four water supply alternatives were drawn up for Target Year 2001 to ascertain the most optimal plan. The water demand and supply balance was further computed for the respective water supply alternative. The water demand and supply balance under the proposed water supply plan is given in Tables 6 to 9 and is summarized below.

(Unit: 10^6 m^3/yr)

Year	Water Demand	Water Withdrawal	Water Deficit	Supply by Dams	Balance
1986	267.0	264.9	214.0	227.5	-13.5
1991	354.0	351.9	306.2	369.7	-63.5
1996	422.6	420.5	371.5	411.0	-39.5
2001	458.5	456.4	404.0	411.0	-7.0

The water balances for the intermediate years are calculated referring to the development sequence of the proposed water supply plan.

2.6.5 Proposed Long-Term Water Supply Plan

All the water supply alternatives were examined in detail from the viewpoint of investment requirement, technical soundness and social problems. As the results, the water supply plan shown in Figs. 5 to 8 is determined to be most promissing plan. The fundamentals of the proposed water supply plan for Target Year 2001 are as follows;

(1) Development of water resources facilities:
Khlong Luang, New Ban Bung, Khlong Thap Ma and Khlong Yai dams

(2) Development of water conveyance systems:
Khlong Luang, Ban Bung, Nongkho, Nong Pla Lai, Bang Lamung, Huai Yai, Dok Krai and Ban Khai systems

(3) Water diversion from the inland area to the coastal area:
Khlong Luang river basin to Chon Buri Pattaya area: 11.0 x $10^6 m^3/yr$
Rayong river basin to Chon Buri-Pattaya area: 31.3 x $10^6 m^3/yr$
Rayong river basin to Sattahip-Map Ta Phut area: 54.8 x $10^6 m^3/yr$.

Water demand and supply balance until the target year 2001 is shown in Fig. 9.

Investment requirement for the proposed water supply plan is roughly estimated to be ฿ 8,827 x 10^6, consisting of ฿ 3,602 x 10^6 for water resources development, ฿ 4,205 x 10^6 for water conveyance system and ฿ 1,020 x 10^6 for irrigation development.

3. KHLONG THAP MA RIVER BASIN

3.1 Natural Conditions

3.1.1 Location and Topography

The Khlong Thap Ma Dam Scheme is one of a series of water resources development projects in the Rayong river basin.

The Rayong river is situated in the eastern part of the Study Area and has a drainage area of approximately 1,730 km^2. The proposed Khlong Thap Ma damsite is located on the Khlong Thap Ma river, a tributary of the Rayong river. The Map of Rayong river basin is shown in Fig. 10.

The Khlong Thap Ma river takes its origin in Mt. Khao Nang Yong (El. 419 m) and flows down almost toward the southeast. It changes its direction to the east in the vicinity of Ban Noen Phra and joins with the Rayong river at approximately 2 km east of Rayong. A drainage area of the Khlong Thap Ma river is 158 km^2 at the proposed damsite.

There are a vast plain inbetween the proposed damsite and the confluence of the Khlong Thap Ma and Rayong rivers. According to the land use, soils and land capability assessments, there is approximately 2,400 ha of land suitable for cultivation of paddy in the downstream from the proposed damsite.

The Khlong Thap Ma river basin is served with well-developed road network systems. One inter-regional and one provincial highways run through the basin as shown in Fig. 10. Inter-regional national highway Route 36 runs from Rayong to the northwest passing near Khlong Thap Ma damsite. Provincial highway Route 3191 connects Map Ta Phut and Dok Krai Reservoir passing north of Khlong Thap Ma damsite. Rural roads are spread over the basin area. Most of the rural roads are laterite-paved with two lanes.

3.1.2 Climate

Details of climate over the Study Area are reported in Sectoral Report VII, Meteorology and Hydrology.

The climate over the Khlong Thap Ma river basin is tropical and monsoonal. There are two distinct seasons in a year. Dry season with the northeast monsoon lasts from November to April, while the wet season with the southwest monsoon extends from May to October. The climatological data at Chon Buri, Sattahip and Ban Nong Mapring stations are presented in Table 12.

Air temperature varies only slightly from the annual average of 29°C. The average annual basin rainfall is approximately 1,300 mm, of which more than 80 % occurs during the wet season. The relative humidity is almost constant throughout the year, 93 % on the average.

3.1.3 Hydrology

No observed stream gauging records are available for the Khlong Thap Ma river. Run-offs at the damsite were estimated from those at Ban Mae Nam Khu stream gauge station, which was situated in the Khlong Dok Krai river, a tributary of the Rayong river. Table 13 shows the estimated monthly mean run-offs for a 14-year period from April, 1968 to March, 1982. The average annual run-off is 1.75 m^3/s, ranging from 0.60 m^3/s in 1979 to 2.47 m^3/s in 1972.

The flood analysis was made by means of unit hydrograph method. The synthesized probable floods at the damsite are as follows:

Return Period (year)	Peak Discharge (m^3/s)
10	540
50	700
100	770
500	920
Probable Max.	1,540

The sediment yield from the basin area is evaluated to be 300 $m^3/km^2/year$.

The run-off and flood analyses and sediment transport are discussed in detail in Sectoral Report VII, Meteorology and Hydrology.

3.1.4 Groundwater

The reconnaissance survey on groundwater resources was carried out as explained in Sectoral Report IX, Groundwater Resources.

Local phreatic aquifers are found in flood plains, which consists of silty sand, sandy clay and rare gravelly sand layers. The aquifers are recharged by rivers and paddy fields. Remarkable descent of groundwater level in the aquifers takes place during the dry season. The aquifers are encountered with salt water intrusion. The salt water is detected in Ban Khai, about 13 km upstream from the estuary.

Regional confined or unconfined aquifers are ascertained to be existent to a very small extent, due to high clay content and resultant low permeability and also low storage capacity in the terrace deposits. The groundwater in the terrace deposits appears to be recharged by vertical infiltration of rainfalls.

According to the inventory and sampling surveys, approximately 80 % of rural population are dependent on shallow dug-wells for their domestic water. The annual groundwater abstraction through the shallow dug-wells are roughly estimated at 4.1×10^6 m^3, all of which is presumed to be domestic use. There are 5 tube-wells in the basin Rayong river at present. They produce 0.2×10^6 m^3 of groundwater annually, of which 40 % are exclusive use for manufacturing.

The groundwater development potential is concluded to be quite low owing to the salt water intrusion deep into the alluvial plains and poor hydraulic characteristics of the terrace deposits.

3.1.5 Geology

The Rayong river basin, including the Khlong Thap Ma river basin, is situated in the geologic province of the pre-Cambrian metamorphic rocks. Gneiss and gneissose granites are cropped out around the eastern divide of the basin, whereas the Triassic intrusive granites are widely developed on the western side of the basin. Small patches of crystalline schists and phyllites are located in the Khlong Thap Ma valley.

The terrace and collunial deposits of Quaternary period are widespread in the basin, covering the metamorphic bedrocks. The river alluvial deposits and flood deposits cover the central parts of the basin, along the river valley.

The Rayong river basin is generally characterized by topography of peneplain in the late stage of erosion. The terrain is flattened by erosion into low undulating hills and wide open valleys. Some isolated hills with rather steep slopes remain only at places. The bedrocks crop out almost solely on those isolated hills.

3.1.6 Soils

From the viewpoint of soils and land capability, the potential irrigation service area of Khlong Thap Ma dam is assessed to be 2,400 ha at the maximum. Figs. 11 and 12 show detail soil map and land capability map respectively.

The soils in the potential irrigable area are classified into two soil groups; soils of recent alluvium and soils of semi-recent alluvium. They are divided into a number of soil series by LDD. Table 14 presents distribution of soils by soil series. The alluvial soils, poorly drained complexes, is the most predominant, which occupies 52 % of the whole potential irrigable area. Rayong series covers 14 % of the area. The generalized brief descriptions on these soil series are as summarized below.

Alluvial Soils, Poorly Drained Complexes (AC-pd): These soils are typical alluvial soils on the low-lying alluvial plain developed along the Rayong river and its tributaries. These soils are characterized by gleic horizon and/or layer. The soils have, in general, fine texture and strong acid reaction. Inherent fertility of the soil is low. Water holding capacity is moderately high. The drainage conditions are externally and internally poor, due to flat or depressed topography and fine soil texture.

Rayong Series (Ry): The soils of this services are mainly found in the old beach sand dunes developed near the present beach. The soils which are defined as unmatured soils consist of coarse quartz sand having no stickness and no plasticity. As for their chemical features, the soils are extremely to slightly acid ranging 4.0 to 6.5 in pH value throughout the profile. Organic carbon mainly occurs in the surface soil. Base saturation degree is very low in common, and the essential plant nutrients are also quite deficient. The lands covered with these soils are excessively permeable due to coarse texture and unfavorable for the profitable farming.

The land capability of the potential irrigable area is referred to Land Capability Map published by LDD and is presented in Table 15. According to the LDD's classification, land capability is broadly divided into two categories, namely, "Suitable" and "Not Suitable". A category of "Suitable" is further sub-divided into (1) Class I, highly suitable, (2) Class II, moderately suitable, (3) Class III, suitable and (4) Class IV, marginally suitable. Nearly 30 % of the potential irrigable area is ascertained to be Classes II and III.

3.2 Administrative Division and Population

The Khlong Thap Ma river basin falls in with Rayong Province and includes 2 townships. The administrative divisions are shown in Fig. 10.

The total population of around 30,000 in 1981 is resided in the basin.

3.3 Regional Agriculture

3.3.1 Farm Population and Households

Agriculture over the proposed irrigation area of 2,400 ha is summarized herein. The Sectoral Report II, Agricultural Development Plan describes thoroughly the regional agriculture over the Khlong Thap Ma river basin.

The population and number of household in the proposed irrigation area are 4,130 and 690, respectively, according to the statistic data obtained from Agricultural Extension Office in Rayong. The average family size is 6.1 persons.

The number of the farm household is estimated at 1,890 and the farm population at 11,500. Potential farm labor force is presumed to be 2 to 3 persons per farm household.

3.3.2 Land Holding and Land Tenure

The average land holding size is 4.8 ha, which is 0.4 ha smaller than that of the entire Rayong Province. According to the Agricultural Census Report, 1978, the households with land holding size of less than 1.0 ha account for 13 % of the total in Rayong Province. The households of 1.6 to 4.0 ha are most predominant, occupying about 48 % of the total.

Approximately 90 % of farms are owner operator and 4 % tenant in Rayong Province, according to the Agricultural Census Report, 1978. Approximately 91 % of the entire farm holding lands is occupied by the owner operators.

3.3.3 Land Use

The land use in the proposed irrigation area was ascertained by land use map in a scale of 1 to 250,000 and field survey. The land use map is shown in Fig. 13.

Although the proposed irrigation area is not provided with irrigation, rice is grown in 2,000 ha of the area under rainfed condition. Approximately 650 ha of the area is used for cultivation of upland crops such as cassava, sugarcane, groundnuts, etc. Perennial crops are grown in about 100 ha of the area.

3.3.4 Cropping Pattern

The cropping pattern prevailing over the proposed irrigation area is shown in Fig. 14.

Rice is planted from the beginning of July to the middle of August and is harvested from the middle of October to the middle of December. It is not cultivated during the dry season owing to lack of irrigation water supply.

Cassava is cultivated in rather limited area. Planting extends over two and half months from the middle of October to the end of December and harvesting lasts also two and half months from the middle of August to the end of october.

The cropping intensity is 100 % under the present condition.

3.3.5 Farming Practices

Many kinds of varieties of rice are cultivated in the proposed irrigation area, all of which are of non-glutinous type. The high yielding varieties have been spread over about 40 % of paddy cultivation area. Applications of fertilizers and agro-chemicals are rarely practiced. Transplanting and harvesting are done still manually. Harvested paddy is threshed mainly by means of trampling of buffaloes.

Cassava is mainly grown for industrial use. Native variety designated as "Rayong" is predominantly cultivated in the proposed irrigation area. Fertilizing is generally not carried out. Planting is made manually at a rate of one set per square meter; 10,000 sets per ha.

Sugarcane is planted with a spacing of 1.3 m by 0.3 m, 25,600 sets per ha. Earthing is done two times during the growing period; the first is one to one and a half month after planting and the second two to three months after planting. Ratooning is commonly practiced after harvesting with cutting the stubbles of harvested cane. Fertilizers are applied at a rate of 310 kg per ha of compound fertilizer (N:15 - P:15 - K:15).

3.3.6 Crop Yield and Production

Yields of crops remain low because of lack of irrigation water supply and less supply of agricultural requisite. Productions of crops vary from year to year, characterized by climatological conditions. Crop yield and production for 1981 are given below.

Crops	Average yield (t/ha)	Production (tons)
Rice, local varieties	1.8	2,120
Rice, high yielding varieties	2.3	1,790
Cassava	16.0	8,160
Sugarcane	43.0	5,160

3.4 Flood Problems

3.4.1 Flood Characteristics

The Khlong Thap Ma river flows through broad alluvial plains subject to frequent overflow, in a reach between the proposed damsite and the confluence with Rayong River. The reach is characterized by flat bed slopes, meandering channels of very small flow capacity, and low banks. The reach is marked by the formation of numerous secondary channels. The average fall of the reach is 0.4 m per kilometer.

According to the stream gauging records at Ban Khai in the main stem of the Rayong river, the basin has been experiencing numerous floods over the years. The recent devastating floods were observed in 1974 and 1981. The floods generally occur during the months of September and October, although it rarely happens in the months of August and November.

3.4.2 Channel Capacity

Critical channel capacities were analyzed for downstream reach from the proposed damsite for the purpose of flood control study. Critical flows or bankful flows were computed by means of non-uniform flow formula based on the longitudinal profile and cross-sectional survey data along the main stem of the Khlong Thap Ma river. Figs. 15 and 16 show the critical channel capacities along the Rayong and Khlong Thap Ma river stretch.

The average bankfull flow is 15 m^3/s. The magnitude of the floods exceed far beyond the critical channel capacity, causing flood damage along the whole stretch.

3.4.3 Flood Magnitude and Frequency

In the Khlong Thap Ma basin, flood records are not available at all. Thus flood run-off analysis of the basin was performed as an integral part of the Rayong river basin by means of flood run-off simulation model. The simulation model is to reveal the magnitude of flood and establish a relationship among frequency, magnitude of flood and flood damage and consists of three basic elements, i.e., (i) flood run-off calculation by sub-basin, (ii) channel routing calculation and (iii) flood regulation by dam.

As shown in the run-off simulation model of Fig. 17, the Khlong Thap Ma river below the dam is treated as one river reach and its basin is divided into two sub-basins. Fig. 18 shows the division of the whole Rayong river basin.

The flood run-off of the respective sub-zone is synthesized by means of unit hydrograph method. The basin rainfall of the sub-zone is obtained based on a relationship between the point rainfall and the areal rainfall. A rate of direct flood run-off is estimated to be 65 % based on the past flood run-off records in the Rayong river basin.

The routing through river channel is computed by applying the storage function method.

The flood run-off at the upstream end of the reach was simulated by a combination of the flood run-off calculation and channel routing calculation. Flood frequency curve thus obtained is shown in Fig. 19.

The flood run-off analysis is discussed in detail in Sectoral Report VII. Meteorology and Hydrology.

3.4.4 Flood Prone Area

Because of insufficient channel capacity, the lower Khlong Thap Ma river basin has been sufferred from floodings. The flooding pose a severe hazard to the population and exert a negative effect on economic growth of the area.

In order to grasp the extent of flooding and the character of flood losses, the flood damage survey was carried out over the Rayong river basin during the period from August to October, 1982 in collaboration with RID. The survey was dependent on a interview survey, which was conducted at 27 spots in the whole basin. As the results, flood inundation area in the whole Rayong river basin has been revealed for the 1974 and 1981 floods as shown in Figs. 20 and 21. The inundation area is estimated to be 21,000 ha for the 1974 flood and 17,000 ha for the 1981 flood. The 1974 and 1981 floods have recurrence intervals of 16.0-year and 2.3-year, respectively, according to the flood frequency curve at Ban Khai weir site.

The inundation areas are classified into four land use categories as shown below, according to the topographic map and land use map.

Land Use	Inundated Area (ha)	
	1974-flood	1981-flood
Paddy field	11,300	10,400
Upland	4,000	1,800
Village area	1,600	1,200
Other lands	4,100	3,600
Total	21,000	17,000

The number of houses subject to flood damage is estimated at 16,570 for the 1974 flood and 12,420 for the 1981 flood.

3.4.5 Flood Damages

The flood damages in the Rayong river basin have been broadly grouped into four categories, namely, (i) rice, (ii) upland crops, (iii) house and household properties and (iv) livestock. Other tangible losses such as impairment of public facilities and utilities and buiseness and financial losses are assumed to be 20 % of the damages of the above categories. Intangible losses are not taken into account.

The damage rate was determined for each damage category depending on the seasonal occurence and frequency of flooding and the characteristics of flooding such as depth and period. The damageable value is also determined for each category. The damageable values of rice and crop are based on their yields and prices prospected to 1990 and are estimated to be ฿ 14,090 per ha and ฿ 14,510 per ha respectively. The damageable values of house and household effect and livestock are estimated to be ฿ 39,600 per household and ฿ 1,160 per household respectively.

The flood damage was calculated based on the damageable value and damage rate for each damage category and flood damage curve is prepared as shown in Fig. 22. The flood damages of the 1974 and 1981 are estimated for the whole Rayong river basin as shown below.

(Unit: ฿ 10^6)

Damage Categories	1974-flood	1981-flood
Rice	48.6	34.2
Upland crops	15.1	6.4
House and household effect	21.2	15.0
Livestock	9.8	7.6
Other tangible	18.9	12.6
Total	113.6	75.8

The average annual flood damage in the Khlong Thap Ma river basin proper is estimated to be ฿ 16.9 x 10^6 based on the flood damage curves, while that of the entire Rayong river basin is ฿ 147.1 x 10^6.

Thorough study on flood damage is compiled in the Sectoral Report XIII, Flood Mitigation Engineering.

4. LAND AND WATER RESOURCES DEVELOPMENT PLAN

4.1 Plan Formulation

4.1.1 Methodology

As is displayed in the Section 2.6. The Khlong Thap Ma Dam Scheme has a nature of multiple-purpose areal-development project. It is designed to serve the irrigation water supply and flood control. Among the two purposes, irrigation water supply has priority over flood control. Therefore, plan formulation was initially directed to the land and water resources development.

The optimum land and water resources development plan will be formulated dealing with three variables; extent of irrigation area, cropping intensity and development scale of dam. The irrigation area is, however, limited to 2,400 ha at the maximum, owing to the soils and land capability conditions.

In order to establish a relationship among the irrigation area, cropping intensity and reservoir active storage, a number of reservoir operation studies were conducted with the aid of a digital computer. Based on the relationship, various development alternatives were arbitrarily selected and their cost and benefit were estimated for economic comparative study. A development plan generating the maximum annual net benefit is selected as the optimum development plan.

The plan formulation on the land and water resources development is elaborated in Sectoral Report XI, Water Resources Engineering.

4.1.2 Reservoir Operation Study

The reservoir operation was simulated at intervals of 10-day period during a 14-year period from April, 1968 to March 1982. The release from reservoir comprises irrigation water supply and river maintenance flow. The reservoir operation study follows the basic conditions set forth as below.

(1) The Khlong Thap Ma dam assures completely all the irrigation water during the aforementioned 14-year period.

(2) The river maintenance flow is sustained throughout the year at a rate of 0.33 m^3/s as adopted in the formulation of the long-term water supply plan.

The simulation of reservoir operation is cited in Fig. 23 for the optimum development plan. Based on the results of the reservoir operation study, the relationship between the irrigation area, cropping intensity and reservoir active storage capacity is developed as shown in Fig. 24. The cropping patterns and corresponding irrigation water requirements are compiled in Sectoral Report II, Agricultural Development Plan and Sectoral Report III, Irrigation Development Plan, respectively.

4.1.3 Development Alternatives

The relationship in Fig. 24 was carefully examined from the viewpoint of the land and water resources development and twelve development alternatives are arbitrarily established to sound their economic feasibility. The twelve alternatives are as under-listed.

Alternatives	Cropping Intensity (%)	Net Irrigation Area (ha)	Reservoir Active Storage (10^6 m^3)
1-1	150	1,900	31.0
1-2	150	2,100	35.5
1-3	150	2,400	42.5
2-1	160	1,900	35.5
2-2	160	2,200	42.5
2-3	160	2,400	49.5
3-1	170	1,500	31.0
3-2	170	2,000	42.5
3-3	170	2,400	56.1
4-1	180	1,500	35.5
4-2	180	2,000	49.5
4-3	180	2,400	68.5

4.1.4 Economic Comparison

The project cost and benefit were calculated for the respective development alternatives as described hereunder.

(1) Project Cost

The construction costs of dam and irrigation facilities were estimated based on the basic layout design and at the price level of 1982.

The project cost was converted into annual equivalent cost at a discount rate of 8 % per annum with economic life of 50 years. The annual O & M cost and replacement cost were also estimated.

(2) Project Benefit

The project benefit, which is derived from the land development, is discussed in Chapter 8. The annual land development benefits are estimated to be ฿ 28,071/ha for cropping intensity 150 %, ฿ 30,986/ha for 160 %, ฿ 34,021/ha for 170 % and ฿ 37,191/ha for 180% respectively..

The annual equivalent cost and benefit and OM & R costs are summarized in Table 15. The annual net benefit is defined as the annual benefit less the annual equivalent cost and OM & R cost. It is calculated for the respective development alternative as shown in Table 15 and is illustrated in Fig. 25.

As is evident in Table 15 and Fig. 25, the development alternative 3-3 generates the highest annual net benefit among the twelve alternatives compared. Therefore, the alternative 3-3 is recommended as an optimam plan for the land and water resources development.

4.2 Optimum Development Plan of Khlong Thap Ma Dam Scheme

The plan formulation on the land and water resources development plan has clarified the optimum reservoir active storage, cropping intensity and irrigation area. Also the plan formulation on the flood mitigation plan has revealed the storage capacity requirement in the Khlong Thap Ma reservoir for flood control. The development scale of Khlong Thap Ma Dam Scheme is finally determined integrating the above study results as shown below.

(1) Multiple-Purpose Dam

Purpose	:	Irrigation water supply
Reservoir	:	
Storage capacity		
Gross	:	74.3 x $10^6 m^3$
Surcharge	:	13.5 x $10^6 m^3$
Active	:	56.1 x $10^6 m^3$
Dead	:	4.7 x $10^6 m^3$
Flood water level	:	El. 26.9 m
High water level	:	El. 25.7 m
Low water level	:	El. 16.2 m
Dam		
Crest elevation	:	El. 28.9 m
Dam height	:	20.4 m above the river bed

(2) Land Development

Irrigation area	:	2,400 ha
Proposed crops	:	Rice, Groundnuts, Vegitables Fruit Trees.
Cropping intensity	:	170 %

4.3 Agricultural Development Plan

4.3.1 Proposed Irrigation Area

The plan formulation manifested that the optimum land development is to irrigate the entire potential irrigable land of 2,400 ha with the proposed cropping pattern having 170 % of cropping intensity.

As shown in DWG No.2-1, the proposed irrigation area lies over both banks of the Khlong Thap Ma river 1,250 ha on the left bank and 1,150 ha on the right bank.

4.3.2 Proposed Cropping Pattern

The proposed cropping pattern with 170 % of cropping intensity is shown in Fig. 14.

Rice will be cultivated predominantly as nation's principal food and export commodity. The Government has been emphasizing in its Fifth National Plan an increase of rice production to cope with future population increase and to improve the international trade balance. The high yielding varieties will be predominant among rice varieties in future and will be planted for 81 % of the proposed irrigation area during the wet season. The traditional varieties will also be grown in the remaining 19 % of the area during the wet season for the sake of distribution of risk and choise in taste.

Groundnuts will be cultivated during the dry season. It is selected from the viewpoint of soil conservation and farmer's cash income.

Vegetables will also be cultivated during the dry season in relatively large area. Consumption of vegetables are predicted to be increased with a leap in the coastal area resulting from the induced population increase.

The future land use in the proposed irrigation area will be as follows.

(Unit: ha)

Crops	Wet Season	Dry Season	Total
Rice			
- Local varieties	440	-	440
- improved variety	1,880	820	2,700
Groundnuts	-	700	700
Vegetables	-	150	150
Fruit trees	(80)	80	80
Total	2,320	1,750	4,070
(Cropping intensity)			170

4.3.3 Proposed Farming Practices

In line with development of advanced irrigation and drainage system, the improved farming practices will naturally be introduced into the area to attain and maintain the high crop productivity. The proposed farming practices by major crop are described hereunder.

(1) Rice

The distribution of seeds of the high quality is essential to increase the crop yield as expected. The RD varieties such as RD-7, RD-9 and RD-25 are recommended as high yielding varieties.

The fertilization is also significant to increase the yield. The fertilizer application rates are proposed as follows:

Varieties of Rice	Application Rate (kg/ha)	
	Nitrogen	Phosphate
High Yield	80 - 100	30 - 50
Local	30 - 40	20 - 30

For plant protection, intensive application of agro-chemicals will be adopted to control insects (stemborers and plant hoppers) and disease (blast). It is recommended to carry out the spraying systematically through the farmer's group.

The proper water management is indispensable for cultivation of rice, particularly the high yielding varieties. Water will be supplied deep in depth during the rooting period of seedlings and critical period for the punicle development and fertilization stage of rice plants.

(2) Groundnuts

To maintain the expected yields of groundnuts, good land preparation, careful pulverizing, optimum application of fertilizers and partinent spraying of agro-chemicals should always be sustained. The recommended fertilizer application rates are as follows.

Fertilizer	Application Rate (kg/ha)
Nitrogen	7 to 13
Phosphate	7 to 13
Potassium	10 to 20

4.3.4 Farm Input

(1) Labour Requirement

The labour force requirements are estimated for "without project" and "with project" conditions respectively, as tabulated below.

(Unit: 10^3 man-day)

Month	Labour Requirement		Available family labour	Month	Labour Requirement		Available family labour
	Without project	With project			Without project	With project	
Jan.	9.3	29.7	37.7	Jul.	25.1	21.3	36.3
Feb.	1.9	14.5	33.4	Aug.	22.4	39.7	34.8
Mar.	1.7	7.9	37.7	Sep.	5.0	7.9	31.9
Apr.	2.1	21.0	36.3	Oct.	8.7	12.4	105.4
May	0.6	11.0	33.4	Nov.	13.8	33.7	37.7
Jun.	3.0	5.0	36.3	Dec.	16.8	18.7	37.7
				Total	110.4	222.8	442.2

A shortage of labour is foreseen to occur in August, being a transplanting period of time. This shortage however, would be remedied by introduction of light agro-machinery.

(2) Material Requirements

The requirements of farming materials such as seed, fertilizers and agro-chemicals will increase substantially due to introduction of advanced farming practices. The material requirements per year are estimated as follows for the full development stage.

Farming Materials	Unit	Quantity
Seed		
Rice, local varieties	t	13
high yielding varieties	t	81
Groundnuts	t	21
Vegitables	t	5
Fertilizer		
Compound (N:16, P:20, K:0)	t	820
(N:15, P:15, K:15)	t	140
(N:13, P:13, K:21)	t	80
Urea	t	220
Agro-chemicals		
Insecticides, Fungicides	kg	6,020
Herbicides	l	7,210
Rodenticides	kg	14,650

4.3.5 Anticipated Yield and Production

The target yields are projected referring to the results of experiments in the Agricultural Experimental Stations and the other information from the Agricultural Extension Office in Rayong. The target crop yields and productions are shown below.

Crops	Target Yield (t/ha)	Production (t)
Rice		
Local varieties	4.0	1,760
High yield varieties (Wet Season)	4.5	8,460
High yield varieties (Dry Season)	5.0	4,150
Groundnuts	2.5	1,750
Vegitables	10.0	1,500
Fruits	7.0	560

A five-year period will be required to reach the target yields for strengthening of agricultural support service systems.

4.4 Irrigation Development Plan

4.4.1 Irrigation Requirement

The irrigation requirement was calculated at intervals of 10-day to perform the plan formulation and to determine the design discharge for the irrigation facilities. The calculation method is briefly described below.

Reference crop evapotranspiration was calculated based on the Modified Penman Method for the respective crop. The climatological records at Chon Buri station was applied for the calculation.

Effective rainfall was derived from a rainfall - effective rainfall relationship, which was developed by RID. The rainfall records observed at Ban Khai rain gauge were adopted.

Irrigation efficiency is determined as shown below.

	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

The diversion requirement was calculated at 1.55 l/s/ha at the maximum. This figure will be employed as design discharge for preliminary design of irrigation facilities.

4.4.2 Drainage Requirement

The drainage improvement will be planned so as to remove within 72 hours excess water resulting from the maximum 3-day continuous rainfall expected to occur at a frequency of 10 years. Three-day ten-year frequency rainfall is 208 mm according to the rainfall records observed at Ban Khai rain gauge. Drain design discharge is calculated at 5.7 l/s/ha.

4.4.3 Irrigation and Drainage Systems

The irrigation service will be directly attained by the Khlong Thap Ma through main canal system as shown in DWG No. 2-1.

The East Main Canal with a total length of 5.3 km will run along the left bank of the Khlong Thap Ma river and commands 1,250 ha. Its conveyance capacity will be 1.80 m^3/s at its head.

The West Main Canal will be aligned along the left bank of the Khlong Thap Ma and commands 1,150 ha. Its total length will be 11.3 km and has a conveyance capacity of 1.66 m^3/s at its head.

The irrigation area will be divided into adequate numbers of lateral and/or sub-lateral units, each of which will be further sub-divided into a number of tertiary units. The maximum command areas of the lateral and tertiary units will be limited to about 600 ha and 40 ha respectively. The total length of the lateral canal would be 17 km and 21 km for the East Area and the West Area respectively.

Systematic drainage system will be provided over the irrigation area. Excess water will be evacuated from the irrigated land principally by natural channels but many of the channels will need improvement. Artificial drains would also be constructed in some areas. The total length of drains is roughly estimated at 39 km, comprising 8 km of the natural channel improvement and 31 km of the artificial drain construction.

5. FLOOD MITIGATION PLAN

5.1. Formulation of Basic Flood Control Plan

5.1.1 Basic Principles

As explained in Section 3.5, flooding have incurred damages on agricultural product, house and housing property, public facilities and utilities, etc. It could be expected that flood hazards to life and health will increase as population expands, and intensified use and occupancy of flood plain lands will result in increased property damage from future floods.

An appropriate flood protection measure will be essential for enhancement and prosperity of economic activity, conservation of land, increase of agricultural productivity and assurance of human life and health. Such protective measure, however, should be in view of long-term perspective.

In the Rayong river basin, Dok Krai dam has been constructed and Nong Pla Lai and Khlong Yai dam schemes are being contemplated to be implemented one after another within several years. These dams will largely contribute to the reduction of flood damage along the main stem of the Rayong river. The Khlong Thap Ma dam is situated in the Khlong Thap Ma river, which joins with the Rayong river at about 3.5 km upstream from the river mouth. Although Khlong Thap Ma dam would eventually have a function of flood control, its effect will be limited to the Khlong Thap Ma river and extreme downstream reach of the Rayong river.

A basic flood control plan is elaborated as a guide in establishment of flood mitigation measure and plan of flood protection works. The plan is based on a standard project flood, which has a recurrence interval of 50 years, and deeply concerned with the basic flood control plan of the Rayong river basin, which are thoroughly explained in Sectoral Report XIII, Flood Mitigation Engineering.

5.1.2 Flood Control Alternatives

The magnitude of the river improvement works is dominated by flood regulation effect by reservoir, which varies with surcharge volume in the reservoir. The surcharge volume is dependent on discharge capacity of spillway. Thus the flood control alternatives were set up by appling the spillway width of Khlong Thap Ma dam as a parameter. Three alternatives are arbitrarily set up as shown below.

Structures	Unit	Alternatives		
		1	2	3
Khlong Thap Ma Dam				
High water level	El.m	25.7	25.7	25.7
Flood water level	EL.m	27.0	26.9	26.8
Surcharge volume	$10^6 m^3$	15.2	13.5	12.8
Spillway width	m	30.0	50.0	70.0
Dam crest	El.m	29.0	28.9	28.8
River Improvement Work				
Length	km	10.5	10.5	10.5
Earthwork	$10^3 m^3$	982	995	1,003

The high water level of Khlong Thap Ma reservoir has been determined at El. 25.7 m through the land and water resources development plan. The spillway is designed as a side-channel spillway without gate and its crest elevation is the same with the high water level. The surcharge volume and flood water level are decided by routing the 500-year inflow flood.

The requirement of the river improvement work between the proposed damsite and the confluence of the Rayong river was worked out subsequent to flood routing by reservoir and according to the flood run-off simulation model presented in Section 3.4. Preliminary design of channel improvement work is carried out based on the criteria recommended by Ministry of Construction, Japan. The quantity of earth

work, practically dike embankment indicates only slight difference among the alternatives, since flood run-offs from the sub-basins in downstream from the dam is so large compared to critical channel capacities.

The construction cost of each structure is estimated for cost comparison among the alternatives. The construction cost of Khlong Thap Ma dam attributable to flood control is presumed to correspond to dam embankment cost above the high water level and spillway cost. The estimated costs are as follows.

(Unit: ฿ 10^6)

Structures	Alternatives		
	1	2	3
Khlong Thap Ma Dam (incremental only)	132.6	131.8	138.6
River improvement work	126.4	127.1	127.5
Total	259.0	258.9	266.1

5.1.3 Proposed Basic Flood Control Plan

The construction cost of the three alternatives are almost even. The alternative 2, however, indicates the minimum cost and its total dam construction cost is also the lowest among the three. Therefore the alternative 2 is proposed as the basic flood control plan.

The Khlong Thap Ma dam retains the surcharge volume of 13.5 x $10^6 m^3$ between El. 25.7 m and El. 26.9 m. The spillway width is determined at 50 m and its crest is set at El. 25.7 m.

Fig. 26 shows the flood discharge distribution diagrams over the Rayong river basin under without and with Khlong Thap Ma dam conditions. The existing Khlong Thap Ma river channel between the damsite and the confluence of the Rayong river will be improved as smooth as possible to flow down the 50-year flood after regulating by the dam. Plan and profile of the proposed river improvement work are shown in Fig. 26.

The basic flood control plan over the Rayong river basin is expressed by condition "with Khlong Thap Ma Dam". Its layout is shown in Fig. 26.

5.2 Flood Control Effects by Dams

5.2.1 Flood Regulation by Reservoir

The Khlong Thap Ma dam retains temporarily a large quantity of flood run-off, resulting in reduction of a rate of peak discharge as shown in Fig. 19. The flood regulation effect by Khlong Thap Ma reservoir extends for a whole stretch of the Khlong Thap Ma river downstream from the damsite and main stem of the Rayong river between the confluence of the Khlong Thap Ma river and the river mouth.

The flood regulation effect by the reservoir is worked out for various probable floods by applying the simulation model. According to the results, flood frequency curves of relevant channel reach were shown in Fig. 19.

5.2.2 Flood Control Benefit by Dams

The flood control benefit due to dam was estimated for the Khlong Thap Ma river basin and Rayong river basin respectively as explained below. For the Khlong Thap Ma river basin it is measured as the difference between the annual damages under unregulated conditions of flooding and those with the reservoir in operation. As to the Rayong river basin, it is counted as the difference between the annual damages under Dok Krai, Nong Pla Lai and Khlong Yai reservoirs in operation and those with Khlong Thap Ma reservoir in operation. The flood control benefits are estimated as follows.

(Unit: ฿ 10^6)

Conditions	Rayong River		Khlong Thap Ma River		Total Benefit
	Residual Damage	Benefit	Residual Damage	Benefit	
(1) Unregulated	130.1	-	16.9	-	147.1
(2) Dok Krai + Nong Pla Lai + Khlong Yai	37.7	92.4	16.9	-	92.4
(3) Dok Krai + Nong Pla Lai + Khlong Yai + Khlong Thap Ma	32.4	5.3	2.7	14.2	19.5

The annual flood control benefit due to Khlong Thap Ma dam is assessed to be ฿ 19.5 x 10^6, which is consequently adopted in economic evaluation of the Scheme.

5.3. Economic Comparison of River Improvement Works

The river improvement plan involved in the basic flood control plan is established for a long-range objective and will be realized as a mean of final flood control resort, since existing channel capacity is excessively small compared to magnitude of flood. It, however, would be planned to be executed in a stage-wise in due consideration of flood damage severities.

Economic viabilities of the Khlong Thap Ma river and Rayong river improvement works were testified respectively for three different risk levels, namely, 10-year, 30-year and 50-year in terms of recurrence interval of flood. The construction cost was estimated based on the preliminary layout design and converted into annual equivalent cost at an assumed discount rate of 8 % per annum. The operation and maintenance cost was also estimated for each measure.

The annual benefit was estimated from the modified flood damage curves after Khlong Thap Ma and Khlong Yai dams. The estimated annual cost and benefit are as shown below.

(Unit: ₿ 10⁶)

River Improvement Works	Annual Cost	Annual Benefit	Annual Net Benefit
1. Khlong Thap Ma River			
Risk Level : 10-year	11.0	2.5	8.5
Risk Level : 30-year	11.3	2.6	8.7
Risk Level : 50-year	12.0	2.7	9.3
2. Reyong River Overall			
Risk level : 10-year	90.9	30.5	60.4
Risk level : 30-year	97.4	33.3	64.1
Risk level : 50-year	102.2	33.9	68.3

As shown in the above, the river improvement works are not economically attractive. However, it is recommendable to execute the flood protective work in some local areas, where flood hazards are serious. It would also be recommended to conduct systematic flood damage statistical survey so that economic and financial losses in the basin will be realistically clarified.

6. PRELIMINARY DESIGN

6.1 Dam and Reservoir

6.1.1 Reservoir

According to the plan formulation studies, the gross storage capacity of the reservoir is determined at 74.3 x 10^6 m^3, consisting of 4.7 x 10^6 m^3 of dead storage, 56.1 x 10^6 m^3 of active storage and 13.5 x 10^6 m^3 of surcharge. The dead storage is decided taking into account sediment deposit over 100 years. The flood water level, high water level and low water level are El. 26.9 m, El. 25.7 m and El. 16.2 m, respectively. The flood water level is determined against a 500-year probable flood. The reservoir water level rises to El. 27.5 m, when probable maximum flood should occur.

DWG No. 1-1 shows the map of reservoir area. Fig. 27 shows the area-storage curve of the reservoir.

6.1.2 Dam

Khlong Thap Ma multiple-purpose dam consists of a main dam and a saddle dam as shown in DWG No. 1-1. The saddle dam is located behind the left abutment of the main dam. DWG Nos. 1-2 and 1-3 show the plan, profile and typical section of the dams.

(1) Dam Crest Elevation

Crest elevation of dam is set at El. 28.9 m allowing 2.0 m of freeboard above the flood water level. Dam height is 20.4 m above the river bed.

(2) Geological and Geotechnical Evaluation

In order to supplement the existing data, additional geological investigation was carried out. The results of the investigation are compiled in Sectoral Report VIII, Geology.

The proposed axis of the main dam is identical with that selected by the previous study. As shown in Fig. 28, Khlong Thap Ma dam and reservoir is situated on the geological province of the pre-Cambrian schists and gneissose granites. Main damsite is featured by relatively prominent hills trending north-south direction in both abutments and by U-shaped valley buried with the terrace deposits and the recent flood plain deposits. The river valley is underlain by granitic rock in the subsurface deeper than 15 m and by overlying terrace deposits of sandy and gravelly clay. The river bed elevation is approximately EL. 8.5 m at the damsite and width of river valley is approximately 800 m at EL. 29.0 m. The geological map of the damsite is shown in Fig. 29 and geological profile along the proposed dam axis is presented in Fig. 30.

In the main damsite, the subsurface geological condition has as far been probed with fourteen bore holes. The unconsolidated deposits in the bottom of the valley, which is about 15 m thick over the bed rock, is divided into two zones; one is the recent flood plain deposit with 5 to 7 m of thickness from the ground surface and the other is the older deposit underlying the former. These deposits are dominantly composed of silty to clayey sand with occasional intercalation of clay layers. They show almost irregularly varied N-values in the standard penetration test, ranging from 2 to more than 50. The N-value shows very often less than 20 in the flood plain deposits, which is, therefore, to be removed from the dam foundation. In the other hand the majority of the N-values in the underlying older deposit is higher than 20 or over 30, while the occasionally intercalating clay layer show very low N-values. It appears, however, in the geological profile that those clay layers are not continuous, and they are deemed to form local lenticular pockets. Accordingly, the dam embankment is to be placed on the surface of the older deposit, after about 5 m deep excavation of the flood plain deposit. Whereas the unconsolidated deposits show as high permeability as in the order of 10^{-3} cm/s, the permeability in the bedrock is within a range from 10^{-4} cm/s to 10^{-5} cm/s; generally in the order of 10^{-5} cm/s.

For the case that an impervious earth cut-off trench, 4 m wide at the bottom, is required to sink to the level of the bedrock surface, the possible leakage is estimated at 6.7 l/s. This is deemed sufficiently acceptable rate.

(3) Type of Dam

Geological and topographic conditions allow to build only a fill type dam at the proposed damsite. A homogeneous earth fill type dam is selected from the viewpoint of the availability of embankment materials such as earth, rock, sand and gravel.

According to the material survey, earth borrow area is selected on the right/left abutment of the main dam. The soils are composed of terrace and colluvium deposits. Riprap and sand and gravel will be produced in Kong Tong Po sand borrow area and Ban Pak Than quarry site, which is located at about 10-20 km southeast of the proposed damsite. The Sectoral Report VIII, Geology contains the material survey.

(4) Zoning

Typical dam section is shown in DWG No. 1-3. Dam body is embanked with homogeneous earth material. An inclined chimney drainage zone with a thickness of 2.5 m is arranged in dam body. The dam foundation is excavated to 3-5 m in depth in the terrace deposits and the flood plains and to about 3 m on the left abutment. The upstream slope is surfaced with a rock riprap and downstream slope with sodding.

(5) Stability Analysis

Based on the stability analysis, the upstream and downstream slopes of dam are determined at 1:3.1 and 1:2.6 respectively. The minimum allowable safety factor is set at 1.2. The design values of materials and results of the stability analysis are shown in Fig. 31 which shows the sliding circles.

The preliminary design of dam and its appurtenant structure is attained as a part of Water Resources Engineering as presented in Sectoral Report XI.

(6) Seepage Analysis

In compliance with the recommendation in the above (2), the foundation treatment for leakage control is required as to sink an impervious earth cut-off wall to a level in weathered gneissose granite, where coefficient of permeability is within the magnitude of 10^{-5} cm/s.

The analysis of seepage through dam body and foundation was attained by applying the Finite Element Method. Detailed analysis data such as mesh of input, potential flow line, flow function, uplift pressure head and vector of flow velocity are compiled in Sectoral Report XI, Water Resources Engineering.

6.1.3 Spillway

The spillway is located on the left abutment of the main dam as shown on DWG No. 1-2.

In accordance with the design criteria of RID, a 500-year probable flood of which peak discharge is 920 m^3/s is adopted as design inflow flood. The design of spillway is made taking into account the retardation effect of the reservoir.

A side-channel spillway is selected as the most suitable type to the proposed damsite. It is shown on DWG No. 1-4. Its crest length is determined at 50 m from the viewpoint of flood mitigation plan as explained in Chapter 5. The crest elevation is set at El. 25.7 m, the same elevation as the high water level. The maximum outflow from the spillway is 140 m^3/s at flood water level El. 26.9 m. The flood regulation by the reservoir is shown in Fig. 32.

In case of occurrence of the probable maximum flood with a peak discharge of 1,540 m^3/s, the reservoir water level rises to El. 27.5m and the spillway discharges 270 m^3/s at the maximum.

The side-channel spillway is connected to chuteway with a total length of 135 m. A stilling basin is provided at the downstream end of chuteway to dissipate the excess energy of flow.

6.2 Irrigation and Drainage System

6.2.1 Intakes

The preliminaray design of the irrigation and drainage system is contained in Sectoral Report III, Irrigation Development Plan. The summary is explained herein.

The intake of west main canal is located on the side of right abutment of main dam as shown on DWG No. 1-2. The intake of east main canal is located on the side of right abutment of saddle dam as shown on DWG No. 1-3. Both intakes comprise intake tower, conduit, outlet with energy dissipator and discharge measuring device, and operation bridge.

The intake tower is equipped with a regulating gate of 1.3 m in height and 1.3 m in width. The sill elevation is set at El. 15.0 m. The conduit with a steel liner of 1.3 m in diameter is embedded deep into foundation to prevent possible piping. Its length is 100.0 m for the East Intake and 87.0 m for the West Intake.

6.2.2 Irrigation Canal and Canal Structures

The alignment of the irrigation canals and longitudinal profile of main canals are shown on DWG Nos. 2-1 and 2-3.

For design of canal, the maximum and minimum velocities are set at 1.2 m/s and 0.6 m/s respectively for concrete-lined canal and at 0.7 m/s and 0.4 m/s respectively for earth canal. The main canals are lined with 7 cm thick plain concrete for their entire reach and have a trapezoidal cross-section with side slope of 1:1.5.

The irrigation system is associated with various canal structures such as culvert, inverted siphon, drop structure, check gate, turnout, spillway, cross-drain, aqueduct and bridge. DWG No. 2-2 shows typical designs for the major canal structures.

6.2.3 Drainage Canal and Related Structures

The drainage network in the irrigation development area is shown in DWG No. 2-1. The natural streams and existing local drains are incorporated into the drainage system as much as possible.

6.2.4 Inspection Road

The inspection road is classified into main inspection road and lateral inspection road. The main inspection roads run along the main canals and have an effective width of 5 m paved with laterite. The lateral inspection roads are aligned almost along with the lateral canals and are 3 m in width.

6.3 Environmental Aspects

6.3.1 NEB Standard

Impacts of the Scheme on environmental conditions are preliminarily evaluated in the present study. The standard established by National Environmental Board (NEB standard) is applied to the evaluation.

The NEB is the responsible agency for preservation of the nation's environment and making recommendations to the Government on environmental impacts of the projects. NEB Standard was prepared in 1979 and includes evaluation standard for dam and reservoir.

6.3.2 Environmental Impact Evaluation

Four categories are presented as to be evaluated for water resources development project, as listed below.

(1) Physical resources

(2) Ecological resources

(3) Human use values

(4) Quality of life values

Each category includes more specific items to be examined.

The following table presents the result of the evaluation focused on the items considered to be related to the Khlong Thap Ma Dam Scheme.

Environmental Resources	Item	Grade	
		Dam and Reservoir	Irrigation System
Physical Resources	Water Quality	2 and (1)	(1)
	Soils	-	(2)
Ecological Resources	Fisheries	2 and (1)	1
	Fauna & Flora	(1)	2
	Forests	(1)	-
	Fertilizer & Agro Chemical	-	(1)
Human Use Value	Water Supply	3	3
	Flood Control	3	-
Quality of Life Values	Socio-economy	3	3
	Public Health	2	1
	Recreation	3	1

Grade is expressed by figures 3, 2, 1 indicating the beneficial impact of major, intermediate and minor, while figures with parentheses indicate adverse effect; (3), (2) and (1) mean major, intermediate and minor adverse effect.

According to the result, the Khlong Thap Ma Dam induces positive effect on the most items in human use value and quality of life values. The Scheme contributes to the improvement of sanitary condition, economic situation and increase of recreational opportunities of the local population either directly or indirectly through water resources development and resultant industrialization and agricultural development of the area.

Although the Scheme poses to induce a little adverse effects on several items of physical resources and ecological resources, it is expected that they will be limited to the minimum level by guaranteeing the river maintenance flow to the downstream of the river. As already explained in sub-section 2.6.2, the concept of river maintenance flow is introduced in the present study in order to minimize or avoid the adverse effect of the water resources development on such items as water quality, fauna and flora and fishery.

6.3.3 Recommendations

Environmental impacts of the Scheme is evaluated preliminarily in the present study. It is proposed that detailed study will be conducted according to the NEB standard at the implementation stage of the Scheme.

Following actions are recommended to be taken by the executive agency before the implementation of the Scheme.

(1) Detailed survey on the environmental conditions in the Scheme area.

(2) Establishment of specific counter measures against possible adverse effect

(3) Establishment of regular monitoring system on water quality, fauna and flora etc.

7. COST ESTIMATE

7.1 Investment Cost

7.1.1 Basic Conditions

The investment cost consists of the direct cost, compensation and land acquisition cost, administration cost of executive agency, engineering service, physical contingency and price contingency. It was estimated based on the 1982 price level. The followings are the basic conditions for the direct cost estimate.

(1) The currency exchange rates were assumed;
US$ 1 = Baht 23 = Japanese Yen 240

(2) All the construction works will be executed by contractors selected through international competitive bidding.

(3) Unit price of each work item included direct cost such as personnel and labour expenses, material costs and operation and depreciation costs of construction equipment. The unit price is divided into foreign currency portion and local currency portion in accordance with the following classification.

Foreign Currency Portion
- Depreciation cost of construction plant and equipment,
- Large gate.

Local Currency Portion
- Labour wages,
- Sand, gravel, timber, board,
- Fuel, oil, lubricant,
- Cement,
- Small gate, reinforcement steel bars,
- Inland transportation cost.

(4) The contractor's overhead and profit was estimated in accordance with the Government's guideline issued in July 30, 1982.

(5) Income taxes to be levied by the Government is also included in accordance with the above guideline.

(6) Import tax and duty on the equipment, plants and materials imported by contractors were not taken into account.

The compensation and relocation cost is referred to the result of the compensation survey, which was directly conducted by RID in 1982.

The administration cost of the executive agencies was assumed to be 2 % and 5 % of the direct cost for dam and irrigation respectively.

The cost of engineering services was assumed to be 10 % and 13 % of the direct cost for the dam and irrigation respectively.

The physical contingency is assumed to be 15% of the sum of the direct cost, compensation and relocation cost, administration cost of the executive agencies and cost of engineering services.

The price contingency was estimated assuming broadly a price escalation of 10% per annum for the local currency portion and of 8% per annum for the foreign currency portion.

7.1.2 Investment Cost

The investment cost estimate is presented in Table 16 and is summarized as follows:

(Unit: ฿ 10⁶)

Project Components	Foreign Currency Portion	Local Currency Portion	Total
Dam	294.5	981.5	1,276.0
Irrigation	97.0	218.4	315.4
Total	391.5	1,199.9	1,591.4

The detailed construction cost estimate of the dam and irrigation components are compiled in the Bill of Quantities attached to the report.

The above investment cost is estimated on the international competitive bid basis, based on which economic evaluation of the project is conducted. However, apart from the above, the investment costs on the basis of force account construction are estimated for dam and irrigation respectively for the purpose of reference. They are compiled in Sectoral Report XI, Water Resources Engineering and Sectoral Report III, Irrigation Development Plan, respectively.

7.2 Operation and Maintenance Cost

The operation and maintenance cost is assumed to be 0.5 % of base cost for dam and irrigation and drainage systems.

The annual operation and maintenance cost is estimated to be ฿ 2,137 x 10^3 for the dam and ฿ 688 x 10^3 for the irrigation and drainage system.

7.3 Replacement Cost

Some facilities and equipment need to be replaced periodically. Economic life and replacement cost are estimated as follows:

Facilities and Equipment	Economic Life (year)	Replacement Cost (฿103)
Irrigation and Drainage System		
Gate	25	8,440
O&M equipment	10	8,930

7.4 Implementation Schedule

The implementation schedule of the Scheme is shown in Fig. 33.

The commencement of the Scheme is assumed to be the beginning of fiscal year 1985. The construction period is scheduled as follows:

Multiple-purpose dam : 1986 to 1989
Irrigation and drainage system : 1986 to 1989

The disbursement schedule of investment cost is presented in Table 17.

7.5 Major Construction Equipment

The major construction plant and equipment required by the project component are listed as shown in Table 18.

8. BENEFIT

8.1 Agricultural Benefit

8.1.1 Agricultural Production

In the Khlong Thap Ma Scheme area, groundnuts will be introduced as second crop after rice. Agricultural production of each crop under without project and with project condition is summarized as follows.

(Unit: t/yr)

Crop	Without Project	With Project	Increment
Rice (Local)	2,120	1,760	-360
Rice (High Yielding)	1,790	12,610	10,820
Groundnuts	30	1,750	1,720
Cassava	8,160	0	-8,160
Sugarcane	5,160	0	-5,160
Vegetable	0	1,500	1,500
Fruit	300	560	260

Figures above table are the annual production at the full development stage. Build-up period is assumed to be five years.

8.1.2 Price Prospect

Economic prices of major agricultural commodities and products are estimated in terms of the international market price prospected for the year 1990 in the 1982 constant price. Prices after 1991 is assumed to be constant. International market price, which are CIF and FOB price at Bangkok or CIF price at other international port, is adjusted to farm gate price by taking into account costs for inland transportation, handling charge and processing etc.

Financial price of agriculture inputs and outputs is obtained from available data at government agencies and local offices and based on the farm survey conducted by the Study Team. Both economic and financial prices are presented in Table 19.

8.1.3. Benefit

Benefit by agricultural development is indicated in Table 20. Total incremental benefit of the Scheme is derived as the difference of total benefit between with project and without project conditions. It is estimated at ฿ 81.7 x 10^6 per annum.

8.2. Flood Control Benefit

Annual flood control benefit by the Khlong Thap Ma dam is estimated in the sub-section 5.2.2. It is ฿ 19.5 x 10^6 per annum.

9. PROJECT EVALUATION

9.1 Economic Evaluation

9.1.1 Basic Assumptions

The economic feasibility of the Scheme is evaluated by economic internal rate of return (EIRR). Further, sensitivity analysis is conducted to assess the impact of possible changes in economic conditions on the economic soundness of the Scheme.

The following assumptions are established in the evaluation.

(1) The project implementation period is 5 years from 1985 to 1989.

(2) Only direct benefit is counted in the evaluation and any indirect or intangible benefit is not taken into account.

(3) Economic price is expressed in terms of the 1982 constant price.

(4) Economic useful life of the project is assumed to be 50 years.

9.1.2 Economic Cost

Economic cost is derived by subtracting transfer payment from the financial cost. Transfer payment includes tax, compensation and relocation cost and price escalation. In addition, 15 % of local currency portion is deducted as transfer payment.

Production foregone is estimated at ₱ 3.1 x 10^6 per annum based on the net production value of crops in the reservoir area. It is extracted from the net incremental benefit.

Disbursement schedule of Economic cost of dam and irrigation facilities is presented in Table 21 and summarized below:

(Unit: ฿ 10⁶)

	F.C.	L.C.	Total
Dam	205.0	281.5	486.5
Irrigation Facilities	67.4	105.0	172.4
Total	272.4	386.5	658.9

9.1.3 Benefit-Cost Stream

Based on the implementation plan and estimated annual benefit, benefit-cost stream of the Khlong Thap Ma Dam and Irrigation Scheme is established as shown in Table 22.

9.1.4 Economic Internal Rate of Return (EIRR)

EIRR is computed based on the benefit-cost stream for the following cases.

(Unit : %)

Condition	EIRR
(1) Standard	12.1
(2) 10 % of Cost Increase	11.1
(3) 10 % of Benefit Decrease	11.0
(4) (2) + (3)	10.0
(5) Delay in Construction for 2 years	10.1

EIRR is found to be 12.1 % for the standard condition indicating the high economic soundness of the project.

9.2 Financial Evaluation

9.2.1 Cost Allocation

Investment cost and O & M cost of the Khlong Thap Ma dam are allocated to irrigation component and flood control component, in order to clarify the size of investment cost to be borne by each related agency.

Investment cost is allocated by "Separable Cost - Remainig Benefit Method". The investment cost by project component is summarized as follows.

(Unit: ฿ 10^6)

Component	Foreign Currency Portion	Local Currency Portion	Total
Irrigation	326.6	983.9	1,310.5
Flood Control	64.9	216.0	280.9
Total	391.5	1,199.9	1,591.4

Allocated cost for flood control will be borne by the Government subsity.

9.2.2 Financial Evaluation of Irrigation System Development

Investment cost for irrigation system development is financed faced on the following asumptions.

a. Foreign currency portion of the investment cost is financed through international loan with an annual interest rete of 3.5 % and with a term of 30 years including 10 years of grace period.

b. Local currency portion is borne by the Government.

Disbursement schedule of allocated investment cost is presented in Table 23.

Operation and maintenance cost is estimated to be ฿ 2.3 x 10^6 per annum. Replacement cost is same as those presented in Section 7.3.

Recovery of investment cost, O & M cost and replacement cost is planned under the conditions.

a. Operation and maintenance cost is recovered by water tariff collected from beneficiaries.

b. Investment cost and replacement cost is borne by the Government.

Cash flow statement is presented in Table 24.

9.2.3 Farm Budget Analysis

Farm budget analysis is conducted to assess the impact of the Scheme on the economy of farm household. Farm household which owns gross land area of 2.0 ha and 4.5 ha are taken up typical farms in the area.

Annual income and outgo under the with project and without project conditions are estimated as below.

(Unit: ฿/yr)

Size of Household	Without Project			With Project			Increment of Reserve
	Income	Outgo	Reserve	Income	Outgo	Reserve	
1.8 ha	21,140	21,140	0	43,690	36,490	7,200	7,200
4.5 ha	37,930	30,260	7,670	108,550	60,150	48,400	40,730

With the implementation of the Scheme, farmer's income is expected to grow remarkably. It is considerd that the farmers will have enough capacity to pay for the water tariff induced on irrigation water use. Water tariff is broadly estimated to be ฿ 960/ha per annum which is equivalent to the annual O&M cost.

10. ORGANIZATION AND MANAGEMENT

10.1 Related Organizations

The water administration in Thailand is directed by the Water Resources Committee although several ministries, government agencies and autonomous institutions have responsibilities and interest in water resources development and conservation.

The RID is engaged in water resources development relevant to agricultural land development. The organization chart of RID is shown in Fig. 34. The RID has 11 Regional Offices. Each regional office assumes a responsibility for construction, operation and maintenance of water resources, irrigation and drainage facilities in its administrative area. The Khlong Thap Ma river basin is within a territorial area of Regional Office No. IX (Region IX).

The proposed development activities are deeply concerned with the Eastern Seaboard Development. The Eastern Seaboard Development Committee (the Committee) is chaired by the Prime Minister and is empowered to rule on behalf of the Cabinet. Fig. 35 shows the organization chart of the Committee. The function of the Committee is the overall control of the development programme related to policy issues.

The NESDB is a part of the Office of the Prime Minister responsible for advising on the economic and social development of Thailand. The Center for the Integrated Plan of Operation is a technical division within NESDB and is the Secretariat Office of the Committee. The CIPO assumes responsibility for preparing the details of the development operation as well as coordinating and monitoring the implementation programmes of all government agencies concerned.

10.2 Executive Agency

The RID will be responsible for the implementation as well as the operation and maintenance of the Scheme. In practice, the Region IX will undertake the operation and maintenance task, since dam and

irrigation area are located within the administrative area of the Region IX. The project manager will be appointed by RID and he will take the whole responsibility to the RID for the proper implementation of the Scheme.