The natural trees, prevailing in the paddy fields in the study area, are mostly the same species as found in the reserved forest such as Teng (Shorea obtusa), Rang (Shorea siamensis), Plaung (Dipterocarpus tuberculatus) and so on. The farmers use these trees for shading or further use including construction, fuelwood source, or using leaves for roofing and wrapping food, and so on. Based on the available aerial photos, the density of trees in the field are ranging from 124-1191 trees/sq.km with average of 570 trees/sq.km.

The demand for fuelwood in the study area of more than 30,000 inhabitants is quite high. Although electricity supply is extending to these rural areas, the demand for fuelwood has not decreased whatsoever. Fuelwood is more important than charcoal in terms of quality, simply because it is more readily available. Basing on the survey conducted by Planning Division of Royal Forest Department in 1983, fuelwood-using households (98.2% of total households) in the rural area can be classified into three categories i.e.: those using only fuelwood (50.2%), those using only charcoal (30.9%) and those using both fuelwood and charcoal (18.9%). The average consumption per household are about 9.6 cu.m/household for fuelwood. The demand for fuelwood in this area is about 24,000 cu.m/annum. Disregarding the Eucalyptus plantation, the total supply of wood in this area is about 15,400 cu.m. It can be seen that the demand for fuelwood in this area exceeds over the supply almost 1.5 times. However, within the study area there are additional source of energy like gas fuel and electricity, in which they are replacing the traditional fuelwood at the present.

3-3-8 Farm Economy

In Thailand, contrary to the buoyancy in recent economic developments, farm economy could not share this trend of economic growth as in other sectors as notified in 2-1 "National Economy". The Northeast mainly depends mainly upon agriculture of rainfed rice cultivation and has been so far regarded as the most depressed area in the whole country due to its regional share in the total GDP at the rate of 1/5 only.

The region is made up by basins of three rivers, Mekong, Chi and Mun, covering 18 changwats which agricultural situation on farm size, farm income and expenditure are shown in APPENDIX I.

The major cause of low farm incomes in the Northeast as well as the study area is in the mainly rainfed rice cultivation which most local inhabitants practice for producing this staple crop as food for self-consumption and capital in case of surplus. This is the main activity

considered in their farm economy. Due to lack of water, half of paddy fields in the study area have been reportedly uncultivated every year.

Based on these conditions, the production of rice in the study area is estimated at approximately 8,000 ton for Amphoe Phra Yun. From these figures, even with condition of production from half of paddy fields, the production of rice for self-consumption is considered more or less sufficient as now.

For off-farm activities, only some small-typed rural industries such as manufactures of plastic sunshades in Ban Non Bo and dress-making in villages of Amphoe Muang are operated.

FIGURE 3-8 AGRICULTURAL INCOME DISTRIBUTION

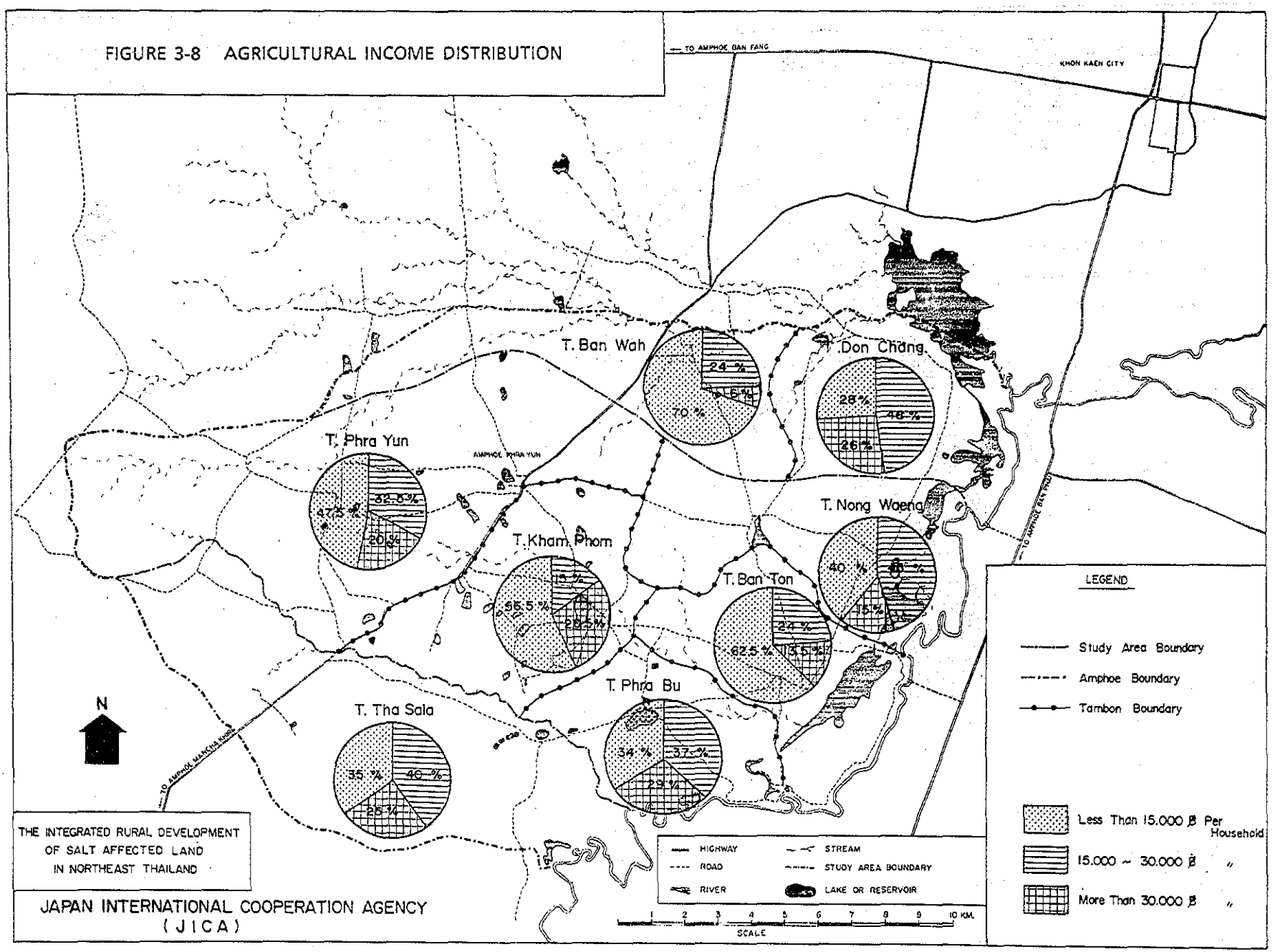
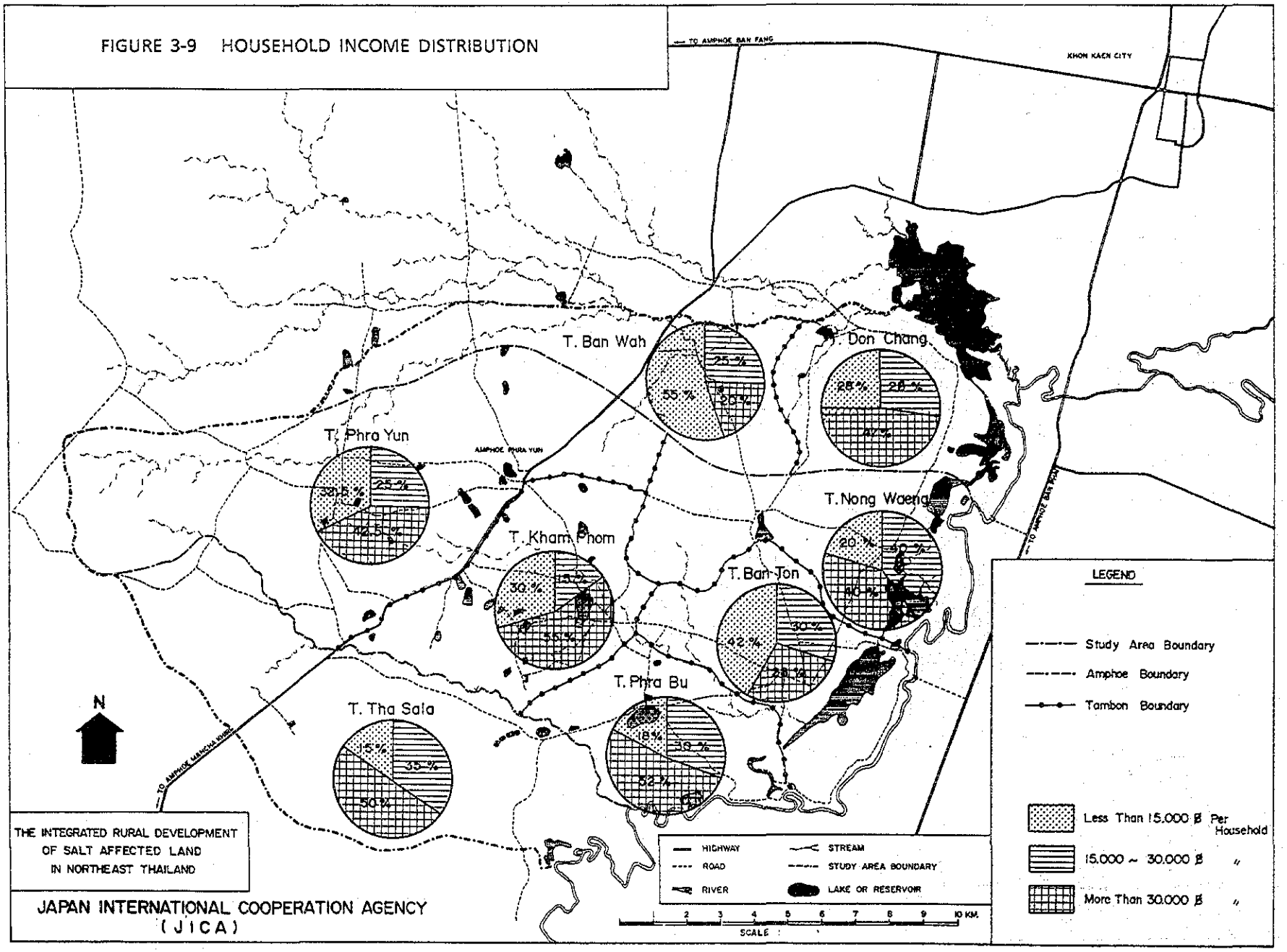


FIGURE 3-9 HOUSEHOLD INCOME DISTRIBUTION



3-4 Agricultural and Rural Infrastructure

3-4-1 Irrigation and Drainage

(1) Present Conditions of Irrigation and Water Resources

Present conditions of irrigation and water resources in the study area are as follows:

- Rainfall concentrates from May to October.
- Long dry spells are recorded even during the rainy season.
- Groundwater contains high salinity which is not available for irrigation.
- There exists no dam site in three basins.
- There are several natural swamps along the Chi river and many storage ponds locally called "Nong".
- Paddy fields located in the high land are only planted once per several years due to shortage of water for land preparation.

Sri Pimon Water User's Group, which was established by beneficiaries of Bang Dong Klang Pumping Station is the only Water User's Group in the study area. Other irrigation facilities are managed by village committees.

(2) Irrigation and Drainage Facilities

1) Irrigation Facilities of Small Scale Irrigation Project (SSIP)

There are six SSIP by RID in the study area. In four projects ponds were constructed with total storage capacity of 204,000 cu.m. The purposes of these projects are not only for irrigation but for domestic, livestock and fishery uses. The total irrigation area was planned to be 200 ha. (refer to APPENDIX F Table F-6).

There are 12 SSIP which are presently being under constructed and designed by RID in the study area of which five construct ponds to be with total storage capacity of 362,000 cu.m.

2) Existing Pumping Stations

There exist four pumping stations in Chi river and swamps, three of which were constructed by NEA and one by the Department of Cooperative and Promotion. Each station has two sets of pump with 400 mm diameter. The outline of these stations is shown below.

- Ban Non Chard Station
  Water resource : Chi river
  Beneficiary area : 105 ha
  Constructed by : NEA

- Ban Pa Leuam Station
  Water resource : Kang Nam Taon (swamp)
  Beneficiary area : 153 ha
  Constructed by : NEA

- Ban Don Klang Station
  Water resource : Nong Kod Khok (swamp)
  Beneficiary area : 0 ha (under repairs)
  Constructed by : NEA

- Ban Don Klang Station
  Water resource : Chi river
  Beneficiary area : 305 ha
  Constructed by : Department Cooperative and Promotion

3) Other Irrigation Facilities

Irrigation Facilities mentioned above and other irrigation facilities in the study area are shown in APPENDIX Figure F-6.

(3) Drainage Condition

In the study area, three rivers namely Huai Yai, Huai Yang and Huai Phra Nao flow generally eastwards and empty into the Chi River. The river gradients are steep, averaging about 1:500. The drainage of the study area is carried out mostly by these three rivers. Drainage facilities are not provided because there are no floodings and inundation problems in the study area.

3-4-2 Rural Road

The road network in the study area consists of the provincial highway No.2062 traversing the middle and five ARD roads surrounding this area, No.11011 and 11025 in the west, No.11039 and 12094 in the north-east, and No.1104 in the south. Besides, rural roads linking villages in the study area connect to the provincial highway or to these ARD roads.

Two bridges are under construction over the Chi river which flows from south to north, forming the border of the study area in the east. These bridges are located near the national highway No.2. The southern bridge is constructed by ARD for linking the national highway No.2 to

Ban Phra Yun and Amphoe Ban Fang on the national highway No.12 via. two main rural roads, Ban Ton-Muban Phra Yun and Ban Phra Yun-Ban Hua Bung in Amphoe Ban Fang. These two main rural roads are narrow, zigzag, and flooding at several places during the rainy season. In addition, three small bridges on the rural roads from Ban Phra Yun to Ban Hua Bung are interruptedly damaged.

On the other hand, the northern bridge constructed by the Highway Department has no connecting road to the ARD road No.11039 in the study area.

Rural roads in the study area are generally narrow in the village areas. As these roads are unpaved or partly sediment paved with small embankment height, inhabitants are suffering from heavy dust by passing vehicles during the dry season and muddy surface during the rainy season.

3-4-3 Communication, Rural Electrification, Water Supply and Sanitation

(1) Communication

Amphoe-office and police-office located in Ban Phra Yun have installations for radio-communication with the central and related Tambons. Most Bans have announcement-installations for important notices to villagers. At Ban Phra Yun, the telephone service is available at post office.

(2) Rural Electrification

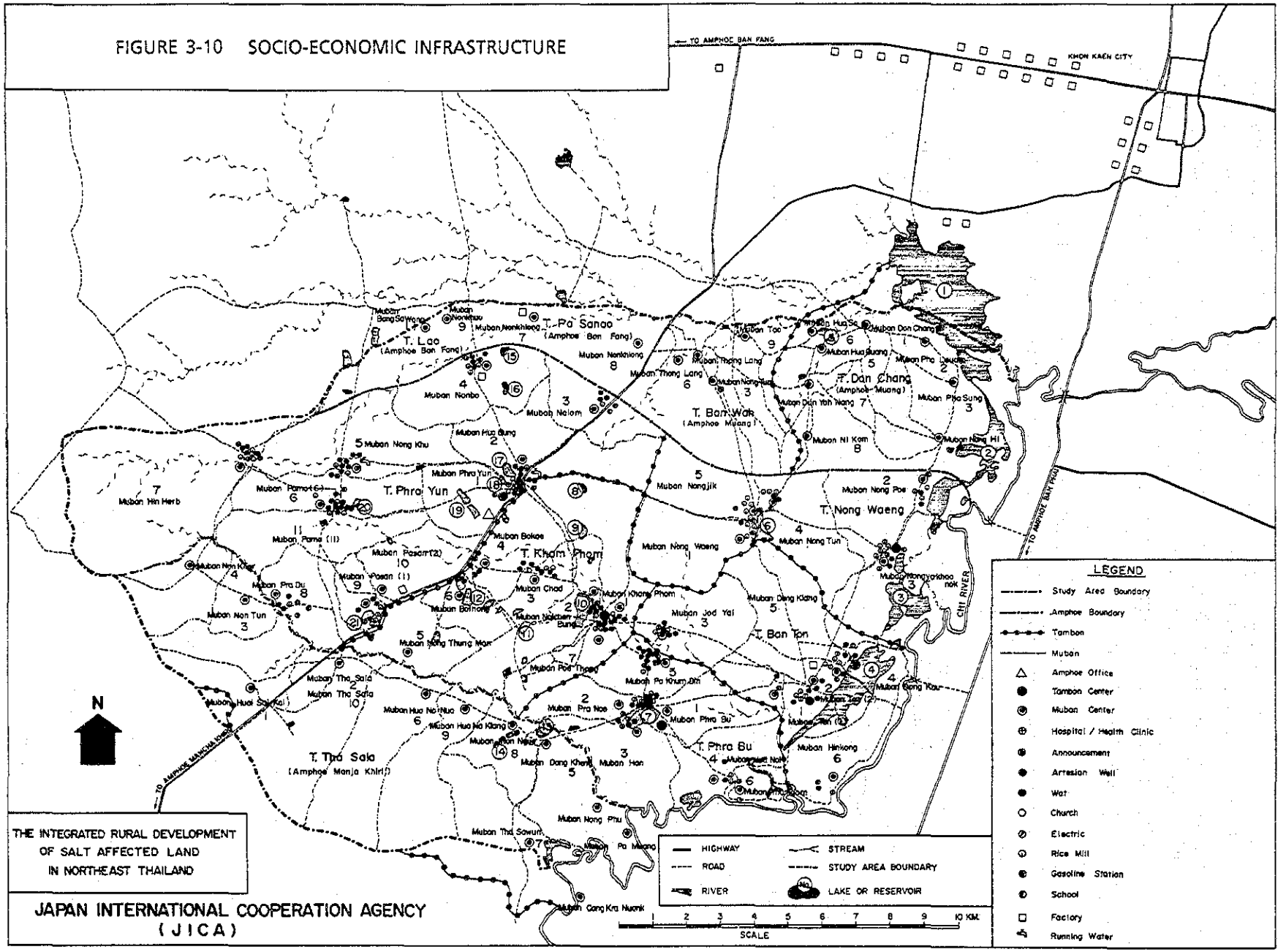
The electricity is supplied to all parts of the study area along the road network. Most of households in the study area are electrified. Rural roads, however, have no lighting. Expenditure for electricity is 100 ~ 200 Baht per month per household. Use is for lighting purpose only. (Supply Voltage: 220 volts)

(3) Water Supply

Regarding water supply for domestic use in the study area, a solar-pump system of groundwater is provided at Nong Bua for supplying running water to Muban Phra Yun at two km distance. The water quality, however, is not preferable by local people. They collect rain water in ceramic/concrete tanks for drinking and water from nearby shallow wells for other purposes.

Normally, each household possesses one to two jars for collecting rain water. They bought these ready-made jars of approx. 2000-ℓ volume

FIGURE 3-10 SOCIO-ECONOMIC INFRASTRUCTURE



THE INTEGRATED RURAL DEVELOPMENT OF SALT AFFECTED LAND IN NORTHEAST THAILAND

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

by credit from the rural development fund supplied to Amphoe.

In some villages in the east side of the study area, concrete tanks of approx. 40,000ℓ-volume were built under Australian-Thai King project for collecting rain/well water for piping supply to a four to five house-unit. Group-maintenance is a problem at now.

(4) Sanitation

A proper sewage-system is not existing in villages. Septic tanks are applied in some places, Amphoe-office, schools, hospital and rich habitation only.

In many villages of the study area, especially in Amphoe Muang where dwelling agglomerations are densely, open sewerage canals are constructed along road-sides, causing a concerned sanitation-problem. This problem would be solved by constructing family-type septic tanks instead of open sewerage.

3-4-4 Health-Care and Education

(1) Health Care

Concerning health-care institutions, a central hospital in Ban Phra Yun and a health-clinic in each Tambon are set up.

The central 10-bed hospital in Ban Phra Yun is a newly built RC building. It has been staffed by two doctors and a staff of 34 nurses and officials. Apart from this central hospital, health-centers and clinics are observed in almost parts of the study area.

(2) Education

Primary schools (Level 1-6) are found in every Tambon in the study area.

There are two secondary schools (Level 1-6) in Amphoe Phra Yun. Phra Yun Wittayakan School in Tambon Phra Yun (19 teachers and 331 students) and Pracharat Vittayasarn School in Tambon Ban Ton. (33 teachers and 351 students)

Concerning education institutions, there happens the gradual decrease of student numbers due to decrease of young inhabitants.

3-4-5 Rural Industry

Some small-scaled rural industries are intensively practiced such as the production of plastic sunshades in Ban Non Bo, the production of plastic mats in Ban Ton and Ban Kham Pom. Besides, the production of "Madmee" (a kind of Thai traditional silk cloth) is made in Amphoe Chon Na Bot near the study area. These small-scaled rural industries contribute a proper measure for generating rural incomes in these rural areas although existing for some specific villages only and having problem in lack of a sufficient supporting system.

In the study area, the cultivation of mulberry for producing cocoon to be used as material for fiber for making "Madmee", is considered proper in saline soils at some degree and lack of abundant water. Presently approximately 5,000 rai of mulberry have been practiced successfully in upland soils of Amphoe Phra Yun. Larger scales of plantation are envisaged with new varieties tolerant to saline soils. The production of "Madmee" in the study area is very prospectful in the aspect of solving idle labour-problem and value added for farm economy.

Food processing of agricultural products, especially meat, fish and fruit is a potential agro-industry also.

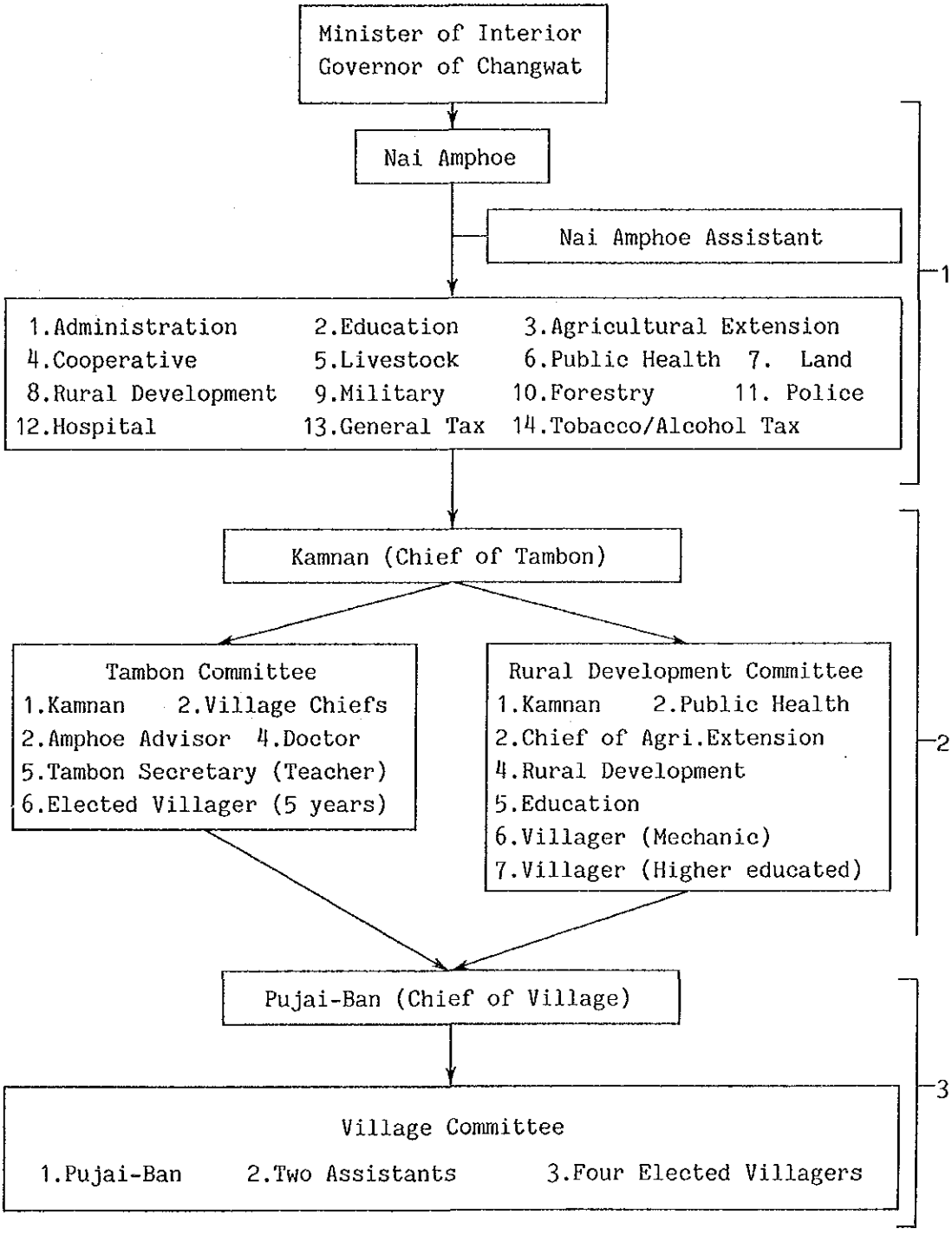
3-4-6 Local Government Organization and Community

A local government system which deals with local administration in the study area. (see FIGURE 3-11) As titles of the members of Tambon organization suggest, development scheme at Tambon level is rather limited, with special reference to rural small scale economic development. However, at Amphoe level, although participating officers with various professional backgrounds reflect characteristics of the rural society, there is a lack of the members for commerce and industry. It reflects the level of economic development achieved in the area to date.

In view of the above, there should be a major reorganization of the government board for development, if the commerce and industry development was potentially found. It is also important to consider beforehand that, if possible, how private sector can participate to the establishment of commerce and industry in the study area.

The village level organization too, should be subject to reorganization in order to reflect thoughts and desires of the people more than what has been done in the past. Moreover, it is imperative to consider participation of woman to the organization since woman labor is equally important within the society.

Figure 3-11 Local Government Organization



Note: 1 Amphoe Level Organization
2 Tambon Level Organization
3 Village Level Organization

CHAPTER 4. DEVELOPMENT PLAN

4-1 Development Concept

4-1-1 Objectives

The Northeast Thailand covering the study area is characterized with low agricultural productivity due to irregular rainfall in wet season, lack of fertile soil and existence of salt-affected land. As a result, farm income in the area is very low compared with other rural and urban areas. In order to relief the hardship of the people in the area, the Thai Government launched the Green Northeast programme in 1988 to develop the region in appropriate ways.

Under such situation, objectives of development in this Master Plan are as follows:

1) To increase income and employment.

2) To conserve and improve natural resources and the environment.

3) To raise the quality of life of the people.

4-1-2 Development Constraints

The study area includes the following constraints for attaining objectives of development:

1) Low return into cash incomes based on rain-fed paddy production.

2) Limitation of available water resources for agricultural use due to erratic rainfall pattern, small scale watershed areas and saline groundwater.

3) Wide distribution of problem soils such as sandy soils and skeletal soils as well as salt-affected soils.

4) Lack of drainage facilities to mitigate soil salinity through artificial or natural leaching.

5) Deficiency of supporting systems for agriculture and rural industries such as cooperatives, distribution system, financial arrangement and technical training.

6) Devastation of the forest and wood shortage due to expanding population and their needs for cultivable lands and for fuelwood.

4-1-3 Development Strategy

The following development strategy is established in order to achieve objectives of development:

1) To provide the land use plan, aiming at promotion of diversified agriculture, enrichment of vegetation to mitigate salt affection in the area and keeping balance of development and environmental conservation.

2) To manage available water resources in the study area properly by provision of irrigation and drainage facilities in order to improve salt-affected land by supplying fresh water for leaching and irrigation in rainy and dry seasons.

3) To undertake overall measures to salinity mitigation of salt-affected soils and to soil conservation to soil erosion and nutrient depletion in order to increase agricultural productivity.

4) To stabilize and diversify agriculture and increase land utility by introduction of agroforestry, sericulture, intensive farming, inland fishery, livestock farming.

5) To strength agricultural supporting services including finance, technique, cooperative and technical training.

6) To promote reforestation for tacking the problem of wood shortage as well as environmental conservation.

7) To improve rural infrastructures, to support economic activities and to make a more communicative society in the area by providing rural road, water supply facilities, markets and recreational facilities.

8) To demonstrate the technical, economic and social feasibility of selected agricultural systems in the salt-affected lands through implementation of the Pilot Area selected in the study.

4-1-4 Related Development Programmes

Among a number of development programmes and projects which are scheduled to be undertaken within the study area, the followings are directly related to the measures to be taken within the frame work of the present study.

(1) The Six National Economic and Social Development Plan

In the Six National Economic and Social Development Plan, rural development programme mentioned in 2-2 "Government's Rural Development Policies" is important to support the overall objectives of development covering economic expansion, income distribution social services development and improvement of the quality of life.

(2) Green E-Sarn Five Year Plan

The Green E-Sarn Five Year Plan is the first and most important step towards achieving the longer term objectives for the Northeast region. The Northeast has few natural advantages over other regions of Thailand in terms of potential productivity and therefore it will be essential for the Government to lend its support through preferential incentives to use appropriate land and water resources.

The objectives and strategy of this Master Plan Study have to require the strong link with the Green E-Sarn Plan.

(3) Khon Kaen Water Supply System, PWA

For Khon Kaen water supply system, whose Phase II Work is scheduled to complete by the year 2005, Kut Kwang intake supplies 7,680 cu.m per day of fresh water. Present water way from Bung Kaeng Nam Tom to Lam Chi will be channelized and that the quality of water should meet the national standard. (see APPENDIX J Figure J-2.)

If accumulated salt in the soil within the study area was washed out by means of hydraulic method, the Huai Yai and Huai Yang water is finally released to Lam Chi through Bung Kaeng Nam Tom. The increase of salinity in Bung Kaen Nam Tom is expected in conjunction with measures for soil improvement expected to undertake within the frame work of the present study. However, this increase would be minimal because of the relatively large body of water at Bung Kaen Nam Tom which could dilute saline water. Further, salt water from Huai Yang passes through a number of marshes, in which a layer of salt water is formed at the bottom while the upper layer becomes fresh water. Thus the water quality in Bung Kaen Nam Tom will be considerably good. If desired, it is advisable that the water intake should be also designed to collect surface water.

(4) Mahasarakam Diversion Weir, NEA

NEA plans to provide a large scale irrigation scheme covering the upper and middle reaches of the Lam Chi River and eastern parts of the

study area.

Water from Nam Phong and, in the near future, water from Lam Pao is impounded into Lam Chi at Mahasarakam Diversion Weir approximately at 2 km downstream from the junction of Nam Phong and Lam Chi. The Mahasarakam Diversion Weir is scheduled to complete in May 1991. After completion, water level in the upstream of the weir is raised to 148 MSL and the tail of back-water reaches as far as Ban Chi Kok Kho which is located far away beyond the south of study area. (see APPENDIX J Figures J-3,4)

The impounded water is then led to one of the swamps in the study area for pumping, Bung Kaeng Nam Tom is the most suitable location for this purpose. The water is then lifted up to 180 MSL near Ban Phra Yung through a pipe by gravity to line where an open canal is constructed for irrigation on the left bank area of Lam Chi.

According to RID's criteria on water quality for irrigation, EC value of less than 250 micromhos/cm should be maintained for irrigation. In the case of water with the value of up to 750 micromhos/cm, it may be allowed to use if good drainage systems are available and leaching is conducted timely in the farmland.

The impounded water in Lam Chi dilutes the saline water drained from the study area, expected to maintain the required level of salinity proper for irrigation.

4-2 Land Use Plan

4-2-1 Basic Concept

Considering that the master plan should be a model of rural development under the natural and social conditions of the salt-affected area in the Northeast Thailand, the land use plan in the study area was formulated aiming at the following objectives;

- To alleviate the poverty and raise up the living standard of inhabitants, by introducing the new land use system with crop diversification for more profitable farm management including, livestock, sericulture and horticulture.

- To apply the appropriate technology and to promote the optimal-scaled development for self-reliable agriculture, by introducing the low-input agriculture by use of self-supplied materials such as green manure, animal manure and nitrogen-fixing plants (leguminous crops) etc.

- To proceed the sustainable development with environmental soundness, by introducing the overall land use system combined with soil and water conservation measures including reforestation and agroforestry for prevention land from soil deterioration, that is, salt accumulation and soil erosion.

- To equalize all the inhabitants and not to cause damages on others, by halting the deforestation on hills surrounding the potentially salt-affected land.

- To proceed the development attracting rural women and youth, by creating the employment opportunities through promoting sericulture and constructing the agricultural processing/marketing center, a training center and the sports/recreation facilities.

- To consistent with the national long term development policy such as "Green Northeast Programme", by combining reforestation, construction of irrigation and water supply facilities.

Furthermore, the following points were considered in the course of land use planning.

(1) Use of Salt-Affected Land in Low Terrace

In the lowland, the paddy fields will be used more intensively to assure the self-supply of glutinous rice, the staple food of the

inhabitants, even though reducing the area of paddy fields. In the salt-affected land, in principle, the existing paddy fields will be used as it is after undertaking necessary measures, because the paddy field is one of the best method to control soil salinity by flooding.

Severely salt-affected land will not be used for cropping but used for alternative purposes. Prevention of salt diffusion to the surroundings should be taken into consideration. The severely salt-affected land in Ban Non Bo, Ban Bo Kae, Ban Thung Mon and Ban Pa San will be used for cattle grazing on salt-tolerant pasture such as Atriplex repens with shading trees such as Tamarix gallica, Casuarina equisetifolia and Prosopis juliflora etc. Also, sports and recreation area for inhabitants will be allocated on these land. For Ban Phra Yun, which is located at the central portion of the study area as well as of Amphoe Phra Yun, the salt-affected land will be allocated to the construction site of a processing and marketing center of agricultural products including livestock and sericulture and a technical training center. In order to prevent the land from salt diffusion, the land will be surrounded by green belt of salt-tolerant trees, namely Casuarina spp and Eucalyptus spp. etc. to lower the saline groundwater table.

Moderately or slightly salt-affected land will be used for paddy fields after drainage improvement to enhance leaching salts by rainfalls as well as application of soil amendments such as gypsum etc. to neutralize soil sodicity. Furthermore, the soil should be improved by cultivation practices such as land leveling, mulching, organic matter application and deep plowing etc.

The land where irrigation water is available, cash crops and vegetables such as tomatoes, asparagus and chilli will be planted under irrigation during the dry seasons as second crop in addition to rice under supplementary irrigation during the rainy seasons.

(2) Introduction of Agroforestry to Middle to High Terrace

The deciduous dipterocarp forests have been cleared for expansion of cropland to food supply, for fuelwood supply and for timber or pulp wood supply under population pressure during the past decades. Reforestation including multi-purpose tree and bamboo is essential because the necessary energy for inhabitants is entirely dependent on fuelwood or charcoal.

In the hills surrounding salt-affected and potentially salt-affected areas, reforestation by Acacia auriculiformis, Casuarina spp. and Eucalyptus spp. etc. will be considered to lower the groundwater table as a preventive measures against expansion of salt-affected land in

lowland. Considering the profitability of inhabitants, agroforestry will be widely introduced.

In cassava fields on hillside, soil deterioration such as soil erosion and nutrient depletion occur. Accordingly, agroforestry will be introduced on these sloping land to conserve the soil from erosion by cover cropping, to supply the plant nutrients to soil, and to prevent the land from flush flood after strong rain. In particular, leguminous trees such as Leucaena leucocephala and Sesbania aculeata will be introduced in order to maintain the soil fertility. The land presently used for rain-fed paddy where frequently lies fallow due to lack of rainfall will be converted to upland field for introducing agroforestry system.

The agroforestry system to be introduced in the study area are classified into the following 4 types, after referring the experimental results obtained from the Phu Wiang Watershed Project (RFD/FAO) which is located near the study area.

Tree + Fruits
Tree + Mulberry
Tree + Cash crops
Tree + Pasture

a. (Tree + Fruits) will be allocated as the expansion of home garden at the surroundings of villages for convenient intensive management and use of reservoir water when seedling and when drought and fruits trees such as mango, jackfruits, cashewnuts, sweet tamarindo (Tamarindus indica) will be grown mainly for local consumption.
b. (Tree + Mulberry) will be allocated to the places having a good access due to farm works. To create the employment opportunity for rural women, sericulture, that is, a speciality in this region will be promoted and a training facilities of "Madmee", traditional silk cloth will be constructed nearby the Amphoe Office. The area of mulberry farm will be determined to meet the anticipated demand for the projected number of sericulture farmers and silkworm rearing plan in the study area.
c. The region is one of supplying area of cattle to other region in the country, however, existing grassland is extremely limited. At present, rice straw and crop residue are used as fodder, however, fodder supply during the dry season is serious problem to livestock production. Accordingly, (Tree + Pasture) will be introduced in the entire study area for promotion of livestock production centering Ban Nong Waeng. Forest grazing will be introduced with planting fodder trees such as Leucaena

leucocephala and mixed pasture consisting of grasses (Bachiaria ruziziensis) and legume (Stylosanthes hamata). The extents of pasture will be determined to meet the demand of the projected heads of cattle and carrying capacity of pasture.

d. In the present cassava field, multi-purpose trees will be planted as green manure such as Leucaena spp. and Sesbania spp for soil conservation and soil fertility management and cash crops such as cassava will be intercropped (Tree + Cash Crop). In particular, steep slope is unsuitable for forest grazing, accordingly; hedge-row intercropping system of cash crops will be introduced. In this system, shading of tree canopy will be problem when trees grow. Therefore, the 5-year rotation, namely, 2-year (Tree-Cash Crops) and 3-year (Tree-Pasture) will be proposed based on 5 - 10 year tree growing period. In other word, cash crops will be inter-cropped during the first 2 years when tree canopy is still small, afterwards, ruzi and hamata will be sown and cattle grazing is undertaken for 3 years.

Reforestation programme undertaking in the forest reserve area at the southern periphery of the study area will be continuously promoted. Along the trunk roads (national and rural) and surrounding the reservoir ponds, furthermore, multi-purpose trees such as Tamarindus indica will be planted for community benefits.

Figure 4-1 shows the relationship between landform and proposed land use schematically.

4-2-2 Proposed Land Use

Based on the soil map, salt-affected area distribution map, and present land use map, a land use plan for the study area was formulated. Figure 4-2 shows the land use plan map, and Table 4-1 gives the area of each land use category.

As a model of rural development on salt-affected land in the Northeast, the proposed land use for the study area has a characteristics of introduction of agroforestry system to upland area which encloses the salt-affected and/or potentially salt-affected land in lowland area. Thus, the salt-affected land will be ameliorated through drainage improvement for promoting the natural leaching by rainfall (short-term countermeasure) as well as reforestation of adjacent hills to lower the shallow saline groundwater table which causes salt accumulation in lowland (long-term preventive countermeasure).

Finally, the land use plan was formulated to achieve the stable supply of rice, namely staple food of inhabitants, to increase farmers' income through sericulture and livestock promotion, and to create employment opportunities for rural women and youth through establishment of silk and agricultural products processing/marketing facilities as well as technical training facilities.

(1) Paddy Field

Farmers continuously want to produce glutinuous rice, and paddy fields will occupy throughout lowland area of 13,030ha or 38.2% of total study area. The irrigated area will expand from 560 ha to 3,720 ha through extension of irrigated area by pumping up from the natural swamps at eastern periphery as well as the construction of irrigation facilities at three rivers flowing into the study area. For the rain-fed paddy fields, construction of tall, tough border will be effective to prevent the field from saline runoff water intrusion and sedimentation. The present paddy fields in the upstream of rivers, and on the land covered with Ubon Series (Aquic Dystropepts) where the suitability for paddy is less, will be converted to upland crop fields under agroforestry system for crop diversification.

(2) Pasture on Salt-Affected Land

Severely salt-affected area will be mainly used for cattle grazing with salt-tolerant pasture such as Atriplex spp., which covers 390ha.

(3) Agroforestry

Cassava fields on the hills surrounding salt-affected areas will be transformed to agroforestry system after planting multi-purpose trees. Agroforestry consisting of forest and cash crops intercropping, fruit tree planting by the people for their own use, forest grazing of cattle, and sericulture will be allocated to 15,830 ha or 46.4% of the study area to control soil erosion and to prevent the adjacent lowland from salinity.

Out of this, (Tree + Fruits) system occupies 1,320ha and (Tree + Cash Crop) system occupies 5,400ha. (Tree + Muberry) and (Tree + Pasture) systems were from the projected silkworm rearing capacity and cattle carrying capacity within the study areas, and allocated as 1,690ha and 7,420ha, respectively. (Tree + Pasture) system will be distributed throughout the study area centering Ban Nong Waeng.

Pure forest will be limited in the forest reserve area in the southern periphery of the study area (Amphoe Mancha Khiri). Most of

FIGURE 4-1 LAND USE PLAN BY LANDFORM

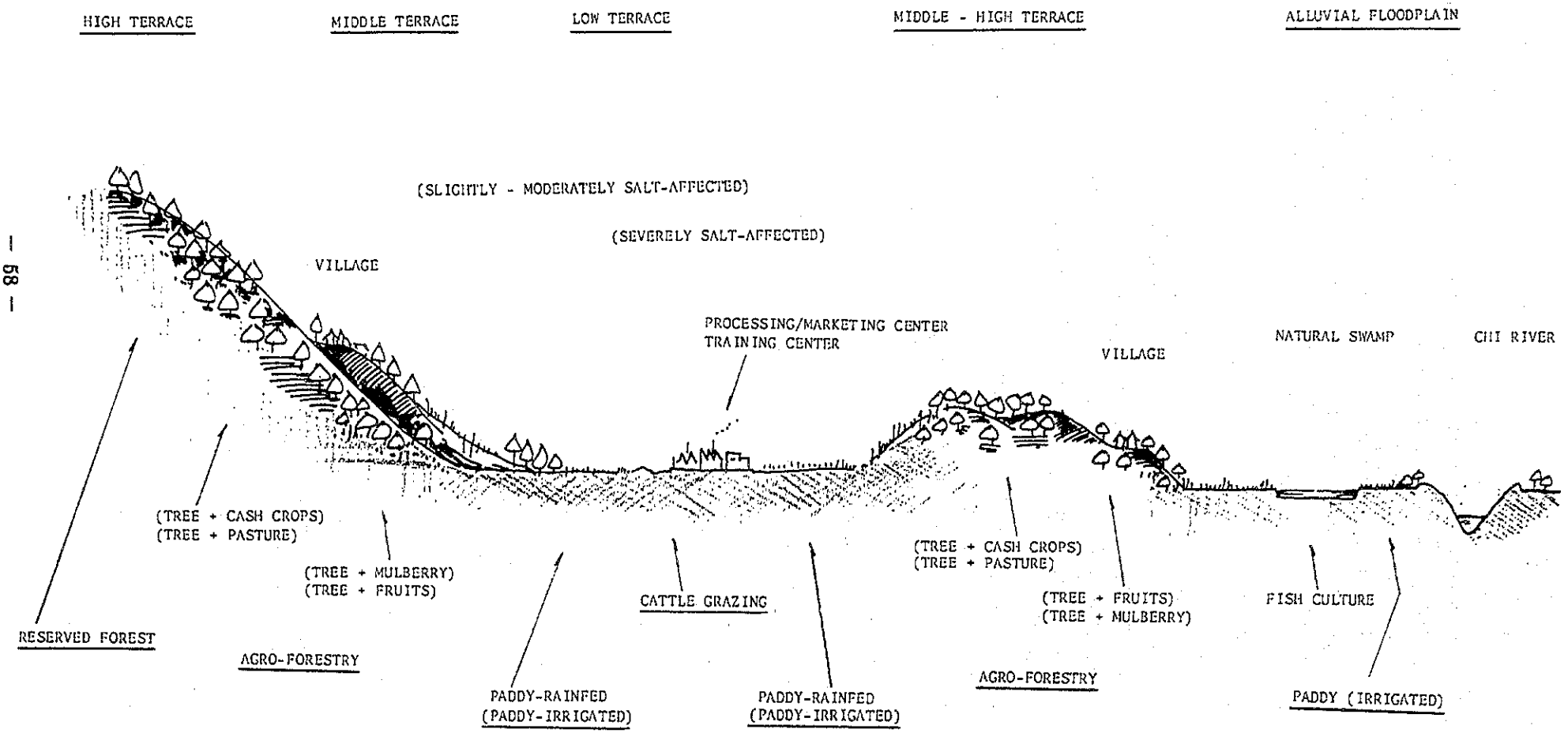
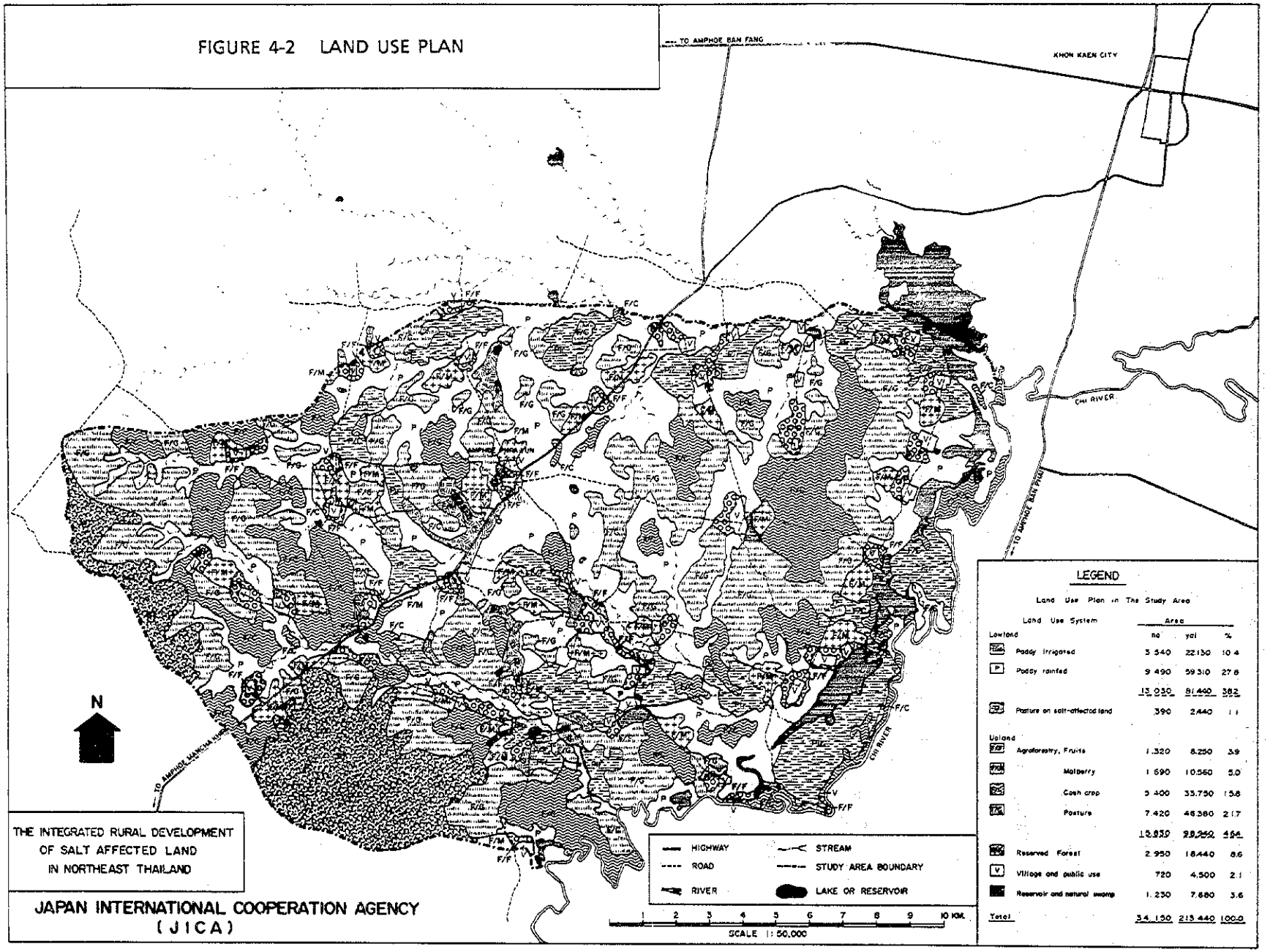


Table 4-1 Land Use Plan in the Study Area

Land Use System	Area		
	ha	rai	%
Lowland			
Paddy, irrigated	3,720	23,250	10.9
〃 rainfed	9,310	58,090	27.3
	13,030	81,440	38.2
Pasture on salt-affected land	390	2,440	1.1
Upland			
Agroforestry, Fruits	1,320	8,250	3.9
Mulberry	1,690	10,560	5.0
Cash crop	5,400	33,750	15.8
Pasture	7,420	46,380	21.7
	15,830	98,940	46.4
Reserved Forest	2,950	18,440	8.6
Village and public use	720	4,500	2.1
Reservoir and natural swamp	1,230	7,680	3.6
Total	34,150	213,440	100.0

FIGURE 4-2 LAND USE PLAN



LEGEND

Land Use Plan in The Study Area

Land Use System		Area ha	rai	%
Lowland				
	Paddy irrigated	5 540	22 130	10 4
P	Paddy rainfed	9 490	59 310	27 8
		15 030	81 440	382
	Pasture on salt-affected land	390	2 440	1 1
Upland				
F/F	Agroforestry, Fruits	1 320	8 250	3 9
F/M	Mulberry	1 690	10 560	5 0
F/C	Cash crop	5 400	33 750	15 8
F/G	Pasture	7 420	46 380	21 7
		15 830	99 940	464
	Reserved Forest	2 950	18 440	8 6
V	Village and public use	720	4 500	2 1
	Reservoir and natural swamp	1 230	7 680	3 6
Total		34 150	213 440	100 0

private own land suitable for forest will be used for more profitable agroforestry.

(4) Village and Public Use

A processing and marketing center of agricultural products and a training center will be allocated at the severely salt-affected area near Ban Phra Yun as a center of the study area; furthermore, two marketing sub-centers will be provided at Ban Ton and Ban Daeng taking into consideration of newly constructed road connecting Ban Ton - Ban Phra Yun - Ban Daeng after crossing the Chi river near Ban Ton.

All villages will be enlarged at the existing site. Social infrastructure will be improved at every village. Reservoir ponds for irrigation will be increased. In a series of natural swamps in the eastern periphery of the study area, more productive inland fishery will be introduced for local consumption.

4-2-3 Major Changes in Land Use

Table 4-2 shows the changes in land use from present to future. The major differences are as follows;

- Rain-fed paddy fields which occupy more than a half of the study area (56.4%) at present will be decreased to 35.9% of the study area. Meanwhile, the irrigated land will be greatly increased from 560ha at present to 3,720ha in future. In spite of reduction of the area, the supply-demand balance of staple food of inhabitants (glutinous rice) can be maintained because the actual land use intensity is very low at present.

- Barren lands due to severe salt accumulation occupy 170ha at present. These lands are available for cattle grazing land (390ha) in future.

- Present upland crop fields of cassava in the middle terrace will be converted to agroforestry in which upland crop field and forestry are combined. Agroforestry system consisting of forestry, cropping, livestock, sericulture, and horticulture will be widely introduced around the present upland crop fields area.

- Reforestation of Eucalyptus spp. has been completed to 1,300 ha in the forest reserve area. Reforestation will be completed in whole reserved area; therefore, forest area will increase to 2,950ha.

- Accompanying by enhancement of social infrastructure, villages and public use area will increase form 600ha 6o 720ha in future. Also, the reservoir area will increase from 1,050ha to 1,230ha due to the construction of irrigation facilities.

Table 4-2 Change in Land Use Pattern in the Study Area

Land Use System	Present		Plan		Change	Planted Area (ha)	
	ha	%	ha	%	ha	Present	Plant
Lowland :							
Paddy irriagated	560	1.6	3,720	10.9	△ 3,160	560	3,720
Paddy rainfed	18,160	53.2	9,310	27.3	▼ 8,850	9,080 [1)]	9,310
(sub-total)	(18,720)	(54.8)	(13,030)	(38.2)	(▼ 5,690)	(9,640)	(13,030)
Barren land	170	0.5	-	-	▼ 170		
Pasture on saline soil	-	-	390	1.1	△ 390		
Upland :							
Field crop	9,080	26.6	-	-	▼ 9,080	4,540 [1)]	1,320
Field crop/Forest	3,040	8.9	-	-	▼ 3,040	1,520 [1)]	1,690
(sub-total)	(12,120)	(35.5)	(-)	(-)	(▼12,120)		3,240 [2)]
Agroforestry	-	-	15,830	46.6	△15,830	(6,060)	(6,250)
Forest :	1,490	4.4	2,950	8.6	△ 1,460		
Village & Public use	600	1.7	720	2.1	△ 120		
Reservoir & Natural swamp	1,050	3.1	1,230	3.6	△ 180		
Total	34,150	100.0	34,150	100.0			

1) 50% of cultivalbe land
2) 60% of total area

4-3 Water Utilization Plan

4-3-1 Mechanism of Salt Emergence

Although many hypotheses have been put forward to explain the mechanism of salt emergence, a satisfactory interpretation may be worked out when the detailed study for groundwater movement in both the consolidated siltstone and unconsolidated Quaternary aquifers is carried out.

The origin of the salt water is of dissolved groundwater from the rock salt which is interbedded member of the siltstone. The rock salt drilling of K-53 conducted by DMR, on Ban Lao Na Di along Huai Yai in the northern end of the study area, reveals that a layer of the rock salt underlines at depth of 180 mbgs with 80 m thick. Depth of the rock salt near Ban Phra Yun is not identified due to lack of drilling data but it estimates almost same as K-53.

The siltstone bed which overlies the rock salt, is interbedded with mudstone and fine sandstone and estimated thickness in the study area is about 170 m. The bed is overlain by thin unconsolidated Quaternary beds. The siltstone aquifer is widely exploited for the groundwater sources but quality of it indicated local variation. A variation of EC in the siltstone aquifer is shown in Figure 4-3. The figure shows that a zone of high EC ranging from 10,000 to 20,000 μS/cm is located in the west of Ban Phra Yun with trending in a north-southerly direction. EC decreases toward east and west of the zone.

The results of the geo-resistivity sounding is quite in agreement with EC distribution that a zone of low resistivity is distributed the west of Ban Phra Yun tending north-southerly direction (see Figure 4-4). This figure shows that the prospected bed indicates extremely low resistivity from maximum sounding depth of 190 m to surface (Figure 4-5). The feature described above suggests that the salt water is discharging through cracky aquifer system in the siltstone from more than 190 m depth to the surface.

Furthermore, a zonal distribution of resistivity and EC indicates that the salt water is concentrically discharging through the particular tectonic zone, e.g. fault, unconformity etc. An upward potential of discharge can be gained at the recharge area in the west of the study area where the Khorat Group is distributed with an altitude of more than 200 MSL. The rain water at the recharge area infiltrates to the deeper part of the rock of Khorat Group through the cracks and beddings which mostly trend to eastward. The infiltrated recharged groundwater can be retained the upward potential by overlying

confined layers in the Khorat Group until it encountered said tectonic zone in the Siltstone where the recharged groundwater ascend through cracks and fissures dissolving the rock salt.

The contour map of the groundwater table in the siltstone aquifer is shown in Figure 4-6.

When the saline groundwater is discharged to the surface of the siltstone, it takes two flow ways, lateral flow in the unconsolidated layers and vertical movement by capillary rise. The velocity and quantity of flows can be regulated by the permeability of overlying sediments.

The gravel bed, for instance the Pa Mo Gravel Bed, takes a part in a lateral flow because of its comparatively high permeability. When a lateral flow arrives a terminal of the gravel bed it decreases velocity and retard in the terminal and finally, it emerge to the surface. The recrystallization of salt on the ground may be observed during dry season.

The drilling records of exploratory wells reveal that outcrops of the Pa Mo Gravel Bed extend to the east end of rolling hill and then it submerge under the Terrace Deposit.

The location of severely salt-affected land delineated by the soil survey is quite identical with the terminal of the gravel bed.

Although the Terrace Deposit is interbedded with laterite gravel, however it seems a bed of low permeability. According to the field permeability test in the Terrace Deposit and Alluvial Formation which conducted by the study, an average permeability of nine soil samples indicated 2.8×10^{-5} cm/sec (see Table B-6, Summarized Results of Permeability Test in APPENDIX B). Also the results of laboratory test of a soil sample at site J-6 indicates 5.0×10^{-4} cm/sec. Based on above data, the Terrace Deposit can be categorized into the semipermeable layer or aquitard (see APPENDIX C-17).

When the salt water emerge to the semi-permeable layers, a vertical groundwater movement may be activated by capillary rise instead of a horizontal movement. However, the groundwater by a vertical rise could not attain to the upper part of the Terrace Deposit if a thickness of the Deposit is greater than a limit of the capillary rise.

Following field data support above idea that EC in the ponds on the terrace terrain shows about less than 600 μS/cm in contrast with EC in

the ponds on the alluvial plain shows ranging from 1,300 to 19,000 μS/cm.

Based on the drilling record of DMR, a distribution of the rock salt in the Korat Plateau, a depth of rock salt on the Plateau is drawn in APPENDIX B Figure B-43.

Summary of the above idea is schematically drawn in Figure 4-7.

4-3-2 Surface Water

(1) River Water

Areal rainfall of the study area was estimated using the rainfall of Amphoe Phra Yun Station by Thiessen method as shown in Appendix A Figure A-3.

No discharge measurement stations are available for Huai Yai, Huai yang and Huai Phra Nao.

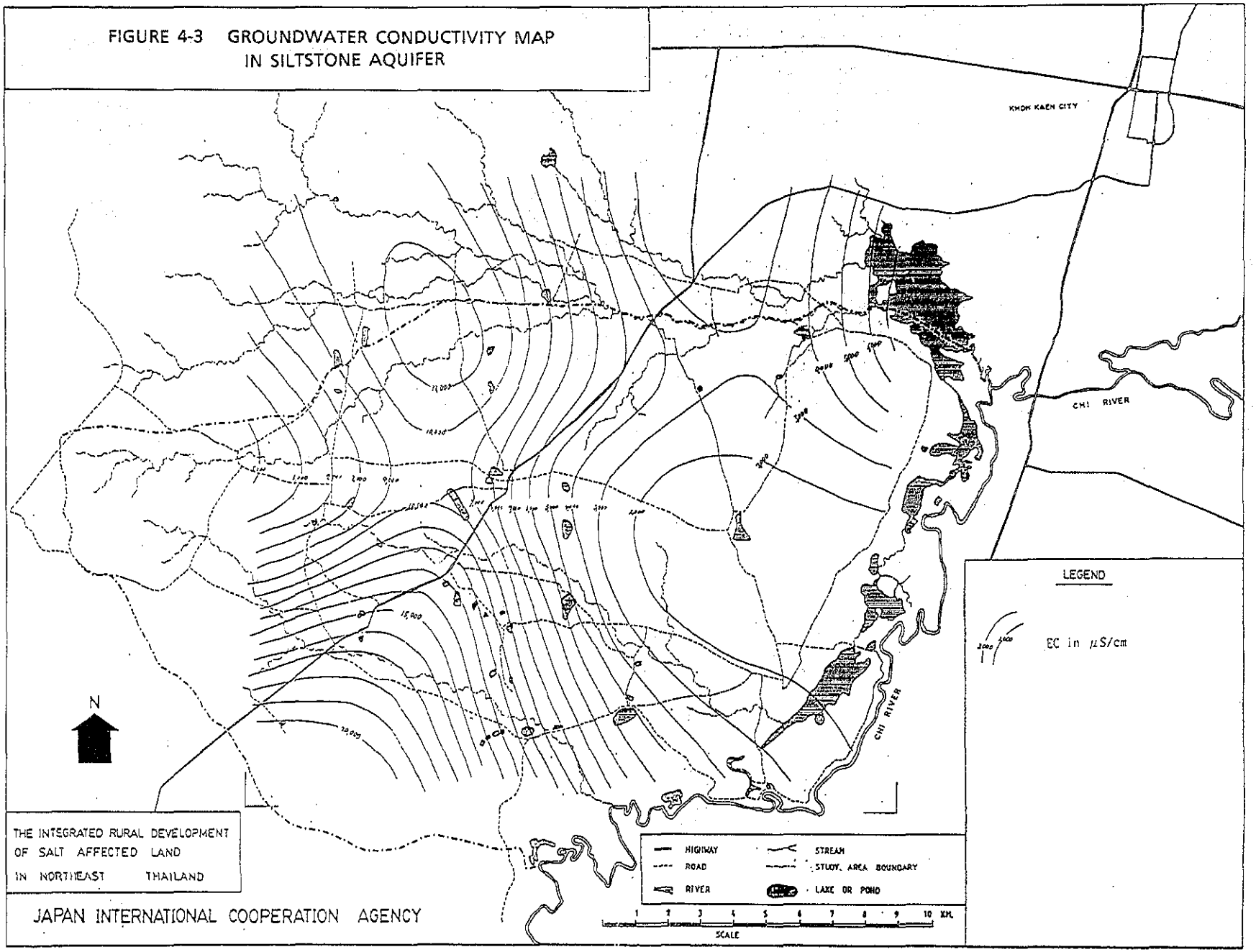
Runoff discharges in the study area were computed from a real rainfall and Runoff Estimation Chart provided by RID as shown in Appendix A Figure A-8.

Normal, 2 years, 3 years, 5 years and 10 years probable annual run of discharges, annual rainfalls and annual mean runoff coefficients for the study area were estimated as presented below.

Probable Runoff Discharges, Annual Rainfall and Runoff Coefficient

Probability	Return Period	Annual Rainfall	Annual Runoff Discharge		Runoff Coefficient %
		mm	MCM	mm	
Normal		969	65.9	193	19.9
1/2	1988	954	42.9	126	13.2
1/3	1984	876	48.3	141	16.1
1/5	1881	864	49.5	145	16.8
1/10	1960	811	38.7	113	13.9

FIGURE 4-3 GROUNDWATER CONDUCTIVITY MAP IN SILTSTONE AQUIFER



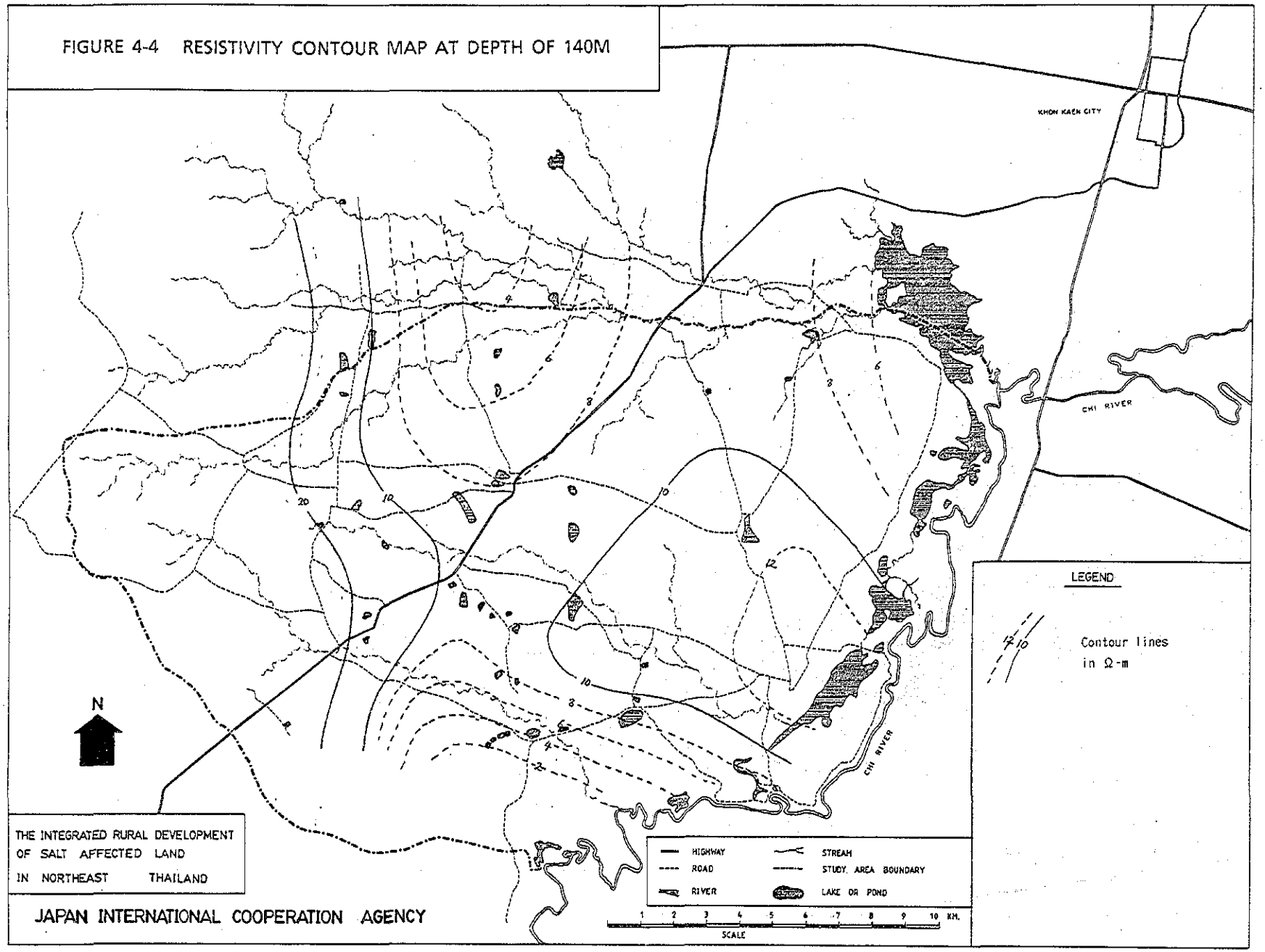


FIGURE 4-4 RESISTIVITY CONTOUR MAP AT DEPTH OF 140M
KHON KAEN CITY
CHI RIVER
CHI RIVER
LEGEND
Contour lines in Ω-m
N
THE INTEGRATED RURAL DEVELOPMENT OF SALT AFFECTED LAND IN NORTHEAST THAILAND
JAPAN INTERNATIONAL COOPERATION AGENCY
HIGHWAY
ROAD
RIVER
STREAM
STUDY AREA BOUNDARY
LAKE OR POND
1 2 3 4 5 6 7 8 9 10 KM.
SCALE

FIGURE 4-5 RESISTIVITY PROFILES

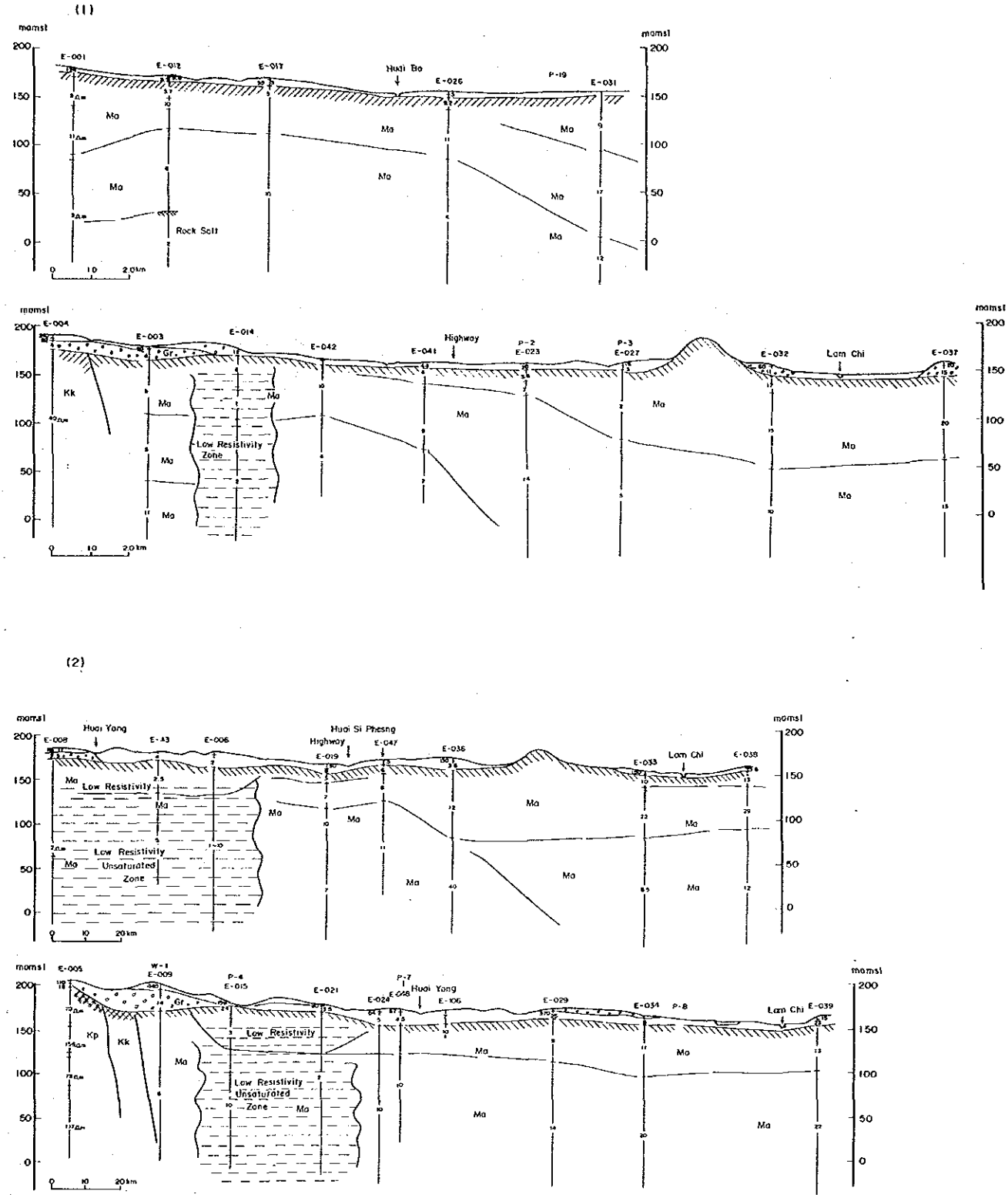


FIGURE 4-6 PIEZOMETRIC SURFACE OF THE SILTSTONE AQUIFER

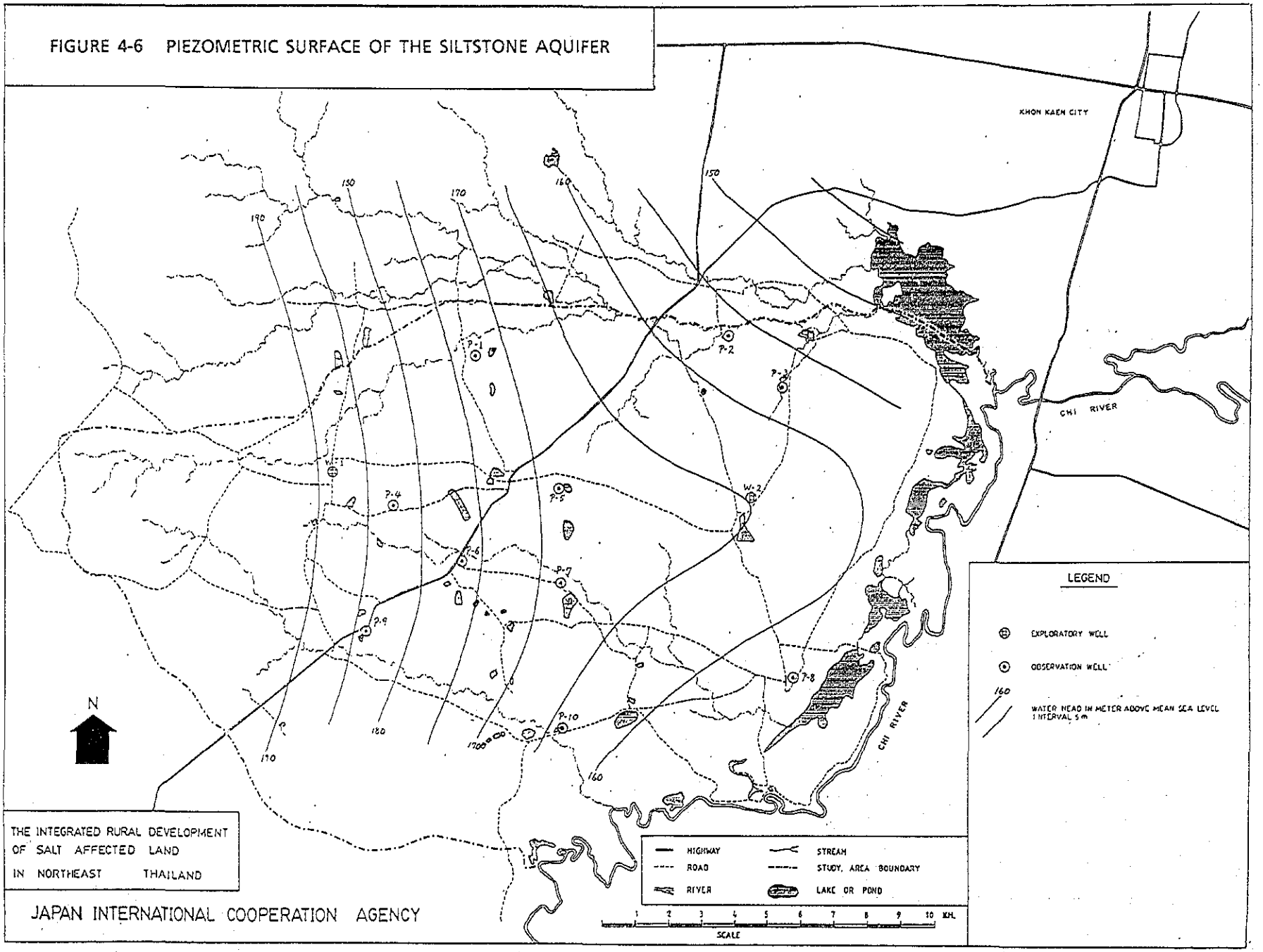
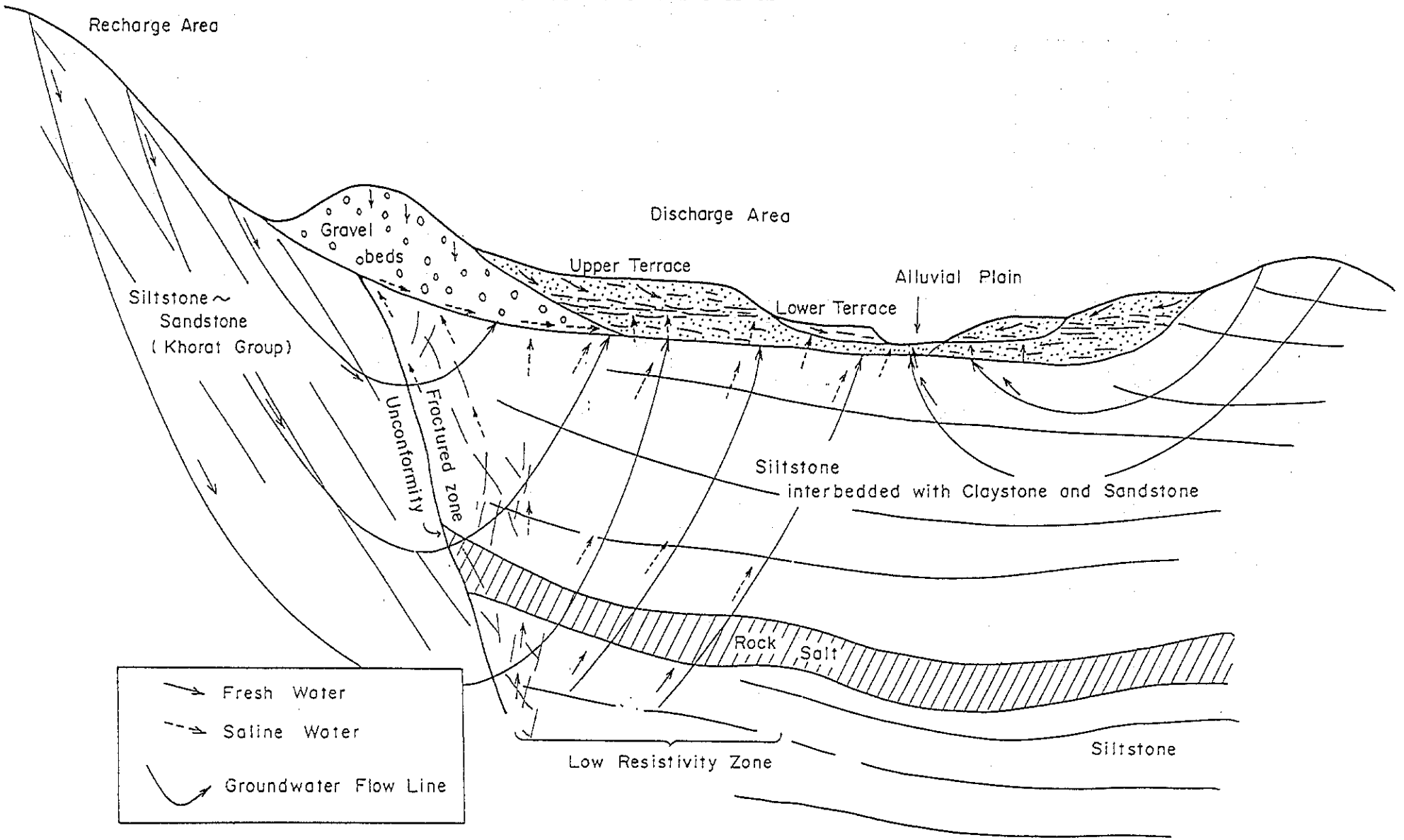


FIGURE 4-7 SCHEMATIC IDEA OF SALT EMERGENCE



Mean Monthly Runoff Discharges (Unit: MCM)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
0.0 (0)	0.2 (0)	0.4 (1)	1.4 (2)	9.1 (14)	10.7 (16)	7.0 (11)	9.8 (15)

Sep.	Oct.	Nov.	Dec.	Annual	Wet	Dry
24.6 (37)	2.6 (4)	0.1 (0)	0.0 (0)	65.9 (100)	61.2 (93)	4.7 (7)

Note Wet: Wet Season (May - Sep.)
Dry: Dry Season (Oct. - Apr.)
( ): Ratio to Annual Amount (%)

(2) Existing Ponds

21 existing ponds in the study area were investigated for surface area. Mean water depth and reservoir capacity in dry and wet seasons were calculated. Location of these ponds are presented in Appendix A Figure A-4. Results are presented below:

Results of the Investigation of Ponds

	Total Surface Area (sq.km)	Mean Water Depth		Total Reservoir Capacity (MCM)	
		Dry	Wet	Dry	Wet
Swamp in Lower-reach	12.6	1.9	2.6	23.5	32.7
Pond	1.1	1.7	2.4	1.4	2.6
Total	13.7	(mean) 1.8	(mean) 2.6	24.9	35.3

4-3-3 Groundwater

(1) Aquifer System

The hydrogeological study reveals that two kinds of aquifer systems, the Siltstone and the Quaternary, are distributed in the study area. The Siltstone is practically impermeable, but infiltration and/or discharge may occur in concentrated points, fracture zone of formation boundary for example, or more generally. It is widely distributed in the study area. The unconsolidated Quaternary aquifers unconformably overlines the Siltstone in the study area and it is distributed in the undulating rolling hill terrace terrain and alluvial

plain. The aquifers in the former two assign to the Pleistocene and the last assign to the Holocene.

(2) The Siltstone Aquifer

The aquifer potential of the Siltstone depends on the presence of fractures in rock because well consolidated siltstone is basically impermeable. Although the fractures develop irregularly, in view of general geologic knowledge, these fractures develop concentrically at a kind of tectonic zone which is represented by faults and unconfomable formation boundary. It is natural that greater yield can be expected if water well is located on these zones.

Based on the aquifer test in the existing wells conducted by GREP, specific capacity of the Siltstone on a central part of terracial terrain which extends from Ban Tao near the middle of Huai Yai to Huai Wan Hin, a tributary of Huai Yai, indicates less than 5 l/min/m in contrast with the west of Ban Phra Yun where specific capacity ranges from 5 to 10 l/min/m.

Based on above specific capacity of 5 l/min/m, well yield can be calculated at 12 cu.m/day if pumping duration applied to 8 hours with drawdown of five meters. It is natural that, well with specific capacity of 10 l/min/m, can yield 24 cu.m/day if pumping of same condition.

In general, the specific capacity of the Siltstone tends to increase on the northwestward and eastward of the study area. Furthermore, a zone of high specific capacity is located on Ban Phra Yun with north-south trendings (see APPENDIX B Figure B-41).

Water quality of the Siltstone aquifer varies with location of wells. Distribution of EC in the existing wells are shown in APPENDIX B Figure B-38.

As easily visualized in the figure, a zone of high EC forms obviously at 2 km west of Ban Phra Yun with the north-south direction where EC ranges from 10,000 to 20,000 μS/cm and decreases toward both sides from the zone.

A location of low resistivity zone is quite identical with zone of high EC because resistivity is reciprocal with conductivity (see APPENDIX B Figure B-4).

Based on the water quality test of groundwater in W-2, which drilled at Ban Non Tun on the rolling hill, EC and TDS indicated 1,600 μS/cm

and 810 mg/l respectively. However, a high concentration of total iron and hardness provided to be inadequate for drinking purpose (see APPENDIX B Table B-8).

Based on the drinking standard of WHO, permissive limit of TDS is 1,500 mg/l which can probably express 2,300 μS/cm in EC. Consequently, only the groundwater in the silstone aquifer on the rolling hill, about 5 km east of Ban Phra Yun, is acceptable for the drinking purpose.

EC of the siltstone aquifer in newly excavated drainage at 3 km south-west of Ban Phra Yun, indicated more than 20,000 μS/cm. There is a large possibility that overlying aquifer is more subject to contaminate by a high concentration of EC when water table of the siltstone aquifer ascends through cracks to the surface of the siltstone.

As mentioned before, groundwater yield of the siltstone aquifer estimates about 20 cu.m/day in promised potential areas. However considering qualitative assessment for drinking purposes, the maximum yield attains 10 cu.m/day on the limited area of rolling hill in the east of the study area.

(3) The Quaternary Aquifers

1) The Pa Mo Gravel Bed

The Pa Mo Gravel Bed on the rolling hill in the west of the study area is about 30 meters in maximum thickness and it forms exploitable potable aquifer in consideration of quantity and quality (see APPENDIX B Table B-8).

The aquifer test in the exploratory well of W-1 reveals that calculated specific capacity and transmissivity are 20 l/min and 70 m^2/day respectively by 21.4 l/min pumping rate. It can lead to a yield of 48 cu.m/day by 8 hours pumping and 5 m drawdown.

Groundwater from this aquifer is utilized in Ban Nong Khu, located in the north of Ban Pa Mo, for the source of village water supply system.

Recommendable area for the development of this aquifer is restricted on a center of the rolling hill where underlies a thick gravel bed. The thickness of bed thins toward both sides of the hill.

2) The Terrace Deposit

The Terrace Deposit is widely distributed in the area and the

permeability of it indicates comparatively low due to lithological composition.

The thickness attains less than 10 m. Its expected potential in this aquifer is low due to its permeability. Although many dug wells are utilized for domestic purposes, depth of the wells is not so deep ranging from 5 to 8 m to prevent vertical seepage of groundwater from the siltstone aquifer.

Based on the aquifer test conducted by the study, the groundwater yield of this aquifer estimated from 2 to 2.5 cu.m/day by 8 hours pumping and 1 m drawdown.

Measured EC in this aquifer indicates less than 600 μS/cm in the comparatively low land where the aquifer is subject to contaminate by the siltstone aquifer of high concentration of EC. EC of the ponds located in alluvial plain where the siltstone is just underlying, indicated extremely high in comparison with ponds located in more higher places. This fact leads to the following idea that the groundwater in the terrace aquifer is contaminated by the groundwater in siltstone aquifer. This aquifer is not utilized by villagers for drinking purpose because of a high concentration of total iron and hardness (see APPENDIX B Table B-10).

3) Alluvial Formation

The aquifer in the Alluvial Formation is distributed in the flood plain of recent river courses, composed of laterite gravel in the bottom, silt and clayey fine sand in the middle, and loamy fine sand in the uppermost. The formation is about 2 m in maximum thickness and it is supportedly subject to contaminate by the groundwater of high EC form the siltstone aquifer when piezometric head of high EC from the siltstone aquifer when piezometric head of the siltstone aquifer ascends to overlying alluvial beds. This idea is supported by the following fact that a great number of ponds in the alluvial plain show high EC ranging from 1,300 to 20,000 μS/cm in comparison with the ponds in higher places.

As compared with the Terrace Deposit, the groundwater potential of the Alluvial Formation is almost equivalent but the quality is inferior.

(4) Utilization Plan

A delineation of the exploitable area of groundwater depend on the quantitative and qualitative limits of the subjected purposes.

<Potable Sources>

The Pa Mo Gravel Bed is sonly groundwater source for village potable water supply system in the area. The bed is distributed on the rolling hill in the west and southwest part of the area and a recommendable well site for the source is probably located at its center or slightly eastward of the hill in view of aquifer thickness and flow direction. Estimated well depth and maximum yield are more than 30 m and 50 cu.m/day, respectively.

<Domestic Sources>

Water quality for domestic use, e.g. washing and/or domestic farming, is more tolerable than for drinking. The siltstone aquifer underlying terrace terrain extending about 3 km east of Ban Phra Yun, is acceptable for the medium salt tolerance vegetables and field crops. Qualitative limitation of EC for this tolerance defines 4,000 μS/cm (D.K. Todd, 1980).

Although careful quantitative assessment is required for the siltstone aquifer due to irregular distribution of cracks and fissures. The exploitable capacity of groundwater is estimated about 10 cu.m/day by a deep tube well.

Exploitable capacity of groundwater from the Terrace Deposit is limited at 2 cu.m/day due to low permeability of the sediments. Groundwater quality, especially its EC is mostly acceptable for domestic use.

The dug well is most suitable for the extraction but bottom of well would not touch the top of siltstone to prevent contamination by high EC.

Groundwater exploitation for the Alluvial Formation requires a careful assessment of quality because it is usually contaminated by a high EC of the siltstone aquifer.

<Sources for Industry>

Limitation of water quality for the industrial use depends on kinds of industries. For instance, regarding to the food processing, required limitation for TDS, hardness and total iron are 580, 250 and 0.2mg/l, respectively (D.K. Todd, 1980). Based on the laboratory quality test in the exploratory well of W-2, groundwater from the siltstone shows within the limitation except total iron which indicated 4.6 mg/l. Based on the EC contour map, TDS in the siltstone aquifer near Ban Phra Yun is estimated at 5,000 mg/l which shows far from the limitation of food processing. Consequently the exploitation of the siltstone aquifer for industrial use requires a

careful qualitative assessment. Exploitable capacity of groundwater from this aquifer is estimated at 10 cu.m/day as stated before.

The quality of groundwater from the Terrace Deposit is generally acceptable for industrial use in villages except the total iron but its exploitable capacity is only 2 cu.m/day (see APPENDIX B Table B-10). The quantitative problem of this aquifer can be solved by use of the existing ponds supplementing rain water during rainy season.

Exploitation of the Alluvial Formation for the industrial use is not recommendable due to deteriorated quality contaminated by the siltstone aquifer.

4-4 Soil Conservation Plan

4-4-1 Problem Soils

Sandy Soils and Skeletal Soils as well as Salt-Affected Soils; so-called problem soils are widely distributed in the Northeast Thailand. In the study area, these problem soils prevail and restrict its agricultural production in addition to the scarcity of stable water resources.

To increase agricultural productivity and ultimately to improve farmers' incomes and living standard, the overall soil conservation measures to soil erosion and nutrient depletion should be undertaken in addition to the countermeasure to salinity problems.

(1) Salt-Affected Soils

1) Genesis of Salt-Affected Soils:

Saline soils are generally classified into Natraqualfs or Halaquepts; however, the salt-affected area appears on other soils, namely Paleaquults also, owing to the landforms and groundwater condition. The previous studies made by DLD and ADRC have revealed that the primary source of salts is sandstone or siltstone of Mesozoic Mahasarakam Formation. The salts, mainly NaCl in the weathered base rocks (clastic layer) are released by erosion and weathering, and transported by groundwater flow. Finally, the salts are accumulated on the surface and form salt patches by capillary upward movement of saline shallow groundwater under high evaporation during the dry season or dry spell in the rainy season.

Meanwhile, human activities such as deforestation due to population pressure are considered to contribute to enhance the salinization. Land clearing for paddy fields or upland crop fields through deforestation induced the imbalance between rainfall and evapotranspiration and has resulted in rising groundwater table which lead to interflow salinization at the adjacent lowland.

Furthermore, the facts that many salt patches are found in the area surrounding reservoir ponds and adjacent area of embanked road explain the enhancement of salinization by civil works without hydrogeological consideration.

2) Distribution of Salt-Affected Soils:

The salt-affected lands in the Northeast are very complicatedly localized. Paddy fields where rice is fairy growing are found just adjacent to the severely salt-affected land (salt patch). Main

component of salts is soluble NaCl and there is strong rainfall during the rainy season. Percolation is active due to sandy topsoil, accordingly, the salts fluctuate widely in the soil by seasons. Thus, the salts movement on the salt-affected soils in the Northeast is quite different from those in the arid zones in Neareast and Africa. The salinity classification method which is usually expressed by salt concentration (or EC) cannot be applied directly for the Northeast.

To show the distribution of salt-affected area, the salt-affected areas have been classified into 6 classes by salt patch coverage as follows;

Class 1 : Severely salt-affected area
Salt patches cover more than 50% of ground surface; locally distributed in lowland around reservoir ponds and embanked roads; natural vegetation of thorny halophitic shrub (*Nam Daeng and Nam Phrom*); very shallow saline water table, and salts accumulated on the surface.

Class 2 : Moderately salt-affected area
Salt patches cover 10-50% of ground surface; distributed in lowland near the denuded hills; natural vegetation of shrubs predominantly Sakaa (Caesalpina crista).

Class 3 : Slightly salt-affected area
Salt patches cover 1-10% of ground surface; distributed in paddy fields in lowland; slightly salinized by brackish groundwater; natural vegetation of shrubs consisting of Teng, Rang and Sakaa etc.

Class 4 : Potentially salt-affected area
Salt patches cover less than 1% of ground surface; extensively distributed in paddy fields in lowland; moderately deep water table and no salt problems appear at present but groundwater quality is poor; to be salinized by deforestation of adjacent hills or careless civil works etc.

Class 5 : Upland area with salt-bearing layer in substrata
No salt patches; salt-bearing Mahasarakam formation in substrata; being used for upland crop fields at present.

Class 6 : Salt-free area
No salt problem; no Mahasarakam formation in substrata

or its depth is very deep; being mainly deciduous dipterocarp forest.

DLD has started the study on salinity problems in the Northeast Thailand since 1982, and has prepared the salt-affected area map scaled 1:250,000 and 1:100,000 by province through LANDSAT imagery analysis of surface coverage of salt patches. These maps are further being modified through repeated field survey and observation of groundwater level and quality, and salt content of weathered base rock in substrata.

The salt-affected area in the study area is shown in Figure 4-8, and the distribution area of each class is given in Table 4-3. As shown in this figure, severely salt-affected lands (Class 1) are located at the center of the study area consisting from Ban Non Bo to Ban Bo Kae and Ban Thung Mon, and occupy 310 ha or 0.9 % of the study area. In adjacent lowland, moderately and slightly salt-affected lands (Classes 2 and 3) are found and occupy 5,030ha or 14.7% of the study area. The major portion of lowland are occupied by potentially salt-affected lands (Class 4) having area of 11,080 ha or 32.4 %.

In the upland area, Class 5 lands which have salt-bearing layer in substrata are distributed widely 10,990 ha or 32.2 % of the study area. On the other hand, salt-free lands are distributed in the sloping land with elevation higher than 200m in the western periphery of the study area and in a hilly, range in the eastern portion of the study area.

To check the expansion of salt patches in the study area, aerophotos taken in 1976 and in 1983 were compared. However, significant increase in salt patches from 1976 to 1983 could not be recognized because almost all forests had disappeared in the middle to high terraces and salt patches had been formed in the depressions, except for the vicinity of newly constracted road and reservoir ponds. Besides, the size of salt patches changes widely depending on rainfall conditions.

Thus, most of lowland are covered by potentially salt-affected land and most of upland are covered by soils having Mahasarakam layer underneath, therefore, there is fear that the salt-affected area will enlarge if such uncontrolled development without considering of sustainability. Conclusively, the preventive measures to salinity problem is essential for the region.

3) Results of Salt Monitoring by Piezometer and Soil Analysis

After soil profile investigation, piezometers were set to monitor the salt concentration in groundwater. Namely, a PVC pipe with slit perforation was inserted into the anger hole after the soil profile survey. Water table, EC and pH of the water sample were checked every two weeks. In the middle terrace, 20 piezometers (6-8 m deep) were set, and 27 piezometers (4 m deep) were provided in the low terrace. Figure 4-9 shows the changes in water table, EC and pH by season at the representative sites. By this moment, the monitoring has not yet completed, therefore, the monitoring works should be continued regularly to understand the salt movement by whole seasons (refer to APPENDIX C-9~C-12).

Figure 4-10 shows the soil profiles in salt-affected areas. The results of soil analyses are shown in APPENDIX C-16. The soil having high salt content (high EC value) shows also high pH (alkaline reaction). The major constituent is sodium chloride (NaCl) and the exchangeable sodium percentage (ESP) is high. These facts suggest the decrease in the permeability when leaching due to sodium dispersion. For the salt-affected soils with strong sodification, necessary amount of gypsum should be applied as chemical amendment.

(2) Sandy Soils

All topsoils of Paleaquults and Paleustults which cover the majority of the study area have sandy texture, while weathered layers above the base rock in substrata contain clay. Besides, Quartzipsamments, which have sandy texture in the entire profile, exist in some portion.

The topsoils of sandy soils have extremely low cation exchange capacity (CEC) and contain little organic matters. Sands consist of quartz and have no potential to release bases. According to the research in ADRC, surface runoff washes selectively clay fraction and organic matters away and leaves sand fraction in topsoils. Therefore, forest clearing for cropland exposes the ground surface and enhance the above process.

(3) Skeletal Soils

Skeletal soils, namely Skeletal Plinthustults or Plinthaquults which have laterite concretions and gravel layers of about one meter thick at shallow depth are distributed in the study area. Generally, mottled clay layers derived from shale or siltstone are found under the laterite layer. Crop roots cannot penetrate the laterite layer; furthermore, the layer causes difficulty in farming. These soils are

used for paddy fields in lower land, on the other hand, they remain as sparse shrubs in higher land.

4-4-2 Countermeasures for Problem Soils

(1) Countermeasures for Salt-Affected Soils

The origin and characteristics of salt-affected soils in the Northeast Thailand are different from those distributed in arid regions in Middle East and Africa. Accordingly, the countermeasures also should be different. Salts accumulated in the surface soil are mainly easily soluble NaCl and texture of the surface soil is sandy. That is, the salts in the soil can be quickly dissolved into the groundwater by rainfall. When the groundwater table is shallow, the salts come up to the surface with the capillary upward movement of saline groundwater, and re-accumulated in/on the surface during the next dry spell. Consequently, the essential point of the countermeasure of salt-affected soils is to control saline groundwater such as drainage improvement.

There are two countermeasures of salt-affected soils, that is, short-term (diagnostic) and long-term (preventive) measures. The followings are countermeasures for the salt-affected soils in the study area.

1) Severely Salt-Affected Area:

Not used for crop cultivation. These land will be used for alternative purposes, that is, for pasture of salt-tolerant plants such as Atriplex spp. for fodder and Tamarix spp., Casaurina spp., and Eucalyptus spp. for shading tree. Owing to the planting, the present shallow saline groundwater table would be lowered. Furthermore, the land will be used for public facilities such as processing/marketing, technical training, and recreation. Salt diffusion to surrounding area should be more carefully considered rather than salt removal from these land.

2) Slightly ~ Moderately Salt-Affected Area:

Used for paddy fields after improvement of drainage condition for amelioration by natural leaching and improvement by cultivation practices such as land leveling, mulching, organic matter application, deep plowing, and introduction of salt-tolerant varieties. Rehabilitated the borders taller and stronger to prevent the topsoil from salt sedimentation.

3) Potentially Salt-Affected Area:

Used for paddy field as it is. As the long-term countermeasure,

reforestation under agroforestry system will be conducted in surrounding upland. The studies conducted by DLD and ADRC suggest that reforestation of Eucalyptus spp. could be effective as preventive measures of salinization through lowering water table. Meanwhile, it is known that Eucalyptus spp. has advantages such as fast growing capacity, drought an salt tolerance an high demand as pulp material. However, it gives unfavorable effects on ecosystem. Therefore, various kinds of trees as multi-purpose deep rooting perennial crops and profitable tree species will be included in reforestation programme; consequently, agroforestry.

(2) Sandy Soils

Sandy soils have low moisture retention capacity, and cropping on them is entirely dependent on rainfalls. Because of low nutrient fixing capacity, chemical fertilizers do not show the effect. On sandy soils, crops which can grow infertile soils and have drought tolerance such as cassava and kenaf are cultivated. Soil management practices, that is, green manuring, leguminous crop cultivation, mulching with crop residue, and organic matter application are studied. At the ADRC, weathered layer above base rock and bottom soils of natural swamps are tested as clayey materials. Furthermore, cropping combined with livestock raising is effective for the soil improvement.

(3) Skeletal Soils

It is essential to prevent the topsoils above the laterite layer from erosion. In middle to high terrace, these soils should be used for forest or pasture land to cover the ground surface with vegetation. Furthermore, agroforestry could be introduced by breaking the laterite layer and planting fruit trees.

(4) Recovery of Soil Fertility

Chemical fertilizers are presently not applied to cassava fields because of uncertainity of the response due to the wide fluctuation of rainfall and the expenses to procurement, while a little amount is applied to paddy fields. As the results, nutrients have been depleted from the upland crop field soils that are infertile by nature. Thus, the soils are deteriorated accompanied by soil erosion. Meanwhile, ADRC studies showed that crop yield under rainfed condition was dependent on the rainfall and fertilizer response could not be recognized in drought years.

Therefore, application of organic matters is the essential of soil fertility recovery in parallel to improvement of soil physical

properties. For this purpose, mulching with crop residue, organic materials applying, and planting of green manure plants (Sesbania spp.) leguminous plants (Leucaena spp.) are effective.

Table 4-3 Salinity Classification in the Study Area

	Land Use System	Area		
		ha	rai	%
1	Severely Salt-Affected Land with salt patches more than 50% of ground surface	310	1,940	0.9
2	Moderately Salt-Affected Land with salt patches 10-50% of ground surface	1,480	9,250	4.3
3	Slightly Salt-Affected Land with salt patches 1-10% of ground surface	3,550	22,190	10.4
4	Potentially Salt-Affected Land with salt patches 1-10% of ground surface	11,080	69,250	32.4
5	Upland with salt bearing layer underneath	10,990	68,690	32.2
6	Salt-Free Land	5,690	35,560	16.7
W	Reservoir & Natural swamp	1,050	6,560	3.1
	Total	34,150	213,440	100.0

FIGURE 4-8 SALT-AFFECTED LAND

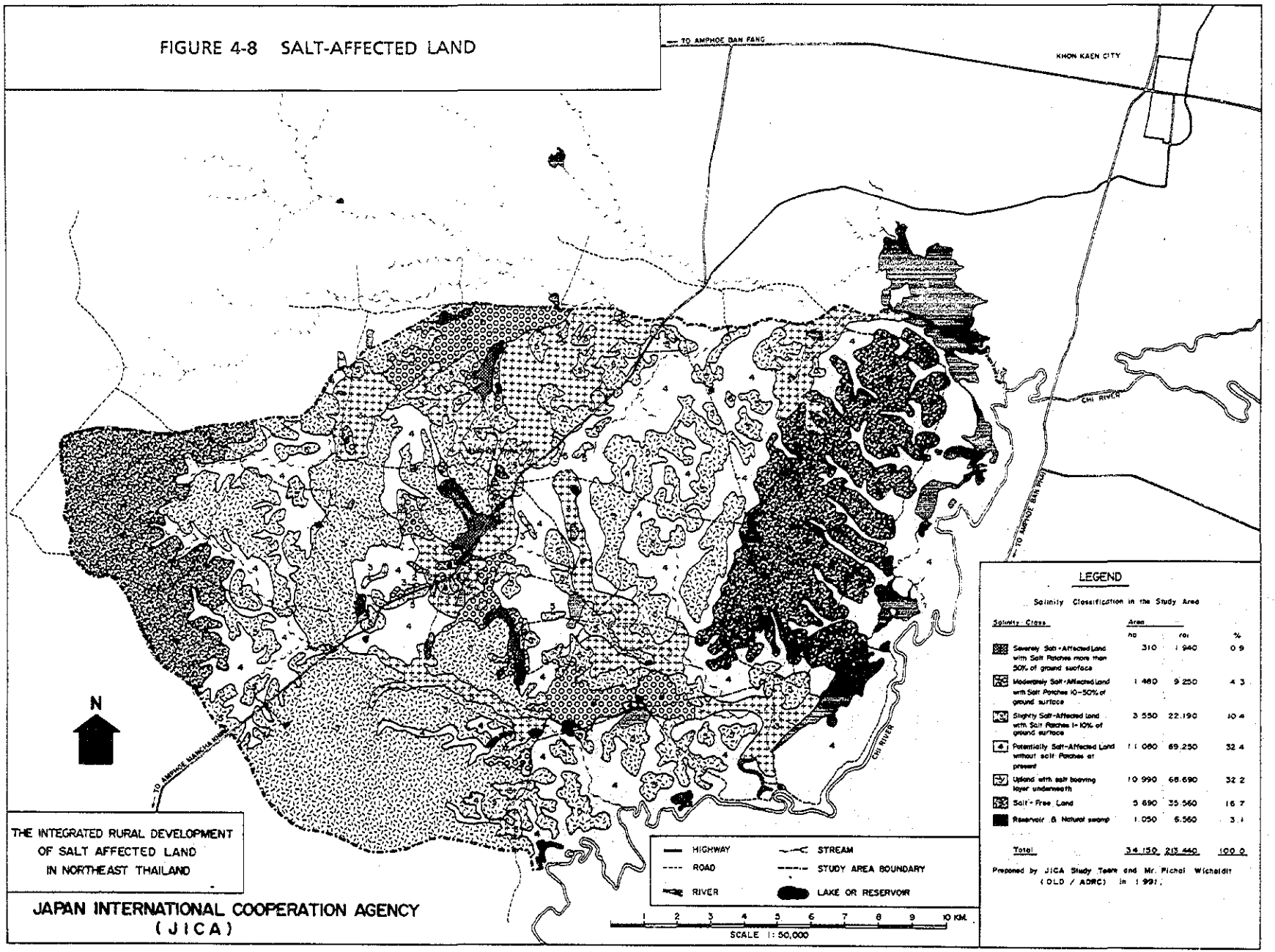


FIGURE 4-9 CHANGE IN WATER TABLE, EC, AND PH

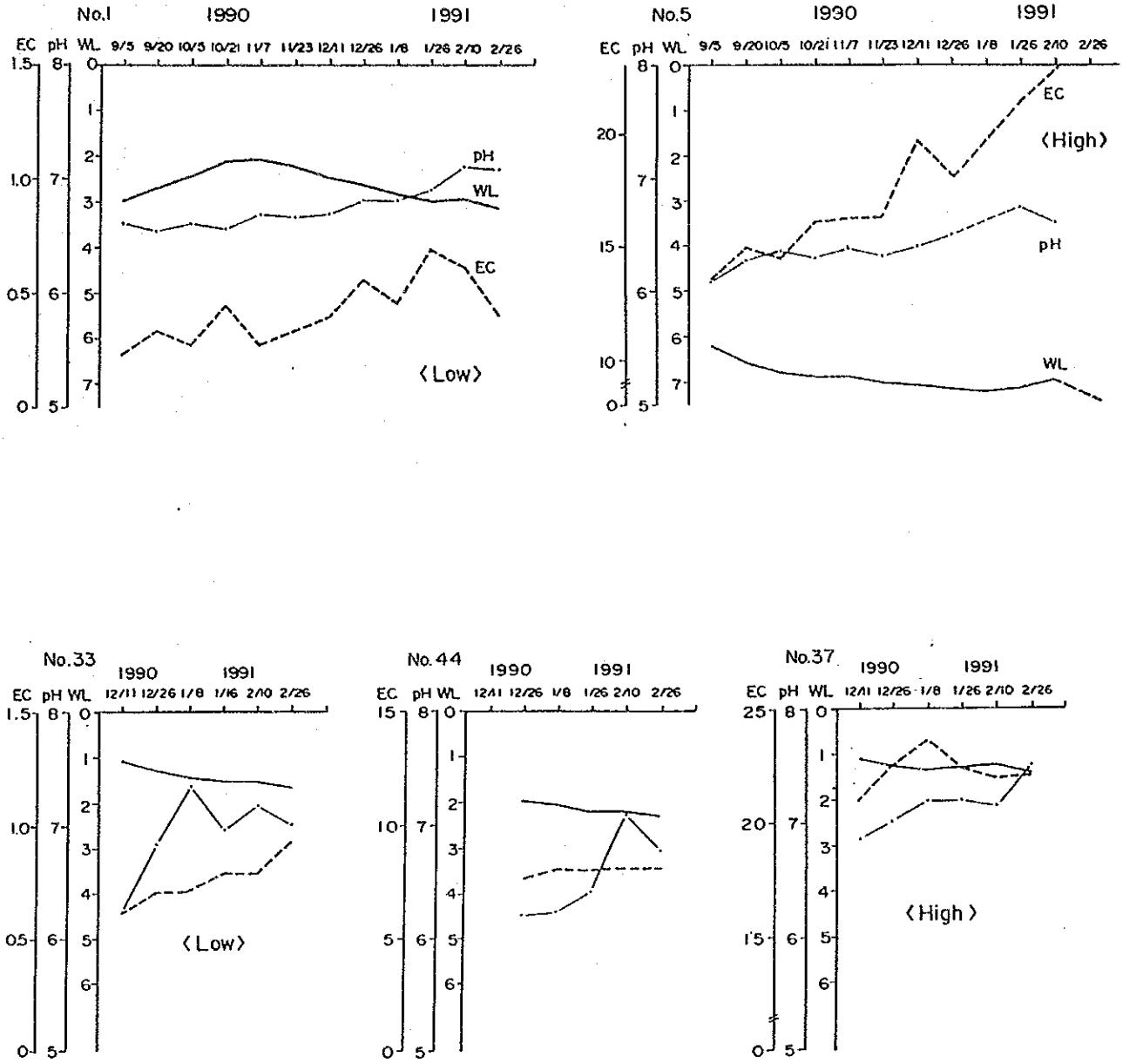
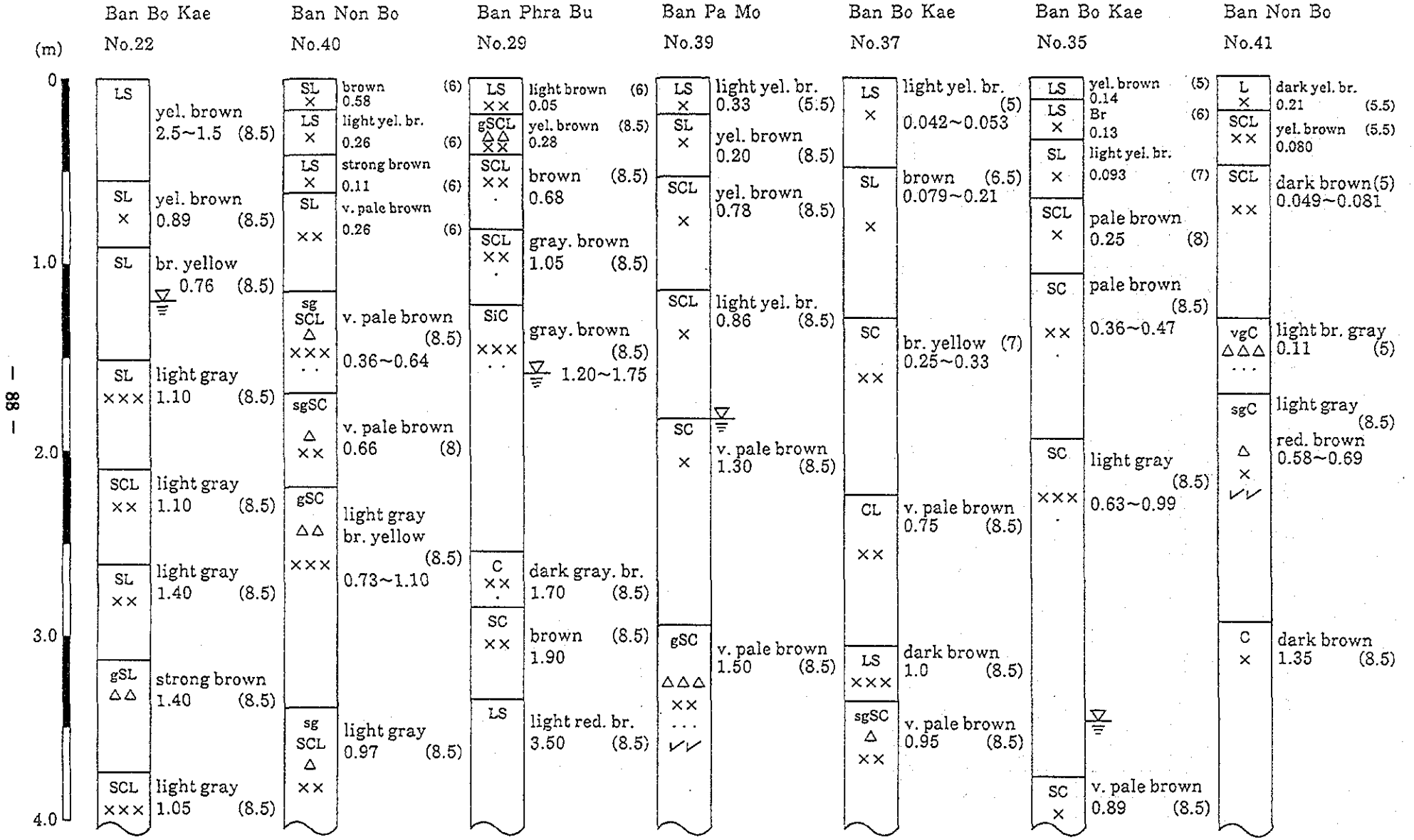


FIGURE 4-10 SOIL PROFILES OF SALT AFFECTED LAND



4-5 Agricultural Development Plan

4-5-1 Objectives and Strategy

(1) Objectives of the Development

Considering the present situation and background of the agriculture, the following objectives are listed.

1) Stabilization and increasing of the rice yield
2) Establishment of the sustainable field crop production
3) Promotion of the crop diversification

(2) Developmental Strategy

1) Stabilization and increasing of the rice yield

The main objective of the rice growing in this area is to keep the staple food for selfconsumption. To get high and stable production following items are requisite;

① Construction of the irrigation facilities to supply water
② Changing the low yield paddy field located at the upper land to the field crops cultivation (agroforestry)
③ Practice of the agricultural countermeasures to the salt affected soil.

Items ① and ② are mentioned in the Irrigation Plan and Land Use Plan respectively. Regarding item ③ following countermeasures are considered.

In the salt affected area there is an impermeable thin soil layer near the surface which is considered as the secondary source of salt. The treatment of this layer will be the first countermeasure.

2) Establishment of the sustainable field crop production

At the upper field land cassava is grown exploitatively as a cash crop, the land utility is decreasing with the rapid expansion of the cultivate land. To change this trend and reclaim the land, the introduction of the agroforestry systems are recommendable. Considering the situation and development of agriculture the suitable agroforestry systems are selected as follows;

Field crops	plus Tree
Fruit	plus Tree
Mulberry	plus Tree
Pasture	plus Tree

3) Diversification of crops

In the study area major crop is rice for self consumption and cassava as a cash crop, however the price of the cash crops is changeable and the farm management can not be stable. Moreover the monoculture easily suffers from environmental damage. To improve these situation, diversification of crops and the integration of farm with sericulture, fishery and livestock is necessary. By the integrated farm management the natural resources and man power will be utilized more effectively. Development of the processing of agricultural products and increase additional value is one of the important way of diversification (Vertical Diversification).

Above mentioned three targets are related to each other. For example the crop diversification will be realized by irrigation and soil improvement as well as introduction of the agroforestry systems. The integrated promotion of these three targets will be necessary.

To realize the above three targets the following five farming systems are favourable to be applied.

① Farming system for stabilization of rice production and introduction of double cropping under irrigation
② Integrated farming system using small farm pond

③ Farming system for the sustainable field crop production
④ Farming system for development of sericulture
⑤ Farming system for animal feedingstuff production

After five or ten years, the agriculture in this area will be changed by implementation of these plans. These systems, however, contain a new conception and technique. Farmer's understanding for these systems is very important. In order to obtain a fruitful result for this system many technical problems e.g. the introduction of a suitable crops should be solved.

Sericulture and livestock raising have been done for self consumption. These should be changed in the agricultural management for business purposes. In order to bring these changes into farmers, extension services are necessary.

4-5-2 Crop Selection and Proposed Cropping Pattern

(1) Crop Selection

1) Background

In Thailand, agricultural development has been conducted based on the Five-Year Plan. In 1986 the Northeast Thailand suffered from drought damages and people recognized the severe natural condition and unstable agriculture. To solve these problems in the Northeast Thailand, the Government introduced the new plan called Green Northeast.

The proposed development strategy consists of the followings:

- Major expansion of oilseed and protein crops under irrigated conditions to enable the region to satisfy its human and livestock nutritional requirements and to allow the development of an export trade in meat;
- Sustaining production of cassava in the more arid areas for animal feedstuffs, alcohol, glucose and continued export;
- Increasing production of fruits and vegetables under irrigated conditions for local consumption and for export as fresh and processed commodities;
- reforestation of encroached areas and areas of marginal agriculture value to provide fuelwood and other forest products;
- major expansion of fish production to meet local needs
- The infrastructure for agro-industry should be developed, including provision of basic services.

Based on the Green E-sarn Project MOAC proposed the following plan;

- Eucalyptus planting and pulp production
- Alcohol production from cassava
- Generation of electric power using fuelwood
- Growing of profitable fruit trees at the basin of Mekong etc.

- Increasing of cotton production

- Increase of milk cow and milk production

In Amphoe Phra Yun the important agriculture projects in 1986 are as follows;

- Promotion of sericulture project

- Substitution of cassava project, introduction of groundnut and jute

- Improvement of agricultural production system in the drought area and problem soils

- Rainfed paddy project in the poor area

- Promotion of pasture seed production

2) Crop Selection

The agriculture in the study area is limited by following three factors, shortage (sometimes surplus) of water, poor soil and salinity of soil. Considering the governmental development plans mentioned above, and following cropping patterns, the crops are selected. These crops are tolerant of drought and salinity.

Land Use Plan		Selected Crops	
		Wet Season	Dry Season
Lowland	Paddy (Irrigated)	Paddy	–
	- ditto - (Second Crop)	–	Tomato, Watermelon, Groundnut, Sweet Corn
	Paddy (Rainfed)	Paddy	–
	Grazing land	Salt tolerant grass	
Upland	Fruit/Tree	Mango, Jackfruit, Tamarind	
	Mulberry/Tree	Bivoltine Cocoon Multivoltine C	
	Cash Crop/Tree	Cassava, Kenaf, Sugarcane	
	Grazing Land/Tree	Ruzi grass Hamata	

(2) Farming Systems

Based on the land use plan and irrigation plan, the following cropping patterns are proposed:

(Land use)	(Irrigation)	(Farming System for)
Paddy field	Irrigation	1. Stabilization of rice production and introduction of double cropping
	Rainfed	2. Integrated farming system using small farm pond
Upland field	Rainfed	3. Sustainable upland crop production
		4. Development of sericulture
Grazing land	Rainfed	5. Forage production in the common and waste land

4-5-3 Farm Management Plan

(1) Paddy field

By introduction of irrigation, farmers have to carry out intensive farm works in the limited period under the irrigation schedule. The peak labor requirement will become a problem for the farm management. To solve this problem, land replacement, labor employment and introduction of labor saving crops have to be considered.

In the farm management plan, the family member is recognized as the fundamental labor power and only at the labor peak time the shortage of labor is supplemented by hired workers. At the farming in the dry season, the labor intensive crop such as tomato and labor saving crops such as groundnut are combined to lower the labor peak. Leguminus crops have also an effect on soil enrichment and their residues will be utilized as a feed stuff.

At present , the intensive agriculture in this area is going on as a vegetable seed production. Since the seed production needs a careful intensive management, the increase of seed production in this area shows that farmers have the ability to carry out the intensive agriculture. In this plan several crops are proposed as dry season crops, but the introduction of new crops should be experimented hereafter. To establish the intensive agriculture, more various ways for instance, the vegetable seed production should be further studied. Farming practices are shown in APPENDIX D Figure D-5~D-7, Table D-25, D-26 as a standard farm management.

Notices for these farming practices are as follows;

When the succeeding cropping is scheduled the early mature rice variety will be used in the rainy season.

Transplanting is adopted and the area of the nursery is 5 % of the paddy field.

Application of the normal amount of fertilizer and organic matter and necessary pesticides have to be established.

Farming countermeasures have to be made to the salt-affected area.

At the "rainy season irrigation area" the yield will become 1.7 times of the present yield and they will be able to get rice production for self consumption with about 1 ha (6 rai). Thus they may introduce other crops into the residual area.

At the "rainfed area" the farming management will not be changed fundamentally.

(2) Farming management in the upland field

In the land use plan ,the upland field area (agroforestry area) increases to 16,000 ha according to the change of the low yield rice field to the upland field and increase of the land use. The growing practice of tree crops is more extensive than that of the annual crops. Thus the introduction of agroforestry is a suitable way to manage a large area.

The agroforestry plan is expected to be implemented by individual farmers. The plan should be attractive to them from the economical point of view. Main crops should be combined with tree crops for making a better income.

1) Tree + Fruits

Fairly intensive management and supplemental irrigation may be required especially at the time of planting. To get high and stable production, introduction of multistory planting system should be effective.

This system is composed of fruit trees (e.g.mango, tamarind, jackfruit, coconut, custtard apple, papaya) and crops (e.g.banana, chilli, ginger and some vegetables), and suitable combinations of them should be studied.

2) Tree + Mulberry

Mulberry is planted along the contour line. Fodder and manure trees such as sesbania, leucaena are intercropped among one row to five rows of mulberry. To avoid compitition between mulberry and manure trees, trimming of manure trees should be done several times a year. Trimmed branches will be placed between rows. If necessary this may be used as feedstuff.

3) Tree + Cash Crops

Combination of cassava or sugarcane with manure tree is considered. Planting ratio of manure trees have to be decided depending upon the field conditions. The planting practice is almost same as the case of mulberry.

4) Tree + Pasture

Combination of pasture with fodder and shading trees is considered. Fodder trees will be useful to keep feedstuffs under severe natural conditions without doing much labor works. The fast grown trees are recommended as shading trees.

4-5-4 Crop Production

(1) The Expected Yield

1) Paddy Rice

The effect of irrigation on paddy rice yield is estimated as follows;

- Increase of planting area. Under rainfed condition the average ratio of planting area to holding area is 36% in usual year at Amphoe Phra Yun. But this figure is variable according to topography. In the area under the irrigation programme the present ratio is estimated at 60% and will be eventually increased to 100%.

- The irrigation will secure the well growth of the rice and surpress the salt affect of the soil. The effect on the yield increase is estimated at 30%.
  Under irrigation farmers will be able to choose their best planting time to ensure an optimum growing period; the effect on the yield is estimated at about 20%. Under irrigation much more fertilizer application will be possible and the effect to the yield is estimated at 20%. According to the statistical data the average paddy rice yield (product/ harvested area) is 280 kg/rai in the study area. Therefore the yield under irrigation at 480 kg/rai is estimated in the plan.

2) Cassava

At Amphoe Phra Yun the average yield of cassava was 2100 kg/rai. In the proposed plan the increase of soil productivity is the main objective, and the final target yield for cassava is set at 3,000 kg/rai.

3) Mulberry

The cocoon yield of this area is estimated at 30 kg/rai. In the plan, the intensive Bivoltine sericulture is considered and 60 kg/rai of cocoon yield can be obtained under proper management.

4) Field Crops and Vegetables

Few actual examples of cultivation of these crops are available in this area. Data and opinion of Agricultural Extension Office and Agricultural Experiment Station are considered.

5) Livestock Feedstuff

The raising number of buffalo and cattle will be limited due to the amount of grass and crop production in this area. The productivity of the improved grass land is estimated at 3.7 (wet season) 1.04 (dry season) cattle/ha (APPENDIX D Table D-28).

Regarding the productivity of Atriplex spp, there is no actual field data in Thailand yet.

6) Rice Yield in Saline Soil and the Effect of Improvement

Rice is salt tolerant during germination but sensitive after the one to two leaf stage. Tolerance progressively increases during the tillering stage, then decreases from panicle formation to flowering and maturation of fertilized florets is apparently less affected. It has been shown that a 50% reduction in yield seems to occur in the salinity range of ECe from 6.0 to 7.0 mmho/cm after germination.

Salt tolerant varieties were bred at IRRI and other research institutions. Some of them endure ECe from 8-10 mmho/cm.

The Northeast soil salinity research project operated salt-affected rice field of 160 ha (1,000 rai), and produced the rice yield of 500 kg/rai. The applied method is a combination of several cultivation techniques and irrigation.

(2) Production

Implementation of the development plan will change the agricultural production as follows (Table 4-4).

Although the paddy field area decreases to 80% of the present area, introduction of irrigation increases the yield and total production, estimated at 20,280 ton (1.8 times of present production) in usual

Table 4-4 Target of Agricultural Production (Study Area)

Land use plan		Irrigation wet	Irrigation dry	Area	Crops, Target yield: Wet season	Crops, Target yield: Dry season	Target production		Present Production
Lowland	Paddy	I		3,720 [3,160]	t/ha (kg/rai) Rice 3.0 (480)	t/ha (kg/rai)	Rice	t 8,124	** Paddy area 18,720 ha Harvested area 6,270 ha Yield 1,75 t/ha. Harvested area (248kg/rai.Harvested area) Production 10,970 t
	Paddy (Second Crop)		I				Rice	813	
						Tomato 23.0(3,680)	50	1,150	
						Watermelon 13.1(2,100)	50	660	
						Groundnut 2.3(370)	110	250	
						Sweetcorn 9.9(1,580)	110	1,090	
	Paddy	R	R	9,310	Rice 1.9 (300) / Harvested A.	-	5,590 ha	10,620 t	
	Pasture (Salt A.)	R	R	390	Atriplex spp. Salt tolerant grass/tree		Cattle	470 head	
Upland	Fruit /tree	R	R	1,320	Mango 3.1 t/ha (500)		528 ha	1,640 t	
					Juckfruit 6.3 (1,000)		396	2,520	
					S.Tamarind 1.0 (160)		396	390	
	Mulberry /tree	R	R	1,690 [1,350]	Bivoltine cocoon 0.4 (60)		1,080 ha	Cocoon 400 t	Multivoltin cocoon 18 kg/rai Cocoon porduction 49 t Mulberry field 440 ha(2,740rai)
					Multivoltine cocoon 0.3 (40)		270	Cocoon 70	
	Cash crop /tree	R	R	5,400 [3,780]	Cassava 18.8 (2,000)		3,000 ha	56,400 t	Uplant field 4,290 ha
					Kenaf (stalk) 5.6 (900)		390	2,180	
					Sugarcane 37.5 (6,000)		390	14,630	Cassava production 53,600 t
	Pasture /tree	R	R	7,420 [5,190]	Ruzi (dry m.) 7.2 (1,150)		3,490 ha	25,130 t	Cattle/Buffalo 17,850 head
					Hamata (dry m.) 6.9 (1,100)		1,700	11,790	
							*Cattle/Buffalo	21,817 head	

Notes: I-Irrigation, R-Rainfed, [ ] the net planting area of main crops. *-Total heads in the polot area
**-Paddy area was based on the Aerophoto data.

year. 47% of the total production (9,470 ton) will be obtained from the irrigated area and the rice production will be more stabilized than now. Rice production per present population will be more than 437 kg in the study area.

The irrigation area in the dry season is not large but in this area the new production of fresh vegetables is expected in the dry season.

The yield of the upland crops will not change so rapidly but the drastic change of the land use will bring clear changes (in kind and amount) of production. In future effect, the soil enrichment will be resulted in a yield increase. Mulberry field area will increase to 3-4 times of the present area and 405 tons of cocoon and 10 tons of homemade raw silk will be produced. Production of cassava, the major field crop, will not change.

4-5-5 Sericulture

Sericulture is an important cash crop in the study area. Silk fabrics are export products from Thailand. This production and export is increasing now (APPENDIX D Table D-20, 21). To produce good quality fabrics for export, long and fine fiber is necessary as warp thread. To promote export, Thai Government set the target of policy on the production of warp thread.

As a result of the cooperative study with Japan, the standard technique of warp production using bivoltine silkworm was established and the production is increasing rapidly, even though 60% of consumption are imported now (Table D-24). Woof thread is made from cocoon of local silkworm varieties. Share of domestic production is larger than wrap but 40% of it provided by imported thread.

In the study area most sericultural farmers are rearing local varieties and reel raw silk at home. Two types of sericulture have different characteristics as follows;

Sericulture for warp production-bivoltine silkworm (adapted to temperate area) is used. Intensive and higher rearing technique is necessary. Silkworm hybrid egg is expensive. Cocoon price is twice of local cocoon. Circulation route of silkworm egg and cocoon has been established by private companies.

Sericulture for woof production-polyvoltine silkworm (adapted to tropical area) is used. It is tolerant to tropical climate and easy to rear. However, the productivity is low. Farmers can produce silkworm egg by themselves. Farmers reel rawsilk and sometimes make fabrics at

home. Since reeling must be finished up before moth appearing, the reeling ability limits the scale of sericulture.

Recently a new type of sericulture is promoted. In this type farmers rear improved polyvoltine silkworm and the produced cocoon is sold to the reeling companies.

A new trend of the silk industry in Thailand is revaluation of traditional silk fabric-"Madmee" silk. Its production is promoted by the Queen of Thailand and one of the objects of this project is to level up the status of women in the Northeast Thailand. Recently the fashionable dress has been made with this material. There is no production community in the study area but the farmers are willing to master the dyeing technique of "Madmee" silk (APPENDIX D Reference D-2).

Mulberry is tolerant to the severe conditions, bringing high income per land area. Sericulture and reeling give women the opportunity for work. The cocoon price is controlled by the Government. For above reasons most cocoon and silk of Thailand are produced in the Northeast. Khon Kaen province holds 13% of the total mulberry field and produces 17% of the total silk production.

In the study area 3,300 farmers are cultivating 430 ha of mulberry field.

In this plan, the merit of both types of sericulture are taken into the plan, aiming at the development of the silk manufacture.

A half of sericulture farmers are estimated to rear bivoltine silkworm in the future. To promote the bivoltine sericulture, 0.64 ha (4 rai) of mulberry field per farmer are necessary. The mulberry field area, will be 1,690 ha in the future.

4-5-6 Livestock

In the study area the most popular animals are buffalo and cattle. They are grown with natural grass. Swine and chicken raising is apt to suffer from the high price of feeds. Development of livestock industry is the major target in the Northeast and to implement this programme, keeping of feedstuff will be considered most important. There is a milk producing area near Khon Kaen city. But in the study area the obtainment of good quality pasture and water is more difficult for this purpose.

In lowlands of the study area buffalo is grown. Cattle for meat is

grown in Tambon Phra Bu, Ban Ton, Non Waeng and Manja Khiri, mainly at the hill side. There is a livestock market and a slaughterhouse at the suburbs of Khon Kaen city. The target on raising cattle for meat and on propagation of superior strains, are planned. In order to achieve this target the production plan of feedstuff is presented.

There is a large salt-affected area as barren land in the study area. Introduce salt tolerant pasture and fodder trees and use this as a grazing land is one of the main objectives of this livestock plan. Grazing land area is planned for 390 ha at lowland salt-affected area and 7,420 ha at upper land as an agroforestry system. This silvopastoral system occupies more than a half of upland areas.

By the implementation of this plan, the potential of raising stock will be 15,000 heads in the dry season, 28,000 heads in the wet season. At present (1988), in the study area 18,000 heads of buffalo or cattle are grown. 1.2 times of the present heads are planned.

Now, there is no pasture land in the study area except for the communal land established by the Government. At present 18,000 heads of cattle are raised without a large pasture land. No cropping area and natural grass land are utilized. This means that the lower cropping ratio of land makes possible to raise such a large number of cattle without pasture land.

This plan will be implemented mainly by individual farmers, the average raising number will be 2.7 heads through a year. The raising heads per farmer will not be so different from now. Therefore, the levelling up of the livestock management to get a higher income will become necessary in the future. The propagation of Holstein will be one of the promised type of such an intensive management.

The pasture growing in the tropic region has many problems. Hamata (Stylosanthes hamata) and ruzzy grass (Brachiaria ruzizinsis) are selected which are grown there already. But for places where the grassland establishment is very difficult, the introduction of fodder trees is recommended. After this establishment, fodder trees can stand against drought conditions.

4-5-7 Fisheries

In the study area, the number of small farm ponds (used for small irrigation and fish raising) is rapidly increasing recently. These small farm ponds have a possibility to change the present farming more diversified one integrated with fishery and horticulture. But to get an abundant water to these ponds is a difficult problem in this area.

Because of water shortage many ponds do not succeed in realizing the expected effect. According to the questionnaire survey, 40% of fish raising farmers stop raising fish by the end of December due to water shortage.

The most important factor in pond management is to keep the water. The runoff amount flowing into ponds should be checked at the time of pond construction. The monthly water level of a pond is estimated as shown in APPENDIX D Table D-27. According to this estimation, if the water storage starts in May the maximum water depth will be 170 cm in October, then decreases to 50 cm in April. Under same conditions, a pond of 0.16 ha (1 rai) needs the catchment area of 2.24 ha (14 rai).

Kinds of fish subjected to raising will be same as at present (several kinds of carp, tilapia etc.). They are tolerant to blakish water and oxygen deficit. Rice bran, kitchen garbage and residues from agricultural products are given as feed. The combination with polutry, swine raising is effective to utilize their droppings as feed for fish. To control diseases and propagation of unexpected fish ponds should be dried up once a year. The expected production of fish is 250 kg/rai. The gross income will be 5,000 to 7,500 Baht per one rai, better than the usual crop production.

The construction of fish ponds is not considered in this plan, but storage ponds proposed in the irrigation plan are avilable for fish raising.

4-5-8 Post-Harvest and Marketing

(1) Post-Harvest Treatment

In order to keep good quality and to increase the additional value of agricultural products, the post-harvest treatment of cocoon, vegetables, fruit and, animal products will be dealt with. The final products of polivoltine sericulture is raw silk or silk fabrics, and on the process from cocoon to fabrics several treatments are necessary. At present these treatments, are very primitive, improvement will be necessary for the cocoon drying and reeling methods. Vegetables, fruit and animal products also inquire proper post-harvest treatments such as cold storage and processing.

(2) Marketing

Marketing plan is proposed as follows:

1) A central market for Amphoe Phra Yun to be built near to the intersection of Muban Phra Yun as first priority for the distribution of products in the study area.

2) Five Tambon-markets as second priority for distribution of products in each Tambon. The construction of Tambon-markets is subjected to the Second Phase of project implementation. From this marketing plan, the distribution of products produced in the study area as well as goods from outside can be performed. This operation is proposed to be done by Amphoe/Tambon.

4-5-9 Supporting Services and Farmers' Organization

1) Agricultural Supporting Services

As aforementioned five farming systems, which will be the nucleus of agricultural development, are new techniques for the Northeast.

In order to obtain a fruitful result from the introduction of these new techniques, the understanding of farmers on these new techniques, is very important.

On the aspect of research institutions, DLD is carrying out researches on the agricultural development in this region, especially on the salt-affected lands, cooperation with DLD regarding this aspect, is necessary.

Besides, ADRC and KKU, as institutional bases for agricultural development in the Northeast which possess related basic data accumulated up to now, should be considered for supporting cooperation, especially in the field of crops and livestock.

There are many research institutions affiliated to the Ministry of Agriculture and Cooperatives in Khon Kaen city i.e. for paddy rice, upland crops, sericulture, livestock and inland fishery. Supports from these institutions on their corresponding field should be promoted.

On the aspect of agroforestry systems the combination of subjected crops and forest is very important. In order to success in these systems a cooperation from lated research fields on agriculture and forestry is necessary. The accumulation of study in this field is not so much at now.

The Agricultural Extension Office in Amphoe Phra Yun is promoting various agricultural projects, but its staff is few and the coverage

of related fields is limited. A combination between different related fields, should be emphasized accordingly.

2) Farmers' Organization

For off-farm activities, new cooperatives regarding related aspects i.e. sericulture, dressmaking, food-processing, livestock-raising etc. should be formed with technical and financial supports from the Technical Training facilities to be installed in the Amphoe office compound.

For technical support, these cooperatives and members can obtain related technical assistances from the technical staff of these facilities.

For financial support, a cooperation between the Technical Training Center. The Amphoe office and BAAC should be formed for financing prospectful businesses from these cooperatives.

For instance, from the recommendation of the Technical Training Center and with the approval of Amphoe-office, BAAC would finance these new cooperatives for operation.

This procedure, however, is subjected to a further study from these related institutions for an effective practice.

4-6 Reforestation Plan

The main purposes of forestry development are to supply wood production as well as to improve the enviromental condition of the area. Since the main portion of the study area, over 90 % belongs to small holders, the plan has definitely to incorporate them as the important componet. In particular to forest reserve land, where some parts have been encroached by adjacent farmers, the reintroduction of forestry will also pose many problems. Factors to be taken into consideration in preparing reforestation programme invoving the private sector and smallholders include in APPENDIX E Table E-1.

The forestation plan for this area can be subdivided into two major schemes, first is the scheme for forest reserve land, another is for non-forest reserve land or farmer-owned lands. The former will be dealing with enrichment planting in which indigenous and multipurpose tree species will be planted to help the natural regeneration of the forest. The latter will be dealing with various patterns of agroforestry system.

4-6-1 Enrichment planting Scheme

The enrichment planting means the introduction of valuable species in forest areas, where socio-economical species are lacking. The long term goal of enrichment planting often is to improve the species composition in a way, that natural regeneration methods can be adopted in the next generation. The area to be considered for the scheme is the forest reserve land where the natural regeneration of economical species are absent or inadequate. The target area for the scheme is in Pa Khok-Laung situating in the west direction of the project area close to Ban Sai Kai, Ban Nontum, Ban Non Khun and Phu Lomkao, covering the project area at about 583 ha.

(1) Method of Planting

The common form of enrichment practiced today is line enrichment. In this area, the following method is proposed.

At intervals of 10-20 meters, strips 2 meters wide are cleared of all vegetation. All desirables are spared. The lines should be run in east-west direction to obtained most favorable light conditions. On both sides of the 2 meter strip the lower stratum, which includes trees up to about 15 meters, is felled in a zone 5 meters wide. If a distance of 20 meters between the lines (from center to center) is adopted, there still remains a zone of 8 meters of untouched forest in

between. (see APPENDIX E Figure E-2.)

Planting is done on lines at a spacing of 4 meters. This amounts to 20-30 trees/rai.

(2) Species to be planted

The scheme is recommended planting with dipterocarps and other valuable species indigenous to the area.

The recommended species to be planted are Pra-du (Pterocarpus macrocarpus), Daeng (Xylia kerrii), Teng (Shorea obtusa), Rang (Pentacme suavis), Plaung (Dipterocarpus tuberculatus), Kra-bok (Irvingia malayana, Sadao (Azadirachta indica), and so on.

(3) Tending Operations

The success of line enrichment needs the tending operations during the first 5 or 6 years: weed control and protection from grazing damage, especially during the first two years. It is absolutely essential that the required funds for these tending operations are guaranteed at the time of planting, otherwise the funds spent for the establishment are spent in vain.

(4) Cost of Establishment

The cost of line enrichment for a 20 meter spacing between the lines covering the area of 16 ha (100 rai) can be estimated in APPENDIX E Table E-3.

(5) Constraint against the Implementation

To establish reforestation programme in the forest reserve land, the following constraints have to be aware, solved and prevented.

1) Forest land Encroachment

If the programme is executed, it will be encountered probably protest form the forest occupants in some area. Most of the occupants are from the adjacent villages with no exact number by this time. However, the programme can be run in the area about 32-80 ha (200-500 rai) in some pieces of the area if necessary. Of

course, the successful programme needs cooperation with the Royal Forest Department, especially Khon Kaen Divisional Forest Office.

2) Forest fire; Forest fire in this area is mainly caused by:

a. the fire spreading from burning agricultural residue of farmers adjacent to or in the forest area;

b. the fire for hunting; namely, farmers always burn weed and litterfall over the ground to ease capturing wild animals; and

c. the fire for browsing; the peoples in and adjacent to the area feed cattles especially cow and buffalo in forest land. Most of the ground vegetation are Ya-Phek (Arundinaria pusilla) and Ya-Kha (Imperata cylindrica). Farmers often burn them to induce fresh growth of palatable young shoots. This kind of activity always cause forest fire in this area.

Forest fire always occur during dry season from December to April. It destroys not only trees but also generates more soil erosion, disturbs soil and water properties. Therefore, fire protection measure is very necessary for the implementation of this forest reserve.

4-6-2 Agroforestry Scheme

The scheme, here, aims at improving woody status in non-forest reserve land as mentioned in 4-2 "Land Use Plan". The term "agroforestry" describes the integration of trees, drops and/or pasture on the same unit of land either simultaneously or sequentially. It can be translated into various patterns or practice. The selection and application of appropriate agroforestry patterns may result to sound management of natural resources and environments.

Various patterns of agroforestry system can be drawn up depending upon combination of trees and agricultural crops. Each pattern would satisfy a particular objective. The combination of the pattern may give rise to multipurpose agroforestry system. However, in accordance with compatibility to the area to be implemented, those patterns can be grouped into three agroforestry schemes.

1) Hedgerow intercropping
2) Shading/fodder tree planting
3) Multistory planting

(1) Hedgerow Intercropping Scheme

1) Objectives

This kind of agroforestry system aims at developing more sustainable agriculture on the upper area which is generally flat to gently rolling topography. It is a form of intercropping several rows of crops in between rows of fast-growing trees, fruit trees shrub. The scheme may be applicable for the combination of pattern tree + fruit (Af-F) and tree + cash crop (Af-C) as mentioned in 4-2 "Land Use Plan".

2) Planting Area and Guidelines

The target area for the hedgerow intercropping is the farmland on the upper area, 200-230 m of elevation. After the appropriate site is selected, the establishment can be done by the following steps (see also APPENDIX E Table E-2).

Step 1 Develop Contour Lines
Step 2 Establish Hedgerow of Leguminous Shrubs and Trees
Step 3 Cultivate Land for Agriculture Crops
Step 4 Plant Tree along Boarders and Long-Term Crops on Every Third Strip
Step 5 Plant Short-Term Crops on Every First and Second Strip
Step 6 Trim the Contour Hedgerows Regularly
Step 7 Manipulate Crop Rotation

3) Cost of Establishment

Cost of establishment for agroforestry farms differ depending upon activities of cropping pattern both in time and space. Assumed that hedgerows of trees are established on 1-rai plot, the special arrangement of trees and crops can be drawn as in APPENDIX E Table E-3.

It is estimated that the hedgerow intercropping of 1-rai plot costs about 1,350 baht for first year and decrease to 660,590,570 baht for the next three years. Cost and revenue for the model may be estimated in APPENDIX E Table E-4.

(2) Shading/fodder Tree Planting Scheme

1) Objectives

The scheme may be applicable for the combination of pattern tree;forage (Af-G) of which the objectives are :

- to increase grazing area as well as soil fertility,
- to produce forage, firewood and timber for vilage consumption

2) Planting Area and Guideline

The target land for this planting scheme is common land or public land of villages. The forage crops such as Stylosanthes hamata are intercropped between row of which lie in the East-West direction, with the tree spacing of 2 × 8 m, if the trees to be grown for timber. In the first three or four years of plantings, the forage crop should be harvested and brought to feed animal at outside the area to prevent tree damage from cattle. After four or five years of planting, cattle are allowed to graze in the plantation.

If fruit trees are preferred, tamarind or mango can be combined with forages, wider spacing either of 8 × 8 m or 8 × 10 m should be applied. Boarder planting can also be included in the scheme.

3) Tending Operation

At the early stage of tree planting, intensive care have to be exercised especially when grazing is allowed to be done within the planting area. Therefore, fencing have to be made to protect damage from cattle browsing as long as the planted trees are not completely survived and able to resist such damage. In case of the large common land, living fences made of spine trees like Pithecellobium dulce should be established so that the carrying capacity of grazing land can be control.

4) Cost of Establishment

The cost of establishment for 100 trees per rai intercropped with forage grass can be estimated in APPENDIX E Table E-5. Shading/fodder tree planting of 1-rai costs about 1765 baht for the first year and decrease to 290,150,150 baht for the next three years.

(3) Multistory Planting Scheme

1) Objectives

Multistory planting is the mixture of several patterns of agroforestry. It will yield higher economical and ecological return than any pattern of agroforestry, especially, if the mentioned agroforestry pattern is for subsistence or semi-subsistence and it is not commercial. Main idea of the scheme in particular to this area is to create the performance of marginal farmland to be most like that of natural forest. So, overall environment in the area will be improved if they are developed.

2) Planting Guide and Cropping Model

Since the multistory planing have diversed patterns depending upon several factors both ecological and socio-economic. So, a specific model should be set up for further consideration and development.

A possible cropping model for multistory planting in this area is drawn up as APPENDIX E Table E-6 and Figure E-5.

In addition, trees species for timber or fuelwood should be planted as the boarder of the plots. Minimum size of the plots should be 5 rai.

3) Cost of Establishment

The cost of establishment for 1 rai is estimated at 1,740 baht for the first year and decrease 500,200,200 baht for the next three year. (see APPENDIX E Table E-7).

4-6-3 Implementing Programme

As aforementioned, reforestation programme for improvement of the forestry situation in this project area consists of two major scheme. For further implementation, the following items should be considered.

(1) Area to be Implemented

The possible area for the programme are forest reserve land and non-forest reserve land. Forest reserve land is part of Pa Khok-Laung

situating in the west direction of the project area (see APPENDIX Figure E-1). The total area in this place is about 583 ha. However, 320 ha may be possible for the implementation in this area.

For non-forest reserve land, they comprise farmers' own land and common land. These kinds of land are expected for agroforestry implementation, that is, hedgerow intercropping, shading/fodder tree planting as well as multistory planting.

Scheme	Estimated area(ha) to be involved
1. Enrichment planting	320
2. Agroforestry	
2.1 Hedgerow intercropping	6,720
2.2 Shading/fodder trees planting	7,420
2.3 Multistory planting	1,690
Total	16,150

From the figure above, it can be seen that the area to be reforested (16,150 ha) is about 47% of total project area (34,150 ha).

(2) Beneficiaries

For successful implementation, all beneficiaries have to realize their respective performances as follows:

- In forest reserve land, forest department through Khon Kaen Divisional Forest Office should clear the possible controversy from existing forest occupants before the scheme is executed.

- In non-forest reserve land, sheriff, chief of Tambons, chief of villages, farmers and extension workers have to be collaborating through the support of implementing agencies-DLD.

- Intensive planting survey has to be carried out in collaboration between extension workers and farmers involved.

(3) Supportive Operation

Since the farmers concerns mainly on the agricultural practice, they are not familiar with tree-crop agriculture or agroforestry, so they may not readily accept such kind of programme. The following have to be exercised,

- Provision of guidance and support through extension services, that is, education of the people, technical advice and technical inputs, grassroots training,

- Demonstration and pilot projects,

- Encourage producer groupings (cooperatives etc.)

In addition, nursery operation is necessarily established to produce seedlings or distributing to interested farmers. Planting operation as well as maintenance operation have to be set up to ensure successful programme.

4-7 Rural Infrastructure Plan

4-7-1 Irrigation and Drainage Plan

(1) Measures on Irrigation for Salt-Affected Lands

Irrigation plan in the study area should be established, considering present specific characteristics prevailing in this salt-affected land. As seen in the area, paddy fields have a function to prevent salt accumulations through natural leaching. From this point of view, paddy field irrigation is desirable to be conducted as much as possible. However, in case high salinity intrusion into paddy fields brought by irrigation water or natural water, damages on crops will not be avoided. Therefore, it is important to provide paddy field with high and solid levees and to check and manage water quality of stored water at irrigation facilities. In upland irrigation, leaching water is requisite to be supplied in addition to normal irrigation water requirement during irrigation.

Most of storage ponds scattered in the study area are not used for irrigation. Water levels of these ponds are lower than elevations of farm lands and pumping facilities are not provided. As available land and water resources is limited, irrigation water should be planned considering multipurpose use.

(2) Irrigation Plan

Location map and irrigation areas are planned as shown in Figure 4-11 and Table 4-5.

1) Pumping Irrigation in Chi River and Natural Swamps

Existing pumping stations in Chi river and swamps were working only for half of the year. This is due to the lowering of river water level and insufficiency of operation and maintenance of main canals. When construction of the Mahasarakam Diversion Weir is completed at downstream of Chi river, the river water level will be raised up.

Cropping calendar and water consumptive use applied for this irrigation plan are same as those in the pilot area.(refer to 7-3-4.) The total irrigation area is planned at 1,234 ha.

2) Irrigation Plan for the Three River Basins

In the river basins with small watershed area, the river water

shall be stored as much as possible in order to keep irrigation water. Dam sites suitable for store and construction are hard to be found in the study area. In addition, it is difficult to store river water in the river bed.

Considering the above conditions, irrigation plan for this area is composed of irrigation systems with ponds connecting the existing or newly constructed weirs. Required facilities are as follows:

Weir	: Construction 6 places, Improvement 11 places
Storage Pond	: Construction 27 places, Improvement 3 places
Canal	: Headrace Canal, Secondary Canal, Tertiary Canal
Pump	: 50 places

Applied cropping calendar and water consumptive use are same as those in the pilot area. The total irrigation area is planned at 2,480 ha.

(3) Water Management Plan

According to the scale of irrigation facilities and irrigation area, daily management is required to be made by Water User's Group organized by beneficial farmers. Public organization will support the Water User's Group for operation and management when large-scale improvement works with high technics and capital are needed.

If the Water User's Group is associated by farmers, users' conditions, culture, social customs and manners etc. should be taken into consideration. This water management will basically accord with the Muang Fai System which has been carried out in Northern Thailand more than 300 years.

TABLE 4-5 Brakedown of planned Irrigation Area in the Study Area

1. Pumping Stations

		Gross (ha)	Net (ha)
NEA pumping station	No.1	210	189
	No.2	307	277
	No.3	107	96
DCP pumping station		610	549
Total		1,234	1,111

2. Yai river basin

	Gross (ha)	Net (ha)
1)	170	136
2)	240	192
3)	200	160
4)	145	116
5)	152	122
6)	176	158
Total	1,083	884

3. Yang river basin

	Gross (ha)	Net (ha)
1)	158	134
2)	166	141
3)	57	47
4)	110	99
5)	133	106
6)	159	127
Total	783	654

4. Phra Nao river basin

	Gross (ha)	Net (ha)
1)	91	73
2)	157	126
3)	132	119
4)	111	89
5)	124	99
Total	615	506

5. Total

Gross 1,234 + 1,083 + 783 + 615 = 3,715 ha

Net 1,111 + 884 + 654 + 506 = 3,155 ha

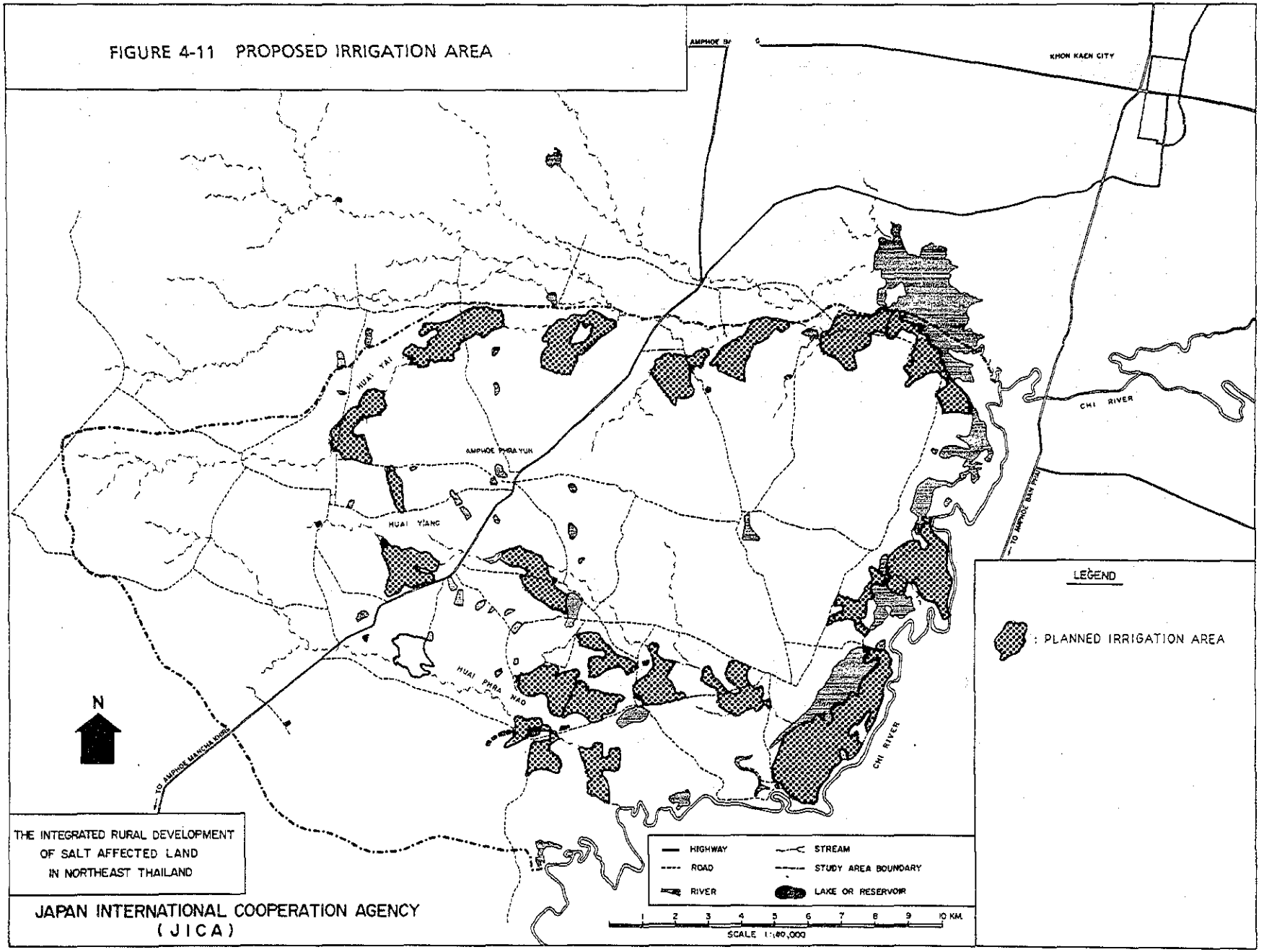


FIGURE 4-11 PROPOSED IRRIGATION AREA
AMPHOE BA
KHON KAEN CITY
HUAI YAI
AMPHOE PHRA YUK
HUAI YIANG
HUAI PHRA MAO
CHI RIVER
TO AMPHOE BAN PHAI
TO AMPHOE MANCHA KHIRI
N
LEGEND
: PLANNED IRRIGATION AREA
HIGHWAY
ROAD
RIVER
STREAM
STUDY AREA BOUNDARY
LAKE OR RESERVOIR
1 2 3 4 5 6 7 8 9 10 KM.
SCALE 1:400,000
THE INTEGRATED RURAL DEVELOPMENT OF SALT AFFECTED LAND IN NORTHEAST THAILAND
JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

(4) Drainage Plan

1) Drainage Area

The drainage area covers two sub-areas (D-1 and D-2 area) with a total area of 5,000 ha, as shown in Figure 4-12. The D-1 area of 1,500 ha is classified as moderately salt-affected area (Class 2) and D-2 area of 3,500 ha is classified as slightly salt-affected land (Class 3). The drainage area will be used for paddy fields in land use planning.

2) Basic Concept

a) This plan covers only groundwater.

b) Intrusion of saline groundwater from upstream into the drainage area must be prevented. Interceptor drain facilities will be provided at the opening portion of drainage area and the end of the interceptor drain will be connected to the evaporation ponds.

c) The drainage area must also be provided with an adequate field drain network where drainage water passes through, washing out the accumulated salts. Since leaching water is not available, rainwater will be used for natural leaching. Such field drain network must also ensure that the water table is maintained at a level, and does not cause capillary rising.

d) D-1 area should be put higher priority than D-2 area for implementation of facility construction.

3) Facilities

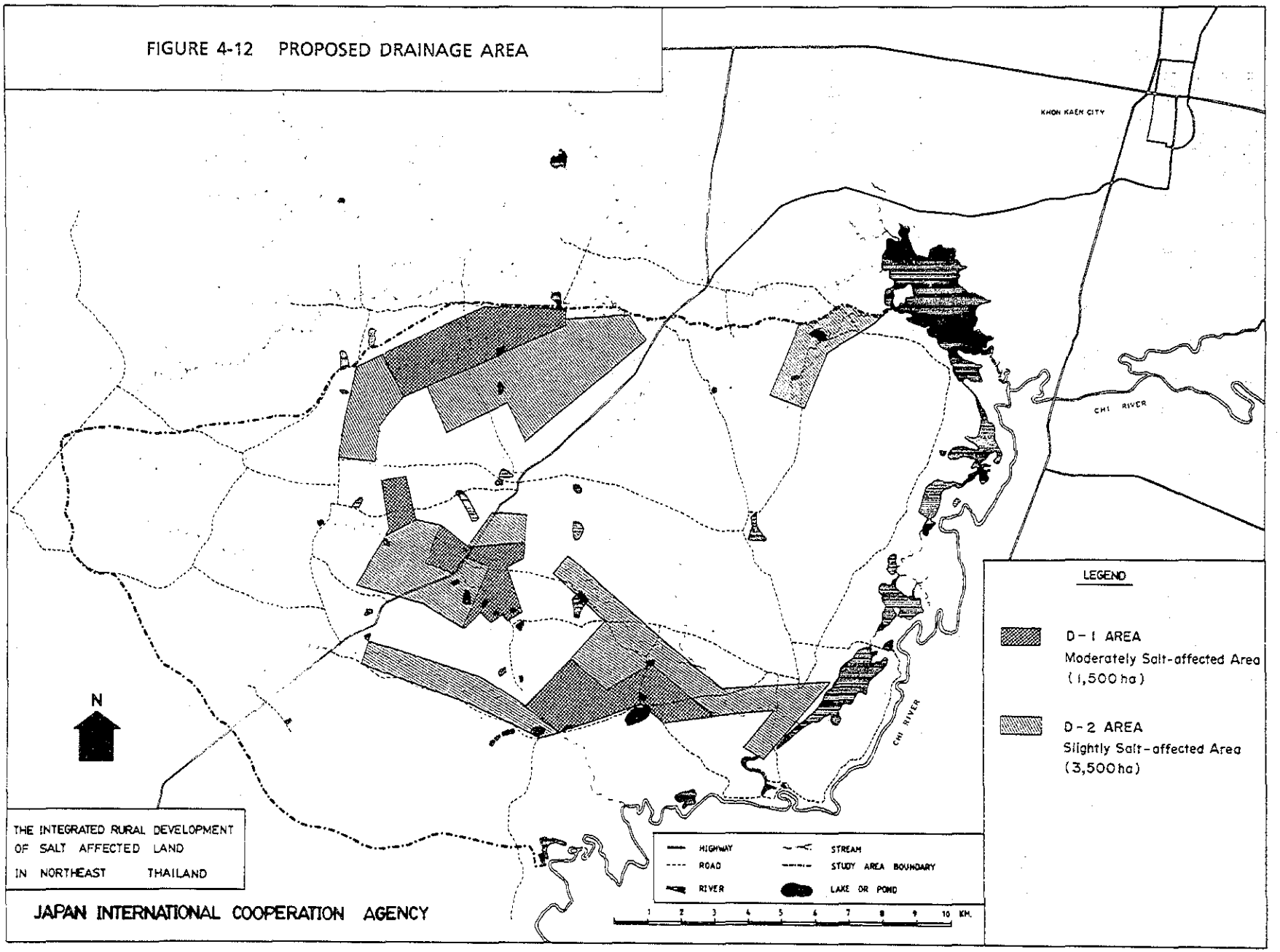
a) Open drains will be installed.

b) The slope and depth of the drains will be designed by using gravity flow, thus pumping will no longer be necessary.

c) Interceptor drain lays out perpendicularly to the running direction of the river. Its depth is approximately 2.0 meters below ground level. Its end is equipped with a gate which opens in rainy season and closes in dry season.

d) Evaporation pond will be divided into two plots of 400 sq.m (20 m × 20m), surrounded by drain ditch. Saline water will be flowed into evaporation pond from interceptor drain.

FIGURE 4-12 PROPOSED DRAINAGE AREA



e) The field drains lay out perpendicularly to the running direction of the river, and are set 200 m apart. Its depth is approximately 1.2 meter below ground level. The gates will be installed at every 500 m to control water level in the field drain.

Figure 4-13 shows the general scheme of drainage.

4-7-2 Rural Road Plan

(1) Proposed Routes

The following three routes are planned as the improvement of rural roads in the study area.

1) Route No.1 : to link the ARD bridge over the Chi river to Ban Phra Yun; existing road improving, 16 km length

2) Route No.2 : to link Ban Phra Yun to Ban Hua Bung; exsisting road improving, 12 km length

3) Route No.3 : to link the Highway Department bridge over the Chi river to the ARD road No.11039 in Ban Nong Pho; newly constructing, 3 km length

(refer to Figure 4-14)

(2) Improvement Standard

Improvements are planned for these three roads with a laterite pavement with 6-meter width as for ARD standard roads. The height of road embankment is proposed at 0.6 m to 1.0 m in order to prevent flooding during the rainy season.

(3) Bridge Construction

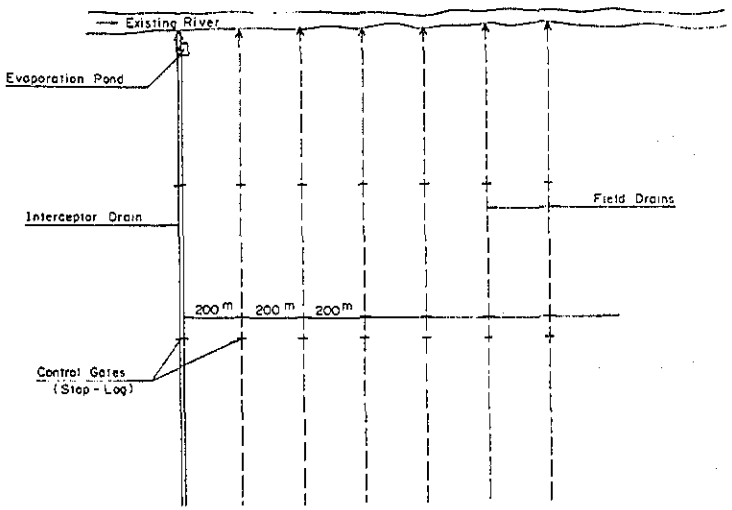
Three bridges on the route No.2 are to be repaired. These bridges will be made of R.C. structure with a 20 m length considering the crossing river width.

(4) Improvement in Village Areas

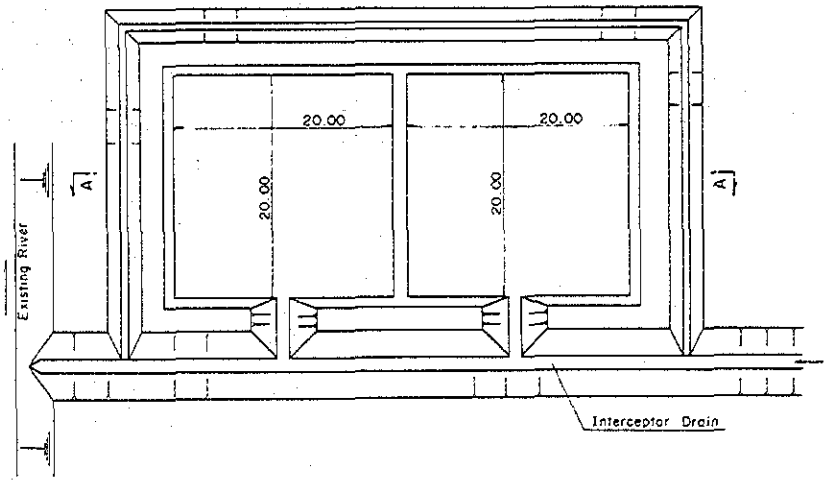
Main rural roads are to be paved for portions passing through village areas by asphalt with the same width of recent roads due to the limitation of land. One or two roads are subjected to be paved for one village.

FIGURE 4-13 GENERAL SCHEME OF DRAINAGE

DRAINAGE LAYOUT

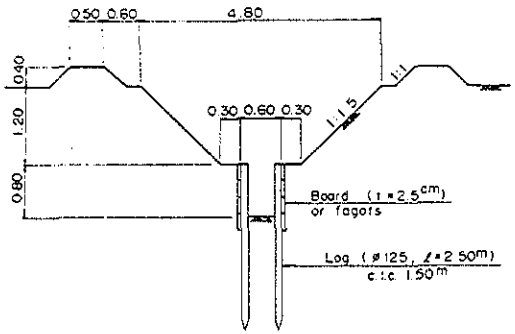


Evaporation Pond

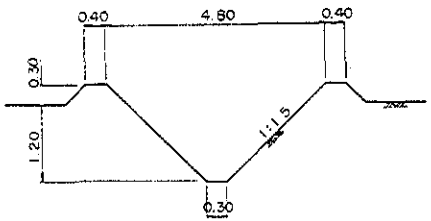


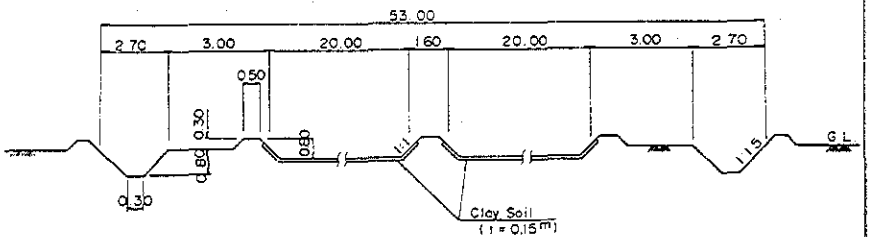
PLAN

Interceptor Drain



Field Drain

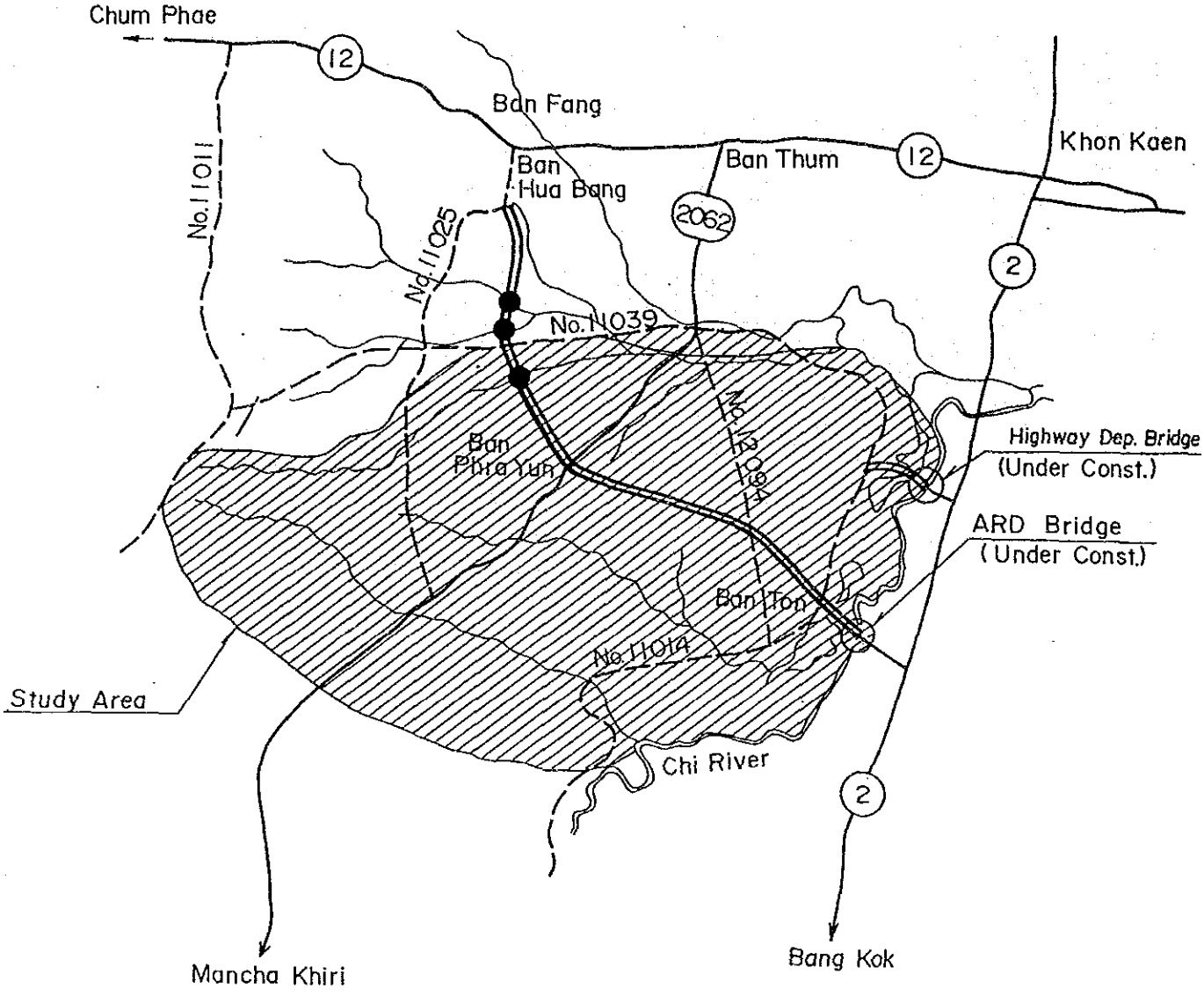




SECTION A-A

THE KINGDOM OF THAILAND MINISTRY OF AGRICULTURE AND COOPERATIVES DEPARTMENT OF LAND DEVELOPMENT
THE MASTER PLAN STUDY ON THE INTEGRATED RURAL DEVELOPMENT ON SALT-AFFECTED LAND IN NORTHEAST THAILAND
DRAINAGE FACILITIES
DWG. No. 3
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

FIGURE 4-14 RURAL ROAD IMPROVEMENT



LEGEND

- National Highway
- ARD Road
- Proposed Rural Road
- Proposed Bridge

(5) Others

Earth filling for road embankment will be planned at topographically low parts to prevent roads from flooding during rainy season. Besides, drainage culverts will be provided under these portions.

4-7-3 Rural Water Supply Plan

(1) Planning Items

As for the rural water supply in the study area, the following facilities are planned.

1) Facilities for drinkinng water supply to two villages, Pa San 1 and 2. These two villages require drinking water seriously.

2) Facilities for drinking water supply to two villages, Phra Yun and Hua Bung, in the center of Amphoe Phra Yun and water supply to facilities in the Amphoe-office compound.

3) Facilities for washing water supply to the Phra Yun Central Market.

Developing the rural water supply widly in the study area is not adequate due to following reasons.

1) According to the result of water quality tests, groudwater in this area is not suitable for drinking except the quaternary aquifer laying under the western hill area in the study area.

2) Surface water quantity of this area is not enough for supplying irrigation and domestic water use in the whole area.

3) Villagers in this area can collect rain water in concrete jars/tanks for drinking purpose at present. In case of water shortage during the dry season, they can use water from nearby shallow wells for drinking, except two villages Pa San 1 and 2.

(2) Facilities

1) Facilities for drinking water supply

a) Villages Pa San 1 and 2

Population: Since the limit of water resources, only betterment at minimum of the present

condition is planned.
The present population (about 1,000 peoples, 200 families) is adopted.

Water resource: The groundwater (the Quaternary aquifer; Pamo gravel bed) in hilly area located in the west of these villages is pumped up by means of 2 wells.

Available water (designed lifting water):
48 cu.m/day (8 hours/day) assumed by the pumping test.
48cu.m × 1/2 = 24 cu.m/day/well
481/day/person

Depth of the well: 30m

Designed water level: GL - 20 m

Supply system: Deep well (Submerged pump)
→ Distribution tank
→Public water taps

b) Two central villages in Amphoe Phra Yun

Villages: Ban Phra Yun and Ban Hua Bung

Population: Present population of about 2,800 persons

Supply amount per person:
45 1/day/person is proposed reffering to the daily consumption amount in Ban Nong Khu where the water supply system is completed.

Proposed daily supply amount:
45 1/day× 3,800 = 124 cu.m/day

Water resources: The Phra Yun pond, where the water quality is better than the ground water in this area and the supply of water is available by precipitation and from the river Yai, is adopted.

Supply system: Pond (pump) → Purification facilities → Public water taps

2) Water Supply System for the Phra Yun Amphoe Office Compound

Subjected Facilites: Phra Yun Amphoe Office and Training Facilites

Proposed daily supply amount: 30 cu.m/day

Water resouce: The Phra Yun pond

Supply system: Using the distribution system for two villages, Phra Yun and Hua Bung, the water is distributed to subjected facilities.

3) Supply system of washing water to the Phra Yun Central Market

Proposed daily supply amount: 30 cu.m/day
Water resouce: The Phra Yun pond
Supply system: Same as 2).

4-7-4 Rural Industry Plan

Based on potentials of local production (agriculture, livestock and fisheries) and especially, the development of sericulture, the aspect of rural industry should be emphasized for enhancing the value added of these products and creating job-opportunities for local inhabitants, especially off-farm jobs.

Two kinds of rural industry, "Madmee" fabrics and food processing, therefore, are taken into consideration.

Two training factories one for "Madmee" fabrics and another for food processing, are subjected to be established in this plan.

4-8 Social Service Plan

4-8-1 Technical Training

(1) Planning Background

Since there are a considerable lack of off-farm job-opportunities for generating household incomes and a chronic situation of idle labor forces, especially during the dry season, in the study area local inhabitants should be trained for prospect off-farm jobs apart from their farming works. Besides, along with the development of sericulture and crop-diversification, works for value-added to these potential products should be considered accordingly. Technical training for these off-farm works, therefore, is subjected to the development plan.

(2) Development Plan

Following three components are considered necessary for implementing this development plan.

* Construction of training facilities
* Installation of Equipments
* Formation of a training and administration staff

The training facilities would be made into three building for administration and training rooms, factory for training handicraft works and factory for training food-processing. Furniture office equipments and training equipments will be installed sufficiently in these buildings for efficient activities. A competent staff for administration and framing should be formed accordingly in order to function this development plan.

4-8-2 Rural Communication

(1) Planning Background

In the study area, facilities and programmes for communications between local inhabitants, especially for young farmers, are considerably deficient. Life in the rural area, therefore, should be activated on this aspect by means of sports and recreation activities.

(2) Development Plan

Two following subjects are considered for this aspect .

* Installation of a public sports ground
* Formation of recreation-programmes

Details of the public sports ground are as follows.

1) A soccer ground with a meeting-hall for communication-purpose
2) A 4m width running track around the soccer ground
3) A 100-seat concrete stand with roof locker-room and shower & WC.
4) Sport equipments (1 set)
5) Righting installation (1 set)

Various sports an theater-programmes should be planned and carried out by a recreation committee formed by representations of young farmers in each Tambon and sponsored by Amphoe-office.

4-9 Project Cost

4-9-1 Component of Project Cost

The Component of project cost consists of construction, procurement of equipment, agricultural extension, land acquisition, administration, consulting services, and physical and price contingencies.
The construction works consist of irrigation and drainage facilities, rural road, rural water supply facilities, reforestation and social service facilities. Those works will be executed on a contract basis.

4-9-2 Project Cost

The project cost was estimated at a 1991 price level based on the work quality, implementation schedule, current unit rates employed in DLD, ARD and RID, physical contingencies and price escalation. Bases of estimations are mentioned at 7-3-9 in detail.

The total project cost amounts to 1,255 million Baht, of which 570 million Baht are local currency component and 685 million Baht are foreign currency component. The project cost is summarized as shown in Table 4-6.

Annual project cost is based on the project implementation schedule, and the summary is shown in Table 4-7.

Table 4-6 Summary of Project Cost

Description	Cost (× 1,000 Baht)		
	L/C	F/C	TOTAL
1.Construction cost			
(1) Irrigation facilities	209,946	357,028	566,974
	(33,955)	(56,861)	(90,816)
(2) Drainage facilities	52,850	10,500	63,350
	(8,669)	(1,723)	(10,392)
(3) Rural roads	23,726	18,949	42,675
	(1,494)	(2,076)	(3,570)
(4) Rural water supply facilities	3,300	7,276	10,576
	(3,300)	(7,276)	(10,576)
(5) Reforestation	52,075	-	52,075
	(6,224)	(-)	(6,224)
(6) Social service facilities	25,936	34,749	60,685
	(22,106)	(30,919)	(53,025)
Sub Total	367,833	428,502	796,335
	(75,748)	(98,855)	(174,603)
2. Equipment	1,742	34,853	36,595
	(1,742)	(34,853)	(36,595)
3. Agricultural extension service	6,453	3,917	10,370
	(2,533)	(2,756)	(5,289)
4. Land acquisition	12,786	-	12,786
	(1,784)	(-)	(1,784)
5. Project administration	19,112	4,778	23,890
	(8,381)	(2,095)	(10,476)
6. Consulting service	4,048	59,133	63,181
	(1,399)	(20,428)	(21,827)
Total 1. ~ 6.	411,974	531,183	943,157
	(91,587)	(158,987)	(250,574)
7. Physical contingency	41,197	53,118	94,315
	(9,159)	(15,898)	(25,057)
Total 1. ~ 7.	453,171	584,301	1,037,472
	(100,746)	(174,885)	(275,631)
8. Price contingency	116,364	100,987	217,351
	(19,108)	(20,679)	(39,787)
Grand total	569,535	685,288	1,254,823
	(119,854)	(195,564)	(315,418)

Note; The values in parentheses are those of the Pilot Area.

Table 4-7 Annual project Costs

Year	Cost (×1,000 Baht)		
	L/C	F/C	TOTAL
1st.	6,797	35,559	42,356
2nd.	105,035	143,628	248,663
3rd.	162,302	165,762	328,064
4th.	118,034	115,654	233,688
5th.	91,783	113,440	205,223
6th.	85,584	111,245	196,829
Total	569,535	685,288	1,254,823

4-10 Environmental Aspect

4-10-1 Physical Resources

(1) Salt-Affected Soils

Salt-affected soils which accumulate soluble salts in the surface are found partly in the study area. The severely salt-affected lands are barren at present after their abandonment from cultivation. Countermeasures for such soils to improve natural environment in the study area will be undertaken in both short-term and long-term measures.

- Short-term measures

  Severely salt-affected area will be used for pasture land covered by salt tolerant grasses. Slightly to moderately salt-affected area will be improved through natural leaching and cultivation practices by provision of drainage facilities, application of land leveling, mulching, organic matter application, deep plowing and introduction of salt-tolerant varieties.

  Those measures will not affect the environment of the area but, at the same time, regenerate vegetation.

- Long-term measures

  Reforestation under agroforestry system is considered for potentially salt-affected areas.

(2) Rivers, Streams and Ponds

Intrusion of saline groundwater from upstream into the drainage area should be prevented to relief the farmland from the expansion of salt-affection. Interceptor drain facilities will be provided at the opening portion of drainage area and the end of the intercepter drain will be connected to evaporation ponds. The field drain networks are sufficiently installed that the water table will be maintained at a level, making no capillary rising.

Rivers, streams and ponds located in the downstream of the study area will not be affected by this drained water containing salts under the above implementation and drainage treatment.

(3) Forestry

The real effects of forest destruction lie in its negative impact of creating intermittent flood and famine. The forest situation in the

study area is in a critical condition in respect to its performance for being as a source of wood supply and, at the same time, as means for environmental protection.

Generally, forest lands are not used only for environmental protection but for providing opportunities to people in the study of nature and for recreational purposes.

In the development plan, the natural forest should be kept in the study area in order to protect damages to the land caused by surface runoff and soil erosion. The agroforesty scheme is requisite to the sustainable development being proceeded in this study with a environmental soundness such as soil and water conservation.

4-10-2 Human Use Value and Quality of Life

(1) Irrigation

The development of water resources for irrigation concentrates upon the utilization of water available within the study area. This small scale development has a merit to make local people participate in development but not to bear large scale land acquisition and submersion under water.

(2) Rural Water Supply

In the study area people collect rain water in ceramic/concrete tanks for drinking. To get clean and stable water is one of major subjects on public health aspect.

Pa San 1 and 2 villages are suffering from serious defficiency of drinking water. Groundwater existing around these villages are available for use of drinking water in it's quality and amount. This water supply plan serves for improving public health conditions.

(3) Social Service

A multi-purposed sporting and technical training facilities will be provided in the study area. Functions of such facilities will raise up rural communication and quality of life.

(4) Rural Industry

Promotion of rural industry is subjected to employ idle labor-forces and generate incomes in the area. This makes a healthy rural society for future generation.

CHAPTER 5. PROJECT IMPLEMENTATION PROGRAMME

5-1 Organization and Management

5-1-1 Project Implementing Agencies

(1) Administrative Coordination and Project management

In the context of implementing the Integrated Rural Development of Salt-Affected Land in the Northeast Thailand, following committees have to provide necessary directives and strong commitments, to guide and to coordinate actions of governmental agencies concerned both in Bangkok and in Changwat in order to ensure the successful performance of the Project.

1) Ministerial Level Committee

Ministerial Level Committee will be chaired by the Permanent Secretary of the Ministry of Agriculture and Cooperatives. Director General of DLD will be a secretary of the Committee.

2) Sub-committee for Project Level

In addition to the Ministerial Committee, the Sub-committee will continue to prepare budgets and reports for Ministerial Committee. It is also expected that the existence of an agreed plan of action at the outset will contribute to field level coordination where required. Sub-committee will be chaired by Director-General of DLD.

3) DLD Working Committee

The DLD Working Committee will be set up in addition to the Ministerial Committee and Sub-committee.

(2) Project Implementing Agencies

It would be assumed that the five governmental agencies under the proposed committees should be responsible for the following functions.

1) Department of Land Development (DLD), MOAC

Planning and construction of irrigation and drainage facilities.

2) Office of Accelerated Rural Development (ARD), MOI

Planning and construction and O/M of rural road.

3) Royal Forestry Department

Planning and implementation of reforestation.

4) Amphoe Office, MOI

Planning and construction of rural water supply and social service facilities.

5) Department of Agricultural Extension (DOAE), MOAC

Assistance in organizing Farmers' Groups.

As mentioned in 4-9 "The Project Cost", major construction works are irrigation and drainage facilities, for which DLD will be the executing agency. In order to implement the project smoothly and satisfactorily, organization of DLD should be strengthened in both software and hardware with technical and economic assistance of experts including foreign one during the project implementation.

5-1-2 Implementation Schedule

After completion of fund arrangement for the project, construction works covering detailed design and land acquisition will be carried out. The construction works are composed of irrigation and drainge facilities, rural roads, rural water supply facilities, reforestation, and social service facilities.

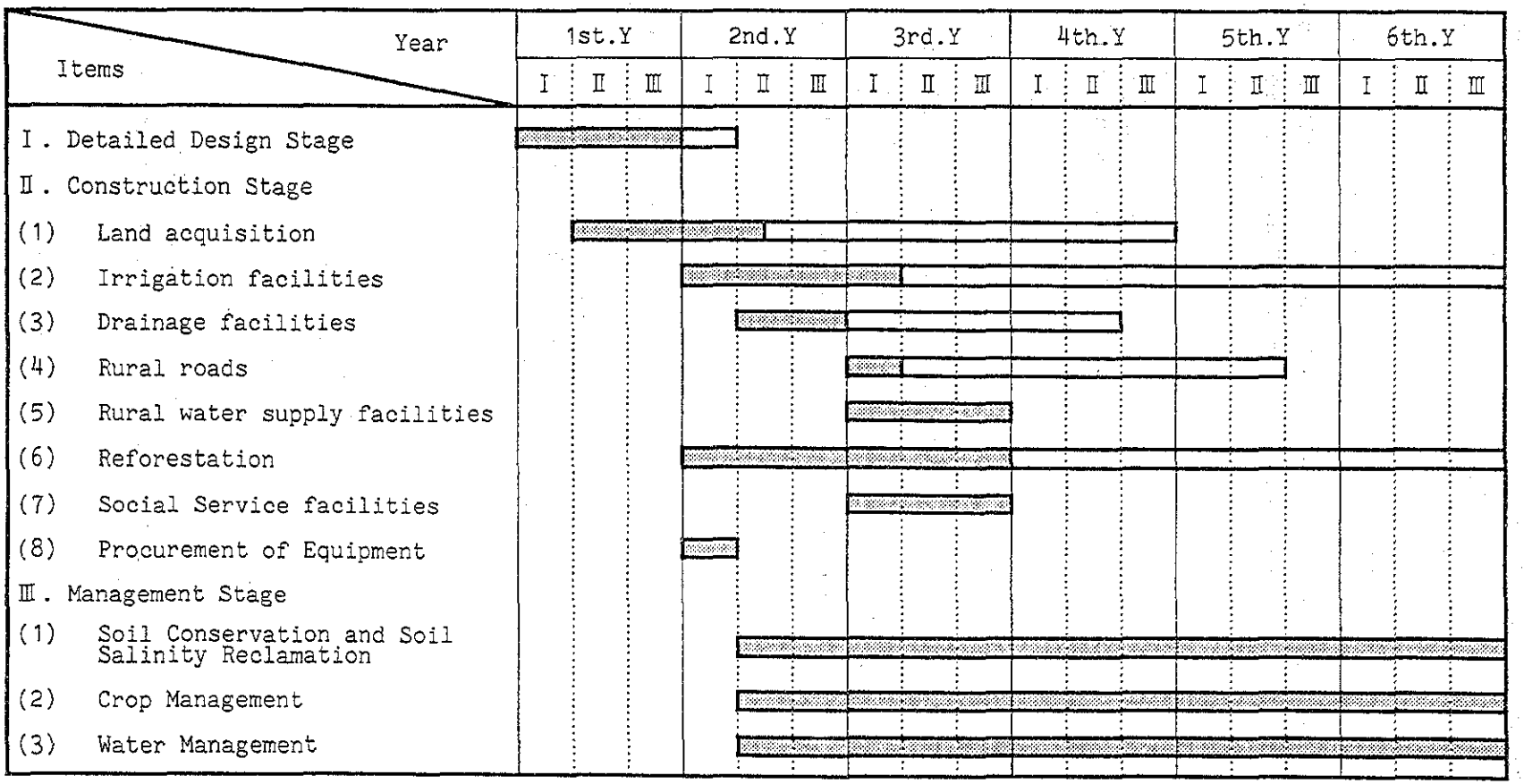
The construction work of the Pilot Area will be implemented first, followed by related works for the Study Area.

Since these construction works require a high construction cost, it should be considered to be implemented with grant or/and loan from an international financing agency or budget from the Government of Thailand. These construction works will be executed on a contract basis.

Based on the project scale, the implementation period of these construction works in scheduled for six years including detailed design.

The project implementation schedule is planned as shown in Figure 5-1.

Figure 5-1 Project Implementation Schedule for the Study Area



: Portion including the schedule for the Pilot Area

5-2 Operation and Maintenance

5-2-1 Responsible Agency

(1) Irrigation and Drainage

Irrigation and drainage facilities will be maintained and operated by Water User's Group organized by beneficiary farmers through the support of DLD.

(2) Rural Road

ARD will be responsible for operation and maintenance for rural roads and bridges.

(3) Rural Water Supply

Water supply facilities for villages will be maintained and operated by Water User's Group organized by beneficiaries with guidance and assistance from Tambon Office. Water supply facilities for the Amphoe Office Compound and the Market will be maintained and operated by Amphoe Office.

(4) Reforestation

In reserve land, RFD will be responsible for operation and maintenance. In no-forest reserve land, sheriff, chief of Tambons, chief of villages, farmers and extension workers have to be collaborated through the support of DLD, RFD, DOAE. Producer groupings will have to be responsible for planting operation as well as maintenance operation.

(5) Social Service

Technical training and communication facilities will have to be maintained and operated by Amphoe Office.

5-2-2 Operation and Maintenance Cost

After the construction works are completed, the following cost will be born every year for operation and maintenance of the project.

Table 5-1 Annual Operation and Maintenance Costs

Description	Cost (×1,000 Baht)
(1) Maintenance cost for facilities	3,411
(2) Operation cost for pumps	7,521
(3) Administration	4,430
Total	15,362

CHAPTER 6. PROJECT EVALUATION

6-1 Introduction

(1) Method of Evaluation

The economic evaluation has been made by calculating an economic internal rate of return (EIRR) in which a project cost and a tangible benefit are to be calculated by applying an economic price (accounting price). On the other hand, a sensitivity analysis is one of method to check the risk of the project to be affected by change of key factors. Project cost and benefits were estimated for 50 years as the project life by constant price as of 1990. The prices to be applied for this analysis is derived on the basis of market prices of the respective good and service.

(2) Prices

All prices to be applied have been estimated on the basis of the recent available information and data so far obtained as of the 1990 as mentioned in Chapter 7, 7-3-10.

6-2 Financial and Economic Cost

The total of project capital cost for the study area is estimated at 1,037.5 million Baht in financial value, which is equivalent to 901.7 million Baht in economic value. The project cost of financial base was converted to the border price by applying the standard conversion factor.

The conversion factor is also applied to the conversion for economic value of operation and maintenance cost. The operation and maintenance cost with project reaches 15.4 million Baht per year on a financial base and 14.1 million Baht per year on an economic base.

On the assumption that the Project will be started in 1993, annual project cost is tabulated as shown below ;

Financial and Economic Cost

(unit: million Baht)

Year	Capital Cost		O & M Cost		Total Project Cost	
	Financial	Economic	Financial	Economic	Financial	Economic
1992	–	–	–	–	–	–
1993	39.3	31.6	–	–	38.3	31.6
1994	219.7	190.3	–	–	219.7	190.3
1995	278.9	242.3	–	–	278.9	242.3
1996	190.5	164.6	–	–	190.5	164.6
1997	160.9	141.6	–	–	160.9	141.6
1998*	149.2	131.3	–		149.2	131.3
1999~	–	–	15.4	14.1	15.4	14.1

6-3 Project Benefits

6-3-1 Quantifiable Benefits

From the national socio-economic point of view, various kinds of directly and indirectly associated benefits would be created from the Project. And, the project benefits consist of quantifiable and unquantifiable benefit.

The quantifiable benefit of the Project is shown in the following and unquantifiable benefit is mentioned in 6-3-2.

Project Benefits

Items	Benefits (million)
Agriculture (include Livestock)	78.1
Fishery	4.7
Domestic Water Supply	0.8
Rural Road	3.7
Total	87.3

6-3-2 Socio Economic Impacts of the Project Implementation

In addition to the above-mentioned benefit, the following benefits are expected to be realized with the Project.

1) Benefits at the National Level

- The Project will improve the rural people's living standard through the proposed intense water use for agriculture, fishery and domestic

need with keeping good balance of saline groundwater and life of local peoples.

- The implementation of the Project is of the effective socio-economic development type, not only for promoting rural welfare but also alleviating the disparity in living standards between the regions.

2) Benefits at the Project Area Level

- Many villagers will have the employment opportunity not only in the construction and O & M of the Project but in the farming works.

- Through cropping, fishing, and rural water use in the new reservoir, the Project will enable the beneficiaries to keep close communication with each other as well, resulting in giving fair knowledge of rain-fed agriculture, irrigation, crop cultivation, fish culture, health and savings as well as the promotion of village cooperative activities as a whole.

- The new improved road network will function also as a connecting road network among villages and between villages and urban areas in various purposes such as communication, communication of employees, students and peoples, public services and commerce. It will benefit not only the farmers but also the whole residents of the Project Area, improving the social and economical environment.

- With the Project, the water supply will be more conveniently utilized for drinking, bathing and washing especially in the dry season.

- The project will liberate the beneficiaries especially women and children from the cruel daily chore of bringing water through the establishment of a stable water supply.

- Through supplying safe water, the project will enable the beneficiaries to prevent the spread of water borne diseases. Moreover, this will improve the public health in the Project Area.

- With the project, the provided hydrant will be more conveniently utilized for fire fighting. Provision of hydrants will certainly wave many lives and house belongings.

- The Project aims to realize the maximum return to the Project to be shared by the largest possible number of the village residents. As a result, the benefits accrue not only to the agricultural households but the non-agricultural households in the Project Area.

6-4 Economic Evaluation

6-4-1 Comparison of Cost and Benefit

The Economic Internal Rate of Return (EIRR) of the Project is estimated at 8.1 percent. Judging from the fact that the opportunity cost of capital in Thailand is 10 to 15 percent, EIRR of the Project is low as the economic index. The comparison of benefit and cost was made without taking into account the cost needed for salt wash-out. The alternative EIRR of the Project is estimated at 10.5 percent, and it can be compared with the economic indexes of the other agricultural development projects.

6-4-2 Farm Budget Analysis

The farm budget analysis has been made as the project financial analysis. The farmer's financial condition with the project is almost same as the Pilot Area. The farm income with-Project becomes 10,790 Baht/year per household in case of irrigated paddy farm, comparing with 2,712 Baht/year per household in case of future without-Project. (refer to 7-3-11.)

CHAPTER 7 FEASIBILITY STUDY ON PILOT AREA

7-1 Selection of Pilot Area

The Pilot Area has been selected under Phase I Study and has been taken up during the Feasibility Study in Phase II Study. The selected Pilot Area is located at the central part of Amphoe Phra Yun. It has an area of 45.6 sq·km and is mostly cultivated land and village area.

The selection criteria of the Pilot Area are as follows:

- The Pilot Area covers 10-15% of the total study area.
- The Pilot Area features all study area through natural and socio-economic viewpoints. The Master Plan on Integrated Rural Development of Salt-Affected Land has been finalized based on the outcome of the feasibility study of the Pilot Area.
- The same development components of integrated rural development that have been included in the whole area also are applied in the Pilot Area.
- The Pilot Area should be accorded high priority for development by Amphoe office.

7-2 Pilot Area

7-2-1 Location and Social Conditions

(1) Location

The Pilot Area is located in the middle part of the study area. It covers an area of 45.6 sq·km with 15 related villages of two Tambon Phra Yun and Kham Pom.

At the middle-north, the provincial highway which divides the Pilot Area into two parts (east and west) is bordered by two most populated Mubans, Phra Yun and Hua Bung, while in the middle-south the area is bordered by two most dry and salt affected Muban of Tambon Phra Yun, Pa San 1 and Pa San 2.

The topography of the Pilot Area is almost flat at an average elevation of 190 m above mean sea level with some hilly parts in the south-west and north-east, making a slight inclination downward to the south-east corner.

Regarding water streams, Huai Yang is streched in the middle of the Pilot Area in the direction from west to east.

(2) Social Conditions

As most of the people in the Pilot Area are living upon agriculture, mostly rain-fed paddy cultivation, living conditions in villages are suffered from insufficient water and salt-affected lands.

From rather scare precipitation of rainfall in the area a lot of artificial ponds as rainfall reservoirs have been made, which have been used mostly for domestic water, fishery and bathing for cattle, rather than for drinking purpose.

For drinking water, except Ban Nong Khu with running water and some places possessing shallow-wells of fresh water, most of local people have to depend solely on rainfall collected into jars and tanks nearby their households.

Every year, during the dry season, due to no agricultural works many farmers have to go to other regions for works such as migrant laborers in sugarcane/rubber plantations.

Other social aspects such as electrification, health-care, education, communications, religion etc., are considered almost

sufficient, requiring only slight improvements, especially for communications.

A considerable market system is not existing in the Pilot Area. A Sunday Market is opened on a road in Ban Phra Yun. The Phra Yun Agricultural Cooperative with its two branch-offices in Ban Ken Pradu and Nalom buy agricultural products and supply some goods to its members. Besides there are some small shops selling daily necessities mainly in Ban Phara Yun and Kham Pom.

The area is under by thick and well consolidated siltstone, gravel beds, terrace deposits and recent river beds. Based on the drilling records, the depth of the siltstone ranges from 4 to 30 mbgs.

Almost all the villages in the Pilot Area have practiced some kind(s) of cottage industries such as weaving, making mats but mainly for self-consumption due to difficulties in marketing. Local people are lacking in capital and proper technology for making marketable products.

7-2-2 Natural Conditions

(1) Topography

The area consists of undulating rolling hill, terrace and recent flood plain which is generally ranging in altitude from 160 to 220 MSL.

The rolling hill is distributed in two areas. One in the west of the Pilot Area extends to north-southerly direction with about 1.5 km with and it slopes gently toward the east and the other in the southern end of the area extends to south-westerly direction.

The terrace is widely distributed in the area with a lower topographic units. A upper terrace is distributed on the east of rolling hill ranging from 187 to 190 MSL and a lower terrace is occupied the rest extensive area. A lower terrace is generally flat and is subjected to erode widely by the rivers. Consequently, the boundary between a lower terrace and the flood plain is not clear in many places.

The Huai Yai, only a river in the area, flows to the southeast and it cut broad and shallow the terrace deposit but nowhere did the downcutting continue enough to remove completely the terrace deposit until the siltstone. On the basis of the above fact, an erosional remnant of the terrace deposit underlies the river bed of the upper