## 3.4. Irrigation, Drainage and On-Farm Condition

The irrigation in the existing paddy fields is practiced by plot to plot method using the river water in the rainy season.

Existing irrigation facilities in the Project Area are comprised of weir, reservoir and pond which was constructed, respectively, by the farmers, RID, and Job Creation Program.

Location and features of these facilities are shown in ANNEX D.

Lam Plai Mat including its tributaries has 42 weirs, 10 reservoirs and many ponds in and around the river course to supply irrigation and/or domestic water. Several weirs have canal systems but these canals are formed by the excavated earth canal which is located at the lower part of the area.

Nong Lum Puk has no irrigation facilities such as weirs, reservoirs and canals except a pond which is located 2 km upstream of the proposed damsite.

Huai Phlu has a weir and a pond which is located 1 km downstream of the proposed damsite, while there is no facility to be incorporated into the proposed irrigation system.

The drainage of the Project Area is conducted mostly by the river course. When the river course is narrow and shallow, existing paddy fields are developed on it and river water flows from plot to plot in the paddy field.

On-farm facilities, such as farm ditch, division box and drain are not provided in the Project Area. The plot size of the present paddy fields ranges from 0.05 to 1.0 rai and both the height and width of dike are mostly 20 to 30 cm.

# CHAPTER IV THE PROJECT

# CHAPTER IV. THE PROJECT

## 4.1. Objective and Components of the Project

### 4.1.1. Objective

The Project, comprising three sub-projects, viz. Lam Plai Mat, Nong Lum Puk and Huai Phlu selected by RID at the end of Study A: "Overall Basin Study", has been prepared in line with the development strategy that enhances the delivery of adequate water supplies to the largest numbers of farmers in the shortest time possible to alleviate the poverty in the backward villages. The distribution of poverty in the Lower Northeast region has been identified to be more significantly related to the wet season rainfed paddy productivity of the land under traditional techniques. In the Project Area, storage dams are essential to irrigation.

In this regard, top priority has been placed upon the provision of supplementary wet season water supply for the paddy fields to a full extent and dry season supply for the field crops to a limited extent as well as of domestic water needs to achieve the water-based integrated muban development. The distribution system to the irrigation service area from proposed medium scale reservoirs should be so planned to be capable of actual deliveries of water to the maximum number of farmers with rather limited water resources and also to fall within a scope that the national socio-economic policy for these sub-projects would permit. And, at the same time, full technical and financial support from the government agencies concerned should be extended to the muban families who could get the maximum benefits possible at the earliest practicable date.

With the above concept in mind, effort has been made for definite materialization of the given objective in a more efficient and practicable manner with a view to the mubans' water-based integrated development in the Project Area. The basic cooperative

patterns in the muban's daily life and their diachronic and synchronic features have been properly evaluated so that some developmental perspectives of each muban in the Project service area could be delineated, and that a plan of the water-based integrated rural development under the proposed Project has been worked out. At the same time, the planning and implementation of such a rural development plan should give adequate consideration to the well-coordinated regional and central planning as well as to the full mobilization of local administration, effective local level organization and participation of the muban people in the planning and implementation processes.

4.1.2. Project Components

The following Project components have been incorporated into each of the three sub-projects:

i) Water resources development:

A storage dam in each sub-project and a diversion weir for only the Lam Plai Mat Sub-Project should be constructed to provide water sources for the potential irrigation services for wet season paddy fields, seedling plots for the remaining rainfed paddy field and dry season upland field to a practical extent as well as for the potential domestic needs for people and animals in the muban to be involved in the irrigation service area.

ii) Irrigated agricultural development:

To develop the proposed irrigated agriculture, main and lateral canal system up to tertiary outlets and drainage channels should be provided with the attached roads as well as on-farm works, together with various kinds of the extension service and technical assistance.

iii) Water-based integrated muban development:

To meet the domestic water needs and develop the village fisheries, a muban pond and related water supply facilities in each muban for the irrigation service areas should be constructed.

A model of the proposed water-based integrated muban development plan generated during the Study is shown in the following page.

With construction of the above mentioned structures and successive development of the irrigated agriculture and other associated activities, the following economic benefits as well as social benefits would be expected, viz., increase of employment opportunities and alleviation of the present poverty resulting in income growth.

1. Irrigation for wet season paddy in the Ordinary Service Units and Muban Cooperative Service Units.

2. Irrigation for dry season field crops in the Muban Cooperative Service Units.

3. Irrigation for the Muban Collective Seedling Plots for wet season rainfed paddy outside the Service Units.

4. Irrigation for the Muban Collective Seedling Plots in the Muban Cooperative Service Units for wet season rainfed paddy inside the Service Units (when the irrigation service area is decreased due to the reservoir operation rule).

5. Water supply from the Muban ponds and successive communal facilities for drinking and domestic use for muban people.

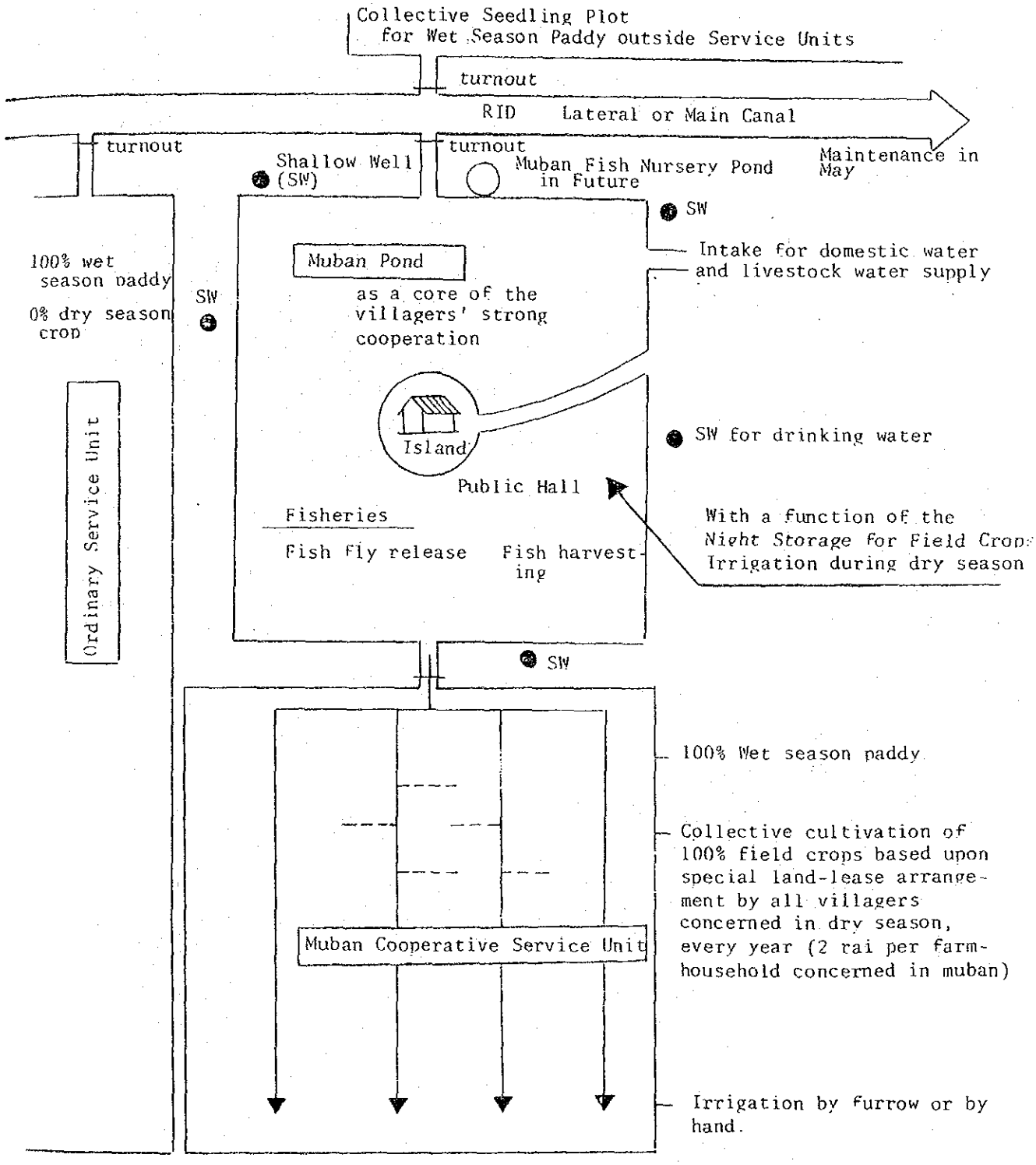
6. Water supply from the muban ponds and successive communal facilities for drinking and bathing use for muban buffaloes and cattle.

7. Fisheries in the muban ponds.

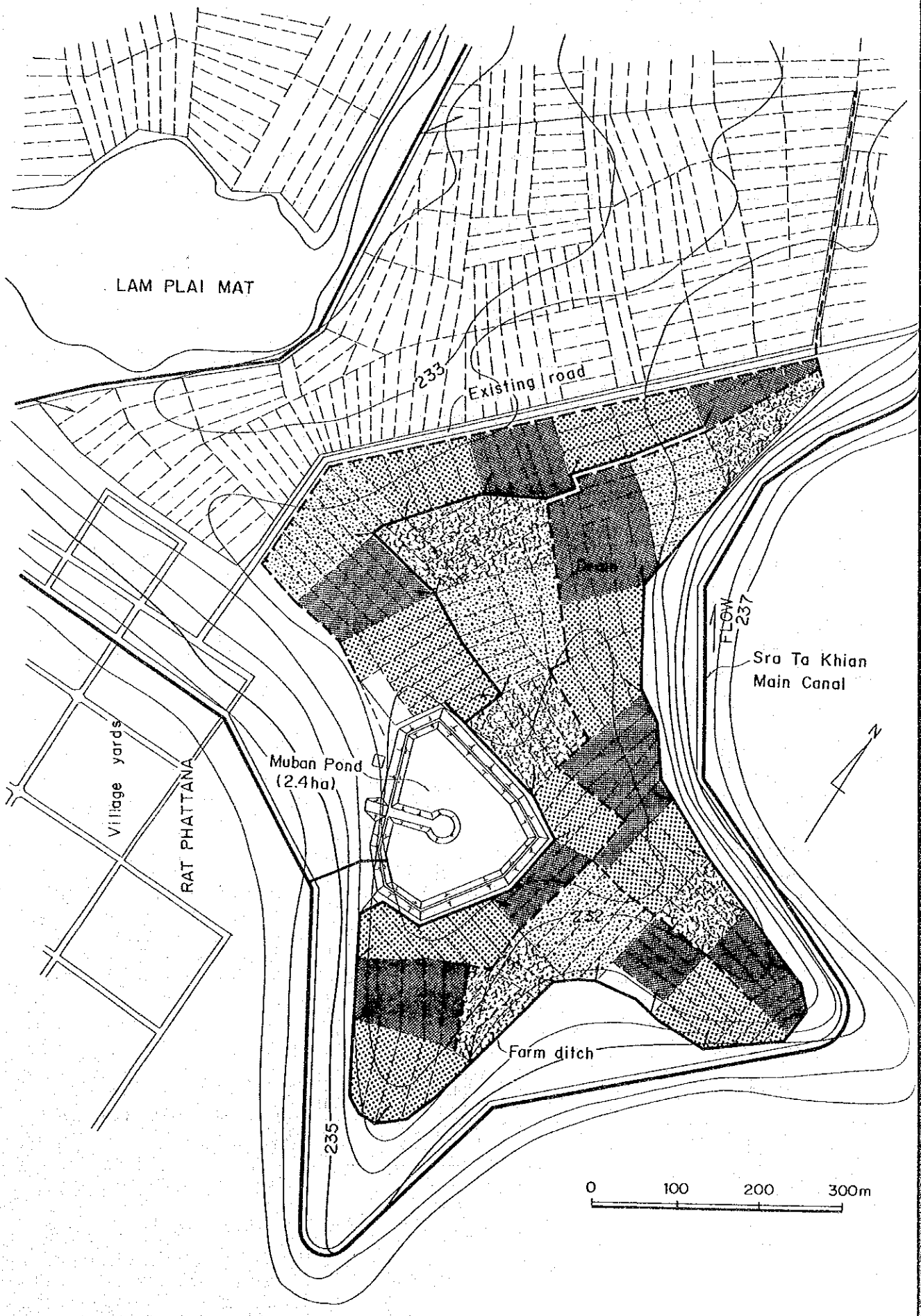
8. Fisheries in the RID-constructed reservoirs.

9. Foreshore field crops in the RID-constructed reservoirs at lower water level (for the Small-Medium Projects).

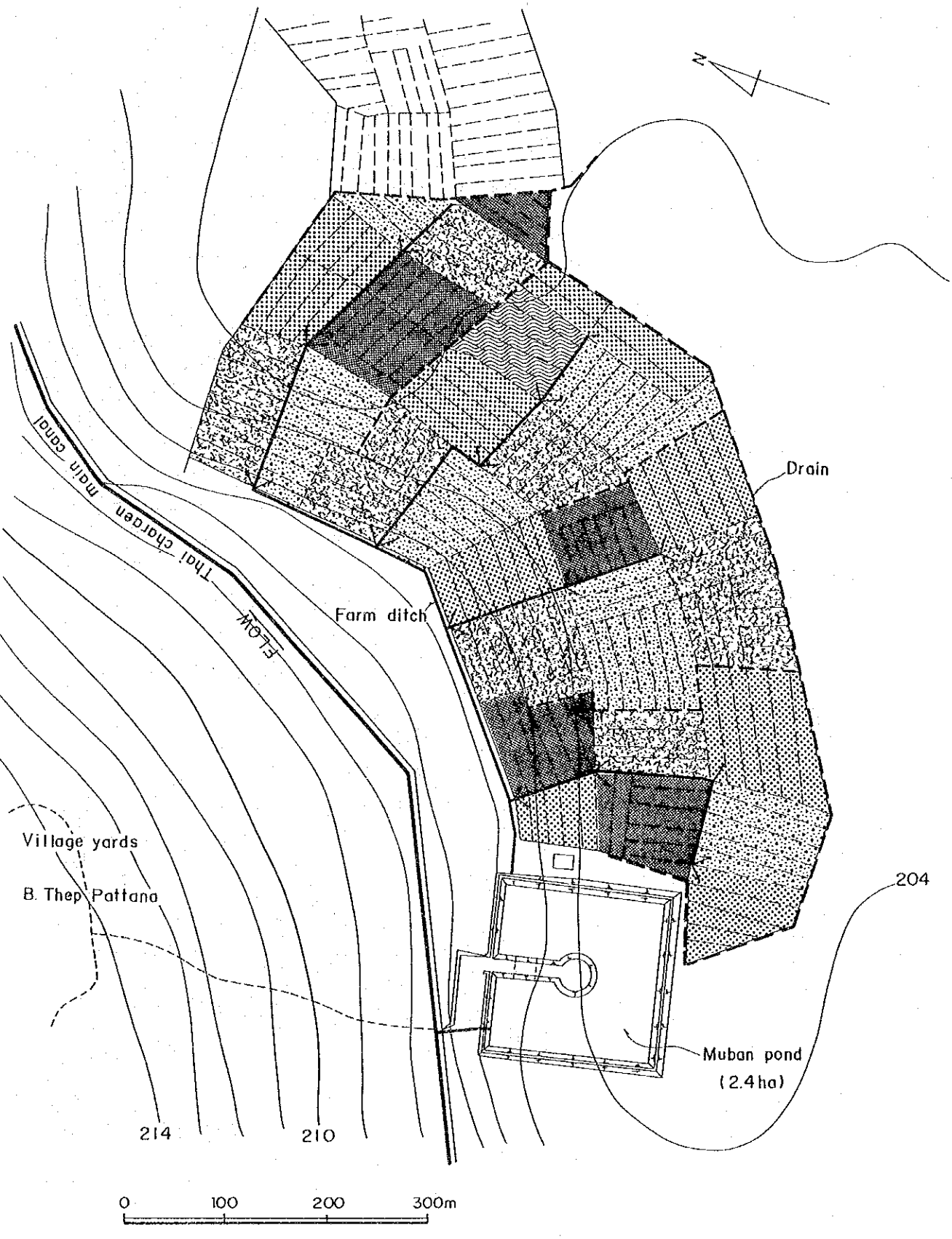
Model of the Water-Based Integrated Muban Development



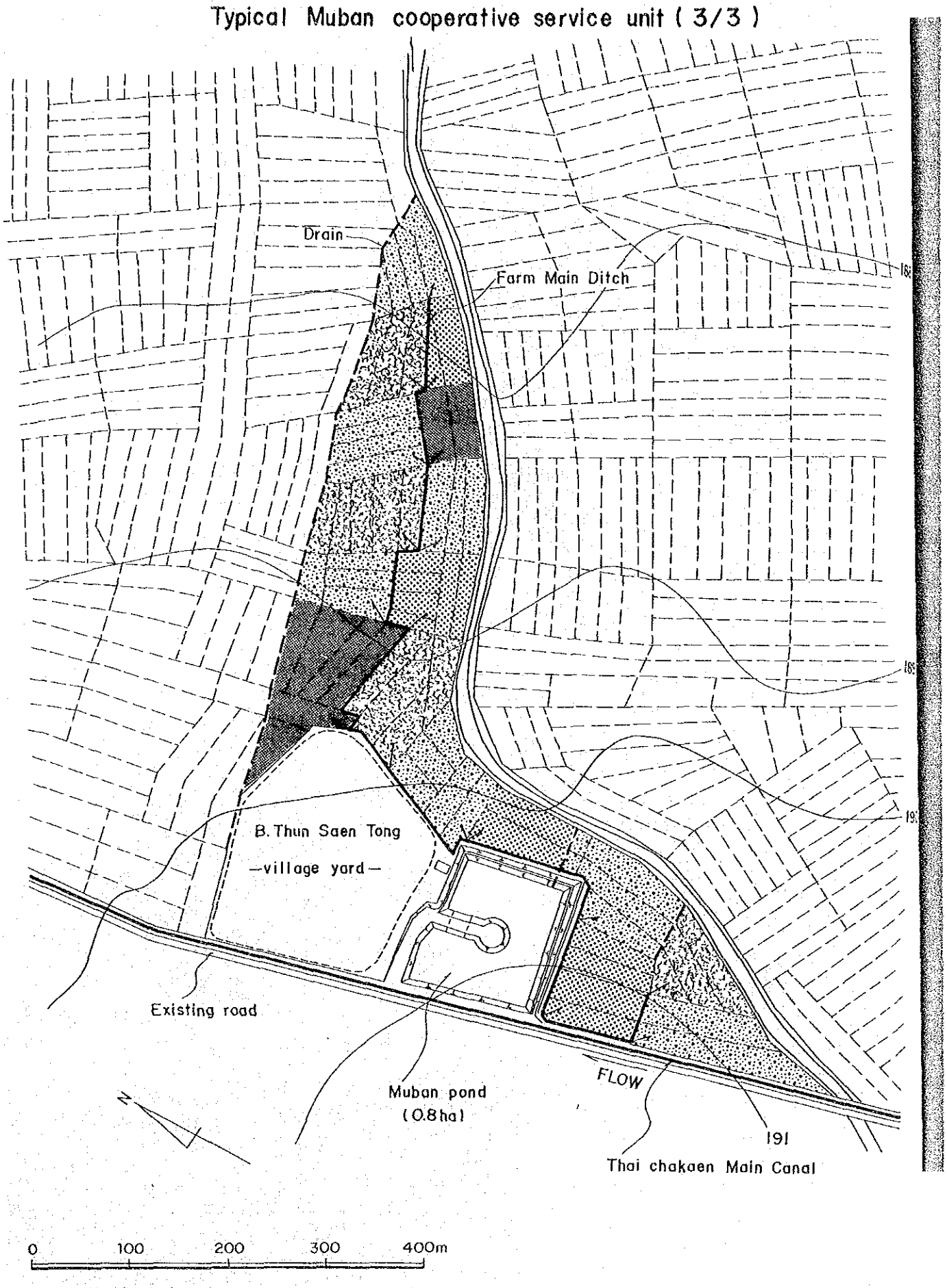
# Typical Muban cooperative service unit ( 1/3 )



# Typical Muban cooperative service unit ( 2/3 )



# Typical Muban cooperative service unit ( 3/3 )



## 4.2. Plan Formulation

### 4.2.1. Location of the Irrigation Service Area

At present there are many primitive weirs along the major river courses from the proposed dams, as mentioned in paragraph 3.4., Chapter III. These weirs, without canal systems in almost all cases, were constructed and then operated and maintained by the farmers themselves working as water user's groups outside the sphere of the RID control. These are called "People's Irrigation Systems" normally under the responsibility of the Ministry of Interior. These weirs are considered too poor in the engineering term to be incorporated in the development plan.

When a plan is introduced where stored water is released from the Project dam to the river and then diverted by its downstream Project weir, it is assumed that such water would be probably diverted by many People's Irrigation Systems without taking heed of the water rights. Consideration of this kind would lead towards a plan that top priority should be given to the paddy fields immediately downstream of the dam for its inclusion in the Project.

(1) Lam Plai Mat Sub-Project

The farm households sample survey for the Lam Plai Mat Sub-Project was conducted covering the area from the proposed damsite to the confluence with the Lam Nang Rong. On the basis of this survey, the income level and distribution of the farm households have been identified for each of the above survey areas divided into three parts, viz., (1) "Upper Stream" from dam to Pa Kham weir, (2) "Middle Stream" from weir to National Road No. 24 and (3) "Lower Stream" until the confluence with the Lam Nang Rong.

The income level and distribution in the Project survey area are presented in the following page of which the salient features are:

| | Poor | Marginal | Better-Off | Wealthy | Overall |
|---|---|---|---|---|---|
| 1) Annual Income Range (฿ per capita) | | | | | |
| - 1982/83 Price Level | 3,500 | 3,500-4,670 | 4,670-7,000 | 7,000 | |
| 2) Income Distribution of Rural Households in Northeast Region, 1975/76 | | | | | |
| - No. of Households (%) | 43.3 | 27.1 | 22.3 | 7.3 | 100.0 |
| - Ave. Household Income (฿) | 9876 | 14,304 | 21,216 | 43,932 | 16,152 |
| - Ave. Household Size | 6.76 | 6.01 | 5.38 | 4.69 | 6.11 |
| - Ave. Household Income, 1982/83 (฿) | 17,450 | 25,270 | 37,480 | 77,620 | 28,537 |
| 3) Income Distribution of the Project Sample Farms, 1928/83 | | | | | |
| Lam Plai Mat Sub-Project | | | | | |
| 1. Upper Stream | | | | | |
| -No. of Households | 23 | 6 | 6 | 4 | 39 |
| - do - (%) | 59.0 | 15.4 | 15.4 | 10.2 | 100.0 |
| -Ave. Household Income (฿) | 15,640 | 23,180 | 31,240 | 54,100 | 23,150 |
| -Ave. Household Size | 6.04 | 5.67 | 5.50 | 4.00 | 5.72 |
| 2. Mid Stream | | | | | |
| -No. of Households | 33 | 7 | 7 | 3 | 50 |
| - do - (%) | 66.0 | 14.0 | 14.0 | 6.0 | 100.0 |
| -Ave. Household Income (฿) | 11,600 | 28,130 | 39,530 | 51,068 | 25,796 |
| -Ave. Household Size | 6.27 | 7.00 | 6.57 | 4.00 | 6.28 |
| 3. Lower Stream | | | | | |
| -No. of Households | 42 | 4 | 3 | 1 | 50 |
| - do - (%) | 84.0 | 8.0 | 6.0 | 2.0 | 100.0 |
| -Ave. Household Income (฿) | 10,495 | 21,384 | 34,895 | 22,290 | 13,067 |
| -Ave. Household Size | 6.83 | 5.50 | 6.33 | 3.00 | 6.62 |
| Total | | | | | |
| -No. of Households | 97 | 18 | 16 | 8 | 139 |
| - do - (%) | 69.8 | 12.9 | 11.5 | 5.8 | 100.0 |
| -Ave. Household Income (฿) | 12,210 | 24,595 | 34,621 | 50,170 | 18,489 |
| -Ave. Household Size | 6.47 | 6.17 | 6.13 | 3.88 | 6.24 |

- The average per capita income in the Lam Plai Mat survey area is ฿2,960 per year accounting for about 60 percent of the rural Northeast average.

- Remarkable poverty situations prevail in the lower stream area which covers the area from National Road No.24 to the confluence with the Lam Nang Rong. The paddy field per household in this area is the largest in size in the Project survey area; however, the actually planted area is only 43 percent or 1.7 ha of the total area of 4.0 ha. In other areas, this ratio ranges from 80 to 90 percent.

Land Use per Household (ha)

| | Paddy Field | | Upland | | |
|---|---|---|---|---|---|
| | Total (1) | Planted | Total (2) | Planted | Total (1)+(2) |
| Lam Plai Mat | 3.3 | 2.2 | 0.8 | 0.8 | 4.1 |
| Upper | 2.2 | 1.8 | 0.7 | 0.7 | 2.9 |
| Mid | 3.3 | 2.9 | 1.3 | 1.3 | 4.6 |
| Lower | 4.0 | 1.8 | 0.3 | 0.3 | 4.3 |

Considering the above income level in each part, examination has been made as to which area should be included in the Project service area, in accordance with the water balance simulations which gave 9,000 ha for irrigable area from the proposed Lam Plai Mat dam;

- First of all, discussion has been made on whether or not to include the lower stream area which is in the lowest income level due to the present farm production of "Rice Main". If the lower area is included in the Project, major parts of the upper and middle areas should be excluded. In this respect, the Thai authorities concerned replied that although alleviation of the poverty in the lower area would be important, equal emphasis should be placed upon development of the upper and middle areas in the border

amphoe as endorsed in the Fifth Plan as well as upon the future prospective of cassava marketing which would not be so bright. In addition, since long distance canal conveyance is definitely inefficient from the economic and water management viewpoints, the lower area has been excluded from the Project service area.

- Existing paddy land in the upper and middle parts totals over 14,000 ha which is larger than 9,000 ha for the Project irrigation potential. In this respect, three alternatives have been established in view of the irrigation distribution and canal alignment.

  ° Alternative 1, covering all the upper area and the upper part of the middle area without Pa Kham diversion weir.

  ° Alternative 2, covering the same irrigation area with Pa Kham diversion weir.

  ° Alternative 3, covering all the middle area and the upper part of the lower area until the Lam Sai Yong, with a 33 km-conveyance canal directly from the dam to the uppermost part of the middle area which is essential to prohibit farmers' water diversion through the People's Irrigation Systems when water is released to the river from the dam. This is called the "Driving Channel Plan" as presented in F.2 "Canal", ANNEX F.

Below is the cost estimate for implementation of each alternative on the basis of preliminary layouts of the proposed irrigation systems whose details are presented in ANNEX.

| | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|
| | | ($10^6$ ฿) | |
| Construction Cost | 300.5 | 283.0 | 339.6 |
| | (1.06) | (1.00) | (1.20) |

Alternative 2 with the proposed Pa Kham weir is the least costly one, and therefore recommended. In this regard, inclusion of the Pa Kham diversion weir in the Project has been justified.

(2) Nong Lum Puk Sub-Project

Three conditions to determine the irrigation service area have been conceived:

- Potential irrigable area on the basis of the reservoir water balance simulations is 350 ha.

- Downstream of the dam, there are only about 100 ha of existing paddy field.

- It is not recommendable to extend the irrigation service to the downstream of the Huai Sadao where the proposed Huai Sadao storage will possibly be developed in near future.

Under these situations, extension of the irrigation service area in the Sub-Project has been made to the Soeng Sang sub-system under the Lam Plai Mat Sub-Project taking canal alignment from the Nong Lum Puk dam along hilly side. It is considered that 300 ha of the irrigation service area would be the maximum, taking into account the intake level at the dam. If the intake level is elevated, it would be possible to expand more; however, it is judged that the increase in dam and canal costs would be too enormous to sustain an economic viability of this sub-project.

Expansion of the irrigation service area to the Soeng Sang sub-system has made it possible to supply water for the center of amphoe Soeng Sang, viz. two muban of Soeng Sang and Nong Lum Puk through the provision of muban ponds. It is recalled that selection of this Sub-Project at the end of Study A by RID emphasized the importance of water supply for the amphoe Soeng Sang which is strategically located in the border areas with the Democratic Republic of Kampuchea.

(3) Huai Phlu Sub-Project

700 ha of the irrigable area on the basis of the Huai Phlu storage water balance study has been distributed from the immediate downstream existing paddy field to the confluence of the Huai Ta Kiew*/ with the Huai Seo, with a view to taking future opportunity to develop the Upper Huai Seo Sub-Project and covering the downstream area of the Huai Ta Kiew.

*/ ... The Huai Phlu first joins the Huai Ta Kiew, and then the Huai Ta Kiew is drained into the Huai Seo.

4.2.2. Proposed Cropping Patterns

(1) Paddy would remain as the dominant crop and be the sole crop grown throughout the proposed Project Area during the wet season. Reliable and timely water supply would enable local farmers to shift from traditional local varieties to high-yielding ones. Even in the With-Project case, the local improved varieties of photo-sensitive type such as Khao Dawk Mali, RD15 and Niaw Sanpahtawang would cover at least 30 percent of the cropped area because the farmers prefer them for their own consumption due to better cooking quality and palatability. It is anticipated that the area coverage of the paddy of non-photo-sensitive (for higher land) and photo-sensitive (for lower land) type would be respectively 50 percent of the total irrigation area taking into account the size, locality and quick yielding nature involved in the medium scale project.

(2) Field crops during the dry season would motivate the villagers to make more effort to increase their production of cash crops. It is said that even if sufficient water could be provided for the dry season, little crop may be grown since off-farm employment yields higher returns, thus drawing off available rural labor supply. Therefore, the field crop cultivation would be possibly operated by women sometimes helped by their daughters.

In the selection of the field crops during the dry season in the Project Area, vegetables probably with higher returns would be excluded due to perishability of the produce and rather long distance to the urban markets. Six crops such as groundnuts, mungbeans, tomatoes, baby corn, shallot and chili, each planted in one-sixth of the total area as a whole have been tentatively proposed for inclusion into the proposed Project Area. Tomatoes would be sent to the existing Nang Rong Tomato Processing Factory.

(3) It would not be easy to give a proper size to the field crop cultivation during the dry season in the Project Area. Two important aspects would be conceived. One is to define a pattern of the farm households who could participate in field crop production because of the intensive labor requirement for operations. The other is to give a proper size to the field crop cultivation that would be manageable by the female workers in individual farm households, since there would be a tendency that neither hired labor nor exchanged labor is used for this kind of cultivation.

For the former item, classification of the farm households, such as (1) "Rice Main", (2) "Rice + Upland Crops" and (3) "Upland Crops Main", which has been given by Tambon Extension Workers is available, and it is assumed that due to labor problems, about 60 percent of the households "Rice Main" and about 40 percent of "Rice + Upland Crops" could participate in the field crop cultivation.

The latter item has been examined through the available publications and interviews with the government agencies concerned as well as the preliminary assessment of the female labor force.

- See ANNEX J-1 where the average size of garden land operated per household in muban Dong Daeng, amphoe Muang, changwat Khon Kaen is presently 1.03 rai in the case of operation.

- AIT "Water for the Northeast" (1978), pp.29 explains that where supplementary wet season irrigation is planned, it may be economically beneficial to increase dry season planting of upland crops to an average of 1 rai or more per family.

- Direct interview with the many government agencies indicates that some reported 1 rai per household and the other 2 rai.

At any rate, a proper size of the dry season field crops would range from 1 rai or 0.16 ha to 2 rai or 0.32 ha per household; therefore, two rai have been employed for the Project. The above conditions have shown that the dry season field crop area would range from 5 percent to 18 percent of the proposed total irrigation service area according to the irrigation sub-system.

(3) During the wet season, a single crop of the transplanted paddy rice dominates the present cropping routines in existing paddy fields. The erratic rainfall pattern in intensity and distribution disturbs the paddy crop establishment and growth in most of this season. Without the Project situation, the preparation of nurseries may progress from May to July, and the subsequent transplanting from May to September. Consequently, seedlings are often kept too long in the nurseries, and the crops should have a shorter growing period for optimal yield because the current rice varieties are photo-sensitive and mature at the beginning of the dry season irrespective of the planting date.

When the rain comes late in the paddy season, nursery bed preparation is delayed with the consequently late transplanting. The latter may also occur because of a prolonged dry spell after the first rain. The farmers may cope with this by transplanting older seedling (more than two months old) directly into the unpuddled soil once it is adequately moist, in the hope that sufficient rain will arrive later. The greatest disturbance may arise when a prolonged drought sets in after transplanting and the young seedlings may not survive. This may occur too late in the season for a new nursery bed to be established.

In general, the drought stress is more critical on the upper paddies than the lower paddies. When good rain comes early, the land preparation and sowing of nursery bed may start from the middle of May. The lower paddies tend to be first transplanted from mid-June, with the upper paddies as late as mid-September or not at all, depending upon the time it takes for sufficient water to accumulate directly from rainfall or supplementary runoff from nearby higher land. More seedlings in the upper paddies would also be transplanted since the older seedlings would produce fewer tillers.

The upper paddies differ considerably from the lower paddies in terms of the main limiting factors that the upper paddies are planted very late and the short growing period, plus drought stress at the end result in considerable yield reductions. How can low rice yields in the upper paddy due to late planting be improved, viz., not only by improved varieties, but by new cultural or water management practices, for example, by transplanting or by altering the number of transplants per rai? To answer this, a direct seedling into the ploughed land around June to July would be advisable. It is said that this technique has shown advantages over transplanting; however, this technique often may cause a serious weed problem and therefore might hardly be applied by the local farmers.

One method to improve the wet season rainfed paddies as mentioned above would be to supply supplementary water for nurseries under the proposed water schedule every year. It is believed that starting the nursery planting earlier would increase the chance of a successful rice crop. The nurseries would take up only 7.5 percent of the main planting field.

(4) Special consideration has been made of the cropping schedule of wet season paddy which needs a large amount of supplementary irrigation water taking into account rainfall in early November for cropping or harvesting.

- Photo-sensitive paddy:

  The proposed cropping schedule has been developed in such a manner that an appropriate transplanting period of early August is determined in view of yield maximization of the photo-sensitive paddy with particular reference to the FAO/Thailand Workshop on Research and Development of Rainfed Crop Production, 1979. There would be no measure to reduce the higher water demand in November, and if the land preparation starts earlier, extension of the period between transplanting and panicle initiation is inevitable resulting in increase of the crop water requirement.

- Non-photo-sensitive paddy:

  Two alternatives for cropping schedule have been discussed from the standpoint of water requirement. The first alternative is to start the harvesting operations in the middle of November due to the inconvenience for paddy drying operations taking into account the present harvesting practices from late November to avoid rainfall. The second alternative is to start the harvesting operations in the beginning of November in line with the

30-year rainfall pattern during the first half of November at amphoe Nang Rong, which is 23 mm on an average, 105 mm in the first maximum (1963) and 73 mm in the second maximum (1972).

In view of the degree of difficulty in harvesting operations due to rainfall during the first half of November as well as considerable difference in the water demand during the month of November between the two, the cropping schedule of non photo-sensitive paddy (2) has been incorporated into the proposed development plan.

(5) Dry season field crops would be planted in December and January. The proposed calendar allows for major maintenance work which takes place in May and early June. Minor maintenance is possible in December when the wet season paddy is harvested.

4.2.3. Irrigation Plan

Irrigation water requirement has been estimated on a ten-day basis in accordance with the proposed cropping pattern.

(1) Crop Evapotranspiration (ETcrop)

To account for the effect of the crop characteristics on crop water requirements, crop coefficients (Kc) are presented. Crop evapotranspiration (ET crop) can be found by ET crop = Kc x ETo. ETo is estimated by the modified Penman method and shown below;

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm/day | 3.8 | 4.4 | 5.3 | 5.3 | 4.5 | 4.2 | 4.0 | 3.7 | 3.4 | 3.9 | 3.9 | 3.7 | - |
| mm/month | 118 | 123 | 164 | 159 | 140 | 126 | 124 | 115 | 102 | 121 | 117 | 115 | 1,524 |

Kc values are generally given taking into account the crop characteristics, time of planting or sowing, and stages of crop development. The Kc values for representative crops have been examined in more detail in the World Bank-assisted Northeast Thailand Irrigation Improvement Project, Stage II Feasibility Study as prepared by Tahal Consulting Engineers in 1976.

| | Percent of Growing Season | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| - Paddy rice | 0.85 | 0.87 | 0.95 | 1.06 | 1.15 | 1.20 | 1.19 | 1.15 | 1.10 | 1.03 | 0.90 |
| - Maize | 0.20 | 0.30 | 0.40 | 0.57 | 0.90 | 1.02 | 1.06 | 1.06 | 0.94 | 0.60 | 0.50 |
| - Groundnuts, Tobacco and Mungbeans | 0.15 | 0.25 | 0.40 | 0.55 | 0.66 | 0.70 | 0.77 | 0.77 | 0.70 | 0.55 | 0.35 |
| - Tomato | 0.20 | 0.20 | 0.25 | 0.35 | 0.56 | 0.74 | 0.82 | 0.72 | 0.48 | 0.35 | 0.20 |

(2) Deep Percolation for Paddy Rice

The current deep percolation rate in the Study area for wet season paddy would be negligibly small under imperfectly to poorly drained conditions and partly because a rather impermeable horizontal layer in the soil is developed as a result of land preparation practices. The Project is equipped with a drainage system deep percolation would be promoted to a certain extent. It is assumed at 2.0 mm per day, which has been taken as a standard value in the Northeast region under the RID's Medium Scale Irrigation Project.

(3) Effective Rainfall

Not all of the local rainfall covering the proposed irrigation service area is effective. The amount of rainfall that can be considered effective would depend upon many factors such as (1) intensity and distribution of rainfall, (2) storage available at the time of rainfall, (3) water requirement, (4) irrigation method, (5) topography and related drainage characteristics, (6) operation of the irrigation systems and others.

A model which simulates the inflow into and outflow from the paddy field or groundwater body has been developed in the "Summary of Monthly and Yearly Hydro-Meteorological Data in the Thai Part of the Lower Mekong Basin" as prepared by the Committee for Co-ordination of Investigations of the Lower Mekong Basin, 1975.

The field water balance equation as used in this Study is introduced below:

$$WDn = WDn-1 + Rn - WRn$$

where WDn = field water level at the end of the day n (mm)
WDn-1 = field water level at the end of the previous day n-1 (mm)
Rn = rainfall on the day n (mm)
WRn = total field water requirement on the day n (mm)

$$= ETcrop + N + LP + P$$

ETcrop = crop evapotranspiration (mm)
N = nursery water requirement (mm)
LP = land preparation water requirement (mm)
P = deep percolation (mm)

(a) In the case of paddy field, there is water stored on the ground surface depending upon the height of dike. Each dike usually has a notch which allows water to flow from one field to another. Taking into account the paddy cultivation practices prevailing in Northeast Thailand, the following assumptions have been made:

| | |
|---|---|
| Maximum Water Level.... + 135 mm (WD max) | The water depth is not allowed to rise above 135 mm. Eventual excess water is assumed to be drained. |
| Normal Water Level..... + 90 mm (WDnor) | As soon as the water depth falls below 45 mm, irrigation application of 45mm or more is made to maintain the normal water depth of 90 mm. |

Minimum Water Level
+ 45 mm (WDmin)

Ground Surface 00 mm.

(b) For the upland crops, consideration could be made which is similar to the conditions of paddy after the standing water on the field is completely drained out 15 days before harvesting. The water holding capacity (WHC) for upland crops at a particular location and a different growth stage would depend upon the depth of the crop root zone.

It would be assumed that the depth of the upland crop zone is 250 mm on an average, among various crops and during the growth stage, and the water holding capacity of soil is assumed at 60 mm. For the upland crops, there should not be pond water on the ground surface.

| | |
|---|---|
| Maximum Water Level = Ground Surface(WD max.) | 0 mm |
| Normal Water Level (WD nor) | -15 mm |
| Minimum Water Level = WHC (WD min) | -60 mm |

Irrigation application of 45 mm or more is made to keep the normal water level at - 15 mm as soon as the water depth falls below - 60 mm.

(c) The water balance analysis to estimate the effective rainfall can be carried out in the following manner:

- When the field water level at the end of the day n is higher than the maximum water level (WD max.), the effective rainfall for the day n (Rn) is estimated as,

  Rn = WD max. + WRn - WDn-1, and
  WDn is corrected to WD max.

- When the tentatively computed WDn is smaller than, or equal to WD max., the effective rainfall for the day n is taken equal to Rn and WDn is taken equal to the tentatively computed WDn unless the tentatively computed WDn is smaller than WD min. in which case WDn is set equal to WDnor with irrigation application.

(4) Additional Water Requirement

(a) Seedling Plot for Paddy

The seedling plot would be prepared 35 days before transplanting in the main field. The seedling plot water demand includes those of soaking for shallow plowing and harrowing, maintaining a water depth of about 50 mm during most of the period, applying this again after each drainage to encourage the growth of vigorous seedlings and supplying the evapotranspiration and deep percolation losses. It is assumed that about 600 mm of water is required during the total period covering about 5 percent of the main transplanting field.

(b) Water Required for Soil Saturation

The water amount needed to saturate the soil in order to facilitate plowing and harrowing would depend upon the soil characteristics, its moisture content at the time of land preparation and the depth to be saturated. This can be calculated from the following formula:

$$S = (n - w) \times D + h$$

where

S = Soil saturation demand in mm
n = Porosity of soil as a fraction of the volume
W = Soil moisture content as a fraction of the volume
D = Depth of soil to be saturated in mm
150 to 300 mm depending upon soil characteristics, crop variety and local plows, implements and practices
h = Depth of ponding water in mm
40 to 60 mm for transplanted rice, while no ponding water for field crops.

In practice, 145 mm of S for the transplanted paddy and 80 mm for the field crops would be assumed.

(5) Efficiency

For the proposed Project after full development in the case of a well designed system, built and operated for some years, the following efficiencies would be applicable in reference to Bos M.G. and Nugteren J. "On Irrigation Efficiencies" Publication 19, International Institute for Land Reclamation and Improvement, 1974 which is based mainly upon a recent comprehensive ICID/ILRI survey and USDA and US (SCS) sources:

Field application efficiency (Ea):
- Paddy cultivation..... 85%
- Upland crop cultivation..... 85%
- Field canal efficiency (Eb)..... 85%
- Conveyance efficiency (Ec):
  - Lined canal..... 85%
  - Unlined canal..... 70%
  - The main canal and about a half of the laterals passing through permeable soils are concrete lined = 80%

Overall efficiencies (Ea x Eb x Ec)
- Paddy cultivation..... 58%
- Upland crop cultivation..... 58%

(6) The monthly irrigation water requirement for each crop which has been introduced in the Project on the basis of 30-year calculation from 1952 to 1981 is summarized in the following page.

4.2.4. Optimum Design of the Reservoirs

(1) Water Balance Simulations

The reservoir water balance simulations study on a ten-day basis for 20 years from 1962 to 1981 has been carried out to determine the optimum size of the proposed reservoir and related wet season paddy

Table 4-2-1. Irrigation Water Requirement

| | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Non-Photosensitive Paddy | | | | | | | | | | | | | |
| Field Water | - | - | 5.7 | 139.0 | 150.6 | 165.8 | 197.5 | 120.5 | 13.9 | - | - | - | 793.4 |
| Average Irrigation | - | - | 3.2 | 105.4 | 26.8 | 9.5 | 59.5 | 62.1 | 0.0 | - | - | - | 266.5 |
| Diversion Water | - | - | 5.5 | 181.7 | 46.2 | 16.4 | 102.6 | 107.1 | 0.0 | - | - | - | 459.0 |
| (2) Photosensetive Paddy | | | | | | | | | | | | | |
| Field Water | - | - | 75.9 | 158.8 | 169.8 | 171.8 | 198.2 | 144.7 | 18.1 | - | - | - | 937.3 |
| Average Irrigation | - | - | 49.9 | 104.0 | 25.4 | 9.6 | 59.7 | 78.7 | 3.1 | - | - | - | 330.4 |
| Diversion Water | - | - | 86.0 | 179.3 | 43.8 | 16.6 | 102.9 | 135.7 | 5.3 | - | - | - | 569.6 |
| (3) Vegetable | | | | | | | | | | | | | |
| Field Water | 8.7 | - | - | - | - | - | - | - | 59.1 | 67.3 | 80.6 | 84.5 | 300.0 |
| Average Irrigation | 0.0 | - | - | - | - | - | - | - | 26.6 | 83.0 | 46.1 | 67.7 | 223.4 |
| Diversion Water | 0.0 | - | - | - | - | - | - | - | 45.9 | 143.1 | 79.5 | 116.7 | 835.2 |
| (4) Seed Bed | | | | | | | | | | | | | |
| Field Water | - | 5.0 | 127.5 | 280.7 | 168.3 | 18.0 | - | - | - | - | - | - | 600.0 |
| Average Irrigation | - | 3.1 | 65.8 | 168.4 | 69.6 | 0.0 | - | - | - | - | - | - | 306.9 |
| Diversion Water | - | 5.3 | 113.4 | 290.3 | 120.0 | 0.0 | - | - | - | - | - | - | 529.0 |

irrigable area, taking into consideration the synthesized river flow at the damsite and 100 percent of the downstream water demand inclusive of the muban water use in the irrigation service area together with effective rainfall, additional water availability downstream and such water losses as evaporation, percolation, conveyance and application.

The water balance simulations, in line with the water development strategy that a plan should be capable of actual deliveries of water to the largest number of local farmers with limited water resources, have shown that the optimum reservoir capacity would fully consider the water shortage that a portion of the downstream water demand could not be met due to an empty reservoir. In addition, the simulations have revealed that the reservoir provides cyclic storage (i.e. water is stored for more than 1 year) taking a form of the long-run carry-over due to very special hydrological events for the past 20 years, which would be prevailing in the Lower Northeast region.

(2) Optimum Size

It can be considered that an optimum size of two variables such as (1) effective reservoir capacity and (2) the wet season paddy irrigation area should be given taking into account (a) the construction cost for the dam and canal system as well as (b) the actual irrigable area to be derived from the water shortage*/. An indicator to select the optimum one has been taken at the minimum of cost per area (฿ per ha), assuming that the yearly stream of cost and benefit for development is identical in each case. It has been observed that the cost per area in the vicinity of the optimum size would be almost the same; therefore, other constraints that are related with the structure of the dam/reservoir and the configuration of irrigation system should be incorporated into final consideration.

*/ ... actual irrigable area = (1 - water shortage rate) x given irrigation area.

With many trials and errors in the water balance study and additional views of the technical feasibility of the dam/reservoir, it has been identified that an effective reservoir size should be very close to 90 MCM in the Lam Plai Mat Sub-Project, 4.0 MCM in the Long Lum Puk Sub-Project and 6.0 MCM in the Huai Phlu Sub-Project. With this reservoir size, an extent of the wet season paddy irrigation service has been varied to look into the minimum value of cost per ha. Then, the optimum irrigation size has been adjusted from the viewpoint of system configuration. Finally, with this irrigation size, the capacity of effective reservoir has been changed for confirmation which shows that the cost per ha in close proximity of the above stated reservoir capacity is almost unchangeable.

The optimization study for irrigation area conducted at the second step in the entire process as mentioned above is summarized below:

| Sub-Project | Case No. | Effective Storage (MCM) | Irrigation Area (ha) | Water Shortage (% of Water Demand in 20 years) | Direct Construction Cost | | | Average Irrigated Area (ha) | Cost/Area (1000₱/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Dam | Irrigation | Total (M₱) | | |
| Lam Plai Mat | 1 | 90.0 | 8,000 | 0 | 301 | 246 | 547 | 8,000 | 68.4 |
| | 2 | 90.0 | 9,000 | 4.4 | 301 | 272 | 573 | 8,604 | 66.6 |
| | 3 | 90.0 | 10,000 | 12.9 | 301 | 298 | 599 | 8,710 | 68.8 |
| | 4 | 90.0 | 11,000 | 20.0 | 301 | 324 | 625 | 8,800 | 71.0 |
| Nong Lum Pui | 1 | 4.0 | 250 | 0.5 | 26.7 | 7.5 | 34.2 | 249 | 137 |
| | 2 | 4.0 | 300 | 6.9 | 26.7 | 9.0 | 35.7 | 279 | 128 |
| | 3 | 4.0 | 350 | 16.3 | 26.7 | 10.5 | 37.2 | 293 | 127 |
| | 4 | 4.0 | 400 | 24.9 | 26.7 | 12.0 | 38.7 | 300 | 129 |
| Huai Phlu | 1 | 6.0 | 600 | 4.0 | 44.8 | 19.7 | 64.5 | 576 | 112 |
| | 2 | 6.0 | 700 | 10.5 | 44.8 | 23.0 | 67.8 | 627 | 108 |
| | 3 | 6.0 | 800 | 21.0 | 44.8 | 26.3 | 71.1 | 632 | 113 |

The optimum size of effective reservoir capacity and the wet season paddy irrigation area in each of the sub-projects thus formulated above are given below:

| Sub-Project/ | Lam Plai Mat | Nong Lum Puk | Huai Phlu |
|---|---|---|---|
| Effective reservoir (MCM) | 90.0 | 4.0 | 6.0 |
| Wet season paddy irrigation (ha) | 9,100 | 300 | 700 |

The water balance calculations for 30 years (1952 to 1981) on the basis of the finally formulated size of reservoir and irrigation area are explained in Figures 4-2-2 and 4-2-3. Annual average water demand for 30 years as incorporated in the above calculations is summarized follow:

| Sub-Project/ | Lam Plai Mat | | Nong Lum Puk | | Huai Phlu | |
|---|---|---|---|---|---|---|
| | (MCM) | (%) | (MCM) | (%) | (MCM) | (%) |
| Wet Season Paddy | 46.8 | 85.9 | 1.54 | 80.2 | 3.60 | 87.4 |
| Dry Season Field Crops | 3.1 | 5.7 | 0.12 | 6.2 | 0.15 | 3.6 |
| Wet Season Nurseries*/ | 3.2 | 5.9 | 0.13 | 6.8 | 0.12 | 4.9 |
| Muban Water Supply | 1.4 | 2.5 | 0.13 | 6.8 | 0.17 | 4.1 |
| Total | 54.5 | 100.0 | 1.92 | 100.0 | 4.12 | 100.0 |

*/... For the rainfed paddy outside the irrigation service.

(3) Water Operations Study

Actual water release from the reservoir when frequent water shortages occur as mentioned previously, should be made in such an operational manner so as not to be in short supply for the downstream water delivery program which is scheduled in advance. In order to achieve this objective, the downstream water demand should be reduced

to a suitable extent in accordance with the residual reservoir capacity after the last irrigation season as well as the predicted rainfall and inflow during the next irrigation season. Detailed examination demonstrates that there would be no method or procedure to predict the rainfall during the next wet season on the basis of any record observed just before the time of decision making; therefore, it has been viewed that the water operating rule for reservoir would probably be given on the basis of only residual water storage after the last irrigation season.

It is considered essential that reduction of the downstream water demand should be made in terms of only supplementary irrigation for the wet season paddy, because other water demands including those of nurseries outside the wet season paddy irrigation could be deemed the basic human needs for poor villagers. Additional consideration has been made of the period required for preparation of the water delivery program for the next irrigation season, taking into account the period of time to disseminate this program to all O & M personnel concerned for operational arrangement and to all farmers for full consensus. The current practices in RID projects show that the water delivery program is prepared about three months before commencement of the next wet season paddy cultivation. It is, therefore, required that the water delivery program including the volume of wet season paddy irrigation in the Project should be prepared in connection with the degree of residual reservoir volume or reservoir water level at the end of February every year.

In accordance with the consideration and arrangement as mentioned above, the water operations study through a series of trials and errors has been carried out to examine an optimum operating rule to reach more irrigable area with less water shortage. To this end, the following have been obtained as possibly the best:

- Lam Plai Mat Sub-Project -

Effective Storage: 90,000,000 cu.m
Total Irrigation Service Area: 9,100 ha
Operating Rule: When the water shortage at the end of February is below 22.2 MCM, the size of the subsequent irrigation area is taken at 80%, or 7,280 ha.

- Nong Lum Puk Sub-Project -

Effective Storage: 4,000,000 cu.m
Total Irrigation Service Area: 300 ha
Operating Rule: When the water storage at the end of February is below 1.9 MCM, the size of the subsequent irrigation area is taken at 70%, or 210 ha.

- Huai Phlu Sub-Project -

Effective Storage: 6,000,000 cu.m
Total Irrigation Service Area: 700 ha
Operating Rule: When the water storage at the end of February is below 2.0 MCM, the size of the subsequent irrigation area is taken at 65%, or 455 ha.

The water operations study on the basis of the optimum operating rule is summarized in Table 4-2-1 and Figure 4-2-4 for the Lam Plai Mat Sub-Project, Table 4-2-2 and Figure 4-2-5 for the Nong Lum Puk Sub-Project, and Table 4-2-3 and Figure 4-2-6 for the Huai Phlu Sub-Project. In Tables 4-2-1, 2 and 3, some adjustments have been made on the actual water service area taking into consideration the probable effects on crop cultivation due to the period and magnitude of water shortage occurrence.

Figure 4-2-1. Water Balance Study (1)

Lam Plai Mat

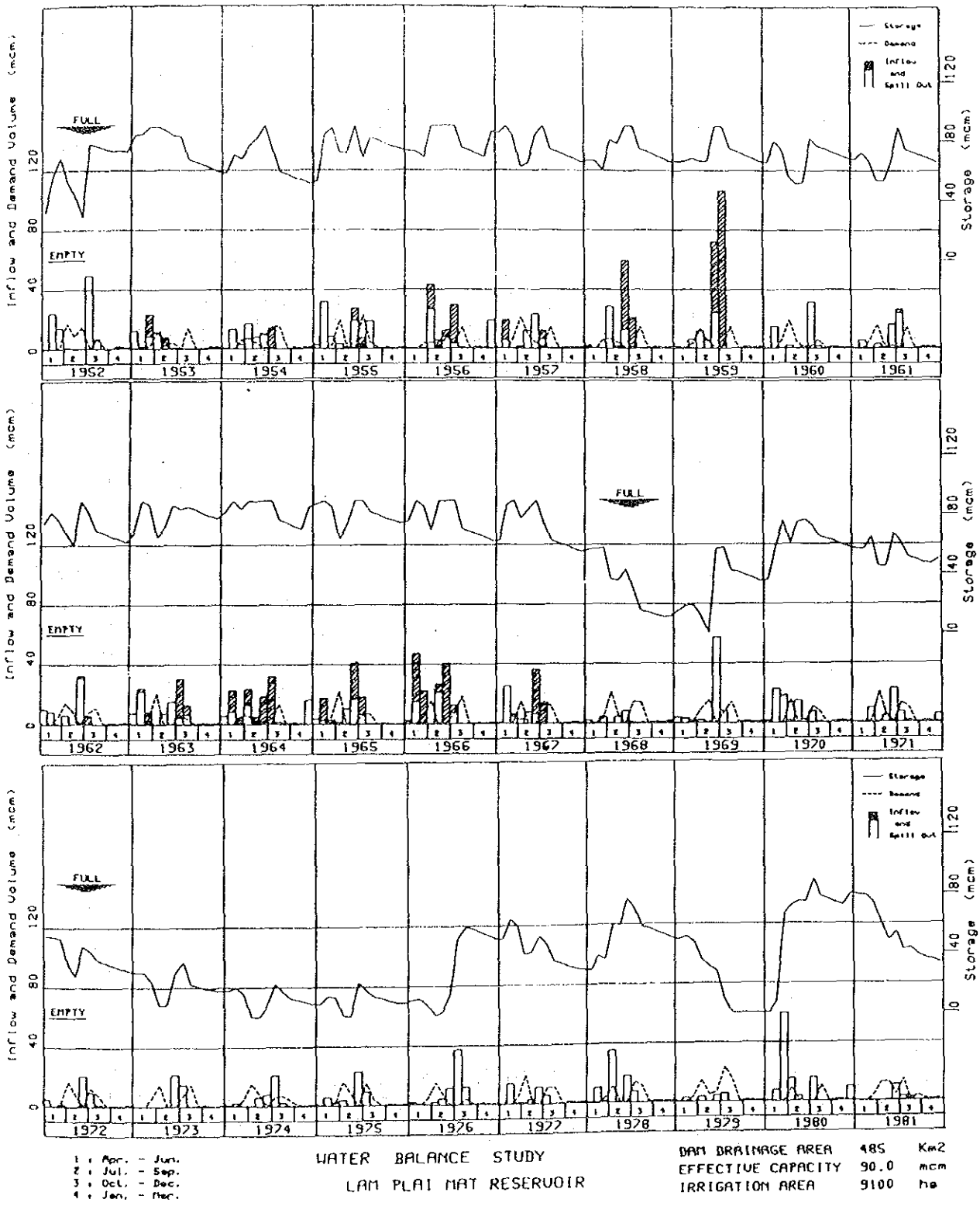


Figure 4-2-2. Water Balance Study (2)

Nong Lum Puk

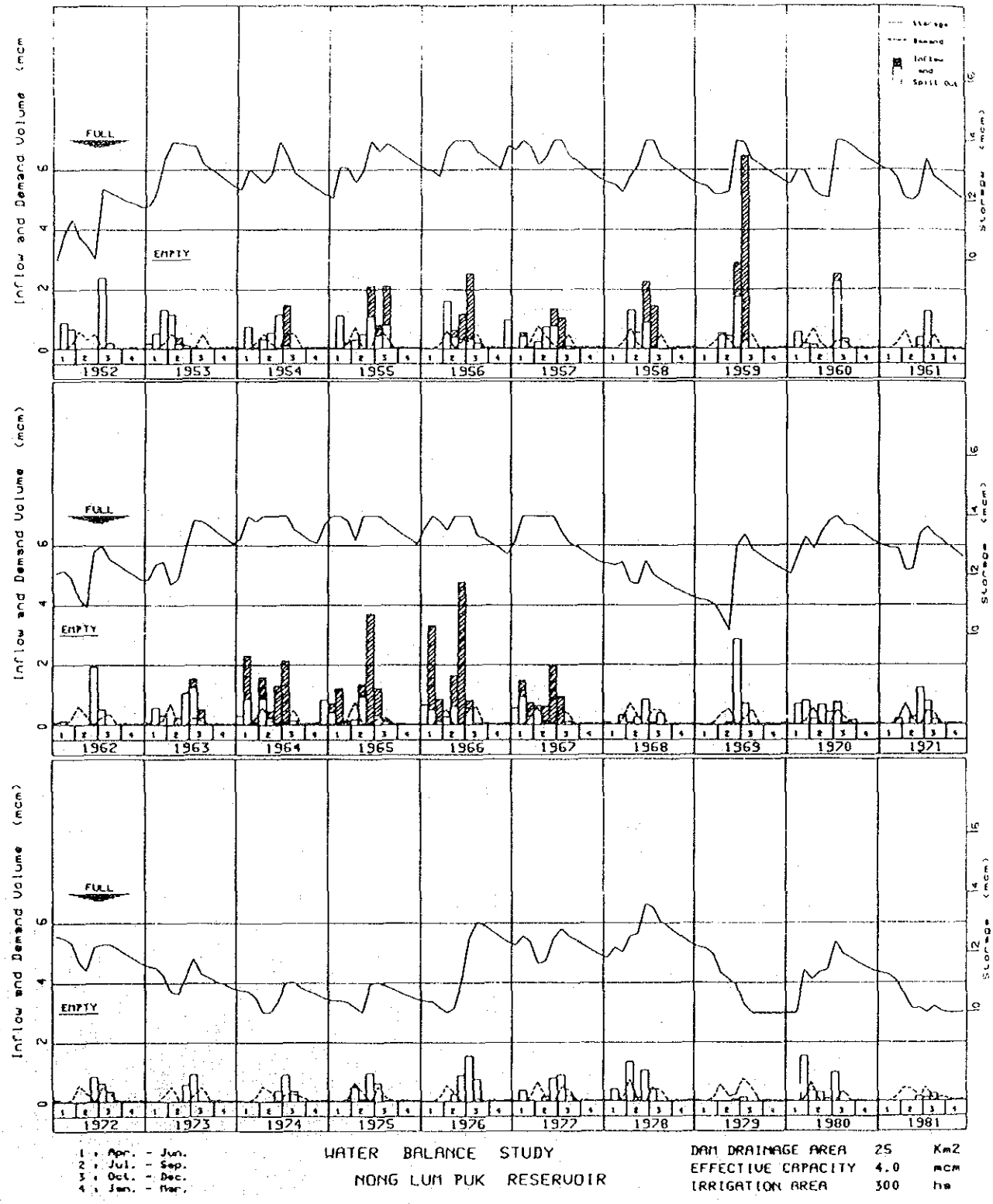


Figure 4-2-3. Water Balance Study (3)

Huai Phlu

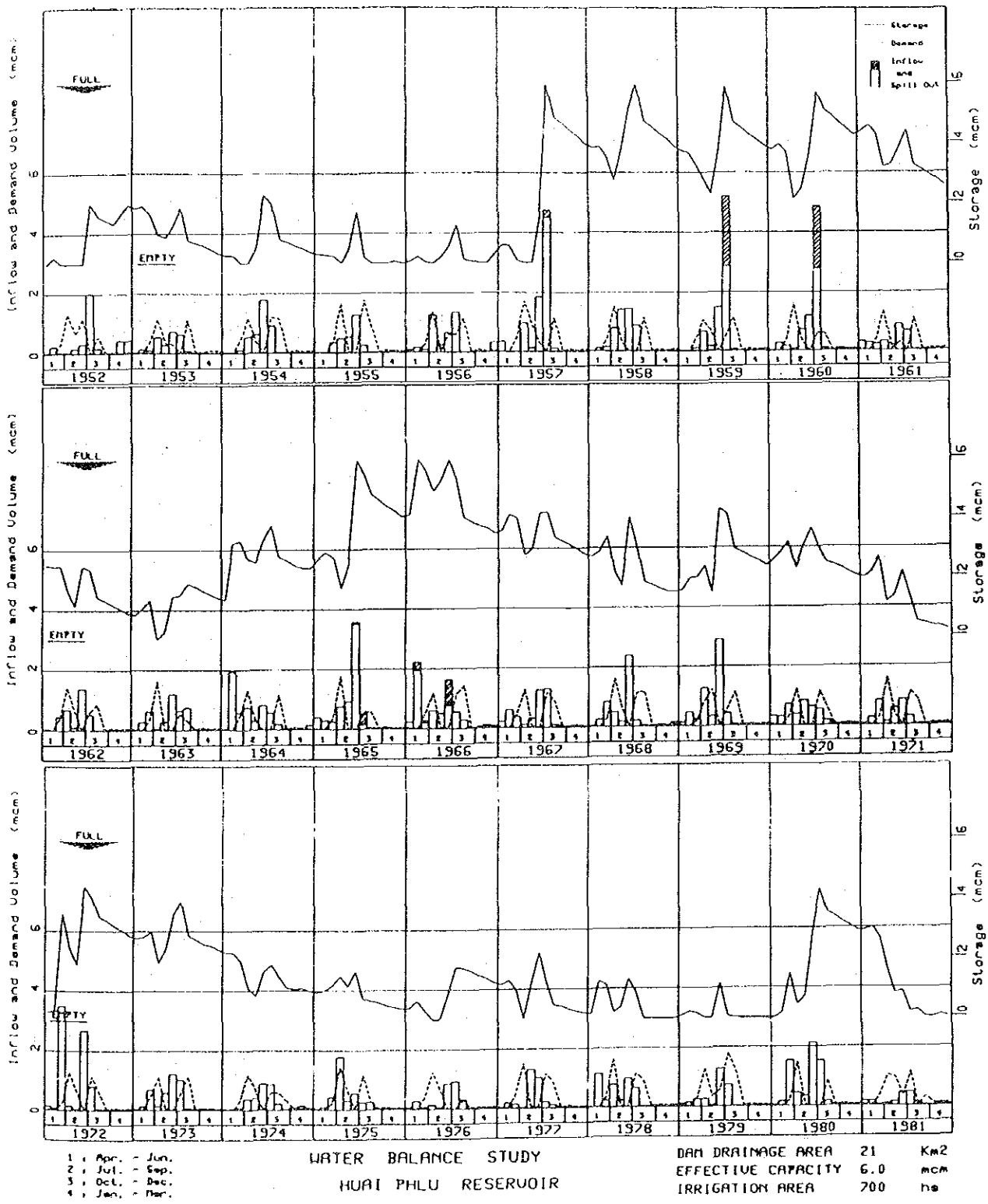


Table 4-2-1. Water Operations Study

- Lam Plai Mat Sub-Project -

Water Year : 1952 to 1981
(April to March in Next Year)

| Water Year | Inflow | Water Demand | Reser-voir Loss | Year End Storage | Spill-out | Water Service: Water Short-age | Ruled Wet S. Paddy | Actual Wet S. Paddy | Dry S. Crops | Water Supply |
|---|---|---|---|---|---|---|---|---|---|---|
| | ($10^6$ cu.m) | | | | | | (ha) | (ha) | (ha) | (%) |
| 1952 | 99.866 | 51.064 | 9.761 | 74.117 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1953 | 58.384 | 40.555 | 10.498 | 58.666 | 22.804 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1954 | 67.625 | 51.026 | 9.725 | 50.725 | 14.813 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1955 | 101.767 | 53.174 | 10.653 | 73.916 | 14.749 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1956 | 112.515 | 37.096 | 10.805 | 86.268 | 52,264 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1957 | 70.383 | 60.345 | 10.730 | 65.686 | 19.890 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1958 | 113.781 | 35.785 | 10.500 | 65.943 | 67.239 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1959 | 205.780 | 42.455 | 10.366 | 65.916 | 152.986 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1960 | 55.849 | 40.779 | 10.511 | 68.674 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1961 | 53.015 | 42.974 | 10.265 | 65.949 | 2.502 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1962 | 64.859 | 51.369 | 10.527 | 61.885 | 7.226 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1963 | 107.543 | 38.568 | 11.026 | 77.692 | 42.147 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1964 | 132.982 | 30.314 | 11.081 | 85.732 | 83.546 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1965 | 98.252 | 45.743 | 11.110 | 74.717 | 54.395 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1966 | 153.459 | 49.158 | 10.652 | 62.715 | 105.651 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1967 | 95.520 | 47.146 | 10.128 | 55.384 | 45.577 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1968 | 26.107 | 62.937 | 6.510 | 12.045 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1969 | 79.152 | 43.455 | 7.203 | 40.538 | 0.000 | 0.000 | 7280 | 7280 | 800 | 100 |
| 1970 | 70.849 | 38.695 | 9.991 | 62.700 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1971 | 55.917 | 52.654 | 9.259 | 54.725 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1972 | 39.818 | 51.481 | 8.204 | 34.858 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1973 | 39.120 | 46.534 | 6.418 | 21.025 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1974 | 42.229 | 39.605 | 5.664 | 17.987 | 0.000 | 0.000 | 7280 | 7280 | 800 | 100 |
| 1975 | 46.948 | 40.738 | 5.714 | 18.484 | 0.000 | 0.000 | 7280 | 7280 | 800 | 100 |
| 1976 | 72.454 | 29.297 | 7.600 | 54.041 | 0.000 | 0.000 | 7280 | 7280 | 800 | 100 |
| 1977 | 58.746 | 51.883 | 8.168 | 32.736 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1978 | 74.084 | 45.068 | 9.085 | 52.668 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| 1979 | 17.465 | 72.241 | 3.862 | .013 | 0.000 | -5.984 | 9100 | 7280 | 800 | 100 |
| 1980 | 113.281 | 18.757 | 9.137 | 82.310 | 5.269 | -.158 | 7280 | 7280 | 800 | 100 |
| 1981 | 18.338 | 56.693 | 8.878 | 35.076 | 0.000 | 0.000 | 9100 | 9100 | 800 | 100 |
| AVERAGE | 77.402 | 45.517 | 9.121 | 55.773 | 22.969 | -.205 | 8796 | 8736 | 800 | 100 |

Table 4-2-2. Water Operations Study

- Nong Lum Puk Sub-Project -

Water Year : 1952 to 1981
(April to March in Next Year)

| Water Year | Inflow | Water Demand | Reser-voir Loss | Year End Storage | Spill-out | Water Service: Water Short-age | Ruled Wet S. Paddy | Actual Wet S. Paddy | Dry S. Crops | Water Supply |
|---|---|---|---|---|---|---|---|---|---|---|
| | ($10^6$ cu.m) | | | | | | (ha) | (ha) | (ha) | (%) |
| 1952 | 4.289 | 1.472 | .797 | 2.130 | 0.000 | 0.000 | 210 | 300 | 30 | 100 |
| 1953 | 3.742 | 1.710 | 1.131 | 2.448 | .582 | 0.000 | 300 | 300 | 30 | 100 |
| 1954 | 4.304 | 2.152 | 1.062 | 2.167 | 1.372 | 0.000 | 300 | 300 | 30 | 100 |
| 1955 | 7.252 | 2.307 | 1.192 | 3.182 | 2.718 | 0.000 | 300 | 300 | 30 | 100 |
| 1956 | 7.196 | 2.020 | 1.217 | 3.816 | 3.326 | 0.000 | 300 | 300 | 30 | 100 |
| 1957 | 4.116 | 2.291 | 1.223 | 2.712 | 1.706 | 0.000 | 300 | 300 | 30 | 100 |
| 1958 | 5.624 | 1.765 | 1.137 | 2.643 | 2.792 | 0.000 | 300 | 300 | 30 | 100 |
| 1959 | 10.462 | 1.985 | 1.101 | 2.634 | 7.386 | 0.000 | 300 | 300 | 30 | 100 |
| 1960 | 3.786 | 1.786 | 1.173 | 3.187 | .274 | 0.000 | 300 | 300 | 30 | 100 |
| 1961 | 1.634 | 1.691 | 1.038 | 2.092 | 0.000 | 0.000 | 300 | 300 | 30 | 100 |
| 1962 | 2.700 | 2.002 | .935 | 1.855 | 0.000 | 0.000 | 300 | 300 | 30 | 100 |
| 1963 | 4.431 | 1.500 | 1.123 | 3.058 | .606 | 0.000 | 300 | 300 | 30 | 100 |
| 1964 | 9.362 | 1.661 | 1.250 | 5.742 | 5.767 | 0.000 | 300 | 300 | 30 | 100 |
| 1965 | 8.842 | 1.697 | 1.267 | 5.053 | 6.565 | 0.000 | 300 | 300 | 30 | 100 |
| 1966 | 12.582 | 2.131 | 1.216 | 2.705 | 9.584 | 0.000 | 300 | 300 | 30 | 100 |
| 1967 | 7.098 | 1.930 | 1.169 | 2.433 | 4.271 | 0.000 | 300 | 300 | 30 | 100 |
| 1968 | 2.088 | 2.563 | .868 | 1.290 | 0.000 | 0.000 | 300 | 300 | 30 | 100 |
| 1969 | 3.759 | 1.518 | .963 | 2.567 | 0.000 | 0.000 | 210 | 300 | 30 | 100 |
| 1970 | 3.873 | 1.688 | 1.218 | 3.097 | .437 | 0.000 | 300 | 300 | 30 | 100 |
| 1971 | 2.717 | 2.093 | 1.116 | 2.605 | 0.000 | 0.000 | 300 | 300 | 30 | 100 |
| 1972 | 1.909 | 1.934 | .925 | 1.654 | 0.000 | 0.000 | 300 | 300 | 30 | 100 |
| 1973 | 1.548 | 1.295 | .751 | 1.155 | 0.000 | 0.000 | 210 | 210 | 30 | 100 |
| 1974 | 1.680 | 1.415 | .623 | .800 | 0.000 | 0.000 | 210 | 210 | 30 | 100 |
| 1975 | 2.322 | 1.437 | .667 | 1.017 | 0.000 | 0.000 | 210 | 210 | 30 | 100 |
| 1976 | 3.551 | 1.106 | .891 | 2.570 | 0.000 | 0.000 | 210 | 210 | 30 | 100 |
| 1977 | 2.561 | 2.024 | 1.005 | 2.103 | 0.000 | 0.000 | 300 | 300 | 30 | 100 |
| 1978 | 3.444 | 2.014 | 1.063 | 2.341 | .129 | 0.000 | 300 | 300 | 30 | 100 |
| 1979 | .233 | 2.612 | .372 | 0.000 | 0.000 | -.410 | 300 | 210 | 30 | 100 |
| 1980 | 3.412 | 1.069 | .715 | 1.655 | 0.000 | -.027 | 210 | 300 | 30 | 100 |
| 1981 | .537 | 1.559 | .523 | .110 | 0.000 | 0.000 | 210 | 300 | 30 | 100 |
| AVERAGE | 4.368 | 1.807 | .991 | 2.227 | 1.584 | -.015 | 276 | 285 | 30 | 100 |

Table 4-2-3. Water Operations Study

- Huai Phlu Sub-Project -

Water Year : 1952 to 1981
(April to March in Next Year)

| Water Year | Inflow | Water Demand | Reservoir Loss | Year End Storage | Spill-out | Water Service: Water Shortage | Water Service: Ruled Wet S. Paddy | Water Service: Actual Wet S. Paddy | Water Service: Dry S. Crops | Water Supply |
|---|---|---|---|---|---|---|---|---|---|---|
| | ($10^6$ cu.m) | | | | | | (ha) | (ha) | (ha) | (%) |
| 1952 | 3.888 | 2.957 | .506 | 2.196 | 0.000 | -1.470 | 455 | 455 | 40 | 100 |
| 1953 | 2.527 | 2.581 | .738 | 1.403 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1954 | 4.063 | 3.254 | .694 | 1.518 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1955 | 3.033 | 3.494 | .510 | .547 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1956 | 4.385 | 3.052 | .546 | 1.334 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1957 | 8.292 | 3.477 | 1.095 | 4.322 | .733 | 0.000 | 455 | 455 | 40 | 100 |
| 1958 | 4.901 | 3.751 | 1.290 | 3.888 | .294 | 0.000 | 700 | 700 | 40 | 100 |
| 1959 | 7.861 | 4.255 | 1.219 | 3.910 | 2.367 | 0.000 | 700 | 700 | 40 | 100 |
| 1960 | 7.541 | 3.824 | 1.271 | 4.255 | 2.105 | 0.000 | 700 | 700 | 40 | 100 |
| 1961 | 2.960 | 3.583 | 1.080 | 2.550 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1962 | 3.320 | 4.299 | .680 | .892 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1963 | 3.941 | 2.267 | .681 | 1.885 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1964 | 5.447 | 3.557 | .986 | 2.789 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1965 | 6.975 | 3.628 | 1.220 | 4.075 | .841 | 0.000 | 700 | 700 | 40 | 100 |
| 1966 | 6.606 | 4.640 | 1.291 | 3.514 | 1.235 | 0.000 | 700 | 700 | 40 | 100 |
| 1967 | 4.484 | 4.153 | 1.062 | 2.782 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1968 | 4.710 | 5.163 | .807 | 1.522 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1969 | 6.017 | 5.006 | 1.046 | 3.487 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1970 | 4.142 | 3.618 | 1.092 | 2.919 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1971 | 3.200 | 4.514 | .709 | .896 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1972 | 7.674 | 2.921 | 1.162 | 4.131 | .356 | 0.000 | 455 | 700 | 40 | 100 |
| 1973 | 4.089 | 3.630 | 1.181 | 3.410 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1974 | 3.210 | 3.971 | .849 | 1.800 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1975 | 3.904 | 2.854 | .831 | 2.018 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1976 | 2.826 | 2.882 | .647 | 1.316 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| 1977 | 3.170 | 3.072 | .548 | .866 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1978 | 4.072 | 3.041 | .658 | 1.239 | 0.000 | 0.000 | 455 | 455 | 40 | 100 |
| 1979 | 2.841 | 3.956 | .285 | 0.000 | 0.000 | -.158 | 455 | 455 | 0 | 0 |
| 1980 | 6.476 | 2.061 | .872 | 3.577 | 0.000 | -.035 | 455 | 455 | 40 | 100 |
| 1981 | 1.693 | 4.387 | .585 | .500 | 0.000 | 0.000 | 700 | 700 | 40 | 100 |
| AVERAGE | 4.608 | 3.528 | .871 | 2.511 | .264 | -.055 | 585 | 594 | 39 | 96 |

Figure 4-2-4. Water Operation Study (1)

Lam Plai Mat

Minimum Ratio of Irrigable Area = 80 (%)
Restricted Effective Storage = 22.2 (mcm)

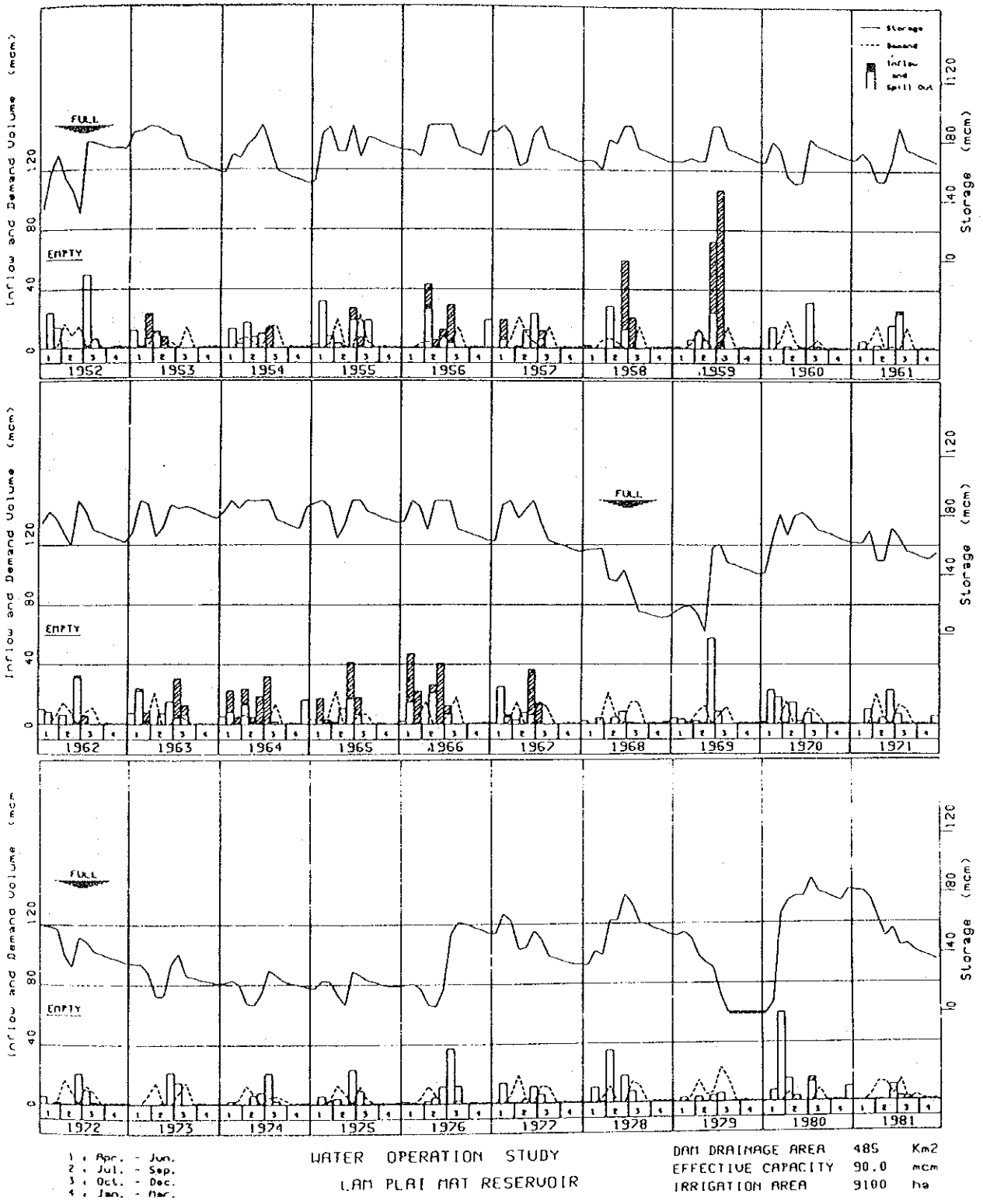


Figure 4-2-5. Water Operation Study (2)

Nong Lum Puk

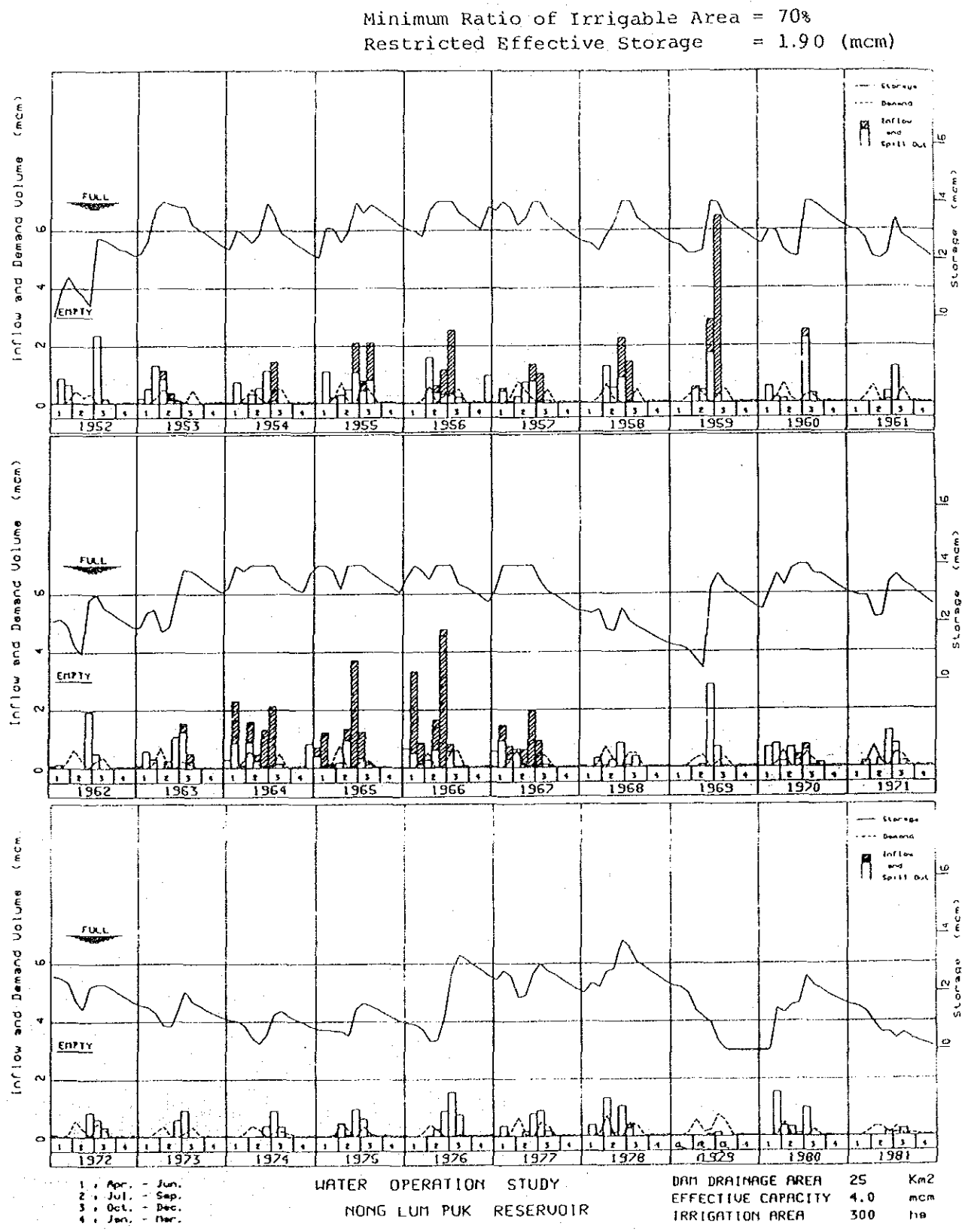
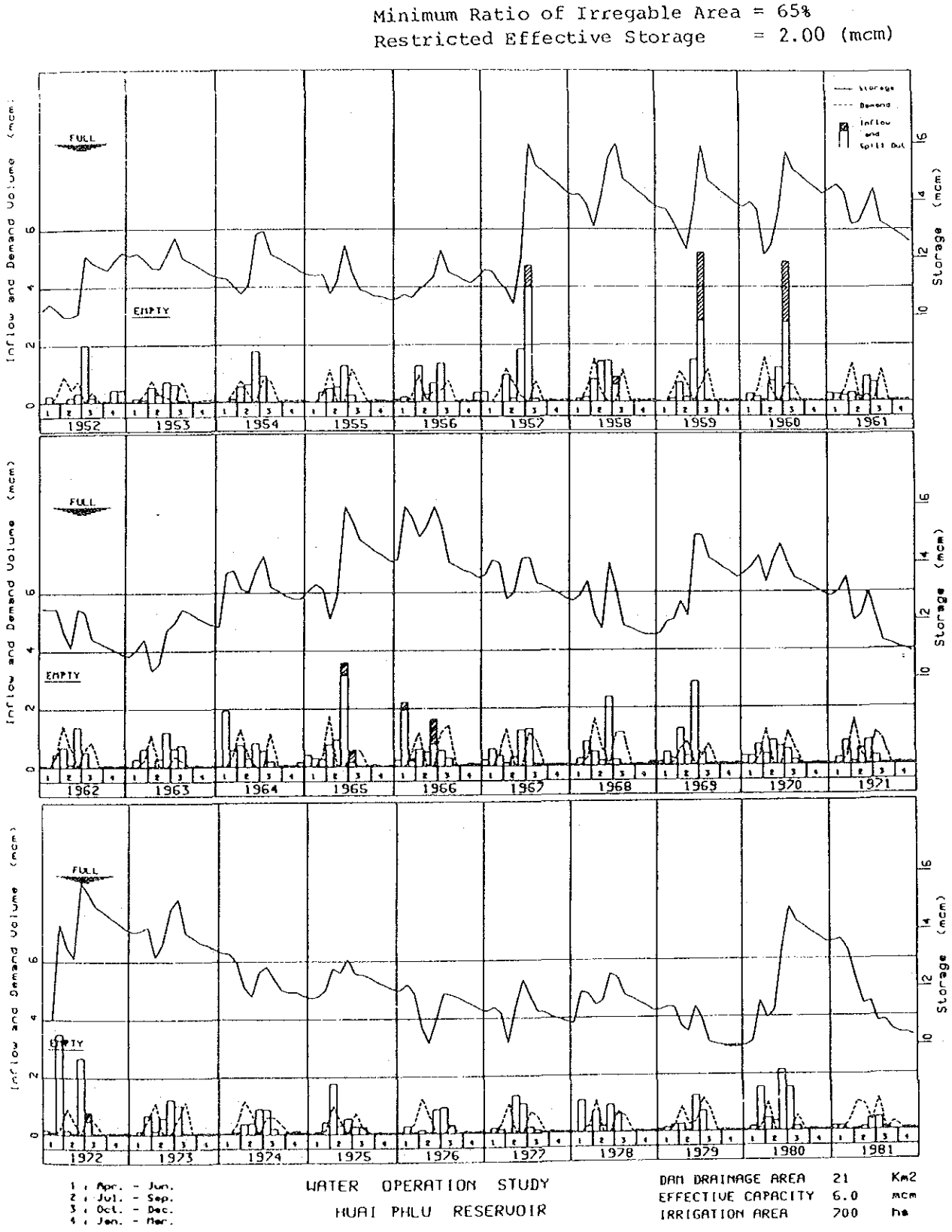


Figure 4-2-6. Water Operation Study (3)

Huai Phlu



The operating rules as given above will be updated on the basis of additional information to be obtained prior to the completion of the dam construction. Attention should be paid to the proper distribution of the scheduled irrigable area after the reduction of the irrigation service area when the reservoir water is in poor condition. Appropriate procedures should be introduced in a simple mode to apply a yearly rotational irrigation scheduling on the basis of the given zones in case of the Lam Plai Mat Sub-Project and of some groups of the given service units in Sub-Projects of Nong Lum Puk and Huai Phlu.

(4) Additional Use of the Reservoirs

- Hydropower generation:

As are seen in Figures 4-2-4, 4-2-5 and 4-2-6, the monthly and yearly fluctuation of the reservoir water level and water demand release in each of the three sub-projects are too large to introduce any hydropower generation scheme that is economically viable.

- Flood control:

Considerable effect on the flood regulation in the proposed reservoirs would be expected because there is great room to incorporate the river flood during the months of August, September, and October when heavy rainfalls usually occur in the reservoir catchment, as is clear in Figures 4-2-4, 4-2-5 and 4-2-6.

Generally speaking, the flood impounding in the Lam Plai Mat reservoir with a drainage basin of 485 sq.km would be more significant to alleviate the present inundations and flash flood damages prevailing in its downstream area that seem not so serious.

- Foreshore field crop cultivation:

When the water level in the reservoir is low, it would be possible to introduce the cultivation of field crops on the upper land of the reservoir site area and to allocate it to the farmers who cannot benefit from the wet season paddy irrigation due to the reservoir operating rule in case of less water storage in the reservoir.

In accordance with the reservoir operating rule based upon the limited water storage level, there would be a possibility to introduce maize cultivation in May to August for many years. This would be applied to such small-medium scale reservoirs as those in the Nong Lum Puk and Huai Phlu Sub-Projects where the water users' association is in charge of operation and maintenance of the dam and reservoir and the Project farmers concerned are living in its vicinity.

Maize cultivation of 42 ha and 80 ha on the average as estimated by the 30-year water operations period in the sub-projects of Nong Lum Puk and Huai Phlu, respectively, has been proposed for inclusion in view of the less harmful effect on the reservoir sediment and others.

4.2.5. On-Farm Works

(1) The D & D Program as authorized by the Field Dikes and Ditches Act in 1962 is essential for the distribution of water in the three sub-projects and is applied to the construction of ditches, from the RID tertiary turnouts along the main and lateral system, to the farmers' lands and to providing structures for controlling water deliveries within the tertiary service unit.

(2) In connection with the on-farm development proposal in the Project service area, two types of on-farm development would be conceived. One is for the Ordinary Service Unit which irrigates 100

percent wet season paddy only, and the other for the Muban Cooperative Service Unit where 100 percent wet season paddy and 100 percent field crops during the dry season are cultivated.

(3) Taking into account the supplementary irrigation for wet season paddy as well as the favorable topography for plot to plot flooding in the service area, the Ordinary Service Unit would be developed in a more extensive mode. Tertiary canals would be aligned as far as possible along property lines to minimize exchange or reallocation of holdings. A farm turnout from the tertiaries would be provided to serve three or four holdings. The density of tertiary canals under this design mode would be about 7 m per rai or 40 m per ha with plot to plot irrigation distance of 200 m to 300m, according to the Lam Takhong Project. Farm roads of 2.5 m wide would be provided along part of the tertiaries to supplement the existing roads and trails linking the muban to the farms.

One problem would be concerned with on-farm drains. There would be adequate slope in most areas for effective plot to plot drainage of excess rainfall which generally occurs during the later growth stage of the wet season paddy. It appears that the farmers at the initial stage would not be aware of the seriousness of this problem and then would be reluctant to grant the necessary right of way through their fields. However, drains will be included in the design of the tertiary systems and could be constructed in the future if farmers become convinced of the need for them.

(4) There would be several items to be examined for the on-farm development of the Muban Cooperative Service Unit (80 to 100 rai) where muban female workers would cultivate intensively the field crops of one to two rai per household during the dry season. In general, such field crops will be grown in row or by broadcasting, hence, irrigation would adopt the furrow, corrugation or border method.

When the surface irrigation method such as furrow is employed, the possibility of "Land Classification" would be conceived including

land levelling, boundary realignment and construction of a rectangular grid of tertiary canals, drains and farm roads. This option, however, would be ruled out since the steeper slopes in the Project service area would involve considerably more earth moving, and in addition to higher cost, this would disturb the thin layer of top soil.

In addition, low field irrigation efficiency would occur when the water rate applied exceeds the infiltration rate and excess is lost by runoff; and when the water depth applied exceeds the storage capacity of root zone, excess is lost by deep drainage. This would be considered uneconomical use of valuable and limited water during the dry season.

Under this situation, it has been proposed that such small-scale irrigation by female workers would be carried out with water buckets in a more careful manner, so that several small ponds should be provided within the tertiary system taking into account the labor to convey water to their field for a maximum distance of about 100 m. Consequently, the construction of Muban Cooperative Service Unit for every muban would be enlarged with more density of tertiary canals than those of the Ordinary Service Unit.

(5) The current RID's policy explains that the on-farm works with a standard size of 50 ha or 300 rai are constructed by RID at its own cost and the maintenance at the farm level should be taken over by the farmers themselves. There would be two aspects of this item to be thoroughly discussed, viz., (1) reduction in size of the service unit, and (2) construction of works by the farmers themselves with limited subsidies supplemented by loans. It appears that the two aspects are regarded as interrelated.

(6) Field interview of the Water Users Group (Chak Group) in the Lam Phra Plerng Project was carried out. That is called the "Ta Kop Chak Group" organized in 1978 and evaluated as most successful with 1,500 rai or 240 ha and 100 member farmers in three muban, while the Ta Kop tertiary system was constructed by RID in 1970. There were

many difficulties explained by the Chak Leader, such as a low degree of cooperation between the water users and several water disputes in controlling equitable water supply among members when rotational distribution is called for. As a matter of fact, the Chak Leader cum Common Irrigator said that his service unit composed of three sub-groups of 160 ha, 48 ha and 32 ha would be too large in size to be properly managed. There are the collapses in many parts of the tertiary earth canals every year which have been repaired by the farmers groups. Their request to RID is that the repair materials, such as cement, sand and stone, would favorably be supplied by RID and, if possible, the tertiary canals would be concrete-lined for good maintenance.

(7) It is said that there are two or three traditional mutual aid systems among close kinsmen in each muban that are commonly found in the Northeast rural areas. RID contends that reduction of the size of the service unit would contribute towards better cooperation and sufficient management by the farmers themselves, and some say that a proper size of the service unit would range from 15 ha or 100 rai to 25 ha or 150 rai. When reduced to this extent, the section of the tertiary canals would become smaller, resulting in considerable decrease of the present troubles and there would be the increased possibility of construction by the farmers themselves, as is seen in the Private or People's Irrigation Systems nominally under the Ministry of Interior. With a greater extension effort for the transfer of technology to eliminate the uncertainty and to inspire confidence among the farmers in a newly changing situation to be generated by the water resources development, strong emphasis should be put upon local farmers' participation in initiating the project, in contributing labor for construction, in cost sharing and in good operation and maintenance of the tertiary system, so that the local people feel the system belong to them.

With this concept, a plan has been conceived to examine from every corner of the on-farm works with a proposed standard size of 20 to 30 ha for the Project. When this new approach is introduced, the RID's canal cost and probably the on-farm work's cost would be slightly increased; however, this increasing cost would be appropriately balanced through the anticipated quick yield of the Project as a whole.

(8) Unfortunately, topographical maps have not been obtained that cover some of the sample areas for the study of on-farm development farms with a scale of 1:2,000 and a contour interval of 0.5 m including the boundary and height of each paddy plot. As an alternative, the topographical maps in the already completed Lam Phra Plerng Project have been obtained which are of similar nature to those available in the vicinity of the Project Area.

Typical layout for the proposed on-farm works in size of 50, 30 and 20 ha has been prepared and subsequent cost estimate for each case has been made. Detailed information of these is compiled in ANNEX F, a salient feature of which is introduced below:

| Size of Service Unit | Length of Canals | | Cost | |
|---|---|---|---|---|
| | Farm Ditch | Farm Drain | Service Unit | RID Lateral Canal |
| | (m/ha) | | (฿/ha) | |
| 50 | 38 | 50 | 4,659 | 0 |
| 30 | 34 | 58 | 4,508 | 3,951 |
| 20 | 29 | 59 | 4,114 | 4,575 |

4.2.6. Water-Based Integrated Muban Development Program

(1) It has been already explained that about 10 percent of the dry season field crops has been proposed for inclusion in the Project. When this cultivation is not properly regulated, the field crops would be cultivated in rather scattered lands and it would become difficult to distribute irrigation water because of large conveyance loss.

Consequently, this cultivation should be requested to be made in a collective manner, and an idea has been introduced of a collective service unit per each muban where the 100 percent wet season paddy as well as the 100 percent dry season field crops are planted.

To materialize this idea, the social dynamics in the Northeast muban have been examined through many publications available as well as through discussions with and comments from the Social Research Institute, Chulalongkorn University in terms of muban in the Project (see ANNEX J). From this basic social study, it has been affirmatively judged that the collective cultivation of dry season field crops by the farm households concerned in each muban would be possibly made based upon special land-lease arrangements that originates from the traditional mutual aid system among close kinsmen. AIT "Water for the Northeast" (1978), pp.86 also states that examples were found in Roi-Et and Ubon Ratchathani where farmers exchange land in dry season, so that every farmer can have an equally small plot of land close to the source of water and pump, because the traditional people's cooperatives in the Northeast have been functioning for centuries.

(2) It is envisaged that the 100 percent dry season crop field in the special service unit in each of the muban would preferably be irrigated in the daytime only. Since a constant flow throughout the day in the RID main and lateral canals is a prerequisite for efficient management, a night storage reservoir is required.

A concept of "Muban Pond" is a possible magnification of the night storage reservoir as mentioned above, for multiple use of the muban people's fisheries and domestic water supply, which should be positively situated as a core of the villagers' strong cooperation that would be a firm foundation for the successful implementation of the proposed water-based integrated rural development as a whole.

In addition, the nurseries for the wet season rainfed paddy outside the proposed irrigation service area as explained previously should be located near the RID main or lateral canal. It is suggested that the Project organize and build a Collective Seedling Plot for each muban in order to maintain continuous water supply to the nurseries and to minimize the water amount in this activity. The village farmers could cultivate the nurseries jointly, rent land for cultivation of the nurseries from farmers adjacent to the canals or buy seedlings from other farmers.

Model and sample layout of the proposed water-based integrated muban development are shown in paragraph 4.1.2. of this chapter.

(3) Additional consideration should be incorporated into the proposed Muban Pond where all the villagers would enjoy fishing activities in order to help increase their protein consumption and get additional cash income.

Department of Fisheries, MOAC explained:

- The given condition that the water supply continues throughout the year from the RID reservoir to the Muban Pond should create the best environment for fish breeding so that an intensive fish production of more than 400 kg per rai (2,500 kg per ha) of the water area would be easily possible.

- Fish species such as Tilapia, Common Carp, Pantius, Indian Carp, Chinese carp, etc. would be recommendable.

- Pond's depth for favorable fish breeding would not be more than 2 m.

- Shape of the pond would be preferably of rectangular type as compared with the round type because of favorable supply of oxygen in the pond water by wind effect.

(4) The most efficient water supply for the muban's need could be achieved through the Muban Pond where RID could supply the upstream reservoir water at all times. Office of ARD explained that the current water demand (ECAFE) is 45 liter per capita per day for people (including 5 liters. for drinking and cooking), 50 liters per head per day for buffalo, 57 liters for cattle and 132 liters for milk cow.

From the sanitary point of view, two intake facilities should be provided in the Muban Pond, viz. one for drinking and cooking use and the other for other miscellaneous supply including those for muban livestocks. The former would be withdrawn from shallow wells with a depth of 4 to 5 m and a capacity of 20 households per well, where the pond water is properly purified through soil percolation. The latter would be to provide a water pool with strainer and hydrants.

Office of ARD explained:

- A hand pump should not be installed at the shallow well, because poor maintenance after a few years would eliminate it according to local experience in the Northeast.

- The proposed water pool for miscellaneous water supply would reduce the use of shallow wells to a larger extent.

(5) During the course of generating the ideas and concept of the proposed water-based integrated muban development plan to be included in the Project, discussions with the government agencies concerned had been made in order to confirm the adequateness and applicability of this model for the proposed Project as well as to point out any difficulties in implementing this plan.

Almost all the discussions have given the Study Team greater appreciation and greater encouragement as the most feasible and attractive model ever experienced so far. Some of the comments received are;

- 100 percent agreement has been given to the development of fisheries and domestic water supply in such manner as explained in the proposed model. It is certain that the muban people could promote their cooperation to the highest level through proper operation of the Muban Pond.

- Some muban would have difficulty in achieving special land-lease arrangements for collective cultivation of the dry season field crops in the Muban Cooperative Service Unit, because the traditional mutual cooperative patterns among close kinsmen have collapsed in certain muban due to modernization in all aspects.

- In certain muban, there are two or three close kin cooperative systems. In this case, two or three Muban Ponds may be requested. The Study Team has the opinion that one Muban Pond should be provided in each muban because this should be a core and symbol of the villagers' strong cooperation and every villager would come to one Muban Pond every evening to enjoy fishing, to take water for household use, to talk together about their daily life and muban's further development.

(6) Muban have their own physical and social characteristics. As a whole, it is suggested that a set of the Muban Pond, Muban Cooperative Service Unit and Collective Seedling Plot should be located close to the muban hamlets within a distance of 1 km, preferably close to the muban temple.

The existing muban pond should be expanded, deepened and protected against leakages as much as possible, while new procurement of the land for this communal facility would be difficult in some muban. To develop a strong sense of ownership, it is imperative that villagers should participate, in real rather than in nominal terms, in the initiation, selection and planning of this muban communal scheme, which would lead towards the successful implementation of this scheme.

(7) Discussion with BAAC has been made on the possible financing of this communal facility; as a result, BAAC explained that because it would be impossible to determine the borrowers in each muban, the BAAC long term investment loan could not be applicable at all. BAAC mentioned that the Office of ARD, Ministry of Interior would be the most appropriate executing agency for implementation of this muban communal scheme, and a part of the construction cost would be borne by the ARD while local contribution should be promoted to the largest extent.

NESDB in "Rural Poverty Eradication Program" (1981) contends that in order to carry out the clean water supply scheme in the Fifth Plan's rural development programs, a revolving fund will be provided for all the target villages for the construction of small water works, rain water tanks and/or water jars, and the funds will be made available for a fixed period and tambon councils will be held responsible for the use and repayment of the funds. Reference is made to paragraph 2.4 of Chapter II.

4.2.7. Social and Economic Features of the Project

Salient features of the Project at full development which has been formulated under the various concepts as mentioned above, with particular emphasis upon the beneficiaries in terms of the Project benefits are summarized below:

| Administrative Division | Sub-Project: Lam Plai Mat | Nong Lum Puk | Huai Phlu | Total |
|---|---|---|---|---|
| Changwat | Nakhon Ratchasima and Buriram(2) | Nakhon Ratchasima(1) | Buriram(1) | 2 |
| Amphoe | 3 | 1 | 1 | 4 |
| Tambon | 8 | 2 | 2 | 11 |
| Muban | 60 | 4 | 9 | 73 |
| **Population and Households in Beneficial Mubans in 1982/83** | | | | |
| Total | | | | |
| No. of Households | 8,731 | 766 | 815 | 10,312 |
| Population | 49,387 | 4,262 | 4,488 | 58,137 |
| Average Household Size | 5.66 | 5.56 | 5.51 | 5.64 |
| No. of Farm Households: | | | | |
| (1)Paddy Only (%) | 2,765 (35) | 64 (32) | 90 (11) | 2,919 (33) |
| (2)Paddy + Upland (%) | 2,716 (36) | 407 (33) | 287 (35) | 3,410 (35) |
| (3)Upland Only (%) | 2,149 (29) | 219 (35) | 433 (53) | 2,801 (32) |
| Total (%) | 7,630(100) | 690(100) | 810(100) | 9,130(100) |
| Farm/Total | 0.87 | 0.90 | 0.85 | 0.87 |
| **Total Paddy Field to be Serviced with the Irrigation Facilities** | | | | |
| (ha) | 9,100 | 300 | 700 | 10,100 |
| **Project Beneficiaries** | | | | |
| 1. Irrigation for Wet Season Paddy | | | | |
| Service Area(ha) | 8,736 | 280 | 586 | 9,602 |
| No. of Households:(1) + (2) | 5,481 | 471 | 377 | 6,329 |
| Area per Household (ha) | 1.59 | 0.53 | 1.55 | 1.52 |
| 2. Irrigation for Dry Season Field Crops 1/ | | | | |
| Service Area (ha) | 773 | 29 | 39 | 841 |
| No. of Households | 2,745 | 201 | 169 | 3,115 |
| 3. Irrigation for Muban Cooperative Seedling Plots for Wet Season Paddy Outside the System | | | | |
| Size of Seedling Plots(ha) | 152 | 9 | 3 | |
| Beneficiary Area (ha) | 2,020 | 120 | 48 | 2,188 |
| No. of Households | 5,481 | 471 | 377 | 6,327 |
| 4. Irrigation for Muban Cooperative Seedling Plots for Wet Season Paddy Inside the System 2/ | | | | |
| Size of Seedling Plots(ha) | 27 | 2 | 9 | 38 |
| Beneficiary Area (ha) | 364 | 20 | 114 | 498 |
| No. of Households | 5,481 | 471 | 377 | 6,327 |
| 5. Water Supply for Drinking and Domestic Use for Muban People | | | | |
| Households (%) | 7,115 (82) | 766(100) | 815 (85) | 8,696 (84) |
| Population (1983) | 39,838 | 4,262 | 4,488 | 48,588 |
| No. of Population (1993) | 53,400 | 5,700 | 6,100 | 65,200 |
| 6. Water Supply for Drinking and Bathing Use for Muban Baffalo and Cattle | | | | |
| No. of Households (%) | 6,811 (85) | 686(100) | 694 (86) | 8,191 (86) |
| No. of Buffalo (1993) | 13,500 | 400 | 900 | 14,800 |
| No. of Cattle (1993) | 2,161 | 132 | 23 | 2,316 |
| 7. Fisheries in Muban Ponds | | | | |
| No. of Households | 7,115 | 766 | 815 | 8,696 |
| 8. Fisheries in RID Reservoirs | | | | |
| No. of Households | ---------- Licensors in and around the Project Mubans ---------- | | | |
| 9. Foreshore Field Crops in RID Reservoirs at Lower Water Level | | | | |
| Cropped Area(ha) | - | 42 | 80 | 122 |
| No. of Households 3/ | - | <444 | <377 | <821 |

1/ ------- ° No. of households to be assigned:
Lam Plai Mat and Huai Phlu: "Paddy main" x 60% + "Paddy + Upland" x 40%
Nong Lum Puk : "Paddy main" x 60% + "Paddy + Upland" x 20%

° Average size per household: 0.32 ha. or 2 rai

2/ ------- When the irrigation service area is reduced due to less water storage under the reservoir operations rule.

3/ ------- To be allocated for the households whose paddy is not irrigated due to less water storage in the case of Small-Medium Scale Reservoir where the Water Users' Association is in charge of O&M and the Project farmers concerned are living in its vicinity.

### 4.2.8. Environmental Effects

Implementation of the Project would not significantly change environmental conditions. A substantial benefit of the Project would be the provision of assured employment among the villagers who might otherwise settle on forest land for practicing of the "slash and burn" agriculture which might invite severe erosion and sedimentation problems. The introduction of irrigation to the Project Area would tend to increase the quality of the return flow which would be good enough for further extension of irrigation downstream. Construction of canals and roads would create many borrow pits which are prized by the local people for fish and frog production. On the other hand, the provision of drainage channels with a marked increase in the use of chemical pesticides could be detrimental to fish production in its lower reaches.

It is reported that no item of archaeological and historical importance would be present in the Project reservoir and service areas. After construction of the reservoirs especially at the Lam Plai Mat, the agency concerned should monitor the volume of visitors to the reservoirs. Since the reservoirs seem to have good tourist potential for local visitors, some facilities may have to be carefully provided.

## 4.3. Agricultural Development Plan

### 4.3.1. Crop Selection and Proposed Cropping Pattern

(1) Crop Selection

In the wet season, it is planned to supply irrigation water not only for the proposed irrigation service area but also for the nurseries outside of irrigation service area.

It is planned that irrigation water is supplied under the rotational irrigation method in each sub-system of the irrigation service area. Where irrigation water is not supplied in a certain sub-system, water is supplied for nurseries.

Following crops are selected as major crops for the Project. The reason for the selection is also indicated below:

(1) Wet Season Crops

Both types of wet season rice, namely, non-photo-sensitive varieties like RD23 and RD7 and photo-sensitive varieties like Khao Dawk Mali 105, RD15, Niaw Sanpahtawng are selected in half of each area for wet season crops as mentioned previously.

In the off-supply area of irrigation water under rotational irrigation and the area outside the irrigation service area, photo-sensitive varieties, mostly the same as the aforesaid photo-sensitive varieties would be planted with the provision of water for nurseries.

(2) Dry Season Crops

As mentioned in the section 4.1. Objective and Components of the Project, the following six crops are mainly selected as the dry

season field crops in the paddy field after harvesting wet season rice with irrigation supply. The selected crops and the reason for selection are as follows:

i) Groundnut .... This is one of the typical cash crops in the Project Area, having firm and nation-wide markets. Moreover, this is one of the ideal crops in crop rotation and soil amendment due to leguminous crops.

ii) Mungbean .... Same as groundnut

iii) Tomato ..... The amphoe Ban Kruat and King amphoe Pa Kham are included as the areas to promote tomato production for processing at the Nang Rong Royal Food Processing Factory.

iv) Baby Corn ... The above-mentioned factory also deals with processing baby corn as canned food.

v) Shallot ..... Drying facility is installed at the same factory for drying shallot.

vi) Chili ..... Same as shallot; moreover, it may give the highest income per unit area among these six crops.

It is recommended that further study on crop selection should be made toward the Project implementation because the crop selection above has been made only at a feasibility study level.

(2) Proposed Cropping Pattern

The proposed cropping calendar is shown in Figure 4-3-1. As for the rice of photo-sensitive varieties, the maximum yield is attained when transplanting is made in early August (see ANNEX D). Therefore, the cropping calendar could be fixed as in the Figure because the varieties have a definite harvesting time under control of photo-periodism. The cropping calendar of non-photo-sensitive is decided in the manner described previously (see 4.2.2. Proposed Cropping Pattern). The cropping calendar of the field crops is decided by referring to collected data from the office of the Department of Agricultural Extension, etc.

The lag period of 45 days for wet season rice and 30 days for dry season field crops are given, taking into account the demand and supply balance of farm labor. The nursery period of both types of wet season rice is 30 days for the irrigation rice, including 10 days of land preparation period. 40 days are given for the nursery in case the water is supplied only for nurseries.

The area allotment of dry season field crops is determined taking into consideration the labor intensity and net production value and the capacity of the said food factory, etc.

4.3.2. Project Crop Production

(1) Improvement of Farming Practices and Inputs Requirement

With conversion from the traditional rainfed agriculture to the irrigated agriculture under the Project, the introduction of improved farming practices as shown in ANNEX D is required, which is accompanied by application of farming inputs. Per hectare requirement of farming inputs by each selected crop is estimated in Table 4-3-1 and the total requirement of farm inputs in the Project Area is calculated as follows:

Figure 4-3-1 Proposed Cropping Calendar

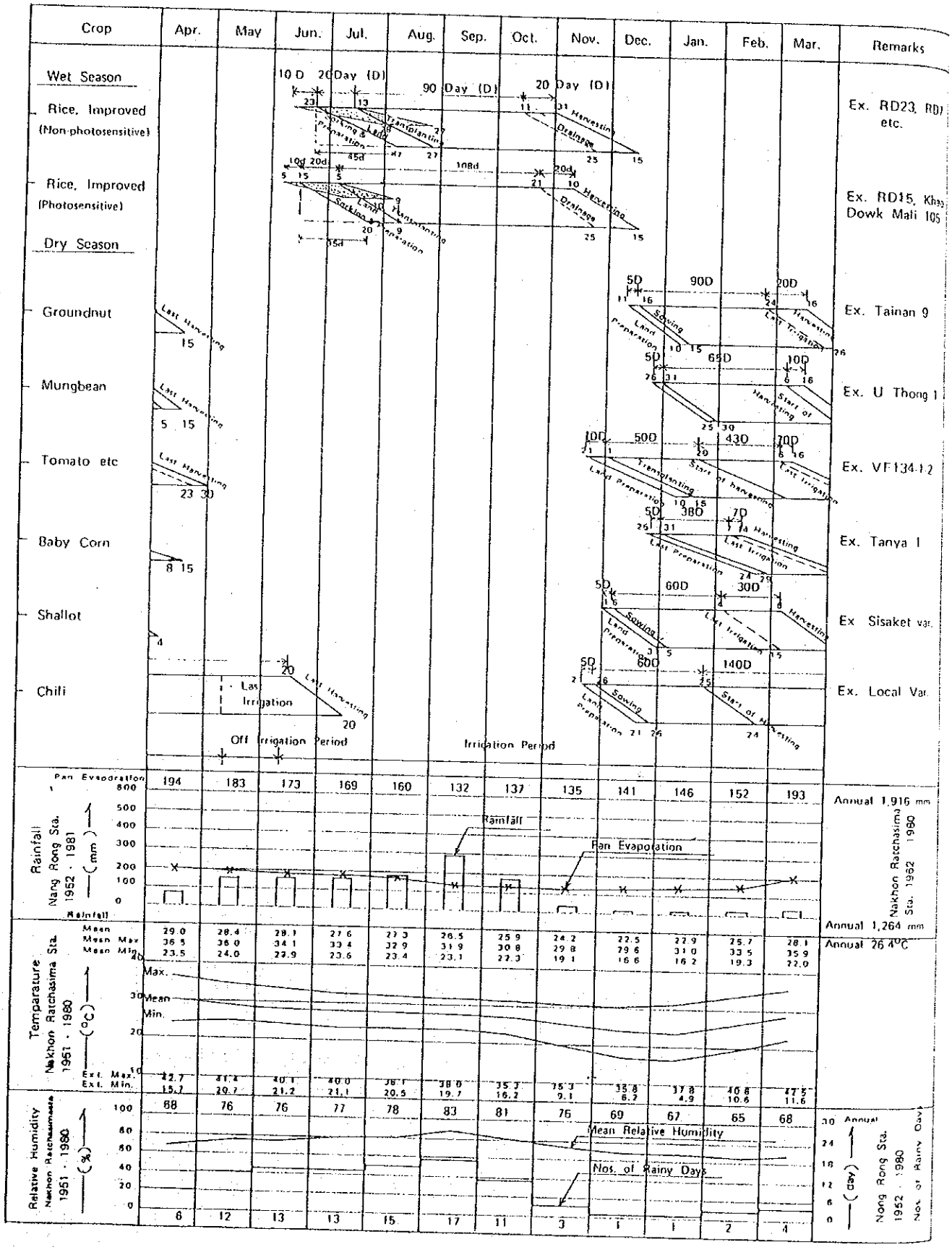
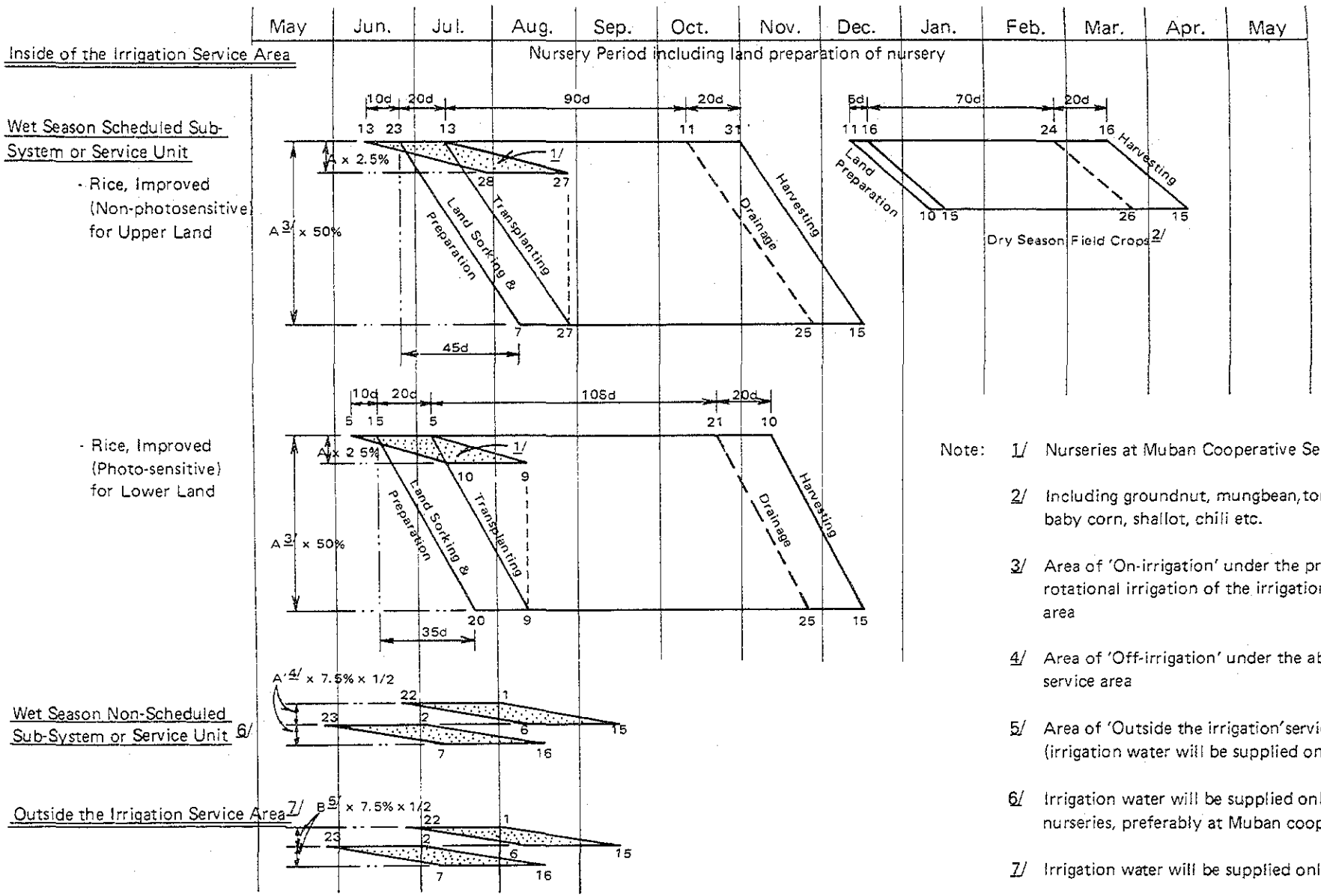


Figure 4-3-2 Proposed Cropping Pattern




Note:
1/ Nurseries at Muban Cooperative Service Unit

2/ Including groundnut, mungbean, tomato, baby corn, shallot, chili etc.

3/ Area of 'On-irrigation' under the proposed rotational irrigation of the irrigation service area

4/ Area of 'Off-irrigation' under the above said service area

5/ Area of 'Outside the irrigation' service area (irrigation water will be supplied only for nursery)

6/ Irrigation water will be supplied only for nurseries, preferably at Muban cooperative units

7/ Irrigation water will be supplied only for nurseries

Farm Inputs Requirement

| Inputs | Unit | Rice | Groundnut | Mungbean | Vegetables | Total |
|---|---|---|---|---|---|---|
| 1. Seeds | ton | 413 | 18 | 2 | 116 kg | |
| 2. Fertilizers | | | | | | |
| - 16-20-0 | ton | 1,463 | 14 | 12 | 204 | 1,693 |
| - 15-15-15 | ton | 559 | - | - | 9 | 568 |
| - Urea | ton | - | - | - | 51 | 51 |
| - Murraite of Potassium | ton | 367 | - | - | - | 367 |
| - Compost | ton | 8,736 | (Gypsum) 39 | 324 | 6,980 | 16,040 |
| 3. Pesticides | | | | | | |
| - Liquid | '000 lit. | 13.12 | 0.07 | 0.04 | 1.28 | 14.51 |
| - Granular & Wettable Powder | ton | - | 0.84 | 1.49 | 7.32 | 9.65 |

The labor requirement of each selected crop is estimated for both cases, that is, "without mechanization" and "with mechanization".

It is assumed that mechanized farming with small machinery would cover one third of cultivation areas of wet season rice and dry season field crops in the paddy fields. The farm labor balance in the area of two sub-projects of the Lam Plai Mat and the Nong Lum Puk and also in the Huai Phlu Sub-Project was studied under the following conditions because the said two sub-projects are neighbouring areas.

i) The farm labor balance is studied on a muban area basis in the above areas.

ii) The available farm labor force per month is estimated for the farm households in 1982 as follows:

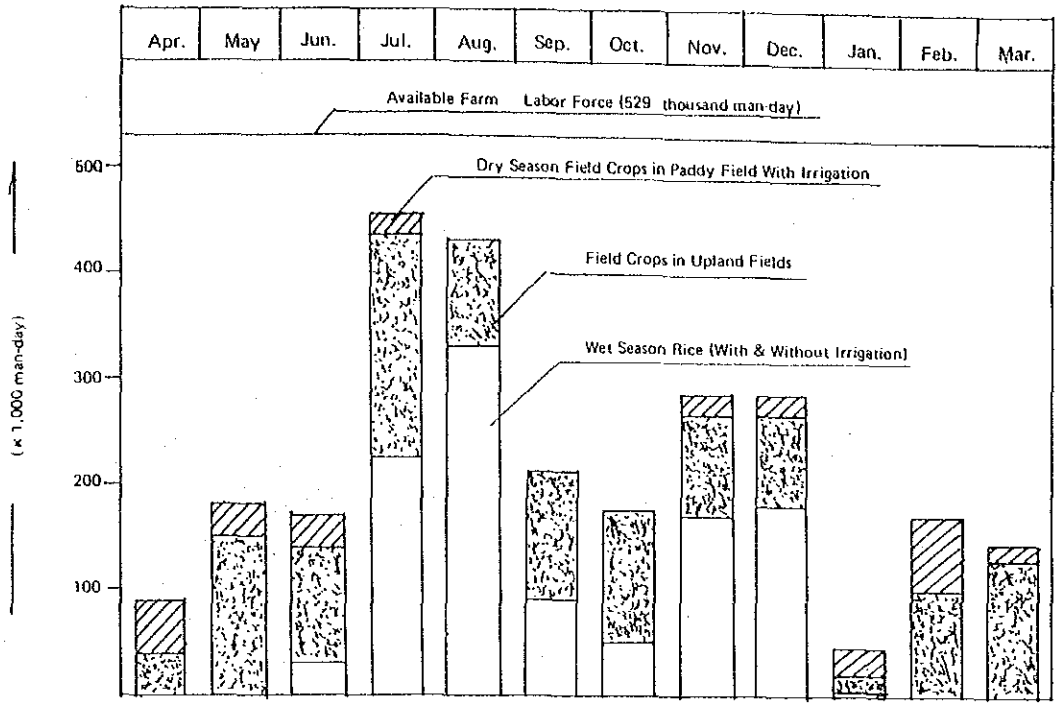
Number of farm labor force per household .. 2.6 man-day
(Converted, Male 1.5 + Female 1.7 x 65%)

Number of working days per month ..... 25 days/month

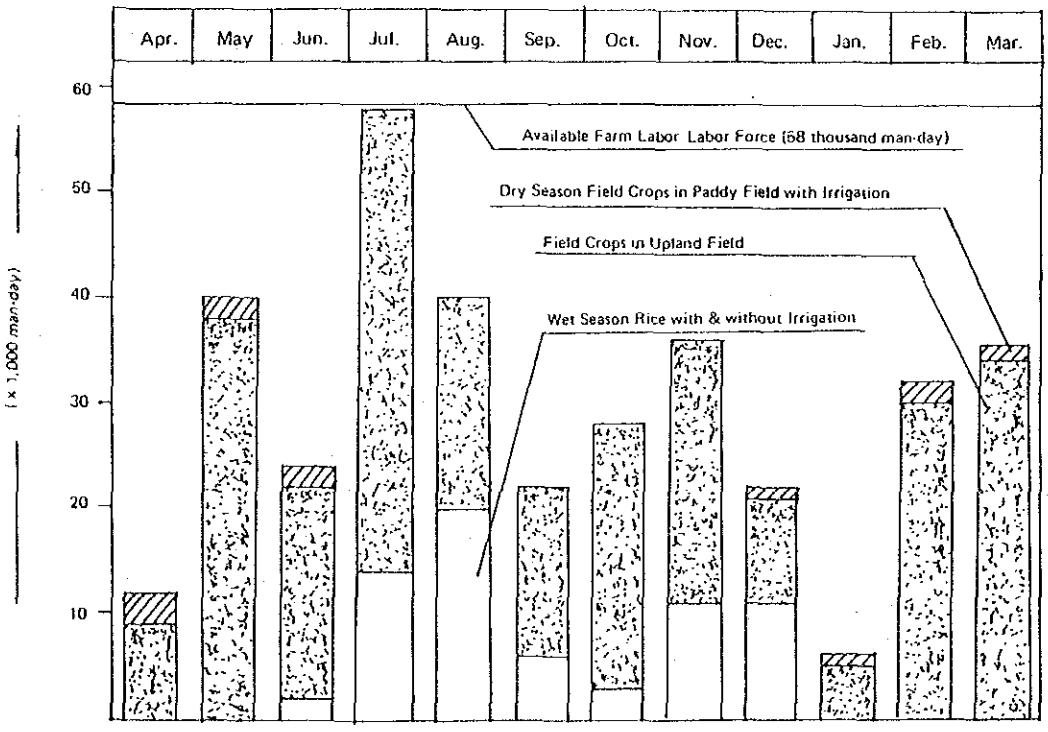
Figure 4-3-3 shows the farm labor balance in the respective areas. Comparing to the present situation, the newly created employment opportunity will solve the problem of underemployment to some extent.

Figure. 4-3-3. Farm Labor Balance in the Project Area

1. Area of the Lam Plai Mat and Nong Lum Puk Sub-Project




2. Area of the Huai Phlu Sub-Project



## Table 4-3-1 Farm Inputs Requirement (With Project)

| Crop | Seed (kg/ha) | Chemical Fertilizers: Compound (kg/ha) | Urea (45-0-0) (kg/ha) | Ammosul (21-0-0) (kg/ha) | MP (0-0-60) (kg/ha) | Compost (ton/ha) | Pesticides: Amount | Pesticides: Kind | Man Power (man/day) | Draft Animal (day) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Rice, Wet Season | | | | | | | | | | |
| - Improved (Non-photo-sensitive) | 40 | 192 (16-20-0) | 84 | - | 43 | 1.0 | 1.5liter | Liquid | 100.1 | 17.1 |
| - Improved (Photo-sensitive) | 40 | 137 (16-20-0) | 44 | - | 43 | 1.0 | 1.5liter | Liquid | 100.1 | 17.1 |
| - Rainfed 1/ | 38 | 16 (16-20-0) | - | - | - | - | - | - | 82.4 | 16.3 |
| 2. Groundnut | 125 | 100 (15-15-15) | - | - | - | (Gypsum) 0.28 | 6.0 kg<br>0.5liter | Granular<br>Liquid | 110.5 | 19.7 |
| 3. Mungbean | 25 | 150 (15-15-15) | - | - | - | 4.0 | 18.0 kg<br>0.5liter | Granular<br>Liquid | 67.0 | 14.5 |
| 4. Vegetables | | | | | | | | | | |
| - Tomato | 0.2 | 250 (16-20-0) | 12 | 208 | - | 10.0 | 3.0liter<br>28.5 kg<br>33.0 kg | Liquid<br>Wettable Powder<br>Granular | 317.0 | 38.0 |
| - Baby Corn | 36 | 320 (16-20-0) | - | - | - | 6.0 | 1.0liter | Liquid | 112.5 | 16.5 |
| - Shallot | 375 | 400 (15-15-15) | - | 120 | - | 18.0 | 2.5liter<br>5.0 kg | Liquid<br>Wettable Powder | 121.5 | 21.7 |
| - Chili | 400 cc | 500 (15-15-15) | 100 | - | - | 10.0 | 3.0liter | Liquid | 2,114.7 | 38.0 |

(2) Projected Crop Production

The total amount of paddy production with Project Area is estimated at about 38,700 tons (about 3.6 times as much as the present production), the breakdown of which is about 35,100 tons (about 3.6 times), 1,200 tons (2.9 times) and 2,400 tons (3.5 times), respectively, in the Lam Plai Mat, Nong Lum Puk and Huai Phlu Sub-Project. The total incremental production of rice between the without and with project is estimated at about 27,800 tons in the three sub-projects. Considering the excess capacity of the existing rice mills in the project amphoe, the existing capacity of the rice mill could cover the total production of paddy including the incremental production.

The production of the respective crops in each sub-project is estimated as follows:

Production of Wet Season Rice in the Project

| Sub-Project | Total Area (ha) | Planted Area (ha) | Harvested Area (ha) | Yield (ton/ha) | Production (ton) |
|---|---|---|---|---|---|
| 1. Lam Plai Mat | 11,120 (100%) | 10,708 (96.3) | 10,386 (93.4) | 3.38 | 35,070 |
| 2. Nong Lum Puk | 420 (100%) | 400 (95.2) | 383 (91.2) | 3.16 | 1,211 |
| 3. Huai Phlu | 748 (100%) | 719 (96.1) | 713 (95.3) | 3.38 | 2,409 |
| Total | 12,288 (100%) | 11,827 (96.2) | 11,482 (93.4) | 3.37 | 38,690 |

Inclemental Crop Production

(Unit: ton)

| Crop/Sub-Project | Present Production (1) | Production with Project (2) | Incremental (3) = (2)-(1) |
|---|---|---|---|
| 1. Wet season rice | | | |
| 1) Lam Plai Mat Sub-Project | 9,788 | 35,070 | 25,282 |
| 2) Nong Lum Puk " | 411 | 1,211 | 800 |
| 3) Huai Phlu | 669 | 2,409 | 1,740 |
| Total | 10,868 | 38,690 | 27,822 |
| 2. Dry season field crops | | | |
| 1) Lam Plai Mat Sub-Project | - | 5,300 | 5,300 |
| 2) Nong Lum Puk " | - | 194 | 194 |
| 3) Huai Phlu " | - | 259 | 259 |
| Total | - | 5,753 | 5,753 |

Note: For further details, see ANNEX D, Table D-6-10.

It is considered that full development will be attained in the fifth year after construction of the Project in the Nong Lum Puk and Huai Phlu Sub-Project because efficient development after construction of the Project is expected in such small scaled project. But it is assumed to take 7 years in case of the Lam Plai Mat Sub-Project. The projected crop yield by year and sub-project is shown in Table 4-3-2.

Table 4-3-2. Projected Yield after Project Construction

(Unit: ton/ha)

| Sub-project/Crop | The Year after Project Construction | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
| 1. Lam Plai Mat | (45.6) | (65.0) | (80.0) | (90.0) | (95.0) | (98.0) | (110.0)2/ |
| (1) Rice, Non-photo-sensitive | 1.80 | 2.60 | 3.20 | 3.60 | 3.80 | 3.92 | 4.00 |
| (2) Rice, Photo-sensitive | 1.57 | 2.27 | 2.80 | 3.15 | 3.32 | 3.43 | 3.50 |
| (3) Groundnut | 1.08 | 1.56 | 1.92 | 2.16 | 2.28 | 2.35 | 2.40 |
| (4) Mungbean | 0.45 | 0.65 | 0.80 | 0.90 | 0.95 | 0.98 | 1.00 |
| (5) Tomato | 11.25 | 16.25 | 20.00 | 22.50 | 23.75 | 24.50 | 25.00 |
| (6) Baby Corn | 0.18 | 0.26 | 0.32 | 0.36 | 0.38 | 0.39 | 0.40 |
| (7) Shallot | 2.25 | 3.25 | 4.00 | 4.50 | 4.75 | 4.90 | 5.00 |
| (8) Chili | 5.40 | 7.80 | 9.60 | 10.80 | 11.40 | 11.76 | 12.00 |
| 2. Nong Lum Puk/ Huai Phlu | (55.0) | (78.0) | (92.0) | (97.0) | (100.0)1/ | | |
| (1) Rice, Non-photo-sensitive | 2.20 | 3.12 | 3.68 | 3.88 | 4.00 | | |
| (2) Rice, photo-sensitive | 1.92 | 2.73 | 3.22 | 3.15 | 3.50 | | |
| (3) Groundnut | 1.32 | 1.56 | 1.92 | 2.16 | 2.40 | | |
| (4) Mungbean | 0.55 | 0.78 | 0.92 | 0.97 | 1.00 | | |
| (5) Tomato | 13.75 | 19.50 | 23.00 | 24.25 | 25.00 | | |
| (6) Baby Corn | 0.22 | 0.31 | 0.36 | 0.38 | 0.40 | | |
| (7) Shallot | 2.75 | 3.90 | 4.60 | 4.85 | 5.00 | | |
| (8) Chili | 6.60 | 9.36 | 11.04 | 11.64 | 12.00 | | |

1/ ... The target yield of the Huai Phlu sub-Project is 4.1 ton/ha.

2/ ... The figures in the parentheses show the percent of yield. (target yield = 100%)

(3) Demand and Supply Balance of Rice

Rice Demand and Supply Balance with Project

| Sub-Project | Supply (Production) 1/ | Demand | | | Balance (Supply = 100) |
|---|---|---|---|---|---|
| | | Consumption 2/ | Seed 3/ and Loss | Total | (At present) |
| 1. Lam Plai Mat | 23,146 | 11,254 | 4,629 | 15,883 | 146(67) |
| 2. Nong Lum Puk | 799 | 969 | 160 | 1,129 | 71(35) |
| 3. Huai Phlu | 1,590 | 1,020 | 318 | 1,338 | 119(52) |
| Total | 25,535 | 13,243 | 5,107 | 18,350 | 139(63) |

Note: 1/ Milled Rice (Conversion Rate from Paddy to Rice = 66%)
2/ 170 kg/capita/year (Source: Farm Survey, 1983)
3/ 20% of Production

4.3.3. Farm Management Plan

There are three types of farm management at present, namely, "Rice Main", "Rice + Upland Crops" and "Upland Crops Main", which have been classified based on the 1978 Agriculture Census. The beneficiary farmers of the irrigation water supply are limited to the farm household of "Rice Main" and "Rice + Upland Crops". The Study Team's "Farm Economic Survey" on the income distribution shows that the sample households which are classified into "poor" and "marginal" are mostly covered by the farm households of "Rice Main" and also some farm households of "Rice + Upland Crops". It has been assumed that 60 percent of the "Rice Main" farm households and 40 percent of the "Rice + Upland Crops" farm households could participate in the cultivation of field crops after harvesting the wet season rice in the paddy field. Total farm households with the cultivation area of dry season field crops are 2,778 with 870 ha in the whole package Project Area. The breakdown is 2,540 farm households with 800 ha, 120 farm households with 30 ha and 136 farm households with 40 ha,

respectively, in the Lam Plai Mat, Nong Lum Puk and Huai Phlu Sub-Project considering the assumed availability of farm labor per household of 1.5 man-day per household during the cropping period of dry season crops.

4.3.4. Supporting Services

The following supporting services are required to realize the proposed development of irrigated agriculture:

(1) Cadastral survey by Land Department. The registration of "NOR SOR 3" is required to cover the whole beneficiary paddy field.

(2) Strengthening of agricultural extension services for irrigated agriculture is indispensable. The increase of the extension staff member at the rate of 500 farmers per one extension staff and the strengthening of extension are required, including seed supply, trials and demonstration on irrigated agriculture.

(3) Strengthening of institutional credit services by BAAC through increasing credit source, etc.

(4) Supply of fly to the Muban Pond and technical assistance and training to the farmers.

(5) Institutional build-up of agricultural cooperatives for short-term credit, procurement of farm inputs and selling farm produce collectively.

(6) Assist muban people in identifying and planning the rural development scheme and help supervising of construction, organize muban people for operation and maintenance and generally act as a liaison between government agencies and the project beneficiaries.

## 4.4. Water Based Muban Development Plan

### 4.4.1. Village Fisheries

Forty muban ponds, proposed to be constructed for multiple use, namely, as farm ponds, muban peoples' fishponds and reservoirs for supplying drinking water, other domestic water and water for animals, aim to provide a firm foundation for successful implementation of the proposed water-based integrated rural development plan. The scale of fishpond is determined as follows:

(a) The production target in each muban in calculated on the basis of the forecasted population for 1994 and supply target at 5.0 kg per capita which is about 22 percent of the present per capita consumption (22 kg/year).

(b) Yield of fishpond is set at 2,500 kg/ha.

(c) Three sizes of fishpond, namely, 2.4 ha (15 rai), 1.6 ha (10 rai) and 0.8 ha (5 rai) are set up, considering the possibility of land acquisition.

(d) The required scales of fishponds were calculated following the above item (a). Then, the scales were adjusted to one of the above three sizes.

The forty proposed Muban Ponds in the Project Area comprise 35 ponds to be newly constructed and five existing ponds to be rehabilitated. So far as the topographic conditions seem to be suited as ascertained by the base map for supplying water, the Muban Ponds are planned to be installed in the respective muban.

### 4.4.2. Rural Water Supply

The size of Muban Ponds is determined by the size of the fishpond because the capacity requirement of fishponds is larger than other capacities. The water supply plan for drinking, domestic and also livestock use is formulated as follows:

(a) Based on the demand of 45 liter per capita per day for people (including 5 liter for drinking and cooking), it is planned to supply this amount of water for 70 percent of the future population in 1994 in the related mubans. The per capita water demand is referred from the standard of ARD. The supply period is planned to be from December to mid-May.

(b) It is considered that the water supply for the remaining 30 percent of population will depond upon the existing shallow wells and deep wells according to the result of Study Team's Farm Economic Survey.

(c) The water for drinking and cooking is planned to be obtained from shallow wells that are dug at areas surrounding places of Muban Ponds. The domestic water other than drinking water is provided by a water pool with strainer.

(d) The water supply for cattle and buffaloes is also planned, based on the demand of 50 liter per head per day for buffaloes and 57 liter for cattle in referring to ARD Standard. The number of buffaloes includes the number to be increased through expansion of rice straw by the Project.

It is expected that about 3,970 heads of buffalo could be increased relating to the increase of rice straw by the Project as follows (For the detail see ANNEX D):

(i) The increase of rice straw is estimated at about 47,830 tons per year in the Project Area.

(ii) Assuming that 60 percent of the increased rice straw (about 28,700 tons) can be used to feed buffalo, the converted amount of TDN (Total digestible nutrient) from the rice straw is equivalent to about 5,230 tons.

(iii) Following number of buffaloes can be fed by TDN of increased rice straw:

| Sub-Project | No. of Buffaloes to be increased 1/ |
|---|---|
| Lam Plai Mat | 3,610 |
| Nong Lum Phuk | 70 |
| Huai Phlu | 290 |
| Total | 3,970 |

Note: 1/ ... This number of buffaloes can be fed on the assumption that 40 percent of TDN requirement are supplied by other source of feed like rice bran and follage (For details, see ANNEX D).

The remaining 40 percent of the increased rice straw (about 19,100) will be utilized to process compost for applying to rice nursery bed and dry season field crops.

## 4.5. Proposed Project Facilities

### 4.5.1. Planning of Proposed Project Facilities

The storage dam and distribution networks are the main project facilities proposed in this Project. The basic concept in planning the proposed project facilities has been studied based on the conditions in topography and geology, the available construction material near the site, the function of the Project facilities, the construction method of the works, etc.

(1) Survey and Investigation Works

The following surveys and investigation works have been carried out by RID for the planning of proposed Project facilities.

(a) Topographical Map

Lam Plai Mat Sub-Project

| | | |
|---|---|---|
| Reservoir Area | : | Scale 1:10,000 by aero-photo |
| Damsite | : | 1:4,000 -do - |
| Irrigation Service Area | : | 1:10,000 by topo-survey |

Nong Lum Puk Sub-Project

| | | |
|---|---|---|
| Reservoir Area | : | Scale 1:10,000 by topo-survey |
| Damsite | : | 1:4,000 by aero-pho |
| Irrigation Service Area | : | 1:10,000 by topo-survey |

Huai Phlu Sub-Project

| | | |
|---|---|---|
| Reservoir Area | : | Scale 1:10,000 by aero-photo |
| Damsite | : | 1:4,000 -do- |
| Irrigation Service Area | : | 1:10,000 -do- |

(b) Geological Investigation

The following core drilling with permeability and penetration test has been carried out at three damsites:

| | | |
|---|---|---|
| Lam Plai Mat Damsite | : | 18 places |
| Nong Lum Puk Damsite | : | 6 " |
| Huai Phlu Damsite | : | 5 " |

(c) Borrow Area Survey

The following test pits are provided at three damsites, and soil test has been carried out in the laboratory.

| | Test Pit | Physical Test | Dynamic Test | Rock Test |
|---|---|---|---|---|
| Lam Plain Mat | 8 | 8 | 8 | 2 |
| Nong Lum Puk | 3 | 4 | - | 1 |
| Huai Phlu | 2 | 2 | - | - |

The result of survey and investigation works is shown in ANNEX F.1.1.

(2) Planning for Storage Dam

(a) Dam Foundation Treatment

The damsite in the Lower Northeast Basin lies generally on the flat topography and on the foundation consisting of well-compacted overburden and well-consolidated rock formation. Therefore, the dam foundation except cut-off trenches is prepared by only stripping one to 0.5 meter in depth to remove the loose overburden covered with vegetation.

The cut-off trench should be provided at the center of dam body in order to attend the pass length of seepage line through the dam foundation. In case the dam foundation consists of pervious material, the trench should be excavated up to the impervious layer or rock formation.

The dam, with a height of more than about 20 m, or with pervious foundation will require the grouting works to improve the dam foundation. The grouting works are generally designed by three rows with interval of three meters in each grout hole. The depth of grout hole is designed depending on the dam height and the foundation geology.

Since the rock formation in the Lower Northeast region consists of basalt or sandstone which is consolidated and less permeable, the cement milk to be injected in the grout hole would be less than 50 kg per linear meter of the hole.

(b) Dam Body Design

In accordance with geological and available construction material at the damsite, the earth fill dam is most suitable. The zone type earth fill dam is designed for the Lam Plai Mat dam whereas the homogeneous type for the small dams of Nong Lum Puk and Huai Phlu. The dam shall be designed with the vertical and horizontal filter drain at the downstream zone to prevent the piping phenomenon through dam body and dam foundation. The riprap at the upstream slope of dam is designed to protect the erosion on the dam slope due to waves in the reservoir.

In case semi-pervious material is used for the dam embankment, particular attention should be paid to the material, because semi-pervious material generally consists of fine sand with a uniform grain size and easily brings about the piping phenomenon through the dam body. The semi-pervious material is not allowed to be used in the upstream zone of the dam body in order to avoid squeezing of the embankment material by the drawdown of the water level in reservoir.

The semi-pervious material can be used for the downstream zone behind the filter drain in the dam body.

The compaction of the earth material belonging to the classification of CL and ML shall be carried out by controlling the moisture content of earth material, especially for the embankment in dry season, otherwise cracks would occur in the embankment and may cause the piping in the dam body.

(c) Dam Standard Section

The dam standard section is designed with the following criteria:

° Freeboard of dam is estimated by wave height depending on the wind velocity and reservoir fetch. The freeboard of 2.0 m will be adopted for Lam Plai Mat dam and Huai Phlu dam and 1.0 m for the small dam of Nong Lum Puk.

° Dam crest elevation is determined by the following equation:

Dam crest EL = F.W.L + Hd + Fb

where F.W.L: Full Water Level
Hd : Overflow Water Depth on Spillway
Fb : Freeboard

° A width of the dam crest is designed 8.0 m for Lam Plai Mat dam and 6.0 m for the small dams of Nong Lum Puk and Huai Phlu.

° Stability analysis will be required for the dam with a height of more than 15 m and has been performed by the slip circle method taking into consideration the property of embankment materials and the following conditions:

| | | |
|---|---|---|
| Condition I | : | At the end of dam construction |
| Condition II | : | Reservoir is at full water level and seepage is steady |
| Condition III | : | Reservoir is at middle water level and seepage is steady |
| Condition IV | : | Reservoir at rapid drawdown from full water level to low water level |

The safety factor of more than 1.3 should be taken for the stability analysis.

(d) Spillway

The design flood discharge with a 500-year return period will be applied for the spillway. However, the surcharge for flood in the reservoir should be considered to determine the flood design capacity for the spillway. In accordance with the study, the design flood capacity for spillway could be reduced by about 30 percent against the design peak discharge estimated, based on a 500-year return period.

The overflow section of spillway should be designed by non-control overflow type without gate due to operation at the remote area. The overflow weir of spillway is designed by concrete structure but the chute and stilling basin will be made without concrete lining in case its foundation is formed by the rock foundation. When the dam height is lower than about 20 m and the spillway foundation is consolidated overburden, the weir, chute and stilling basin will be placed on the overburden.

(e) Intake Facilities

The intake facilities are composed of the inlet, the conduit pipe protected by steel liner and the outlet. The facilities are placed on the formation of rock or consolidated overburden at the left or right bank. Two inlet water levels are designed: one is the intake water level corresponding to the reservoir low water level for the permanent intake and the other is the water level which is a little lower than the low water level. The latter water level maintains the reservoir water below the low water level in case the reservoir is empty in an exceptionally dry year. This inlet mouth will be closed in case the sedimentation in the reservoir will reach its water level.

(3) Planning for Distribution Networks

(a) Diversion Weir

When the irrigation canal to be started from the reservoir covers the large and slender service area along the river course like the Lam Plai Mat Sub-Project, it is recommendable to provide a diversion weir at the middle part of the river and to introduce irrigation water to the canal by the weir due to the following advantages.

- A diversion weir can receive not only the reservoir water to be released by the dam but also the run of river flow between the damsite and weir site. This planning concept can increase available water for irrigation and expand service areas as compared with available water by the reservoir only.

- The canal discharge capacity at the section before the diversion weir should be increased in case the reservoir water is delivered directly by canal from the reservoir to the downstream service area without the diversion weir. This system entails a high construction cost of canal.

- The operation and maintenance of a long distance canal covering a large area will be rather difficult, especially from the viewpoint of water management.

A diversion weir is designed with concrete structure to keep the intake water level for the irrigation canal and to release the river flood smoothly without inundation problems at the upstream service area.

The diversion facilities will consist of section of a concrete fixed weir to release the ordinary flood, high water channel on ground surface to release a high flood, scouring sluiceway to scour sedimentation, and intake facilities to introduce water to the irrigation canals.

(b) Canal Alignment

Since the service area lies on flat topography in a strip shape along the river course in the three sub-projects, the alignment of the irrigation main canal is placed along both banks of the river course.

The canal alignment is selected with the following considerations:

- To place canal alignment so as to be designed by gravity flow.

- To minimize earth moving works and acquire balance of excavation and fill volume.

- To place canal alignment near the SSIP reservoir to use as the regulating reservoir for a long distance canal.

- To place canal alignment near villages to supply domestic and fishery water at newly constructed ponds by Muban communal facilities.

° To extend lateral canal alignment to cover the terminal service area of 20 to 30 ha for the purpose of easy construction of the on-farm development works and simple water management by the farmers' association.

(c) Design of Irrigation Canal

The following concept is adopted for the preliminary design of the irrigation canal in accordance with the service area conditions and the criteria prevailing in RID.

° Irrigation canal with a bottom width of more than 0.5 m is designed with concrete lining taking into consideration that the soil in the service area consists of pervious sandy materials.

° Peak diversion requirement of canal is 1.3 liter/sec/ha based on the water operation study in the Project Area.

° Hydraulic design is made by the Manning formula with the following roughness coefficient:

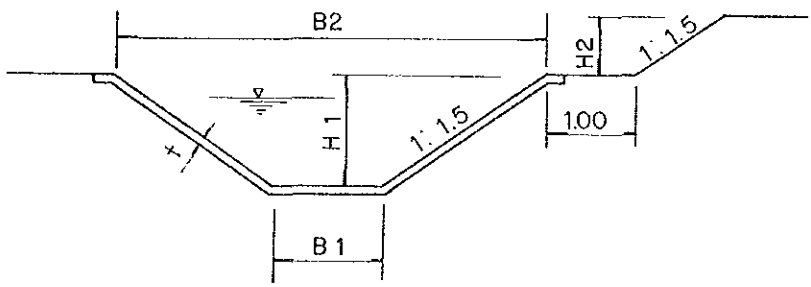
| Hydraulic Radius | Manning's "M" |
|---|---|
| concrete lined canal | |
| 0 - 0.75 m | 0.014 |
| 0.75 - 1.25 | 0.0145 |
| 1.25 - 2.25 | 0.015 |
| 2.25 - 4.0 | 0.0155 |
| 4.0 - 5.0 | 0.016 |
| earth canal | 0.025 |

° Canal standard cross section is designed as in Figure 4.5.1.

Figure 4-5-1 Canal Cross Section

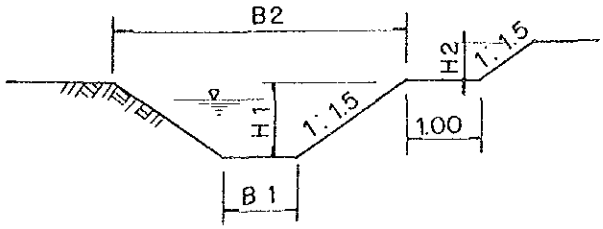
Lined canal

| TYPE | Discharge (CMS) | B1 m | B2 m | H1 m | H2 m | t cm |
|---|---|---|---|---|---|---|
| L 1 | 6.69 ~ 6.37 | 1.80 | 7.80 | 2.00 | 0.80 | 7 |
| L 2 | 6.04 ~ 5.69 | 1.70 | 7.55 | 1.95 | 0.75 | 7 |
| L 3 | 5.59 ~ 5.02 | 1.60 | 7.30 | 1.90 | 0.75 | 7 |
| L 4 | 4.49 ~ 4.37 | 1.50 | 6.75 | 1.75 | 0.70 | 6 |
| L 5 | 2.60 ~ 2.55 | 1.20 | 5.40 | 1.40 | 0.60 | 6 |
| L 6 | 2.24 ~ 1.74 | 1.10 | 5.00 | 1.30 | 0.60 | 5 |
| L 7 | 1.89 ~ 1.46 | 1.00 | 4.75 | 1.25 | 0.55 | 5 |
| L 8 | 1.30 ~ 1.00 | 0.90 | 4.20 | 1.10 | 0.50 | 5 |
| L 9 | 1.22 ~ 0.66 | 0.80 | 3.95 | 1.05 | 0.50 | 5 |
| L 10 | 0.80 ~ 0.52 | 0.70 | 3.25 | 0.85 | 0.45 | 5 |
| L 11 | 0.60 ~ 0.32 | 0.60 | 3.00 | 0.80 | 0.45 | 5 |
| L 12 | 0.46 ~ 0.06 | 0.50 | 2.45 | 0.65 | 0.40 | 5 |




Unlined canal

| TYPE | Discharge ($m^3$/sec) | B1 m | B2 m | H1 m | H2 m |
|---|---|---|---|---|---|
| E 1 | 0.01 ~ 0.05 | 0.30 | 1.65 | 0.45 | 0.35 |
| E 2 | 0.05 ~ 0.10 | 0.40 | 2.05 | 0.55 | 0.35 |
| E 3 | 0.10 ~ 0.20 | 0.50 | 2.45 | 0.65 | 0.35 |
| E 4 | 0.20 ~ 0.30 | 0.60 | 2.85 | 0.75 | 0.40 |
| E 5 | 0.30 ~ 0.40 | 0.70 | 3.10 | 0.80 | 0.40 |
| E 6 | 0.40 ~ 0.50 | 0.70 | 3.25 | 0.85 | 0.40 |



(d) Related structures of canals

The following related structures of canals are planned:

- Head regulation will be provided to divert irrigation water from the main to lateral canal or from the lateral to sub-lateral. Distributors will also be installed as measuring devices at the head of the structure to keep accurate water diversion.

- Farm turnouts will be placed at the head of service units and designed by a pipe barrel of 300 mm in diameter with a constant head orifice as measuring devices.

- Check structures will be provided at the downstream of the head regulator and turnout, and used to control diversion water and maintain a certain water level of canal. The check structures are designed with a combined type of fixed overflow weir and manually operated slide gate.

- Drop structures are designed at the place where dissipation of surplus energy is required due to different elevation of canal water level.

- Siphons will be provided at places where canals cross the existing streams to release the flood from streams into the river. Precast concrete pipe is used for siphons with a discharge of less than 1.0 cu.m/sec and the cast-in-place concrete for a discharge of more than 1.0 cu.m/sec.

- Spillway of the side channel overflow type will be provided on the canal to spill the excess water in the canal. The waterway will be also be provided with manually operated slide gate.

- Crossing structures will be provided to deliver the canal water under free flow conditions at the crossing points of canal and road. The crossing structure is designed with the precast concrete pipe for discharge of less than 1.0 cu.m/sec, the cast-in-place concrete for discharge of less than 2.50 cu.m/sec and the bridge for discharge of more than 2.50 cu.m/sec.

- Bridges are provided over irrigation canals at the place where the canal crossings are required for villages.

- Muban ponds for domestic water use will be furnished at the place required for the Muban cooperative service units.

(e) Design of Drainage Canal

There are may existing streams connecting the main river in the service area. These streams will be used for drainage canals through improvement.

The design capacity of drainage canals inside the service area is estimated at 4.9 liter/sec/ha for the Lam Plai Mat basin and 5.7 liter/sec/ha for the Huai Phlu basin based on the rainfall record with a frequency of 1/5 year. The drainage capacity outside of the service area is estimated at 126 mm/day for the Lam Plai Mat basin and 140 mm/day for the Huai Phlu basin based on the rainfall record with a frequency of 1/10 year.

4.5.2. Lam Plai Mat Sub-Project

The Project facilities of Lam Plai Mat Sub-Project consist of the following:

- A storage dam of earthfill zone type with a height of 44.6 m and a length of 1,160 m.

- A diversion weir of concrete structure with a height of 2.6 m and a length of 260 m.

- Canal networks, covering the service area of 9,100 ha, consisting of the main irrigation canal of 94.9 km, lateral irrigation canal of 120.2 km and drainage canal of 44.5 km.

Basic data and results of analysis for the planning of these project facilities are shown in ANNEX F.

(1) Lam Plai Mat Dam

(a) Engineering Geology of Damsite

The damsite is placed at an elevation of 230 m in the riverbed and formed with a very gentle slope of 1:4 at the right bank and 1:10 at the left bank.

In accordance with the field investigation and the result of 18 core drillings carried out by RID, the damsite is covered with overburden consisting of slope detritus, alluvial formation and terrace deposit. The depth of overburden is as shallow as 2 to 10 meters at both banks but is as deep as 15 to 18 meters at the riverbed section.

Since the overburden is well compacted and has enough bearing capacity to support the dam body, the dam foundation, except the cut-off trench, will be prepared by stripping only one meter to remove the loose surface material covered with vegetation.

The rock formation being called the Phra Wiham formation is exposed on both upper banks of the damsite and gradually goes down toward the central section of the damsite being covered with overburden. The rock formation at the central section of the damsite near the riverbed lies about 15 to 18 m below the original ground surface.

The rock formation consists of interbedded mudstone, siltstone, sandstone and well consolidated conglomerate. In accordance with the investigation result by core drillings, the permeability of rock formation shows a value of $10^{-3}$ to $10^{-4}$ cm/sec at the upper layer and $10^{-4}$ to $10^{-5}$ cm/sec at the lower layer. The compressive strength of sandstone in the upper layer presents 303 to 403 kg/sq.cm.

The cut-off trench is provided at the center of the dam body and all overburden materials are excavated up to rock formation. A core trench is not required at the rock formation except the weathered part and some trimming on trench foundation will be required. The deepest excavation, with a depth of 18 m from the river bed, will be made at the central section, but the excavation, with a shallow depth of 2.0 to 10 m, will be carried out at both banks.

The curtain grout at the core trench in the dam section where deep water depth is planned, and the blanket grout is made for dam section with a shallow water depth at the both upper banks.

(b) Dam Embankment Materials

Three borrow areas for earth embankment material were surveyed at the upstream area of the damsite near a conjunction point of the Lam Plai Mat and the Huai Sai Kong as shown in ANNEX F. About two million cu.m of impervious material could be obtained in these three borrow areas and will be sufficient for the designed earth embankment volume of about 1.5 million cu.m.

The earth material in the borrow area mostly belongs to Class CL and ML in the Unified Soil Classification and is suitable for dam embankment material. The property of earth material in accordance with the laboratory test is as follows:

Physical Property

| | C.L. | M.L. |
|---|---|---|
| Specific gravity | 2.59 - 2.61 | 2.57 - 2.62 |
| Content of less than 0.074 mm | 66.5 - 88.5% | 71.0 - 98.5% |
| Plasticity index | 9.5 - 13.7 | 11.3 - 1.64 |
| Shrinkage limit | 9.1 - 10.6% | 9.6 - 13.7% |

Dynamic Property

| | | |
|---|---|---|
| Optimum moisture content | 14.1 - 21.2% | 17.6 - 24.3% |
| Maximum dry density | 1.59 - 1.82 $g/cm^3$ | 1.52 - 1.72 $g/cm^3$ |
| Permeability coefficient | $1.31x10^{-6}$ - $4.22x10^{-7}$ cm/s | $1.95x10^{-6}$ - $6.3 x^{10-7}$ cm/s |
| Cohesion | 3.5 - 3.8 ton/sq.m | 7.0 - 10 ton/sq.m |
| Friction angle | 2.45 - 26.0° | 10.5 - 14.5° |

Since the earth material includes a high percentage of clay materials with a grain size of less than 0.074 mm, the compaction of material should be made on the little wet side from the optimum moisture content to prevent cracks in embankment.

Pervious and semi-pervious materials are found at the upper area of both banks and at the excavation site of the spillway. These materials could be used for the embankment at the downstream random zone although laboratory test has not been made in this study.

The excavated material of about 200,000 cu.m at dam foundation and spillway is expected to be used for the random zone. However, the excavated material in the riverbed is not recommendable for use for the embankment, because the material consists of mostly fine sand with a uniform grain size and has weak characteristics for piping phenomenon.

Rock material excavated at the spillway site could be used for the riprap on the embankment of dam.

Filter material consisting of sand and gravel is difficult to find at the Lam Plai Mat basin and will be transported from the upstream of the Mae Nam Mun.

(c) Dam Type and Dam Standard Section

The Lam Plai Mat dam is planned to be of the earthfill zone type from the viewpoints of dam height, availability of material and dam stability.

The dam standard section has been studied based on the design concept mentioned in 4.5.1 (2) and determined as shown in Drawings.

The stability analysis for the standard section has been conducted for the following value, taking into consideration the result of soil tests and data of other similar dams:

| Zone | Wet Density ($t/m^3$) | Saturated Density ($t/m^3$) | Cohesion ($t/m^3$) | Internal Angel (degree) |
|---|---|---|---|---|
| Impervious Zone | 1.92 | 1.97 | 3.5 | 24.5 |
| Random Zone | 1.92 | 1.97 | 3.5 | 24.5 |
| Filter Zone | 1.92 | 2.14 | 0 | 35.0 |

Since the laboratory test was not made for random material, the same design value as the impervious material is applied for the random zone in the preliminary design.

The result of stability analysis is as follows:

| Conditions | Earthquake Factor | Water Level | Slope | Safety Factor |
|---|---|---|---|---|
| 1 | K = 0.05 | - | Upstream | 1.96 |
| | | | Downstream | 1.72 |
| 2 | K = 0.05 | 261.8 m | Upstream | 1.79 |
| | | | Downstream | 1.61 |
| 3 | K = 0.05 | 256.8 m | Upstream | 1.66 |
| | | 251.8 m | Downstream | 1.57 |
| 4 | K = 0.05 | FWL 261.8 m | Upstream | 1.53 |
| | | LWL 246.6 m | | |

The details of preliminary design for dam body are described in ANNEX F.

(d) Spillway

The spillway site was selected on the right bank taking into consideration the topographical and geological conditions of the damsite that the spilled flood is smoothly released into the river, the excavation of overburden is minimized, and the spillway structure is placed on the firm rock foundation.

The design flood discharge for the spillway was decided as 984 cu.m/sec based on the surcharge effect of the reservoir against the planned flood discharge of 1,366 cu.m/sec in a 500-year return period.

The double side channel type is applied to the overflow section of the spillway. The concrete weir with an overflow depth of 2.8 m and a length of 100 m is designed for the design discharge capacity of 984 cu.m/sec.

The chute with a length of 614 m and a width of 16 m to guide the spilled water from the weir to the river is designed so as to place the structure on the rock foundation without concrete lining.

The stilling basin to dissipate the flow energy is also provided by excavation of the rock formation without concrete structure.

The detail of preliminary design of the spillway is shown in the Drawing.

(e) Intake Facilities

Intake facilities are installed at an elevation of 244.0 m on the consolidated rock formation on the right bank taking into consideration that the reservoir water can be taken and released smoothly downstream the damsite.

The intake facilities are designed with an intake discharge capacity of 11.83 cu.m/sec and consists of an inlet made by a concrete structure, conduit pipe protected by a steel liner and outlet facility with a jet flow gate of 1.3 m in diameter. The released water from the intake facilities is divided into three portions for the right canal, the left canal and the river.

The inlet and conduit pipe will be constructed at the beginning stage of dam construction, because these facilities should be used for the diversion channel at the second stage of dam construction.

(f) Dimensions of Reservoir and Dam

Dimensions of the reservoir and dam based on the Project planning and the preliminary design are shown in Table 4-5-1 and Drawings.

(2) Pa Kham Diversion Weir

(a) Layout Plan of Weir

Pa Kham diversion weir is located at Tambon Khok Mamuang, King Amphoe Pa Kham, which is about 31 km downstream the Lam Plai Mat damsite. The weir site lies in an elevation of 207 to 210 m with a flood plain width of about 500 m, which is the narrowest in the Lam Plai Mat basin. The river at the wier site is shifted to the left bank and flows down with a stable river course and with a slope of 1:1,600. The right bank of the weir site is placed at a higher elevation of 209 to 210 m which has a difficult condition to introduce the river water smoothly.

The area of weir site area is presently covered with forestry without the paddy field and is inundated in the flood season.

The layout plan of the diversion weir is made with the following considerations:

- Intake water level is placed at 209.5 m based on the water level of canal covering the downstream service area.

- The intake discharge capacity of 9.29 cu.m/sec in total is adopted at the intake facilities provided at the left bank and is divided into 6.69 cu.m/sec for the left canal and 2.60 cu.m/sec for the right canal.

- Flood water level of 212.0 m is adopted based on the design discharge capacity of 1,067 cu.m/sec estimated by a 50-year return period.

- Fixed concrete weir of non-control overflow type with a length of 240 m and a height of 2.6 m is provided at the left bank to keep the water level. The scouring sluiceway with a length of 20 m is also provided at the left side of fixed weir to scour sedimented materials in front of intake facilities.

- Ordinary flood of about 200 cu.m/sec could be released by the weir and scouring sluiceway at an elevation of 210.5 m. When the design flood discharge of 1,067 cu.m/sec in a 50-year return period takes place, the flood of about 700 cu.m/sec can be released by the weir and scouring sluiceway at a high water level of 212.0 m. The remaining flood of about 370 cu.m/sec will be released through a high water channel section of about 300 m long, which is provided on the original ground surface at the right bank. Since the flood discharge velocity at the high water channel section is as low as 70 cm/sec in case of the flood of 1,065 cu.m/sec, no protection is required for the high water channel section.

- The intake facilities should be provided at the left bank taking into consideration the existing stable river course and smooth intake of river water to the canal. The water of the right bank canal is introduced by the pipe culvert, which is embedded in the fixed weir and under the high water channel.

(b) Summary of Structural Design

The structures of weir, scouring sluiceway, and intake facilities are designed as shown in the Drawing. The major features of structures are as follows:

- The foundation of weir and scouring sluiceway is reinforced by concrete pile and sheet pile to increase the bearing capacity of foundation and to protect the scouring by flood overflowing the weir.

- The fixed weir is designed by concrete structure with Ogee section of 2.6 m in height. The downstream of the weir is protected with a concrete apron of 1.10 m in thickness and stone pitching.

- Scouring sluiceway with a total length of 20 m and with three radial gates of a span length of 6.0 m is provided at the end portion of the weir in the left bank.

- The intake facilities consist of a total length of 13.2 m and 5 sluice gates of 2.0 m in height. Three gates are used for the left canal and two gates for the right canal. The water to the right canal is introduced with a pipe culvert of 1.50 m in diameter from the inlet at the left bank to the right bank. The pipe culvert is embedded at an elevation of 206.8 m in the high water channel section to avoid the damage by flood.

(3) Canal Networks

(a) Layout Plan of Canal Networks

The Lam Plai Mat service area is divided into the following five irrigation service areas from the viewpoint of irrigation canal function to supply the water smoothly by gravity system, minimize the construction cost of canal, and carry out easy water management.

| Service Area | Water Diversion Point | Service Area (ha) | Canal Length (km) | Maximum Discharge (cu.m/sec) |
|---|---|---|---|---|
| Sra Ta Khian | Dam | 940 | 25.8 | 1.22 |
| Soeng Sang | Dam | 1,010 | 12.3 | 1.31 |
| Pa Kham | Diversion Weir | 2,000 | 30.4 | 2.60 |
| Nong Bua | -ditto- | 1,740 | | |
| Thai Charoen | -ditto- | 3,410 | 26.4 | 6.69 |
| Total | | 9,100 | 94.9 | |

Main irrigation canals of Sra Ta Khian (STMC) and Soeng Sang (SSMC) start from the outlet of the Lam Plai Mat dam and cover the upstream area at the left bank and the right bank, respectively. Main irrigation canals of Pa Khan (PKMC) and Thai Charoen (TCMC) start from the Pa Khan diversion weir and cover the downstream service area at the right bank and the left bank, respectively.

The service area of Nong Bua is also covered with the TCMC. The diagram of irrigation and drainage networks is shown in Figures 4-5-3 and 4-5-4.

(b) Major Features of Main Canal

Major features of the main canal preliminary design are shown in ANNEX F and summarized as follows:

° The canals are designed mostly with a concrete lining except a canal bottom width of less than 0.5 m and with the following dimensions:

| | |
|---|---|
| Canal Slope: | 1/1,500 - 1/5,000 |
| Discharge Velocity: | 0.34 - 0.92 m/sec |
| Canal Bottom Width: | 0.5 - 1.8 m |

° Number of related structures at main canal is as follows:

| | STMC | SSMC | PKMC | TCMC | Total |
|---|---|---|---|---|---|
| Head Regulators | 9 | 7 | 19 | 32 | 67 |
| Farm Turnouts | 37 | 39 | 76 | 184 | 336 |
| Checks | 11 | 6 | 12 | 13 | 42 |
| Drops | 2 | 2 | 1 | 3 | 8 |
| Syphons | 2 | 2 | 1 | - | 5 |
| Spillway | 2 | 2 | 1 | 3 | 8 |
| Crossing Structures | 3 | 1 | 3 | 4 | 11 |
| Cross Drains | 3 | 4 | 7 | 11 | 25 |

(c) Major Features of Lateral Canal

The lateral canal is designed with the earth canal except for those with bottom width of more than 0.5 cu.m/sec which will have concrete lining with the following conditions:

Canal Slope: 1/1,000 - 1/5,000
Discharge Velocity: Maximum 0.8 m/sec
Canal Bottom Width: 0.3 - 1.1 m

The preliminary design of lateral canals is shown in the Drawings and the major features are summarized as follows:

| | STMC | SSMC | PKMC | TCMC | Total |
|---|---|---|---|---|---|
| No. of Laterals | 9 | 7 | 19 | 32 | 67 |
| Total Length | 9.6km | 17.4km | 20.9km | 72.3km | 120.2km |
| No. of Checks | 8 | 13 | 17 | 58 | 96 |
| No. of Drops | 4 | - | 9 | 24 | 37 |
| No. of Syphons | - | 3 | - | 2 | 5 |
| No. of Spillways | - | 3 | - | 2 | 5 |
| No. of Crossing Structures | 1 | 3 | 4 | 9 | 17 |
| No. of Cross Drains | - | - | - | 2 | 2 |

(d) Major Features of Drainage Canal

The drainage canal is made by earth canal and its preliminary design is shown in the Drawings. The major features and dimensions of the drainage canal are summarized as follows:

Canal Slope: 1/2,000 - 1/5,000
Discharge Capacity: 0.47 - 1.83 cu.m/sec
Canal Bottom Width: 0.8 - 1.3 m

| | STMC | SSMC | PKMC | TCMC | Total |
|---|---|---|---|---|---|
| Canal Length | 5.9km | 5.3km | 5.9km | 27.4km | 44.5km |

4.5.3. Nong Lum Puk Sub-Project

The Nong Lum Puk Sub-Project consists of the storage dam of homogeneous earthfill type with a height of 12.0 m and a length of 1,156 m, and the distribution networks of 10.2 km and 2.5 km of the main and lateral canal, respectively, coveirng a service area of 300 ha.

(1) Nong Lum Puk Dam

(a) Engineering Geology of Damsite

The damsite is located at an elevation of 225 m in the river bed and formed with a very gentle slope. In accordance with the field investigation and the result of six core drillings, the following geological features are observed.

The dam foundation is underlain by three different formations, alluvial formation, slope and residual detritus, and basalt. The valley slopes at the dam axis are underlain by the slope and residual detritus consisting of clayey gravel, gravelly clay and tufferceous clay. Both banks of the dam are formed by the slope detritus and

locally by residual detritus delivered from the basalt and tuff. The detritus thickness ranges from 2 to 8 m. The alluvial formation underlies in 170 m width of the valley and consists of gravelly clay with a thickness of about 4 m. The basalt formation is formed by interbedded tuff and located under the slope and residual detritus and alluvial formation. The basalt rock formation is found at four meters deep in the river bed and about 10 m deep in the right bank.

Since the overburden consisting of the alluvial formation and slope and residual detritus is well compacted and impervious, the ground surface at damsite is stripped about 0.5 meter in depth. However, the small cutoff trench should be placed at the center of dam section to extend the seepage line through dam foundation. This cutoff trench should be connected to the upstream impervious layer in the reservoir, which will fulfill the function of natural blanket. The grouting works are not required due to a low dam height of 12.0 m and the impervious foundation.

(b) Dam Embankment Materials

The borrow area is selected at the right bank of about 400 to 1,000 m downstream the damsite, as shown in ANNEX F.1.1. The borrow area extends over the area of about 200,000 sq.m with a usable depth of 4.0 m and would have earth materials of about 800,000 cu.m, which is sufficient for the dam embankment volume of 196,000 cu.m.

The earth material in borrow area is mainly classified into GM and MH by the Unified Soil Classification System in accordance with the result of physical test in the laboratory. The physical property of earth material is as follows:

| Physical Property | GM | MH |
|---|---|---|
| Specific gravity | 2.80 - 2.95 | 2.70 |
| Content of less than 0.074 mm | 17.0 - 19.0% | 61.0% |
| Content of less than 0.05 mm | 9.5 - 17.0% | 25.0% |
| Plasticity index | 18.7 - 23.7% | 14.6% |
| Shrinkage limit | 18.4 - 19.8% | 15.8% |

The earth materials belonging to GM and GC are more favourable than the materials of MH for embankment of the dam, because GM and GC are well graded mixture of clay, silt, sand and gravel including 15 to 20 percent content of less than 0.05 mm and would have a higher shearing strength for dam stability. Therefore, the borrow area consisting of GM and GC will be used for the dam embankment.

The material to be excavated in the spillway is assumed as GM containing the gravel with a diameter of 4 to 64 mm and will also be suitable for the dam embankment. The excavation material of about 80,000 cu.m could be available for the dam earth embankment. The basalt rock formation is found near the damsite and could be used for the riprap material and aggregate in accordance with the field reconnaissance and observation of core sampled at boreholes in the damsite.

(c) Dam Type and Dam Standard Section

Since the dam height is as low as 12 m and sufficient earth materials are found near the dam and spillway site, the dam is designed with homogeneous earthfill type with horizontal and vertical drain. The dam standard section is determined as shown in the Drawings with upstream slope of 1:3.0 and downstream slope of 1:2.5. The stability analysis of the dam section is not made due to a low dam height of less than 15.0 m.

(d) Spillway

The spillway site and alignment were selected at the right bank taking into consideration the topographical conditions that a stream flows downstream on the right bank of the damsite and could be used for releasing the spilled flood smoothly. The spillway is designed with a non-controlled overflow type without gate.

The design flood discharge capacity for spillway was decided at 100 cu.m/sec taking into consideration the surcharge effect of the reservoir against the planned flood capacity of 135 cu.m/sec in a 500-year return period.

Although the rock formation does not appear at a shallow depth in the spillway site at the right bank, the spillway foundation consists of very compacted overburden composed of gravel clay with less permeability and enough bearing capacity. Therefore, it would not be a problem to place the overflow weir of the spillway at the overburden formation.

The overflow weir is a designed concrete structure with an overflow depth of 1.0 m and a length of 60 m.

The chute of the spillway is placed in the compacted overburden with a gentle slope of 1:100 and protected by riprap.

The preliminary design of the spillway is shown in the Drawings.

(e) Intake Facilities

The intake facilities are provided at an elevation of 227.3 m in the right bank of the damsite. The intake facilities are designed with an intake capacity of 0.39 cu.m/sec and an inlet consists of an inlet concrete structure, conduit pipe protected with steel plate and, the outlet facility with a jet flow gate of 0.25 m in diameter.

The outlet and conduit pipe will be constructed at the early stage of dam construction due to its utilization for releasing the river water during dam construction.

(2) Canal Networks

(a) Layout Plan

The service area of Nong Lum Puk Sub-Project extends immediate downstream of the damsite. The irrigation canal is placed at the right bank covering the existing service area and reaches the amphoe Soeng Sang to supply domestic water.

The diagram of irrigation networks is shown in Figure 4-5-3.

(b) Major Features of Canals

The preliminary design of the canals is shown in the Drawings, and the major features of the canal are summarized as follows:

| | Main Irrigation Canal | Lateral Irrigation Canal |
|---|---|---|
| Length of Canal | 10.2 km | 2.5 km (3 canals) |
| Maximum Discharge Capacity | 0.39 cu.m/sec | - |
| Canal Slope | 1:4,000 | 1:1,000-1:4,000 |
| Discharge Velocity | 0.34-0.5 m/sec | - |
| Canal Bottom Width | 0.5-0.6 m | 0.3-0.4 m |
| No. of Head Regulators | 3 | - |
| No. of Farm Turnouts | 7 | 8 |
| No. of Checks | 4 | 2 |
| No. of Drops | - | 4 |
| No. of Syphons | - | 1 |
| No. of Crossing Structures | 3 | - |
| No. of Cross Drains | 4 | 1 |

The drainage canal was not considered because the existing stream sufficiently fulfills its function.

4.5.4. Huai Phlu Sub-Project

The Huai Phlu Sub-Project consists of the storage dam of homogeneous earthfill type with a height of 20 m and a length of 844 m, and the distribution networks of 19.8 km of main and 8.8 km of lateral canal covering a service area of 700 ha.

(1) Huai Phlu Dam

(a) Engineering Geology of Damsite

In accordance with the core drillings of 7 holes, the damsite is covered with an overburden consisting of slope detritus and alluvial formation. The overburden consists of mostly sandy material and its depth is 2.2 m at the riverbed and 5 to 7.7 m in both abutments of the damsite.

This overburden should be excavated up to the rock formation at the cutoff trench provided in the center of the dam body.

The rock formation known as the Sao Khua formation is underlain by the overburden layer and consists of siltstone and fine to medium grained sandstone with dipping to the right side. The permeability ranges from $10^{-2}$ to $10^{-3}$ cm/sec in the upper formation and $10^{-5}$ cm/sec in the lower formation of about 10 m below the original rock surface.

Since the dam height of Huai Phlu dam is planned to be 20 m, and the rock foundation is pervious, the grouting works are required as shown in the Drawings.

(b) Dam Embankment Material

Since the area near the damsite mostly consists of pervious sandy material, the borrow area is selected at the upstream area of about 1.5 km from the damsite. This borrow area consists of

alternate layers of silty clay and fine sand and is placed under unfavourable conditions as compared with the borrow area of Lam Plai Mat or Nong Lum Puk. The earth material of silty clay will be used for the upstream of the dam body and the mixed earth material of silty clay and fine sand will be used for the downstream zone although the dam is planned to be of a homogeneous type.

The borrow area is about 200,000 sq.m, which could supply the impervious silty clay material of about 300,000 cu.m against the total earth embankment volume of 256,000 cu.m. The borrow area with more favourable conditions will be surveyed in the detail design stage, although the selected borrow area will have sufficient volume of impervious material for the embankment at the upstream zone of dam.

The physical properties of earth material based on the laboratory test are as follows:

| Physical Property | ML |
|---|---|
| Specific gravity | 2.62 |
| Content of less than 0.074 mm | 51.0% |
| Content of less than 0.05 mm | 27.0% |
| Plasticity index | 3.4% |
| Shrinkage limit | 10.4% |

When the earth material with the above physical property is used, the compaction for embankment should be made on the wet side of the optimum moisture content as mentioned in the dam embankment material of Lam Plai Mat dam.

The material to be excavated in the dam foundation and spillway mostly consists of sandy material and could not be used for the impervious material at the upstream zone of the dam. However, some of the excavated material could be used at the downstream embankment of the dam. Excavation material of about 45,000 cu.m is expected to be used for embankment.

Since the riprap material is of small quantity (9,400 cu.m), the existing quarry site in Buriram will be used.

(c) Dam Type and Dam Standard Section

The Huai Phlu dam is also designed as the homogeneous earth fill type with horizontal and vertical drains due to a low dam of 20.0 m in height. However, the impervious material will be embanked at the upstream zone and the semi-pervious or pervious material will be placed at the downstream zone, because the pervious material generally consists of fine sand with uniform grain size and easily brings about the piping and squeezing phenomenon with the water level fluctuation in the reservoir.

The dam standard section was determined based on the conditions as mentioned in the Lam Plai Mat dam design and is shown in the Drawings.

The dam stability analysis has been made with a similar design value for earth material with the Lam Plai Mat dam and its result is shown in the following table:

Result of Stability Analysis

| Condition | Earthquake Factor | Water Level | Slope | Safety Factor |
|---|---|---|---|---|
| 1 | K = 0.05 | - | Upstream | 2.51 |
| | | | Downstream | 2.00 |
| 2 | K = 0.05 | 243.8m | Upstream | 2.11 |
| | | | Downstream | 1.86 |
| 3 | K = 0.05 | 239.0m | Upstream | 1.99 |
| 4 | K = 0.05 | FWL 243.8m<br>LWL 233.7m | Upstream | 1.71 |

(d) Spillway

The spillway site is selected at the left bank based on the topographical and geological conditions that the excavation is minimized and the rock formation appeared at a shallow depth. The spillway is designed with a non-controlled side channel weir.

The major features of the preliminary spillway design are as follows:

° Designed flood capacity --- 140 cu.m/sec in a 500 year return period
83 cu.m/sec by reservoir surcharge

° Side channel weir with a length of 30 m and an overflow depth of 1.2 m is a designed with concrete structure on rock formation.

° Chute and stilling basin is placed on rock foundation without concrete lining.

(e) Intake Facilities

The intake facilities are placed at an elevation of 234.0 m at both banks, taking into consideration the low water level of reservoir.

Two intake facilities for the right bank canal of 0.38 cu.m/sec and the left bank canal of 0.53 cu.m/sec are provided at both banks taking into consideration the smooth water operation for the canal in both banks. Jet flow gates of 0.30 m and 0.25 m are installed at the outlet of the left and right banks to control the discharge.

(2) Canal Networks

(a) Layout Plan

The service area of Huai Phlu Sub-Project extends over both banks of the river downstream of the damsite. Therefore, the irrigation canal is placed at both banks, namely, Nong Mai Ngam right canal (NRMC) and Nong Mai Ngam Left Canal (NLMC). The NRMC and NLMC cover the service area of 289 ha and 411 ha, respectively. The diagram for the irrigation network is shown in Figure 4-5-3.

(b) Major Features of Canals

The preliminary design of the canal networks is shown in the Drawings, and the summary of the major features of the canal is as follows:

- Main Canal

| | NRMC | NLMC | Total |
|---|---|---|---|
| Irrigation | 289 ha | 411 ha | 700 ha |
| Length of Main Canal | 8.8 km | 11.0 km | 19.8 km |
| Maximum Discharge | 0.38 cu.m/sec | 0.53 cu.m/sec | 0.91 cu.m/sec |
| Canal Slope | 1:1,500 | 1:1,500 | - |
| Discharge Velocity | 0.6-0.5 m/sec | 0.6-0.5 m/sec | - |
| No. of Head Regulators | 6 | 4 | 10 |
| No. of Farm Turnouts | 2 | 6 | 8 |
| No. of Checks | 6 | 9 | 15 |
| No. of Drops | 8 | 6 | 14 |
| No. of Syphons | - | - | - |
| No. of Spillways | - | - | - |
| No. of Crossings | 2 | 2 | 4 |
| No. of Cross Drains | 5 | 3 | 8 |

- Lateral Canal:

| | NRLC | NLLC | Total |
|---|---|---|---|
| No. of Laterals | 6 | 4 | 10 |
| Length of Canal | 3.3 km | 5.5 km | 8.8 km |
| Slope of Canal | 1/3000-1/1000 | 1/3000-1/1000 | - |
| No. of Farm Turnouts | 16 | 13 | 29 |
| No. of Checks | 3 | 3 | 6 |
| No. of Drops | 3 | 8 | 11 |
| No. of Syphons | - | 2 | 2 |
| No. of Spillways | - | 3 | 3 |
| No. of Crossings | 2 | 2 | 4 |
| No. of Cross Drains | 2 | - | 2 |

The existing stream is used for the drain canal and only 0.7 km of the drainage canal is newly constructed with a maximum discharge capacity of 0.62 cu.m/sec.

Table 4-5-1. Outline of Reservoir and Dam

| Description | Unit | Lam Plai Mat | Nong Lum Puk | Huai Phlu |
|---|---|---|---|---|
| 1. General | | | | |
| Name of Basin | | Lam Plai Mat | Lam Plai Mat | Lam Chi Noi |
| Name of River | | Lam Plai Mat | Huai Nong Lum Puk | Huai Phlu |
| Base Rock Formation | | Sandstone | Basalt | Sandstone |
| Catchment Area | sq.km | 485 | 25 | 21 |
| Annual Mean Rainfall | mm | 1,065 | 1,065 | 1,312 |
| Annual Mean Runoff | MCM | 77.4 | 4.37 | 4.61 |
| 2. Reservoir | | | | |
| Reservoir Area | sq.km | 10.4 | 1.20 | 1.44 |
| Total Reservoir Capacity | MCM | 97.3 | 4.38 | 6.32 |
| Effective Reservoir Capacity | MCM | 90.0 | 4.00 | 6.00 |
| Dead Water Capacity | MCM | 7.3 | 0.38 | 0.32 |
| High Water Level | m | 264.3 | 236.0 | 245.0 |
| Full Water Level | m | 261.8 | 235.0 | 243.8 |
| Low Water Level | m | 246.6 | 228.6 | 233.7 |
| Effective Water Depth | m | 25.2 | 6.4 | 10.1 |
| 3. Dam | | | | |
| Dam Type | | Zone | Homogeneous | Homogeneous |
| Dam Height | m | 44.6 | 12.0 | 20.0 |
| Dam Length | m | 1,160 | 1,156 | 844 |
| Dam Crest Width | m | 8.0 | 6.0 | 6.0 |
| Dam Crest Elevation | m | 266.6 | 237.0 | 247.0 |
| Embankment Volume | 1,000 $m^3$ | 1,656 | 190 | 275 |
| 4. Spillway | | | | |
| Type | | Double Side Channel | Chute | Side Channel |
| Designed Flood Discharge | $m^3$/sec | 1,366 | 135 | 140 |
| Designed Flood Capacity for Spillway | $m^3$/sec | 984 | 100 | 83 |
| Overflow Depth | m | 2.8 | 1.0 | 1.2 |
| Overflow Length | m | 100 | 60 | 30 |
| 5. Intake Facilities | | | | |
| Type | | Conduit | Conduit | Conduit |
| Maximum Intake Capacity | $m^3$/sec | 11.83 | 0.39 | Left 0.53<br>Right 0.38 |
| Jet Flow Gate | mm | ϕ1,300 | ϕ250 | Left ϕ300<br>Right ϕ250 |

Table 4-5-2. Outline of Pa Kham Diversion Weir

1. General

| | |
|---|---|
| Name of Basin: | Lam Plai Mat |
| Name of River: | Lam Plai Mat |
| Catchment Area: | 1,050 sq.km |
| Annual Mean Rainfall: | 1,065 mm |
| Designed Flood Capacity: | 1,067 cu.m/sec (50-yrs return period) |

2. Diversion Weir

| | |
|---|---|
| Weir Type: | Concrete Ogee Solid Gravity |
| Weir Height: | 2.6 m |
| Weir Length: | 240 m |
| High Water Level | 212.0 m |
| Full Water Level | 209.5 m |

3. Scouring Sluiceway

| | |
|---|---|
| Sluiceway Length: | 20 m |
| Radial Gate: | (6 m x 2.25 m) x 3 sets |

4. Intake Facilities

| | |
|---|---|
| Intake Capacity: | Total 9.29 cu.m/sec |
| | Left 6.09 " |
| | Right 2.60 " |
| Intake Width: | 13.2 m |
| Sluice Gate: | Left (2.2 x 2.0) x 3 sets |
| | Right (1.8 x 2.0) x 2 sets |

5. Major Works

| | |
|---|---|
| Excavation: | 32,000 cu.m. |
| Concrete: | 10,300 cu.m |

Table 4-5-3 Outline of Canal Networks

(1) Lam Plai Mat Sub-Project

| Description | Unit | Sra Ta Khian | Soeng Sang | Pa Khan | Thai Charoen | Total |
|---|---|---|---|---|---|---|
| Intake Point | | Dam | Dam | Weir | Weir | - |
| Service Area | Ha | 940 | 1,010 | 2,000 | 5,150 | 9,100 |
| Discharge Capacity | $m^3$/sec | 1.22 | 1.31 | 2.60 | 6.69 | 11.82 |
| Length of Main Canal | km | 25.8 | 12.3 | 30.4 | 26.4 | 94.9 |
| No. of Lateral Canals | No. | 9 | 7 | 19 | 32 | 67 |
| Length of Lateral Canal | km | 9.6 | 17.4 | 20.9 | 72.3 | 120.2 |
| Length of Drainage " | km | 5.9 | 5.3 | 5.9 | 27.4 | 44.5 |

(2) Nong Lum Puk and Huai Phlu Sub-Project

| Description | Unit | Nong Lum Puk | Huai Phlu |
|---|---|---|---|
| Intake Point | | Dam | Dam |
| Service Area | Ha | 300 | 700 |
| Discharge Capacity | $m^3$/sec | 0.39 | 0.91 |
| Length of Main Canal | km | 10.2 | 19.8 |
| No. of Lateral Canal | No. | 3 | 10 |
| Length of Lateral Canal | km | 2.5 | 8.8 |
| Length of Drainage Canal | km | - | 0.7 |

Figure 4-5-2 Irrigation System (1/2)

Lam Plai Mat & Nong Lumpuk

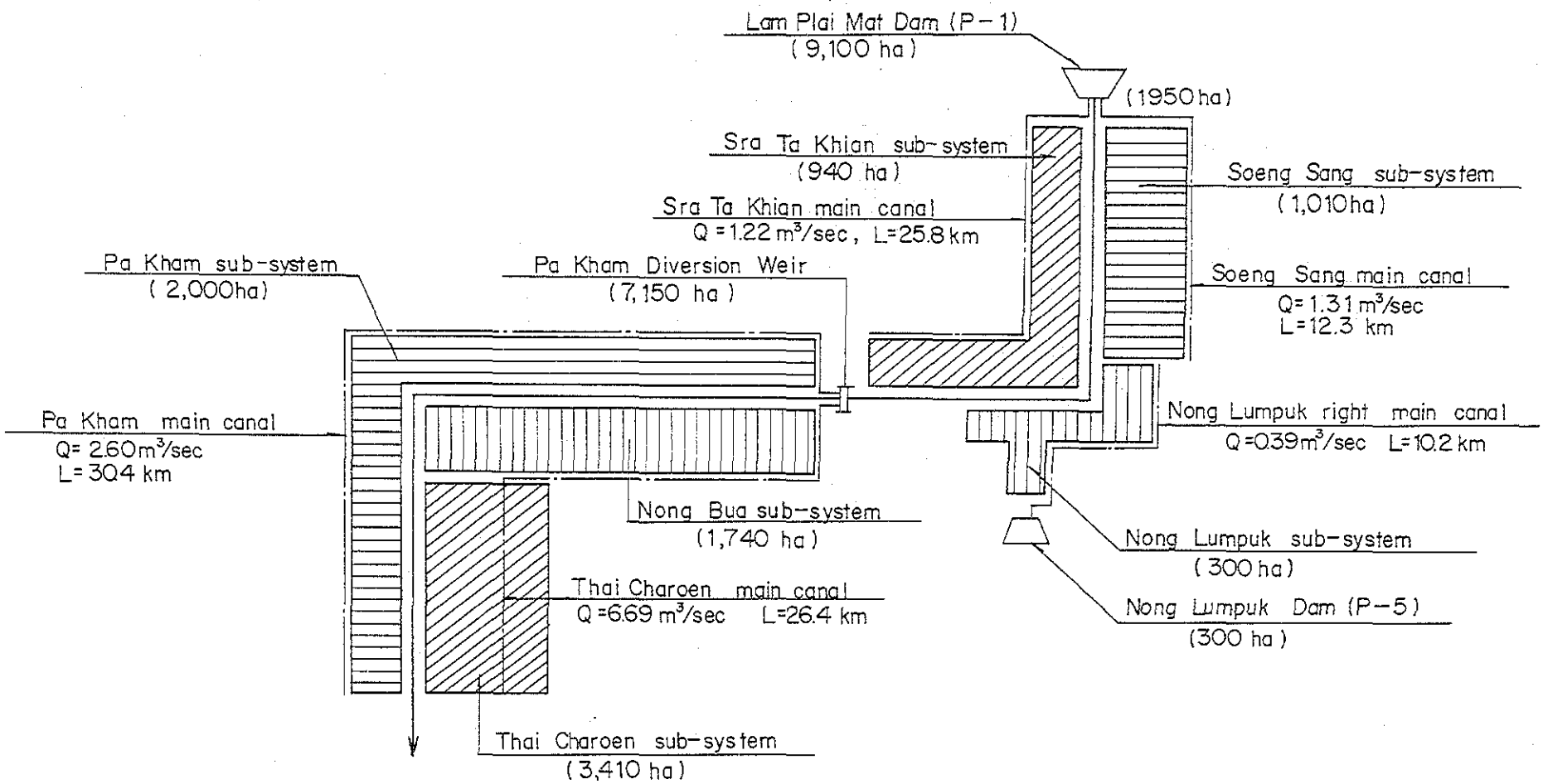


Figure 4-5-2 Irrigation System (2/2)

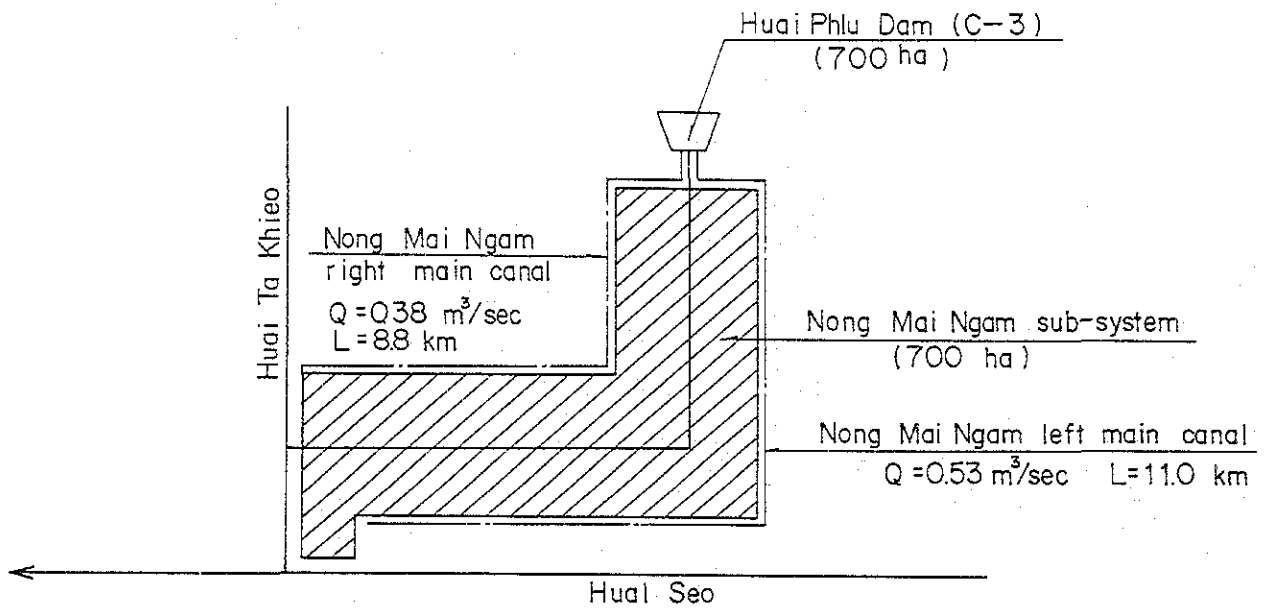


Figure 4-5-3 Irrigation Diagram (1/6)

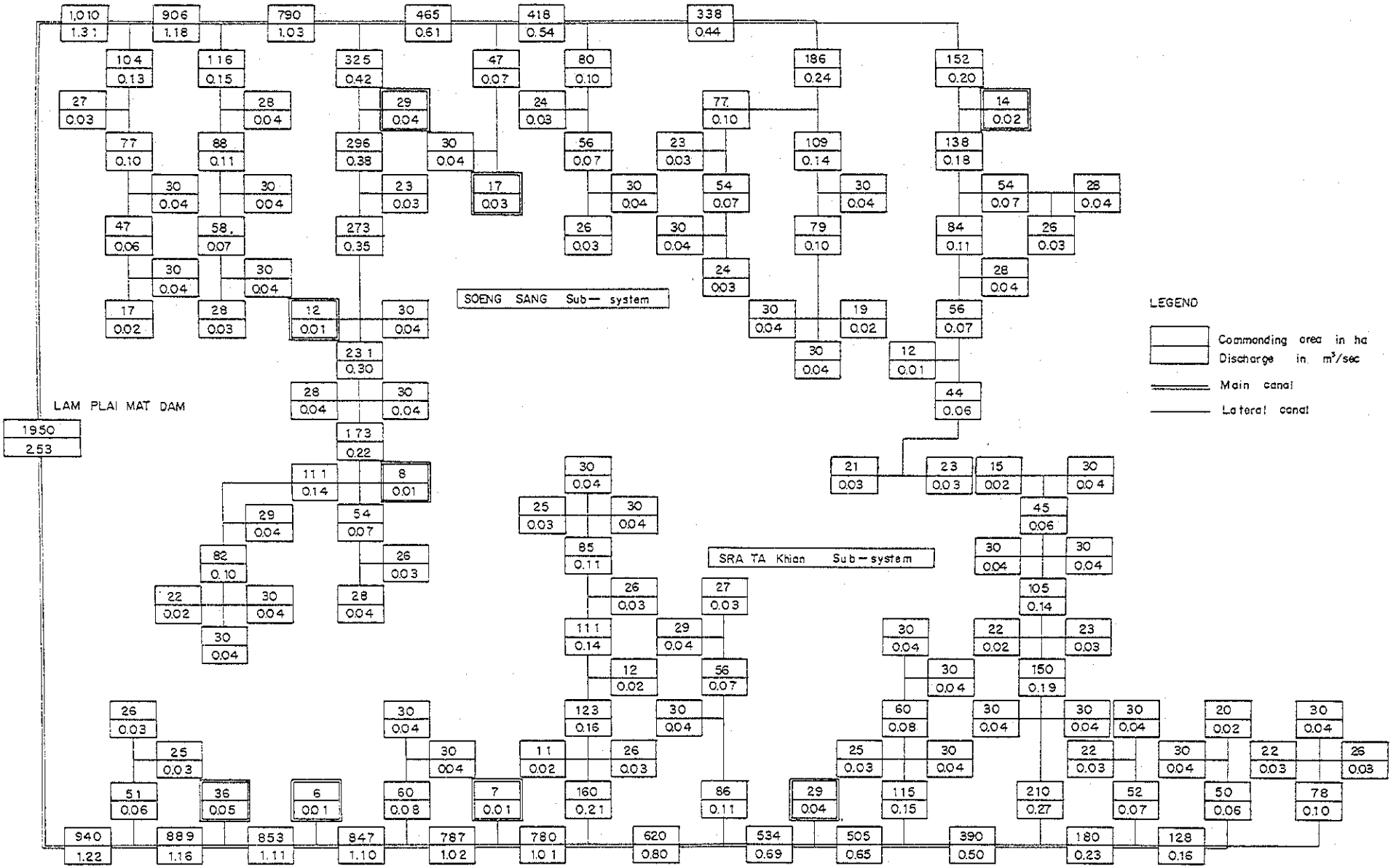


Figure 4-5-3 Irrigation Diagram (2/6)

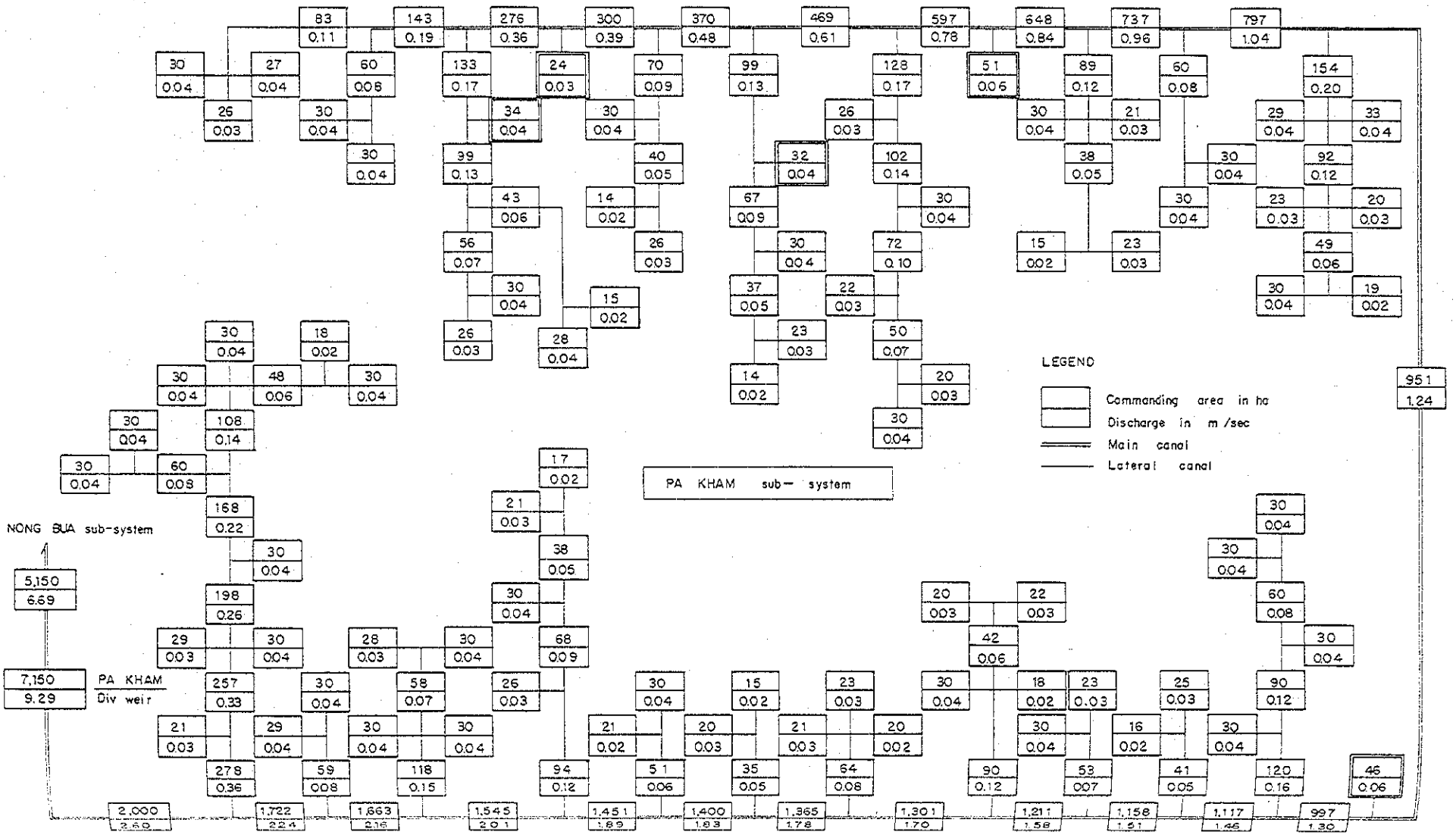


Figure 4-5-3 Irrigation Diagram (3/6)

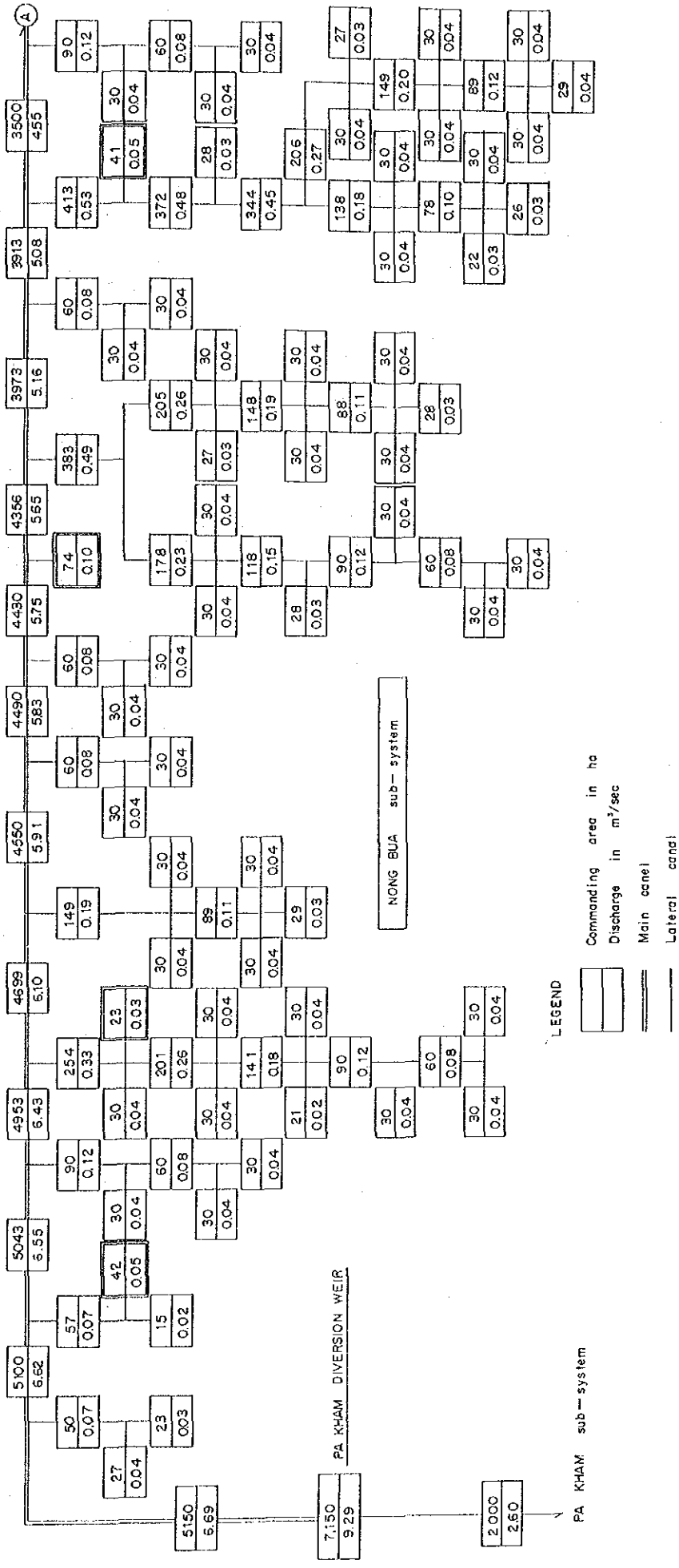


Figure 4-5-3 Irrigation Diagram (4/6)

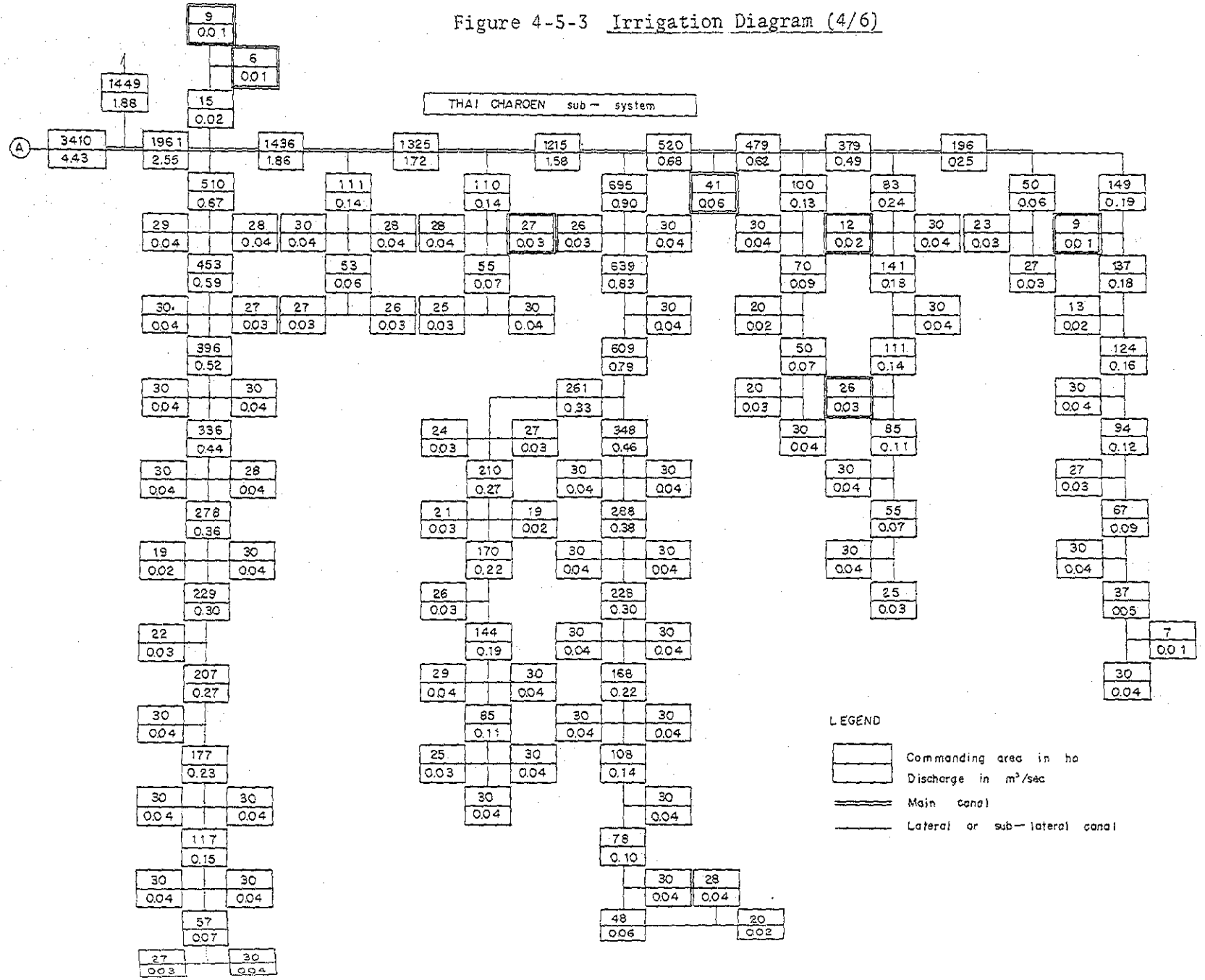


Figure 4-5-3 Irrigation Diagram (5/6)

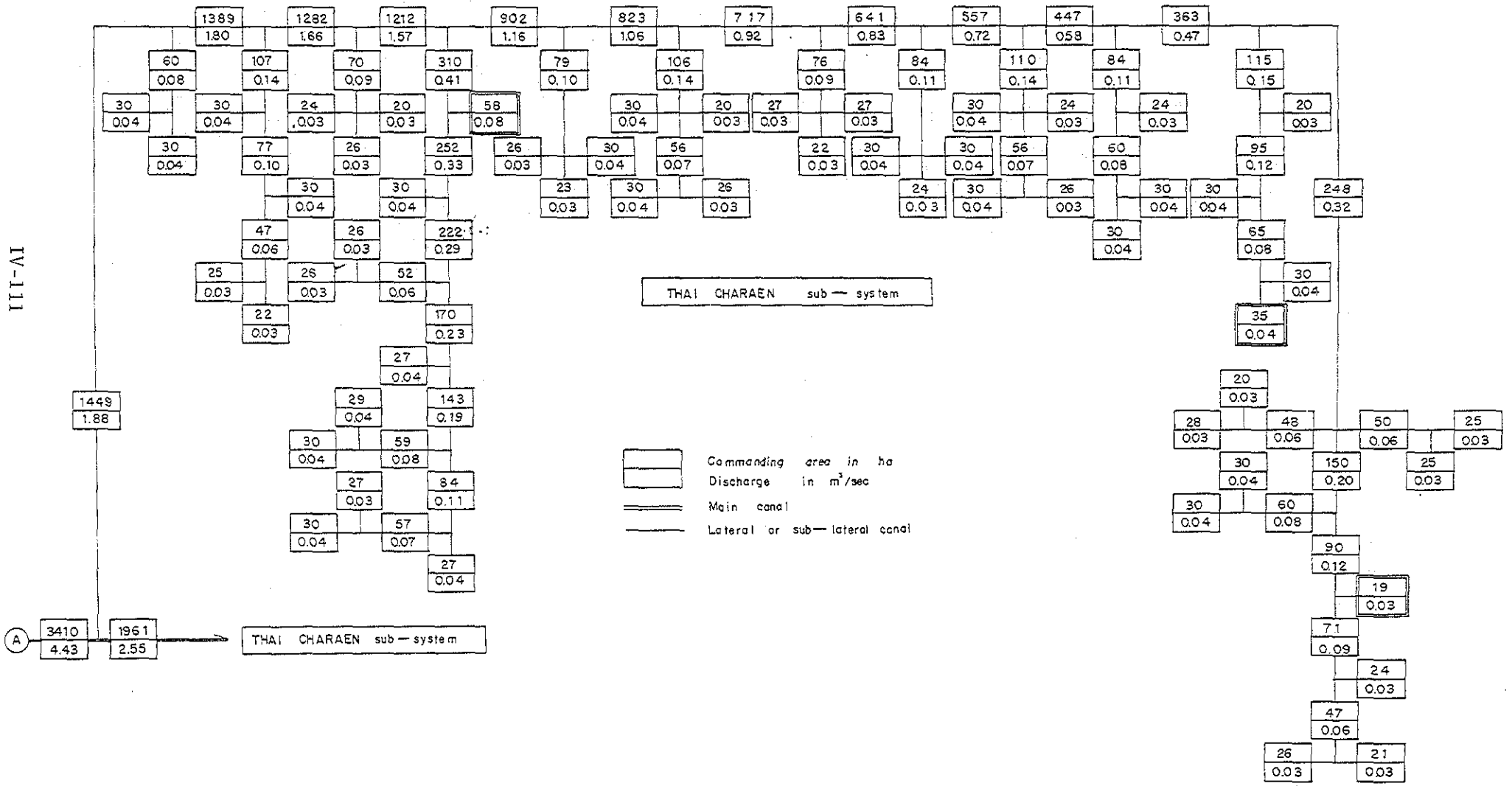


Figure 4-5-3 Irrigation Diagram (6/6)

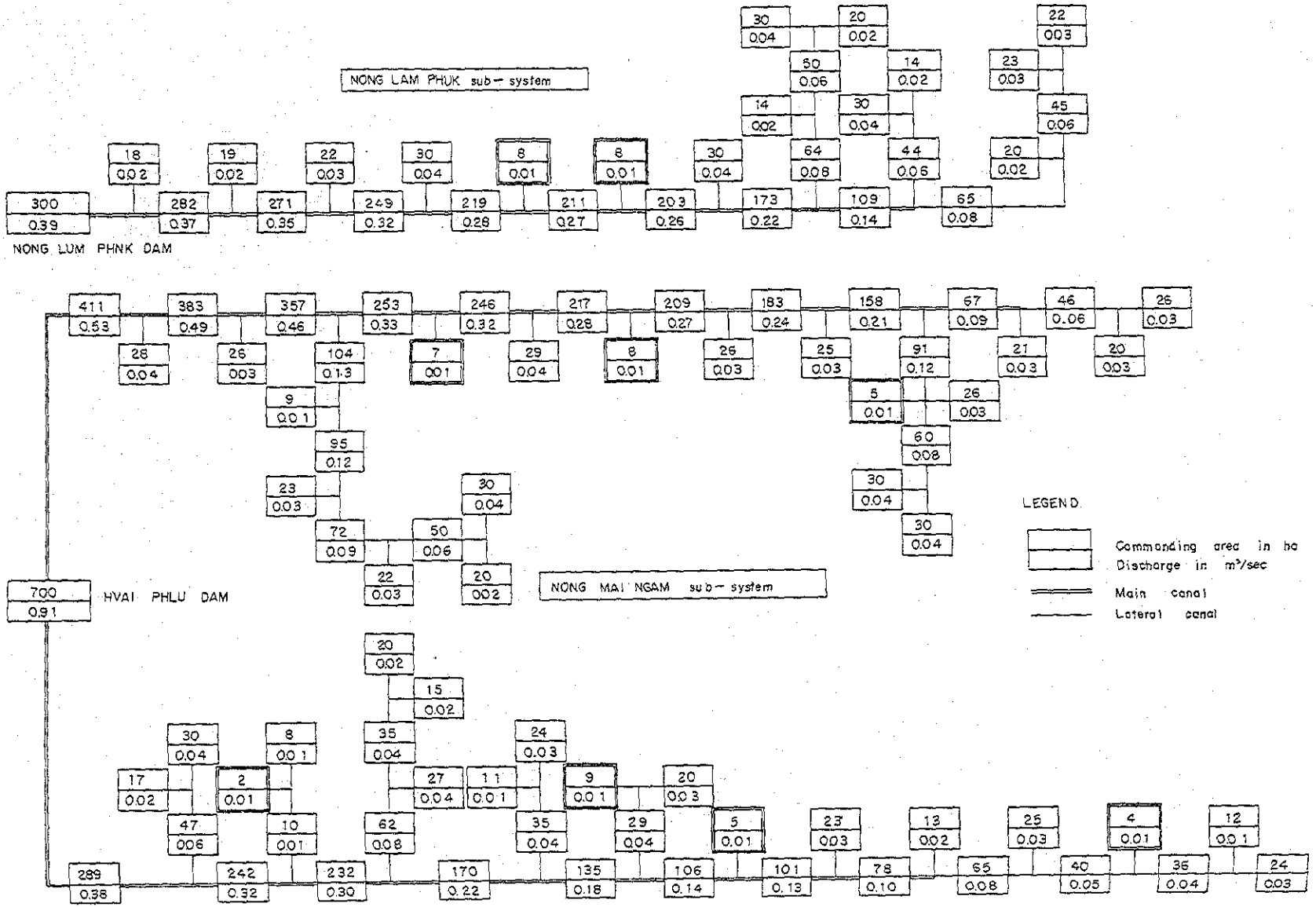


Figure 4-5-4 Drainage Diagram