ANNEX–V
IRRIGATION AND DRAINAGE

ANNEX - V

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IRRIGATION AND DRAINAGE

1. INTRODUCTION

More than 20 years ago, irrigation development in the Mae Wong river basin has voluntarily been commenced by the local people. About 71% of the existing paddy field or 230,000 rai (36,800 ha) in the basin, are presently covered with the existing farmer's irrigation systems. Thereafter, serious disputes for river water use often occured between farmers in the upstream areas and those in the downstream areas. Since mid-1970's, RID provided the regulators at the heads of farmer's irrigation systems to control the intake of irrigation water and also constructed the intake weirs to assure the stable intake of irrigation water under the medium and small irrigation projects in response to the local people's request. However, the farmers in the basin are still suffering from shortage of irrigation water.

In order to solve the above problems, the optimum development plan should be formulated through sufficient understandings and grasp of present conditions in the basin and technical and economical considerations to them. In this ANNEX, irrigation and drainage aspects for the optimum development are studied laying emphasis on the irrigation and drainage water requirements and planning and design of project facilities.

2. EXISTING IRRIGATION AND DRAINAGE SYSTEM

2.1 General

There exist three medium scale irrigation projects and seven small scale irrigation projects in the Mae Wong river basin. These projects have mainly been implemented during the recent five years by RID in response to the local people's request in the basin. The main works of projects were only to provide the regulators or diversion weirs with intake facilities at the diversion places. The irrigation canal networks were constructed by farmers themselves. The location map of existing irrigation projects is shown in Fig. V-1.

An intensive inventory survey of existing farmer's irrigation systems was conducted during about one month from mid-July to mid-August, 1985. The number and kind of structures and their present condition as well as present condition of canals were clarified through the inventory survey.

2.2 Medium Scale Irrigation Project

2.2.1 Wang Kun Pao and Khun Lard Boriban regulators

There exist two channels to divert the water of the Mae Wong river. These channels were constructed by farmers themselves more than 20 years ago. After construction of these channels, much water of the Mae Wong river was diverted through these channels to outside of the Mae Wong river basin. Subsequently, downstream areas of the Mae Wong river were suffered from irrigation water shortage. In response to the farmer's request downstream of the Mae Wong river, RID constructed the regulators at the heads of these channels in 1975 to 1977, namely Wang Kun Pao regulator and Khun Lard Boriban regulator.

The Wang Kun Pao regulator is located at the left bank of the Mae Wong river, 24 km downstream of the proposed Upper Mae Wong dam. The regulator covers the irrigation service area of 105,000 rai (16,800 ha). The Khun Lard Boriban regulator is located at the left bank of the Mae Wong river, 56 km downstream of the proposed Upper Mae Wong dam. The irrigation service area covered by the regulator is 55,000 rai (8,800 ha). No records on diversion water amount from the Mae Wong river at both regulators are available.

2.2.2 Khlong Nam Hom Irrigation Project

The Khlong Nam Hom area of 10,000 rai (1,600 ha) is located at the right bank of the Mae Wong river, middle part of the Mae Wong river basin. The main water source for irrigation is the Mae Wong river. The return flow from the small scale irrigation project areas along the left bank of the Khlong Pho river is used for augmentation of irrigation for the area. The major facilities of the project comprise a diversion weir constructed in 1975 to 1976 by RID and canal system constructed by farmers.

At the end of July 1985, the Huai Sadao Sai weir was constructed on the Mae Wong river, just downstream of diversion place to the Khlong Nam Hom irrigation area, under the small scale irrigation project. The main function of the Huai Sadao Sai weir is to assure the irrigation water to the Khlong Nam Hom area. After completion of the weir, the old bank openning to the Khlong Nam Hom area was closed.

2.3 Small Scale Irrigation Project

There exist seven small scale irrigation projects in the Mae Wong river basin. The total irrigation area covered with all these projects is 60,000 rai (9,600 ha) as shown below.

Name of Project	Irrigation Area
1. Ban Wang Nam Kao	3,000 rai (480 ha)
2. Khlong Saingu	10,000 rai (1,600 ha)
3. Huai Hin Lab	3,000 rai (480 ha)
4. Wang Ma	26,000 rai (4,160 ha)
5. Lan Eai Dieo	4,000 rai (640 ha)
6. Nong Yao	4,000 rai (640 ha)
7. Wang Hin Phoeng	10,000 rai (1,600 ha)

These projects were implemented by RID in 1977 to 1984 and have canal systems constructed by farmers. In addition to the above projects, the Huai Sadao Sai weir was constructed on the Mae Wong river in 1985 as already stated in the preceding section.

2.4 Drainage Systems

Most of the existing canals constructed by farmers have dual purposes for irrigation and drainage. Besides the above farmer's irrigation systems, many natural streams traverse the existing irrigation areas. These streams are also used for drainage purpose.

2.5 Pump Irrigation Services by RID

RID Regional Office VII provides pump irrigation services with free charge for the farmers who have rainfed paddy field along the rivers and streams in the basin. The regulations of the services are as follows:

- Operation hours of pump unit are 22 hrs/day,
- Irrigation service period is 120 days, and
- The regulations limit farmers receiving the services for only one crop season, wet season or dry season.

The records of pump irrigation services by RID for recent five years are shown in Table V-1. The pump irrigation services increase year by year, average annual increasing rate of 11%, except for 1983 of flood year.

2.6 Inventory Survey of Existing Farmer's Irrigation Systems

2.6.1 Methodology of inventory survey

In order to incorporate the existing farmer's irrigation systems into the project as far as possible, an inventory survey is conducted to grasp such their present conditions as dimension, degree of deterioration, etc.

The inventory survey is broadly divided into the spot survey and the canal route survey.

(1) Spot survey

Prior to the survey, major structure sites and crossing points of canals and roads are selected by using the topographic maps on a scale of 1 to 10,000. The spot survey is carried out to collect the following data and information of the existing farmer's irrigation systems at the selected sites.

- Canal type
- Canal dimension
- Extent of its damage
- Kind of structure

- Dimension of structure
- Material of structure
- Extent of its damage
- Type of road (pavement material)
- Width of road

Aboout 150 spot survey sites are selected on the topographic maps. The results of spot survey are compiled in the "DATA BOOK I, PHOTO REPORT OF INVENTORY SURVEY".

(2) Canal route survey

The canal route survey is carried out to investigate the number and kind of structures and their present conditions as well as conditions of canals. The intensive canal route survey on the right bank upstream of the Mae Wong river (so called main canal B). As for the other existing canals, only interview survey to the farmers is make taking the limited survey period and the accessibility to the site into consideration.

2.6.2 Results of inventory survey

Main features of structures for the existing medium and small scale irrigation projects are listed in Table V-2. The average density of canal and road networks for each area are tabulated below:

Area	Irrigation Area (ha)	Total Canal Length (m)	Density of Canal (m/ha)	Total Road Length (m)	Density of Road (m/ha)
A	16,800	181,000	10.8	216,100	12.9
B	2,560	114,200	44.6	42,300	16.5
C	11,680	136,300	11.7	131,900	11.3
D	1,600	41,600	26.0	52,000	32.5
E	4,160	15,400	3.7	54,100	13.0
Whole Area	36,800	488,500	13.3	496,400	13.5

The followings are found through the inventory survey.

- All the canals are unlined canals.
- Most of canals have dual purposes of irrigation and drainage.
- Existing canals were constructed by farmers, irrespective of topography.
- The water management is far from the proper water delivery, because of few control structures.

- There are no operation records of intake facilities even in case of the intake facilities constructed by RID.

- The irrigation water is taken by farmers, irrespective of irrigation area size. It means that the upstream area is more advantageous than the downstream.

- Most of existing irrigation areas have the problem on the difficulty of gravity irrigation, because of improper canal route alignment. Under such situations, the farmers are using the small tractor's engine to pump the irrigation water up from the canals to their fields. The Regional Office VII of RID also provides the pump irrigation services for the farmers.

- Based on the results of inventory survey, it seems that approximate half of the existing irrigation area faces the difficulty of gravity irrigation.

2.7 Present Condition of Operation and Maintenance

2.7.1 Current situation of water management in Thailand

In Thailand, each irrigation project is managed by a regional engineer, who is a head of the Regional Office of RID. Each project is headed by a project engineer, who is assisted by one or more water masters. A water master is in charge of a region and supervises a number of zonemen and gate tenders. Zonemen supervise irrigation in a zone of approximately 10,000 rai and gate tenders are in charge of a structure, i.e. a headwork, a cross-regulator or an intake regulator.

Nowadays, RID is facing with the following constraints and problems in operation and maintenance for the irrigation projects:

- Insufficient budget,
- Insufficient staff and qualified staff to operate the project,
- Insufficient equipment for operation and maintenance such as motor cycles, vehicles, construction machinery, etc.,
- Poor communication system, i.e. telephone, wireless set, walky-talky, etc., and
- Poor cooperation among the farmers and RID staff.

Table V-3 and Table V-4 show the operation and maintenance staff situation and the annual operation and maintenance cost for the existing large scale irrigation projects in Thailand, respectively. The projects in the above tables have the same problems mentioned above.

2.7.2 Water management in the Mae Wong river basin

As stated in the preceding section, the existing irrigation systems in the Mae Wong river basin were voluntarily constructed by farmers. Only intake weirs and/or head regulators were constructed by RID under the medium or small scale irrigation projects. At present, the water management for the existing irrigation systems is carried out by the voluntary farmer's group. There are no established water management procedures for the systems. As a result, there are no operation records on the systems and the dispute on water use of the Mae Wong river often occurs between the upstream farmers and the downstream those.

3. DELINEATION OF DEVELOPMENT AREA

3.1 Basic Development Concept

In order to realize the concepts for agricultural development, the following basic concepts for irrigation and drainage development are envisaged in conformity with the concepts for water resources development:

- First priority for irrigation development would be given to the supplemental irrigation for wet season paddy cultivation in the existing irrigation areas,

- Possible further extension of irrigable area would be examined taking the topographic and soil conditions into consideration. If the exploited water resources are available, either the supplemental irrigation for the wet season paddy cultivation in the above extension area or the irrigation for the dry season upland crop cultivation in the existing irrigation areas would be considered,

- In principle, the farmer's irrigation systems in the existing irrigation areas would be incorporated into the project as far as possible to minimize the project cost. From viewpoints of water management, the extent of upgrading or integrated plan of the existing farmer's systems would be considered,

- Basin-wise water management organization and method would be recommended to timely and fairly distribute the exploited water to each irrigation block. Establishment of water user's organization would also be recommended for proper water management at farm level, and

- The natural streams in the basin would be used for drainage as many as possible. The collector drains would be provided for proper drainage in each block.

3.2 Delineation of Development Area

There exist the existing irrigation areas of 230,000 rai (36,800 ha) in total, which are covered by the farmer's irrigation systems. These irrigation areas would be incorporated into the development plan. Other than the existing irrigation areas, there are the following three potential areas, in where the paddy cultivation is mainly made under the rainfed condition:

- Potential area of 35,000 rai (5,600 ha) on the right bank in the upstream reach of the Mae Wong river,

- Potential area of 20,000 rai (3,200 ha) on the right bank in the middle to downstream reach of the Mae Wong river, and

- Potential area of 7,000 rai (1,100 ha) on the left bank in the downstream reach of the Mae Wong river.

The potential areas were delineated carefully with special attention to the topographic condition, present land use and land capability for irrigation. The selected potential areas are all irrigable by gravity and are endowed with productive soils suitable for irrigated paddy cultivation. Through the water balance study and optimization study, it was concluded that all the above potential areas would be developed under the project as well as the existing irrigation areas.

The potential areas for irrigation development are thus delineated at 291,900 rai (46,700 ha) as shown below:

Existing Irrigation Area	Rainfed Area	Total
230,000 rai (36,800 ha)	61,900 rai (9,900 ha)	291,900 rai (46,700 ha)

The lands outside the delineated potential areas are generally not irrigable due to their undulating topography coupled with poor soil conditions.

4. IRRIGATION WATER REQUIREMENTS

4.1 General

Irrigation water requirements under the following conditions are calculated:

- Irrigation water requirements under the present condition based on the present cropping pattern to grasp the areas actually irrigated through the present water balance calculation, and

- Irrigation water requirements under the with-project condition based on the proposed cropping pattern to determine the project scale through the optimization study.

The calculation of irrigation water requirements is made on the monthly basis through the following procedures:

- Estimation of consumptive use of water by crop,
- Estimation of percolation rate of paddy crop,
- Estimation of water requirement for nursery and land preparation of paddy crop,
- Estimation of effective rainfall, and
- Estimation of diversion water requirement based on the overall irrigation efficiency.

4.2 Consumptive Use of Water by Crop

(1) Cropping pattern

Both present and proposed cropping patterns are shown in Fig. V-2 and Fig. V-3, respectively.

(2) Potential evapotranspiration (ETp)

Since no data on the field measurement of consumptive use of water by crop are available in the Mae Wong river basin, the consumptive use of water is estimated based on the potential evapotranspiration made by the authorized method.

The FAO Group on Crop Water Requirement recommends the following prediction method:

- Blaney - Criddle,
- Radiation,
- Modified Penman, and
- Pan evaporation.

Among the above methods, it is said that the modified Penman method would offer the best results, if accurate climatic data are available.

In order to determine the methods to give the most reliable potential evapotranspiration, a study was conducted by comparing with the direct measurement of lysimeter in two crop seasons from 1978 to 1980/1. In the study, the following methods were studied:

/1: POTENTIAL EVAPOTRANSPIRATION AND CROP COEFFICIENT FOR RICE IN THAILAND by Mr. Direk Tongaram, Crop Water Requirement Experimental Project, Irrigated Agricultural Branch, Operation and Maintenance Division, RID

- Perman,
- Christiansen - Hargreaves,
- E-pan,
- Makkink,
- Blaney - Criddle, and
- Thorntkwaite.

From the results of study, the resport concluded that the Penman method was the best for the climate in Thailand.

Thus, the modified Penman method was adopted for estimation of potential evapotranspiration. Estimation of potential evapotranspiration is made based on the climatic data for about 30 years at Nakhon Sawan. The estimated potential evapotranspiration is shown in Table V-5.

(3) Crop coefficient (Kc)

According to the Chao Phraya - Meklong Basin Study made by Acres International, Canada, the crop coefficient in the Chao Pharaya - Meklong basin has been evaluated using evapotranspiration measurement at Somchock Experimental Station as shown below:

Crop	Month				
	1st	2nd	3rd	4th	5th
Transplanted (local)	0.85	1.02	1.03	0.93	0.81
High Yielding Variety	1.00	1.30	1.32	0.87	-
Field Crops	0.30	0.50	1.00	0.80	-

These figures are used for estimation of consumptive use of water by crop.

(4) Consumptive use of water by crop (Cu)

The consumptive use of water by crop is calculated by the following formula.

$$Cu = ETp \cdot Kc$$

where, Cu: consumptive use
ETp: potential evapotranspiration
Kc: crop coefficient

4.3 Percolation Rate

In the previous pre-feasibility study, the percolation rate was assumed at 1.0 mm/day in the calculation of irrigation water requirements for paddy crop. Afterward, the soil survey was conducted by RID under the additional survey and investigation program which was requested by the JICA study team in the Pre-feasibility Study Report on the Sakae Krang River Basin Irrigation Project, March 1985. According to the results of soil survey, the soils in the irrigation area are rather sandy. The results of soil infiltration tests in the fields indicate slightly high rate. Taking such results into consideration, the percolation rate is changed the previous figure of 1.0 mm/day into 1.5 mm/day.

4.4 Water Requirement for Nursery and Land Preparation

The area required for the nursery bed covers about 6% of the cropping area. Nurseries are operated in the same area and during the same period as land preparation. Accordingly, it can be assumed that nursery water requirement is covered by water to be supplied for land preparation.

The following figures are assumed for land preparation and ploughing, and standing water prior to transplanting.

Soil saturation	140 mm
Standin water	40 mm
Total	180 mm

Duration of land preparation = 30 days

The land preparation requirement is estimated by using Zylstra and Van de Goor formula.

$$We = a \cdot \frac{e^{\frac{a \cdot T}{b}}}{e^{\frac{a \cdot T}{b}} - 1}$$

where, We: water requirement for land preparation (mm/day)

a: value of open water evaporation and percolation (mm)

b: quantity of water needed for soil saturation and standing water (mm)

T: duration of land preparation (day)

Estimated water requirement for land preparation varies from 270 mm to 300 mm.

4.5 Effective Rainfall

The effective rainfall for paddy crop is estimated by using the relationship curve between total and effective monthly rainfall derived from the Chao Phraya - Meklong Basin Study as shown in Fig. V-4. This curve was worked out through the simulation of field water levels in the present agricultural practice condition with minimal storage of field in the Chao Pharaya - Meklong basin. The effective rainfall estimated by this curve shows rather conservative figures than that by the effective rainfall chart made by RID shown in Fig. V-5. The effective rainfall for upland crop is estimated by the above RID's chart.

In the previous pre-feasibility study, the monthly rainfall data at the Thap Than station were used for estimation of effective rainfall, because the station is located in the center of irrigation service area in the Sakae Krang river basin. The center of irrigation service area in the Mae Wong river basin is Lat Yao, capital city of Amphoe Lat Yao. Consequently, the monthly rainfall data at the Lat Yao station are used for estimation of effective rainfall in this feasibility study. The mean monthly rainfalls for 29 years from 1954 to 1982 at both station are shown as follows:

Station	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Thap Than	126	141	199	311	145	39	3	9	13	40	76	147	1,249
Lat Yao	102	125	147	246	145	32	6	14	10	28	68	139	1,062

4.6 Net Water Requirement and Diversion Water Requirement

The net water requirement is calculated using the following formula.

Paddy

$$Wn = Cu + P + We - Re$$

Upland Crop

$$Wn = Cu - Re$$

where, Wn: net water requirement
Cu: consumptive use of water
P: percolation rate
We: water requirement for land preparation including nursery requirement
Re: effective rainfall

The diversion water requirement is calculated by the following formula:

$$Wd = Wn \times \frac{100}{E}$$

where, Wd: diversion water requirement
Wn: net water requirement
E: overall irrigation efficiency

Generally, the diversion water requirement is calculated by adding the net water requirement to the irrigation losses. The irrigation losses consist of conveyance loss on the irrigation canal and application loss of the field. Factors affecting conveyance loss are size of the irrigation service area, canal lining, the technical and managerial skillness on the water management by the project staff. The application loss to the field is primarily affected by method and control of operation, the type of soils, length of field canals, size of the irrigation block, etc.

Referring to the study results on irrigation efficiencies in the Chao Phraya - Meklong Basin Study, the following overall irrigation efficiencies are assumed for calculation of diversion water requirement.

Present condition

Paddy : 45%
Upland crop : 40%

With-project condition

Paddy : 55%
Upland crop : 45%

The following two cases of irrigation water requirements for both "present" and "with-project" conditions are calculated.

Present condition

- irrigation water requirements in the irrigated field
- irrigation water requirements in the semi-irrigated field

With-project condition

- irrigation water requirements for with-upgrading of existing farmer's irrigation systems (overall irrigation efficiency of 55% for paddy and 45% for upland crop)
- irrigation water requirements for without-upgrading of existing farmer's irrigation systems (overall irrigation efficiency of 45% for paddy and 40% for upland crop)

The calculated irrigation water requirements for both conditions are shown in Tables V-6 to V-9.

4.7 Unit Design Irrigation Requirement

In case of with-upgrading of existing farmer's irrigation systems, the peak unit irrigation requirement of with-project condition varies from 0.75 ℓ/sec/ha (0.120 ℓ/sec/rai) to 1,303 ℓ/sec/ha (0.208 ℓ/sec/rai). The peak unit irrigation water requirement with 5-year return period is estimated at 1.10 ℓ/sec/ha (0.18 ℓ/sec/rai). The unit design water duty for canals and related structures is determined at 1.25 ℓ/sec/ha (0.20 ℓ/sec/rai) taking an allowance of 10%.

5. DRAINAGE MODULUS

5.1 Criteria

The design capacity of drainage canal is estimated in accordance with the following criteria which is generally applied to the drainage plan in the humid Asian countries such as Thailand, Philippines, Malaysia and Indonesia.

- Return period of design rainfall is five years,
- Design rainfall is of three days consecutive rainfall,
- Design rainfall shall be drained off for three day, and
- On-field storage of an average surcharge of 75 mm.

5.2 Drainage Modulus

Design rainfall with return period of five years is determined at 170 mm based on the daily rainfall records at Lat Yao from 1931 to 1983. The drainage modulus of paddy fields is estimated using the following formula.

$$q = \frac{(R - h) \times 10^{-3} \times 10,000 \times 10^{3}}{86,400 \times d}$$

where, q: drainage modulus (ℓ/sec/ha)
R: design rainfall (170 mm)
h: on-field storage of an average surcharge (75 mm)
d: allowable duration of inundation (3 days)

The drainage modulus of paddy fields is determined at 3.67 ℓ/sec/ha.

As for the drainage modulus of the high terraces and hills, it is estimated at 4.84 ℓ/sec/ha based on the floods with return period of five years at the CT5A station.

5.3 Runoff Reduction Ratio

The above estimated drainage modulus is applied for the drainage area less than 3 km^2. The following runoff reduction ratio is applied for the drainage area larger than 3 km^2.

Drainage Area (km^2)	Reduction Ratio
0 - 3	1.00
3 - 4	0.95
4 - 6	0.90
6 - 8	0.86
8 - 12	0.80
12 - 16	0.76
16 - 20	0.74
20 - 28	0.70
28 - 40	0.66
40 - 60	0.61
60 - 80	0.58
80 - 120	0.55
120 - 160	0.52

6. PLANNING AND DESIGN OF PROJECT FACILITIES

6.1 Intake Weirs

Two (2) intake weirs are proposed to divert the irrigation water to the Ban Tha Ta Yu irrigation area of 105,000 rai (16,800 ha) and the Khlong Saingu irrigation area of 51,000 rai (8,160 ha). For design of these weirs, RID prepared the topographic maps on a scale of 1/1,000 at the sites (See DWG No. 12 to DWG No. 15).

(1) Design flood discharge

According to the hydrologic study, the flood discharge with 50-year return period at the Upper Mae Wong damsite is estimated at 1,200 m^3/sec. The flow capacity of the Mae Wong river, however, is supposed to be less than 100 m^3/sec. The flood discharges of intake weirs for the existing small scale irrigation project is so designed as to be the same as the river flow capacity at the sites. Subsequently, the design flood discharges for the proposed intake weirs are estimated at 88 m^3/sec for the Ban Tha Yu and 63 m^3/sec for the Khlong Saingu based on the flow capacity calculated at the sites.

(2) Intake discharge

The unit peak irrigation water requirement with 5-year return period is estimated at 1.25 ℓ/sec/ha (0.20 ℓ/sec/rai) based on the results of irrigation water requirement estimation. Accordingly, the intake discharges to the irrigation service areas are calculated as follows:

Ban Tha Ta Yu area: 21 m^3/sec

Khlong Saingu area: 10.2 m^3/sec

(3) Design of intake weir

The intake weir of Ban Tha Ta Yu irrigation area would be 2.7 m high and 30 m long including the scouring sluice portion. In the left end of the weir, a scouring sluice with 2 sets of gate, 2.0 m wide and 1.5 m high, would be provided so that the deposited sand can be flashed down. The scouring sluice gate would be operated by man power. The intake gate would consist of 4 sets of slide gate, each 2.0 m wide and 2.5 m high, which would be operated by man power.

The intake weir of Khlong Saingu irrigation area would be 1.3 m high and 28 m long. Two (2) scouring sluice with stop-logs, 1.5 m wide and 0.8 m high would be provided on the intake weir body. The intake gate would not be necessary, because RID already constructed the Khlong Saingu regulator.

6.2 Layout Planning of Canal System

6.2.1 Irrigation canal

The preliminary layout planning of irrigation canal is made on the topographic maps on a scale of 1/10,000 prepared by RID. In the planning, the following matters are taken into consideration:

- Canal alignment should be straight and short as far as possible,
- Existing farmer's irrigation systems are to be incorporated into the project as far as possible, and
- Embankment portion should be minimized as far as possible.

For the upgrading plan of existing farmer's irrigation systems, the following concepts are considered:

- Existing intake weirs and regulator (gate) would be integrated under the project to simplify the water management on the Mae Wong river,
- Existing intake weirs and regulator other than the proposed or integrated ones under the project would be removed and all cutting of the Mae Wong river bank by farmers would be reclosed to assure the stable intake of irrigation water released from the Upper Mae Wong dam to each irrigation area,
- Existing farmer's irrigation systems with difficulty of gravity irrigation would be embanked to raise the water level in the canals for assured gravity irrigation,

- Related structures such as check, turnout, drop, syphon, spillway, cross drain, culvert, etc. would be provided to assure the distribution of irrigation water in a timely and efficient manner as to meet the crop water requirements,

- Measuring devices would at least be provided at the head of main canal for proper water management, and

- There exist no inspection roads along the existing canals. Inspection roads would be provided for proper operation and maintenance of irrigation facilities.

The layout of irrigation canal system is shown in Fig. V-6.

6.2.2 Drainage canal

The preliminary layout planning of drainage canal is also made on the topographic maps on a scale of 1/10,000. In the layout, the existing natural streams in the areas are incorporated into the drainage canal system as many as possible. The layout of drainage canal system is shown in Fig. V-6.

6.3 Design of Canal System

6.3.1 Design of irrigation canal

(1) Design discharge

The design discharge for the irrigation canals is calculated based on the unit irrigation water requirement of 1.25 ℓ/sec/ha (0.20 ℓ/sec/rai) estimated in Section 4.7. Taking water management, soil textures, cropping patterns, adjustment of timing of irrigation water supply during the day, etc. into consideration, the following adjustment factor is adopted from USBR design standard.

Area (ha)	Adjustment Factor
20 - 50	3.0
50 - 150	1.75
150 - 250	1.20
250 - 500	1.15
500 - 1,500	1.10
1,500 - 2,500	1.05
2,500 and greater	1.00

Using above figure and adjustment factor, the schematic irrigation diagrams are made as shown in DWG No. 16 to DWG No. 19.

(2) *Canal lining*

The proposed main canal route runs along the Cenozoic Quarternary Pleistocen diluvial lower terrace on the upstream right bank of the Mae Wong river. The diluvial deposit is comparatively consolidated consisting gravels, sands, silts and laterite. The permeability is rather high. Consequently, the proposed main canal would be lined by concrete with 10 cm thick to protect seepage from the canal bank and bottom.

On the other hand, the lowlying area along the Mae Wong river is covered by the Recent flood plain alluvial on the above diluvial deposit. The alluvial consists of organic silt and clay. No canal lining would be required.

(3) Velocity

The maximum and minimum permissible velocities are determined as follows so as to avoid the scouring of canal bed and not to induce the growth of aquantic plants and to deposit the sediments.

Item	Maximum Velocity (m/sec)	Minimum Vecolity (m/sec)
Concrete-lined canal	1.5	0.8
Unlined canal	0.7	0.5

(4) Flow formula and roughness coefficient

The Manning formula is applied for hydraulic calculation of all canals:

$$Q = A \cdot V$$

$$V = \frac{1}{n} \cdot R^{2/3} \cdot I^{1/2}$$

where, Q: design discharge (m^3/sec)
A: flow area (m^2)
V: mean velocity (m/sec)
n: roughness coefficient
R: hydraulic radius (m)
I: hydraulic gradient

The Manning's roughness coefficient "n" is assumed as follows:

	Roughness Coefficient
Concrete-lined canal	0.015
Unlined canal	0.030

(5) Freeboard and waste bank

Freeboard is decided so as to absord the fluctuation of water level due to the variation of actual roughness coefficient, conversion of velocity head to the statistic head and wave action caused by wind or regulating structure operation. The minimum freeboard is determined as follows:

Discharge (m^3/sec)	Minimum Freeboard (m)
Less than 3.0	0.15
3.0 - 21.0	0.20

The height of waste bank is determined to be 0.3 to 0.4 m for concrete-lined canal and 0.45 to 0.60 m for unlined canal.

(6) Canal base width/water depth (B/h) ratio

The ratio of canal base width and water depth is determined at 1.0 to 3.0 B/h.

(7) Side slope

The side slope of canal is assumed at 1:1.5 referring the results of soil mechanical investigation in the irrigation area.

Considering above design criteria, the preliminary designs of main canal and lateral are made as shown in DWG No. 23 to DWG No. 32.

6.3.2 Design of related structure

Many different types of structures related to the irrigation canal are required in the irrigation canal system to effectively and efficiency convey and regulate the irrigation water. The following canal structures are envisaged to be constructed under the project.

(1) Check

The check would be provided to regulate the canal water surface upstream of the structure and control the downstream flow. The structure would comprise a reinforced concrete flume and transition with gradually varied sections at both up- and downstream of the flume. The flume would be equipped with steel slide gate to regulate the water surface in the canal.

(2) Turnout

The turnout would be divert irrigation water from the main or lateral to lateral or tertiary unit. The structure would consist of an inlet transition, a conduit and an outlet transition. The turnout structure is divided into two types, namely open channel type and orifice type, to simplify and standardize the structural features for easy and quick construction.

Open channel type: Open channel type turnout is designed to divert irrigation water from main canal to lateral. The turnout would consist of an inlet transition, a slide gate, a concrete channel with rectangular section and an outlet transition with gradually varied section.

Orifice type: Orifice type turnout is designed to divert irrigation water from lateral to sub-lateral or tertiary unit. The turnout would consist of an inlet transition, a slide gate, a precast concrete pipe and an outlet transition with gradually varied section.

(3) Drop

The function of drop is to convey irrigation water from a higher position to a lower elevation and to dissipate excessive energy resulting from the drop. The drop would consist of upstream transition, inlet, stilling pool and outlet transition. In order to prevent canals from scouring and erosion in unlined canal, riprap would be necessary at the upstream and downstream of drop structures.

(4) Syphon

The syphon structures would be provided at the places where the main and lateral canals cross over the existing streams. The structure would consist of an inlet transition, cast-in-place concrete conduit with rectangular section and an outlet transition.

(5) Culvert

The culvert (road crossing) is used to convey irrigation water under the road. The culvert would consist of a rectangular reinforced conduit and transition with gradually varied section at inlet and outlet of the conduit.

(6) Spillway and wasteway

The spillway and wasteway would be provided to waste excessive water which may result from misoperation, heavy rainfall or floods caused by break of canal embankment. The wasteway would be also provided to empty the canal for inspection, maintenance, seasonal shutdown, or in an emergency such as canal bank failure. For the purpose mentioned above, the spillway and wasteway would be provided upstream of syphon and/or near check, which divert large amount of irrigation water. The spillway and wasteway would be composed of gate structure in combination with a side channel spillway.

(7) Cross drain

The main canal would cross some streams coming from the high terraces or hills. The cross drain would be provided at those cross points. The cross drain would consist of inlet transition, cast-in-site concrete single or multifarrel conduit and outlet transition.

(8) Water measuring device

Parshall flume would be provided at the head of main and lateral canals for the purpose of canal water measurement.

(9) Bridge

The bridge would be constructed where the inspection road crosses over the irrigation canal or existing small streams. The bridge of concrete slab type would be proposed.

The typical drawings of related structures are shown in DWG No. to DWG No. 33 to DWG No. 37.

6.3.3 Design of drainage canal and its related structures

According to the drainage modulus estimated in Section 5.2, the design discharges of respective drainage canals are calculated as shown in DWG No. 20 to DWG No. 22. The related structures to the drainage canals include cross drains and culverts. They are planned and designed with the same principles as those of the related structures for irrigation canals. The typical cross section of drainage canal is shown in DWG No. 23.

6.4 Inspection Road

For proper operation and maintenance of project facilities, well arranged inspection roads are of vital importance.

(1) Main inspection road

The main inspection road is required for inspection, operation and maintenance of the main canal. Considering the future increase of vehicles for the inspection and operation and heavy construction to be required for the canal maintenance and repair, all the main inspection roads are so designed as to have a width of 5 m and effective width of 4 m to be laterite-paved. These roads are also used for transportation of agricultural products, equipment and goods.

(2) Lateral inspection road

The lateral inspection road is mainly provided alongside the lateral canal. All these roads have a width of 4 m.

The typical cross section of inspection road is shown in DWG No. 23.

6.5 Land Reclamation

The potential maximum area of 291,900 rai (46,700 ha) includes about 13,100 rai (2,100 ha) of upland where, if irrigation water is provided, paddy cultivation would become possible. These upland areas are to be reclaimed into new paddy fields. The rough levelling works would be carried out for the areas of 6,200 rai (1,000 ha) to make the cultivation land for paddy. The remaining areas of 6,000 rai (1,100 ha) would be reclaimed by clearing works by manpower, because of flat topography.

6.6 Main Features of Irrigation Facilities

The main features of irrigation facilities are summarized in Table V-10.

Table V-1 PUMP IRRIGATION SERVICE AREA (1/2)

Year	Season/1	Size of Pump (inch)	Location Changwat	Amphoe	Tambon	Benefited Area (rai) Paddy	Upland Crop
1981	Dry	Ø 8"	Uthai Thani	Sawang Arom	Nong Luang	600	100
1981	Wet	Ø 10"	Nakhon Sawan	Lat Yao	Huai Nam Hom	800	-
1982	Dry	Ø 6"	Uthai Thani	Sawang Arom	Nong Luang	300	100
1982	Wet	Ø 12"	Nakhon Sawan	Lat Yao	Wang Ma	1,500	-
		Ø 10"	Nakhon Sawan	Lat Yao	Wang Muang	1,000	-
		Ø 8"	Nakhon Sawan	Lat Yao	Huai Nam Hom	700	-
		Ø 8"	Nakhon Sawan	Lat Yao	Huai Nam Hom	900	-
		Ø 8"	Nakhon Sawan	Lat Yao	Map Kae	420	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	370	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	300	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	450	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	400	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	390	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	650	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	500	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	530	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	300	-
		Ø 6"	Nakhon Sawan	Lat Yao	Map Kae	470	-
	Sub-total					8,880	-
1983	Dry	Ø 6"	Uthai Thani	Sawang Arom	Nong Luang	300	100
1983	Wet	Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	600	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	350	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	480	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	460	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	500	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	430	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	470	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	510	-
		Ø 8"	Nkhonn Sawan	Lat Yao	Wang Ma	600	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	420	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	520	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	495	-
		Ø 8"	Nakhon Sawan	Lat Yao	Map Kae	600	-
		Ø 8"	Nakhon Sawan	Lat Yao	Lat Yao	570	-
		Ø 8"	Nakhon Sawan	Lat Yao	Lat Yao	415	-
		Ø 8"	Nakhon Sawan	Lat Yao	Lat Yao	450	-
	Sub-total					7,870	-
1984	Dry	Ø 6"	Nakhon Sawan	Lat Yao	Mae Wong	300	-
		Ø 6"	Nakhon Sawan	Lat Yao	Mae Wong	340	-
		Ø 6"	Nakhon Sawan	Lat Yao	Lat Yao	420	-
		Ø 6"	Nakhon Sawan	Lat Yao	Lat Yao	380	-
		Ø 6"	Nakhon Sawan	Lat Yao	Map Kae	320	-
		Ø 6"	Nakhon Sawan	Lat Yao	Soy La Khon	350	-
		Ø 6"	Nakhon Sawan	Lat Yao	Map Kae	520	-
	Sub-total					2,630	-
1984	Wet	Ø 10"	Nakhon Sawan	Lat Yao	Wang Muang	900	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	610	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	460	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	495	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	576	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	520	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	500	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	400	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	360	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	613	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	450	-
		Ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	376	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	508	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	500	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	505	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	430	-
		Ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	629	-
		Ø 8"	Nakhon Sawan	Lat Yao	Lat Yao	700	-
		Ø 6"	Nakhon Sawan	Lat Yao	Huai Nam Hom	410	-
	Sub-total					9,942	-

Table V-1 PUMP IRRIGATION SERVICE AREA (2/2)

Year	Season/1	Size of Pump (inch)	Location			Benefited Area (rai)	
			Changwat	Amphoe	Tambon	Paddy	Upland Crop
1985	Dry	ø 8"	Nakhon Sawan	Lat Yao	Huai Nam Hom	800	-
1985	Wet	ø 8"	Nakhon Sawan	Lat Yao	Huai Nam Hom	700	-
		ø 8"	Nakhon Sawan	Lat Yao	Huai Nam Hom	890	-
		ø 8"	Nakhon Sawan	Lat Yao	Map Kae	620	-
		ø 8"	Nakhon Sawan	Lat Yao	Map Kae	650	-
		ø 8"	Nakhon Sawan	Lat Yao	Lat Yao	580	-
		ø 8"	Nakhon Sawan	Lat Yao	Lat Yao	560	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	560	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	630	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Muang	685	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	560	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	610	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	575	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	475	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	410	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	620	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	750	-
		ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	410	-
		ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	395	-
		ø 6"	Nakhon Sawan	Lat Yao	Wang Ma	540	-
		ø 8"	Nakhon Sawan	Lat Yao	Wang Ma	800	-
Sub-total						12,020	-

Source : Regional Office VII, RID (August, 1985)

/1 : Dry season : February to May

Wet season : August to November

Table V-2 MAJOR FEATURES OF THE EXISTING MEDIUM AND SMALL SCALE IRRIGATION PROJECT

Project Name	Irrigation Area (rai)	Main Features of Facilities	Intake Structure	Construction Year
Weir				
I. Medium Scale Irrigation Project				
1. Khun Lard Boriban	55,000	Radial Gate : 6 m x 3 m x 1		1975 - 1977
2. Wang Khun Pao	105,000	Radial Gate : 4 m x 3 m x 1		1975 - 1977
3. Khlong Nam Hom	10,000	Weir : L = 18 m, H = 2.5 m	Ø 1.0 m x 3 with slide gates 1.2 m x 1.2 m x 3	1975 - 1976
II. Small Scale Irrigation Project				
1. Ban Wan Nam Kao	3,000		Right Bank Ø 1.25 m x 2	1984
2. Klong Saingu	10,000	Regulater : 2.3 m x 2.0 m x 3	-	1982
3. Huai Hin Lab	3,000	Weir : L = 392 m x H = 4.5 m	-	1984
4. Wang Ma	26,000	Weir : L = 25 m x H = 3.0 m	Left Bank Ø 1.00 m x 2 with slide gates 1. 45 m x 1.10 m x 2	1977
5. Sawang A-Rom	200	Weir : L = 40 m x H = 3.0 m	-	1982
6. Lan Bai Dieo	4,000	Weir : L = 25 m x H = 2.0 m	Right Bank Ø 1.00 m x 2	1982
7. Nong Yao	4,000	Weir : L = 15 m x H = 1.5 m	Right Bank Ø 1.00 m x 1	1983
8. Wang Hin Phoeng	10,000	Weir : L = 14 m x H = 1.5 m	Left Bank Ø 1.00 m x 2 Right Bank Ø 2.0 m x 2.0 m x 1	1981
9. Huai Sadao Sai	13,000	Weir : L = 29.4 m x H = 3.1 m	Left Bank Ø 1.00 m x 1 Right Bank Ø 1.5 m x 1.5 m x 1	1985

Table V-3 O & M STAFFING SITUATION OF LARGE SCALE PROJECT

Position	Lam Pao (Regional 5)				Lam Nam Oon (Regional 5)				Lam Dom Noi (Regional 5)				Nong Wai/Nam Pong (Regional 4)				Huai Luang (Regional 4)			
	(1)	(2)	(3)	(3)/(1)	(1)	(2)	(3)	(3)/(1)	(1)	(2)	(3)	(3)/(1)	(1)	(2)	(3)	(3)/(1)	(1)	(2)	(3)	(3)/(1)
Project Engineer	1	1	1	1.00	1	1	1	1.00	1	1	1	1.00	1	1	1	1.00	1	1	1	1.00
Irrigation/Civil Eng. C 6	11	3	3	0.27	18	3	3	0.38	6	1	1	0.17	10	4	3	0.30	5	1	1	0.20
Irrigation/Civil Eng. C 4-5	22	7	7	0.32	14	4	4	0.29	10	0	0	0.00	18	7	6	0.33	8	3	2	0.25
Irrigation/Civil Tech. C 2-3	5	0	0	0.00	3	0	0	0.00	2	0	0	0.00	5	2	0	0.00	2	2	0	0.00
Construction Technician	0	0	0	0.00	0	0	0	0.00	0	1	0	0.00	2	2	2	1.00	3	3	3	1.00
Zoneman	53	17	17	0.32	35	4	2	0.06	15	10	0	0.00	52	19	16	0.31	8	8	4	0.50
Sub-total	92	28	28	0.30	61	12	10	0.16	34	13	2	0.06	88	35	28	0.32	27	18	11	0.41
Gate Tender	113	15	14	0.12	110	21	20	0.18	47	42	30	0.64	247	26	25	0.10	11	11	10	0.91
Canal Tender	219	92	86	0.39	117	17	17	0.15	63	58	50	0.79	170	168	127	0.75	81	81	28	0.35
Sub-total	332	107	100	0.30	227	38	37	0.16	110	100	80	0.73	417	194	152	0.36	92	92	38	0.41
Hydrographer	10	4	4	0.40	8	0	0	0.00	4	1	0	0.00	7	6	6	0.86	3	2	2	0.67
Surveyor	4	2	2	0.50	2	0	0	0.00	3	1	1	0.33	3	1	1	0.33	2	1	1	0.50
Draftsman	2	2	2	1.00	2	0	0	0.00	2	1	1	0.50	2	2	2	1.00	2	2	1	0.50
Agronomist	5	1	1	0.20	4	1	1	0.25	3	1	1	0.33	7	5	5	0.71	2	2	2	1.00
Sub-total	21	9	9	0.43	16	1	1	0.06	12	4	3	0.25	19	14	14	0.74	9	7	6	0.67
Mechanical Engineer	2	0	0	0.00	3	0	0	0.00	3	1	1	0.33	3	0	0	0.00	2	0	0	0.00
Mechanic/Electrician	2	2	1	0.50	6	2	0	0.00	7	6	4	0.57	4	2	2	0.50	2	2	2	1.00
Communication Tech.	5	2	1	0.20	4	2	0	0.00	2	1	1	0.50	4	4	4	1.00	2	2	1	0.50
Teletphon/Radio Operator	10	2	2	0.20	7	2	2	0.29	3	3	2	0.67	9	4	4	0.44	5	5	3	0.60
Sub-total	19	6	4	0.21	20	6	2	0.10	15	11	8	0.53	20	10	10	0.50	11	9	6	0.55
Administrator	13	8	8	0.62	9	1	1	0.11	7	5	2	0.29	12	9	9	0.75	4	4	3	0.75
Accountant	4	2	2	0.50	2	1	1	0.50	2	1	1	0.50	2	2	2	1.00	2	2	2	1.00
Store Keeper	4	3	2	0.50	3	1	1	0.33	3	2	1	0.33	3	3	3	1.00	2	2	2	1.00
Typist	2	2	2	1.00	2	1	1	0.50	2	1	1	0.50	2	2	0	0.00	1	1	1	1.00
Nurse	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00
Janitor	1	1	0	0.00	1	1	1	1.00	1	1	1	1.00	1	1	1	1.00	1	1	1	1.00
Watchman	58	31	27	0.47	50	34	33	0.66	38	36	31	0.82	53	48	47	0.89	27	12	26	0.96
Skilled Labour	52	26	26	0.50	29	15	13	0.45	22	19	17	0.77	50	40	40	0.80	18	17	14	0.78
Labour/Gardener	124	58	57	0.46	74	61	61	0.82	39	36	28	0.72	35	27	22	0.63	46	47	40	0.87
Driver	18	3	3	0.17	11	3	3	0.27	6	4	4	0.67	15	5	5	0.33	5	5	4	0.80
Boat Driver	2	2	2	1.00	0	0	0	0.00	1	1	0	0.00	1	1	0	0.00	1	1	1	1.00
Sub-total	278	136	129	0.46	181	118	115	0.64	121	106	86	0.71	174	137	129	0.74	107	92	94	0.88
Total	742	286	270	0.36	505	175	165	0.33	292	234	179	0.61	718	390	333	0.46	246	218	155	0.63

Note: (1) Staff required according to O & M accepted guideline
(2) Staff requested from the Budget Bureau
(3) Presently available staff in the project

Compiled from information received from RID O & M Division Bangkok and O & M staff of the Regional Office on March 12, 1985

Source : O & M Division, RID

Table V-4 ANNUAL OPERATION AND MAINTENANCE COST
(1985 FISCAL YEAR)

Item	Boromathat (Regional 7)		Samchook (Regional 7)		Chanasut (Regional 7)	
	฿	%	฿	%	฿	%
Administration	767,000	7	743,500	11	1,142,000	19
Water operation	330,000	3	180,000	3	510,000	8
Maintenance	9,851,000	90	5,600,000	86	4,370,000	73
Total	10,948,000	100	6,523,500	100	6,022,000	100
Irrigable area	365,000 rai (58,400 ha)		305,000 rai (48,800 ha)		434,300 rai (75,900 ha)	
Unit cost	฿ 30/rai (฿ 187/ha)		฿ 21/rai (฿ 135/ha)		฿ 14/rai (฿ 79/ha)	

Item	Nam Pong-Nong Wai (Regional 4)		Nam On (Regional 5)		Lam Pao (Regional 5)	
	฿	%	฿	%	฿	%
Administration	1,126,900	15	3,862,000	60	1,216,600	50
Water operation	300,000	4			225,000	9
Maintenance	5,941,000	81	2,592,400	40	995,000	41
Total	7,367,900	100	6,454,400	100	2,436,600	100
Irrigable area	268,700 rai (43,000 ha)		185,800 rai (30,000 ha)		313,200 rai (50,100 ha)	
Unit cost	฿ 27/rai (฿ 171/ha)		฿ 35/rai (฿ 215/ha)		฿ 8/rai (฿ 49/ha)	

Source : Water Operation Branch of Operation and Maintenance Division, RID

Table V-5 POTENTIAL EVAPOTRANSPIRATION

Nakhon Sawan Station

	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T mean	°C	25.6	28.3	30.7	31.9	30.6	29.6	29.0	28.5	28.0	27.9	26.7	25.2
RH mean	%	63	62	61	61	70	74	75	78	82	80	73	67
ea	mbar	32.8	38.5	44.2	47.3	43.9	41.5	40.1	39.0	37.8	37.6	35.1	32.1
ed	mbar	20.7	23.9	27.0	28.9	30.7	30.7	30.1	30.4	31.0	30.1	25.6	21.5
ea-ed	mabr	12.1	14.6	17.2	18.4	13.2	10.8	10.0	8.6	6.8	7.5	9.5	10.6
U	km/day	25	37	60	64	44	44	33	34	18	21	30	30
$f(u) = 0.27(1 + \frac{u}{100})$		0.34	0.37	0.43	0.44	0.39	0.39	0.36	0.36	0.32	0.33	0.35	0.35
1-W		0.26	0.23	0.22	0.20	0.21	0.22	0.23	0.23	0.23	0.23	0.24	0.26
W		0.74	0.77	0.78	0.80	0.79	0.78	0.77	0.77	0.77	0.77	0.76	0.74
Ra	mm/day	12.0	13.3	14.7	15.6	16.0	15.9	15.9	15.7	15.0	13.9	12.4	11.6
n/N		0.75	0.75	0.67	0.69	0.61	0.48	0.43	0.44	0.43	0.63	0.75	0.79
$(1-\alpha)(0.25+0.50\,n/N)$		0.47	0.47	0.44	0.45	0.42	0.37	0.35	0.35	0.35	0.42	0.47	0.48
Rns	mm/day	5.6	6.3	6.5	7.0	6.7	5.9	5.6	5.5	5.3	5.8	5.8	5.6
f(T)		15.8	16.4	16.9	17.2	16.9	16.7	16.5	16.4	16.3	16.3	16.0	15.7
f(ed)		0.14	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.12	0.13
f(n/N)		0.78	0.78	0.70	0.72	0.65	0.53	0.49	0.50	0.49	0.67	0.78	0.81
Rnl	mm/day	1.7	1.5	1.4	1.4	1.1	0.9	0.8	0.8	0.8	1.1	1.5	1.6
Rn = Rns - Rnl	mm/day	3.9	4.8	5.1	5.6	5.6	5.0	4.8	4.7	4.5	4.7	4.3	4.0
W.Rn	mm/day	2.9	3.7	4.0	4.5	4.4	3.9	3.7	3.6	3.5	3.6	3.3	3.0
(1-W)f(u)(ea-ed)	mm/day	1.1	1.2	1.6	1.6	1.1	0.9	0.8	0.7	0.5	0.6	0.8	1.0
Rs = Rns/0.75	mm	7.5	8.4	8.7	9.3	8.9	7.9	7.5	7.3	7.1	7.7	7.7	7.5
RH max	%	87.3	86.9	87.3	86.5	89.1	90.5	91.5	92.9	95.5	94.7	92.4	89.9
U	m/sec	0.3	0.4	0.7	0.7	0.5	0.5	0.4	0.4	0.2	0.2	0.3	0.4
C		1.02	1.02	1.01	1.03	1.03	1.00	1.00	1.01	1.02	1.03	1.03	1.02
ETP	mm/day	4.1	5.0	5.7	6.2	5.7	4.8	4.5	4.3	4.1	4.3	4.2	4.1
	mm/month	127	140	177	186	177	144	140	133	123	133	126	124

Σ = 1,733 mm

Note: Claculated by the Modefied Penman Method.

Table V-6 IRRIGATION WATER REQUIREMENT OF PRESENT CONDITION (IRRIGATED FIELD)

(Unit : mm)

Year	Wet Season Crop (Paddy)							Dry Season Crop (Paddy)					Dry Season Crop (Mung Bean)			
	JUN	JUL	AUG	SEP	OCT	NOV	Total	DEC	JAN	FEB	MAR	Total	DEC	JAN	FEB	Total
1954	0	187	206	144	292	256	1,085	43	822	501	345	1,711	116	318	210	644
1955	0	160	218	173	417	136	1,104	43	822	414	436	1,715	116	318	162	596
1956	6	170	214	174	265	250	1,079	43	796	501	357	1,697	116	304	210	630
1957	0	196	220	134	266	224	1,040	43	744	501	387	1,675	116	278	210	604
1958	0	217	253	134	281	256	1,141	43	822	501	364	1,730	116	318	210	644
1959	0	143	230	134	310	245	1,062	43	822	501	498	1,864	116	318	210	644
1960	0	172	249	193	243	211	1,068	43	822	453	498	1,816	116	318	182	616
1961	0	206	206	183	241	256	1,092	39	822	501	470	1,832	95	318	210	623
1962	0	167	226	134	308	240	1,075	43	822	465	465	1,795	116	318	190	624
1963	0	222	205	162	238	153	980	43	822	501	487	1,853	116	318	210	644
1964	0	155	193	134	254	228	964	43	822	356	498	1,719	116	318	127	561
1965	0	226	161	139	295	239	1,060	43	552	487	474	1,556	116	173	202	491
1966	0	175	220	264	238	151	1,048	34	822	501	498	1,855	75	318	210	603
1967	0	235	282	179	297	207	1,200	43	822	479	446	1,790	116	318	198	632
1968	0	141	294	265	293	250	1,243	43	681	501	450	1,675	116	249	210	575
1969	0	168	257	134	319	145	1,023	43	822	496	333	1,694	116	318	207	641
1970	0	211	281	204	243	234	1,173	38	691	420	488	1,637	93	253	165	511
1971	0	245	180	170	295	239	1,129	43	822	477	422	1,764	116	318	196	630
1972	0	254	226	143	243	221	1,087	37	822	496	449	1,804	88	318	207	613
1973	0	280	196	134	364	242	1,216	43	822	501	385	1,751	116	318	210	644
1974	0	155	219	147	243	214	978	43	561	463	466	1,533	116	181	188	485
1975	0	181	246	177	253	111	968	31	822	501	377	1,731	65	318	210	593
1976	0	218	228	196	279	244	1,165	43	822	501	449	1,815	116	318	210	644
1977	29	272	233	186	299	221	1,240	37	646	448	498	1,629	87	232	180	499
1978	0	127	210	158	267	248	1,010	43	822	441	498	1,804	116	318	176	610
1979	0	186	215	147	422	256	1,226	43	822	501	486	1,852	116	318	210	644
1980	0	156	214	136	257	226	989	42	822	501	338	1,703	112	318	210	640
1981	0	175	212	189	305	102	983	43	822	501	451	1,817	116	318	210	644
1982	0	220	231	201	278	189	1,119	41	762	501	495	1,799	107	287	210	604
Mean	1	194	225	168	286	214	1,088	41	783	480	442	1,746	109	298	198	605

Table V-7 IRRIGATION WATER REQUIREMENT OF PRESENT CONDITION (SEMI-IRRIGATED FIELD)

Year	Wet Season Crop (Paddy)						
	JUL	AUG	SEP	OCT	NOV	DEC	Total
1954	96	150	123	294	370	140	1,173
1955	67	167	158	420	209	140	1,161
1956	78	162	158	268	362	140	1,168
1957	107	170	111	269	326	140	1,123
1958	130	217	111	284	370	140	1,252
1959	49	184	111	313	355	140	1,152
1960	80	211	182	245	310	140	1,168
1961	118	151	170	244	370	125	1,178
1962	75	179	111	310	348	140	1,163
1963	135	149	145	241	231	140	1,041
1964	61	132	111	257	332	140	1,033
1965	140	87	118	297	346	140	1,128
1966	84	170	266	241	228	110	1,099
1967	150	257	164	299	304	140	1,314
1968	46	274	266	296	362	140	1,384
1969	76	222	111	322	221	140	1,092
1970	123	256	194	245	340	124	1,284
1971	161	114	155	298	347	140	1,215
1972	170	178	122	245	323	120	1,158
1973	188	137	111	366	350	140	1,292
1974	61	169	127	245	314	140	1,056
1975	91	206	162	225	175	102	991
1976	131	181	185	282	353	140	1,272
1977	183	189	173	301	323	119	1,288
1978	30	156	140	269	359	140	1,094
1979	96	163	126	424	370	140	1,319
1980	63	162	114	259	330	137	1,065
1981	84	158	177	307	163	140	1,029
1982	133	185	191	280	279	134	1,202
Mean	104	177	151	289	313	135	1,169

Table V-8 IRRIGATION WATER EQUIPMENT OF WITH-PROJECT CONDITION (WITH UPGRADING WORKS)

(Unit : mm)

Year	Wet Season Crop							Dry Season Crop				
	JUL	AUG	SEP	OCT	NOV	DEC	Total	JAN	FEB	MAR	APR	Total
1954	75	177	147	244	142	13	798	35	233	250	40	558
1955	45	190	172	345	79	13	844	35	176	313	75	599
1956	55	186	172	223	139	13	788	32	233	259	56	580
1957	87	192	138	224	125	13	779	26	233	283	83	625
1958	113	226	138	236	142	13	868	35	233	265	76	609
1959	40	203	138	259	136	13	789	35	233	354	83	705
1960	58	222	189	205	118	13	805	35	201	354	57	647
1961	99	178	180	203	142	12	814	35	233	335	51	654
1962	52	199	138	257	134	13	793	35	209	332	70	646
1963	118	177	162	201	88	13	759	35	233	347	60	675
1964	43	165	138	214	127	13	700	35	135	354	82	606
1965	123	132	143	247	133	13	791	3	224	338	78	643
1966	62	192	249	201	87	10	801	35	233	354	66	688
1967	133	259	176	248	116	13	945	35	219	319	31	604
1968	40	273	249	245	139	13	959	20	233	322	71	646
1969	53	230	138	266	84	13	784	35	230	240	66	571
1970	105	258	198	205	130	12	908	21	180	347	72	620
1971	146	152	169	247	133	13	860	35	217	304	31	587
1972	156	198	146	205	124	11	840	35	230	321	79	665
1973	175	168	138	302	134	13	930	35	233	282	51	601
1974	43	191	150	205	120	13	722	5	207	332	54	598
1975	69	218	175	213	66	10	751	35	233	275	51	594
1976	114	200	191	234	136	13	888	35	233	321	48	637
1977	169	206	183	250	124	11	943	16	198	354	56	624
1978	36	182	159	224	138	13	752	35	193	354	64	646
1979	75	187	149	349	142	13	915	35	233	346	80	694
1980	43	186	140	216	126	13	724	35	233	244	53	565
1981	62	184	185	255	61	13	760	35	233	322	53	643
1982	115	203	195	233	107	13	866	28	233	352	67	680
Mean	86	198	167	240	120	13	824	31	219	316	62	628

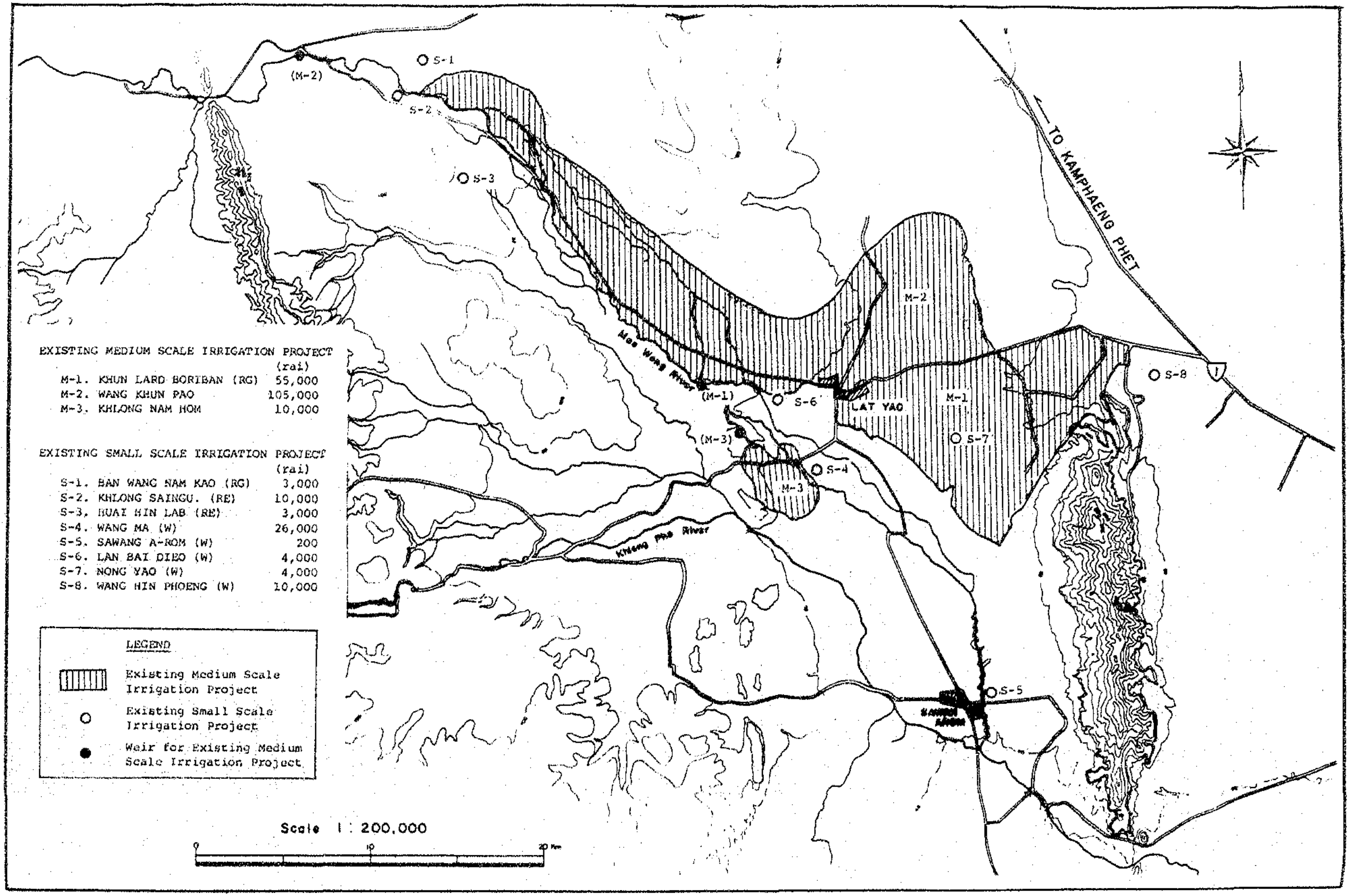
Table V-9 IRRIGATION WATER REQUIREMENT OF WITH-PROJECT CONDITION (WITHOUT UPGRADING WORKS)

(Unit : mm)

Year	Wet Season Crop							Dry Season Crop				
	JUL	AGU	SEP	OCT	NOV	DEC	Total	JAN	FEB	MAR	APR	Total
1954	92	217	180	298	173	16	976	40	263	281	45	629
1955	54	232	210	422	96	16	1,030	40	199	352	85	676
1956	67	228	210	273	170	16	964	36	263	291	64	654
1957	106	235	169	274	153	16	953	30	263	318	93	704
1958	138	276	169	288	173	16	1,060	40	263	298	86	687
1959	49	248	169	317	167	16	966	40	263	398	93	794
1960	70	271	231	250	145	16	983	40	226	398	64	728
1961	121	218	220	249	173	15	996	40	263	377	58	738
1962	63	243	169	314	163	16	968	40	235	373	78	726
1963	144	216	198	246	107	16	927	40	263	390	68	761
1964	53	201	169	261	155	16	855	40	152	398	93	683
1965	151	162	175	301	162	16	967	4	252	380	88	724
1966	76	235	304	246	106	13	980	40	263	398	74	775
1967	163	316	216	304	142	16	1,157	40	246	359	35	680
1968	49	334	305	300	170	16	1,174	23	263	362	80	728
1969	64	281	169	326	102	16	958	40	259	270	74	643
1970	128	315	242	250	159	14	1,108	24	203	390	82	699
1971	178	185	207	302	163	16	1,051	40	244	342	35	661
1972	190	242	179	250	151	14	1,026	40	259	361	89	749
1973	214	205	169	369	164	16	1,137	40	263	317	57	677
1974	53	234	183	250	147	16	883	6	233	374	61	674
1975	84	267	213	260	80	12	916	40	263	309	58	670
1976	139	244	233	286	166	16	1,084	40	263	361	54	718
1977	207	251	223	306	151	14	1,152	18	222	398	63	701
1978	44	222	194	274	168	16	918	40	217	398	72	727
1979	91	229	182	427	173	16	1,118	40	263	389	90	782
1980	53	228	171	264	154	16	886	40	263	275	60	638
1981	75	224	226	311	75	16	927	40	263	363	59	725
1982	141	248	239	285	130	16	1,059	32	263	396	76	767
Mean	105	242	204	293	146	16	1,006	35	247	356	70	708

Table V-10 MAIN FEATURES OF IRRIGATION FACILITIES

1.	Source of Irrigation Water	:	Mae Wong River		
2.	Net Irrigable Area	:	46,700 ha		
			Up-grading 36,800 ha		
			New development 9,900 ha		
3.	Intake Weir				
	(1) Ban Tha Ta Yu weir				
	Type	:	Ogee type		
	Length	:	30.0 m		
	Height	:	2.7 m		
	Scouring sluice	:	Gates, W 2.0 m x H 1.5 m x 2 sets		
	Intake	:	Gates, W 2.0 m x H 2.5 m x 4 sets		
	(2) Khlong Saingu weir				
	Type	:	Ogee type		
	Length	:	28.0 m		
	Height	:	1.3 m		
	Scouring sluice	:	Stop log, W 1.5 m x H 0.8 m		
	Intake	:	Existing regulator		
4.	Main Canal				
	(1) Type & length of canal		Upgrading	New construction	Total
	Trapezoidal unlined canal	:	64.7 km	12.0 km	64.7 km
	Trapezoidal concrete lined canal	:		12.0 km	12.0 km
	(2) Side slope of canal		1 : 1.5	1 : 1.5	
	(3) Related structures				
	Culvert	:		2 nos.	2 nos.
	Check structure	:		53 nos.	53 nos.
	Turnout	:		63 nos.	63 nos.
	Water measuring device	:		5 nos.	5 nos.
	Spillway	:		6 nos.	6 nos.
	Drop	:		5 nos.	5 nos.
	Syphon	:		3 nos.	3 nos.
	Bridge	:		3 nos.	3 nos.
5.	Lateral and Sub-lateral Canal				
	(1) Type & length of canal				
	Trapezoidal unlined canal	:	171.4 km	112.2 km	283.6 km
	Trapezoidal concrete lined canal	:		1.6 km	1.6 km
	(2) Side slope of canal	:	1 : 1.5	1 : 1.5	
	(3) Related structures				
	Cluvert	:		38 nos.	38 nos.
	Check structure	:		244 nos.	244 nos.
	Turnout	:		274 nos.	274 nos.
	Water measuring device	:		27 nos.	27 nos.
	Apillway	:		12 nos.	12 nos.
	Drop	:		8 nos.	8 nos.
	Syphon	:		8 nos.	8 nos.
	Bridge	:		21 nos.	21 nos.
6.	Drainage Canal				
	(1) Length of canal	:	96.1 km	108.1 km	204.2 km
	(2) Related structures				
	Cross drain	:		20 nos.	20 nos.
	Culvert	:		26 nos.	26 nos.
7.	Inspection Road				
	(1) Main inspection road				
	Road width	:		5 m	
	Pavement material	:		Laterite	
	Width of pavement	:		4 m	
	Length	:		76.7 km	
	(2) Lateral and sub-lateral inspection road				
	Road width	:		4 m	
	Pavement material	:		-	
	Width of pavement	:		-	
	Lnegth	:		285.2 km	
8.	Land Reclamation	:		6,000 rai (1,100 ha)	



EXISTING MEDIUM SCALE IRRIGATION PROJECT

		(rai)
M-1.	KHUN LARD BORIBAN (RG)	55,000
M-2.	WANG KHUN PAO	105,000
M-3.	KHLONG NAM HOM	10,000

EXISTING SMALL SCALE IRRIGATION PROJECT

		(rai)
S-1.	BAN WANG NAM KAO (RG)	3,000
S-2.	KHLONG SAINGU. (RE)	10,000
S-3.	HUAI HIN LAB (RE)	3,000
S-4.	WANG MA (W)	26,000
S-5.	SAWANG A-ROM (W)	200
S-6.	LAN BAI DIEO (W)	4,000
S-7.	NONG YAO (W)	4,000
S-8.	WANG HIN PHOENG (W)	10,000

LEGEND

- Existing Medium Scale Irrigation Project
- ○ Existing Small Scale Irrigation Project
- ● Weir for Existing Medium Scale Irrigation Project

Fig. V-1 Location Map of Existing Irrigation Project

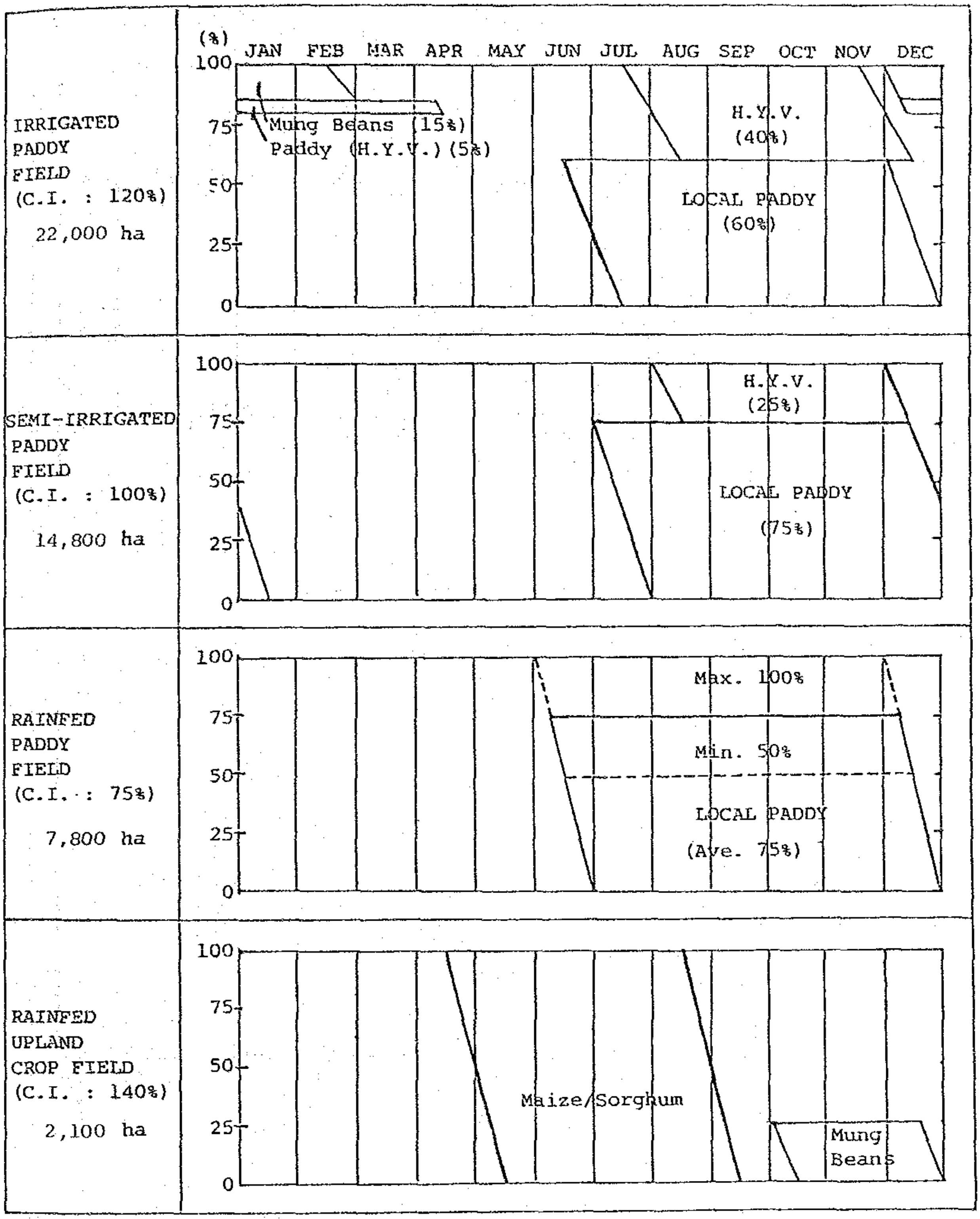


Fig. V-2 Present Cropping Pattern

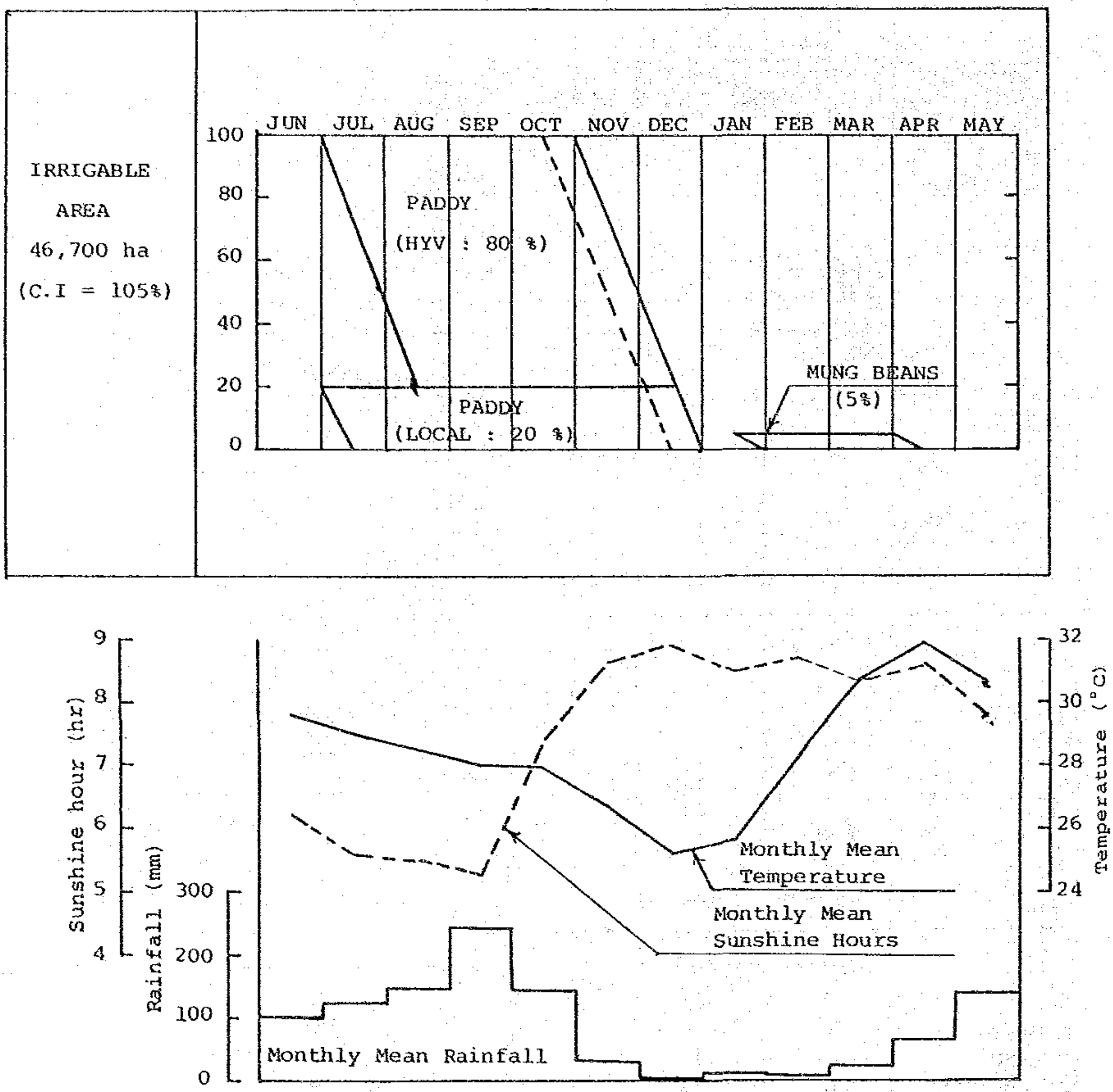


Fig. V-3 Proposed Cropping Pattern

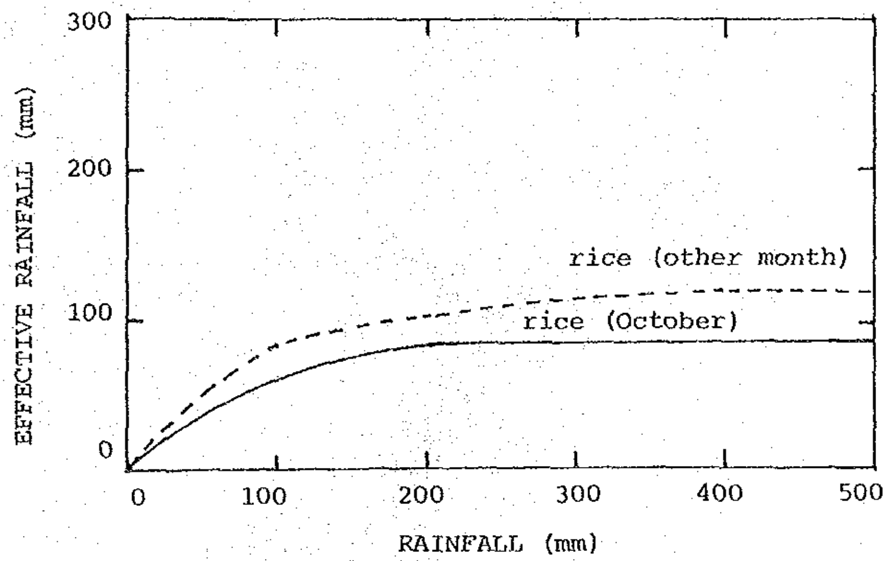


Fig. V-4 Effective Rainfall by Chao Phraya - Meklong Basin Study

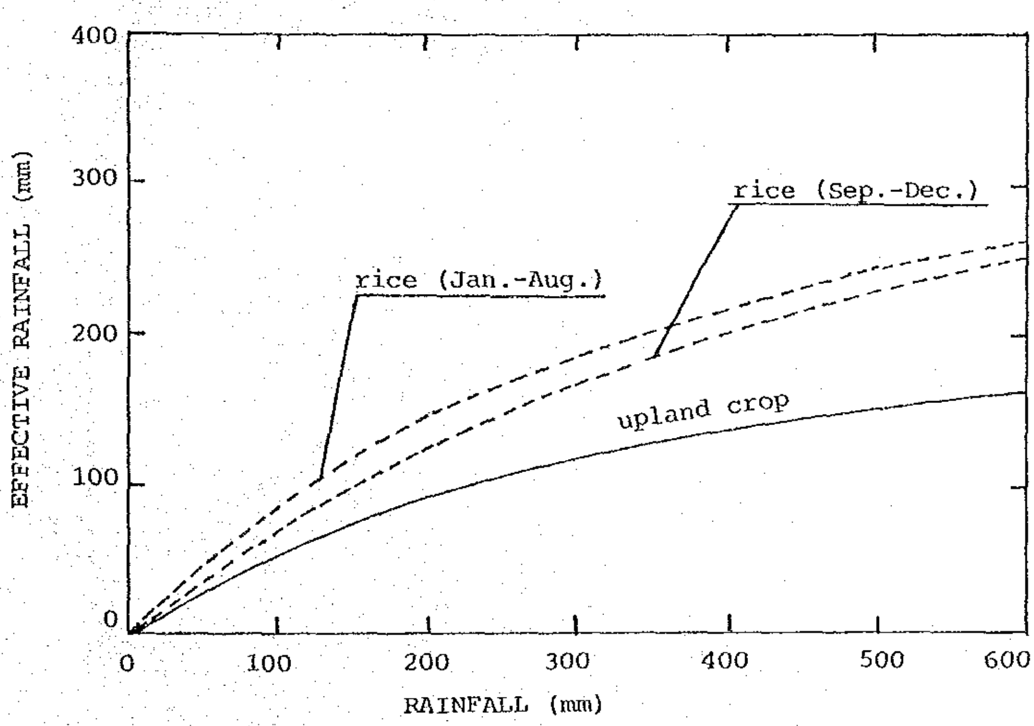


Fig. V-5 Effective Rainfall Chart by RID

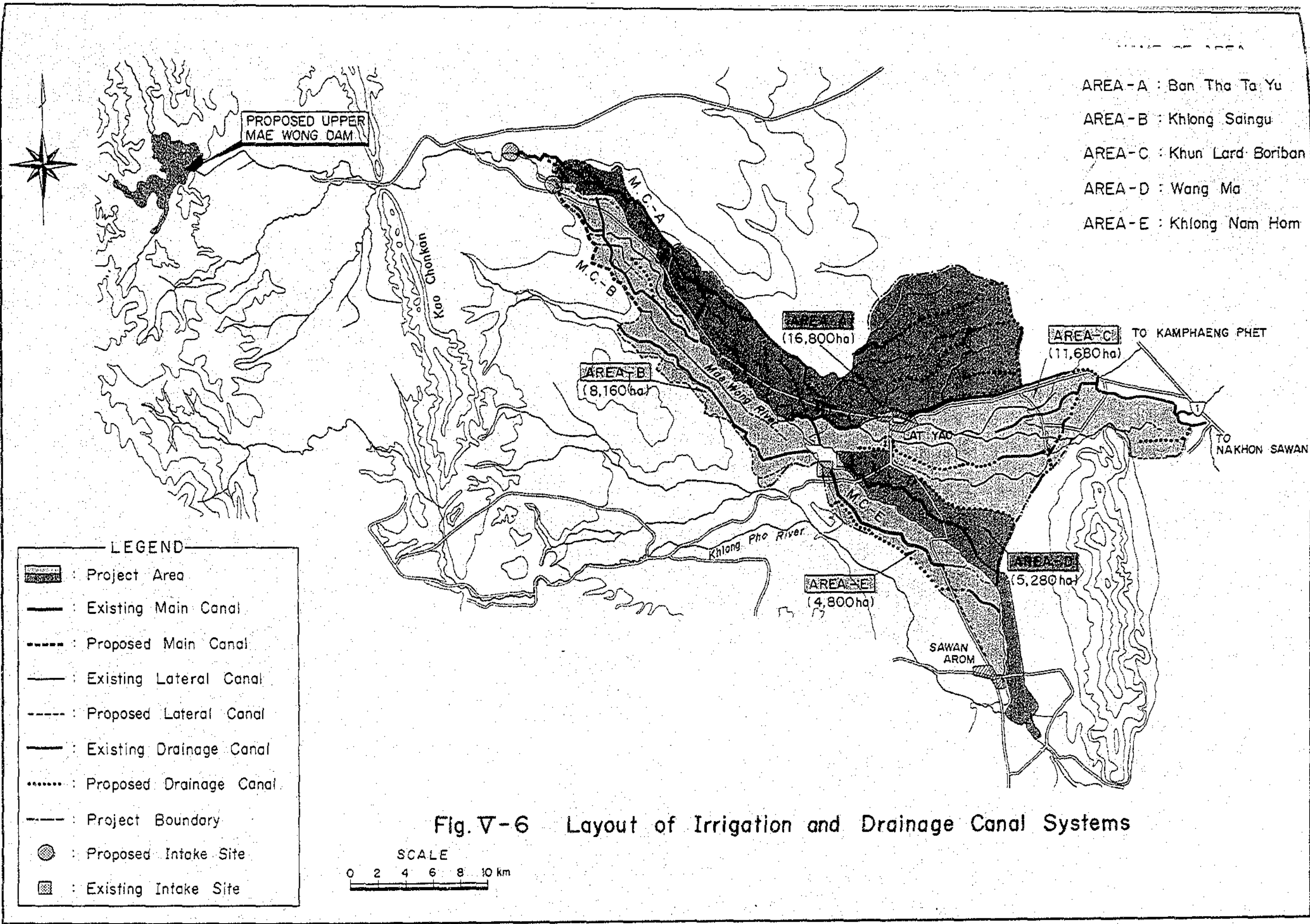


Fig. V-6 Layout of Irrigation and Drainage Canal Systems

ANNEX–VI
HYDROPOWER

ANNEX - VI

HYDROPOWER

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HYDROPOWER

1. POWER DEMAND

1.1 National and Regional Power Demand

The power demand in Thailand has shown such a high annual growth rate of more than 13% on the average in the 1970s although this annual growth rate of the power demand was lowered in some years because of the first world-wide oil-crisis.

The early 1980s have seen the most severe and prolonged setback to the economy of the country due to the second oil crisis occured on a global scale. The average annual growth rates of Peak Demand and Energy Demand throughout Thailand were tapered down to be 9.3% and 7.5% respectively for three years from 1980 to 1982.

It is anticipated that the power demand in Thailand will maintain similar annual increase rates in correspondence with and according to her projection for sound and steady economic advancement.

In Northern Region of Thailand where agriculture and commerce are major industries, large power demand is hardly recognized in view of the total power demand arising from the whole of Thailand.

It is foreseen that power demand in the category of "Domestic Demand" including residential energy consumption will be increased with the implementation progress of the ongoing electrification schemes in the said region.

Northern Region is divided into three regions with regard to power supply: viz. Region I, Region II and Region III. Power supply to the Project are come under Region III and necessary power supply is made through Nakhon Sawan Substation.

The Peak Demand and Energy Demand in Region III are recorded to be 86.03 MW and 367.04 GWh in 1982. These figures account for 30% or more of the total power consumption in Northern Region. As for the load allotted to Nakhon Sawan Substation, the power demand is 25 MW in terms of Peak Demand and 166.314 GWh in terms of Energy Demand, constituting 29% each of the total of Northern Region in the same year.

Power demand forecast is prepared by the "Load Forecast Working Group for Power Tariff Study Sub-committee" composed of representative of EGAT, MEA, PEA, NEA and NESDB. This forecast is to be reviewed and modified every year, based on actual record in the previous year. Accordingly, it can be said that the above-mentioned forecast projects increase in power demand to a considerably accurate extent. The results of power demand forecast compiled by the Sub-committee are as shown in Fig. VI-1.

1.2 Power Demand in Mae Wong River Basin and Adjacent Areas

Power supply to the Mae Wong irrigation area is made through 22 kV transmission lines from Nakhon Sawan Substation to Ban Rai via Amphoe Lat Yao.

Villages scattered in the distance approximately 30 km long between Upper Mae Wong dam and Ban Rai are not yet to be supplied with electricity.

The actual records of power and energy consumption at Nakhon Sawan Substation during the period from 1974 through 1983 give that the Domestic Demand (residential consumption) was 7 GWh in 1974 and increased to 62.4 GWh in 1983 (refer to Table VI-1 for details).

The above figures show that the energy consumption increased nine-fold for the 10 years. The cause of such a remarkable growth of consumption is attributable to the great progress of the rural electrification scheme and to an increase in the energy consumption of each household thanks to the enhancement of the livelihood of the populace.

According to the power demand forecast made in June 1964 by PEA, the total number of households are 189,935 in Nakhon Sawan Province, of which 39% is electrified. It electrification of unelectrified areas is further accelerated, increase in power demand can be easily expected. A considerably high growth rate of power demand could be anticipated if consideration is taken into potential demand for residential energy consumption.

2. POWER GENERATION PLAN

2.1 Basic Considerations

2.1.1 Assumptions

Since the Upper Mae Wong dam is to be built mainly for irrigation purposes, it has been planned that this reservoir be operated according to an operation rule of the reservoir to supply the required quantity of water for irrigation.

Irrigation water which will be regulated and released by the reservoir with an effective capacity of 230 MCM has been planned to flow into the Mae Wong River immediately downstream of the above-mentioned dam.

The power generation plan is to fully utilize water to be released from the Upper Mae Wong dam. Consequently, it has been planned that the power plant be of a type to utilize the head of the dam. Water, once used at the power plant, will be diverted through an outlet pipe and flowed out.

2.1.2 Hydrological data

Since the power generation plan will completely rely upon release water of the dam, necessary data have been sorted and arranged according to a plan for release water of the dam for a period of 28 years from 1953 through 1982 and have been used for the study.

The average monthly release water of the dam during the above-mentioned period is as follows:

(Unit: m3/sec)

Month	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Average for 28 years	0.18	0.23	0.26	9.51	20.1	10.6	19.7	12.2	0.85	0.3	0.97	1.61

The average monthly release water of the dam in each year is as given in Table VI-2.

2.2 Maximum Discharge

The discharge of a turbine is not to exceed the maximum quantity of discharge to pass through an outflow pipe of the dam because the discharge released from the dam will be diverted halfway the outflow pipe and then used for power generation. The duration curve giving the average monthly discharge to be released according to the most appropriate operation rule of the reservoir has been prepared for a period of 28 years from 1953 through 1982.

The following five (5) cases are taken up from the above-mentioned duration curve shown in Fig. VI-2 for selection of the maximum discharge.

	Case I	Case II	Case III	Case IV	Case V
Max. Discharge (m^3/sec)	26.03	22.86	21.16	18.5	14.92
Duration Ratio (%)	5	8	10	12	20
Annual Energy Projection (GWh)	16.994	16.640	15.898	15.238	13.618
Construction Cost (M.฿)	185.00	168.00	160.30	144.00	131.50
฿/kWh	10.89	10.10	10.08	9.45	9.66

In determination of effective heads, the maximum output is assumed to be obtained when the water level of the reservoir reaches one-third (1/3) of the effective drawdown, thereby determining the elevation to be 197.00.

The release water level is to correspond with the respective quantity of water to be used. The difference between the water level of the reservoir and the level of release water, viz. "total head" has been calculated. The losses of heads are assumed to be 5% of the total heads. Thus the monthly energy production has been obtained. Thereafter construction costs of each equipment, facility and relevant work have been estimated. The most appropriate maximum discharge has been selected through a series of the procedures as stated above.

The annual energy production corresponding to the maximum discharge is as given in Table VI-3.

"Qmax. 18.5 m^3/sec" shown in Case IV has been finally selected as the most economical maximum discharge out of the five cases mentioned above in obtaining the annual energy production.

2.3 Rated Head

The operating water level of Upper Mae Wong dam varies from a normal high water level with an elevation of 204.5 metres to a low water level with that of 180 metres. The difference between both levels is 24.5 metres.

This dam has been planned in correspondence with the droughtiest year and is to be operated at a high level in ordinary years. A rated water level is apart to be determined to be as high as possible in ordinary dams. However, in case of the rated head of this dam, it has been planned that the water level of the reservoir be higher than the gravity water level, which is equivalent to one-third of the drawdown. Thus, studies were conducted on the four cases shown hereunder. As a result of comparison of the four cases, the most efficient case giving He = 42.5 m (Case 4) has been selected.

	Rated Effective Head	Water Level of Reservoir	Annual Average Energy Production (MWh)	Mean Efficiency of Turbine & Generator (%)
Case 1	47	201.50	15,425	74
Case 2	45.5	200.00	15,263	75.8
Case 3	44.2	198.50	15,290	78.1
Case 4	42.5	197.00	15,040	80.0

Annual energy production has been calculated in connection with the above four (4) cases, based on water levels and discharge data for the last ten years from 1973 to 1982.

The duration curve of reservoir elevation of Upper Mae Wong dam for 28 years from 1953 to 1982 is as shown in Fig. VI-3. The above figure clearly shows that a rated water level of 197.00 metres can be obtained during 71% of the entire period.

In addition, raising of the dam to a higher level than the present irrigation plan for obtaining rated heads as much as possible will cause a cost per kWh to be more expensive. It can hardly be said that this conception is economical. In other words, supply of discharge for irrigation is the primary objective as already stated. Accordingly, a benefit obtainable through dam raising will be incremental energy production caused by an increase of heads. As a result of the study roughly made, raising of a head by 5 metres will incur the following costs.

Incremental Energy	:	1,770 MWh
Incremental Cost of Raising Dam	:	100 million Baht
Incremental Cost per kWh	:	56.5 Baht/kWh

Hence, it is considered disadvantageous to secure heads by means of raising the dam only under the framework of the power sector.

2.4 Result of Study

As a result of a series of the studies, Case IV has proven to have an optimum scale. The following are details of the proposed dam scheme with the optimum scale.

Maximum high water level	:	207.5 m
Normal high water level	:	204.5 m MSL
Rated water level (in case of maximum output)	:	197.0 m MSL
Minimum water level	:	180 m MSL
Tail water level	:	152.3 m MSL
Gross head	:	44.7 m
Rated effective head	:	42.5 m
Maximum discharge	:	18.5 m^3/sec
Maximum output	:	6,500 kW
Annual energy production	:	15,238 MWh

3. PRELIMINARY DESIGN

3.1 Civil Structures

Design of civil structures has been made based on topographical (1/1,000) maps prepared by RID (See Fig. VI-4).

(1) Penstock

The route of a penstock will be determined according to the locations of an outlet pipe and powerhouse. The penstock for Upper Maw Wong Power Station is to be diverted from the effluent pipe to the right side at a place 38.20 metres downstream on the left side bank.

The penstock is to be of welded steel pipe construction and to be buried under the ground in view of the operation and maintenance thereof. The inner diameter of the penstock is 3.0 metres.

(2) Powerhouse

The location of the powerhouse has been determined so as to obtain heads as much as possible, taking into account a route of an outlet pipe for conduiting water from the dam and the topography of the site.

The powerhouse has been determined to be built on the plateau on the right side bank of the outlet pipe. The power station is of a semi-underground type and has been so designed as to be able to bring necessary materials and equipment directly to the powerhouse through an access road.

(3) Tailrace

The tailrace has been designed so that water, once passed through the power station can return to the outlet water way. The section is to be of an open channel type while the width of its bottom is to be 3 metres.

3.2 Electrical Equipment

(1) Turbine and generator

This power station is designed with a normal effective head of 42.5 m, an effective depth of reservoir 24.5 m and a maximum discharge of 18.5 m^3/sec. It is Francis type turbine that will meet the above requirements. The capacity of this turbine is to have a capacity of 6,500 kW and revolving speed of 300 r.p.m. The generator is to have a capacity of 7,000 kVA and a voltage of 6.0 kV. (see Fig. VI-5)

(2) Outdoor type switchyard equipment

The single line diagram is as shown in Fig. VI-5. The switchyard equipment is of an outdoor type. Circuit breakers for transmission lines, disconnecting switches and protective devices are to be installed.

The bus of the switchyard and the number of the transmission line has been designed to be of a single bus system and one (1) circuit, since the number of the generator is to be one (1) unit with a capacity of 7,000 kVA and the annual operation hours of the generator will be smaller (shorter).

3.3 Transmission Line

The transmission line route is to cover the distance from the switchyard of Upper Mae Wong Power Station to the existing distribution lines (connected with Nakorn Sawang Substation), which is as shown on Fig. VI-5.

The supporting structure for the transmission line is to be concrete poles. The pin-type insulator is to be used for insulation.

4. THE SALIENT FEATURES OF UPPER MAE WONG HYDROPOWER SCHEME

The salient features of the Upper Mae Wong Hydropower Scheme are as follows:

(1) Reservoir

Catchment area	:	612 km^2
Total storage volume	:	250 MCM
Effective storage volume	:	230 MCM
Dead storage volume	:	20 MCM
Water level		
Total storage level	:	EL. 204.5 m
Flood surcharge level	:	EL. 207.5 m
Dead storage level	:	EL. 180.0 m
Reservoir area		
Total storage area	:	17.6 km^2

(2) Penstock

Type	:	Enbeded
Inner diameter	:	3 m

(3) Powerhouse

Type	:	Semi-underground type
Dimensions (main building)	:	Width 19 m x length 19 m

(4) Power Generation Facilities

Unit capacity	:	6,500 kW
Number of unit	:	1
Type of turbine	:	Horizontal Francis type
Normal effective head	:	42.5 m
Discharge quantity	:	18.5 cu.m/sec
Rated capacity	:	6,500 kW
Revolving speed	:	300 RPM

(5) Transmission System

Distance from switchyard to Lat Yao Branch	:	30 km
Voltage classification	:	32 kV
Electric system	:	1 circuit line of 3 phase 3 wire system
Supporting structure	:	Concrete pole

5. COST ESTIMATE

Preliminary cost estimate is made based on the salient features as follows:

(Unit: 10^6 ฿)

Work Item	Foreign Currency	Local Currency	Total
1. Preparatory Works	-	5.7	5.7
2. Civil Works	3.9	3.4	7.3
3. Penstock & Inlet Valve	5.9	1.5	7.4
4. Electro-Mechanical Equipment	67.0	11.8	78.8
5. Transmission System	10.8	1.2	12.0
6. EGAT Administration	1.6	6.8	8.4
7. Engineering Services	8.9	2.2	11.1
Sub-total	98.1	32.6	130.7
8. Physical Contingency	10.0	3.2	13.4
Total	108.2	35.8	144.0
9. Price Contingency	16.1	6.4	22.5
Grand Total	124.3	42.2	166.5

Table VI-1 RECORD OF ENERGY CONSUMPTION AT NAKHON SAWAN SUBSTATION (1/2)

(Unit: kWh)

Year	Street Lighting	Residen-tial	Small Business	Large Business	Small Industry	Large Industry	Government Hospital, Health Service and Insti-tute of Education	Agri-culture Pumping	Tem-porary	Total	Free of Charge
1974	181,354	8,762,558	21,223,716	15,314,253	15,743,461	1,331,120		6,318	30,604	62,593,384	272,865
1975	172,429	9,599,490	19,324,057	13,943,528	14,334,319	1,211,976		1,151,260	27,127	59,764,186	288,911
1976	174,260	11,428,299	19,932,831	14,382,797	14,785,900	1,250,157		924,200	30,092	62,909,344	308,768
1977	209,792	26,625,220	14,509,020	10,469,180	10,762,597	909,985		941,400	84,033	64,511,235	2,998,415
1978	329,651	33,252,200	16,324,545	11,779,191	12,109,323	1,023,851		186,900	160,342	75,166,091	1,886,737
1979	243,146	36,932,409	19,246,306	13,887,484	14,276,704	1,207,105		2,302,073	131,546	88,226,853	1,863,914
1980	213,810	43,542,392	22,887,536	12,219,251	12,546,360	2,793,020		112,715	271,262	94,586,346	552,717
1981	206,887	42,375,699	20,707,855	14,942,026	15,360,802	1,298,766		5,850	352,156	95,250,041	551,660
1982	235,894	54,674,017	19,240,019	16,155,764	16,279,983	2,266,042		17,600	401,274	109,271,193	636,225
1983	260,059	62,421,882	20,252,115	16,575,903	17,780,480	2,854,830	2,674,853	500	496,208	123,316,910	736,289

Table VI-1 RECORD OF ENERGY CONSUMPTION AT NAKHON SAWAN SUBSTATION (2/2) (OCTOBER 1983 - SEPTEMBER 1984)

Month	Year	No. of Consumers	Energy Consumption (kWh)	Revenue (฿)	Average Price (฿/kWh)	Per Capita Consumption (kWh)
Oct.	1983	77,609	10,680,758	17,966,216.79	1.68	137.62
Nov.	1983	78,074	10,262,265	17,213,363.24	1.68	131.44
Dec.	1983	78,335	9,827,132	16,300,610.70	1.66	125.45
Jan.	1984	78,808	9,776,661	16,378,449.31	1.68	124.06
Feb.	1984	79,489	10,661,153	17,866,760.16	1.68	134.12
Mar.	1984	79,827	11,573,129	19,524,609.14	1.69	144.98
Apr.	1984	80,465	12,601,110	21,311,126.72	1.69	156.60
May	1984	81,062	12,954,217	21,728,078	1.68	159.81
June	1984	81,657	12,855,424	17,618,518.92	1.37	157.43
July	1984	82,135	12,136,649	20,480,757.36	1.69	147.76
Aug.	1984	93,508	12,001,097	20,169,675.40	1.68	128.34
Sep.	1984	82,615	12,354,104	20,930,021.29	1.69	149.54
Total		973,584	137,683,699	227,488,187.53	1.65	141.42

Table VI-2 MONTHLY AVERAGE OF RELEASE WATER FROM UPPER MAE WONG RESERVOIR

(Unit : m^3/sec)

YEAR	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	ANNUAL	AVERAGE
1955	0.155	0.117	0.060	0.512	16.494	3.825	38.425	9.851	3.026	0.117	0.629	1.748	74.959	6.247
1956	0.162	0.117	0.060	4.991	13.074	1.143	13.256	18.974	0.734	0.117	1.131	1.049	54.808	4.567
1957	0.120	0.117	0.060	2.399	10.876	21.116	39.443	17.048	0.682	0.117	1.054	1.226	94.258	7.855
1958	0.209	0.117	0.060	7.820	25.884	1.009	23.910	20.515	0.860	0.117	1.341	1.357	83.199	6.933
1959	0.238	0.117	0.060	0.996	11.665	13.876	31.473	18.379	0.857	0.117	1.366	2.516	81.660	6.805
1960	0.704	0.117	0.060	4.707	26.175	13.982	3.552	12.298	1.142	0.117	1.089	2.630	66.573	5.548
1961	0.269	0.117	0.060	10.573	7.267	5.553	25.170	18.214	0.727	0.117	1.371	2.264	71.702	5.975
1962	0.120	0.117	0.060	2.307	16.470	7.765	31.195	18.989	0.953	0.117	1.065	2.197	81.306	6.776
1963	0.308	0.117	0.060	15.637	16.387	2.864	9.982	14.289	0.917	0.117	1.406	2.415	64.499	5.375
1964	0.199	0.117	0.103	9.022	12.187	28.657	40.154	16.978	0.642	0.117	0.090	2.070	110.336	9.195
1965	0.211	0.117	0.060	16.004	10.162	4.471	25.987	15.481	0.721	0.117	0.682	1.734	74.847	6.237
1966	0.120	0.117	0.060	5.829	18.290	18.115	11.209	5.523	0.083	0.117	0.763	2.007	62.233	5.186
1967	0.120	0.117	0.060	18.495	38.577	15.416	21.859	15.283	0.677	0.117	0.919	1.753	113.393	9.449
1968	0.120	0.117	0.060	0.206	25.567	15.156	7.323	2.575	0.834	0.117	1.133	1.327	54.535	4.545
1969	0.204	0.117	0.060	2.315	5.173	2.873	25.772	3.562	0.098	0.117	1.631	1.289	43.211	3.601
1970	0.133	0.117	0.060	13.862	18.974	10.527	0.906	10.275	0.058	0.117	0.167	1.891	57.087	4.757
1971	0.120	0.117	0.060	18.521	14.970	8.490	16.436	10.356	0.058	0.117	1.057	1.686	71.988	5.999
1972	0.120	0.117	0.060	24.065	26.310	5.169	2.069	5.540	0.058	0.117	0.357	0.985	64.967	5.414
1973	0.120	0.117	0.060	22.866	21.116	8.594	14.945	10.827	0.058	0.117	0.380	0.601	79.801	6.650
1974	0.120	0.117	0.060	3.928	21.944	15.041	51.161	23.041	4.030	3.398	1.274	1.255	125.369	10.447
1975	0.120	1.897	5.045	7.286	31.046	6.404	9.344	13.517	4.153	1.950	0.830	0.986	82.578	6.881
1976	0.120	1.546	0.630	16.945	26.033	7.763	11.953	13.139	0.080	0.117	1.573	2.149	82.048	6.837
1977	0.120	0.117	0.060	26.465	31.380	22.152	15.122	2.224	0.775	0.117	0.590	0.338	99.460	8.288
1978	0.127	0.117	0.060	0.038	17.477	2.458	6.638	17.334	0.217	0.117	1.115	2.628	48.326	4.027
1979	0.127	0.117	0.060	9.962	27.608	8.262	33.545	2.024	0.874	0.117	0.607	0.167	83.470	6.956
1980	0.252	0.089	0.060	0.881	22.481	6.223	5.705	12.792	0.144	0.117	1.045	0.797	50.587	4.216
1981	0.120	0.117	0.060	4.702	21.567	15.438	16.441	0.118	0.059	0.117	1.364	1.966	62.069	5.172
1982	0.120	0.117	0.060	14.919	27.647	24.851	20.758	13.807	0.188	0.117	1.120	2.005	105.709	8.809
AVERAGE	0.178	0.231	0.260	9.509	20.100	10.614	19.744	12.248	0.847	0.300	0.968	1.608	76.607	6.384

Table VI-3 ANNUAL ENERGY PRODUCTION
(1953 - 1982)

Unit: MWh

Year	(9,000 kW) Case 1	(8,000 kW) Case 2	(7,400 kW) Case 3	(6,500 kW) Case 4	(5,200 kW) Case 5
1955	13,368	13,226	12,810	12,089	11,119
1956	12792	13,010	12,890	13,183	12,259
1957	20,936	20,087	19,251	17,355	14,674
1958	21,248	19,602	18,216	16,438	13,699
1959	19,325	18,755	18,140	17,045	14,825
1960	13,528	12,816	12,259	12,753	11.914
1961	16,224	15,728	15,111	15,369	13,868
1962	18,866	18,353	17,527	16,335	13,644
1963	15,450	16,018	15,716	15,982	14,490
1964	24,366	23,107	22,117	20,666	17,916
1965	18,616	18,117	17,586	17,002	15,424
1966	13,382	14,946	14,655	15,289	13,664
1967	22,668	22,132	21,433	19,829	17,051
1968	7,434	6,863	7,364	6,795	6,260
1969	4,769	4,216	3,799	3,372	2,219
1970	7,826	9,233	8,899	9,690	8,867
1971	16,346	17,011	16,804	17,254	16,035
1972	11,199	10,122	10,491	9,267	8,379
1973	21,249	20,809	19,942	18,991	16,813
1974	23,905	22,019	20,664	18,696	16,919
1975	14,798	15,610	14,999	16,099	15,327
1976	20,417	19,896	19,292	18,780	16,897
1977	20,168	18,711	17,652	15,911	13,354
1978	8,057	8,410	8,337	8,699	7,739
1979	13,696	12,614	11,717	10,256	9,880
1980	8,391	10,167	9,734	9,647	9,098
1981	14,912	14,780	14,273	14,526	12,537
1982	24,350	23,387	22,465	20,774	17,611
Average (1978-1982)	16,994	16,640	15,898	15,238	13,618

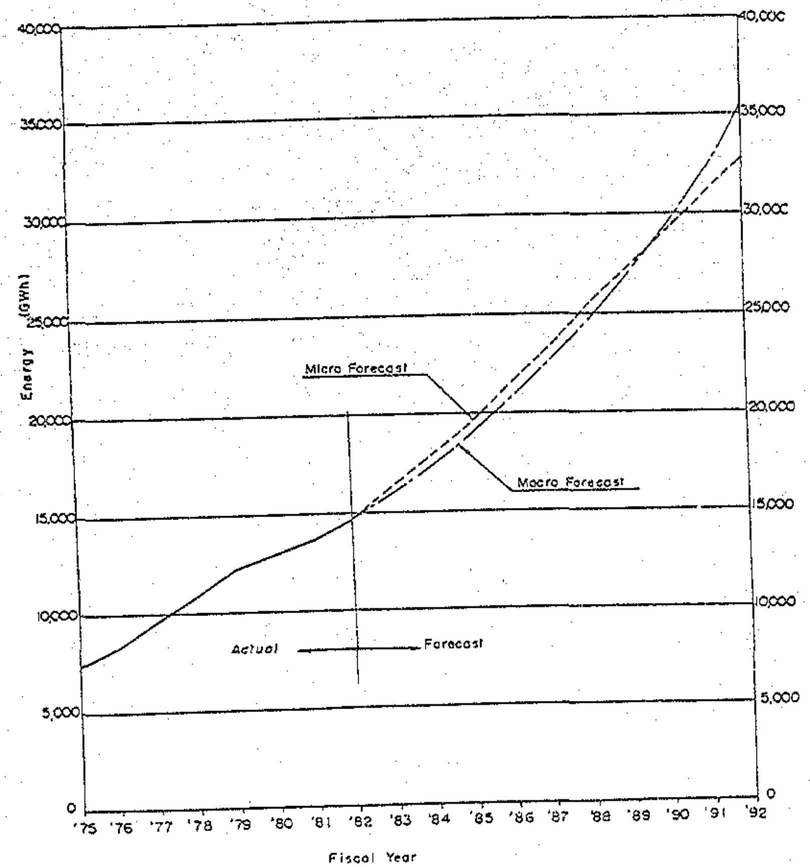

Fig. VI-1 Comparison of Micro and Macro Forecast

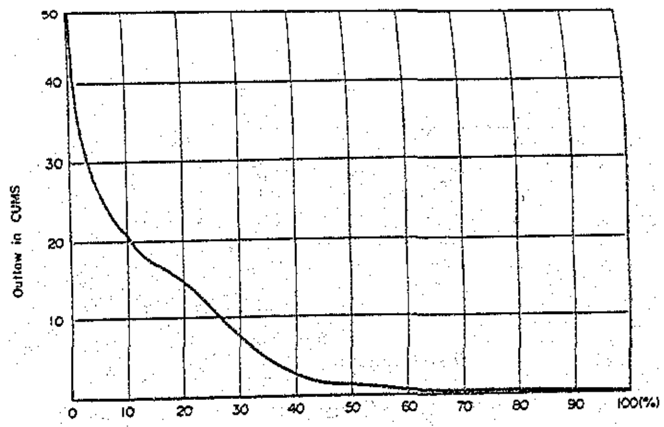

Fig. VI-2 Monthly Outflow Duration Curve

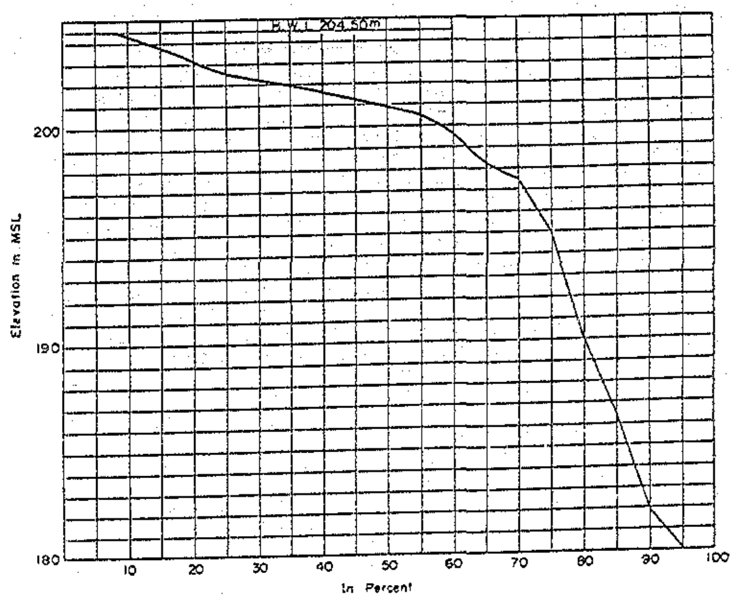

Fig. VI-3 Duration Curve of Reservoir Elevation of Upper Mae Wong Dam

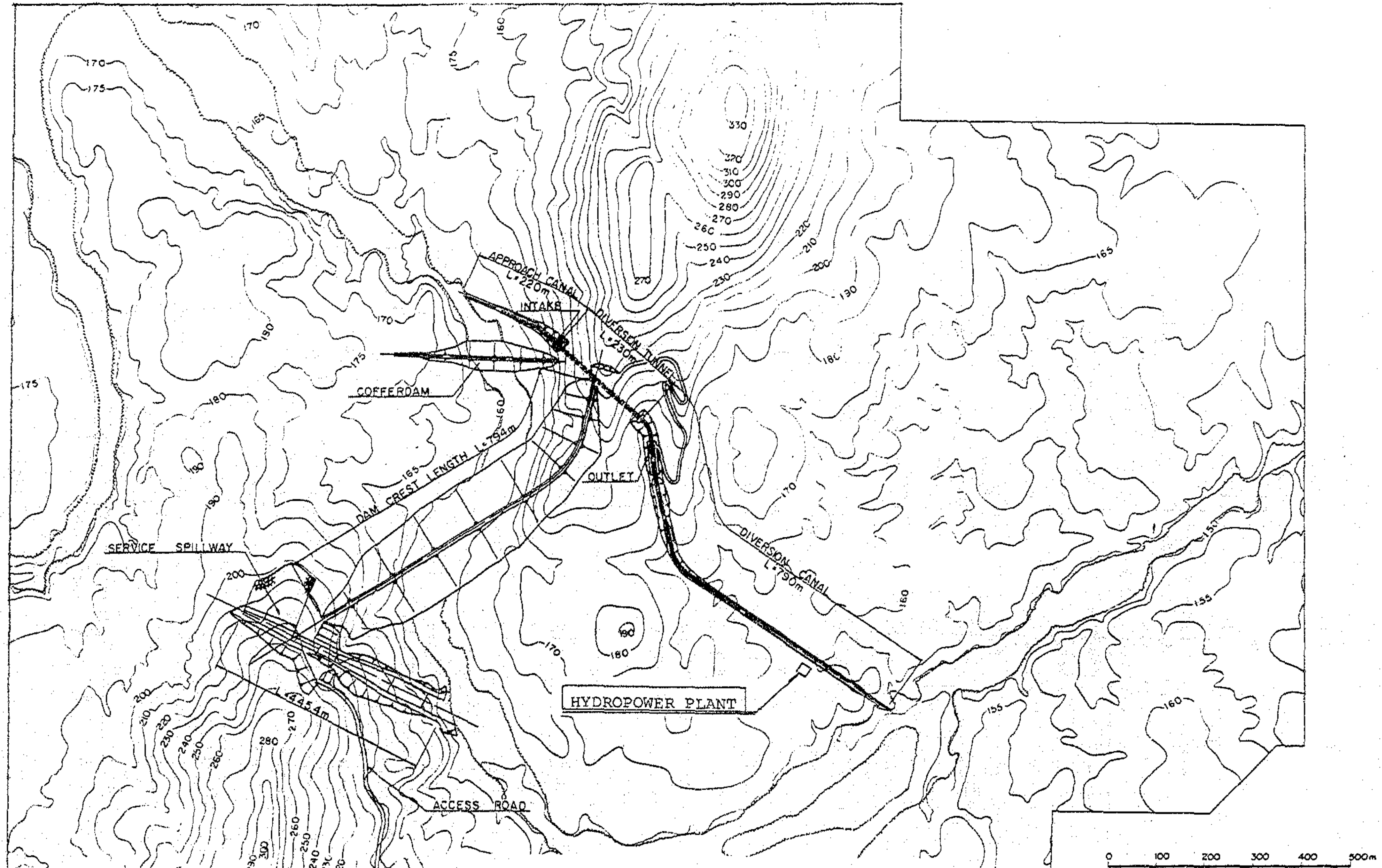

Fig. VI-4 Location Map of Hydropower Plant

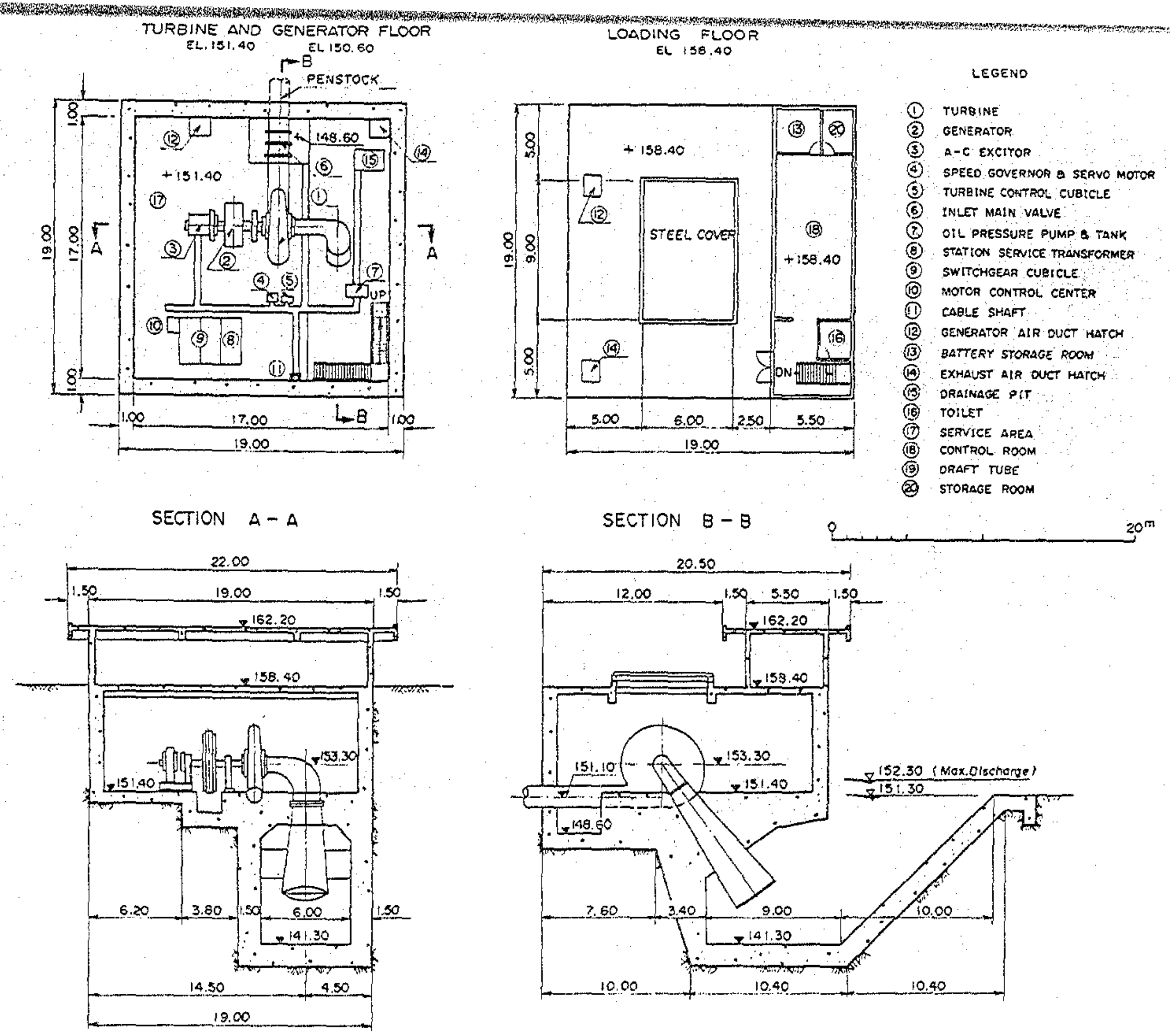

Fig. VI-5 Upper Mae Wong Hydropower Station

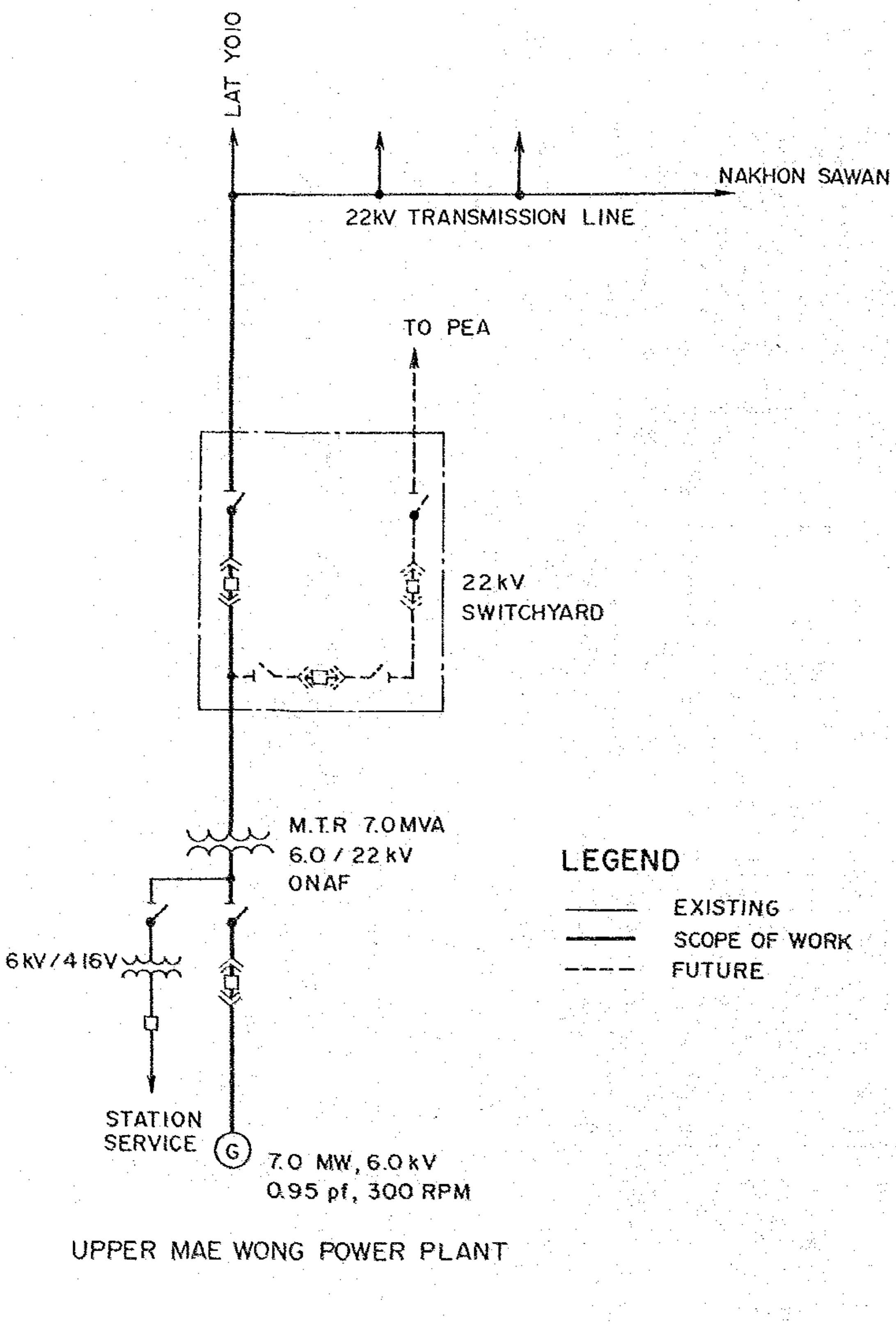

Fig. VI- 6 Upper Mae Wong Project Single Line Diagram

ANNEX–VII
SOIL AND LAND CLASSIFICATION

ANNEX - VII

SOIL AND LAND CLASSIFICATION

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SOIL AND LAND CLASSIFICATION

1. GENERAL

The present soil study aims at identifying major soil groups and their distribution in the Mae Wong irrigation area to evaluate the endowed land resources, and also examining the irrigation suitability of each soil group identified in the prospective irrigation area through the review of the past soil studies and supplementary investigations.

The detailed-reconnaissance soil survey has been made for the whole country by the Department of Land Development (hereafter referred to as "DLD"), the ministry of Agriculture and Cooperatives, and the survey results are presented on the topographic maps scaled 1/100,000. In most cases, the basic unit for soil classification is "Soil Series". The land capability classification has also been carried out by DLD in order to evaluate the land suitability in the country.

The present soil classification study is primarily based on the detailed-reconnaissance soil maps prepared by DLD. The land capability study is, however, made on the basis of the actual field survey in the prospective irrigation areas, which has been carried out by the Soil and Geology Division of RID.

2. PHYSIOGRAPHY AND SOILS

2.1 *Physiography*

The Sakae Krang river basin occupies the north-western part of the Central Chao Phraya Plain; it is bordered by the mountain ridges on the west, the Chao Phraya river on the east, the northern ridge of the Mae Wong river on the north and southern ridge of the Khok Khwai river on the south. The total area of the Sakae Krang river basin is about 6,300 km^2.

According to the geological map prepared by the Department of Mineral Resources, the surface layers of the area is mainly composed of recent and pleistocene alluvial deposits. Recent alluvial deposits dominate broadly along the Sakae Krang river system. Pleistocene alluvial deposits are extensively observed over the rest of the area. Recent alluvial levee materials are found in narrow bands on both sides of the Chao Phraya river. Isolated hills and mountain are scattered over the central and eastern parts of the Sakae Krang river basin. The mountain ridges stretch in north-south direction in the western part of the area. The land of the Sakae Krang river basin is classified into the following six (6) land from categories:

Land-Form Categories		Area (km2)	%
(1)	Flood Plain	195	3.1
(2)	Semi-recent Fan and Alluvium	1,699	27.0
(3)	Low Terraces	407	6.5
(4)	High Terraces	907	14.4
(5)	Dissected Erosion Surface	1,337	21.2
(6)	Mountains	1,755	27.8
	Total	6,300	100.0

The Mae Wong river is the largest tributary of the Sakae Krang river, forming the largest sub-basin with a total area of 2,170 km^2 or 34% of the Sakae Krang river basin, and is located northernmost of the basin. The shape of the Mae Wong river sub-basin is long and narrow stretching from north-west to south-east. The longest distance in this direction is about 50 km, and the width ranges from 10 to 20 km. The prospective irrigation area envisaged under the Mae Wong Scheme is located on eastern part of the Mae Wong river sub-basin with a total area of 495 km^2, occupying the most of the downstream areas.

From physiographic point of view, the lands in the Mae Wong sub-basin and the prospective irrigation area are classified as follows:

Land-Farm Categories	Mae Wong Sub-basin			Prospective Irrigation Area		
	(rai)	(km^2)	(%)	(rai)	(km^2)	(%)
(1) Flood Plain	-	-	-	-		-
(2) Semi-recent Fan and Alluvium	340,000	544	25.1	169,400	271	54.7
(3) Low Terrace	116,900	187	8.6	115,600	185	37.4
(4) High terraces	341,300	546	25.1	24,400	39	7.9
(5) Dissected Erosion Surface	160,000	256	11.8	-	-	-
(6) Mountains	398,700	638	29.4	-	-	-
Total	1,356,900	2,171	100.0	309,400	495	100.0

The major soils covering the Mae Wong irrigation area are those developed on (1) semi-recent fan and alluvium and (2) low terraces of old alluvium. These occupy 92% of the total area. The soils developed on (5) dissected erosion surface and (6) mountains are not included in the irrigation area due to topographic reasons. Even if the lands are partly irrigable, these are not suited to irrigation farming due to their general features of sandy and/or gravelly texture, shallow soil depth and low inherent fertility. The soils on (3) high terrace of old alluvium are marginal for irrigation, however, the area of these soils is relatively small.

2.2 Soil Classification

Five (5) Great Soil Groups and 12 Soil Series are identified on the Mae Wong irrigation area.

They are:

Land-Form	Great Soil Group/1	Soil Series (Field Symbol)	Area (rai)	Area (ha)	%
Semi-recent Fan and Alluvium	Non Calcic Brown Soils	Kamphaeng Phet (Kp)	3,100	500	0.9
		Nakhon Pathom (Np)	56,900	9,100	18.4
		Phetchaburi (Pb)	35,000	5,600	11.4
		Kampaeng Saen (Ks)	15,000	2,400	4.9
		Mae Sai (Ms)	59,300	9,500	19.1
	Sub-total		169,300	27,100	
Low Terrace	Low Humic Gley Soils	Deum Bang (Db)	36,200	5,800	11.7
		Pak Tho (Pth)	64,400	10,300	20.8
		Roi Et (Re)	13,800	2,200	4.5
	Gray Podzolic Soils	Ubon (Ub)	1,300	200	0.4
	Sub-total		115,700	18,500	
High Terraces	Regosols	Korat (Kt)	3,100	500	1.1
	Reddish Brown Lateritic Soils	Nam Phong (Np)	1,300	200	0.4
		Chiang Khan (Ch)	20,000	3,200	6.4
	Sub-total		24,400	3,900	
	Total		309,400	49,500	100.0

Note: /1: Major Soils of Southeast Asia, R. Dudal and F.R. Moorman, Jour.of Trop. Geog. Vol. 18, 1964.

The detailed results of soil classification is given in Table VII-1. The distribution of the identified soil groups are shown in Fig. VII-1 (Soil Map). The soil map was compiled on the basis of the detailed reconnaissance soil maps scaled 1 to 100,000 prepared by DLD and has been confirmed through the field observations. The major characteristics of the soil series identified in each of land-form are as follows:

(1) Flat semi-recent alluvium

KAMPHAENG PHET SERIES (Kp)

The soils are formed from semi-recent alluvium and occur on river levees and alluvial fan. Relief is almost flat to slightly undulating. The soils are well drained. Permeability is moderate. Surface runoff is slow. Floding, occuring as a flash flood from the stream or river, is generally common. They are deep soils characterized by brown or dark brown coloured and loam or silty clay loam textured argillic B horizon. Soil reaction is medium acid to neutral in the surface horizon and strongly acid to slightly acid in the subsoil. The soils are mainly found on lower position adjacent to semi-recent terrace located on the upstream of Mae Wong river systems.

The soils are classified as Non Calcic Brown Soils (National) or Ultic Haplustalfs (USDA). The soils are mostly used for transplanted rice.

NAKHON PATHOM SERIES (Np)

The soils of this group are formed from semi-recent alluvium and occur on low terraces. Relief is flat or nearly flat. Slopes are 1% or less. The effective soil depth is very deep and the soil is clay loamy to clayey textured. The colour of the A horizon is dark brown and that of B horizon is dark greyish brown. The soil structure is weak coarse blocky, and the reaction is slightly acid to moderately alkaline because of calcareous nature of the sub-soil. The soils are mainly distributed in the downstream area of Mae Wong river systems.

The soils are classified as Non Calcic Brown Soils (National) or Ultic Haplustalfs (USDA). Nakhon Pathom series are mainly used for transplanted rice cultivation.

PHETCHABURI SERIES (Pb)

The parent materials of this soil series are semi-recent alluvium. The soils occur on the lower parts of the semi-recent levees. Relief is flat to nearly flat. Slopes are 2% less. The effective soil depth is very deep. The texture of A horizon is sandy loam and that of B horizon is clay loam. The structure in the A horizon is massive to weak, medium blocky due to puddling for rice cultivation. Soil reaction is medium acid to neutral. The soils are somewhat poorly drained. Permeability is moderate and surface runoff is slow. The soils are characterized by a brown to dark brown A horizon, overlying a brown or yellowish brown, weakly developed argillic B horizon.

The soils of this group are classified as Ultic Haplustalfs (USDA) or Non Calcic Brown Soils (National). Phetchaburi series are predominantly used for transplanted rice cultivation. The soils extend over the upstream area of the Mae Wong river system.

KAMPHAENG SAEN SERIES (Ks)

The soils of this group are formed from semi-recent alluvium and occur on old levees and breach deposits or semi-recent terraces. Relief is flat to nearly flat, with a slightly undulating micro-relief. The effective soil depth is very deep and the structure is weak to moderate, medium blocky. The soils are characterized by a brown or dark brown coloured and loamy or clay loam texture A horizon, overlying a brown or dark brown coloured, clay loam textured, weakly developed, argillic B horizon. The soils are generally well drained. Permeability is moderate and surface runoff is slow. Soil reaction in the surface soil is slightly acid, and is mildly alkaline in the sub-soil. The soils are scattered in small extent along the Mae Wong river.

The soils are classified as Non Calcic Brown Soils (National) or Ultic Haplustalfs (USDA). Kamphaeng Saen series are mainly used for transplanted rice cultivation. In places, they are cultivated for crops such as maize, cotton and sugarcane.

MAE SAI (Ms)

These soils are formed from alluvium deposits on semi-recent terraces. Relief is flat or almost flat. The effective soil depth is very deep.

The soils are characterized by a dark gray or dark grayish brown coloured and silty clay loam textured A horizon, overlying a grayish brown to brown coloured and silty clay loam or silty clay textured argillic B horizon. Soil reaction is medium acid to alkaline. The structure of A horizon is weak to moderate fine or medium blocky, and that of B horizon is moderate medium to coarse blocky. The soils are somewhat poorly drained. Permeability and surface runoff are slow. These soils are widely developed along the Mae Wong river systems. Mae Sai series are members of Non Calcic Brown Soils (National) or Aeric Tropaqualfs (USDA). The soils are mainly used for transplanted rice cultivation in rotation with some irrigated crops such as soy beans and mung beans.

(2) Low terraces

DEUM BANG SERIES (Db)

The soils of this group are formed from the old alluvium and occur on the low-lying parts of local, coalescing alluviul fans. Relief is flat or nearly flat. The effective soil depth is very deep and the soil texture is sandy loam to sandy or silty clay. The A horizon of the soils is dark grayish brown or grayish brown coloured, overlying brown or yellowish brown coloured sub-soil. Soil reaction is slightly acid to mildly alkaline. Secondary lime modules commonly occur in the deeper sub-soil below approximately 80 cm from the soil surface. The soils are somewhat poorly drained and permeability is moderate.

The soils are classified as Low Humic Gley Soils (National) or Aeric Tropaqualfs (USDA). Deum Bang Soils are predominantly used for transplanted rice cultivation.

ROI ET SERIES (Re)

These soils are formed from old alluvium and occur on the low terraces. They also occur to a limited extent in low-lying depressions of the middle terraces. Relief is almost flat and the slopes are 2% or less. The effective soil depth is deep. The soils are characterized by grayish brown or light brown coloured and sandy loam textured A horizon, overlying a light brown or pinkish brown coloured and sandy clay loam or loam texturėd argillic B horizon. Soil structure is weak medium and coarse blocky in surface, and is massive to weak coarse blocky in sub-soil. Soil reaction is medium acid to strongly acid. They are poorly drained soils. Permeability is rapid and runoff is slow. The Roi Et series is a family of Low Humic Gley Soils (National) or Aeric Palequults (USPA). The soils are used for transplanted rice in the wet season.

UBON SERIES (Ub)

The soils of this group are found on the higher parts of the low and the middle terraces, formed on sandy alluvium. The relief is flat to gently undulating, and slopes are 2% or less. The effective soil depth is deep, and the soil texture in surface soil is loamy sand overlying sandy loam sub-soil. The soil colour in A horizon is brown and that in B horizon is pinkish, light brown or light reddish brown. The soil structure in A horizon is single grain and/or weak blocky, and that in B horizon is weak to moderate coarse blocky. Soil reaction is medium to slightly acid. The soils are naturally well drained. Permeability is rapid and the surface runoff is slow.

The soils are classified as Gray Podzolic Soils (National) or Aquic Dystropepts (USDA). The soils are mainly used for transplanted rice.

PAK THO SERIES (Pth)

The soils of this group are formed from old alluvium and occur on low terraces. Relief is flat to nearly flat. The effective soil depth is very deep and the soil texture is loam to clay loam. The soil colour in surface is grayish brown, light grayish brown or pinkish gray, and that in sub-soil is light brown. The soil structure is weak coarse blocky throughout the profile. Soil reaction is strongly to medium acid. The soils are somewhat poorly drained. Permeability and surface runoff are slow. Cutans and clay coatings occur in B horizon.

The soils are classified as Low Humic Gley Soils (National) or Aeric Paleaquuts (USDA). Pak Tho soils are predominantly used for transplanted rice cultivation.

(3) High terraces

KORAT SERIES (Kt)

The soils of this group are formed from old alluvium and occur on high terraces. Relief is undulating, varying between 2 and 6%. The effective soil depth is deep. The soils have a medium texture, sandy loam or loamy sand in surface, and sandy loam to loam in the sub-soil. The soils are grayish brown or very dark grayish brown coloured in A horizon, and light brown or pale brown coloured in B horizon. The soil structure is weak to moderate medium to coase blocky in A horizon, and weak to moderate medium or coarse blocky in B horizon. These soils are excessively to mederately well drained. Permeability and sufrace runoff are rapid. The soil reaction is medium to strongly acid. The soils of this group have a very weak horizon differentiation.

The Soils are classified as Regosols (National) or Oxic Paleustnlts (USDA). Some of the soils of this group do not show evidence of clay translocation. In that case, they are classified as Ustoxic Dystropepts. In this area, parts are cleared for upland crops such as kenaf, water melon, maize, cotton, beans, castor bean, cassava, etc. and settlement areas. Mostly are dry dipperocarp forest and mixed diciduos forest.

NAM PHONG SERIES (Ng)

The soils of this group are formed from sandy old alluvium and locally colluvium, and occur on middle terraces and footslopes. Relief is undulating to rolling which slopes range from 3 to 10%. The soils are somewhat excessively drained. Permeability and surface runoff are rapid. The effective soil depth is shallow and the texture is sand to loamy sand. The thickness of A horizon varies from 10 to 20 cm, and the soil structure is weak to medium blocky or single grain. Soil reaction is medium to slightly acid. The soils are dark grayish brown, grayish brown or light brown coloured in A horizon.

The soils are classified as Reddish Brown Lateritic Soils (National) or Ustoxic Quartzipsamments (USDA). Nam Phong soils are mainly low opened dipterocarp forest. Parts are cleared for shifting cultivation such as kenaf, water melon, and maize.

CHIANG KHAN SERIES (Ch)

The soils of this group are formed from residuum and local colluvium derived from shale and metamorphic rock equivalent to shale, and mainly occur on erosion surface and footslopes. Relief is undulating to hilly which slopes range from 4 to 20 percent. The soils are shallow gravelly, and loamy to gravelly clayey textured. Soil reaction is medium to strongly acid. The soils of this series are well drained soils. Permeability and surface runoff are rapid. The soil structure is moderate fine and medium at the uppermost of layer and moderate fine and medium blocky at the lower part of horizon. The soils are dark brown or dark reddish brown coloured in surface, overlying a reddish brown or yellowish red coloured argillic B horizon.

Chiang Khan soils are classified as Reddish Brown Lateritic Soils (National), or Paleustults (USDA). This area is originally mixed diciduos forest. Parts are cleared for shifting cultivation such as corn, cotton and also used as road building material.

2.3 Results of Soil Laboratory Analysis

Soil samples were taken at 35 selected sites for physico-chemical analysis. About 210 samples were analyzed at RID laboratory. The results of soil analysis are given in Table VII-2. The sampling sites are indicated on the soil map (Fig. VII-1).

The results of soil analysis are summarized as follows:

(1) Soil Reaction (pH)

Method : 1:2.5 soil : water suspension

Range : from 5.1 to 6.7 in surface

Interpretation : preferred range for rice cultivation

(2) Particle Size Distribution

Method : hydrometer method

Result : from clay to sandy loam

Interpretation : normally satisfactory for rice cultivation

(3) Electric Conductivity

Method : soil paste

Range : less than 2.0 (EC x 10^3: mmho)

Interpretation : no salinity problem will be anticipated

(4) Organic Matter (O.M.%)

Method : Walkley-black

Range : from 0.6(%) to 2.0(%) in sufrface, and from 0.2(%) to 0.7(%) in sub-soil

Interpretation : normally low or medium in organic matter content

(5) Total Nitrogen (N%)

Method : Kjeldahl

Range : from 0.002(%) to 0.11(%)

Interpretation : normally suitable for rice cultivation

(6) Available Phosphorus (ppm)

Method : Bray (dilute HCl/NH_4F)

Range : from 4.2 (ppm) to 87 (ppm)

Interpretation : i) normally low or medium in available P content
ii) satisfactory for rice cultivation

(7) Total Potassium (ppm)

Method : Bray (II) method

Range : from 50 (ppm) to 200 in surface, and from 40 to 210 (ppm) in subsoil

Interpretation : normally suitable for rice cultivation

(8) Cation Exchange Capacity (me/100 g soil)

Method : ammonium acetate extraction, adjusted at pH 7.0

Range : from 6 to 25 me/loo g soil

Interpretation : suitable for rice cultivation

(9) Exchangeable Cations (me/100 g soil)

Exchangeable Sodium (ES)

Range : from 0.02 to 1.9 me/100 g soil

Interpretation : negligible for sodium effect

Exchangeable Potasium (EP)

Range : from 0.14 to 0.63 meq/100 g soil

Interpretation : normally suitable for rice cultivation

(10) Base Saturation (%)

Range : from 21% to 80%

Interpretation : moderately to highly saturated by exchangeable bases such as Ca, Mg, K and Na

(11) Available Moisture (%)

Method : centrifugal method (between 0.05 and 15 bar tensions)

Range : from 3.1 to 19.4 (%)

INterpretation : moderate to high moisture content

3. LAND CLASSIFICATION

3.1 Field Procedure and Mapping

Land classification survey for the Mae Wong irrigation area was carried out by the Soil and Geology Division of RID. Soil profile survey including test pits and auger boring observations was made at the representative points selected through interpretation of aerial photos scaled 1/15,000, and the soil was described by the horizons and the representative soil samples were taken for laboratory analysis. (see Table VII-2)

Location of sample points and observation points (see Fig. VII-1) were marked on transparent overlays of 1/15,000 scale aerial photos, and land classification boundaries were drawn directly onto these overlays using the field data and information. At the same time, and details of the present land use at each observation point was plotted onto a second, transparent overlays.

The field mapping on these 1/15,000 scale aerial photos were then reduced directly onto 1/50,000 topographic maps. Field checking and compilation of these field maps was carried out by the Team.

3.2 Land Classification System

The land classification system used in this study is that developed in the Greater Mae Khlong Multipurpose Project in 1968, and since adopted in many project studies by RID.

The RID system has been formulated through the past experience of the observations and studies on soil, drainage and topographic characteristics and their effects on crop productivity. The standard specification for land classification is shown in Table VII-3. The framework of the system is basically three (3) classes rating for rice and upland crops. Limitations on suitability of land due to soil, drainage and topography are indicated by the symbols "s", "d" and "t", either individually and collectively. The definitions of these land class groups are as follows:

Land Class Group	Definition
U1	Land best suited for upland irrigation crops.
U2	Land less suitable for upland irrigated crops with one or two limitations in the soils, topography or drainage.
U3	Land of distinctly restricted suitability for upland irrigated crops because of extreme limitations in the soil, topography or drainage characteristics.

- to be continued -

Land Class Group	Definition
R1	Land best suited for irrigated rice production.
R2	Land adapted for rice production but with one or more limitations.
R3	Land usable for rice production but with severe limitations often necessitating special methods of cultivation, or cultivation only when general conditions permit.
U2/U3	Land suitable for either upland crops or rice particularly, but with one or more limitations for both upland crops and rice.
6	Non-arable land. Land unsuitable for the production of crops.

3.3 Results of Land Classification

The land classification for the proposed irrigation area was made in accordance with the RID specification, and the following land class groups were identified.

Land Class Group	Land Class	Area		
		rai	ha	%
R1	U3sd/R1	92,500	14,800	30.0
	U3sd/R1	15,600	2,500	5.0
	U2s/R1	3,800	600	1.2
	Sub-total	111,900	17,900	36.2
R2	U2s/R2s	120,600	19,300	39.0
	U2sd/R2sd	10,700	1,700	3.5
	Sub-total	131,300	21,000	42.5
R3	U2s/R3s	31,900	5,100	10.3
	U2t/R3st	15,600	2,500	5.0
	U1/R3s	5,600	900	1.8
	U3st/R3st	13,100	2,100	4.2
	Sub-total	66,200	10,600	21.3
	Total	309,400	49,500	100.0

The results of land classification study shows that most of the proposed irrigation area are suitable for irrigated paddy production, of which about 179 km^2 are best suitable for paddy and 316 km2 are suitable both for paddy and upland crops.

The land classification map covering the Mae Won irrigation area is given in Fig. VII-2. The general features of the major land classes are summarized, together with suggested land use for each land class, in Table VII-4.

4. INFILTRATION RATE MEASUREMENT

4.1 Method of Measurement

Infiltration rates of water into soils was measured by RID at the locations indicated on the Land Classification Map (Fig. VII-2). The double ring infiltrometer method was adopted, and the measurements were made both at the ground surface and at the depth of around 20 cm below the surface. All the measurement sites were selected on the existing paddy field and the measurement was made during the dry season (February - May, 1985). Evaporation during the measurement period of time (4 hours) was disregarded.

4.2 Evaluation of Infiltration Results

Table VII-5 shows the partial infiltration result of different soils at 15 selected sites, and may give some idea of rates of water entry into soils which will be expected under irrigation.

Table VII-1 MAJOR CHARACTERISTICS OF SOIL SERIES (1/2)

Land-form and Parent Materials	National Soil Series Names & Symbols	Classification/1 1. National 2. USDA-1975	Range of Slope (%)	Effective/2 Soil Depth	Texture Profile a. Top Soil b. Sub Soil	Colour Profile a. Top Soil b. Sub Soil	Structure/3 a. Top Soil b. Sub Soil	a. Drainage/4 b. Permeability c. Surface Runoff	Organic/5 Matter (0-30cm)	CEC/6 a. 0-30cm b. 30cm	Base Satu-/7 ration (%) a. 0-30cm b. 30cm	Available/8 Phosphorus a. 0-30cm b. 30cm	Exch./9 Potassium a. 0-30cm b. 30cm	Reaction (pH) a. 0-30cm b. 30cm	Land Use	(km^2)
Flat Semi-recent Alluvium of Recent Riverline Alluvium	1. Kamphaeng Phet (Kp)	1. Non Calcic Brown Soils 2. Ultic Haplustalfs	1-3	deep	a. loam or silty loam b. silty clay loam	a. dark brown b. brown	a. moderate medium and coarse subangular b. weak medium and coarse sub-angular blocky	a. well b. moderate c. slow	medium	a. medium b. medium	a. medium b. medium	a. medium b. moderately high	a. high b. medium	a. 6.0-7.0 b. 5.0-6.0	rice	5
	2. Nakhon Pathom (Np)	1. Non Calcic Brown Soils 2. Ultic Haplustalfs	<1	very deep	a. clay loam b. light clay or clay loam	a. dark brown b. dark gray-ish brown	a. moderate fine subangular blocky b. medium subangular blocky	a. poor b. slow c. slow	medium	a. moderately high b. high	a. medium b. medium	a. moderately high b. high	a. very high b. very high	a. 6.0-7.0 b. 7.0-8.0	rice	91
	3. Phetchaburi (Pb)	1. Non Calcic Brown Soils 2. Ultic Haplustalfs	<2	very deep	a. loam or sandy loam b. clay loam	a. brown b. yellowish brown	a. massive to weak medium subangular blocky b. weak medium sub-angular blocky	a. poor b. slow c. slow	low	a. low b. low	a. medium b. medium	a. low b. low	a. low b. low	a. 6.0 b. 6.5	rice	56
	4. Kamphaeng Saen (Ks)	1. Non Calcic Brown Soils 2. Udic Haplustalfs	<1	very deep	a. loam b. clay loam	a. brown b. brown	a. weak coarse sub-angular blocky b. weak to moderate medium subangular blocky	a. well b. medium c. slow	low	a. moderately low b. moderately low	a. high b. medium	a. very high b. very high	a. medium b. low	a. 6.5 b. 7.5	rice	24
	5. Mae Sai (Ms)	1. Non Calcic Brown Soils 2. Aeric Tropaqualfs	<1	very deep	a. silty loam b. silty clay loam	a. dark gray b. grayish brown	a. weak coarse angular blocky b. fine angular and subangular blocky	a. poor b. slow c. slow	medium	a. high b. high	a. low b. low	a. high b. medium	a. high b. high	a. 6.0 b. 7.5	rice	95
Sub-total																271
Low Terraces of Old Riverine	6. Deum Bang (Db)	1. Low Humic Gley Soils 2. Aeric Tropaqualfs	<1	very deep	a. sandy loam b. sandy clay	a. grayish brown b. grayish brown	a. weak fine crumb b. medium subangular blocky	a. poor b. medium c. medium	low	a. low b. medium	a. medium b. low	a. low b. low	a. low b. medium	a. 5.0 b. 6.0	rice	58
	7. Pak Tho (Pth)	1. Low Humic Gley Soils 2. Aeric Paleaquults	<2	very deep	a. loam b. clay loam	a. grayish brown b. Light gray	a. weak medium sub-angular blocky b. moderate medium to coarse sub-angular blocky	a. poor b. rapid-slow c. slow	low	a. low b. medium	a. medium b. low	a. low b. low	a. low b. medium	a. 5.0-5.5 b. 4.5-5.0	rice	103
	8. Roi Et (Re)	1. Low Humic Gley Soils 2. Aeric Paleaquults	<2	deep	a. sandy loam b. sandy clay loam	a. grayish brown b. light brown	a. weak fine sub-angular blocky b. moderate coarse subangular blocky	a. poor b. rapid-slow c. slow	low	a. low b. medium	a. medium b. low	a. low b. low	a. low b. medium	a. 5.0-6.5 b. 4.5-6.0	rice	22
	9. Ubon (Ub)	1. Gray Podzolic Soils 2. Aquic Dystropepts	<2	deep	a. loamy sand b. sandy loam	a. light brown b. light brown	a. weak coarse sub-angular blocky b. weak coarse sub-angular blocky	a. well b. rapid c. slow	medium	a. medium b. medium	a. low b. very low	a. moderately high b. low	a. very high b. high	a. 6.0 b. 6.0	rice	2
Sub-total																185
	10. Korat (Kt)	1. Gray Podzolic Soils 2. Oxic Paleustulfs	2-6	deep	a. sandy loam or loamy sand b. loam or sandy loam	a. grayish brown b. brown	a. moderate medium and coarse sub-angular blocky b. weak coarse sub-angular blocky	a. well b. rapid c. rapid	low	a. medium b. low	a. low b. low	a. moderately high b. moderately high	a. medium b. low	a. 5.5-6.5 b. 4.5-5.5	forest	5
	11. Nam Phong (Ng)	1. Regosols 2. Ustoxic Quantzipsamments	3-10	shallow	a. loamy sand b. loamy sand	a. grayish brown b. pinkish brown	a. weak fine granular and single grain b. weak fine to medium granular	a. excessive b. rapid c. rapid	low	a. high b. high	a. high b. high	a. high b. high	a. high b. medium	a. 5.0-6.5 b. 4.5-5.5	forest	2
	12. Chiang Kham (Ch)	1. Reddish Brown Lateritic Soils 2. Paleustults	4-20	shallow	a. gravelly loam b. gravelly clay loam	a. dark brown b. reddish brown	a. moderate medium crumb b. moderate fine subangular blocky	a. well b. rapid c. rapid	medium	a. medium b. high	a. moderately low b. moderately low	a. low b. low	a. medium b. low	a. 5.5-7.0 b. 4.5-5.5	forest and upland crops	32
Sub-total																39
Total																495

Table VII-1 MAJOR CHARACTERISTICS OF SOIL SERIES (2/2)

FOOT NOTES

/1: Classification

(1) National : Based on "Major Soils of Southeast Asia" by R. Dudal and F.R. Moorman, Jour. of Trop. Geog. Vol. 18

(2) USDA (1975): Soil Taxonomy, Agricultural Handbook No. 436

/2: Effective Soil Depth

Rating	Range (cm)
Very Shallow	< 25
Shallow	25 - 50
Moderately deep	50 - 100
Deep	100 - 150
Very deep	> 150

/3: Structure

Structure is described following standard terms as defined in the USDA Soil Survey Manual, with one exception; the term 'blocky' is used for both angular blocky and subangular blocky.

/4: Drainage

Ratings are described following standard terms as defined in the USDA Soil Survey Manual.

Permeability Definition of ratings is as follows:

Rating	Hydraulic Conductivity (cm/hr.)
Slow	< 0.5
Moderate	0.5 - 15
Rapid	> 15

Surface Runoff

Definition of ratings is as follows:

Slow : Surface water flows away so slowly that free water lies on the surface for considerable periods or immediately enters the soil. Much of water either passes through the soil or is last to evaporation. Soils are subject to little or no erosion hazard.

Medium: Free water stagnants on the soil surface for only short period. Erosion hazards are slight or moderate.

Rapid : A large proportion of precipitation moves rapidly over the soil surface. Erosion hazards are serious.

/5: Organic Matter

Rating	Range (%)
Very low	< 0.5
Low	0.5 - 1.0
Moderately low	1.0 - 1.5
Medium	1.5 - 2.5
Moderately high	2.5 - 3.5
High	3.5 - 4.5
Very high	> 4.5

/6: Cation Exchange Capacity (CEC)

	Range (%)
Very low	< 3
Low	3 - 5
Moderately low	5 - 10
Medium	10 - 15
Moderately high	15 - 20
High	20 - 30
Very high	> 30

/7: Base Staturation Degree

Rating	Range (%)
Low	< 35
Medium	35 - 75
High	> 75

/8: Available Phosphorus

Rating	Range (ppm)
Very low	< 3
Low	3 - 6
Moderately low	6 - 10
Medium	10 - 15
Moderately high	15 - 25
High	25 - 45
Very high	> 45

/9: Available Potassium

Rating	Range (ppm)
Very low	< 30
Low	30 - 60
Medium	60 - 90
High	90 - 120
Very high	> 120

Table VII-2 RESULTS OF SOIL ANALYSIS (1/4)

Location No.	Soil Classification National (Series)	Depth (cm)	Particle Size Analysis (%) Sand	Silt	Clay	Soil Texture	pH Water 1:1	pH KCl 1:2	Ec (mmoh)	$CaCO_3$ (%)	Org. Matter (%)	Total N (%)	Avail. P (ppm)	Total K (ppm)	CEC (meq/100g)	Exchangeable Cations (meq/100g) Na	Ca+Mg	Ca	K	Base Sat. (%)	Avail. (15 bar) Moisture (%)	Land Class
1.	Reddish Brown	0-20	55.4	30.0	14.6	SL	8.2	7.2	0.76	0.98	1.90	-	53	246	13.0	0.13	/1	/1	0.63	-	12.3	U3st
	Lateric Soils	20-60	53.6	27.0	19.4	SL	7.7	6.4	0.31	0.35	0.66	-	52	113	10.0	0.18	7.3	5.8	0.29	78	9.3	R3st
	(Chiang Khan)	60-120	56.8	25.8	17.4	SL	7.4	5.8	0.19	-	0.13	-	40	94	6.0	tr.	4.5	3.9	0.24	80	9.4	
		120-180	54.8	25.0	20.2	SCL	7.5	5.5	0.23	-	-	-	-	-	-	-	-	-	-	-	8.1	
		180-210	56.8	23.0	20.2	SCL	7.7	5.4	0.24	-	-	-	-	-	-	-	-	-	-	-	8.8	
		210-240	62.0	28.8	9.2	SL	8.1	5.9	0.24	-	-	-	-	-	-	-	-	-	-	-	10.8	
		240-280	60.0	20.8	19.2	SL	7.6	5.4	0.33	-	-	-	-	-	-	-	-	-	-	-	7.9	
2.	Non Calcic	0-10	32.2	30.6	37.2	CL	4.8	-	1.50	-	-	-	-	-	-	-	-	-	-	-	-	U2st
	Brown Soils	10-40	35.2	31.6	33.2	CL	5.4	-	0.43	-	-	-	-	-	-	-	-	-	-	-	-	R2st
	(Phetchaburi)	40-90	39.2	32.4	28.4	CL	5.0	-	0.37	-	-	-	-	-	-	-	-	-	-	-	-	
		90-160	39.2	32.6	28.2	CL	5.2	-	0.49	-	-	-	-	-	-	-	-	-	-	-	-	
		160-240	73.4	15.4	11.2	SL	6.1	-	0.44	-	-	-	-	-	-	-	-	-	-	-	-	
		240-300	84.5	8.4	7.1	LS	6.6	-	0.29	-	-	-	-	-	-	-	-	-	-	-	-	
3.	Non Calcic	0-15	39.4	32.6	28.0	CL	6.2	4.4	0.34	-	1.90	-	41	137	22	0.26	7.70	5.30	0.35	38	19.4	U2s
	Brown Soils	15-50	42.4	28.6	29.0	CL	8.6	6.2	1.10	0.51	0.46	-	14	78	19	1.50	7.40	4.50	0.20	48	12.0	R2s
	(Phetchaburi)	50-100	37.4	32.6	30.0	CL	8.9	6.7	1.70	0.56	0.20	-	15	70	22	2.40	8.50	4.10	0.18	50	10.9	
		100-150	57.4	19.6	23.0	SCL	9.1	6.8	1.60	-	-	-	-	-	-	-	-	-	-	-	12.0	
4.	Non Calcic	0-15	73.8	13.4	12.8	SL	6.7	6.0	0.41	-	0.56	-	6.5	55	3.4	0.15	2.20	1.80	0.14	73	3.1	U3st
	Brown Soils	15-60	69.8	14.0	16.2	SL	6.9	5.6	0.25	-	0.32	-	3.2	35	3.0	tr.	2.00	1.00	0.09	71	3.2	R3st
	(Phetchaburi)	60-120	64.0	12.8	23.2	SCL	5.6	4.3	0.14	-	0.33	-	4.2	66	4.3	tr.	1.80	0.97	0.17	47	4.2	
		120-150	62.0	12.8	25.2	SCL	5.7	4.4	0.19	-	-	-	-	-	-	-	-	-	-	-	4.2	
5.	Non Calcic	0-10	40.4	21.6	38.0	CL	5.8	4.6	0.35	-	1.70	-	55	113	20	tr.	8.20	6.00	0.29	43	15.1	
	Brown Soils	10-50	39.4	29.6	31.0	CL	6.5	4.7	0.18	-	1.00	-	36	125	21	tr.	9.60	4.70	0.32	47	14.7	
	(Phetchaburi)	50-110	61.2	21.6	17.0	SL	6.3	4.3	0.11	-	0.11	-	14	78	9.6	tr.	5.00	2.10	0.20	55	8.9	
		110-150	73.0	18.0	9.0	SL	6.5	5.4	0.35	-	-	-	-	-	-	-	-	-	-	-	5.7	
6.	Non Calcic	0-20	45.6	34.8	19.6	L	6.8	-	0.67	-	-	-	-	-	-	-	-	-	-	-	-	U2s
	Brown Soils	20-70	40.8	34.8	24.4	L	5.5	-	0.58	-	-	-	-	-	-	-	-	-	-	-	-	R2s
	(Mae Sai)	70-100	32.0	37.6	30.4	CL	5.4	-	1.50	-	-	-	-	-	-	-	-	-	-	-	-	
		100-150	39.2	39.4	21.4	L	7.3	-	1.40	-	-	-	-	-	-	-	-	-	-	-	-	

Note: /1: Lime is found in soil sample.

Table VII-2 RESULTS OF SOIL ANALYSIS (2/4)

Location No.	Soil Classification National (Series)	Depth (cm)	Particle Size Analysis (%) Sand	Silt	Clay	Soil Texture	pH Water 1:1	pH KCl 1:2	Ec (mmoh)	$CaCO_3$ (%)	Org. Matter (%)	Total N (%)	Avail. P (ppm)	Total K (ppm)	CEC (meq/100g)	Exchangeable Cations (meq/100g) Na	Ca+Mg	Ca	K	Base Sat. (%)	Avail. (15 bar) Moisture (%)	Land Class
7.	Non Calcic	0-10	37.2	28.0	34.8	CL	5.0	4.0	0.86	-	1.90	0.11	45	164	23	0.06	6.60	4.30	0.42	31	17.4	U2s
	Brown Soils	10-50	31.2	31.0	37.8	CL	5.3	3.6	0.42	-	0.54	0.04	15	82	23	0.39	5.40	3.50	0.21	26	13.2	R2s
	(Mae Sai)	50-110	28.6	30.8	40.6	C	5.7	3.8	0.62	-	0.74	0.05	11	106	28	1.30	8.00	3.90	0.27	34	13.6	
		110-140	61.8	15.8	22.4	SCL	7.9	5.8	0.82	-	-	-	-	-	-	-	-	-	-	-	7.7	
		140-200	51.0	12.6	36.4	SC	8.2	5.4	1.10	-	-	-	-	-	-	-	-	-	-	-	10.6	
		200-230	58.4	11.4	30.2	SCL	8.5	6.7	0.86	-	-	-	-	-	-	-	-	-	-	-	10.5	
		230-300	47.4	10.4	42.2	SC	8.3	6.5	0.74	-	-	-	-	-	-	-	-	-	-	-	11.3	
8.	Non Calcic	0-10	17.6	38.0	44.4	C	4.8	3.8	0.26	-	1.70	-	14	82	18	tr.	5.4	2.9	0.21	31	13.4	U3s
	Brown Soils	10-60	16.6	35.8	47.6	C	5.0	3.7	0.10	-	0.53	-	6.5	51	18	tr.	3.6	1.1	0.13	21	12.4	R1
	(Phetchaburi)	60-90	26.4	26.0	47.6	C	5.1	3.7	0.08	-	0.50	-	4.2	86	18	0.24	4.4	1.2	0.22	27	12.0	
		90-150	35.6	17.8	46.6	C	5.1	3.7	0.01	-	-	-	-	-	-	-	-	-	-	-	11.2	
9.	Non Calcic	0-10	36.2	25.0	38.8	CL	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	U2s
	Brown Soils	10-40	49.4	17.8	32.8	SCL	6.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R2s
	(Phetchaburi)	40-90	58.4	19.0	22.6	SCL	6.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		90-150	45.4	29.0	25.6	L	5.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10.	Non Calcic	0-10	37.8	26.2	36.0	CL	5.3	4.5	2.4	-	2.10	0.11	87	191	21	0.06	8.8	6.5	0.49	44	14.7	U3s
	Brown Soils	10-80	31.8	27.2	41.0	C	5.2	4.0	1.9	-	0.27	0.04	42	152	19	0.25	7.3	3.9	0.39	42	11.7	R1
	(Nakhon Pathom)	80-140	23.8	25.2	51.0	C	6.0	4.7	3.1	-	0.14	0.02	20	145	36	1.5	13	4.7	0.37	41	13.0	
		140-210	43.8	21.2	35.0	CL	7.8	6.0	1.5	-	-	-	-	-	-	-	-	-	-	-	14.9	
		210-300	33.6	28.4	38.0	CL	8.2	6.2	0.76	-	-	-	-	-	-	-	-	-	-	-	16.2	
11.	Non Calcic	0-30	74.6	15.5	10.1	SL	6.2	5.2	0.27	-	0.66	0.04	54	86	6.1	tr.	4.8	2.8	0.22	83	7.5	U3s
	Brown Soils	30-60	78.6	12.7	8.7	SL	6.8	5.2	<0.20	-	0.23	0.02	51	51	4.5	0.20	3.1	2.1	0.13	76	9.2	R1
	(Kamphaeng Saen)	60-150	79.3	13.5	7.2	LS	6.4	4.6	<0.20	-	0.19	0.02	54	43	3.9	tr.	2.5	1.3	0.11	68	8.7	
		150-210	88.0	5.7	6.3	S,LS	6.8	4.8	<0.20	-	-	-	-	-	-	-	-	-	-	-	5.0	
		210-270	91.0	5.2	3.8	S	6.9	4.9	<0.20	-	-	-	-	-	-	-	-	-	-	-	5.3	
		270-300	91.9	4.3	3.8	S	7.3	5.6	<0.20	-	-	-	-	-	-	-	-	-	-	-	5.4	
12.	Non Calcic	0-20	44.4	39.2	16.4	L	6.0	4.5	0.50	-	0.67	0.07	15	70	9.3	0.32	3.9	2.2	0.18	47	13.4	U3s
	Brown Soils	20-45	36.4	37.0	26.6	L	6.4	4.7	0.46	-	0.33	0.04	6.5	59	15	1.1	3.9	2.0	0.15	34	12.4	R1
	(Mae Sai)	45-90	25.0	40.4	28.6	CL	6.8	4.8	0.24	-	0.07	0.03	8.4	109	21	1.6	6.7	3.2	0.28	41	16.2	
		90-120	21.0	32.4	46.6	C	6.0	3.9	0.20	-	-	-	-	-	-	-	-	-	-	-	14.6	
		120-150	34.0	20.4	45.6	C	5.8	3.6	0.20	-	-	-	-	-	-	-	-	-	-	-	11.2	

Table VII-2 RESULTS OF SOIL ANALYSIS (3/4)

Location No.	Soil Classification National (Series)	Depth (cm)	Particle Size Analysis (%) Sand	Silt	Clay	Soil Texture	pH Water 1:1	pH KCl 1:2	Ec (mmoh)	$CaCO_3$ (%)	Org. Matter (%)	Total N (%)	Avail. P (ppm)	Total K (ppm)	CEC (meq/100g)	Exchangeable Cations (meq/100g) Na	Ca+Mg	Ca	K	Base Sat. (%)	Avail. (15 bar) Moisture (%)	Land Class
13.	Non Calcic	0-10	36.4	30.0	33.6	CL	5.5	4.3	0.41	-	1.30	0.09	18	117	22	0.13	8.0	2.5	0.30	38	16.3	U3s
	Brown Soils	10-60	40.2	27.2	32.6	CL	5.4	3.9	0.24	-	0.27	0.05	8.4	78	21	0.36	7.3	1.4	0.20	37	13.2	R1
	(Mae Sai)	60-90	31.0	26.4	42.6	C	5.2	3.4	<0.20	-	0.20	0.03	4.7	90	31	0.62	8.6	1.8	0.23	30	12.6	
		90-150	43.0	25.2	31.8	CL	5.9	4.0	<0.20	-	-	-	-	-	-	-	-	-	-	-	12.0	
		150-200	48.0	21.0	31.0	SCL	8.0	6.6	0.45	-	-	-	-	-	-	-	-	-	-	-	11.9	
		200-260	38.0	19.0	43.0	C	8.1	6.6	0.50	-	-	-	-	-	-	-	-	-	-	-	12.2	
		260-300	39.0	19.0	42.0	C	8.4	6.7	0.51	-	-	-	-	-	-	-	-	-	-	-	12.3	
14.	Non Calcic	0-10	47.6	30.6	21.8	L	5.7	4.6	0.50	-	1.10	0.07	8.3	55	11	0.16	4.9	3.7	0.14	47	9.4	U3s
	Brown Soils	10-40	27.6	19.6	52.8	C	5.6	3.8	<0.20	-	0.91	0.06	6.1	66	26	0.48	6.8	2.6	0.17	29	13.0	R1
	(Phetchaburi)	40-100	27.6	22.6	49.8	C	5.1	3.2	<0.20	-	0.65	0.03	6.1	82	26	0.76	5.2	1.4	0.21	24	12.6	
		100-150	23.8	23.6	52.6	C	5.1	3.1	<0.20	-	-	-	-	-	-	-	-	-	-	-	12.8	
15.	Non Calcic	0-10	43.0	27.2	29.8	CL	5.3	4.1	0.54	-	1.1	0.08	4.8	105	15	0.07	5.4	3.0	0.27	38	14.8	U3s
	Brown Soils	10-40	15.0	36.0	49.0	C	6.0	4.6	0.22	-	1.0	0.06	3.7	66	23	0.27	7.4	4.5	0.17	34	12.7	R1
	(Phetchaburi)	40-100	28.0	19.0	53.0	C	5.5	3.6	<0.20	-	0.58	0.04	4.7	102	24	0.37	6.3	2.4	0.26	29	12.8	
		100-160	39.0	17.0	44.0	C	5.2	3.3	<0.20	-	-	-	-	-	-	-	-	-	-	-	11.4	
		160-210	35.8	21.0	43.2	C	5.2	3.5	<0.20	-	-	-	-	-	-	-	-	-	-	-	15.7	
		210-260	36.6	22.0	41.4	C	5.3	3.6	<0.20	-	-	-	-	-	-	-	-	-	-	-	16.5	
		260-300	36.4	22.2	41.4	C	5.5	3.6	<0.20	-	-	-	-	-	-	-	-	-	-	-	17.5	
16.	Non Calcic	0-10	20.2	25.4	54.4	C	4.8	-	0.57	-	-	-	-	-	-	-	-	-	-	-	-	U3sd
	Brown Soils	10-60	13.2	23.4	63.4	C	6.4	-	0.78	-	-	-	-	-	-	-	-	-	-	-	-	R2d
	(Kamphaeng Phet)	60-110	18.8	21.6	59.6	C	6.3	-	0.24	-	-	-	-	-	-	-	-	-	-	-	-	
		110-150	82.8	5.6	11.6	LS	6.2	-	0.27	-	-	-	-	-	-	-	-	-	-	-	-	
		150-210	32.8	7.6	59.6	C	4.9	-	0.06	-	-	-	-	-	-	-	-	-	-	-	-	
		210-250	38.8	5.4	55.8	C	4.8	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	
		250-300	60.8	11.4	27.8	SCL	4.5	-	0.07	-	-	-	-	-	-	-	-	-	-	-	-	
17.	Non Calcic	0-10	56.2	25.6	18.2	SL	5.9	4.6	0.44	-	1.3	-	5.6	133	13	0.21	7.1	4.4	0.34	59	11.1	U2s
	Brown Soils	10-80	43.4	22.4	34.2	CL	6.8	4.8	0.33	-	0.50	-	5.7	102	23	0.42	11	5.6	0.26	51	10.4	R2s
	(Kamphaeng Saen)	80-120	52.4	19.4	28.2	SCL	8.0	6.2	0.35	0.45	0.07	-	12	109	18	0.16	12	6.4	0.28	60	10.6	
		120-150	60.6	18.2	21.2	SCL	8.2	6.2	0.31	-	-	-	-	-	-	-	-	-	-	-	8.9	

Table VII-2 RESULTS OF SOIL ANALYSIS (4/4)

Location No.	Soil Classification National (Series)	Depth (cm)	Particle Size Analysis Sand	Silt	Clay	Soil Texture	pH Water 1:1	pH KCl 1:2	Ec (mmoh)	$CaCO_3$ (%)	Org. Matter (%)	Total N (%)	Avail. P (ppm)	Total K (ppm)	CEC (meq/100g)	Exchangeable Cations (meq/100g) Na	Ca+Mg	Ca	K	Base Sat. (%)	Avail. (15 bar) Moisture (%)	Land Class
18.	Non Calcic	0-5	56.6	21.4	22.0	SCL	5.5	4.4	0.76	-	0.94	0.07	11	94	8.0	<0.05	4.7	3.6	0.24	62	7.7	U2s
	Brown Soils	5-50	44.8	18.0	37.2	CL	7.2	5.8	0.53	-	0.40	0.04	7.0	195	20	0.75	12	9.6	0.50	66	11.6	R2s
	(Nakhon Pathom)	50-110	40.8	21.0	38.2	CL	8.4	7.1	0.82	1.1	0.20	0.03	9.3	211	25	1.9	19	13	0.54	86	15.0	
		110-150	41.8	15.0	43.2	C	8.1	7.2	0.84	-	-	-	-	-	-	-	-	-	-	-	15.4	
19.	Low Humic	0-10	70.3	20.6	9.1	SL	5.8	-	0.50	-	-	-	-	-	-	-	-	-	-	-	-	U2s
	Gley Soils	10-50	70.0	16.0	14.0	SL	7.2	-	0.77	-	-	-	-	-	-	-	-	-	-	-	-	R2s
	(Deum Bang)	50-90	51.0	17.0	32.0	SCL	7.7	-	0.42	-	-	-	-	-	-	-	-	-	-	-	-	
		90-180	40.2	22.8	37.0	CL	7.3	-	0.26	-	-	-	-	-	-	-	-	-	-	-	-	
		180-240	24.2	35.0	40.8	C	7.6	-	0.67	-	-	-	-	-	-	-	-	-	-	-	-	
		240-300	24.2	43.0	32.8	CL	8.0	-	1.50	-	-	-	-	-	-	-	-	-	-	-	-	
20.	Low Humic	0-15	62.2	21.0	16.8	SL	5.5	-	0.41	-	-	-	-	-	-	-	-	-	-	-	-	U2s
	Gley Soils	15-50	47.2	20.8	32.0	SCL	5.3	-	0.31	-	-	-	-	-	-	-	-	-	-	-	-	R2s
	(Roi Et)	50-110	39.2	16.8	44.0	C	5.4	-	0.10	-	-	-	-	-	-	-	-	-	-	-	-	
		110-150	54.2	16.8	29.0	SCL	6.9	-	0.16	-	-	-	-	-	-	-	-	-	-	-	-	
		150-200	73.2	5.8	21.0	SCL	7.1	-	0.17	-	-	-	-	-	-	-	-	-	-	-	-	
		200-260	69.2	4.8	26.0	SCL	7.1	-	0.21	-	-	-	-	-	-	-	-	-	-	-	-	
		260-300	75.0	4.0	21.0	SCL	7.2	-	0.22	-	-	-	-	-	-	-	-	-	-	-	-	

Table VII-3 SPECIFICATION FOR LAND EVALUATION

Classification Characteristics	Upland			Rice Land		
	U1	U2	U3	R1	R2	R3
Soil Texture	SL-CL	LS-C(p) (LS < 30 cm)	LS-C(sp) (LS < 60 cm)	CL-C(vsp) (LS < 10 cm)	SL-C(vsp) SL < 15 cm L < 30 cm CL > 30 cm	LS-C(vsp) LS < 15 cm
Depth of soil	150 cm	120 cm	90 cm	90 cm	60 cm	30 cm
pH (Paste)	5.5 - 8.0	5.0 - 8.5	4.5 - 8.5	5.0 - 8.0	4.5 - 8.5	4.0 - 8.5
Ece x 10^3	<4.0	<6.0	<8.0	<4.0	<6.0	<8.0
Exchangeable Sodium (meq/100 g)	<2.0	<2.0	<3.0	<3.0	<4.0	<4.0
Water Holding Capacity in 120 cm Depth	15 cm	11 cm	8 cm	N.A.*	N.A.*	N.A.*
<u>Topography</u>						
Relief	Smooth	Uneven	Rough	Smooth	Uneven	Rough
Slope	<2%	<4%	<6%	<2%	<4%	<4%
Levelling Requirement	Low	Medium	High	Low	Low	Medium
Gravel or Rock	Few	Few	Some but tillable	Few	Few	Some but tillable
Rock Removal	None	None	Some	None	None	Some
Traee or Brush Cover	Slight Clearing	Moderate Clearing	Heavy Clearing	Slight Clearing	Moderate Clearing	Heavy Clearing
<u>Drainage</u>						
Surface	Good	Good-Fair	Fair-Good	Good	Good-Fair	Fair-Poor
Sub-surface	Good	Good-Fair	Fair-Good	Poor	Good-Fair	Good
Flood	None	None	Occasional	Infrequent Damaging Floods	Periodic Damaging Floods	Annual Damaging Floods

Note: Class 6 non-arable - these include all lands which do not meet the minimal requirement for classes 1, 2 and 3.

*: Not applicable.

Table VII-4 GENERAL FEATURES OF LAND CLASSES AND SUGGESTED LAND USE

Land Class	Area (km^2)	Agricultural Limitations for 1) Rice Cultivation, and 2) Upland Cropping	Present Land-use	Suggested Land-use	Management Factors for Suggested Land-use
R1 : U3sd/R1 U3s/R1 U2s/R1	179	1) No limitation 2) Heavy texture, poor drainage, moderate fertility	Irrigated rice	Best suitable for irrigated double cropping of rice or raining season paddy combined with upland dry season cropping under irrigation	Use of fertilizers on the basis of experimentation
U2/R2: U2sd/R2sd	17	1) Low fertility 2) Poor drainage, heavy texture	Semi-irrigated rice	Suitable for irrigated rice cultivation or combination with irrigated upland cropping	Drainage improvement, adequate use of fertilizers
U2/R2: U2s/R2s	193	1) Low fertility, loamy texture 2) Low fertility	Semi-irrigated rice or rainfed rice	Suitable for either irrigated upland crops or irrigated rice cultivation	Rotational cropping for upgrading soil fertility and adequate supplies of water and fertilization
R3 : U2s/R3s U2t/R3st U1/R3s U3st/R3st	106	1) Slightly coarse texture, moderate infiltration, low fertility 2) Low fertility	Mung beans, maize and in places, rainfed rice cultivation	Suitable for irrigated upland cropping or adaptable for irrigated rice cultivation	Land levelling and laying out of small fields, and adequate water supplies and fertilization
Total	495				

Table VII-5 SOIL INFILTRATION RATE AT 15 SITES IN THE PROJECT AREA (1/4)

Soil Series : / Land Class :		Hole 1 Phetchaburi U2s/R2s		Hole 2 Nakhon Pathom U3s/R1		Hole 3 Mae Sai U3s/R1		Hole 4 Nakhon Pathom U3s/R1	
Time between Rending (min)	Cumulative Time (min)	0 cms	20 cms	0 cms	20 cms	0 cms	20 cms	0 cms	21 cms
0	0	-	-	-	-	-	-	-	-
5	5	34.8	7.2	13.2	6.0	14.4	7.2	3.6	1.2
5	10	2.4	2.4	1.2	0.0	4.8	1.2	2.4	1.2
10	20	3.0	0.6	0.6	0.0	0.6	0.6	1.2	1.8
10	30	1.8	0.0	1.2	0.6	0.0	0.0	1.8	0.0
15	45	0.4	0.0	0.8	0.0	0.4	0.0	0.8	0.4
15	60	0.4	0.0	0.4	0.4	0.0	0.4	0.4	0.0
30	90	0.6	0.2	0.4	0.6	0.6	0.2	0.6	0.2
30	120	0.2	0.0	0.2	0.0	0.2	0.0	0.4	0.0
30	150	0.8	0.0	0.2	0.0	0.4	0.2	0.6	0.2
30	180	0.2	0.2	0.0	0.2	0.0	0.0	0.6	0.0
60	240	0.1	0.0	0.1	0.1	0.0	0.0	0.2	0.2
Cumulative Infiltration (cm)		44.7	10.6	18.3	7.9	21.4	9.8	12.6	5.2
Average Infiltration Rate (cm per hour)		11.2	2.7	4.6	2.0	5.4	2.5	3.2	1.3
Infiltration Category/1		Moderately rapid	Moderate	Moderate	Moderately slow	Moderate	Moderate	Moderate	Moderately slow

Table VII-5 SOIL INFILTRATION RATE AT 15 SITES IN THE PROJECT AREA (2/4)

Soil Series : / Land Class :		Hole 5 Phetchaburi U2s/R2s		Hole 6 Mae Sai U3s/R1		Hole 7 Roi Et U2s/R3s		Hole 8 Pak Tho U2s/R2s	
Time between Rending (min)	Cumulative Time (min)	0 cms	22 cms	0 cms	21 cms	0 cms	23 cms	0 cms	21 cms
0	0	-	-	-	-	-	-	-	-
5	5	19.2	6.0	22.8	1.2	12.0	4.8	21.6	7.2
5	10	4.8	0.0	1.2	0.0	3.6	1.2	3.6	0.0
10	20	0.0	0.0	0.6	0.6	3.6	3.0	1.2	0.6
10	30	0.0	0.0	0.6	0.0	1.8	1.2	0.0	0.0
15	45	0.0	0.0	0.8	0.0	0.0	0.8	0.0	0.0
15	60	0.0	0.0	0.4	0.0	0.0	0.4	0.4	0.0
30	90	0.0	0.0	0.0	0.0	0.2	0.8	0.0	0.0
30	120	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
30	150	0.0	0.0	0.0	0.2	0.0	2.0	0.2	0.0
30	180	0.0	0.0	0.4	0.2	0.0	0.6	0.0	0.0
60	240	0.1	0.0	0.1	0.0	0.1	0.3	0.1	0.1
Cumulative Infiltration (cm)		24.1	6.0	27.3	2.4	21.3	15.1	27.1	7.9
Average Infiltration Rate (cm per hour)		6.0	1.5	6.8	0.6	5.3	3.8	6.8	2.0
Infiltration Category/1		Moderate	Moderately slow	Moderately rapid	Moderately slow	Moderate	Moderate	Moderately rapid	Moderately slow

Note: /1: Van Beers (1976). The auger hole method. Forth Edition. ILRI. Bull 1, 9-32.

Table VII-5 SOIL INFILTRATION RATE AT 15 SITES IN THE PROJECT AREA (3/4)

Soil Series :		Hole 9 Deum Bang		Hole 10 Phetchaburi		Hole 11 Mae Sai		Hole 12 Kamphaeng Saen	
Land Class :		U2s/R2s		U2s/R2s		U2s/R2s		U2s/R2s	
Time between Rending (min)	Cumulative Time (min)	0 cms	22 cms	0 cms	23 cms	0 cms	20 cms	0 cms	21 cms
0	0	-	-	-	-	-	-	-	-
5	5	12.0	6.0	18.0	7.2	44.4	2.4	6.0	6.0
5	10	8.4	0.0	1.2	1.2	15.6	2.4	0.0	0.0
10	20	2.4	0.0	2.4	0.0	9.0	0.6	1.2	0.0
10	30	2.4	0.0	0.0	0.6	4.2	0.0	0.0	0.0
15	45	0.4	0.0	0.4	0.4	3.2	0.0	0.4	0.8
15	60	1.6	0.4	0.4	0.4	2.0	0.0	0.8	0.0
30	90	0.0	0.0	0.2	0.0	2.0	0.0	0.2	0.2
30	120	0.4	0.0	0.2	0.0	1.0	0.0	0.2	0.4
30	150	0.4	0.4	0.2	0.0	0.4	0.4	0.2	0.0
30	180	0.2	0.0	0.2	0.0	0.6	0.0	0.0	0.0
60	240	0.1	0.1	0.1	0.0	0.5	0.4	0.1	0.1
Cumulative Infiltration (cm)		28.3	6.9	23.3	9.8	82.9	6.2	9.1	7.5
Average Infiltration Rate (cm per hour)		7.1	1.7	5.8	2.5	20.7	1.6	2.3	1.9
Infiltration Category/1		Moderately rapid	Moderately slow	Moderate	Moderate	Rapid	Moderately slow	Moderate	Moderately slow

Note: /1: Van Beers (1976). The auger hole method. Forth Edition. ILRI. Bull 1, 9-32.

Table VII-5 SOIL INFILTRATION RATE AT 15 SITES IN THE PROJECT AREA (4/4)

Soil Series : Land Class		Hole 13 Phetchaburi U2s/R2s		Hole 14 Phetchaburi U2s/R2s		Hole 15 Nakhon Pathom U2s/R2s	
Time between Reading (min)	Cumulative Time (min)	0 cms	21 cms	0 cms	21 cms	0 cms	23 cms
0	0	-	-	-	-	-	-
5	5	24.0	6.0	48.0	1.2	14.4	1.2
5	10	6.0	0.0	15.6	1.2	3.6	1.2
10	20	1.2	0.0	9.6	1.8	1.8	0.0
10	30	1.8	0.0	6.6	1.2	1.2	1.2
15	45	0.8	0.0	5.2	1.2	0.8	0.0
15	60	1.2	0.0	7.2	0.4	1.2	0.4
30	90	0.0	0.0	5.0	0.6	0.4	0.0
30	120	0.0	0.0	4.0	0.4	0.2	0.0
30	150	0.0	0.0	3.0	0.4	0.0	0.0
30	180	0.0	0.0	2.6	0.4	0.2	0.2
60	240	0.0	0.0	2.0	0.2	0.2	0.1
Cumulative Infiltration (cm)		35.0	6.0	108.8	9.0	24.0	4.3
Average Infiltration Rate (cm per hour)		8.8	1.5	27.2	2.3	6.0	1.1
Infiltration Category/1		Moderately rapid	Moderately slow	Rapid	Moderate	Moderate	Moderately slow

Note: /1: Van Beers (1976). The auger hole method. Forth Edition. ILRI. Bull 1, 9-32.