# ANNEX-III
# WATER BALANCE STUDY AND OPTIMIZATION STUDY

ANNEX - III

# WATER BALANCE STUDY AND OPTIMIZATION STUDY

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ANNEX - III

# WATER BALANCE STUDY AND OPTIMIZATION STUDY

## 1. *INTRODUCTION*

The water balance study aims at clarifying the followings over the Mae Wong river basin:

- to clarify the present use of existing farmer's irrigation system in the basin and reveal the areas actually irrigated in the existing irrigation service areas under the water balance study of present condition, and

- to clarify the relationship among the proposed dam scale, irrigable area and cropping intensity for each alternative development plan under the water balance study of with-project condition and consequently get the useful results for determination of optimum development scale.

The alternative development plans on the relationship among dam scale, irrigable area and cropping intensity clarified through the water balance study are studied for determining the optimum development scale. The optimum development plan is selected through the evaluation on the basis of the criteria for selection.

## 2. WATER BALANCE STUDY OF PRESENT CONDITION

### 2.1 Procedures

#### 2.1.1 Layout of irrigation water supply system

A systematic layout of irrigation water supply system of present condition is shown in Fig. III-1. In the water balance calculation, the existing irrigation service areas in the basin are divided into the following 7 blocks:

| Block | Name of Service Area | Acreage | |
|---|---|---|---|
| | | rai | ha |
| 1 | Ban Tha Ta Yu | 105,000 | 16,800 |
| 2 | Khlong Saingu | 10,000 | 1,600 |
| 3 | Huai Hin Lab | 3,000 | 480 |
| 4 | Ban Wang Nam Khao | 3,000 | 480 |
| 5 | Khun Lard Boriban | 73,000 | 11,680 |
| 6 | Khlong Nam Hom | 10,000 | 1,600 |
| 7 | Wang Ma | 26,000 | 4,160 |
| | Total | 230,000 | 36,800 |

### 2.1.2 Definitions

(1) Simulation period and calculation interval

Calculation of water balance at each irrigation block is carried out for the period from 1954 to 1982 on the basis of runoff estimated in the hydrologic study and estimated irrigation water requirement of each block. The calculations are made on 10-day basis.

(2) Return flow

Generally, a part of irrigated water to the fields returns to rivers and can be reused for further downstream areas. According to the Chao Phraya-Meklong Basin Study, the return flow factor of 75% can be considered as effective return flow available for reuse. Rather conservative figure of 60% is used for the water balance study. The derivation of effective return flow is given as follows:

Overall irrigation efficiency: 45%

$$\begin{aligned}\text{Effective return flow} &= (1 - 0.45) \times \text{Return Flow Factor}\\ &= (1 - 0.45) \times 0.60\\ &= 0.33 \text{ of diversion requirement}\end{aligned}$$

(3) Excess water of rainfall from paddy field

The rainfall in the paddy field is effectively used as parts of irrigation water. Non-effective rainfall (excess water of rainfall) is drained into the river together with the return flow of irrigation water. The excess water of rainfall is assumed as follows:

$$\text{Excess water of rainfall} = 0.2 \times (\text{Rainfall} - \text{Effective Rainfall})$$

(4) Water balance calculation

A basic balance at an irrigation block is simply expressed as below:

If Runoff $\geq$ Diversion Requirement

Surplus = Runoff - Diversion Requirement

If Runoff < Diversion Requirement

Deficit = Diversion Requirement - Runoff

where, Runoff : Natural runoff at the diversion point to irrigation block including return flow and excess water of rainfall from upstream

Diversion Requirement: Irrigation requirement at the diversion point to irrigation block

A flow chart for the present water balance calculation is shown in Fig. III-2.

## 2.2 Basic Data

### 2.2.1 Runoff

The observed runoff and runoff generated by the Tank Model method at the CT 5A station in the hydrologic study are used for the water balance calculation (See ANNEX-I).

### 2.2.2 Irrigation water demand

Irrigation water requirements estimated on the present cropping patterns in the basin are used for the water balancd calculation (See ANNEX-V).

### 2.2.3 Rainfall

The rainfall data at the Lat Yao station are used for calculation on excess water of rainfall from the paddy field (See ANNEX-I).

## 2.3 Results of Water Balance Calculation

### 2.3.1 Verification of systematic diagram and assumption

There is a gauging station (CT 4) at the middlestream reach of the Mae Wong river. Rather long-term and recent discharge records are available at the station. The monthly mean river discharge simulated on the systematic diagram is compared with the observed river discharge at the CT 4 station as shown in Table III-1. The simulated river discharge is satisfactorily similar to the observed discharge as shown in Fig. III-3.

### 2.3.2 Present water use and deficit of irrigation water in the basin

Figure III-4 shows the present water use in the basin of the different years such as average year, drought year with 5-year return period and the droughtiest year. The deficit ratio of irrigation water in each block is shown in Fig. III-5. As shown in the figure, the deficit of irrigation water in the downstream reach is severer than that in the upstream reach.

### 2.3.3 Actually irrigated areas

The areas actually irrigated are estimated based on the ratio of deficit amount versus irrigation water demand in each irrigation block. Table III-2 shows the estimated areas actually irrigated on the results of water balance calculation. From the table, it can be said that the irrigation ratio of the Mae Wong river basin is about 60% in the drought year with 5-year return period.

### 2.3.4 Overall water balance in the Mae Wong river basin

The overall water balance in the Mae Wong river basin is shown in Fig. III-6. In the drought year, the water used for irrigation occupies about 60% of total surface water available in the basin.

### 2.3.5 Present observation network for water use of Mae Wong river

Since no actual records on diversion water to the existing irrigation areas were available, the JICA study team recommended to establish the observation network for water use of the Mae Wong river in the previous pre-feasibility study. In accordance with the recommendation, RID installed the staff gauges at six (6) main diversion points of the Mae Wong river to observe the water level (See Fig. III-7). The observation of water level was commenced from mid-April, 1985. The observed water level records are available from mid-April to August, 1985. As the records do not cover the full crop season, the continuous observation for at least two (2) crop seasons is expected.

## 3. WATER BALANCE STUDY OF WITH-PROJECT CONDITION

### 3.1 Procedures

### 3.1.1 Layout of irrigation water supply system

Figure III-8 shows the systematic layout of irrigation water supply system in the Mae Wong river basin under the with-project condition.

### 3.1.2 Calculation step

The water balance calculations of with-project condition are divided into the following two steps:

Step 1: The water balance of irrigation area is calculated in accordance with the same procedures as water balance calculation of the present condition. Through this calculation, required water amount for irrigation to be released from the proposed storage dam is estimated.

Step 2: The reservoir operation is carried out to determine the possible irrigable areas and reservoir capacity of the proposed dams by trial and error method based on the released water amount for irrigation estimated through Step 1 and given reservoir capacity.

In calculation of reservoir operation, a balance of inflow and outflow of a reservoir to be created at a proposed damsite is calculated for 29 years period on the basis of the runoff data from 1954 to 1982. The balance of a certain 10-day period of calculation is given as follows:

$Se = Sb + I - Or - E - Os$

where, Se: Reservoir storage of the end of the period

Sb: Reservoir storage of the beginning of the period

I: Inflow to the reservoir during the period

Or: Outflow from the reservoir during the period, this is equal to the release water for irrigation estimated through the water balance calculation downstream of the proposed dam in Step 1.

E: Evaporation from the reservoir surface during the period

Os: Spillout discharge during the period, if any. Because the storage at the end of the period is limited to the storage at the full supply water level in the maximum, the excess water is defined as spillout discharge.

A flow chart of reservoir operation is shown in Fig. III-9.

### 3.1.3 Definitions

(1) Simulation period and calculation interval

Water balance and reservoir operation calculations are carried out for 29 years period from 1954 to 1982 on the basis of runoff data and irrigation water demand. The calculations are made on 10-day basis.

(2) Return flow

The derivation of effective return flow is given as follows:

Overall irrigation efficiency: 55%

$$\begin{aligned}\text{Effective return flow} &= (1 - 0.55) \times \text{Return flow factor}\\ &= (1 - 0.55) \times 0.60\\ &= 0.27 \text{ of diversion requirement}\end{aligned}$$

(3) Excess water of rainfall from paddy field

Excess water of rainfall = 0.2 x (Rainfall - Effective rainfall)

(4) Determination of possible irrigable area

Possible irrigable area is determined through the reservoir operation calculation in Step 2 on conditions that reservoir is completely depleted five times at least for the 29 years period, or in other word, drought damage recurs by 5 years return.

### 3.2 Basic Data

#### 3.2.1 Runoff

Runoff data used for the water balance study of with-project condition are the same ones for the present water balance study.

#### 3.2.2 Irrigation water demand

Irrigation water requirements for with-project condition estimated on the basis of the proposed cropping pattern are used for calculation (See ANNEX-V).

#### 3.2.3 Rainfall

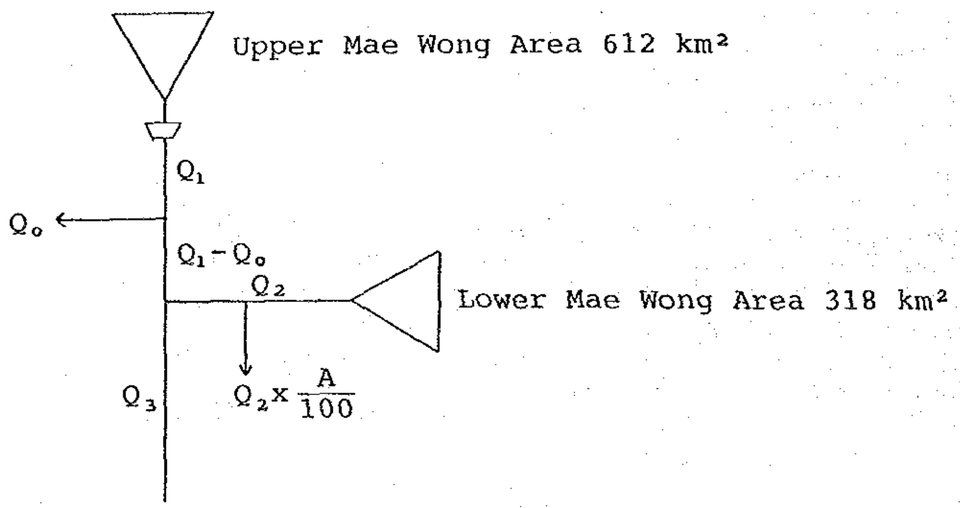
The rainfall data at the Lat Yao Station are used for calculation on the excess water of rainfall from paddy field.

#### 3.2.4 Evaporation

Evaporation from the proposed reservoir surface in the reservoir operation calculation is based on the evaporation data at Nakhon Sawan. The evaporation loss from reservoir surface is assumed to be the estimated evaporation depth shown in Table III-3 multiplied by the reservoir surface.

### 3.3 Water use of Lower Mae Wong Area

The water use for the people living in the Lower Mae Wong area is considered in the form of allowance in the water balance study. Through the discussion with RID, the following water balance methodology in the Lower Mae Wong area was mutually agreed.



$$Q_3 = (Q_1 - Q_0) + Q_2 \times (100 - A)/100$$

where, $Q_3$: River flow at the proposed Lower Mae Wong dam ($m^3$)

$Q_0$: Released water for water use of Lower Mae Wong area ($m^3$)

$Q_1$: Released water from the Upper Mae Wong storage dam ($m^3$)

$Q_2$: Runoff from the Lower Mae Wong catchment area excluding the Upper Mae Wong catchment area ($m^3$)

A: Reduction rate (%) which is different in the wet and dry seasons

Basic figures are estimated as follows:

- Released water for water use of Lower Mae Wong area ($Q_0$)

  Certain amount of water ($Q_0$) released from the Upper Mae Wong dam for the Lower Mae Wong area is estimated on the irrigation water use of potential paddy field along the main course of Mae Wong river. The potential paddy field is limited to 625 rai (100 ha) due to soil condition and topographic condition. Then, the released water ($Q_0$) is estimated as follows:

  Wet season

  $Q_0$ = Irrigation water requirement x potential paddy field
  = 1,000 mm x $10^{-3}$ x 100 ha x $10^4$
  = 1,000,000 $m^3$/season
  = 0.06 $m^3$/sec (June to December)

  Dry season

  $Q_0$ = Irrigation water requirement x potential paddy field
  = 1,500 mm x $10^{-3}$ x 100 ha x $10^4$
  = 1,500,000 $m^3$/season
  = 0.12 $m^3$/sec (January to May)

- Reduction rate (A) of runoff from the Lower Mae Wong area

  The reduction rate of runoff from the Lower Mae Wong area is estimated on population, number of livestock, the extent of potential paddy field area, etc. in the Lower Mae Wong area.

| | |
|---|---|
| Population | = 24,000 persons |
| Potential paddy field areas along the tributaries of Mae Wong river in the Lower Mae Wong area | = 2,690 rai (430 ha) |
| Number of livestock | = not available |

The domestic water use in the area is estimated as follows:

Domestic water use (DW) = Water consumption per person x population
= 100 l/day x 24,000
= $100 \times 10^{-3} \times 24,000$
= 2,400 $m^3$/day

Finally, the domestic water use in the area is calculated below taking into account the water use of livestock which is assumed at 20% of human domestic water use.

DW = 2,400 x 1.2 = 2,800 $m^3$/day
= 87,500 $m^3$/month

The irrigation water use from June to December in the Lower Mae Wong area is estimated as follows:

Irrigation water use (IW) = Irrigation requirement x area
= 1,000 mm x $10^{-3}$ x 430 ha x $10^4$
= 4,300,000 $m^3$/season

On the other hand, the runoff from the Lower Mae Wong area is estimated below:

Wet season (Jun. to Dec.) = $107.7 \times 10^6$ $m^3$

Dry season (Jan. to May) = $7.5 \times 10^6$ $m^3$

Then, the reduction rate (A) is calculated as shown below:

Reduction rate in the wet season

$$= \frac{4,300,000 \text{ m}^3 + 87,500 \text{ m}^3 \times 7 \text{ months}}{107.7 \times 10^6 \text{ m}^3}$$

= 0.05 (5%)

Reduction rate in the dry season

$$= \frac{87,500 \text{ m}^3 \times 5 \text{ months}}{7.5 \times 10^6 \text{ m}^3}$$

= 0.06 (6%)

## 3.4 Alternative Development Plan

In order to determine the optimum development scale, the alternative development plans are made based on the combination of irrigation service area, reservoir capacity and cropping intensity. The alternative development plans for the project are shown in Table III-4.

The alternative plans are broadly divided into the following cases:

Case 101 to Case 104: In these plans, the upgrading works for the existing farmer's irrigation system would not be carried out. To secure the delivery of irrigation water to the paddy fields, the small size pumps would be provided at certain places in the areas.

Case 201 to Case 302: In these plans, the updating works for the existing farmer's irrigation system would be carried out to secure the delivery of irrigation water to the paddy fields by gravity.

### 3.5 Results of Water Balance Calculation

Through the water balance calculation, the relationship among the dam scale, irrigable area and cropping intensity is clarified as shown in Table III-5 and Figures III-10 to III-11. As shown in Fig. III-10, it is confirmed that the gross reservoir capacity of 250 MCM is the maximum capacity to be expected from the hydrologic viewpoint, because no more extension of irrigable area is expected even if the reservoir capacity increases more. Subsequently, the alternative plans of Case 104, Case 204 and Case 302 are deleted in the optimization study of development scale. The alternative plan of Case 203 is also deleted in the study, because the irrigable area of 48,300 ha exceeds the potential maximum development area of 46,700 ha in the Mae Wong river basin.

As stated hereafter, the alternative development plan of Case 301 is selected as the optimum scale of development. Table III-6 shows the irrigation demand for each irrigation block in Case 301. The results of water balance calculation for Case 301 are summarized in Table III-7. From Table III-6 and Table III-7, the ratio of water supplied from the Upper Mae Wong dam is derived as shown in Fig. III-12. The water amount of 66% out of total irrigation demand is released from the Upper Mae Wong reservoir to fill the deficit in the drought year with 5-year return period. The storage change of reservoir in Case 301 is shown in Fig. III-13.

The change of river flow pattern after construction of the Upper Mae Wong dam is examined based on the results of water balance calculation (Case 301). The river flow at CT 5A before and after construction of the Upper Mae Wong dam are shown in Table III-8 and Table III-9, respectively. As shown in Fig. III-14, it is expected that the river flow after construction of the Upper Mae Wong dam will become more steady than the present natural river flow, especially in the drought year.

## 4. OPTIMIZATION STUDY OF DEVELOPMENT SCALE

### 4.1 Alternative Plan

From the results of water balance calculation, the following 11 cases of alternative plans are examined for the determination of optimum development scale:

| Alternative Case | Irrigable Area (ha) | Gross Reservoir Capacity (MCM) | Cropping Intensity (%) |
|---|---|---|---|
| 101 | 36,800 | 200 | 100 |
| 102 | 36,800 | 250 | 105 |
| 103 | 37,600 | 250 | 100 |
| 201 | 36,800 | 120 | 100 |
| 202 | 36,800 | 250 | 130 |
| 205 | 42,400 | 170 | 100 |
| 206 | 42,400 | 250 | 116 |
| 207 | 45,600 | 200 | 100 |
| 208 | 45,600 | 250 | 108 |
| 209 | 46,700 | 220 | 100 |
| 301 | 46,700 | 250 | 105 |

The upgrading works of existing farmer's irrigation system would not be done in the alternative plans of Cases 101 to 103. Only two intake weirs would be provided to assure the stable intake of irrigation water at the diversion places to the Ban Tha Ta Yu and Khlong Saingu irrigation service areas.

### 4.2 Preliminary Estimate of Cost and Benefit

#### 4.2.1 Construction cost

The construction cost for each alternative dam scale is estimated as shown in Table III-10 by using the relationship curve between the dam scale and the direct construction cost in Fig. III-15. The construction cost of irrigation facilities for each alternative plan is also estimated as shown in Table III-10 based on the construction cost of Case 301 (Details are referred to ANNEX-IX).

#### 4.2.2 Other costs

Such other costs as land acquisition, resettlement and compensation cost, O & M equipment cost, administration cost and engineering services cost are estimated as shown in Table III-10 based on the cost estimate results for Case 301 (Details are referred to ANNEX-IX).

### 4.2.3 O & M cost and replacement cost

The annual operation and maintenance cost are preliminarily estimated dividing into staff salaries and labor wages, office expenses and operation and maintenance cost, except for the alternative plans of Case 101 to Case 103. In case of the alternative plans of Case 101 to Case 103, the upgrading works of existing farmer's irrigation systems would not be executed under the project. As stated in ANNEX-V, the gravity irrigation to all existing irrigation areas is not expected by the farmer's irrigation systems, unless irrigation water is assured at the diversion points by the release water from the Upper Mae Wong reservoir. The irrigation by small pump is required for the areas where the irrigation is difficult. Taking the above situation into consideration, the annual operation and maintenance costs for pump irrigation are estimated as shown in Table III-11.

The replacement cost is also estimated as shown in Table III-11.

### 4.2.4 Irrigation benefit

Preliminary estimates of irrigation benefit are made on the following assumptions:

(1) The proposed potential irrigation area is considerably matured for agricultural production, where numerous farmer's irrigation systems have been implemented and available water is fully utilized with almost fixed cropping system. Under such conditions, significant changes in agricultural production will not be expected unless new water resources are exploited. With this in view, agricultural economy under future condition without the project is considered same as that under present condition.

(2) Crop yield under future condition without project is estimated as follows:

| | | |
|---|---|---|
| Wet season paddy | | |
| - Irrigated | : | 450 kg/rai (2.8 tons/ha) |
| - Semi-irrigated | : | 250 kg/rai (1.6 tons/ha) |
| - Rainfed | : | 200 kg/rai (1.3 tons/ha) |
| Dry season paddy | : | 560 kg/rai (3.5 tons/ha) |
| Mung beans (Paddy field) | : | 100 kg/rai (0.6 tons/ha) |
| Mung beans (Upland) | : | 80 kg/rai (0.5 tons/ha) |
| Maize | : | 350 kg/rai (2.2 tons/ha) |

(3) Crop yield under future conditions with the project is estimated as follows:

Wet season paddy

- H.Y.V. : 720 kg/rai (4.5 tons/ha)
- Improved local : 640 kg/rai (4.0 tons/ha)

Mung beans : 190 kg/rai (1.2 tons/ha)

(4) The economic prices of agricultural products are estimated as follows:

Paddy : ฿4,230/ton

Mung beans : ฿6,920/ton

Maize : ฿2,470/ton

(5) Crop production costs under future condition both with and without the project area estimated as follows:

Without project

- Wet season paddy
  - Irrigated : ฿4,270/ha
  - Semi-irrigated: ฿3,780/ha
  - Rainfed : ฿3,480/ha
- Dry season paddy: ฿4,930/ha
- Mung beans (Paddy field) : ฿2,250/ha
- Mung beans (Upland) : ฿2,250/ha
- Maize : ฿2,660/ha

With project

- Paddy : ฿5,680/ha
- Mung beans : ฿3,660/ha

The irrigation benefits for each case of alternative plans are summarized in Table III-12. Details of benefit calculation are given in Table III-13.

## 4.3 Evaluation

The evaluation for each alternative plan is made in terms of economic internal rate of return (EIRR) which has been calculated on the following assumptions:

- The economic useful life of the project facilities will be 50 years.

- Only agricultural benefit is counted in the evaluation, and any indirect or intangible benefits are not taken into account in calculation of IRR.

- The construction period will be seven (7) years including two (2) years for detailed design and preparatory works.

- The economic costs and benefits are used in the evaluation; the weighted conversion factors for cost components are used for converting the financial capital cost into the economic cost (See ANNEX-X).

- The annual fund requirements for each alternative plan are calculated on the basis of the construction schedule designed for each alternative.

- The benefits will initially accure from upgrading of existing farmer's irrigation systems in 6th year by 10% of full incremental benefit and 20% in 7th year, and after completion of dam construction, the annual benefit will increase gradually during the build-up period of 5 years from 60% in 8th year to 100% in 12th year.

Using the costs and benefits estimated in the foregoing section, the economic internal rate of return (EIRR) are calculated as follows (for details, see Table III-14:

| Alternative Case | Reservoir Capacity (MCM) | Irrigation Area (ha) | Cropping Intensity (%) | IRR (%) |
|---|---|---|---|---|
| 101 | 200 | 36,800 | 100 | 11.6 |
| 102 | 250 | 36,800 | 105 | 11.6 |
| 103 | 250 | 37,600 | 100 | 11.5 |
| 201 | 120 | 36,800 | 100 | 11.5 |
| 202 | 250 | 36,800 | 130 | 12.1 |
| 205 | 170 | 42,400 | 100 | 12.0 |
| 206 | 250 | 42,400 | 116 | 12.5 |
| 207 | 200 | 45,600 | 100 | 12.6 |
| 208 | 250 | 45,600 | 108 | 12.9 |
| 209 | 220 | 46,700 | 100 | 12.8 |
| 301 | 250 | 46,700 | 105 | 13.0 |

### 4.4 Selection of Optimum Development Plan

#### (1) Criteria for selection

Following the development concepts, the criteria for selection of optimum development plan are prepared as given below:

Criteria-1: The alternative plans with higher economic internal rate of return should be first selected.

Criteria-2: Higher priority should be given to the alternative plans with larger irrigation area because larger number of farmers could be benefited.

Criteria-3: Dry season cropping should be considered as a secondary importance so as to expand the irrigation area in the wet season.

Criteria-4: The alternative plan with the most sizable reservoir should be selected within economically reasonable range, in view of maximum exploitation of the endowed water resources.

Criteria-5: The alternative plan providing larger agricultural benefits should be selected in view of greater contribution to the regional economy.

(2) Assessment of alternative plans and selection of optimum development plan

The assessment of alternative plans is summarized as follows:

- All the alternative cases are economically feasible, with more than 11.5% of EIRR.

- The alternative plans from Case 101 to Case 103 show a bit lower economic viability. This means that upgrading of the existing farmer's irrigation systems will create greater benefit by saving enourmous operation and maintenance costs.

- The alternative plans with the reservoir capacity of 250 MCM show higher internal rates of return as compared with those of ones having other capacity of reservoirs. This indicates that the dam with a capacity of 250 MCM has the highest efficiency in irrigation area/effective storage and/or dam construction cost. The alternative plans with 250 MCM reservoir capacity should be put under further consideration and others be disregarded.

- Among four alternative plans, i.e., Cases 202, 206, 208 and 301 which have 250 MCM reservoir capacity, only the alternative Case 301 meets all the criteria given above.

Considering all these, it is recommended that the alternative Case 301 with the following features should be selected as the optimum development plan:

| Reservoir Capacity | Irrigation Area | Cropping Intensity |
|---|---|---|
| 250 MCM | 291,900 rai (46,700 ha) | 105% |

Table III-1 RIVER DISCHARGE AT CT4 STATION

Observed River Discharge at CT4 Station

(Unit : MCM)

| Year | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 14.0 | 12.3 | 16.9 | 70.7 | 103.2 | 51.2 | 11.1 | 6.6 | 2.7 | 0.8 | 0.7 | 13.8 | 304.0 |
| 1976 | 2.9 | 1.4 | 7.9 | 99.2 | 105.3 | 88.6 | 11.1 | 5.6 | 1.9 | 1.9 | 2.1 | 2.9 | 330.8 |
| 1977 | 0.5 | 0.0 | 0.2 | 18.3 | 17.3 | 6.1 | 1.6 | 0.7 | 0.0 | 0.0 | 0.1 | 8.9 | 53.9 |
| 1978 | 3.3 | 30.4 | 25.7 | 76.7 | 119.1 | 18.3 | 6.8 | 1.7 | 0.1 | 0.1 | - | - | - |
| 1979 | - | - | - | - | - | - | - | - | - | - | 0.4 | 37.2 | - |
| 1980 | 86.9 | 26.8 | 30.6 | 81.7 | 134.7 | 30.9 | 8.0 | 2.5 | 0.1 | 0.2 | 0.4 | 7.6 | 410.4 |
| 1981 | 8.0 | 6.1 | 20.3 | 36.3 | 63.6 | 164.5 | 32.8 | 10.0 | 1.6 | 0.6 | 1.7 | 5.4 | 350.9 |
| Mean | 19.3 | 12.8 | 16.9 | 63.8 | 90.5 | 59.9 | 11.9 | 4.5 | 1.1 | 0.6 | 0.9 | 12.6 | 294.8 |

Simulated River Flow at CT4 Station

(Unit : MCM)

| Year | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | APR. | MAY | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 26.8 | 9.6 | 2.8 | 70.2 | 124.0 | 50.6 | 22.6 | 12.7 | 1.1 | 1.2 | 2.8 | 20.6 | 344.9 |
| 1976 | 5.4 | 1.0 | 8.8 | 75.3 | 78.0 | 115.3 | 11.5 | 5.4 | 0.4 | 0.4 | 2.3 | 5.6 | 309.3 |
| 1977 | 2.2 | 0.6 | 1.4 | 11.0 | 5.2 | 1.7 | 2.1 | 1.7 | 0.5 | 0.2 | 1.3 | 13.0 | 40.8 |
| 1978 | 8.2 | 20.1 | 6.0 | 79.4 | 147.6 | 6.7 | 8.8 | 4.7 | 0.6 | 0.2 | 0.8 | 7.5 | 290.6 |
| 1979 | 33.7 | 2.9 | 2.0 | 103.3 | 35.0 | 1.5 | 2.4 | 1.5 | 0.2 | 0.2 | 0.3 | 89.6 | 272.5 |
| 1980 | 35.8 | 16.1 | 5.9 | 80.2 | 202.8 | 14.7 | 8.9 | 5.3 | 0.7 | 1.4 | 4.1 | 19.2 | 395.0 |
| 1981 | 27.4 | 15.3 | 8.3 | 47.7 | 77.7 | 49.7 | 26.9 | 6.4 | 0.5 | 0.5 | 2.0 | 12.6 | 275.2 |
| Mean | 19.9 | 9.4 | 5.0 | 66.7 | 95.8 | 34.3 | 11.9 | 5.4 | 0.6 | 0.6 | 1.9 | 24.0 | 275.5 |

## Table III-2 ACTUALLY IRRIGATED AREA

(Unit : rai)

| Irrigation Block | Irrigation Service Area | Actually Irrigated Area: Average Year (1954 to 1982) | 80% Dependable Year (1982) | Dryest Year (1977) |
|---|---|---|---|---|
| MW1 | 105,000 | 85,000 | 81,900 | 48,300 |
| MW2 | 10,000 | 6,600 | 4,900 | 1,600 |
| MW3 | 3,000 | 2,800 | 2,900 | 2,100 |
| MW4 | 3,000 | 1,800 | 1,200 | 300 |
| MW5 | 73,000 | 44,500 | 30,000 | 11,000 |
| MW6 | 10,000 | 9,200 | 9,700 | 7,000 |
| MW7 | 26,000 | 13,500 | 6,800 | 2,300 |
| Total | 230,000 | 163,400 (71%) | 137,400 (60%) | 72,600 (32%) |

Note ; BW1 : Ban Tha Ta Yu
BW2 : Khlong Saingu
BW3 : Huai Hin Lab
BW4 : Ban Wang Nam Khao
BW5 : Khun Lard Boriban
BW6 : Khlong Nam Hom
BW7 : Wang Ma

## Table III-3 ESTIMATED EVAPORATION DEPTH

NUMBER OF RAINLESS DAY AT CT-5A

(Unit: day)

| Year | A | M | J | J | A | S | O | N | D | J | F | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1970 | 24 | 14 | 6 | 9 | 6 | 10 | 20 | 25 | 25 | 31 | 26 | 29 |
| 1971 | 24 | 13 | 21 | 18 | 16 | 11 | 17 | 28 | 31 | 31 | 29 | 31 |
| 1972 | 26 | 20 | 18 | 31 | 25 | 14 | 20 | 23 | 28 | 31 | 28 | 24 |
| 1973 | 29 | 8 | 12 | 18 | 15 | 13 | 20 | 26 | 31 | 30 | 27 | 22 |
| 1974 | 19 | 20 | 23 | 15 | 18 | 11 | 15 | 26 | 31 | 20 | 27 | 25 |
| 1975 | 28 | 15 | 23 | 19 | 16 | 14 | 13 | 25 | 30 | 31 | 28 | 28 |
| 1976 | 26 | 15 | 20 | 19 | 11 | 11 | 17 | 24 | 31 | 31 | 28 | 29 |
| 1977 | 23 | 20 | 24 | 22 | 20 | 11 | 21 | 30 | 30 | 31 | 24 | 31 |
| 1978 | 29 | 19 | 21 | 8 | 13 | 10 | 19 | 30 | 31 | 30 | 27 | 31 |
| 1979 | 28 | 23 | 17 | 21 | 22 | 11 | 27 | 30 | 31 | 31 | 28 | 29 |
| 1980 | 27 | 22 | 12 | 10 | 17 | 4 | 19 | 30 | 31 | 31 | 28 | 28 |
| 1981 | 26 | 23 | 13 | 15 | 10 | 12 | 17 | 25 | - | - | - | - |
| 1982 | 30 | 22 | 23 | 19 | 17 | 9 | 17 | 25 | 31 | 30 | 28 | 29 |
| Average | 26.1 | 18.0 | 17.9 | 17.2 | 15.9 | 10.9 | 18.6 | 26.7 | 30.1 | 29.8 | 27.3 | 28.0 |
| Ratio | 0.87 | 0.58 | 0.60 | 0.56 | 0.51 | 0.36 | 0.60 | 0.89 | 0.97 | 0.96 | 0.97 | 0.90 |

EVAPORATION DEPTH

(Unit: mm)

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ep | 4.9 | 6.2 | 7.5 | 8.7 | 7.1 | 6.1 | 5.6 | 4.9 | 4.3 | 4.5 | 4.4 | 4.5 |
| Ed | 3.06 | 3.91 | 4.39 | 4.92 | 2.68 | 2.38 | 2.04 | 1.62 | 1.01 | 1.76 | 2.55 | 2.84 |

Note: Ep = Mean monthly evaporation at Nakhon Sawan
Ed = Estimated evaporation depth
= Ep x Ratio of Rainless Day x 0.65

Table III-4 ALTERNATIVES OF WATER BALANCE CALCULATION UNDER WITH-PROJECT CONDITION

| Alternative Case | Irrigable Area (ha) | Gross Reservoir Capacity (MCM) | Cropping Intensity (%) | Remarks |
|---|---|---|---|---|
| 101 | 36,800 | estimated | 100 | without rehabilitation/1 |
| 102 | 36,800 | 250 | estimated | - do - |
| 103 | estimated | 250 | 100 | - do - |
| 104 | estimated | 290 | 100 | - do - |
| 201 | 36,800 | estimated | 100 | with rehabilitation/2 |
| 202 | 36,800 | 250 | estimated | - do - |
| 203 | estimated | 250 | 100 | - do - |
| 204 | estimated | 290 | 100 | - do - |
| 205 | 42,400 | estimated | 100 | - do - |
| 206 | 42,400 | 250 | estimated | - do - |
| 207 | 45,600 | estimated | 100 | - do - |
| 208 | 45,600 | 250 | estimated | - do - |
| 209 | 46,700 | estimated | 100 | - do - |
| 301 | 46,700 | 250 | estimated | - do - |
| 302 | 46,700 | 290 | estimated | - do - |

/1 : overall irrigation efficiency : paddy 45 %, Mung beans 40 %

/2 : overall irrigation efficiency : paddy 55 %, Mung beans 45 %

Table III-5 RESULTS OF WATER BALANCE CALCULATION UNDER WITH-PROJECT CONDITION

| Alternative Case | Irrigable Area (ha) | Gross Reservoir Capacity (MCM) | Cropping Intensity (%) |
|---|---|---|---|
| 101 | 36,800 | 200 | 100 |
| 102 | 36,800 | 250 | 105 |
| 103 | 37,600 | 250 | 100 |
| 104 | 37,600 | 290 | 100 |
| 201 | 36,800 | 120 | 100 |
| 202 | 36,800 | 250 | 130 |
| 203 | 48,300 | 250 | 100 |
| 204 | 48,300 | 290 | 100 |
| 205 | 42,400 | 170 | 100 |
| 206 | 42,400 | 250 | 116 |
| 207 | 45,600 | 200 | 100 |
| 208 | 45,600 | 250 | 108 |
| 209 | 46,700 | 220 | 100 |
| 301 | 46,700 | 250 | 105 |
| 302 | 46,700 | 290 | 105 |

Note : Existing Irrigation Area = 36,800 ha
Potential Maximum Development Area = 46,700 ha

Table III-6 IRRIGATION DEMAND (CASE 301)

(Unit : $10^3$ $m^3$)

| Year | B-1 | B-2 | B-3 | B-4 | B-5 | Total |
|---|---|---|---|---|---|---|
| 1954 | 138,972 | 67,502 | 96,619 | 39,703 | 43,673 | 386,469 |
| 1955 | 146,902 | 71,351 | 102,134 | 41,971 | 46,169 | 408,527 |
| 1956 | 137,406 | 66,742 | 95,532 | 39,451 | 43,187 | 382,318 |
| 1957 | 136,195 | 66,149 | 94,685 | 38,911 | 42,805 | 378,745 |
| 1958 | 150,920 | 73,305 | 104,928 | 51,439 | 47,430 | 428,022 |
| 1959 | 138,684 | 67,357 | 96,419 | 39,625 | 43,589 | 385,674 |
| 1960 | 140,630 | 68,306 | 97,776 | 40,182 | 44,195 | 391,089 |
| 1961 | 142,352 | 69,143 | 98,969 | 40,671 | 44,741 | 395,876 |
| 1962 | 138,552 | 67,298 | 96,325 | 39,587 | 43,544 | 302,175 |
| 1963 | 133,285 | 64,735 | 92,665 | 38,030 | 41,890 | 370,605 |
| 1964 | 122,744 | 59,618 | 85,334 | 35,070 | 38,572 | 341,338 |
| 1965 | 138,323 | 67,189 | 96,170 | 39,523 | 43,478 | 384,683 |
| 1966 | 140,295 | 68,145 | 97,537 | 40,086 | 44,093 | 390,156 |
| 1967 | 164,169 | 79,739 | 114,137 | 46,905 | 51,599 | 456,549 |
| 1968 | 166,705 | 80,970 | 115,900 | 47,634 | 52,389 | 463,598 |
| 1969 | 136,437 | 66,266 | 94,857 | 38,984 | 42,879 | 379,423 |
| 1970 | 157,618 | 76,558 | 109,582 | 45,032 | 49,539 | 438,329 |
| 1971 | 149,568 | 72,647 | 103,979 | 42,738 | 47,006 | 415,938 |
| 1972 | 146,564 | 71,186 | 101,893 | 41,876 | 46,062 | 407,581 |
| 1973 | 161,494 | 78,435 | 112,274 | 46,142 | 50,754 | 449,099 |
| 1974 | 126,357 | 61,373 | 87,848 | 36,104 | 39,713 | 351,395 |
| 1975 | 131,061 | 63,662 | 91,116 | 37,441 | 41,185 | 364,465 |
| 1976 | 154,455 | 75,019 | 107,382 | 44,133 | 48,539 | 429,528 |
| 1977 | 163,571 | 79,450 | 113,724 | 46,737 | 51,409 | 454,891 |
| 1978 | 131,911 | 64,070 | 91,708 | 37,687 | 41,455 | 366,831 |
| 1979 | 159,700 | 77,570 | 111,031 | 45,630 | 50,190 | 444,121 |
| 1980 | 126,590 | 61,484 | 88,006 | 36,168 | 39,789 | 352,037 |
| 1981 | 132,968 | 64,583 | 92,444 | 37,992 | 41,789 | 369,776 |
| 1982 | 151,217 | 73,444 | 105,131 | 43,207 | 47,525 | 420,524 |
| Mean | 143,643 | 69,769 | 99,866 | 41,333 | 45,144 | 399,755 |

Note : Cropping Intensity = 105 % (Paddy + Mung Beans)

Table III-7 RESULTS OF WATER BALANCE CALCULATION (CASE 301)

(Unit : $10^3$ $m^3$)

| Year | Inflow | Release for Irrigation /1 | Evaporation | Spillout | Deficit |
|---|---|---|---|---|---|
| 1954 | 186,570 | 158,271 | 15,771 | 75,389 | 0 |
| 1955 | 180,776 | 193,279 | 14,075 | 2,072 | 0 |
| 1956 | 196,781 | 144,626 | 15,164 | 0 | 0 |
| 1957 | 275,353 | 96,354 | 16,122 | 151,228 | 0 |
| 1958 | 221,851 | 170,294 | 15,630 | 50,161 | 0 |
| 1959 | 230,936 | 120,083 | 15,744 | 96,106 | 0 |
| 1960 | 169,826 | 174,190 | 14,409 | 0 | 0 |
| 1961 | 232,091 | 120,114 | 15,761 | 68,411 | 0 |
| 1962 | 218,252 | 138,071 | 15,569 | 76,718 | 0 |
| 1963 | 230,919 | 115,113 | 16,435 | 56,839 | 0 |
| 1964 | 309,768 | 60,024 | 17,271 | 231,020 | 0 |
| 1965 | 195,743 | 152,539 | 16,401 | 44,942 | 0 |
| 1966 | 182,081 | 163,908 | 16,122 | 0 | 0 |
| 1967 | 123,339 | 301,460 | 6,459 | 0 | 0 |
| 1968 | 135,804 | 298,943 | 2,784 | 0 | 154,407 |
| 1969 | 155,223 | 201,911 | 5,009 | 0 | 87,876 |
| 1970 | 259,108 | 198,794 | 10,619 | 0 | 48,698 |
| 1971 | 195,740 | 188,611 | 12,644 | 0 | 0 |
| 1972 | 252,293 | 183,007 | 13,832 | 0 | 0 |
| 1973 | 239,414 | 213,530 | 15,730 | 0 | 0 |
| 1974 | 376,448 | 92,700 | 17,360 | 242,150 | 0 |
| 1975 | 236,002 | 137,644 | 17,379 | 80,978 | 0 |
| 1976 | 215,393 | 200,379 | 16,886 | 13,099 | 0 |
| 1977 | 57,336 | 361,315 | 4,065 | 0 | 98,042 |
| 1978 | 221,867 | 150,871 | 9,304 | 0 | 0 |
| 1979 | 182,122 | 316,153 | 2,855 | 0 | 93,852 |
| 1980 | 282,828 | 134,009 | 13,531 | 0 | 0 |
| 1981 | 204,075 | 165,131 | 16,019 | 0 | 0 |
| 1982 | 108,338 | 279,883 | 8,021 | 0 | 0 |
| Mean | 209,527 | 180,386 | 12,999 | 41,004 | 16,651 |

/1 : Including the release water of 2,652 x $10^3$ $m^3$ for the people living in the Lower Mae Wong area.

Table III-8 RIVER FLOW AT CT-5A BEFORE CONSTRUCTION OF UPPER MAE WONG DAM

| Year | J | J | A | S | O | N | D | J | F | M | A | M | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1954 | 8,332 | 17,036 | 37,722 | 77,783 | 120,561 | 8,424 | 3,336 | 2,716 | 1,592 | 936 | 844 | 5,804 | 285,306 |
| 1955 | 19,656 | 25,365 | 48,394 | 89,859 | 6,272 | 10,857 | 4,305 | 3,369 | 2,808 | 2,340 | 1,780 | 5,148 | 220,153 |
| 1956 | 16,756 | 12,356 | 58,782 | 101,184 | 77,315 | 14,509 | 5,241 | 4,400 | 3,464 | 2,808 | 2,433 | 1,780 | 301,028 |
| 1957 | 11,700 | 45,398 | 70,015 | 99,220 | 161,186 | 13,305 | 5,428 | 4,588 | 3,744 | 3,088 | 2,152 | 1,497 | 421,121 |
| 1958 | 13,573 | 36,598 | 36,973 | 98,191 | 126,645 | 10,952 | 4,773 | 3,837 | 2,808 | 1,965 | 1,497 | 1,404 | 339,216 |
| 1959 | 7,301 | 19,001 | 72,918 | 100,531 | 124,305 | 15,069 | 4,773 | 3,837 | 2,908 | 1,592 | 376 | 468 | 352,979 |
| 1960 | 8,144 | 14,789 | 34,258 | 58,222 | 102,684 | 25,741 | 3,837 | 2,996 | 2,060 | 1,216 | 468 | 5,428 | 259,843 |
| 1961 | 25,833 | 19,001 | 74,790 | 97,255 | 104,180 | 18,909 | 4,400 | 3,744 | 2,716 | 1,592 | 1,124 | 1,312 | 354,856 |
| 1962 | 5,148 | 20,500 | 53,634 | 108,580 | 120,468 | 11,513 | 4,492 | 3,556 | 2,620 | 1,684 | 844 | 748 | 333,787 |
| 1963 | 2,528 | 11,981 | 40,625 | 81,903 | 147,894 | 51,202 | 4,588 | 3,744 | 2,716 | 1,592 | 844 | 3,652 | 353,269 |
| 1964 | 30,797 | 38,845 | 51,390 | 114,384 | 164,650 | 52,230 | 5,616 | 4,680 | 3,837 | 3,184 | 2,060 | 2,060 | 473,733 |
| 1965 | 15,802 | 13,760 | 35,194 | 91,171 | 95,663 | 23,025 | 5,336 | 5,241 | 4,400 | 3,652 | 2,901 | 3,184 | 299,329 |
| 1966 | 11,608 | 13,573 | 43,433 | 80,124 | 66,178 | 36,973 | 6,177 | 5,709 | 4,680 | 3,369 | 2,716 | 3,932 | 278,472 |
| 1967 | 16,568 | 13,760 | 11,232 | 45,022 | 62,527 | 14,133 | 5,428 | 4,492 | 3,556 | 2,620 | 2,528 | 9,453 | 191,319 |
| 1968 | 17,504 | 34,633 | 65,242 | 32,105 | 29,765 | 10,204 | 4,868 | 4,400 | 3,464 | 2,433 | 1,312 | 1,780 | 207,710 |
| 1969 | 3,932 | 5,241 | 21,249 | 65,710 | 51,106 | 57,942 | 10,109 | 4,024 | 1,684 | 1,312 | 1,497 | 13,665 | 237,471 |
| 1970 | 24,617 | 10,764 | 43,150 | 49,702 | 125,804 | 57,659 | 52,606 | 11,888 | 5,336 | 3,464 | 2,901 | 8,517 | 396,408 |
| 1971 | 12,824 | 17,972 | 30,514 | 64,494 | 102,120 | 47,270 | 10,952 | 6,084 | 2,996 | 2,248 | 1,124 | 748 | 299,346 |
| 1972 | 748 | 3,932 | 5,428 | 67,487 | 145,461 | 81,143 | 43,994 | 14,321 | 6,460 | 5,524 | 2,996 | 8,049 | 385,835 |
| 1973 | 31,450 | 18,909 | 17,597 | 74,975 | 120,093 | 38,874 | 18,533 | 10,389 | 5,992 | 5,336 | 10,484 | 12,449 | 366,081 |
| 1974 | 8,705 | 8,332 | 29,861 | 160,998 | 207,892 | 93,416 | 18,721 | 16,381 | 7,769 | 5,056 | 3,837 | 14,789 | 575,757 |
| 1975 | 21,904 | 13,105 | 14,228 | 74,695 | 124,493 | 55,602 | 19,189 | 10,484 | 5,336 | 3,652 | 2,809 | 15,352 | 360,849 |
| 1976 | 4,400 | 4,868 | 21,529 | 82,559 | 89,672 | 100,904 | 10,389 | 5,241 | 2,060 | 1,312 | 2,248 | 4,212 | 329,394 |
| 1977 | 1,872 | 3,276 | 5,428 | 26,117 | 24,805 | 8,800 | 3,276 | 1,872 | 1,312 | 1,404 | 1,312 | 8,237 | 87,711 |
| 1978 | 5,896 | 33,605 | 24,897 | 84,151 | 149,486 | 19,564 | 8,517 | 4,120 | 1,780 | 1,216 | 1,404 | 4,773 | 339,409 |
| 1979 | 26,865 | 6,740 | 7,396 | 96,787 | 52,042 | 8,049 | 3,652 | 2,152 | 1,216 | 656 | 1,216 | 71,795 | 278,566 |
| 1980 | 29,110 | 21,809 | 25,085 | 81,623 | 206,208 | 28,457 | 8,800 | 5,148 | 3,744 | 3,184 | 4,588 | 14,789 | 432,545 |
| 1981 | 22,372 | 17,597 | 26,021 | 55,226 | 90,235 | 55,602 | 23,025 | 5,992 | 2,808 | 2,060 | 2,152 | 8,985 | 312,075 |
| 1982 | 15,445 | 12,824 | 17,224 | 25,273 | 57,846 | 13,760 | 7,396 | 5,148 | 3,556 | 3,369 | 560 | 3,464 | 165,865 |
| Mean | 14,531 | 17,778 | 35,318 | 78,805 | 105,433 | 33,972 | 10,758 | 5,674 | 3,425 | 2,547 | 2,173 | 8,189 | |

Table III-9 RIVER FLOW AT CT-5A AFTER CONSTRUCTION OF UPPER MAE WONG DAM

| Year | J | J | A | S | O | N | D | J | F | M | A | M | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1954 | 7,056 | 25,238 | 59,095 | 45,733 | 119,619 | 57,995 | 4,454 | 1,252 | 4,670 | 4,289 | 674 | 2,321 | 332,416 |
| 1955 | 6,960 | 10,112 | 61,102 | 41,018 | 106,201 | 29,292 | 4,205 | 1,478 | 2,552 | 5,503 | 1,038 | 2,094 | 271,555 |
| 1956 | 5,956 | 17,570 | 54,997 | 37,987 | 62,666 | 54,302 | 3,795 | 1,835 | 3,941 | 3,793 | 1,154 | 928 | 248,824 |
| 1957 | 4,206 | 21,938 | 53,242 | 89,077 | 160,212 | 48,719 | 3,722 | 1,900 | 3,854 | 4,363 | 1,287 | 830 | 393,350 |
| 1958 | 4,854 | 33,615 | 82,222 | 36,603 | 107,530 | 56,967 | 3,970 | 1,640 | 4,216 | 4,320 | 1,135 | 798 | 337,870 |
| 1959 | 2,683 | 9,163 | 56,779 | 70,763 | 126,402 | 52,855 | 3,960 | 1,640 | 4,391 | 7,303 | 1,955 | 474 | 338,368 |
| 1960 | 2,975 | 17,730 | 81,560 | 56,395 | 45,065 | 40,785 | 4,397 | 1,349 | 3,350 | 7,475 | 860 | 2,191 | 264,132 |
| 1961 | 9,098 | 34,846 | 44,955 | 48,059 | 103,208 | 53,756 | 3,478 | 1,608 | 4,257 | 6,624 | 701 | 766 | 311,356 |
| 1962 | 1,938 | 13,086 | 62,777 | 57,711 | 124,435 | 53,206 | 4,120 | 1,543 | 3,373 | 6,477 | 1,090 | 571 | 330,327 |
| 1963 | 1,031 | 45,958 | 57,675 | 35,775 | 79,497 | 54,761 | 4,056 | 1,608 | 4,458 | 7,028 | 809 | 1,576 | 294,232 |
| 1964 | 10,923 | 37,758 | 50,479 | 113,874 | 163,708 | 62,085 | 3,678 | 1,932 | 1,640 | 6,660 | 1,260 | 1,025 | 455,022 |
| 1965 | 5,632 | 47,674 | 38,816 | 43,146 | 99,956 | 48,096 | 3,794 | 2,126 | 3,206 | 5,921 | 1,316 | 1,414 | 301,097 |
| 1966 | 4,174 | 20,250 | 63,906 | 74,689 | 52,548 | 27,115 | 2,365 | 2,288 | 3,482 | 6,556 | 1,252 | 1,673 | 260,298 |
| 1967 | 5,891 | 53,332 | 101,172 | 55,542 | 80,742 | 44,506 | 3,707 | 1,867 | 3,536 | 5,613 | 1,187 | 3,584 | 366,679 |
| 1968 | 6,215 | 12,526 | 91,388 | 50,398 | 29,753 | 10,206 | 3,934 | 1,835 | 3,946 | 4,322 | 982 | 928 | 216,433 |
| 1969 | 1,517 | 7,966 | 21,257 | 30,192 | 86,215 | 29,288 | 3,769 | 1,705 | 4,525 | 3,894 | 863 | 5,042 | 196,233 |
| 1970 | 8,677 | 40,771 | 64,787 | 44,489 | 46,117 | 46,590 | 18,365 | 4,427 | 2,235 | 6,275 | 1,316 | 3,260 | 287,309 |
| 1971 | 4,595 | 55,803 | 49,733 | 44,331 | 77,955 | 43,205 | 4,147 | 2,418 | 3,674 | 5,294 | 701 | 571 | 292,427 |
| 1972 | 415 | 65,760 | 71,715 | 36,757 | 56,239 | 42,547 | 15,384 | 5,269 | 3,034 | 4,521 | 1,349 | 3,098 | 306,088 |
| 1973 | 11,042 | 68,056 | 62,757 | 48,227 | 82,841 | 41,866 | 6,571 | 3,908 | 2,965 | 3,450 | 3,941 | 4,621 | 340,245 |
| 1974 | 3,169 | 13,265 | 69,089 | 94,713 | 206,919 | 92,057 | 17,189 | 14,739 | 5,826 | 5,136 | 1,640 | 10,399 | 534,141 |
| 1975 | 20,658 | 23,819 | 88,130 | 42,454 | 68,914 | 54,283 | 17,667 | 8,807 | 3,917 | 3,901 | 1,284 | 9,693 | 343,527 |
| 1976 | 3,157 | 47,059 | 76,566 | 48,698 | 63,525 | 68,984 | 3,814 | 2,126 | 4,486 | 6,219 | 1,090 | 1,770 | 327,494 |
| 1977 | 804 | 71,961 | 85,926 | 66,459 | 48,294 | 8,811 | 3,197 | 960 | 1,896 | 1,379 | 782 | 3,163 | 293,632 |
| 1978 | 2,197 | 11,788 | 54,707 | 35,498 | 70,580 | 51,702 | 3,556 | 1,738 | 3,284 | 7,479 | 817 | 1,964 | 245,310 |
| 1979 | 9,455 | 29,017 | 76,550 | 54,918 | 102,292 | 8,033 | 3,590 | 1,057 | 1,970 | 678 | 1,072 | 25,091 | 318,723 |
| 1980 | 10,232 | 9,836 | 68,775 | 44,383 | 87,578 | 43,008 | 3,447 | 2,094 | 3,804 | 3,242 | 1,900 | 5,431 | 283,730 |
| 1981 | 7,900 | 18,557 | 66,961 | 59,130 | 75,843 | 19,553 | 8,126 | 2,386 | 4,240 | 5,978 | 1,057 | 3,422 | 273,153 |
| 1982 | 5,502 | 44,483 | 79,928 | 73,162 | 75,399 | 40,550 | 3,078 | 2,094 | 3,933 | 6,544 | 1,112 | 1,511 | 337,296 |
| Mean | 5,825 | 31,343 | 65,622 | 54,489 | 90,181 | 44,311 | 5,846 | 2,746 | 3,609 | 5,181 | 1,229 | 3,455 | |

Table III-10 CONSTRUCTION COST OF ALTERNATIVE PLAN

(Unit: $10^6$ ฿)

| Work Item | Alternative Plan | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 101 | 102 | 103 | 201 | 202 | 205 | 206 | 207 | 208 | 209 | 301 |
| 1. Construction Cost (including overhead, profit, tax) | | | | | | | | | | | |
| 1.1 Dam Construction | 1,006.6 | 1,051.0 | 1,051.0 | 824.6 | 1,051.0 | 955.4 | 1,051.0 | 1,006.6 | 1,051.0 | 1,042.5 | 1,051.0 |
| 1.2 Irrigation Facilities | 10.6 | 10.6 | 23.7 | 449.3 | 449.3 | 590.0 | 590.0 | 626.3 | 626.3 | 626.3 | 638.8 |
| 1.3 Office & Quarters | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 |
| Sub-total | 1,041.4 | 1,085.8 | 1,098.9 | 1,298.1 | 1,524.5 | 1,569.6 | 1,665.2 | 1,657.1 | 1,701.5 | 1,705.5 | 1,714.0 |
| 2. Land Acquisition, Resettlement & Compensation | 17.3 | 17.3 | 17.3 | 25.7 | 25.7 | 27.0 | 27.0 | 27.7 | 27.7 | 28.0 | 28.0 |
| 3. O & M Equipment | 44.6 | 44.6 | 44.6 | 44.6 | 44.6 | 44.6 | 44.6 | 44.6 | 44.6 | 44.6 | 44.6 |
| 4. Pump | 47.7 | 47.7 | 47.7 | - | - | - | - | - | - | - | - |
| 5. Administration | 26.0 | 27.1 | 27.5 | 32.5 | 38.1 | 39.2 | 41.6 | 41.4 | 42.5 | 42.6 | 42.9 |
| 6. Physical Contingency | 117.7 | 122.3 | 123.6 | 140.1 | 163.3 | 168.0 | 177.8 | 177.1 | 181.6 | 182.1 | 183.0 |
| 7. Engineering Services | 117.7 | 117.7 | 119.7 | 210.4 | 210.4 | 224.5 | 224.5 | 235.3 | 230.4 | 230.4 | 235.3 |
| Sub-total | 371.0 | 376.7 | 380.4 | 453.3 | 482.1 | 503.3 | 515.5 | 526.1 | 526.8 | 527.7 | 533.8 |
| Total | 1,412.4 | 1,462.5 | 1,479.3 | 1,751.4 | 2,006.6 | 2,072.9 | 2,180.7 | 2,183.2 | 2,228.3 | 2,233.2 | 2,247.8 |

Note: Price contingency is excluded.

## Table III-11 ECONOMIC O & M COST AND REPLACEMENT COST

| Case | O & M Cost ($10^6$ ฿) | Replacement Cost | |
|---|---|---|---|
| | | O & M Equipment /1 ($10^6$ ฿) | Gate /2 ($10^6$ ฿) |
| 101 | 48.1 | 44.2 | 27.3 |
| 102 | 48.4 | 44.2 | 27.3 |
| 103 | 48.7 | 44.2 | 27.5 |
| 201 | 13.4 | 44.2 | 40.9 |
| 202 | 14.4 | 44.2 | 40.9 |
| 205 | 16.7 | 44.2 | 42.9 |
| 206 | 17.2 | 44.2 | 42.9 |
| 207 | 17.7 | 44.2 | 44.1 |
| 208 | 17.9 | 44.2 | 44.1 |
| 209 | 18.1 | 44.2 | 44.6 |
| 301 | 18.1 | 44.2 | 44.6 |

Note: /1: Useful life 10 years
/2: Useful life 25 years

## Table III-12 IRRIGATION BENEFITS OF ALTERNATIVE CASES

| Case | Gross Reservoir Capacity (MCM) | Irrigation Area (ha) | Cropping Intensity (%) | Net Production Value | | | Benefit per ha (฿/ha) |
|---|---|---|---|---|---|---|---|
| | | | | Without Project (M฿) | With Project (M฿) | Incremental Benefit (M฿) | |
| 101 | 200 | 36,800 | 100 | 228.2 | 475.8 | 247.6 | 6,730 |
| 102 | 250 | 36,800 | 105 | 228.2 | 484.1 | 255.9 | 6,950 |
| 103 | 250 | 37,600 | 100 | 229.8 | 486.3 | 256.5 | 6,820 |
| 201 | 120 | 36,800 | 100 | 228.2 | 475.8 | 247.6 | 6,730 |
| 202 | 250 | 36,800 | 130 | 228.2 | 526.8 | 298.6 | 8,110 |
| 205 | 170 | 42,400 | 100 | 242.0 | 548.2 | 306.2 | 7,220 |
| 206 | 250 | 42,400 | 116 | 242.0 | 579.8 | 337.8 | 7,970 |
| 207 | 200 | 45,600 | 100 | 248.5 | 589.8 | 341.3 | 7,480 |
| 208 | 250 | 45,600 | 108 | 248.5 | 606.5 | 358.0 | 7,850 |
| 209 | 220 | 46,700 | 100 | 250.8 | 604.1 | 353.3 | 7,570 |
| 301 | 250 | 46,700 | 105 | 250.8 | 614.8 | 364.0 | 7,790 |

## Table III-13 IRRIGATION BENEFIT ESTIMATES (1/11)

Case 101

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (₿/ton) | G.P.V (M₿) | Unit Production Cost (₿/ha) | Total Production Cost (₿/ha) | N.P.V (M₿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | - | - | - | - | - | - | - | - |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | - | - | - | - | - | - | - | - |
| Maize | - | - | - | - | - | - | - | - |
| Total | | | | | 390.8 | | 162.6 | 288.2 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (₿/ton) | G.P.V (M₿) | Unit Production Cost (₿/ha) | Total Production Cost (₿/ha) | N.P.V (M₿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 29,400 | 4.5 | 132,300 | 4,230 | 559.6 | 5,680 | 167.0 | 392.6 |
| - Improved Local | 7,400 | 4.0 | 29,600 | 4,230 | 125.2 | 5,680 | 42.0 | 83.2 |
| Mung Beans | - | - | - | - | - | - | - | - |
| Total | | | | | 684.8 | | 209.0 | 475.8 |

(3) Incremental Benefit 247.6

## Table III-13 IRRIGATION BENEFIT ESTIMATES (2/11)

Case 102

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (₿/ton) | G.P.V (M₿) | Unit Production Cost (₿/ha) | Total Production Cost (₿/ha) | N.P.V (M₿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | - | - | - | - | - | - | - | - |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | - | - | - | - | - | - | - | - |
| Maize | - | - | - | - | - | - | - | - |
| Total | | | | | 390.8 | | 162.6 | 228.2 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (₿/ton) | G.P.V (M₿) | Unit Production Cost (₿/ha) | Total Production Cost (₿/ha) | N.P.V (M₿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 29,400 | 4.5 | 132,300 | 4,230 | 559.6 | 5,680 | 167.0 | 392.6 |
| - Improved Local | 7,400 | 4.0 | 29,600 | 4,230 | 125.2 | 5,680 | 42.0 | 83.2 |
| Mung Beans | 1,800 | 1.2 | 2,200 | 6,920 | 14.9 | 3,660 | 6.6 | 8.3 |
| Total | | | | | 699.7 | | 215.6 | 484.1 |

(3) Incremental Benefit 255.9

## Table III-13 IRRIGATION BENEFIT ESTIMATES (3/11)

Case 103

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | 800 | 1.3 | 1,000 | 4,230 | 4.4 | 3,480 | 2.8 | 1.6 |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | - | - | - | - | - | - | - | - |
| Maize | - | - | - | - | - | - | - | - |
| Total | | | | | 395.2 | | 165.4 | 229.8 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 30,100 | 4.5 | 135,500 | 4,230 | 573.0 | 5,680 | 171.0 | 402.0 |
| - Improved Local | 7,500 | 4.0 | 30,000 | 4,230 | 126.9 | 5,680 | 42.6 | 84.3 |
| Mung Beans | - | - | - | - | - | - | - | - |
| Total | | | | | 699.9 | | 213.6 | 486.3 |

(3) Incremental Benefit 256.5

## Table III-13 IRRIGATION BENEFIT ESTIMATES (4/11)

Case 201

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61.600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | - | - | - | - | - | - | - | - |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | - | - | - | - | - | - | - | - |
| Maize | - | - | - | - | - | - | - | - |
| Total | | | | | 390.8 | | 162.7 | 228.2 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 29,400 | 4.5 | 132,300 | 4,230 | 559.6 | 5,680 | 167.0 | 392.6 |
| - Improved Local | 7,400 | 4.0 | 29,600 | 4,230 | 125.2 | 5,680 | 42.0 | 83.2 |
| Mung Beans | - | - | - | - | - | - | - | - |
| Total | | | | | 684.8 | | 209.0 | 475.8 |

(3) Incremental Benefit 247.6

## Table III-13 IRRIGATION BENEFIT ESTIMATES (5/11)

Case 202

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | - | - | - | - | - | - | - | - |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | - | - | - | - | - | - | - | - |
| Maize | - | - | - | - | - | - | - | - |
| Total | | | | | 390.8 | | 162.6 | 228.2 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 29,400 | 4.5 | 132,300 | 4,230 | 559.6 | 5,680 | 167.0 | 392.6 |
| - Improved Local | 7,400 | 4.0 | 29,600 | 4,230 | 125.2 | 5,680 | 42.0 | 83.2 |
| Mung Beans | 11,000 | 1.2 | 13,200 | 6,920 | 91.3 | 3,660 | 40.3 | 51.0 |
| Total | | | | | 776.1 | | 249.3 | 526.8 |

(3) Incremental Benefit 298.6

## Table III-13 IRRIGATION BENEFIT ESTIMATES (6/11)

Case 205

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | 3,500 | 1.3 | 4,550 | 4,230 | 19.2 | 3,480 | 12.2 | 7.0 |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | 800 | 0.5 | 400 | 6,920 | 2.8 | 2,250 | 1.8 | 1.0 |
| Maize | 2,100 | 2.2 | 4,620 | 2,470 | 11.4 | 2,660 | 5.6 | 5.8 |
| Total | | | | | 424.2 | | 182.2 | 242.0 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 33,900 | 4.5 | 152,550 | 4,230 | 645.3 | 5,680 | 192.6 | 452.7 |
| - Improved Local | 8,500 | 4.0 | 34,000 | 4,230 | 143.8 | 5,680 | 48.3 | 95.5 |
| Mung Beans | - | - | - | - | - | - | - | - |
| Total | | | | | 789.1 | | 240.9 | 548.2 |

(3) Incremental Benefit 306.2

## Table III-13 IRRIGATION BENEFIT ESTIMATES (7/11)

Case 206

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | 3,500 | 1.3 | 4,550 | 4,230 | 19.2 | 3,480 | 12.2 | 7.0 |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | 800 | 0.5 | 400 | 6,920 | 2.8 | 2,250 | 1.8 | 1.0 |
| Maize | 2,100 | 2.2 | 4,620 | 2,470 | 11.4 | 2,660 | 5.6 | 5.8 |
| Total | | | | | 424.2 | | 182.2 | 242.0 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 33,900 | 4.5 | 152,550 | 4,230 | 645.3 | 5,680 | 192.6 | 452.7 |
| - Improved Local | 8,500 | 4.0 | 34,000 | 4,230 | 143.8 | 5,680 | 48.3 | 95.5 |
| Mung Beans | 6,800 | 1.2 | 8,160 | 6,920 | 56.5 | 3,660 | 24.9 | 31.6 |
| Total | | | | | 845.6 | | 265.8 | 579.8 |

(3) Incremental Benefit 337.8

## Table III-13 IRRIGATION BENEFIT ESTIMATES (8/11)

Case 207

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | 6,700 | 1.3 | 8,710 | 4,230 | 36.8 | 3,480 | 23.3 | 13.5 |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | 800 | 0.5 | 400 | 6,920 | 2.8 | 2,250 | 1.8 | 1.0 |
| Maize | 2,100 | 2.2 | 4,620 | 2,470 | 11.4 | 2,660 | 5.6 | 5.8 |
| Total | | | | | 441.8 | | 193.3 | 248.5 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 36,500 | 4.5 | 164,250 | 4,230 | 694.8 | 5,680 | 207.3 | 487.5 |
| - Improved Local | 9,100 | 4.0 | 36,400 | 4,230 | 154.0 | 5,680 | 51.7 | 102.3 |
| Mung Beans | - | - | - | - | - | - | - | - |
| Total | | | | | 848.8 | | 259.0 | 589.8 |

(3) Incremental Benefit 341.3

## Table III-13 IRRIGATION BENEFIT ESTIMATES (9/11)

Case 208

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | 6,700 | 1.3 | 8,710 | 4,230 | 36.8 | 3,480 | 23.3 | 13.5 |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | 800 | 0.5 | 400 | 6,920 | 2.8 | 2,250 | 1.8 | 1.0 |
| Maize | 2,100 | 2.2 | 4,620 | 2,470 | 11.4 | 2,660 | 5.6 | 5.8 |
| Total | | | | | 441.8 | | 193.3 | 248.5 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 36,500 | 4.5 | 164,250 | 4,230 | 694.8 | 5,680 | 207.3 | 487.5 |
| - Improved Local | 9,100 | 4.0 | 36,400 | 4,230 | 154.0 | 5,680 | 51.7 | 102.3 |
| Mung Beans | 3,600 | 1.2 | 4,320 | 6,920 | 29.9 | 3,660 | 13.2 | 16.7 |
| Total | | | | | 878.7 | | 272.2 | 606.5 |

(3) Incremental Benefit 358.0

## Table III-13 IRRIGATION BENEFIT ESTIMATES (10/11)

Case 209

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,680 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | 7,800 | 1.3 | 10,140 | 4,230 | 42.9 | 3,480 | 27.1 | 15.8 |
| Dry Season Paddy | 1,100 | 3.5 | 3,850 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 1,980 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | 800 | 0.5 | 400 | 6,920 | 2.8 | 2,250 | 1.8 | 1.0 |
| Maize | 2,100 | 2.2 | 4,620 | 2,470 | 11.4 | 2,660 | 5.6 | 5.8 |
| Total | | | | | 447.9 | | 197.1 | 250.8 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 37,400 | 4.5 | 168,300 | 4,230 | 711.9 | 5,680 | 212.4 | 499.5 |
| - Improved Local | 9,300 | 4.0 | 37,200 | 4,230 | 157.4 | 5,680 | 52.8 | 104.6 |
| Mung Beans | - | - | - | - | - | - | - | - |
| Total | | | | | 869.3 | | 265.2 | 604.1 |

(3) Incremental Benefit 353.3

## Table III-13 IRRIGATION BENEFIT ESTIMATES (11/11)

Case 301

(1) Without Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - Irrigated | 22,000 | 2.8 | 61,600 | 4,230 | 260.6 | 4,270 | 93.9 | 166.7 |
| - Semi-irrigated | 14,800 | 1.6 | 23,100 | 4,230 | 100.2 | 3,780 | 55.9 | 44.3 |
| - Rainfed | 7,800 | 1.3 | 9,800 | 4,230 | 42.9 | 3,480 | 27.1 | 15.8 |
| Dry Season Paddy | 1,100 | 3.5 | 3,900 | 4,230 | 16.3 | 4,930 | 5.4 | 10.9 |
| Mung Beans (Paddy Field) | 3,300 | 0.6 | 2,000 | 6,920 | 13.7 | 2,250 | 7.4 | 6.3 |
| Mung Beans (Upland) | 800 | 0.5 | 400 | 6,920 | 2.8 | 2.250 | 1.8 | 1.0 |
| Maize | 2,100 | 2.2 | 4,600 | 2,470 | 11.4 | 2,660 | 5.6 | 5.8 |
| Total | | | | | 447.9 | | 197.1 | 250.8 |

(2) With Project

| Crops | Cultivated Area (ha) | Unit Yield (ton/ha) | Production (ton) | Unit Price (฿/ton) | G.P.V (M฿) | Unit Production Cost (฿/ha) | Total Production Cost (฿/ha) | N.P.V (M฿) |
|---|---|---|---|---|---|---|---|---|
| Wet Season Paddy | | | | | | | | |
| - H.Y.V. | 37,400 | 4.5 | 168,300 | 4,230 | 711.9 | 5,680 | 212.4 | 499.5 |
| - Improved Local | 9,300 | 4.0 | 37,200 | 4,230 | 157.4 | 5,680 | 52.8 | 104.5 |
| Mung Beans | 2,300 | 1.2 | 2,760 | 6,920 | 19.1 | 3,660 | 8.4 | 10.7 |
| Total | | | | | 888.4 | | 273.6 | 614.8 |

(3) Incremental Benefit 364.0

## Table III-14 ECONOMIC COMPARISON OF ALTERNATIVE CASES

| Alternative Case | G.R.C (MCM) | Irrigation Area (ha) | Cropping Intensity (%) | Constrruction Cost (Economic) Dam (MB) | Irrigation (M฿) | Total (M฿) | O/M Cost (M฿) | Annual Benefit (M฿) | IRR (%) |
|---|---|---|---|---|---|---|---|---|---|
| 101 | 200 | 36,800 | 100 | 1,132.8 | 109.4 | 1,242.2 | 48.1 | 247.6 | 11.6 |
| 102 | 250 | 36,800 | 105 | 1,176.6 | 109.4 | 1,286.0 | 48.4 | 255.9 | 11.6 |
| 103 | 250 | 37,600 | 100 | 1,176.6 | 123.8 | 1,300.4 | 48.7 | 256.5 | 11.5 |
| 201 | 120 | 36,800 | 100 | 954.3 | 575.8 | 1,530.1 | 13.4 | 247.6 | 11.5 |
| 202 | 250 | 36,800 | 130 | 1,176.6 | 575.8 | 1,752.4 | 14.4 | 293.6 | 12.1 |
| 205 | 170 | 42,400 | 100 | 1,082.7 | 724.7 | 1,807.4 | 16.7 | 306.2 | 12.0 |
| 206 | 250 | 42,400 | 116 | 1,176.6 | 724.7 | 1,901.3 | 17.2 | 339.8 | 12.5 |
| 207 | 200 | 45,600 | 100 | 1,142.3 | 761.4 | 1,903.7 | 17.7 | 341.3 | 12.6 |
| 208 | 250 | 45,600 | 108 | 1,176.6 | 761.4 | 1,938.0 | 17.9 | 358.0 | 12.9 |
| 209 | 220 | 46,700 | 100 | 1,164.4 | 782.4 | 1,946.8 | 18.1 | 353.3 | 12.8 |
| 301 | 250 | 46,700 | 105 | 1,176.6 | 782.4 | 1,959.0 | 18.1 | 364.0 | 13.0 |

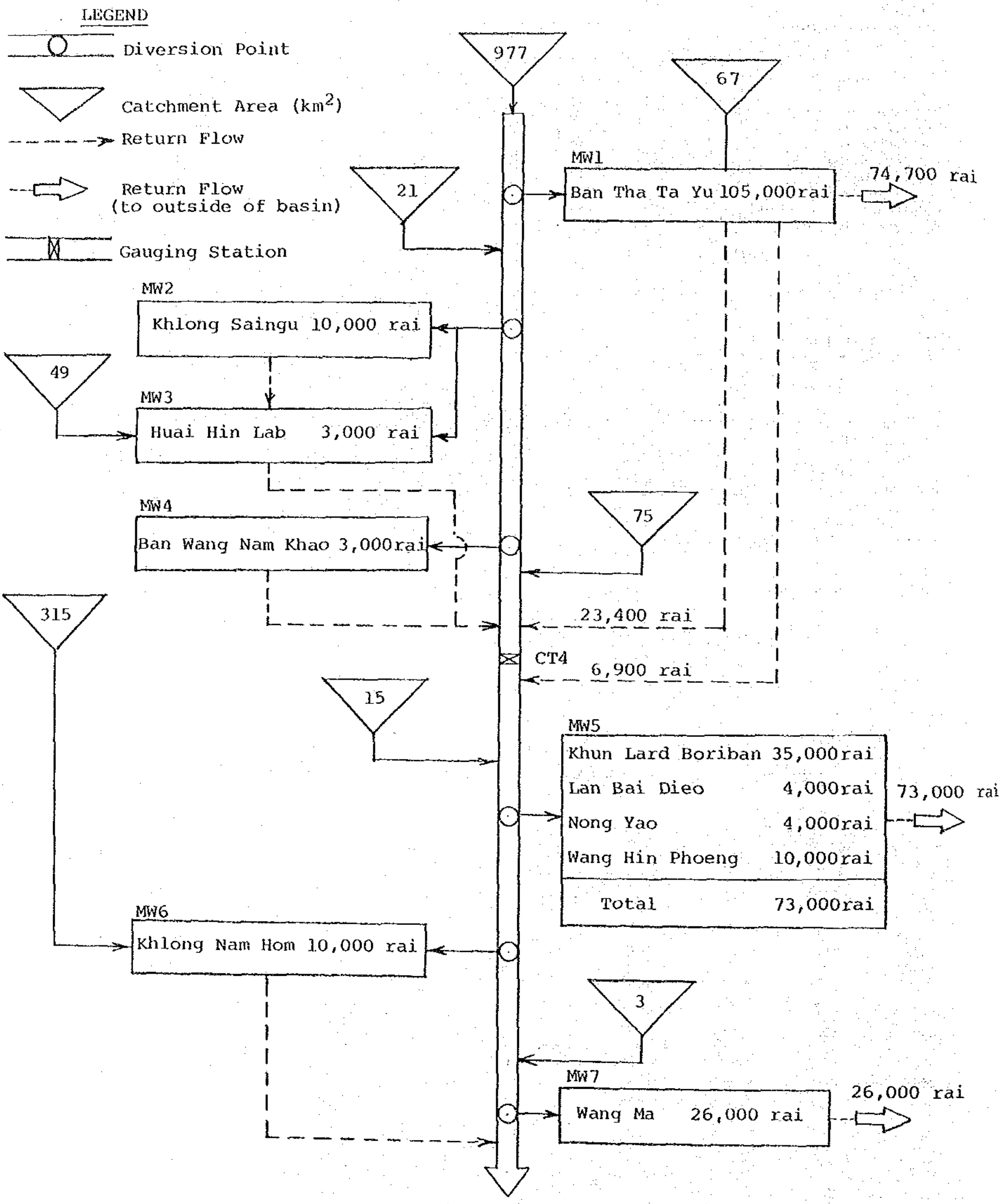



Fig. III-1 Systematic Diagram of Mae Wong River Basin for Water Balance Study Under Present Condition

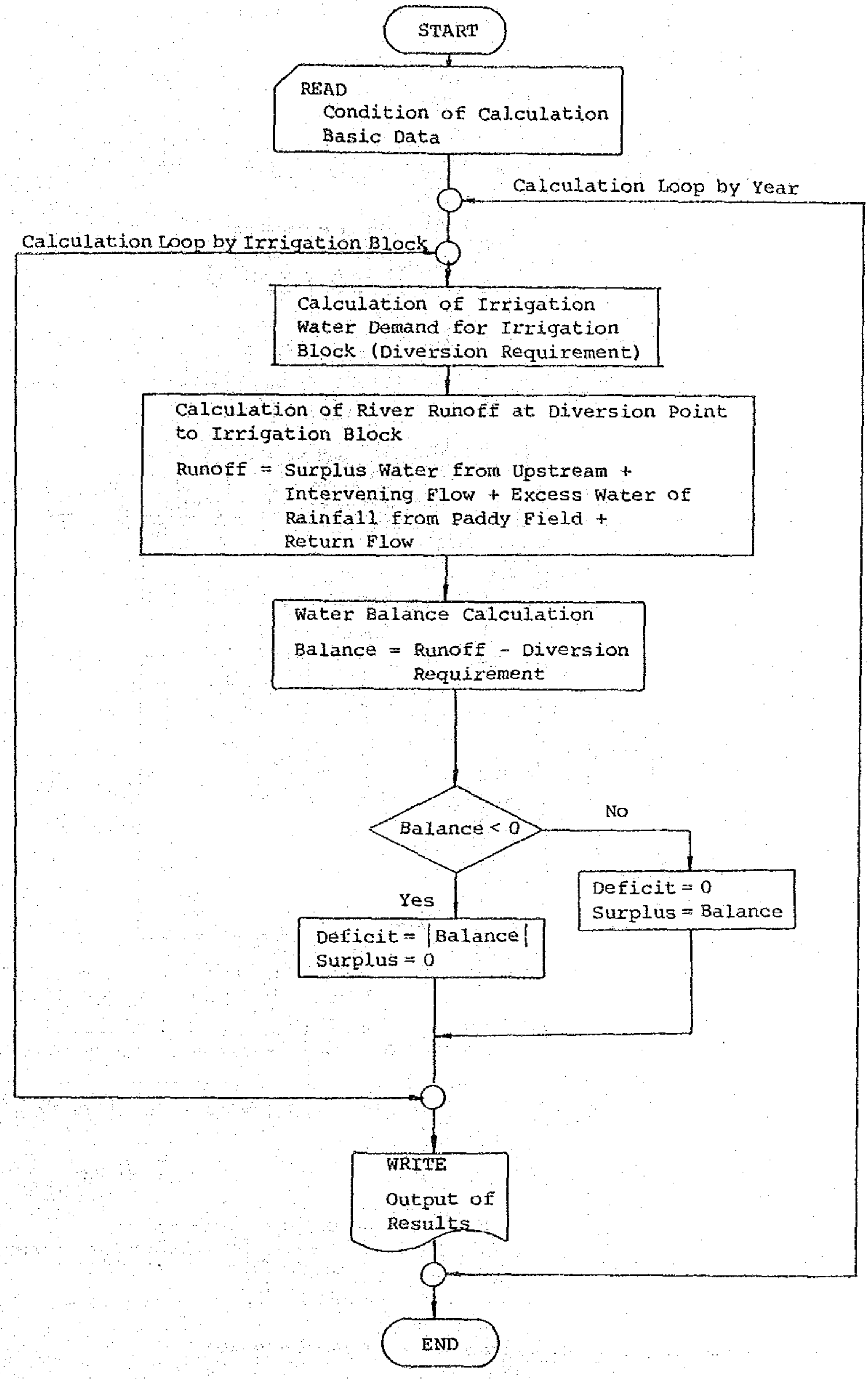



Fig. III-2 Flow Chart of Water Balance Calculation

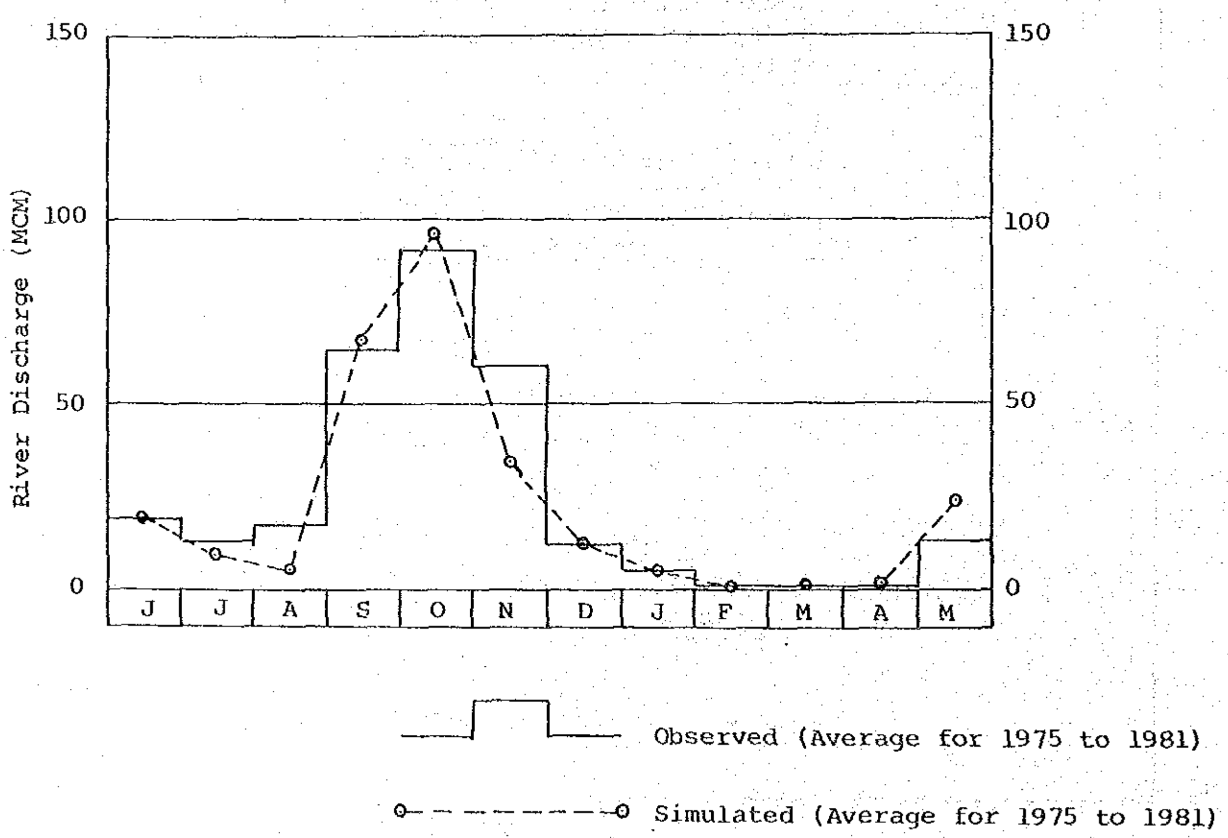



Fig. III-3 Monthly Mean River Discharge at CT 4 Station

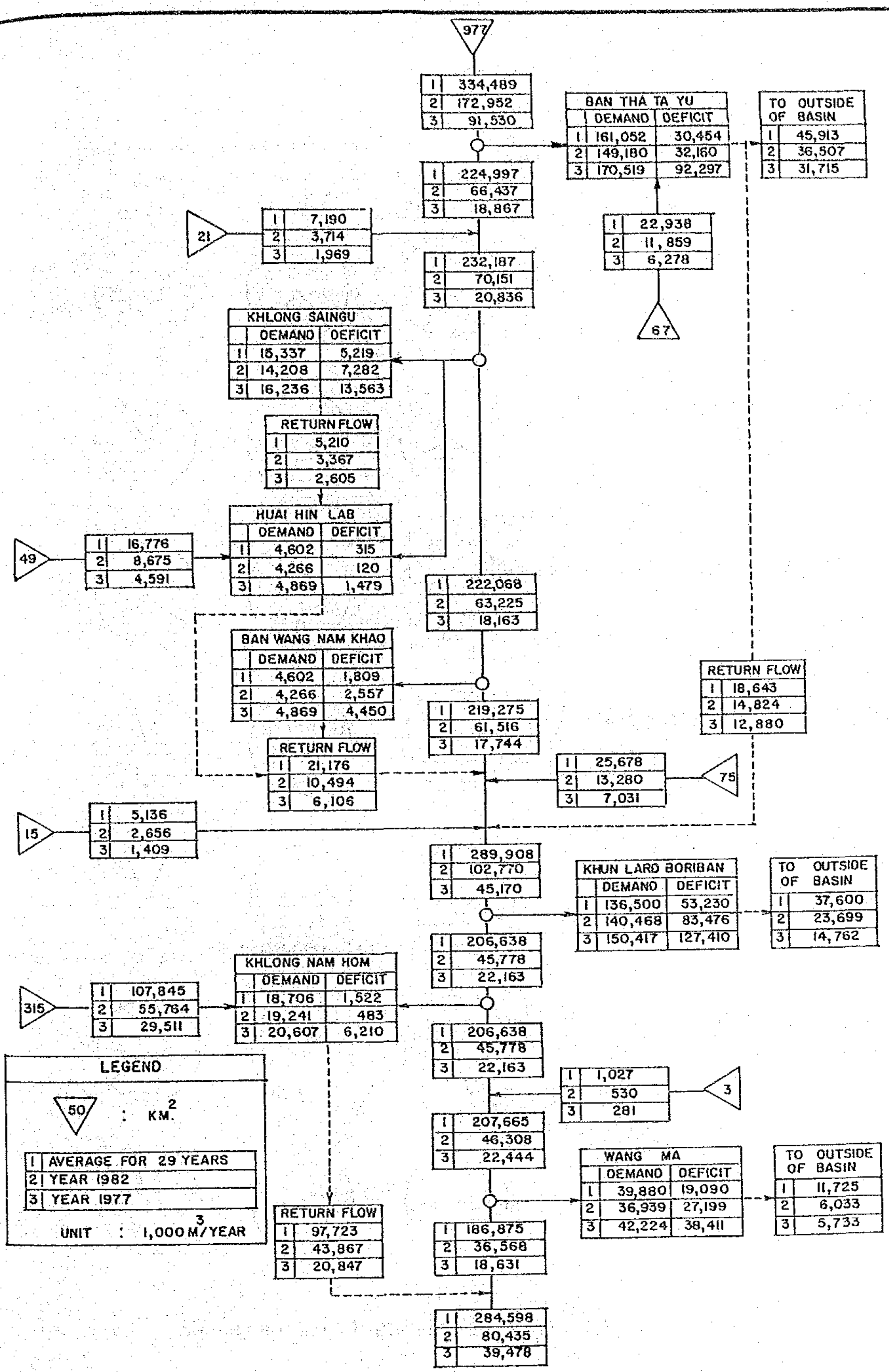



Fig. III-4 Present Water Use in Mae Wong River Basin

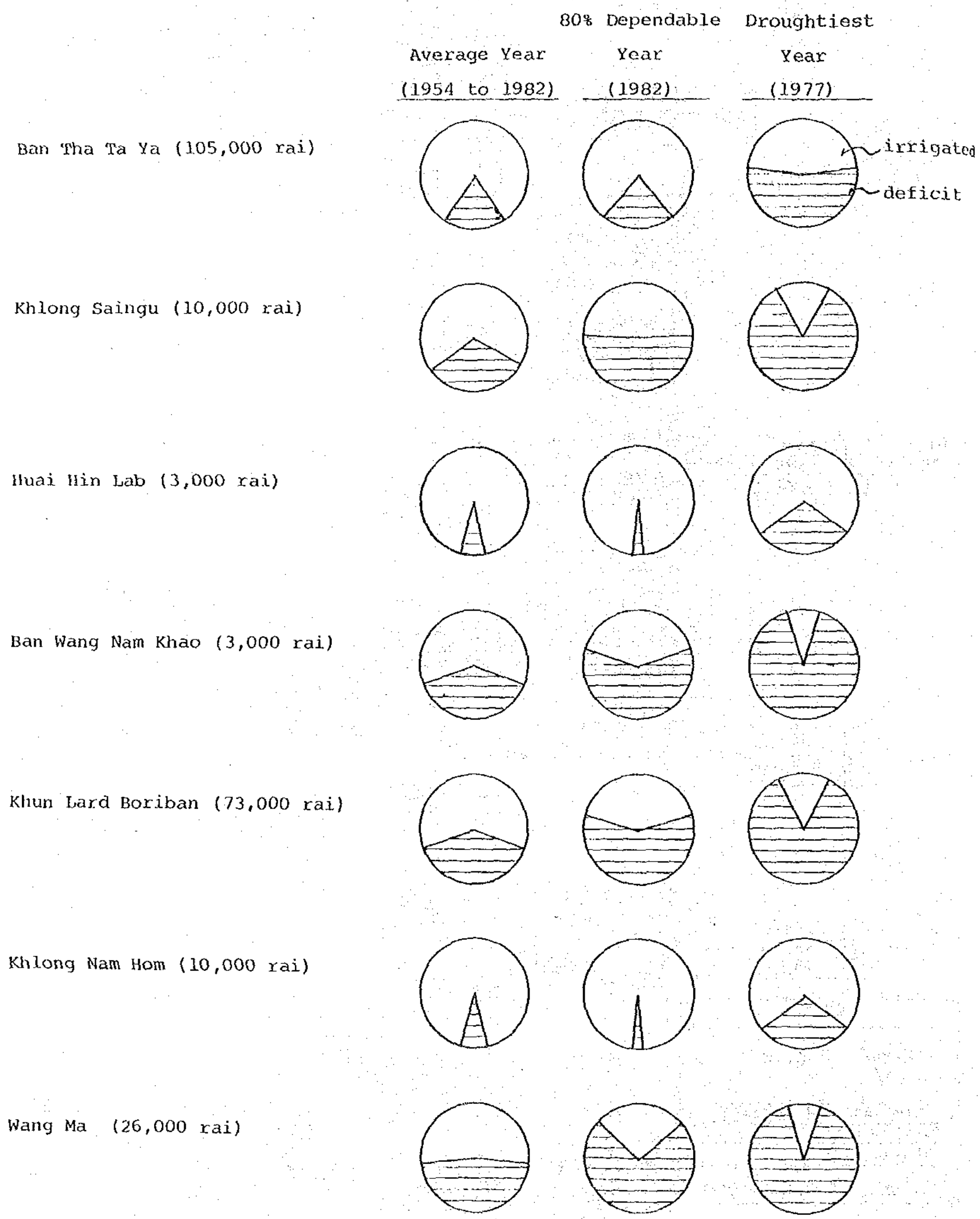
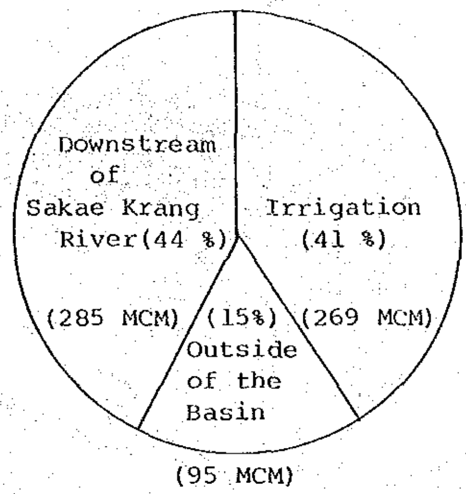


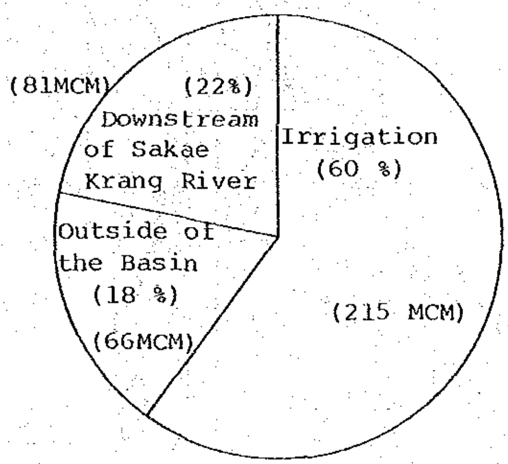

Fig. III-5 Deficit Ratio of Existing Irrigation Area

Average for 29 years
(1954 to 1982)



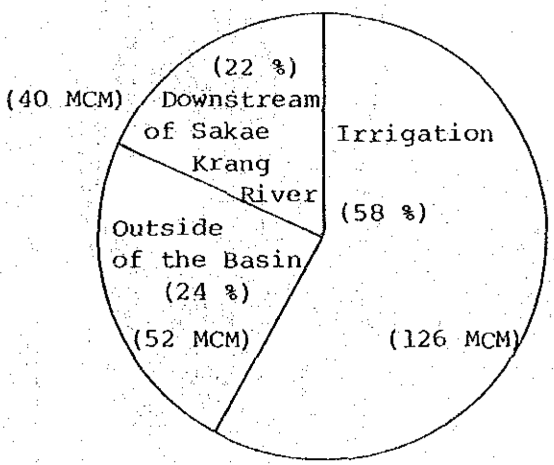

| | | |
|---|---|---|
| Runoff | : | 521 MCM |
| Rainfall in the irrigation block | : | 39 MCM |
| Return flow | : | 89 MCM |
| Total | | 649 MCM |

80 % dependable Year
(1982)




| | | |
|---|---|---|
| Runoff | : | 269 MCM |
| Rainfall in the irrigation block | : | 22 MCM |
| Return flow | : | 71 MCM |
| Total | | 362 MCM |

Droughtiest Year
(1977)




| | | |
|---|---|---|
| Runoff | : | 143 MCM |
| Rainfall in the irrigation block | : | 33 MCM |
| Return flow | : | 42 MCM |
| Total | | 218 MCM |

Fig. III-6 Overall Present Water Balance of Mae Wong Basin

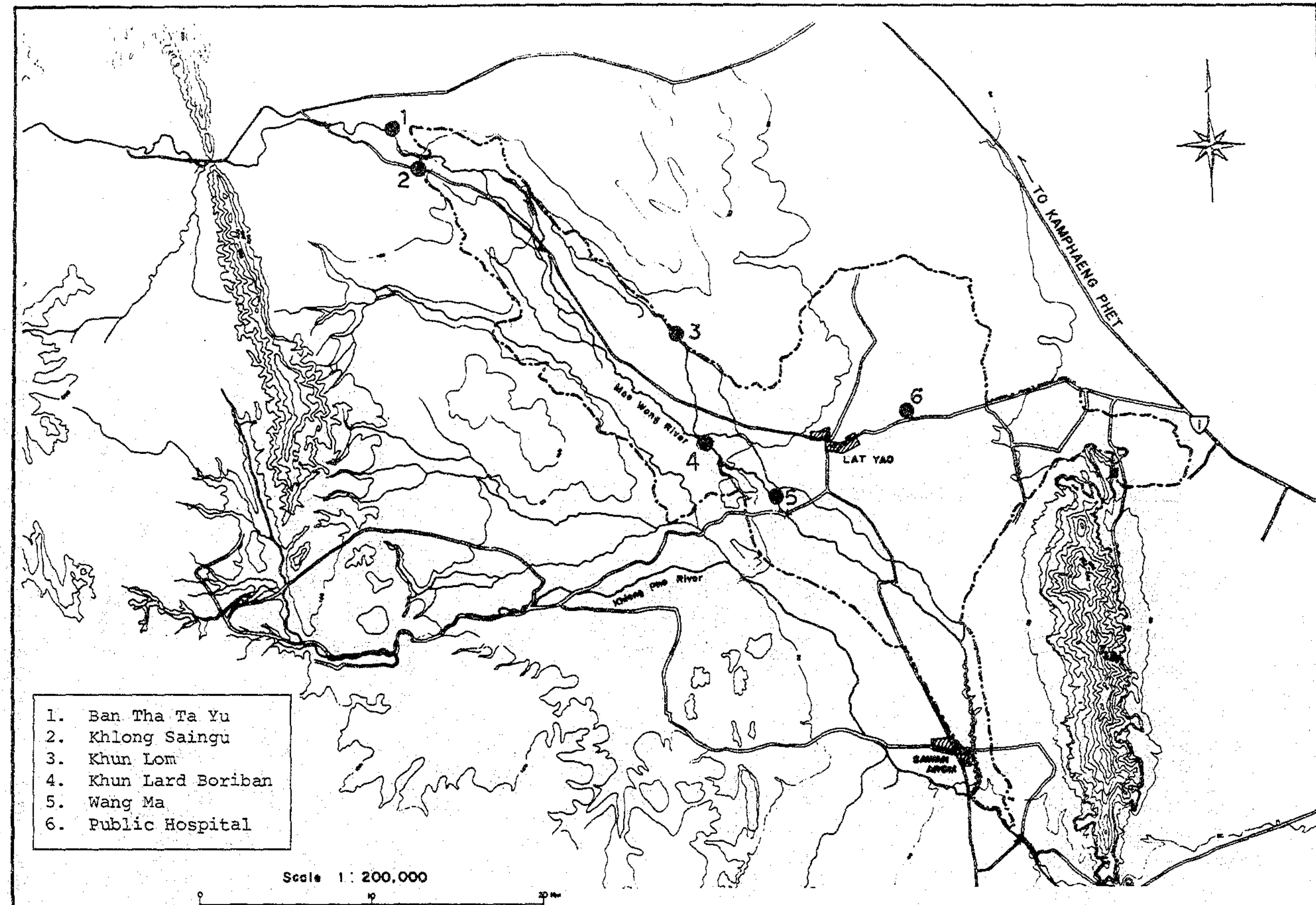



Fig. III-7 Location Map of Water Level Observation Network

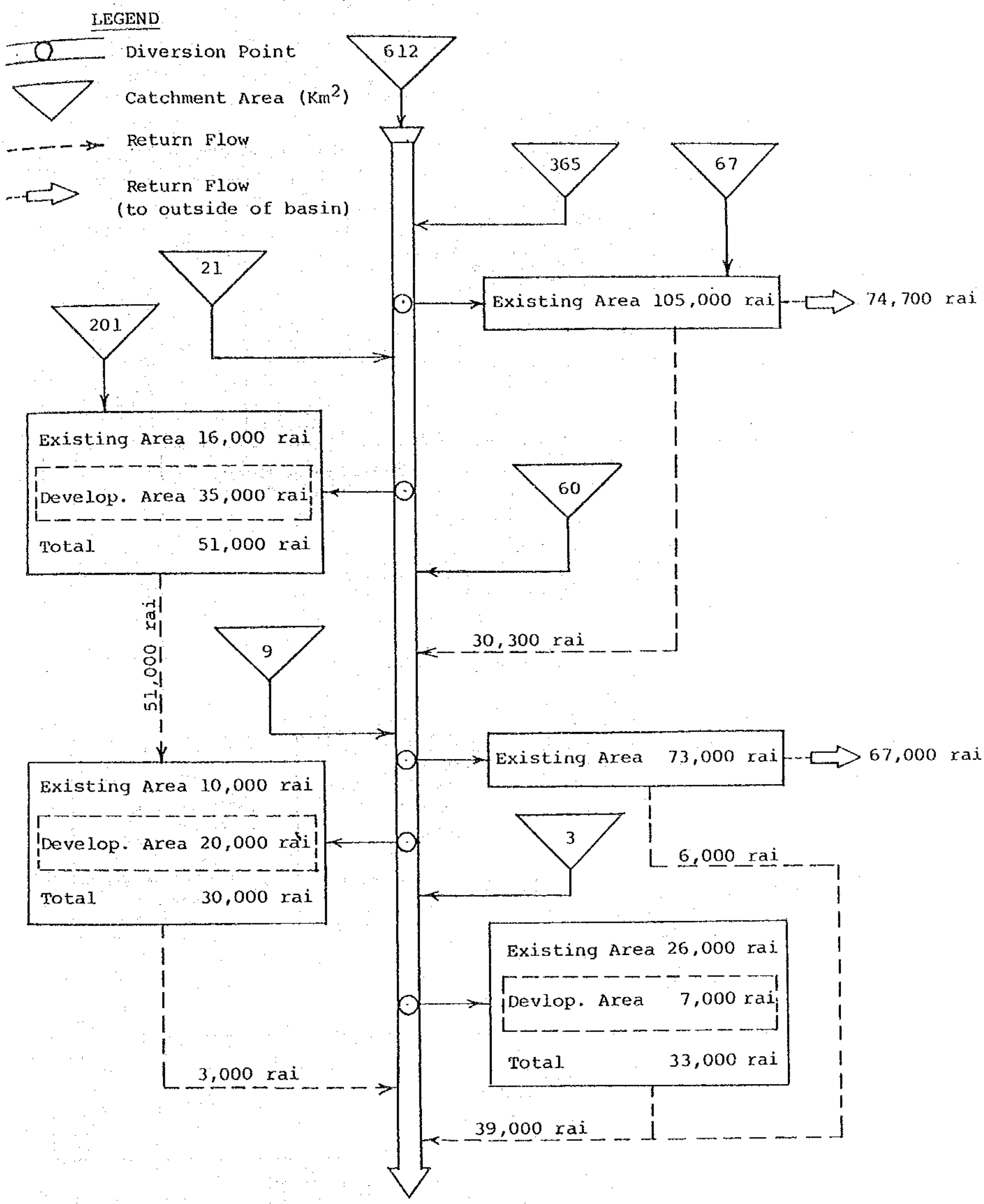



Fig. III-8 Systematic Diagram of Mae Wong River Basin for Water Balance Study Under With-Project Condition

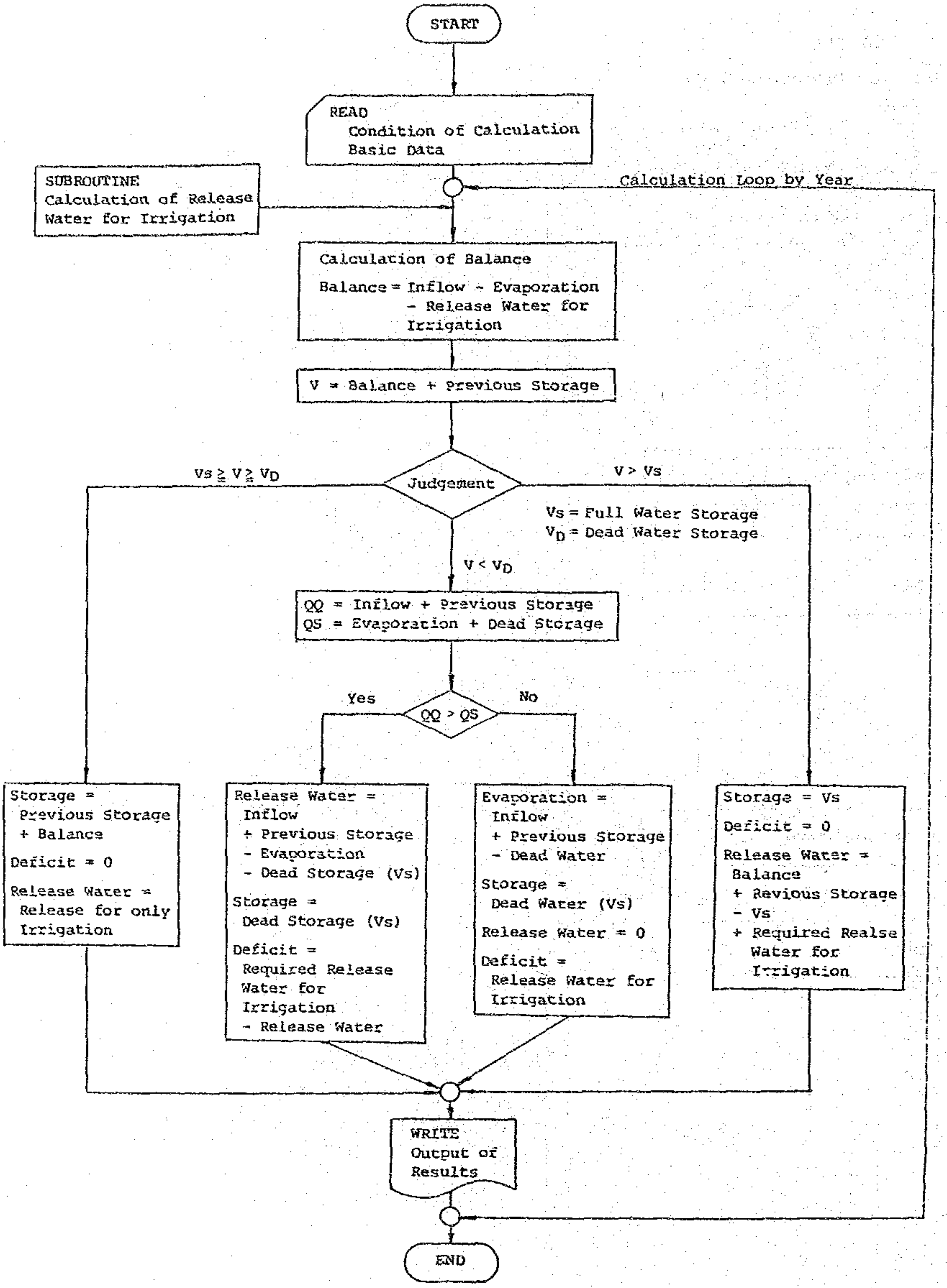



Fig. III-9 Flow Chart of Reservoir Operation

Calculation Condition

Cropping Pattern : Wet Season Paddy

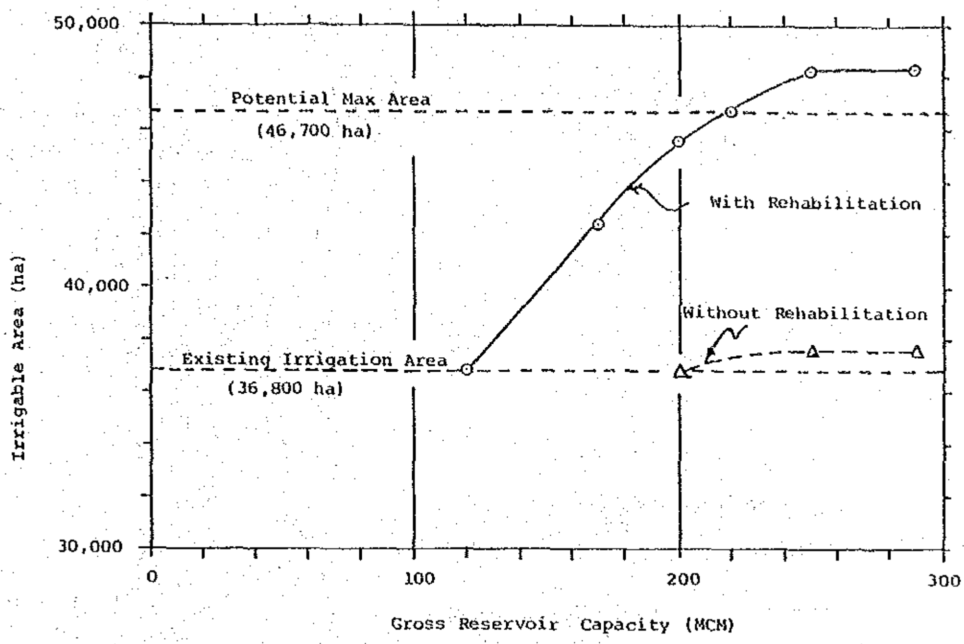
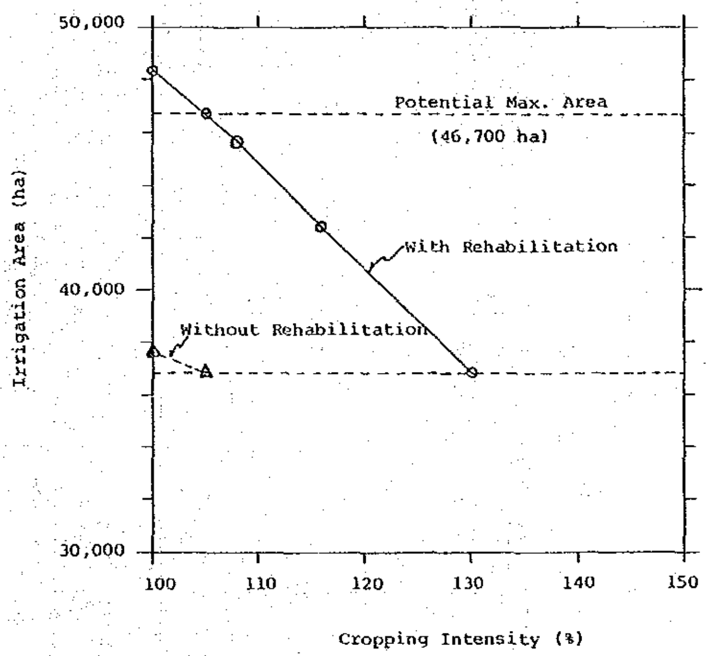



Fig. III-10 Relationship between Gross Reservoir Capacity and Irrigable Area




Calculation Condition

Gross Reservoir Capacity : 250 MCM

Cropping Pattern : Paddy + Mung Bean

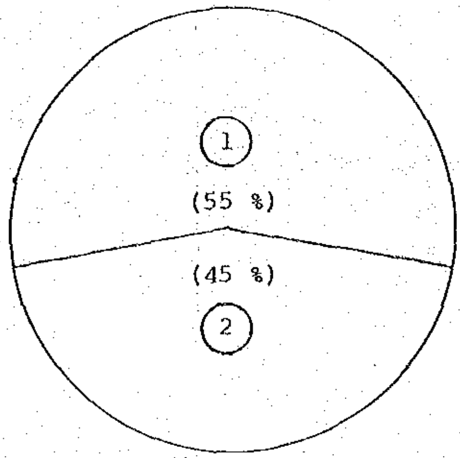
Fig. III-11 Relationship between Irrigable Area and Cropping Intensity

Average for 29 Years

(1954 to 1982)

Total Irrigation Requirement

$399,755 \times 10^3\ m^3$

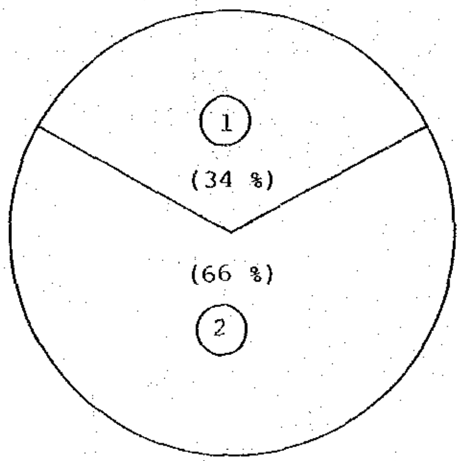



80 % Dependable Year

(1982)

Total Irrigation Requirement

$420,524 \times 10^3\ m^3$

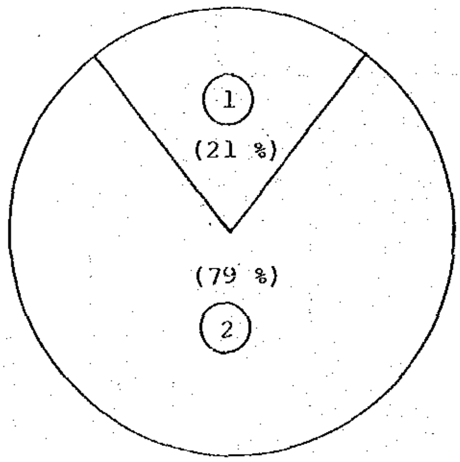



Dryest Year

(1977)

Total Irrigation Requirement

$454,891 \times 10^3\ m^3$




1 : Supplied from the downstream basin

2 : Supplied from the Upper Mae Wong Dam

Fig. III-12 Ratio of Water Supplied from Upper Mae Wong Dam in Irrigation Demand

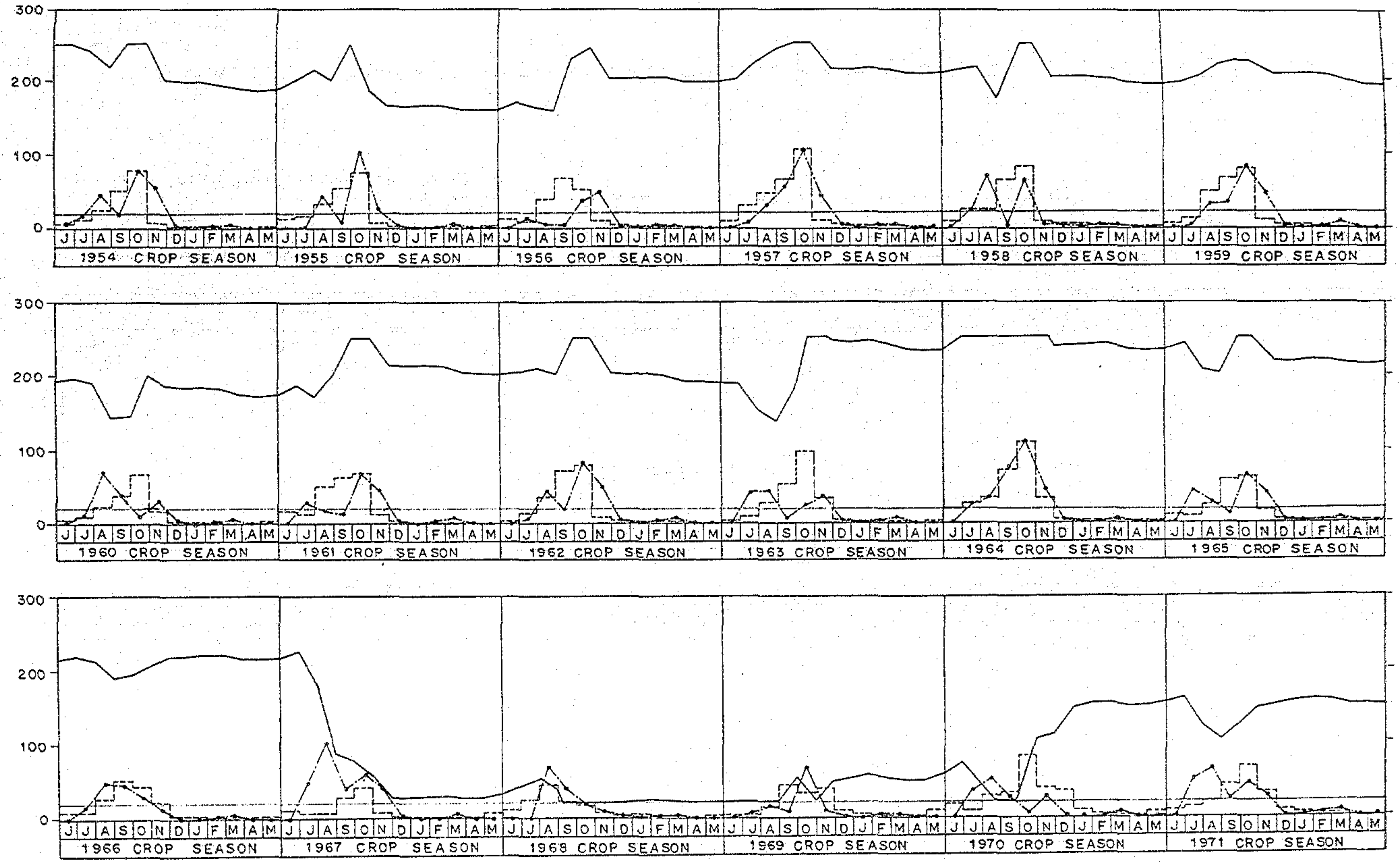



Fig. III-13 Storage Change of Upper Mae Wong Reservoir (1/2)

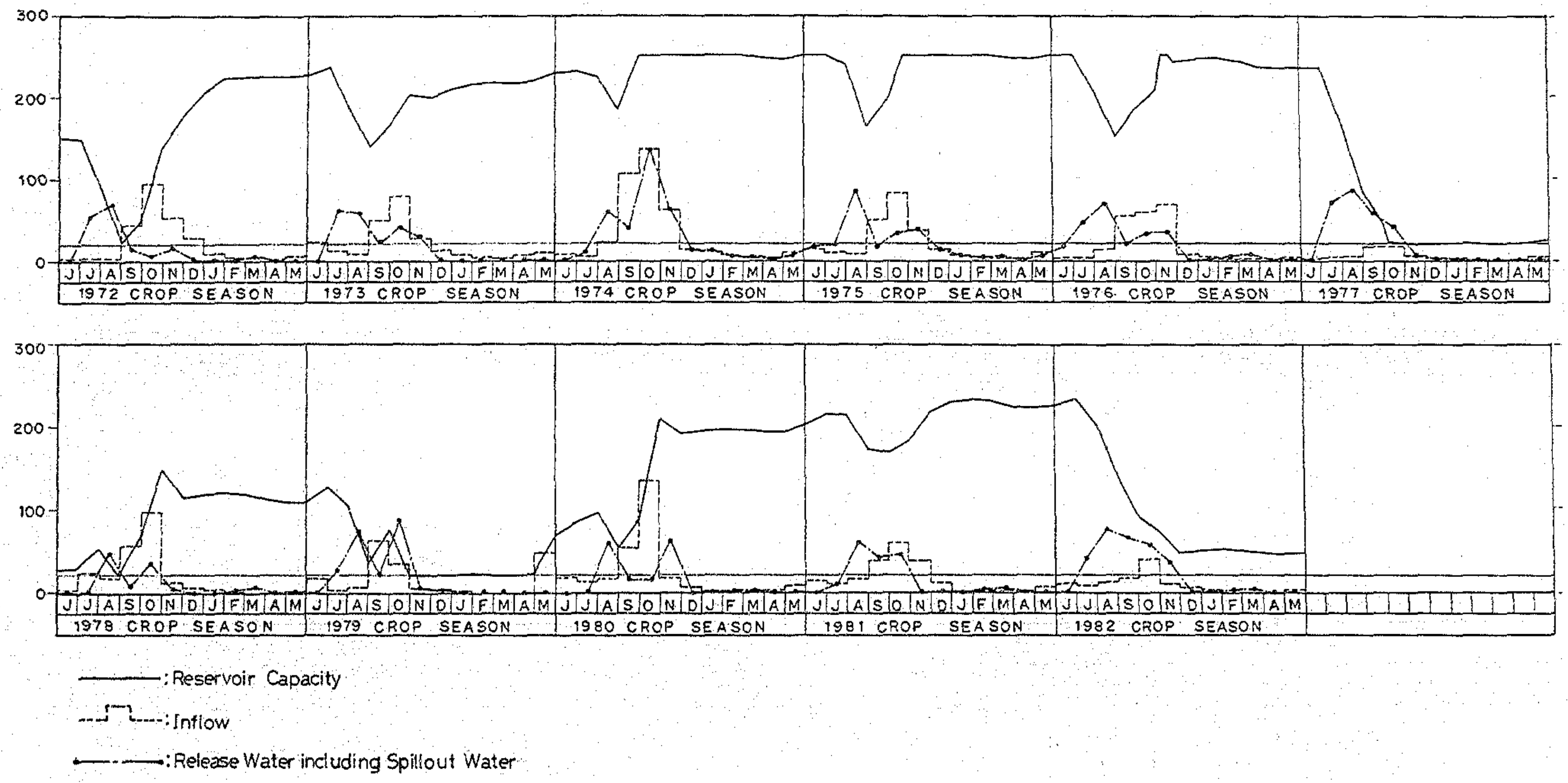
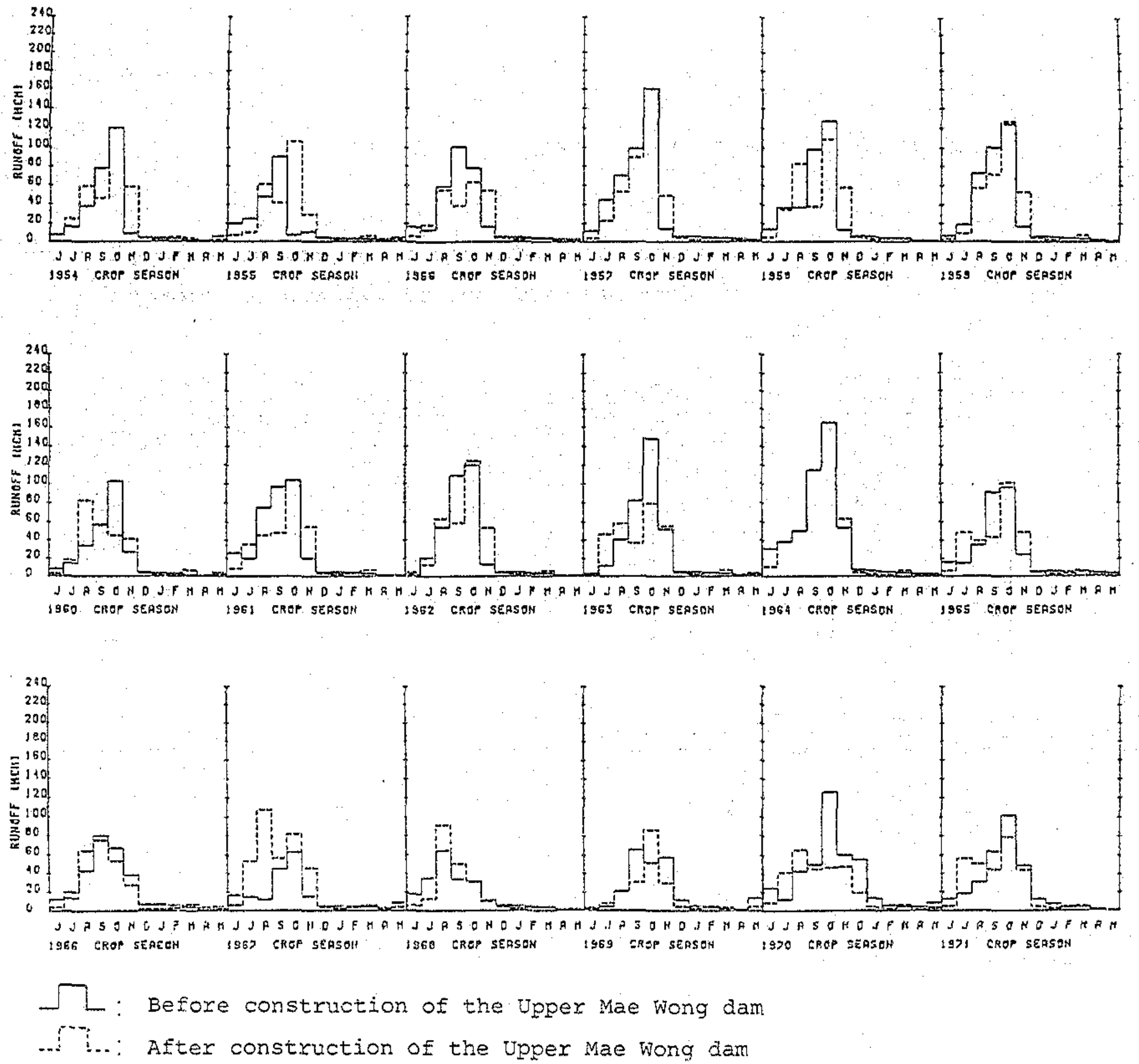


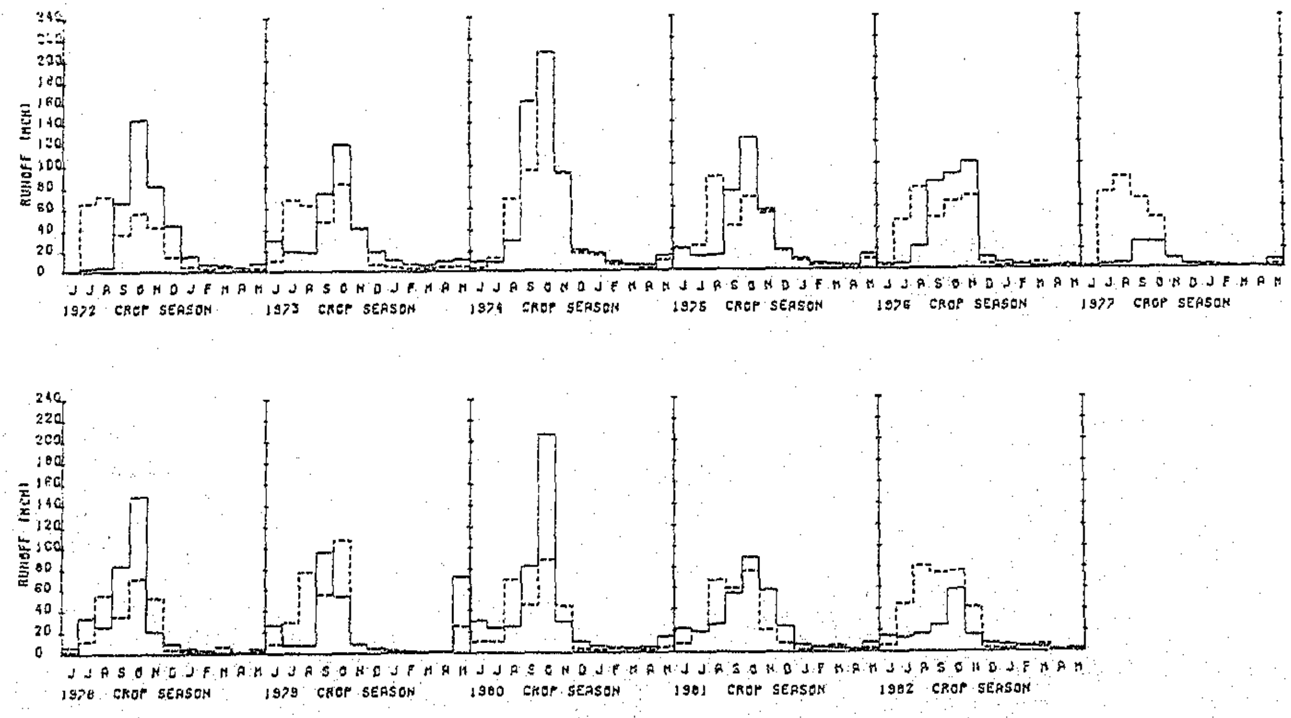

Fig. III-13 Storage Change of Upper Mae Wong Reservoir (2/2)




: Before construction of the Upper Mae Wong dam

: After construction of the Upper Mae Wong dam

Fig. III-14 Change of River Flow at CT 5A (1/2)




: Before construction of the Upper Mae Wong dam

: After construction of the Upper Mae Wong dam

Fig. III-14 Change of River Flow at CT 5A (2/2)

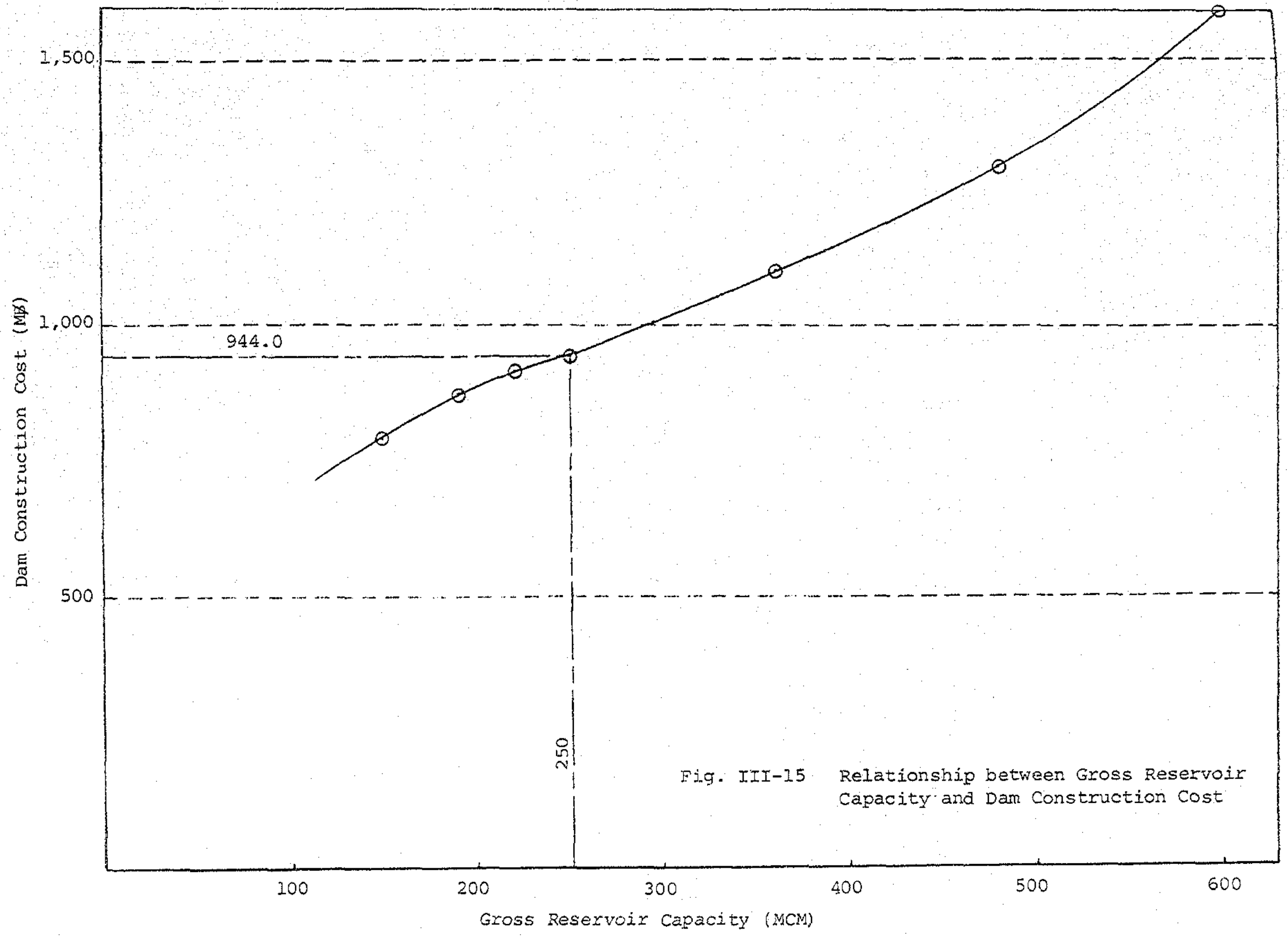



Fig. III-15 Relationship between Gross Reservoir Capacity and Dam Construction Cost

# ANNEX–IV
# DAM AND RESERVOIR

# ANNEX - IV

# DAM AND RESERVOIR

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ANNEX - IV

# DAM AND RESERVOIR

## 1. GENERAL CONDITION

A plan of the damsite and site map are shown on Fig. IV-2 and Fig. IV-3. The Upper Mae Wong dam is a center cored rockfill dam assuring water-tightness by founding the imprevious core entirely on sound rock with grout curtain beneath.

The dam has a crest length of about 800 m, width of 10 m and the maximum height of about 57 m above the base of impervious core. The impervious core is 4 m wide at crest elevation and about 22 m at base at the maximum dam section.

The upstream surface of the dam was designed with slope of 1.75 horizontal to 1 vertical. The downstream surface was designed with slope of 1.6 horizontal to 1 vertical. Total volume of earth and rock materials in the embankment is about 2,500,000 $m^3$.

The dam cross section is shown in Fig. IV-4 and major dimensions of dam are summarized in Table IV-1.

### 1.1 Location and Accessibility

The Upper Mae Wong damsite is located on the Mae Wong river and on the boundary of Kamphaeng Phet and Nakhon Sawan provinces, approximately at Latitude 15°55'N and Longitude 99°19'50"E. The nearest village is Ban Taling Sung, about 13 km downstream.

The damsite is easily accessible during dry season by 4WD vehicle through cart road from the village but not always during wet season. This road is about 20 km in length and would be widened, straightened and surfaced for use as an access road during the period of construction.

### 1.2 Investigations

#### 1.2.1 Topography

A topographic map of 1:1,000 scale with 1-meter contour intervals covering about 10 $km^2$, a distance of 1.5 km upstream and 1.5 km downstream from the damsite, was completed in June 1985 and used in the design of the dam. Another map of 1:10,000 scale with 5-meter contour intervals covering about 60 $km^2$ was also made at the same period of time and used in designing the area-storage capacity curves for the proposed reservoir. An aerial topographic map of 1:50,000 with 20-meter contour intervals was used for general purposes.

The first two basic maps were prepared by RID. The method used in the ground survey consisted of the horizontal control referred to RID grid system and the vertical control referred to the mean sea level.

### 1.2.2 Geology and soil mechanical investigation

A geological investigation of the damsite and the reservoir area was carried out to determine the soundness of the site and the water-tight qualities of the reservoir. Twelve holes, including percolation tests and standard penetration tests, were drilled to a total depth of 297.95 m. Rock was drilled by diamond bits of Nwm and Bwm with double core tube.

Nineteen test pits of 2 x 2 m were excavated, for a total depth of 37.7 m in order to investigate the embankment materials and to obtain the samples for soil mechanical tests. Twenty nine auger-hole drillings were conducted around dam axis for total depth of 26.8 m. All these geological investigations and soil mechanical laboratory tests were conducted by RID.

### 1.2.3 Hydrology

The catchment area of proposed damsite is 612 $km^2$. The annual inflow to the reservoir varies from 55 MCM to 541 MCM with an average of 220 MCM. The effective storage capacity of 230 MCM is required to irrigate 46,700 ha. The reservoir capacity and the height of the dam was determined on the basis of optimization study. The area-capacity curve of the reservoir is shown in Fig. IV-1. The summary of reservoir hydrological data is as follows:

| | |
|---|---|
| Total storage capacity | 250 MCM |
| Effective storage capacity | 230 MCM |
| Dead storage capacity (100 year) | 20 MCM |
| Water level at total storage (FWL) | EL 204.5 m |
| Water level at dead storage (DWL) | EL 180.0 m |
| Flood water level (HWL) | El 207.5 m |
| Area at total storage | 17.6 $km^2$ |
| Area at flood water level | 19.8 $km^2$ |

## 2. DAM TYPE AND DAM AXIS

### 2.1 Selection of Dam Type

Selection of dam type was based on the studies laying stress on the available materials near the damsite, foundation conditions and economical construction cost. During the initial phases of investigations of dam, concrete type, rockfill type and earthfill type were considered.

Since the height of dam is expected to be about 57 m, the embankment materials, especially impervious materials for filltype dams, should have sufficient shearing strength against shear failure and should be uniform in quality. Well decomposed and deeply weathered granite and diluvial deposits, located along right side of the river about 2 km downstream, were found to satisfy such requirements for impervious materials of the filltype dam. However, the obtainable quantity will be limited at maximum about 1,000,000 $m^3$ in gross. Rock materials such as granite, schist, calc-silicate and quartzite are predominant around damsite. These rocks are suitable for high embankment or sufficiently hard and solid for foundation of all types of dams. Surface coverages, soils and weathered portion of these rocks are very thin.

Earthfill type dam was not selected with the following reasons:

(1) Sufficient volume of earth materials would not be obtainable in the vicinity of dam.

(2) Excavated materials from the appurtenant structures of dam, would not be balanced with the embankment, which would result high construction cost with plentiful disposals of excavated rocks.

The factors leading to the selection of a concrete dam were the savings assumed from river diversion and spillway over the dam body. The river diversion would be planned on the confinement of flows to one side of the river channel during initial stage, followed by diversion through partially completed blocks during the second stage. The spillway would be designed on the dam body. These designs would result generally considerable savings over construction cost through diversion tunnel and side spillway as would be required on the dam abutments with a filltype dam.

However, the valley shape of the damsite is so wide, about 400 m at the base of dam and about 800 m at the crest of dam, that total concrete volume of the dam would be excessively large, not less than 700,000 $m^3$. Comparing with the embankment volume of about 2,500,000 $m^3$ for rockfill dam, the construction cost of concrete dam would be more than 2 times of construction cost of rockfill dam.

As stated in the design of dam, the zoning of rockfill dam was so designed as to fully utilize the excavated rock materials from the appurtenant structures. Borrow area would be required for embankments of impervious and semi-pervious zones. All rock zones embankments would be supplied from the excavated materials from spillways and diversion canals.

It was therefore concluded that rockfill type dam was suitable in all aspects such as material availability, suitability for high dam and economic construction.

## 2.2 Selection of Dam Axis

Detailed study on available topographic maps and geologic conditions led to the comparison study on the alternative dam axes. The topographic conditions of damsite are relatively complicated; the directions of ridges on both abutments are in discord, the river course is crossing damsite in almost parallel with dam axis and a depression, small but deep and steep, is located at right abutment.

The surveyed dam axis, selected from the aerial topographic map of 1:50,000 scale, was considered unsuitable as it is located on the said depression and its crest length is considered too long. Three alternative dam axes were selected for comparison as shown in Fig. III-5.

Preliminary designs and cost estimates were conducted on the alternative dam axes. The results are summarized below and dam center line No. 2 was selected. In this comparison, the costs for intake and outlet facilities, foundation treatment, emergency spillway and temporary works are excluded since they are common for each dam axis and the cost of temporary works will be proportional to the direct cost.

Work Quantity

| | | Dam Center Line | | |
|---|---|---|---|---|
| | | No. 1 | No. 2 | No. 3 |
| 1. River diversion | | | | |
| 1-1 Diversion tunnel | (m) | 370 | 230 | 390 |
| 1-2 Diversion canal | ($m^3$) | 152,300 | 138,300 | 66,000 |
| 1-3 Diversion dam | ($m^3$) | 75,600 | 78,700 | 213,500 |
| 2. Dam | | | | |
| 2-1 Excavation | ($m^3$) | 126,000 | 108,000 | 99,000 |
| 2-2 Embankment | ($m^3$) | 2,654,000 | 2,388,000 | 2,769,000 |
| 3. Service spillway | | | | |
| 3-1 Earth works | ($m^3$) | 463,000 | 659,000 | 304,000 |
| 3-2 Concrete works | ($m^3$) | 44,000 | 53,400 | 50,300 |

Construction Cost

(Unit: MCM ฿)

| | Dam Center Line | | |
|---|---|---|---|
| | No. 1 | No. 2 | No. 3 |
| 1. River diversion | | | |
| 1-1 Diversion tunnel | 74 | 46 | 78 |
| 1-2 Diversion canal | 8 | 7 | 3 |
| 1-3 Diversion dam | 3 | 4 | 9 |
| Sub-total | 85 | 57 | 90 |
| 2. Dam | | | |
| 2-1 Excavation | 24 | 21 | 19 |
| 2-2 Embankment | 584 | 525 | 609 |
| Sub-total | 608 | 546 | 628 |
| 3. Service spillway | | | |
| 3-1 Earth work | 69 | 99 | 46 |
| 3-2 Concrete work | 97 | 117 | 111 |
| Sub-total | 166 | 216 | 157 |
| Total | 859 | 819 | 875 |

## 3. EMBANKMENT MATERIALS AND DESIGN VALUE

### 3.1 Rock Materials

The charactors of rocks from structural excavation for diversion canal, tunnel, service spillway and emergency spillway are based essentially on core borings and laboratory tests. It is expected that these excavations would yield a substantial amount of large rock suitable for use in the outer rockfill zone of embankment, as well as smaller sizes for transition zone. Structural excavation rocks would be quartzite, calc-silicate and schist.

During the course of investigation, additional quarry sites were also found. One is located at about 3.0 km upstream right side of the river. According to the boring No. 9, rock will be quartzite. The other is located at about 3.5 km upstream, left side of the river and will produce granite rocks. Characteristics of rocks are summarized as follows:

| Rock | Gs | w (%) |
|---|---|---|
| Quartzite | 2.63 - 2.68 | 0.2 - 0.8 |
| Calc-silicate | 2.68 - 2.92 | 0.6 - 0.9 |
| Schist | 2.65 - 2.70 | 0.2 - 0.4 |
| Schistose Granite | 2.65 - 2.67 | 0.3 - 0.7 |
| Mean | 2.68 | 0.54 |

Note: Gs: Specific gravity
w: Water absorption ratio

It is generally accepted in the dam engineering that the rock materials having characteristics of specific gravity more than 2.5 and water absorption ratio less than 1.0% are suitable for large dam embankment. Rock materials available in the vicinity of damsite are considered to have good quality for embankment.

### 3.1.1 Design value

(1) Embankment density

Density of embankment zone will depend on quality, shape and gradation of materials, spreading thickness and compaction method. Generally, large and boulder-size rocks are placed in outer rock zone and boulder to gravel size in transition zone. Both zones will form shell structure of dam embankment. Evaluating from the boring core and field investigations, the porosity (n) to calculate density was estimated as follows at the condition of applying vibration equipment for embankment:

Rock zone $n = 30\%$

Transition zone $n = 25\%$

Then, the density of embankment zones are calculated.

(a) Rock zone

Void ratio : $e = \frac{n}{1 - n} = 0.429$

Wet density: $\gamma t = \frac{Gs}{1 + e} \times \gamma w = 1.88\ t/m^3$

where, Gs: Specific gravity at SSD condition
$GS = 2.68$ (mean value)

$\gamma w$: Unit weight of water
$\gamma w = 1.0\ t/m^3$

Saturated density: $\gamma sat = \frac{Gs + e}{1 + e} \times \gamma w = 2.18\ t/m^3$

(b) Transition zone

$$e = \frac{n}{1 - n} = 0.333$$

$$\gamma t = \frac{Gs \cdot \gamma w}{1 + e} = 2.01 \ t/m^3$$

$$\gamma sat = \frac{Gs + e}{1 + e} \times \gamma w = 2.26 \ t/m^3$$

(2) Shear strength

Shear strength of material is expressed usually, by two components of internal friction angle ø and cohesion C. Tri-axial compression test for rock material was not conducted but the test results for weathered granite or semi-pervious materials are available. The internal friction angle obtained from the tri-axial test for the weathered granite of damsite is 40 degrees in effective strength at maximum density. Internal friction angle for hard rock material is usually larger than the value for weathered semi-pervious materials. Based on the tri-axial test results on the ordinary granite rocks in Japan as shown in ANNEX II, and considering the above value for weathered granite at damsite, the design values of the shear strength were determined as follows:

| | |
|---|---|
| Rock zone | ø = 44.0 degree |
| Transition zone | ø = 42.0 degree |

In case of rock material, the cohesion component of shear strength is neglected for stability analysis.

3.2 Impervious Materials (Core Zone)

The impervious materials for core zone of embankment will be obtained from the borrow area located at about 2 km downstream rightside of the river.

The impervious earth materials are fine to medium graded decomposed granite. This granite particles contain large amount of feldspar which will be easily decomposed and become clayey through weathering and stock piling. The groundwater level in the borrow area is low and decomposed thickness will be limited at 1.5 to 2.5 m below top soil cover. The borrow area is estimated about 100 ha, extending about 400 to 450 m in width and about 2.5 km in length.

Estimated maximum yield of impervious materials from this borrow area would be 1,000,000 $m^3$ in gross.

### 3.2.1 Design value

(1) Embankment density

The results of standard Proctor compaction test on the representative core samples obtained from the test pits at the said borrow area are summarized as follows:

| Test Pit No. | | TP-2 | TP-3 | TP-12 | Average |
|---|---|---|---|---|---|
| $\gamma dmax$ | $t/m^3$ | 1.995 | 1.980 | 1.900 | 1.958 |
| Wopt | % | 9.2 | 9.2 | 11.5 | 10.0 |

Note: Energy applied in the compaction test was $5.625\ kg \cdot cm/cm^3$.

Impervious materials to be utilized for core zone of high embankment should be required to have sufficient strength in addition to the impreviousness. Following density control for imperious materials will be necessary during construction.

Dry density ($\gamma d$) $\geq \gamma dmax \times 95\%$

Considering these conditions and based on the test results, design values for embankment design were determined as follows:

Dry density : $\gamma d = 1.958 \times 0.95 = 1,860\ t/m^3$

Void ratio : $e = \frac{Gs \times \gamma w}{\gamma d} - 1 = 0.430$

Moisture content : $w = 10.0\%$ (= Wopt)

Wet density : $\gamma t = \gamma d \times (1 + \frac{w}{100}) = 2.05\ t/m^3$

Saturated density: $\gamma sat = \frac{(Gs + e)\gamma w}{1 + e} = 2.16\ t/m^3$

(2) Shear strength

Design values for shear strength are determined from the results of tri-axial compression test (undrained and consolidated condition and expressed by effective stress).

| Test Pit No. | Shear Strength | | Sample Condition | |
|---|---|---|---|---|
| | ø(degree) | C ($t/m^2$) | Dry Density | Moisture Content |
| TP-13 | 23.0 | 2.0 | $\gamma dmax \times 95\%$ | Wopt |
| TP-12 | 32.5 | 1.3 | $\gamma dmax \times 95\%$ | Dry side |

Samples from TP-12 show very high shear strength because of low moisture content. Permeability test on samples from TP-12 give greater value classified into semi-pervious. Samples from TP-13 give impervious values with condition of Wopt. Therefore, the results of TP-13 were applied for design values for impervious zone.

(3) Permeability

Most of results of permeability tests on core materials give permeability coefficient less than 1 x $10^{-6}$ cm/sec. Accordingly, the design values for construction is recommended to be 1 x $10^{-5}$ cm/sec which is quite common value for rockfill type dam.

## 3.3 Semi-Pervious Materials

The borrow area for semi-pervious materials are located in the reservoir area at about 2 km upstream of damsite. The material is decomposed and weathered granite graded medium to coarse and contains about 10% of silt particle. The groundwater level is low and materials are in dry side of embankment, having less plasticity.

### 3.3.1 Design value

(1) Embankment density

The results of standard proctor compaction tests (SPCT) on representative soil samples are as follows:

| Test Pit No. | 4 | 4 | 6 | 7 | Average |
|---|---|---|---|---|---|
| Sample depth | 0 - 2.2 m | 2.2 - 3.6 m | 0 - 2.4 m | 0 - 1.8 m | |
| $\gamma$dmax t/$m^3$ | 2,026 | 1,975 | 2,020 | 2,050 | 2,018 |
| Wopt % | 8.5 | 9.5 | 8.6 | 8.2 | 8.7 |
| Gs | 2.67 | 2.67 | 2.63 | 2.65 | 2.66 |

Note: $\gamma$dmax: Maximum density of SPCT
Wopt: Optimum moisture content
Gs: Specific gravity of soil particles

Natural water content is estimated at about 3 to 4% from the field investigations on test pits. Moisture control by sprinkling water will be necessary during construction. Assuming the condition of being 95% of $\gamma$dmax for the density control, the design values are claculated as follows:

Dry density : $\gamma d = \gamma d max \times 0.95 = 1,917\ t/m^3$

Void ratio : $e = \frac{Gs \times \gamma w}{\gamma d} - 1 = 0.388$

Moisture content : w = 8% (nearly equal to Wopt)

Wet density : $\gamma t = \gamma d \times (1 + \frac{w}{100}) = 2.07\ t/m^3$

Saturated density: $\gamma sat = \frac{(Gs + e) \times \gamma w}{1 + e} = 2.20\ t/m^3$

(2) Shear strength

The tri-axial tests with conditions of consolidated and undrained was conducted for samples from TP-6 to determine the design values of shear strength.

| Test Pit | | Shear Strength | | Sample Condition | |
|---|---|---|---|---|---|
| | | ø (degree) | C ($t/m^2$) | $\gamma d$ ($t/m^3$) | w (%) |
| TP-6 | No. 1 | 40.0 | 3.0 | 2,020 | 8.0 |
| | No. 2 | 36.5 | 3.0 | 1,919 | 8.0 |

Note: No. 1: Initial sample condition is at $\gamma dmax$ and Wopt.
No. 2: Initial sample condition is at $\gamma dmax \times 0.95$ and Wopt.

Taking safety measurement for design, smaller value was adopted.

Internal friction angle: ø = 36 degrees

Cohesion : $C = 3.0\ t/m^2$

3.4 Filter Material

Filter materials are obtained from the river deposit containing medium to coarse sand and less gravel and clay. Relatively coarse textured sand is deposited along left side of river course. Laboratory tests to determine the design values for embankment were not conducted. Common values were adopted for the study.

Wet density : $\gamma t = 1.90\ t/m^3$

Saturated density: $\gamma sat = 2.00\ t/m^3$

Shear strength : ø = 30.0 degree
$C = 0\ t/m^2$

## 3.5 Summary of Design Value

| Zone | $\gamma t$ $(t/m^3)$ | $\gamma sat$ $(t/m^3)$ | $\phi$ (degree) | C $(t/m^2)$ |
|---|---|---|---|---|
| Rock | 1.88 | 2.18 | 44.0 | 0 |
| Transition | 2.18 | 2.26 | 42.0 | 0 |
| Semi-pervious | 2.07 | 2.20 | 36.0 | 3.0 |
| Impervious (Core) | 2.05 | 2.16 | 23.0 | 2.0 |
| Filter | 1.90 | 2.00 | 30.0 | 0 |

# 4. DESIGN OF DAM

## 4.1 Basic Design Condition

### 4.1.1 Seismic force

Seismic force is one of the major components in the design of large dam. Data on the distribution of epicenter locations and their magnitudes are available for the period from 1912 to 1981 in the Studies and Research Division of the Meteological Department and they are shown in Fig. IV-6. The most of epicenters are located along the Indian ocean plate which has arciform extending from Indonesia to Burma. Reliable epicenters of greater magnitude are not recorded within Thailand.

(1) Seismic acceleration force distribution

Along the epicenter arciform belt, the maximum magnitude of M = 8 was recorded at two points but eastern area of arciform belt has relatively minor magnitude epicenters. Drawing the envelope line along the eastern edge of the recorded epicenter locations and assuming M = 7 to 8 magnitude on the envelope with depth of 40 km from the ground surface, the seismic acceleration force (gal) distribution was estimated. The results are shown in Fig. IV-7. In the calculation of relation between distance from the epicenter and seismic force (gal), the following formula were adopted.

(a) Seed (1968)

$$\log Gmax = 2.04 + 0.35\ M = 1.6 \log L$$

(b) Okamoto (1979)

$$\log \left(\frac{Gmax}{1{,}000}\right) = \frac{L + 50}{100}\ (-\ 4.93 + 0.89\ M - 0.043\ M^2)$$

where, M: Magnitude
Gmax: Maximum acceleration (gal)
L: Distance from epicenter (km)

(2) Seismic force coefficient

The Upper Mae Wong damsite is located about 300 km away from the eastern edge of epicenter zone. The seismic acceleration force at damsite will be 5 to 10 gal according to the choice of magnitude at 7 to 8. The seismic coefficient Kh is then derived at 0.01 by 10 gal/980. Taking safety factor at 3, Kh will be 0.03. However, according to the information given by Dr. Suphon, Geology Div., the latest earthquake record in 1983 will result greater value of seismic coefficient of about 0.02. Taking same safety factor 3, the design value for Kh was then determined at 0.06. This will be reasonably conservative for a well-constructed dam on a sound rock foundation, in an area of historically limited earthquake activity.

### 4.1.2 Dam dimension

(1) Freeboard

Freeboard above flood surcharge water level is given as follows:

Freeboard = R + 1.0 m > 2.0 m

where, R: Wave creep height to the upstream slope

For estimation of R, the Fig. IV-8 is adopted. The minimum freeboard is 2.0 m.

(2) Crest detail

(a) Core zone crest elevation

Core crest elevation should not be less than (H.W.L + Freeboard), where H.W.L is flood surcharge water level.

(b) Dam crest elevation

Dam crest elevation = Core crest + Crest road thickness

(c) Dam crest width

Dam crest is often used as a part of local road and the crest width is determined as follows, taking a minimum width of 8 m:

$B = 3.6\sqrt[3]{H} - 3.0$ for earthfill dam

$B = 0.05 H + 6.0$ for rockfill dam

H: Dam height (m)

4.1.3 Allowable factors of safety

The following minimum allowable factors of safety against slope failure were adopted as criteria in the design:

| Operating Condition | Minimum Factor of Safety |
|---|---|
| End of construction | |
| Static condition | 1.40 |
| Rapid drawdown | |
| Static condition | 1.20 |
| With seismic coefficient 0.03* | 1.10 |
| Steady-state seepage | |
| With seismic coefficient 0.06 | 1.30 |

Note: *: Rapid drawdown of water level is not expected frequently and probability of simultaneous occurrence of earthquake must be very low. Therefore, a half of seismic coefficient is adopted.

## 4.2 Embankment Design

### 4.2.1 Crest design

(1) Freeboard

The freeboard is designed at 3.0 m taking design factors as follows:

| | | |
|---|---|---|
| Distance to the opposite shore | : | F = 6.2 km |
| Maximum wind velocity | : | V = 30 m/sec |
| Embankment slope | : | 1:1.7 |
| Slope surface | : | Rugged surface |
| Wave creep height | : | R = 1.7 m |

Hf = 1.7 + 1.0 = 2.7 m, rounded at 3.0 m

(2) Crest of core zone

H.W.L. + Hf = El. 207.5 + 3.0 = El. 210.5 m

H.W.L.: Flood water surcharge level

(3) Dam crest

El. 210.5 + Crest road 0.5 m = El. 211 m

(4) Crest width

$B = 6 + 0.05 H = 8.9$ m

$B = 3.6 \times {}^{3}H - 3 = 10.9$ m

Taking average value, crest width is designed at 10 m.

4.2.2 Zoning of dam

Dam type and its zoning are always determined from mainly three factors, i.e. material availability at site, soil mechanical characteristics and construction cost. Sometime, the dam foundation condition will be added to these factors. In case of the Upper Mae Wong dam, as for material availability, rock materials of good quality will be produced from the structural excavations for service spillway, emergency spillway, foundation excavation and diversion tunnel. Besides these, quarry sites are located at both abutments and almost everywhere in the reservoir area. As for core material, the supply source is located at about 2 km downstream of damsite but available volume will be limited. Following five zones were designed by trial and error on the balance of material supply, economic comparison and stability analysis. Sloping of dam was determined at 1.75 horizontal to 1 vertical at upstream surface and 1.6 horizontal to 1 vertical at downstream surface.

(1) Impervious zone (Core zone)

Owing to the limited supply of impervious materials, relatively narrow center core was selected to keep reservoir seepage losses to a practical minimum. The core is 4 m wide at the crest, 22 m at the base and sloping of upstream and downstream at 0.16 horizontal to 1 vertical.

(2) Rock zone

Rock zone will work as a shell of embankment to control and improve total stability of embankment. Material sources for this zone are structural excavations at service spillway and emergency spillway.

(3) Transition zone

This zone is designed at inner zone of outer rock zone. The function of this is to form a shell of embankment same as outer rock zone but finner rocks will be placed to adjust grain size distribution between rock zone and semi-pervious zone. In the course of rock excavation at structural site, production of finner size rock are inevitable and supply sources for this zone are both spillways excavation and dam foundation excavation.

(4) Semi-pervious zone

This zone is designed between transition rock and filter zone. Sometimes it is called random zone. From the single point of dam stability, replacement of rock zone by this zone is not recommendable as the shear strength is usually lower. However, construction cost of rock zone is always high and production of random materials, not so impervious as core material but not so strong as rock, is inevitable in all damsite. Considering these conditions, this zone was also designed within the safety measurement of stability. Material sources are common soil at both spillway site, diversion canal excavation and borrow area at upstream of damsite.

(5) Filter zone

Reservoir seepage through the embankment and underlying foundation is controlled by 3.0 m wide filter zone along the downstream face of impervious core zone. Drainage blanket and finger drains are placed on the foundation downstream of the core to carry both under-seepage and water from the filter zone to the downstream toe.

The upstream filter zone was also designed to provide for relief of internal hydrostatic pressure and improved stability during rapid fluctuations in reservoir level.

Material sources for the filter zone will be diversion tunnel excavation and river sand.

### 4.2.3 Stability analysis

Stability of the dam against sliding was analyzed by means of sliced slip circle method. A safety factor obtained by the slip circle method is derived by the following formula:

$$Fs = \frac{\Sigma\{C'\ell + (N-Ne) \cdot \tan \phi'\}}{\Sigma(T + Te)}$$

where,
- Fs: Safety factor
- N: Normal effective force acting on sliced slip circle
- T: Tangent effective force acting on sliced slip circle
- Ne: Normal force by seismic load on sliced slip circle
- Te: Tangent force by seismic load on sliced slip circle
- C', $\phi'$: Cohesion and internal friction angle of embankment material
- $\ell$: Arc length of sliced slip circle

Operating conditions for stability analysis are as follows:

Case A: End of construction with static condition

Case B: Rapid drawdown of reservoir water level with seismic coefficient of 0.03

Case C: Steady-state seepage condition with seismic coefficient of 0.06

Case D: Surface sliding calculated by surface plate sliding method

As for cohesionless materials, the slip circle method has characteristics that the safety factor would become smaller when the slip circle becomes shallow. Therefore, the analysis for such case is made by surface plate sliding method as shown below:

$$F_S = \frac{\left(1 - m \cdot k \frac{\gamma sat}{\gamma'}\right)}{m + \frac{\gamma sat}{\gamma'} \cdot k} \tan \phi'$$

where, $F_S$: Safety factor
$m$: Gradient of slope
$k$: Seismic coefficient
$\phi'$: Angle of internal friction of materials
$\gamma sat$: Saturated density of material
$\gamma'$: Submerged density of material

The above formula was applied to the slope under the water level of reservoir, and for the slope above the water level, the formula can be applied by substituting the wet density ($\gamma t$) for both $\gamma sat$ and $\gamma'$.

The results of stability analysis are summarized as follows:

| Case | Reservoir Water Level | Slope | Seismic Coefficient | Safety Factor | Minimum Safety Factor |
|---|---|---|---|---|---|
| A | Empty | Upstream | 0 | 1.60 | 1.40 |
| A | Empty | Downstream | 0 | 1.44 | 1.40 |
| B | El. 204.5 m - El. 180 m | Upstream | 0.03 | 1.42 | 1.10 |
| C | El. 204.5 m | Upstream | 0.06 | 1.35 | 1.30 |
| C | El. 204.5 m | Downstream | 0.06 | 1.39 | 1.30 |
| C | El. 190.0 m | Upstream | 0.06 | 1.38 | 1.30 |
| D | —— | Upstream | 0.06 | 1.33 | 1.20 |
| D | —— | Downstream | 0.06 | 1.36 | 1.20 |

Above results of analysis satisfy the stipulated safety factors and imply that the dam is reasonably safe against sliding.

## 4.3 Spillway

The Upper Mae Wong spillway consists of service spillway and emergency spillway to utilize topographic features of damsite. Service spillway is located at rightside abutment and an emergency spillway at about 1.5 km north where the topography is in saddle shape and ground elevation is about 210 m and lower than the dam crest elevation.

### 4.3.1 Design flood

An extensive hydrometeorological study was undertaken, concentrating on the climatology and hydrology of the Mae Wong river basin with due consideration on the overall hydrological conditions of the Sakae Krang river basin. The results of study are given in ANNEX I.

The spillway design flood was determined to be 20 percent increased value of flood which derived from one-day rainfall of 260 mm with 200-year return period, occurring uniformly over the entire basin. The design flood was determined at 1,770 $m^3$/sec which coincides with the flood probability scale of about 600-year return period.

Flood routing study was conducted to clarify the function of flood retention capacity expected between the designed flood surcharge level of El. 207.5 m and spillway crest level of El. 204.5 m. The results of study are presented in ANNEX I. It was then confirmed that, within the designed surcharge water level, the reservoir will allow to control the flood inflow scale up to 2,000 $m^3$/sec or flood probability of 1,500-year return period.

| Flood Scale | Peak Flood ($m^3$/sec) | Max. Reservoir Water Level (m) |
|---|---|---|
| 10-year | 860 | El. 206.4 |
| 50-year | 1,200 | 206.8 |
| 100-year | 1,340 | 206.9 |
| Design flood | 1,770 | 207.3 |
| 1,500-year | 2,000 | 207.5 |

### 4.3.2 Service spillway

Service spillway was designed to release the flood of 1,200 $m^3$/sec, corresponding to the flood scale of 50-year return period. Service spillway consists of un-gated side-flow intake crest, of 110 m in length and 3.0 m of overflow design depth, guide channel of 16 m in width, chute channel and stilling basin of 35 m in width, 21 m in height and 75 m in length. Total concrete volume required is estimated at about 50,000 $m^3$.

The spillway alignment was selected to minimize the excavation volume and the area of excavated slope surface above the spillway.

### 4.3.3 Emergency spillway

Emergency spillway was designed to have several purposes.

(1) to release flood water of 570 $m^3$/sec,

(2) to improve saddle shape topography of lower elevation than the dam crest elevation,

(3) to treat a geologic fault expected from boring No. 8, and

(4) to supply rock materials for dam embankment.

The emergency spillway was designed to be of un-gated chute type with crest length of 210 m, crest elevation at 206.0 m and overflow depth of 1.5 m. Concrete volume required would be about 19,000 $m^3$. Excavated rock volume would be about 500,000 $m^3$. Foundation grouting was also designed with 6 m depth and 2 lines under the spillway crest.

## 4.4 River Diversion

### 4.4.1 Diversion requirement

A diversion capability of 480 $m^3$/sec was required from historical peak flow records. The design discharge of 480 $m^3$/sec was determined from the probability analysis on the peak flow discharges recorded at gaging stations in the Sakae Krang river basin.

| Gaging Station | Flood Scale ($m^3$/sec/$km^2$) | | |
|---|---|---|---|
| | 5-year | 10-year | 20-year |
| CT-5 | 0.11 | 0.15 | 0.19 |
| CT-5A | 0.48 | 0.64 | 0.80 |
| CT-6 | 0.44 | 0.60 | 0.76 |
| CT-7 | 0.56 | 0.78 | 1.02 |
| CT-9 | 0.23 | 0.33 | 0.43 |

Flood scale of 10-year return period was adopted considering the required period of 5 years for dam construction works.

Specific discharge of 0.78 $m^3$/sec/$km^2$ at CT-7 was applied for the river diversion discharge, which corresponds to the maximum flow discharge recorded for past 14 years at CT-5A gaging station located at about 13 km downstream of damsite. Discharges derived from CT-7 probability calculation and from maximum flow record at CT-5A are compared as follows:

| | CT-7 | | CT-5A | |
|---|---|---|---|---|
| | 10-year | 20-year | Max. | Ave. (14 years) |
| Specific Discharge ($m^3$/s/$km^2$) | 0.78 | 1.02 | 0.75 | 0.33 |
| Damsite ($m^3$/s) | 480 | 620 | 460 | 200 |

### 4.4.2 Diversion tunnel

The diversion of the Mae Wong river would be accomplished through a horseshoe-shaped tunnel of 7.6 m inside diameter, which bypass the damsite through left abutment. The design of diversion tunnel is shown in Fig. IV-9.

The tunnel was designed to accommodate a flow of 480 $m^3$/sec at water surface of elevation 173 m. The diversion tunnel, together with lead channel at upstream and diversion channel at downstream would be constructed while the river is flowing in its natural channel.

### 4.4.3 Coffer dam

Coffer dam was designed to protect over-topping of dam body during early stage of construction and to raise the flood water level giving necessary hydraulic head to pass the flood through diversion tunnel. Taking about 1.0 m of free-board above the flood water level at designed diversion flood, the crest of coffer dam was determined at El. 174.0 m. Major dimensions of coffer dam are as follows:

| | | |
|---|---|---|
| Height | | 15.0 m |
| Crest width | | 7.0 m |
| Crest elevation | | El. 174.0 m |
| Crest length | | 330.0 m |
| Embankment slope | Upstream | 1:2.0 |
| | Downstream | 1:1.5 |

## 4.5 Intake Structure

### 4.5.1 Design intake capacity

Design intake capacity is determined from the water balance calculation applying following formula:

$$Qd = Kmax \times 2g \cdot Hmax$$

where, Qd: Design intake capacity ($m^3$/sec)
K: Variable ($m^2$)
H: Available hydraulic head for intake (m)
g: Gravity acceleration coefficient, 9.8 m/$sec^2$

Values of minimum H and maximum K are calculated for each year from water balance calculation for 30 years as shown in Table IV-2. Then the design intake capacity is determined at 43 $m^3$/sec.

$$Qd = 2.078 \times 2 \times 9.8 \times (180 - 158.23)$$
$$= 43 \ m^3/sec$$

In the above calculation, the value 158.23 means the elevation of outlet elevation at the end of outlet pipe.

### 4.5.2 Intake structure

Intake structure was designed as drop inlet type located at the entrance of diversion tunnel. The intake pipe is to be placed through the diversion tunnel. Major dimensions of intake structure are as follows:

| | | |
|---|---|---|
| Drop inlet | Diameter | 5.0 m |
| Intake pipe | Length | 281 m |
| | Diameter | 3.4 m |
| Outlet valves | Diameter | 1.5 m and 1.4 m |

Table IV-1 SUMMARY OF RESERVOIR AND DAM

| | | |
|---|---|---|
| **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 | $km^2$ |
| Flood surcharge area | 19.8 | $km^2$ |
| Dead storage area | 3.0 | $km^2$ |
| **2. Dam** | | |
| Type | Center-cored rockfill type | |
| Height | 57 | m |
| Crest elevation | El 211 | m |
| Crest length | 794 | m |
| Crest width | 10 | m |
| Slopes | upstream 1 : 1.75 | |
| | downstream 1 : 1.6 | |
| Embankment volume | 2,500,000 | $m^3$ |
| **3. Spillway** | | |
| Service spillway | Ungated side channel type | |
| Design discharge | 1,200 | $m^3/s$ |
| Crest length | 110 | m |
| Emergency spillway | Ungated chute type | |
| Design discharge | 570 | $m^3/s$ |
| Crest length | 210 | m |
| **4. River diversion** | | |
| Approach canal | 220 | m |
| Diversion tunnel | 230 | m |
| Diameter | 2R Horse shoe 7.6 | m |
| Diversion canal | 790 | m |
| Diversion dam | 90,000 | $m^3$ |
| **5. Intake and outlet works** | | |
| Intake design discharge | 43 | $m^3/sec$ |
| Intake structure | Drop inlet | |
| Outlet pipe diameter | 3.4 | m |

Table IV-2 CALCULATION OF K

| Year | Intake for Irrigation ($m^3$/sec) | Min. Reservoir Water Level (m) | K |
|---|---|---|---|
| 1954 | 22.503 | 201.11 | 0.776 |
| 1955 | 51.304 | 200.09 | 1.791 |
| 1956 | 21.547 | 201.23 | 0.742 |
| 1957 | 19.178 | 202.04 | 0.654 |
| 1958 | 26.998 | 199.07 | 0.954 |
| 1959 | 21.245 | 201.09 | 0.732 |
| 1960 | 30.289 | 199.00 | 1.071 |
| 1961 | 22.323 | 202.09 | 0.761 |
| 1962 | 21.740 | 204.17 | 0.724 |
| 1963 | 21.256 | 196.71 | 0.774 |
| 1964 | 16.520 | 203.75 | 0.553 |
| 1965 | 19.366 | 202.39 | 0.658 |
| 1966 | 22.027 | 201.19 | 0.759 |
| 1967 | 39.104 | 195.05 | 1.456 |
| 1968 | 30.203 | 180.00 | 1.462 |
| 1969 | 29.630 | 184.90 | 1.296 |
| 1970 | 27.718 | 182.03 | 1.283 |
| 1971 | 24.741 | 193.31 | 0.944 |
| 1972 | 30.355 | 184.22 | 1.345 |
| 1973 | 29.335 | 201.28 | 1.010 |
| 1974 | 23.428 | 201.03 | 0.809 |
| 1975 | 31.639 | 198.51 | 1.126 |
| 1976 | 30.138 | 199.95 | 1.054 |
| 1977 | 31.867 | 194.34 | 1.198 |
| 1978 | 24.038 | 183.15 | 1.088 |
| 1979 | 47.728 | 185.14 | 2.078 |
| 1980 | 24.090 | 188.93 | 0.982 |
| 1981 | 26.188 | 197.87 | 0.940 |
| 1982 | 29.492 | 189.51 | 1.191 |

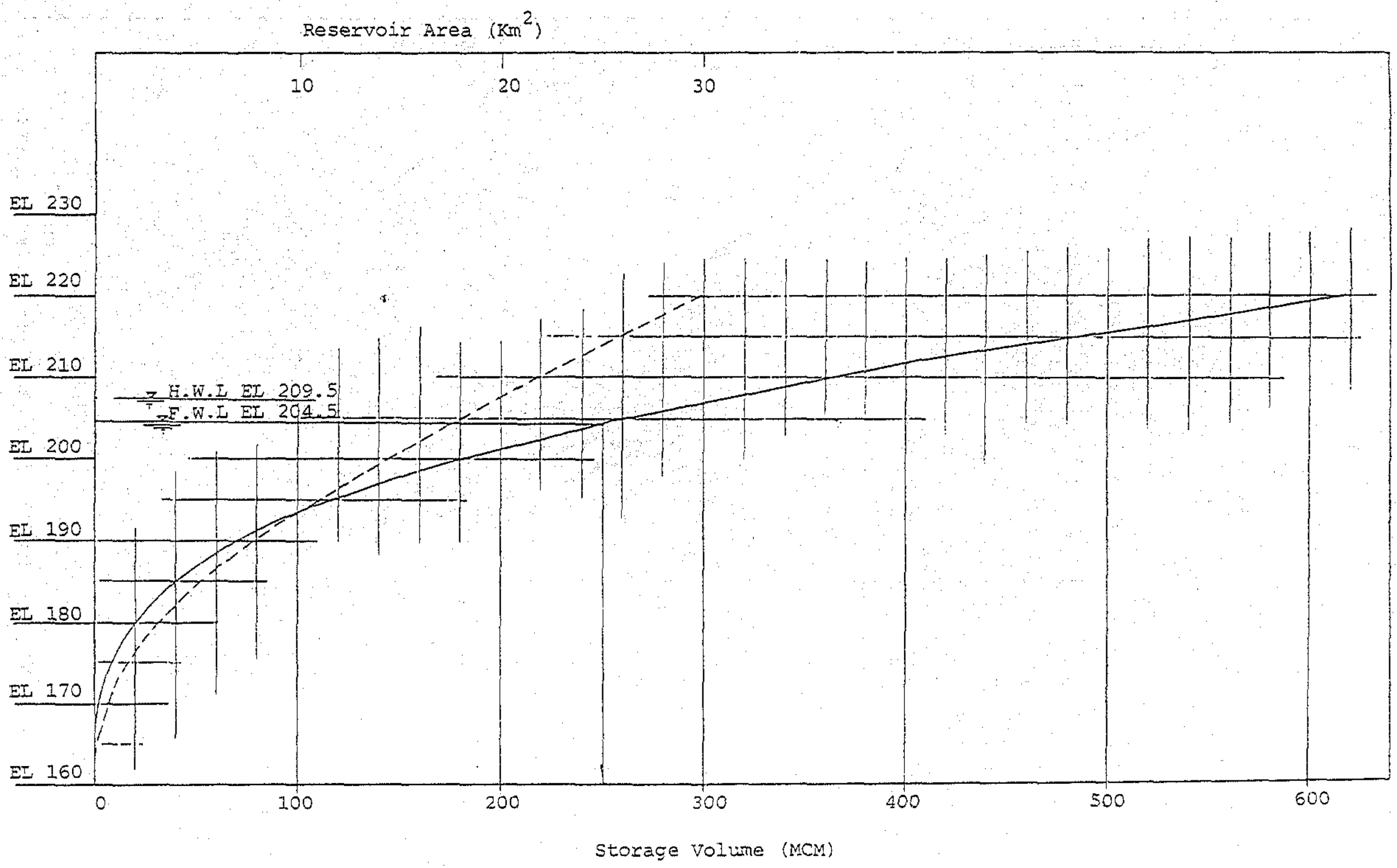



Fig. IV-1 Area-Capacity Curve

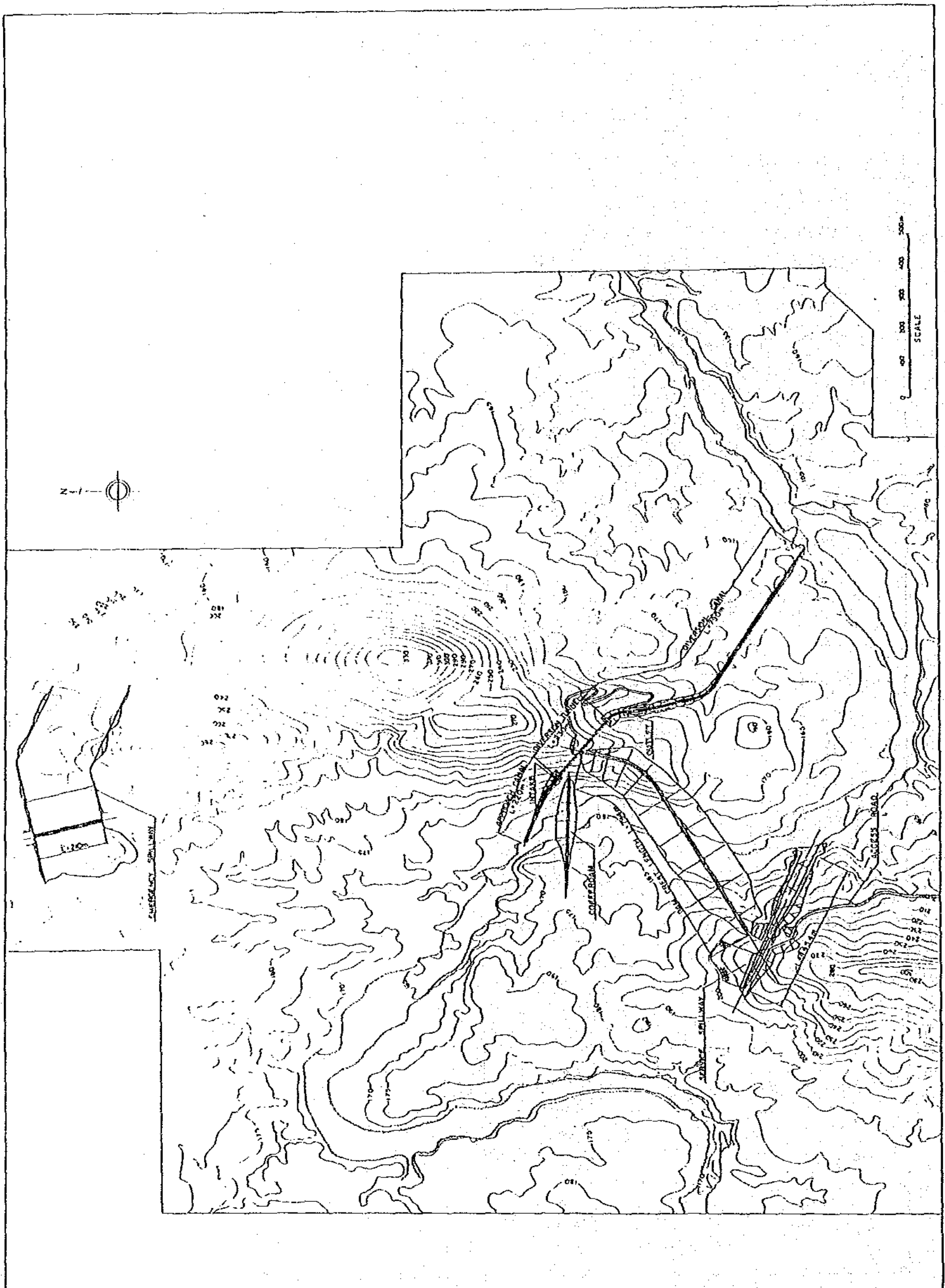



Fig. IV-2 Site Map

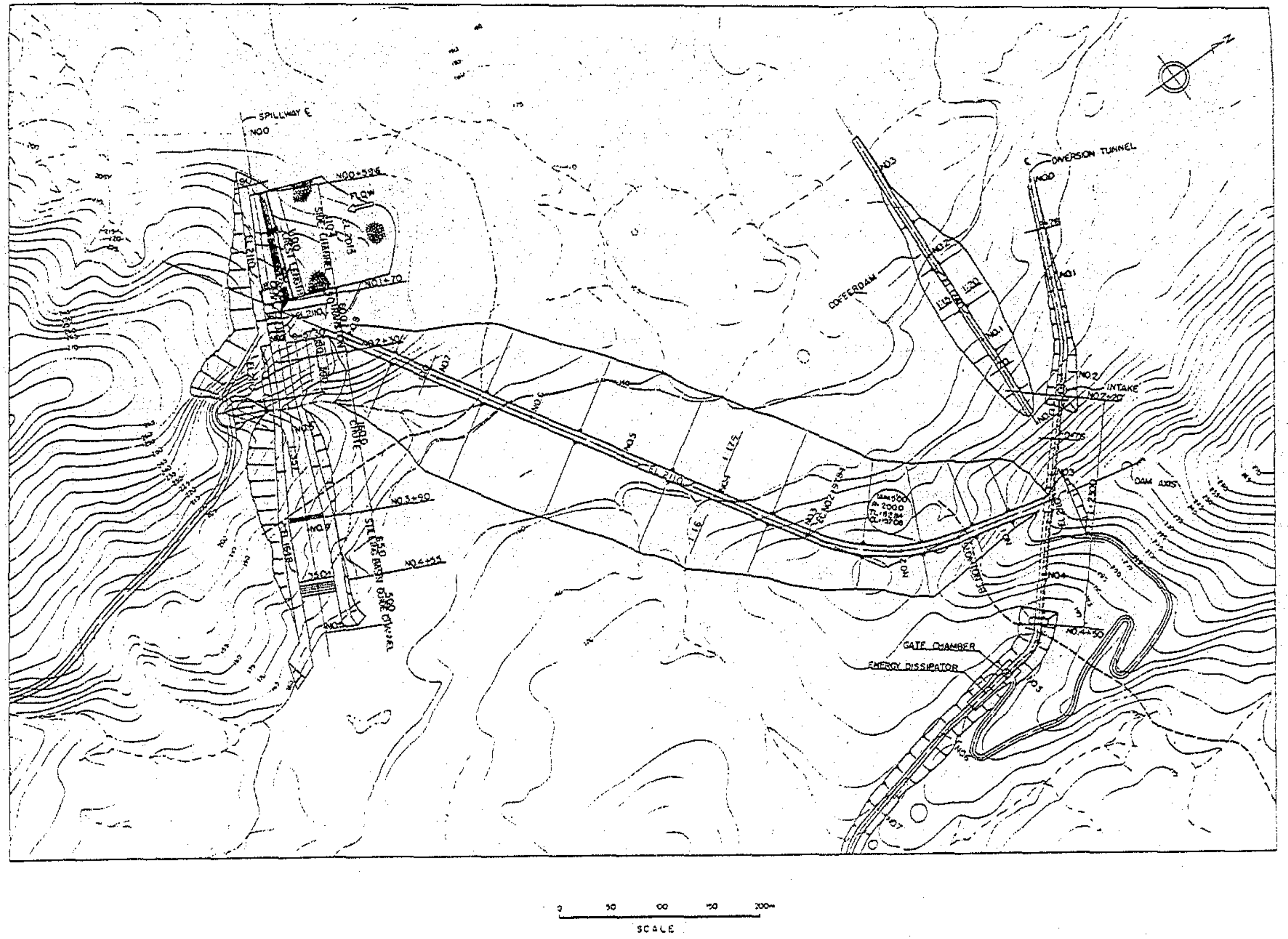



Fig. IV-3 General Plan

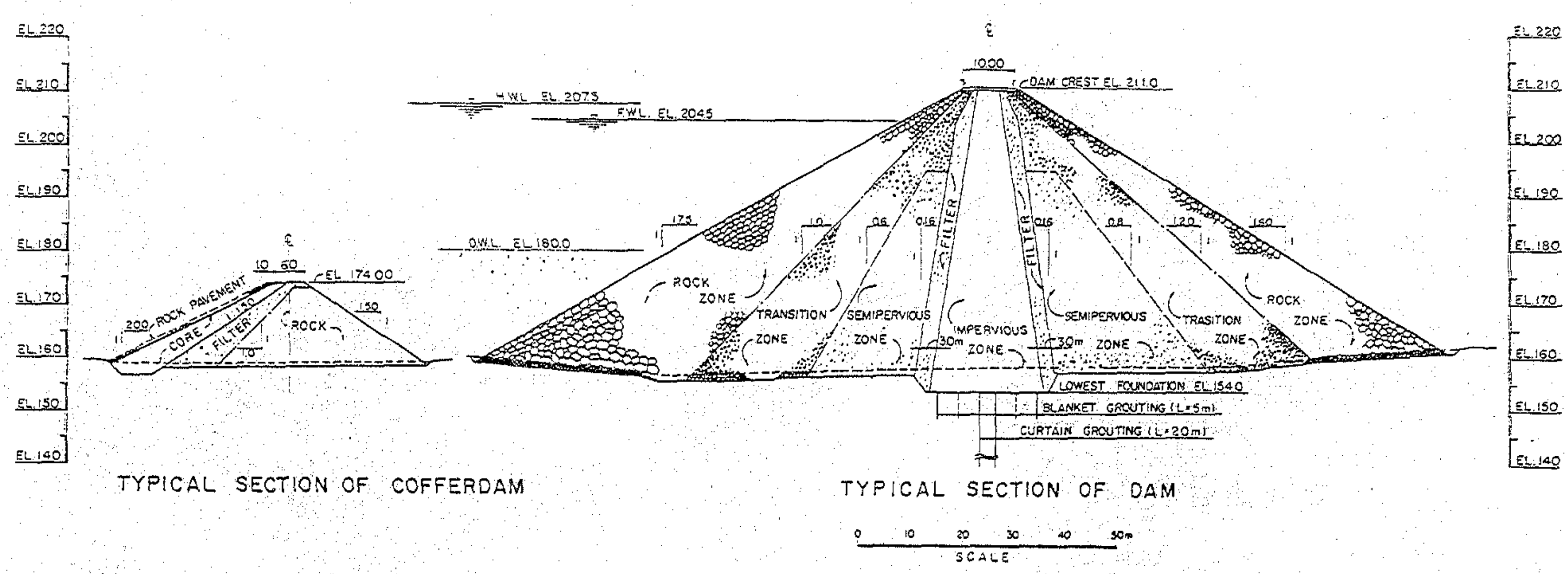



Fig. IV-4 Cross Section of Dam

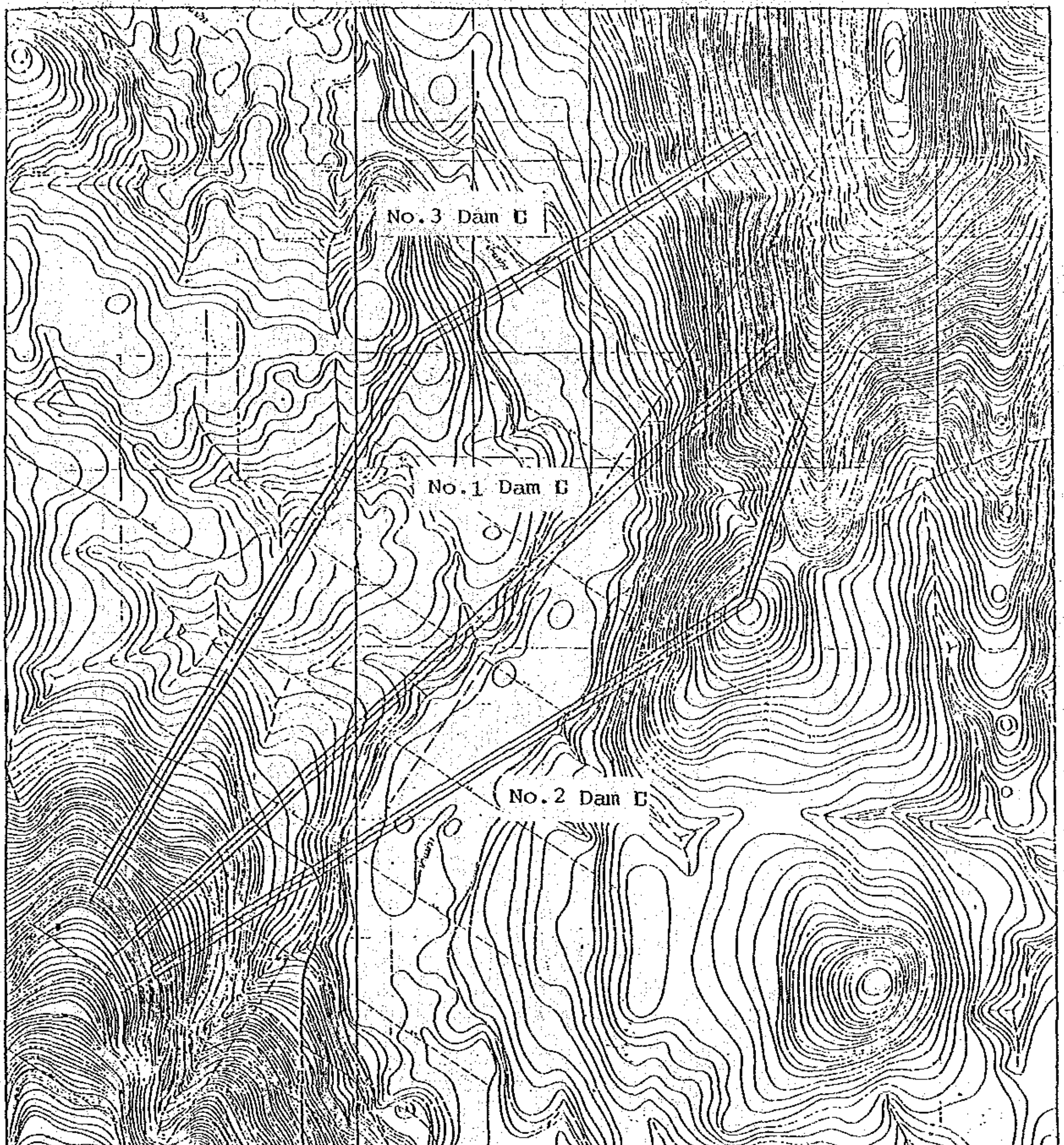
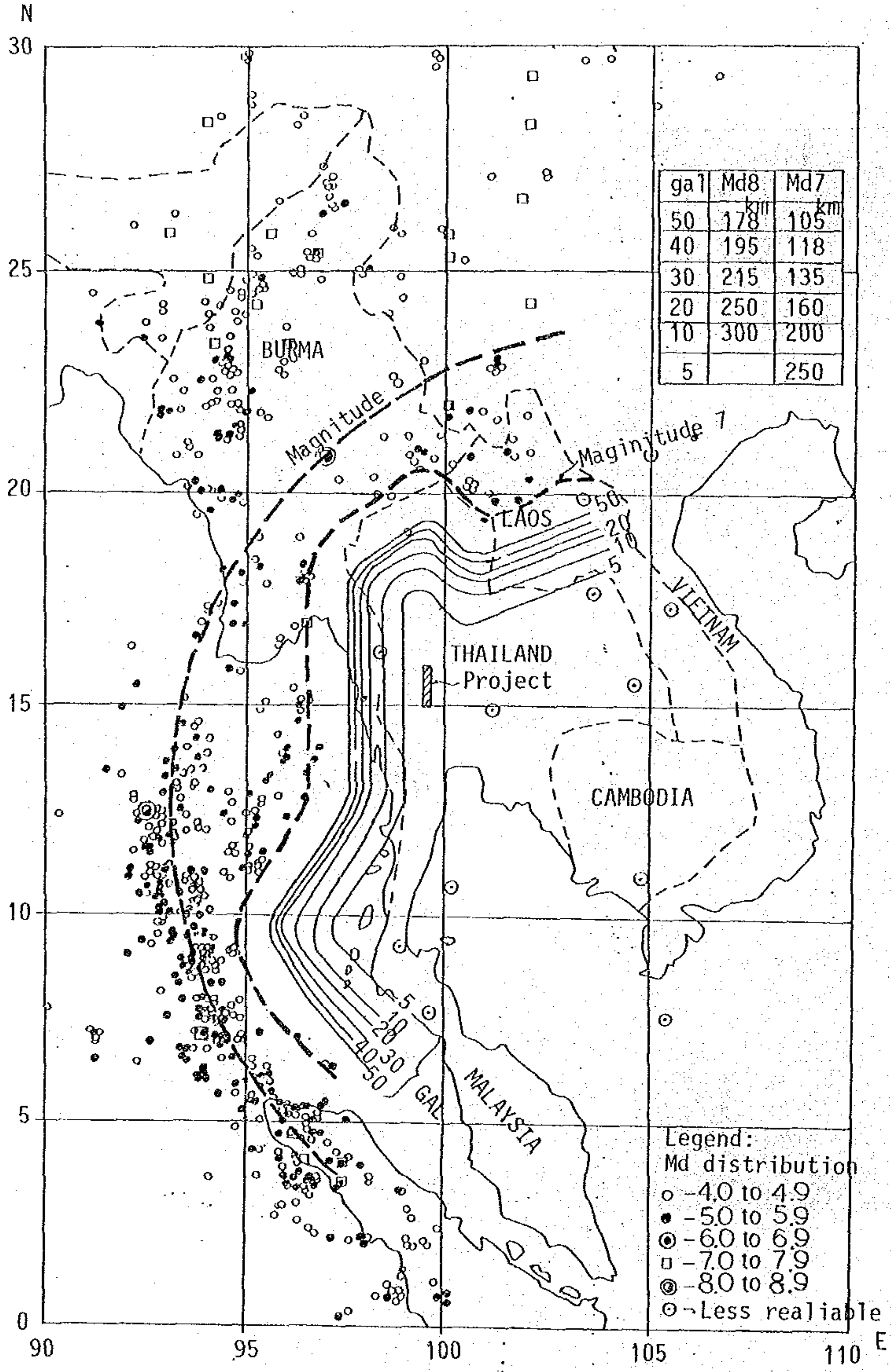



Fig. IV-5 Alternative Dam Axis




Ref. : Studies and Research Div.
Meteorological Department.

Data : 1900 - 1981

Fig. IV-6 Seismic Force Distribution

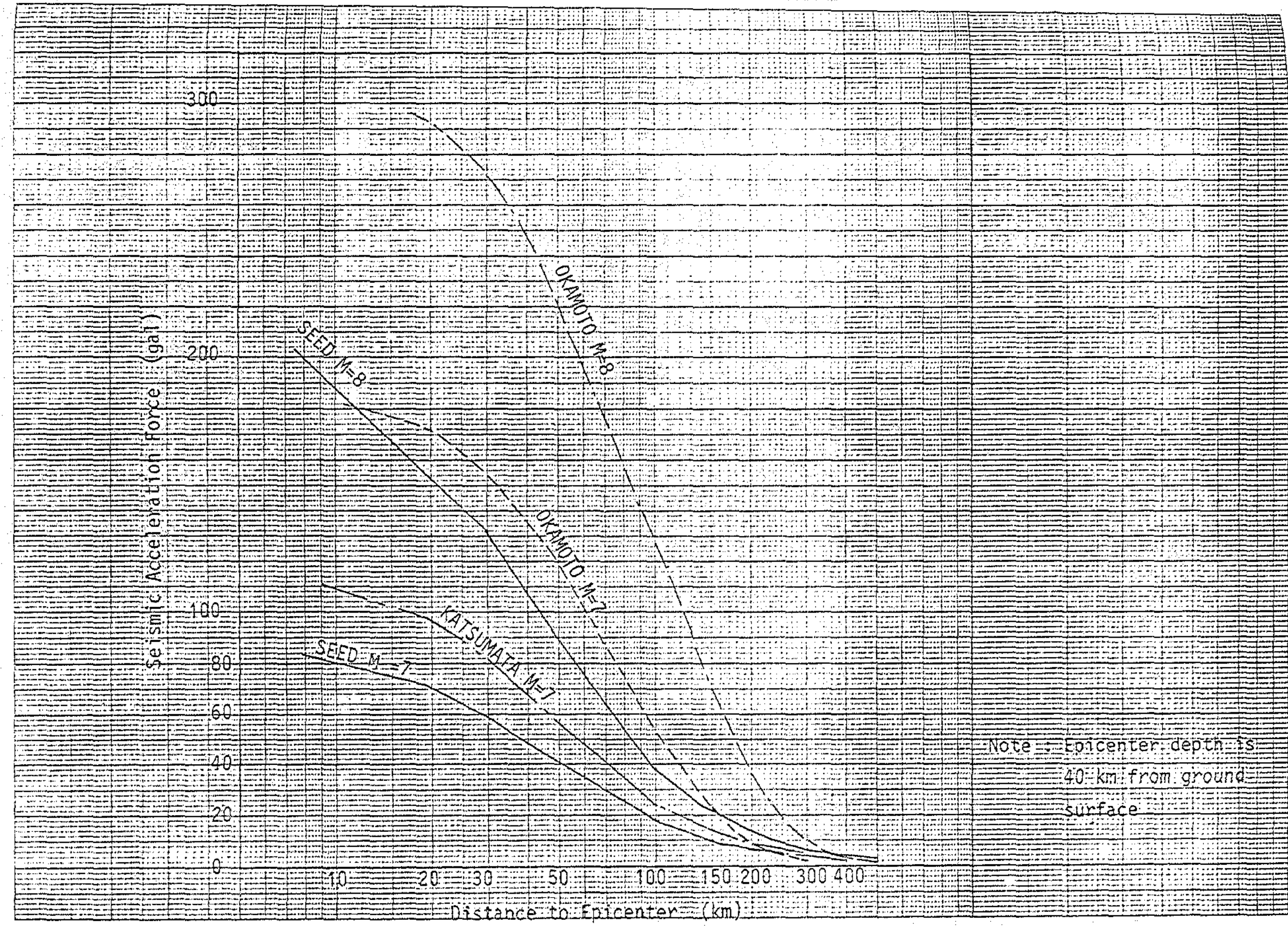



Fig. IV-7 Relation between Seismic Acceleration Force and Distance to Epicenter

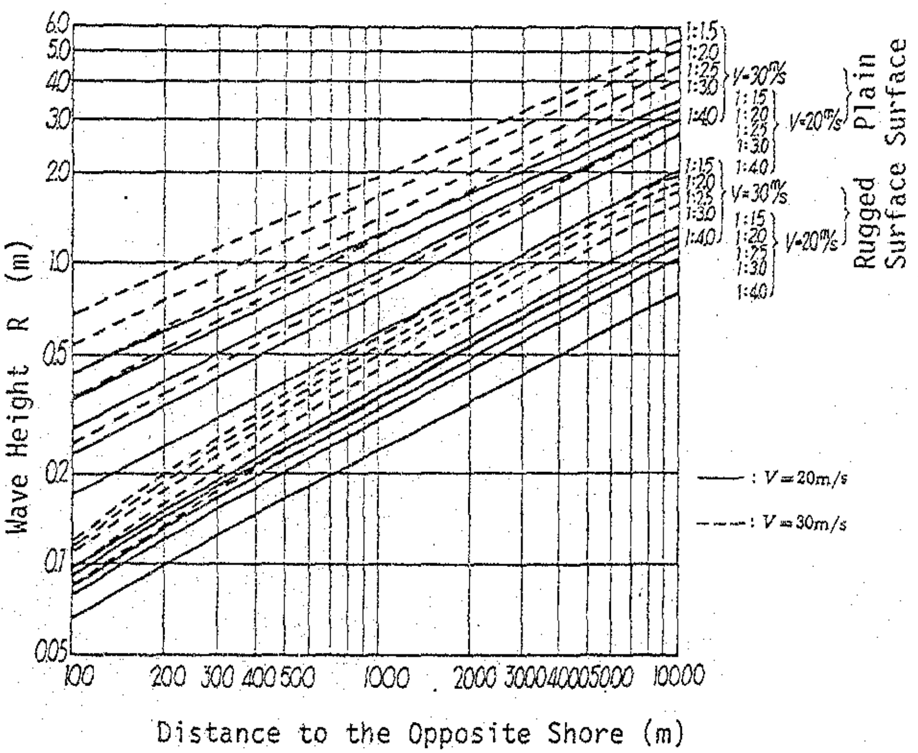



Fig. IV-8 Wave Creep Height

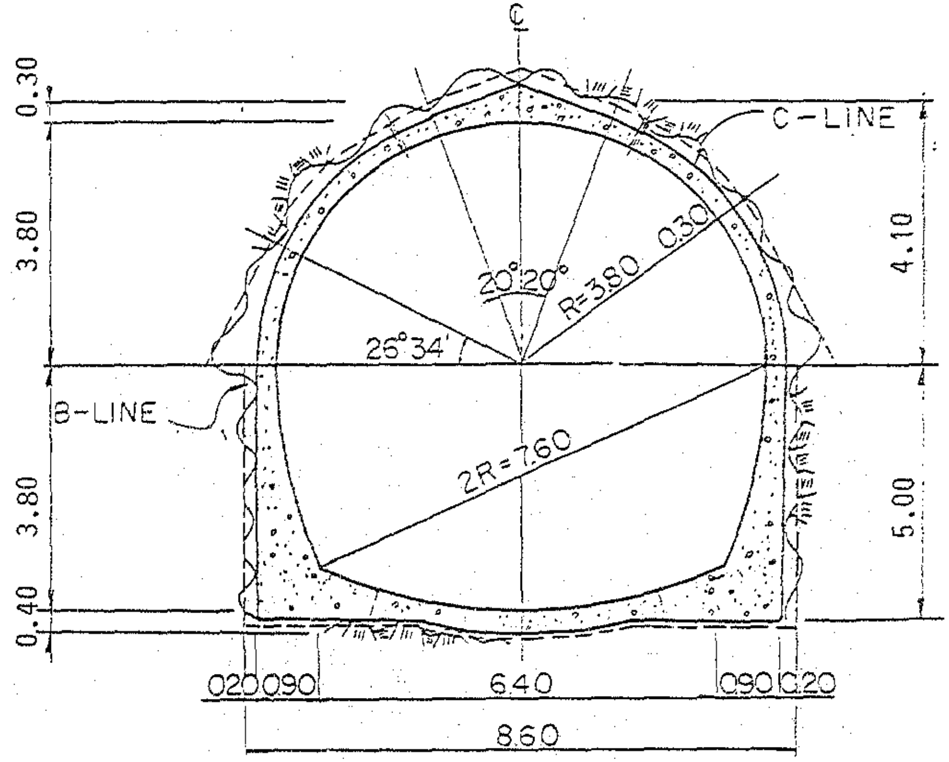



Fig. IV-9 Standard Cross Section of Diversion Tunnel