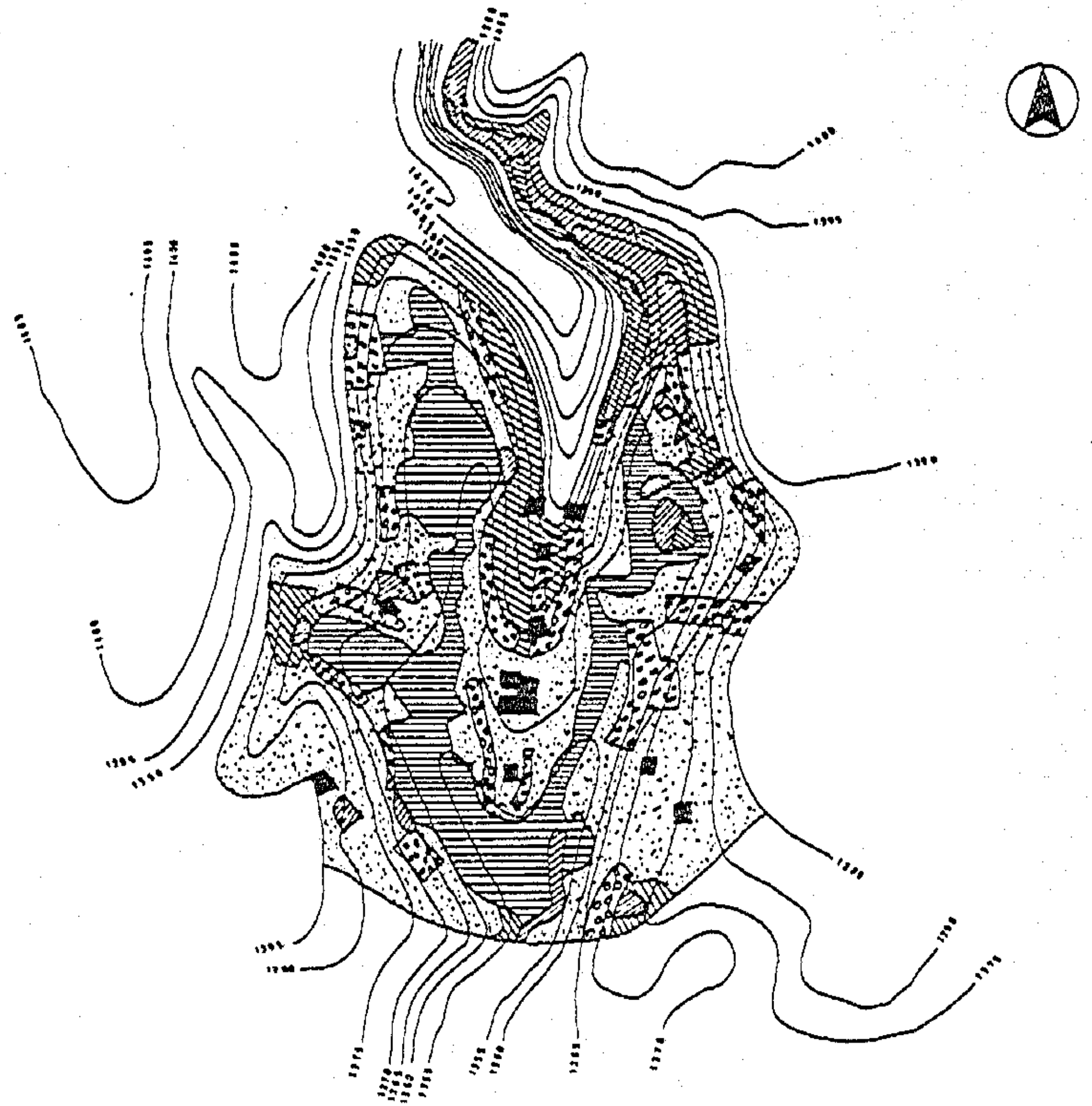

| LEGEND | Area ha | Area (%) |
|---|---|---|
| Coffee | 14.0 | (9.9) |
| Maize etc. | 66.7 | (47.0) |
| Forest | 99 | (17.0) |
| Bush | 18.6 | (13.1) |
| Swampy Grassland | 31.1 | (21.9) |
| Residential | 1.6 | (1.1) |
| Total | 141.9 | (100.0) |

REMARKS: 1 Number of farm households is assumed to be 28.

2 Elevation below 1380 m will be sunk under the water.

SCALE 0 500m

Fig. V-10 LAND USE MAP OF PROPOSED THIBA DAMSITE

# ANNEX - VI

# IRRIGATION AND DRAINAGE

# ANNEX - VI

# IRRIGATION AND DRAINAGE

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# 1. PRESENT CONDITION OF IRRIGATION AND DRAINAGE SYSTEM

## 1.1 Irrigation and Drainage System

### 1.1.1 Scheme area

MIS Scheme area is divided into two parts, i.e. Nyamindi part and Thiba part (Fig. VI-1, to be referred). Nyamindi part has only one section, Tebere Section. Thiba part is composed of four (4) sections; Mwea, Thiba, Wamumu and Karaba Sections.

Furthermore each section consists of some units as shown below:

| Section | Unit | No. |
|---|---|---|
| Tebere | T2, T5-T8, T11, T13, T15-T23, T25 | 17 |
| Mwea | M1-M17 | 17 |
| Thiba | H1-H8, H18-H20 | 11 |
| Wamumu | W1-W7 | 7 |
| Karaba | K1-K8 | 8 |

The Scheme, having the gross area of about 11,600 ha, includes the existing irrigation area of 6,900 ha in gross or 5,860 ha in net which have been put under rice cultivation. The other area of the Scheme comprises upland crop area, unirrigable area, residential areas and roads. Some of upland crop areas are irrigated by the water distributed from the existing irrigation canal. The irrigation area of each section is summarized below (for details, see Table VI-1):

(Unit: ha)

| Section | Irrigation Area | | Other Area | Total |
|---|---|---|---|---|
| | Net | Gross | Gross | Gross |
| <u>Nyamindi part</u> | | | | |
| Tebere | 1,300 | 1,600 | 1,700 | 3,300 |
| <u>Thiba part</u> | | | | |
| Mwea | 1,220 | 1,400 | 900 | 2,300 |
| Thiba | 1,150 | 1,400 | 900 | 2,300 |
| Wamumu | 1,120 | 1,300 | 500 | 1,800 |
| Karaba | 1,070 | 1,200 | 700 | 1,900 |
| Total | 5,860 | 6,900 | 4,700 | 11,600 |

### 1.1.2 Irrigation system

The existing MIS Scheme has two different irrigation systems which are dependent on the water supply of two major rivers, Nyamindi river and Thiba river.

Nyamindi irrigation system consists of a unit of headworks, a main canal, three (3) branch canals and related structures, and supplies the water to Tebere section.

Thiba irrigation system comprises a unit of headworks, a main canal, four (4) branch canals and related structures, and distributes the water to Mwea, Thiba, Wamumu and Karaba sections. A rubble weir is established about 10 km downstream from Thiba headworks for supply of water to unit T20 in Tebere section. Two other rivers, i.e. the Kiwe and Nyaikungu rivers, also supply the water to the Scheme. The Kiwe river flows through Nguka Swamp area, joining the Thiba river between Thiba headworks and rubble weir and contributes to irrigation of Unit T20 in Tebere Section. The Nyaikungu river is blocked by Thiba main canal and distribute the water to main canal. However, the water of these two rivers is not regarded as the reliable water resources for the Scheme.

There is continuous water flow in canals mostly throughout the year. Even in off-cropping season, irrigation water is still conveyed for domestic purpose and/or for irrigation of other crops. Only during maintenance work and heavy rain, canals are closed only for short periods.

The irrigation water taken from offtakes in main and branch canals runs through a main feeder canal in a unit to respective feeder canals which in their turn distribute the water to the individual fields.

The flow in feeder canals is intermittent and respective fields are irrigated in rotation.

### 1.1.3 Drainage system

The Scheme has four (4) rivers which act as drains, i.e. Nyamindi, Murubara, Thiba and Kiruara rivers. Some units which are located along the river, have field drains flowing directly into the river. Each river collects the drainage water from the following sections.

| | | |
|---|---|---|
| a. | Nyamindi/Murubara rivers | : Tebere section |
| b. | Thiba river | : Northeastern part of Mwea, eastern part of Thiba, Wamumu and Karaba sections |
| c. | Kiruara river | : Western part of Mwea and Thiba sections |

There are three (3) main drains in Nyamindi system which collect the water from two or more units and evacuate the water to one of above rivers. Thiba system has five (5) main drains and two (2) branch drains. The downstream parts of the Mukou and Nyaikungu rivers are used as main drain-III and -IV.

Field drain runs almost along the opposite side of field to feeder canal. Drainage water from field drain is collected in a collector drain and is evacuated out of a unit.

The irrigation and drainage diagram of the existing MIS Scheme is presented in Fig. VI-2 and Fig. VI-3.

## 1.2 Irrigation and Drainage Facilities

The major existing irrigation and drainage facilities are classified as follows:

(1) Nyamindi headworks
(2) Thiba headworks
(3) Irrigation and drainage canals
(4) Irrigation and drainage related structures
(5) Farm roads
(6) On-farm facilities

The present conditions of the above facilities are described hereinafter:

### 1.2.1 Nyamindi headworks

Nyamindi headworks was completed in 1956 and commands the irrigation area of Tebere section. Nyamindi headworks is composed of the following components according to the inventory survey (see Fig. VI-4):

| | | | |
|---|---|---|---|
| a. | Fixed type weir | : | Crest length - Approx. 20m |
| b. | Scouring sluiceway | : | Width - Approx. 1.6m<br>Sluice gate (Approx. 1.23 m x 1.25 m, 1 no.) |
| c. | Intake structure | : | Sluice gate (Approx. 1.25 m x 1.6 m, 3 nos.) |

The headworks is constructed on stable rock foundation and properly maintained. It is not subject to much deterioration from structural viewpoint.

However, the protection works for side slopes are much deteriorated or disappeared upstream and downstream of headworks. The existing scouring sluiceway is prevented from its proper function for flashing out the siltation since there is retaining wall just in front of the scouring sluiceway.

### 1.2.2 Thiba headworks

Thiba headworks was completed in 1957 and distributes the irrigation water to Mwea, Thiba, Wamumu and Karaba sections. Thiba headworks consists of the following components according to the inventory survey (see Fig. VI-5):

| | | |
|---|---|---|
| a. | Fixed type weir | : Crest length - Approx. 30 m |
| b. | Scouring sluiceway | : Width - Approx. 1.9 m<br>Sluice gate (Approx. 1.3 m x 1.5 m, 1 no.) |
| c. | Intake structure | : Sluice gate (Approx. 1.4 m x 1.5 m, 3 nos.) |

The headworks is provided at suitable location with stable rock foundation and well functioned. The protection works of side slopes are destroyed and sedimentation is found on left side upstream of the weir.

### 1.2.3 Irrigation and drainage canals

Nyamindi system has a main, three (3) branch irrigation canals and three (3) main drains. In Thiba system, there are a main, four (4) branch irrigation canals, five (5) main and two (2) branch drains. The length of each canal is as follows:

(1) <u>Irrigation canal</u>

(Unit: km)

| | | |
|---|---|---|
| a. | Nyamindi main canal (NMI) | 4.5 |
| b. | Nyamindi branch canal - I (NBI-I) | 6.7 |
| c. | Nyamindi branch canal - II (NBI-II) | 6.2 |
| d. | Nyamindi branch canal - III (NBI-III) | 3.7 |
| e. | Thiba main canal (TMI) | 12.4 |
| f. | Thiba branch canal - I (TBI-I) | 3.4 |
| g. | Thiba branch canal - II (TBI-II) | 4.9 |
| h. | Thiba branch canal - III (TBI-III) | 5.8 |
| i. | Thiba branch canal - IV (TBI-IV) | 16.1 |
| | Total | 63.7 |

(2) Drainage canals

(Unit: km)

| | | |
|---|---|---|
| a. | Nyamindi main drain - I (NMD-I) | 1.2 |
| b. | Nyamindi main drain - II (NMD-II) | 4.0 |
| c. | Nyamindi main drain - III (NMD-III) | 0.7 |
| d. | Thiba main drain - I (TMD-I) | 5.5 |
| e. | Thiba branch drain - I-1 (TMD-I-1) | 2.3 |
| f. | Thiba main drain - II (TMD-II) | 2.1 |
| g. | Thiba main drain - III (TMD-III) | 3.0 |
| h. | Thiba main drain - IV (TMD-IV) | 4.6 |
| i. | Thiba branch drain - IV-1 (TBD-IV-1) | 1.1 |
| j. | Kiruara main drain (KMD) | 8.3 |
| | Total | 32.8 |

The type of both irrigation and drainage canals are unlined open channel with trapezoidal section.

Both side slopes of irrigation and drainage canals are eroded to some extent in most routes of canals. As for the irrigation canals, remarkable erosion is made in black cotton soils area and where the drop structures are completely collapsed. As a result of the side slope erosion, the canals are silted in large part of canal routes. In addition, the irrigation canals especially in Nyamindi system are covered by thick weeds to some extent.

In connection with drainage canals, canals are also silted by eroded soils of side slopes and canal bottom is shallowed. The downstream of cross sections of some drains become smaller than those of the upstream. As a result, the overflow was found in Thiba branch drain-I-1 during survey period. Most of main drains in Thiba part are covered by thick weeds.

### 1.2.4 Related structures

Many kinds of related irrigation structures are provided for distribution of irrigation water, regulation of discharge and water level and crossing with road and rivers.

The major related structures provided in irrigation canals are listed below:

- Turnout or offtake
- Check structure and horse shoe weir
- Drop and chute
- Culvert and bridge

- Concrete flume and washing step
- Spillway and cross drain
- Parshall flume and Cipolletti weir

The location of the above related structures are shown in Fig. VI-6.

Turnouts or offtakes are provided at bifurcation or intake points to distribute the water from main canal to branch or from main or branch canal to main feeder canal. Two kinds of gates, i.e. single orifice steel gate and double orifice wooden gate, are installed on turnouts and offtakes. About 25% of the gates and concrete walls is damaged on an average among all existing offtakes.

Check structures and horse shoe weirs, which are constructed downstream of offtakes to regulate the water level, are almost properly maintained. However, the downstream portion of these structures are eroded due to the shortage of protection works.

Drop and chute structures are installed to dissipate the excess water energy. Chute structures are maintained well. The canal downstreams of most drop structures are eroded with the length of about 20 m and considerably widened. The protection works of drop structures should be rehabilitated to protect from canal erosion. The much deterioration and complete collapse are observed in about 50% out of all the existing drop structures.

Washing steps are provided near the village and some of them are destroyed, being affected by canal erosion.

Two types of culverts, i.e. pipe culvert and box culvert, are provided for crossing with road. The culverts of about 30% among all the existing ones are destroyed to side wall and/or barrel, and lacks earth covering. The protection works are almost deteriorated.

Bridges have three (3) types, i.e. steel, concrete and wooden bridges, and are well maintained.

Concrete flume is provided with the length of about 2.9 km in Nyamindi main canal. There exist many holes, cracks, slidings and collapse in concrete flume.

Parshall flumes are installed in Nyamindi main canal, Thiba main canal, Thiba branch canal-II and -III. The gauge well is covered by thick grass and seems to be in condition without use.

The kind and number of major related irrigation structures are presented in Table VI-2.

Four (4) kinds of related drainage structures such as culvert, drop, drainage inlet and check are provided at crossing with road, regulating the water level and protecting canals. The number of above structures are listed in Table VI-3.

About 60% of the existing culverts are destroyed on the side walls or barrels and silted inside of barrels.

### 1.2.5 Farm roads

Farm roads in the Scheme are sufficiently developed with enough width. However the ground level of roads are mostly lower than that of the paddy field.

The roads are sometimes flooded by overflow from the canals and interrupt the smooth traffic conditions. The roads need the re-embankment to prevent from such occasional flooding.

### 1.2.6 On-farm facilities

On-farm facilities consist of the following components:

a Main feeder canal and feeder canal

b. Field drain and collector drain

c. Related structures such as offtake with check, culvert, check with drop, field inlet and outlet.

d. On-farm roads

The typical layout of the existing Irrigation Unit is shown in Fig. VI-7. Inventory survey of on-farm facilities was made in Unit T7, M14, H4, H7 and K4 during second stage period, and the following results were obtained:

Main feeder and feeder canals are properly maintained. Field drain and collector drain are more or less silted.

Offtakes with single orifice steel gate are almost provided at intake point from main feeder canal to feeder canal and functioned well. Check structures with stop log are accompanied with offtake and in good condition.

Check structures with drop are provided in feeder canal and considerably deteriorated. According to the result of inventory survey, about 40% of check structures in a unit, on an average, are collapsed and need the rehabilitation.

On-farm roads are well developed in each Unit. However, the roads in black cotton soils are prevented from smooth traffic due to the characteristics of the soils which become muddy in the rainy season and cracked in the dry season.

The density of on-farm road was calculated at 58 m/ha. The length of on-farm roads in each section is given below:

(Unit: km)

| Section | Tebere | Mwea | Thiba | Wamumu | Karaba | Total |
|---|---|---|---|---|---|---|
| Length | 82.6 | 78.9 | 81.3 | 73.6 | 82.3 | 398.7 |

## 2. IRRIGATION DEVELOPMENT PLAN

### 2.1 Irrigation Water Requirement

The water requirement for the proposed cropping pattern is estimated on 10-day basis hereinafter.

The basic year for irrigation plan was determined to be 1980 based on the drought year with 5-year return period in regards to annual rainfall in the irrigation area.

#### 2.1.1 Irrigation water requirement for rice

(1) Crop water requirement (CWR)

The crop water requirement is defined as the amount of water needed to meet the consumptive demand of crop for optimum growth from seeding to harvesting. It consists of nursery, puddling and field crop requirements as shown below:

CWR = Kn x NU + Kp x PU + Kf x FC

Where,
- CWR: Crop water requirement (mm/day)
- Kn: Area factor of nursery
- NU: Nursery requirement (mm/day)
- Kp: Area factor of puddling
- PU: Puddling requirement (mm/day)
- Kf: Area factor of planted main field
- FC: Field crop requirement (mm/day)

(i) Nursery requirement (NU)

The nursery requirement is the amount of water needed for nursery preparation and growth of seeding until it is transplanted to main field.

$NU = Sn/N + Kc \times ETo + P$

$Sn = Ds \times (Sc - Mc)/100$

Where,
- NU: Nursery requirement (mm/day)
- Sn: Soil saturation requirement (mm)
- Ds: Depth of soil saturation (300 mm)
- Sc: Soil saturation capacity (% in volume)
- Mc: Soil moisture content before water supply (% in volume)
- N: Nursery period (30 days)
- Kc: Crop coefficient (Kc = 1.0)
- ETo: Potential Evapotranspiration (mm/day)
- P: Percolation rate (0.1 mm/day)

In the above equation, the rates of Sc and Mc are determined as shown below:

| Soil Texture | Sc (%) | Mc (%) |
|---|---|---|
| Clay | 53 | 36 |

The percolation rate is estimated to be in order of 0.05 mm/day - 0.1 mm/day in the "Mwea Water Use Study". The actual measurement was carried out in Unit M17 by the Study Team during the field survey period. The result of field measurement shows the average percolation rate of 0.08 mm/day as shown in Table VI-4. The percolation rate adopted in the Study is therefore determined to be 0.1 mm/day.

(ii) Puddling requirement (PU)

The puddling requirement is defined as the amount of water needed to saturate the soil prior to the initial breaking and pond the rice field for transplanting, and the needed evaporation and percolation in the rice field.

$PU = (Sn + Sp)/N + Ev + P$

Where,
- PU: Puddling requirement (mm/day)
- Sn: Soil saturation requirement (51 mm)
- Sp: Depth of ponding for transplanting (75 mm)
- N: Puddling period (30 days)
- Ev: Evaporation (mm/day)
- P: Perccolation rate (0.1 mm/day)

(iii) Field crop requirement (FC)

The field crop requirement is the amount of water consumed by the crop during the period from transplanting to 20 days before harvesting and the needed percolation in the rice field.

$$FC = Kc \times ETo + P$$

Where, FC: Field crop requirement (mm/day)
Kc: Crop coefficient
ETo: Potential evapotranspiration (mm/day)
P: Percolation rate (0.1 mm/day)

The crop coefficient at each growth stage of rice is shown in Fig. VI-8, which results from the actual investigaion in "Mwea Water Use Study, 1982, NOB". In the Water Use Study, the investigation of crop coefficient was carried out in different units. However, the reliable data were obtained from only two units. The mean value of the above data is adopted as the crop coefficient for rice in the calculation.

The potential evapotranspiration is estimated by two different methods, Modified Penman method and Pan Evaporation method, using the meteorological data obtained at Embu-Mwea Meteorological Station. The estimated results are compared as shown in Fig. VI-9. The result by Modified Penman method was adopted in the calculation of crop water requirement, since the Modified Penman method seems to offer better results and also is familiar to the irrigation planners in Kenya.

(2) Farm water requirement (FWR)

The farm water requirement was assessed on 10-day basis, deducting the effective rainfall from crop water requirement as follows:

$$FWR = CWR - RE$$

Where, FWR: Farm water requirement (mm/10-day)
CWR: Crop water requirement (mm/10-day)
RE: Effective rainfall (mm/10-day)

The effective rainfall was estimated by the daily water depth balance method, using the daily rainfall of basic year:

(i) The basic year was determined to be 1/5 drought year with regard to annual rainfall at Embu-Mwea Meteorological Station.

(ii) The design daily rainfall (RD), which is adopted for the effective rainfall calculation, was determined as follows:

$R(i) < RI : RD(i) = 0$
$R(i) \geq RI : RD(i) = R(i)$

Where, RD(i): Design daily rainfall (mm/day)
R(i): Daily rainfall of basic year (mm/day)
RI: Ineffective rainfall (5 mm)

(iii) The daily water depth calculation was made, assuming the field outlet height of 100 mm as shown below:

$PWL(i) = PWL(i-1) - CWR(i) + RD(i)$

Where, PWL(i): Water level in paddy field (mm)
i: Day considered
CWR(i): Crop water requirement (mm/day)
RD(i): Design daily rainfall

(iv) Using above equation, an overflow comes about when the computed PWL(i) exceeds the field outlet height. The amount of effective rainfall was therefore calculated as follows:

Without overflow : $RE(i) = RD(i)$
With overflow : $RE(i) = FOH - PWL(i-1) + CWR(i)$

Where, RE(i): Effective daily rainfall (mm/day)
RD(i): Design daily rainfall (mm/day)
FOH : Field outlet height (100 mm)
PWL(i): Water level in paddy field (mm)
CWR(i): Crop water requirement (mm/day)

The estimated design rainfall on 10-day basis is shown in Table VI-5. The calculated results of effective rainfall and farm water requirement are shown in Table VI-6.

(3) Unit diversion water requirement (DWR)

The diversion water requirement is defined as the amount of farm water requirement plus allowances for application loss, operation loss and conveyance loss, and calculated as follows:

$DWR = FWR/EF/100$

Where, DWR: Diversion water requirement (mm/10-day)
FWR: Farm water requirement (mm/10-day)
EF: Irrigation efficiency (%)

The actual field measurement was made in Unit M14 for obtaining irrigation efficiency at unit level (about 100 ha on average) and field lot level (1.6 ha). The irrigation efficiency at unit level was measured at 64% and the efficiency at field lot level at 86% as presented in Table VI-7. Assuming the irrigation efficiency in main and branch irrigation system is 90% after the establishment of the proper water management system, the overall irrigation efficiency was estimated at 58%.

On the basis of the results of actual field measurement and "Mwea Water Use Study, 1982, NIB", the unit diversion water requirement is roughly estimated and shown in Table VI-8, applying the overall irrigation efficiency of 55% as shown below:

| Item | Efficiency (%) |
|---|---|
| Application efficiency | 80 |
| Operation efficiency | 76 |
| Conveyance efficiency | 90 |
| Overall irrigation efficiency | 55 |

### 2.1.2 Irrigation water requirement for horticultural crops

(1) Crop water requirement (CWR)

The crop water requirement comprises land preparation requirement and field crop requirement:

CWR = LP + FC

Where, CWR: Crop water requirement (mm/day)
LP: Land preparation requirement (mm/day)
FC: Field crop requirement (mm/day)

(i) Land preparation requirement (LP)

The land preparation requirement is the amount of water needed to make satisfactory field condition for seedings of crop.

LP = PR/N

PR = De x (Fc - Pw) x As/100

Where,
LP: Land preparation requirement (mm/day)
PR: Pre-irrigation requirement (mm)
N: Land preparation period (20 days)
De: Depth of effective root zone (mm)
Fc: Field capacity (% in weight)
Pw: Permanent wilting point (% in weight)
As: Apparent specific gravity

The soil texture in the horticultural crops field is generally classified as silty clay loam and values of FC, Pw and As are determined as follows:

| Soil Texture | Fc (% in volume) | Pw (% in volume) | As |
|---|---|---|---|
| Silty clay loam | 31 | 15 | 1.30 |

The root zone for each crop (De) is determined:

| Crops | Effective Root Zone (De) |
|---|---|
| French beans | 600 mm |
| Onions | 400 mm |
| Tomatoes | 900 mm |

(ii) Field crop requirement (FC)

The field crop requirement is the amount of water consumed by crops during the period from seeding to harvesting.

FC = Kc x ETo

Where,
FC: Field crop requirement (mm/day)
Kc: Crop coefficient
ETo: Potential evapotranspiration (mm/day)

The crop coefficient at each growth stage of crop is estimated on the basis of the "Design Manual for Water Supply in Kenya, 1986" published by the Ministry of Water Development. The crop coefficient of each crop is shown in Fig. VI-10 through Fig. VI-12.

(2) Farm water requirement (FWR)

The farm water requirement is obtained on 10-day basis, deducting the effective rainfall from the crop water requirement as shown below:

FWR = CWR - RE

| | | |
|---|---|---|
| Where, | FWR: | Farm water requirement (mm/10-day) |
| | CWR: | Crop water requirement (mm/10-day) |
| | RE: | Effective rainfall (mm/10-day) |

The effective rainfall is estimated by daily moisture level balance method by use of the daily rainfall of basic year as shown below:

(i) The basic year and the design daily rainfall are determined as described in the previous section.

(ii) The water holding capacity after 24 hours from soil saturation in the root zone is estimated, based on the method of "Crop Water Requirements" published by FAO, as shown in Table VI-9.

(iii) The daily moisture level in the root zone is calculated by use of the following formula:.

$$ML(i) = ML(i-1) - CWR(i) + RD(i)$$

| | | |
|---|---|---|
| Where, | ML(i): | Moisture level in the effective root zone (mm) |
| | i : | Day considered |
| | CWR(i): | Crop water requirement (mm/day) |
| | RD(i): | Design daily rainfall (mm/day) |

(iv) The effective rainfall was obtained from the daily moisture level in the root zone and the estimated water holding capacity as follows:

In case of $ML(i) < MH_{24}$: $RE(i) = RD(i)$
In case of $ML(i) > MH_{24}$: $RE(i) = MH_{24} - ML(i-1) + CWR(i)$

| | | |
|---|---|---|
| Where, | RE(i): | Effective daily rainfall (mm/day) |
| | $MH_{24}$ : | Water holding capacity after 24 hours from soil saturation (mm) |
| | ML(i): | Moisture level in the root zone (mm) |
| | CWR(i): | Crop water requirement (mm/day) |

The calculated results of effective rainfall and farm water requirement on 10-day basis for each crop are shown in Table VI-6.

(3) Unit diversion water requirement

The diversion water requirement is defined as the amount of farm water requirement plus allowance for irrigation losses.

DWR = FWR/EF/100

where, DWR: Diversion water requirement (mm/10-day)
FWR: Farm water requirement (mm/10-day)
EF: Irrigation efficiency (%)

The irrigation efficiency for horticultural crops was assumed to be about 55%. According to the assumed irrigation efficiency, the unit diversion water requirement was roughly calculated from farm water requirement and their results are shown in Table VI-18.

### 2.1.3 Re-use of return flow

In the existing MIS area, the drainage water from upper part of the unit is re-used as irrigation water in lower part of same unit or in lower adjacent units, or restored to lower reaches of main and branch canals.

There are some re-use structures in the drainage canals to divert the drainage water to irrigation canals; some of re-use structures are not effectively functioning due to improper maintenance and the lack of control structures. By the rehabilitation of these structures, the effective use of return flow would be realized. The location of re-use point is indicated in Fig. VI-13.

The rate of return flow was estimated to be 25% of the irrigation water supplied, considering the efficiency of irrigation losses as follows:

(i) The conveyance loss in the unit is ignored for the estimate of return flow.

(ii) The irrigation efficiency in the Unit is assumed to be 64% (operation efficiency: 80% x application efficiency: 80%). The total losses in the unit is therefore 36% of the water supplied.

(iii) The rate of return flow was estimated at 25% of the water supplied, assuming 70% out of the above losses will be effectively re-used in the lower rice fields commanded by re-use structures.

The irrigable areas by each re-use structure are listed in Table VI-10. The total irrigable area by re-use of return flow is estimated at about 500 ha.

### 2.1.4 Diversion water requirement

The diversion water requirement for respective irrigation systems was estimated on 10-day basis, taking into account the re-use of return flow from paddy fields in MIS area as shown in Table VI-11.

The irrigation diagram for respective irrigation parts is illustrated in Fig. VI-14.

## 2.2 Proposed Irrigation System

### 2.2.1 Basic consideration

There are existing irrigation facilities in the MIS area and no facilities in Mutithi extension area. These existing facilities were, therefore, incorporated as much as possible in the final layout of the definite plan for the whole irrigation system.

Based on the result of study on the optimum scale of the development plan, the following irrigation works were proposed:

(1) Construction of a storage dam, new Nyamindi headworks and Ruamuthambi headworks

(2) Construction of new facilities such as link canals, headraces and related structures for diverting irrigation water from Nyamindi system to Thiba system and from Ruamuthambi headworks and Thiba system to Mutithi system.

(3) Establishment of irrigation facilities such as canals and related structures for Mutithi extension area and horticultural crops field which are proposed to be newly irrigated in the Project.

(4) Rehabilitation of the existing irrigation facilities in MIS area.

### 2.2.2 Diversion method of irrigation water

The diversion method of irrigation water to the respective irrigation system is mentioned below and shown in Fig. VI-15.

(1) <u>Nyamindi irrigation system</u>

The irrigation water for Nyamindi irrigation system will be taken at the new Nyamindi headworks which will be constructed at 2.1 km upstream of the existing Nyamindi headworks. The irrigation water will be distributed to existing main canal of the system through Nyamindi headrace, Nyamindi diversion works and new Nyamindi main canal. Unit T20 will be independently supplied the water from the existing rubble weir constructed in Thiba river.

(2) Thiba irrigation system

The water stored in the reservoir will be released to Thiba river and the excess water over the demands for Nyamindi system will be diverted to Thiba river just upstream of existing Thiba headworks through link canal-I.

The irrigation water for Thiba system will be taken from the existing Thiba headworks in Thiba river, which will be rehabilitated and distributed to the existing Thiba main canal through link canal-II which is a part of the existing main canal to be improved.

(3) Mutithi irrigation system

The water for Mutithi irrigation system will be taken from the existing Thiba headworks and diverted to main canal through link canal-II, Thiba diversion works, link canal-III and regulating basin. In addition, Ruamuthambi headworks will divert the water to main canal of this system through headrace and regulating basin.

### 2.2.3 Irrigation system

The proposed irrigation system is divided into three (3) irrigation systems, i.e. Nyamindi, Thiba and Mutithi system. Nyamindi and Thiba systems are respectively composed of one (1) and four (4) sections as the same as the existing ones. Mutithi system consists of two (2) sections; Kibiriri and Rukanga sections.

Each section comprises of several units as shown below:

| Section | Unit | No. |
|---|---|---|
| Nyamindi system | | |
| Tebere | T1-T26 | 26 |
| Thiba system | | |
| Mwea | M1-M17 | 17 |
| Thiba | H1-H8, H18-H20 | 11 |
| Wamumu | W1-W7 | 7 |
| Karaba | K1-K8 | 8 |
| (Sub-total) | | 43 |
| Mutithi system | | |
| Kibiriri | I1-I17 | 17 |
| Rukanga | R1-R24 | 24 |
| (Sub-total) | | 41 |
| Total | | 110 |

The total irrigation area is 9,560 ha, which comprises of paddy area of 8,330 ha and horticultural crops area of 1,230 ha as shown below.

(Unit: ha)

| Irrigation system | Paddy | | Horticultural Crops | | Total | |
|---|---|---|---|---|---|---|
| | Net | Gross | Net | Gross | Net | Gross |
| Nyamindi system | 1,300 | 1,600 | 600 | 705 | 1,900 | 2,305 |
| Thiba system | 4,560 | 5,300 | 200 | 235 | 4,760 | 5,535 |
| Mutithi system | 2,470 | 2,900 | 430 | 510 | 2,900 | 3,410 |
| Total | 8,330 | 9,800 | 1,230 | 1,450 | 9,560 | 11,250 |

The net irrigation area of each unit is summarized in Table VI-12 and the average area is about 90 ha.

The irrigation canal layout of the existing irrigation systems; i.e. Nyamindi and Thiba systems, will not be changed (Nyamindi system: a main canal and three (3) branch canals, Thiba system: a main canal and four (4) branch canals). Mutithi irrigation system consists of a main canal and five (5) branch canals to be newly developed.

The general layout of the proposed irrigation system is shown in Fig. VI-16. The discharge of main and branch canals are determined on the basis of the proposed cropping pattern and the irrigation diagram is illustrated in Fig. VI-14.

# 3. DRAINAGE DEVELOPMENT PLAN

## 3.1 Drainage Water Requirement

The drainage water requirement for design of the proposed drainage system is determined, separately one for the excess rainfall from rice fields and the other for the run-off from the land surrounding the irrigated paddy field, on the basis of the design daily rainfall with a 5-year return period, which is estimated at 100 mm/day by Thomas Method by use of annual maximum daily rainfall records from 1979 to 1986 at the Embu-Mwea Meteorological Station.

### 3.1.1 Drainage water requirement for paddy field

The design rainfall in the paddy field should be removed within one day. The drainage water requirement is calculated using the following equation:

$$QP = (R_{24} \times 10^{-3} \times A \times 10^{4})/(T \times 60 \times 60)$$

Where,
- QP: Drainage water requirement for paddy field ($m^3$/sec)
- $R_{24}$: Design daily rainfall (100mm/day)
- T: Drainage period (24 hours)
- A: Drainage area (ha in gross)

The unit drainage water requirement for paddy field is thus estimated at 11.6 l/sec/ha.

### 3.1.2 Drainage water requirement for surrounding area

The drainage water requirement for the run-off in the surrounding areas is estimated by McMath formula suggested in "Drainage Manual", USBR:

$$QH = 9.15 \times 10^{-3} \times C \times i \times S^{1/5} \times A^{4/5}$$

Where,
- QH: Drainage water requirement for surrounding areas ($m^3$/sec)
- C: Coefficient representing the surrounding areas' characteristics (0.36)
- i: Rainfall intensity for the time of flood concentration (mm/hr)

$$i = R_{24} \times (1/24)^{1/3}$$

- S: Average slope (1/150)
- A: Drainage area (ha)

The unit drainage water requirement for the surrounding areas is estimated at 12.4 l/sec/ha.

### 3.1.3 Design drainage water requirement

The design drainage water requirement at each section of drainage area was calculated by use of the following formula:

$$Q = (Qp \times Ap + Qh \times Ah)$$

Where,
- Q: Design drainage water requirement ($m^3$/sec)
- Qp: Unit drainage water requirement for rice field (0.0116 $m^3$/sec/ha)
- Qh: Unit drainage water requirement for surrounding areas (0.0124 $m^3$/sec/ha)
- Ap: Area of paddy field (ha)
- Ah: Area of surrounding land (ha)

The drainage diagram is illustrated in Fig. VI-17.

## 3.2 Proposed Drainage System

### 3.2.1 Basic consideration

The drainage plan in the project was made by mean of rehabilitating the existing facilities in Nyamindi and Thiba systems and new construction of drainage facilities such as main drains, branch drains and related structures for Mutithi system.

The rehabilitation plan for the existing drains was formulated according to the following basic consideration.

(1) The smooth longitudinal profiles of the drains should be made. The existing rivers are utilized as main drains, of which gradient is rather steep. The sedimentation is noticeable in the whole canal routes and downstream cross sections become smaller than upstream. In such cases, smooth profiles are first designed regardless of the design criteria as much as possible not to prevent the smooth drain from irrigated fields.

(2) The rehabilitation of the cross section is to be kept within the existing cross sections as much as possible.

### 3.2.2 Drainage system

The proposed drainage system is divided into three (3) systems, namely Nyamindi, Thiba and Mutithi systems. The drainage canal layout of the existing systems, i.e. Nyamindi and Thiba systems, will not be changed basically (Nyamindi system: three (3) drains, Thiba system: five (5) main drains and two (2) branch drains). Mutithi drainage system comprises five (5) màin drains and two (2) branch drains.

The general layout of the proposed drainage system is shown in Fig. VI-16 and the drainage diagram is presented in Fig. VI-17.

The total drainage area covered by the above main and branch drains is about 11,910 ha, which is composed of paddy field area of about 5,750 ha and surrounding land area of 6,160 ha and the total drainage blocks are 103 as summarized below:

(Unit: ha)

| Drainage System | No. of Drainage Blocks | Paddy Field | Surrounding Land | Total |
|---|---|---|---|---|
| Nyamindi system | 8 | 649 | 258 | 907 |
| Thiba system | 49 | 3,364 | 3,261 | 6,625 |
| Mutithi system | 46 | 1,734 | 2,638 | 4,372 |
| Total | 103 | 5,747 | 6,157 | 11,904 |

The drainage water from other area in the Project area is evacuated directly to the rivers, i.e. Nyamindi, Murubara, Thiba, Kiruara and Tana rivers.

The drainage area of each drainage block is presented in Table VI-13.

## 4. FARM ROAD DEVELOPMENT

### 4.1 Basic Consideration

For adequate operation and maintenance of the Project facilities and effective agricultural activities after implementation of the Project, the *establishment of the farm road system is indispensable.*

There are existing farm road system in the MIS area, which are sufficiently developed with enough width. However the ground level of roads are as a whole lower than that of the paddy field, which causes the traffic difficulty in poor drainage area. The roads will be re-embanked to prevent from such occasional flooding and in addition provided laterite pavement for strengthening the road surface.

Mutithi part has no farm road system and proper system will be newly constructed with sufficient width and in good surface conditions.

### 4.2 Proposed Farm Road System

The proposed farm road system will be provided to cover every four units in average and to link the Project area and national roads. The existing roads in Nyamindi and Thiba parts are also improved in conformity to the above.

Nyamindi system consists of twelve (12) farm roads, Thiba system of 19 and Mutithi system of 20.

The length of farm roads is about 244 km in total as shown below:

| Road System | | Length (m) | Density (m/ha) |
|---|---|---|---|
| Nyamindi | | 41,000 | 22 |
| Thiba | | 122,720 | 26 |
| Mutithi | | 80,620 | 28 |
| | Total | 244,340 | Average 26 |

# 5. ON-FARM DEVELOPMENT PLAN

## 5.1 Basic Consideration

Based on the water balance study, the net irrigation area in the Project comprises the paddy area of 8,330 ha and horticultural crop area of 1,230 ha. Among them, the existing paddy area is 5,860 ha. For the introduction of the modernized farming practice in the Project, the following on-farm works are proposed;

(1) Reclamation of paddy field in Mutithi extension area.

(2) Reclamation of horticultural crop field in Mutithi and the MIS area.

(3) Construction of on-farm facilities such as main feeder canals, feeder canals, collector drains, field drains, their related structures and on-farm roads for Mutithi extension area and horticultural crop area.

(4) Rehabilitation of the existing on-farm facilities in the MIS area.

The average slope of the paddy field in Mutithi extension area is about 1/200 with the elevation of 1,135m to 1,195m. The land levelling will be the major works for the reclamation. The field lot will be generally reclaimed in parallel to the contour line and to be of rectangular shape in order to minimize the earth moving volumes and the cutting depth as small as possible.

The average land slope of the proposed horticultural crops field in brownish red soils area is about 1/40. The furrow irrigation method will be applied and furrow direction is planned nearly in parallel with contour line. The field reclamation with improvement of original land slopes will be applied, considering future introduction of large size mechanized farming. The cutting of and/or banking on the original ground with surface soil handling will be required to some extent.

## 5.2 Proposed On-Farm Development Plan

### 5.2.1 Typical farm layout

In the development plan of main irrigation system, one hundred ten (110) units in total will be formulated, of which net average area is about 90 ha.

The standard sizes of farmland block to be reclaimed to paddy field in Mutithi extension area will be the same as those in the MIS as below:

| Paddy Farmland Block | Size |
|---|---|
| Field lot | 0.4 ha (100 m x 40 m) |
| Field block | 10.0 ha (100 m x 1,000 m) |
| Farm block | 20.0 ha (200 m x 1,000 m) |

The typical layout of unit for Mutithi extension area is referred to the existing unit shown in Fig. VI-7.

The standard sizes of farmland block for horticultural crops field were determined as follows, taking into consideration the farming practice, topography and soil conditions.

| Horticultural Crops Farmland Block | Size |
|---|---|
| Field lot | 0.4 ha (100 m x 40 m) |
| Field block | 6.0 ha (100 m x 600 m) |
| Farm block | 12.0 ha (200 m x 600 m) |

The furrow intake rate test was carried out at Unit T3, T4 and T14 in brownish red soils area during the second stage by the Study Team. The results of furrow intake rate test are shown in Fig. VI-18. According to the above results, available water in root zone and field crop requirement of horticultural crops mentioned in previous section, the irrigation interval and the proper length of furrow were determined to be 7 days and 100 m respectively.

The typical layout of the horticultural crops field is shown in Fig. VI-19.

### 5.2.2 On-farm irrigation system

Every unit is supplied the irrigation water by main feeder canal through offtake which is provided in main and branch canal. A unit is composed of several farm blocks. Each farm block is commanded by offtake with check in main feeder canal.

Farm block consists of two field blocks which comprises some field lots. Feeder canal for paddy field runs between two field blocks and commands two field blocks as shown in Fig. VI-7. Irrigation water is distributed to each field lot by field inlet installed along feeder canal. Field inlet is provided at the first field lot of every four field lots and three other field lots are supplied the irrigation water by plot-to-plot irrigation method. A check with stop planks is installed just downstream of field inlet to regulate the water level in feeder canal.

Feeder canal for horticultural crops field is established in one side of field block and commands one field block as shown in Fig. VI-19. Field inlet is provided at each field lot. Feeder ditch is provided in field along feeder canal and distributes the water directly to respective furrows. Check with stop planks is also established just downstream of field inlet in feeder canal.

### 5.2.3 On-farm drainage system

Excess water from unit is drained to main and branch drains by collector drain which collects the drainage water from field drains in each field block.

Two field drains for paddy field are provided at both opposite sides of farm block to feeder canal and collects the excess water from field outlet which is established at last field lot of every four ones.

A field drain for horticultural crops field is provided at the opposite side of feeder canal in each field block. There is no field outlet in field lot.

Farm approaches for carrying the farm machinery in the fields will be newly provided in field drain.

### 5.2.4 On-farm road system

For operation and maintenance of the on-farm facilities and effective agricultural activities, the proper on-farm roads will be established.

On-farm roads will be banked 0.30 m higher than the ground surface of paddy field to prevent from occasional flooding and provided laterite pavement for strengthening the road surface.

## 6. PRELIMINARY DESIGN OF IRRIGATION AND DRAINAGE FACILITIES

### 6.1 Headworks

#### 6.1.1 Basic design condition

New Nyamindi headworks and Ruamuthambi headworks will be newly constructed and the existing Thiba headworks will be rehabilitated. The following criteria was applied to the design of headworks.

(1) Design intake discharge:

| | | |
|---|---|---|
| | Nyamindi | 7.01 $m^3$/sec |
| | Thiba | 11.12 $m^3$/sec |
| | Ruamuthambi | 2.30 $m^3$/sec |

(2) Design flood discharge with a 50-year return period (Q) was determined by the following formula:

where, $Q = f \times r \times A/3.6$ ($m^3$/sec)
f: Runoff coefficient (0.3)
r: Rainfall intensity (mm/hr)
A: Catchment area ($km^2$)

| Item | New Nyamindi | Ruamuthambi |
|---|---|---|
| Catchment area ($km^2$) | 283.0 | 118.6 |
| Rainfall intensity (mm/hr) | 16.5 | 18.2 |
| Design flood discharge ($m^3$/sec) | 390 | 180 |

(3) Freeboard was considered as follows:

| Discharge ($m^3$/sec) | Freeboard (m) |
|---|---|
| $Q \leqq 200$ | 0.6 |
| $200 < Q \leqq 500$ | 0.8 |

### 6.1.2 Design of headworks

The design of headworks on the basis of the above criteria is described hereinafter.

(1) New Nyamindi and Ruamuthambi headworks

(a) Weir

| Item | New Nyamindi | Ruamuthambi |
|---|---|---|
| Location | 2.1 km upstream from existing headworks | 0.5 km downstream from national road B20/1 |
| Type | Fixed concrete type | Fixed concrete type |
| Crest elevation (m) | EL. 1,209.50 | EL. 1,213.00 |
| Crest length (m) | 45.0 | 36.0 |
| Crest width (m) | 1.0 | 1.0 |
| Weir height (m) | 4.5 | 3.5 |
| Side slope (Upstream) | vertical | vertical |
| (Downstream) | 1: 0.75 | 1: 0.75 |

(b) Length of protection (Lp)

$$Lp = 0.67 \times C \times \sqrt{Ha \times q} \times f$$

where, Lp: Length of apron (m)

C: Coefficient of Bligh method

Ha: Distance between weir crest and water level in the right down of the weir (m)

q: Design discharge per meter of crest weir

f: Safety factor (1.0)

| Item | New Nyamindi | Ruamuthambi |
|---|---|---|
| Lp (m) | 22.0 | 13.5 |

(c) Length of Apron (La)

$$La \geqq 0.6 \times C \times \sqrt{D_1}$$

where, La: Length of apron (m)

C: Coefficient of Bligh method

$D_1$: Difference in elevation between weir crest and apron (m)

q: Design discharge per meter of crest weir

f: Safety factor (1.0)

| Item | New Nyamindi | Ruamuthambi |
| --- | --- | --- |
| La (m) | 8.0 | 6.5 |

(d) Intake structure

| Item | New Nyamindi | Ruamuthambi |
| --- | --- | --- |
| Intake gate | Slide gate | Slide gate |
| Width | 1.5 m | 1.3 m |
| Height | 2.1 m | 1.1 m |
| Number | 3 | 2 |

(e) Scouring sluiceway

| Item | New Nyamindi | Ruamuthambi |
| --- | --- | --- |
| Scouring gate | Slide gate | Slide gate |
| Width | 2.0 m | 2.0 m |
| Height | 3.1 m | 2.1 m |
| Number | 2 | 1 |

(f) Measuring device

The intake water will be measured by cipolletti weir installed downstream of intake structure. The overflow depth will be observed under the complete overflow condition.

(g) The operation decks for intake gate and scouring gate is 3.0 m in width.

(h) For easier maintenance of intake gates, stop logs will be provided in both sides of the gates.

(i) Difference in elevation between intake-sill and scouring sluiceway (Hs) and intake velocity (v) will be as follows:

$$Hs \geqq 1.0 \text{ m}$$
$$0.6 \text{ m/sec} < v < 1.0 \text{ m/sec}$$

(j) Screen made of steel net will be provided in front of intake gate.

(2) Existing Thiba headworks

The existing Thiba headworks will divert the irrigation water to Thiba irrigation system and Mutithi system through link canal-II which will be established by the improvement of a part of the existing Thiba main canal. In order to take the design discharge of 11.12 $m^3$/sec, weir height will be raised with height of 0.5 m, taking account of the necessary heads at intake gate, because water surface elevation in link canal-II after improvement becomes the same as crest elevation of the existing weir.

In addition, the protection works for left side slope and downstream river bed will be rehabilitated.

## 6.2 Headraces and Link Canals

### 6.2.1 Basic design condition

The following criteria were applied to the design of headraces, link canals and related structures.

(1) Hydraulic calculation

(a) The following "Manning Formula" was adopted for the hydraulic calculation.

$$Q = A \times V$$
$$V = 1/n \times R^{2/3} \times I^{1/2}$$

where, Q: Design discharge ($m^3$/sec)
A: Flow area ($m^2$)
V: Mean velocity (m/sec)
n: Roughness coefficient
R: Hydraulic radius
I: Hydraulic gradient

(b) Roughness coefficient (n) was determined as follows:

| Kinds of Canals | Roughness Coefficient |
|---|---|
| Earth canal | 0.030 |
| Concrete lining canal | 0.015 |
| Masonry lining canal | 0.025 |

(c) Allowable maximum and minimum velocities were assumed as follows:

| Kinds of Canals | Min. | Max. |
|---|---|---|
| Earth canal | 0.3 | 0.7 |
| Concrete lining canal | 0.3 | 2.0 |
| Masonry lining canal | 0.3 | 3.0 |

(2) <u>Structural design of canals</u>

(a) Canal section is a trapezoidal type

(b) Inside slope of canal is 1:1.5

(c) Ratio (B/d) between base width (B) and water depth (d) is as follows:

| Canal | Ratio |
|---|---|
| Earth canal | 1.3 |
| Lining canal | 1.7 |

(d) Freeboard of canal is as follows:

| Design Discharge ($m^3$/sec) | Freeboard (m) |
|---|---|
| $Q \leqq 3.0$ | 0.3 |
| $3.0 < Q \leqq 6.0$ | 0.4 |
| $6.0 < Q$ | 0.5 |

(e) The base and slopes of canals aligned in red soils area will be replaced by the compacted soils mixed red soils with gravel soils for prevention of seepage.

(3) Related structures

Some related structures will be required in conjunction with headraces and link canals for diversion, regulation and measurement of irrigation water.

(a) Division works

Division works will be constructed at the both ends of Nyamindi headrace and link canal-II to direct the water to respective irrigation systems.

*Nyamindi diversion works consist of regulating basin and four* slide gates and Thiba division works are composed of small basin and five slide gates.

(b) Regulating basin

Regulating basin will be provided to mitigate the energy of water flow of which Ruamuthambi headrace and link canal-II are joined and to protect the side slopes.

(c) Other related structures such as offtakes, drops, culverts and cipolletti weirs will be required in headraces and link canals for conveyance, regulation and measurement of irrigation water, and protection of canals. The characteristics and design criteria of these structures are referred to section 6.3.2.

### 6.2.2 Design of headraces and link canals

Major features of designed headraces, link canals and related structures are summarized as below and the location of these facilities is shown in Fig. VI-20.

(1) Headraces and link canals

(a) Headraces

| Headraces | Nyamindi | Ruamuthambi |
|---|---|---|
| Design discharge ($m^3$/sec) | 7.01 | 2.30 |
| Gradient | 1/5,000 | 1/4,000 |
| Base width (m) | 2.90 | 1.80 |
| Water depth (m) | 2.13 | 1.35 |
| Velocity (m/sec) | 0.54 | 0.44 |
| Embankment height (m) | 2.70 | 1.70 |
| Length (km) | 0.64 | 6.3 |

(b) Link canals

| Link Canals | I | II | III |
|---|---|---|---|
| Design discharge ($m^3$/sec) | 4.91 | 11.12 | 3.62 |
| Gradient | 1/5,000 | 1/3,200 - 3,400 | 1/5,000 |
| Base width (m) | 2.50 | 5.00 - 7.00 | 2.30 |
| Water depth (m) | 1.87 | 1.71 - 2.02 | 1.65 |
| Velocity (m/sec) | 0.49 | 0.68 - 0.69 | 0.46 |
| Embankment height (m) | 2.30 | 2.30 - 2.60 | 2.10 |
| Length (km) | 7.5 | 3.4 | 2.4 |

(c) New Nyamindi main canal

| | |
|---|---|
| Design discharge ($m^3$/sec) | 2.28 |
| Gradient | 1/4,000 |
| Base width (m) | 1.80 |
| Water depth (m) | 1.35 |
| Velocity (m/sec) | 0.44 |
| Embankment height (m) | 1.70 |
| Length (km) | 0.6 |

(2) Related structures

(a) Nyamindi division works

- Regulating basin : about 110 $m^2$ in area
  3.0 m in depth
- Gates : B 1.0 m x H 1.0 m x 2 nos.
  (To Nyamindi system)
  B 1.5 m x H 1.0 m x 2 nos.
  (To Thiba and Mutithi systems)

(b) Thiba division works

Those works, which will divert discharge to Thiba main canal and Mutithi extension area comprise a small basin, a culvert, 2 gates with 1.5 m x 1.0 m for Thiba system and 3 gates with 1.2 m x 1.0 m for Mutithi extension area.

(c) Regulating basin

Regulating basin will be constructed at confluence of Ruamuthambi headrace and Link canal-III. Basin area is about 180 $m^2$ with concrete wall of 3.0 m in height.

(d) Other related structures such as offtake, culverts, drops and cipolletti weir are provided in these canals. The numbers of related structures are shown in Table VI-14.

## 6.3 Irrigation Canals and Related Structures

The design criteria given hereinafter will be mainly applied to irrigation and drainage facilities established under new development plan of Mutithi extension area and horticultural crops area. These will also be referred to the rehabilitation and improvement works in MIS area where applicable.

### 6.3.1 Design of irrigation canals

Irrigation canals were in principle designed as unlined earth canal with trapezoidal section. However, canals aligned in red soils area were designed as concrete lining or concrete flume. The design of the irrigation canals were made in conformity to the basic design criteria mentioned below:

(1) Design discharge

Based on the irrigation water requirement and the commanding area, the design discharges for irrigation canals were estimated. Irrigation diagram for the proposed irrigation system is shown in Fig. VI-14.

(2) Design water level

The design water level in the irrigation canal was determined based on the required water level at offtake diverting the water to a unit.

The required water level in the canal at offtake was estimated at 0.50 m higher than the field surface elevation taking into account head losses caused at several structures and in canals through which the irrigation water would be transferred to each field lot.

(3) Velocity

The maximum permissible velocity of canals was determined so as not to cause scouring of canal. The minimum permissible velocity was determined so as not to induce the growth of aquatic plant and moss, and not to cause the sedimentation in canal. Permissible velocity of each canal was determined as follows:

| Canals | Min. | Max. |
|---|---|---|
| Earth canal | 0.3 m/sec | 0.7 m/sec |
| Concrete lining canal | 0.3 m/sec | 2.0 m/sec |
| Wet masonry lining canal | 0.3 m/sec | 3.0 m/sec |

(4) Roughness coefficient

The roughness coefficient of irrigation canals was determined as below, considering the texture of canal construction material and the canal inside condition with proper maintenance after the project implementation.

| Canals | Roughness Coefficient |
|---|---|
| Earth canal | 0.030 |
| Concrete lining canal | 0.015 |
| Masonry lining canal | 0.025 |

(5) Freeboard

The freeboard of the canal was designed based on the following criteria:

$$Fb \geqq Fbmin$$

$$Fbmin = 0.05 \times d + hv + 0.10$$

$$hv = \frac{V^2}{2 \times g}$$

| | | |
|---|---|---|
| where, | Fb: | Freeboard (m) |
| | Fbmin: | Minimum freeboard (m) |
| | V: | Mean velocity (m/sec) |
| | d: | Water depth (m) |
| | hv: | Velocity head (m) |
| | V: | Velocity (m/sec) |
| | g: | Acceleration of gravity (9.8 m/sec$^2$) |

(6) Canal section

The canal section was designed taking into account the effective water flow and the canal slope stability.

The relationship between the canal base width and designed water depth was determined so that the ratio of water depth to base width will be more than one under the condition that the water depth be less than 1.5 m.

The canal inside slope was determined at 1:1.5 in accordance with the soil mechanical condition.

General features of the irrigation canal are shown in Table VI-15 and the typical canal sections are presented in DRAWINGS.

### 6.3.2 Related structures

Various related structures would be required in conjunction with irrigation canals for conveyance, regulation and measurement of irrigation water and protection of canal system.

The general characteristics and design criteria of these structures are briefed as follows:

(1) Turnout and offtake

Turnouts will be provided to divert the required water from main canal to branch canal. Offtakes will be installed to distribute the irrigation water from main or branch canals to main feeder canal.

Turnout consists of inlet from main canal, slide gate, pipe culvert under farm road or canal embankment and outlet transition to branch canal. The discharge measurement for branch canal will be made by cipolletti weir provided downstream of turnout. Offtakes will be provided double orifice gates. Two staff gauges will be provided upstream and downstream of the first gate to measure the head across the orifice.

(2) Drop

The function of drop structure is to convey the water from a higher to a lower elevation and dissipate excess energy resulting due to the drop. The vertical drop type with maximum drop head of 1.0 m was adapted. The drop consists of upstream transition, throat section, stilling basin and downstream transition.

(3) Chute

Chutes are used to convey water from a higher elevation to a lower elevation. Chute consists of upstream transition, chute section of rectangular flume, stilling basin and downstream transition.

(4) Culvert

Culverts will be constructed where a road crosses over the canal. These culverts will be strong enough for the increase of heavy traffic after the project implementation. Three types such as double box barrel type, single and double pipe barrel types are considered depending on design discharge. The conduit consists of upstream transition, box or pipe conduit and downstream transition.

(5) Cross drain

Cross drains will be provided under canals to cross the rivers. Three types such as double box barrel type, and single and double pipe barrel types of cross drains are considered depending on the design discharge. Cross drain consists of inlet protection and transition, barrel section, outlet transition and protection.

(6) Check

In order to maintain the required water level at the site of offtaking even during periods of off-peak discharge, check will be provided at just or near downstream of offtake and at the end of branch canals. In consistence with canal longitudinal profile, two types of the check were considered. One is the ordinary type and the other is the combination type of check and drop.

The ordinary type check consists of upstream transition, overflow section and downstream transition, and will be equipped with one rectangular slide gate and operation deck in overflow section. On the other hand, the check with drop will have the stilling basin between the throat and the downstream transition.

(7) Cipolletti weir

Cipolletti weirs are overflow structures built across canals to measure the rate of flow of water. Cipolletti weir consists of downstream transition, overflow section which is attached with trapezoidal weir, stilling basin and downstream transition.

Cipolletti weirs will be provided mainly downstream of bifurcation between main and branch canals.

(8) Spillway

Spillways will be constructed in the canal system for the purpose of spilling out excess flow or flushing off all water in the canals in case of the emergency and the canal clearing and repairing. Spillway consists of side spillway, slide gate for waste of water, culvert under road and outlet transition. For the culvert, two types of box and pipe are considered for the waste water discharges.

(9) Washing step

Washing steps will be constructed on canal inside slope for washing and other purpose of villagers.

The numbers of all structures for the proposed irrigation system are shown in Table VI-16.

### 6.3.3 Rehabilitation of the existing canals and related structures

(1) Canals

According to the proposed irrigation system, the existing irrigation system will be required the rehabilitation works. The existing canal profiles and sections were checked their flow capacities for the proposed design discharges, on the basis of the canal route survey results carried out by Surtech Ltd. In order to meet the design discharge, canal base which is shallowed owing to erosion of inside slopes and sedimentation will be necessary to be excavated and the destroyed inside slopes will be required to be re-embanked.

General features of the existing irrigation canals are given in Table VI-15.

(2) Related structures

The existing related structures in main and branch irrigation canals will be required to be rehabilitated and improved according to the results of inventory survey and check of canal profile sections.

The numbers of related structures to be rehabilitated and improved are listed in Table VI-16.

## 6.4 Drainage Canals and Related Structures

### 6.4.1 Design of drainage canals

All drainage canals were designed as unlined earth canals with trapezoidal sections. The design of the drainage canals were made based on the basic design criteria described as follows:

(1) Design discharge

Based on the drainage water requirement calculated in previous chapter and the catchment area, the design discharges for drainage canals were estimated. Drainage diagram for the proposed drainage system is shown in Fig. VI-17.

(2) Design water level

The required water level in canals at drainage inlet was estimated at 0.9 m lower than the field surface elevation taking into account the required groundwater level at each field lot and head losses caused at junctions and in canals in the on-farm drainage system.

(3) Velocity

Considering the frequency and the duration of design drainage condition, the maximum permissible velocity for drainage canals was set a little higher than that for irrigation canals.

Maximum velocity : 1.0 m/sec
Minimum velocity : 0.3 m/sec

(4) Roughness coefficient

The roughness coefficient of drainage canals was determined as below, considering the soil texture in the project area and the canal maintenance condition after the project implementation.

Roughness coefficient : $n = 0.035$

(5) Canal section

The canal section was designed taking into account the efficient construction works at the implementation in addition to the effective water flow and the canal slope stability.

The relationship between the canal base width and designed water depth was determined so that the ratio of water depth to base width will be more than one under the condition that the water depth be less than 1.5 m.

The canal inside slope was determined at 1: 1.5 in accordance with the soil mechanical condition.

General features of the main and branch drainage are shown in Table VI-17.

### 6.4.2 Related structures

The structures related to the drainage system are as follows:

(1) Drainage junction

A drainage junctions will be constructed at the confluence of main drain and branch drain for protection of the canal inside slope.

(2) Drainage inlet

Drainage inlets will be provided to receive the drained water from collector drain on main and branch drains crossing under farm road.

In accordance with design discharges, three types such as double box barrel type, single and double pipe barrel types of drainage inlets were designed from the viewpoint of economic construction.

Drainage inlet consists of inlet protection, culvert and outlet protection on the inside surface of parent canal.

(3) Drop

Drops of inclined chute type are applied considering large discharge. The drop consists of upstream transition, throat section, chute, stilling basin and downstream transition.

(4) Culvert

Culverts are classified into four types depending on design drainage discharges. Four types are single and double pipe barrel types and double and triple box barrel types. The culvert consists of upstream transition, box barrel section and downstream transition.

(5) Syphon

Syphons will be constructed across the existing water supply pipeline and farm roads. Two types such as double box barrel type and single pipe barrel types of syphons are considered depending on the design discharge. Syphon consists of inlet transition, barrel inlet, barrel section, barrel outlet and downstream protection.

The numbers of structures for the proposed drainage system are shown in Table VI-18.

### 6.4.3 Rehabilitation of existing canals and related structures

The related drainage structures and canals to be rehabilitated are as follows:

(1) Canals

The existing canal profiles and sections were also checked their flow capacities for the design discharge based on the canal route survey results. Most of canals will be required to be expanded for obtaining the design water level and enough flow capacities, and eroded inside slopes will be re-embanked.

General features of the existing canals are shown in Table VI-17.

(2) Related structures

The existing related structures in main and branch drains will have to be rehabilitated and improved on the basis of the results of inventory survey and check of canal profile sections.

The numbers of related structures to be rehabilitated and improved are presented in Table VI-18.

There are 16 re-use structures in MIS area, which will be rehabilitated. In addition, re-use structures of 7 nos. will be newly constructed.

## 6.5 Farm Road

### 6.5.1 Design of farm roads

Laterite pavement will be made on farm roads as required. The design criteria of roads are as follows:

| | | |
|---|---|---|
| Total width | : | 6.0 m |
| Effective width | : | 5.0 m |

| | | |
|---|---|---|
| Side slope | : | 1: 1.0 |
| Pavement thickness | : | 0.2 m |
| Embankment height | : | 0.5 m |

The proposed farm road system is shown in Fig. VI-21 and the length of each farm road are given in Table VI-19.

### 6.5.2 Rehabilitation of existing farm roads

According to the above criteria, the existing farm roads in MIS area will be rehabilitated and some farm roads will be expanded to link the project area to the national road.

The farm road system to be rehabilitated is shown in Fig. VI-21 and the length of each farm road are presented in Table VI-19.

## 6.6 On-farm Facilities

### 6.6.1 On-farm irrigation facilities

(1) Design of on-farm irrigation canals

The basic design condition and criteria are as follows:

(a) Design discharge of main feeder canals will range from 0.01 $m^3$/sec to 0.37 $m^3$/sec.

(b) Design water level

The following design water level above the field surface was used for the typical design.

| | | |
|---|---|---|
| Main feeder canal | : | 0.30 m |
| Feeder canal | : | 0.20 m |

(c) Canal section

The ratio of water depth to the canal base width will be nearly one under the condition that the minimum base width will be 0.30 m.

General features of on-farm irrigation canals are as follows:

| Canals | Canal Base Width (m) | Canal Height (m) | Canal Inside Slope |
|---|---|---|---|
| Main feeder canal | 0.50-0.30 | 0.60-0.40 | 1:1.0 |
| Feeder canal | 0.30 | 0.40 | 1:1.0 |

The typical canal sections of on-farm irrigation canals are shown in Fig. VI-22.

(2) Related structures

In relation to the above canals, some related structures such as offtakes, checks, culverts, field inlets and outlets will be provided to distribute and regulate water and to protect the canals.

(a) Offtake

Off-takes will be provided to distribute the required water from main feeder canal to feeder canal, and will be equipped with check with stop planks.

The discharge measurement will be made by the method using the orifice flow. The difference of water levels between upstream side of the gate and downstream side will be measured by gauging staffs.

(b) Check

Checks will be provided just downstream of field inlet in feeder canal to keep the required water level for field lot, and will be equipped with stop planks. On the other hand, the check with drop will also be provided as required.

(c) Culvert

Culverts will be provided in main feeder canal to cross under on-farm road. The culvert consists of pipe barrel and vertical walls at upstream and downstream ends.

(d) Field inlet and outlet

Field inlets will be installed at first field lot for every four field lots and field outlets be at last field lot. Field inlet and outlet are simple pre-fabricated concrete structures with stop planks.

### 6.6.2 On-farm drainage facilities

(1) Design of on-farm drainage canals

The basic design conditions and criteria are as follows:

(a) Design water level

To keep the enough low groundwater level for upland crops such as tomatoes, etc., following design water level below the field surface will be used for typical design.

Collector drain : 0.60 m
Field drain : 0.50 m

(b) Canal section

The ratio of water depth to the canal base width will be nearly one under the condition that the minimum base width will be 0.30 m.

General features of on-farm drainage canals are as follows:

| Canals | Canal Base Width (m) | Canal Height (m) | Canal Inside Slope |
|---|---|---|---|
| Collector drain | 0.70-0.50 | 1.40-1.20 | 1:1.0 |
| Field drain | 0.30 | 1.10 | 1:1.0 |

Typical canal sections of on-farm drainage canals are shown in Fig. VI-22.

(2) Related structures

In relation to the above drainage canals, structures such as drainage junctions, culverts, drops and farm approaches will be provided to convey drainage water and to protect the canals.

(a) Drainage junction

Drainage junctions will be provided at inflow points from field drain to collector drain. Drainage junctions will be constructed as a protection work with thin gabion.

(b) Culvert

Culverts will be provided in collector drains tp cross under on-farm roads. Culverts consist of single pipe barrel and vertical walls at upstream and downstream ends.

(c) Drop

Drops will be provided in field drain in the sloped land area. Drops consist of inlet protection, vertical wall with rectangular throat and outlet protection.

(d) Farm approach

Farm approaches will be provided in field drain for carrying the farm machinery to the fields. Farm approach consists of pipe barrels.

### 6.6.3 On-farm roads

(1) <u>On-farm road</u>

On-farm roads were designed as laterite pavement road. The design criteria of the roads are as follows:

| | | |
|---|---|---|
| Total width | : | 5.0 m |
| Effective width | : | 4.4 m |
| Pavement thickness | : | 0.15 m |
| Embankment height | : | 0.30 m |
| Slide slope | : | 1: 1.0 |

Typical cross section of on-farm road is shown in Fig. VI-22.

### 6.6.4 Rehabilitation of existing on-farm facilities in the MIS area

Major items to be rehabilitated are as follows:

(a) Rehabilitation of related structures such as offtakes, culverts, checks, field inlets and outlets in on-farm irrigation and drainage canals.

(b) Construction of new drainage junctions of gabion mat for protection at the junction of field drains and collector drains.

(c) Rehabilitation of on-farm roads with re-embankment and laterite pavement. The length of farm roads in each section is as shown below:

| Section | Tebere | Mwea | Thiba | Wamumu | Karaba | Total |
|---|---|---|---|---|---|---|
| Length (km) | 82.6 | 78.9 | 81.3 | 73.6 | 82.3 | 398.7 |

(d) Construction of new farm approach:

One farm approach for every four plots (1.6 ha) will be newly provided in field drains. Farm approaches will be made from concrete pipes.

(e) Construction of required on-farm facilities in horticultural crops field to be newly reclaimed.

## 6.7 Work Quantities

On the basis of the preliminary design mentioned above, the drawings were prepared for major facilities such as headworks, headraces, link canals, irrigation and drainage canals, and their related structures.

The drawings for respective facilities are attached in DRAWINGS. The work quantities of the major facilities were estimated from these drawings.

The work quantities of on-farm facilities were estimated by the sample calculations based on the typical on-farm layout.

The work quantities of those facilities are summarized as shown in Table VI-20.

Table VI-1 Net Area under Rice Cultivation in Each Unit

(Unit: ha)

| Tebere | | Mwea | | Thiba | | Wamumu | | Karaba | |
|---|---|---|---|---|---|---|---|---|---|
| T2 | 22 | M1 | 80 | H1 | 73 | W1 | 130 | K1 | 208 |
| T5 | 117 | M2 | 41 | H2 | 92 | W2 | 195 | K2 | 165 |
| T6 | 57 | M3 | 53 | H3 | 108 | W3 | 173 | K3 | 132 |
| T7 | 110 | M4 | 132 | H4 | 90 | W4 | 132 | K4 | 145 |
| T8 | 159 | M5 | 75 | H5 | 156 | W5 | 163 | K5 | 148 |
| T11 | 129 | M6 | 64 | H6 | 111 | W6 | 206 | K6 | 111 |
| T13 | 71 | M7 | 49 | H7 | 83 | W7 | 121 | K7 | 131 |
| T15 | 34 | M8 | 25 | H8 | 96 | | | K8 | 30 |
| T16 | 77 | M9 | 51 | H18 | 115 | | | | |
| T17 | 23 | M10 | 33 | H19 | 111 | | | | |
| T18 | 59 | M11 | 48 | H20 | 115 | | | | |
| T19 | 105 | M12(A) | 29 | | | | | | |
| T20 | 115 | M12(B) | 48 | | | | | | |
| T21 | 79 | M13 | 68 | | | | | | |
| T22 | 74 | M14 | 106 | | | | | | |
| T23 | 46 | M15 | 47 | | | | | | |
| T25 | 23 | M16 | 132 | | | | | | |
| | | M17 | 139 | | | | | | |
| Total: | 1,300 | | 1,220 | | 1,150 | | 1,120 | | 1,070 |

Source: NIB

Table VI-2 The Existing Related Irrigation Structures

(Unit: No.)

| No. | Name of Structure | NMI | NBI-I | NBI-II | NBI-III | TMI | TBI-I | TBI-II | TBI-III | TBI-IV | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Parshall flume | 1 | - | - | - | 1 | - | 1 | 1 | - | 4 |
| 2. | Culvert | 1 | 3 | 4 | 1 | 3 | 4 | 7 | 7 | 17 | 47 |
| 3. | Bridge | 4 | - | - | - | 3 | - | 1 | - | 2 | 10 |
| 4. | Turnout or offtake | 6 | 8 | 9 | 3 | 14 | 6 | 6 | 11 | 9 | 72 |
| 5. | Chute | 1 | - | 1 | - | - | - | - | - | - | 2 |
| 6. | Concrete flume | 1 | - | - | - | - | - | - | - | - | 1 |
| 7. | Drop | 15 | 16 | 15 | 11 | 32 | 5 | 13 | 21 | 28 | 156 |
| 8. | Check | 1 | 9 | 5 | 3 | 8 | - | 3 | 1 | 1 | 31 |
| 9. | Washing step | - | 2 | - | 1 | - | - | 1 | - | 2 | 6 |
| 10. | Spillway | - | - | 1 | 1 | - | - | 1 | - | - | 3 |
| 11. | Concrete lining | - | - | - | - | 1 | - | - | - | - | 1 |
| 12. | Cross drain | - | - | - | - | 1 | - | - | - | - | 1 |
| 13. | Horse shoe weir | - | - | - | - | 1 | - | - | 6 | 8 | 15 |
| 14. | Stone masonary lining | - | - | - | - | - | - | - | - | 1 | 1 |
| 15. | Cipolletti weir | - | - | 1 | - | - | - | - | - | - | 1 |
| | Total | 30 | 38 | 36 | 20 | 64 | 15 | 33 | 47 | 68 | 351 |

Table VI-3 The Existing Related Drainage Structures

(Unit: No.)

| No. | Name of Structure | NMD-I | NMD-II | NMD-III | TMD-I | TBD-I-1 | TMD-II | TMD-III | TMD-IV | KMD | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Culvert | 3 | 3 | 1 | 3 | 1 | 5 | 3 | 3 | 4 | 26 |
| 2. | Drop | 2 | - | - | - | 2 | 1 | - | - | - | 5 |
| 3. | Check | - | - | - | - | - | 1 | - | - | - | 1 |
| 4. | Drainage inlet | - | - | - | 4 | 7 | - | - | - | 5 | 16 |
| 5. | Aqueduct | - | - | - | - | - | - | 1 | - | 1 | 2 |
| | Total | 5 | 3 | 1 | 7 | 10 | 7 | 4 | 3 | 10 | 50 |

## Table VI-4 Percolation Test Result

(Unit: cm)

| No. | Date | Record (Without Base) | | ET+P | Record (With Base) | | ET | P |
|---|---|---|---|---|---|---|---|---|
| 1 | 87-08-15 | 10.70 | | | 11.90 | | | |
| 2 | 87-08-16 | 11.90 | | 1.20 | 12.40 | | 0.50 | |
| 3 | 87-08-17 | 12.80 | | 0.90 | 13.50 | | 1.10 | |
| 4 | 87-08-18 | 13.80 | | 1.00 | 14.40 | | 0.90 | |
| 5 | 87-08-19 | 13.90 | | 0.10 | 15.40 | | 1.00 | |
| 6 | 87-08-20 | 15.90 | | 2.00 | 16.90 | | 1.50 | |
| 7 | 87-08-21 | 15.00 | | -0.90 | 16.00 | | -0.90 | |
| 8 | 87-08-22 | 15.80 | 8.50 | 0.80 | 17.00 | 11.00 | 1.00 | |
| 9 | 87-08-23 | 8.70 | | 0.20 | 11.50 | | 0.50 | |
| 10 | 87-08-24 | 8.90 | | 0.20 | 11.90 | | 0.40 | |
| 11 | 87-08-25 | 10.50 | | 1.60 | 12.40 | | 0.50 | |
| 12 | 87-08-26 | 12.00 | | 1.50 | 13.40 | | 1.00 | |
| 13 | 87-08-27 | 12.50 | | 0.50 | 14.00 | | 0.60 | |
| 14 | 87-08-28 | 13.00 | | 0.50 | 14.90 | | 0.90 | |
| 15 | 87-08-29 | 13.50 | | 0.50 | 15.50 | | 0.60 | |
| 16 | 87-08-30 | 13.90 | | 0.40 | 15.80 | | 0.30 | |
| 17 | 87-08-31 | 14.90 | | 1.00 | 16.80 | | 1.00 | |
| 18 | 87-09-01 | 16.50 | 15.50 | 1.60 | 18.80 | 12.50 | 2.00 | |
| 19 | 87-09-02 | 16.00 | | 0.50 | 13.00 | | 0.50 | |
| 20 | 87-09-03 | 16.90 | | 0.90 | 14.00 | | 1.00 | |
| 21 | 87-09-04 | 18.00 | | 1.10 | 15.00 | | 1.00 | |
| 22 | 87-09-05 | 18.30 | | 0.30 | 15.50 | | 0.50 | |
| 23 | 87-09-06 | 18.50 | | 0.20 | 15.90 | | 0.40 | |
| 24 | 87-09-07 | 18.90 | | 0.40 | 16.40 | | 0.50 | |
| 25 | 87-09-08 | 19.00 | | 0.10 | 16.80 | | 0.40 | |
| 26 | 87-09-09 | 19.50 | 14.00 | 0.50 | 16.90 | 12.00 | 0.10 | |
| 27 | 87-09-10 | 15.00 | | 1.00 | 12.80 | | 0.80 | |
| 28 | 87-09-11 | 15.90 | | 0.90 | 13.00 | | 0.20 | |
| 29 | 87-09-12 | 16.50 | | 0.60 | 14.70 | | 1.70 | |
| 30 | 87-09-13 | 16.90 | | 0.40 | 15.60 | | 0.90 | |
| 31 | 87-09-14 | 17.90 | 10.00 | 1.00 | 16.00 | 10.00 | 0.40 | |
| 32 | 87-09-15 | 11.00 | | 1.00 | 11.00 | | 1.00 | |
| 33 | 87-09-16 | 11.50 | | 0.50 | 12.00 | | 1.00 | |
| 34 | 87-09-17 | 12.80 | | 1.30 | 12.90 | | 0.90 | |
| 35 | 87-09-18 | 13.50 | | 0.70 | 14.00 | | 1.10 | |
| 36 | 87-09-19 | 14.90 | | 1.40 | 14.50 | | 0.50 | |
| 37 | 87-09-20 | 15.00 | | 0.10 | 14.80 | | 0.30 | |
| 38 | 87-09-21 | 16.00 | | 1.00 | 15.00 | | 0.20 | |
| 39 | 87-09-22 | 16.50 | | 0.50 | 16.50 | | 1.50 | |
| 40 | 87-09-23 | 17.60 | | 1.10 | 17.00 | | 0.50 | |
| | Average | | | 0.7333 | 14.65 | | 0.7256 | 0.0077 |

Note: ET: Evapotranspiration
P: Percolation

Table VI-5 Rainfall of Basic Year and Design Rainfall

(Unit: mm)

| Month | Day | Rainfall of Basic Year | Design Rainfall | Month | Day | Rainfall of Basic Year | Design Rainfall |
|---|---|---|---|---|---|---|---|
| Jan. | 1-10 | 0 | 0 | Jul. | 1-10 | 0 | 0 |
| | 11-20 | 0 | 0 | | 11-20 | 0 | 0 |
| | 21-31 | 5 | 0 | | 21-31 | 0 | 0 |
| Feb. | 1-10 | 0 | 0 | Aug. | 1-10 | 15 | 14 |
| | 11-20 | 0 | 0 | | 11-20 | 8 | 6 |
| | 21-28 | 0 | 0 | | 21-31 | 1 | 0 |
| Mar. | 1-10 | 21 | 21 | Sep. | 1-10 | 0 | 0 |
| | 11-20 | 0 | 0 | | 11-20 | 0 | 0 |
| | 21-31 | 18 | 15 | | 21-30 | 0 | 0 |
| Apr. | 1-10 | 30 | 29 | Oct. | 1-10 | 0 | 0 |
| | 11-20 | 51 | 44 | | 11-20 | 2 | 0 |
| | 21-30 | 27 | 26 | | 21-31 | 48 | 43 |
| May | 1-10 | 162 | 161 | Nov. | 1-10 | 174 | 171 |
| | 11-20 | 33 | 25 | | 11-20 | 76 | 68 |
| | 21-31 | 25 | 23 | | 21-30 | 41 | 39 |
| Jun. | 1-10 | 0 | 0 | Dec. | 1-10 | 9 | 9 |
| | 11-20 | 0 | 0 | | 11-20 | 2 | 0 |
| | 21-30 | 0 | 0 | | 21-31 | 0 | 0 |
| Total | | | | | | 748 | 694 |

Table VI-6 Effective Rainfall (ER) and Farm Water Requirement (FWR)

(Unit: mm)

| Crops | | Rice(L) | | Rice(S) | | Beans S(L) | | Beans S(S) | | Onions(L) | | Tomatoes(S) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Day | ER | FWR | ER | FWR | ER | FWR | ER | FWR | ER | FWR | ER | FWR |
| Jan. | 1-10 | - | - | 0 | 19 | - | - | 0 | 53 | - | - | 0 | 62 |
| | 11-20 | - | - | 0 | 6 | - | - | 0 | 57 | - | - | 0 | 66 |
| | 21-31 | - | - | - | - | - | - | 0 | 65 | - | - | 0 | 74 |
| Feb. | 1-10 | - | - | - | - | - | - | 0 | 63 | - | - | 0 | 69 |
| | 11-20 | 0 | 10 | - | - | - | - | 0 | 52 | - | - | 0 | 56 |
| | 21-28 | 0 | 25 | - | - | - | - | 0 | 32 | - | - | 0 | 34 |
| Mar. | 1-10 | 21 | 43 | - | - | - | - | 21 | 18 | - | - | 21 | 19 |
| | 11-20 | 0 | 67 | - | - | 0 | 12 | 0 | 16 | 0 | 10 | 0 | 15 |
| | 21-31 | 15 | 75 | - | - | 15 | 36 | 15 | 4 | 15 | 31 | 15 | 3 |
| Apr. | 1-10 | 29 | 48 | - | - | 14 | 36 | - | - | 19 | 27 | - | - |
| | 11-20 | 38 | 39 | - | - | 20 | 33 | - | - | 27 | 25 | - | - |
| | 21-30 | 25 | 45 | - | - | 10 | 41 | - | - | 18 | 35 | - | - |
| May | 1-10 | 90 | 1 | - | - | 30 | 28 | - | - | 53 | 14 | - | - |
| | 11-20 | 25 | 28 | - | - | 15 | 30 | - | - | 15 | 37 | - | - |
| | 21-31 | 23 | 30 | - | - | 23 | 13 | - | - | 12 | 37 | - | - |
| Jun. | 1-10 | 0 | 29 | - | - | 0 | 24 | - | - | 0 | 37 | - | - |
| | 11-20 | 0 | 21 | - | - | 0 | 28 | - | - | 0 | 40 | - | - |
| | 21-30 | 0 | 13 | - | - | 0 | 32 | - | - | 0 | 42 | - | - |
| Jul. | 1-10 | 0 | 4 | - | - | 0 | 34 | - | - | 0 | 40 | - | - |
| | 11-20 | - | - | 0 | 7 | 0 | 37 | - | - | 0 | 40 | - | - |
| | 21-31 | - | - | 0 | 24 | 0 | 42 | - | - | 0 | 43 | - | - |
| Aug. | 1-10 | - | - | 14 | 33 | 14 | 30 | - | - | 14 | 30 | - | - |
| | 11-20 | - | - | 6 | 47 | 6 | 31 | - | - | 6 | 30 | - | - |
| | 21-31 | - | - | 0 | 65 | 0 | 30 | - | - | 0 | 29 | - | - |
| Sep. | 1-10 | - | - | 0 | 82 | 0 | 24 | - | - | 0 | 23 | - | - |
| | 11-20 | - | - | 0 | 83 | 0 | 14 | 0 | 11 | 0 | 13 | 0 | 14 |
| | 21-30 | - | - | 0 | 75 | 0 | 4 | 0 | 33 | 0 | 4 | 0 | 41 |
| Oct. | 1-10 | - | - | 0 | 63 | - | - | 0 | 44 | - | - | 0 | 56 |
| | 11-20 | - | - | 0 | 60 | - | - | 0 | 48 | - | - | 0 | 60 |
| | 21-31 | - | - | 43 | 26 | - | - | 41 | 34 | - | - | 43 | 45 |
| Nov. | 1-10 | - | - | 70 | 0 | - | - | 25 | 30 | - | - | 54 | 31 |
| | 11-20 | - | - | 38 | 25 | - | - | 26 | 22 | - | - | 27 | 31 |
| | 21-30 | - | - | 39 | 23 | - | - | 14 | 20 | - | - | 12 | 29 |
| Dec. | 1-10 | - | - | 9 | 40 | - | - | 9 | 21 | - | - | 9 | 26 |
| | 11-20 | - | - | 0 | 37 | - | - | 0 | 35 | - | - | 0 | 41 |
| | 21-31 | - | - | 0 | 30 | - | - | 0 | 44 | - | - | 0 | 52 |

## Table VI-7 Field Measurement Results on Irrigation Efficiency

### (1) Irrigation Efficiency at Unit Level

| Date | Qa | Qb | Qc | Qb + Qc | EF |
|---|---|---|---|---|---|
| 87-Sep-23 | 0.2011 | 0.0679 | 0.0039 | 0.0718 | 64.3 |
| 87-Sep-23 | 0.2245 | 0.0603 | 0.0035 | 0.0638 | 71.6 |
| 87-Sep-23 | 0.2298 | 0.0523 | 0.0037 | 0.0560 | 75.6 |
| 87-Sep-24 | 0.2218 | 0.0547 | 0.0035 | 0.0581 | 73.8 |
| 87-Sep-24 | 0.1688 | 0.0679 | 0.0028 | 0.0707 | 58.1 |
| 87-Sep-24 | 0.1592 | 0.0687 | 0.0044 | 0.0731 | 54.1 |
| 87-Sep-25 | 0.1640 | 0.0620 | 0.0128 | 0.0748 | 54.4 |
| 87-Sep-25 | 0.1592 | 0.0477 | 0.0088 | 0.0565 | 64.5 |
| 87-Sep-25 | 0.1616 | 0.0477 | 0.0114 | 0.0591 | 63.4 |
| Average | 0.1878 | 0.0588 | 0.0061 | 0.0649 | 64.4 |

Source: Qa: Discharge supplied to unit ($m^3$/sec)
Qb+Qc: Discharge drained out of unit ($m^3$/sec)
EF: Irrigation efficiency (%)

### (2) Irrigation Efficiency at Field Lot Level

| Date | Qa | Qb | Qa - Qb | FC | EF |
|---|---|---|---|---|---|
| 87-Sep-23 | 4.16 | 2.81 | 1.35 | 1.18 | 87.4 |
| 87-Sep-23 | 6.22 | 4.90 | 1.32 | 1.18 | 89.4 |
| 87-Sep-23 | 5.95 | 4.65 | 1.30 | 1.18 | 90.8 |
| 87-Sep-24 | 5.68 | 4.16 | 1.52 | 1.18 | 77.6 |
| 87-Sep-24 | 3.92 | 2.40 | 1.53 | 1.18 | 77.1 |
| 87-Sep-24 | 2.20 | 0.85 | 1.35 | 1.18 | 87.4 |
| 87-Sep-25 | 2.40 | 0.99 | 1.40 | 1.18 | 84.3 |
| 87-Sep-25 | 1.30 | 0.03 | 1.27 | 1.18 | 92.9 |
| 87-Sep-25 | 1.64 | 0.25 | 1.39 | 1.18 | 84.9 |
| Average | 3.72 | 2.34 | 1.38 | 1.18 | 85.5 |

Source: Qa: Discharge supplied to field lots (ℓ/sec)
Qb: Discharge drained out of field lots (ℓ/sec)
FC: Calculated field crop requirement in field lots (ℓ/sec)
EF: Irrigation efficiency (%)

Table VI-8 Unit Diversion Water Requirement for Respective Crops

(Unit: ℓ/sec/ha)

| Month | Day | Rice(L) | Rice(S) | Beans(L) | Beans(S) | Onions(L) | Tomatoes(S) |
|---|---|---|---|---|---|---|---|
| Jan. | 1-10 | - | 0.40 | - | 1.12 | - | 1.30 |
| | 11-20 | - | 0.13 | - | 1.20 | - | 1.39 |
| | 21-31 | - | - | - | 1.24 | - | 1.41 |
| Feb. | 1-10 | - | - | - | 1.32 | - | 1.45 |
| | 11-20 | 0.22 | - | - | 1.09 | - | 1.17 |
| | 21-28 | 0.65 | - | - | 0.84 | - | 0.88 |
| Mar. | 1-10 | 0.90 | - | - | 0.38 | - | 0.39 |
| | 11-20 | 1.42 | - | 0.25 | 0.33 | 0.22 | 0.06 |
| | 21-31 | 1.44 | - | 0.69 | 0.08 | 0.58 | - |
| Apr. | 1-10 | 1.01 | - | 0.75 | - | 0.58 | - |
| | 11-20 | 0.81 | - | 0.70 | - | 0.53 | - |
| | 21-30 | 0.96 | - | 0.86 | - | 0.73 | - |
| May | 1-10 | 0.01 | - | 0.60 | - | 0.29 | - |
| | 11-20 | 0.60 | - | 0.64 | - | 0.78 | - |
| | 21-31 | 0.57 | - | 0.24 | - | 0.71 | - |
| Jun. | 1-10 | 0.61 | - | 0.51 | - | 0.77 | - |
| | 11-20 | 0.45 | - | 0.60 | - | 0.84 | - |
| | 21-30 | 0.28 | - | 0.68 | - | 0.88 | - |
| Jul. | 1-10 | 0.09 | - | 0.72 | - | 0.85 | - |
| | 11-20 | - | 0.15 | 0.77 | - | 0.85 | - |
| | 21-31 | - | 0.46 | 0.80 | - | 0.83 | - |
| Aug. | 1-10 | - | 0.70 | 0.64 | - | 0.64 | - |
| | 11-20 | - | 0.99 | 0.65 | - | 0.63 | - |
| | 21-31 | - | 1.24 | 0.58 | - | 0.55 | - |
| Sep. | 1-10 | - | 1.72 | 0.51 | - | 0.48 | - |
| | 11-20 | - | 1.74 | 0.30 | 0.23 | 0.27 | 0.29 |
| | 21-30 | - | 1.58 | 0.09 | 0.07 | 0.09 | 0.87 |
| Oct. | 1-10 | - | 1.34 | - | 0.93 | - | 1.17 |
| | 11-20 | - | 1.27 | - | 1.00 | - | 1.26 |
| | 21-31 | - | 0.49 | - | 0.65 | - | 0.86 |
| Nov. | 1-10 | - | 0.00 | - | 0.62 | - | 0.65 |
| | 11-20 | - | 0.52 | - | 0.46 | - | 0.65 |
| | 21-30 | - | 0.49 | - | 0.43 | - | 0.62 |
| Dec. | 1-10 | - | 0.85 | - | 0.44 | - | 0.55 |
| | 11-20 | - | 0.79 | - | 0.74 | - | 0.87 |
| | 21-31 | - | 0.57 | - | 0.84 | - | 0.99 |

Note: L: Long rains
S: Short rains

Table VI-9 Water Holding Capacity of Horticultural Crop Field

| Crops | Root Zone (mm) (1) | Fraction (P) of Available Soil Water (2) | Field Capacity (% in Volume) (3) | Water Holding Capacity (mm) Correction by $ET_{Crop}$ | | |
|---|---|---|---|---|---|---|
| | | | | $ET_{Crop} \leq 3mm/day$ (1)x(2)x(3)x1.3 | $3mm/day < ET_{Crop} < 8mm/day$ (1)x(2)x(3) | $8mm/day \leq ET_{Crop}$ (1)x(2)x(3)x0.7 |
| French Beans | 600 | 0.45 | 40 | 140 | 108 | 76 |
| Onions | 400 | 0.25 | 40 | 52 | 40 | 28 |
| Tomatoes | 900 | 0.40 | 40 | 187 | 144 | 101 |

Note : $ET_{Crop} = Kc \times ETo$

Source : "Crop Water Requirement", Irrigation and Drainage Paper, Revised 1977, FAO

Table VI-10 Irrigable Area by Re-use Structure

| No. | Catchment Area | | Commanded Area | | Irrigable Area |
|---|---|---|---|---|---|
| | Unit No. | Area (ha) | Unit No. | Area (ha) | (ha) |
| Nyamindi Part | | | | | |
| 1 | T2 | 22 | T5 | 85 | 6 |
| 2 | T5 | 7 | T13 | 71 | 2 |
| 3 | T6 | 57 | T7 | 15 | 14 |
| 4 | T7 | 54 | T8 | 28 | 14 |
| 5 | T8 | 28 | T8 | 9 | 7 |
| 6 | T8 | 7 | T11 | 20 | 2 |
| 7 | T13 | 38 | T13 | 19 | 10 |
| 8 | T19 | 18 | (To NBI-II) | 78 | 5 |
| (Sub-total) | | (231) | | (325) | (60) |
| Thiba Part | | | | | |
| 1 | M3 | 7 | M3 | 2 | 2 |
| 2 | M4 | 74 | M4 | 10 | 10 |
| 3 | M4 | 15 | M4 | 18 | 4 |
| 4 | M7 | 14 | (To TMC) | 3,943 | 4 |
| 5 | M9,M10 | 27 | M11 | 16 | 7 |
| 6 | M12(B) | 12 | M12(B) | 3 | 3 |
| 7 | M15 | 32 | (To TMC) | 3,215 | 8 |
| 8 | M9-14,H18,H19 | 534 | (To TBI-IV) | 1,688 | 134 |
| 9 | M15,M16,H20 | 150 | (To TBI-II) | 290 | 38 |
| 10 | H1,H3 | 181 | (To TBI-II) | 179 | 45 |
| 11 | H2,H4 | 182 | (To TBI-III) | 497 | 46 |
| 12 | H5 | 156 | H8<br>(To TBI-III) | 5<br>172 | 5<br>34 |
| 13 | W6, K1 | 414 | (To TBI-IV) | 564 | 104 |
| (Sub-total) | | (1,789) | | (10,602) | (444) |
| Total | | (2,029) | | (10,932) | (504) |

## Table VI-11 Diversion Water Requirement (DWR)

(Unit: $m^3/sec$)

| Irrigation Part | | Nyamindi | | | Thiba | | | Mutithi | | | T-20 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area (ha) | | 1185(60) | 571 | 1756(60) | 4560(444) | 200 | 4760(444) | 2470 | 430 | 2900 | 115 | 29 | 144 |
| Month | Day | RDWR | HDWR | DWR | RDWR | HDWR | DWR | RDWR | HDWR | DWR | RDWR | HDWR | DWR |
| Jan. | 1-10 | 0.45 | 0.69 | 1.14 | 1.65 | 0.24 | 1.89 | 0.99 | 0.52 | 1.51 | 0.05 | 0.04 | 0.09 |
| | 11-20 | 0.15 | 0.74 | 0.89 | 0.54 | 0.26 | 0.80 | 0.32 | 0.56 | 0.88 | 0.01 | 0.04 | 0.05 |
| | 21-31 | 0.00 | 0.76 | 0.76 | 0.00 | 0.27 | 0.27 | 0.00 | 0.57 | 0.57 | 0.00 | 0.04 | 0.04 |
| Feb. | 1-10 | 0.00 | 0.79 | 0.79 | 0.00 | 0.28 | 0.28 | 0.00 | 0.60 | 0.60 | 0.00 | 0.04 | 0.04 |
| | 11-20 | 0.25 | 0.65 | 0.90 | 0.91 | 0.23 | 1.14 | 0.54 | 0.49 | 1.03 | 0.03 | 0.03 | 0.06 |
| | 21-28 | 0.73 | 0.49 | 1.22 | 2.68 | 0.17 | 2.85 | 1.61 | 0.37 | 1.98 | 0.07 | 0.02 | 0.09 |
| Mar. | 1-10 | 1.01 | 0.22 | 1.23 | 3.70 | 0.08 | 3.78 | 2.22 | 0.17 | 2.39 | 0.10 | 0.01 | 0.11 |
| | 11-20 | 1.60 | 0.32 | 1.92 | 5.84 | 0.11 | 5.95 | 3.51 | 0.24 | 3.75 | 0.16 | 0.02 | 0.18 |
| | 21-31 | 1.62 | 0.41 | 2.03 | 5.93 | 0.14 | 6.07 | 3.56 | 0.31 | 3.87 | 0.17 | 0.02 | 0.19 |
| Apr. | 1-10 | 1.14 | 0.38 | 1.52 | 4.16 | 0.13 | 4.29 | 2.49 | 0.29 | 2.78 | 0.12 | 0.02 | 0.14 |
| | 11-20 | 0.91 | 0.35 | 1.26 | 3.33 | 0.12 | 3.45 | 2.00 | 0.27 | 2.27 | 0.09 | 0.02 | 0.11 |
| | 21-30 | 1.08 | 0.46 | 1.54 | 3.95 | 0.16 | 4.11 | 2.37 | 0.34 | 2.71 | 0.11 | 0.02 | 0.13 |
| May | 1-10 | 0.01 | 0.26 | 0.27 | 0.04 | 0.09 | 0.12 | 0.02 | 0.19 | 0.21 | 0.00 | 0.01 | 0.01 |
| | 11-20 | 0.68 | 0.41 | 1.09 | 2.47 | 0.14 | 2.61 | 1.48 | 0.31 | 1.79 | 0.07 | 0.02 | 0.09 |
| | 21-31 | 0.64 | 0.27 | 0.91 | 2.35 | 0.10 | 2.45 | 1.41 | 0.21 | 1.62 | 0.07 | 0.01 | 0.08 |
| Jun. | 1-10 | 0.69 | 0.37 | 1.06 | 2.51 | 0.13 | 2.64 | 1.51 | 0.28 | 1.79 | 0.07 | 0.02 | 0.09 |
| | 11-20 | 0.51 | 0.41 | 0.92 | 1.85 | 0.14 | 1.99 | 1.11 | 0.31 | 1.42 | 0.05 | 0.02 | 0.07 |
| | 21-30 | 0.32 | 0.45 | 0.77 | 1.15 | 0.16 | 1.31 | 0.69 | 0.34 | 1.03 | 0.03 | 0.02 | 0.05 |
| Jul. | 1-10 | 0.10 | 0.45 | 0.55 | 0.37 | 0.16 | 0.53 | 0.22 | 0.34 | 0.56 | 0.01 | 0.02 | 0.03 |
| | 11-20 | 0.17 | 0.46 | 0.63 | 0.62 | 0.16 | 0.78 | 0.37 | 0.35 | 0.72 | 0.02 | 0.02 | 0.04 |
| | 21-31 | 0.52 | 0.47 | 0.99 | 1.89 | 0.16 | 2.05 | 1.14 | 0.35 | 1.49 | 0.05 | 0.02 | 0.07 |
| Aug. | 1-10 | 0.79 | 0.37 | 1.16 | 2.88 | 0.13 | 3.01 | 1.73 | 0.28 | 2.01 | 0.08 | 0.02 | 0.10 |
| | 11-20 | 1.11 | 0.37 | 1.48 | 4.07 | 0.13 | 4.20 | 2.45 | 0.28 | 2.73 | 0.11 | 0.02 | 0.13 |
| | 21-31 | 1.40 | 0.33 | 1.73 | 5.10 | 0.11 | 5.21 | 3.06 | 0.25 | 3.31 | 0.14 | 0.02 | 0.16 |
| Sep. | 1-10 | 1.94 | 0.29 | 2.23 | 7.08 | 0.10 | 7.18 | 4.25 | 0.22 | 4.47 | 0.20 | 0.01 | 0.21 |
| | 11-20 | 1.96 | 0.31 | 2.27 | 7.16 | 0.11 | 7.27 | 4.30 | 0.24 | 4.54 | 0.20 | 0.02 | 0.22 |
| | 21-30 | 1.78 | 0.50 | 2.28 | 6.50 | 0.18 | 6.68 | 3.90 | 0.38 | 4.28 | 0.18 | 0.03 | 0.21 |
| Oct. | 1-10 | 1.51 | 0.60 | 2.11 | 5.52 | 0.21 | 5.73 | 3.31 | 0.45 | 3.76 | 0.15 | 0.03 | 0.18 |
| | 11-20 | 1.43 | 0.65 | 2.08 | 5.23 | 0.23 | 5.46 | 3.14 | 0.49 | 3.63 | 0.15 | 0.03 | 0.18 |
| | 21-31 | 0.55 | 0.43 | 0.98 | 2.02 | 0.15 | 2.17 | 1.21 | 0.33 | 1.54 | 0.06 | 0.02 | 0.08 |
| Nov. | 1-10 | 0.00 | 0.37 | 0.37 | 0.00 | 0.13 | 0.13 | 0.00 | 0.28 | 0.28 | 0.00 | 0.02 | 0.02 |
| | 11-20 | 0.59 | 0.32 | 0.91 | 2.14 | 0.11 | 2.25 | 1.28 | 0.24 | 1.52 | 0.06 | 0.02 | 0.08 |
| | 21-30 | 0.55 | 0.30 | 0.85 | 2.02 | 0.11 | 2.13 | 1.21 | 0.23 | 1.44 | 0.06 | 0.02 | 0.08 |
| Dec. | 1-10 | 0.96 | 0.29 | 1.25 | 3.50 | 0.10 | 3.60 | 2.10 | 0.22 | 2.32 | 0.10 | 0.01 | 0.11 |
| | 11-20 | 0.89 | 0.46 | 1.35 | 3.25 | 0.16 | 3.41 | 1.95 | 0.35 | 2.30 | 0.09 | 0.02 | 0.11 |
| | 21-31 | 0.64 | 0.53 | 1.18 | 2.35 | 0.18 | 2.53 | 1.41 | 0.40 | 1.81 | 0.07 | 0.03 | 0.10 |

Note: RDWR: Diversion water requirement for rice HDWR: Diversion water requirement for horticultural crops
Fitures in parenthesis shows irrigable area by re-use of return flow.

## Table VI-12 Net Irrigation Area in Each Unit

(Unit: ha)

| Nyamindi System | | | |
|---|---|---|---|
| Tebere Section | | | |
| No. | P | H | T |
| T1 | - | 52 | 52 |
| 2 | 22 | 32 | 54 |
| 3 | - | 43 | 43 |
| 4 | - | 19 | 19 |
| 5 | 117 | 21 | 138 |
| 6 | 57 | - | 57 |
| 7 | 110 | - | 110 |
| 8 | 159 | - | 159 |
| 9 | - | 119 | 119 |
| 10 | - | 113 | 113 |
| 11 | 129 | - | 129 |
| 12 | - | 17 | 17 |
| 13 | 71 | 20 | 91 |
| 14 | - | 80 | 80 |
| 15 | 34 | - | 34 |
| 16 | 77 | 15 | 92 |
| 17 | 23 | - | 23 |
| 18 | 59 | 23 | 82 |
| 19 | 105 | - | 105 |
| 20 | 115 | 29 | 144 |
| 21 | 79 | - | 79 |
| 22 | 74 | - | 74 |
| 23 | 46 | - | 46 |
| 24 | - | 7 | 7 |
| 25 | - | 10 | 10 |
| 26 | 23 | - | 23 |
| | 1,300 | 600 | 1,900 |

| Thiba System | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mwea Section | | | | Thiba Section | | | | Wamumu Section | | | | Karaba Section | | | |
| No. | P | H | T | No. | P | H | T | No. | P | H | T | No. | P | H | T |
| M1 | 80 | - | 80 | H1 | 73 | - | 73 | W1 | 130 | - | 130 | K1 | 208 | - | 208 |
| 2 | 41 | - | 41 | 2 | 92 | 6 | 98 | 2 | 195 | - | 195 | 2 | 165 | - | 165 |
| 3 | 53 | - | 53 | 3 | 108 | - | 108 | 3 | 173 | - | 173 | 3 | 132 | - | 132 |
| 4 | 132 | 59 | 191 | 4 | 90 | 16 | 106 | 4 | 132 | - | 132 | 4 | 145 | - | 145 |
| 5 | 75 | - | 75 | 5 | 156 | 10 | 166 | 5 | 163 | - | 163 | 5 | 148 | - | 148 |
| 6 | 64 | 5 | 69 | 6 | 111 | - | 111 | 6 | 206 | - | 206 | 6 | 111 | - | 111 |
| 7 | 49 | 25 | 74 | 7 | 83 | - | 83 | 7 | 121 | 14 | 135 | 7 | 131 | - | 131 |
| 8 | 25 | - | 25 | 8 | 96 | - | 96 | | | | | 8 | 30 | - | 30 |
| 9 | 51 | 4 | 55 | 18 | 115 | - | 115 | | | | | | | | |
| 10 | 33 | 26 | 59 | 19 | 111 | - | 111 | | | | | | | | |
| 11 | 48 | - | 48 | 20 | 115 | - | 115 | | | | | | | | |
| 12A | 29 | - | 29 | | | | | | | | | | | | |
| 12B | 48 | - | 48 | | | | | | | | | | | | |
| 13 | 68 | - | 68 | | | | | | | | | | | | |
| 14 | 106 | 13 | 119 | | | | | | | | | | | | |
| 15 | 47 | - | 47 | | | | | | | | | | | | |
| 16 | 132 | 8 | 140 | | | | | | | | | | | | |
| 17 | 139 | 14 | 153 | | | | | | | | | | | | |
| | 1,220 | 154 | 1,374 | | 1,150 | 32 | 1,182 | | 1,120 | 14 | 1,134 | | 1,070 | - | 1,070 |

| Mutiti System | | | | | | | |
|---|---|---|---|---|---|---|---|
| Kibiriri Section | | | | Rukanga Section | | | |
| No. | P | H | T | No. | P | H | T |
| I1 | 14 | - | 14 | R1 | 29 | - | 29 |
| 2 | - | 131 | 131 | 2 | 12 | - | 12 |
| 3 | - | 22 | 22 | 3 | 37 | - | 37 |
| 4 | 93 | - | 93 | 4 | 60 | - | 60 |
| 5 | - | 18 | 18 | 5 | 69 | - | 69 |
| 6 | 74 | - | 74 | 6 | 89 | - | 89 |
| 7 | - | 163 | 163 | 7 | 90 | - | 90 |
| 8 | 84 | - | 84 | 8 | 54 | - | 54 |
| 9 | 57 | - | 57 | 9 | 20 | 12 | 32 |
| 10 | 47 | - | 47 | 10 | - | 28 | 28 |
| 11 | 128 | - | 128 | 11 | - | 42 | 42 |
| 12 | 82 | - | 82 | 12 | 96 | - | 96 |
| 13 | 124 | - | 124 | 13 | 92 | - | 92 |
| 14 | 114 | - | 114 | 14 | 82 | - | 82 |
| 15 | 99 | - | 99 | 15 | 84 | - | 84 |
| 16 | 137 | - | 137 | 16 | 86 | - | 86 |
| 17 | 67 | - | 67 | 17 | 61 | - | 61 |
| | | | | 18 | 82 | - | 82 |
| | | | | 19 | 29 | 5 | 34 |
| | | | | 20 | 74 | 9 | 83 |
| | | | | 21 | 58 | - | 58 |
| | | | | 22 | 86 | - | 86 |
| | | | | 23 | 42 | - | 42 |
| | | | | 24 | 18 | - | 18 |
| | 1,120 | 334 | 1,454 | | 1,350 | 96 | 1,446 |

Note: P - Paddy area
H - Horticultural crops area
T - Total area = P + H

# Table VI-13 Drainage Area of Each Drainage Block

(Unit: ha)

**Nyamindi System**

| NMD-I No. | P | S | T | NMD-II No. | P | S | T | NMD-III No. | P | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 95 | 66 | 161 | 1 | - | 5 | 5 | 1 | 91 | 158 | 249 |
| | | | | 2 | 104 | 22 | 126 | | | | |
| | | | | 3 | - | 7 | 7 | | | | |
| | | | | 4 | 15 | - | 15 | | | | |
| | | | | 5 | 182 | - | 182 | | | | |
| | | | | 6 | 162 | - | 162 | | | | |
| | 95 | 66 | 161 | | 463 | 34 | 497 | | 91 | 158 | 249 |

**Thiba System**

| TMD-I No. | P | S | T | TRD-I-1 No. | P | S | T | TMD-II No. | P | S | T | TMD-III No. | P | S | T | TMD-IV No. | P | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 316 | 25 | 341 | 1 | 8 | - | 8 | 1 | 5 | - | 5 | 1 | - | 20 | 20 | 1 | 12 | 121 | 133 |
| 2 | - | 35 | 35 | 2 | 16 | - | 16 | 2 | 30 | - | 30 | 2 | 78 | 80 | 158 | 2 | - | 21 | 21 |
| 3 | 124 | - | 124 | 3 | 133 | - | 133 | 3 | 33 | - | 33 | 3 | 34 | - | 34 | 3 | - | 40 | 40 |
| 4 | - | 27 | 27 | 4 | 35 | 8 | 43 | 4 | 21 | - | 21 | 4 | 12 | - | 12 | 4 | 33 | - | 33 |
| 5 | 192 | - | 192 | 5 | 487 | 1,354 | 1,841 | 5 | 183 | 229 | 412 | 5 | 133 | 47 | 180 | 5 | - | 37 | 37 |
| 6 | 153 | - | 153 | | | | | | | | | | | | | 6 | 16 | 95 | 111 |
| 7 | - | 2 | 2 | | | | | | | | | | | | | 7 | - | 61 | 61 |
| 8 | 297 | 200 | 499 | | | | | | | | | | | | | 8 | - | 18 | 18 |
| | | | | | | | | | | | | | | | | 9 | 358 | 36 | 394 |
| | 1,082 | 289 | 1,371 | | 679 | 1,362 | 2,041 | | 272 | 229 | 501 | | 257 | 147 | 404 | | 419 | 429 | 848 |

(Unit: ha)

**Thiba System**

| TBD-IV-1 No. | P | S | T | KOM No. | P | S | T |
|---|---|---|---|---|---|---|---|
| 1 | 18 | 64 | 82 | 1 | 110 | 24 | 134 |
| | | | | 2 | 131 | 5 | 136 |
| | | | | 3 | 125 | - | 125 |
| | | | | 4 | - | 66 | 66 |
| | | | | 5 | 12 | 63 | 75 |
| | | | | 6 | 31 | - | 31 |
| | | | | 7 | 38 | - | 38 |
| | | | | 8 | 34 | - | 34 |
| | | | | 9 | 88 | 52 | 140 |
| | | | | 10 | 68 | - | 68 |
| | | | | 11 | - | 4 | 4 |
| | | | | 12 | - | 3 | 3 |
| | | | | 13 | - | 393 | 393 |
| | | | | 14 | - | 131 | 131 |
| | 18 | 64 | 82 | | 637 | 741 | 1,378 |

**Mutithi System**

| TAMD-I No. | P | S | T | TAMD-II No. | P | S | T | KMD-I No. | P | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 105 | 22 | 127 | 1 | 96 | - | 96 | 1 | - | 3 | 3 |
| 2 | 81 | 11 | 92 | 2 | 101 | - | 101 | 2 | 72 | 25 | 97 |
| 3 | - | 143 | 143 | 3 | 97 | - | 97 | 3 | - | 1 | 1 |
| 4 | - | 269 | 269 | 4 | 93 | - | 93 | 4 | 99 | 24 | 123 |
| 5 | - | 44 | 44 | 5 | 71 | 9 | 80 | 5 | 55 | 8 | 63 |
| | | | | 6 | 15 | - | 15 | 6 | - | 33 | 33 |
| | | | | 7 | 44 | - | 44 | 7 | 69 | 53 | 122 |
| | | | | 8 | 23 | 60 | 83 | 8 | - | 9 | 9 |
| | | | | 9 | - | 10 | 10 | 9 | 15 | - | 15 |
| | | | | 10 | 48 | 11 | 59 | 10 | - | 7 | 7 |
| | | | | 11 | - | 7 | 7 | 11 | 113 | 13 | 126 |
| | | | | 12 | - | 74 | 74 | 12 | 84 | - | 84 |
| | | | | 13 | - | 292 | 292 | 13 | - | 308 | 308 |
| | | | | 14 | - | 308 | 308 | | | | |
| | 186 | 489 | 675 | | 588 | 771 | 1,359 | | 507 | 484 | 991 |

| KBD-II No. | P | S | T | KMD-II-1 No. | P | S | T | KMD-III No. | P | S | T | KMD-III-1 No. | P | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 23 | 23 | 1 | 87 | - | 87 | 1 | - | 4 | 4 | 1 | 79 | - | 79 |
| 2 | - | 16 | 16 | 2 | - | 156 | 156 | 2 | - | 6 | 6 | 2 | 161 | - | 161 |
| 3 | 109 | - | 109 | | | | | 3 | - | 161 | 161 | 3 | - | 211 | 211 |
| 4 | 17 | 177 | 194 | | | | | 4 | - | 8 | 8 | | | | |
| | | | | | | | | 5 | - | 112 | 112 | | | | |
| | 126 | 216 | 342 | | 87 | 156 | 243 | | - | 311 | 311 | | 240 | 211 | 451 |

Note: P - Paddy area
S - Surrounding land area
T - Total area = P+S

NMD - Nyamindi Main Drain
TMD - Thiba Main Drain
TBD - Thiba Branch Drain

TAMD - Tana Main Drain
KMD - Kiruara Main Drain
KBD - Kiruara Branch Drain

Table VI-14 Related Structures in Headraces, Link Canals and Nyamindi New Main Canal

(Unit: No.)

| Name of Structures | Headraces Nyamindi | Headraces Ruamuthambi | Link Canals I | Link Canals II | Link Canals III | New Nyamindi Main Canal | Total |
|---|---|---|---|---|---|---|---|
| Offtake | - | 2 | - | - | - | - | 2 |
| Culvert (Type C) | 2 | - | - | 1 | - | - | 3 |
| (Type D) | - | 4 | 13 | - | 5 | 4 | 26 |
| Drop | - | 15 | 1 | 1 | - | 11 | 28 |
| Cross drain | - | 1 | 11 | 1 | - | - | 13 |
| Cippolleti Weir | 1 | 1 | 1 | 1 | 1 | 1 | 6 |
| Total | 3 | 23 | 26 | 4 | 6 | 16 | 78 |

Table VI-15 General Feature of Irrigation Canals

| Canal Name | Canal Length (m) | Design Discharge ($m^3$/sec) | Base Width (m) | Water Depth (m) | Canal Height (m) |
|---|---|---|---|---|---|
| Nyamindi System | | | | | |
| NMI | 4,480 | 2.28-1.95 | 5.50-2.00 | 0.69-0.56 | 0.80-0.90 |
| NBI-I | 6,400 | 0.99-0.04 | 2.00-0.30 | 0.72-0.14 | 0.90-0.30 |
| NBI-II | 5,600 | 1.01-0.05 | 1.00-0.30 | 0.81-0.12 | 1.00-0.30 |
| NBI-III | 3,550 | 0.24-0.04 | 0.60-0.30 | 0.32-0.15 | 0.50-0.30 |
| Thiba System | | | | | |
| TMI | 8,850 | 6.35-4.06 | 6.50-4.00 | 1.31-1.10 | 1.50-1.40 |
| TBI-I | 3,460 | 0.92-0.33 | 2.00-1.50 | 0.70-0.50 | 0.90-0.70 |
| TBI-II | 4,900 | 0.48-0.16 | 1.50-1.00 | 0.69-0.30 | 0.90-0.50 |
| TBI-III | 5,800 | 1.56-0.30 | 2.00-1.50 | 1.08-0.36 | 1.30-0.60 |
| TBI-IV | 15,870 | 2.73-0.28 | 3.50-1.50 | 1.23-0.40 | 1.40-0.60 |
| Mutithi System | | | | | |
| MMI | 1,100 | 4.46-1.53 | 2.00-1.10 | 1.53-0.91 | 1.70-1.10 |
| MBI-I | 4,110 | 0.44-0.13 | 0.70-0.30 | 0.53-0.17 | 0.70-0.40 |
| MBI-II | 7,460 | 0.77-0.09 | 0.90-0.70 | 0.90-0.23 | 0.90-0.40 |
| MBI-III | 9,110 | 1.72-0.17 | 1.20-0.40 | 1.19-0.34 | 1.40-0.50 |
| MBI-IV | 8,130 | 1.53-0.25 | 1.10-0.40 | 1.10-0.38 | 1.30-0.60 |
| MBI-V | 3,110 | 0.35-0.12 | 0.70-0.40 | 0.67-0.33 | 0.90-0.40 |

Table VI-16 Related Structures in Irrigation Canals (1/2)

- Nyamindi and Thiba System -

| Structure | NMI | | | NBI-I | | | NBI-II | | | NBI-III | | | TMI | | | TBI-I | | | TBI-II | | | TBI-III | | | TBI-IV | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE |
| PF | 1 | | | | | | | | | | | | 1 | | | | | | 1 | | | 1 | | | | | | 4 | | |
| CV | 1 | | | 3 | | | 2 | 2 | | | 1 | | 2 | | | 3 | 1 | | 6 | 1 | | 3 | 4 | | 12 | 5 | | 32 | 14 | |
| BG | 4 | | | | | | | | | | | | 4 | | | | | | 1 | | | | | | 2 | | | 11 | | |
| TO | 4 | 2 | 1 | 6 | 2 | 3 | 3 | 6 | 2 | 2 | 1 | 1 | 12 | 1 | | 6 | | 1 | 6 | | | 6 | 5 | | 8 | 1 | 1 | 53 | 18 | 9 |
| CH | | 1 | | | | | 1 | | | | | | | | | | | | | | 1 | | | 1 | | | | 1 | 1 | 2 |
| CF | | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| DR | | 15 | 5 | 15 | 1 | 3 | 14 | 1 | 2 | 11 | | 1 | 26 | 5 | 10 | 1 | 4 | 5 | 1 | 12 | 1 | 6 | 15 | 3 | 6 | 22 | 10 | 80 | 75 | 40 |
| CK | | 1 | 1 | 8 | 1 | 2 | 5 | | 6 | 3 | | 1 | 7 | | 2 | | | | 2 | 1 | 2 | 1 | | 3 | 1 | 2 | | 27 | 5 | 17 |
| WS | | | | 1 | 1 | | | | | 1 | | | | | 3 | | | 1 | | 1 | 2 | | | | | 2 | 3 | 2 | 4 | 9 |
| SP | | | | | | | 1 | | | | 1 | | | | 1 | | | | 1 | | | | | | | | | 2 | 1 | 1 |
| CL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CD | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HS | | | | | | | | | | | | | 1 | | | | | | | | | 5 | 1 | | 6 | | | 12 | 1 | |
| SM | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | 1 | | |
| CW | | | | | | 1 | 1 | | | | | 1 | | | | | | 1 | | | 1 | | | 1 | | | 1 | 1 | | 6 |
| Sub-total: | 10 | 20 | 7 | 33 | 5 | 10 | 27 | 9 | 10 | 17 | 3 | 4 | 53 | 6 | 16 | 10 | 5 | 8 | 18 | 15 | 7 | 22 | 25 | 8 | 36 | 32 | 15 | 226 | 120 | 85 |
| Total: | | 37 | | | 48 | | | 46 | | | 24 | | | 75 | | | 23 | | | 41 | | | 55 | | | 83 | | | 431 | |

Note: EX - Existing structures unnecessary for rehabilitation
RE - Existing structures to be rehabilitated
NE - New structures to be constructed

PF - Parshall flume
CV - Culvert
BG - Bridge
TO - Turnout or offtake
CH - Chute

CF - Concrete flume
DR - Drop
CK - Check
WS - Washing step
SP - Spillway

CL - Concrete lining
CD - Cross drain
HS - Horse shoe weir
SM - Stone masonry
CW - Cipolletti weir

Table VI-16 Related Structures in Irrigation Canals (2/2)

- Mutithi System -

| Structure Name | MMI | MBI-I | MBI-II | MBI-III | MBI-IV | MBI-V | Total |
|---|---|---|---|---|---|---|---|
| DR | 3 | 15 | 19 | 39 | 30 | 1 | 107 |
| CV | | | 1 | 4 | 3 | | 8 |
| CK | 2 | 6 | 8 | 10 | 9 | 2 | 37 |
| TO | 4 | 6 | 8 | 10 | 13 | 2 | 43 |
| CW | 2 | 1 | 1 | 2 | 1 | 1 | 8 |
| WS | | 1 | 4 | 3 | 5 | 1 | 14 |
| CD | | | 2 | 1 | 1 | 1 | 5 |
| CH | | | | 1 | 2 | | 3 |
| Total: | 11 | 29 | 43 | 70 | 64 | 8 | 225 |

Note:
DR - Drop
CV - Culvert
CK - Check
TO - Turnout or offtake
CW - Cipolletti weir
WS - Washing step
CD - Cross drain
CH - Chute

Table VI-17 General Feature of Drainage Canals

| Canal Name | Canal Length (m) | Design Discharge ($m^3$/sec) | Base Width (m) | Water Depth (m) | Canal Height (m) |
|---|---|---|---|---|---|
| <u>Nyamindi System</u> | | | | | |
| NMD-I | 1,230 | 1.92 | 1.5 | 0.85 | 1.10 |
| NMD-II | 4,020 | 6.07-2.01 | 2.5-1.5 | 1.38-0.76 | 1.5-1.00 |
| NMD-III | 600 | 3.01 | 2.0 | 0.96 | 1.20 |
| <u>Thiba System</u> | | | | | |
| TMD-I | 5,580 | 40.90-3.45 | 10.00-1.50 | 2.83-1.33 | 3.20-1.60 |
| TBD-I-1 | 2,300 | 24.77-5.65 | 15.00-3.00 | 1.41-1.36 | 1.70-1.60 |
| TMD-II | 2,100 | 5.99-2.12 | 2.50-1.50 | 1.50-0.84 | 1.80-1.00 |
| TMD-III | 2,970 | 4.80-2.13 | 2.00-1.50 | 1.00-0.82 | 1.30-1.10 |
| TMD-IV | 4,560 | 11.18-4.15 | 3.00-1.50 | 1.35-0.69 | 1.60-1.20 |
| TMD-IV-1 | 1,140 | 1.0 | 1.0 | 0.42 | 0.70 |
| KMD | 8,300 | 16.58-1.62 | 10.00-2.00 | 1.48-0.60 | 1.70-0.80 |
| <u>Mutithi System</u> | | | | | |
| TAMD-I | 6,390 | 8.22-0.55 | 2.40-0.60 | 2.36-0.45 | 2.60-0.70 |
| TAMD-II | 7,800 | 16.38-8.36 | 2.60-2.00 | 2.56-1.82 | 2.90-2.00 |
| KMD-I | 4,320 | 11.68-3.82 | 8.00-4.00 | 1.21-0.75 | 1.50-1.00 |
| KMD-II | 4,200 | 7.08-2.39 | 6.50-2.00 | 0.93-0.78 | 1.10-1.00 |
| KBD-II-1 | 1,800 | 2.94-1.93 | 3.00-2.50 | 0.52-0.41 | 0.70-0.60 |
| KMD-III | 3,400 | 25.59-16.58 | 3.30-2.60 | 3.23-2.59 | 3.60-2.90 |
| KBD-III-1 | 3,600 | 5.40-2.62 | 1.50-1.20 | 1.49-1.02 | 1.80-1.30 |

Table VI-18 Related Structures in Drainage Canals (1/2)

- Nyamindi and Thiba System -

| Structure | NMD-I | | | NMD-II | | | NMD-III | | | TMD-I | | | TBD-I-1 | | | TMD-II | | | TMD-III | | | TMD-IV | | | KMD | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE | EX | RE | NE |
| CV | | 3 | | 2 | 1 | | 1 | | | | 3 | 2 | | 1 | | | 5 | | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 9 | 17 | 7 |
| DR | 2 | | 2 | | | 21 | | | 3 | | | 9 | | 1 | 1 | | 1 | 4 | | | 8 | | | 2 | | | 34 | 2 | 2 | 84 |
| DI | | | 2 | | | | | | | 4 | | | 4 | 4 | | | | | | | 1 | | | 1 | 2 | 3 | 3 | 10 | 7 | 7 |
| DJ | | | | | | | | | | | | 1 | | | | | | | | | | | | 2 | | | | | | 3 |
| CK | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | 1 | |
| AD | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | | | 2 | 0 | |
| Sub-total: | 2 | 3 | 4 | 2 | 1 | 21 | 1 | | 3 | 4 | 3 | 12 | 4 | 6 | 1 | | 7 | 4 | 3 | 1 | 11 | 2 | 1 | 7 | 5 | 5 | 38 | 23 | 27 | 101 |
| Total: | | 9 | | | 24 | | | 4 | | | 19 | | | 11 | | | 11 | | | 15 | | | 10 | | | 48 | | | 151 | |

Note:
EX - Existing structures unnecessary for rehabilitation
RE - Existing structures to be rehabilitated
NE - New structures to be constructed

CV - Culvert
DR - Drop
DI - Drainage inlet

DJ - Drainage junction
CK - Check
AD - Aqueduct

Table VI-18 Related Structures in Drainage Canals (2/2)

- Mutithi System -

| Structure Name | TAMD-I | TAMD-II | KMD-I | KMD-II | KMD-III | KBD II-1 | KBD III-1 | Total |
|---|---|---|---|---|---|---|---|---|
| CV | 3 | 5 | 4 | 2 | 1 | 2 | 3 | 20 |
| DR | 17 | 32 | 16 | 20 | 16 | 4 | 11 | 116 |
| DI | 4 | 6 | 9 | 2 | 2 | 1 | 2 | 26 |
| SY | 2 | 2 | | | | | | 4 |
| DJ | | 3 | | | | | | 3 |
| Total: | 26 | 48 | 29 | 24 | 19 | 7 | 16 | 169 |

Note:
DR - Drop
CV - Culvert
DI - Drainage inlet
SY - Syphon
DJ - Drainage junction

Table VI-19 Farm Roads

| Nyamindi Part | | Thiba Part | | Mutithi Part | |
|---|---|---|---|---|---|
| Road Name | Length(m) | Road Name | Length(m) | Road Name | Length(m) |
| FR-N-1 | 11,420 | FR-T-1 | 21,840 | FR-M-1 | 10,800 |
| 2 | 15,440 | 2 | 8,400 | 2 | 1,000 |
| 3 | 2,160 | 3 | 38,780 | 3 | 7,400 |
| 4 | 1,660 | 4 | 17,000 | 4 | 400 |
| 5 | 2,040 | 5 | 3,640 | 5 | 950 |
| 6 | 3,000 | 6 | 1,000 | 6 | 950 |
| 7 | 780 | 7 | 1,320 | 7 | 1,350 |
| 8 | 460 | 8 | 2,840 | 8 | 22,700 |
| 9 | 200 | 9 | 3,040 | 9 | 1,720 |
| 10 | 2,900 | 10 | 1,460 | 10 | 620 |
| 11 | 640 | 11 | 2,600 | 11 | 2,770 |
| 12 | 300 | 12 | 4,460 | 12 | 3,180 |
| | | 13 | 2,060 | 13 | 1,300 |
| | | 14 | 2,600 | 14 | 300 |
| | | 15 | 1,840 | 15 | 15,670 |
| | | 16 | 2,400 | 16 | 2,300 |
| | | 17 | 1,580 | 17 | 1,740 |
| | | 18 | 3,060 | 18 | 2,120 |
| | | 19 | 2,800 | 19 | 2,630 |
| | | | | 20 | 720 |
| Total | 41,000 | | 122,720 | | 80,620 |

Table VI-20 Work Quantities (1/6)

| Work Items | Unit | Quantity |
|---|---|---|
| I. Headworks | | |
| 1. New Nyamindi Headworks | | |
| a) Excavation/Hauling, Soil | $m^3$ | 13,500 |
| b) Excavation/Hauling, Rock | $m^3$ | 2,700 |
| c) Embankment | $m^3$ | 2,000 |
| d) Plain concrete | $m^3$ | 950 |
| e) Reinforced concrete | $m^3$ | 1,200 |
| f) Form work | $m^2$ | 3,600 |
| g) Steel reinforcement | ton | 60 |
| h) Wet mansonry | $m^2$ | 400 |
| i) Riprap | $m^3$ | 150 |
| j) Slide gates | ton | 23.0 |
| k) Intake screen | ton | 1.0 |
| 2. Ruamuthambi Headworks | | |
| a) Excavation/Hauling, Soil | $m^3$ | 3,000 |
| b) Excavation/Hauling, Rock | $m^3$ | 1,000 |
| c) Embankment | $m^3$ | 1,000 |
| d) Plain concrete | $m^3$ | 480 |
| e) Reinforced concrete | $m^3$ | 470 |
| f) Form work | $m^2$ | 1,500 |
| g) Steel reinforcement | ton | 24 |
| h) Wet masonry | $m^2$ | 200 |
| i) Riprap | $m^3$ | 100 |
| j) Slide gates | ton | 7.1 |
| k) Intake screen | ton | 0.3 |
| 3. Improvement of Existing Thiba Headworks | | |
| a) Plain concrete | $m^3$ | 280 |
| b) Reinforced concrete | $m^3$ | 290 |
| c) Form work | $m^2$ | 580 |
| d) Steel reinforcement | ton | 14 |
| e) Wet masonry | $m^2$ | 200 |
| f) Riprap | $m^3$ | 350 |
| g) Slide gates | ton | 7.8 |
| h) Intake screen | ton | 0.6 |
| II. Headraces, Link Canals and Related Facilities | | |
| 1. Nyamindi Headrace | | |
| a) Excavation | $m^3$ | 108,000 |
| b) Earth lining | $m^3$ | 6,800 |
| c) Wet masonry | $m^2$ | 510 |
| d) Measuring device | nos. | 1 |
| e) Culvert | nos. | 2 |
| f) Laterite pavement | $m^2$ | 2,800 |

Table VI-20 Work Quantities (2/6)

| Work Items | Unit | Quantity |
|---|---|---|
| 2. Nyamindi Division Works | | |
| a) Excavation | $m^3$ | 1,300 |
| b) Embankment | $m^3$ | 200 |
| c) Reinforced concrete | $m^3$ | 140 |
| d) Steel reinforcement | ton | 10 |
| e) Form work | $m^2$ | 710 |
| f) Slide gates | ton | 4.8 |
| g) Screen | ton | 0.5 |
| 3. Nyamindi New Main Canal | | |
| a) Excavation | $m^3$ | 31,400 |
| b) Earth lining | $m^3$ | 1,900 |
| c) Plain concrete | $m^3$ | 200 |
| d) Form work | $m^3$ | 2,000 |
| e) Measuring device | nos. | 1 |
| f) Culvert | nos. | 4 |
| g) Drop | nos. | 11 |
| h) Laterite pavement | $m^2$ | 2,700 |
| 4. Link Canal-I | | |
| a) Excavation | $m^3$ | 267,700 |
| b) Embankment | $m^3$ | 69,500 |
| c) Earth lining | $m^3$ | 58,400 |
| d) Murubara Syphon | m | 170 |
| e) Measuring device | nos. | 1 |
| f) Culvert | nos. | 13 |
| g) Drop | nos. | 1 |
| h) Reinforced concrete | $m^3$ | 20 |
| i) Steel reinforcement | ton | 1 |
| j) Wet masonry | $m^2$ | 3,030 |
| k) Laterite pavement | $m^2$ | 30,200 |
| l) Asphalt pavement | $m^2$ | 100 |
| m) Cross drain | nos. | 11 |
| n) Form work | $m^2$ | 53 |
| o) Screen, Murubara siphon | ton | 0.5 |
| 5. Link Canal-II | | |
| a) Excavation | $m^3$ | 26,000 |
| b) Embankment | $m^3$ | 10,000 |
| c) Earth lining | $m^3$ | 20,000 |
| d) Measuring device | nos. | 1 |
| e) Drop | nos. | 1 |
| f) Wet masonry | $m^2$ | 600 |
| g) Culvert | $m^2$ | 1 |
| 6. Thiba Division Works | | |
| a) Excavation | $m^3$ | 4,300 |
| b) Embankment | $m^3$ | 850 |
| c) Reinforced concrete | $m^3$ | 250 |
| d) Steel reinforcement | ton | 18 |

Table VI-20 Work Quantities (3/6)

| Work Items | Unit | Quantity |
|---|---|---|
| e) Plain concrete | $m^3$ | 20 |
| f) Form work | $m^2$ | 1,030 |
| g) Wet masonry | $m^2$ | 170 |
| h) Slide gate | ton | 7.5 |
| i) Screen | ton | 0.8 |
| 7. Link Canal-III | | |
| a) Excavation | $m^3$ | 76,000 |
| b) Embankment | $m^3$ | 5,400 |
| c) Earth lining | $m^3$ | 18,700 |
| d) Measuring device | nos. | 1 |
| e) Culvert | nos. | 5 |
| f) Wet masonry | $m^2$ | 1,100 |
| g) Laterite pavement | $m^2$ | 10,600 |
| 8. Ruamuthambi Headrace | | |
| a) Excavation | $m^3$ | 115,000 |
| b) Embankment | $m^3$ | 27,000 |
| c) Earth lining | $m^3$ | 27,200 |
| d) Concrete lining | $m^3$ | 850 |
| e) Form work | $m^2$ | 8,800 |
| f) Measuring device | nos. | 1 |
| g) Drop | nos. | 15 |
| h) Cross drain | nos. | 1 |
| i) Offtake | nos. | 2 |
| j) Culvert | nos. | 4 |
| k) Laterite pavement | $m^2$ | 27,700 |
| 9. Regurating Basin | | |
| a) Excavation | $m^3$ | 50 |
| b) Plain concrete | $m^3$ | 2 |
| c) Reinforced concrete | $m^3$ | 30 |
| d) Form work | $m^2$ | 140 |
| e) Steel reinforcement | ton | 2 |

Table VI-20 Work Quantities (4/6)

| Work Items | | Unit | Quantity | |
|---|---|---|---|---|
| | | | MIS | Mutithi |
| **III. Irrigation Facilities** | | | | |
| 1. Irrigation Canal | | | | |
| 1-1. Canal Works | | | | |
| a) Excavation | | $m^3$ | 113,000 | 25,900 |
| b) Embankment | | $m^3$ | 93,900 | 69,804 |
| c) Reinforced concrete lining | | $m^3$ | 4,900 | - |
| d) Plain concrete lining | | $m^3$ | 1,100 | 696 |
| e) Steel reinforcement | | ton | 240 | - |
| f) Form work | | $m^2$ | 20,400 | 7,560 |
| g) Demolishing | | $m^2$ | 3,140 | - |
| 1-2. Related Structures | | | | |
| a) Turnout | (NE) | nos. | - | 5 |
| b) Offtake | (RE) | nos. | 18 | - |
| | (NE) | nos. | 9 | 38 |
| c) Culvert | (RE) | nos. | 14 | - |
| | (NE) | nos. | - | 8 |
| d) Chute | (RE) | nos. | 1 | - |
| | (NE) | nos. | 2 | 3 |
| e) Concrete flume | (RE) | nos. | 1 | - |
| | (NE) | nos. | 1 | - |
| f) Drop | (RE) | nos. | 75 | - |
| | (NE) | nos. | 40 | 107 |
| g) Check | (RE) | nos. | 5 | - |
| | (NE) | nos. | 17 | 37 |
| h) Washing step | (RE) | nos. | 4 | - |
| | (NE) | nos. | 9 | 14 |
| i) Spillway | (RE) | nos. | 1 | - |
| | (NE) | nos. | 1 | - |
| j) Horse shoe weir | (RE) | nos. | 1 | - |
| | (NE) | nos. | - | - |
| k) Cipolletti weir | (RE) | nos. | - | |
| | (NE) | nos. | 6 | 8 |
| l) Cross drain | (RE) | nos. | - | - |
| | (NE) | nos. | - | 5 |
| 2. Drainage Canal | | | | |
| 2-1. Canal Works | | | | |
| a) Excavation | | $m^3$ | 307,000 | 837,870 |
| b) Embankment | | $m^3$ | 7,800 | 1,320 |
| 2-2. Related Structures | | | | |
| a) Culvert | (RE) | | 17 | - |
| | (NE) | | 7 | 20 |
| b) Drop | (RE) | | 2 | - |
| | (NE) | | 84 | 116 |

Table VI-20 Work Quantities (5/6)

| Work Items | | Unit | Quantity | |
|---|---|---|---|---|
| | | | MIS | Mutithi |
| c) Drainage inlet | (RE) | | 7 | - |
| | (NE) | | 7 | 26 |
| d) Drainage junction | (RE) | | - | - |
| | (NE) | | 3 | 3 |
| e) Check | (RE) | | 1 | - |
| | (NE) | | - | - |
| f) Re-use structure | (RE) | | 16 | - |
| | (NE) | | 7 | - |
| g) Syphon | (NE) | | - | 4 |
| 3. Farm Road | | | | |
| a) Embankment | | $m^3$ | 177,000 | 200,000 |
| b) Laterite pavement | | $m^2$ | 272,100 | 403,000 |
| c) Cross drain | | nos. | 3 | 3 |
| IV. On-farm Facilities | | | | |
| 1. Paddy Field | | | | |
| 1-1. Land Reclamation | | | | |
| a) Excavation/Embankment | | $m^3$ | - | 618,000 |
| b) Levee | | km | - | 618 |
| 1-2. Irrigation and Drainage Facilities | | | | |
| a) Feeder canal, Excavation | | $m^3$ | 38,500 | 81,000 |
| b) Feeder canal, Embankment | | $m^3$ | 38,500 | 81,000 |
| c) Drainage canal, Excavation | | $m^3$ | 82,000 | 212,400 |
| d) Drainage canal, Embankment | | $m^3$ | 23,200 | 48,900 |
| e) Farm road, Embankment | | $m^3$ | 57,400 | 121,000 |
| f) Farm road, Laterite pavement | | $m^2$ | 281,300 | 592,800 |
| g) Related structures | | | | |
| - Offtake | (RE) | nos. | - | - |
| | (NE) | nos. | 30 | 140 |
| - Culvert | (RE) | nos. | 60 | - |
| | (NE) | nos. | - | 270 |
| - Check | (RE) | nos. | 1,950 | - |
| | (NE) | nos. | - | 860 |
| - Farm approach | (RE) | nos. | - | - |
| | (NE) | nos. | 3,660 | 1,710 |
| - Drainage junction | (RE) | nos. | - | - |
| | (NE) | nos. | 1,760 | 740 |

Table VI-20 Work Quantities (6/6)

| Work Items | | Unit | Quantity | |
|---|---|---|---|---|
| | | | MIS | Mutithi |
| 2. Horticultural Crops Field | | | | |
| 2-1. Land Reclamation | | | | |
| a) Excavation/Embankment | | $m^3$ | 125,000 | 67,200 |
| 2-2. Irrigation and Drainage Facilities | | | | |
| a) Feeder canal, Excavation | | $m^3$ | 51,500 | 27,700 |
| b) Feeder canal, Embankment | | $m^3$ | 51,500 | 27,700 |
| c) Drainage canal, Excavation | | $m^3$ | 77,400 | 41,600 |
| d) Drainage canal, Embankment | | $m^3$ | 16,700 | 9,000 |
| e) Farm road, Embankment | | $m^3$ | 43,700 | 23,500 |
| f) Farm road, Latelite pavement | | $m^2$ | 213,000 | 114,800 |
| g) Related Structures | | | | |
| - Offtake | (NE) | nos. | 130 | 70 |
| - Culvert | (NE) | nos. | 130 | 70 |
| - Check with drop | (NE) | nos. | 500 | 270 |
| - Farm approach | (NE) | nos. | 500 | 270 |
| - Drainage drop | (NE) | nos. | 1,340 | 720 |
| - Drainage junction | (NE) | nos. | 200 | 110 |

Note: RE - Existing structures to be rehabilitated.
NE - New structures to be constructed.

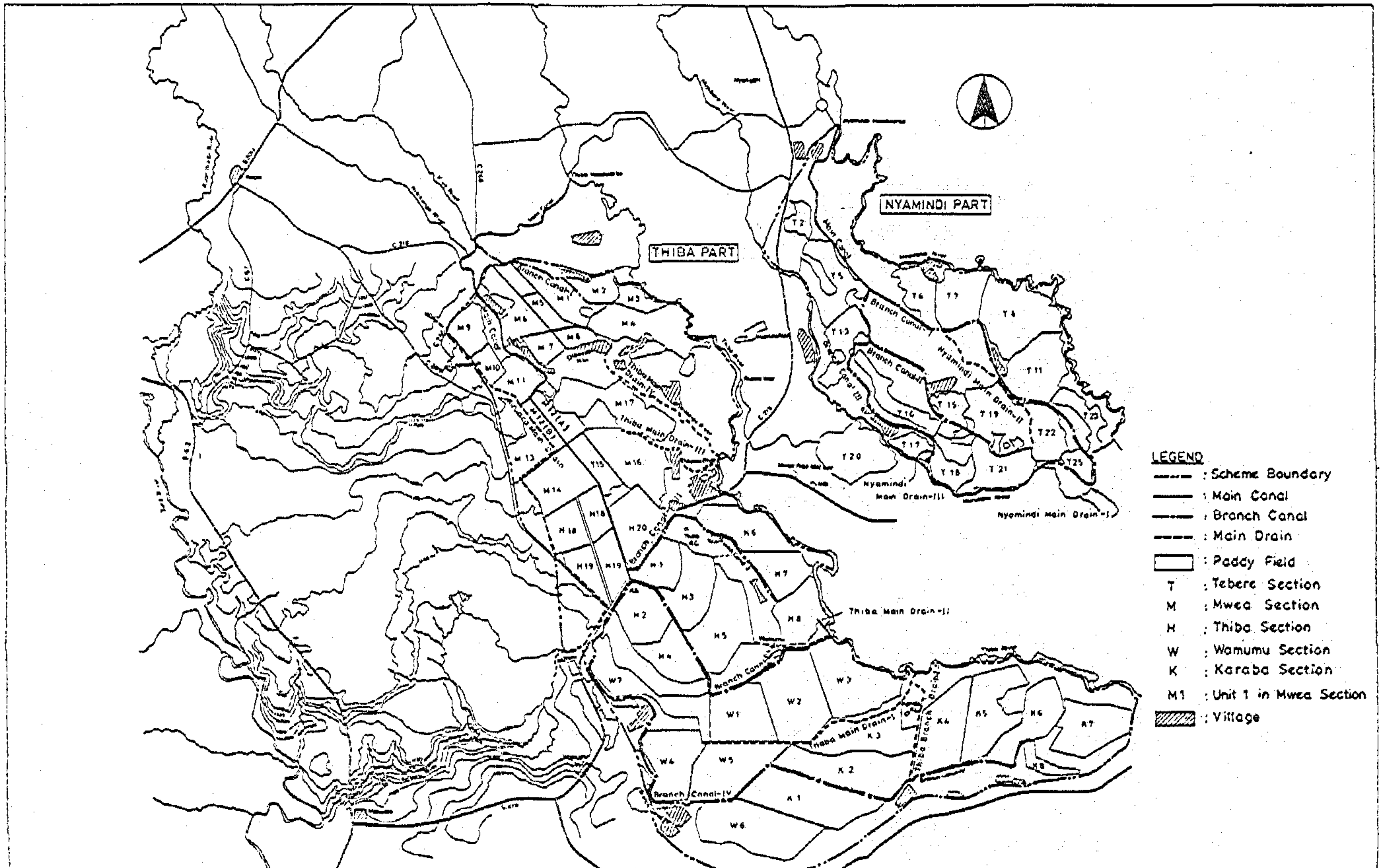



Fig.VI-1 MIS AREA, IRRIGATION AND DRAINAGE CANALS

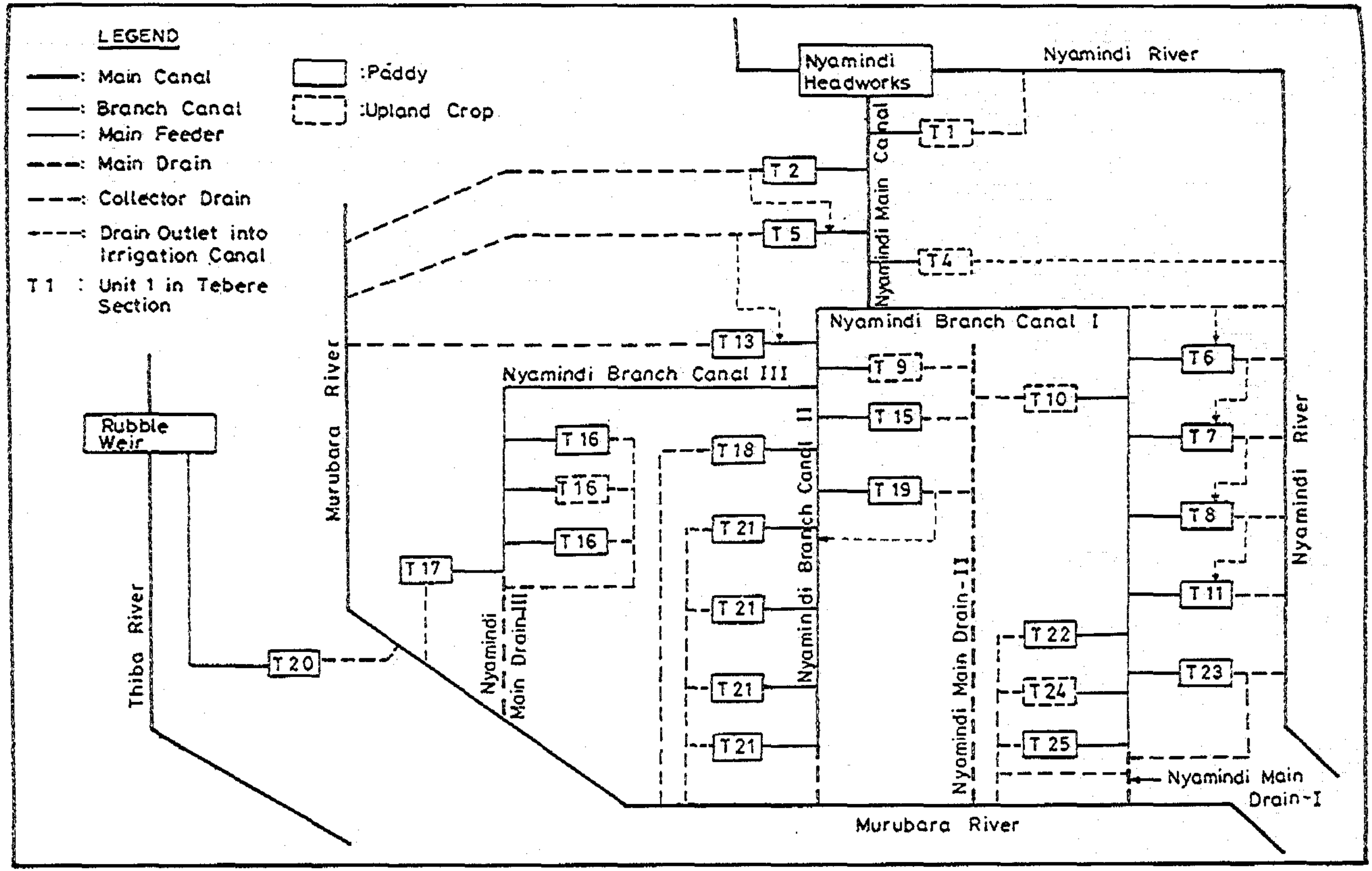



Fig. VI - 2 IRRIGATION AND DRAINAGE DIAGRAM (NYAMINDI PART)

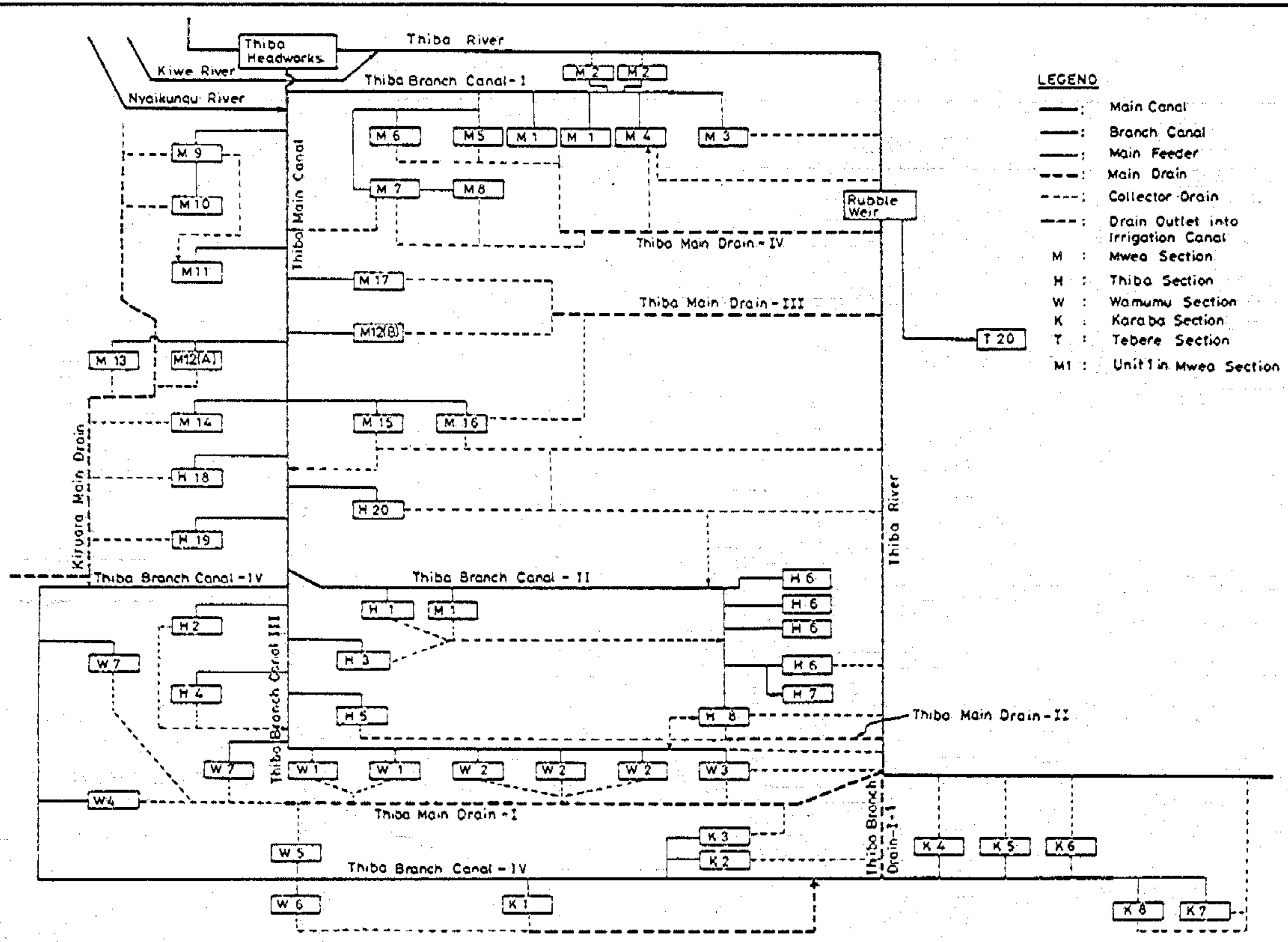



Fig.VI-3 IRRIGATION AND DRAINAGE DIAGRAM
(THIBA PART)

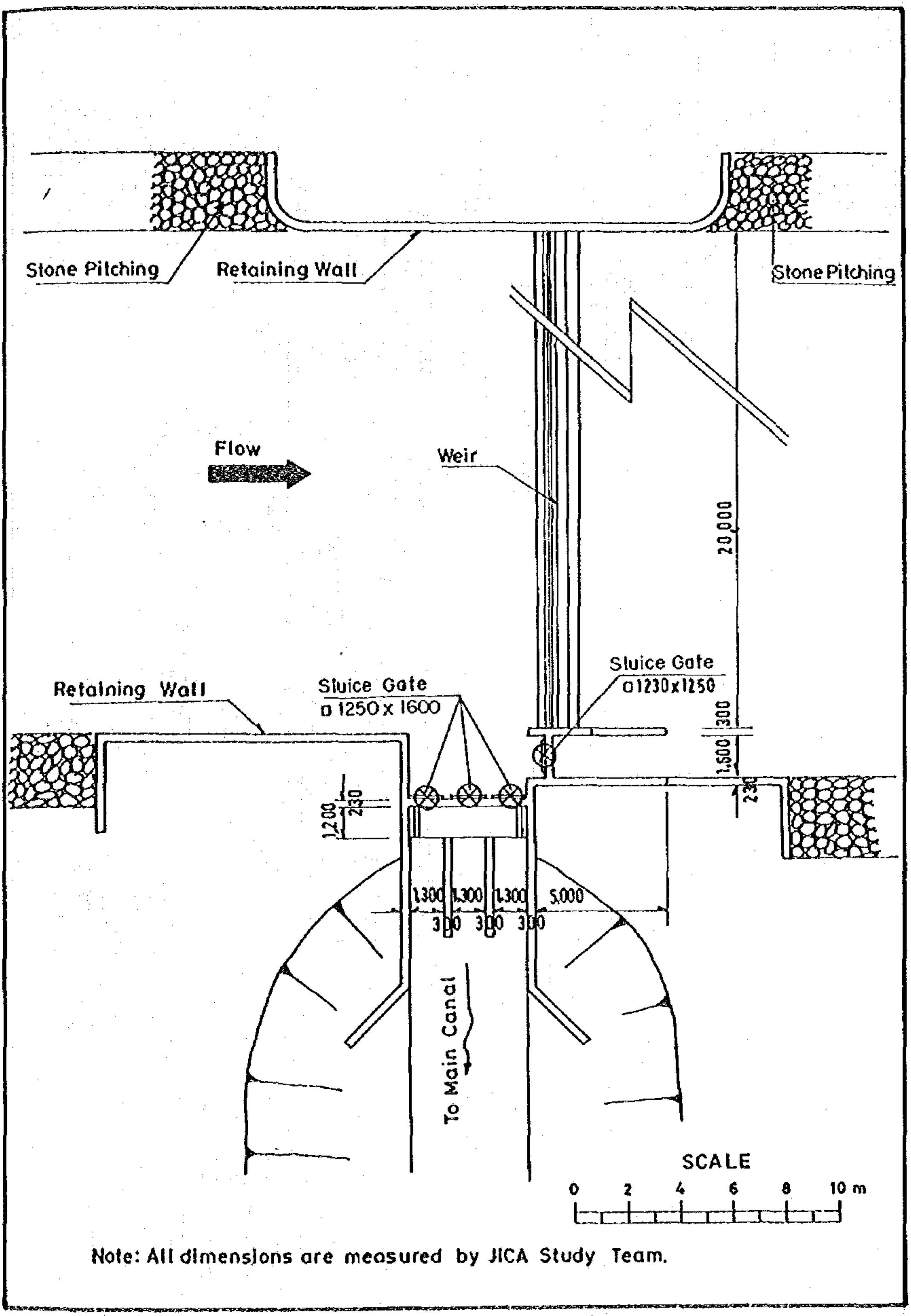



Fig. VI-4 PLAN OF NYAMINDI HEADWORKS

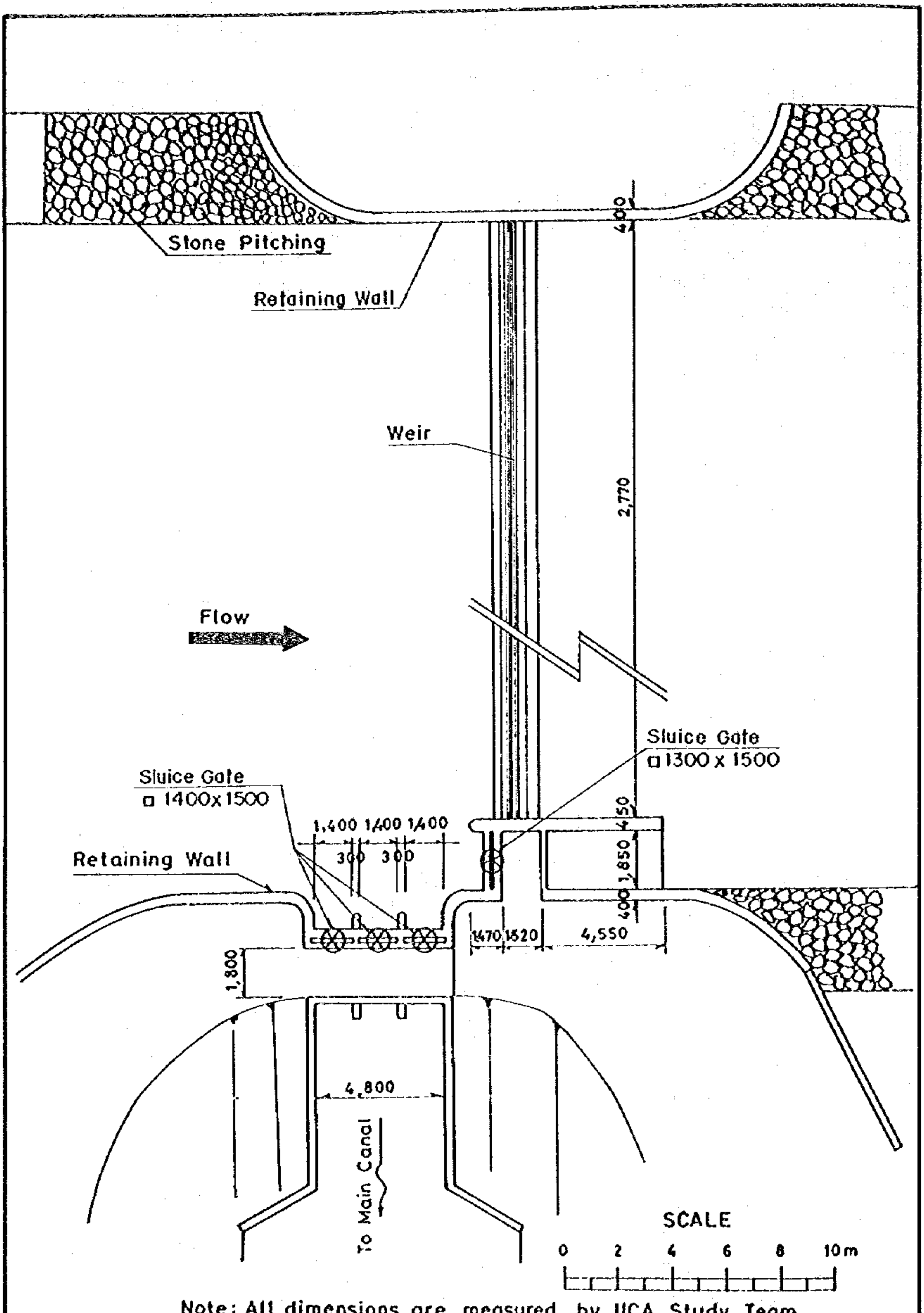



Fig. VI-5 PLAN OF THIBA HEADWORKS

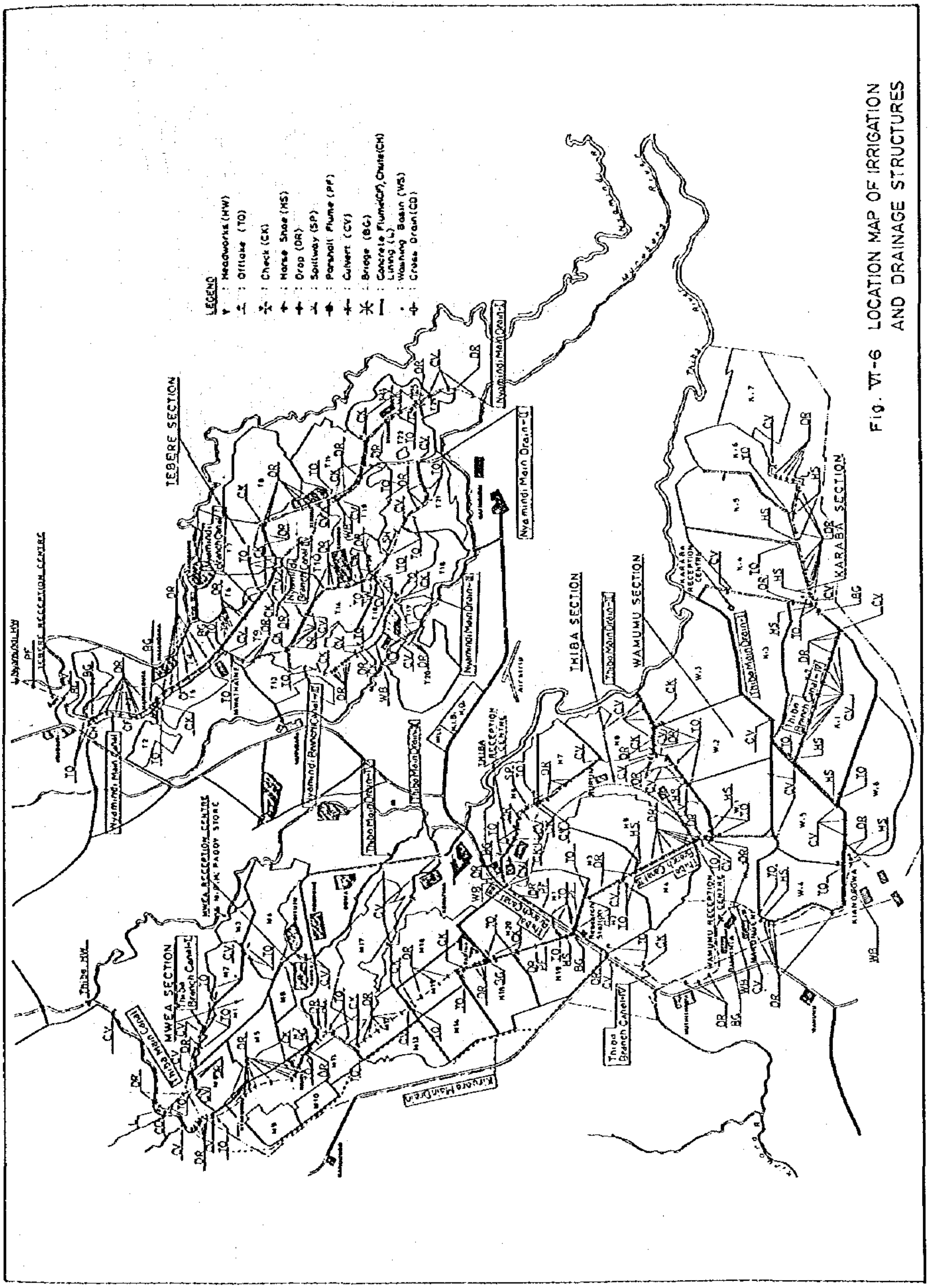


Fig. VI-6 LOCATION MAP OF IRRIGATION AND DRAINAGE STRUCTURES

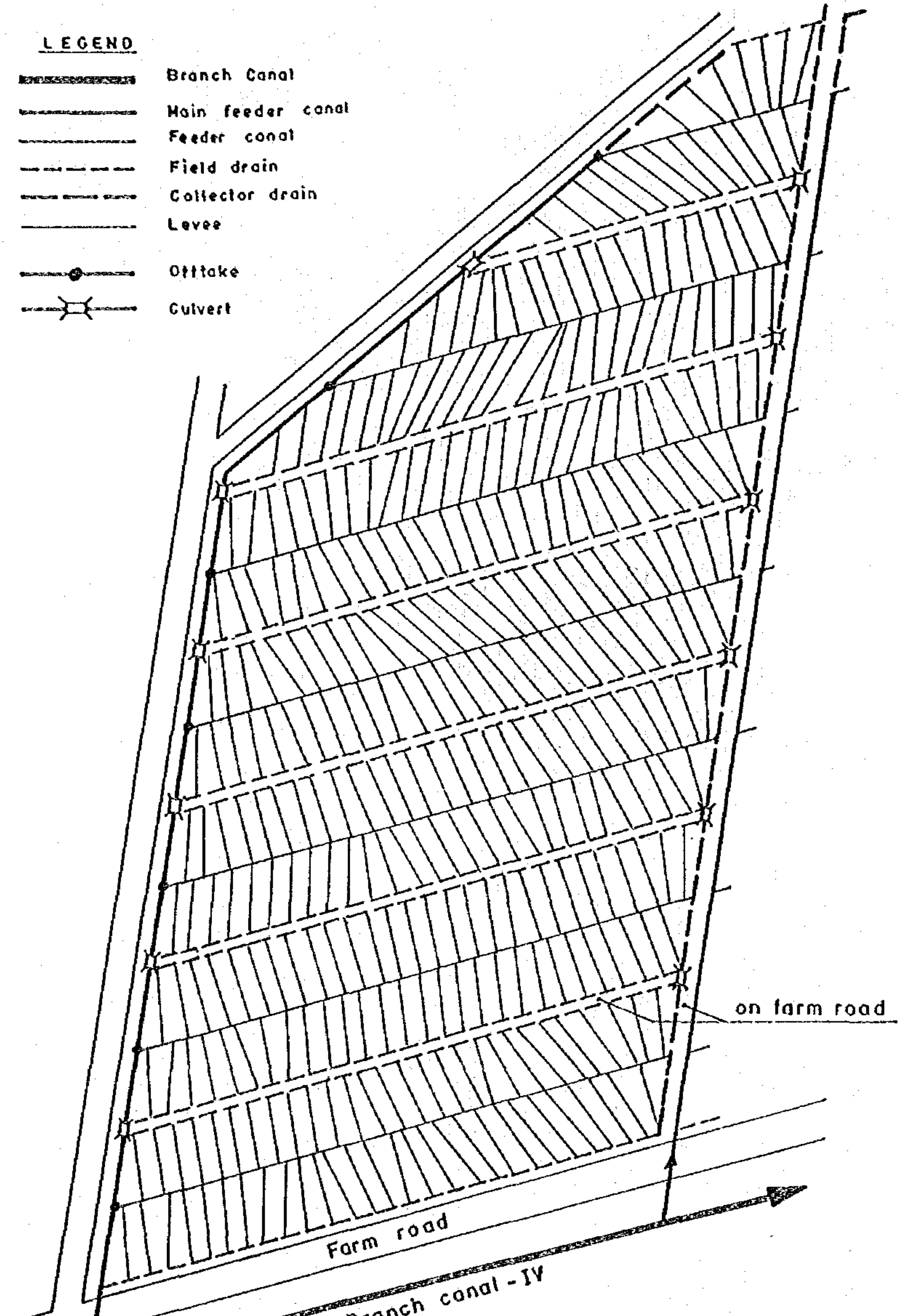



Fig.VI-7 TYPICAL LAYOUT OF UNIT (K4)

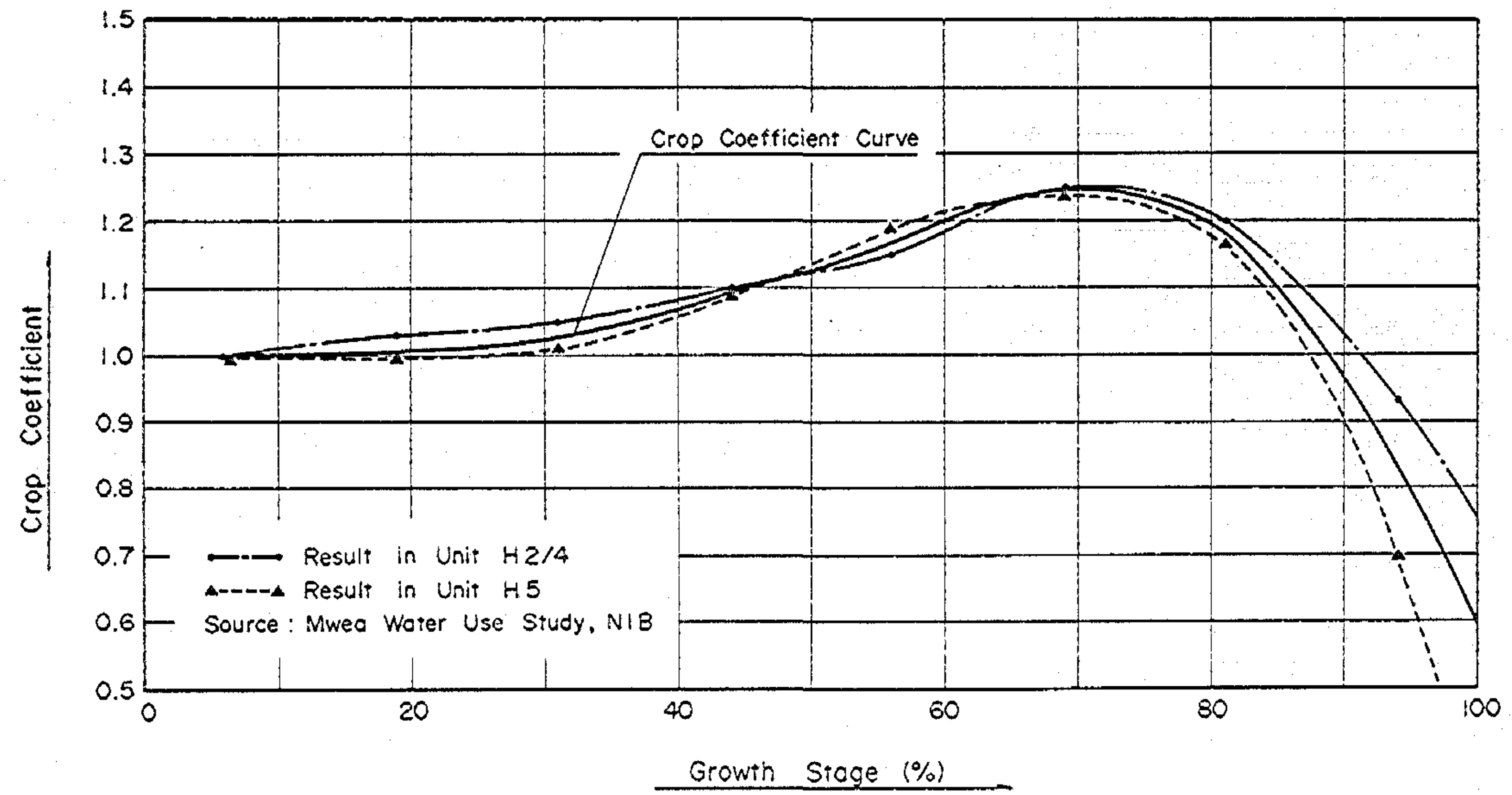
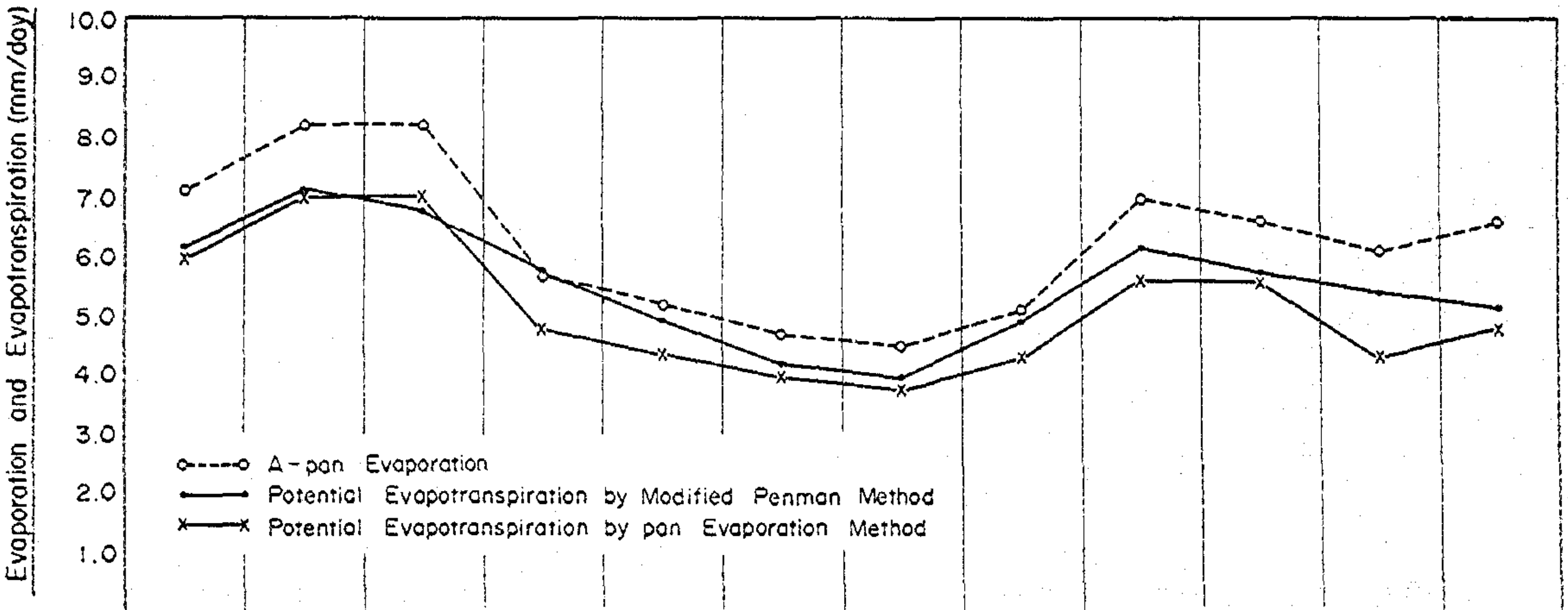



Fig. VI - 8 CROP COEFFICIENT CURVE FOR RICE




| Month | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-pan (mm/day) | 7.1 | 8.2 | 8.2 | 5.7 | 5.2 | 4.7 | 4.5 | 5.1 | 7.0 | 6.6 | 5.1 | 5.6 |
| Modified Penman(mm/day) | 6.2 | 7.1 | 6.8 | 5.7 | 5.0 | 4.2 | 4.0 | 4.9 | 6.1 | 5.7 | 5.4 | 5.2 |
| Pan Evaporation (mm/day) | 6.0 | 7.0 | 7.0 | 4.8 | 4.4 | 4.0 | 3.8 | 4.3 | 5.6 | 5.6 | 4.3 | 4.8 |

Fig. VI-9 POTENTIAL EVAPOTRANSPIRATION

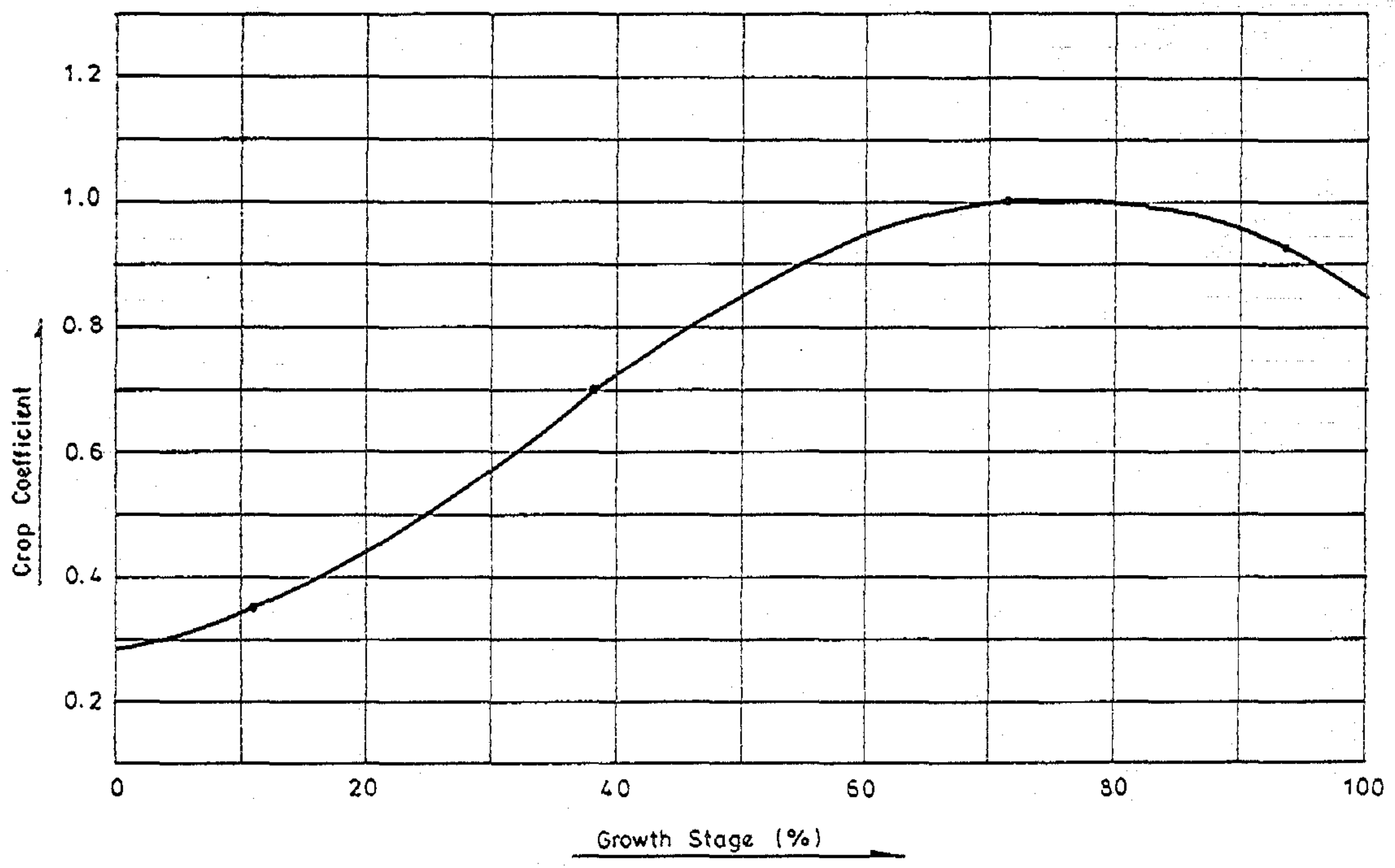



Fig. VI-10 CROP COEFFICIENT CURVE FOR BEANS

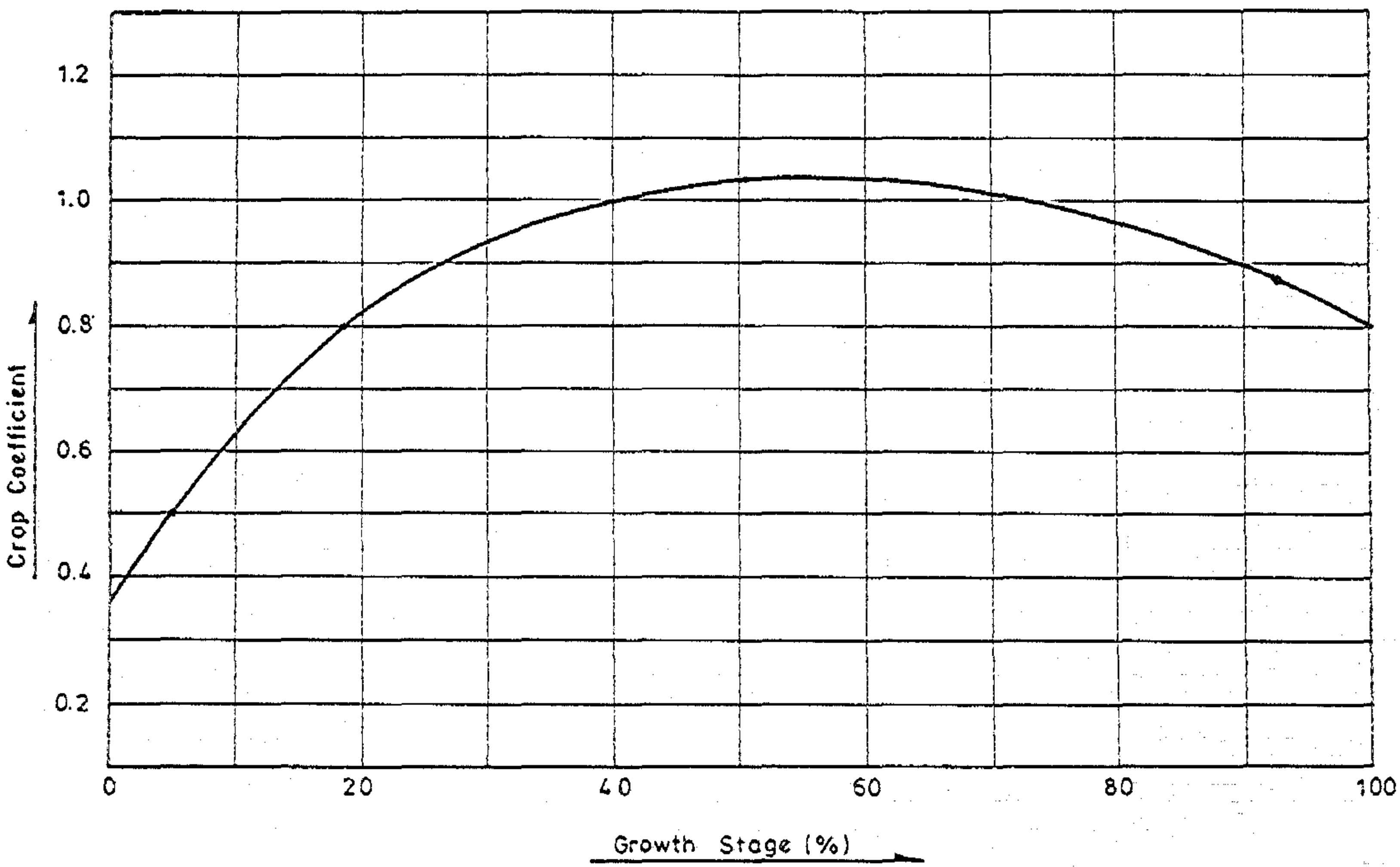



Fig.VI-11 CROP COEFFICIENT CURVE FOR ONIONS

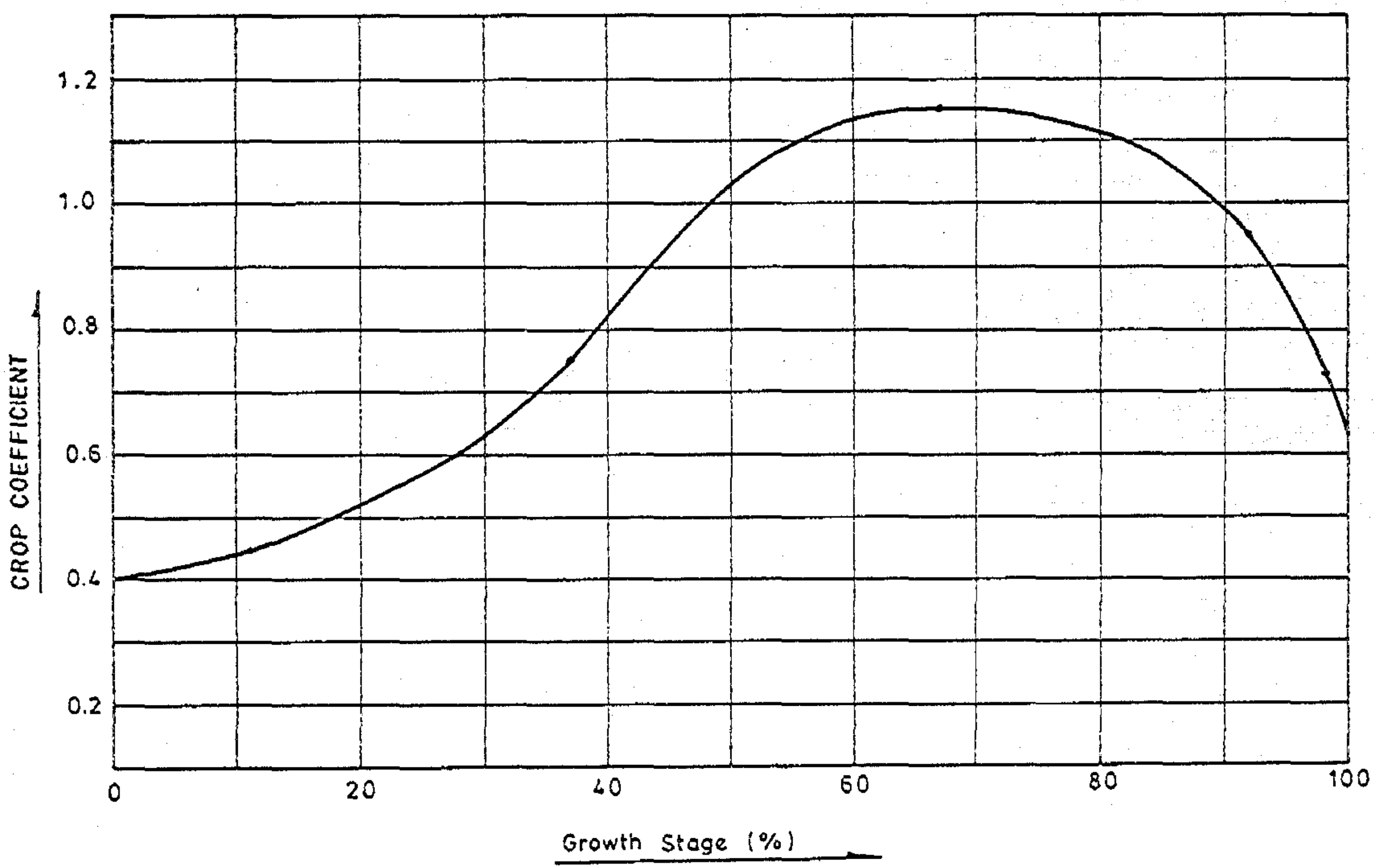



Fig.VI-12 CROP COEFFICIENT CURVE FOR TOMATOES

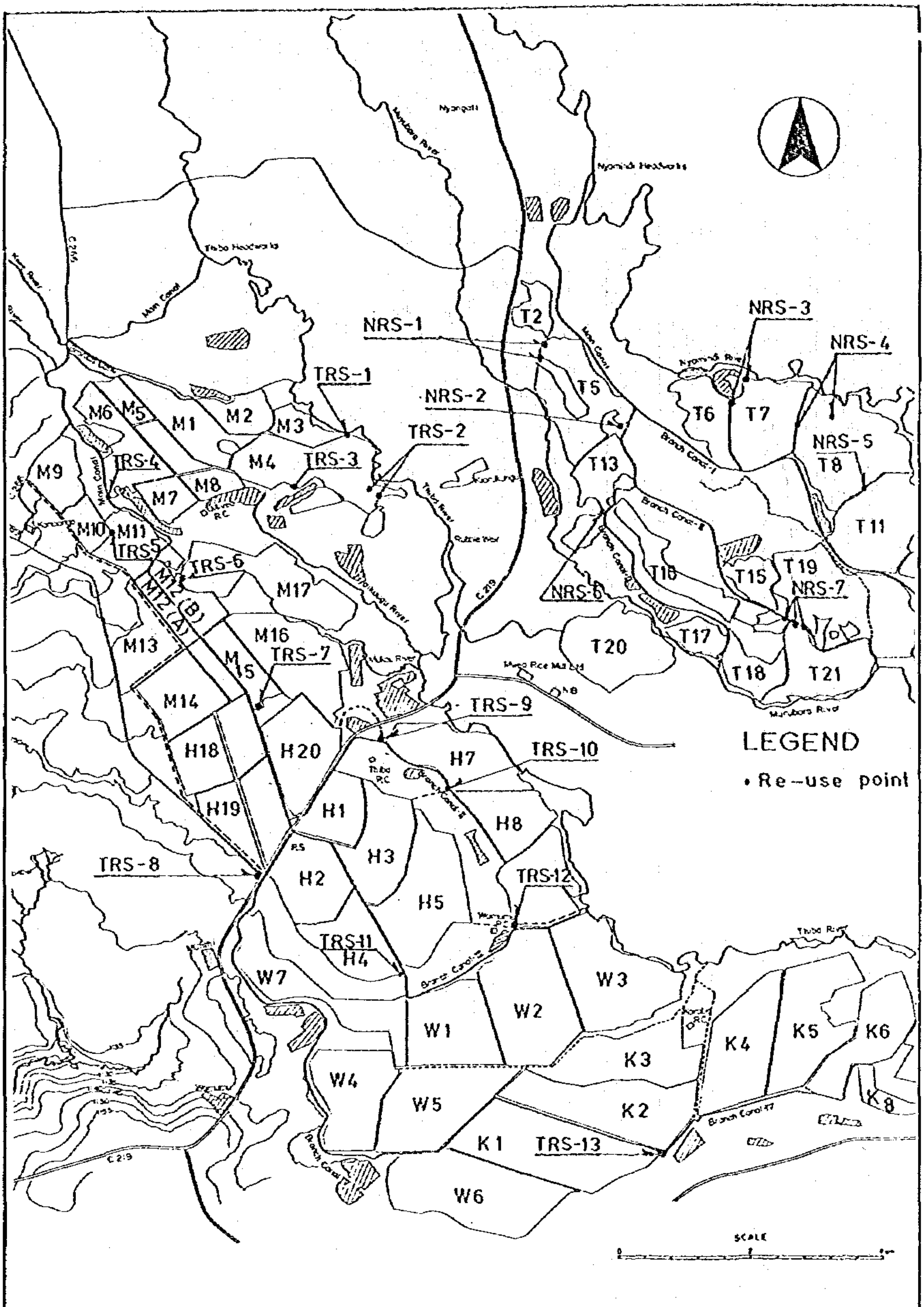



Fig. VI-13 LOCATION OF RE-USE POINT

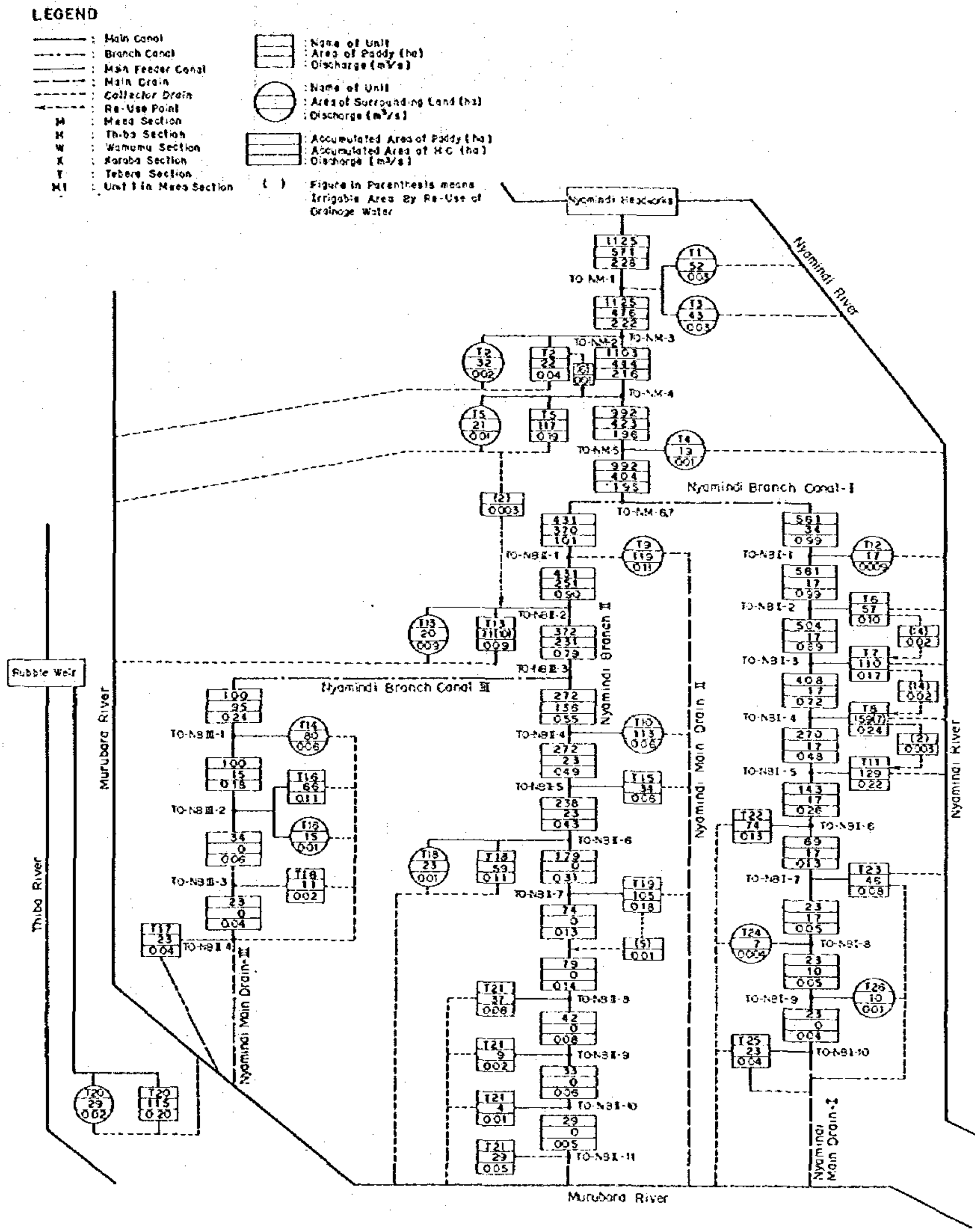



Fig. VI-14 IRRIGATION DIAGRAM (Nyamindi Part, 1/3)

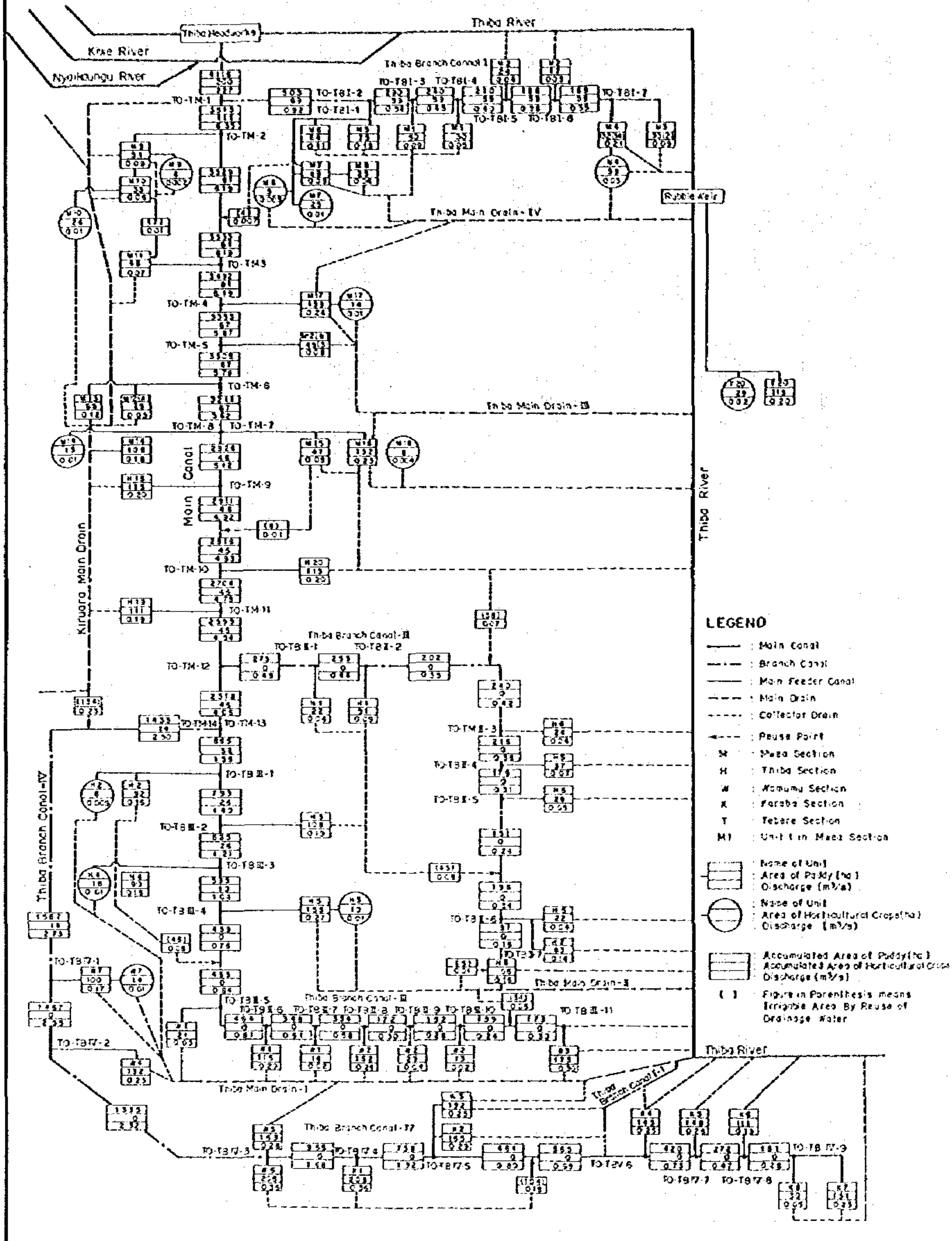



Fig. VI-14 IRRIGATION DIAGRAM (Thiba Part, 2/3)

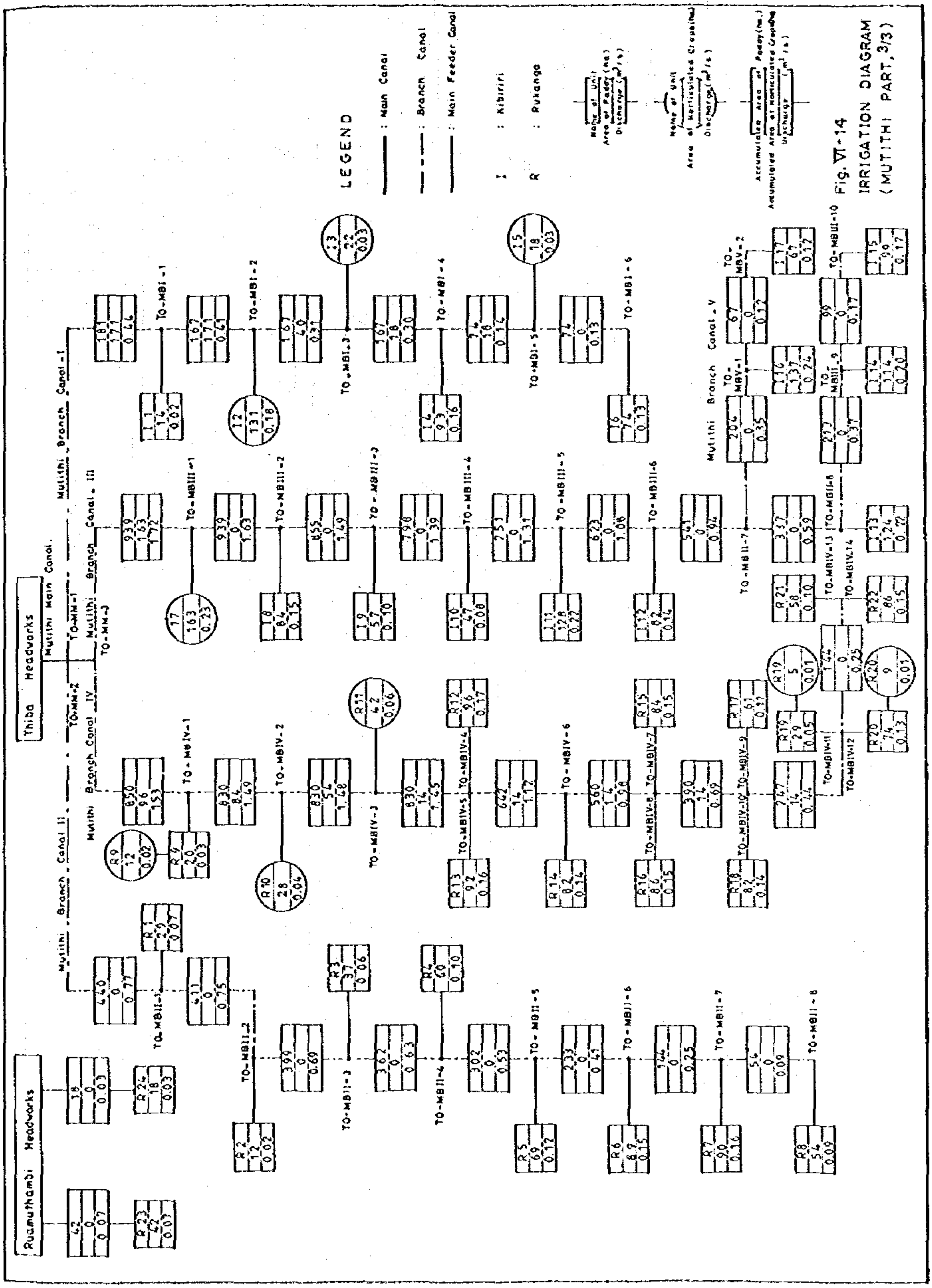


Fig. VI-14
IRRIGATION DIAGRAM
(MUTITHI PART, 3/3)

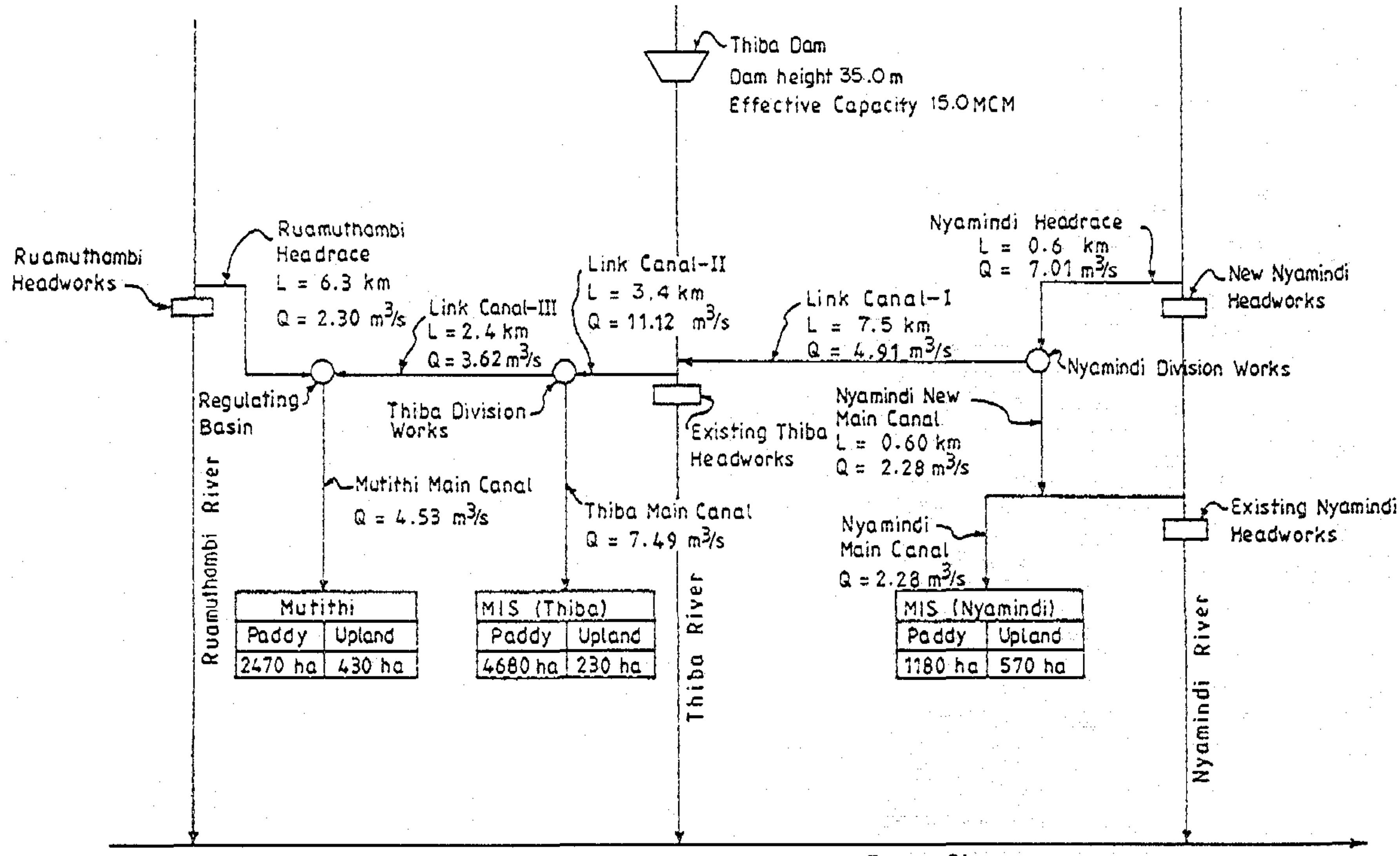



Fig. VI-15 SCHEMATIC DIAGRAM OF DIVERSION

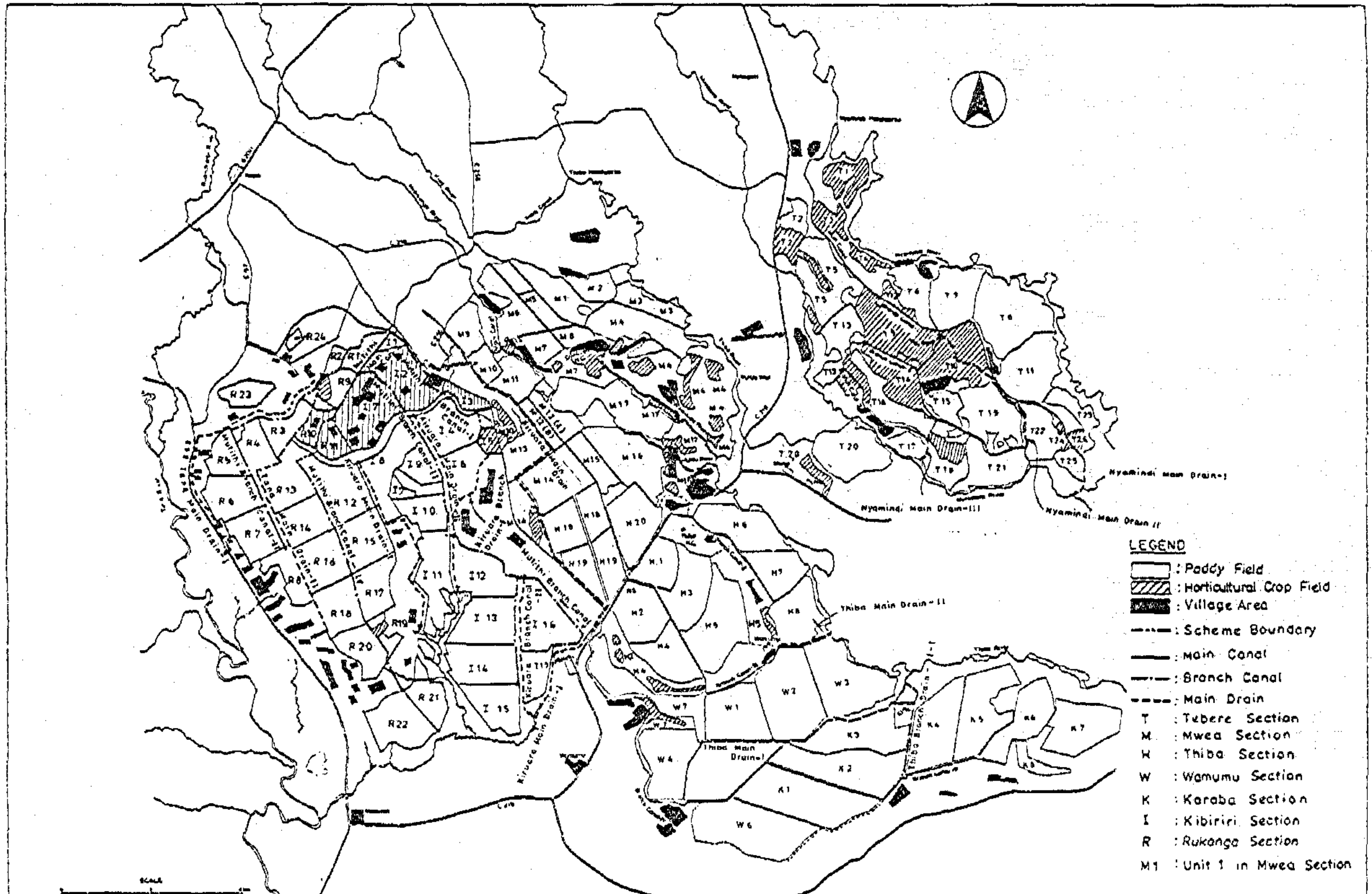



Fig. VI-16 PROPOSED IRRIGATION AND DRAINAGE SYSTEM

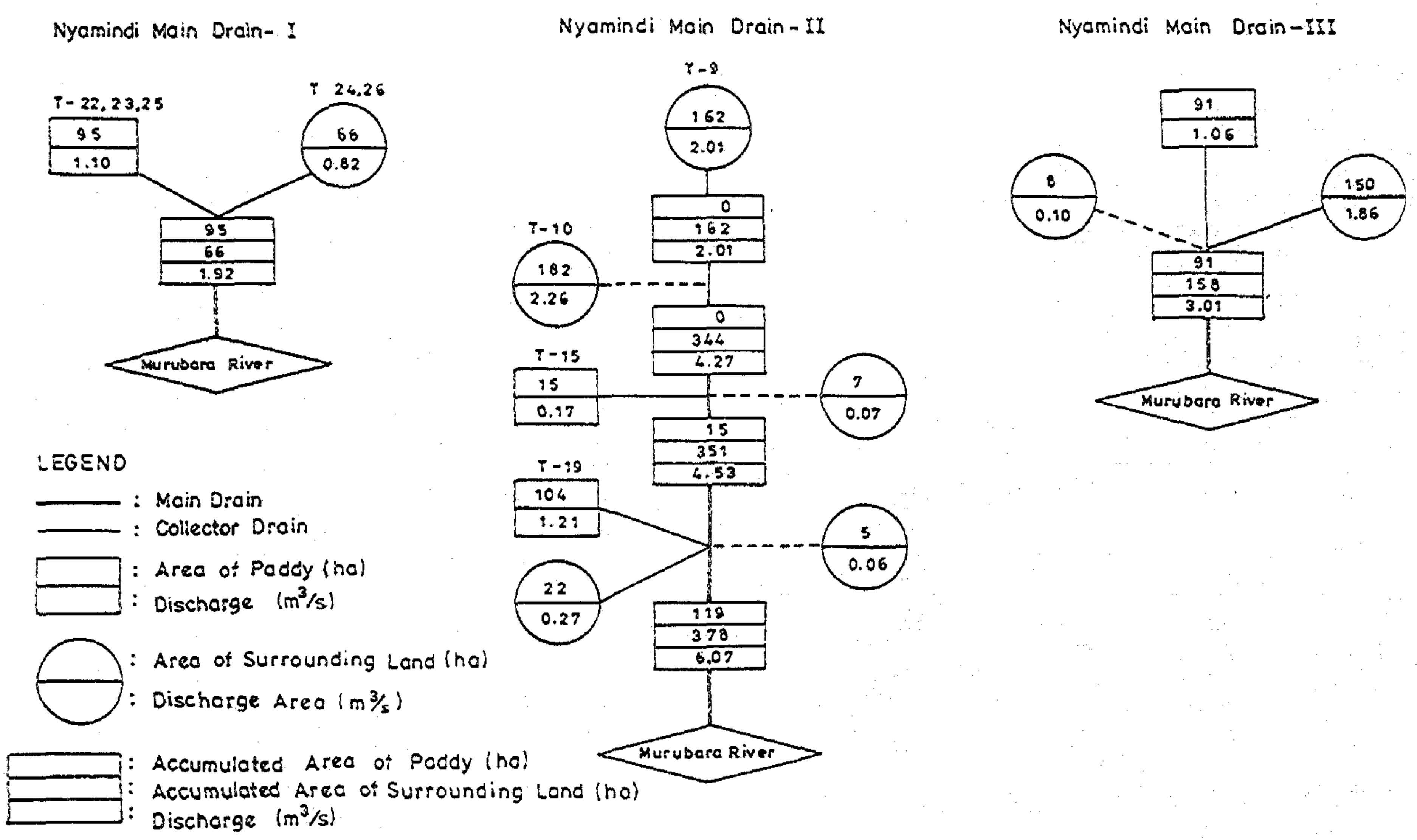



Fig.VI-17 DRAINAGE DIAGRAM (1/5) (NYAMINDI PART)

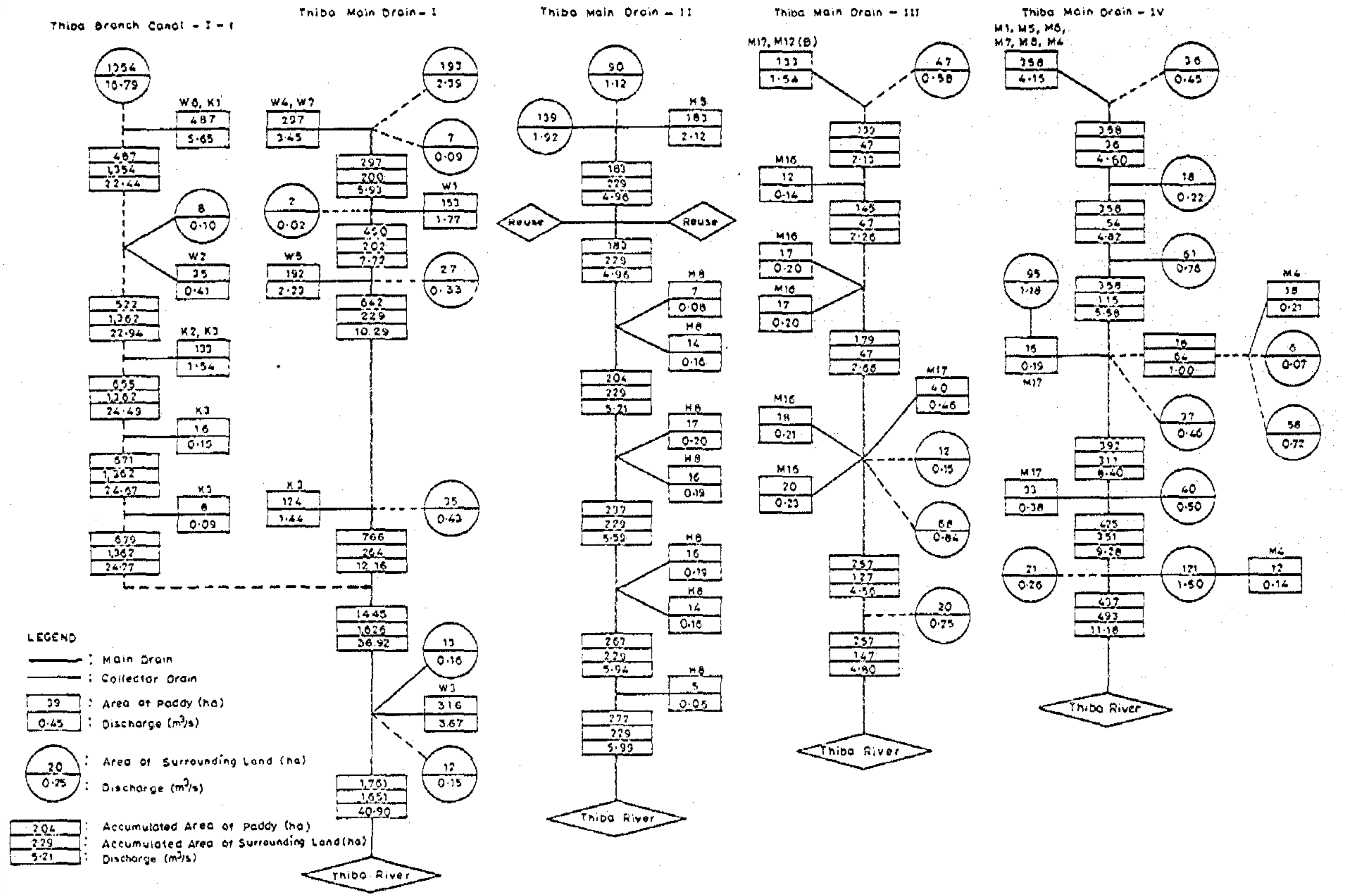



Fig. VI-17 DRAINAGE DIAGRAM (2/5) (THIBA PART)

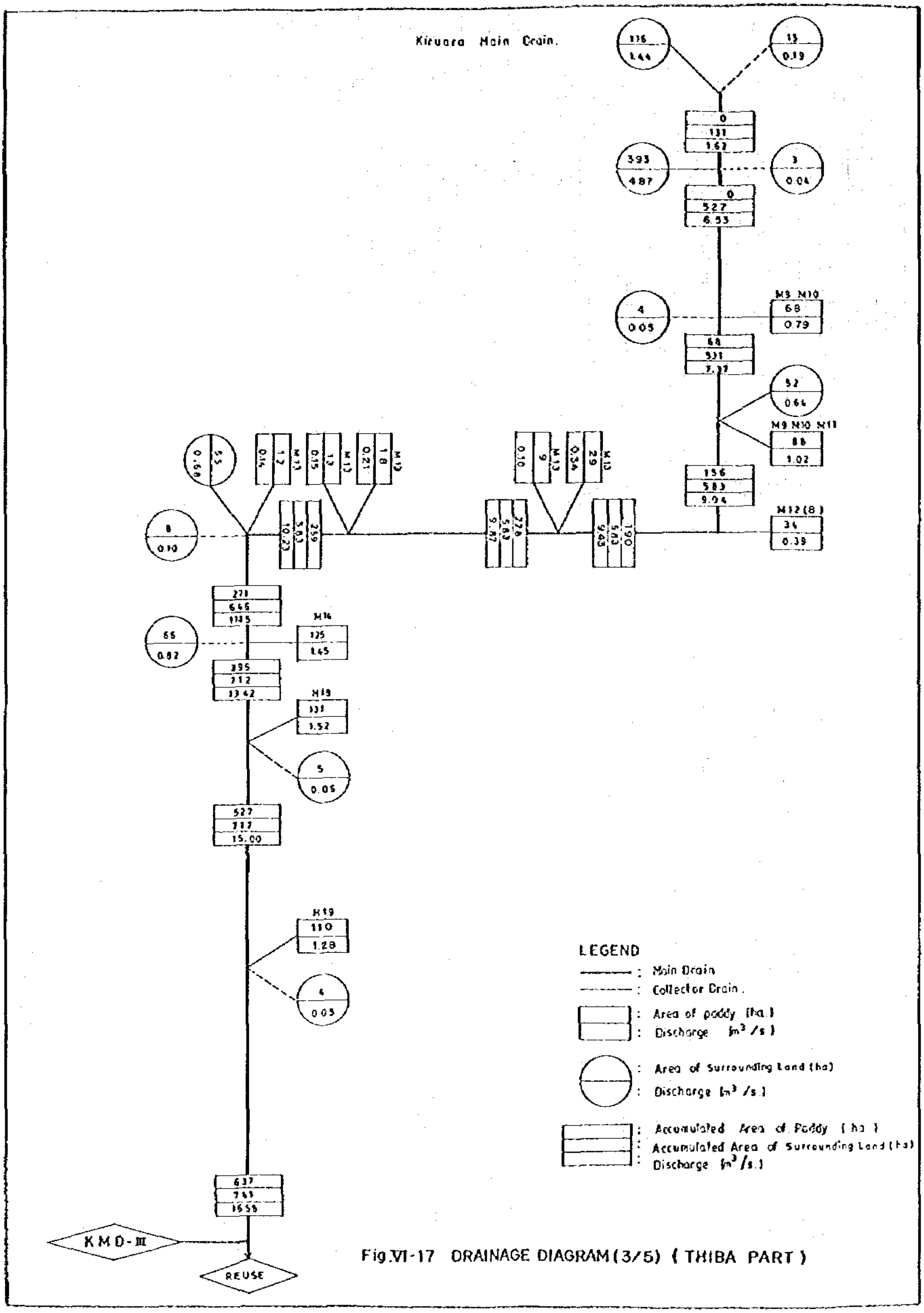



Fig.VI-17 DRAINAGE DIAGRAM (3/5) (THIBA PART)

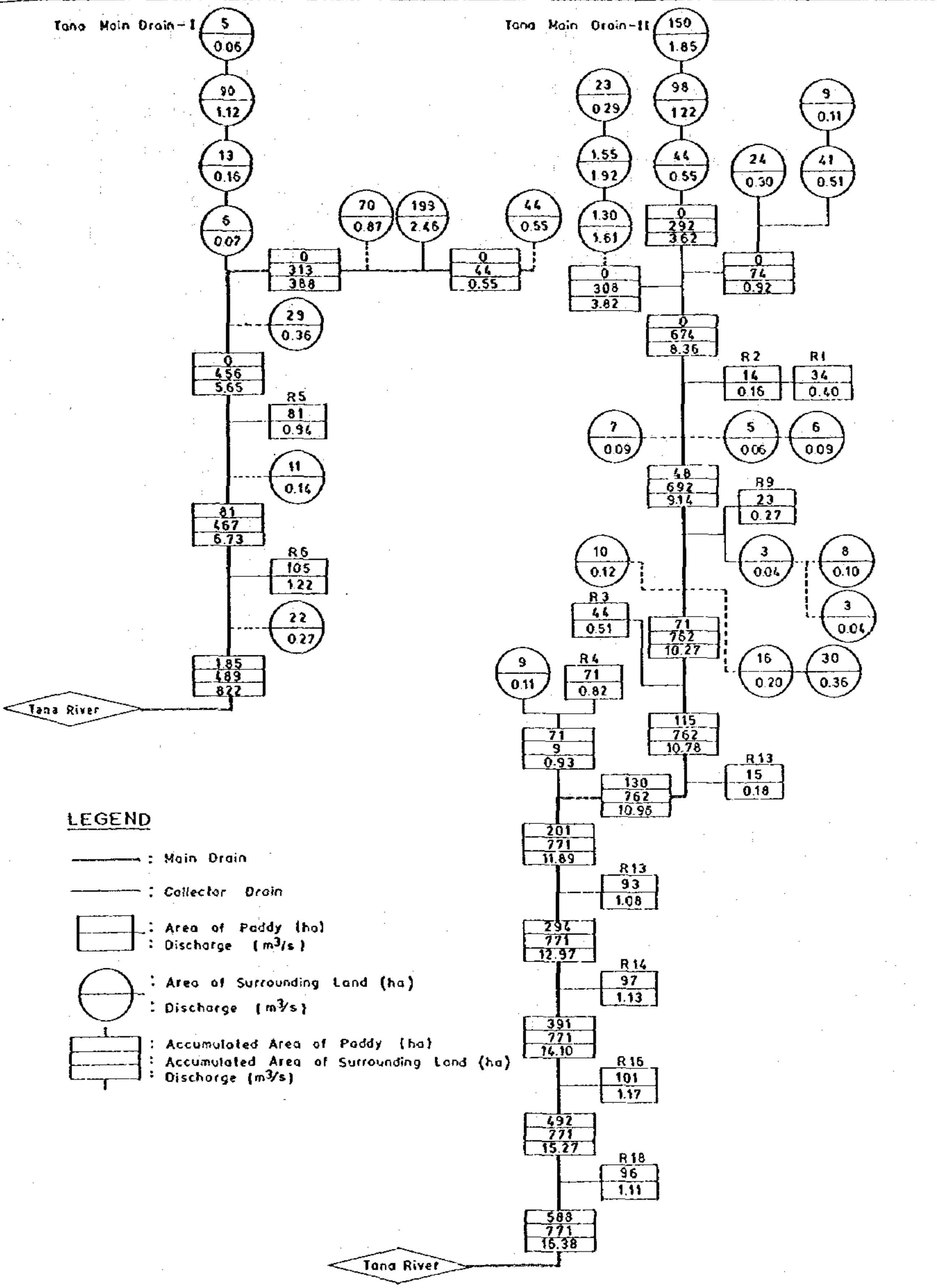



Fig. VI-17 DRAINAGE DIAGRAM (4/5) (MUTITHI PART)

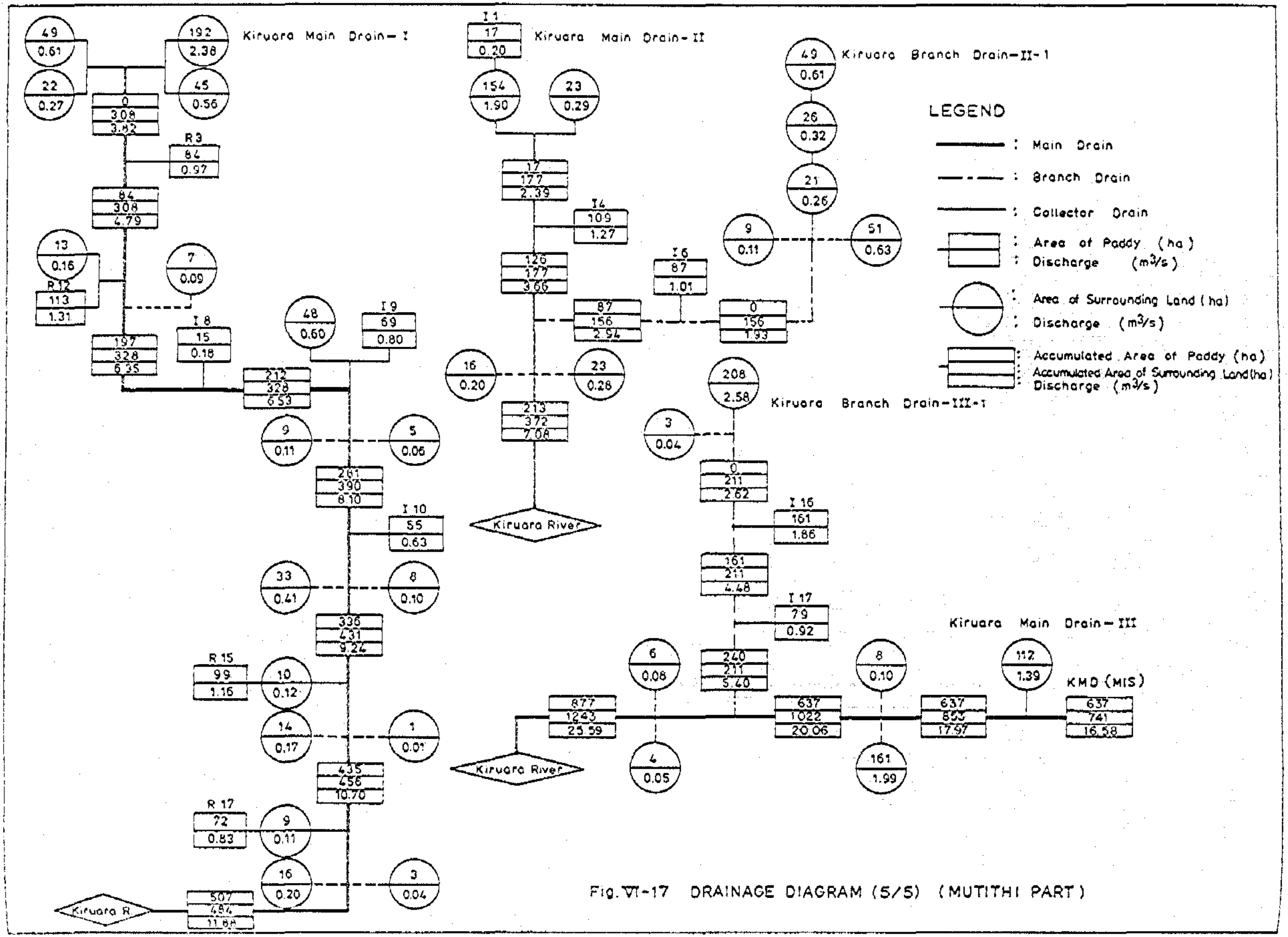



Fig. VI-17 DRAINAGE DIAGRAM (5/5) (MUTITHI PART)

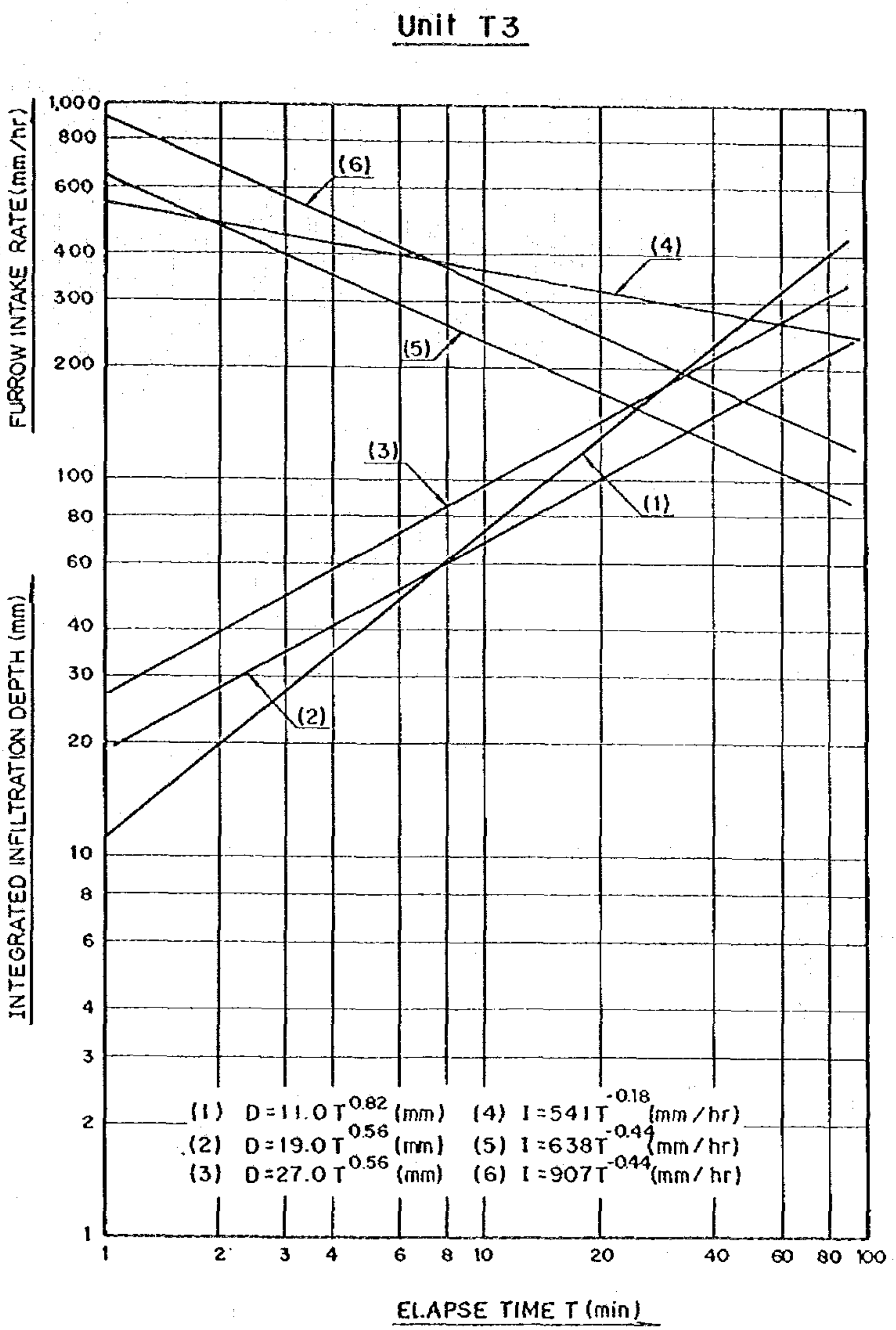



Fig.VI-18 FURROW INTAKE RATE (1/3)

## Unit T4

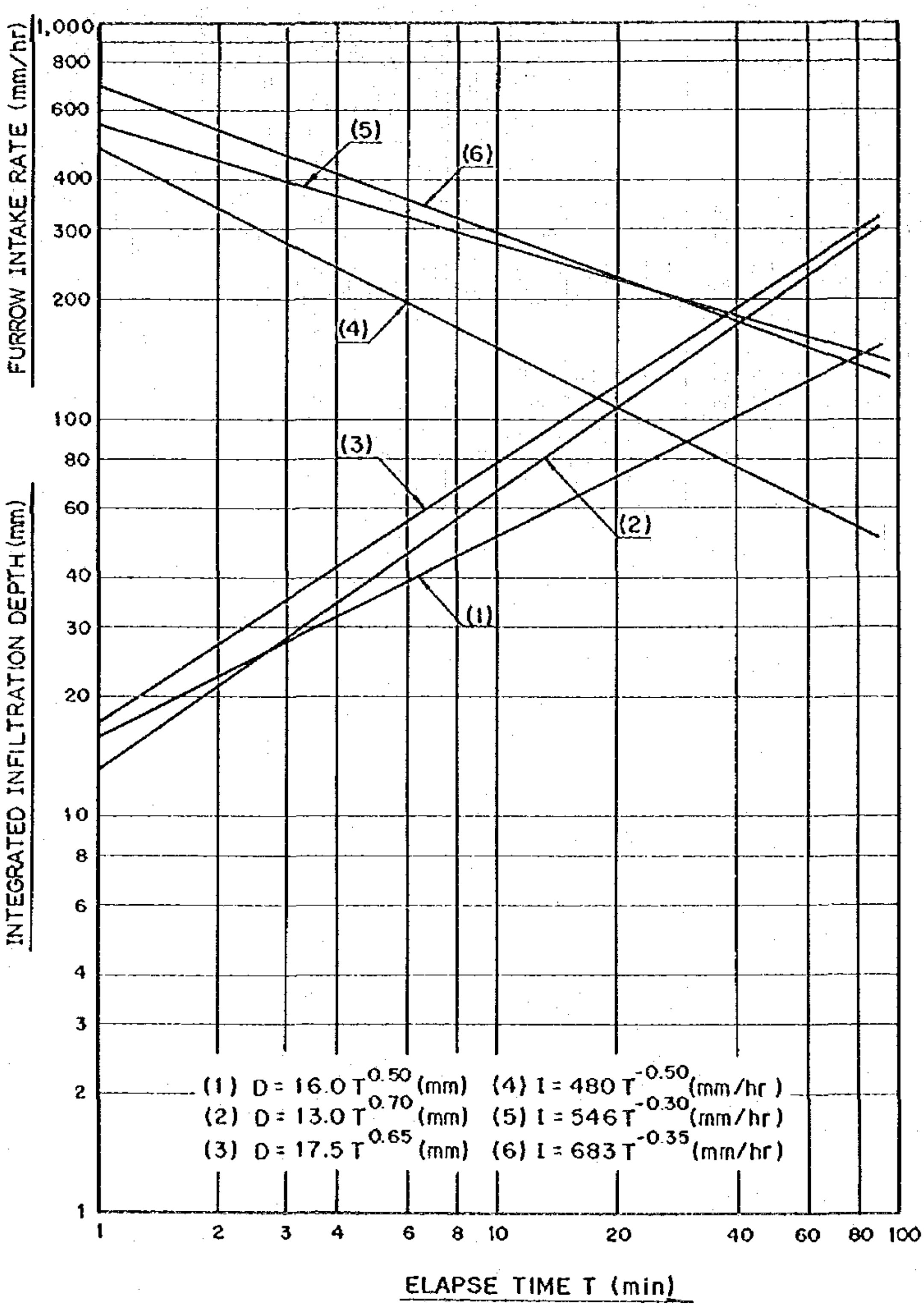



Fig.VI-18 FURROW INTAKE RATE (2/3)

## Unit T14

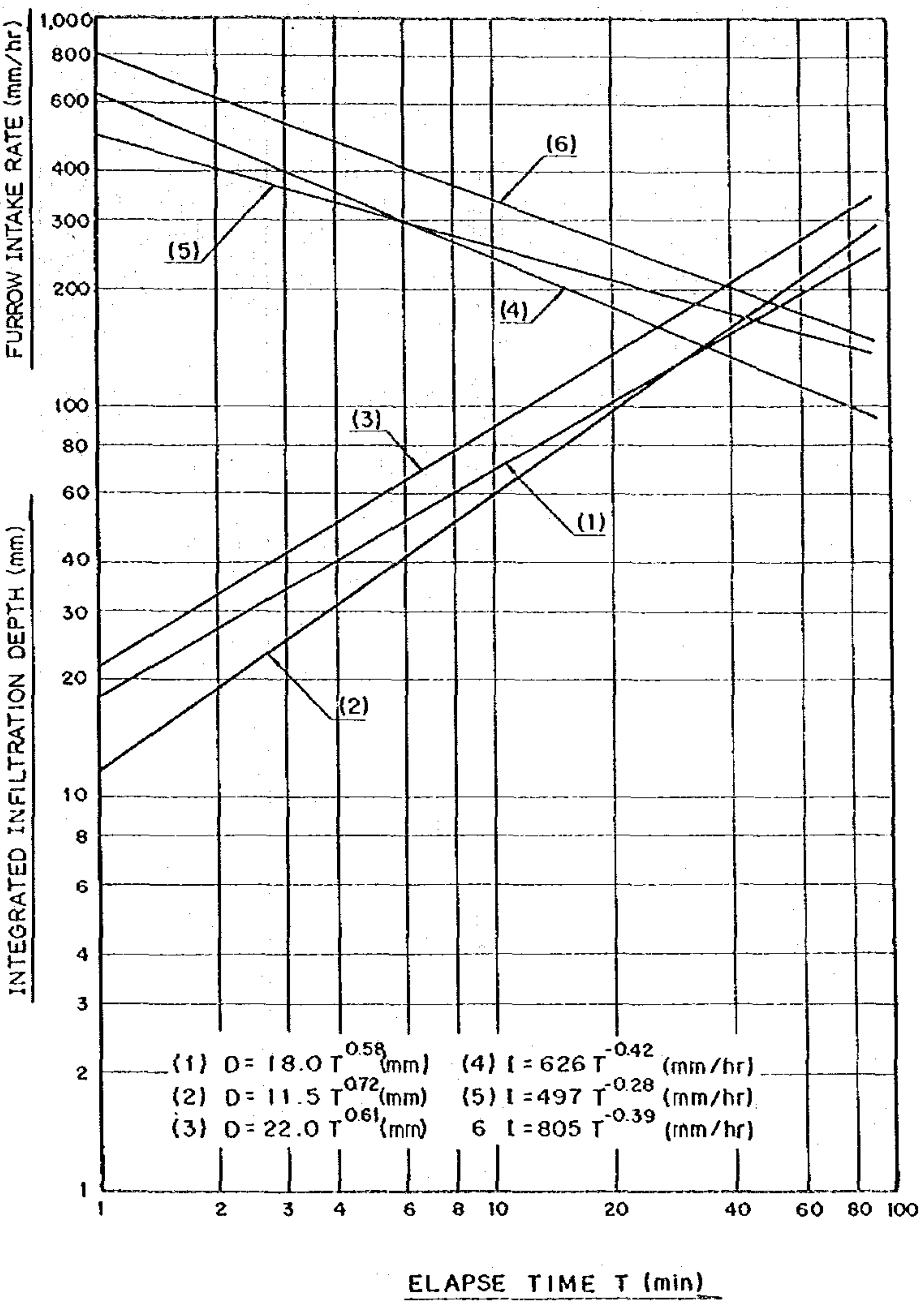



Fig. VI-18 FURROW INTAKE PATE (3/3)

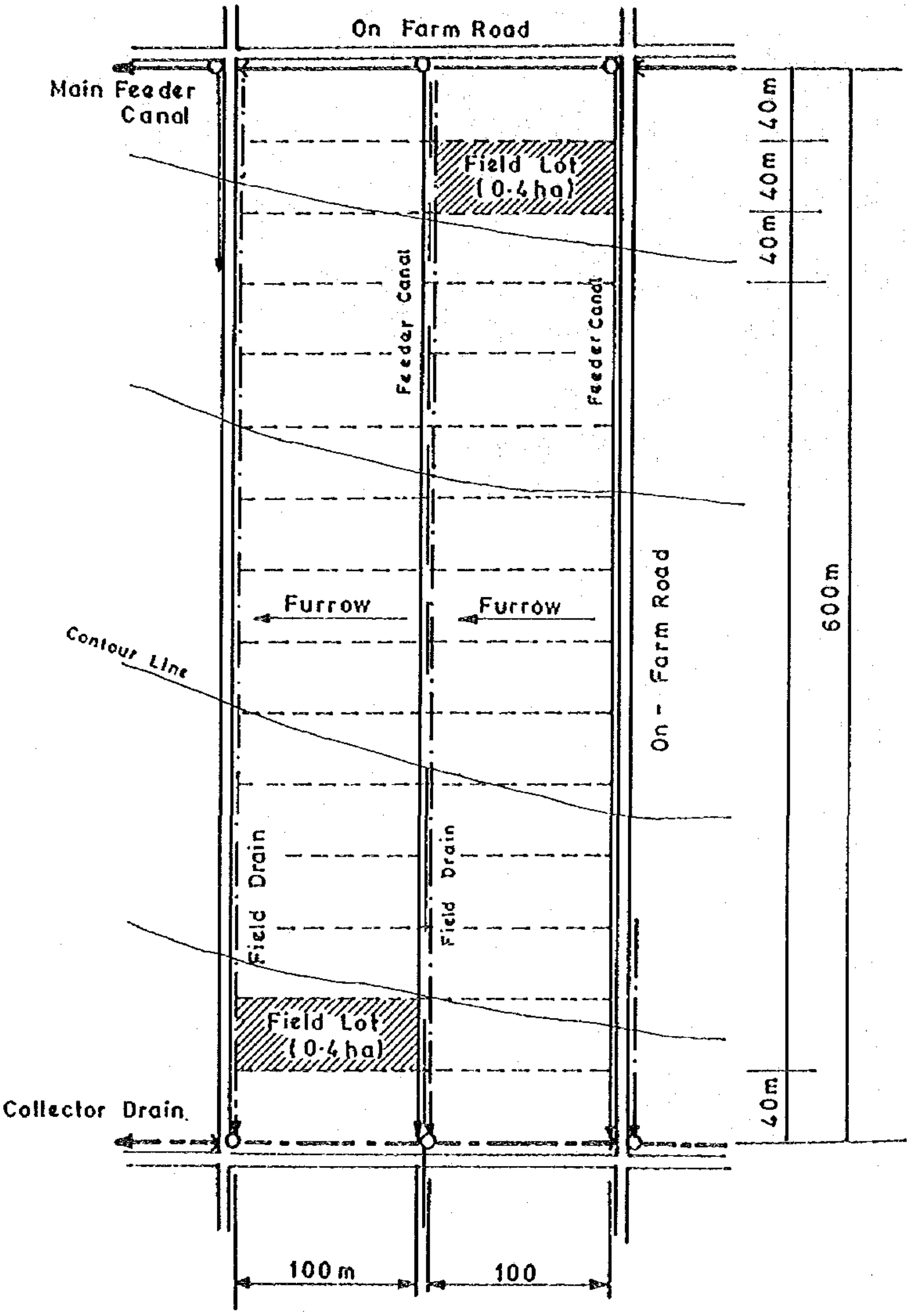



Fig. VI-19 TYPICAL LAYOUT OF HORTICULTURAL CROP FIELD

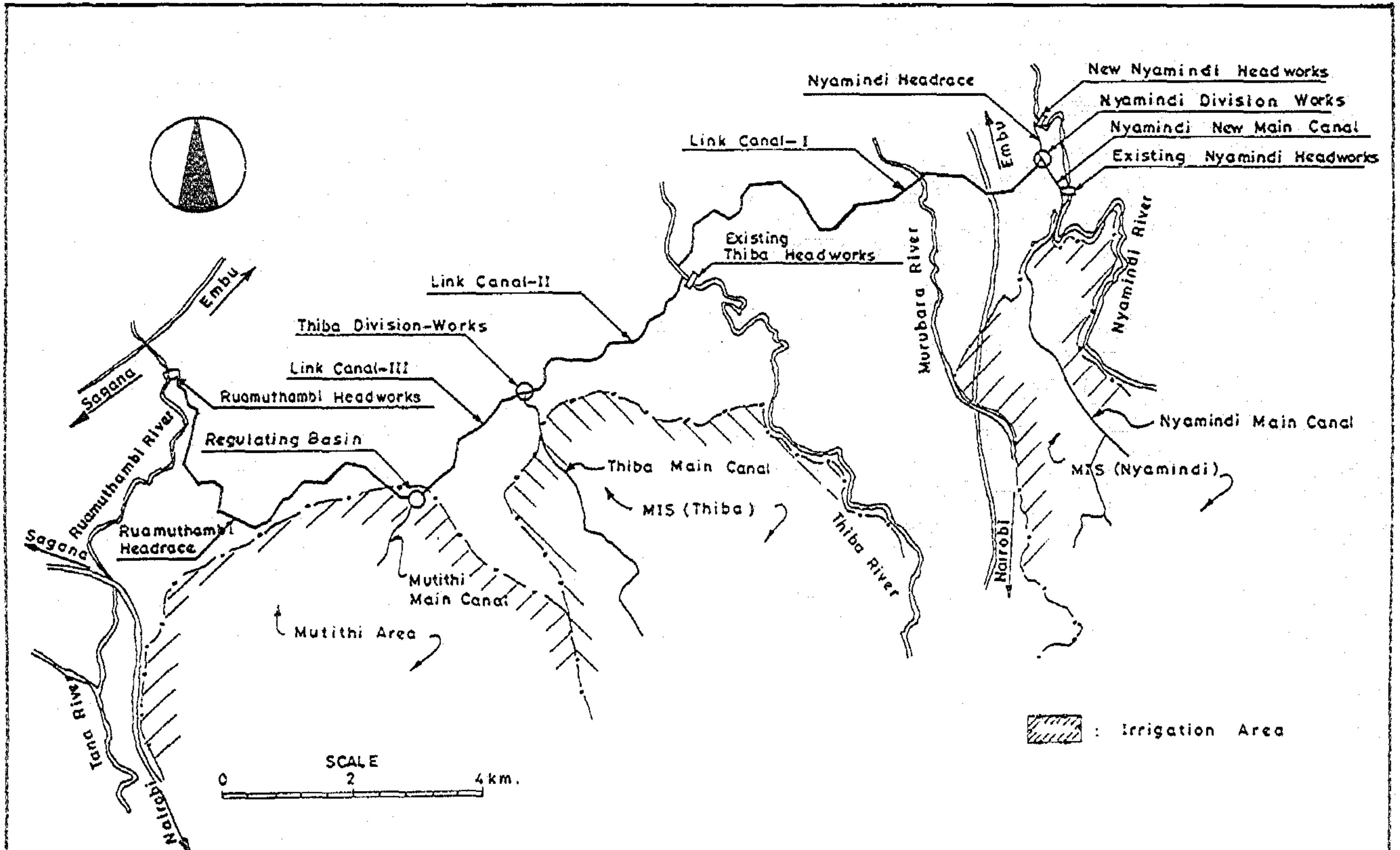



Fig. VI-20 LOCATION MAP OF MAJOR DIVERSION FACILITIES

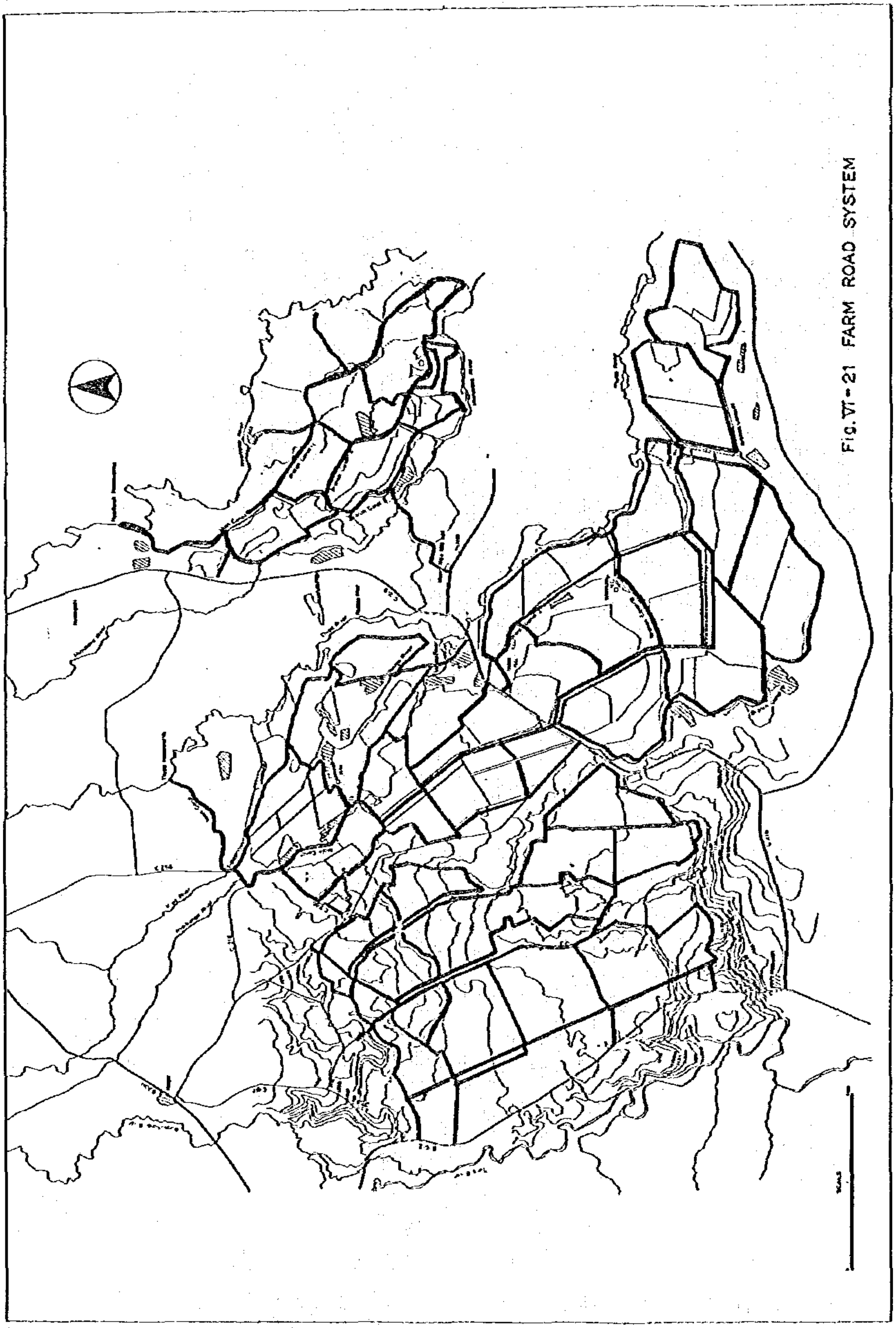
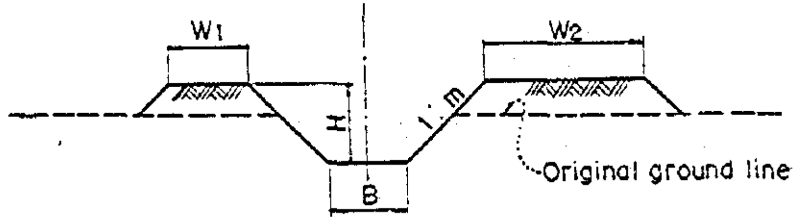


Fig.VI-21 FARM ROAD SYSTEM

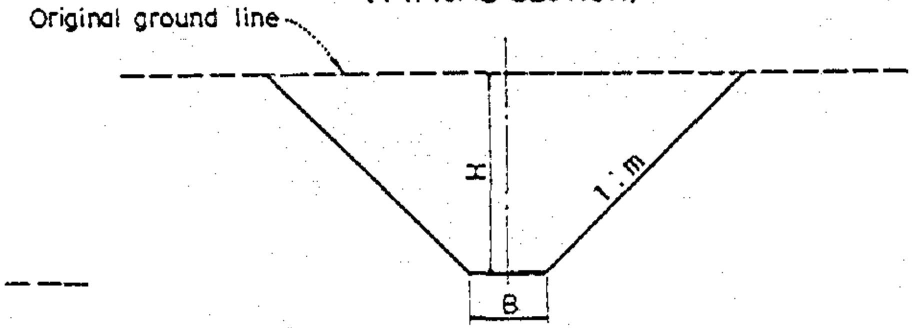
IRRIGATION CANALS
(TYPICAL SECTION)




(DIMENSIONS)

| Canal Name | B | H | W1 | W2 | m |
|---|---|---|---|---|---|
| Main Feeder Canal | 0.5~0.3 | 0.6~0.4 | 0.5 | 1.0 | 1.0 |
| Feeder Canal | 0.3 | 0.4 | 0.5 | 1.0 | 1.0 |

DRAINAGE CANALS
(TYPICAL SECTION)




(DIMENSIONS)

| Canal Name | B | H | m |
|---|---|---|---|
| Main Feeder Canal | 0.7~0.5 | 1.4~1.20 | 1.0 |
| Feeder Canal | 0.3 | 1.0 | 1.0 |

ON-FARM ROAD
(TYPICAL SECTION)

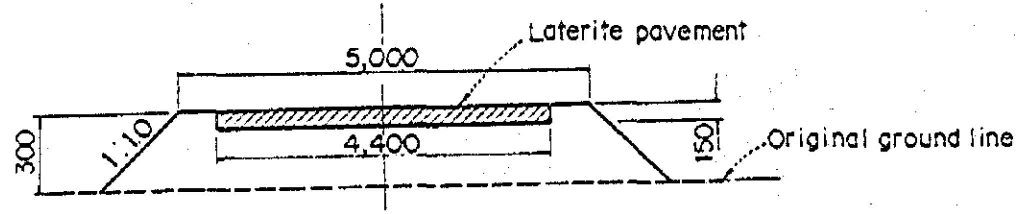



Fig. VI-22 TYPICAL SECTION OF ON - FARM CANALS AND ROADS

# ANNEX - VII

# AGRICULTURE AND AGRO-ECONOMY