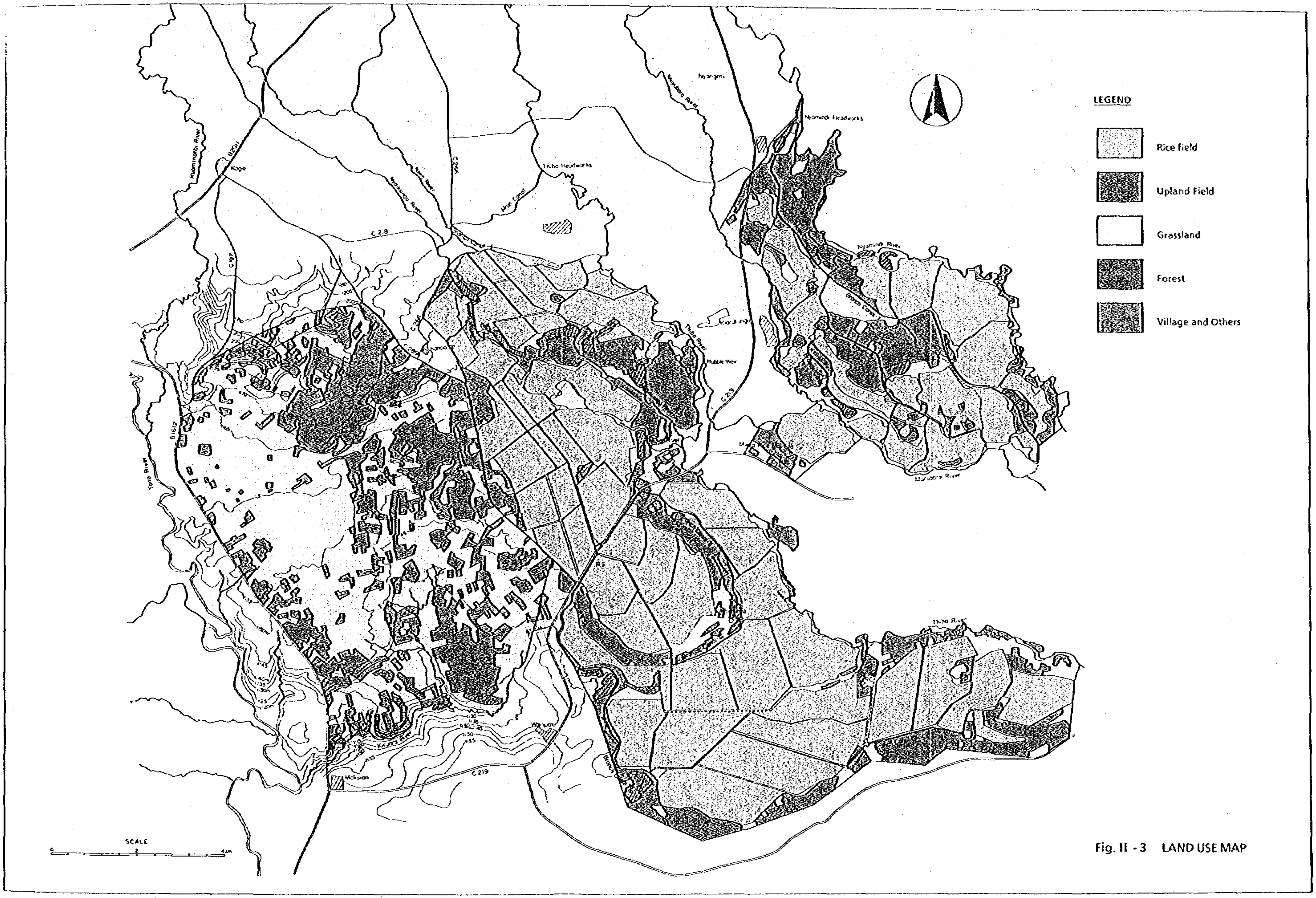


Fig. II - 3 LAND USE MAP

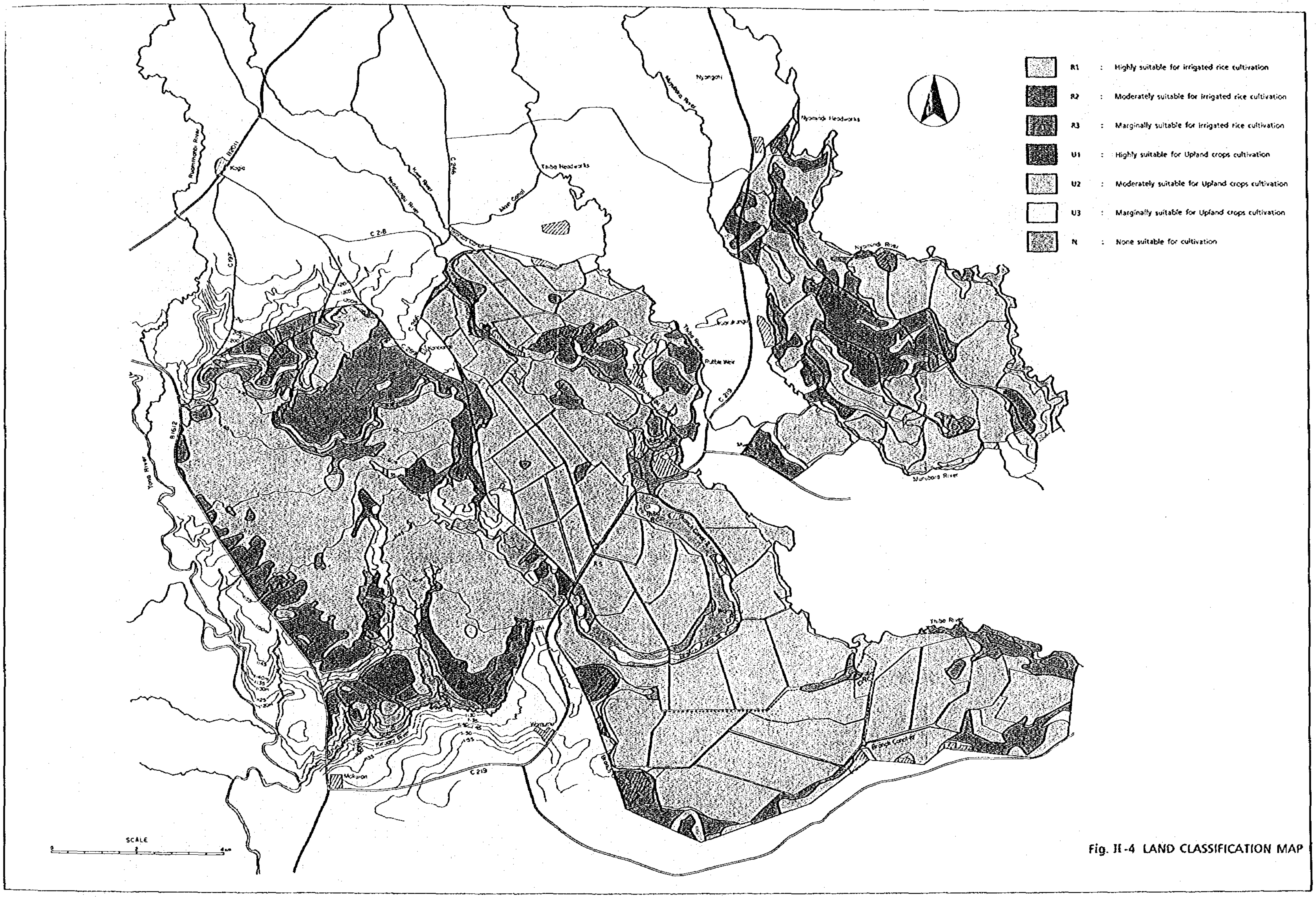


Fig. II-4 LAND CLASSIFICATION MAP

ANNEX - III

GEOLOGY AND SOIL MECHANICS

ANNEX - III

GEOLOGY AND SOIL MECHANICS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. GEOLOGICAL CONDITION

The Cenozoic volcanic materials cover the whole Study Area on the basement of gneisses. The following volcanic rocks are observed in the Study Area:

Rocks	Distribution
Gneisses (Archean)	Right bank area of the Tana river
Basalts (Pleistocene)	Almost whole Study Area
Agglomerates (Tertiary)	Southern outside of the Study Area
Tuffs (Tertiary)	Western and northern outside of the Study Area
Phonolites (Tertiary)	Left bank area of the Nyamindi river

The distribution of these rocks is illustrated on Fig. III-1 (Geological Map).

1.1 Geological Conditions at Damsites

The following geological survey was executed under the contract with Surtech Ltd.:

Survey period : July 17 - August 17, 1987

Location : Nyamindi damsite (Fig. III-2) and Thiba damsite (Fig. III-3)

Work Quantity :	<u>Nyamindi</u>	<u>Thiba</u>
Nos.of boring	2	2
Length of boring	60 m	55 m
Permeability test	6 times	7 times

(1) <u>Nyamindi damsite</u>

The Pleistocene basalts and Tertiary phonolites are observed around the Nyamindi damsite. The basalts extensively develop over the prospective reservoir area in southeast-northwest direction. The phonolites occur, on the other, on northern and northeastern part of the prospective reservoir area. In general, particularly around the prospective dam axis, the completely weathered pyroclastic materials (mainly soil-like weathered tuffs) cover these base rocks with an average thickness of 10-20 m. The geological condition at the Nyamindi damsite is shown on Fig. III-4 and Fig. III-5.

The foundation rock at the damsite has deep impermeable layer of about 20 meters which shows 0.3-1.3 Lu (Lugeon unit). The layer underlying the foundation rock is cracky and semi-permeable (50 Lu); however, its permeability could be improved by grouting. The pyroclastic materials overlying the foundation rocks are completely weathered, showing soil-like nature, and improvement of its permeability by grouting is difficult. In addition to this, the bearing capacity and shear strength of the natural ground seem to be small (N-value: 20±). Considering all these, it is recommended that the impervious blanket method be adopted for cut-off of leakage and stability of the dam.

(2) Thiba damsite

The Pleistocene basalts and Tertiary agglomerates are developed around the Thiba damsite. The completely weathered pyroclastic materials (mainly soil-like weathered tuffs) are observed over these basement rocks with an average thickness of 10-20 m. The geological condition at the Thiba damsite is shown on Fig. III-6 and Fig. III-7.

The completely weathered agglomerates with a thickness of 4 m are observed between Pleistocene basalts and Tertiary agglomerates which constitute the foundation rocks. This completely weathered layer shows soil-like nature with rather high Lugeon unit of 62 Lu; therefore, improvement of its permeability by grouting is difficult. It is recommended that the impervious blanket method be adopted to prevent the leakage from the foundation.

1.2 Geological Conditions at Major Structure Sites

The geological conditions at other major structural sites are summarized as follows:

Structure	Geological Condition
Nyamindi New Headworks	The Pleistocene basalts are out-cropped on the river bed.
Ruamuthambi Headworks	The Pleistocene basalts are out-cropped on the river bed and a thin layer of terrace deposits is observed on flat both banks.
Murubara Syphon	Muddy soils are accumulated on the foundation rocks of Pleistocene basalts.
Nyamindi Division Works	The Pleistocene basalts are out-cropped at the site.

In general, the proposed major structural sites have no special problem from the viewpoint of engineering geology.

2. SOIL MECHANICS

The following soil mechanical tests were executed under the contract with Surtech Ltd.:

Item	First Stage	Second Stage
Survey Period	Feb.1 - Mar.5	Jul.27 - Aug.17
Nos. of Samples	42 samples	21 samples
Nos. of Test Items	6 items	9 items

The locations of soil sampling are shown in Fig. III-8. The results of these soil mechanical tests are given in Table III-1 (soil samples from MIS Scheme area) and Table III-2 (soil samples from Nyamindi and Thiba damsites). Particle size distribution curves are shown in Fig. III-9 and Fig. III-10.

The general characteristics of soils and rocks extending over the Study Area are summarized as in the following:

2.1 Black Cotton Soils

The black cotton soils have generally high moisture contents, and they shrink and make deep open cracks when they are dried, and on the contrary, they swell when they are wet. Canal side slopes composed of the black cotton soils are likely to slide down due to seasonal alteration of shrinking and swelling. In order to prevent such canal slope sliding, the soils should not be dried. For preventing the soils from drying, the surface of the soils be covered with other materials like permeable gravelly sands which are available in the red soils area. The bearing capacity of the black cotton soils is rather high, showing $Q_a \leq 10$ t/m^2.

2.2 Red Soils

The moisture content of the red soils is generally low, compared to the black cotton soils. The bearing capacity of the red soils is around $Q_a = 20$ t/m^2. The red soils are generally permeable with a coefficient of permeability of (n x 10^{-4}) and are cohesionless; therefore, canal side slopes of the red soils are likely to be eroded. Careful maintenance with occasional compaction of the canal slope surface will be required, or lining of canal inside surface is considered as a semi-permanent countermeasure.

2.3 Embankment Materials

(1) Embankment materials for canal and road construction

Considering such characteristics of black cotton soils and red soils, the proper materials are found in and around the Study Area. The following sites are considered suitable as the borrow pits:

(i) Hill near Nyangati village located outside of northern boundary of the Study Area, and

(ii) Kiarukungu village situated at the center of the Study Area.

The quantity of the endowed materials is estimated to be some 10 MCM that is sufficient for the estimated requirement of embankment volume.

(2) Availability of aggregates

The present survey results suggest that the favourable quarry sites for both fine and coarse aggregate are not to be found in and near around the Study Area.

Considering the river conditions with steep river bottom slope and narrow width, it is supposed that the prospected large sedimentation of sand and gravel is caused in more downstream reach of the rivers. Then, it is to be considered as one alternative to use crushed sand and stone produced from bed rock existing over the whole Study Area.

(3) Borrow sites for dam construction

The proposed borrow sites at the Nyamindi and Thiba damsite are shown on Fig. III-2 (Nyamindi dam) and Fig. III-3 (Thiba dam). The estimated endowed volumes are as follows:

(i) Nyamindi dam

Earth materials	:	3.6 MCM
Rock materials	:	1.8 MCM

(ii) Thiba dam

Earth materials	:	2.0 MCM
Rock materials	:	1.5 MCM

Table III - 1 Results of Soil Mechanical Test for M.I.S.

Description	Black Cotton Soil	Red Soil	Transition
1. Physical properties.			
1-1 Natural water content (Wf)	43% (27 - 55)	27% (16 - 38)	24% (15 - 36)
1-2 Specific gravity (Gs)	2.61 (2.55 - 2.71)	2.80 (2.64 - 2.86)	2.73 (2.61 - 2.82)
1-3 Grain size distribution (Refer to Fig. 3.5.9			
gravel (>2.0mm)	0 - 4%	0 - 12%	0 - 12%
sand (2 - 0.05mm)	7 - 21%	40 - 49%	14 - 39%
silt (0.05 - 0.002mm)	19 - 20%	22 - 24%	17 - 34%
clay (0.002mm<)	56 - 73%	15 - 38%	32 - 52%
1-4 Liquid limit (L.L.)	89% (81 - 100)	47% (44 - 56)	54% (44 - 71)
1-5 Plastic limit (P.L.)	27% (24 - 32)	26% (18 - 30)	25% (22 - 30)
2. Mechanical properties			
2-1 Maximum dry density (rd max)	1.40 - 1.44 $t/_{m^3}$	1.40 - 1.53 $t/_{m^3}$	
2-2 Strength parimeters (Ø cu)	20 - 25°	30 - 35° 1)	
(Ccu)	8 - 10$t/_{m^2}$	4 - 8$t/_{m^2}$ 1)	
2-3 Cofficiant of permeability (k)	1 x 10^{-5} - 1 x 10^{-6}	x 10^{-5}	

note: 1). The values were assumed from other properties because the quantity of the sheartest for black cotton soil and red soil was small in this survey.

Table Ⅲ-2 Results of Soil Mechanical Test for Damsite

Description	Nyamindi	Thiba
1. Physical properties		
1-1 Natural water content (Wf)	55% (43 - 67)	30 (23 - 33)
1-2 Specific gravity (Gs)	2.55 (2.4 - 2.66)	2.68(2.55 - 2.81)
1-3 Grain size distribution (Refer to Fig. 3.5.10)		
Gravel (> 2.0mm)	0 - 1%	0 - 1%
Sand (2.0 - 0.05mm)	3 - 21%	3 - 23%
Silt (0.05 - 0.002mm)	42 - 56%	42 - 53%
Clay (0.002mm <)	22 - 55%	23 - 55%
1-4 Liquid limit (L.L.)	66% (59 - 70)	62% (57 - 79)
1-5 Plastic limit (P.L.)	45% (39 - 48)	40% (36 - 40)
2. Mechanical properties		
2-1 Maximum dry density (rd max)	1.29 - 1.33t/m³	1.35 - 1.40t/m³
2-2 Strength parameters (Ø cu)	30 - 35°	30 - 35°
(C cu)	5 - 7t/m²	±5t/m²
2-3 Cofficient of permeability (k)	1.2×10^{-5} - 1.1×10^{-6}	8.7×10^{-5} - 1.1×10^{-6}
2-4 Compression index (Cc)	0.16	0.17

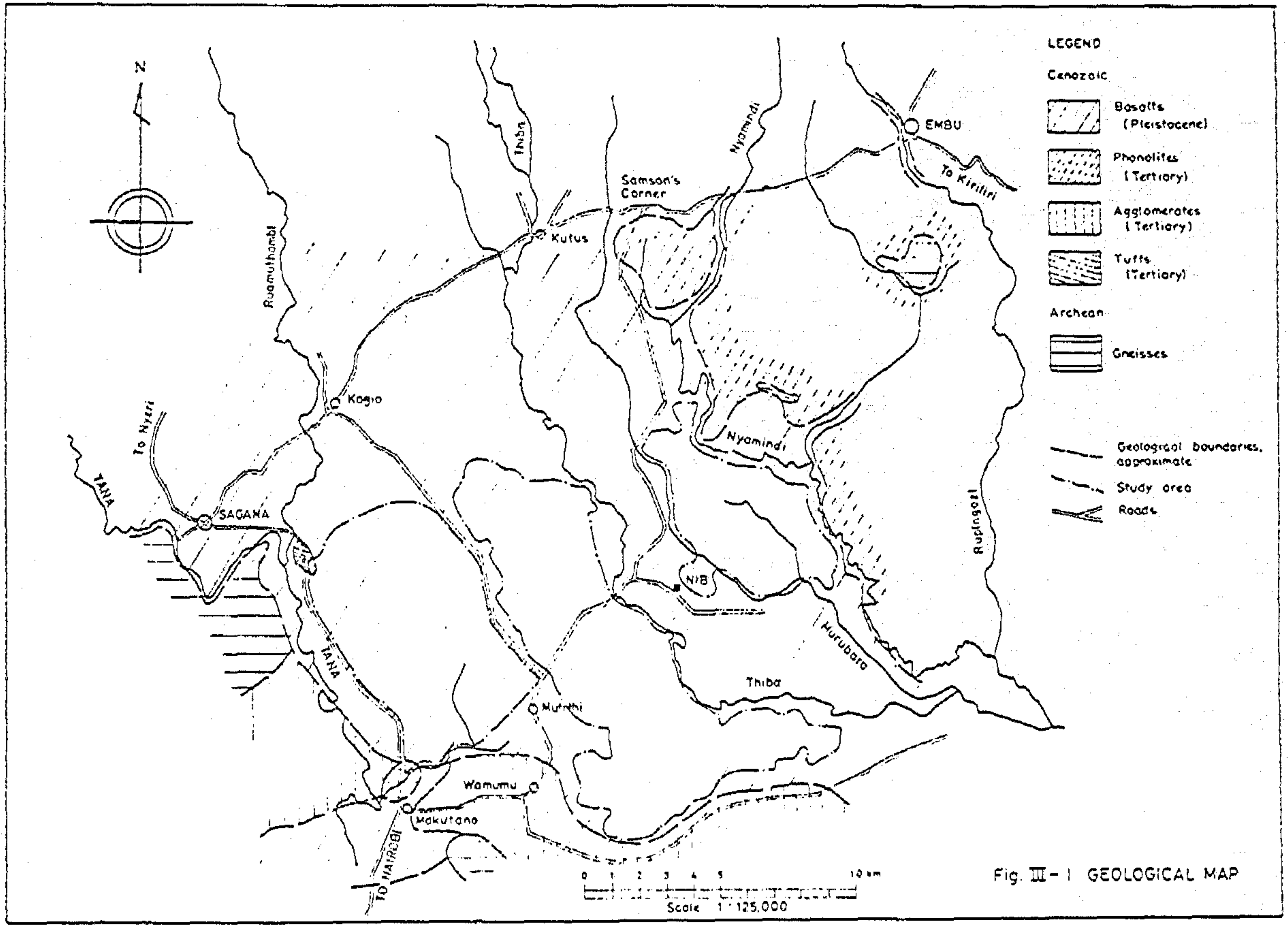


Fig. III-1 GEOLOGICAL MAP

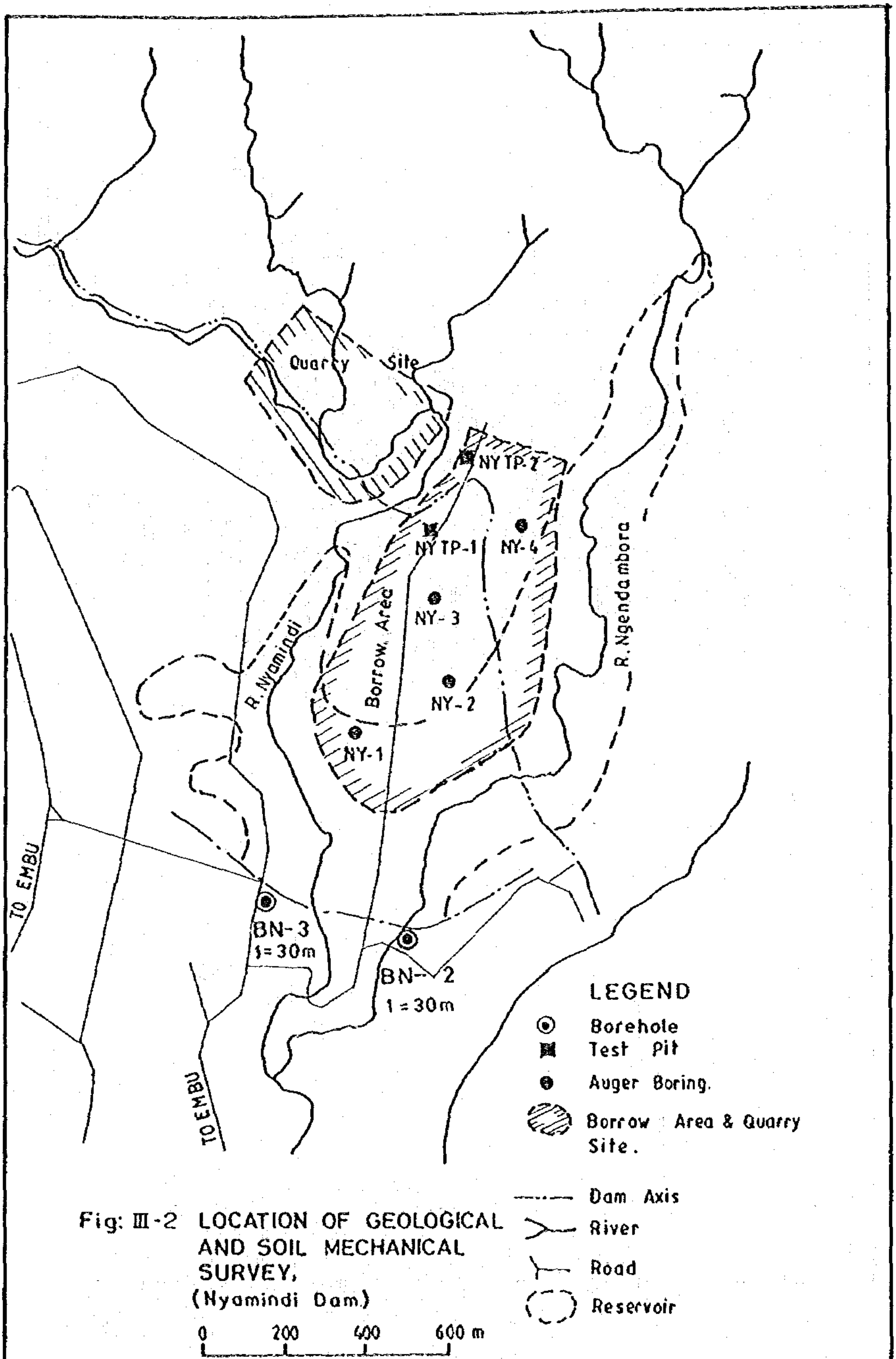


Fig: III-2 LOCATION OF GEOLOGICAL AND SOIL MECHANICAL SURVEY,
(Nyamindi Dam)

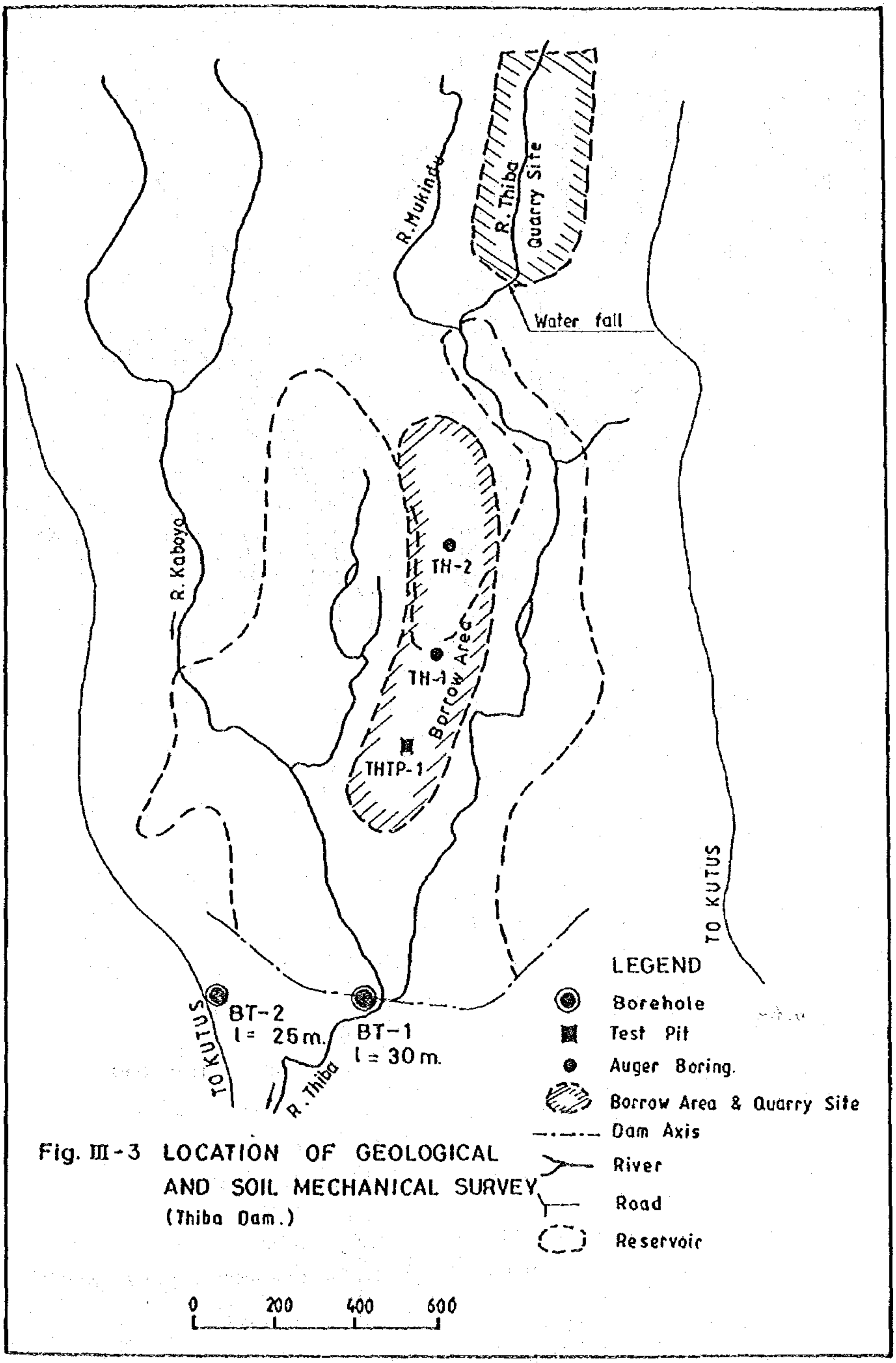


Fig. III-3 LOCATION OF GEOLOGICAL AND SOIL MECHANICAL SURVEY (Thiba Dam.)

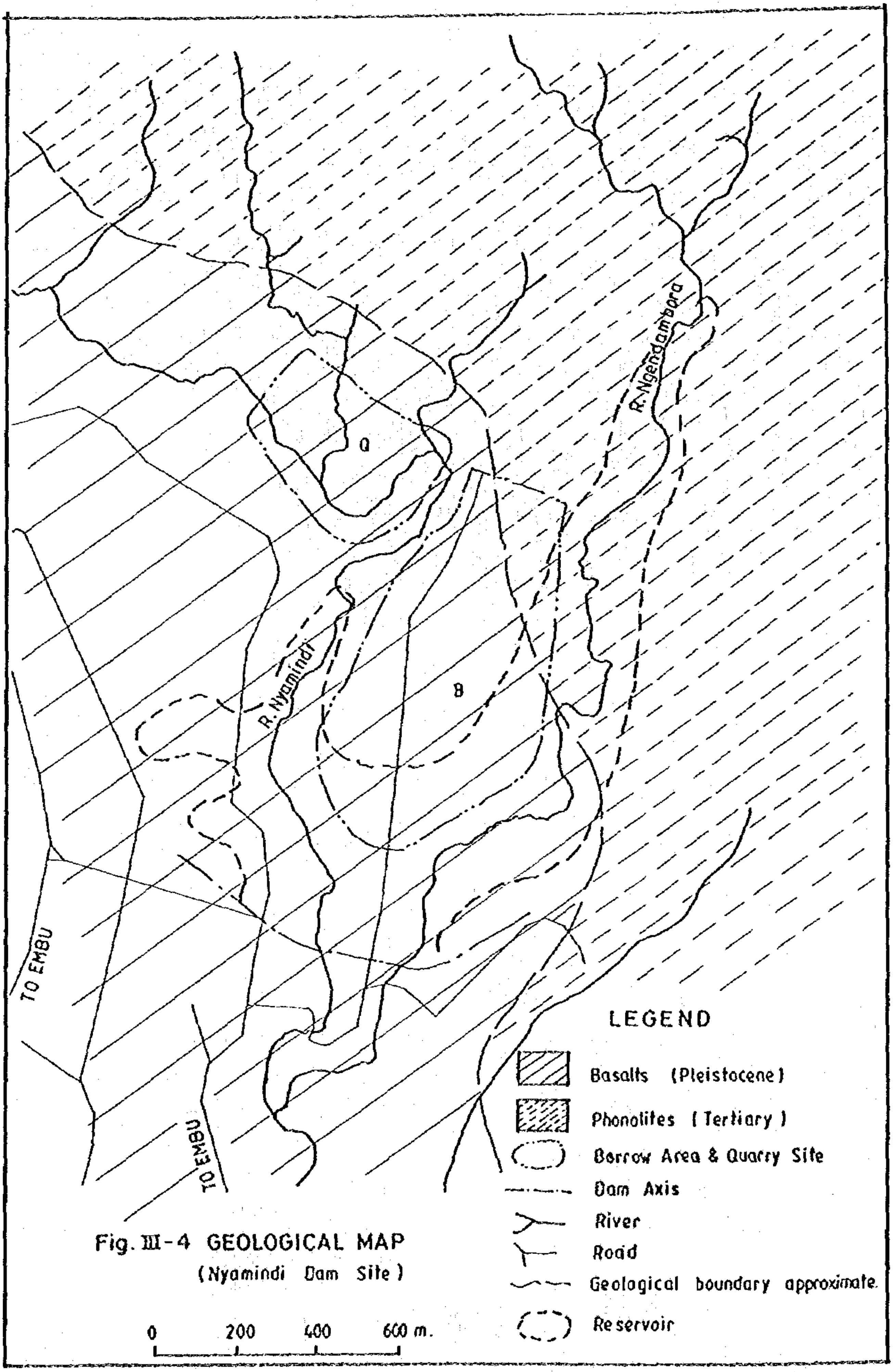


Fig. III-4 GEOLOGICAL MAP
(Nyamindi Dam Site)

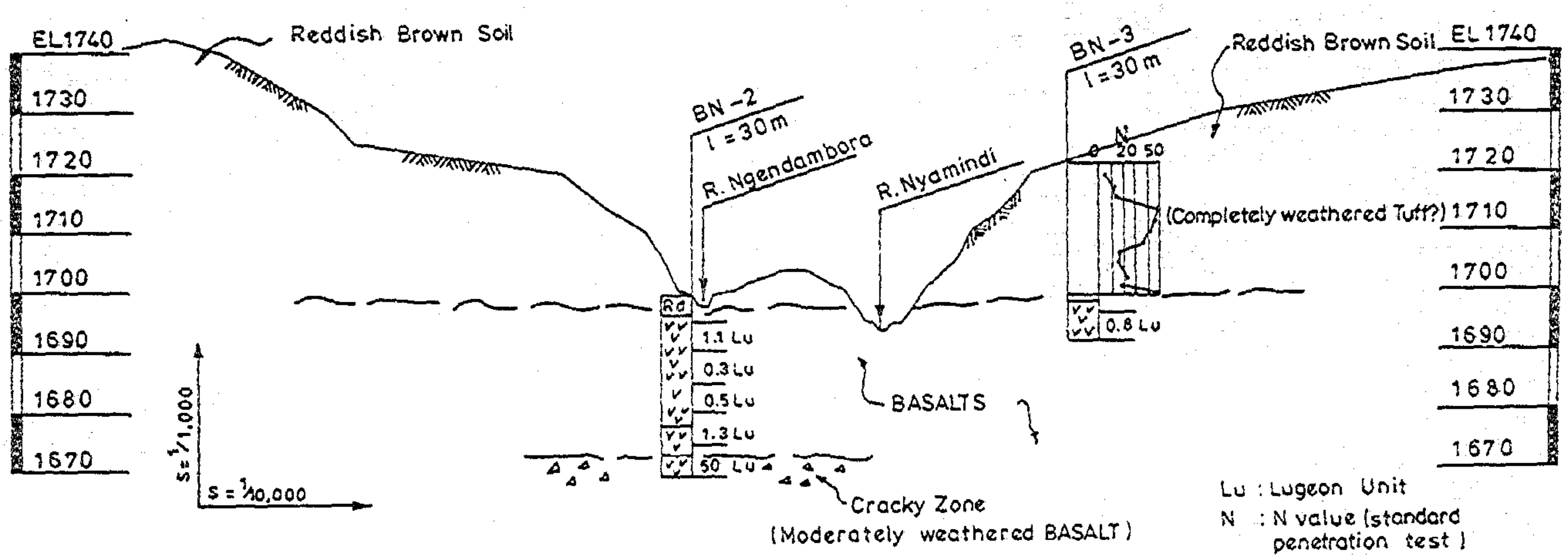


Fig. III-5 GEOLOGICAL PROFILE
(Dam Axis, Nyamindi)

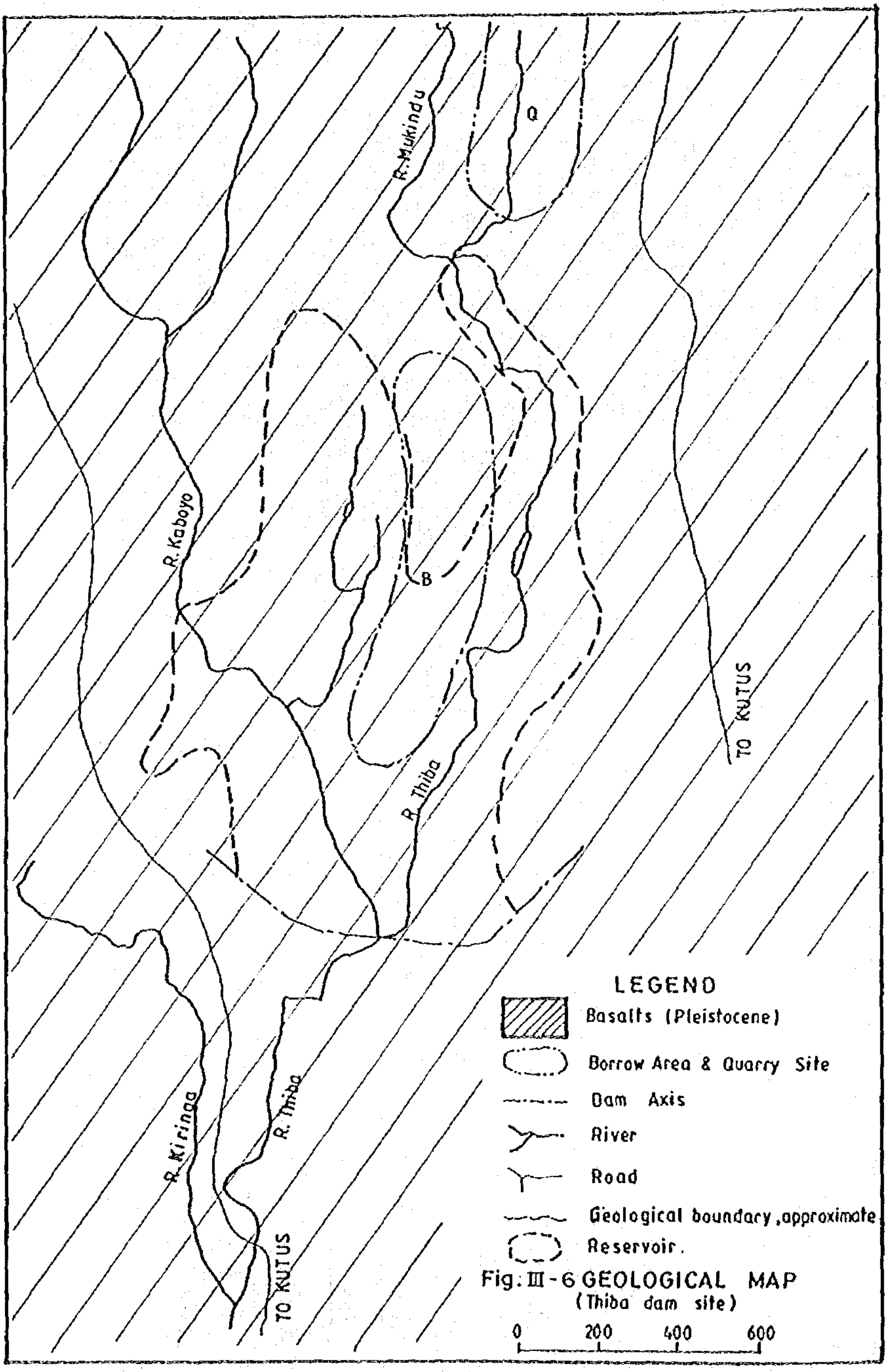


Fig. III-6 GEOLOGICAL MAP
(Thiba dam site)

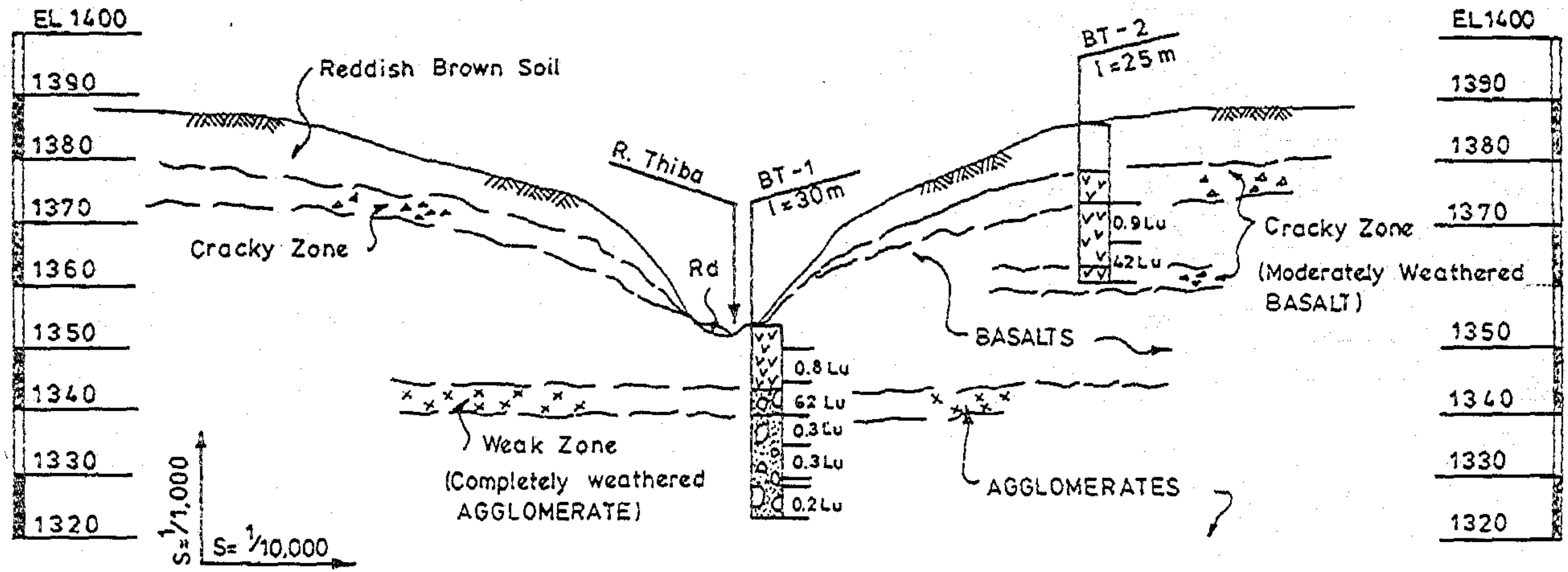


Fig. III-7 GEOLOGICAL PROFILE
(Dam axis, Thiba)

Lu : Lugeon Unit

Rd : River deposits

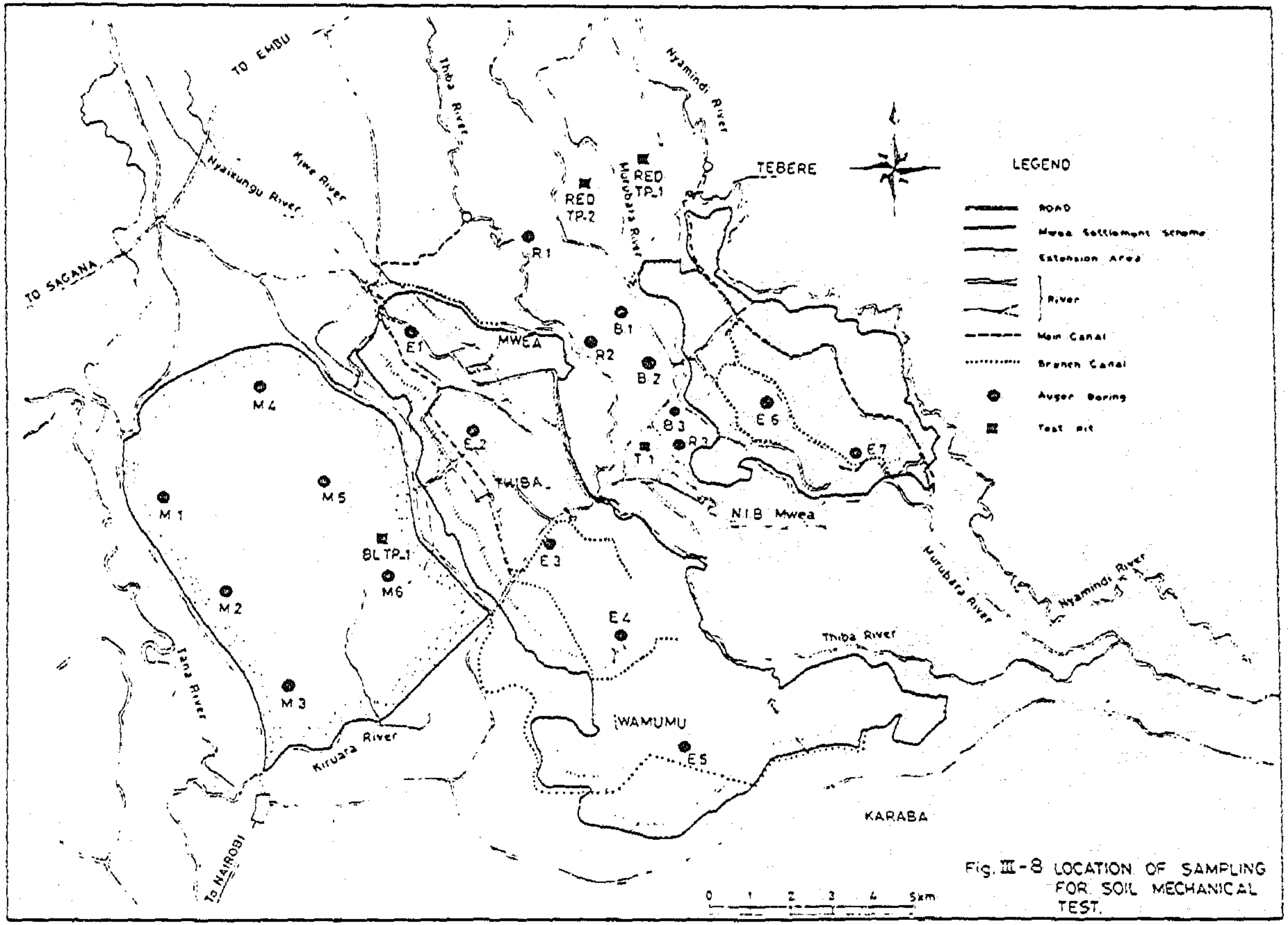


Fig. III-8 LOCATION OF SAMPLING FOR SOIL MECHANICAL TEST.

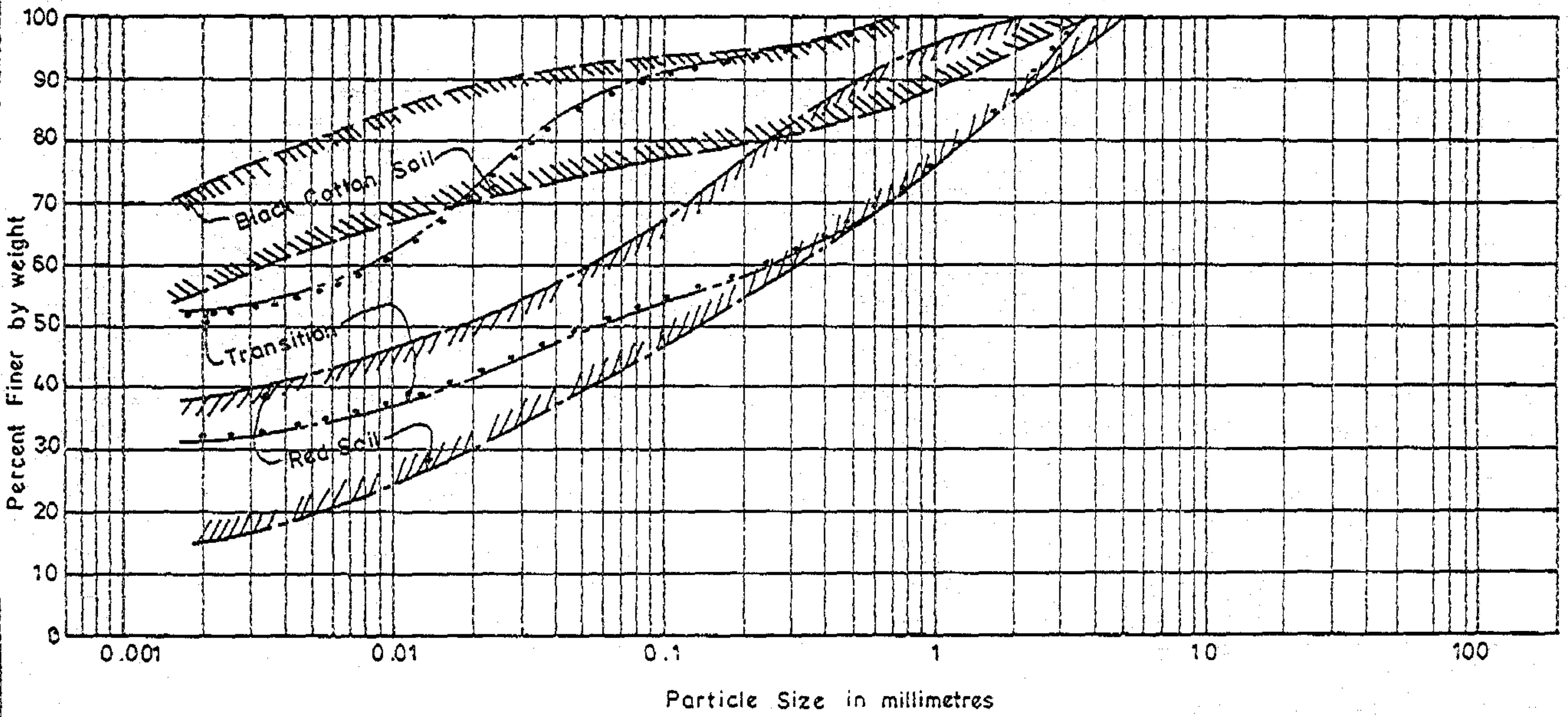


Fig. III-9 PARTICLE SIZE DISTRIBUTION CURVES (M.I.S.)

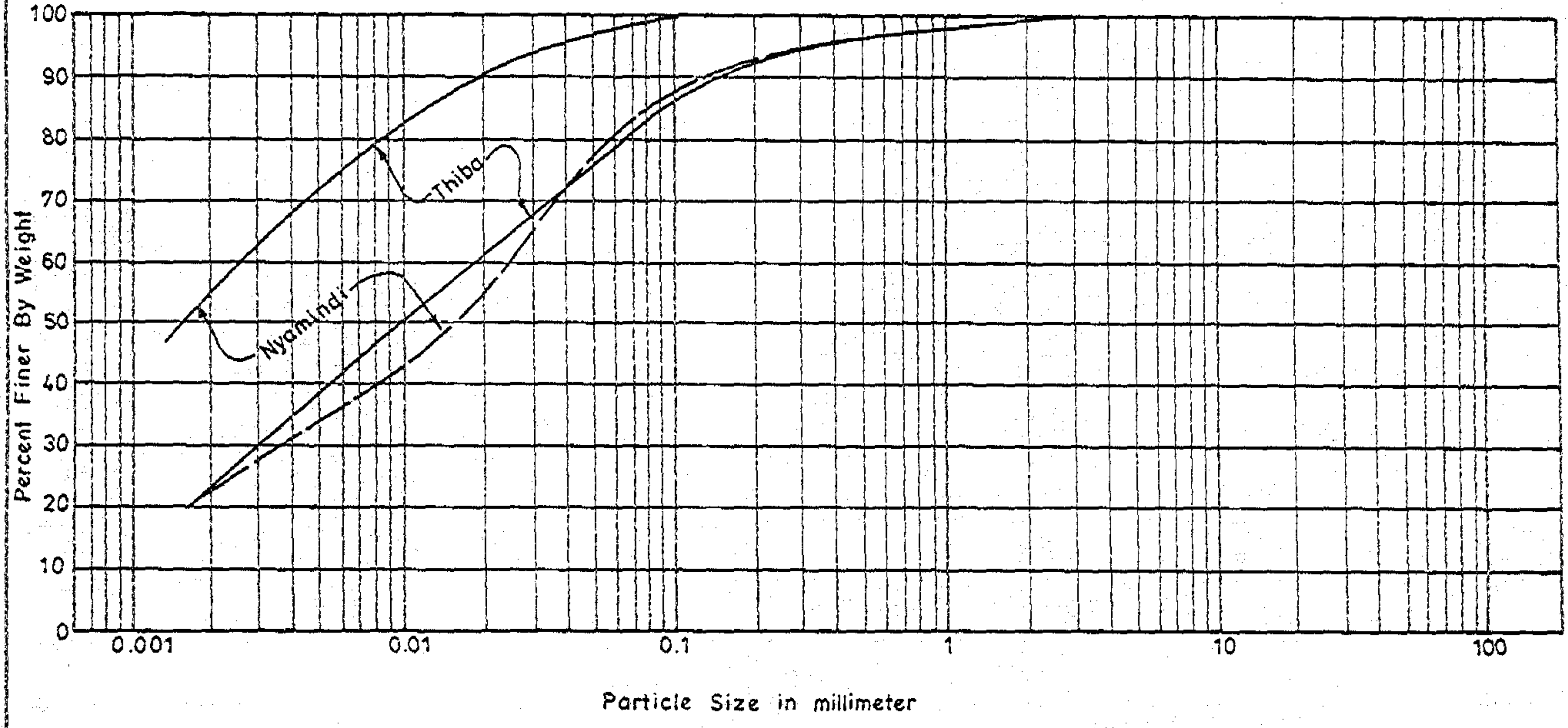


Fig. III-10 PARTICLE SIZE DISTRIBUTION CURVES (Thiba, Nyamindi)

ANNEX - IV

WATER BALANCE STUDY AND SELECTION OF BEST DEVELOPMENT ALTERNATIVE

ANNEX - IV

WATER BALANCE STUDY AND SELECTION OF BEST DEVELOPMENT ALTERNATIVE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. IRRIGABLE AREAS BY DROUGHT DISCHARGES

The irrigable areas by drought discharges of the Nyamindi, Thiba and Ruamuthambi rivers are limited to 5,520 ha in total which correspond to only 58% of the potential maximum area (9,560 ha) as shown below:

Month	Nyamindi	Thiba	Ruamuthambi	Total
Jan.	1,750	4,910	2,870	9,530
Feb.	1,750	4,910	1,100	7,760
Mar.	1,590	3,530	400	5,520
Apr.	1,750	4,910	860	7,520
May.	1,750	4,910	2,900	9,560
Jun.	1,750	4,910	2,040	8,700
Jul.	1,750	4,910	1,260	8,520
Aug.	1,750	4,910	1,250	7,910
Sep.	1,750	3,400	620	5,770
Oct.	1,750	3,380	620	5,750
Nov.	1,750	4,910	2,900	9,560
Dec.	1,750	4,910	2,840	9,500

The study is carried out under the condition that the drought discharges of the Nyamindi and Thiba rivers will be exclusively used for MIS Scheme area and that of the Ruamuthambi for the Mutithi area. And the calculation is made on the year of 1980, the drought year with five return period.

Detailed results are shown in Table IV-1.

2. SUPPLEMENTAL WATER SOURCES

In order to expand the irrigable area under the Project, supplemental water sources will be required. The following potential water sources are therefore studied.

- Thiba dam
- Nyamindi dam
- Ruamuthambi river
- Tana river
- Small streams

As a result, the dam and reservoir plan is chosen with the reasons as follows:

(1) The drought discharges of the Tana river are already exclusively occupied by water right holders in downstream of the considerable intake points of headworks, especially by Tana Power Station of Kenya Power and Lighting Company Limited.

(2) Small streams such as the Kiwe and the Nyaikungu river cannot be considered as dependable water sources. On the other hand, more complicated operation of irrigation facilities would be required if these minor water sources were taken into account.

(3) The study above mentioned, "IRRIGABLE AREAS BY DROUGHT DISCHARGES", shows the necessity of the storage dam, because the natural flow of the Nyamindi, Thiba and Ruamuthambi river is not sufficient to irrigate the whole potential maximum area for irrigation development.

3. PROSPECTIVE DEVELOPMENT ALTERNATIVES

The potential maximum area for irrigation development in the Study Area is 9,560 ha in total.

Water resources for irrigation development in the Study Area are, on the contrary, limited to three (3) rivers; the Nyamindi, Thiba and Ruamuthambi. Possible development plans for these water resources are as follows:

(1) Nyamindi river

a. Construction of new dam
b. Construction of new headworks
c. Rehabilitation of existing headworks

(2) Thiba river

a. Construction of new dam
b. Rehabilitation of existing headworks

(3) Ruamuthambi river

a. Construction of new headworks

The irrigation development plan in the Study Area will be formulated, with a view to utilizing these land and water resources to the full extent for maximum production of rice and other horticultural cash crops. The plan should, however, be justified from both technical and economic viewpoints; it means that the best and final plan will have to be technically feasible and moreover be largest in development scale within economically reasonable range, and it also means that in other words, the best alternative will be optimum in scale and not always simply be maximum scale of development.

With this in view, the following seven (7) possible development alternatives are set out:

ALTERNATIVE : T - 1

(1) Thiba dam

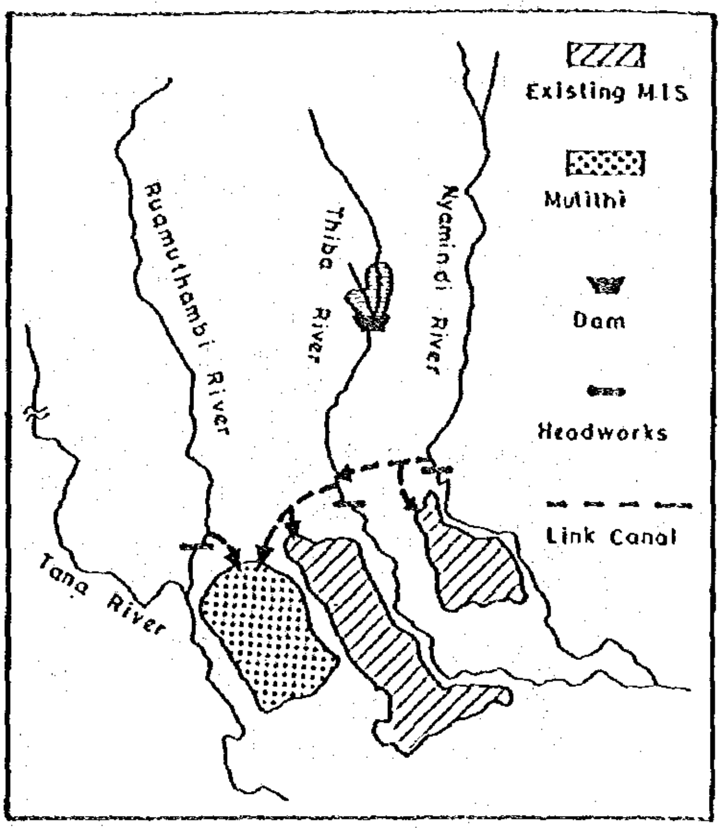
(2) New Nyamindi headworks

(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks

(4) Ruamuthambi headworks and headrace canal

(5) Rehabilitation of MIS

(6) Development of Mutithi and red soils areas



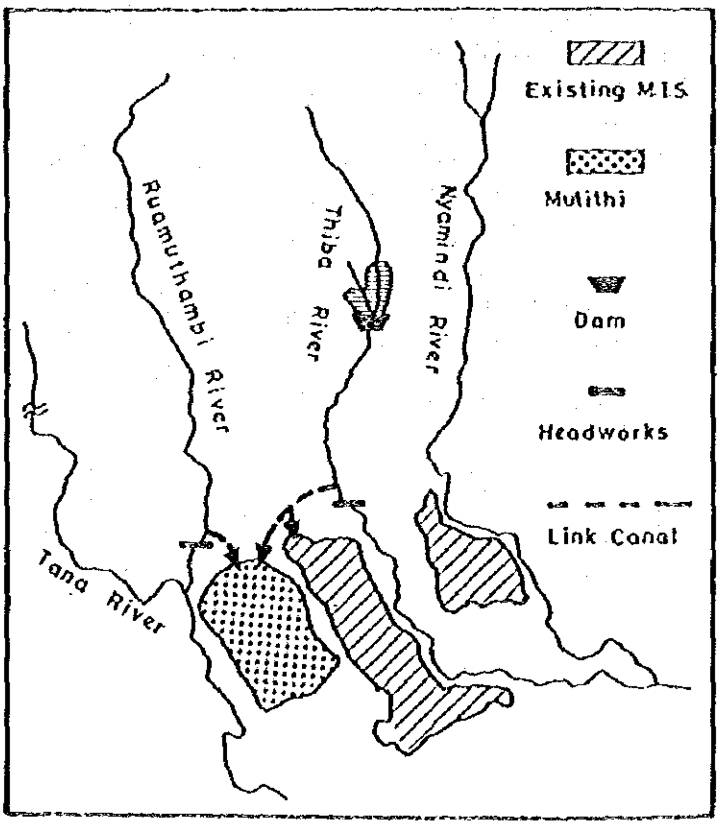
ALTERNATIVE : T - 2

(1) Thiba dam

(2) Ruamuthambi headworks and headrace canal

(3) Rehabilitation of MIS

(4) Development of Mutithi and red soils areas



ALTERNATIVE : T - 3

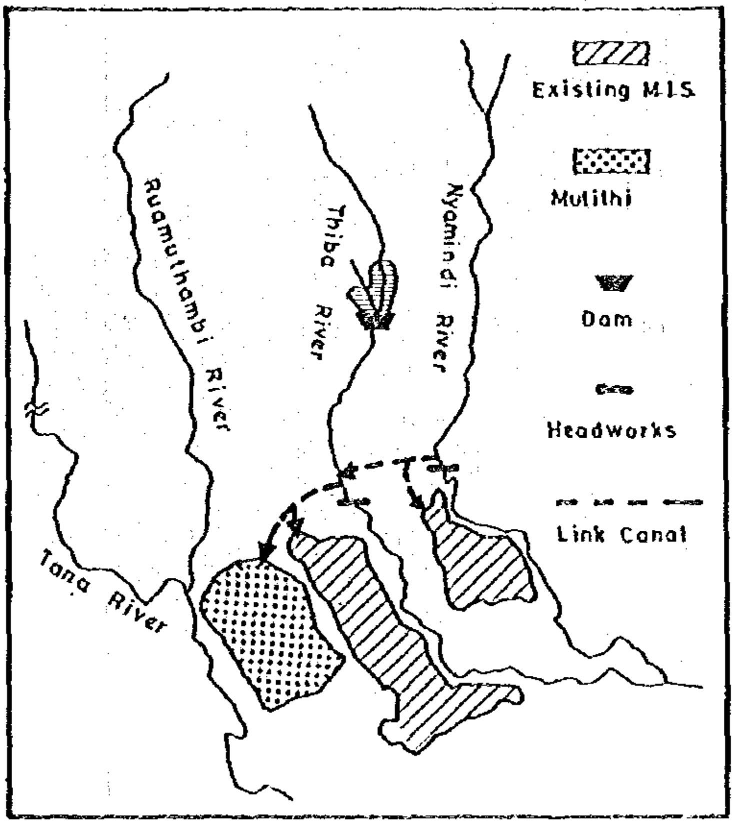
(1) Thiba dam

(2) New Nyamindi headworks

(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks

(4) Rehabilitation of MIS

(5) Development of Mutithi and red soils areas

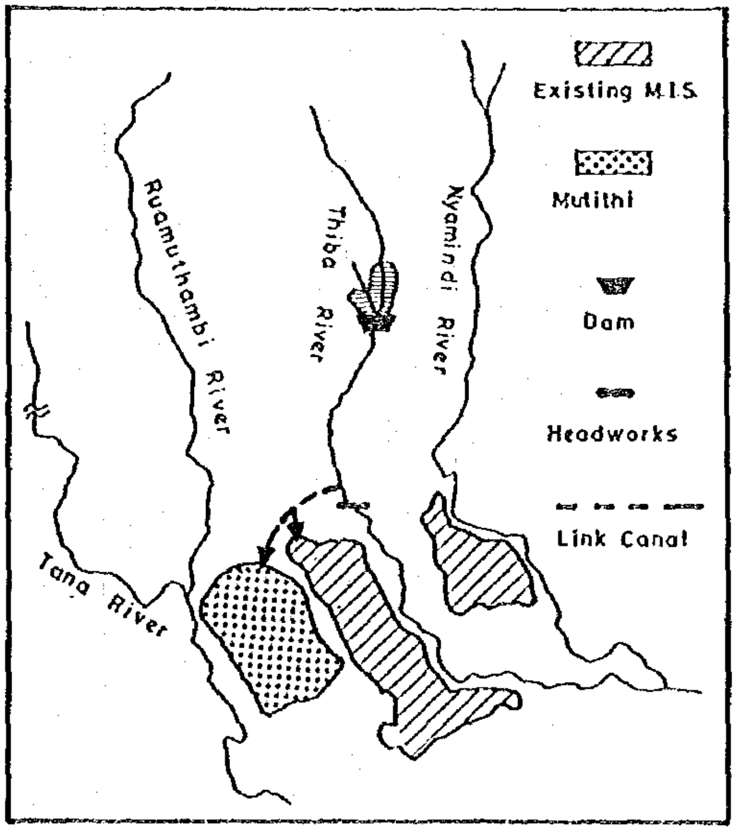


ALTERNATIVE : T - 4

(1) Thiba dam

(2) Rehabilitation of MIS

(3) Development of Mutithi and red soils areas



ALTERNATIVE : N - 1

(1) Nyamindi dam

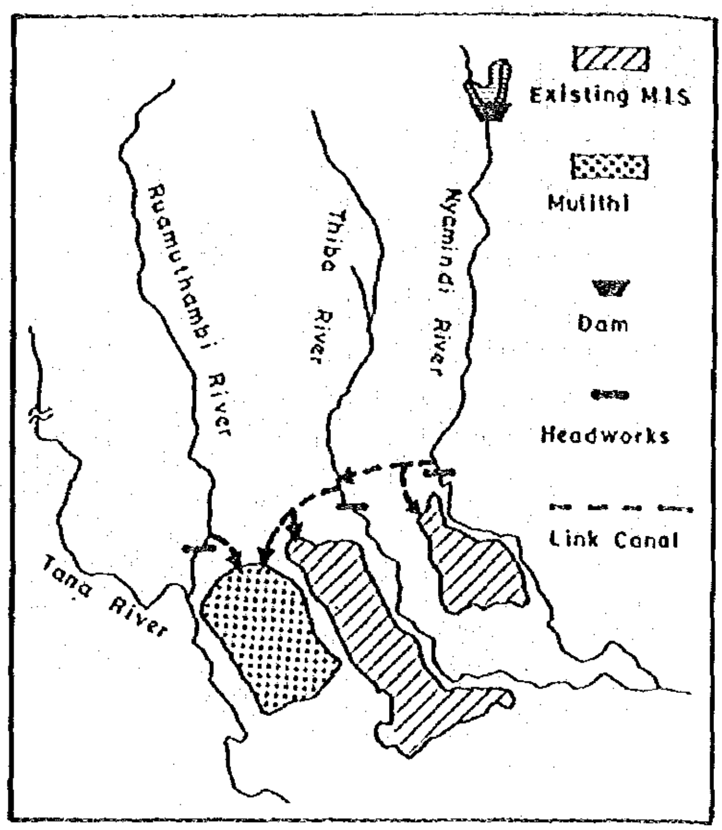
(2) New Nyamindi headworks

(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks

(4) Ruamuthambi headworks and headrace canal

(5) Rehabilitation of MIS

(6) Development of Mutithi and red soils areas



ALTERNATIVE : N - 2

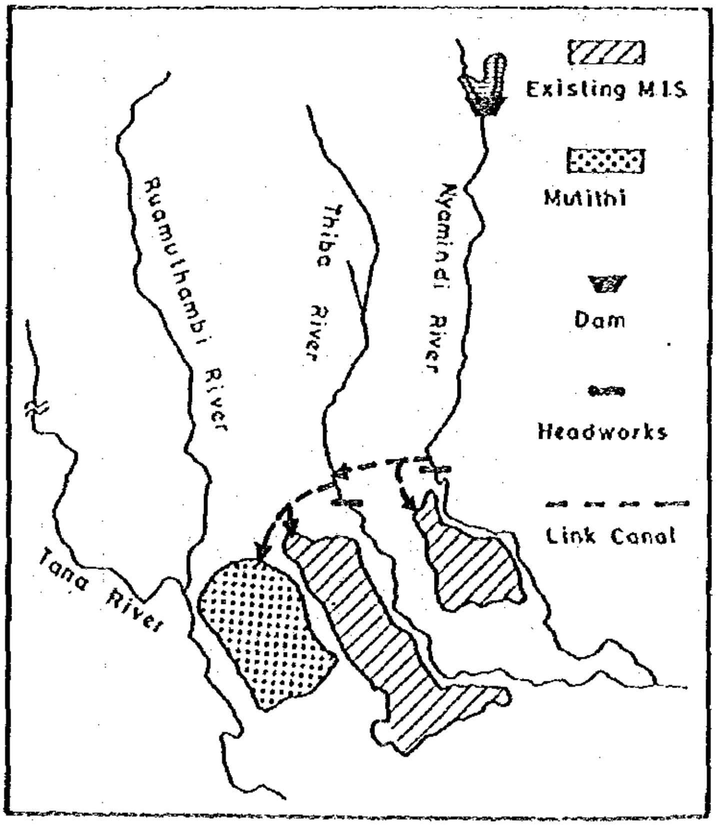
(1) Nyamindi dam

(2) New Nyamindi headworks

(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks

(4) Rehabilitation of MIS

(5) Development of Mutithi and red soils areas

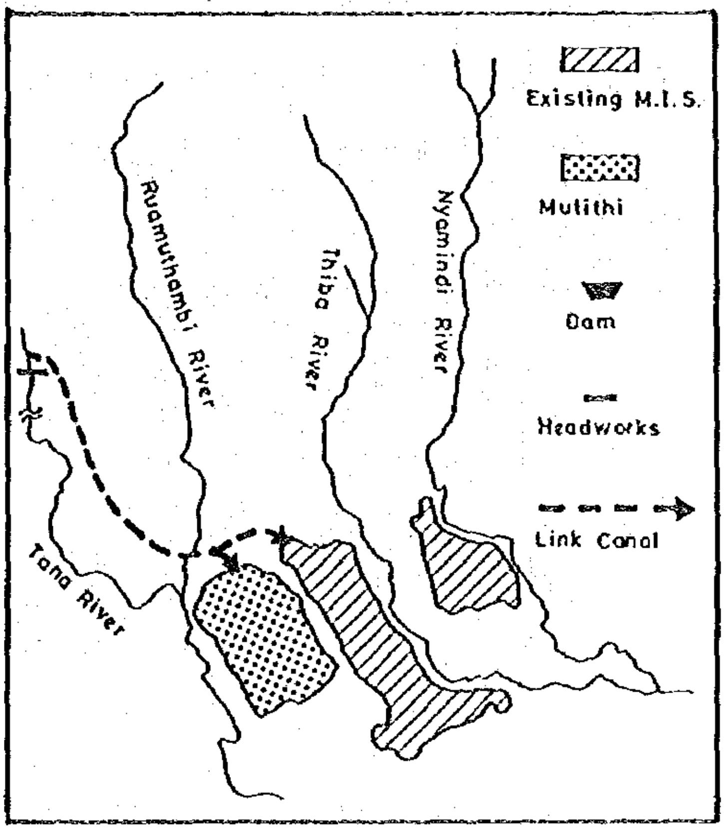


ALTERNATIVE : TA - 1

(1) New diversion from the Tana river by gravity

(2) Rehabilitation of MIS

(3) Development of Mutithi and red soils areas



The alternative TA-1 has been recognized as the least priority plan because the prospective canal of about 19 km would cross the railway running within the densely populated area and also the Tana Power Station of Kenya Power and Lighting Co., Ltd. has been granted by the Ministry of Water Development the water right to use the full of the normal flow and 17 m^3/sec (610 cusec) of flood flow. The alternative TA-1 is, therefor, not a possible plan in a practical sense.

4. WATER BALANCE CALCULATION AND IRRIGABLE AREAS

4.1 Flow Chart of Water Balance Calculation

The flow chart of the water balance calculation is shown on Fig. IV-1. The major conditions on the water balance calculation are as follows:

(1) Potential maximum for irrigation development is 9,560 ha.

(2) Potential maximum scales of the Thiba and Nyamindi dams are fixed as follows:

	Dan Height	Total Storage Capacity
Thiba	35 m	18 MCM
Nyamindi	35 m	10 MCM

The locations of the prospective damsites are shown in Fig. IV-2. And area-capacity curves of the Thiba and Nyamindi dam are shown in Fig. IV-3 and Fig. IV-4.

(3) Priority order in irrigation water utilization is as follows:

First : existing paddy field of 5,860 ha in MIS Scheme.

Second : prospective paddy field of 2,470 ha in the Mutithi area.

Third : prospective horticultural crops field of 800 ha in MIS Scheme.

Fourth : prospective horticultural crops field of 430 ha in the Mutithi area.

(4) The priority is given to the natural flow of the relevant river in water resources utilization, and storage water in the prospective reservoir will come last after natural flow is exhausted.

(5) Diversion water requirements for the paddy field to be irrigated by use of re-use water in MIS Scheme (60 ha in the Nyamindi part, 440 ha in the Thiba part) are not considered in the water balance calculation.

(6) Losses counted in the water balance calculation are as follows:

a. An overall irrigation efficiency of 55% is counted in calculation of the diversion requirement.

b. Losses from dam to headworks in the river, including intake losses at the headworks, are 5% of the required net storage capacity of the dam.

c. Losses in the reservoir, comprising evaporation from the water surface and seepage loss, are 5% of the required net storage capacity.

d. Effective storage capacity of the dam is therefore determined to be 1.1 times net storage capacity.

(7) Service discharge from the headworks to downstream comprises the total discharge with water right between the headworks and the junction to the Tana river plus a maintenance flow.

Service discharge from the dam to headworks consists of the total discharge with water right between the dam and headworks plus a maintenance flow.

Two kinds of water right are granted by the Ministry of Water Development; one is for normal flow and the other is for flood flow. The water right above mentioned means that for flood flow. The river maintenance flow is assumed to be 15% of the minimum mean discharge on a 10-day basis. The said service discharge from the dam is limited within the drought inflow discharge at the damsite.

(8) The water balance calculation is made on a 10-day basis, using data for the year of 1980, the drought year with five return period.

(9) The proposed irrigation networks of Alternative T-1, T-2, T-3 and T-4 are shown in Fig. IV-5 and for Alternative N-1 and N-2 in Fig. IV-6.

4.2 Results of Water Balance Calculation

4.2.1 Irrigable areas

The water balance calculation gives the following results:

(Unit: ha)

Irrigable Area		T-1	T-2	T-3	T-4	N-1	N-2
1.	MIS						
	Paddy	5,860	5,860	5,860	5,860	5,860	5,860
	Vegetables	800	570	450	570	0	0
	Sub-total	6,660	6,430	6,310	6,430	5,860	5,860
2.	Mutithi						
	Paddy	2,470	1,660	2,410	1,060	2,070	1,460
	Vegetables	430	0	0	0	0	0
	Sub-total	2,900	1,660	2,410	1,060	2,070	1,460
3.	Total	9,560	8,090	8,720	7,490	7,930	7,320

The above results indicate that only Alternative T-1 can cover the potential maximum area of 9,560 ha.

The procedures and diagrams of water balance calculation are indicated on Table IV-2 and Fig. IV-7

4.2.2 Reservoir capacities and dam heights

Based on the required net storage capacities computed from the water balance calculation, reservoir capacities and dam heights are decided as follows:

Item	T-1	T-2	T-3	T-4	N-1	N-2
1. Reservoir Capacity ($\times 10^3 m^3$)						
Required Net Storage Capacity	12,800	13,700	13,700	13,700	6,500	6,500
Effective Storage Capacity	14,100	15,000	15,000	15,000	7,200	7,200
Dead Storage Capacity	2,600	2,600	2,600	2,600	2,500	2,500
Total Storage Capacity	16,700 ≒17,000	17,600 ≒13,000	17,600 ≒18,0000	17,600 ≒18,000	9,700 ≒10,000	9,700 ≒10,000
2. Dam Height (m)	34.5	35.0	35.0	35.0	35.0	35.0

The above results indicate that the Thiba dam has a surplus storage capacity of 1 MCM in Alternative T-1 case.

5. SELECTION OF BEST DEVELOPMENT ALTERNATIVE

5.1 Preliminary Estimate of Cost and Benefit

5.1.1 Project cost

The preliminary development work quantities and costs for each alternative are shown in Table IV-3 and IV-4.

The project costs for each development alternatives comprise of the following items.

(1) Construction cost

Construction cost comprises direct construction cost, cost for preparatory works, contractor's field expenses and overhead expenses.

(2) Initial farm investment

Initial farm investment comprises the costs for agricultural machinery, O/M equipment and farm building. The initial farm investment for each development alternative is estimated on the basis of the current prices in Kenya.

(3) Administration cost

Administration cost is roughly estimated on the assumption that NIB would supervise the construction works directly. The cost is estimated at 3% of the total cost for the above two (2) items. Administration costs for each development alternative are estimated applying this percentage (3%) to the total of the above two (2) items.

(4) Engineering service

The cost for engineering service is roughly estimated on the assumption that the consultants will be engaged in the detailed design and construction supervision. The estimated cost is fixed at 11% of the total cost for direct construction cost and cost for preparatory works. Engineering service costs for each development alternative are estimated, applying this percentage (11%) to the total of two (2) items mentioned above.

(5) Physical contingency

Physical contingency is fixed at 10% of the total for the above four (4) items.

(6) <u>Price contingency</u>

Price contingency is fixed at 35% of the total for the above five (5) items.

5.1.2 Irrigation benefits

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

(1) The unit yield of rice will decrease under future condition without the Project and agricultural economy will become lower than that under the present condition.

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

Short rains rice	:	3.5 ton/ha
Maize	:	1.3 ton/ha
Beans	:	6.0 ton/ha

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

Long rains rice	:	6.0 ton/ha
Short rains rice	:	6.0 ton/ha
Tomatoes	:	15.0 ton/ha
Onions	:	10.0 ton/ha
French Beans	:	10.0 ton/ha

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

Rice	:	3,600 KShs./ton
Tomatoes	:	3,200 KShs./ton
Onions	:	3,900 KShs./ton
French Beans	:	3,200 KShs./ton

(5) Crop production costs under future conditions both with and without the Project estimated as follows:

<u>Without project</u>

- Short rains rice	:	4,623 KShs./ha
- maize	:	2,776 KShs./ha
- Beans	:	3,531 KShs./ha

With project

- Long rains rice : 5,598 KShs./ha
- Short rains rice : 5,598 KShs./ha
- Tomatoes : 13,377 KShs./ha
- Onions : 13,464 KShs./ha
- French Beans : 8,155 KShs./ha

Annual incremental benefits for each cases of alternative plan are shown in Table IV-5 and summarized as follow:

Alternative	Irrigation Area (ha)	Irrigation Benefit (KShs. million)	Irrigation Benefit per ha (KShs./ha)
T-1	9,560	282	29,500
T-2	8,090	222	27,500
T-3	8,720	240	27,600
T-4	7,490	203	27,100
N-1	7,930	207	26,100
N-2	7,320	188	25,600

5.1.3 Economic Cost

The financial project costs are converted into the economic costs by multiplying the financial project costs less price contingencies and taxes by the standard conversion factors (SCF) of 0.86 for foreign costs component (70%) and SCF of 1.00 for domestic costs component (30%). The economic costs for each case of alternative plan are shown as follows:

Alternative Plan	Irrigation Area (ha)	Economic Cost (KShs. million)	Economic Cost per ha (KShs./ha)
T-1	9,560	1,070	112,100
T-2	8,090	914	113,000
T-3	8,720	1,028	117,000
T-4	7,490	845	112,800
N-1	7,930	1,065	134,400
N-2	7,320	989	135,000

5.2 Economic Evaluation

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

a. The construction period will be five(5) years in each alternative plan.

b. Economic useful life of the project facilities will be 50 years. However, machinery, buildings and gates will be replaced at 5, 20,and 25 years after completion of the construction works, respectively.

c. Annual O/M cost of each alternative plan is tentatively fixed at four (4)% of the total cost.

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

e. The benefits will initially accrue from rehabilitation of the existing MIS rice field in 4th year after commencement of construction by 60% of full incremental benefit in MIS. The benefit from MIS will increase gradually during the build-up period of 5 years from 60% in 4th year to 100% in 8th year. While, the benefits from the Mutithi extension area will accrue after completion of dam construction and increase gradually during the build-up period of 5 years from 60% in 4th year to 100% in 8th year.

f. The production losses in the prospective reservoir areas are estimated to be KShs.0.4 million for the Thiba dam and KShs.2.2 million for the Nyamindi dam, on the basis of the land use maps in the reservoir areas and the results of farm economic survey. Such production losses are considered in the costs and benefits stream over 50 years as a negative benefit, while compensation cost such as resettlement and land acquisition is included in the dam construction cost.

Using assumptions mentioned above, the economic internal rate of return (EIRR) in each alternative plan are calculated as follows:

Alternative Plan	EIRR (%)
T-1	17.7
T-2	16.9
T-3	15.9
T-4	17.0
N-1	12.8
N-2	12.6

5.3 Selection of Best Development Alternative

It is recommended that the development alternative T-1 be selected as the best and prospective development plan on the following reasons:

a. The alternative T-1 shows the highest EIRR of 17.7% among all the possible alternatives.

b. Only the alternative T-1 can irrigate the potential maximum area of 9,560 ha, including the Mutithi and red soils area.

c. The alternative T-1 gives the largest paddy production of about 100,000 tons per annum.

d. The alternative T-1 benefits the largest number of farmers among all the possible alternatives.

Table IV-1 Calculation of Irrigable Areas by Drought Discharges in 1980

Month	Day	Unit Water Req. (P)	Unit Water Req. (H)	(Exist. Nyamindi Headworks) (A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
JAN	1 - 10	0.40	1.22	1.82	1.57	1.14	0.00	1.36	1,180	570	1,750
	11 - 20	0.12	1.32	1.46	1.16	0.89	0.00	1.25	1,180	570	1,750
	21 - 31	2.00	1.33	1.62	1.29	0.79	0.07	1.53	1,180	570	1,750
FEB	1 - 10	0.00	1.39	3.26	1.94	0.79	0.00	1.15	1,180	570	1,750
	11 - 20	0.22	1.23	1.66	1.34	0.85	0.00	1.45	1,180	570	1,750
	21 - 29	0.65	0.84	1.99	1.47	1.22	0.00	0.45	1,180	570	1,750
MAR	1 - 10	0.90	0.39	3.27	2.85	1.23	0.00	1.62	1,180	570	1,750
	11 - 20	1.42	0.56	2.63	2.21	1.91	0.00	0.40	1,180	570	1,750
	21 - 31	1.44	0.71	1.23	1.91	2.67	0.11	0.00	1,180	410	1,590
APR	1 - 10	1.31	0.47	3.30	2.94	1.51	0.00	1.49	1,180	570	1,750
	11 - 20	0.81	0.62	5.21	4.85	1.26	0.00	3.63	1,180	570	1,750
	21 - 30	0.94	0.82	6.52	6.20	1.53	0.00	4.67	1,180	570	1,750
MAY	1 - 10	0.01	1.45	15.87	15.55	1.27	0.00	14.28	1,180	570	1,750
	11 - 20	0.46	0.71	13.95	13.43	1.08	0.00	12.35	1,180	570	1,750
	21 - 31	0.57	0.48	7.14	6.84	0.91	0.00	5.93	1,180	570	1,750
JUN	1 - 10	0.61	0.64	5.39	5.07	1.05	0.00	4.02	1,180	570	1,750
	11 - 20	0.45	0.72	4.03	3.71	0.91	0.00	2.80	1,180	570	1,750
	21 - 30	0.36	0.78	3.31	2.99	0.76	0.00	2.23	1,180	570	1,750
JUL	1 - 10	0.09	0.79	3.03	2.71	0.55	0.00	2.16	1,180	570	1,750
	11 - 20	0.15	0.81	2.99	2.67	0.63	0.00	2.04	1,180	570	1,750
	21 - 31	0.46	0.82	2.84	2.52	0.98	0.00	1.54	1,180	570	1,750
AUG	1 - 10	0.70	0.64	3.07	2.75	1.13	0.00	1.55	1,180	570	1,750
	11 - 20	0.99	0.64	10.27	9.95	1.47	0.00	8.48	1,180	570	1,750
	21 - 31	1.24	0.57	5.16	4.84	1.71	0.00	3.13	1,180	570	1,750
SEP	1 - 10	1.72	0.56	3.61	3.29	2.21	0.00	1.08	1,180	570	1,750
	11 - 20	1.74	0.55	3.54	3.22	2.26	0.00	0.96	1,180	570	1,750
	21 - 30	1.58	0.88	4.43	4.11	2.27	0.00	1.84	1,180	570	1,750
OCT	1 - 10	1.34	1.05	9.08	8.76	2.30	0.00	6.46	1,180	570	1,750
	11 - 20	1.27	1.13	3.93	3.61	2.07	0.00	1.54	1,180	570	1,750
	21 - 31	0.49	0.76	6.28	5.96	0.98	0.00	4.98	1,180	570	1,750
NOV	1 - 10	0.00	0.64	7.62	7.30	0.36	0.00	6.94	1,180	570	1,750
	11 - 20	0.52	0.56	10.27	9.95	0.90	0.00	9.05	1,180	570	1,750
	21 - 30	0.49	0.53	9.35	9.03	0.65	0.00	8.38	1,180	570	1,750
DEC	1 - 10	0.85	0.50	5.74	5.42	1.24	0.00	4.18	1,180	570	1,750
	11 - 20	0.79	0.81	5.02	4.70	1.35	0.00	3.35	1,180	570	1,750
	21 - 31	0.57	0.92	4.27	3.95	1.14	0.00	2.81	1,180	570	1,750
	TOTAL	25.45	27.85	191.04	179.52	44.38	0.11	135.26	-	-	-

Month	Day	(Exist. Thiba Headworks) (A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
JAN	1 - 10	4.96	4.64	1.97	0.00	2.67	4,680	230	4,910
	11 - 20	4.44	3.54	0.85	0.00	2.69	4,680	230	4,910
	21 - 31	4.75	3.89	0.31	0.00	3.56	4,680	230	4,910
FEB	1 - 10	4.57	3.67	0.32	0.00	3.35	4,680	230	4,910
	11 - 20	3.60	2.78	1.19	0.00	3.59	4,680	230	4,910
	21 - 29	4.24	3.34	2.95	0.00	0.39	4,680	230	4,910
MAR	1 - 10	1.72	4.82	3.91	0.00	0.91	4,680	230	4,910
	11 - 20	3.56	4.46	4.15	1.45	0.00	3,720	0	3,720
	21 - 31	5.35	4.45	6.27	1.82	0.00	3,530	0	3,530
APR	1 - 10	5.52	4.64	4.44	0.00	0.16	4,680	230	4,910
	11 - 20	5.75	4.85	3.56	0.00	1.27	4,680	230	4,910
	21 - 30	7.10	6.29	4.25	0.00	2.04	4,680	230	4,910
MAY	1 - 10	7.17	6.27	0.11	0.00	6.12	4,680	230	4,910
	11 - 20	12.84	11.94	2.71	0.00	9.23	4,680	230	4,910
	21 - 31	11.53	10.63	2.53	0.00	8.10	4,680	230	4,910
JUN	1 - 10	5.16	4.26	1.73	0.00	5.53	4,680	230	4,910
	11 - 20	7.94	7.04	2.07	0.00	4.97	4,680	230	4,910
	21 - 30	6.98	6.08	1.37	0.00	4.71	4,680	230	4,910
JUL	1 - 10	4.83	3.93	0.56	0.00	3.37	4,680	230	4,910
	11 - 20	6.18	5.28	0.82	0.00	4.46	4,680	230	4,910
	21 - 31	5.85	4.95	2.14	0.00	2.81	4,680	230	4,910
AUG	1 - 10	7.12	6.22	3.12	0.00	3.10	4,680	230	4,910
	11 - 20	7.77	6.87	1.34	0.00	2.53	4,680	230	4,910
	21 - 31	7.64	6.74	5.39	0.00	1.35	4,680	230	4,910
SEP	1 - 10	7.03	6.13	7.41	1.28	0.00	4,000	0	4,000
	11 - 20	6.37	5.47	7.50	2.03	0.00	3,580	0	3,580
	21 - 30	5.59	4.69	6.90	2.21	0.00	3,400	0	3,400
OCT	1 - 10	4.84	3.94	5.92	1.98	0.00	3,380	0	3,380
	11 - 20	4.94	4.04	5.44	1.40	0.00	3,620	0	3,620
	21 - 31	6.62	5.72	2.25	0.00	3.47	4,680	230	4,910
NOV	1 - 10	9.07	8.17	0.15	0.00	8.02	4,680	230	4,910
	11 - 20	12.15	11.25	2.33	0.00	8.92	4,680	230	4,910
	21 - 30	12.63	11.73	2.20	0.00	9.53	4,680	230	4,910
DEC	1 - 10	9.02	8.12	3.72	0.00	4.40	4,680	230	4,910
	11 - 20	7.90	7.00	3.54	0.00	3.46	4,680	230	4,910
	21 - 31	8.02	7.12	2.63	0.00	4.49	4,680	230	4,910
	TOTAL	252.89	226.49	114.31	11.47	118.60	-	-	-

Month	Day	(New Rwamuthambi Headworks) (A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	Σ (F)	Σ (G)	Σ (H)
JAN	1 - 10	1.76	1.48	1.51	0.03	1.06	2,470	400	2,870	8,330	[illegible]	[illegible]
	11 - 20	1.32	1.64	0.88	0.06	0.16	2,470	430	2,900	8,330	1,230	9,560
	21 - 31	1.52	1.24	0.57	0.00	0.67	2,470	430	2,900	8,330	1,230	9,560
FEB	1 - 10	1.40	1.12	0.60	0.00	0.52	2,470	430	2,900	8,330	1,230	9,560
	11 - 20	1.11	0.83	1.03	0.20	0.00	2,470	280	2,750	8,330	1,080	9,410
	21 - 29	1.00	0.72	1.98	1.26	0.00	1,130	0	1,130	6,990	800	7,790
MAR	1 - 10	0.97	0.69	2.39	1.70	0.00	760	0	760	6,620	800	7,420
	11 - 20	0.88	0.60	3.75	3.14	0.00	420	0	420	5,320	570	5,890
	21 - 31	0.86	0.58	3.86	3.28	0.00	400	0	400	5,110	410	5,520
APR	1 - 10	1.15	0.87	2.78	1.91	0.00	860	0	860	6,720	800	7,520
	11 - 20	1.36	1.08	2.27	1.19	0.00	1,130	0	1,130	6,990	800	7,790
	21 - 30	2.14	1.86	2.72	0.85	0.00	1,930	0	1,930	7,790	800	8,590
MAY	1 - 10	2.95	2.67	0.22	0.00	2.45	2,470	430	2,900	8,330	1,230	9,560
	11 - 20	2.73	2.45	1.79	0.00	0.66	2,470	430	2,900	8,330	1,230	9,560
	21 - 31	2.95	2.67	2.61	0.00	0.06	2,470	430	2,900	8,330	1,230	9,560
JUN	1 - 10	1.53	1.25	1.78	0.53	0.00	2,040	0	2,040	7,900	800	8,700
	11 - 20	1.25	0.97	1.42	0.45	0.00	2,150	0	2,150	8,010	800	8,810
	21 - 30	1.14	0.86	1.03	0.17	0.00	2,470	210	2,680	8,330	1,010	9,340
JUL	1 - 10	1.35	1.07	0.56	0.00	0.51	2,470	430	2,900	8,330	1,230	9,560
	11 - 20	1.22	0.94	0.72	0.00	0.22	2,470	430	2,900	8,330	1,230	9,560
	21 - 31	1.14	0.86	1.49	0.63	0.00	1,860	0	1,860	7,720	800	8,520
AUG	1 - 10	1.68	1.40	3.00	1.61	0.00	1,600	0	1,600	7,460	800	8,260
	11 - 20	2.35	2.07	2.72	0.65	0.00	2,290	0	2,290	8,150	800	8,950
	21 - 31	1.84	1.56	3.31	1.75	0.00	1,250	0	1,250	7,110	800	7,910
SEP	1 - 10	1.55	1.27	4.46	3.19	0.00	730	0	730	5,910	570	6,480
	11 - 20	1.20	0.92	4.53	3.61	0.00	520	0	520	5,280	570	5,850
	21 - 30	1.27	0.99	4.28	3.29	0.00	620	0	620	5,200	570	5,770
OCT	1 - 10	1.12	0.84	3.76	2.92	0.00	620	0	620	5,180	570	5,750
	11 - 20	1.01	0.73	3.63	2.90	0.00	570	0	570	5,370	570	5,940
	21 - 31	2.33	2.04	1.54	0.00	0.50	2,470	430	2,900	8,330	1,230	9,560
NOV	1 - 10	3.22	2.94	0.28	0.00	2.66	2,470	430	2,900	8,330	1,230	9,560
	11 - 20	4.98	4.70	1.53	0.00	3.17	2,470	430	2,900	8,330	1,230	9,560
	21 - 30	3.03	2.75	1.64	0.00	1.11	2,470	430	2,900	8,330	1,230	9,560
DEC	1 - 10	2.57	2.29	2.31	0.03	0.00	2,470	370	2,840	8,330	1,170	9,500
	11 - 20	2.61	2.33	2.30	0.00	0.03	2,470	430	2,900	8,330	1,230	9,560
	21 - 31	2.24	1.96	1.90	0.04	0.00	2,470	380	2,850	8,330	1,180	9,510
	TOTAL	43.70	33.62	74.84	34.25	13.93	-	-	-	-	-	-

Remarks

1. Unit: (P), (H) = (l/sec/ha),
   (A), (B), (C), (D), (E) = (m^3/sec),
   (F), (G), (H) = (ha).

2. (P)=Rice,
   (H)=Horticultural Crops,
   (A)=Drought Discharge at the Headworks,
   (B)=Available Drought Discharge at the Headworks = (A)-Total Water Rights-Maintenance Flow,
   (C)=Diversion Requirement of The Potential Maximum Area,
   (D)=Deficit of Irrigation Water=(C)-(B)>0,
   (E)=Surplus of Available Drought Discharge=(B)-(C)>0,
   (F)=Irrigable Area of Rice Including Re-use Area,
   (G)=Irrigable Area of Horticultural Crops,
   (H)=Total Irrigable Area =(F) + (G).

3. Figures through (A) to (E) are rounded off to two decimal places.

   Figures of (F) and (G) are omitted below the first digit.

Table IV-2 Water Balance Calculation (1/3)

(Total Diversion Requirement for Water Balance Calculation (Alternative: T-1)

MONTH	DAY	(UNIT IRRI.REQ) (A)	(B)	(MIS(NYAMINDI)) (A)	(B)	Subtotal	(MIS(THIBA)) (A)	(B)	Subtotal	(MUTITHI) (A)	(B)	Subtotal	Total
				1,180-60 =1,120ha	570ha		4,680-440 =4,240ha	230ha		2,470ha	430ha		
JAN	1 - 10	0.40	1.21	0.45	0.69	1.14	1.70	0.28	1.97	0.99	0.52	1.51	4.62
	11 - 20	0.13	1.30	0.15	0.74	0.89	0.55	0.30	0.85	0.32	0.56	0.88	2.62
	21 - 31	0.00	1.33	0.00	0.76	0.76	0.00	0.31	0.31	0.00	0.57	0.57	1.64
FEB	1 - 10	0.00	1.39	0.00	0.79	0.79	0.00	0.32	0.32	0.00	0.60	0.60	1.71
	11 - 20	0.22	1.13	0.25	0.64	0.89	0.93	0.26	1.19	0.54	0.49	1.03	3.11
	21 - 29	0.65	0.86	0.73	0.49	1.22	2.76	0.20	2.95	1.61	0.37	1.98	6.15
MAR	1 - 10	0.90	0.39	1.01	0.22	1.23	3.82	0.09	3.91	2.22	0.17	2.39	7.53
	11 - 20	1.42	0.56	1.59	0.32	1.91	6.02	0.13	6.15	3.51	0.24	3.75	11.81
	21 - 31	1.44	0.71	1.61	0.40	2.02	6.11	0.16	6.27	3.56	0.31	3.86	12.15
APR	1 - 10	1.01	0.67	1.13	0.38	1.51	4.28	0.15	4.44	2.49	0.29	2.78	8.73
	11 - 20	0.81	0.62	0.91	0.35	1.26	3.43	0.14	3.58	2.00	0.27	2.27	7.10
	21 - 30	0.96	0.80	1.08	0.46	1.53	4.07	0.18	4.25	2.37	0.24	2.72	8.50
MAY	1 - 10	0.01	0.45	0.01	0.26	0.27	0.04	0.10	0.15	0.02	0.19	0.22	0.63
	11 - 20	0.60	0.71	0.67	0.40	1.08	2.54	0.16	2.71	1.48	0.31	1.79	5.57
	21 - 31	0.57	0.48	0.64	0.27	0.91	2.42	0.11	2.53	1.41	0.21	1.61	5.05
JUN	1 - 10	0.61	0.64	0.68	0.36	1.05	2.59	0.15	2.73	1.51	0.28	1.78	5.56
	11 - 20	0.45	0.72	0.50	0.41	0.91	1.91	0.17	2.07	1.11	0.31	1.42	4.41
	21 - 30	0.28	0.78	0.31	0.44	0.76	1.19	0.18	1.37	0.69	0.34	1.03	3.15
JUL	1 - 10	0.09	0.79	0.10	0.45	0.55	0.38	0.18	0.56	0.22	0.34	0.56	1.68
	11 - 20	0.15	0.81	0.17	0.46	0.63	0.64	0.19	0.82	0.37	0.35	0.72	2.17
	21 - 31	0.46	0.82	0.52	0.47	0.98	1.95	0.19	2.14	1.14	0.35	1.49	4.61
AUG	1 - 10	0.70	0.64	0.78	0.36	1.15	2.97	0.15	3.12	1.73	0.28	2.00	6.27
	11 - 20	0.99	0.64	1.11	0.36	1.47	4.20	0.15	4.34	2.45	0.28	2.72	8.54
	21 - 31	1.24	0.57	1.39	0.32	1.71	5.26	0.13	5.39	3.06	0.25	3.31	10.41
SEP	1 - 10	1.72	0.50	1.93	0.29	2.21	7.29	0.12	7.41	4.25	0.22	4.46	14.08
	11 - 20	1.74	0.55	1.95	0.31	2.26	7.38	0.13	7.50	4.30	0.24	4.53	14.30
	21 - 30	1.58	0.88	1.77	0.50	2.27	6.70	0.20	6.90	3.90	0.39	4.29	13.45
OCT	1 - 10	1.34	1.05	1.50	0.60	2.10	5.68	0.24	5.92	3.31	0.45	3.76	11.78
	11 - 20	1.27	1.13	1.42	0.64	2.07	5.38	0.26	5.64	3.14	0.49	3.62	11.33
	21 - 31	0.49	0.76	0.55	0.43	0.98	2.08	0.17	2.25	1.21	0.33	1.54	4.77
NOV	1 - 10	0.00	0.64	0.00	0.36	0.36	0.00	0.15	0.15	0.00	0.28	0.28	0.79
	11 - 20	0.52	0.56	0.58	0.32	0.90	2.20	0.13	2.33	1.28	0.24	1.52	4.76
	21 - 30	0.49	0.53	0.55	0.30	0.85	2.08	0.12	2.20	1.21	0.23	1.44	4.49
DEC	1 - 10	0.85	0.50	0.95	0.29	1.24	3.60	0.12	3.72	2.10	0.22	2.31	7.27
	11 - 20	0.79	0.81	0.88	0.46	1.35	3.35	0.19	3.54	1.95	0.35	2.30	7.19
	21 - 31	0.57	0.92	0.64	0.52	1.16	2.42	0.21	2.63	1.41	0.39	1.80	5.59
	TOTAL	25.45	27.85	28.50	15.87	44.38	107.91	6.41	114.32	62.86	11.98	74.84	233.53

REMARKS

1. UNIT: UNIT IRRI. REQ. (l/sec/ha)
   OTHERS (m³/sec)

2. (A)=Rice
   (B)=Horticultural Crops

3. Above figures are rounded off to two decimal places.

Table IV-2 Water Balance Calculation (2/3)

(Water Balance Calculation of Headworks (Alternative: T-1)

(UNIT: m³/sec)

MONTH	DAY	(NYAMINDI HEADWORKS) (A)	(B)	(C)	(D)	(E)	(THIBA HEADWORKS) (A)	(B)	(C)	(D)	(E)	(RUAMUTHAMBI HEADWORKS) (A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
JAN	1 - 10	2.81	2.49	1.14	0.00	1.35	4.96	4.06	1.97	0.00	2.09	1.76	1.48	1.51	0.03	0.00	0.03	3.44	0.00	2.09
	11 - 20	2.45	2.13	0.89	0.00	1.24	4.44	3.54	0.85	0.00	2.69	1.32	1.04	0.88	0.00	0.16	0.00	4.09	0.00	2.69
	21 - 31	2.60	2.28	0.76	0.00	1.52	4.75	3.85	0.31	0.00	3.54	1.52	1.24	0.57	0.00	0.67	0.00	5.74	0.00	3.54
FEB	1 - 10	3.24	2.92	0.79	0.00	2.13	4.57	3.67	0.32	0.00	3.35	1.40	1.12	0.60	0.00	0.52	0.00	6.00	0.00	3.35
	11 - 20	2.65	2.33	0.89	0.00	1.44	3.68	2.78	1.19	0.00	1.59	1.11	0.83	1.03	0.20	0.00	0.20	3.03	0.00	1.59
	21 - 29	1.98	1.66	1.22	0.00	0.44	4.24	3.34	2.95	0.00	0.39	1.00	0.72	1.98	1.26	0.00	1.26	0.83	0.43	0.00
MAR	1 - 10	3.15	2.83	1.23	0.00	1.60	5.72	4.82	3.91	0.00	0.91	0.97	0.69	2.39	1.70	0.00	1.70	2.51	0.00	0.82
	11 - 20	2.62	2.30	1.91	0.00	0.39	5.56	4.66	6.15	1.49	0.00	0.88	0.60	3.75	3.14	0.00	4.63	0.39	4.24	0.00
	21 - 31	2.22	1.90	2.02	0.12	0.00	5.35	4.45	6.27	1.82	0.00	0.86	0.58	3.86	3.28	0.00	5.10	0.00	5.10	0.00
APR	1 - 10	3.28	2.96	1.51	0.00	1.45	5.52	4.62	4.44	0.00	0.18	1.15	0.87	2.78	1.92	0.00	1.92	1.63	0.28	0.00
	11 - 20	5.18	4.86	1.26	0.00	3.60	5.75	4.85	3.58	0.00	1.27	1.36	1.08	2.27	1.19	0.00	1.19	4.87	0.00	1.27
	21 - 30	8.48	8.16	1.53	0.00	6.63	7.19	6.29	4.25	0.00	2.04	2.14	1.86	2.72	0.85	0.00	0.85	8.66	0.00	2.04
MAY	1 - 30	15.79	15.47	0.27	0.00	15.20	7.17	6.27	0.15	0.00	6.12	2.95	2.67	0.22	0.00	2.46	0.00	23.78	0.00	6.12
	11 - 20	13.88	13.56	1.08	0.00	12.48	12.84	11.94	2.71	0.00	9.23	2.73	2.45	1.79	0.00	0.66	0.00	22.38	0.00	9.23
	21 - 31	7.12	6.80	0.91	0.00	5.89	11.53	10.63	2.53	0.00	8.10	1.95	1.67	1.61	0.00	0.06	0.00	14.05	0.00	8.10
JUN	1 - 10	5.36	5.04	1.05	0.00	3.99	9.16	8.26	2.73	0.00	5.53	1.53	1.25	1.78	0.53	0.00	0.53	9.52	0.00	5.53
	11 - 20	4.01	3.69	0.91	0.00	2.78	7.94	7.04	2.07	0.00	4.97	1.25	0.97	1.42	0.45	0.00	0.45	7.74	0.00	4.97
	21 - 30	3.29	2.97	0.76	0.00	2.21	6.98	6.08	1.37	0.00	4.71	1.14	0.86	1.03	0.17	0.00	0.17	6.93	0.00	4.71
JUL	1 - 10	3.01	2.69	0.55	0.00	2.14	6.83	5.93	0.56	0.00	5.37	1.35	1.07	0.56	0.00	0.51	0.00	8.01	0.00	5.37
	11 - 20	2.97	2.65	0.63	0.00	2.02	6.18	5.28	0.82	0.00	4.46	1.22	0.94	0.72	0.00	0.22	0.00	6.70	0.00	4.46
	21 - 31	2.83	2.51	0.98	0.00	1.53	5.85	4.95	2.14	0.00	2.81	1.14	0.86	1.49	0.63	0.00	0.63	4.34	0.00	2.81
AUG	1 - 10	3.00	2.68	1.15	0.00	1.53	7.12	6.22	3.12	0.00	3.10	1.68	1.40	2.00	0.61	0.00	0.61	4.64	0.00	3.10
	11 - 20	10.22	9.90	1.47	0.00	8.43	7.77	6.87	4.34	0.00	2.53	2.55	2.27	2.72	0.45	0.00	0.45	10.95	0.00	2.53
	21 - 31	5.15	4.83	1.71	0.00	3.12	7.64	6.74	5.39	0.00	1.35	1.84	1.56	3.31	1.75	0.00	1.75	4.47	0.00	1.35
SEP	1 - 10	3.59	3.27	2.21	0.00	1.06	7.03	6.13	7.41	1.28	0.00	1.55	1.27	4.46	3.19	0.00	4.47	1.06	3.41	0.00
	11 - 20	3.52	3.20	2.26	0.00	0.94	6.37	5.47	7.50	2.03	0.00	1.20	0.92	4.53	3.62	0.00	5.65	0.94	4.71	0.00
	21 - 30	4.41	4.09	2.27	0.00	1.82	5.59	4.69	6.90	2.21	0.00	1.27	0.99	4.28	3.29	0.00	5.50	1.82	3.68	0.00
OCT	1 - 10	9.03	8.71	2.10	0.00	6.61	4.64	3.94	5.92	1.98	0.00	1.12	0.84	3.76	2.92	0.00	4.91	6.61	0.00	0.00
	11 - 20	3.91	3.59	2.07	0.00	1.52	4.94	4.04	5.64	1.60	0.00	1.01	0.73	3.62	2.90	0.00	4.50	1.52	2.98	0.00
	21 - 31	6.25	5.93	0.98	0.00	4.95	6.62	5.72	2.25	0.00	3.47	2.32	2.04	1.54	0.00	0.50	0.00	8.91	0.00	3.47
NOV	1 - 10	7.58	7.26	0.36	0.00	6.90	9.07	8.17	0.15	0.00	8.02	3.22	2.94	0.28	0.00	2.66	0.00	17.58	0.00	8.02
	11 - 20	10.22	9.90	0.90	0.00	9.00	12.15	11.25	2.33	0.00	8.92	4.98	4.70	1.53	0.00	3.17	0.00	21.09	0.00	8.92
	21 - 30	9.30	8.98	0.85	0.00	8.13	12.61	11.71	2.20	0.00	9.51	3.03	2.75	1.44	0.00	1.31	0.00	18.95	0.00	9.51
DEC	1 - 10	5.71	5.39	1.24	0.00	4.15	9.02	8.12	3.72	0.00	4.40	2.57	2.29	2.31	0.03	0.00	0.03	8.55	0.00	4.40
	11 - 20	4.99	4.67	1.35	0.00	3.32	7.90	7.00	3.54	0.00	3.46	2.61	2.33	2.30	0.00	0.03	0.00	6.82	0.00	3.46
	21 - 31	4.25	3.93	1.16	0.00	2.77	8.01	7.11	2.63	0.00	4.48	2.04	1.76	1.80	0.04	0.00	0.04	7.25	0.00	4.48
	TOTAL	190.05	178.53	44.38	0.12	134.27	252.89	220.49	114.31	12.42	118.60	63.70	53.62	74.84	34.15	12.93	46.57	265.79	24.84	117.93

REMARKS

1. (A)=Drought Discharge at the Headworks.
   (B)=Available Drought Discharge at the Headworks = (A) - Total Water Rights - Maintenance Flow.
   (C)=Diversion Requirement to the Headworks,
   (D)=Deficit of Irrigation water = (C)-(B)>0.
   (E)=Surplus of Available Drought Discharge = (B)-(C)>0.
   (F)=Total Deficit of THIBA and RUAMUTHAMBI Headworks = THIBA H.(C)+RUAMUTHAMBI H.(C),
   (G)=Total Surplus of Three Headworks = Σ(E),
   (H)=Irrigation Water Requirement to THIBA Dam = (F)-(G)>0.
   (I)=Room for Available Discharge at THIBA Headworks = THIBA H. (E)-(J)>0.
   where, (J)= Supply Water from Surplus of THIBA Headworks = (F)-(K)>0.
   where, (K)=Total Surplus of NYAMINDI and RUAMUTHAMBI Headworks = NYAMINDI H. (E) + RUAMUTHAMBI H.(E).
2. Above figures are rounded off to two decimal places.

Table IV-2 Water Balance Calculation (3/3)

(Water Balance Calculation for Estimation of Storage Capacity
(Alternative: T-1)

MONTH	DAY	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
JAN	1 - 10	1.89	1.41	0.00	2.09	0.00	0	1.41	1.89
	11 - 20	1.63	1.15	0.00	2.69	0.00	0	1.15	1.63
	21 - 31	1.78	1.30	0.00	3.54	0.00	0	1.30	1.78
FEB	1 - 10	1.70	1.22	0.00	3.35	0.00	0	1.22	1.70
	11 - 20	1.26	0.78	0.00	1.59	0.00	0	0.78	1.26
	21 - 29	1.54	0.00	0.43	0.00	0.00	-336,077	0.00	1.97
MAR	1 - 10	2.26	1.78	0.00	0.82	0.39	0	0.43	1.87
	11 - 20	2.18	0.00	4.24	0.00	0.00	-3,666,809	0.00	6.42
	21 - 31	2.08	0.00	5.10	0.00	0.00	-8,511,654	0.00	7.18
APR	1 - 10	2.16	0.00	0.28	0.00	0.00	-8,758,082	0.00	2.45
	11 - 20	2.27	1.79	0.00	1.27	1.27	-7,658,210	0.00	1.00
	21 - 30	2.98	2.50	0.00	2.04	2.04	-5,899,452	0.00	0.94
MAY	1 - 10	2.97	2.49	0.00	6.12	2.49	-3,749,917	0.00	0.48
	11 - 20	5.74	5.26	0.00	9.23	4.34	0	0.92	1.40
	21 - 31	5.10	4.62	0.00	8.10	0.00	0	4.62	5.10
JUN	1 - 10	3.94	3.46	0.00	5.53	0.00	0	3.46	3.94
	11 - 20	3.34	2.86	0.00	4.97	0.00	0	2.86	3.34
	21 - 30	2.87	2.39	0.00	4.71	0.00	0	2.39	2.87
JUL	1 - 10	2.80	2.32	0.00	5.37	0.00	0	2.32	2.80
	11 - 20	2.48	2.00	0.00	4.46	0.00	0	2.00	2.48
	21 - 31	2.32	1.84	0.00	2.81	0.00	0	1.84	2.32
AUG	1 - 10	2.94	2.46	0.00	3.10	0.00	0	2.46	2.94
	11 - 20	3.26	2.78	0.00	2.53	0.00	0	2.53	3.26
	21 - 31	3.20	2.72	0.00	1.35	0.00	0	1.35	3.20
SEP	1 - 10	2.90	0.00	3.41	0.00	0.00	-2,945,395	0.00	6.31
	11 - 20	2.58	0.00	4.71	0.00	0.00	-7,017,007	0.00	7.29
	21 - 30	2.20	0.00	3.68	0.00	0.00	-10,200,450	0.00	5.88
OCT	1 - 10	1.83	0.00	0.00	0.00	0.00	-10,200,450	0.00	1.83
	11 - 20	1.88	0.00	2.98	0.00	0.00	-12,774,080	0.00	4.86
	21 - 31	2.70	2.22	0.00	3.47	2.22	-10,665,180	0.00	0.48
NOV	1 - 10	3.90	3.42	0.00	8.02	3.42	-7,712,981	0.00	0.48
	11 - 20	5.40	4.92	0.00	8.92	4.92	-3,459,624	0.00	0.48
	21 - 30	5.63	5.15	0.00	9.51	4.00	0	1.14	1.62
DEC	1 - 10	3.87	3.39	0.00	4.40	0.00	0	3.39	3.87
	11 - 20	3.32	2.84	0.00	3.46	0.00	0	2.84	3.32
	21 - 31	3.38	2.90	0.00	4.48	0.00	0	2.90	3.38
	TOTAL	104.29	71.97	24.84	117.93	25.09	MAX.-12,774,080	43.31	104.02

REQUIRED
NET STORAGE CAPACITY

REMARKS

1. UNIT: (F) (m^3)
   Others (m^3/sec)

2. (A)=Drought Discharge at THIBA Dam Site,
   (B)=Available Drought Discharge at THIBA Dam Site =(A)-Total Water Rights-Maintenance Flow,
   (C)=Irrigation Water Requirement to THIBA Dam,
   (D)=Room for Available Discharge at THIBA Headworks,
   (E)=Actual Impounding Discharge of THIBA Dam = MIN((B), (D), (V)),
   where, (V)=Previous |(F)| ÷ 86,400 (sec) ÷ Number of days,
   (F)=Required Net Storage Capacity of THIBA Dam = Previous (F)-((C)-(E)) x 86,400(sec) x Number of Days,
   (G)=Invalid Water of Possible Impounding Discharge at THIBA Dam = MIN((B), (D)) -(E),
   (H)=THIBA River Discharge Just under the THIBA Dam = (A)-(E), when (C) = 0,
   (A)+(C), when (C) >0.

3. Above figures without (F) are rounded off to two decimal places.

Table IV-3 Summary of Each Development Alternative

WORK		ITEM	DESCRIPTION	UNIT	T - 1	T - 2	T - 3	T - 4	N - 1	N - 2
CONSTRUCTION	Dam works	Thiba Dam	Storage capacity	m^3	17,000,000	18,000,000	18,000,000	18,000,000	-	-
			Dam height	m	34.5	35.0	35.0	35.0	-	-
			Embankment volume	m^3	1.287,000	1,350,000	1,350,000	1.350.000	-	-
		Nyamindi Dam	Storage capacity	m^3	-	-	-	-	10,000,000	10,000,000
			Dam height	m	-	-	-	-	35.0	35.0
			Embankment volume	m^3	-	-	-	-	1,567,000	1,567,000
	Headworks	New Nyamindi Headworks	Intake discharge	m^3/s	7.01	-	6.86	-	6.48	6.24
			Concrete volume	m^3	1,940	-	1,940	-	1,940	1,940
		Ex. Nyamindi Headworks	Intake discharge	m^3/s	-	-	-	-	-	-
			Concrete volume	m^3	-	30	-	30	-	-
		Ex Thiba Headworks	Intake discharge	m^3/s	11.12	9.43	11.49	9.20	10.15	9.91
			Concrete volume		120	120	120	120	120	120
		Ruamthambi Headworks	Intake discharge	m^3/s	2.30	1.64	-	-	2.05	-
			Concrete volume	m^3	950	950	-	-	950	-
	Link Canals	Nyamindi Headrace	Design discharge	m^3/s	7.01	-	6.86	-	6.48	6.24
			Length of canal	m	640	-	640	-	6.40	6.40
		Nyamindi New Main Canal	Design discharge	m^3/s	2.28	-	2.24	-	1.96	1.96
			Length of canal	m	600	-	600	-	600	600
		Link Canal I	Design discharge	m^3/s	4.91	-	5.01	-	4.53	4.37
			Length of Canal	m	8,000	-	8,000	-	8.000	8.000
		Link Canal II	Design discharge	m^3/s	11.12	9.43	11.49	9.20	10.15	9.91
			Length of canal	m	3,500	3,500	3,500	3,500	3,500	3,500
		Link Canal III	Design discharge	m^3/s	3.62	2.07	4.19	1.82	2.79	2.55
			Length of canal	m	2.400	2.400	2.400	2.400	2.400	2.400
		Ruamthambi Headrace	Design discharge	m^3/s	2.30	1.64	-	-	2.05	-
			Length of canal	m	6.300	6.300	-	-	6.300	-
		Improvement of Ex. M.I.S.	Paddy field	ha	5,860	5,860	5.860	5.860	5.860	5,860
			Upland field	ha	800	570	450	570	-	-
		Reclamation of Mutithi Area	Paddy field	ha	2.470	1,660	2.410	1.060	2,070	1,460
			Upland field	ha	430	-	-	-	-	-
FARM INVESTMENT		Agricultural Machinery	Nos. of Machinery	Nos.	241	234	241	195	228	208
		O/M Equipment	Heavy equipment	Nos.	39	39	39	39	39	39
			Light equipment	Nos.	69	61	69	61	69	61
			Telecommunication system	Nos.	12	9	12	9	12	9
			Dam Management equipment	L.S.	1	1	1	1	1	1
		Farm building		m^2	64,800	53,300	61,900	47,300	56,000	49,200

Table IV-4 Summary of the Project Cost for Each Alternative

(Unit: MKShs.)

Description	T-1	T-2	T-3	T-4	N-1	N-2
1. Construction cost	682.6	571.5	649.7	525.2	693.0	644.5
Dam Works	306.1	315.4	315.4	315.4	387.5	387.5
Head works	10.8	3.8	7.7	0.7	10.8	7.7
Link canals	71.5	22.4	58.4	10.0	64.2	51.0
Improvement of M.I.S.	147.7	138.6	133.8	138.6	116.1	116.1
Development of Mutithi Area	146.5	91.3	134.4	60.5	114.4	82.2
2. Initial Farm Investiment	264.4	236.7	258.7	221.6	248.9	230.0
Agricultural Machinery	138.9	122.1	137.6	109.7	130.6	117.9
O/M Equipment	101.0	97.5	101.0	97.5	101.0	97.5
Farm building	24.5	17.1	20.1	14.4	17.3	14.6
3. Administration cost	28.4	24.2	27.3	22.4	28.3	26.2
4. Engineering cost	104.2	88.9	99.9	82.1	103.6	96.2
Sub Total	1,079.6	921.3	1,035.6	851.3	1,073.8	996.9
5. Physical Contingency	108.0	92.1	103.6	85.1	107.4	99.7
Total	1,187.6	1,013.4	1.139.2	936.4	1,181.2	1,096.6
6. Price Contingency	415.7	354.7	398.7	327.7	413.4	383.8
Grand Total	1,603.3	1,368.1	1,537.9	1,264.1	1,594.6	1,480.4

Table IV-5 Irrigation Benefit Estimates (1/2)

Alternative Plan: T-1

Crops	Cultivated Area (ha)	Unit Yield (ton/ha)	Total Production (ton)	Unit Price (Kshs./ton)	Gross Production Value (Kshs.)	Unit Production Cost (Kshs./ha)	Total Production Cost (MKshs.)	Net Production Value (MKshs.)
Without Project								
I. MIS								
1. Rice								
Short Rains Rice	5,860	3.5	20,510	3,600	73.8	4,623	27.1	46.7
2. Horticultural Crops								
Maize	600	1.3	780	2,900	2.3	2,776	1.7	0.6
Beans	200	6.0	1,200	3,200	3.8	3,531	0.7	3.1
II. Mutithi								
1. Horticultural Crops								
Maize	430	1.3	559	2,900	1.6	2,776	1.2	0.4
Total	-	-	-	-	81.5	-	30.7	50.8
With Project								
I. MIS								
1. Rice								
Long Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
Short Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
2. Horticultural Crops								
French Beans	800	10.0	8,000	3,200	25.6	8,144	6.5	19.1
Onion	400	10.0	4,000	3,900	15.6	13,464	5.4	10.2
Tomatoes	400	15.0	6,000	3,200	19.2	13,377	5.4	13.8
II. Mutithi								
1. Rice								
Long Rains Rice	2,470	6.0	14,820	3,600	53.4	5,598	13.8	39.6
Short Rains Rice	2,470	6.0	14,820	3,600	53.4	5,598	13.8	39.6
2. Horticultural Crops								
French Beans	430	10.0	4,300	3,200	13.8	8,144	3.5	10.3
Onion	215	10.0	2,150	3,900	8.4	13,464	2.9	5.5
Tomatoes	215	15.0	3,225	3,200	10.3	13,377	2.9	7.4
Total	-	-	-	-	452.9	-	119.8	333.1
III. Incremental Benefit	-	-	-	-	-	-	-	
(With Project - Without Project)								282.3

Alternative Plan: T-2

Crops	Cultivated Area (ha)	Unit Yield (ton/ha)	Total Production (ton)	Unit Price (Kshs./ton)	Gross Production Value (Kshs.)	Unit Production Cost (Kshs./ha)	Total Production Cost (MKshs.)	Net Production Value (MKshs.)
Without Project								
I. MIS								
1. Rice								
Short Rains Rice	5,860	3.5	20,510	3,600	73.8	4,623	27.1	46.7
2. Horticultural Crops								
Maize	430	1.3	559	2,900	1.6	2,776	1.2	0.4
Beans	140	6.0	840	3,200	2.7	3,531	0.5	2.2
II. Mutithi								
1. Horticultural Crops								
Maize	-	1.3	-	2,900	-	2,776	-	-
Total	-	-	-	-	78.1	-	28.8	49.3
With Project								
I. MIS								
1. Rice								
Long Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
Short Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
2. Horticultural Crops								
French Beans	570	10.0	5,700	3,200	18.2	8,144	4.6	13.6
Onion	285	10.0	2,850	3,900	11.1	13,464	3.8	7.3
Tomatoes	285	15.0	4,275	3,200	13.7	13,377	3.8	9.9
II. Mutithi								
1. Rice								
Long Rains Rice	1,660	6.0	9,960	3,600	35.9	5,598	9.3	26.6
Short Rains Rice	1,660	6.0	9,960	3,600	35.9	5,598	9.3	26.6
2. Horticultural Crops								
French Beans	-	10.0	-	3,200	-	8,144	-	-
Onion	-	10.0	-	3,900	-	13,464	-	-
Tomatoes	-	15.0	-	3,200	-	13,377	-	-
Total	-	-	-	-	368.0	-	96.4	271.6
III. Incremental Benefit								
(With Project - Without Project)								222.3

Alternative Plan: T-3

Crops	Cultivated Area (ha)	Unit Yield (ton/ha)	Total Production (ton)	Unit Price (Kshs./ton)	Gross Production Value (Kshs.)	Unit Production Cost (Kshs./ha)	Total Production Cost (MKshs.)	Net Production Value (MKshs.)
Without Project								
I. MIS								
1. Rice								
Short Rains Rice	5,860	3.5	20,510	3,600	73.8	4,623	27.1	46.7
2. Horticultural Crops								
Maize	340	1.3	442	2,900	1.3	2,776	0.9	0.4
Beans	110	6.0	660	3,200	2.1	3,531	0.4	1.7
II. Mutithi								
1. Horticultural Crops								
Maize	-	1.3	-	2,900	-	2,776	-	-
Total	-	-	-	-	77.2	-	28.4	48.8
With Project								
I. MIS								
1. Rice								
Long Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
Short Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
2. Horticultural Crops								
French Beans	450	10.0	4,500	3,200	14.4	8,144	3.7	10.7
Onion	225	10.0	2,250	3,900	8.8	13,464	3.0	5.8
Tomatoes	225	15.0	3,375	3,200	10.8	13,377	3.0	7.8
II. Mutithi								
1. Rice								
Long Rains Rice	2,410	6.0	14,460	3,600	52.1	5,598	13.5	38.6
Short Rains Rice	2,410	6.0	14,460	3,600	52.1	5,598	13.5	38.6
2. Horticultural Crops								
French Beans	-	10.0	-	3,200	-	8,144	-	-
Onion	-	10.0	-	3,900	-	13,464	-	-
Tomatoes	-	15.0	-	3,200	-	13,377	-	-
Total	-	-	-	-	391.4	-	102.3	289.1
III. Incremental Benefit								
(With Project - Without Project)								240.3

Table IV-5 Irrigation Benefit Estimates (2/2)

Alternative Plan: E-4

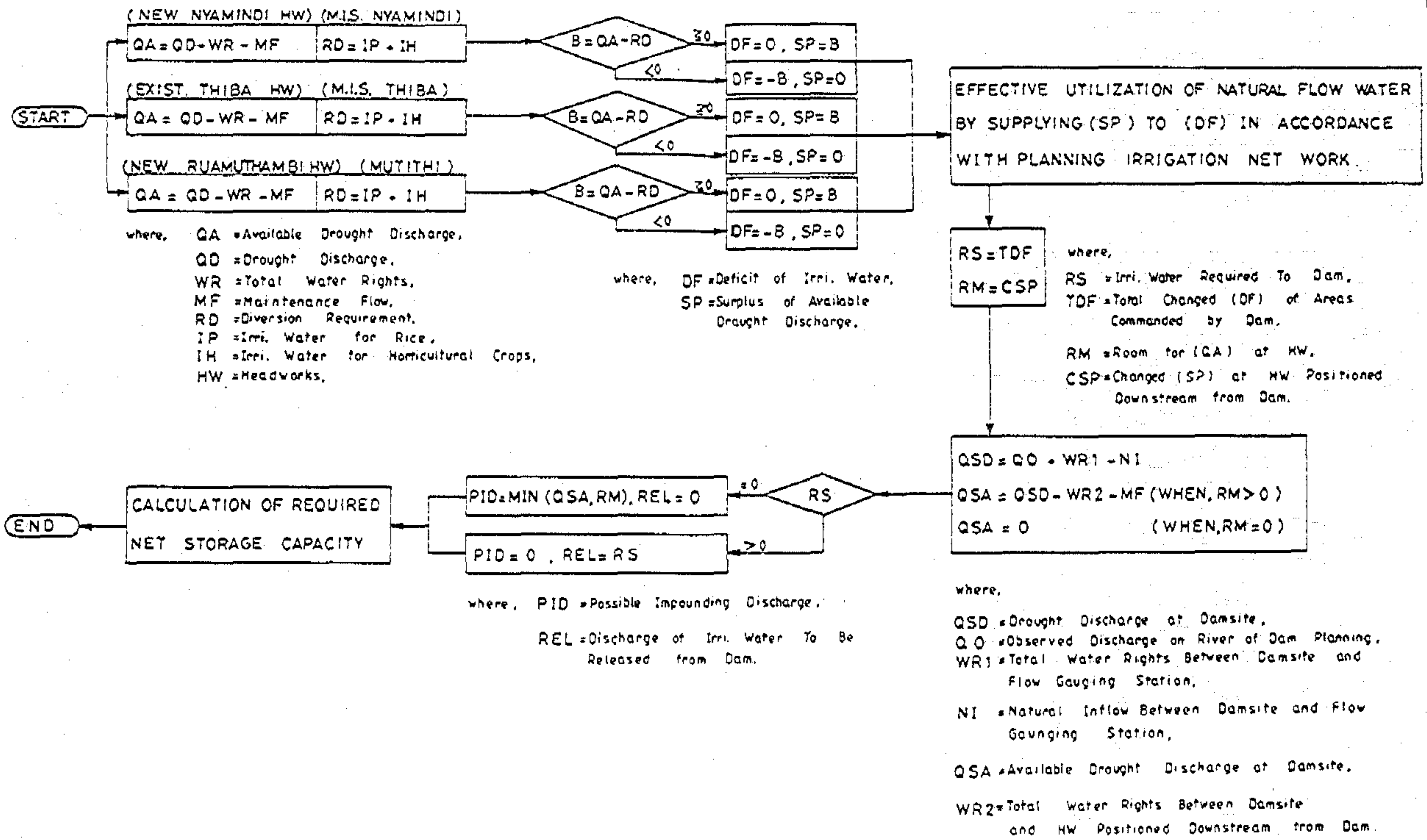
Crops	Cultivated Area (ha)	Unit Yield (ton/ha)	Total Production (ton)	Unit Price (Kshs./ton)	Gross Production Value (Kshs.)	Unit Production Cost (Kshs./ha)	Total Production Cost (MKshs.)	Net Production Value (MKshs.)
Without Project								
I. MIS								
1. Rice								
Short Rains Rice	5,860	3.5	20,510	3,600	73.8	4,623	27.1	46.7
2. Horticultural Crops								
Maize	430	1.3	559	2,900	1.6	2,776	1.2	0.4
Beans	140	6.0	840	3,200	2.7	3,531	0.5	2.2
II. Mutithi								
1. Horticultural Crops								
Maize	-	1.3	-	2,900	-	2,776	-	-
Total	-	-	-	-	78.1	-	28.8	49.3
With Project								
I. MIS								
1. Rice								
Long Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
Short Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
2. Horticultural Crops								
French Beans	570	10.0	5,700	3,200	18.2	8,144	4.6	13.6
Onion	285	10.0	2,850	3,900	11.1	13,464	3.8	7.3
Tomatoes	285	15.0	4,275	3,200	13.7	13,377	3.8	9.9
II. Mutithi								
1. Rice								
Long Rains Rice	1,060	6.0	6,360	3,600	22.9	5,598	5.9	17.0
Short Rains Rice	1,060	6.0	6,360	3,600	22.9	5,598	5.9	17.0
2. Horticultural Crops								
French Beans	-	10.0	-	3,200	-	8,144	-	-
Onion	-	10.0	-	3,900	-	13,464	-	-
Tomatoes	-	15.0	-	3,200	-	13,377	-	-
Total	-	-	-	-	342.0	-	89.6	252.4
III. Incremental Benefit (With Project - Without Project)								203.1

Alternative Plan: N-1

Crops	Cultivated Area (ha)	Unit Yield (ton/ha)	Total Production (ton)	Unit Price (Kshs./ton)	Gross Production Value (Kshs.)	Unit Production Cost (Kshs./ha)	Total Production Cost (MKshs.)	Net Production Value (MKshs.)
Without Project								
I. MIS								
1. Rice								
Short Rains Rice	5,860	3.5	20,510	3,600	73.8	4,623	27.1	46.7
2. Horticultural Crops								
Maize	-	1.3	-	2,900	-	2,776	-	-
Beans	-	8.0	-	3,200	-	3,531	-	-
II. Mutithi								
1. Horticultural Crops								
Maize	-	1.3	-	2,900	-	2,776	-	-
Total	-	-	-	-	73.8	-	27.1	46.7
With Project								
I. MIS								
1. Rice								
Long Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
Short Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
2. Horticultural Crops								
French Beans	-	10.0	-	3,200	-	8,144	-	-
Onion	-	10.0	-	3,900	-	13,464	-	-
Tomatoes	-	15.0	-	3,200	-	13,377	-	-
II. Mutithi								
1. Rice								
Long Rains Rice	2,070	6.0	12,420	3,600	44.7	5,598	11.6	33.1
Short Rains Rice	2,070	6.0	12,420	3,600	44.7	5,598	11.6	33.1
2. Horticultural Crops								
French Beans	-	10.0	-	3,200	-	8,144	-	-
Onion	-	10.0	-	3,900	-	13,464	-	-
Tomatoes	-	15.0	-	3,200	-	13,377	-	-
Total	-	-	-		342.6	-	88.6	253.8
III. Incremental Benefit (With Project - Without Project)								207.1

Alternative Plan: N-2

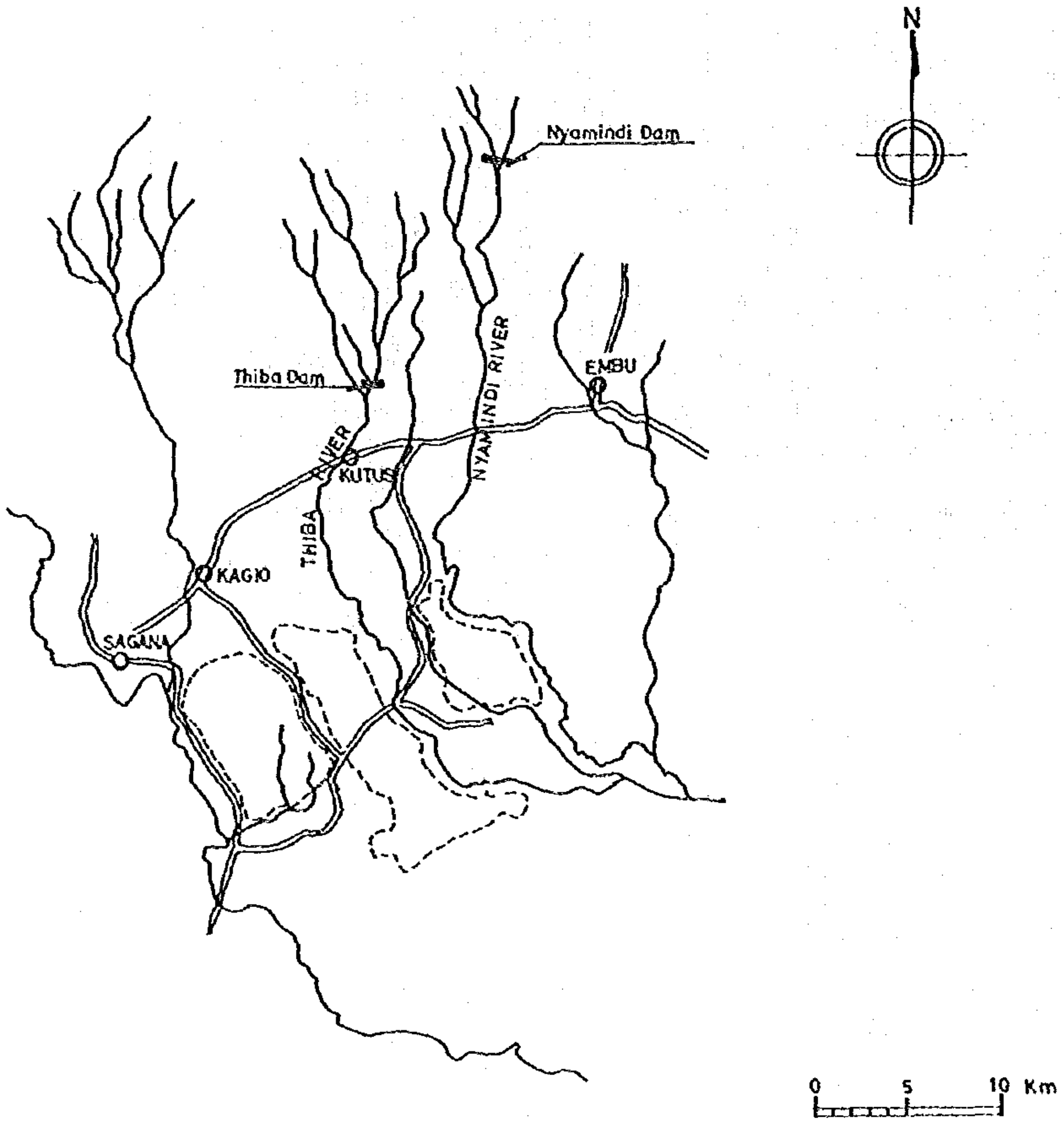
Crops	Cultivated Area (ha)	Unit Yield (ton/ha)	Total Production (ton)	Unit Price (Kshs./ton)	Gross Production Value (Kshs.)	Unit Production Cost (Kshs./ha)	Total Production Cost (MKshs.)	Net Production Value (MKshs.)
Without Project								
I. MIS								
1. Rice								
Short Rains Rice	5,860	3.5	20,510	3,600	73.8	4,623	27.1	46.7
2. Horticultural Crops								
Maize	-	1.3	-	2,900	-	2,776	-	-
Beans	-	8.0	-	3,200	-	3,531	-	-
II. Mutithi								
1. Horticultural Crops								
Maize	-	1.3	-	2,900	-	2,776	-	-
Total	-	-	-	-	73.8	-	27.1	46.7
With Project								
I. MIS								
1. Rice								
Long Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
Short Rains Rice	5,860	6.0	35,160	3,600	126.6	5,598	32.8	93.8
2. Horticultural Crops								
French Beans	-	10.0	-	3,200	-	8,144	-	-
Onion	-	10.0	-	3,900	-	13,464	-	-
Tomatoes	-	15.0	-	3,200	-	13,377	-	-
II. Mutithi								
1. Rice								
Long Rains Rice	1,460	6.0	8,760	3,600	31.5	5,598	8.2	23.3
Short Rains Rice	1,460	6.0	8,760	3,600	31.5	5,598	8.2	23.3
2. Horticultural Crops								
French Beans	-	10.0	-	3,200	-	8,144	-	-
Onion	-	10.0	-	3,900	-	13,464	-	-
Tomatoes	-	15.0	-	3,200	-	13,377	-	-
Total	-	-	-		316.2	-	82.0	234.2
III. Incremental Benefit (With Project - Without Project)								187.5



REMARKS

1. Water balance calculation for one year is completed through repeating the same flow in 36 times.
2. Unit : Required net storage capacity (m^3), others (m^3/sec).

Fig. IV - 1 WATER BALANCE CALCULATION FLOW CHART



Nyamindi Dam — NIANGENI SUBLOCATION,
NGARIANA DIVISION,
KIRINYAGA DISTRICT.

Thiba Dam — KIRITINI SUBLOCATION,
GICHUGU DIVISION,
KIRINYAGA DISTRICT.

Fig. IV - 2 LOCATION OF POSSIBLE DAMSITES

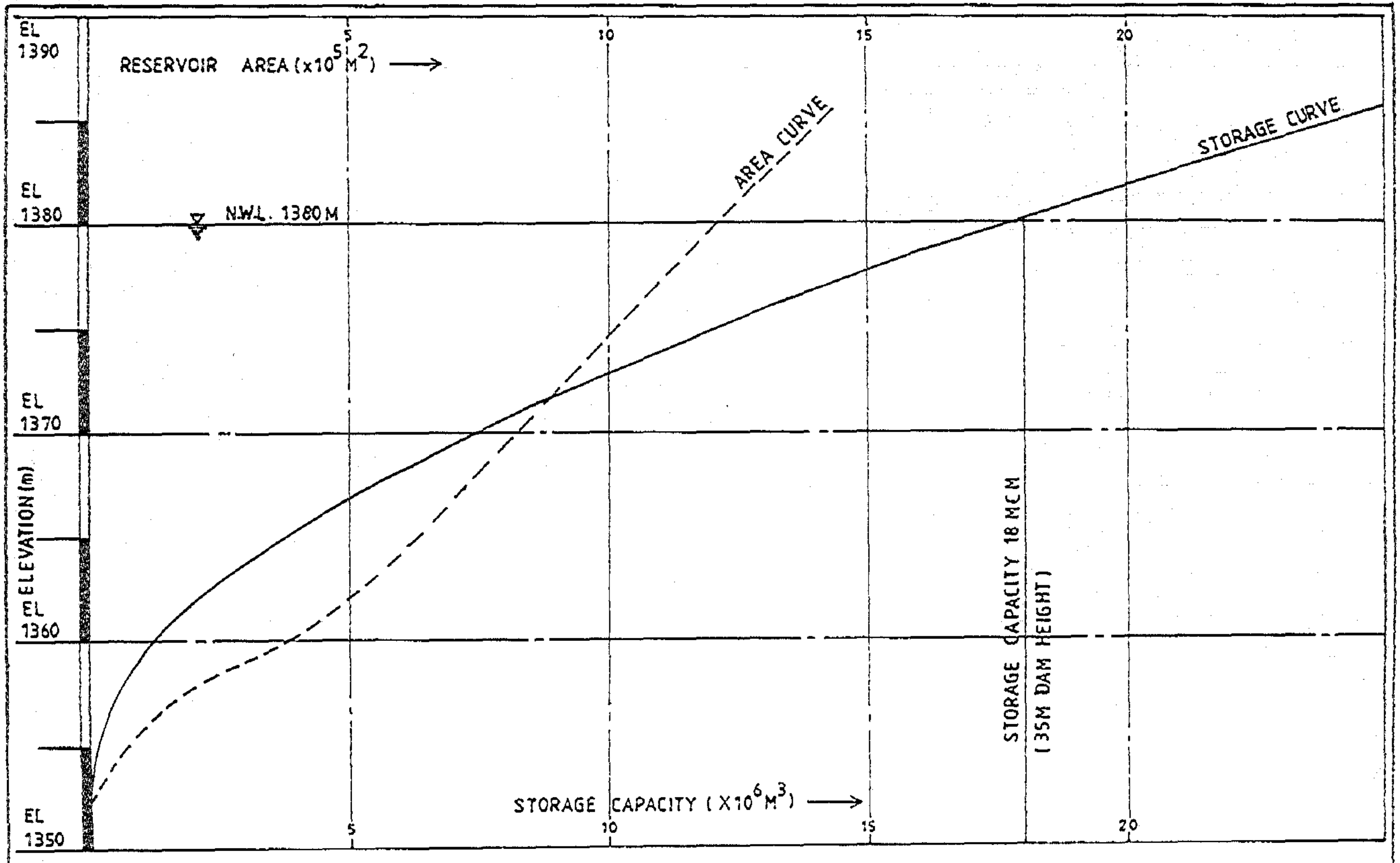


Fig. IV – 3 AREA–CAPACITY CURVE OF THIBA DAM

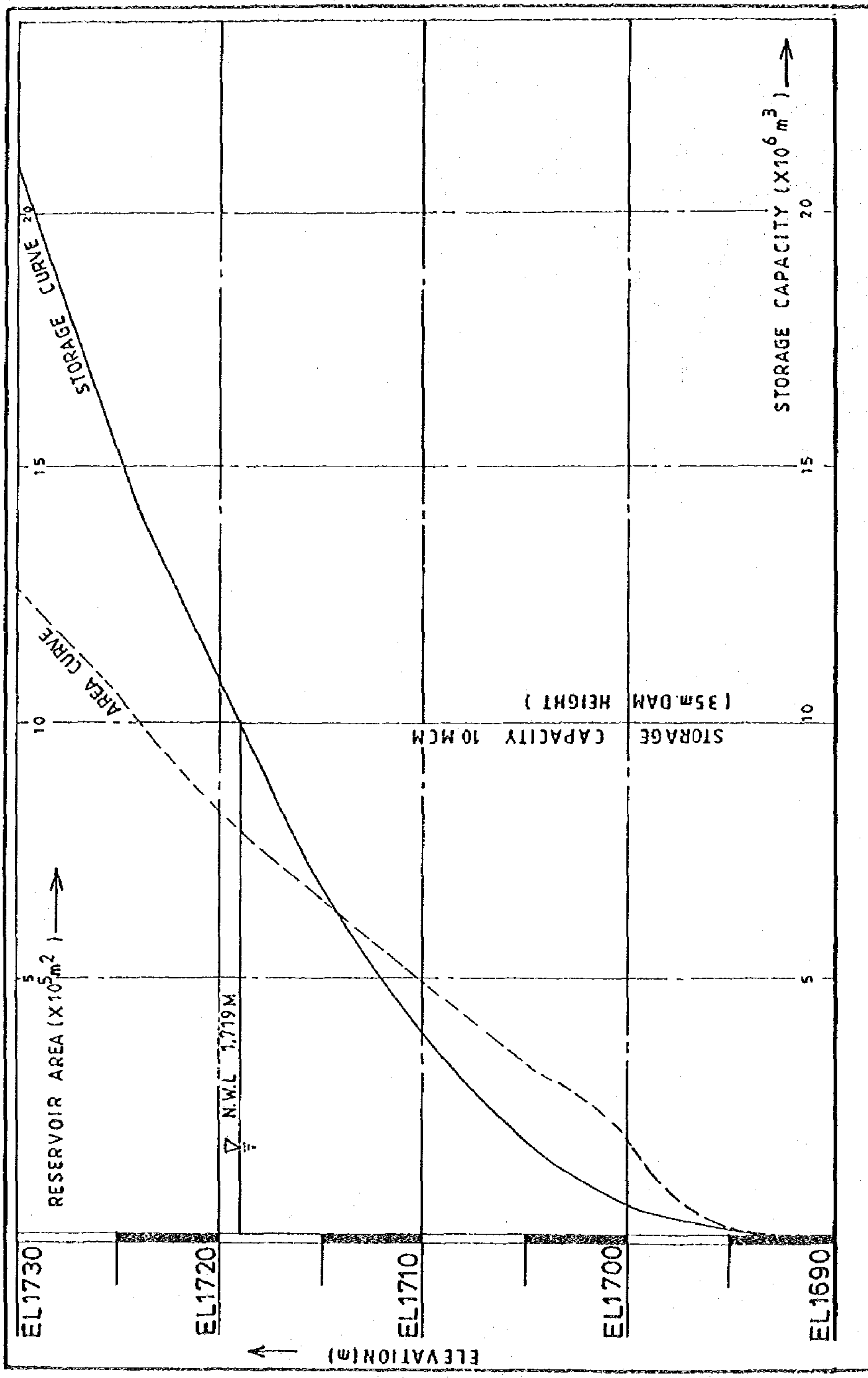
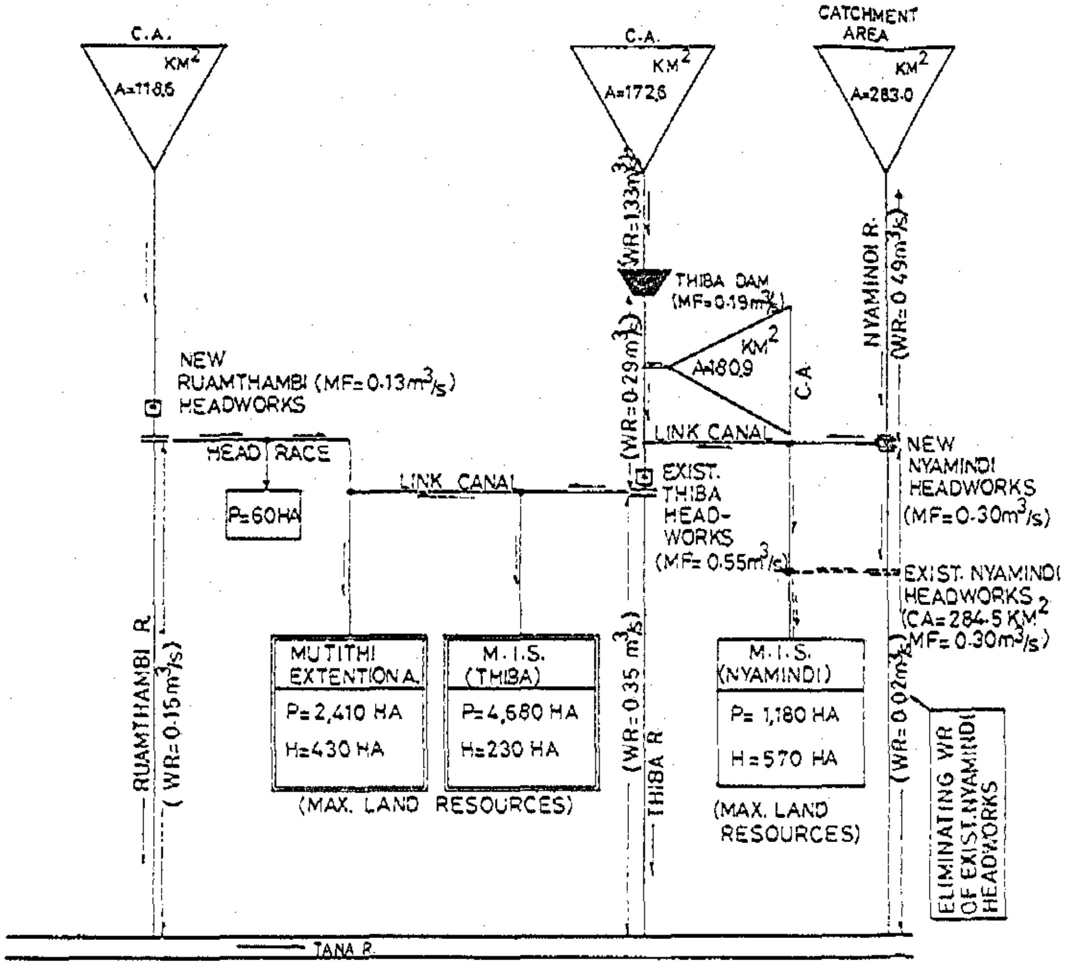


Fig: IV-4 AREA- CAPACITY CURVE OF NYAMINDI DAM



PLANNING IRRIGATION NETWORK
(ALTERNATIVE T-1, T-2, T-3, T-4)

COMBINATION OF WATER SUPPLY RIVER TO THE PROJECT AREA WITH THIBA DAM CONSTRUCTION

RIVER / ALTERNATIVE	NYAMINDI RIVER	THIBA RIVER	RUAMTHAMBI RIVER
T — 1	○	○	○
T — 2	○(*)	○	○
T — 3	○	○	×
T — 4	○(*)	○	×

SYMBOLS

○ : WITH WATER SUPPLY FROM THE RIVER,

× : WITHOUT WATER SUPPLY FROM THE RIVER,

(*) : IN ALTERNATIVE T-2 AND T-4, NYAMINDI RIVER DOES NOT SUPPLY IRRIGATION WATER TO THE EXISTING THIBA HEADWORKS.

REMARKS OF PLANNING IRRIGATION NETWORK

P : AREA OF RICE,

H : AREA OF HORTICULTURAL CROPS,

WR : TOTAL WATER RIGHTS,

MF : MAINTENANCE FLOW,

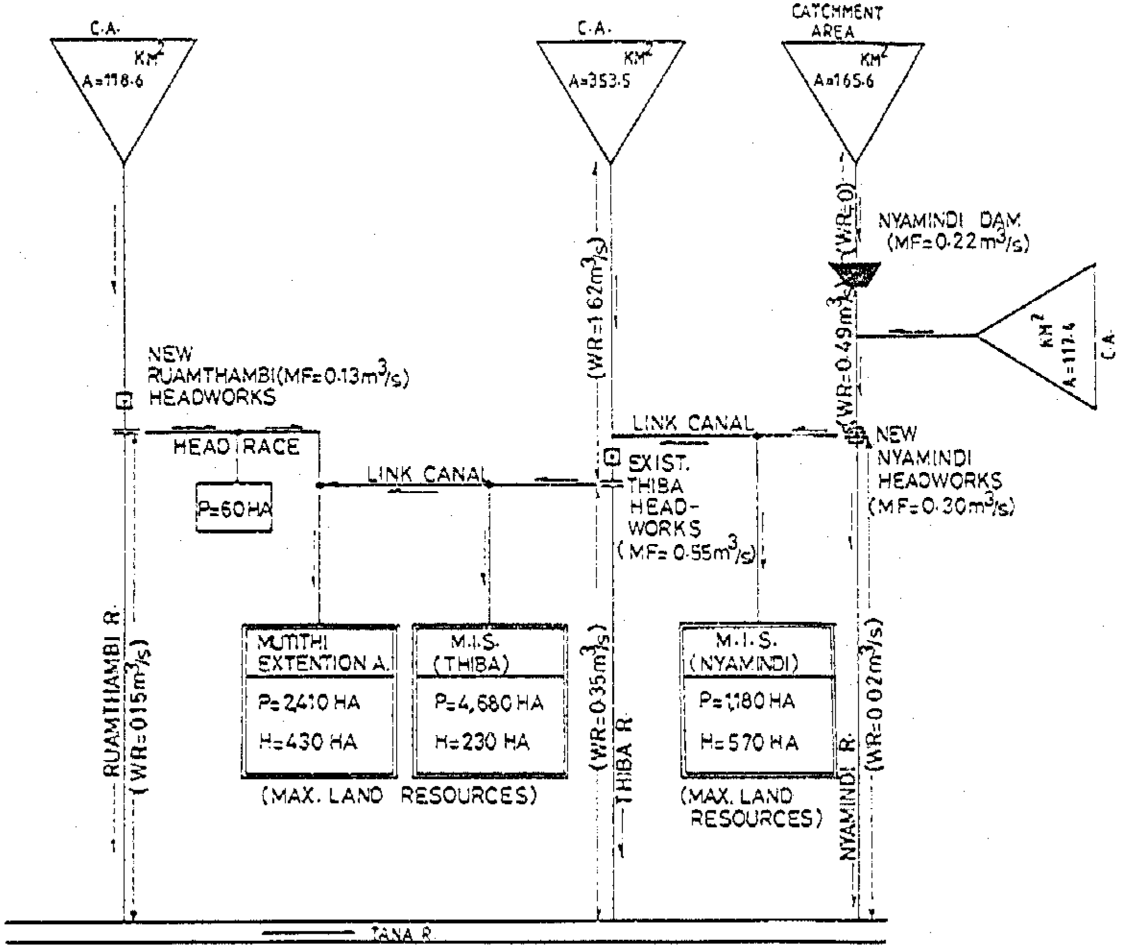
▭ : AREA COMMANDED BY THIBA DAM,

⊡ : FLOW GAUGING STATION,

AT NYAMINDI RIVER (CATCHMENT AREA = 283.0 Km^2),
AT THIBA RIVER (" " = 253.0 Km^2),
AT RUAMTHAMBI RIVER (" " = 116.8 Km^2),

- - - : PLANNING IRRIGATION NETWORK OF ALTERNATIVE T-2 AND T-4 CONCERNING NYAMINDI RIVER.

Fig. IV-5 PLANNING IRRIGATION NETWORK
(ALTERNATIVE T-1, T-2, T-3 AND T-4)



PLANNING IRRIGATION NETWORK
(ALTERNATIVE N-1, N-2)

COMBINATION OF WATER SUPPLY RIVER TO THE PROJECT AREA WITH NYAMINDI DAM CONSTRUCTION

RIVER / ALTERNATIVE	NYAMINDI RIVER	THIBA RIVER	RUAMTHAMBI RIVER
N - 1	○	○	○
N - 2	○	○	×

SYMBOLS

○ : WITH WATER SUPPLY FROM THE RIVER,

× : WITHOUT WATER SUPPLY FROM THE RIVER.

REMARKS OF PLANNING IRRIGATION NETWORK

P : AREA OF RICE,
H : AREA OF HORTICULTURAL CROPS,
W R : TOTAL WATER RIGHTS,
M F : MAINTENANCE FLOW,

▭ : AREA COMMANDED BY NYAMINDI DAM,

⊡ : FLOW GAUGING STATION,

AT NYAMINDI RIVER (CATCHMENT AREA = 263.0 Km²),
AT THIBA RIVER (" " = 353.0 Km²),
AT RUAMTHAMBI RIVER (" " = 116.8 Km²).

Fig. IV-6 PLANNING IRRIGATION NETWORK
(ALTERNATIVE N-1 AND N-2)

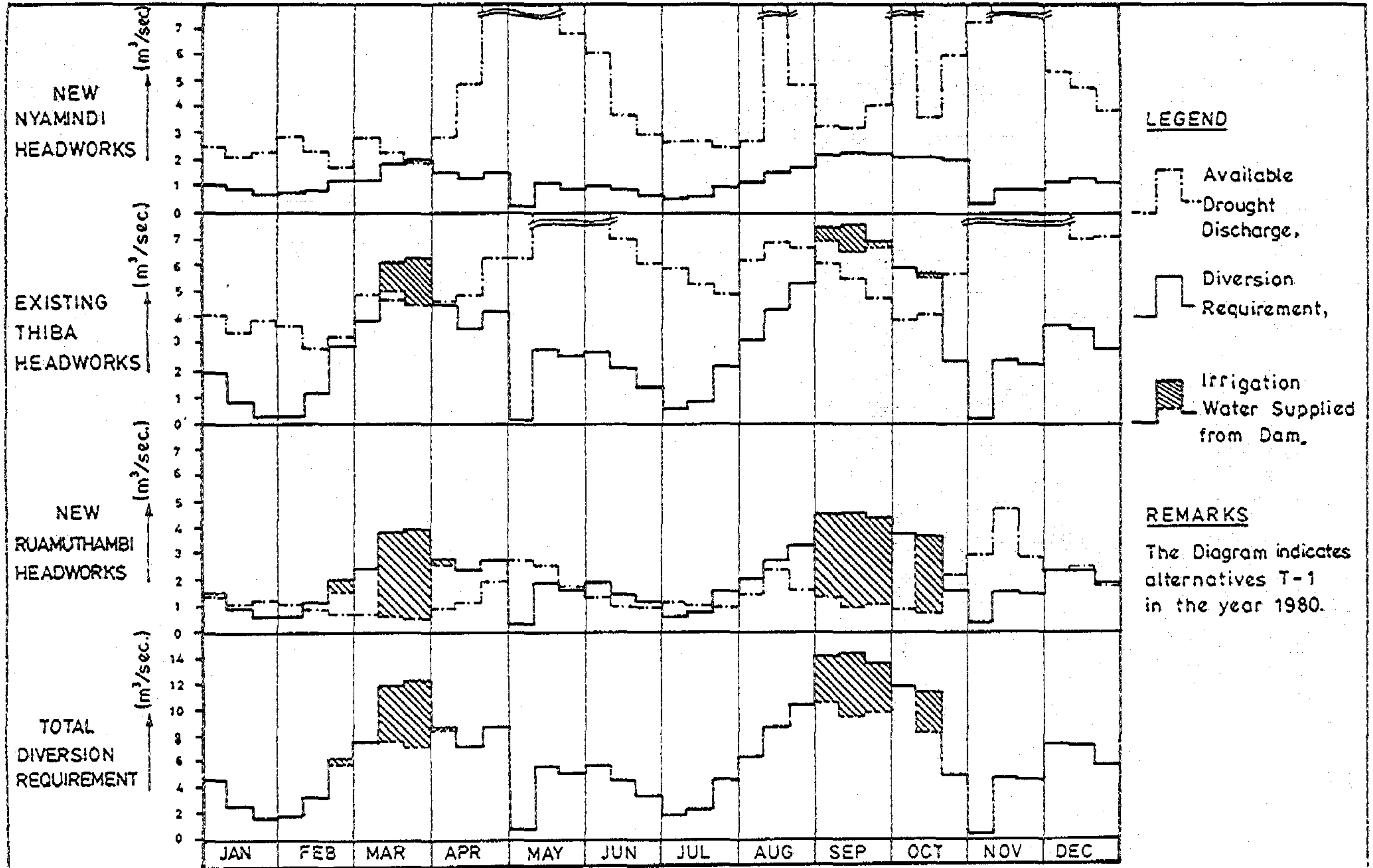


Fig. IV-7 HEADWORKS WATER BALANCE DIAGRAM

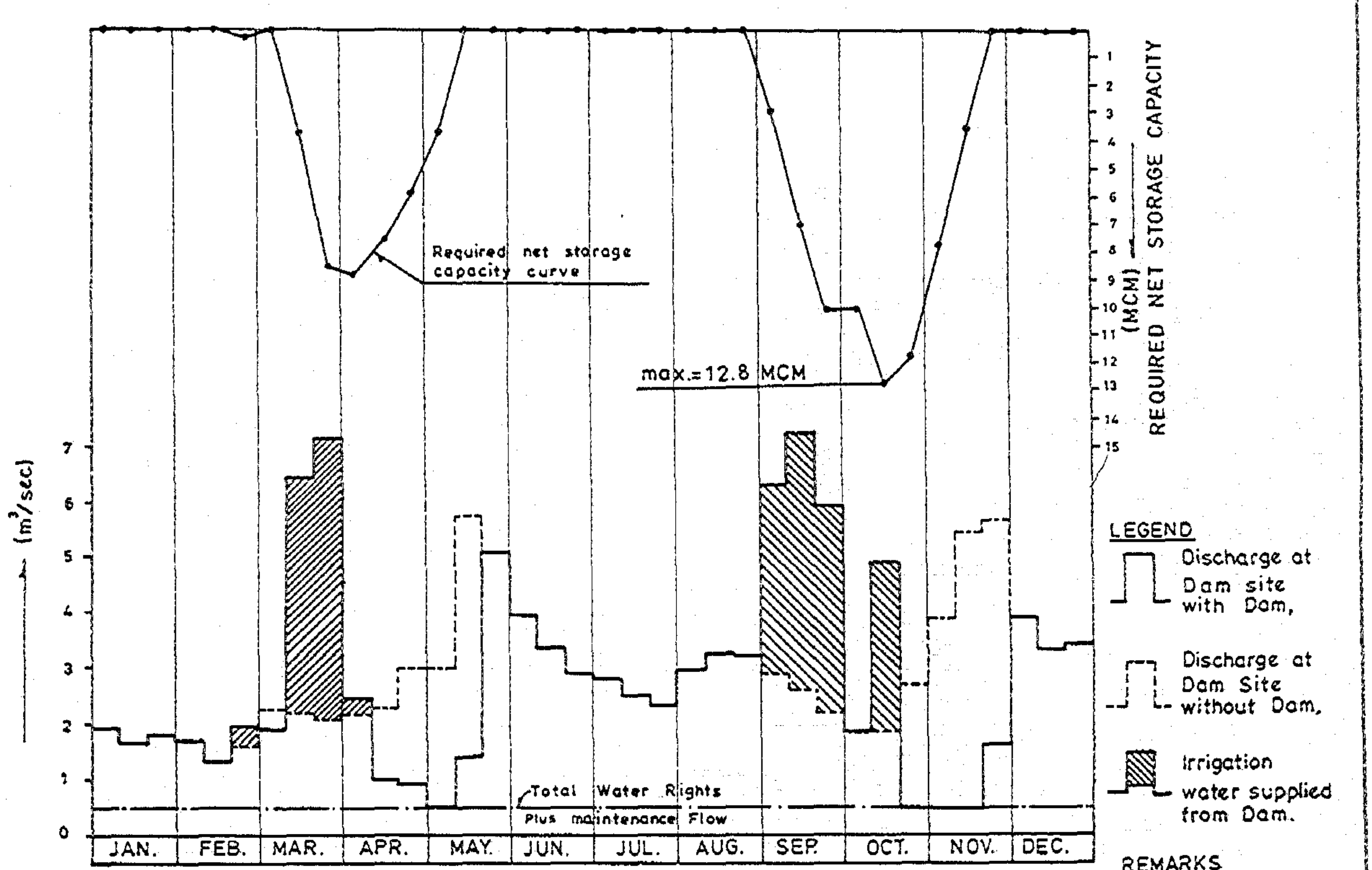


Fig. IV-8 THIBA DAM WATER BALANCE DIAGRAM

ANNEX - V

DAM AND RESERVOIR

ANNEX - V

DAM AND RESERVOIR

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

1. GENERAL CONDITION

The plan of the damsite is shown on Fig. V-1. The Thiba dam is a zoned fill dam with inclined impervious core. A impervious blanket for the river bed part and a grout curtain for the both abutments are designed to assure the water-tightness.

The dam has a crest length of about 1,350 m, width of 8 m and the maximum height of 35 m above the base of impervious core. Total volume of earth and rock materials in the embankment is about 1,200,000 m^3. The dam cross section is shown in Fig. V-2 and major dimensions of dam are summarized in Table V-1.

1.1 Location and Accessibility

The Thiba damsite is located on the Thiba river, about 4 km to the north of the Route B20/1, and in the Kiritini Sublocation, Gichugu Division, Kirinyaga District.

The damsite is easily accessible from the Route C198 or C199 that would not be widened, straightened and surfaced for use as an access road.

1.2 Investigations

1.2.1 Topography

A topographic map of 1:5,000 scale with 5-meter contour intervals covering Thiba damsite and reservoir area was completed in August 1987 under the contract with Surtech Ltd. This map is used in the design of the dam and the area-storage capacity curve for the proposed reservoir. An aerial topographic map of 1:50,000 with 50-feet contour intervals is used for general purposes.

1.2.2 Geology and soil mechanical investigation

Geological investigations of the Thiba damsite and the reservoir area were carried out to determine the soundness of the site and the water-tight qualities o45f the reservoir. Two holes, including permeability tests and standard penetration tests, were drilled to a total depth of 55 m.

One test pit of 1 x 1 m was excavated for a depth of 2.5 m in order to investigate the embankment materials and to obtain the samples for soil mechanical tests. Two auger borings were conducted around the prospective borrow area for a total depth of 5 m. All these geological investigations and soil mechanical laboratory tests were executed under the contract with Surtech Ltd.

1.2.3 Hydrology

The catchment area of the proposed Thiba damsite is 172.6 km^2. The annual inflow to the reservoir is about 92 MCM in the year 1980, 1/5 drought year. The total storage capacity of 18 MCM is required to irrigate 9,560 ha with a surplus storage capacity of 1 MCM. The reservoir capacity and the dam height are determined on the basis of the comparative study. The area-capacity curve of the reservoir is shown in Fig. V-3. The summary of reservoir hydrological data is as follows:

Total storage capacity	18 MCM
Effective storage capacity	15 MCM
Dead storage capacity (100 year)	2.6 MCM
Water level at total storage (N.W.L)	EL. 1,380.0 m
Water level at dead storage (D.W.L)	EL. 1,363.0 m
Flood water level (H.W.L)	EL. 1,382.5 m
Area at total storage	1.2 km^2

2. DAM TYPE AND DAM AXIS

2.1 Selection of Dam Type

It is quite evident that a concrete dam would not be economical on the geological conditions.

Completely weathered agglomerates with a thickness of about 4 m are observed in the damsite foundation, so impervious blanket is recommendable as the foundation treatment. In such case, the inclined impervious core type is advantageous on the smooth joint between blanket and core zone. In addition to the smoothness above mentioned, the inclined core can cope with the deformation caused by the settlement of foundation.

Available embankment materials near the Thiba damsite are red soils, highly weathered agglomerates, moderately weathered basalts and faint weathered basalts. The abundant materials are red soils and faint weathered basalts.

A fill dams are classified into homogeneous type, zoned type and facing type. The zoned fill dam is selected with the following reasons.

(1) In case of the homogeneous type dam, the shear strength of the embankment materials is low, so the gentle slopes are required. In addition to the large embankment volume, compaction control by moisture content is difficult in the weather conditions like Kenya.

(2) In general, facing type dam is adopted for lack of the impervious materials, and is not economical.

(3) There should be the possibility of the hydraulic fracturing caused by the arch action in the core zone, if rock materials are embanked in the transition zone between inclined core zone and downstream rock zone.

(4) In case of the zoned fill dam, the shear strength of the embankment materials is high. And execution management of the embankment is not difficult in the weather conditions like Kenya.

And to confirm the zoned fill type dam, the unit water cost comparisons between proposed zoned type and rockfill type are performed preliminarily to be shown in Fig. V-4. From the results of the comparisons, it is proved that proposed dam type is economical than rockfill type.

It is therefore concluded that zoned fill dam is suitable in all aspects such as materials availability, suitability for dam height and economic construction.

Dissolvable limestone groups or gypsum are not expected in the reservoir geology. In general, sufficient investigations are indispensable to be sure on the dam type.

2.2 Selection of Dam Axis

The study on available topographic map of 1:50,000 scale leads to the comparison study on the alternative dam axes. Three alternative dam axes are selected for comparison as shown in Fig. V-5. The selection of dam axis is carried out from the viewpoint of the potential storage capacity. The results are summarized below and dam center line No. 3 is selected.

Potential Storage Capacity

Dam Center Line	Storage Capacity
No. 1	8 MCM
No. 2	13 MCM
No. 3	18 MCM

3. POTENTIAL ECONOMIC MAXIMUM DAM HEIGHT

3.1 Potential Economic Maximum Dam Height

(1) Premises on analyses

The following premises are set out on the analyses from the damsite conditions:

a. Zoned fill type dam to be decided from materials availability and construction cost.

b. Blanket treatment to be required from foundation conditions.

c. Inclined core type to be selected from blanket treatment and response to deformation.

(2) The dam height will be determined through comprehensive studies on the following aspects, keeping the above in mind:

a. Geological conditions
b. Topographic conditions
c. Availability of materials

The general relationships between dam height and these conditions are illustrated as follows:

Item	Low	←	(Dam Height)	→	High
Geological conditions	Reduction	←	Necessary (Blanket) Extension	→	Enlargement
Topographic conditions	Rapid decrease in embankment	←	A Certain (Boundary of) Dam Height	→	Rapid increase in embankment
Availability of materials	Sharp	←	(Slope of Dam)	→	Gentle

The above diagram shows that the higher the dam height, the bigger the embankment volume.

(3) Maximum limits of dam height

The earth fill type dams in Japan, in the sense of the rock zone area in the ratio under 50% on the typical cross section, are studied in order to set the limits on the potential maximum dam height, and rough idea is given as follows:

Dam Type	Zoned Inclined Core	Zoned Center Core	Homogeneous
Limits of Potential Max.Dam Height	30 m	40 m	35 m

Considering the zoning of the dam and the seismic forces in Kenya, the limits of 30-40 m in height of the zoned fill type dam with inclined core should be acceptable.

(4) Potential economic maximum dam height

The unit water cost of dam is considered as a parameter to determine the potential economic maximum dam height. The dam height which gives the minimum value of the unit water cost should be the potential economic maximum dam height.

The unit water costs at the dam height of 30 m, 35 m and 40m are calculated as shown in Fig. V-4. From the results above mentioned, dam height of 35 m is decided as the potential economic maximum dam height of both Thiba and Nyamindi dam.

3.2 Potential Maximum Reservoir Capacity

Potential maximum reservoir capacity which corresponds to the potential economic maximum dam height is as follows:

Item	Thiba Dam	Nyamindi Dam
Maximum dam height	35 m	35 m
Maximum reservoir capacity	18 MCM	10 MCM

Area - capacity curve of the Thiba dam is shown in Fig. V-3.

4. DESIGN OF DAM

4.1 Basic Design Conditions

4.1.1 Seismic force

Seismic force is one of the major components in the design of large dam. Data on the total numbers of earthquakes is Kenya and the seismic zoning map showing maximum observed intensities are available for the period from 1892 to 1969. These data are cited from "A CATALOGUE OF FELT EARTHQUAKES IN KENYA 1892-1969", by I.S. LOUPEKINE.

The most of epicenters in Kenya are located along the Rift Valley. Total numbers of earthquakes in Kenya for the period 1892-1969 are summarized below:

Period	Maximum Observed Intensities (M.M. Scale)							
	IX	VIII	VII	VI	V	IV	III-II	Total
1892-1927	0	0	1	8	14	24+	4+	51+
1928-1953	1	0	1	8	67	259	10+	346+
1954-1969	0	0	1	12	47	99	11+	170+
(1892-1969)	1	0	3	28	128	382+	25+	567+

(1) Maximum observed intensities

Seismic zoning map showing maximum observed intensities is shown in Fig. V-6. The maximum observed intensities at the Thiba damsite is VII from the map above mentioned. All intensities in this study refer to the Modified Mercalli Scale of 1931 (Wood and Neumann, 1931), supplemented by Richter's version (1956).

(2) Seismic force coefficient

The acceleration in correspondence to the Modified Mercalli Scale studied by the U.S.C.G.S. (1948) are as follows:

(Unit: gal)

M.M. Scale	II	III	IV	V	VI	VII	VIII	IX
Acceleration Range	1-5	1-8	2-46	2-75	5-175	18-140	51-350	250
Mean Max. Acceleration	2.3	3.1	9.3	13.3	40	67	172	250

The seismic acceleration force at the damsite will be 18 to 140 gal with the mean maximum acceleration of 67 gal according to the maximum observed intensities of VII. The seismic coefficient Kh is then derived at 0.02 (18 gal/980) to 0.14 (140 gal/980). Taking safety factor at 2 for the mean maximum acceleration, Kh will be 0.14 (2 x 67 gal/980). The design value for Kh is then determined at 0.14.

4.1.2 Dam dimension

(1) Storage capacity

(a) Dead storage capacity

Dead storage capacity is considered for the future accumulation of the sedimentation. The volume of the sedimentation is given as follows:

VS = A x q x L

where,
- VS : Volume of the sedimentation
- A : Catchment area = 172.6 km^2
- q : Sediment load (m^3/km^2/year)
- L : Design life = 100 year

Dead storage capacity is designed at 2.6 MCM taking sediment load of 150 m^3/km^2/year. For estimation of the sediment load, the Fig. V-7 is adopted.

(b) Effective storage capacity

Effective storage capacity is defined that the required net storage capacity plus losses which comprise the following items:

i) Evaporation from the reservoir surface

ii) Seepage (0.05% of the storage volume per day)

iii) Losses from dam to headworks in the river, including intake losses at the headworks (5% of the required net storage capacity)

The study of evaporation and seepage losses results in that their volume is equivalent to about 5% of the net storage capacity, using evaporation data at Embu meteorological station in the year 1980. Effective storage capacity is therefore determined to be 1.1 times net storage capacity. Effective storage capacity is designed at 15 MCM taking surplus storage capacity of about 1 MCM.

Required Net Storage Capacity	12.8 MCM
Required Net Storage Capacity Plus Losses	14 MCM
Surplus Storage Capacity	1 MCM
Effective Storage Capacity	15 MCM

(c) Total storage capacity

Total storage capacity is calculated as a total of the effective storage capacity and the dead storage capacity.

Effective Storage Capacity	15 MCM
Dead Storage Capacity	2.6 MCM
Total Storage Capacity	17.6 ≑ 18 MCM

The designed total storage capacity of 18 MCM is the potential maximum reservoir capacity which corresponds to the potential economic maximum dam height of 35 m, and it corresponds to the normal water level (N.W.L) of EL. 1,380 m.

(2) Freeboard

(a) Net freeboard

The net freeboard is water height over the spillway crest during the design flood when the outlet is closed. The net freeboard is designed at 2.5 m.

(b) Gross freeboard

The gross freeboard is computed from the net freeboard plus a safety factor as follows:

Gross Freeboard = Net Freeboard + hw + 1.0 m
> Net Freeboard + 2.0 m

where, hw : Wave creep height to the upstream slope

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

The gross freeboard is designed at 4.5 m taking hw of 0.8 m.

Gross Freeboard = 2.5 + 0.8 + 1.0 < 2.5 + 2.0 = 4.5 m

(3) Core zone crest elevation

Core crest elevation should not be less than (N.W.L + Gross Freeboard), where N.W.L is normal water level.

N.W.L + Gross Freeboard = EL. 1,380 + 4.5 = EL. 1,384.5 m

(4) Dam crest elevation

Dam crest elevation = Core crest + Crest road thickness
= EL. 1,384.5 m + Crest road 0.5 m
= EL. 1,385 m

(5) Dam crest width

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

$B = 3.6 \sqrt[3]{H} - 3.0 = 8.8$ m, for earthfill dam
$B = 0.05H + 6.0 = 7.8$ m, for rockfill dam

where, H : Dam height = 35 m

Taking average value, crest width is designed at 8 m.

4.2 Embankment Design

4.2.1 Embankment materials

Available embankment materials near the Thiba damsite are as follows:

(1) Red soils

The content of fine-grained soil under the 74 in particle size is rather high, and the plasticity index is about 20. Therefore, red soils have enough imperviousness as a core but slightly small resistance for a piping. The borrow area is located at about 1 km upstream.

(2) Highly weathered agglomerates

Highly weathered agglomerates are suitable for transition materials. They will become gravelly soil through the excavation. Quarry site is located at about 3.5 km upstream.

(3) Moderately weathered basalts

Moderately weathered basalts are firm as rock, and joints are well developed. Quarry site is located at about 2 km upstream.

(4) Faint weathered basalts

Faint weathered basalts are suitable for rock materials. Faint cracks are developed, and masses of rocks will be produced. Quarry site is located at about 2 km upstream.

The abundant materials are red soils and faint weathered basalts.

4.2.2 Zoning of dam

The Thiba dam cross section is shown in Fig. V-2. Following five zones are designed as follows:

(1) Upstream rock zone

This zone will work as a fore shell of the embankment to ensure the stability of the embankment, to prevent the erosion from the waves and to prevent the occurrence of the residual pore water pressure at the draw down.

(2) Core zone

The width of the core zone is designed at about 40% of the water depth of the reservoir. Mixture with gravels and red soils would be adopted if low shear strength or high consolidation settlement should become clear with future soil mechanical tests.

(3) Transition zone

Red soils or highly weathered agglomerates are used as embankment materials. Drains to dissipate the excess pore water pressure are designed in the bank of the red soils. One of the purposes of this zone is to mitigate the arch action in the core zone by embanking the medium materials between core zone and downstream rock zone in the sense of the modulus of deformation.

(4) Downstream rock zone

This zone will work as a back shell of the embankment to ensure the stability of the embankment and to prevent the erosion from the rainfall.

(5) Impervious blanket

Red soils are used as embankment materials. The purpose of this zone is to control the seepage from the foundation.

4.2.3 Stability analysis

Stability of the dam against sliding is analyzed preliminarily by means of the surface slide method. A safety factor obtained by the method is derived by the following formula:

$$Fs = \frac{1 - \tan a \cdot k}{\tan a + k} * \tan f$$

where, Fs : Safety factor
a : Incline of slope of dam
k : Design value of seismic force coefficient = 0.14
f : Internal friction angle of rock material = 39°
(evaluated)

The results of stability analysis are summarized as follows:

Slope	Fs
Upstream (1:3.0)	1.3
Downstream (1:2.3)	1.3

Above results of analysis imply that the dam is reasonably safe against sliding.

4.2.4 Seepage water

The rate of the seepage water is estimated preliminarily. The results of the calculation are summarized as follows:

Section	Seepage Water
Dam	1,600 m^3/day
Foundation	900 m^3/day
Total	2,500 m^3/day

The seepage water amounts to about 0.01%/day of the total storage water of 18 MCM.

4.3 Foundation Treatment

The Pleistocene basalts and Tertiary agglomerates are developed around the Thiba damsite. The completely weathered pyroclastic materials are observed over these basement rocks with an average thickness of 10-20 m.

The completely weathered agglomerates with a thickness of about 4 m are observed at the borehole No. BT-1. It is recommended that the impervious blanket method be adopted to prevent the leakage from the foundation, because the improvement of its permeability by grouting is difficult. As for the seepage control of cracky zone in both abutments, the improvement of its permeability by curtain grouting will be possible. The joints of the impervious blanket and the curtain grouting are shown in Fig. V-1.

A relief well is designed to reduce the uplift from the dam foundation at the draw down.

4.4 Spillway

There is no suitable site for the emergency spillway at the Thiba damsite from the viewpoint of property conditions. Therefore, in order to make up for the emergency spillway, the main spillway should afford to withstand the flood of 1,000-year return period with sufficient freeboard allowance. The main spillway is located at rightside abutment.

4.4.1 Design flood

The spillway design flood is determined to be the peak flood derived from one-day rainfall of 275 mm with 625-year return period, occurring uniformly over the entire basin. The design flood is determined at 560 m^3/sec.

Flood Scale	Probably Rainfall (mm/day)	Peak Flood (m^3/sec)	Reservoir Water Level (m)
10-year	140	280	EL. 1,381.6
50-year	190	390	1,382.0
100-year	215	440	1,382.2
625-year (Design flood)	275	560	1,382.5
1,000-year	290	590	1,382.6

Thomas Plot of maximum annually daily rainfall at the Kianyaga raingauge station is shown in Fig. V-9.

4.4.2 Main spillway

Main spillway is designed to release the flood of 625-year return period with due freeboard allowance. Main spillway consists of un-gated side-flow intake crest of 75 m in length and 2.5 m of overflow design depth, guide channel of 16 m in width, chute channel of 10 m in height and 175 m in length, stilling basin of 15.5 m in height and 75 m in length. It is confirmed that the main spillway can afford to withstand the flood of 1,000-year return period with sufficient freeboard allowance.

4.5 River Diversion

4.5.1 Diversion requirement

Flood scale of 10-year return period is adopted considering the required period of about 5 years for dam construction works. The design discharge of 280 m^3/sec is determined from the probability analysis on the one-day rainfall recorded at the Kianyaga raingauge station.

4.5.2 Diversion tunnel

The diversion of the Thiba river would be accomplished through a horseshoe-shaped tunnel of 6.3 m inside diameter, which bypass the damsite through right abutment. The tunnel is designed to accommodate a flow of 280 m^3/sec at water surface of elevation 1,360 m. The diversion tunnel, together with lead channel at upstream and diversion channel at downstream would be constructed while the river is flowing in its natural channel.

4.5.3 Coffer dam

Coffer dam is designed to protect over-topping of dam body during early stage of construction and to raise the flood water level giving necessary hydraulic head to pass the flood through diversion tunnel. Taking about 1.0 m of freeboard above the flood water level at designed diversion flood, the crest of coffer dam is determined at EL. 1,361 m.

4.6 Intake and Outlet Structure

4.6.1 Design intake capacity

Design intake capacities are determined from the water balance calculation and the draw down for the emergency. Design intake capacities are as follows:

Irrigation	7.1 m^3/sec
Service discharge	0.5 m^3/sec
Draw down	25.0 m^3/sec

The period of the draw down for the emergency is considered about 7 days.

4.6.2 Intake structure

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

Drop inlet	6.3 m x 6.3 m	
Intake pipe	Length	560 m
	Diameter	2 m

4.6.3 Outlet structure

Outlet structure is located at the end of the diversion tunnel. The jet flow gates are installed in the outlet conduits. Major dimensions of outlet structure are as follows:

Jet flow gate	Diameter	2.0 m (for Irrigation and Draw down)
Jet flow gate	Diameter	0.4 m (for Service)

5. ENVIRONMENTAL IMPACTS

Environmental impacts on the dam construction comprise those on socio-cultural values, ecological resources, physical resources and quality of life values, etc. These impacts should be carefully studied in the future. Land use map of the damsite is shown on Fig. V-10.

6. HYDROPOWER DEVELOPMENT

6.1 Power Demand

Power supply to the Mutithi and Mwea area is made through 11 kV transmission line from Sagana Substation. This line has a supply capacity of 2,500 kVA, but on the other hand connected load is about 950 kVA at present. The above figures show that the supply capacity is always there but the power demand is very low.

6.2 Power Generation

Hydropower development is studied to fully utilize the irrigation water to be released from the dam. The possibility of the hydropower generation is outlined below in case of the Thiba dam for the year 1980:

Maximum output	:	200 kW
Annual energy production	:	800,000 kWh
Maximum discharge	:	1.5 m^3/sec
Duration ratio	:	25 %

Hydropower development is not considered in the Project.

LIST OF REFERENCES

1. "A CATALOGUE OF FELT EARTHQUAKES IN KENYA 1892-1969", I.S. LOUPEKINE
2. DESIGN STANDARD OF MINISTRY OF AGRICULTURE, FORESTRY AND FISHERY OF JAPAN, DAM

Table V-1 Summary of Reservoir and Dam

Item	Thiba Dam
1. Reservoir	
Catchment area	172.6 km^2
Reservoir capacity	
Effective storage capacity	15.0 MCM
Dead storage capacity	2.6 MCM
Total storage capacity	17.6 = 18.0 MCM
Water level	
Normal water level	EL. 1,380.0 m
High water level	EL. 1,382.5 m
Dead water level	EL. 1,363.0 m
Reservoir area	
Total storage area	1.2 km^2
High water level area	1.3 km^2
2. Dam	
Type	Inclined - core zoned fill type
Height	35.0 m
Crest elevation	El. 1,385.0 m
Crest length	1,350 m
Crest width	8 m
Slopes	
Upstream	1:3.0
Downstream	1:2.3
Embankment volume	1,200,000 m^3
3. Spillway	
Main spillway	Ungated side channel type
Design discharge	560 m^3/sec
Crest length	75 m
4. River diversion	
Diversion requirement	280 m^3/sec
Diversion tunnel	550 m
Diameter	2R Horse shoe 6.3 m
Coffer dam height	7 m
5. Intake and outlet works	
Intake capacity (draw down)	25 m^3/sec
Intake structure	Drop inlet
Outlet pipe diameter	2.0 m

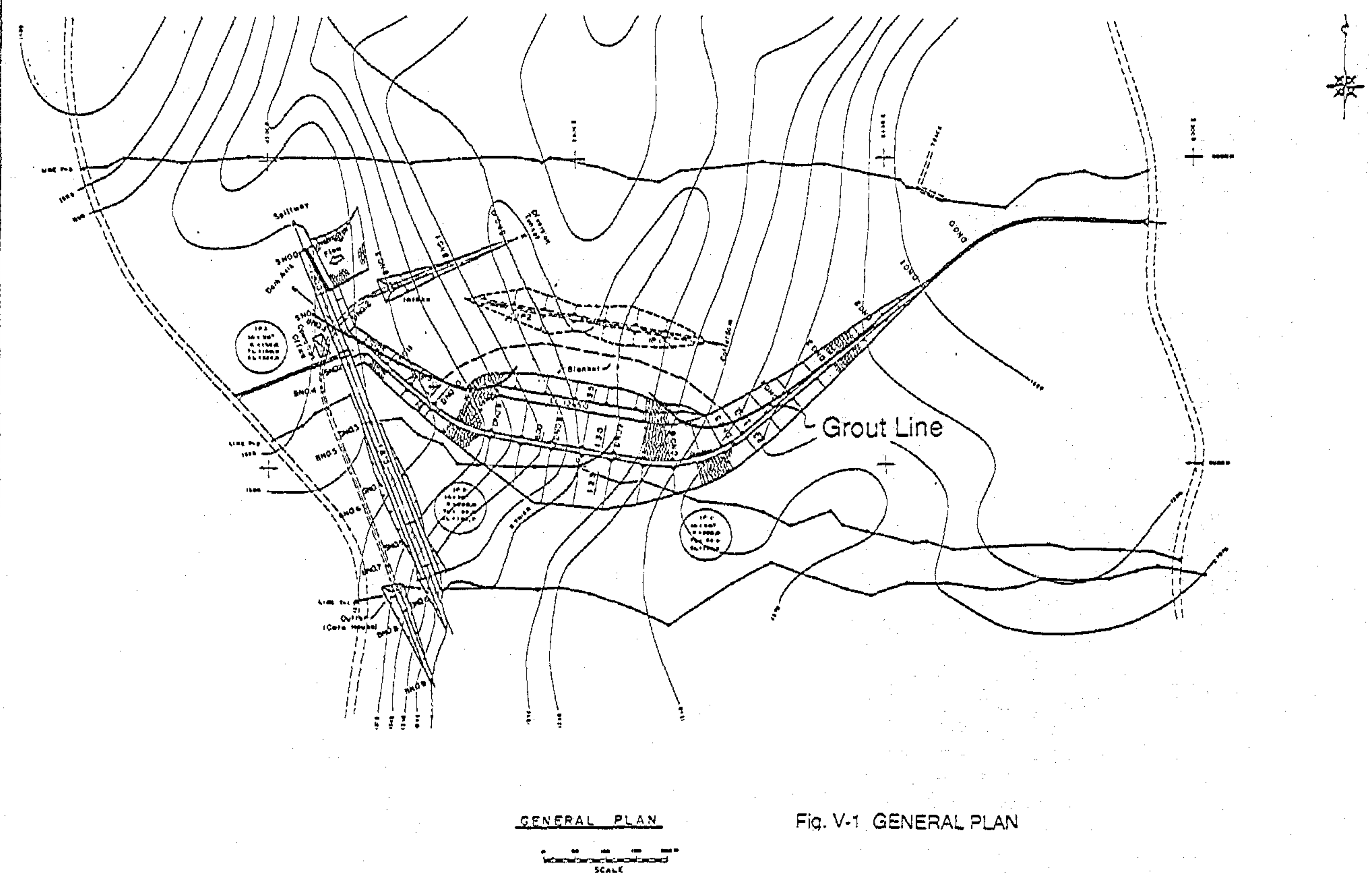
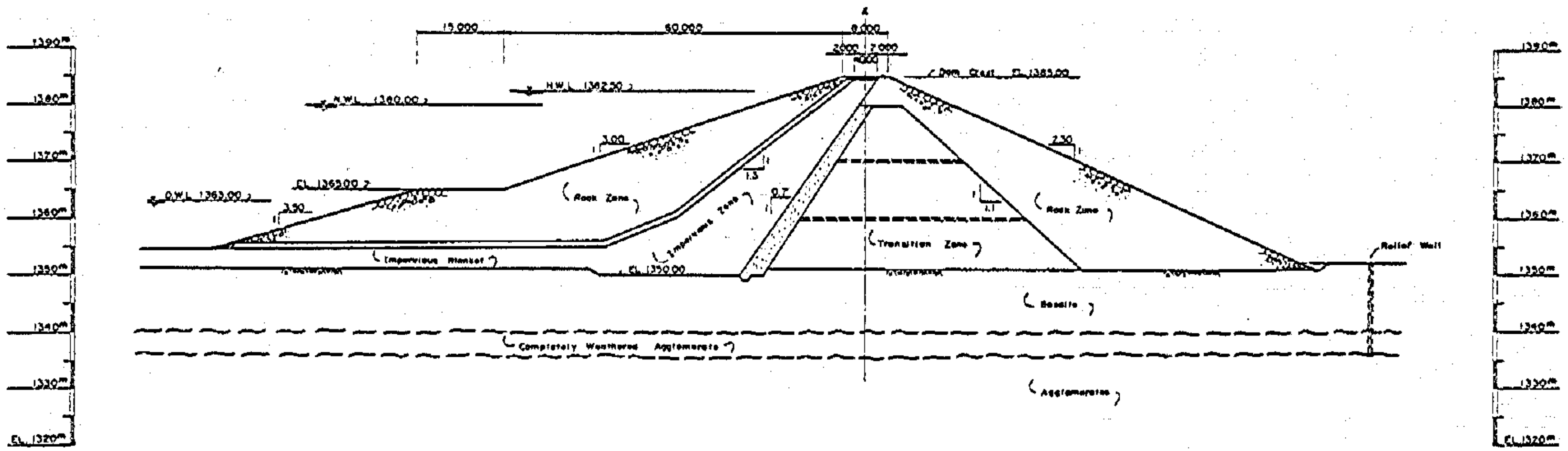


Fig. V-1 GENERAL PLAN



TYPICAL CROSS SECTION

SCALE - A

Fig. V-2 CROSS SECTION OF DAM

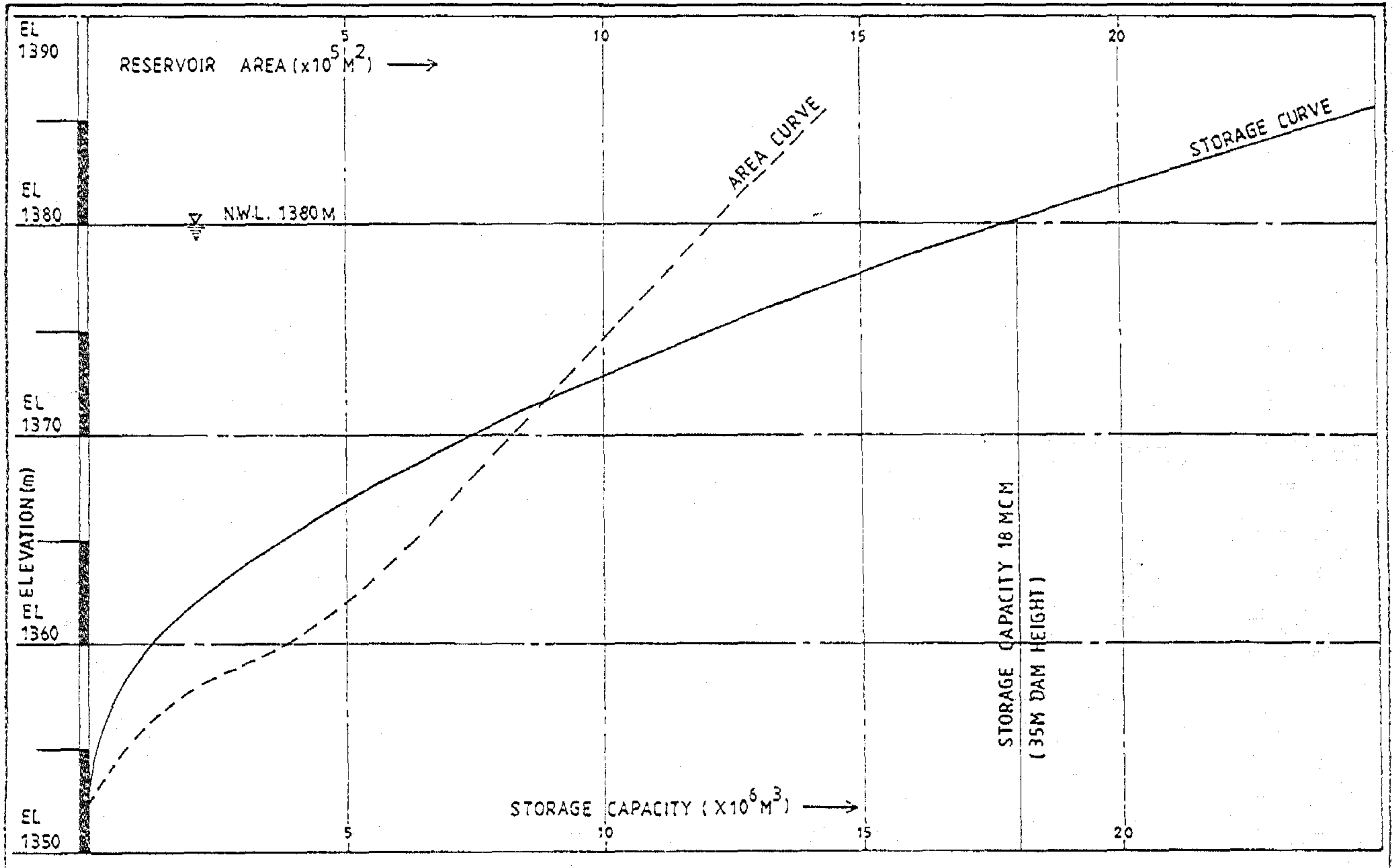
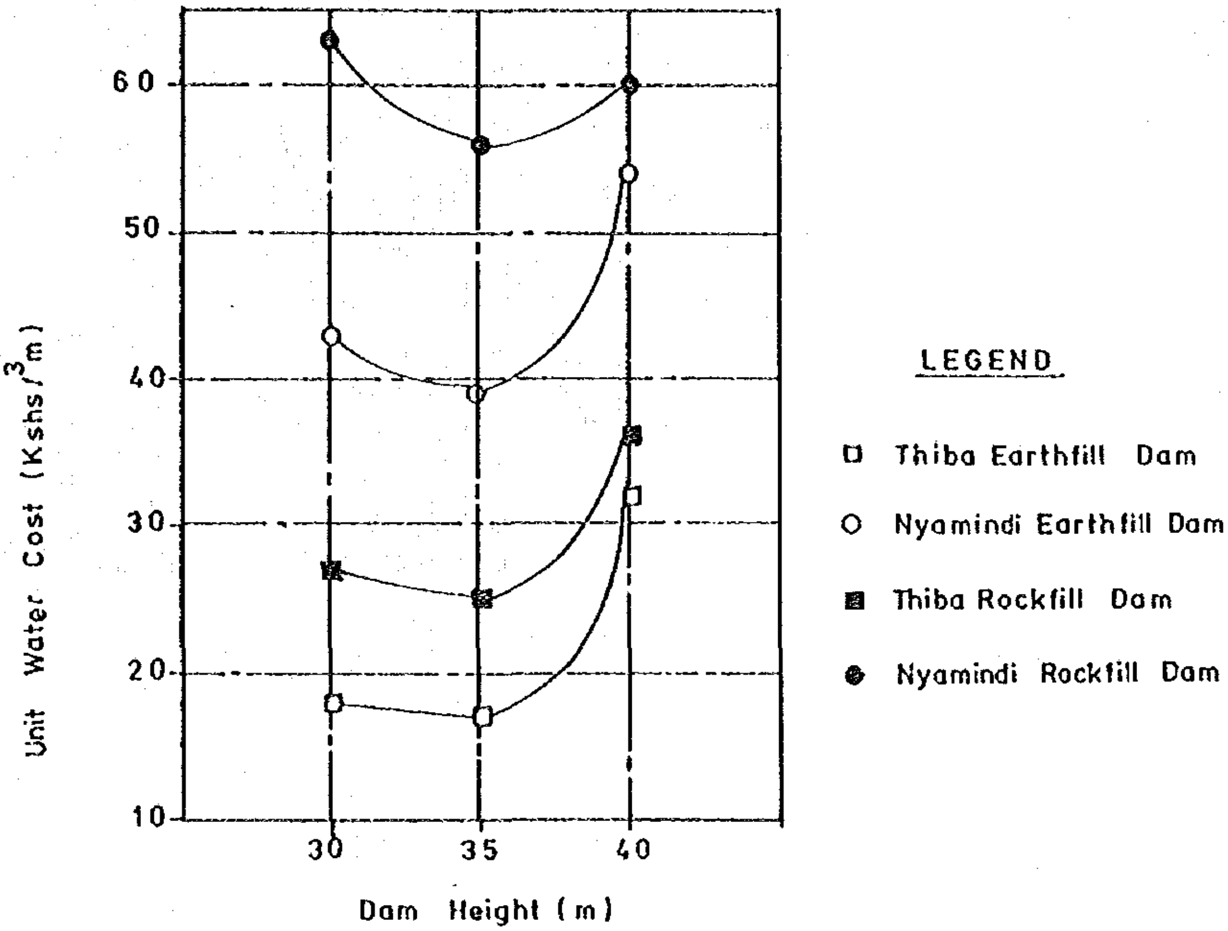


Fig. V-3 AREA-CAPACITY CURVE OF THIBA DAM



Dam Height (m)		Thiba Dam Dam Cost (Mkshs)	Thiba Dam Total Capacity (MCM)	Thiba Dam Unit Water Cost (Kshs/m³)	Nyamindi Dam Dam Cost (Mkshs)	Nyamindi Dam Total Capacity (MCM)	Nyamindi Dam Unit Water Cost (Kshs/m³)
30	E	220	12	18	260	6	43
	R	320	12	27	380	6	63
35	E	310	18	17	390	10	39
	R	450	18	25	560	10	56
40	E	760	24	32	760	14	54
	R	860	24	36	840	14	60

REMARKS
E : Earthfill Dam
R : Rockfill Dam

Fig. V-4 UNIT WATER COST

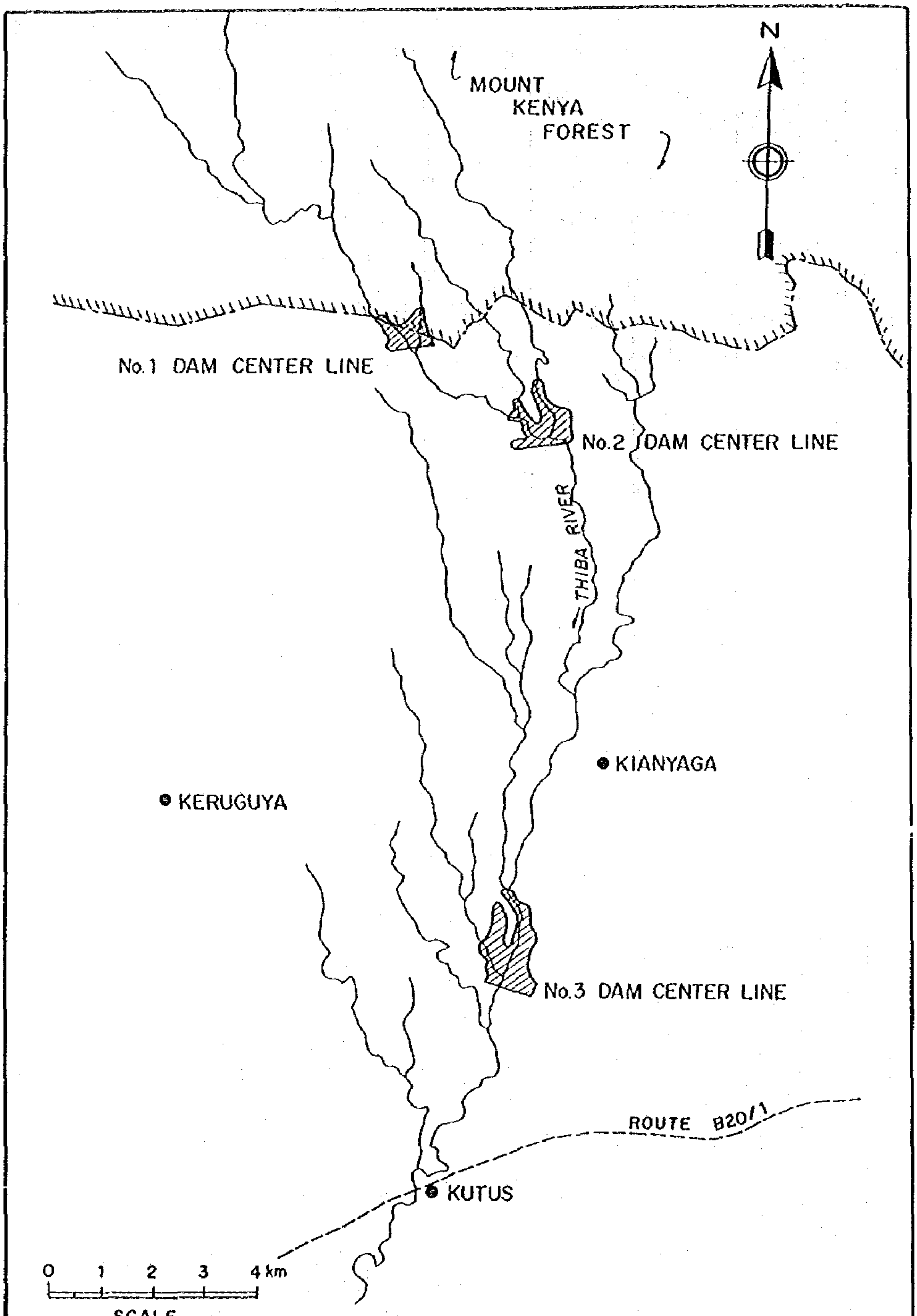


Fig. V-5 ALTERNATIVE DAM AXIS

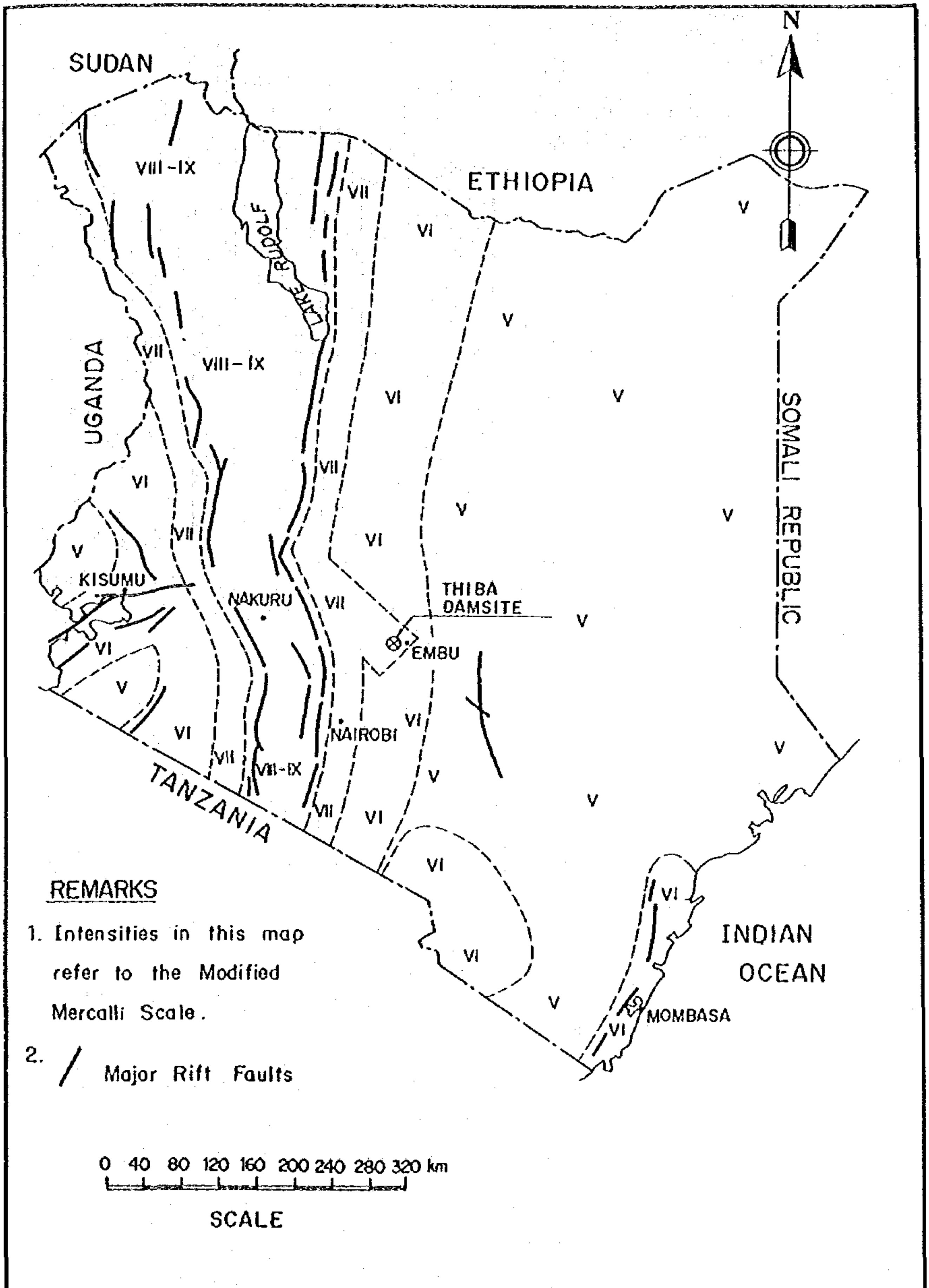


Fig. V-6 SEISMIC ZONING MAP OF KENYA SHOWING MAXIMUM OBSERVED INTENSITIES

(UNIT: $m^3/km^2/Year$)

*TOPOGRAPHY	**GEOLOGY	CATCHMENT AREA (Km^2) < 2	2–5	5–10	10–30	30–50	50–100
Early Manhood	Zone – A			100 ~ 300	300 ~ 800		800 ~ 1,200
	Zone – B			100 ~ 200	200 ~ 500		500 ~ 1,000
	Zone – C			100 ~ 150	150 ~ 400		400 ~ 800
Late Manhood	Zone – A		100 ~ 200		200 ~ 500		500 ~ 1,000
	Zone – B		100 ~ 150		150 ~ 400		400 ~ 1,000
	Zone – C		50 ~ 100		100 ~ 350		300 ~ 500
Old Age	Zone – B	~ 50	50 ~ 100		100 ~ 350		300 ~ 500
	Zone – C	~ 50		50 ~ 100		100 ~ 200	
Peneplain	Zone – B	~ 50		50 ~ 100		100 ~ 200 (Adopted Case)	
	Zone – C	~ 50			50 ~ 100		100 ~ 200

Note) * Characteristics of Topography

Topography	River Channel Erosion
Early Manhood	Highest erosion and stream bank erosion
Late Manhood	High erosion and scour hole erosion
Old Age	Slight erosion excepting flood time
Peneplain	Slight erosion even during flood time

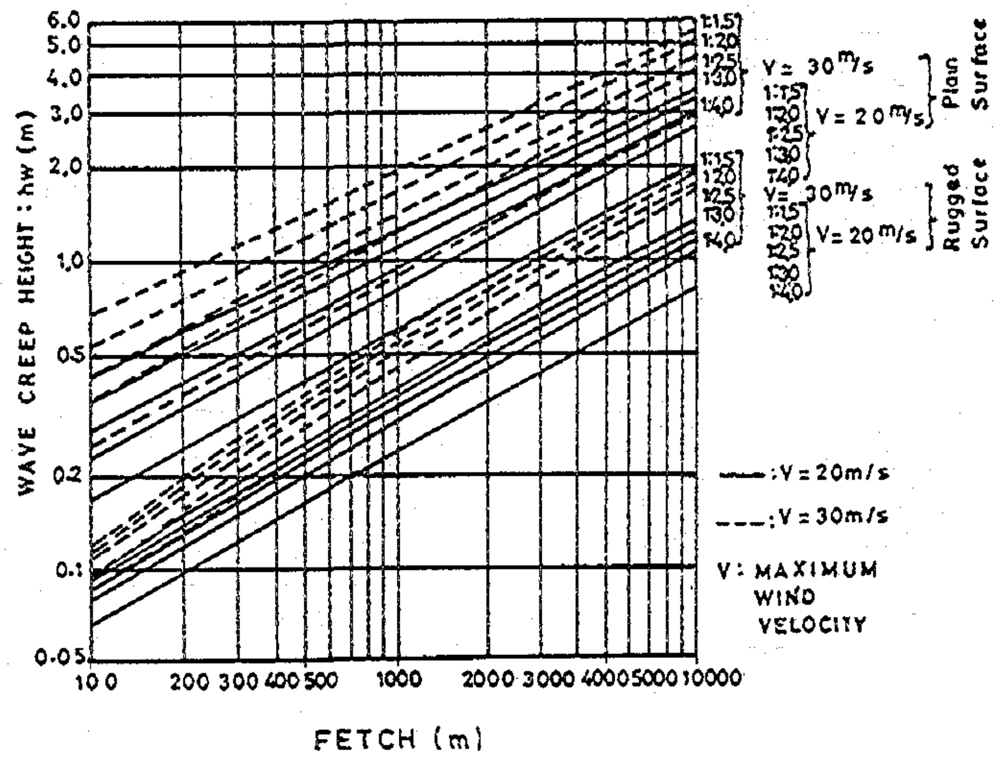
** Conditions of Geology

Zone – A ; More than 1/3 of the catchment area is classified into alluvial foothills or landslide area or quarternary loose volcanic materials area.

Zone – B ; 1/5 – 1/3 of the catchment area is classified into areas above mentioned.

Zone – C ; Zone excepting Zone – A and Zone – B.

Fig. Ⅴ-7 UNIT SEDIMENT LOAD



DAM	FETCH	SURFACE MAX. WIND VELO. EMBANKMENT SLOPE	WAVE CREEP HEIGHT	NET FREE-BOARD	GROSS FREEBOARD
THIBA	2,200m	RUGGED 30m/sec 1 : 3.0	0.8m	2.5m	2.5 + 0.8 + 1.0 < 2.5 + 2.0m = 4.5m
NYAMINDI	2,500m	RUGGED 30m/sec 1 : 3.0	0.8m	2.5m	2.5 + 0.8 + 1.0 < 2.5 + 2.0m = 4.5m

Fig. V-8 WAVE CREEP HEIGHT AND GROSS FREEBOARD

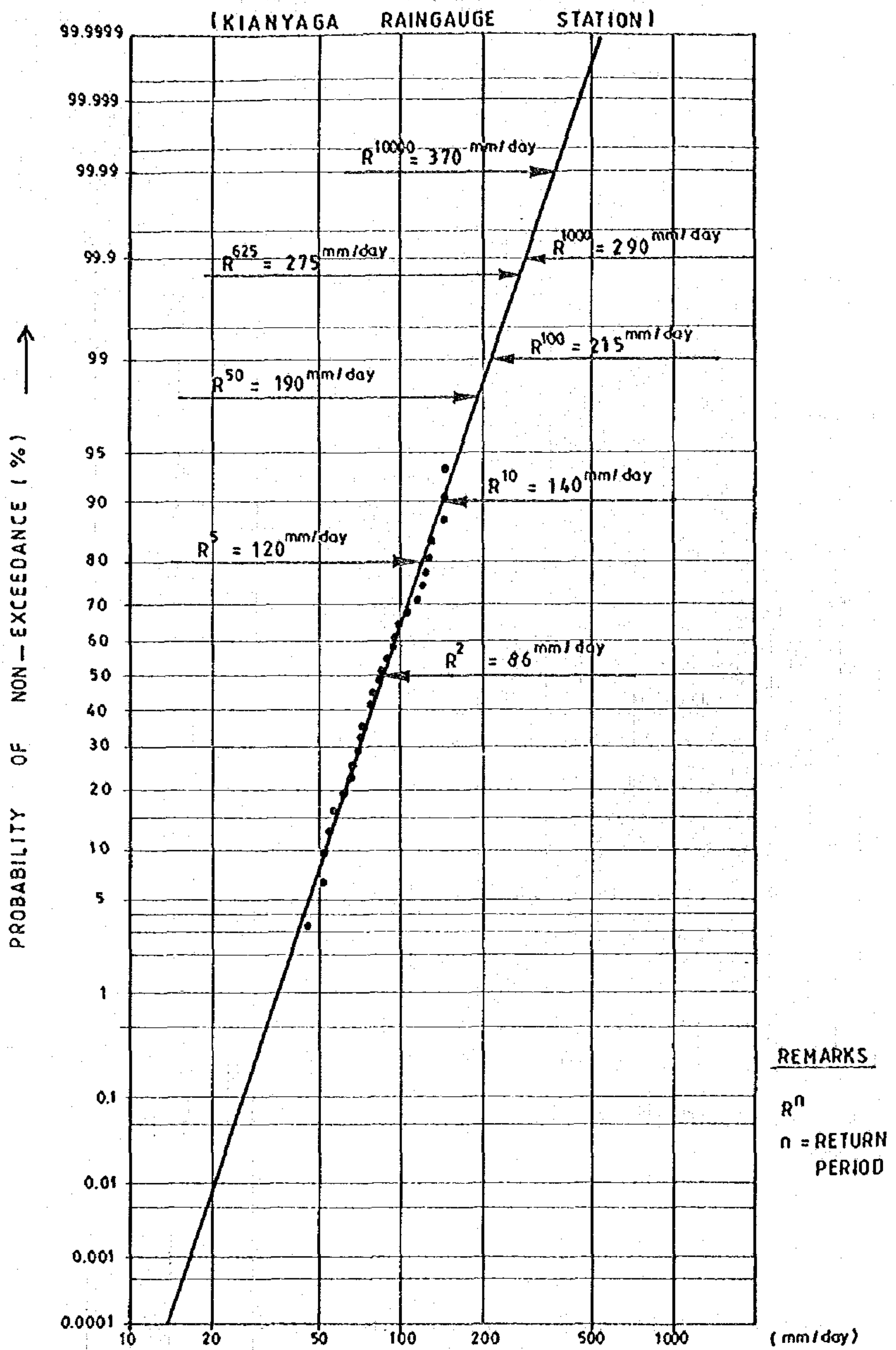


Fig. V-9 THOMAS PLOT OF MAXIMUM ANNUALLY DAILY RAINFALL