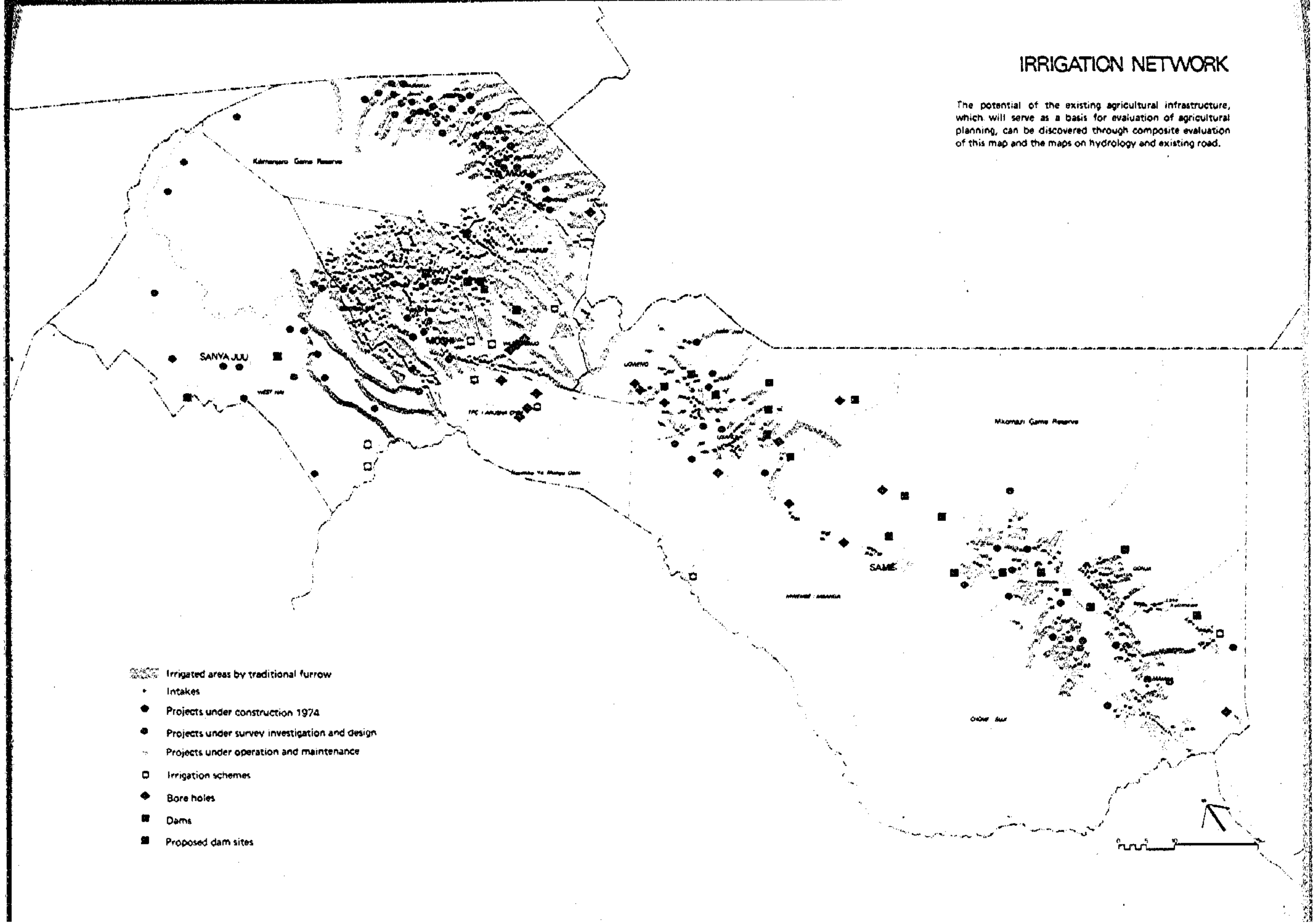
KILIMANJARO IDP

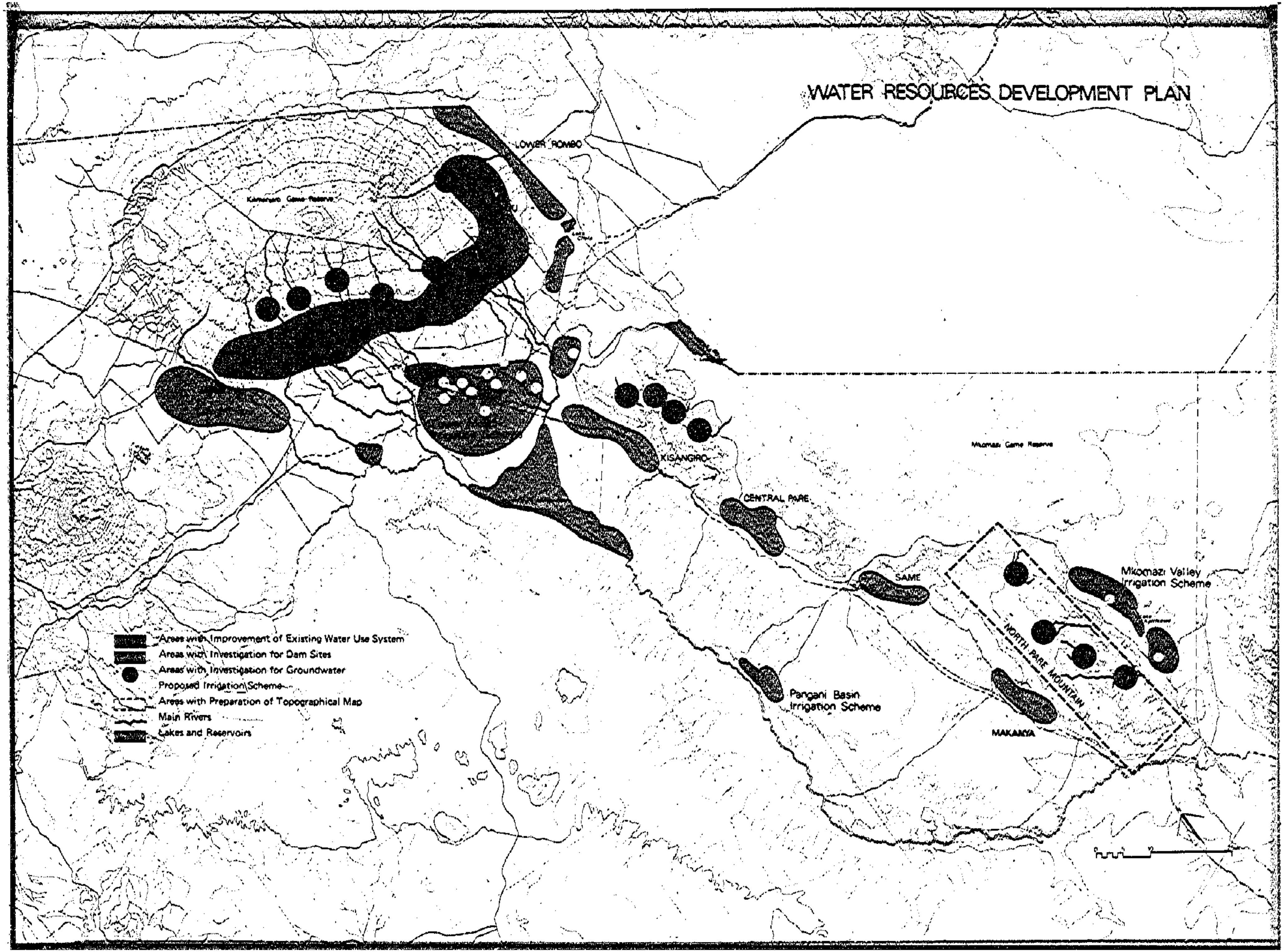
WATER RESOURCES

8

IRRIGATION NETWORK

The potential of the existing agricultural infrastructure, which will serve as a basis for evaluation of agricultural planning, can be discovered through composite evaluation of this map and the maps on hydrology and existing road.




WATER RESOURCES DEVELOPMENT PLAN
LOWER ROMBO
Kilimanjaro Game Reserve
KISANGIRO
CENTRAL PARE
SAME
Mkomazi Game Reserve
NORTH PARE MOUNTAIN
Mkomazi Valley
Irrigation Scheme
Pangani Basin
Irrigation Scheme
MAKANYA
Areas with Improvement of Existing Water Use System
Areas with Investigation for Dam Sites
Areas with Investigation for Groundwater
Proposed Irrigation Scheme
Areas with Preparation of Topographical Map
Main Rivers
Lakes and Reservoirs

WATER RESOURCES

Contents

INTRODUCTION

Most of the area of East Africa is classified as semi-arid. A major hydrometeorological condition is the Influence of the intertropical Convergence, which determines the duration and the time of the rainy and dry seasons.

Due to rainfall ranging from 1,500 mm to 2,000 mm per year at high altitudes on Mt. Kilimanjaro and 800 mm to 1,300 mm in the Pare Mountains, the hydrological condition of the region is more favourable than that of other regions in Tanzania.

This favourable condition is reflected in the highly developed system of agricultural on mountain slopes and in the existence of the artificial lakes of the Nyumba ya Mungu and Kalimawe dams down below.

On the vast expanse of low-lying flat area, however, there is only 400 mm to 600 mm rainfall of a year and a long dry season. Accordingly thickets or savanna is the predominan vegetation.

Considerable variation of rainfall in time and space is the most specific hydrometeorological characteristic of this area. Even perennial mountain streams decrease remarkably in their amount of flow during the dry season.

The major objectives of this chapter are to determine surpluses and deficits of water resources in the region through the assessment of existing water resources and their use so as to be able to estimate the amount of water that will be required in the future and to determine how it is to be provided.

1. RIVER SYSTEMS

The region is divided into two major catchments, the Pangani and the Mkomazi. (Fig.-1 and Fig.-2)

Most of the flow into the Pangani is from innumerable streams and springs on the southern slopes of Mt. Kilimanjaro via two main tributaries, the Kikuletwa to the northwest and the Ruvu to the northeast. The Kiluletwa and the Ruvu join at the Nyumba ya Mungu Reservoir, from which the Pangani flows out southward to the Tanga Region.

Passing through a vast dry plain, the waters collected from Mt. Meru in the Arusha Region flow into the Kikuletwa in the northwestern corner of the region. The yield, however, is minimal [0.15 m^3/s]. The yield of other catchment areas of the Kikuletwa's tributaries on mountain slope varies from 350 milimeters per year (mm/y) to 450 mm/y. Because of less rainfall on the western slopes of Kilimanjaro, the Sanya yields a minimal 230 mm/y. At the confluence of the Kikuletwa and the Sanya there is a group of springs (Rundugai, Chemka and Chockaa) which yields almost 40% of the entire flow of the Kikuletwa.

The catchment area of the Ruvu occupies the eastern half of the southern slopes of Mt. Kilimanjaro. On the eastern slopes most of the flow disappears at an altitude of about 1,200 m above sea level in many streams, and there are no perennial streams in this area. The discharge from the eastern slopes during the rainy season flows into Kenya and Lake Jipe, which is on the national border on the northeastern side of the North Pare Mountains, and then into the Ruvu. The Annual discharge from the southern slopes into the Ruvu is approximately 400 mm. There are also springs in the Kahe Basin on the lower slopes. The total yield of these springs amounts to about 30% of the entire flow of the Ruvu.

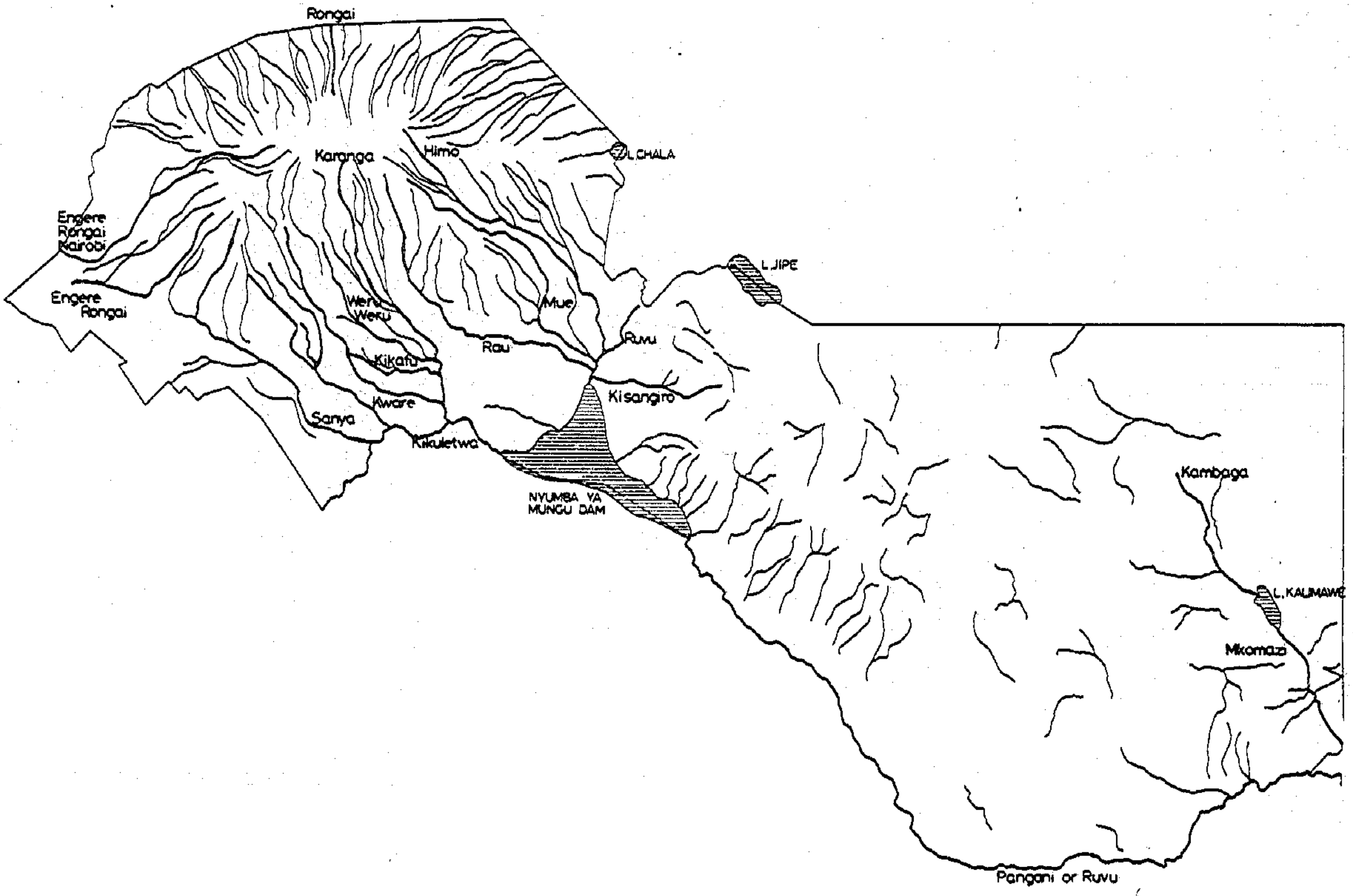
These spring waters are apparently supplied by percolation of rainwater on the upper slopes of Mt. Kilimanjaro, and the recharge zone extends over hundreds of square kilometers. The average annual recharge rate is estimated at 300 mm - 400 mm. Accordingly, huge amounts of ground water (160 million m^3) are presumably stored in the Kahe Basin and Sanya Chini each year.

The main river course of the Pangani has a wide catchment area (7,700 km^2, including the Kikuletwa and Ruvu basins). However, owing to the flat physiography and low rainfall (400 mm/y-500 mm/y), the yield of this catchment area is minimal. The run-off coefficient (percentage that total discharge represents of total rainfall) presumably does not exceed 10%.

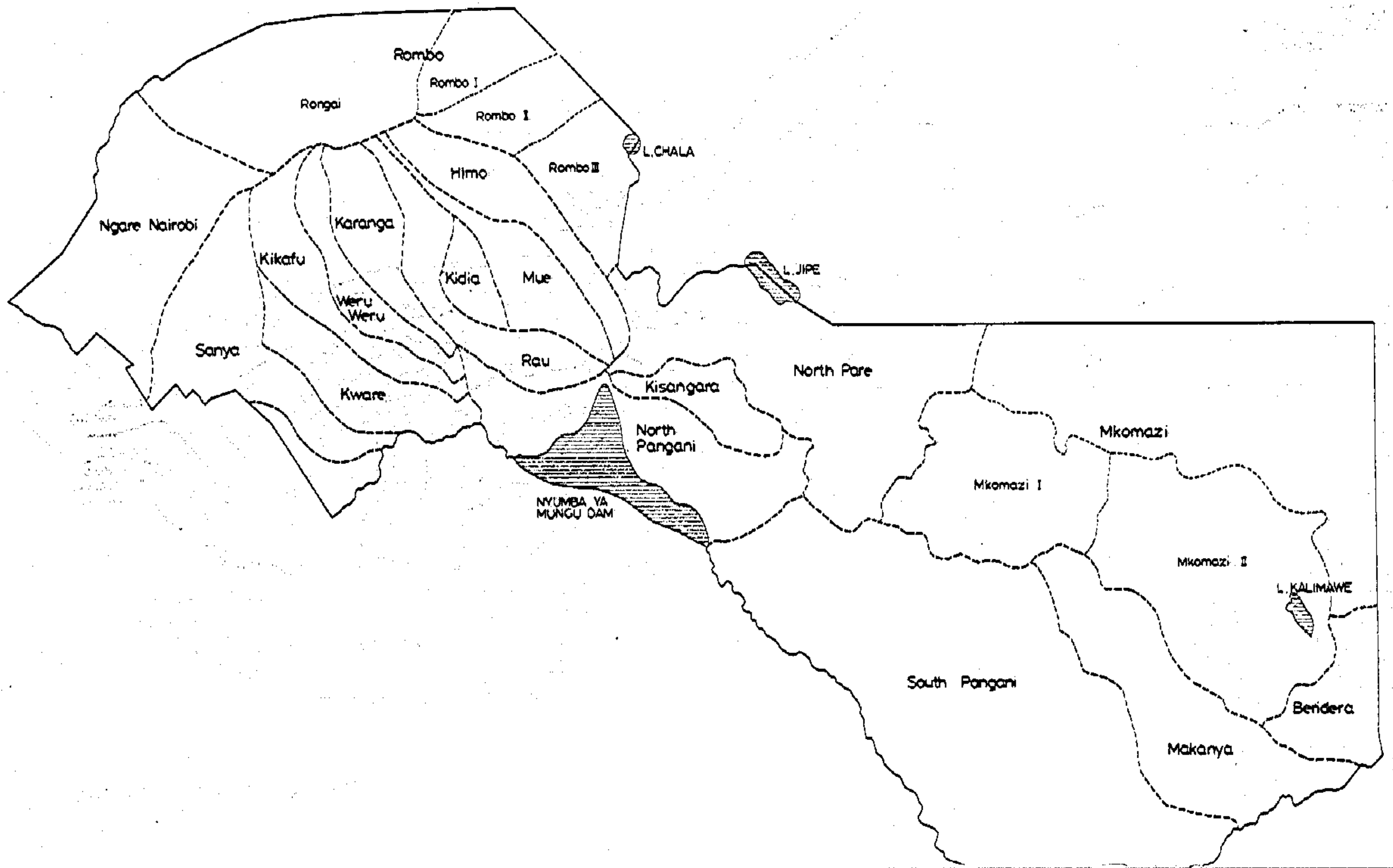
The major water source of the Mkomazi is the eastern slopes of the South Pare Mountains. The average annual yield from these slopes is estimated at 230 mm. In the rest of the vast expanse to the north and east of the catchment area there is apparently no developed river sourse except for some minor ephemeral rivers because of the low rainfall (500 - 600 mm/y) and the low-lying flat physiography.

The Mkomazi Valley is developed along a tectonic block faulting zone, and the valley bottom is filled with thick alluvial deposits. Because of less rainfall that on Mt. Kilimanjaro and less favourable geological conditions (mainly Pre-Cambrian metamorphic rocks) for ground water recharge that on Mt. Kilimanjaro, ground water sources similar to the Kahe Basin can not be expected in this area. The main productive aquifers are to be found along fault or fracture zones in the area of Gonja and are recharged only in wet years, which represent only of every 10-odd years.

Existing Rivers (Fig.-1)



Catchment Area (Fig.-2)



2. RUN-OFF OF RIVERS

2.1 General Aspect of River Discharge in the Region

Significant discharge as surface water occurs only on the southern slopes of Mt. Kilimanjaro and the eastern slopes of the Pare Mountains. Run-off from the rest of the catchment area is of no great importance in terms of face water resources.

(1) Slopes of Mt. Kilimanjaro

The average annual total flow amounts to 738 million m^3/y from the Kikuletwa and 454 million m^3/y from the Ruvu, of which springs account for 75% and 35%, respectively. In years of 20% unexceedence, the annual discharge appears to be almost 80% of the average. However, at those tributaries which have no spring inflow, discharge decreases to less than half of the average in years of 20% unexceedence.

There is a peak flow during the period April to June, when 60%-70% of total annual flow occurs. The Sanya and Himo rivers have another minor peak of flow during December. The minimum flow is observed in September and October.

(2) Pangani Main River Course

During an average year, 1,192 million m^3 flows into the main river course of the Pangani and into the Nyumba ya Mungu Dam reservoir. Of this amount, 851.5 million m^3 (27 m^3/s) is released downstream to meet the needs of the Hau Power Station.

Discharge of surface flow from the catchment area downstream of the Nyumba ya Mungu reservoir is possible since run-off takes place as a flood of sheet wash or through ephemeral rivers only after sporadic torrential showers.

(3) Mkomazi River

The average annual flow in this valley is estimated at 280 million m^3, 80% of which is from the eastern slope of the South Pare Mountains. In years of 20% unexceedence annual flow decreases to 160 million m^3. There are peak flows in December and in the period March - April, when 50% of annual flow takes place.

2.2 Run-off Structure

For the viewpoint of surface hydrology, these catchment areas on the southern slopes of Mt. Kilimanjaro and the eastern slopes of the Pare Mountains are playing a most important role in terms of the water resources of the region.

In order to estimate the magnitude of each component determining run-off structure in these areas, the hydrological water balance is analysed as follows.

The magnitude of Ep, varying remarkably in time and place, is estimated as 40% - 50% of annual rainfall (1,200 mm - 1,700 mm) at an altitude of 1,500 m and 50% - 60% of annual rainfall (600 mm - 800 mm) at an altitude of 800 m - 800 m.

Accordingly, the annual hydrological water balance on the southern mountain slope of Kilimanjaro during an average year is estimated as below.

Annual Water Balance (Table-1)

Catchment	Catchment area (km^2)	Pe (mm)	R (mm)	G (mm)	dS (mm/month)	Ratio of R to Pe (%)
Kikafu	194.9	609	413	148	45	68
Weruweru	150.2	617	332	226	44	54
Karanga	227.1	613	469	157	42	76
Himo	270.3	570	344	219	29	60

The formula given below shows the hydrological water balance in a catchment area.

$$P = R + G + Ep + dS \qquad (1)$$

$$Pe = P - Ep = R + G + dS \qquad (2)$$

where

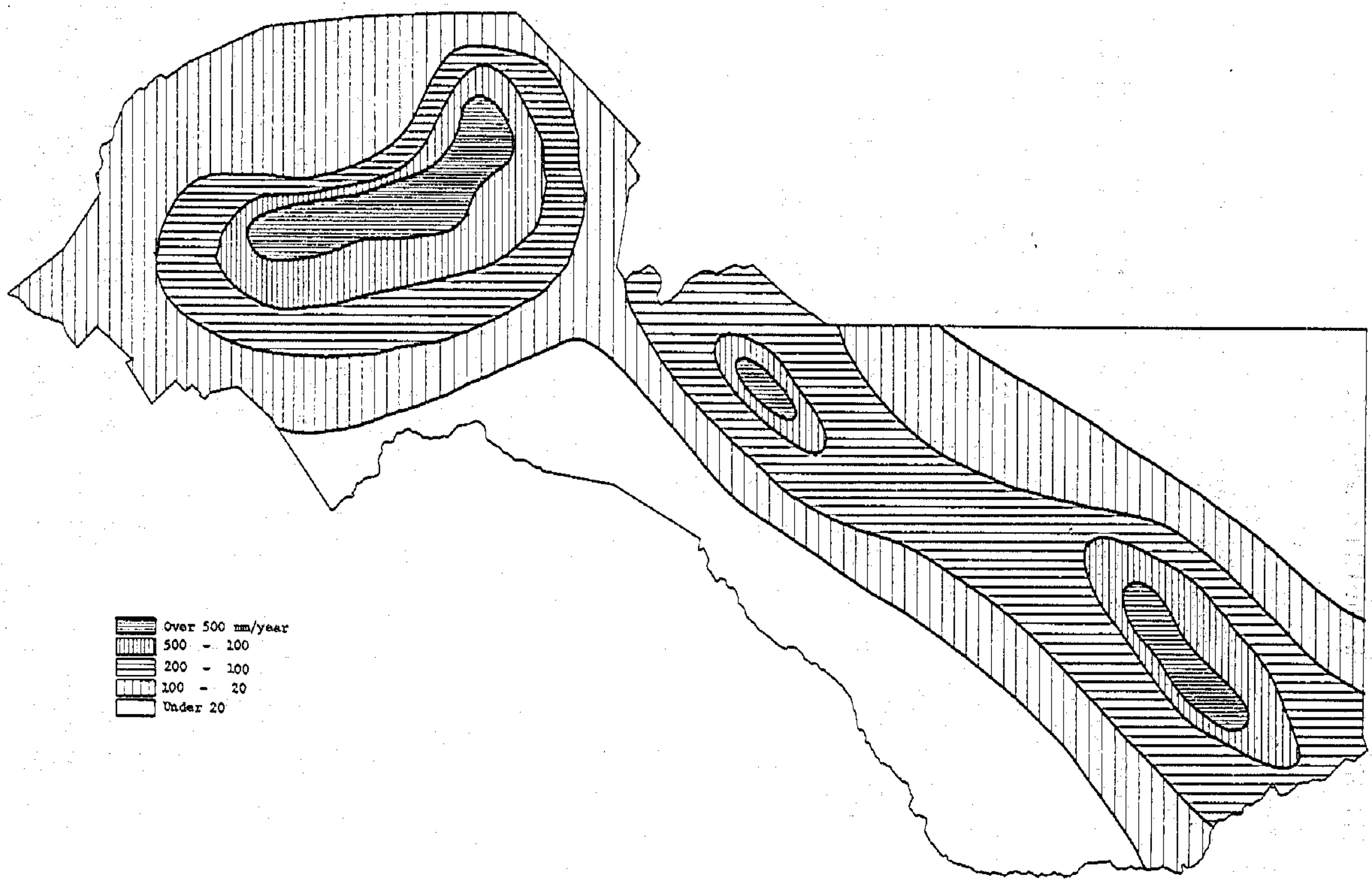
P : rainfall
Pe : effective rainfall
R : discharge
G : ground water recharge
Ep : evapotranspiration
dS : storage in the catchment

The ratio of R to Pe varies from 54% to 76% of effective rainfall and the rate of ground water recharge is about 30% of effective rainfall in these catchment areas.

Further details are discussed in Appendix 2 of Volume II, Hydrometeorology of Water Master Plan.

Specific yield of each part of the region is estimated as per Fig.-3.

Specific Yield of Surface Run-Off mm/year (Fig.-3)



3. PRESENT STATE OF WATER USE METHODS

3.1 Reservoir

There are 11 dams and reservoirs in the region. Except for the Nyumba ya Mungu Dam, completed in 1968, most of them, as listed in Table-2, were built in the second half of the 1950's.

Of these dams and reservoirs four, were transferred to the authority of the regional irrigation officer in 1975, since their main objective is irrigation.

The Nyumba ya Mungu and Kilimawe dams have rather great efficiency owing to favorable topographical conditions. The rest of the dams, however, have an efficiency coefficient of less than 20 because of poor topographical conditions for constructing dam and reservoir on mountain slope.

Except for the Nyumba ya Mungu dam, most of the have sustained breaching damage, mainly at sprillways and in some cases even on the main walls.

Finally, it should be noted that construction of reservoirs on volcanic formations in usually subject to seepage.

Existing Dams and Reservoirs in the Region (Table-2)

		Capacity of storage (1,000 m^3)	Volume of embankment (m^3)	Height (m)	Dam efficiency (m^3/m)	Design capacity (m^3/d)	Remarks
	Pare District						
1.	Nyumba ya Mungu	1,140,000	603,000	43	1,890	2,000,000	
2.	Kalimawe	24,700	18,733	8.8	1,320	49,000	Irrigation
3.	Shungula	247	14,411	10.6	17.1	13,600	Irrigation
4.	Dindira	739	55,800	4.0	1.3	4,050	
5.	Shatto	286	18,730	8.2	15.2	8,900	Ababdonned
6.	Ranzi	396	55,044	4.6	7.2	2,200	Irrigation
7.	Kavateta						
	Moshi District						
8.	Sholo	90	21,000	9.2	4.3	1,130	
9.	Urenga	180	35,000	10.7	5.1	1,500	Irrigation
10.	Mworoworo	158	26,950	10.4	5.8	2,500	
11.	Ukiashi	158	67,760	12.2	2.3	875	

3.2 Gravitational Piped Water Supply

(1) General

This is the type of water supply system predominating in the region. Because of their high mountains both the pare and Kilimanjaro areas have perennial mountain streams providing water for this water supply system.

Construction of pipes for water supply based on mountain stream or springs water sources began late in the 1950's. Since independence, such construction has been encouraged, and the total length of pipelines has been increasing. As shown in Fig.4, the total length of pipelines reached almost 1,000 km in 1977, and about 280,000 people in the region are now serviced with clean water by this system.

Since the water is taken from high mountain streams or from springs, this water supply system has some technical advantages which favor water quality and require no energy cost. This system, already predominant in the region, will be extended in future where suitable water sources are available.

(2) Present State of Gravitational Piped Water Supply

As shown in Fig.-4, the total length of pipeline has reached almost 1,000 km, making it possible to service 280,000 people in the region, or about 33% of the total population, with 5.5 million m^3 of water a year.

There are 45 schemes under operation in the Mt. Kilimanjaro area, and 20 schemes in the Pare Mountains area, the most remarkable one being the East Kilimanjaro Trunk Main. A part from these, ten more schemes are under construction, and 43 other projects are now in the survey or designed stage.

(3) Technical Aspect of Gravitational Piped Water Supply

Most remarkable advantage of this water supply system is that no energy cost is involved. Secondary construction of intake is rather simple, and the cost is minimal in comparison with other kinds of water supply (Ch. VI, Technical Report Vol. IV, Engineering Water Master Plan).

In addition, because of use of natural gravity, the size of the pipelines is smaller than in the case of a pumped distribution system. Though construction of break pressure tanks is necessary in order to release excess hydraulic pressure when the slope of the ground surface is more than the head of hydraulic losses of water flow in the pipes, the construction cost of rising mains is much cheaper than that of the pump system when design capacity is large.

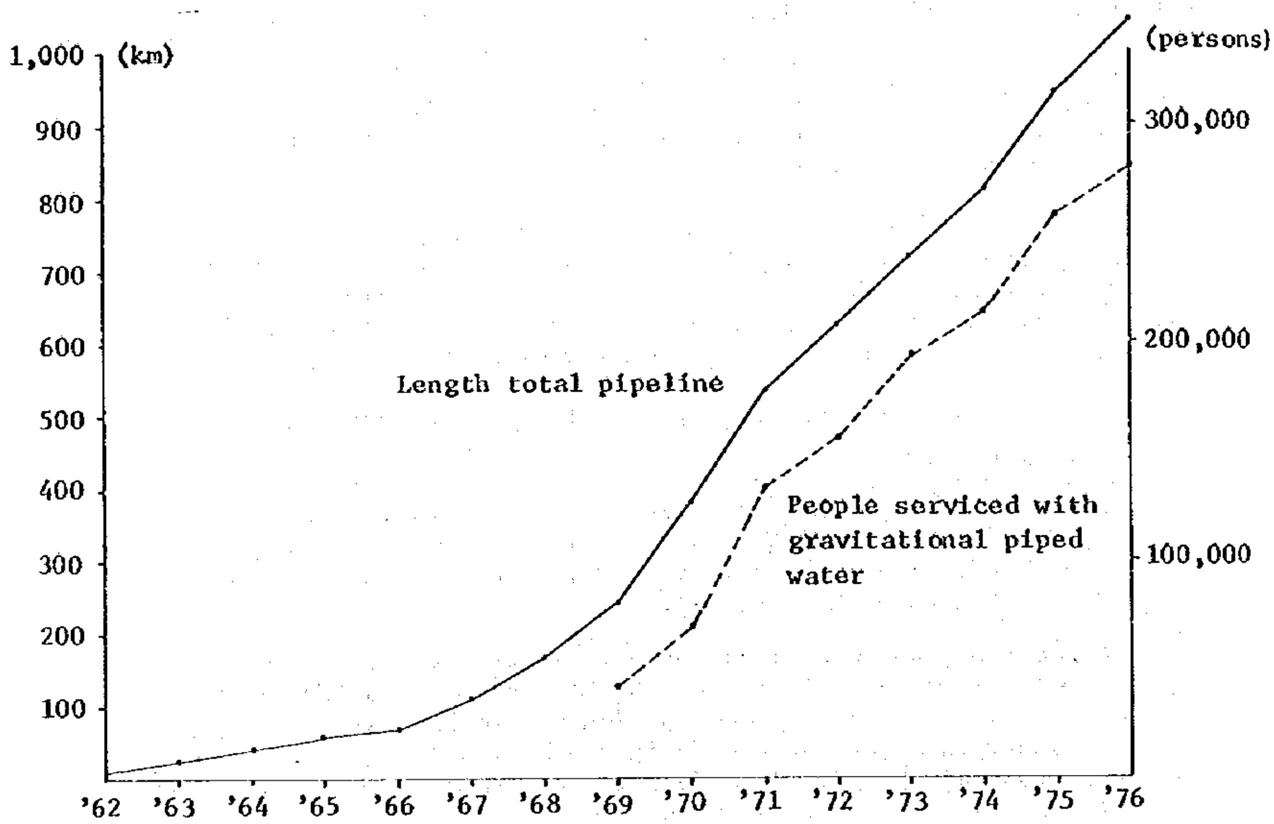
Since water sources are loosted on mountain slopes above villages, they are free from contamination. At the same time, from the viewpoint of public hygiene this gives the adovantage to the gravitational water supply system of not entailing any treatment cost.

A maximum cost of rural water supply of 100 sh/d/person is proposed by the ministry. In this region, however, the average cost of gravitational piped water supply is 32 sh/d/person in the Mt. Kilimanjaro area and 140 sh/d/person in the Pare Mountains, including the capacity for future extention of pipelines. When extention is completed, the average figure will be 31 sh/d/person in the Mt. Kilimanjaro area and 56 sh/d/person in the Pare Mountains. As the distance from the water source to domestic points is great in the Pare Mountains, unit cost is greater than in the Mt. Kilimanjaro area.

Occasionally there are complaints of insufficiency of storage tank capacity. In most cases, however, it is caused by overdrawal of water by more people than design capacity gathering from places more than 500 m from the tap. When implementation of rural water supply schemes are completed and water taps are available within 500 meters as designed, presumably this problem will be solved.

Finally, in the future some allowance should be made for private connections.

Pipeline Construction (Fig.-4)



3.3 Traditional Furrows

(1) General

Kilimanjaro region is famous for its traditional furrows, which have been intensively developed by local people. Furthermore customary water rights have been controled by local communities. At present, the total length of these traditional furrows on the slopes of Mt. Kilimanjaro is 920 km, vs. 780 km in the Pare Mountains. Almost 60% of them have been used for more than a hundred years.

The major purpose of these furrows is to irrigate agricultural fields during the dry season and to supply domestic water. The total amount of water consumed in the region through these furrows is estimated at 187.1 million m^3/y. A list for all such furrows, with details, as shown in Vol. VII, Water Master Plan.

(2) Present State of Traditional Furrows

The total number of traditional furrows in the Mt. Kilimanjaro area is 567, with a total length of 900 km. The longest one extends about 10 km; most of them, however, are two or three kilometers long. The majority of these furrows (70% of the total) are distributed on mountain slopes above 1,000 m.

Since rainfall conditions are unfavourable on the western slopes of Mt. Kilimanjaro, there is only a limited number of furrows there. On the other hand, because of favourable rainfall conditions in terms of amount and seasonal distribution (all Vol. II, Chap. V-4-2 of Water Master Plan), there has been less development and utilization of traditional furrows as means of irrigation on the eastern slopes.

The where such furrows prevail catchments on the southern slopes of Mt. Kilimanjaro.

A part from these furrows on mountain slopes, some traditional furrows 30% of the total are located on lower slopes and alluvial plains where the main crops are rice, maize, and beans.

In the Pare Mountains area there are 207 traditional furrows. As in the case of the Mt. Kilimanjaro area, about 70% of the total length of 780 km is located on mountain slopes, the other 30% being located on lower slopes and alluvial plains.

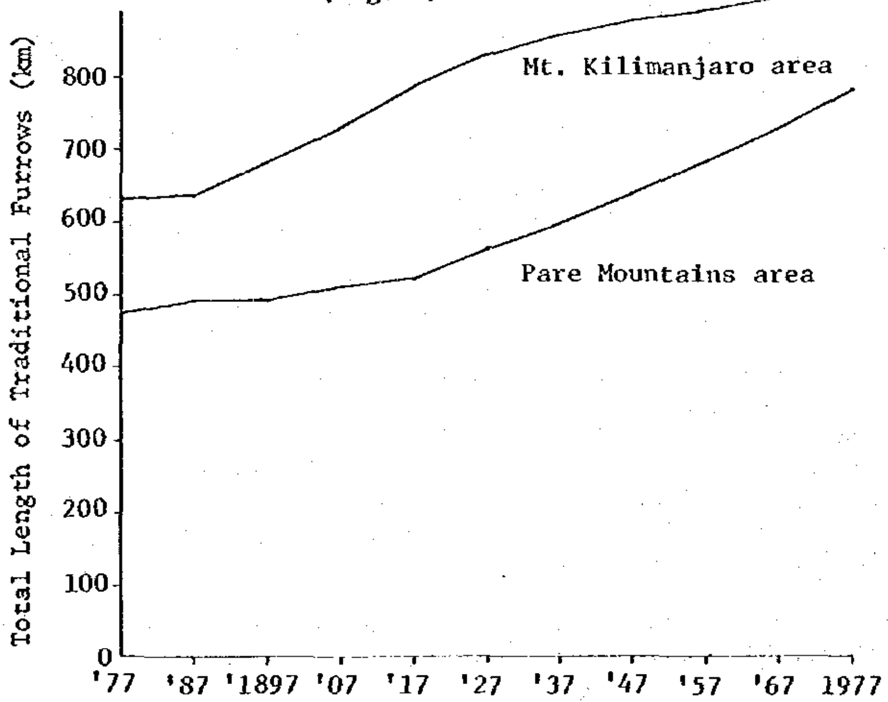
The most conspicuous area is the Mkomazi Valley from Gonja to Kinurio. There is also intensive use of these furrows in the area along the Kisangara and Makanya Rivers on the western slopes of the Pare Mountains.

These furrows have been used for many years in both the Mt. Kilimanjaro and Pare Mountain areas, and about 60% of them are more than 100 years old. Moreover, their numbers are still increasing year by year (Fig.-5).

The water sources of these furrows are surface flow and springs and occasionally reservoirs. The structure of intake is usually a weir made of nearby available materials such as banana stems or stones or a simple diversion canal. There are no flow control devices at intakes, and as these are not permanent structures, repair works are necessary periodically and after heavy floods.

Since most of these furrows are simply dug earth canals, they are constantly subject to erosion and collapse of walls. Therefore, periodical repair and bottom cleaning are necessary as routine maintenance. Usually the width of these furrows is 30 cm to 60 cm, and the depth 30 cm.

Traditional Furrows (Fig.-5)



The major use of traditional furrows is to irrigate agricultural fields of mixed crops of coffee, bananas, and beans on mountain slopes during the months from December through March. Since there is sufficient rainfall for these crops from April through June, no irrigation is required then, and the chief role of furrows during this period is to supply domestic water.

On the other hand, on lower slopes and the alluvial plain below rainfall is unreliable in terms of both distribution and amount. Accordingly, irrigation is required even during the rainy season is some areas and in others gives more satisfactory harvests if provided. Thus, water is used from April through June for agricultural purposes.

Annual water consumption by traditional furrows is given in the table below.

Water Consumption by Traditional Furrows (Table-3)

(unit: million m^3/y)

	Water source					
	Springs		Streams		Total	
Mt. Kilimanjaro area	5.4	(3.4)	78.2	(8.2)	83.6	(11.6)
Pare	8.1	(1.1)	32.3	(1.3)	40.4	(2.4)
Pangani Valley	0		63.1	(0.1)	63.1	(0.1)
Total	13.5	(4.5)	173.6	(9.6)	187.1	(14.1)

Note: Figures in parentheses are for domestic supply.

These furrows are maintained and controlled by local communities. Construction and repair works of main canals or intakes are participated in by members of the local community.

(3) Technical Aspects of Traditional Furrows

As mentioned above, these traditional furrows have been developed by local farmers and made intensive use of by them. However, from a technical point of view, water consumption by means of these furrows involves considerable losses. First of all, as there are no flow control devices at intakes, presumably there is occasionally greater inflow than the amount needed downstream, and water may continue flowing through the furrow even when it is not required, though intake is usually carefully controlled by local people. Also, the simple dugout diversion of intake is always subject to erosion. Consequently, it is strongly recommended to provide water flow control devices in order to take water only in the necessary amounts and only at times when it is needed.

Secondly, conveyance losses, which are permanent losses of a structural nature, are considerable since all of the furrows are earthen canals. On the higher mountain slopes, the gradient of the ground surface is rather steep, which makes it necessary for the furrows to run along contour lines to reduce the velocity of the water. This results in greater length of furrows than on lower slopes. Along their entire length, these earthen canals are constanth subject to erosion and collapse of their walls, which can be a cause of additional leakage.

On the flat alluvial plain below the water flows at a much lower velocity. Accordingly, a large cross section is required, which allows water weeds to grow in the furrow. These water weeds reduce the efficiency of the canal, and transpiration through them is not negligible.

Conveyance losses of well maintained traditional furrows is estimated at approximately 40% of flow per kilometer (see Vol. IV. of Water Master Plan), while for the usual concrete canal it is estimated at 5% to 10%. Therefore, taking future pressure of increasing water demand into consideration, it is recommended to improve intakes and furrow lining.

As shown in Fig. 5, the number of traditional furrows is still increasing. In the Mt. Kilimanjaro area the rate of increase fell during the 1930's, and at present it is 2% a decade. However, there is still a rapid increase in the Pare Mountains of 5% of a decade. If this rate of increase is continued, the increase in water demand for traditional furrows will be 1.6 million m^3 in the Mt. Kilimanjaro area and 2 million m^3 in the Pare area each decade.

At the same time, water use is remarkably high on the slopes of Mt. Kilimanjaro and in the Pare Mountains, especially during Feburary, when the rate of water use reaches almost 90% of total discharge. Since the water sources of these traditional furrows are located on high mountain slope where the headwaters of streams are easily drawn off, this may cause increasingly great drop down of discharge downstream if the number of intakes continues to increase without any controls.

Therefore, taking existing and future demand of downstream areas into consideration, it is necessary to take measures for equitable allocation and control of water among mountain slope areas, lower slopes and alluvial plains, and areas further downstream.

3.4 Underground Water

(1) General

As in the case of water sources for gravitational water supply and traditional furrows, hydrogeological conditions in the region are favourable because of the existence of high mountains.

There are two types of aquifers in the region: one developed in alluvial deposits below the southern slopes of Mt. Kilimanjaro and the other formed along the fault or fructure zone of block faulting along the Pare Mountains.

At present these aquifers are used to draw ground water for water supply and irrigation, and there is potential for greater grounds water development in the region.

Further details are discussed in Vol. III, Hydrogeology, of the Water Master Plan.

(2) Present State of Underground Water Use

All of the bore holes in the region are listed in Table 4, and their location is indicated in Fig.-6.

Below the southern slopes of Mt. Kilimanjaro, there is a flat and wide alluvial plain called the Kahe Basin, where the sub-surface has a basin-like structure and is filled with thick alluvial deposits washed off the mountain slopes. These alluvial deposits developed the most favourable aquifers in the region, yielding ground water from a single hole at a rate in the order of 100 m^3/hr. These aquifers are recharged by rainfall on the mountain slopes, and the recharge rate is estimated at 100 mm/y to 200 mm/y over 500 km^2 of mountain slope (Vol. II., Chap. VI-6, of Water Master Plan).

The most remarkable ground water use in this basin is found in the southwestern corner of the basin, where the Tanganyika Plantation Company is irrigating over 7,800 ha. of sugar cane. Together with surface flow, ground water is used at the rate of about 4,400 m^3/hr (equivalent to 45 cusec of water right). There are 14 production holes on this plantation, the maximum yield from a single hole being 690 m^3/hr. and the others also providing 100 m^3/hr to 490 m^3/hr. The average depth of the holes is 100 m, and water is pumped from various aquifer layers.

Water for T.P.C. irrigation used to be taken from the Kikuletwa River. Since the late 1960's, however, as agricultural acreage grew use began to be made of ground water as well.

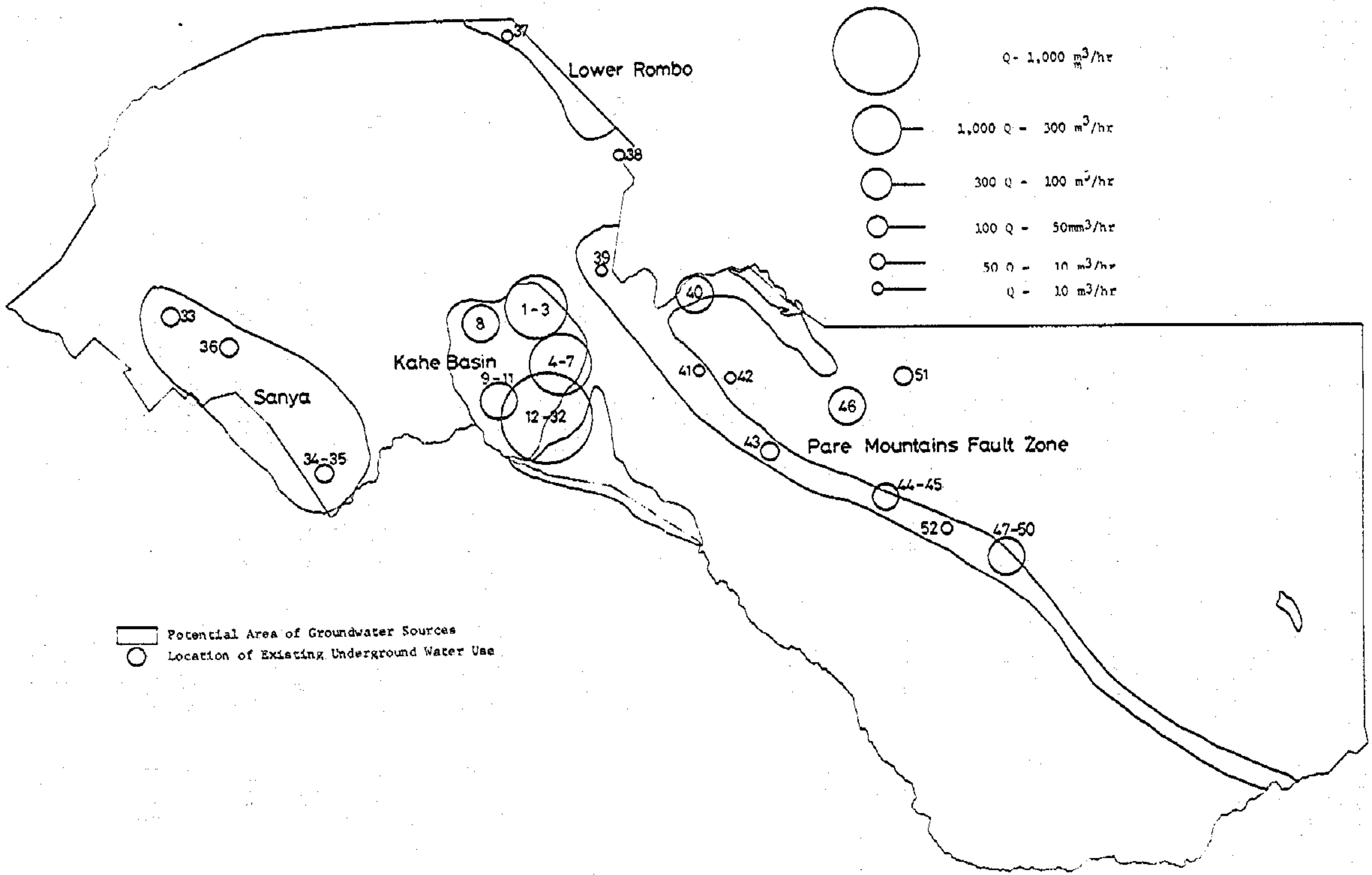
The second greatest use of ground water in the Kahe Basin is in the Miwaleni-Kahe area in the eastern part of the basin. At present seven production wells are under operation at the National Food Cooperation farm, the experimental fields of the Ministry of Agriculture, and some Miwaleni at have villages.

Existing Bore Holes in the Region (Table-4)

	B/H Number	Location	Depth (m)	Water strike	Water level	Draw down	Yield (m^3/hr.)	Specific capacity
Kahe Miwaleni								
1	36/64	Miwaleni	60.0	23-35	3.7	12.5	104	
2	27/65	"	74.0	35-60	8.0	15.0	120.4	
3	29/65	"	67	13, 36 55, 67	2.1	25.0	94.4	
4	8/65	Kahe	61	22.5-50	7.93	10.7	100.3	
5	12/65	"	53	9.15	6.9	11.0	100.3	
6	22/65	"	55	9.15	6.4		173.8	
7	31/71	"	61	7.6	4.3		12.8	
8	60/68	Mandaka	131.2	10, 30, 40	58.0		112.5	
9	21/72	Arusha Chini	91.5	4.9	1.4	3.8	22.2	
10	249/73	"	91.5	1.8	0.9		161.7	
11	47/70	"	161.7	2.1	2.9		161.7	
12	146/72	T.P.C.	97.6		1.4		22.2	
13	8/71	"	91.5		3.3		-	
14	80/70	"	30.5		0.6	-	-	
15	55/69	"	164.6			39.2	493.2	
16	87/69		156.2		2.1		95.8	
17	73/69		61.0		7.0		47.1	
18	21/72		91.4			13.5	690.5	
19	52/71		86.9			22.4	493.2	
20	15/70		155.4			39.6	197.3	
21	201/73		91.5		4.7		10.1	
22	202/73		91.5	6.7	1.0		12.6	
23	221/73		93.0			0.5	493.2	
24	174/73		99.1			5.3	493.2	
25	260/73		91.5		1.0		10.0	
26	33/74		97.5			27.6	443.9	
27	142/74		91.4			16.6	493.2	
28	95/74		97.5	10.7-32.9			266.3	
29	244/74		97.5	22.6	19.5	0.5	197.3	
30	269/74		97.5	Various depths		0.5	29.6	
31	230/74		97.5			0.5	493.2	
32	165/75	T.P.C	91.4			18.3	493.2	

	B/H Number	Location	Depth (m)	Water strike	Water level	Draw down	Yield (m^3/hr.)	Specific capacity
Sanya								
33	28/70	Sanya Juu	89.4	24.4	28.0	28.2	45.6	39
34	104/70	Inter. N. Airport	91.5	82.4	49.7		8.2	
35	82/69	"	91.5	24, 36, 82	30.7	54.6	38.8	
36	12/58	Sanya Juu	61.0	4.9	2.1	–	10.9	
Rombo								
37	7/65	Shoshoro	91.5	94.7 79.3	68.3	85.4	9.6	2.7
38	8/64	Chala	160.1	134, 151	132.2	–	6.0	
39	1/64	Latema	58.5	47.6	46.4	–	9.1	
North Pare								
40	42/53	Kirisini	80.0	24.4	19.8	–	117.0	
41	21/63	Kisangiro	58.3	28.7, 45.7	28.1	–	7.9	
42	12/61	Mwanga		•9, 8, 17.1, 23.4, 25.6			9.1	
43	7/54	Lembem	27.8	10.7	8.2	–	10.9	
44	43/70	Mgagao	152.8	86.1, 122, 152.8	53.7	128.3	2.84	0.5
45	25/52	Ngangau	91.5	83.5	73.2		50.2	
46	24/61	Kimori	94.6	61.0	55		100.3	
South Pare								
47	25/52	Same	81.7	–	39.7	–	112.5	
48	80/69	"	140.3		43.6	–	14.5	6.5
49	17/56	"	80.8	46.1, 74.7	35.4	53.7	8.2	
50	17/52	"	82.0	50.6, 77.8	40	–	11.4	
51	28/61	Ndea	106.8	80, 90	61.0	–	13.7	
52	13/61	Njoro	65.6	48.8, 62.6	47.7	–	9.1	

Present State of Water Use (Fig.-6)



Yield of water from a single hole varies from 94 m^3/hr. to 173 m^3/hr, and the total ground water use in this area is 700 m^3/hr. (2.6 million m^3/y). Various aquifers providing water range from 10 m to 70 m, and the static water level varies from 2 m to 8 m.

To the north of the T.P.C. in the Kahe Basin there are also four production wells, the yields of which range from 12 m^3/hr. to 160 m^3/hr. from various kinds of different aquifers.

The total amount of ground water use in Kahe Basin is 5,500 m^3/hr. (15.2 million m^3/y), 80% of which is at the T.P.C.

The Sanya Plain to the southwest of Mt. Kilimanjaro is covered by Mt. Meru Lahar, which is easily weathered and has partly developed ground water aquifers. There used to be some bore holes and dug wells. At present, however, most of them have been abondonned because of oldness and some contamination by flouride.

At present there are four bore holes in this area, and since squifers are developed in weathered Lahar, the depth of water-holding aquifers ranges from 20 m to 80 m, and the depth of holes is about 90 m. The range of yields of these holes is 10 m^3/hr. to 50 m^3/hr, and a total of 103 m^3/hr. (0.37 million m^3/y) is being used at present.

On the lower eastern slopes of Mt. Kilimanjaro there are three holes. The hydrogeological conditions in this area almost the same as on the southern slopes, but the parts of the continuous lower plain where good aquifers are to be found are located inside Kenya. Therefore, in this area ground water is to be found on lower slopes above major aquifers. This is reflected in the yield of holes in this area, which rangies from 6 m /hr. to 9 m /hr, and the depth of water-holding aquifers, which is greater than 75 m. The total amount of ground water use in this area is 25 m^3/hr. (0.09 million m^3/y). Accordingly, the price of water is rather high compared with other areas in the region. Since no surface water is available, ground water is of very great importance in this area.

In the Pare Mountains, annual rainfall is much less than on Mr. Kilimanjaro. In the fault or fructure zones along block faulting mountains, ground water is available, though the amount is much less than in the Kahe Basin and the water level is deeper. Since there is little rainfall on the western sides of the mountains and the slope is steep, no surface water is available in this area although there is some ground water.

At present there are 13 holes distributed along a narrow strip on the western side of the mountains. The yield of a single hole ranges from 8 m^3/hr. to 120 m^3/hr, and the total amount of ground water use in this area is 467 m^3/hr. (1.7 million m^3/y).

Present State of Ground Water Use (Table-5)

(unit: million m /y)

Area	Domestic supply	Irrigation	Total
Sanya	0.37	0	0.37
Kahe Basin	0.20	15.01	15.22
Lower Rombo	0.09	0	0.09
North Pare	1.09	0	1.09
South Pare	0.62	0	0.62
Total	2.37	15.01	17.38
	13.6 %	86.4 %	100 %

A total amount of 17.38 million m^3/y of ground water is used in the region, 88% of it in the Kahe Basin for irrigation and the rest in other areas for domestic supply only.

4. PRESENT STATE OF WATER USE IN THE REGION

4.1 Water Use by Catchment

Each above-mentioned component of water use in the region will be further analyzed here by catchment in order to determine the present state of water use in major catchment areas (Table6-1 ∿ 4).

(1) Kikuletwa Catchment

This consists of four subcatchment areas (Fig.-2). The total amount of water use in this catchment is 42 million m^3/y, of which 97% is represented by surface water, including spring discharges. The water for the town water supply at Moshi (2.9 million m^3/y) is piped from the Shiri and Nsere Springs in the Weruweru subcatchment.

Most of the water used in this area (80% of total consumption) is consumed by irrigation through traditional furrows distributed in the subcatchments of Kikafu, Weruweru, and Karanga on the western half of southern slope of Mt. Kilimanjaro. The water rights of T.P.C. at Weruweru (5 m^3/s) effect water consumption in the North Pangani area since most of this water is used in that subcatchment area.

A part of the discharge from the Rundugai Spring is utilized for paddy irrigation in the lower part of the Kware subcatchment. However, the rest of it as well as that of the Chokaa and Chemka springs goes to the Kikuletwa Power Station for power generation. Though the discharge from this power station is a rather steady flow, as measured at 1DD54, the flow is not used for any purpose until it reaches the Kahe Basin 10 km below the power station where the river cuts deeply into the lava of the valley bed.

There is only limited use of ground water in this catchment. Total ground water use is only 0.3 million m^3/y, with three piped water supplies in the Sanya subcatchment.

Consumption for domestic purposes amounts to 6.6 million m^3/y, including the urban water supply for Moshi Town, and 8.7% of the water used is consumed in the rural water supply system.

Kikuletwa Catchment (Table-6a)

	Sanya	Kware	Kikafu	Weruweru	Karanga	Total
• Springs	0	(3)				
Irrigation	-	0.072	(24) 0.360	(21) 0.562	(1) 0.058	1.052
Ha	-	10	64	78	8	160 Ha
Domestic P/w	-	0	(2) 0.195	(2) Moshi w/s 2,980	(1) 0.083	3.258 Moshi (2.98)
Population	-	0	11,950	(Moshi town)	800	
Domestic Furrows	-	0.011	(18) 0.457	(19) 0.330	(1) 0.005	0.803
Population			640	9,040	300	
• Streams	*			Excluding T.P.C.		
Irrigation	1.367	(19) 1.382	(19) 10,728	(33) 7.258	(46) 10.361	31.096
Ha	192	188	1,503	1,016	1,376	4,275 Ha
Domestic P/w	(2) 0.440	(1) 0.322	(1) 0.363	0	(2) 0.664	1,789
Population	37,900	9,300	13,400		10,490	
Domestic Furrows	(10) 0.090	0.9	0.9	(29) 0.488	(46) 0.679	0.679
Population						
• Reservoirs	-	-	-	-	-	
Irrigation	-	-	-	-	-	
Ha	-	-	-	-	-	
Domestic P/w	-	-	-	-	-	
Population						
• Ground water						
Irrigation	-	-	-	-	-	
Ha	(37) 0.37	-	-	-	-	0.37
Domestic						
Population						

Note: ( )* Number of schemes.

(2) Ruvu Catchment

This tributary has five subcatchment areas. The Rombo subcatchment is an isolated area on the eastern slopes of Mt. Kilimanjaro. The North Pare and Kisangara subcatchments are located in the North Pare Mountains and on the plain below them. The Himo, Mue, and Rau subcatchments are on the western half of the southern slopes of Mt. Kilimanjaro.

The total amount of water use in this catchment is 98 million m^3/y, which is equivalent to 30% of total regional water use.

Intensive water use by traditional furrows on the eastern half of the southern slopes of Kilimanjaro is one of the remarkable characteristics of water use in the catchment as in the case of the Kikuletwa catchment. However, the most remarkable water use is that of the large-scale farm of the National Food Co-operation (NAFCO) in the low-lying alluvial plain area of the Rau subcatchment. The water source of this farm (33 million m^3/y) is the Miwaleni Spring in the Mue subcatchment, which yields 3 m^3/s, with very little seasonal functuation.

Water use by traditional furrows on the alluvial plain of the Kahe Basin is an another characteristic of this area. The total amount of water use for irrigation by traditional furrows is estimated at 20 million m^3/y, with greatest use in the lower part of the Rau subcatchment area.

Although the total amount of present use of ground water is negligible compared with sourface water use, ground water is an important supplementary water source in this area. As the northeastern half of the Kahe Basin is included in this area, the yield of a single bore hole is about 100 m^3/d. There are seven holes of this scale of yield at NAFCO and Miwaleni. Total ground water use in a part of the Kahe Basin and the fault zone on the western side of North Pare is 3.2 million m^3/y at present and is expected to increase in the future (Technical Report: Hydrogeology, Vol. III of Kilimanjaro Region Water Master Plan).

There are five small earth dams on the mountain slopes of this catchment area which are intensively used for domestic supply and irrigation.

Ruvu Catchment (Table-6b)

	Rau	Kidia	Mue	Himo	Rombo	North Pare	Kisangara	Total
• Springs								
Irrigation	33,106 (9) (0.317)	(10) 0.403	(1)	(1) 0.058	(7) 0.230	(13) 1.469	0	35,583
Ha	KAHE 1492 Tra (44)	72		8	32	204	0	
Domestic P/W	(2) 0.305	(1) 0.009	(1) 0.513	(2) -3.384	(4) -0.508	(1) 0.147	-	4.866
Population	14,800	500	8,100	5,700	25,500	10,500	-	
Domestic Furrow	(22) 0.266	(A) 0.139	(6) 0.034	2,025	0.123	(33) 0.460	(5) 0.048	3.095
Population	11,000	25,000		9,030				
• Streams								
Irrigation	(62) 19,763	(15) 2,376	(14) 3.427	(36) 7.769	(12) 2.131	(22) 2.592	(11) 0.835	38.893
Ha	2,800	322	489	710	296	360	116	
Domestic P/W	(2) 0.308	(1) 0.047	0	(4) 604	(3) 0.543	(4) 0.196	(2) 0.812	2.510
Population	15,000	2,200	0	28,200	24,800	8,600	11,500	
Domestic Furrows	0.756	(14) 0.101	(14) 0.207	0.505	0.207	(21) 0.114	(11) 0.334	2.224
Population	26,000	77,000	12,300	30,039				
• Reservoirs								
Irrigation			(2) 0.605		(1) 0.576	(2) 2.160		3.431
Ha			84		80	300		
Domestic P/W		(1) 0.411	(1) 0.288			-	-	0.699
Population		4,400	4,000			-	-	
Domestic Furrows			0		(1) 0.017			0.017
Population			0		1,000			
• Ground Water	Kahe (1) 1.147				0			
Irrigation			(3) 0.547		-	-	-	1,694
Ha	44		76		-	-	-	
Domestic	(4) 0.200	(1) 0.033			(3) 0.089	(15) 1.090	(2) 0.061	1.474
Population	2,100	1,500			1,000	7,000	3,000	
Total	56,168	3,519	5,621	14,345	4,407	8,245	2.09	94,396

(3) Pangani Valley

This catchment area consiste of the south western half of the Kahe Basin in the north, the western half of the South Pare mountain slopes, and the alluvial plain along the Pangani River. The total amount of water consumption in this catchment is 161 million m /y, which is 50% of the total water use in the region. Surface flow accounts for 90%.

In the southwestern part of the Kahe Basin almost 50% of total water use is accounted for by irrigation of 7,800 ha. of sugar cane at TPC. Water sources for this irrigation are the Kikuletwa River, including its tributary the Warweru (74 million m^3/y), and ground water (13 million m^3/y). Since TPC is located in the Kahe Basin, abundant ground water is available the yield of a single hole ranging from 200 m^3/h to 690 m^3/h. There are 14 production wells on this farm. The rest of the ground water use in this area occurs on the western slopes of the South Pare mountains, where there is no surface water.

The second greatest water consumption in this catchment is that of irrigation water by farms downstream of the Nyumba ya Mungu Dam. Total water use in this area is 63 million m^3/y, the source being the River. .

Traditional furrows are also intensively utilized on the western slopes of the South Pare mountains, the total amount of water use being 14 million m^3/y.

Since the greater part of the water is used for irrigation of plantations, the amount of domestic supply is relatively small (3%) in this catchment.

(4) Mkomazi Valley

The total amount of water use in this catchment is 27 million m^3/y, and it is consumed mainly on the eastern mountain slopes of South Pare and the alluvial plain in the Mkomazi Valley. Ground water is used only in the Mkomazi Game Reserve area and for domestic purposes only (0.05 million m^3/y), the source of the rest of the water being surface water, of which 9% is supplied from springs.

Almost all of the water is used for irrigation (94 million m^3/y), only 1.6 million m^3/y being used for domestic purposes.

Pangani Valley (Table-6c)

	North Pangani	S. Pangani	Mailanya	Total
• Springs	0	0		
Irrigation	0	0	(21) 2.959	2.959
Ha	0	0	411	
Domestic P/W	0	0	0	
Q Population	0	0	0	
Domestic furrows	0	0	(35) 0.390	0.390
Population	0	0		2 m^3/sec.
• Streams	Most of the amount comes from the Weru-weru			
Irrigation	(16) 74.174	(8) 32.1 8.986	(51) 5.782	143.056 1 cusec 50 acre
Ha	T.P.C. 5,800 Tradi (114)	1,248	803	
Domestic P/W	0	Trad. 0	(3) 0.284	0.284
Population	0	0	13,970	
Domestic furrows	(16) 0.021	(11) 0.070	(51) 0.484	0.575
Population	1,470			
• *Reservoirs*				
Irrigation		0		
Ha		0		
Domestic P/W	0.015	0		0.015
Population	700	0		
Domestic furrows		0		
Population		0		
• Ground water				13,316 50 acres per cusec
Irrigation	(18) T.P.C. 13,316			
Ha	2,000			
Domestic	(13) 0.128	(15) 0.156		0.284
Population	5,000	6,000		

There is intensive use of traditional furrows on mountain slope. However, more than half of the total water use is for paddy and maize irrigation on the alluvial plain of the valley.

In this valley water from the Kalimawe Dam is used for irrigation of paddy rice, maize, and cotton at the rate of 10 million m^3/y.

Mkomazi Valley (Table-6d)

• Springs		• Reservoirs	
Irrigation	(14) 2.462	Irrigation	(1) 10.300
Ha	342	Ha	1,448
Domestic P/W	(1) 0.024	Domestic P/W	-
Q Population	3.322	Population	-
Domestic furrows	0.165	• Ground Water	
Population		Irrigation	
• Steams		Domestic P/W	(1) 0.005
Irrigation	(30) 12.435	Population	
Ha	1,252		
Domestic P/W	(13) 0.840		
Population	11,200		
Domestic furrow	0.375		
Population			

4.2 Summary of Present State of Water Use

Total annual water consumption in the region is estimated at 325 million m^3/, of which irrigation water accounts for 91.5%. Moreover, 30% of the irrigation water consumed by the large-scale NAFCO and TPC forms, the rest being utilized by local farmers by means of traditional furrows. This state of present water use presents a prespective of intensive agricultural activities in the region in the region in spite of senere spatial limitations. (see Table-7).

The remainding 8.5% (27.6 million m^3/y) of total water use is accounted for by sources of domestic supply, gravitational water supply schemes accounting for 60% (16.8 million m^3/y) and domestic supply through furrows for the remaining 40% (10.8 million m^3/y). These figures indicate much better water supply services in the region than in other regions. Many springs are preferentially utilized as water sources for domestic supply.

The main water source is surface water (95-6% of total use), and utilization of reservoirs is noteable at Kalimawe (10 million m^3/y). Besides this, however, there is only the 3.3 million m^3/y in the Ruvu catchment area, though the Nyumba ya Mungu reservoir indirectly serves irrigation schemes downstream.

The contribution of ground water to total water use in the region is rather small (5.4%; 17.4 million m^3/y). However, in consideration of its widespread availability, it is utilized intensively at Miwaleni, Kahe and TPC, where there are well-developed aquifers among alluvial deposits in the Kahe Basin. The rest of ground water use occurs only in a few areas where there is no surface water available.

Present State of Water Use (Table-7)

Catchment	Surface Water				Ground Water			
	Irrigation	Domestic pipelines	Domestic furrows	Total	Irrigation	Domestic	Total	Total
Kikuletwa	32.148	5.047	1.482	38.677	0	0.370	0.37	39.047
Ruvu	78.997	8.075	7.775	94.847	1.694	1.474	3.168	98.015
Pangani Valley	146.015	0.299	1.025	147.339	13.316	0.521	13.837	161.176
Mkomazi	25.200	1.005	0.540	26.745	-	0.005	0.005	26.750
Total	282.36	14.426	10.822	307.608	15.0	2.370	17.380	324.988

Note:	Total water use	324.988 million m^3/y	
	Irrigation	297.36	91.5%
	Domestic	27.618	8.5%
	(Pipelines	16.796	
	Furrows)	10.822	
	Surface water	281.782	95.6%
	G/W	17.380	4.4%

5. WATER RESOURCES IN THE REGION

5.1 Rainfall

Rainfall is the first input of water resources, and the greater part of agricultural production in the region depends directly on it.

Where rainfall conditions are favourable, the efficiency of indirect water use by reservoir or ground water is less than that of direct water use.

Rainwater, upon reaching on the ground surface, is immediately absorbed to a certain extent by the soil in shallow layers and then is subject to evaporation during fine weather, especially when the soil layers are developed from crystalline metamorphic rocks. This is a typical phenomena in areas where rainfall is caused by convectional disturbance of air masses. For this reason, the run-off coefficient is relatively small in such areas. The loss of water in this way is as much as 40% - 50% of total annual rainfall even in areas with the most favourable rainfall conditions in the region (see Technical Report Vol. II of Water Master Plan). This shenomenon is called as a "loss" in discharge analysis. When it occurs on agricultural plots, however, it represents water consumption by crops, which results in production gains.

After reduction of rainwater by heavy losses, discharge occurs, with some flow into reservoirs. When the reservoir is located in a low-lying depression or valley bottom, the area around the dam and downstream of it have been subject to heavy evaporation for thousands of years. This may have resulted in accumulation of salts in the area, and this may cause heavy evaporation losses. Accordingly irrigation schemes undertaken in such cases are characterized by evaporation loss in poor soil conditions.

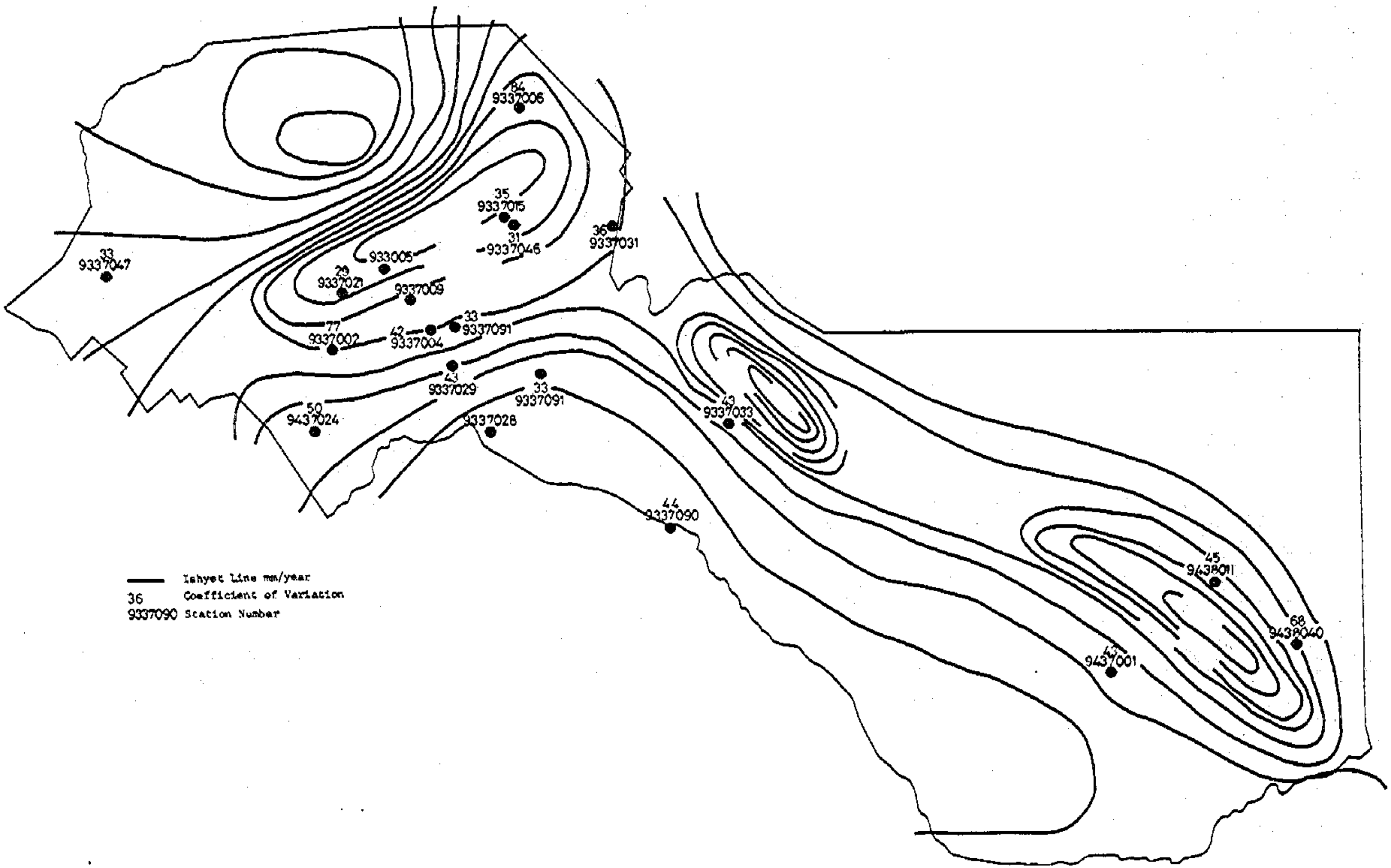
Needless to say, irrigation is important and necessary in the region for achievement of efficient use of limited water resources. However, it should be borne in mind that rain-fed agriculture plays a major role in agricultural production in the region for all but a few kinds of crops.

The most important aspects of rainfall are total amount, seasonal distribution, and annual variation. The distribution pattern of annual rainfall in the region shows two isolated islands of high rainfall level. The southeastern slopes of Mt. Kilimanjaro and the Pare Mountains (see Fig.-7 & -8). As a matter of fact, the areas of favourable distribution and low variability of monthly rain coincide with these two isolated areas (Technical Report Vol. III of Water Master Plan).

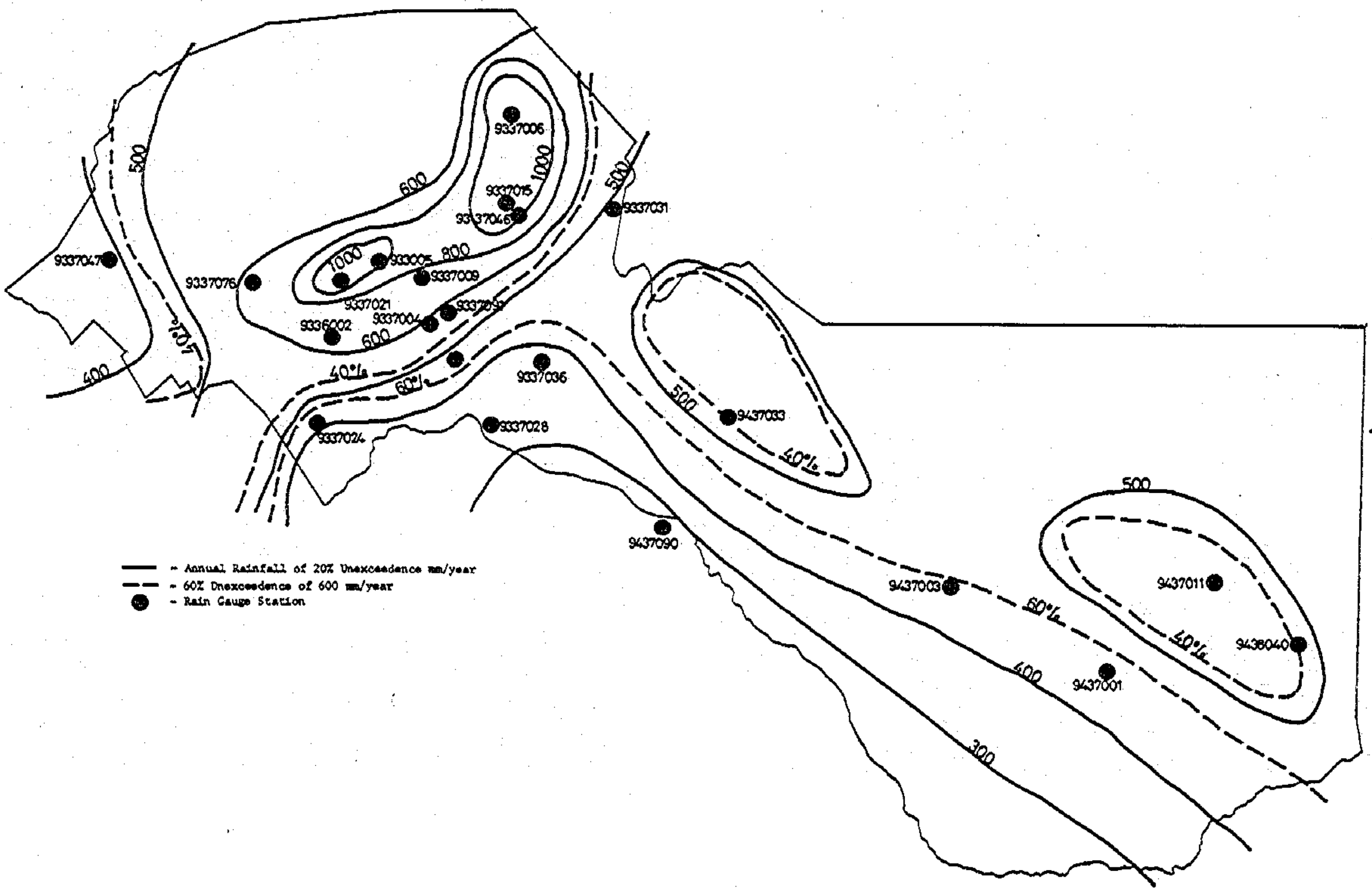
These areas have been intensively developed by local farmers, and at present overpopulation is one of their social problems. At the same time, these areas have been playing a major role in agricultural production and will continue to do so in the future.

Rainfall conditions in the rest of the region are not as favourable for agriculture as in the areas mentioned above because of either insufficient amount or unreliable distribution. As rapidly growing population is expected to exert increasing preasure on the land, areas receiving only a medium amount of rainfall, say, more than 600 mm/y, should be made greater use of in the future, through the cultivation of rain-fed crops resistant to dry weather. Nevertheless, it should be noted that even such areas are limited in the region (Fig.-7).

Mean Annual Rainfall and Coefficient of Variation (Fig.-7)



Annual Rainfall 20% unexceedence (Fig.-8)



5.2 Surface Water

(1) Introduction

The water balance of the region is analysed here by catchment area in order to determine the present adequacy of surface water resources.

The amount of present water use as ascertained by detailed field survey and a list of all of water use facilities in the region are given in the Technical Report Vol. VII of the Water Master Plan.

Discharge cycles of 2 years and 5 years are assumed for comparison of discharge with the amount of water consumed in each subcatchment. The 5-year cycle (20% nonexceedence probability) is not arbitrary but rather as the threshold at which water shortage starts in most subcatchment areas in the region.

The results are summarized in Table 8 and shown in Fig. 9. The seasonal water balance is also analysed in detail in this Chapter.

(2) Water Balance of Tributaries

During an average year the total discharge of the Kikuletwa catchment is 703 million m^3, and during a year of 20% nonexceedence it is 30% less, or 508 million m^3. Because of the large inflow from the Chemka and Chockaa springs (40% of total discharge in an average year), variation in annual discharge of this tributary is relatively small. However, variation in surface discharge from each subcatchment of Kikuletwa is much greater than that of the mainstream measured at IDDI.

Discharge from the Ruvu is estimated at 552 million m^3, and 40% less or 334 million m^3 in a year of 20% nonexceedence. Since there is only one major spring, Miwaleni Spring (3 m^3/s), in this catchment, variation of annual discharge is greater than in the Kikuletwa catchment.

However, the discharge measured at IDC2A had the same variation as the Kikuletwa main stream at IDDI because of the buffer effect of Lake Jipe.

These subcatchments on the southern slopes of Mr. Kilimanjaro account for 40% and 57%, respectively, of the total discharges of the Kikuletwa and Ruvu rivers.

At the same time, there is intensive water use in these subcatchment areas. Almost 10% of total annual discharge is consumed in the subcatchments of Kikafu, Weruweru, and Karanga. Annual water consumption in each of these subcatchments is about 10 million m^3. However, water consumption in the Mue and Rau subcatchments of the Ruvu catchment is 30% of total discharge, which is much higher than that in the Kikuletwa subcatchments. These figures reflect intensive agricultural activities in these areas.

(3) Water Balance of Mainstream of River

Annual inflow from the Kikuletwa and Ruvu rivers into the Nyumba ya Mungu reservoir is estimated as follows.

	50% nonexceedence	20% nonexceedence
Kikuletwa	703.3 million m /y	507.7 million m /y
	(22.3 m^3/s)	(16.1 m^3/s)
Ruvu	551.9 million m^3/y	334.3 million m^3/y
	(17.5 m^3/s)	(10.6 m^3/s)

Though the efficiency of this reservoir is large (1890), losses appear to be rather high. Annual losses are estimated at 448.7 million m^3 (8.2 mm/d, 14.2 m^3/s) and are presumably caused by evaporation. (Chap. II, Technical Report, Vol. IV of Water Master Plan). Accordingly, the net inflow to the dam is only 26.8 m^3/s in an average year and 13.0 m^3/s in a year of 20% nonexceedence.

The main purposes of this dam are to control flow for irrigation schemes and the Hale Power Station downstream, which is especially important when other major power station have operational troubles.

Accordingly, the dam has to meet minimum water demand downstream and at the same time keep the water level sufficiently high for generation of hydroelectric power when it is required.

The minimum requirement downstream of the dam is estimated at 748.8 million m^3/y at present.

Hale Power Station	544.3 million m^3/y	
Existing irrigation schemes	32.1	"
Losses from main river channel	172.8	"
Minimum water requirement downstream	748.8	

The average monthly minimum requirement is estimated at 24.7 m^3/s, with fluctuation between 15 m^3/s and 30 m^3/s. As shown in Table-9, the operational condition of the dam is tight, for total inflow in an average year is 1,293 million m^3 while the minimum requirement of water downstream is 1,217 million m^3. Even in an average year, monthly inflow exceeds monthly minimum discharge only during the period of April - July.

In a year of 20% nonexceedence it exceeds required discharge only in April and May. Accordingly, in a hydrological year of 20% nonexceedence when the dam is operated to meet the minimum water requirement downstream, its storage will be reduced by 334.6 million m^3. If the water level is higher than 130 ft at the beginning of such a year, it will be reduced by 10 ft, and if the initial water level is less than 120 ft, it will be reduced by 15 ft by the end of the year, resulting in heavy reduction of potential for hydroelectric power generation at the dam. Though very rarely is there 20% nonexceedence in consecutive two years, power generation capacity will be considerably reduced.

Annual water use downstream of the dam amounts to 32.1 million m^3, which is taken from the Pangani main river course. There are eight irrigation schemes in the area. At the same time, there is intensive water use by means of traditional furrows on the western slopes of the South Pare mountains. Total annual water use in the area is 14.8 million m^3, which is equvalent to 10% of the total discharge of the area. However, the area in which this water is used is restricted to mountain slopes as the rest of this vast catchment is scareely populated because of severe climatic conditions.

(4) Mkomazi Valley

The main surface water source is the headwaters of various streams on the eastern mountain slopes of South Pare Mountains in the Mkomazi II subcatchment, the discharge from the Mkomazi I subcatchment being minimum since the greater part of it consists of the rather flat land of the Mkomazi Game Reserve. For the same reason as in the case of the Mkomazi I, subcatchment discharge from the Mkomazi III subcatchment is also very low. Consequently, population and agricultural activity are concentrated only in the Mkomazi II area (Technical Report Vol. V and VI of Water Master Plan).

The total discharge in this valley is estimated at 98.2 million m^3/y, of which 78.5 million m^3/y is accounted for by the Mkomazi II subcatchment area.

Water use in this catchment is as high as 35% of annual total discharge. Kilimawe dam is made good use of for irrigation of rice paddies and maize fields. The total amount of water used from this reservoir is estimated at 10 million m^3/y.

(5) Monthly Water Balance by Catchment Area

A major portion of agricultural water is consumed by way of traditional furrows. There are two types of water use patterns of traditional furrows. One prevails on mountain slopes where annual rainfall exceeds 800 mm, and the other is found where annual rainfall is less (Fig.-7). The difference between the two is due to the distribution of monthly rainfall. Usually there are two peaks of monthly rainfall in the region, one during November and December and the other from April to May. The former peak is lower than the latter in most cases.

Water use by way of traditional furrows on mountain slopes during the first rainfall peak is for irrigation of permanent crops of coffee and bananas starting in December. After March irrigation is not necessary since the second peak of rain provides crops with a sufficient amount of water. As most of the furrows for this purpose are supplied from the headwaters of mountain streams, water is easily available, and the total amount of consumption is much greater than in the case of the second type of furrows.

Water use by way of the second type of furrows prevails on lower mountain slopes and flat alluvial plains along rivers below. In these areas, the amount and distribution of rainfall during the first rainfall peak are unfavourable for cultivation, and the water level of the streams from which furrow water is taken is insufficiently high for the water to be drawn. Therefore water use by way of furrows of this type takes place during the second rainfall peak from March to June as a supplement to rainfall when the water level of streams is high enough on lower slopes and the plains below.

Irrigation secuirs during the first rainfall peak where water is available from large springs such as those of Miwaleni and Rundugai.

As shown in Fig.-10, it should be noted that the rate of water consumption is considerably high during the first peak of rainfall. It is remarkable that in most subcatchment areas on mountain slopes there is a water shortage during January and February in years of 20% nonexceedence.

There is a surplus of water in the Mue and Himo subcatchment areas during these months. Since distribution of seasonal rainfall in the Himo subcatchment area is more favourable than in any of the other areas, irrigation is less necessary in this area. In the Mue subcatchment the main water source is the Miwaleni Spring the same being true of the Kware subcatchment area as well.

There is a large surplus in North Pangani, but this is the water source for the Nyumba ya Mungu Dam (Chap. VII Technical Report Vol. II of the Water Master Plan), and the surplus in South Pangani is the minimum flow need for the Hale Power Station.

(6) Conclusion

Because of the high mountains in the region the region, the general state of surface water resources is rather good in compalison with other regions. However, water is already being used considerably wherever it is available, and because of the need to maintain satisfactory, operation of the Nyumba ya Mungu Dam there is only a limited surplus of surface water resources in the region.

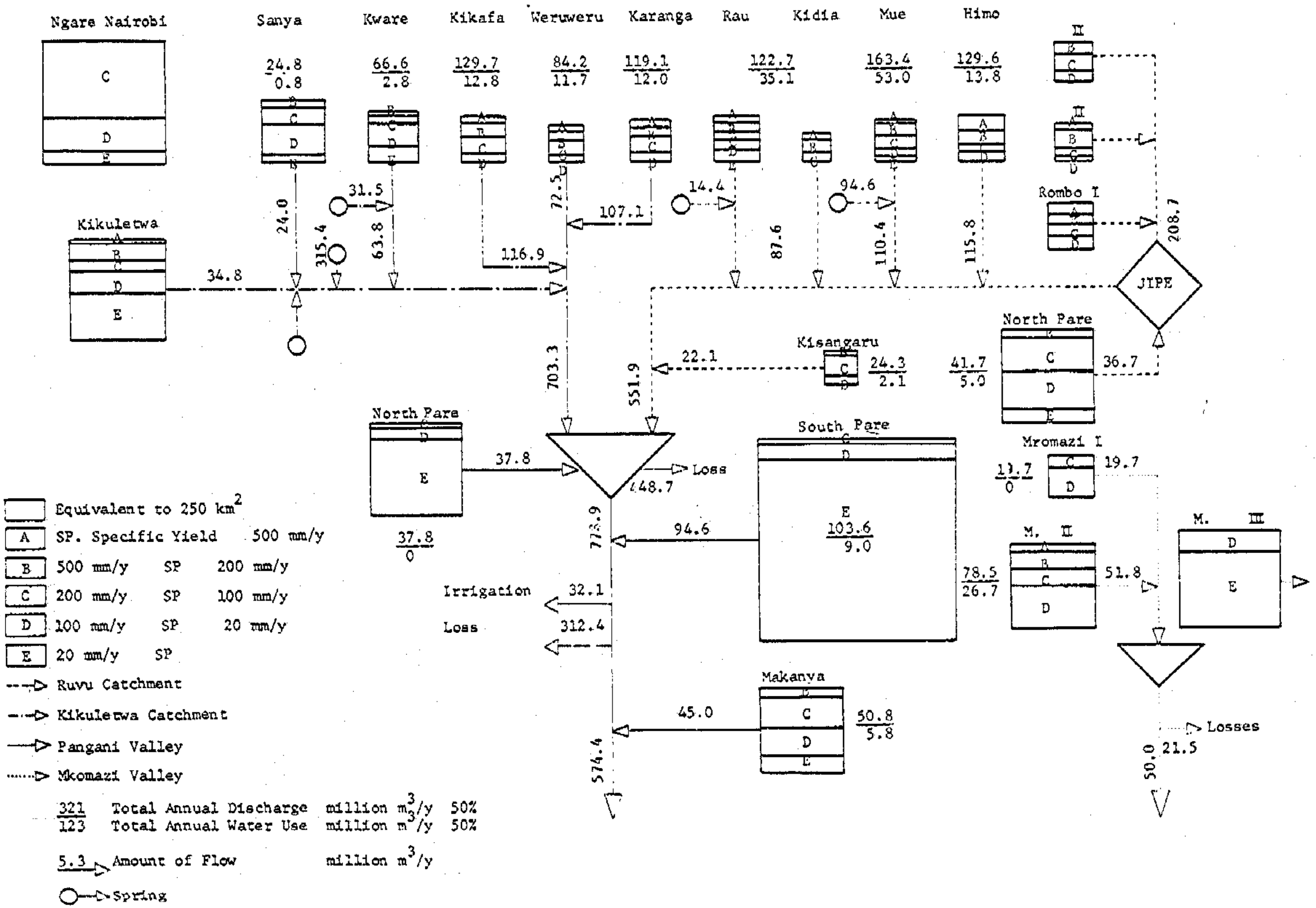
It can be concluded that water consumption is fairly high in subcatchment areas on mountain slopes and the plains below where the specific yield is large. The percentage of the available amount of water representedly water consumption is extremely high during January and February.

Furthermore, there is a shortage of water during the same period in years of 20% nonexceedence. In addition to this the operation condition of the Nyumba ya Mungu dam is rather tight. Therefore there is no large surplus of surface water for immediate purposes in the region. At the same time, present water use systems involve a large amount of loss. Accordingly, it is recommended that present water use systems be improved to prevent losses and to obtain maximum output with limited water resources through the establishment of most efficient water use methods.

Discharge of Major Streams to Nyumba Ya Mungu (m^3/sec.) (Table-8)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
50%													
1DC2A	5.3	5.7	6.9	6.4	5.3	6.3	9.3	11.3	7.7	6.7	6.3	5.7	6.9
Himo	1.6	3.1	2.6	2.2	2.7	5.8	10.0	8.4	5.2	1.6	0.6	0.8	3.7
Mue	3.7	4.2	1.0	0.6	0.6	2.6	8.0	6.8	4.9	3.2	3.7	3.3	3.6
Rau	1.4	0.2	0.9	0.03	0.1	3.7	12.0	3.2	6.3	2.2	1.4	0.7	2.7
Kisangara	0.4	1.4	1.2	0.4	0.7	1.6	2.1	0.7	0.05	0	0.04	0.1	0.7
Direct in Flow	0.8	2.3	1.7	0.5	1.0	2.4	3.4	1.3	0.2	0.1	0.2	0.2	1.2
Iddi	13.0	15.2	17.0	16.2	14.0	15.2	34.0	54.4	33.5	24.0	17.0	14.0	27.3
Total	26	32.1	31.3	26.3	24.4	37.6	78.8	86.1	57.9	37.8	29.2	24.8	41.0
20%													
1DC2A	4.3	4.2	5.4	5.0	4.0	4.5	5.5	8.1	5.3	4.5	4.8	4.7	5.0
Himo	0.5	1.2	0.2	0.6	0.6	1.0	5.1	4.6	3.1	0.9	0.6	0.4	1.5
Mue	3.2	3.4	0	0	0	0.5	5.4	4.4	3.8	2.7	3.6	3.2	2.5
Rau	0.4	0.8	0	0	0	0	4.2	2.6	3.4	1.2	1.2	0.5	1.2
Kisangara	0.1	0.1	0.2	0.2	0.6	0.3	1.6	0.4	0.03	0	0.01	0	0.3
Direct in Flow	0.4	1.2	0.7	0.1	0.3	1.0	1.7	0.7	0.1	0.1	0.1	0.1	0.5
Iddi	11.0	9.6	10.8	11.0	11.0	11.7	23.0	38.0	23.0	19.0	13.7	11.8	16.1
Total	19.9	20.6	17.3	16.4	16.5	19.0	46.4	58.8	38.7	28.4	24.0	20.7	27.2

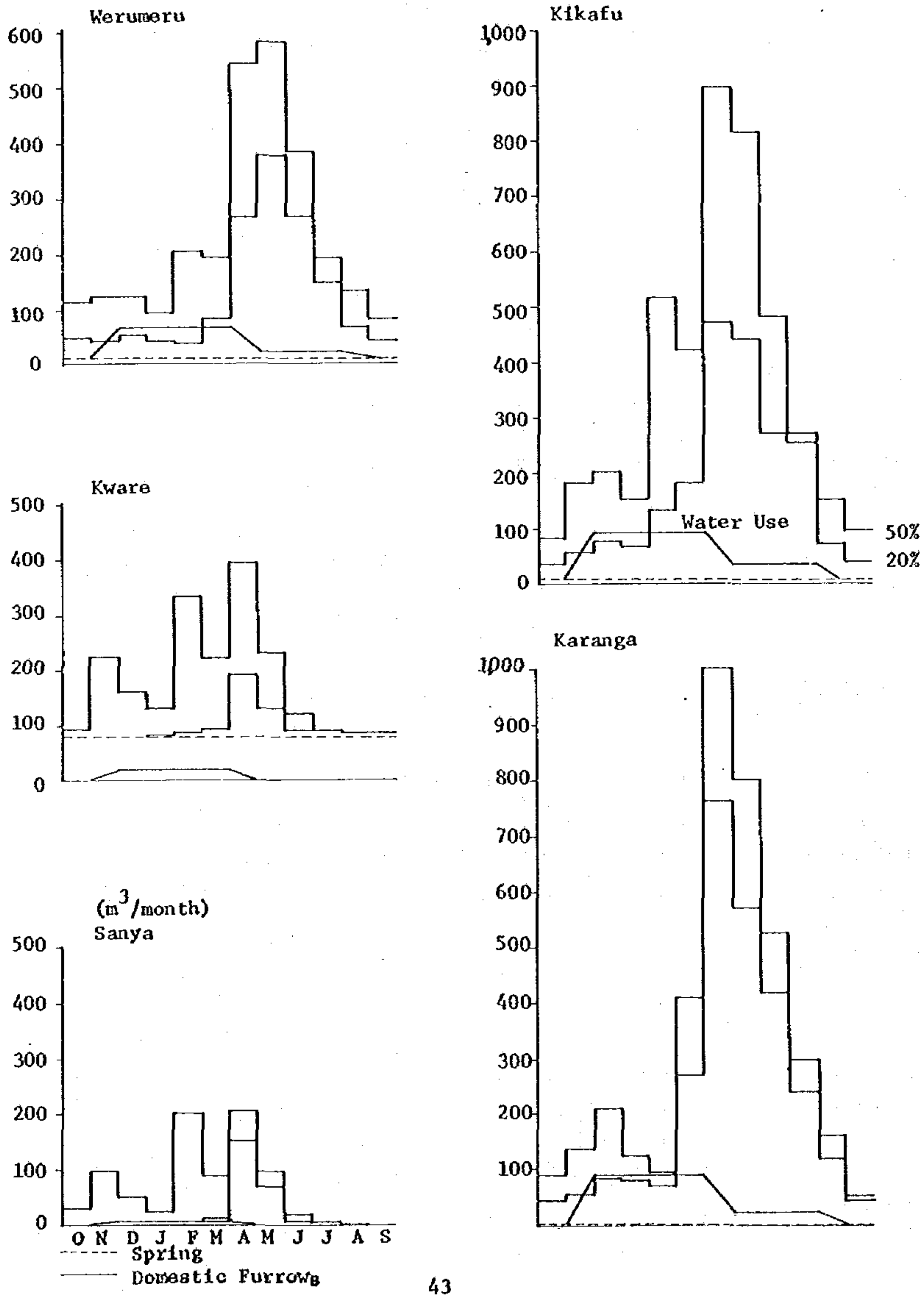
Balance of Surface Water (Fig.-9)



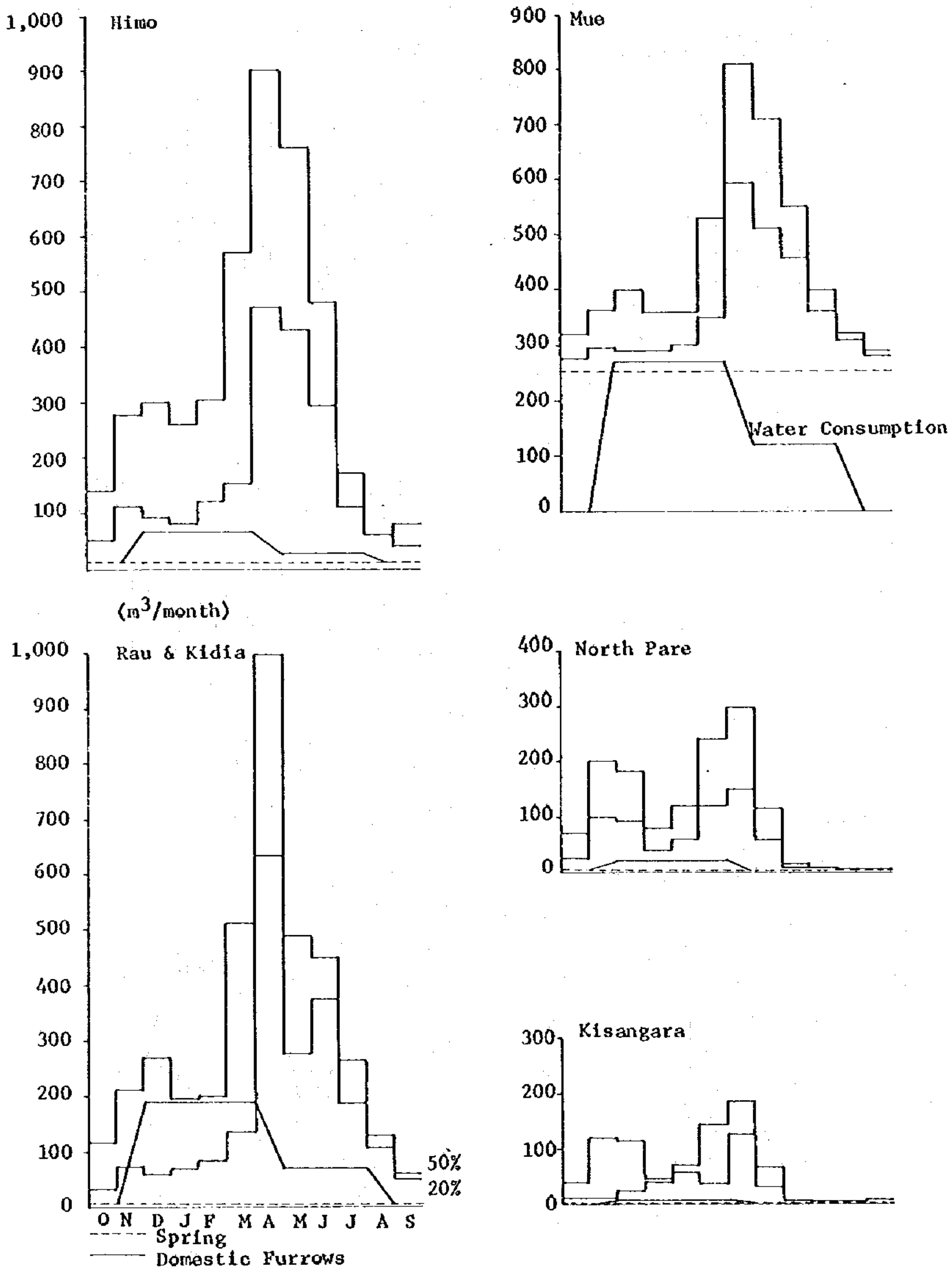
Surface Water Balance (million m^3/y) (Table-9)

Catchment	50% nonexceedence			20% nonexceedence		
	Total	Water Use	Net Discharge	Total Discharge	Water Use	Net Discharge
• Kikuletwa						
Kikuleiwa			37.8			16.4
Sanya	24.8	0.8	24.0	7.5	0.6	6.9
Springs *	–	–	315.4	–	–	315.4
1DD52			394.2			358.7
Kware	66.6	2.8	63.8	36.9	2.8	34.1
Kikafu	129.7	12.8	116.9	12.4	12.4	49.3
Weruweru	84.2	11.7	72.5	4.8	4.8	35.9
Karanga	119.1	12.0	107.1	10.5	10.5	74.2
Loss			31.2			-24.5
Iddi			703.3			507.7
• Ruvu						
North Pare	41.7	5.0	36.7	21.9	5.0	16.9
1DC2A	217.6		217.6			157.7
Himo	129.6	13.8	115.8	61.2	10.7	50.8
Mue	163.4	53.0	110.4	130.3	51.5	79.1
Rau	122.7	35.1	87.6	64.8	28.2	36.9
Kisangara	24.3	2.1	22.1	11.0	1.2	9.8
Loss			-1.6			
			551.9			334.3
• Pangani Valley						
Direct in flow	N. Pancani		37.8			18.9
Total in flow	to N ya	37.8+703.3+551.9=1,293.0				
	Mungu	Loss *2			Loss *2	
Inflow	1,293.0	448.7	844.3	860.9	448.7	412.2
Disch 168C	778.9	32.1	746.8	778.9	32.1	746.8*
South Pangani	103.6	9.0	94.6			47.3
Makanya	50.8	5.8	45.0			22.5
Loss			-312.4			-242.2
1D12			574.4			674.4
Minimum Requirement at 1612			551.9			551.9
Mkomazi I	19.7	0	19.7	9.9	0	9.9
Mkomazi II	78.5	26.7	51.8	48.4	24.7	23.7
			-21.5			-10.1
Loss			50.0			23.5
To Tanga						

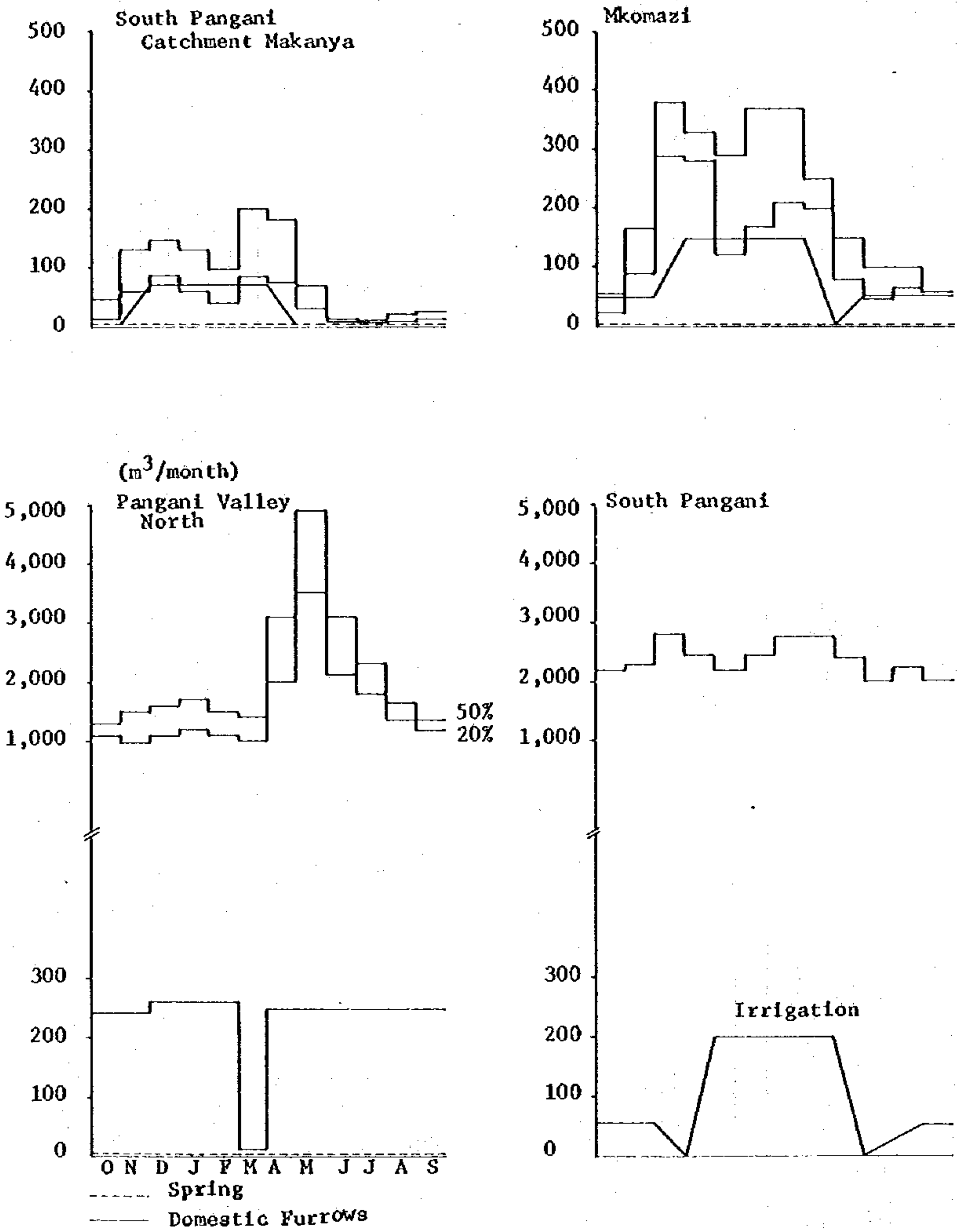
Monthly Water Balance of Surface Flow Kikuleture Catchment (Fig.-10a)



Ruvu Catchment (Fig.-10b)



Surface Water Balance (Fig.-10c)



5.3 Ground Water

(1) Introduction

As discussed in the previous chapter, there is intensive use of ground water in the region, though only in a few areas. From a hydrogeological point of view, the ground water sources of the region can be classified into three categories:

Ground water in structural basin deposits
Ground water in weathered volvanic deposits
Ground water in fracture and fault zones

The location of ground water sources in the region is summarized in Fig.-11. Further details are discussed in the Technical Report, Vol. III, Hydrogeology, of the Water Master Plan.

(2) Ground Water in Structural Basin

The ground water in the Kahe Basin falls under this category. This basin is located at the north end of the Pangani Trough between the fault of the Pare Mountains to the east and the Lelatema fault to the west. The northern end of the trough is blocked by the massive rise of the tertiary volcano, Mr. Kilimanjaro, and to the south the basement of a precambrian formation rises up to the ground surface around the Nyumba ya Mungu Dam. Though the Kikuletwa River passes through the western end of the basin, most of this basin is incorporated in the Rau and Mue river regime.

This structural basin underlain by a precambrian basement of metamorphic rocks is filled with thick alluvial and volcanic deposits mainly consisting of clay, sand, gravel and other materials of volcanic origin. These layers are un consolidated and are favourable for holding water. The maximum depth of these deposits is presumably greater than 100 m.

Recharge of ground water in this basin, estimated at million 350 m^3/y, occurs on the southern slopes of Mt. Kilimanjaro. At present almost 50% of the toral storage including the discharge of the Miwaleni Spring is used in the Kahe Basin. It would presumably possible to develop an additional 50 million m^3/y of ground water resources in this basin in the future.

Since ground water is held in different kinds of aquifers, their physical characteristics vary from place to place, and maximum safe yield from depths between 10 m and 70 m ranges from 10 m^3/h. to 500 m^3/h.

(3) Ground Water in Weathered Volcanic Deposits

Ground water in the Sanya area falls under this category, and that in the lower Rombo area has the characteristics of both Category 1 and Category 2.

(i) Sanya Area

This are is extensively covered by Meru Lahar, which is rather easily weathered and strata suitable for holding water are developed. However, the maximum rate of safe yield in this area is much less than in the Kahe Basin. Since hydrogeological surveys of this area have not yet been completed, only limited information is available on the details of condition of yield. The safe yield of ground water in this area varies from 10 m^3/h to 40 m^3/h, and the depth of water holding strata ranges from 20 m to 80 m.

There is occasional fluoride contamination in this area. Nevertheless it is absolutely necessary to develop ground water sources to a high degree of efficiency since in most of the area surface water is not available.

(ii) Lower Rombo

The hydrogeological situation in this area is similar to that on the upper slopes of the Kahe Basin. Since this area covers only lower mountain slopes and down further the area, which presumably is suited for ground water storage, lies across the national boundary with Kenya, it is rather difficult to detect water holding strata below lava. For the same reason, the location of aquifers is rather is high, and the general state of production is less favourable than in the Sanya area. However, the possibilities of ground water development in the area should be further examined as no surface water is available.

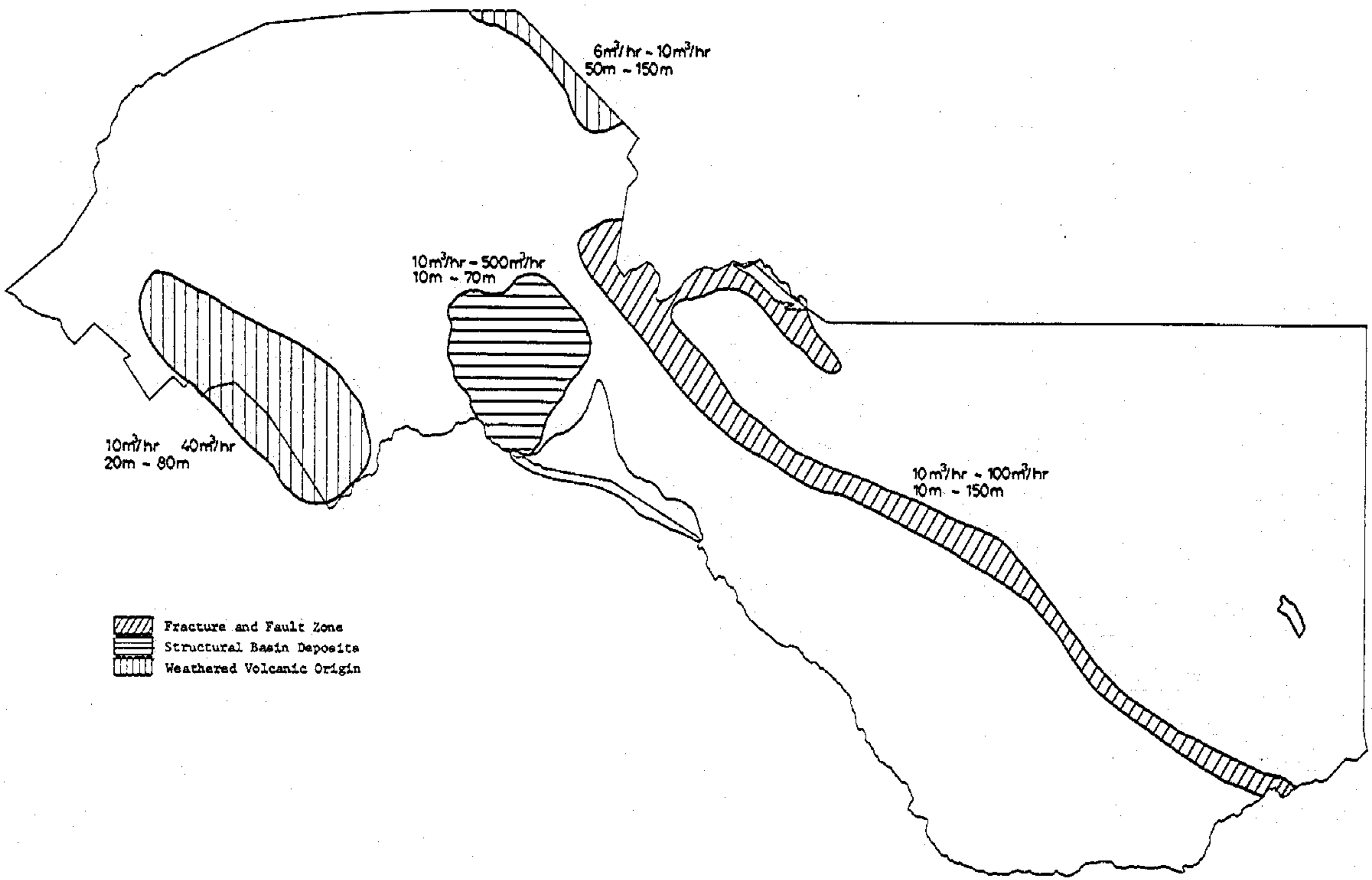
(4) Ground Water in Fracture and Fault Zone

From a hydrogeological point of view, the origin of equifers under this category is different from that of the aquifers mentioned above. In this case water holding strata are found in the fracture or fault zone along the block faulting of the Pare Mountains. Consequently, aquifers are to be found only along a narrow strip, and yield varies considerably within a short distance.

Maximum safe yield in this area, on which the depth of the water holding strata (10 m - 150 m) has no bearing varies from 10 m^3/h to 100 m^3/h.

Although there is a salinity problem in some cases, this area is more favourable in terms of productivity than the Sanya area. Moreover, ground water will be further developed in the future for domestic purposes since there is no surface water available.

Potential of Ground water (Fig.-11)



6. DSTRIBUTION OF WATER RESOURCES IN THE REGION

The water resources of the region are to be found in those areas where specific yield is satisfactorily high and conditions are favourable for ground water storage, and this will continue to be the case in the future. Therefore future development of water resources can be summarized as follows:

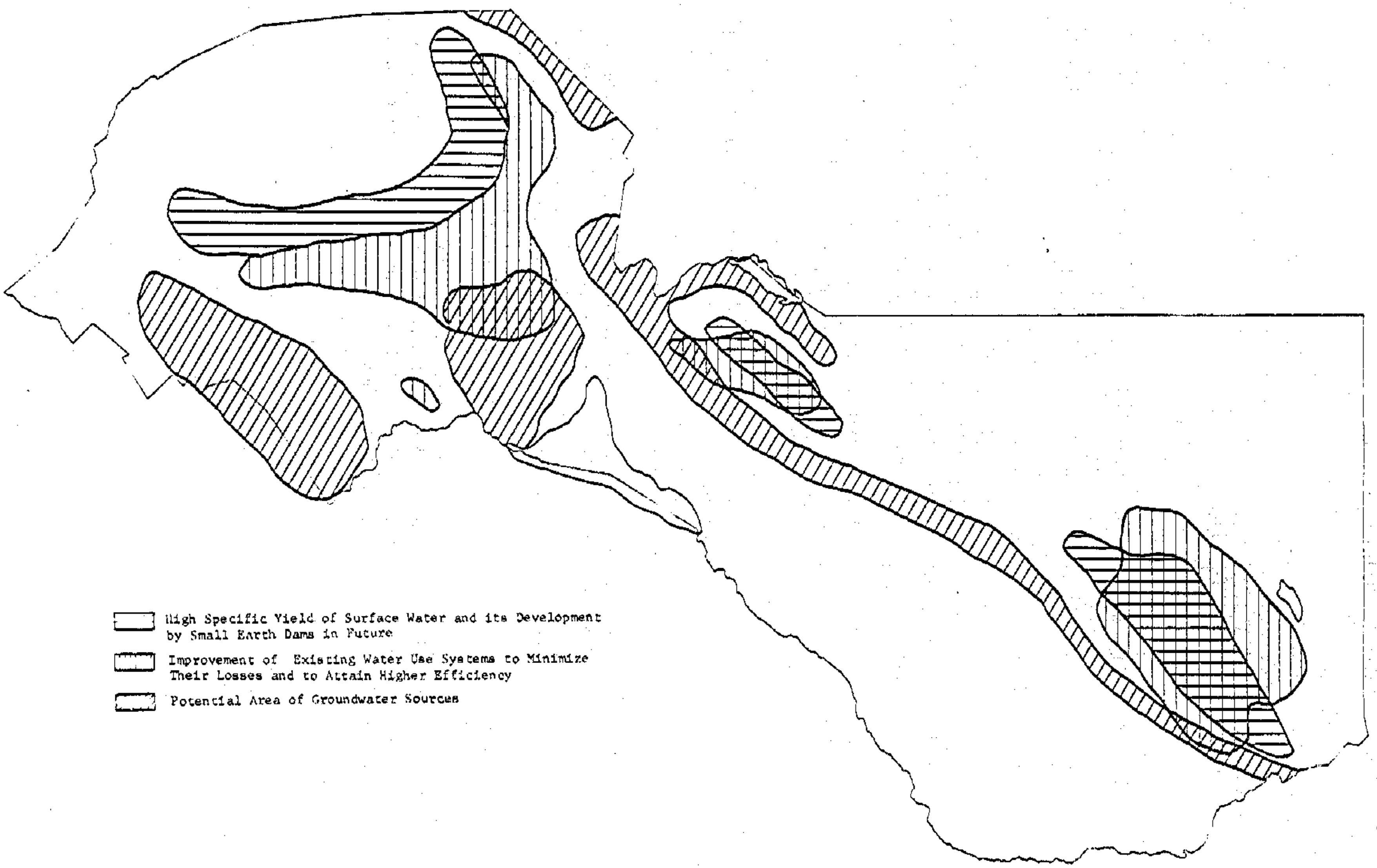
(1) Development of high specific yield areas through construction of small earth dams;

(2) Improvement of existing water use systems to minimize their losses and attain higher efficiency; and

(3) Development of potential ground water sources.

The areas applicable in each case are indicated in Fig.-12.

Availability of Water Sources in the Region (Fig.-12)



7. PROJECTED WATER REQUIREMENTS

Water is used in the region mainly for irrigation and domestic purposes though there is some water consumption by agroindustries such as coffee pulping and sisal processing. This situation will continue during the period covered by this project.

7.1 Water Supply

In 1991 the entire population of the region will have to be serviced by an adequate and safe water supply. It is estimated that by the end of 1,990 the total population of the region will be 1,342,000. At present, the total population serviced by piped water supply is 280,000, or 33% of the total population of the region.

In order to achieve the above target, the annual increase in population serviced by piped water will have to be 63,000, and by the end of 1979/80 580,000 persons (57% of total population at that time) will have to be served by an adequate and safe water supply.

The necessary provision of water for piped water supply for this purpose will be 9.5 million m^3/y (26,000 m^3/d) in 1,980 and 29.4 million m^3/y (80,520 m^3/d) in 1990.

At present total existing intake capacity is 37,600 m^3/d, which is enough to supply 690,000 persons by additional extension of pipeline. This compares with a total surface water supply potential of 80,495 m^3/d confirmed by regional hydrologists. Apparently, therefore, water resources on mountain slopes and nearby are adequate.

In areas where no surface water is available but which are near favourable ground water sources, the latter should be exploited. However, it would be very inefficient to supply water to areas neither with surface water sources nor near favourable ground water sources since the population in them is very sparse. What is needed therefore in such areas is measures to relocate population.

As mentioned above, it can be concluded that there will be no include difficulty in providing the region the water supply that it will need in the future, provided that the schemes employed are economically and technically sound.

7.2 Irrigation

In order to achieve self-sufficency in staple food supply, it is estimated that 280,000 ha. of agricultural fields will be necessary in 1995.

The present irrigated area in the region is 15,900 ha, us 156,000 ha. of agricultural fields. This praparation is slightly better than the 9% target that has been set for future irrigation development in Tanzania.

Fourteen irrigation projects are proposed in the context of this plan, for an increase in irrigation field acreage of 7,800 ha. by the end of 1980. This will entail provision of 69 million m^3/y of irrigation water, or 23% more than the present figure (see Table-12).

Since there is no large surplus of water from the water sources presently being utilized (only a 2.99 million m^3/y surplus from streams), the water sources for the proposed projects will have to be chiefly springs which have not yet been utilized, which will be able to furnish 7.5 million m^3/a year. Also, four projects are to be supplied by bore hole as an additional water source in the Ruvu catchment (15 million m^3/y).

Below the Nyumba ya Mungu Dam four projects are to take of water from the main stream of the Pangani River, or 2.8% of its total average flow downstream of the dam. These projects will involve improvement and some extension of existing systems.

8. STRATEGY FOR FUTURE WATER RESOURCE MANAGEMENT

8.1 Water Resources

At present a considerable amount of water is used in the region, and there is a shortage for traditional irrigation on mountain slopes and areas immediately below them in years of 20% nonexceedence, which come once about every 5 years. The operation condition of Nyumba ya Mungu Dam is rather precarious since total annual inflow in an average year exceeds the storage requirement of the dam at full supply level by only 5%. At present, therefore, there is no immediate surplus of supply in the region.

In a few areas ground water is available, and further detailed ground water surveys are to be carried out. In the Kahe Basin ground water will be available at the rate of 100 m^3/h. from each bore hole, total ground water storage being estimated at 300 million m^3. It will presumably be possible to develop another 50 million m^3/y in the future (see Technical Report, Hydrogeology, Vol. III, Water Master Plan). On the Sanya Plain development potential is less than in the Kahe Basin. Nevertheless, detailed investigation of such potential will be necessary for determination of available amount and distribution since only a limited amount of surface water is available in this area. The same is true of the Lower Rombo area and the western belt of the Pare Mountains.

The diesel engine driven pumping system, however, is expensive and will continue to be so in the future. Development of ground water should therefore be geared to electrification of the development areas, and first priority should be given to domestic water supply sources.

Since no additional surface water sources are foreseen in the immediate future, improvement of existing furrow irrigation systems is the major task at hand. Conveyance loss of these furrows is 35% to 50% per kilometer and even greater on lower mountain slopes and adjacent plains in the Kahe Basin and the Mkomazi Valley. In addition, flow control devices should be installed at furrow intakes so that only the necessary amount will be taken and for only the required period, the rest of the flow being released downstream.

Several good sites for small dams have been identified, but further detailed surveys will be necessary. These dams will not be needed immediately but considering rapid population growth and greater future water needs, feasibility studies, at least, including installation of hydrological observation sites, topographic map surveying, and geological and geophysical surveys should be undertaken soon.

During the period required for such investigations, existing water use systems should be improved, especially irrigation systems because water supply involving dams is expensive. It is estimated that the unit price of water from small earth dams in the region is 40 times that of water supplied by means of gravitational intake even under in the most favourable conditions. (see Technical Report, Engineering, Vol. IV, Water Master Plan). The cost of operation of diesel driven bore hole pumps is also high. Consequently, unless efficient water use systems are established, future irrigation projects will not be justified economically.

It is therefore recommended that the first priority of future water resource development be improvement of existing water use systems for more efficient use of limited water resources. Also, as an immediate measure, more efficient use should be made of spring water.

8.2 Organization

As already discussed, the activities of the Regional Engineer's Office include many kinds of surveying, investigations, and designing and construction of water supply schemes, as well as maintenance of existing water use facilities, which is no small task.

For the purpose of the future water development proposed above it is necessary to reinforce now the corresponding organization as follows:

1) As hydrological data collection and analysis will be the initial task for implementation of the projects, one qualified hydrologist has to supervise National and Regional Hydrologists in order to arrange and analyse raw data into the appropriate forms for various purposes.

2) Most engineering activities will be for improvement of existing water use facilities and preparation of earth dam constructions. This type of engineering work can be done only by qualified and experienced civil engineers. At present the amount of routine engineering work exceeds the capacity of engineers at the Regional Water Engineer's Office. Accordingly, one qualified and experienced civil engineer with an adequate staff will be needed to perform such duties and to cooperate with the irrigation division under the Regional Development Director.

3) Investigation of dam sites will involve much work for which the services of engineering geologists will be required. This will not be permanent work, but rather will be concentrated in the early stages of the project.

4) A team of hydrogeologists, including geophysicists, and a team of drillens will be required for development of the ground water sources available in the region.

5) As the region is one of the most developed in Tanzania, a great deal of data and information have been accumulated. The present filing system, however, does not allow for systematic compilation of these materials. It is therefore recommended to set up a section to sort out these files so that past data and records can be easily consulted in future project preparation.

9. PROPOSED PROJECTS

9.1 Improvement of Existing Water Use System

(1) Improvement of intakes of furrows and pipe water supply to take only the necessary amount during the necessary time.

(2) Improvement of traditional furrows to reduce conveyance losses.

(3) Leveling of irrigation field surfaces to increase yield.

9.2 Surveys of Additional Water Resources

(1) Field Investigation of Dam Sites

(i) Installation of Observation Sites

Rain Gauging Stations	Sites
Kilimanjaro	7
North Pare	3
South Pare	2
Kisangara	1
Njaor Same	1
Makanya	1
Total	15

Discharge Measurement Sites	Recorder Sites	Staff Gauge Sites
Kilimanjaro	7	13
North Pare	1	3
Mkomazi	2	2
Kisangara	1	1
Makanya	1	1
Total	12	20

(ii) Surveying

Kilimanjaro	6 sites
North Pare	4 "
South Pare	10 "

(iii) Geological Survey

Kilimanjaro	6 sites
North Pare	4 "
South Pare	4 "

(iv) Feasibility Study for Dam Construction

(v) Preparation of Topographic Maps of South Pare Mountains

(2) Ground Water Survey

catchment areas	Surface geology	resistivity survey (point)	test hole drilling (hole)	pumping test	area to be surveyed (km^2)
Sanya	*	200	8	8	40
Kahe Basin	*	200	10	10	80
Rombo	*	100	6	6	20
Kileo	*	20	3	3	6
Kifaru	*	40	2	2	9
Kisangara	*	40	3	3	15
Njoro Same	*	40	4	4	8
Same	*	40	2	2	6
Makanya	*	40	3	3	8
Pangani	*	40	2	2	4

All project areas are indicated in Fig.-13.

Estimated Cost (sh.) of Proposed Projects (Fig.-10)

	1977/78	1978/79	1979/80	1980/81
Improvement of Existing Water Use System				
Improvement of furrow intakes	-	-	-	-
Survey of water loss in earth channels	-	-	-	-
Improvement of irrigated land	-	-	-	-
Survey of Additional Water Sources				
Surface water (dam site investigation)				
o Construction of observation stations				
Rain gauging	100,000	-	-	-
Discharge measurement	213,000	-	-	-
Operation & maintenance	136,800	136,800	136,800	136,800
o Surveying	67,040	67,040	32,400	-
o Geological survey				
Surface geology	41,600	41,600	29,400	-
Geophysical survey	-	108,880	108,880	108,880
Designing	-	-	-	-
o Topographical maps of South Pare Mountains	-	-	-	-
Ground water survey				
o Surface geology & preliminary survey	27,200	-	-	-
o Resistivity survey	47,000	34,100	-	-
o Test holes & pump test	420,000	420,000	420,000	
Total	1,052,640	808,420	727,480	245,680

Water Development Plan (Fig.-13)