- Kibungo-Rwamagana road: 46km long via Karembo in Mugesera Commune, slippery in rain.
- Kibungo-Rusumo road: (to Rusumo Fall): 62km long, paved road
- Kibungo-Rukira-Mpanga road: (to the Lake). A narrow road, which will be improved for tourism.
- Kibungo-Rukira road: 16km long, partially paved
- Kayonza-Kibungo road: 37km long, paved
- Kabarondo-Rwinkwavu-Kayonza road (to Akagera Hotel): 28km long; can be used even during the rainy season, although it is slippery.

3.9.2 Electrification

Partial electrification of Kibungo city was recently achieved. Electrification in other rural areas however, has made little progress due to lack of a power distribution system.

3.10 Water Projects

At present, two projects are in the planning stage and one project is under construction in Kibungo Prefecture, as presented in the following table.

TABLE III-9

WATER PROJECTS IN KIBUNGO PFEFECTURE

Project	Place	Project Cost (FRW)	Fund
Water Supply in Sub-Prefecture Kirehe (Rusumo) (Planning)	Kirehe	10,798,966	Belgium Canada
Water Supply in Rukira Commune (Planning)	Gahini Parish	54,710,945	Parish (75%) Government (25%)
*Extension of potable water distribution system in Kibungo and Rwamagana (under construction)	Kibungo Rwamagana other 3 sites	566,075,145	World Bank

* Outside the study area

3.11 Present Situation of Water Supply and Use

At present, the rural population in the project area is served by point water sources such as lakes, marshes, streams and springs with no distribution system. In the project area, for daily domestic water supply, people depend mainly on two existing point sources: protected springs which were developed by AIDR from 1976 to 1982, and traditional surface water sources such as lakes, marshes ponds and streams. Though overall information on water supply is scarce, according to AIDR'S report, 47% of the rural population in the area is now covered by 273 existing protected springs. The rest of the population reportedly still relies on traditional surface water.

Another minor water source is rain water which is collected and utilized in a few social and public institutions such as churches and hospitals; however, average rural people cannot afford the relatively high cost required for installation of the necessary facilities for rain water collection and storage.

AIDR'S estimate of 47% coverage by protected springs seems somewhat exaggerated according to results of the field survey carried out by the study team. In fact, more than half of the population may depend on traditional surface water which is located in easily accessible places and often heavily contaminated. The 273 existing springs do, however, play a very important role as a dependable water source at present which can provide relatively clean water almost year-round.

A protected spring typically serves 50 to 100 families in the vicinity, depending on the discharge capacity of the spring, which is usually 10 to 20ℓ/min. In fact, the rural areas have a rather low population density, and the inhabitants must spend hours to obtain their daily water supply. Due to cultural tradition, water is carried exclusively by women and children who walk for 2 to 4 hours (4 to 8km), 3 times a day, to obtain water. Bathing and laundry usually takes place at, or near the water sources. Actual water consumption figures are unknown; however, consumption is estimated as follows:

- Drinking and Cooking : 8-12ℓ/c.p.d.
- Washing : 2- 3ℓ/c.p.d.

TABLE III-1

SUMMARY OF ADMINISTRATIVE UNITS

	Administrative Institution		M.R.N.D. Organization
	Commune	Number of Sectors	Number of Cellules
1	BIRENGA	12	59
2	KABARONDO	12	60
3	KAYONZA	8	38
4	KIGARAMA	11	66
5	MUGASERA	15	75
6	MUHAZI	12	66
7	RUKARA	8	52
8	RUKIRA	10	58
9	RUSUMO	10	99
10	RUTONDE	9	51
11	SAKE	13	70
	TOTAL	120	694

TABLE III-2

POPULATION & POPULATION DENSITY

No.	Commune	Area	Population 1982	Population 1983	Population 1984	Population Density 1982	Population Density 1983	Population Density 1984
1.	BIRENGA	263.6	37.550	37,353	40,435	142.45	149.1	155.40
2.	KABARONDO	160.3	26,551	27,531	28,004	165.63	171.75	174.20
3.	KAYONZA	190.0	23,406	23,760	23,933	123.19	125.05	125.90
4.	KIGARAMA	273.3	34,407	35,597	36.610	125.89	130.25	133.96
5.	MUGESERA	144.1	40,091	41,509	42,460	278.22	288.06	294.66
6.	MUHAZI	91.6	32,197	33,559	34,500	351.50	366.36	376.64
7.	RUKARA	261.9	30,683	31,542	32,446	117.16	120.44	123.69
8.	RUKIRA	253.2	28,301	30.344	31,902	117.77	119.84	126.00
9.	RUSUMO	788.8	44,399	46,972	49,010	56.29	56.55	62.13
10.	RUOTNDE	93.7	27,117	27,726	28,339	289.40	295.90	302.44
11.	SAKE	146.1	32,695	34,198	35,276	223.19	234.07	241.45
Total		2,666.6	357,397	374,905	382,915	134.02	139.46	143.60

TABLE III-3

MONTHLY PRECIPITATION OBSERVED AT THE KIBUNGO METEOROLOGICAL STATION (1979-1983)

Month \ Year	73	74	75	76	77	78	79	80	81	82	83	Average
JANUARY	52.5 (7)	70.0 (7)	51.8 (14)	65.1 (9)	121.9 (20)	133.4 (10)	57.1 (14)	62.9 (7)	119.2 (15)	86.1 (13)	67.1 (4)	80.6 (10.9)
FEBRUARY	61.6 (7)	81.5 (11)	75.2 (7)	168.0 (23)	75.1 (11)	89.7 (14)	101.9 (12)	76.3 (8)	105.8 (9)	41.5 (8)	62.6 (9)	85.4 (10.8)
MARCH	82.5 (8)	82.0 (8)	82.7 (17)	64.1 (15)	144.8 (21)	230.2 (16)	231.1 (10)	114.3 (10)	280.0 (22)	96 (7)	182.4 (17)	144.6 (13.7)
APRIL	106.0 (15)	155.2 (13)	127.8 (20)	171.1 (22)	244.8 (20)	201.3 (17)	200.5 (23)	84.9 (18)	112.6 (15)	113.7 (18)	173.4 (19)	153.7 (18.2)
MAY	148.0 (13)	149.0 (11)	116.5 (16)	98.8 (17)	109.1 (13)	57.0 (9)	152.4 (12)	98.7 (16)	70/8 (11)	147.3 (18)	58.2 (10)	109.6 (13.3)
JUNE	0 (0)	50.8 (4)	5.5 (4)	16.8 (2)	17.1 (3)	2.6 (1)	52.4 (4)	4.7 (2)	2.4 (2)	15.4 (2)	1.5 (2)	15.4 (2.3)
JULY	0 (0)	44.6 (3)	34.5 (6)	0 (0)	0 (0)	0 (0)	NT (0)	NT (NT)	NT (NT)	0.7 (1)	NT (NT)	7.3 (1.3)
AUGUST	0 (0)	0 (0)	16.6 (3)	181.1 (6)	55.9 (7)	41.8 (6)	26.1 (3)	NT (NT)	61.4 (8)	1.2 (2)	22.3 (6)	36.9 (3.7)
SEPTEMBER	96.2 (12)	58.5 (3)	86.8 (19)	54.6 (10)	55.9 (9)	37.5 (5)	35.9 (5)	47.0 (6)	81.1 (11)	39.1 (13)	54.8 (6)	58.9 (9)
OCTOBER	62.0 (7)	44.1 (3)	213.8 (23)	48.4 (8)	34.8 (6)	96.2 (10)	36.8 (8)	26.7 (10)	72.1 (12)	82.7 (15)	76.8 (16)	72.2 (10.7)
NOVEMBER	104.1 (16)	119.5 (10)	44.7 (11)	149.8 (13)	135.1 (25)	133.6 (17)	76.3 (14)	141.3 (18)	64.7 (15)	90.6 (19)	154.7 (17)	111.1 (15.9)
DECEMBER	50.0 (4)	52.0 (18)	121.1 (13)	125.3 (15)	155.7 (13)	82.1 (10)	18.9 (11)	100.3 (13)	124.4 (16)	90.0 (14)	129.9 (15)	95.4 (12.9)
TOTAL	762.9 (09)	907.4 (90)	977.0 (153)	1143.1 (140)	1150.4 (148)	1105.4 (115)	984.4 (116)	757.1 (108)	1094.5 (136)	812.5 (130)	983.7 (121)	971.1 (122.7)

TABLE III-4

ANNUAL PRECIPITATION OBSERVED AT EACH METEOROLOGICAL STATION (1974-83)

Year	74	75	76	77	78	79	80	81	82	83	Average
BARE	-	-	-	-	-	1050.8	918.8	938.5	1270.4	829.3	1001.6
GAHORORO	989.1	1028.1	1137.5	1164.2	1274.1	1306.6	880.3	1124.7	1113.9	1101.3	1112.0
GATARE	-	-	-	-	-	-	-	1074.7	1314.1	-	1194.4
KIBUNGO	907.4	977.0	1143.1	1150.2	1105.4	989.4	757.1	1894.5	812.5	983.7	992.0
NYARUBUYE	800.6	873.0	649.7	1002.0	1048.7	981.5	751.1	770.3	1058.0	695.9	863.1
MUHAZI	-	1074.5	929.2	895.6	1099.7	827.9	775.4	950.3	913.0	902.7	929.8
RUKIRA	915.5	920.3	908.9	1219.2	1110.1	924.5	1018.5	909.2	964.7	1019.9	991.1
RUSUMO	-	-	-	-	-	763.2	641.5	759.0	1323.1	792.0	855.8
RWAMAGANA	890.1	1141.0	682.0	997.4	1383.5	917.8	841.3	1173.2	522.7	1084.8	963.4
RWINKWAVU	662.3	976.6	760.0	980.7	1219.5	825.3	835.7	817.3	922.6	849.5	865.0
ZAZA	-	-	1096.6	1111.0	1162.6	1090.7	982.8	1212.9	1351.1	908.9	1114.5

TABLE III-5

MONTHLY AVERAGE TEMPERATURE OBSERVED AT THE KIBUNGO METEOROLOGICAL STATION (1974-1983)

Month \ Year	74	75	76	77	78	79	80	81	82	83	Av-Max / Min
JANUARY	17.7 (26.4) (12.0)	17.9 (27.8) (11.9)	18.2 (28.5) (10.0)	17.7 (28.0) (11.7)	19.0 (28.9) (11.6)	18.9 (28.2) (12.1)	18.2 (29.1) (12.0)	18.3 (28.0) (14.2)	17.8 (28.6) (13.3)	- - -	18.1 (29.0) (10.0)
FEBRUARY	17.8 (27.5) (13.0)	17.7 (28.7) (10.7)	16.6 (29.9) (10.2)	17.4 (27.6) (12.2)	19.5 (29.5) (12.4)	17.8 (27.2) (12.7)	18.9 (29.6) (13.0)	18.2 (29.6) (14.9)	17.9 (29.8) (13.8)	- - -	17.9 (29.8) (10.2)
MARCH	18.0 (28.0) (13.4)	17.5 (27.5) (12.0)	18.4 (29.4) (11.2)	17.9 (27.0) (11.4)	17.8 (29.8) (12.2)	18.7 (28.2) (12.2)	18.8 (29.7) (11.2)	17.9 (29.6) (14.3)	18.4 (29.4) (14.0)	- - -	18.1 (29.8) (11.2)
APRIL	17.4 (27.6) (12.5)	17.8 (26.4) (11.4)	17.4 (26.7) (10.7)	17.2 (26.4) (12.4)	17.8 (25.7) (11.9)	17.3 (27.0) (12.1)	18.2 (27.0) (12.6)	18.5 (27.2) (14.6)	17.6 (27.2) (14.3)	18.3 (27.8) (15.4)	17.7 (27.8) (10.7)
MAY	17.3 (26.0) (12.3)	17.8 (26.8) (11.8)	17.9 (26.7) (13.2)	18.1 (27.0) (12.0)	17.3 (26.4) (12.2)	17.8 (26.7) (12)	17.5 (26.7) (13.5)	18.2 (27.5) (14.8)	17.7 (26.5) (14.4)	18.8 (26.8) (15.0)	17.8 (27.5) (11.8)
JUNE	17.4 (26.5) (13.7)	17.6 (25.7) (11.8)	17.6 (26.7) (10.5)	18.0 (28.3) (10.8)	17.7 (26.7) (11.6)	17.0 (26.6) (10.2)	18.2 (27.5) (13.3)	18.1 (27.6) (13.2)	17.9 (26.1) (14.0)	18.9 (27.3) (15.5)	17.8 (28.3) (10.2)
JULY	16.5 (26.3) (11.5)	17.0 (26.4) (11.6)	17.9 (27.3) (12.7)	18.2 (27.5) (12.2)	17.7 (27.2) (10.7)	17.6 (27.5) (11.2)	18.3 (28.3) (12.9)	17.8 (27.3) (13.9)	17.8 (26.8) (13.0)	19.0 (28.7) (14.6)	17.8 (28.7) (10.7)
AUGUST	18.5 (28.3) (13.2)	18.1 (26.3) (12.7)	18.1 (28.4) (12.0)	18.4 (28.7) (11.6)	18.6 (27.8) (10.3)	17.9 (28.9) (12.1)	19.4 (28.4) (13.9)	18.2 (28.5) (14.3)	18.9 (28.5) (14.2)	19.0 (28.3) (14.4)	18.5 (28.9) (10.3)

SEPTEMBER	18.0	17.6	19.2	19.5	19.3	19.4	20.3	19.0	19.7	19.3	19.1
	(27.8)	(27.2)	(28.8)	(28.7)	(29.8)	(29.7)	(29.7)	(28.8)	(30.2)	(29.2)	(30.2)
	(12.7)	(11.7)	(11.8)	(12.8)	(11.5)	(12.5)	(13.8)	(11.1)	(14.6)	(14.4)	(11.1)
OCTOBER	19.2	18.2	20.4	20.5	19.2	20.5	20.1	19.3	18.7	18.9	19.5
	(29.1)	(25.9)	(28.8)	(29.2)	(23.0)	(30.2)	(29.2)	(28.8)	(28.2)	(27.2)	(30.2)
	(13.0)	(11.5)	(12.8)	(12.6)	(12.2)	(13.4)	(14.1)	(14.3)	(12.9)	(13.6)	(11.5)
NOVEMBER	18.4	18.6	11.0	18.2	18.2	19.1	18.5	18.7	18.3	18.6	18.5
	(26.8)	(28.6)	(28.6)	(25.6)	(27.5)	(29.0)	(27.4)	(27.4)	(26.5)	(27.2)	(29.0)
	(12.0)	(11.5)	(10.6)	(11.8)	(10.8)	(12.5)	(14.0)	(14.5)	(14.3)	(13.7)	(10.6)
DECEMBER	17.2	17.9	19.0	18.9	18.7	17.4	18.6	18.5	-	17.6	18.2
	(26.7)	(27.2)	(27.2)	(27.5)	(27.0)	(27.9)	(27.1)	(28.0)	-	(25.6)	(28.0)
	(11.3)	(11.7)	(12.2)	(12.0)	(12.2)	(13.0)	(13.0)	(14.2)	-	(13.4)	(11.3)
Ave. Max / Min	17.8	17.8	18.3	18.3	18.4	18.3	18.8	18.4	18.2	18.7	18.3
	(29.1)	(28.7)	(28.8)	(29.2)	(29.8)	(30.2)	(29.7)	(29.6)	(30.2)	(29.2)	(30.2)
	(11.3)	(10.7)	(10.0)	(10.8)	(10.3)	(10.2)	(11.2)	(11.1)	(12.9)	(13.4)	(10.0)

TABLE III-6

MONTHLY AVERAGE HUMIDITY OBSERVED AT THE KIBUNGO METEOROLOGICAL STATION (1974-1983)

Month \ Year	74	74	76	77	78	79	80	81	82	83	Average
January	79.8	85.0	82.2	90.3	88.6	63.5	85.7	86.9	89.6	-	85.7
February	79.5	81.4	90.6	90.8	83.6	89.6	84.3	86.3	84.0	-	85.7
March	79.9	87.5	85.0	88.1	93.5	83.7	79.8	90.6	84.0	-	85.5
April	90.0	85.8	91.6	93.2	91.8	93.2	88.8	89.5	92.7	89.7	90.6
May	88.0	87.3	86.2	87.8	81.6	88.5	87.7	88.2	92.8	83.1	87.1
June	81.6	73.0	77.0	78.9	75.6	79.9	76.6	77.7	80.0	71.7	77.2
July	79.2	-	69.5	66.9	68.0	67.7	64.5	72.7	69.6	63.7	69.1
August	64.5	64.4	71.5	69.3	69.2	67.0	61.8	73.9	67.0	70.9	68.0
September	68.6	80.6	72.9	-	70.4	67.2	70.5	77.4	71.4	72.9	72.6
October	69.7	83.2	67.6	68.9	79.9	68.1	75.3	79.8	81.2	80.7	75.4
November	85.3	77.8	79.3	90.0	86.2	80.7	85.2	82.5	89.4	85.0	84/1
December	88.5	84.0	82.3	85.9	89.7	86.2	75.6	83.8	-	82.6	84.2
Average	79.6	80.9	79.6	82.7	81.5	79.6	78.0	82.4	82.0	77.8	80.4

TABLE III-7

DRAINAGE BASINS OF THE STUDY AREA

Name of Basin	Area (km^2)	Total Precipitation $x10^8$ m^3/y	$x10^5$ m^3/d	Available Water $x10^4$ m^3/d
Ngungu River Basin	130	1.24	3.38	4.06
Eastern Basin of River Akagera	329	2.82	7.72	9.24
Nyakora River Basin	298	2.89	7.92	9.50
Nasho Lake Basin	260	2.24	6.15	7.38
Subtotal	1,017	9,19	25,2	30,2
Mugesera Lake Basin	407	4.05	11.10	13.3
Sake Lake Basin	264	2.63	7.19	8.63
Western Basin of River Akagera	170	1.66	4.54	5.45
Southern Basin of River Akagera	253	2.40	6.58	7.90
Subtotal	1,747	17,00	46,7	56,1
Mubazi Lake Basin	283	2.69	7.37	8.84
Total	3,047	28,9	79,3	95,1

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : BIRENGA

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. BARE	4	0	361.2	1,897	42.7	507.5
2. BIRENGA	4	0	90.7	2,087	47.0	115.8
3. GAHARA	2	0	35.4	5,436	122.3	17.4
4. GAHULIRE	4	0	114.0	2,765	62.2	110.0
5. GASHONGORA	2	0	60.5	4,193	94.3	38.5
6. KIBAYA	3	0	261.8	2,967	66.8	235.1
7. KIBARA	0	0	0	3,406	76.6	0
8. KIBIMBA	4	0	392.3	2,947	66.3	355.0
9. KIBUNGO	1	0	30.2	2,998	67.5	26.8
10. MATONGO	1	0	30.2	2,998	67.5	26.8
11. NDAMIRA	3	0	109.7	2,349	52.9	124.4
12. SAKARA	7	0	232.4	3,866	87.0	160.3
TOTAL	35	0	1,705.5	39,307	884.4	57.8

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : KABARONDO

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. BISENGA	0	0	0	2,104	47.3	0
2. CYINZOVU	2	0	166.8	2,418	54.4	184.0
3. KABARONDO	2	0	63.9	2,101	47.3	81.1
4. MURAMA	2	0	70.0	1,461	32.9	127.7
5. NKAMBA	3	0	147.7	2,955	66.5	133.3
6. RUBIRA	2	0	51.0	2,296	51.7	59.2
7. RUKIRA	0	0	0	1,963	44.2	0
8. RUNDA	4	0	0	2,908	65.4	0
9. RURAMIRA	2	0	63.1	2,866	64.5	58.7
10. RUSERA	1	1	163.3	1,875	42.2	232.2
11. RUYONZA	2	0	122.7	2,238	50.4	146.1
12. SHYANDA	0	0	0	2,346	52.8	0
TOTAL	16	1	848.5	27,531	619.4	56.7

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : KAYONZA

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. GASOGI	0	0	0	2,738	61.6	0
2. KAYONZA	0	0	0	3,247	73.1	0
3. MUBURABUTORO	2	0	65.7	1,982	44.6	88.4
4. MUSUMBAMURAMA	1	0	26.8	2,454	55.2	29.1
5. NYAMIRAMA	2	0	39.7	3,524	79.3	30.0
6. RUTARE	2	1	105.4	2,410	54.2	116.7
7. RWINKWAVU	0	0	0	4,784	107.6	0
8. SHYOGO	1	0	12.1	2,621	59.0	12.3
TOTAL	8	1	249.7	27,760	534.6	26.3

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : KIGARAMA

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. FUKWE	2	1	7.8	3,744	84.2	5.6
2. GASETSA	4	0	59.6	2,436	54.8	65.3
3. GASHANDA	2	2	47.5	2,622	59.0	48.3
4. KABARE I	4	1	278.2	2,473	55.6	300.2
5. KABARE II	3	0	190.1	4,156	93.5	122.0
6. KABERANGWE	2	0	75.2	3,366	75.7	59.6
7. KANSANA	8	0	547.8	3,462	77.9	421.9
8. REMERA	3	0	96.8	2,327	52.4	110.8
9. RUBONA	0	0	0	5,389	121.3	0
10. RURENGE	2	1	90.7	2,168	48.8	111.5
11. VUMWE	2	1	59.6	3,454	77.7	46.0
TOTAL	32	6	1,453.3	35,597	800.9	59.7

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : MUGESERA

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. CYIZIHIZA	3	0	62.2	2,919	65.7	56.8
2. GATARE	0	0	0	3,015	67.8	0
3. KAGASHI	0	0	0	3,537	79.6	0
4. KAREMBO	3	0	143.4	2,092	47.1	182.7
5. KIBARE	9	0	206.5	3,444	77.5	159.9
6. KIBILIZI I	8	0	418.2	3,061	68.9	364.2
7. KIBILIZI II	2	0	34.6	2,082	46.8	44.4
8. KIRAMBO	5	0	279.1	2,454	55.2	303.4
9. KUKABUYE	6	0	197.9	3,427	77.1	154.0
10. MATONGO	3	0	37.2	2,583	58.1	38.4
11. NGARA	9	1	645.4	2,895	65.1	594.8
12. NYANGE	0	0	0	2,085	46.9	0
13. SANGAZA	0	0	0	2,839	63.9	0
14. SHYWA	6	0	318.8	2,691	60.5	316.2
15. ZAZA	7	1	378.4	2,385	53.7	422.8
TOTAL	35	0	1,705.5	39,307	884.4	57.8

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : MUHAZI

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. GATI	1	0	4.3	3,286	73.9	3.5
2. GISHALI	2	0	13.0	3,910	88.0	8.9
3. KABARE	0	0	0	3,025	68.1	0
4. KITAZIGURWA	0	1	0	2,359	53.1	0
5. MUKARANGE	0	0	0	2,219	49.9	0
6. MUNYIGINYA	2	0	27.6	2,577	58.0	28.6
7. MURAMBI	1	0	17.3	3,129	70.4	14.7
8. NKOMANGWE	0	0	0	2,271	51.1	0
9. NYAGATOVU	1	0	15.6	2,700	60.8	15.4
10. NYARUBUYE	0	0	0	2,810	63.2	0
11. NYARUGALI	0	0	0	2,399	54.0	0
12. RUHUNDA	1	0	19.0	2,814	63.3	18.0
TOTAL	8	1	96.8	33,499	753.7	7.7

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : RUKARA

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. GAHINI	0	0	0	5,111	115.0	0
2. KAWANGIRE	0	0	0	03,492	78.6	0
3. KIYENZI	0	0	0	3,355	75.5	0
4. NYAKABUNGO	2	0	47.5	2,663	59.9	47.6
5. NYAWERA	1	0	14.7	3,809	85.7	10.3
6. RUKARA	1	0	14.7	6,049	136.1	6.5
7. RWIMISHINYA	0	0	0	4,609	103.7	0
8. RYAMANYONI	2	0	72.6	2,454	55.2	78.9
TOTAL	6	0	149.5	31,542	709.7	12.6

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : RUKARA

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. GASHIRU	0	0	0	3,245	73.0	0
2. GITUKU	3	0	381.9	3,057	68.8	333.1
3. GITWE	1	0	19.0	3,552	79.9	14.3
4. MUBAGO	1	0	65.7	3,466	78.0	50.5
5. MURAMA	1	0	65.7	3,134	70.5	55.9
6. MUSHIKIRI	0	0	0	2,997	67.4	0
7. NUTRARUKA	0	0	0	2,997	67.4	0
8. RUGARAMA	3	0	381.9	2,171	48.8	469.5
9. RURAMA	1	0	51.8	3,151	70.9	43.8
10. RURENGE	0	0	0	a3,261	73.4	0
TOTAL	10	0	804.4	30,344	682.7	35.0

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : RUSUMO

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. GATORE	0	0	0	6,088	137.0	0
2. GISENYI	0	0	0	2,346	52.8	0
3. KANKOBWA	3	0	64.8	4,225	95.1	40.9
4. KIGARAMA	2	0	65.7	5,711	128.5	30.7
5. KIGINA	7	0	158.1	5,296	119.2	79.6
6. KIREHE	2	0	190.1	4,792	107.8	105.8
7. MUSAZA	6	0	358.6	6,509	146.5	146.9
8. NYABITARE	4	0	101.1	3,177	71.8	84.8
9. NYAMUGALI	0	0	0	3,614	81.3	0
10. NYARUBUYE	6	0	193.5	5,214	117.3	99.0
TOTAL	30	0	1,131.9	46,972	1,056.9	57.2

TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : RUTONDE

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. KADUHA	5	0	578.0	3,262	73.4	472.5
2. KIGABIRO	2	0	74.3	3,417	76.9	58.0
3. NKUNGU	2	0	67.4	2,866	64.5	62.7
4. NSINDA	1	1	13.0	2,731	61.4	12.7
5. NYARUSANGE	6	0	196.1	3,161	71.1	165.5
6. RUTONDE	6	1	202.2	3,273	73.6	164.8
7. RWERU	4	1	115.8	3,235	72.8	95.4
8. RWINKUBO	4	1	146.9	3,022	68.0	129.6
9. SOVU	4	1	367.2	2,759	62.1	354.8
TOTAL	34	5	1,760.9	27,726	623.8	81.3

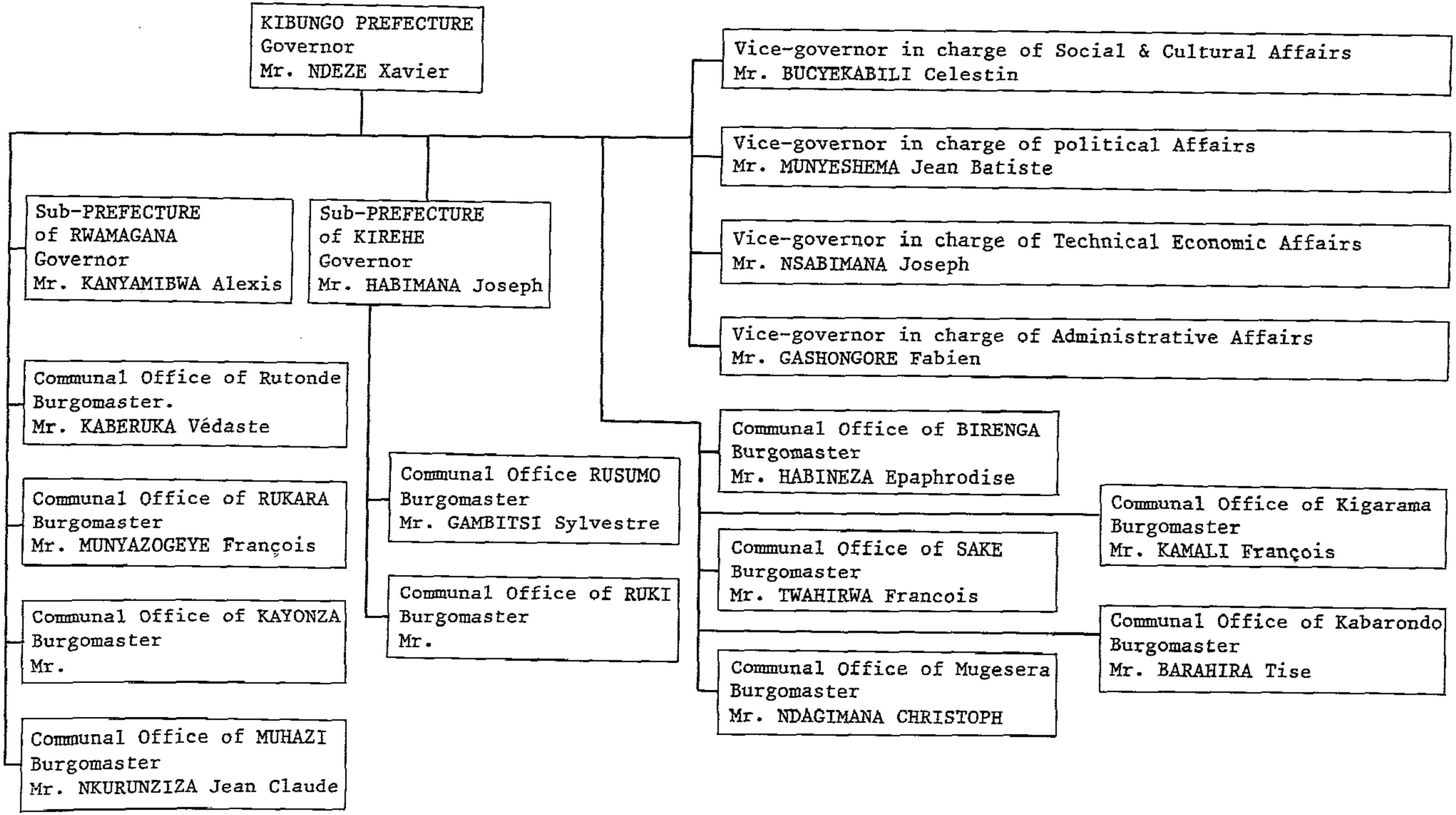
TABLE III-8

WATER DEMAND AND AVAILABILITY OF SPRING WATER FOR EACH SECTOR OF THE STUDY AREA

Commune : SAKE

Sector	Number of Springs		Daily yield (m^3/d)	1983		
	Used	Unused		Population	Demand (m^3/d)	Availability (%)
1. GITUZA	0	0	0	2,830	63.7	0
2. MABUGA I	0	0	0	2,228	50.1	0
3. MABUGA II	0	0	0	2,295	51.6	0
4. MBUYE	0	0	0	3,031	68.2	0
5. MURWA	4	0	470.9	3,541	79.7	0
6. NGOMA	0	0	0	2,228	50.1	564.0
7. NSHILI I	3	0	187.5	2,641	59.4	189.4
8. NSHILI II	3	0	267.8	2,263	50.9	315.7
9. RUBAGO	0	0	0	3,315	74.6	0
10. RUKUMBELI	0	0	0	3,320	74.7	0
11. RUYEMA I	2	0	49.2	1,731	38.9	75.9
12. RUYEMA II	5	0	525.3	1,604	36.1	873.1
13. SHOLI	0	0	0	3,091	69.5	0
TOTAL	17	0	1,516.7	34,118	767.7	29.5
FULL TOTAL	257	16	12,438.9	371,905	8,367.8	45.4

Fig. III-1 Administrative organization chart of the Kibungo Prefecture



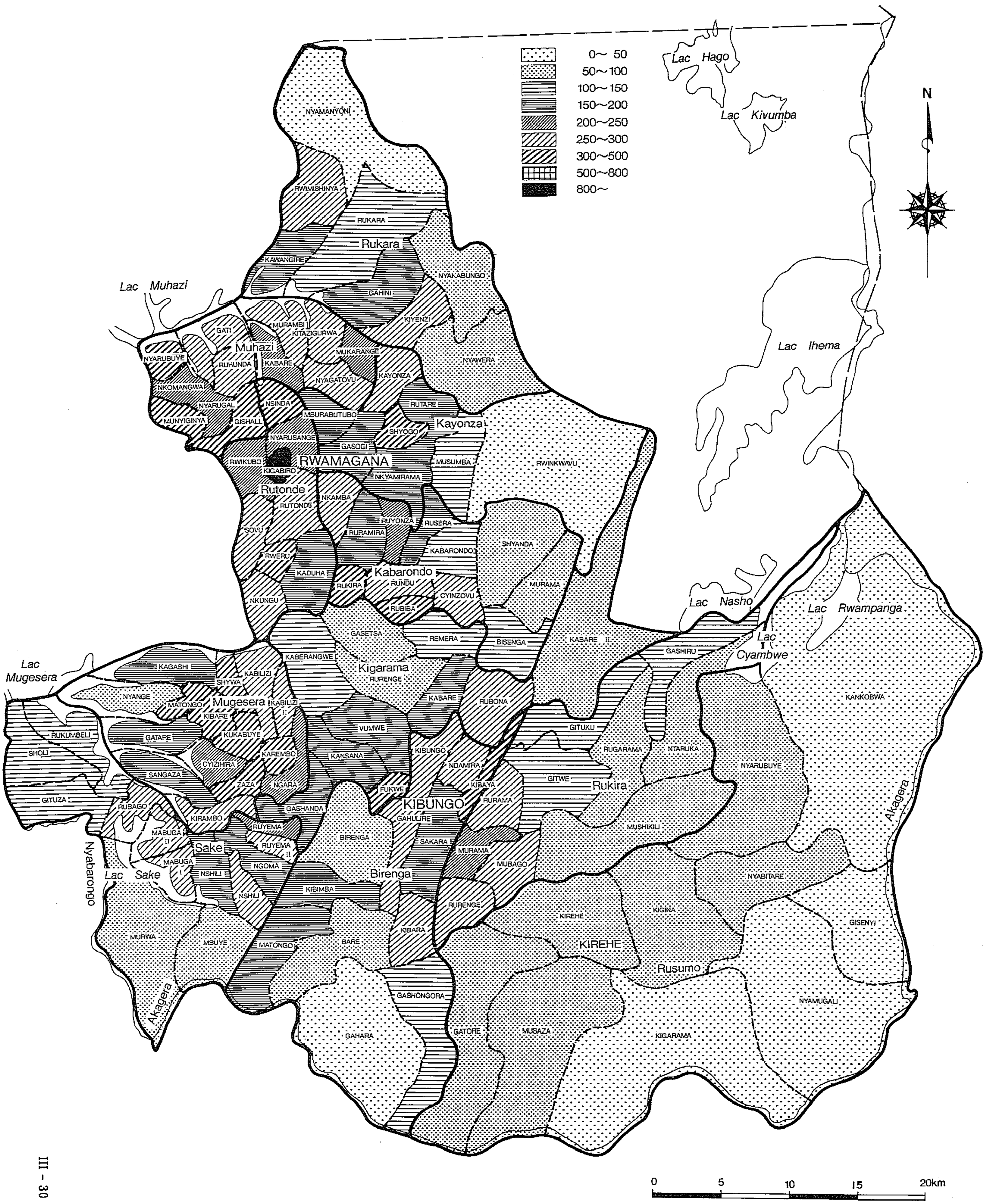


Fig. III-2 Population Density

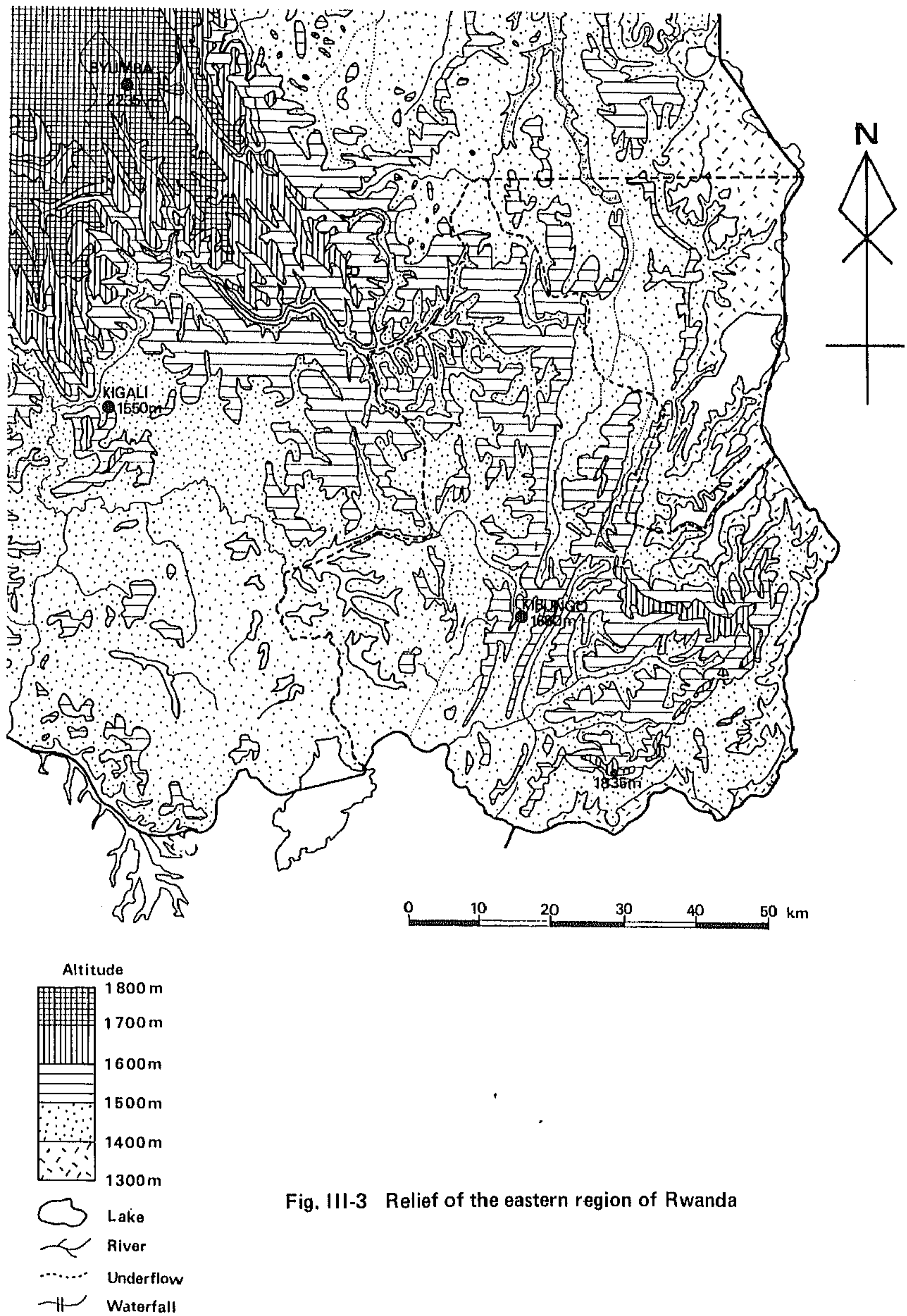


Fig. III-3 Relief of the eastern region of Rwanda

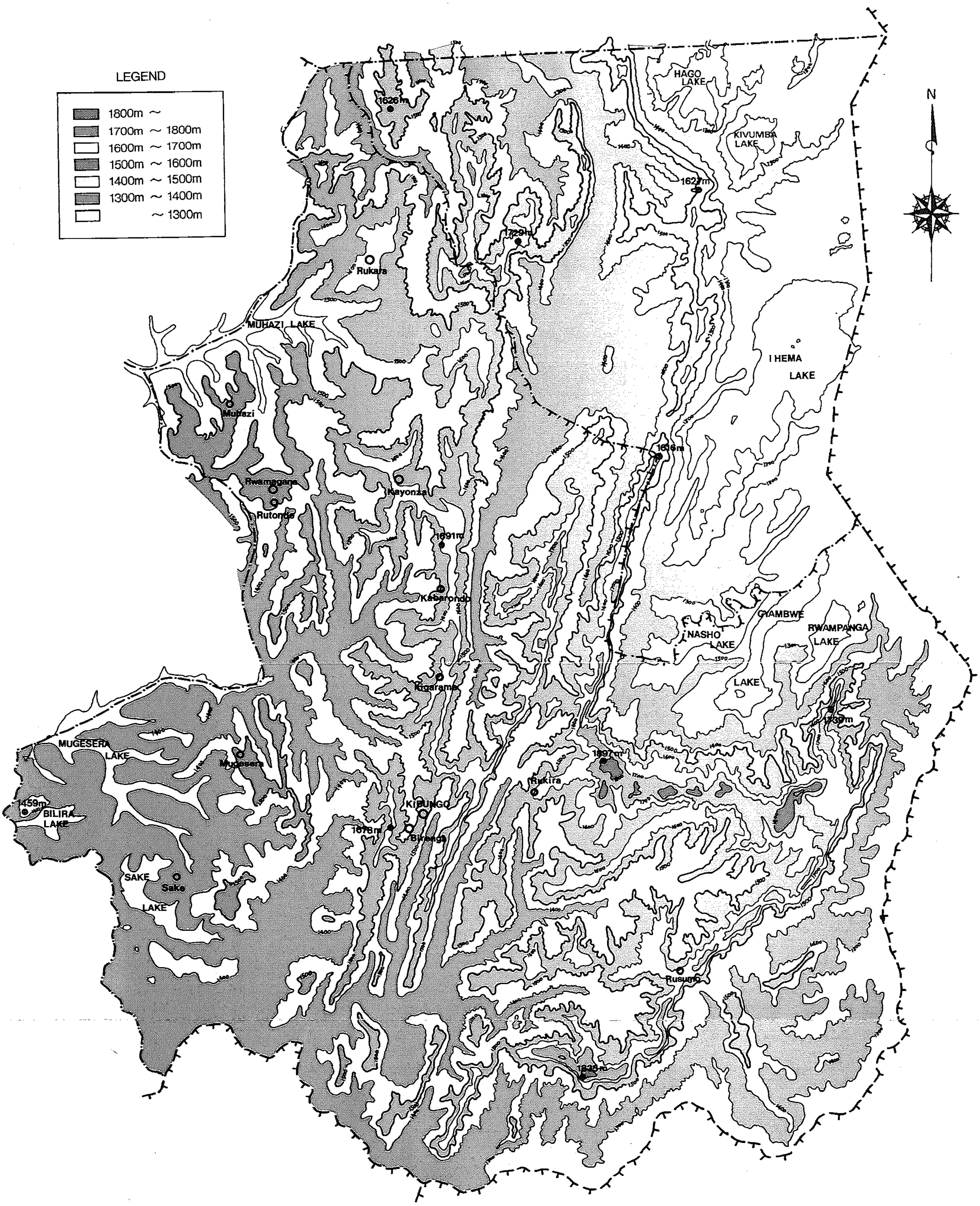


Fig. III-4 Topographic Map of the Kibungo Prefecture

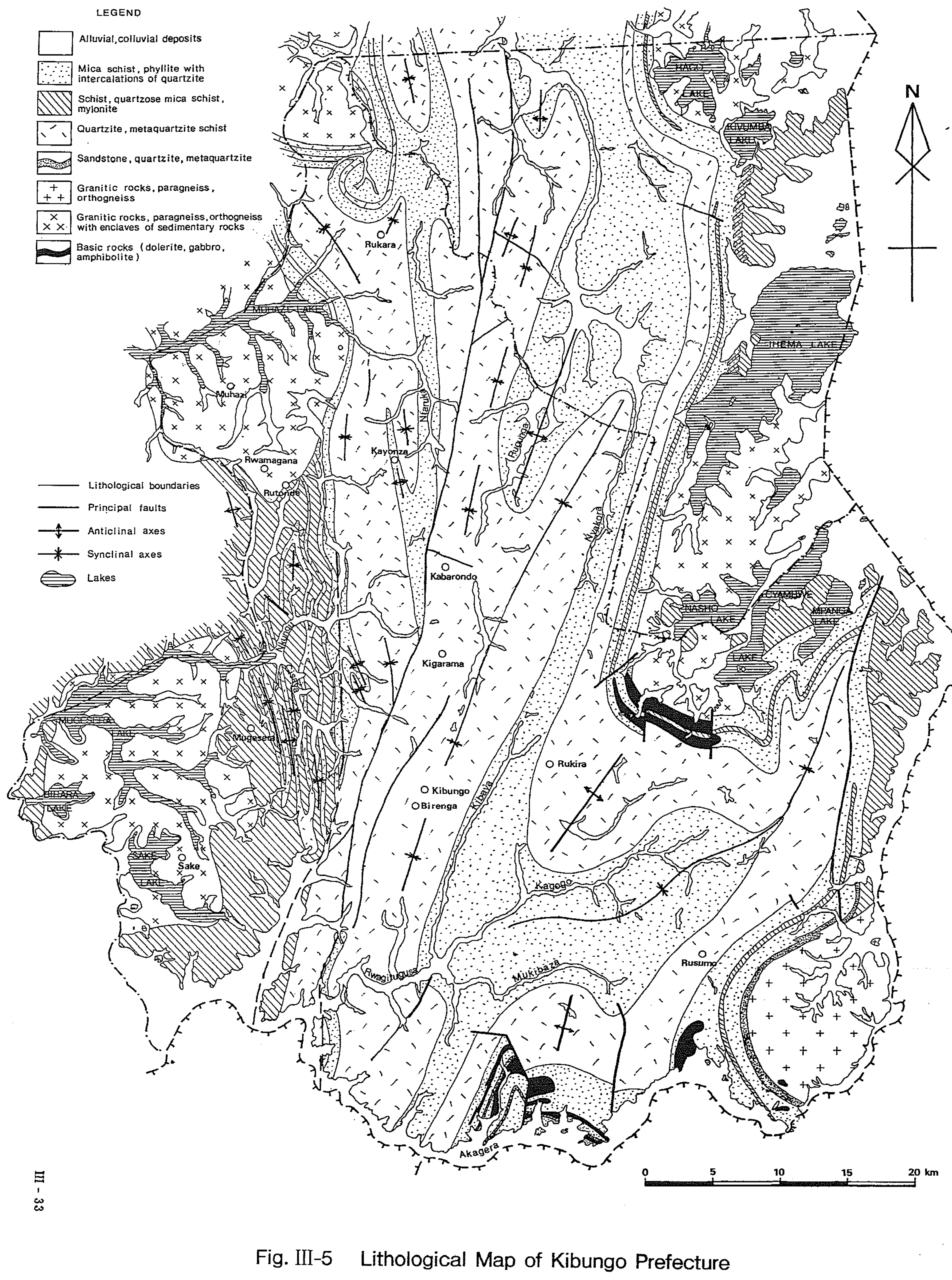


Fig. III-5 Lithological Map of Kibungo Prefecture

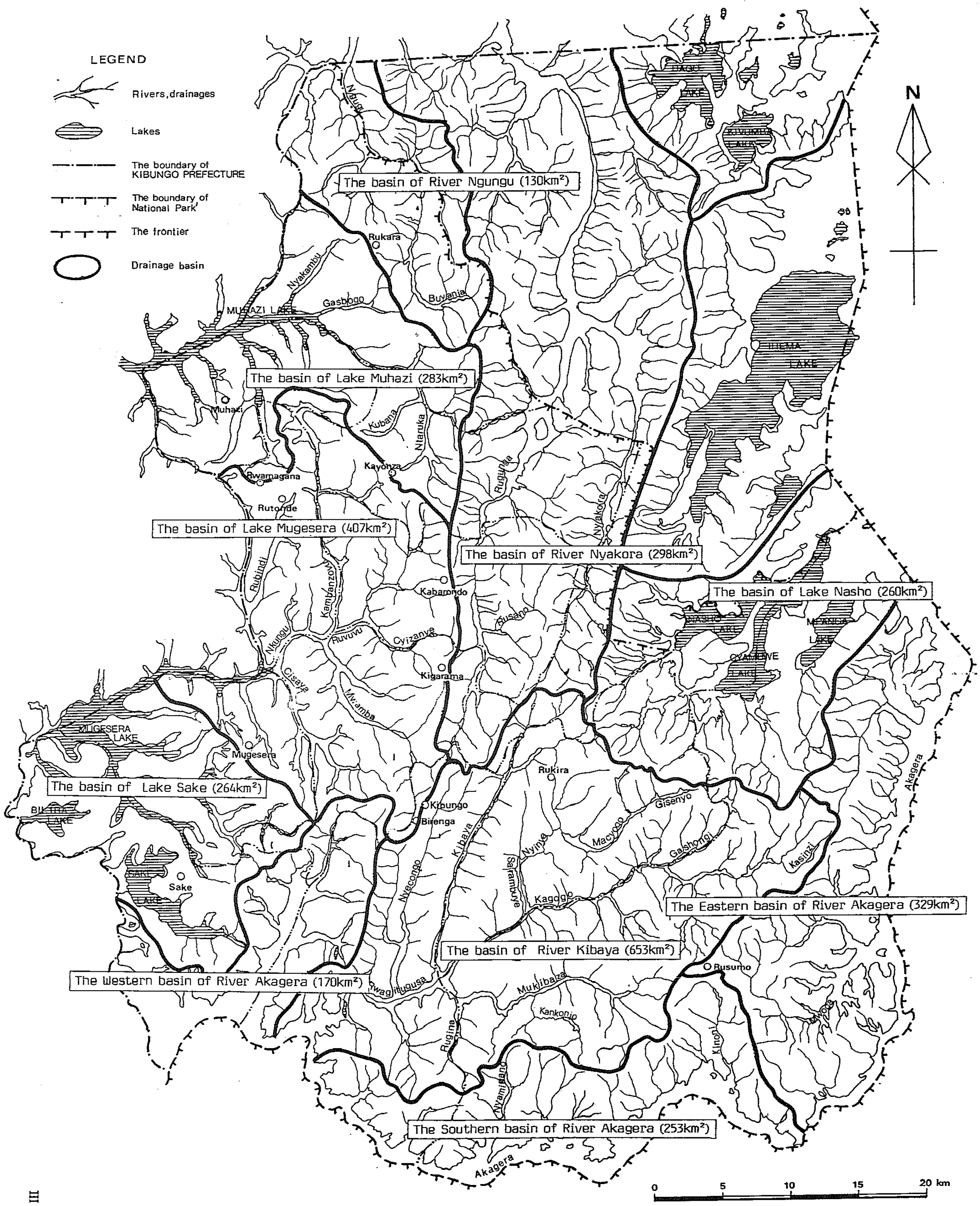


Fig. III-7 Drainage basins of the study area

CHAPTER Ⅳ. THE PROJECT

CHAPTER IV

THE PROJECT

4.1 Objective of the Project

The main objective of the project is to provide a safe water supply to meet the domestic needs of the rural population in the project area up to the year 1990, when the total rural population in the area is projected to reach 475,043.

At present, the rural population in the project area is facing a serious shortage of safe water and is forced to rely on unsafe traditional sources of water such as lakes, marshes, streams, springs and other surface supplies which are already heavily contaminated with human and animal wastes.

The project aims to strengthen, expand and improve water supply sources in the project area, putting particular emphasis upon ground water development which has not yet been carried out in Rwanda. Under the project, water supply source will be converted from contaminated surface water to protected wells equipped with pumps.

Also, provision of a sufficient number of reasonably distributed wells in the rural areas will markedly reduce labor required in obtaining water from the source. This will, in turn, have a significant and beneficial impact upon the standards of living and public health of the rural population in the project area.

4.2 Approach

The approach adopted in formulation of an overall plan follows the basic policy framed in the preliminary studies with additional detailed information obtained through this study.

4.2.1 Selection of Ground Water as a Main Water Source

Until recently, water resource development efforts in the rural area of Rwanda focused on the development of springs at the foot of hills or in valleys. However, almost all conveniently located springs have been developed and chances of finding undeveloped springs are scarce. Although surface water supply is sufficient to provide water for more than half of the rural population, it is subject to severe contamination and poses a serious risk to the health and welfare of the rural people.

Considering such difficulties and the limitations of existing water sources, utilization of ground water, which is comparatively plentiful in the project area with high annual recharge by rainfall, was given priority in water resource development.

4.2.2 Minimum Operation Cost and Maintenance Work

From the first stage of the preliminary study, minimization of operation cost and maintenance work was given priority in consideration of the low income level of the rural area and lack of trained technicians. Accordingly introduction of advanced facilities and equipment was avoided as they inevitably entail greater fuel consumption and maintenance work.

This concept was reconfirmed as a reasonable approach to the project by the observations of the study team; on the other hand, there is a strong desire for more advanced facilities and equipment by the Rwandan people. Therefore, although at present the above approach is emphasized in design of facilities and equipment, due consideration will be given to the desires of the Rwandan people in future planning.

4.2.3 Reduction of Time and Labor Expended for Obtaining Water

As previously described, the rural population often does not utilize safe water sources when they are located at a relatively far distance. Instead, they opt for the nearest water source even if it is clearly contaminated. When planning development of new water sources it is therefore desirable to establish as many small point sources as possible throughout the area in accordance with the population distribution pattern.

In this project, the Cellule is selected as the most suitable unit water supply district. The project proposed provision of at least one well per Cellule to reduce the walking distance for users, with a maximum distance of 1-2km (one way).

4.2.4 Water Supply Where Ground Water is Unavailable

As described in 4.1, the main objective of the Project is to supply domestic water by utilizing ground water resources. However there are many regions where a reasonably accessible and adequate aquifer is not available. One permanent solution for this problem may be extension of a piping system to transport water from another dependable water source.

Such a solution however, requires a considerable investment cost for piping facilities as well as a long construction period. It is thus an impractical method for satisfication of urgent water demand in most rural areas at present. As a temporary solution, utilization of rain water should be considered as it requires minimal investment cost and can be implemented immediately.

4.3 Project Description

The project will provide suitable water supply facilities in eleven (11) Communes of the project area and will consist of:

- Construction of 186 tube wells;
- Supply and installation of sufficient manually operated pumps for the above wells;
- Supply and construction of all necessary facilities to protect wells from external contamination, such as platforms, ditches for drainage and fences;
- Supply and construction of 12 rainfall storage units for districts where development of ground water is practically impossible;
- Supply and construction of a workshop for maintenance of drilling machines, supporting equipment, pumps and tube wells;
- Provision of engineering and construction services including electric sounding to carry out the detailed design;
- Provision of the above services for managing and supervising overall construction works; and,
- Proper training of local staff and technicians in electric sounding, drilling operations and maintenance of machines and equipment.

Water supply facilities adaptable to the project comprise the following types.

1) Shallow dug wells
2) Tube wells with manual pumps
3) Deep tube wells with electric pumps
4) Rainfall storage units
5) Springs

4.3.1 Shallow Dug Wells

Existing wells in the project area are mostly hand dug wells and mainly supply drinking water for livestock. Manually dug wells are too shallow to obtain water from the aquifer. Consequently, dug wells are located close to existing surface water such as lakes, marshes and streams to obtain water at a shallow depth. Surface water inevitably flows into these wells, resulting in contamination of well water. The quality of water from shallow dug wells is very poor and is not suitable for drinking. Moreover as shallow wells must be located near surface water, users must often walk long distances to reach the source.

Considering these disadvantages, this type of well should not be adopted under the project even where other types are infeasible.

4.3.2 Tube Wells with Manual Pumps

This type of well is drilled by a drilling machine and protected by the well casing from contamination by surface water. The manual pump does not require elaborate operation and maintenance and the cost of the pump and spare parts is quite inexpensive. Accordingly, this type of facility is preferable as the main facility under the project.

The typical manual pump can lift water up to 50m with a maximum design capacity of 1,000ℓ/h. As it has a rather large lifting capacity, location near valleys to catch shallow ground water is unnecessary and hence it can be located in a much broader area than dug shallow wells. Installation near the users households will greatly reduce distance and time required for hauling water. Particularly if wells are installed at the center of Cellules, the average walking distance may be reduced from the present 2-5km to 1-2km.

4.3.3 Deep Tube Wells with Power Pump

The depth of the manual pump mentioned above is restricted to less than 80m. Where ground water is located in a deeper zone, a motor driven or engine driven pump should be adopted.

The deep tube well equipped with power pump is common in rural districts throughout the world; however, before adopting a power pump, actual conditions in the project area must be considered. The concentration of population in Kibungo Prefecture is sparse with most households distributed thinly along the hill tops or hill sides. Electrification and water pipe distribution will thus be difficult and uneconomical.

Use of power pumps with diesel generators is questionable in view of fuel consumption and maintenance work required. The level of technology for operation and maintenance required for such pumps is presently beyond the capacity of the rural labor force and operation and maintenance costs would represent a heavy financial burden for rural communities. In consideration of the above, use of deep tube wells equipped with power pumps was not adopted in the project at this time, excepting one well in Kayonza.

4.3.4 Springs (Kano)

At present, half of the rural inhabitants rely on developed springs; however, as mentioned in 4.2.1, development of further spring sources is unlikely. In fact, the role of springs as point water sources is expected to be gradually replaced with new deep tube wells, becoming supplementary water supply sources.

Hence, conventional development of springs as point sources is not included in the project.

4.4 Design Criteria

4.4.1 Design Year and Supply Population

In consideration of the goal of the United Nations' "International Drinking Water Supply and Sanitation Decade", 1990 was selected as the design year of the project. The water supply scheme proposed under the project will be planned to meet water demand up to 1990 in the project area.

4.4.2 Supply Population

The total population of Kibungo Prefecture is 371,905 as of 1983. Though overall information on rural water supply in the prefecture is scarce, only 5% of the total population is estimated to have reasonable access to permanent piped water services in Kibungo and Rwamagana city. Approximately 45.4% of the total population is estimated to utilize protected springs developed by AIDR. The rest of the population (49.6%) is forced to rely on unsafe traditional sources of water such as lakes, streams and marshes. These people are regarded as the beneficiaries of the new water sources to be developed by the project.

Generally, the majority of the rural population in the project area is scattered in a uniformly thin distribution throughout the hills and other areas. Partially concentrated villages or clusters are not common in this area. The population of the project area in 1990 is estimated at 475,043. Yearly population growth rates used for this estimation were calculated on the basis of the population of individual sectors from 1978 through 1983, using the population statistics available for each.

Although Cellules rather than Sectors are supposed as suitable water supply districts, population data for Cellules were unavailable except for the number of families. On the other hand, reasonably accurate data were available for population of Sectors and accordingly the population of Cellules is estimated from that of Sectors including: calculation of the average number of members in a family for each Sector; estimation of the future average number of members in a family for each Sector by applying the growth rate of the population of the relevant Sector; and calculation of the population of Cellules by multiplying the number of the average future members of the family by the number of families in each Cellule.

According to the above calculations, the population in the project area in 1990 is estimated at 475,043. The possibility of division of Cellules in the future due to over-population was not considered in calculation as such a division is principally a political decision of Rwanda, and no actual plan of Cellule reorganization has been issued in the past 10 years. The results of calculation are summarized in TABLE IV-1.

4.4.3 Per Capita Water Consumption and Design Water Demand

(1) Per Capita Water Consumption

The levels of water service in Rwanda were planned in the Sector Study carried out by World Bank and WHO, in July 1978, and indicated in the general report of the first conference for "Décennie Internationale de l'Approvisionnement en Eau Potable et de l'Assainissement (DIEPA)", issued as RWA/BSM/001.

The contents of the same are summarized as follows:

1) Target up to 1985

In the urban area, 40% of the population will be served by private connections with a daily supply of 70ℓ per capita, and 35% by public standpipes with a daily supply of 20ℓ per capita. In the rural area, 70% of the population will be served by public standpipes, springs, wells, and small distributions (no mention of daily supply).

2) Target up to 1990

In the urban area, 45% of the population will be served by private connections with a daily supply of 80ℓ per capita, and 45% by public standpipes with a daily supply of 22.5ℓ per capita. In the rural area, 80% will be served by public standpipes, springs, wells, and small distributions (no mention of daily supply).

In the project area, average daily water consumption is estimated at 10ℓ per capita or less. This consumption level is very low compared with the worldwide standard.

There is no official design criteria for daily water consumption per capita in the rural area. At present, other water supply projects using springs have applied a daily rate of 22.5ℓper capita for gravity distribution systems with public standpipes. In this project also, 22.5ℓ/ha/day will be applied for a similar distribution system to be installed in the water district of Kayonza Zone I with electric pump and standpipe distribution.

In the case of point sources (hand pump and springs), a daily water consumption per capita of 22.5ℓ is excessively high considering the findings from monitoring of the pilot well (No.1).

The main factors that should be considered in determination of daily water consumption per capita are as follows:

a) Average actual daily per capita water consumption is 9.5ℓ according to the results of monitoring the pilot well (No.1). This value represents little increase over the former water consumption rate before pilot well installation as beneficiaries must wait about one or two hours to obtain suitable quality water from the well.

b) Daily water consumption is expected to increase to 10-15ℓ per capita, while time required to obtain pure water will be reduced by installation of a number of wells in the same area.

c) Water for washing can be supplied from existing springs, streams, and lakes.

d) Taking a daily water consumption per capita of 22.5ℓ for the urban area (stand pipe) into consideration, about 20ℓ per capita is considered as the minimum amount for drinking and hygienic use to preserve health and prevent the spread of water-borne and related diseases.

In this project, a daily water consumption per capita of 15ℓ is therefore adopted in calculations for proposed wells. This figure is obtained by subtracting 5ℓ for washing from the minimum of 20ℓ. This water consumption level will be sufficient even with the expected increases from the present level (8-10ℓ/h/day) which will arise with improvements in rural living conditions.

(2) Evaluation of Existing Water Sources and Net Design Water Demand for the Project

In order to estimate the net water demand to be covered by the project, demand covered by the existing water sources must be evaluated and subtracted from the gross demand in the project area.

In Kibungo Prefecture, 273 springs were developed under the "Aménagement des petites sources" from 1976 to 1983. These springs serve approximately 42% of the gross water demand in Kibungo Prefecture (45.4% estimated by the study team as per III-8). Generally, most of the existing springs are located in inconvenient places and spring-rich zones in this Prefecture are concentrated in certain areas. People who live far from springs must spend a large portion of time hauling water.

Despite the various limitations however, existing springs can be used as supplemental water sources together with proposed ground water development. In consideration of seasonal fluctuation of spring water, 60% of effluents will be regarded as effective water supply. Traditionally used surface water, such as lakes, marshes and streams, should not be considered as existing water sources to cover water demand under the project as the quality of the same is unsatisfactory.

The design water demand for the project is summarized in TABLE IV-2.

4.5 Criteria for Determination of Water Source

(1) Hydrogeological Classification of Type of Water Source

Photogeological and hydrogeological study have revealed that the types of water sources exploitable in the study area can be classified into eight (8) categories as listed in TABLE IV-3.

TABLE IV-3 **CLASSIFICATION OF WATER SOURCES**

Water Source Category	Symbols	Characteristics of Aquifier	Rock Type of Aquifer	Remarks
(1) Rivers and lakes	R/L	-	-	localized pollution of water
(2) Springs	Sp	-	-	seasonal fluctuation of water level
(3) Precipitation	Pr	-	-	seasonal fluctuation
(4) Shallow wells (under 30m in depth)	S1	unconfined	quartzite.	fulluvial deposits
(5) Shallow wells (under 30m in depth)	S2	unconfined	quartzite	abundant boulders
(6) Deep wells (over 30m in depth)	D1	confined	quartzite	dominant schist
(7) Deep wells (over 30m in depth)	D2	confined	quartzite	dominant quartzite
(8) Deep wells (over 30m in depth)	D3	confined	granitic rocks	extensive joint system weathered zone

Water sources such as rivers and lakes, springs and precipitation, are discussed in section IV-8 and accordingly the present section mainly focuses on shallow and deep wells.

1) Shallow Wells

A shallow well is defined as a well less than or equal to 30m in depth, and is subdivided into 2 categories, S1 and S2, according to geological conditions. S1 sites are mainly composed of fulluvial deposits (sand and gravel), whereas S2 sites are composed of fulluvial deposits and colluvial deposits (abundant boulders).

The ground water obtained from shallow wells is generally unconfined. Areas where ground water will be obtained from S1 or S2 shallow wells are shown in FIG. IV-1.

2) Deep Wells

A deep well is defined as a well more than 30m in depth, and is subdivided into 3 categories, D1, D2 and D3, according to geological conditions. Both D1 and D2 wells are located in areas composed mainly of interbedded quartzite and schist. Schist is dominant at D1 sites, whereas quartzite is dominant at D2 sites. Quartzite forms a good aquifer as it is well jointed, whereas schist may form confining beds as it is generally impermeable.

D3 type wells are located in areas mainly composed of granitic rocks. Although granitic rocks themselves are impermeable, they often form an extensive joint system in rocks, parallel and/or perpendicular to the ground surface and at right angles to each other. In addition to this, granitic rocks may contain weathered zones. Both the joint system and the transitional zone between fresh and weathered rock may offer opportunities for aquifers with limited supply. The locations of such aquifiers are, however, strongly controlled by weathering and are usually localized.

Therefore, D3 sites should be selected according to the results of electric soundings and test boring. FIG. IV-1 shows the areas where ground water will be obtained from D1, D2 and D3 deep wells, together with the areas of S1 and S2 shallow wells.

(2) Geophysical Ground Water Survey

Two different geophysical methods, the ELF-MT (magnetotelluric) method and the Schlumberger electric sounding method, were used for ground water survey in the study area.

The ELF-MT survey revealed the outline of horizontal distribution of apparent resistivities related to rock type and water content in the surveyed area, while the Schlumberger electric sounding revealed the vertical distribution of resistivities related to the depth and thickness of layers at each site of measurement.

The number and locations of each geophysical survey are summarized in TABLE IV-4.

TABLE IV-4 **SUMMARY OF GEOPHYSICAL GROUND WATER SURVEY SITES**

Area / Method	ELF-MT	Electric Sounding	Test Boring
(1) Kayonza	-	4	No. 1
(2) Kabarondo	-	3	No. 2
(3) Kigarama	-	3	No. 5
(4) Sake	16	2	No. 6
(5) Rukira I	12	2	-
(6) Birenga	14	1	No. 7
(7) Rukira II	-	1	No. 3
(8) Rusumo	15	2	No. 4
(9) Muhazi	35	3	-
(10) Mugesera	15	1	-
(11) Rwamagana		1	-
TOTAL	139 sites	23 sites	7 sites

FIG. IV-2 shows the locations of geophysical ground water survey sites. FIG. IV-3 (1) - (7) and FIG. IV-4 (1) - (23) in the supporting Report illustrate the results of the ELF-MT survey and Schlumberger electric soundings, respectively. The results of the geophysical ground water survey in the study area are summarized as follows:

1) Kayonza area: (see Fig. IV-3(1) and IV-4(1)-(4))

FIG. IV-3 (1) indicates low resistivity zones (less than 200ohm.m), stretching along the Nyankora valley from southwest to northeast which may be mainly caused by ground water.

Electric soundings were carried out across the valley to outline a geological section passing the area where the lowest resistivity was obtained (site No 1). FIG. IV-4 (1) - (4) shows the results of the electric soundings. The figures in the column designate resistivities in ohm.m assigned to each layer, and the figures allocated outside of the column designate the depths of the boundaries between successive layers.

FIG. IV-4 (1) - (4) are summarized in FIG. IV-5 as a geological section inferred from the results of the electric soundings. According to the results, ground water appears to occur at depth of approximately 5 to 20m and below 30m, in general. As the upper aquifer mainly consists of alluvial sediments of soil, clay, sand and gravels with poor permeability and high porosity, ground water yield may be scarce, while the lower aquifer comprising of well-jointed quartzite and schist will yield sufficient ground water.

Similar geological structure may be inferred at any place along the Nynkora valley by the extrapolation of the geological structure shown on FIG. IV-5.

One of the test borings (referred to as N° 1) was carried out at site N° 1 shown on FIG. IV-3 (1).

2) <u>Kabarondo area</u>: (see FIG. IV-4(5)-(7))

FIG. IV-4 (5)-(7) show the results of the electric soundings carried out in the Kabarondo area.

According to the data obtained at site N° 1, where test boring (No. 2) was carried out, two aquifers may exist, one at a depth of less than approximately 20m and the other deeper than approx. 30m. As the former is mainly composed of alluvial sediments and boulders with thick layer of soil and clay, permeability may be poor while porosity is very high.

The latter is mainly composed of well-jointed quartzite and schist. At this site, the target depth of the boring should be more than 40-50m in order to reach the deeper ground water which may be subject to less contamination than upper ground water.

3) <u>Kigarama area</u>: (see FIG. IV-4(8)-(10))

FIG. IV-4 (8)-(10) show the results of electric soundings carried out in the Kigarama area.

According to the data obtained at site N° 1, where test boring (N° 5) was carried out two aquifers may exist one at a depth of less than 20m and the other at a depth below 50m. The former may consist mainly of alluvial sediments of sand and gravels, while the latter may consist of interbedded quarzite with dominant schist.

The target depth of the boring should be deeper than 50m up to 70m in order to reach the deeper aquifer.

4) <u>Sake area</u>: (see FIG. IV-3(2) and FIG. IV-4(11)-(12))

FIG. IV-3 (2) and FIG. IV-4 (11)-(12) show the results of the ELF-MT survey and the electric soundings carried out in the Sake area.

As this area mainly consists of impermeable granitic rocks, it is rather difficult to determine the location of ground water. However, according to the data obtained at site N° 2, where test boring (N° 6) was carried out, the existence of two aquifers is inferred; one is at a depth of less than approximately 40m and the other is at a depth below approximately 50-120m. As the latter is too deeply located for the use of a manual pump, the target depth of the boring should be 50 to 80m.

As shown on FIG. IV-3(2), the electromagnetically anomalous area is distributed in the vicinity of Lake Birara. This may be attributable to the difference of terrain height in the area. Hence, the vicinity of lakes is recommended as the location for wells which might be exploited in future.

5) Rukira I area: (see FIG.IV-3(3) and FIG.IV-4(13)-(14))

FIG. IV-3 (3) and FIG. IV-4 (13)-(15) show the results of the ELF-MT survey and the electric soundings carried out in the Rukira area. This area has topographical disadvantages. As the valleys are deeply dissected, the ground water table should be relatively deep, and the boring site must be located on slopes or in the valley. However, accessibility of the valleys is very poor.

As shown on FIG. IV-3 (3), an anomalous area of resistivity is found in the valley (Rwangakobo area). The data shown on FIG. IV-4 (13) were obtained at the site near station N° 9 of the ELF-MT survey shown on FIG. IV-3 (3).

The existence of ground water is not evident in the data; however, from a small deflection of the curve at a depth from 10 to 20m, ground water is inferred to exist at a depth of more than 20m at this site. The target depth of the boring should be 30 to 50m in the valley.

Although FIG. IV-4 (14) indicates favorable ground water conditions with an estimated depth of approximately 7 to 30m, accessibility to the site is very poor hindering transportation of equipment for boring.

6) Birenga area: (see FIG. IV-3(4) and FIG. IV-4(16))

FIG. IV-3 (4) shows the results of the ELF-MT survey carried out in the Birenga area. As this area consists mainly of dominant quartzite steeply inclined to the west, the resistivity values shown on FIG. IV-3 (4) are very high, and an anomalous area was not found.

FIG. IV-4 (16) shows the results of the electrical sounding carried out at the site near station N° 14 of the ELF-MT survey shown on FIG. IV-3 (4). According to the results, ground water may exist at a depth of more than 35m from the ground surface. The target depth of boring at this site should be from 40 to 80m.

7) Rukira II area: (see FIG. IV-4(15)

FIG. IV-4 (15) shows the results of the electrical sounding carried out at site N° 3 where test boring (N° 3) was performed. According to the results, two ground water aquifers may be expected, one at a depth of less than 22m and the other below 30-100m. As the upper aquifer mainly consists of alluvial sediments with high porosity but poor permeability, the target depth of boring at this site should be 50 to 80m in order to reach the lower aquifer.

8) Rusumo area: (see FIG. IV-3(5) and FIG. IV-4(17)-(18))

FIG. IV-3 (5) shows the results of the ELF-MT survey carried out in the Rusumo area. It is obvious from FIG. IV-3 (5) that the anomalous area of resistivity stretches along a valley, especially at sites N° 10, 11 and 14.

The electric sounding data shown on FIG. IV-4 (17) and FIG. IV-4 (18) were obtained at station N° 11 and N° 1 of the ELF-MT survey, respectively. According to FIG. IV-4 (17), (18) the depth of the aquifers are estimated at approximately 10 to 30m and below 140m. The depth of the deeper aquifer is beyond the capacity of a manual pump. Hence, the target depth of the boring should be 40 to 50m in the valley.

9) Muhazi area: (see FIG. IV-3(6) and FIG. IV-4(19)-(21))

FIG. IV-3 (6) shows the results of the ELF-MT survey carried out in the Muhazi area. As this area mainly consists of granitic rocks, the resistivity values measured are very high in general. Electric soundings were carried out at sites near stations N° 10 and N° 32 of the ELF-MT survey, at which relatively low resistivities (less than 1,000 ohm.m) were measured.

FIG. IV-4(19) shows the results of electric sounding carried out at the site near N° 32. A significant low resistivity zone is designated from approximately 10 to 65m. This zone is likely attributable to a weathered zone on top of fresh granitic rocks. The target depth of the boring should be 70 to 80m.

10) <u>Mugesera area</u>: (see Fig. IV-3(7) and FIG. IV-4(22)-(23)

Fig.IV-3(7) shows the results of the ELF-MT survey carried out in the northeastern area of the Mugesera Commune. It is obvious from the results that the low resistivity zones are distributed over the mountain or hillside. Hence, wells which will be exploited in future should be located in or near valleys.

FIG. IV-4 (22)-(23) show the results of the electric soundings carried out in the western part of the Mugesera Commune. According to FIG. IV-4 (22), there are two low resistivity zones, one at a depth from 3 to 15m and the other deeper than 70m. The former may be attributable to a weathered zone on top of fresh granitic rocks, whereas the latter may be caused by ground water.

The target depth of the boring which will be carried out at this site should be more than 70m up to a maximum depth of 100m. Other data shown on FIG. IV-4 (23) revealed that a weathered zone may exist from 13 to 20m from the ground surface; however, no ground water can be expected in the vicinity of site N° 1.

Tentative hydrogeological conditions of the aquifers at each test boring site are summarized in TABLE IV-5.

(3) Test Boring

1) Selection of Boring Sites

Seven test boring sites were selected in areas representative of each type of well based on the well classification map (FIG. IV-1) which was formulated from the results of water quality, hydrology, electrical prospecting and other surveys. Location of each site is shown in FIG. IV-2 while site features including geology, hydrology and topography are summarized in TABLE IV-5.

2) Boring Results

Test boring results are summarized in TABLE IV-6 and FIG. IV-6 (1)-(7). Of the five test wells, water yield was particularly abundant in No.1 Kayonza district and No.5 in Kigarama district, and installation of electric pumps for lifting is considered the optimum method for future well use.

Aquifer depth is 30-52m and as the possibility of obtaining a good aquifer increases with depth, proposed well depth is from 50-80m (average 60m). Total number of days required for boring is estimated as follows on the basis of test boring results.

Work Item	No. of Days Required
Transportation	2
Temporary facilities	2
Drilling (40m)	5
Logging and strainer setting	1
Cleaning	2 (minimum)
Well test	1
Removal	2
Total	15

The above estimation assumes use of a rotary type drilling machine as well as good access conditions. Ample time should be allotted for cleaning operations in the case of well drilling as insufficient cleaning will affect water yield from the well. The above figures represent the minimum time required for cleaning and it is preferrable that even more time be allocated for the same in the overall work schedule.

3) Well Test

A well test was conducted for the two well sites (Kayonza No.1 and Kigarama No.5) which had particularly high yield and where use of electric pumps is considered viable. Two test methods were employed; Jacob's Method in which water is lifted continuously until a stable water level is reached for a fixed quantity of water and variations in water level are measured; and the Recovery Method in which recovery of the water level in the well after lifing has ceased is measured. Data from the above procedures are summarized in TABLE IV-7 (1)-(4) while results of analysis are presented hereunder. Symbols used in calculation are defined as follows:

- Q: lift volume (m^3/sec)
- r: well radius (m)
- T: transmissivity coefficient (m^2/h)
- K: permeability coefficient (m/h)
- S: storage coefficient
- t: observation period
- t': time passed after lifting stopped (sec)
- to: standard time from working drawing (sec)
- s: drop in water level (m)

a) Kayonza District (No.1)

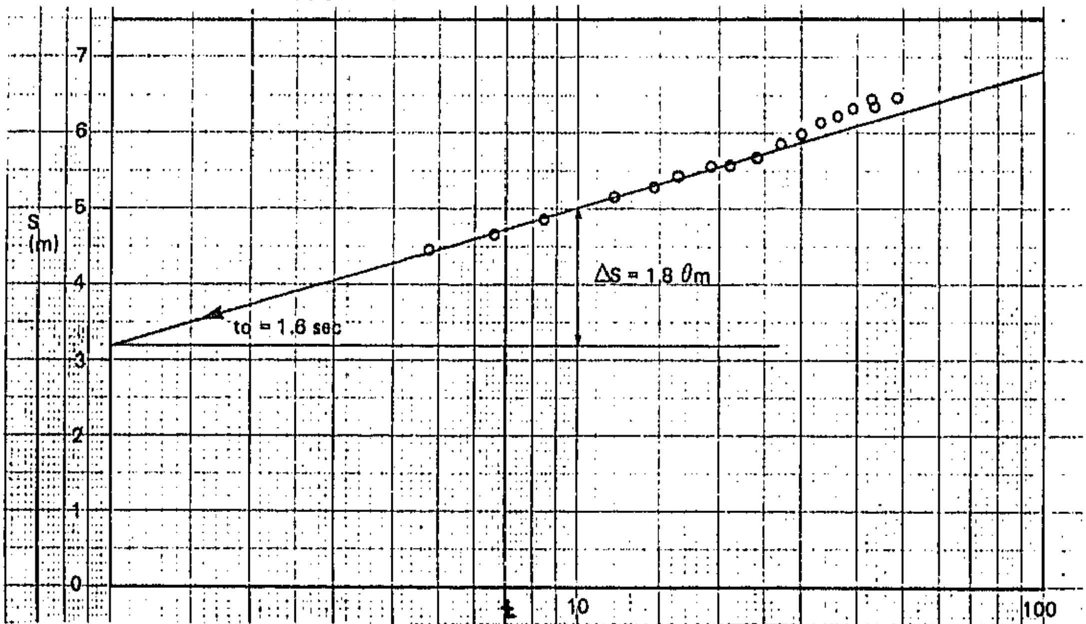
Jacob's Method

Q = $9.1 m^3/h = 2.53 \times 10^{-3}$ (m^3/sec)

s = 1.80m

r = 0.10m

to = 1.6 sec



$$T = \frac{2.3Q}{4\pi\Delta S}$$

$$= \frac{2.3 \times 2.53 \times 10^{-3}}{4 \times 3.14 \times 1.8} = 2.57 \times 10^{-4} \ (m^3/sec)$$

$$S = \frac{2.25\ T\ to}{r^2}$$

$$= \frac{2.25 \times 2.57 \times 10^{-4} \times 1.6}{0.01} = 9.25 \times 10^{-2}$$

$$K = \frac{T}{\Delta h} = \frac{2.57 \times 10^{-4}}{5} = 5.14 \times 10^{-5} \ (m/sec)$$

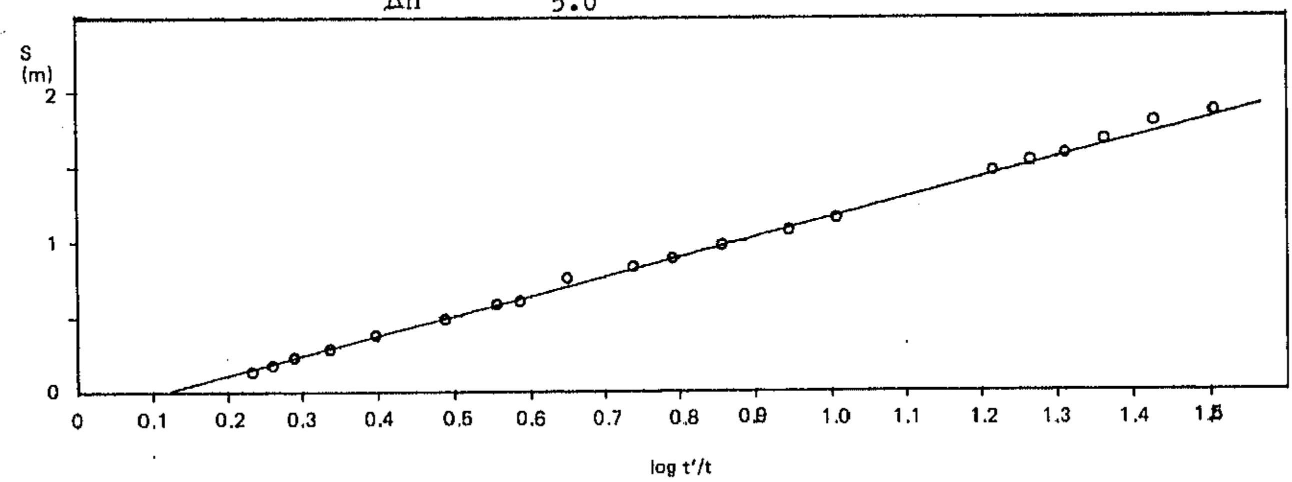
2) Recovery Method

$$T = \frac{0.189\ Q}{S} \cdot \log \frac{t}{t'}$$

$$= \frac{0.189 \times 2.53 \times 10^{-3}}{1.47} \times 1.217$$

$$= 3.96 \times 10^{-4} \ (m^2/sec)$$

$$K = \frac{T}{\Delta h} = \frac{3.96 \times 10^{-4}}{5.0} = 7.92 \times 10^{-5} \ (m/sec)$$



The permeability coefficients obtained by both the Jacob and Recovery methods were of almost the same order. The permeability coefficient is equal to that of silty sand or well jointed metamorphic rocks designating lower permeability in comparison with the gravel layers.

The storage coefficient obtained was substantially larger than the value for confined aquifers (0.005-0.00005), corresponding to the value of unconfined aquifers (0.05-0.4). Accordingly the possibility of an unconfined aquifer occurring at this well is high.

b) Kigarama District (No.5)

Jacob's Method

$Q = 6.9m^3/h = 1.92 \times 10^{-3}m^3/sec$

$\Delta S = 3.65m$

$r = 0.1m$

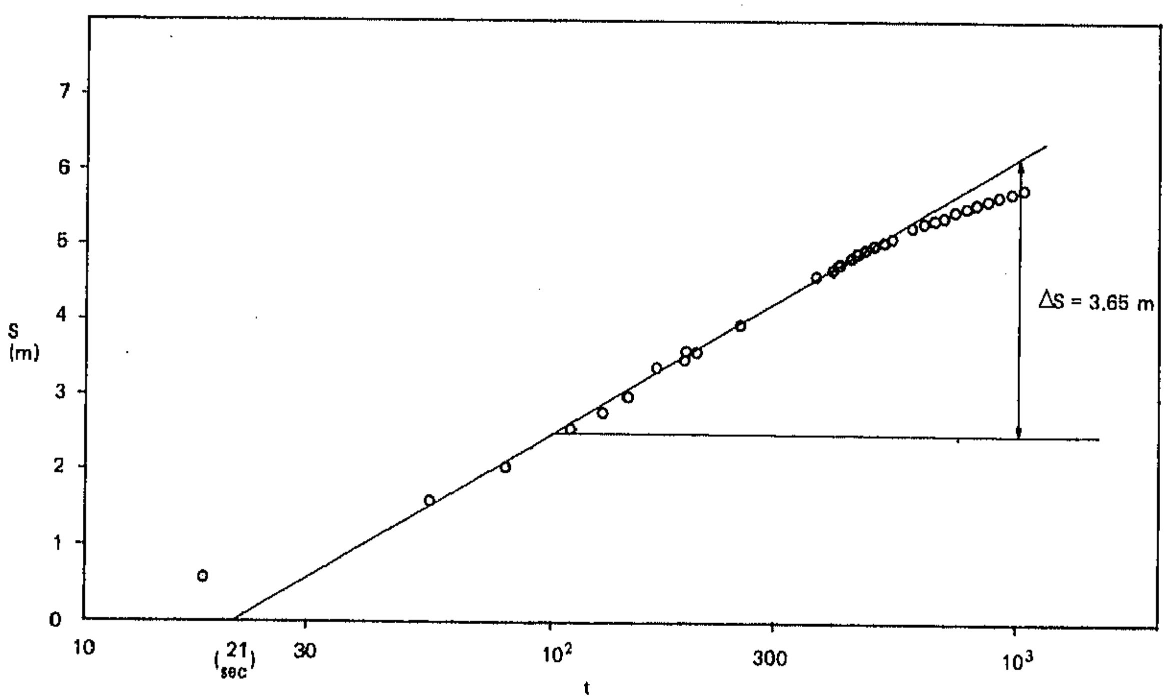
$$T = \frac{2.3\ Q}{4\ \Delta S}$$

$$= \frac{2.3 \times 1.92 \times 10^{-3}}{4 \times 3.14 \times 3.65} = 4.55 \times 10^{-1}\ (m^2/sec)$$

$$S = \frac{2.25\ T\ to}{r^2}$$

$$= \frac{2.25 \times 9.63 \times 10^{-5} \times 21}{0.01} = 4.55 \times 10^{-1}$$

$$K = \frac{T}{\Delta h} = \frac{9.63 \times 10^{-5}}{5} = 1.93 \times 10^{-5}\ (m/sec)$$



Recovery Method

$Q = 6.9m^3/h = 1.92 \times 10^{-3} m^3/sec$

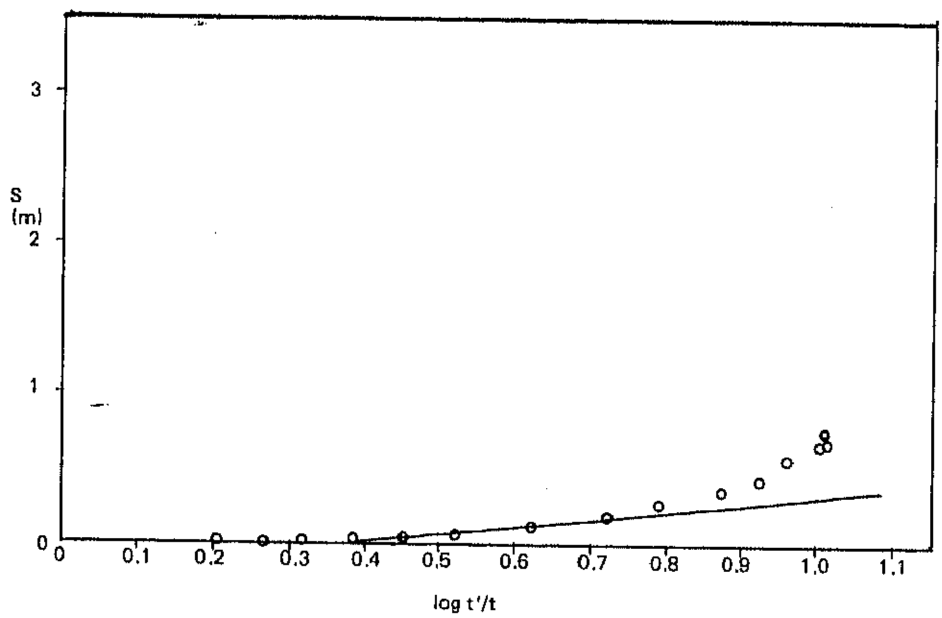
$$T = \frac{0.189\ Q}{S} \cdot \log \frac{t}{t'}$$

$$= \frac{0.189 \times 1.92 \times 10^{-3}}{0.04} \times 0.449$$

$$= 4.07 \times 10^{-3}\ (m^2/sec)$$

$$K = \frac{T}{h}$$

$$= \frac{4.07}{5} \times 10^{-3} = 8.14 \times 10^{-4}\ (m/s)$$



The values of the permeability coefficients obtained are of the same order as those for sandstone or well jointed metamorphic rock, and are smaller than the value for the gravel layer. As in the case of Kayabonza No.1 site, the value of the storage coefficient is representative of an unconfined aquifer.

4.6 Quality of Water

Rural inhabitants usually settle in elevated areas such as the top or side of hills, and almost none of the settlements have latrines or a system for collection and treatment of sewage. Under such conditions, waste water flows to the lower elevations and valley bottoms with insufficient time for natural purification.

Existing water sources for the rural population consist of streams, stagnant water and springs located in the valley. Hence, these sources are becoming increasingly contaminated due to lack of protection from waste materials.

Results of water quality tests on ground water obtained through test boring and on water from rivers, marshes and springs in the area are presented in TABLE IV-6. As the said table indicates, the quality of water obtained from the newly drilled wells is good and water can be drunk directly from the same without treatment. In contrast, water from rivers and marshes which is presently being used by the local inhabitants is contaminated by colon bacili and other bacteria as well as polluted by organic material, etc.

Although this water is unsafe for human consumption, no alternative water source other than natural springs has been available. Installment of wells for provision of safe water supply is therefore extremely urgent.

For quality control of drinking water in urban areas, the latest WHO's standard is applied; in the rural area however, quality control has yet to be established. As a first step for rural water quality control, occasional bacterial tests and simple disinfection should be started by the authorities, while domestic use of untreated surface water should be gradually prohibited. Water quality of samples taken from new test wells is satisfactory. Analytical data is separately attached.

4.7 Classification of Water Supply Districts

4.7.1 Size of Water Supply District

As mentioned previously, the population of the project area is thinly scattered. This settlement pattern makes provision of a centralized pipe water system very uneconomical.

When point sources are used in a water supply system, the physical area of individual water supply districts is restricted. Rural populations often do not make use of improved water sources if the location of the same is too far. They prefer to use nearby sources, even if they are seriously contaminated. Therefore, as mentioned in 4.2.3, the development of new point sources for safe water supply should also take into consideration ease of access; otherwise improvements will have no practical significance in the rural area.

Considering the above, the Cellule was selected as the most suitable unit water supply district for the project, depending on the point source. Since the Cellule is not an administrative unit, its area can not be identified exactly on the map of the Commune. The location of Cellules is indicated without boundaries on the administrative map (scale /25,000).

As Cellule boundaries do not exist, further investigation will be required in the project implementation stage to determine water supply districts on a Cellule basis. For the time being, although the location and the area of Cellules are not clear, the water supply districts are identified on the basis of reliable population data and the hypothetical territory of Cellules bounded by streams and valleys. The hypothetical territory of each Cellule is estimated to be 3-4km, which is supported by the following estimation derived from statistical data.

The area of each water supply district was obtained from the hypothetical Cellule area: approximately $4km^2$ - total usable land of Kibungo Prefecture divided by the number of Cellules.

A : Total usable land of Kibungo Prefecture: $2,666.6km^2$.

B : Total number of Cellules: 694

A ÷ B = $4km^2$/Cellule

Assuming that the shape of the water supply district is rectangular or circular, the longest side would be about 2km. When a well is installed at the center, the maximum distance for transporting water from the well to the houses in the Cellule is 1km.

4.7.2 Water Supply Districts by Wells

At first, a full allocation of the water supply districts throughout the project area was prepared, attempting to cover the area as comprehensively as possible but considering actual distribution of ground water resources. The total number thus obtained amounts to 625 districts (ideal allocation).

These districts were then reviewed to eliminate districts which might require an excessive development cost including the following:

a) Districts which require construction of long access roads for well installation.

b) Districts where inexpensive manual pumps can not be applied due to the depth of the aquifer.

c) Districts with granite bedrock where probability of striking water by drilling is low.

In consideration of the above, a total of 168 districts were finally selected as feasible.

4.7.3 Water Supply Districts by Rainfall Storage Units

As described in 4.1.4, to solve temporarily shortages of domestic water supply in the districts where development of ground water is not feasible, 136 rainwater storage units have been allocated for 136 districts in the project area in addition to 489 well districts.

The rain water storage unit requires a relatively wide water catching surface. It is a common practice to utilize the roofs of buildings for the catching surface which greatly reduces construction cost. However, in the case of Kibungo Prefecture, only a few existing buildings suitable for utlization are available. Therefore, 12 hospitals and dispensaries were selected for utilization and 12 rainfall storage units are planned to be installed.

4.7.4 Summary of the Working Plan for Water Supply Districts

A summary of the water supply districts in each Commune is shown in TABLE IV-7 (ideal plan and working plan) and essential detailed data for each water supply district (186) are shown in TABLE IV-8 and IV-9. The districts are classified in 12 regional zones the locations of which are shown in FIG. ______.

4.7.5 Served Population and Served Area

The estimated, population in Kibungo prefecture in 1984 is 382,915. Only 5%, less than 20,000 people, has access to the safe water supply system in Kibungo city and Ruwamagana city. Another 45.5% about 170,00 people is to be served by protected springs which were developed by AIDR. Therefore, the remaining 49.5% or 190,000 people must rely on contaminated surface water.

This population is therefore the target of the new supply system planned under the project. According to calculations based on the working plans of the water districts described in 4.7.2, 3, 4, the population and area to be served under the plan are as follows:

Served population: 67,600 (about 18% of the total)

Served area: about 750km^2 (about 30% of total)

Under this new allocation of water supply districts, 35% of the population which presently lacks access to safe water supply will be provided with reasonable access to safe water supply from the wells.

4.8 Number and Type of Water Supply Facilities

The type of water supply facility adaptable for an individual water supply district was decided by the following method.

Water demand and available discharges for the existing springs in each Cellule are first estimated and compared. If the water demand is greater than the available discharges from the existing springs, the number of water supply facilities is calculated at the next step. The number of pumps required is obtained from the net water demand divided by the pump capacity of 10 m^3/day (No. of pumps = $\frac{\text{net demand}}{\text{capacity}}$).

The number of wells required is determined from the number of pumps required. One well can be equipped with one pump. If the water demand is less than the available discharge from the springs, at least one well with a pump will be allocated in each Cellule to ensure ease of access regardless of the existing spring's capacity. The location of the well is determined at the shortest walking distance from users.

In some districts, ground water development is complicated by hydrogeological and geophysical factors. Those districts are excluded from the objective area for well drilling but as an alternative, temporary solution, 12 districts with hospitals and dispensaries will be provided with rainfall storage units designed to supply the minimum amount of drinking water.

4.9 Standard Design of Facilities

4.9.1 Tube Well

The diameter of the manual pump to be installed in the well is 70mm for shallow wells and 90mm for deep wells. The basic requirements to be satisfied by the wells are as follows:

Yield	more than 1,000ℓ/hour
Water Quality	not specified

(1) Casing

1) Temporary Surface-casing

During the drilling work of the well, a temporary surface casing is inserted to be removed from the hole on completion of drilling. Concurrent with removal of the temporary casing, the annular space around the permanent pump chamber-casing is filled with grout seal.

2) Pump Chamber-casing (pump housing)

The pump chamber-casing is an essential part of the well, furnishing a direct connection between ground surface and aquifer, sealing out undesirable shallow ground water, and supporting the side of the hole.

Polyvinyl chloride (PVC) was chosen among various kinds of pipe material, because of such advantages as its light weight, ease of installation, excellent corrosion resistance, availability in the local market and moderate price.

The recommended pump chamber-casing diameter is a minimum of 150mm (6in.). FIG. IV-7 and FIG. IV-8 shows the typical design of the well and the typical design of the pump platform, respectively.

The length of the pump chamber-casing is to be determined by estimating projected pumping levels, static water level and probable drawdown caused by pumping. The top of the pump chamber-casing should be set at least 300mm (12 in) above the proposed top elevation of the pump foundation. Any excess at the top may be cut off when the permanent pump is installed. The pump chamber-casing should be grouted with cement mortar; this should be done just when the temporary surface casing is withdrawn.

3) Screen Assembly

The most important characteristics of a screen are slot size and amount of open area to stabilize sides of the hole and keep sand out of the well. These are determined from mechanical analyses of the formation samples and electric well logging after drilling. The screen assembly consists of the screen proper (perforated PVC pipe) and bottom seals. Slot opening ranges from about 0.25mm (0.010 in.) for large slots. Below the bottom of the lowest screened section, a bottom seal will be installed.

4.9.2 Manual Pump

A reliable manual pump which is specially designed for countries where water is scarce and located deep underground is required to meet VLOM (Village Level Operation and Maintenance). In a selection of the type of pump, the following essential features should be considered.

(1) Joint Pump Operation

In the project area, women and children draw water together. Therefore the pump should have a suitable lever or device which is operable by two people joining hands.

(2) Maximum Simplicity for Operation and Maintenance

Maximum simplicity of the well mechanism is required to eliminate elaborate maintenance. The wearing parts should be located above ground for easy replacement.