2) Well

Except for the 72 pumps installed under the grant aid cooperation of the Government of Japan, no pumps existed in the area. Lowlands along lakes and rivers were potential areas for shallow well development.

(2) Surface Water

1) River

Since many of the rivers in the Area ran dry and become heavily contaminated, few of them could be used as water sources without reservoir facilities.

2) Lake

The lakes in the Study Area had ample water, though the water was also heavily contaminated.

As the amount of water contained in the lakes (total volume of 690 million m3) was significant and stable compared to that of river water and the seasonal fluctuation of the water table was slight, it would be more beneficial to use the lakes as sources for urban water supply. Rwamagana Urban Water Supply used the lake water.

(3) Rainwater

Due to the types of houses, little rainwater harvesting was used by the residents. Comparatively large-scale rain-water harvesting facilities using the strong roofs of hospitals and churches were seen in the Study Area.

4.2 HYDROGEOLOGY

By assessing the hydrogeological survey results obtained by the Feasibility Study (F/S) conducted in 1985 by JICA, the results of the Phase I project, and by clarifying the results of the field survey, the hydrogeological conditions of the Study Area were classified.

4.2.1 Summary of Previous Study and Data

Hydrogeological Characteristics

In view of the bedrock geology and water use conditions, the hydrogeological environment of the Area was classified into the two areas suitable for;

- shallow well sites (less than 30 m in depth) two categories; S1 and S2,
- deep well sites (more than 30 m in depth) three categories; D1, D2 and D3, and
- eliminated area - N (mountainous areas higher than elevation of 1,500 m)

Groundwater development was mainly made in the alluvial and diluvial strata areas for the Phase I project.

4.2.2 GEO-ELECTRIC PROSPECTING (refer to Appendix G)

Based on the results of hydro-geological surveys, geo-electric prospecting was conducted using the Schlumberger method and the new EM method in order to obtain the basic data necessary for determining the hydro-geological structure.

. Contents of Prospecting

The Schlumberger method	98 points
The EM method	199 points

(1) Evaluation of the Prospecting Results

Relation between Schlumberger Method and EM Method:

Relative resistivities of different rocks measured by the Schlumberger Method and the EM Method were as shown in the following table:

	Prospecting Method	
Type of Rock	Schlumberger Method	EM Method
Schist	200 to 1,000 ohm-m	400 to 2,000 ohm-m
Quartzite	200 to more than 3,000 ohm-m	More than 2,000
Granite	100 to 700 ohm-m	More than 1,000 ohm-m

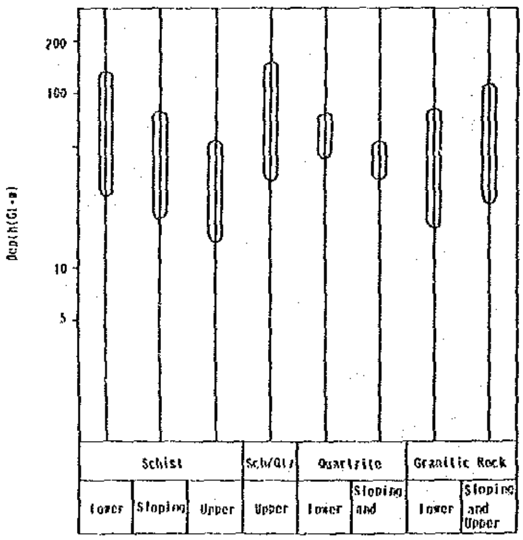
For an upper horizon distributed at a depth of 20 to 30 m from the ground surface, the EM Method's relative resistivity values (the reciprocals of conductivities) obtained from the results of the horizontal multi-layer formation analyses agreed with the analysis results of the Schlumberger Method. For the lower horizon, the EM Method's relative resistivity values were larger than those obtained by the Schlumberger Method.

It was considered that a quantitative evaluation was impossible with the EM Method's horizontal prospecting. However, the EM Method was very useful for selecting potential well drilling sites within certain areas.

Strata Formation and Relative Resistivity:

Based on the analyzed relative resistivities and depths, a relative resistivity profile diagram was prepared as given in Fig. G.2 of Appendix G.

It was confirmed that each geological area was composed of more than three strata. The following figure shows the elevations of the tops of the deepest strata (bedrock) in each area.



Depth of Non-altered Parts

The elevations of the top surface of the deepest strata deviated to a great extent. In the schist and quartzite areas, the elevations became lower from the lowland areas towards the slope and ridge areas.

In the granite areas, the elevations became higher from the lowland areas towards the slope and ridge areas. It was considered that this tendency was caused not only by the different stages of the weathering process (except in the Rusumo area where the weathering of granite was advanced) but also by the existence or thickness of the covering layer.

4.2.3 Test Drilling and Pumping Test (refer to Appendix H)

Five(5) test borings (total drilling depth of 633.5 m) were made for the Study to obtain the basic data necessary to evaluate shallow and deep well development possibilities.

The geological conditions and geophysical logging results of each well (see Fig. H.3 "Geological Columnar") were obtained from the Test Boring.

The descriptions of each drilling point and results were outlined as below:

80 m deep well

Br.1: Shallow groundwater investigations at lowland of Lake Muhazi basin which had the highest lake water table in the Study Area.

GL 0.0 GWT=GL-6.9 m

to -28.0m: Heavily weathered schist layer. Mixture of clay, sand and gravel.

to -64.0m: Schist layer. 10 to 20 m fractures and soft portions were occasionally found below GL-40.0m.

to -83.0m: Rock became harder. No fissures were found.

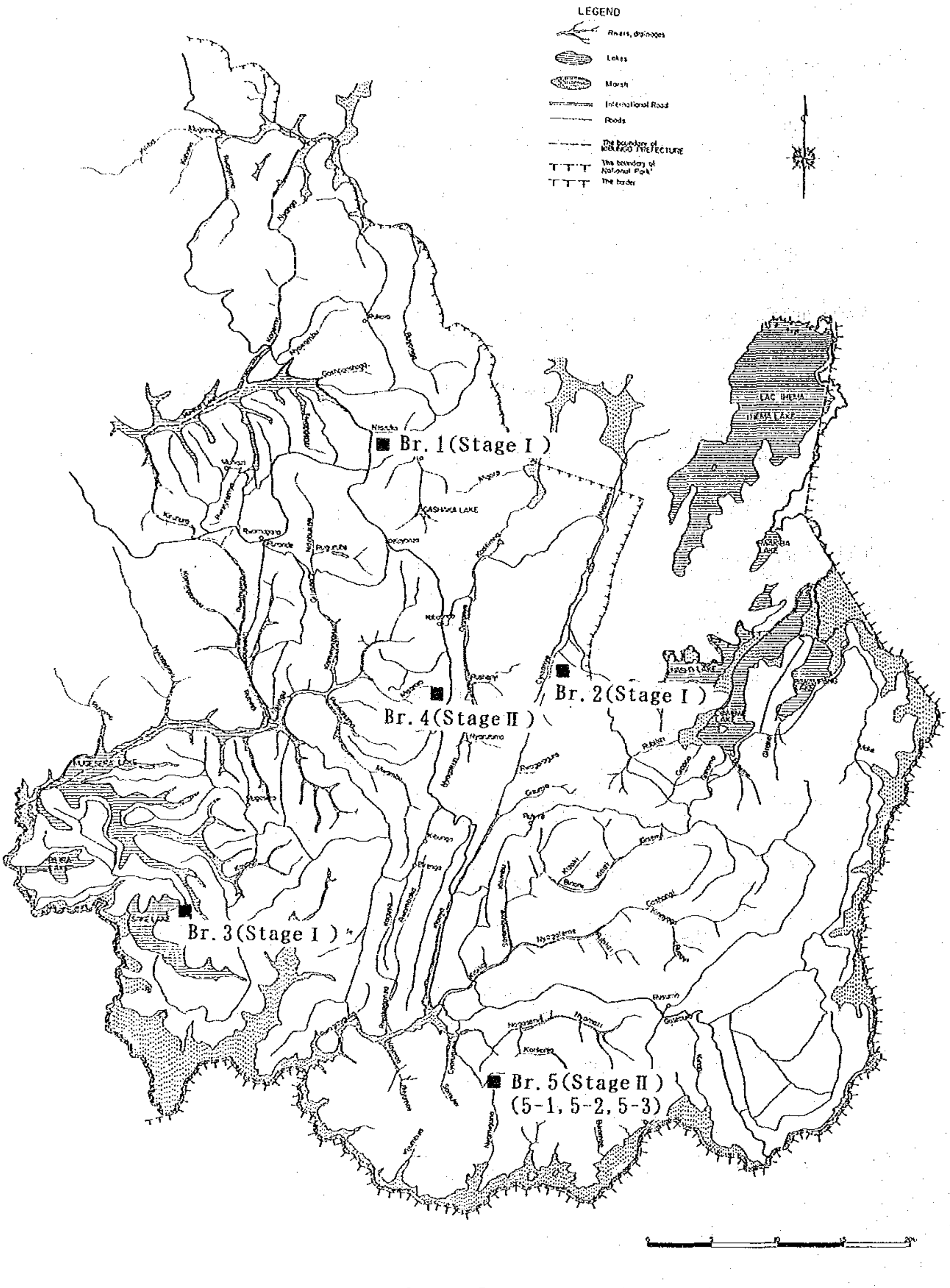


Fig. 4.1 Location of Test Boring Points

Br.2: Shallow groundwater investigation on broad gentle slope of the fan where social increase of population by migration were found. Western portion of Lake Nasho basin.

GL 0.0 GWT=GL-3.8 m
to -22.1m: Composed of clay, sandy clay, gravel mixed sandy clay and gravel mixed clayey sand.
to -23.9m: Quartzite boulders and cobblestones.
to -81.0m: Composition of schist and micaceous schist. Rock became harder as boring progressed deeper.

Br.3: Shallow groundwater investigations at the weathered zones of granite on the shore of Lake Sake.

GL 0.0 GWT=GL-10.8 m
to -15.0m: Mainly clay mixed sand
to -40.0m: Granite. Became harder.
to -81.0m: Alternate hard and soft strata. Well developed fissures and a soft portion were found between GL -63.5 m and -69.2 m. Weathered granite.

150 m deep well

Br.4: Investigation of the potentiality of deep groundwater developments in densely inhabited areas.

GL 0.0 GWT=GL-60.0 m
to -6.0m: Gravel mixed clayey soil.
to-122.0m: Highly weathered schist. The rock was extremely soft.
to-141.0m: Weathered schist. Thick quartzite schist layer was found below GL-133m.

Br.5: Deep groundwater investigation at hard rock areas (quartzite) of southern parts of the area(Rusumo).

GL 0.0 GWT=GL-22.0 m
to -99.3m: Fracture zone consisting of alternate layers of soft(extremely weathered) rock and quartzite (lightly weathered).
to-104.5m: Extremely hard quartzite(drilling speed became less than 1.0 m/day).

Well Logging Results

The resistivity of weathered formations varied from 30 to 700 ohm meter, whereas the schist formations had a high resistivity from 400 to 1,200 ohm-meter. The mixed strata had a medium value. The plots and the corresponding drilling log had good correlations.

SP measurements were not correct due to interference from an underground 0.1 Hz leakage current. Observation values of the plot is shown in Fig. H.3 of Volume II.

Pumping Test Results

Two types of pumping tests were conducted; interval and continuous pumping tests.

According to the "Interval Pumping Test", the following critical pumping amount of each well was obtained:

Br.1 : 210 l/min. Br.4 : 15 l/min
Br.2 : 250 l/min. Br.5 : 170 l/min
Br.3 : 100 l/min.

The data obtained from the "Continuous Pumping Test" was analyzed by using non-equilibrium equations, i.e., the Jacob's straight line analysis method and the recovery method. The results of the pumping-test analysis were outlined as follows:

Table 4.1 Coefficient Aquifer

Location	Thickness of Aquifer (m)	Transmissibility(m2/sec)		Permeability(m/sec)		Storativity
		Jacob	Recovery	Jacob	Recovery	Jacob
Br. 1	21.1	7.63 E-5	2.03 E-4	3.62 E-6	9.62 E-6	1.29 E-1
Br. 2	20.9	2.89 E-4	5.84 E-4	1.38 E-5	2.79 E-5	1.32
Br. 3	12.0	3.27 E-5	2.15 E-5	2.73 E-6	1.79 E-6	4.34 E-1
Br. 4	32.0	1.20 E-5	1.45 E-5	3.75 E-7	4.53 E-7	6.22 E-2
Br. 5-3	19.1	7.38 E-5	5.94 E-5	3.86 E-6	3.11 E-6	1.51 E-1

From the results of the well tests, recommendations for well construction works were made and the details described in Section 4.3.

4.2.4 Outline of Hydrogeological Conditions

The underlying geology of the Area was mainly schist, quartzite, an alternation of schist/sandstone/quartzite and granitic rock as mentioned above. Geological cross sections of the Area indicated a saw shape relief with a straight dip of Pre-cambrian stratum, except granitic rock areas which were relatively gentle.

Drainage systems generally followed the geological structures,such as a NS strike and the main faults/fold axes of a NNE-SSW trend. In the hilly area, narrow and long ridges were also well developed in a NNE-SSW direction.

The Area was divided into six(6) bed rock geological groups;

A : Alluvial Area
Q : Quartzite Area
SQ : Alternation Area of Schist and Quartzite
S : Schist Area
Gn : Gneissose Granite Area
Gr : Massive Granite Area

According to the above geomorphological/geological conditions, the following characteristics of hydrogeology in the Study Area were estimated.

- The permeation and flow of the groundwater were greatly influenced by the degree of the bedrock's weathering condition.

- Except for some fissured areas, good quality aquifers were believed to be limited to alluvial lands and their small lowland fringes, no large aquifer development was expected.

- However, groundwater at many alluvial swampy lands was also stagnant and the deoxidized condition of groundwater was observed with high contents of divalent Fe/Mn ions.

4.2.5 Conditions of Spring Water

According to the spring-water use records of the communes spring-water survey data, more than 5 m3/day/km2 of spring-water had been used in Kabarondo, Rutonde, Sake, Mugesera and Kigarama Communes and around 1 m3/day/km2 of specific production was used in the remaining Communes.

However, the existing discharge records of spring water conflict with observations indicating lower capacities than those of the existing data.

Spring conditions in the Study Area were outlined as below:

- The catchment areas of streams and springs were relatively small. Consequently, the quantities of spring water were smaller and more unsettled than other prefectures of Rwanda.

- The high production areas of spring water were scattered on the southern low lying lands of Muhazi Lake, the western/northern lower parts of central broad high lands and the lower portions of southern broad hard rock mountainous areas.

- Most of the springs discharged water in a relatively small range, from 1 to 30 lit/min(1 m3 to 40 m3/day), with heavy fluctuations, except a few springs of over 100 m3/day yields which were water sources of existing supply systems.

- The spring water qualities were suitable for drinking purpose.

Based on the present environment mentioned above, the remaining high potential areas of spring water development for Phase III were considered to be Mugesera/Sake/Rukira /Rusumo Communes.

4.2.6 Characteristics of Aquifers

The following characteristics of aquifers were estimated based on the hydrogeological environment.

- Basically, groundwater was recharged in ridge areas and flowed down in transmitting horizons of upper weathered/unconsolidated zones into alluvial low land, parallel with the ground surface.

- Groundwater flow was therefore limited to relatively small sections, forwarded by streams and/or by relatively lower parts.

- Aquifers, suitable for a limited development, were generally found in alluvial lands and their surrounding areas. Therefore, many small scale aquifers were developed along stream lines.

- Continuance of aquifers was not expected in the Study Area and narrow/small aquifers of discontinuity were scattered.

- Groundwater circulation in the Study Area was therefore not considered to be of a long term cycle.

The following conditions and classification of the aquifers in the Study Area were judged from the above-mentioned characteristics of hydrogeology and aquifers.

Table 4.2 Characteristics of Aquifer

Classification of Aquifer	WT (m-GL)	Thickness of Aquifer(m)
SHALLOW GROUNDWATER		
-Alluvial Deposits(Gravel,Sand/Clay)	0- 20	<20
-Debris & Weathered Materials at Low level(Granular Granite, Fracture Zone)	15<	25-45
DEEP GROUNDWATER		
-Debris & Weathered Materials at Slope	50<	20<
-Weathered & Fractured Rocks	50<	20<
LOW PERMEABLE HORIZON		
-Weathered Fine to Medium Materials	-	-
-Unaltered Massive Bed Rocks	-	-

4.2.7 Hydrogeological Characteristics of Each Basin

The Study Area was divided into eleven(11) drainage basins (see Section 3.1.4). On the basis of the above hydro-geological classification, the features of each basin were generally as follows:

A Basin

[Gn: northern lowland, SQ: southern higher part]

Transmitted and/or yielded groundwater only around main streams and alluvial lands in some quantities, except massive unaltered parts and pelitic schist areas of the southern high lands. Deeper groundwater was estimated to be available on the north lowland.

B Basin

[Gn: around Muhazi Lake, S: eastern slightly higher parts]

Yielded groundwater around the lake/main streams/alluvial lands in some quantities, except massive unaltered parts. Influent stream of groundwater from Muhazi Lake was estimated on account of the highest lake water table of Muhazi Lake in the Study Area.

C Basin

[Q: ridge and sloping areas, S: lower/bottom areas]

Recharged or transmitted in the higher parts and/or yielded groundwater in relatively lower portions and alluvial lands in some quantities, except for massive unaltered parts and a large pelitic schist area on a gentle to flat bottom.

D Basin

[Gn: around eastern lakes, SQ+diorite: western to southern higher parts]

Yielded groundwater around lakes/main streams and a few areas of the alluvial fan in some quantities, except for massive unaltered parts. Effluent streams of the groundwater to the lake was estimated because of the higher mountainous area surrounding the lakes.

E Basin

[S+(SQ) with many slender alluvial lands]

Mainly impervious areas that obstructed the groundwater flow with low permeability, except for alluvial lands, and debris & coarser weathered parts of the sloping areas which were small aquifers at the lower sections. The aquifers were considered to be narrow/small, discontinuous and scattered. A few springs were found in the relatively lower parts.

F Basin

[Gn: around Mugesera and Sake Lakes, SQ: eastern higher parts]

Transmitted in limited parts and/or yielded groundwater around the lakes/main streams and alluvial lands in some quantities, except for massive unaltered parts and higher pelitic schist areas. A few springs occurred on the boundaries between SQ and Gn areas.

G Basin

[S+(SQ) with swampy alluvial lands in the center]

Mainly impervious areas that obstructed the groundwater flow, except for alluvial lands and debris & coarser weathered parts of the sloping areas where narrow/small discontinuous aquifers were developed at the lower parts.

H Basin

[Q: ridge and steep sloping areas, S: rolling lands/lower slope areas]

A large area of recharged or transmitted in the higher parts and/or yielded groundwater in the sloping areas, lower portions and alluvial lands in some quantities except for massive unaltered parts. A few springs in quartzite areas were found.

I and K Basin

[Q: ridge and steep sloping areas, SQ+diorite: lower slope areas]

Recharged or transmitted in the higher parts and/or yielded groundwater in the sloping areas, lower portions and alluvial lands in some quantities except for unaltered parts. A few springs in sloping areas were found.

J Basin

[Gr: gentle lands, Q+S: northern sections]

Aquicludes except for fractured zones of faults and joints in tensile zones and north quartzite/schist areas where small aquifers were developed. Only deeper groundwater was expected in the granite areas.

The spatial distribution of hydrogeological groups were as presented in the attached "**Hydrogeological Map**".

4.2.8 Hydrogeological Parameters

Hydrogeological parameters in the Study Area were analyzed, based upon existing data, information and field pumping tests during this study period. The hydrogeological parameters of the Study Area were outlined to be as follows:

Table 4.3 Hydrogeological Parameter

	Transmissibility [T](m2/day)	Permeability [k](cm/sec)	Storativity [S]
.Alluvial Deposits	10 - 35	5 x 10E-4 - 1 x 10E-3	1 x 10E-1 - 1.5
.Weathered Schist/Quartzite	5 - 20	1 x 10E-3	5 x 10E-2
.Weathered & Fractured Granite	1 - 3	1 x 10E-4	5 x 10E-1

4.3 WATER BALANCE SIMULATION (refer to Appendix J)

4.3.1 Introduction

It was estimated that the stress of the hydrological environment, including groundwater cycles exerted by development, would be evident throughout with the more intensive groundwater/surface-water used for the improvement of Rwanda's living conditions.

Then, the considerations of environmental stress by water resources would be required, when more water development than ever is formulated.

The assessment of groundwater balance may also be very important in groundwater studies, in order to determine/evaluate to what degree output was required and groundwater extraction for domestic uses was possible.

4.3.2 Hydrological Condition for Water Balance Simulation

(1) System of Hydrological Cycle

To formulate the hydrological cycle, the parts/elements were separated and the system simplified. Generally, the system of the hydrological cycle consisted of some sub-systems. The sub-systems were joined by precipitation, evaporation, percolation, surface runoff and sub-surface runoff which are hydrological processes.

(2) Comprehensive Review of Existing Data

The basic conditions of the hydrological cycle in the Area, except for geomorphology and geology which were described in Sections 3.1 and 4.1, and the availability of data utilization for the water balance simulation model were examined. A review of existing data for the simulation was given as follows:

- Precipitation
  At the examination, the daily rainfall basic data of Kigali and Kibungo stations between 1981 and 1985, were used.

- Evaporation
  The water balance simulations were conducted using the average values (1985 - 1987) of Kigali meteorological station which were the daily evaporation potential for each month.

- Discharge
  The data for Mugesera L., Sake L.(within the Study Area) and Mwange R.(located in the northern part of Kigali Prefecture) were mainly used in definition of the water balance simulation model because of the high availability.

4.3.3 Formulation of Water Balance Simulation Model

The model was generally expressed as a formula of the system components. To formulate the model, the following procedure was required:

. Decomposition of The System
. Formulation of The Model and Computer Programming
. Identification of The Model
. Forecast of Hydrological Condition

Selection of Water Balance Model

In order to simulate the hydrological condition of the area, the Groundwater Tank Model was considered as the most applicable. This was a macro model but it was still possible to estimate the daily water balance condition of a large scale area, using rainfall and discharge data only.

Examination and selection of the model took into account the following conditions of the area:

- According to the dissecting rolling terrain and discontinuous structure of the subsurface (having many folds/faults), the groundwater flow was estimated to be discontinuous and each groundwater basin had a limited extent.
- Detailed time series records of groundwater table and discharge, necessary to simulate/identify a parameter distribution model, were not observed within the Study Area.

Therefore, it was considered that a parameter distribution model such as a finite element method (FEM) was not suitable for the hydrological conditions. Generally, the tank model precisely reproduced the difference of runoff caused by the type of rainfall and was commonly used for both flood and low-water analyses of discharge.

The structure of the Groundwater Tank Model for drainage basins in the Study Area was as given in Fig.J.9 of Volume III.

The basic structure and parameter range of the model such as the number of stages, coefficient of outflow rate, height of orifice and evaporation were determined by trial simulation, referring to the hydrological/geomorphological/geological characteristics of the basin and using actual observation records of rainfall at Kigali meteorological station and river discharge at Mwange R.

Simulations of Mugesera and Sake Lake Basins were also conducted to finalize/confirm the model structure and parameter range, using observation rainfall data.

4.3.4 Results of The Water Balance Simulation

The results indicated the following features of the water balance condition (hydrological cycle) in the Study Area:

- The average annual discharge (including direct runoff and basic runoff) in the 11 Drainage basins (3,680 km2) are 1,040 million m3 (280,000 m3/km2 p.a.)

  This value indicated around 30% of the total rainfall (input) in the Area. A maximum unit discharge of 570,000 m3/km2 p.a. and a minimum of around 120,000 m3/km2 p.a. were simulated.

- Evaporation ranged from:
  400 mm to 690 mm p.a.(approx. 550 mm on average)
- Recharge to aquifer in the Study Area was estimated as:
  590 million m3 p.a. (160,000 m3/km2 p.a.)
  (11% to 18% of total rainfall)
- Basic groundwater runoff was simulated at:
  590 million m3 p.a. (160,000 m3/km2 p.a.)
  (approx. 18% of total rainfall)
- Surface direct runoff was estimated at:
  450 million m3 p.a. (125,000 m3/km2 p.a.)
  (13% of total rainfall)

The simulation results of each drainage basin in the Study Area were outlined in the table below.

Table 4.4 Result of Water Balance Simulation

Unit:mm p.a.

Basin	Area (km2)	Rainfall	Evp.	Basic Runoff	Total Discharge
A	349	1,019	689	221	306
B	346	1,019	689	183	272
C	502	978	674	223	300
D	267	688	402	130	145
E	243	978	674	223	300
F	420	978	331	137	576
G	167	978	596	148	369
H	658	905	456	187	219
I	226	688	402	112	126
J	161	688	402	105	118
K	152	688	402	104	133

The basic situation of the hydrological cycle in the Study Area was as presented in Fig. 4.1.

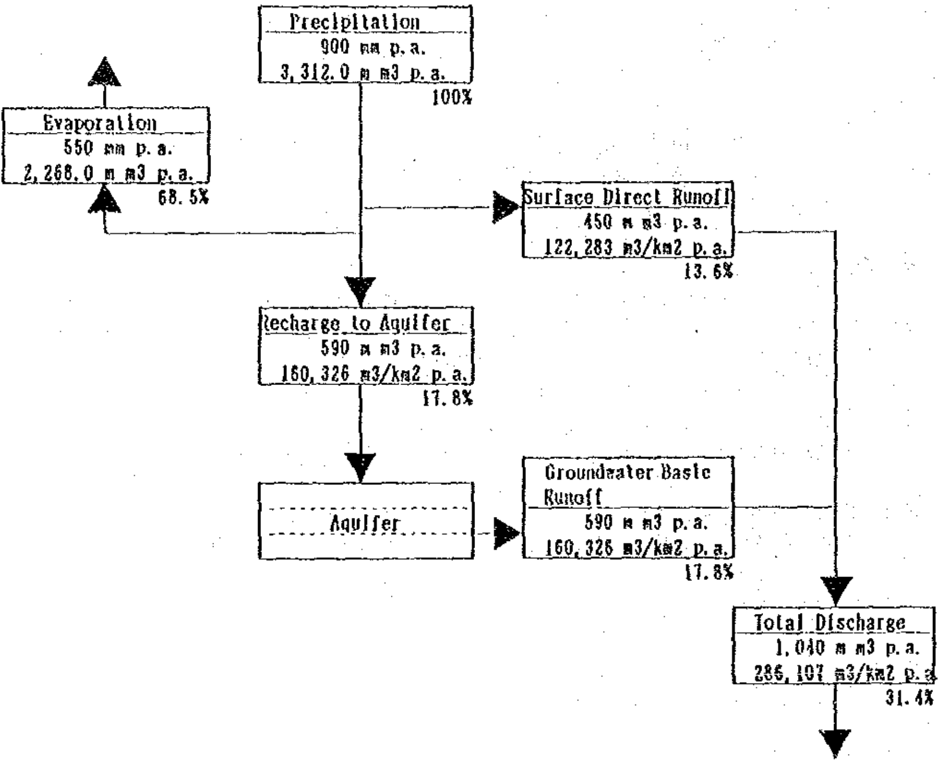


Fig. 4.2 Estimated Hydrological Cycle in the Area

4.3.5 Assessment of the Impact of Groundwater Development

According to the long-term pumping simulation using the Groundwater Tank Model, a pumping-rate of less than 75 m3/day/km2 was considered to be sustainable for groundwater development on account of a few decreases of the groundwater table (GWT). The gradient of the drawdown curve of the simulation showed that a pump rate of over 75 m3/day/km2 would result in a significant drawdown of the GWT.

4.4 GROUNDWATER DEVELOPMENT POTENTIALITY

4.4.1 Classification of Groundwater Development Potentiality

Based on the hydrogeological classification in the Study Area mentioned above, the potentiality of groundwater development was examined and the following eight(8) classifications were established:

Sa: Suitable for a shallow groundwater development with lower limitations of both quantity and quality
Sb: Moderately suitable for a shallow groundwater development with low limitation of quantity but a few limitations of quality
Sc: Moderately suitable for a shallow groundwater development with high limitation of drilling work
Sd: Marginally suitable for a shallow groundwater development with limitations of quantity
M : Marginally suitable for a shallow groundwater development and moderately suitable for a deep groundwater development
Da: Moderately suitable for a deep groundwater development
Db: Marginally suitable for a deep groundwater development
N : Non-suitable for groundwater development (Groundwater development is not proposed at this project stage because of the deep groundwater table of 150 m and the high development cost.)

The distributions were as presented in the attached map **"Classification of Groundwater Development Potentiality"**.

4.4.2 Examination of the Safe Yield of Groundwater

The examination of the safe groundwater yield was carried out by two methods; Hydrological method and Hydraulic method.

The safe yield of groundwater was summarized as follows:

Hydrological Method
Water Balance: 315-835m3/km2/day (305,000m3/km2 p.a.)
Long-term Pumping
Simulation : 75m3/km2/day (27,000m3/km2 p.a.)

Hydraulic Method
: 77 m3/well/day (Hand-pump at "Sa,Sb,Sc")
8 m3/well/day (- do - at "Sd")
123 m3/well/day (Shallow well + motor pump)
196 m3/well/day (Deep well with motor pump)

Consequently, the safe yield for the Project sites was considered to have no constraint on groundwater source if the proposed yield of groundwater was less than 77 m3 for a hand-pump well at "Sa,Sb,Sc", 8 m3 at "Sd" and 123 m3/day for a shallow well with motor-pump.

In addition, well location and density would be studied, taking into consideration a maximum yield of 75 m3/km2 /day which was recommended to sustain the groundwater environment at a maximum.

4.5 WATER QUALITY

Since water quality was an important element for rural water supply planning, consequently, sampling, field testing and detailed analyses in the laboratory by ELECTROGAZ were carried out. The results were summarized in Table 4.5.

The water quality varied much in the different water-sources. The specific electric conductivity however, was mainly below 300 micro mhos/cm and Ph values ranged from 7.0 to 8.1, which would be acceptable for drinking purposes.

(1) Surface water

Surface water contamination was widely observed in the Study Area. It was estimated that rural waste water was the main cause of the wide contamination of surface water.

The comparison of river and lake water qualities was as given below:

	Turbidity (NTU)	Hue (APHA)	Ph	Electrical Conductivity (s/cm)	KMnO4 Consumption (mg/liter)
River Water	22	137	7.2	240	4.2
Lake Water	9	118	8.1	293	9.3

The difference between the river water and lake water qualities was believed to be attributable to the affect of decomposed plants, such as papyrus, on the lake water.

When the surface water was used as a source of drinking water, the problem was how to establish the improvement targets for the turbidity and hues.

(2) Groundwater

Because of the purification capabilities of nature, no coliform bacteria or other bacteria was contained in the groundwater. However, in order to prevent contamination of the Groundwater, the well location would not be located close to stagnated surface water.

The quality of spring water was believed to be good. However, the amount of water was generally too small to develop.

In addition, from the water quality point of view, the water from springs, having an improper environment, was contaminated with coliform bacteria and other bacteria that were influenced by domestic sewage.

Finally, careful re-examinations of the problems of water quality for drinking purposes, in the Study Area, would be required at the Implementation stage of the Project.

Table 4.5 Characteristics of Water Quality in the Area

Item	Unit	LAKE WATER			RIVER WATER			WELL WATER		
		Min	Max	Value Adopted	Min	Max	Value Adopted	Min	Max	Value Adopted
Turbidity	NTU	4.0	12.5	9.2	16.0	26.0	22.0	3.4	22.0	4.5
Colour	APHA	40	190	118	120	160	137	30	80	37
pH		7.0	8.5	8.1	7.0	7.5	7.2	6.5	7.5	7.0
Conductivity	mS/cm	104	480	293	198	240	219	38	240	240
T-Hardness	mg/lit	40	170	93	70	80	77	40	70	53
Free CO2	mg/lit	0.0	10.0	1.9	2.0	49.0	18.3	6.0	74.0	74.0
DO	mg/lit	2.0	5.0	3.9	1.0	4.0	2.7	3.0	3.0	3.0
KMnO4 Consumed	mg/lit	5.2	12.7	9.3	1.5	6.8	4.2	2.3	4.1	3.4
NH4-N	mg/lit	0.22	0.50	0.35	0.22	0.36	0.31	0.13	0.32	0.30
SS	mg/lit	4	18	10	16	30	21	0	8	2
ANION										
Cl	mg/lit	8.0	57.0	25.9	38.0	45.0	40.7	0.0	37.0	37.0
NO2	mg/lit	0.00	0.10	0.02	0.00	0.01	0.01	0.01	0.13	0.13
NO3	mg/lit	0.00	3.08	1.07	1.32	1.76	1.47	0.88	2.60	2.20
SO4	mg/lit	4.0	13.0	8.3	8.0	17.0	13.7	2.0	33.0	27.0
PO4	mg/lit	0.04	0.17	0.09	0.06	0.12	0.09	0.01	0.80	0.40
CACION										
Ca	mg/lit	40.0	130.0	78.6	50.0	70.0	63.3	10.0	70.0	40.0
Mg	mg/lit	0.0	40.0	11.4	0.0	30.0	13.3	0.0	70.0	20.0
Mn	mg/lit	0.0	0.2	0.1	0.03	0.2	0.1	0.01	0.06	0.04
Fe(III)	mg/lit	0.0	1.0	0.3	0.4	1.6	0.9	0.0	1.0	1.0
NH4	mg/lit	0.28	0.65	0.45	0.28	0.46	0.39	0.36	0.67	0.67
Coliform Organisms		++	++	++	++	++	++	-	-	-
Total Colinies		++	++	++	++	++	++	-	-	-

4.6 DEVELOPMENT POTENTIALITY OF WATER RESOURCES

4.6.1 Future Water Demand

The Study Area's water supply and demand at the present time and in the year 2000 are listed in the following table. In the year 2000, the amount of water necessary for domestic use would be approximately 20% of the total water demand. Water for agricultural would be about 76% of the total water use amount and includes irrigation water but not rainwater.

(M: Million)

ITEM	1988	2000
Population	433,000	653,000
Population Density	162.4/km2	245.1/km2
Water Demand	13.5 M m3/year	26.2 M m3/year
- Domestic Use	3.0 M m3/year	5.2 M m3/year
- Industrial Use	0.5 M m3/year	1.0 M m3/year
- Agricultural Use	10.0 M m3/year	20.0 M m3/year
Domestic Use Water Supply	1.0 M m3/year	5.2 M m3/year
- Surface Water	0.1 M m3/year	1.7 M m3/year
- Improved Springs	0.5 M m3/year	0.7 M m3/year
- Groundwater (wells)	0.4 M m3/year	2.8 M m3/year
Number of Water Supply Recipients	105,475	-
Service Coverage Rate of Water Supply	24.8%	-

By the year 2000 approximately 27 million m3 of water would be required annually. Judging from the amount of existing water resources in the Area, there should be no problem in meeting the figures estimated by the water balance simulation.

Annual rainfall: 900 mm x 2,667 km2	= 2,400 Mm3
Annual evapotranspiration: rainfall x 68.5%	= 1,640 Mm3
Groundwater flow (nourishment): precipitation x 17.8%	= 430 Mm3
Other waters (surface runoff into rivers and lakes): precipitation x 13.6%	= 390 Mm3

4.6.2 Outline of the Evaluation

In view of the existing rural water supply, it would be advantageous to make the water source selection with priority given to the following order and by taking into account construction costs, the reduction of costs for management and the management/operation works:

(1) Groundwater

1) Spring

In general, spring water requires no further treatment and are the most desirable water source. However, existing springs in the Study Area are already been developed and only a few would be available for the new project use, except for small springs which were unavailable for the system design.

2) Wells

Since groundwater does not require further treatment either, it was also the most desirable water source along with spring water.

However, in cases where shallow groundwater close to the water surface(area of "Sb"), would be developed, a detailed selection of well points and examinations of possible protection schemes would be carried out.

(2) Surface Water

The water in the rivers and lakes in the Study Area were extremely contaminated by domestic sewerage and would require treatment before use. As the discharge of small and medium size rivers decreased considerably during the dry seasons, lake water could be used at this stage because of the large amount and less fluctuation of the lake water table.

(3) Rainwater

Rainwater was considered a promising water source in mountainous areas where the previously described sources were not available. However, during the dry season an alternate water source must be provided. Rainwater on the roof of public facilities would be utilized as a supplementary water source.

4.6.3 Development Priority of Water Resources

By taking into consideration the water resource development potential, physical and socio-economical conditions, and existing infrastructure in the Study Area, the water resource development concept of the basic plan for the Phase III Project was as follows:

1) To give priority to the development of groundwater (springs and wells) that required minimum water treatment costs.

   - Springs located in high elevation areas where water could be distributed by gravity flow. Thus, springs having large water yield amounts were already being used as water sources of the existing system. For future water resource development, more reliance would be placed on wells for groundwater.

   - As the locations and water yield amounts of small size springs were uncertain, they would be regarded as supplemental water sources without being developed for the Project.

2) To develop surface water in those areas where it would be difficult to develop springs or groundwater.

   - The contamination levels of river and lake water were about the same; therefore, lake water would be used because of its stable supply.

   - To use lake water, a means would be devised to prevent the intrusion of decomposed aquatic plants and algae.

3) To install rainwater harvesting systems in sparsely populated hilly areas.

   - To make the installation realistic, the supply amount would secure the resident's minimum water requirement of 3 liters/pers./day(WHO).

CHAPTER 5

OVERVIEW OF THE WATER SUPPLY DEVELOPMENT PLAN

5. OVERVIEW OF THE WATER SUPPLY DEVELOPMENT PLAN

5.1 PRESENT ENVIRONMENT FOR THE BASIC PLAN

By clarifying the environment in view of the formulation of a strategy for the Basic Plan, the following problems and constraints were pointed out.

5.1.1 Physical Environment

The precipitation in the Study Area was relatively high and many lakes existed in the said Area. The potential for water supply development therefore was not low, except for the following points:

(1) Items related to water resources

Topography and Climate

The areas suitable for constructing shallow wells, the best suited water resources for drinking purpose, because of their convenience, were limited to the narrow valleys and alluvial lands that were far from the villages.

The densely populated undulating areas that were composed of soft rock (mainly schist) had little potential for the development of deep wells, from the yield point of view.

The precipitation during the four-month long dry season (June to September) was extremely low.

Construction

Well construction in hard rock formation areas was unsuitable on account of the high costs and low ability of drilling works for extremely hard rock.

Spring Water

There was a small amount of spring water yield but this was unstable throughout the year as a planned water source, except for a few springs which had been utilized in the existing water supply system, and had a large yield.

Water Quality

Contaminated shallow groundwater was found on low lying land adjacent to water surfaces.

As domestic waste water flowed into the lakes and rivers, the surface water was heavily contaminated.

Groundwater Development Potential

As a result of the Area's water balance simulation, the groundwater development potential was estimated at a range of 100,000 to 300,000 m3/km2/year and 27,000 m3/km2 p.a. of sustainable groundwater yield.

The safe yield of groundwater was estimated as less than 8 m3 and/or 77 m3/day for hand-pump wells and 123 m3/day for shallow wells with a motor-pump.

(2) Items Related to the Preparation of the Water Supply Plan

Topography and Settlement Pattern

The structures and arrangements of water conveying facilities would be subjected to large head differences because of the large relief terrain.

Settlers were widely scattered in undulating to rolling lands and complicated arrangements of water conveying facilities would require planning.

For the present situation and development constraints, the following subjects were considered:

- A careful examination of water supply conditions during dry seasons would be made.
- Priority given to large yield springs and shallow wells constructed in valley areas.
- The necessity of constructing deep wells in specific areas would be examined.
- In the case where shallow groundwater existed, it would be required to construct a well at those parts not close to water surface.
- In the case where groundwater was to be developed, it would be necessary to examine the possible groundwater yield and the safe pumping amount.
- In the case where surface water was to be developed, it would be required to examine the possible improvement/treatment scheme.
- Water supply facilities would be planned by taking into account the management and operation of the facilities having large head differences and include all safety measures.
- The boundaries of the water service areas and the water supply service level would be carefully examined.

5.1.2 Economic and Social Environment

The economic and social environment/constraints were clarified by classifying them into items concerning water supply facility constructions and items related to the management, operation/maintenance of the facilities.

(1) Items concerning water supply facility construction

Topography
Because of the topographical conditions, the cost for constructing water supply facilities was considered to be relatively high.

Budget and Instruction
Due to the insufficiency of budgetary funds for rural water supply development and the insufficiency of qualified engineers, the promotion of water supply projects was constrained.

Infrastructure
Infrastructure, such as roads and power supply facilities, in the Study Area were inadequate. Thus, prior to the improvement of water supply facilities, an improvement of the infrastructure would be proposed.

(2) Items related to the management, operation and maintenance of water supply facilities

O/M Cost
The costs for facility management would be high due to the characteristics of the area topography. Low level techniques would also be required for the management.

To sustain facility management and operations, the water fee collecting system would be introduced taking into account the financial capabilities of the residents.

Public Health
Due to the insufficiency of public health and hygienic facility/education, the occurrence rates of diseases related to drinking water was high. The importance of public water supply was not fully understood by the residents.

Institution
The supporting system for the operation/maintenance works of water supply facilities had not, as yet, been established.

Due to the unstable supply of fuel/inadequate management and operating skills/insufficient budgetary funds/and the lack of spare parts, some existing water supply systems were not functioning.

In view of the above development constraints and measures, the examination of the Basic Plan would take into account the following aspects:

- By referring to the size and service areas of existing water supply systems, the boundaries of newly proposed systems and their construction cost limits would be examined.
- For preparing the Project's implementation plan, the budgetary schedule and the upgrading of technical levels would be taken into consideration.
- The water supply plan would be examined taking into account the existing infrastructures and the future infrastructures development plan.
- The service areas would be examined by taking into account the institutional conditions of the regions for operation and maintenance.
- After examining the management system, including water use fee collecting methods of the facilities, the water supply system would be proposed.
- It would be necessary to examine the financial capabilities of the residents and the methods for collecting water use fees.
- The establishment of a training program would be required to upgrade technical levels and offer instructions to workers and residents, with information concerning public health and hygiene.

5.1.3 Classification of the Development Levels in the Area

The Study Area was classified by considering the population scale/density, facilities for public services, economic activities and infrastructure levels as follows:

Vf: Farming village order
Vs: Service village order
LT: Locality town order
D : District center
H : Higher district center

(refer to Fig. 5.1)

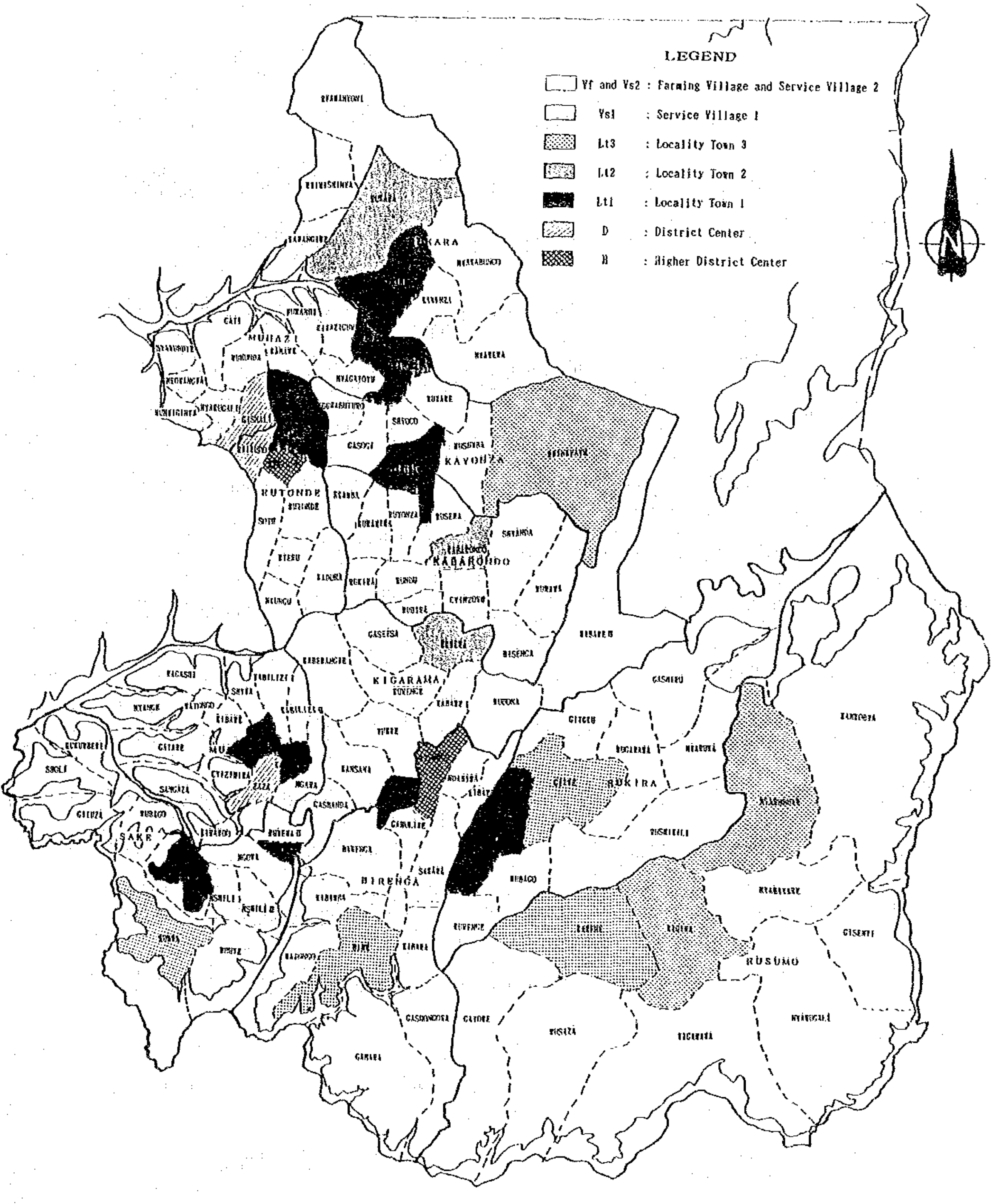


Fig. 5.1 Classification of Rural Center for Development

5.2 BASIC DEVELOPMENT POLICY

5.2.1 Basic Policy of the Development

By examining the Government of Rwanda's development policies, the intention of MINITRAPEE, and the present condition of the Study Area, it was apparent that the Rural Water Supply Project (Phase III) in the Eastern Region was based on the following development policies:

- **To promptly provide maximum benefits to residents using a limited amount of funds**

- **To select the most appropriate technology for the Study Area**

  - The highest priority would be given to the system requiring the easiest and most economical operation and maintenance work.
  - High quality of water would be utilized to the greatest extent.
  - The operation and maintenance of the water supply system would require cooperation from the residents.
  - Step-by-step water supply development would be carried out in pace with the development of infrastructure.

- **To select facilities and service areas by considering the management and operation of the systems**

  For the smooth future introduction of the operation and maintenance and the water fee collection systems, the basic unit for a water supply area would be examined.

- **To establish a water supply plan that corresponded to the financial capabilities of residents and the infrastructure conditions**

- **To conform with the higher level development plan and related projects**

- **To provide as many residents as possible with a constant supply of safe and sanitary water by the target year 2000**

  The Basic Plan's target year was 2000 on the basis of the national development policy.

5.3 FORMULATION OF THE BASIC PLAN

5.3.1 Approach to Planning

The approach to Phase III Plan was outlined in Fig.5.2. The approach was divided into the following 5 Steps:

Step 1: Definition and Examination of Planning Area
Step 2: Selection of Suitable Water Supply System Options
Step 3: Water Resources Selection
Step 4: Examination of the System Selection Procedure
Step 5: System Selection and Preliminary Design

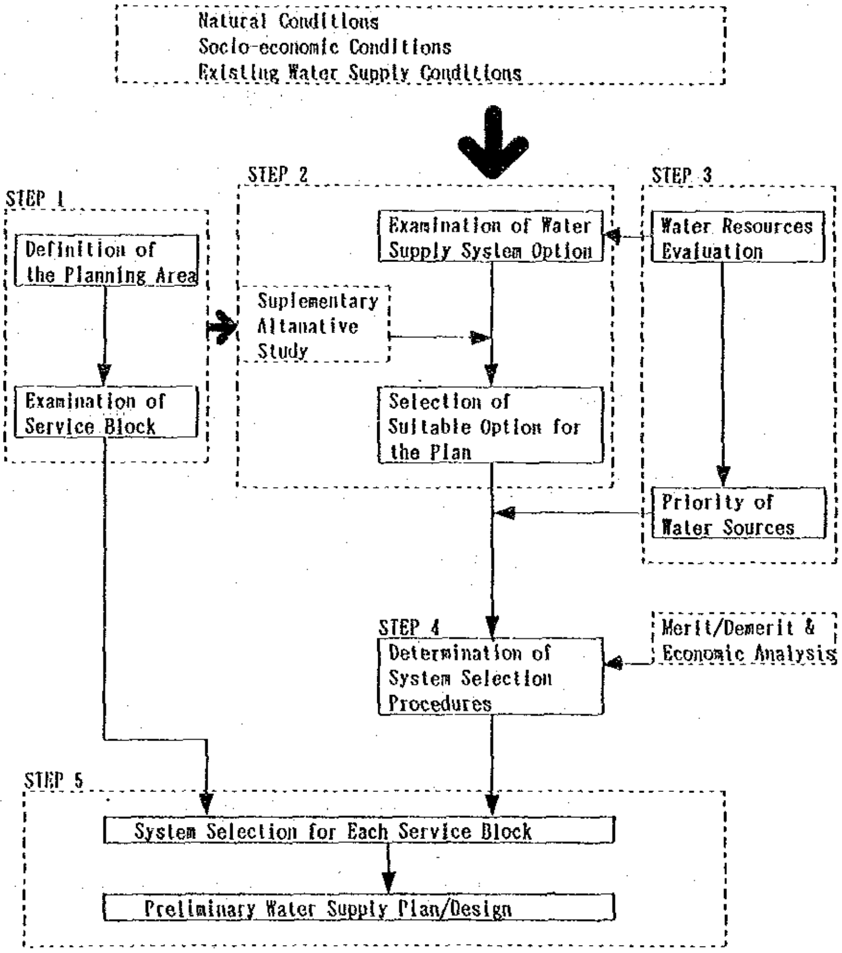


Fig. 5.2 Approach to Phase III Planning

5.3.2 Definition of the Planning Area

In the Study Area, there were some existing water supply systems and on-going water supply projects by other official agencies. A few existing and planned systems, which were considered able to satisfactorily meet water demand within the service areas, were excluded from the Basic Plan Area of Phase III.

The condition of the existing systems were discussed/ evaluated in Section 3.5. Based on this evaluation, the Study Area was divided into five zones to conform with other projects and avoid the redundant projects as follows:

ZONE A : Phase I Project Supply Area
ZONE B : Phase II Project Supply Area
ZONE C : Existing Water Supply Area
ZONE D : On-going Project Area
ZONE E : the Basic Plan Area

The locations of the zones A to D were as shown in Fig. 5.3 and the population/area of each zone was shown below:

Table 5.1 Population and Area of Each Zone

Zone	Project	Area (km2)	Population (1988)	Population (2000)
Zone A	Phase I	184	36,100	51,600
Zone B	Phase II	373	50,100	85,500
Zone C	Existing	178	37,200	52,600
Zone D	On-going	239	62,400	94,100
Zone E	Basic Plan	1,693	247,200	369,700
Total		2,667	433,000	653,500

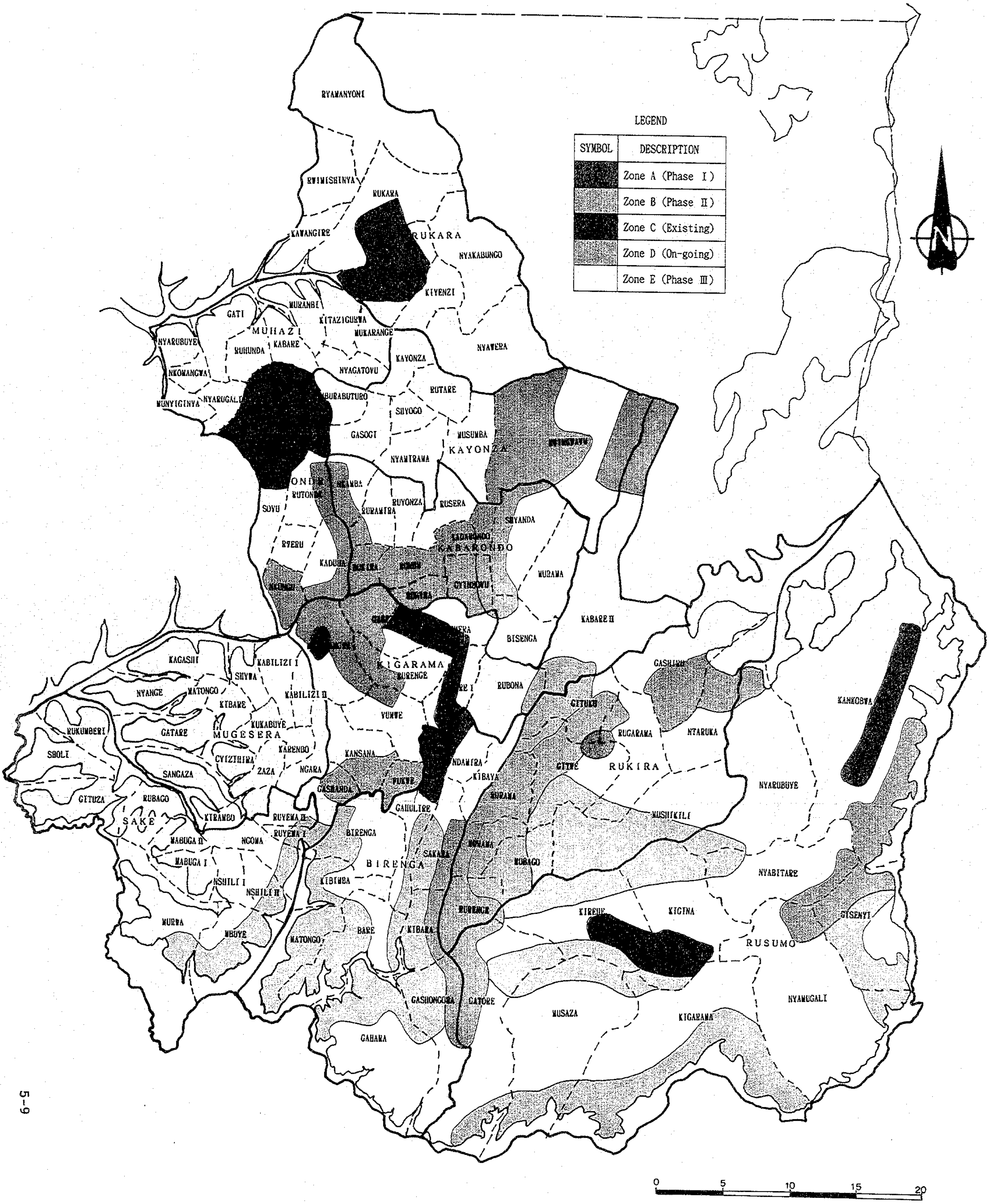


Fig. 5.3 ZONE CLASSIFICATION

5.3.3 Examination of Water Supply System Options

To select the water supply system and establish the water supply area, the following alternative water supply systems were examined.

Alternative	Water Supply System
A :	Small scale piped water supply system of spring water delivered by gravity
B :	Shallow tube-well with hand pump
C :	Tube-well with power-pump (deep well) without piped water supply facilities
D :	Small scale piped water supply system with power pump using groundwater
E :	Small scale piped water supply with power pump and generator using groundwater
F :	Large Scale piped water supply system with treatment facilities using surface water
G :	Extension of existing urban supply system
H :	Rainwater harvesting by roof catchment
I :	Rainwater harvesting by slope catchment

The selection of suitable systems was shown in Table 5.2. Options A, B, D, E, F, and H could be selected as possible systems for installation. However, Options A and H would be selected if the following points were considered.

Option A:
As most of the springs having a large water yield were already used for existing supply systems, it would be more realistic to select Option A in combination with Options D, E, or F.

Option H:
The dry season in the Study Area continued for several months and it was difficult to secure sufficient amounts of water. It would be appropriate to select Option H only as a low priority system.

Table 5.2 Merit/Demerit Table of Water Supply System Options

	Option	Evaluation	Water Source and Topography	Water Use, Operation and Management	Economic Aspects
Ⓐ	Small-scale water distribution system of spring water by gravity flow	Suitable except securing of sufficient water amount. Prefer to combine with Option D, E, or F.	△ Difficult to secure sufficient amount of water with new spring development. ◎ No water quality problem exists.	◎ No energy required for system operation. ○ Local residents can operate and manage the system. ◎ Easy to place residents into the management organization structure	◎ Per capita capital cost is very low. ◎ Operation and maintenance cost is low.
Ⓑ	Shallow tube-well with hand pump	Suitable	○ No water quality problem exists if well sites are appropriately selected. △ May be possible to select well sites close to existing water sources. But, in lowlands, it is difficult to secure access roads.	Same as above	Same as above
C	Tube-well with power pump (deep well)	Unsuitable	△ Difficult to select well drilling sites.	△ Electricity or fuel oil is needed to operate. △ High levels of operation and maintenance skills are required. × It is difficult to maintain by the management structure of the small number of residents. Convenient to obtain water	× Capital cost per capita is very high because this system does not have the water distribution sytem. × Operation and maintenance cost is very high.
Ⓓ or Ⓔ	Small-scale water distribution system with electric motor pump or generator operated power pump using groundwater	Suitable in population concentrated area if the operation and maintenance cost meets the requirements. If possible, use river water or groundwater with a shallow well.	○ Difficult to select a deep well site. Difficult to secure sufficient amount of water with a shallow well. △ Difficult to install a pipeline because of variable topography.	△ Electricity or fuel oil is needed to operate. △ High levels of operation and maintenance skills are required. ○ A certain number of population is needed to maintain the management structure. Convenient to obtain water.	○ Capital cost becomes high if the area has less than a certain number of population. ○ Operation and maintenance cost becomes high if the area has less than a certain number of population.
Ⓕ	Large-scale water distribution system with treatment facilities using surface water (river or lake)	Same as above	○ Treatment facilities are required for obtaining good quality water. ◎ No problem exists for securing a large amount of water △ Special attention is needed to install a pipeline in an area having variable topography.	Same as above	Same as above
G	Extension of existing urban water distribution system	Unsuitable	Extension of existing urban water distribtuion systems in Kibungo and Rwamagana cities are being conducted. Thus, this option is not included in the Phase III Project.		
△H	Rainwater storage by roof catchment	Suitable only for special cases	△ Difficult to obtain sufficient amount of water and maintain the water quality	◎ Energy is not needed to operate. ◎ Operation and maintenance work can be conducted by local residents. × Inconvenient.	◎ Capital cost is very low. ◎ Operation and maintenance cost is very low.
I	Rainwater storage by slope catchment	Unsuitable	△ Difficult to obtain sufficient amount of water and maintain the water quality. Lands are highly used and none is available for the slope catchment method.	Same as above	Same as above

5.3.4 Suitable System

(1) Options for the Basic Plan

By clarifying the examination of options, the following four water supply systems were thought to be appropriate for installation in the Basic Plan. They were all considered suitable for the area characteristics of Kibungo Prefecture and because they satisfied the policy of the Basic Plan:

System 1: Large-scale piped water supply system, Option F plus Option A (spring water used within the capacities of available springs)

System 2: Small-scale piped water supply system, Option D or E plus Option A (spring water used with the capacities of available springs)

System 3: Shallow well with hand-pump system, Option B

System 4: Roof catchment system, Option H (to be selected as a last resort only in special cases)

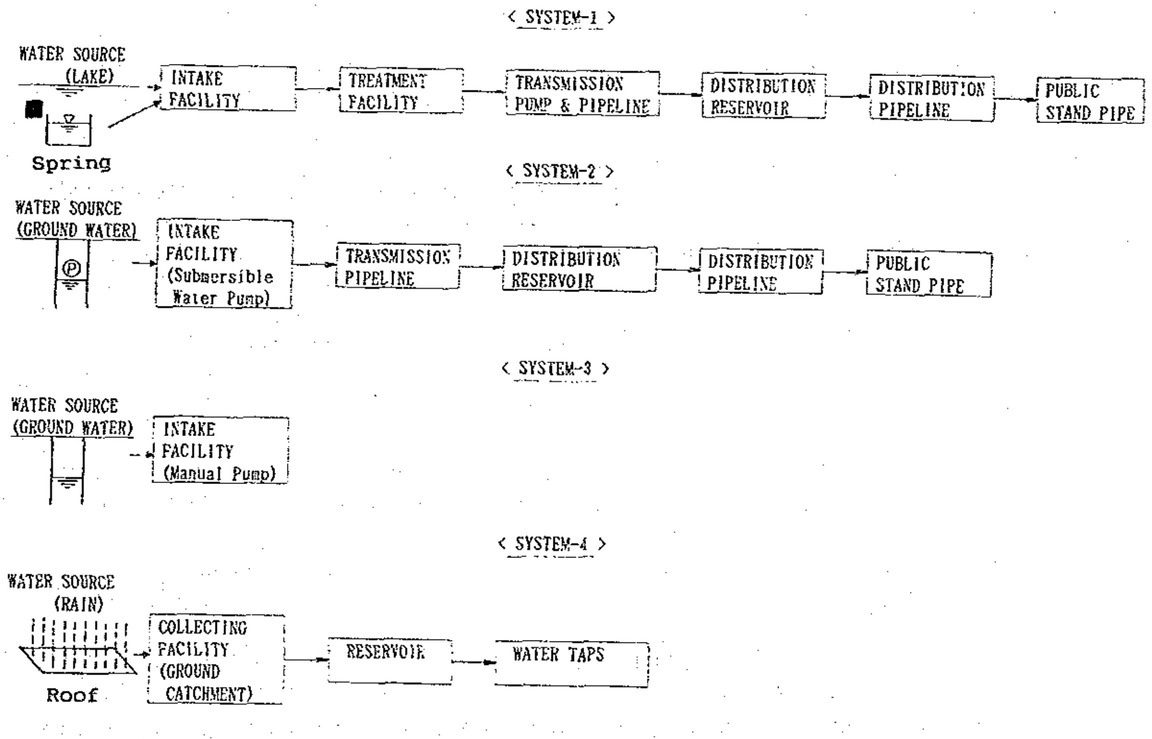


Fig. 5.4 Diagram of Water Supply Systems

(2) Examination of the Possibility of Introducing Solar Energy Pumps

When the solar energy pump was used for more than 120 m of lift, the daily pumping amount would be restricted to less than 30 m3. Therefore, the possible areas to introduce a solar energy pump would be limited.

Based on the examination given in Appendix R of Volume II, the introduction of solar energy pumps to the Study Area was considered to be unsuitable on account of the following reasons:

- Higher cost compared with generator system
- Requirement of high maintenance technique
- Unstable workability during rainy seasons

5.3.5 Development Priority of Water Resources

At this planning stage, the development potentiality of water resources for the water supply systems was presented, see the Table below by taking into consideration the water quality, water quantity and water conveying systems as mentioned in Section 4.6.

Table 5.3 Development Priority of Water Resources

Water Resources	Water Quality	Water Quantity	Gravity Water Supply	Priority of Development Potential
.Spring	Good	(Un)Stable	Possible	1
.Groundwater	Good	Stable	Impossible	1
.Rainwater	Good	Unstable	Possible	2
.Lake	Bad	Stable	Impossible	3
.River	Bad	Unstable	Impossible	4

By summarizing the above descriptions, the basic water source development concept for each system was established (see Section 6.1.4).

5.3.6 Service Block

According to the service coverage of the existing water supply system within the Area, the service block sizes and boundaries of the proposed systems would be planned as follows:

System	Service area (km2)	population served	Remarks
1	40<	20,000-40,000	
2	10-20	4,000- 8,000	Maximum Production 240 m3/day/2 wells
3	< 4	< 500	
4	family unit	6	

By taking into consideration the future operation and maintenance organization structure, one service block would not cover more than one commune.

5.3.7 Cost Analysis for System Selection

The following Model Studies were conducted to obtain the basic data necessary, such as estimating the per capita construction cost and per household O/M cost, and selecting conditions for introducing the proposed Systems in each water supply system service block.

Model Study 1 : By assuming the service area as being 40 km2 for the introduction of System 1.

Model Study 2 : By assuming the served population as being 20,000 for introducing System 1.

Model Study 3 : By assuming the service area as being 10 km3 for introducing System 2.

Based on the Model Study results and existing cases of water supply projects in developing countries, the following conditions of system selection, in each service block, were determined (refer to Appendix L of Volume II):

(1) Maximum Initial Cost per Capita

The maximum per capita initial cost, as the bases for introducing System 1 or System 2, was to be US$150. This would take into consideration the actual cases in developing countries and the actual per capita initial cost of System 3 introduced into sparsely populated areas of the Prefecture.

(2) Maximum O/M Cost per Household

By adopting the World Bank's definition, it was believed to be appropriate that the per household operation and maintenance costs for the Basic Plan's facilities were to be less than 5% of the household expenditure, i.e. US$1.50 to 2.00/month/household.

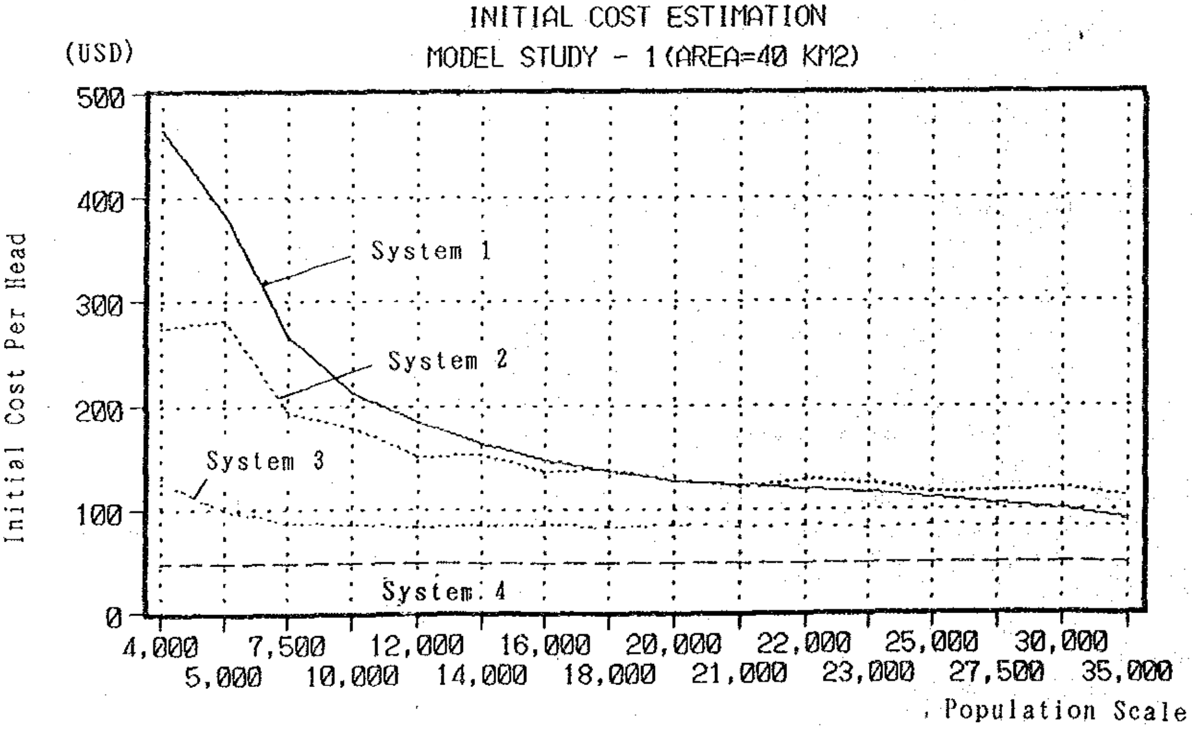
MODEL STUDY - 3

Area = 10km2(constant) Unit : US$/month/family

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
1,000	100	6.92	2.90	0.90	0.12
2,000	200	4.24	1.92	0.65	0.12
3,000	300	3.34	1.60	0.57	0.12
4,000	400	2.90	1.43	0.59	0.12
5,000	500	2.63	1.56	0.60	0.12
6,000	600	2.45	1.46	0.57	0.12
7,000	700	2.32	1.38	0.58	0.12

(3) Population Scale for System 1 Selection

The per capita initial cost for different population scales was obtained in the Model Study 1 and shown in Appendix L. When an area had a population of more than 21,000, the per capita construction cost of System 1 would be less than that of System 2. The cost was also less than the maximum per capita initial costs of US$150.



(4) Population Density for System 2 Selection

The population density of areas suited to installing System 2 was obtained as being more than 600 persons/km2 by the Model Study 1, where per capita construction cost was lower than that of System 3.

MODEL STUDY - 3

Area = 10km2(constant) Unit : US$/capital

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
1,000	100	1,075.3	494.0	150.0	48.4
2,000	200	559.0	255.3	100.0	48.4
3,000	300	387.0	175.7	83.3	48.4
4,000	400	300.8	155.9	87.5	48.4
5,000	500	249.2	170.5	90.0	48.4
6,000	600	214.8	144.8	83.3	48.4
7,000	700	190.2	126.5	85.7	48.3

(5) Extension of System 1 or System 2 to Shallow Well Suitable Areas

As a result of Model Studies, pipeline extension would be selected when construction costs become less than that of shallow well construction within the following population scales:

Groundwater development potential Sa : Over 700/km2
" Sb and Sc : Over 500/km2
" Sd : Over 400/km2

Shallow well Construction Cost per 4 km2

(Unit : 1,000USD)

Population (pers./km2)	Classification Sa	Sb, Sc	Sd
250	100	120	120
300	100	120	180
375	150	180	180
400	150	180	240
500	200	240	300
600	200	240	300
700	250	300	300

5.3.8 System Selection Procedures and the Proposed Systems for the Service Blocks

(1) System Selection Procedure

When a water supply system for a certain area was to be selected from the water supply system options, the following basic concepts were applied:

i) Priority was given to System 3 (hand-pump installation) for the following reasons:

- Its per capita construction cost and per household operation and maintenance cost were generally less than for other Systems.
- It would be constructed by Rwandan themselves.
- It would be operated and maintained by local residents.
- Residents can participate in its construction and also manage the operation and maintenance organization.

ii) In areas with difficulties constructing System 3, the water supply systems would be planned as follows:

a) In areas having, a concentrated population or having high levels of public facilities, System 1 or System 2 would be installed by taking into consideration the balance with existing water supply systems in the surrounding areas.

However, the construction cost per capita and the O/M cost per household for the new systems would not exceed the recommended maximum costs.

For the appropriateness and evaluation of the system selection, the following two basic points were taken into consideration:

- A maximum per capita construction cost of US$150
- A maximum per household operation and maintenance cost of US$2.00/month

b) From the results of Model Studies, the selection standards for System 1 and 2 were as follows:

System 1: For an area having a densely concentrated population and where the number of residents were more than 21,000.

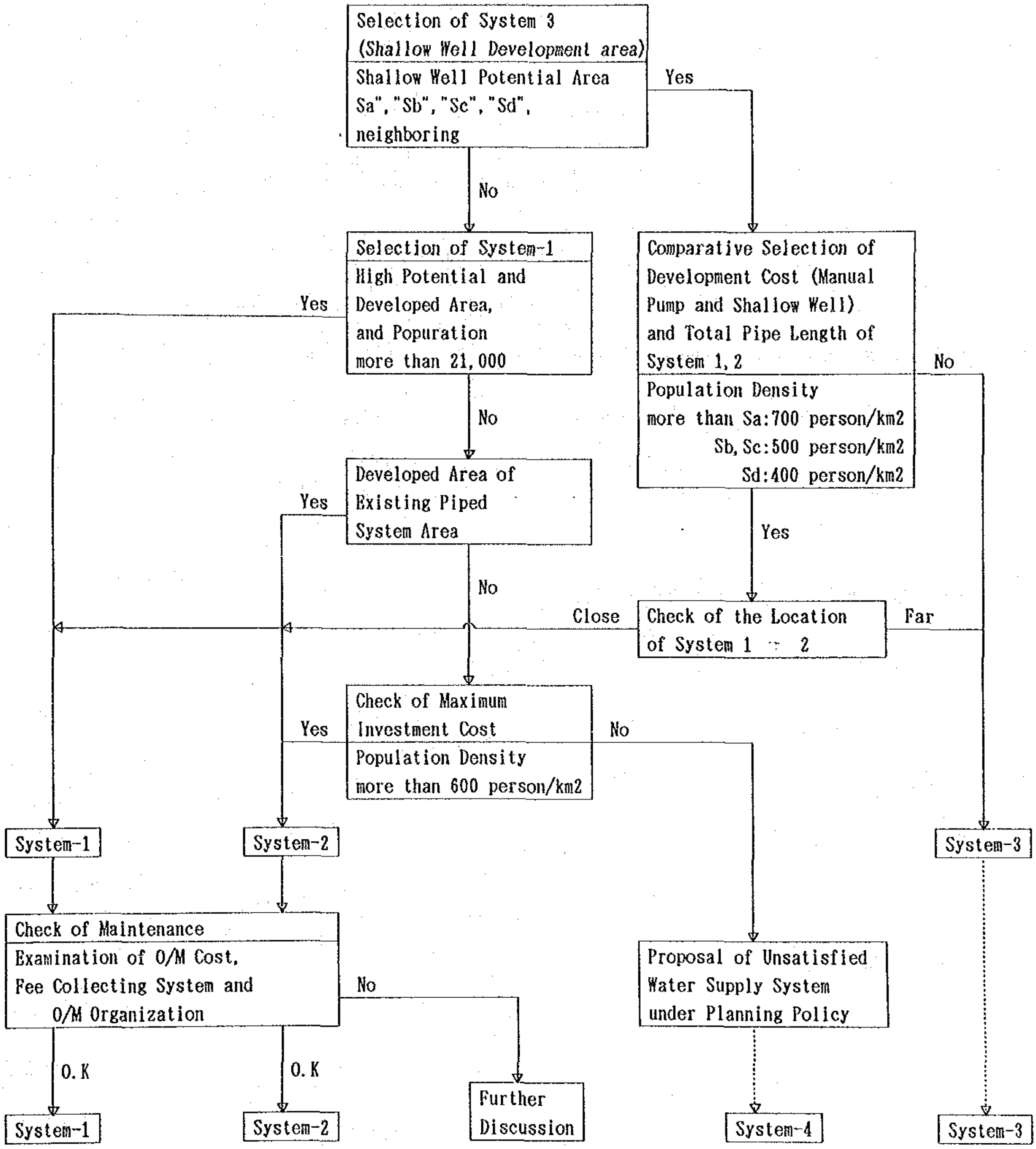


Fig. 5.5 Water Supply Systems Selection Flow

System 2: For an area having a higher development potentiality with concentrated population, having a population density of more than 600/km2 or having an existing piped system of water supply.

iii) In a sparsely populated hilly area, if the per capita construction cost and per household operation and maintenance cost were higher than the maximum values, it would be recommended to install such a system even though the planning policies were not 100% satisfied.

System 4 (Rainwater harvesting)	->	Reduce the per capita supply amount (3 l/pers./d)

Based on the concept mentioned above, the procedure was determined and presented in Fig. 5.5 as a selection flow of water supply system.

(2) Selection of Water Supply System in Each Service Block

As a result of the discussion in Section 4.1 and 4.2, the 4 systems would be adopted as a water supply system in Phase III Basic Plan.

Fig.5.6 and Table 5.4 show the adopted systems of the service blocks in the Basic Plan Area outlined as below:

System	Number of service blocks	Service area(km2)	%	Population served	%
1	2 blocks	94.0	5.6	55,809	15.1
2	8 blocks	102.2	6.0	44,016	11.9
3	477 wells	1,009.9	59.6	219,844	59.5
4	8,351 families	487.0	28.8	50,030	13.5

Table 5.4 Selected Water Supply System

Service block			Population served 2000	Density	Develop.* class
System 1		Secteur			
MUHAZI	5		21,944	550	Lt-Vs
SAKE	9		33,865	626	Lt-Vf
Total	14	Secteurs	55,809	594	
System 2		Secteur			
KAYONZA-1	2		4,374	339	Lt
KAYONZA-2	2		3,508	428	Lt-Vs
RUTONDE	1		3,720	620	Vs
KABARONDO	2		5,956	379	Vs
BIRENGA	1		3,588	386	Vs
RUSUMO-1	2		7,300	487	Lt-Vf
RUSUMO-2	1		8,292	601	Lt-Vf
RUSUMO-3	2		7,278	342	Vf
Total	13	Secteurs	44,016	431	
System 3		Secteur			
RUKARA	7		27,428	173	(Lt)-Vf
MUGESERA	14		51,802	407	(D)-Vf
SAKE	4		19,255	282	(Lt)-Vf
KAYONZA	7		14,423	229	(Lt)-Vf
RUTONDE	3		8,839	367	Vs-Vf
KABARONDO	7		10,173	302	(Lt)-Vf
KIGARAMA	10		26,231	184	(Lt)-Vf
RUKIRA	5		7,682	158	Vf
BIRENGA	8		17,242	220	(Lt)-Vf
RUSUMO	9		36,769	139	Vf
Total	74	Secteurs	219,844	218	
System 4		Family			
RUKARA	1,430		8,566	181	Vf
KAYONZA	743		4,453	46	Vf
RUTONDE	151		902	291	Vf
KABARONDO	850		5,092	127	Vf
KIGARAMA	606		3,632	120	Vf
RUKIRA	663		3,959	96	Vf
BIRENGA	645		3,862	147	Vf
RUSUMO	3,263		19,564	97	Vf
Total	8,351	Families	50,030	103	
TOTAL			369,699	218	

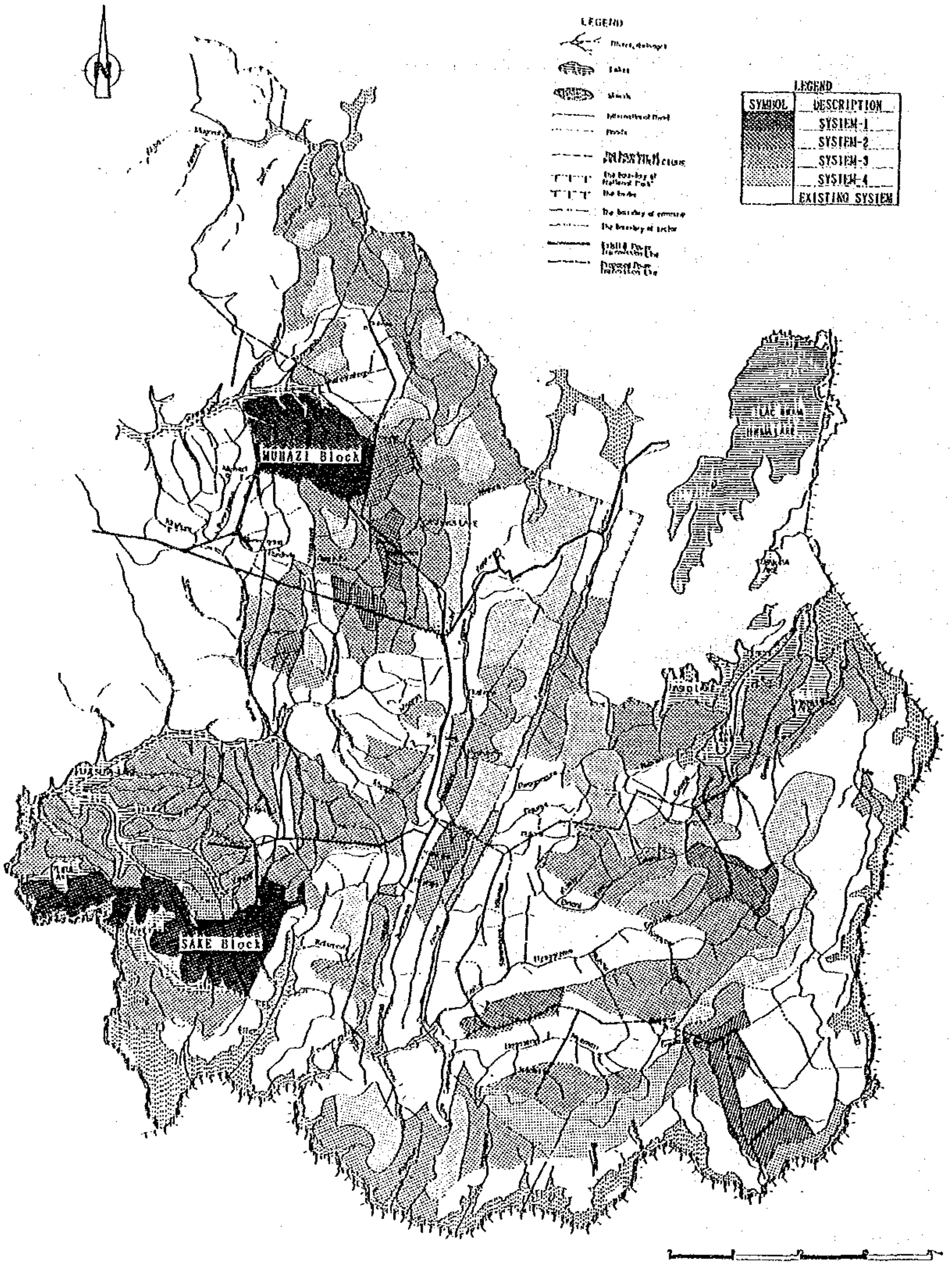


Fig. 5.6 Proposed Water Supply Plan

CHAPTER 6

THE BASIC PLAN

6.1 CONDITION OF BASIC PLANNING

6.1.1 Service Level

(1) Water Supply Methods

Water supply methods were classified into the following levels:

a) Individual house connection
b) Yard connection
c) Public standpipe
d) Well
e) Rainwater harvesting

To improve sanitary conditions, it would be desirable to employ the individual house connection method. However, to provide as many residents as possible with a supply of water with limited funds, it would be advisable to use the yard connection, public standpipe, or well method all of which are inferior to the house connection method.

Judging from the conditions of the existing water supply facilities in Kibungo Prefecture, the public standpipe method would be adopted in areas having piped water supply systems.

The well method would be adopted in areas where shallow well construction would make it possible to utilize the high quality groundwater.

In the sparsely populated mountainous areas where proper water sources were not available, the rainwater harvesting method would be adopted.

An allowable distance between the benefitted area and the proposed public standpipe and/or well would be less than 1 km.

(2) Water Supply Systems

The water supply plan would be established by classifying the water supply systems into the following four levels:

System 1: The public standpipe method using surface water. In this system, the surface water would be treated and distributed through pipes and supplied to users via public standpipes. One standpipe would cover approximately 200 families.

System 2: The public standpipe method using groundwater. This system would distribute high quality groundwater requiring no water treatment. The service level would be one standpipe for approximately 143 households.

System 3: well method
The maximum yield of one well would be 10 m3/day including the consumption of public facilities. One well was estimated as able to supply water to approximately 77 households.

System 4: The rainwater supply method
Water collected by roof catchment. The service block for System 4 would be per household.

6.1.2 Target Year

The Basic Plan's target year would be the year 2000 as referred to in the national development policy.

6.1.3 Planned Service Area and Proposed System

As a results of the discussions in Section 5.3, the planned service area of Phase III Basic Plan was classified as Zone E and the following 4 systems would be proposed for the service blocks within Phase III Basic Plan. The adopted systems of the Basic Plan Area were given in Fig. 5.4.

System 1: Piped supply system with treatment facilities and public standpipes
System 2: Small scale piped supply system with pump facilities
and public standpipes
System 3: Shallow wells with manual pump
System 4: Rainwater harvesting

6.1.4 Choice of Water Resources

By taking into consideration the development priority of water resources (refer Sections 4.6 and 5.3.5), the basic water resource development concept for each system was established as follows:

System 1

1) First priority should be given to such springs that had a stable yield amount and good water quality.

2) For design purposes, a spring's water yield would be its minimum yield during the dry season.

3) The shortage of spring water needed to fulfill the design water supply amount would be supplemented by treated lake water.

System 2

1) Priority should be given to the use of spring water. However, in areas where, during the planning stage, it was uncertain if sufficient amounts and satisfactory qualities of water could be obtained, consideration would be given to the development of groundwater by drilling a well.

2) During the project implementation stage, the location of springs, the water yield, and the water qualities would be re-examined and a priority assigned to the use of direct water intake methods or the horizontal boring method for the development of springs.

3) For design purposes, a spring's water yield would be its minimum yield during the dry season.

4) In case of a shortage of spring water, Water supply would be taken from wells.

System 3

1) Groundwater use by drilling wells.

2) First priority of "Sa-Development Potentiality Class" would be given.

System 4

1) Harvesting rainwater from roofs.

6.1.5 Service Area and Population of Each System

The service area and population served by communes of each system were tabulated below. It was evident that the southern area of the Kibungo Prefecture, which had not yet developed or improved comparatively, had a large population served.

Table 6.1 Service Area and Population

Commune		System 1	System 2	System 3	System 4	Total
RUKARA	Area	0	0	158.4	47.4	205.8
	Population	0	0	27,428	8,566	35,994
MUHAZI	Area	39.9	0	0	0	39.9
	Population	21,944	0	0	0	21,944
MUGESERA	Area	0	0	127.4	0	127.4
	Population	0	0	51,802	0	51,802
SAKE	Area	54.1	0	68.2	0	122.3
	Population	33,865	0	19,255	0	53,120
KAYONZA	Area	0	21.1	63.1	96.9	181.1
	Population	0	7,882	14,423	4,453	26,758
RUTONDE	Area	0	6.0	24.1	3.1	33.2
	Population	0	3,720	8,839	902	13,461
KABARONDO	Area	0	15.7	33.7	40.0	89.4
	Population	0	5,956	10,173	5,092	21,221
KIGARAMA	Area	0	0	142.9	30.2	173.1
	Population	0	0	26,231	3,632	29,863
RUKIRA	Area	0	0	48.5	41.1	89.6
	Population	0	0	7,682	3,959	11,641
BIRENGA	Area	0	9.3	78.4	26.3	114.0
	Population	0	3,588	17,242	3,862	24,692
RUSUMO	Area	0	50.1	265.2	202.0	517.3
	Population	0	22,870	36,769	19,564	79,203
Total	Area	94.0	102.2	1,009.9	487.0	1,693.1
	Population	55,809	44,016	219,844	50,030	369,699

Note: The population figure is estimated for the year 2000.

6.1.6 Design Water Demand

(1) Unit of Water Demand and Supply Recipients

Referring to the existing water demand within the developing countries, the water supply unit for the Rural Drinking Water Supply Manual of the DGW, MINITRAPEE which was under preparation, was considered to be suitable for the Phase III Planning. Thus, the manual was adopted for estimating the water demand.

The consumption types and unit water demand were given in Appendix M of Volume III and is outlined below:

<u>General Households</u>

- Unpiped system: 90 liter/family/day (including demand for livestock)
- Piped system: 130 liter/family/day (- ditto -)

<u>Public Facilities</u>

- Health: Hospitals, health centers, dispensary and nutrition centers
- Educational: Primary schools, secondary schools and vocational training centers
- Administrative: Prefectural offices, associate prefectural offices, commune offices, sector offices
- Others: Courts, churches, markets, prisons and military stations

(2) Design Criteria and Capacity

The design criteria of the preliminary design was based on the above Manual. The design capacities of piped water supply of System 1 and 2 were as given below:

Table 6.2 Design Criteria

Item	System 1	System 2
1. Maximum Daily Water Demand	(Average Daily Water Demand) x 1.15	same as System 1
2. Design Intake Discharge	(Max. Daily Water Demand) x 1.10 note) 0.10 is for the wash water of filtration materials.	(Max. Daily water demand)
3. Design Discharge of Purified Water	(Max. Daily Water Demand)	-
4. Duration of Pump Operation	24 hr/day	24 hr/day
5. Design Hourly Pump Discharge	(Max. Daily Water Demand)/24	same as System 1
6. Capacity of Distribution Reservoir	(Max. Daily Water Demand)/2	same as System 1
7. Maximum Hourly Water Demand (For decision of distribution pipe diameter)	(Max. Daily Water Demand)/24 x 2	same as System 1