5.4 Groundwater Quality

(1) Groundwater Quality of the Laterite Aquifer

The groundwater of the shallow laterite aquifer is highly contaminated with coliforms derived from the human activities according to the results of the water quality analysis. It also contains high concentration of Mn and Fe which are delivered from the laterite layers and the nitrates exceeds WHO standard in some wells as well.

Therefore, it is concluded that the groundwater of the shallow laterite aquifer is inadequate for potable use and it cannot be used for urban water supply from the view points of hygiene.

(2) Groundwater Quality of the Bedrock Aquifer

As mentioned in Chapter 4.4, coliforms were detected in every water samples from the bedrock aquifer and the Fe and Mn concentrations in the groundwater exceed the WHO standards in most of the wells tapped the bedrock aquifer.

As shown in the hydrogeological map (see Fig.5.1.1), groundwater quality of the bedrock aquifer gets better along the high permeable zones in which the groundwater quality meets to the WHO standard for potable water excepting the coliforms. It is inferred that the fresh groundwater is flowing along the faults. The groundwater is stagnant in the unfractured sound bedrock and receives dissolution of Mn and Fe ion during the contact with the layers for long term.

The recharge water is originally contaminated with coliforms, because the recharge area is densely populated area of the Bangui City. Therefore, the sterilization must be needed for the potable use even the groundwater of the bedrock aquifer. Furthermore, it should be noted that the regular monitoring on groundwater quality must be done after the commencement of the groundwater development because the deterioration of the groundwater quality may be accelerated due to the further urban development of the Bangui City .

(3) Hydrogeochemistry

Strong correlation among the main ion concentration is found as shown in Fig.5.4.1. Namely, strong correlation among Na – (SO_4+CL) and (Ca + Mg) – HCO_3 are clearly detected and their correlation coefficients are more than 0.9.

As shown in Fig.5.4.1, the shallow groundwater can be classified as Na－SO_4－CL type and the deep groundwater can be classified as Ca－Mg－HCO_3 type. Both of the shallow and deep groundwater change their ion concentration in linear and successive relation .

The main ion composition is plotted on Piper diagram and Durov Diagram in Fig.5.4.2. The relationship of the main ion composition between the shallow and the deep groundwater is also shown in these diagrams. As shown in triangle diagrams, the main cation changes from Na to Ca + Mg and main anion changes from Cl to HCO_3 from the shallow to the deep in successive relationship.

The four-cornered diagrams show the main ion composition in combination of cation and anion. The composition of SO_4, HCO_3 as anion and Mg, Na as cation is shown in the Piper diagram. In the Durov diagram, the composition of Cl, HCO_3 as anion and Na, Ca as cation is shown. The triangle diagram of Durov plot shows much clearer correlation of main ion composition because SO_4 and Mg ions have no particular correlation with other main ions in the Study Area.

As shown in the four-cornered diagram of the Durov plot, linear relationship can be found in the manner of the change of the main ion composition from Na + Cl composition in the shallow part to Ca + HCO_3 composition in the deep part.

The change of the main ion composition is inferred to be caused by the ion exchange between the groundwater and layers in the course of the groundwater seepage from the shallow part to the deep part. From the phenomena which is the successive change of the main ion composition in linear relationship from the shallow part to the deep part, it is concluded that the deep groundwater is originated from the shallow groundwater in the Study Area.

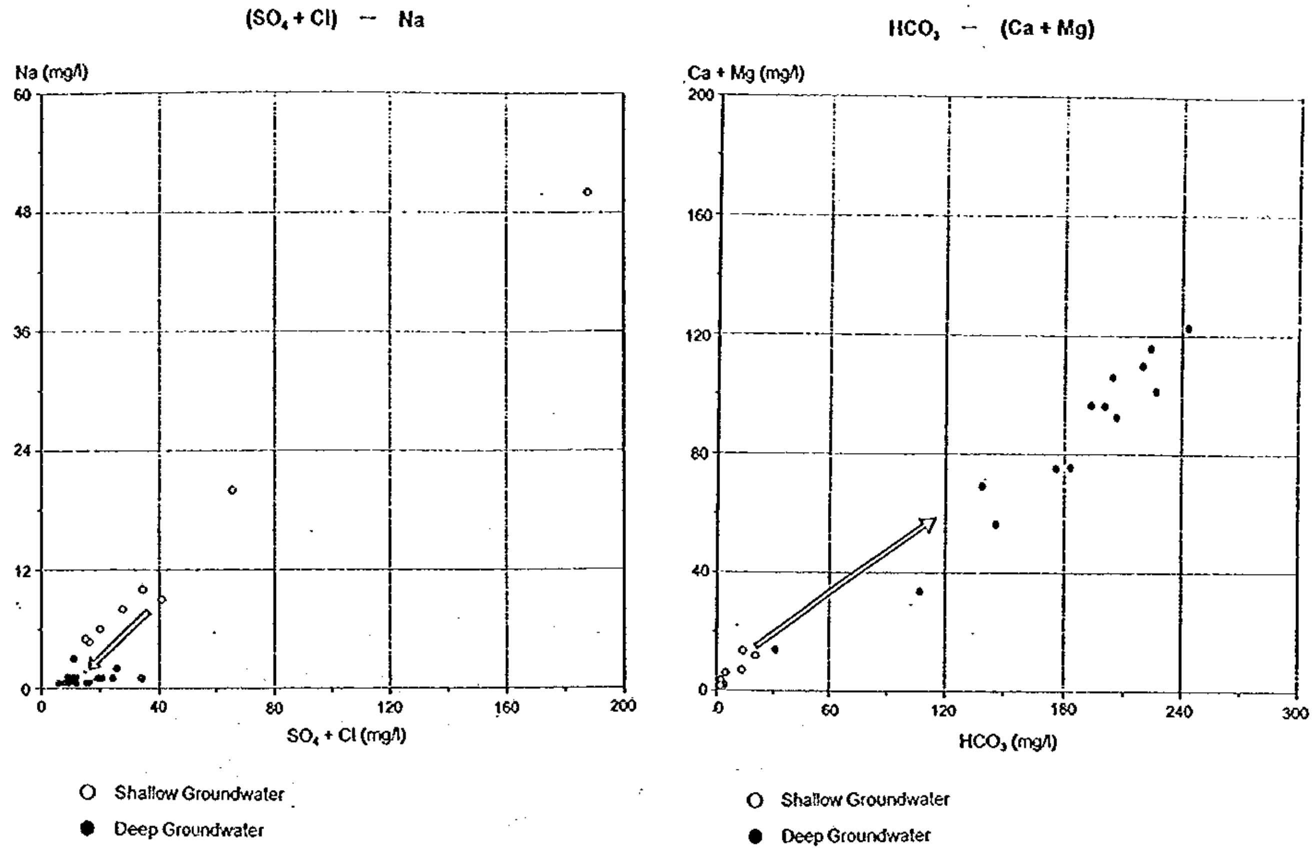


Fig.5.4.1 Correlation among the Main Ion Concentration of the Groundwater

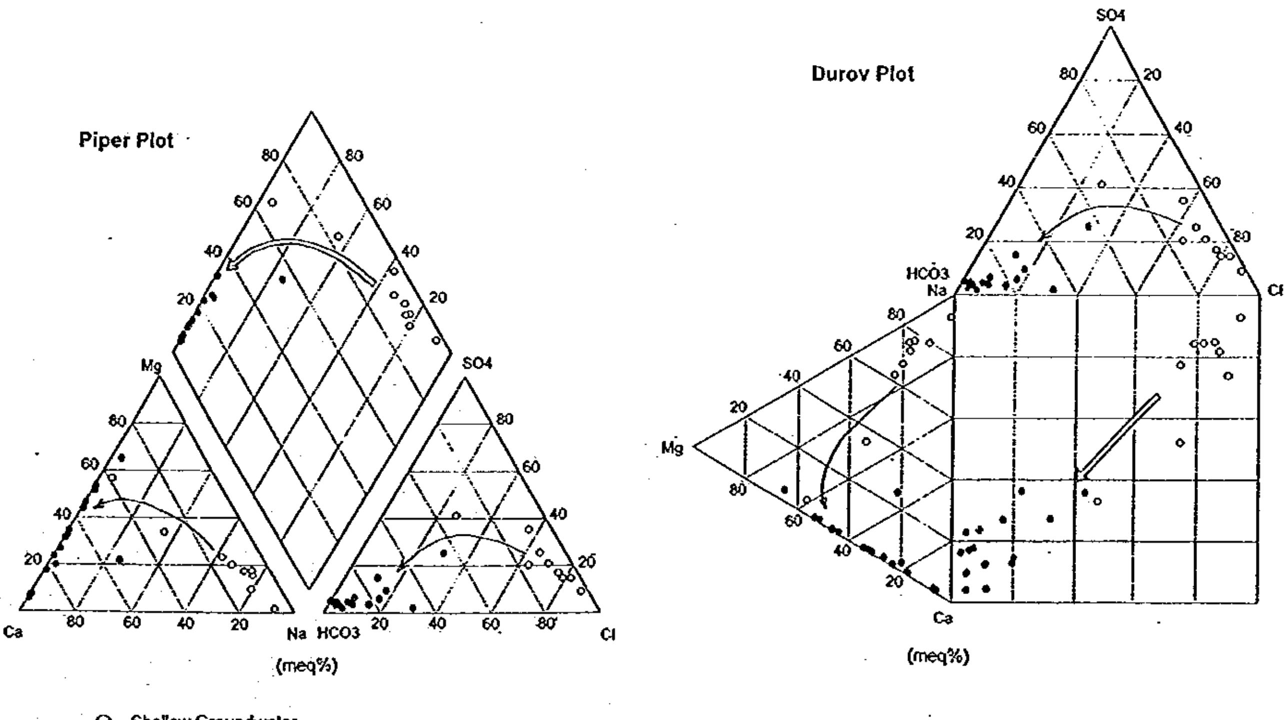


Fig.5.4.2 Main Ion composition of the Groundwater

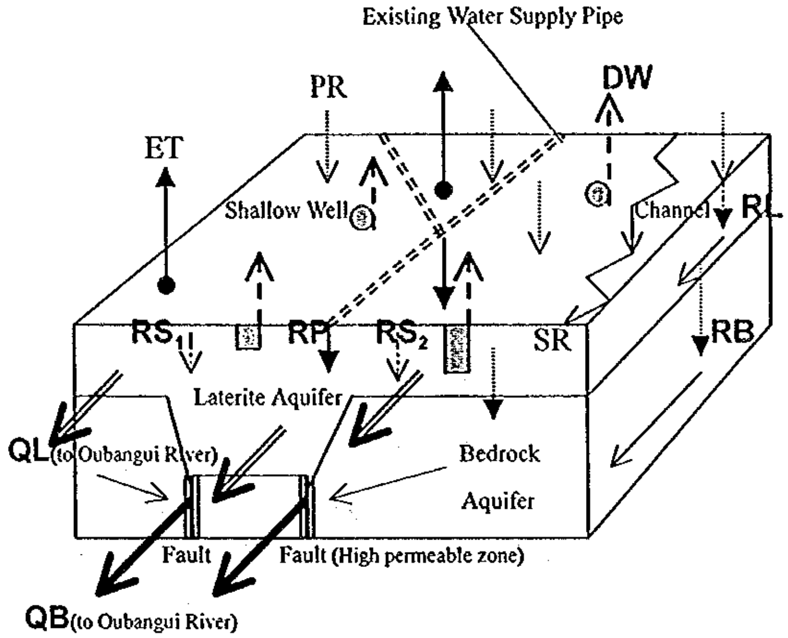
5.5 Groundwater Balance

The examination on the groundwater balance is conducted on the target groundwater basin located in the Bangui city area. The other two groundwater basins do not seem to promise for urban water supply because any high permeable zones (faults) cannot be found in them as shown in Fig.5.1.1.

(1) Flow System of the Groundwater in the Target Groundwater Basin

The groundwater in the Study Area is originated from the rainwater (precipitation) and infiltrated rainwater firstly recharges the laterite aquifer. Recharged water to the laterite aquifer is discharged by the shallow wells for domestic use and it turns to sewage and is drained to the channels. Some part of the sewage infiltrates and again recharges the laterite aquifer as the contaminant of coliforms and nitrate. Most of the sewage is finally drained to the Oubangui River. The leakage from the existing water supply system is also important resource of the groundwater recharge especially in the target groundwater basin where urbanization is advanced.

Some part of the groundwater in the laterite aquifer seeps underneath and recharges the bedrock aquifer. The groundwater flowing in both aquifer finally flows into the Oubaugui River. The flow system of the groundwater in the target groundwater basin is schematically drawn in next figure.



Where, PR : Precipitation	RL : Recharge to the Laterite Aquifer
RB : Recharge to the Bedrock Aquifer	RS_1: Recharge from the Sewage Originated Groundwater
RP : Recharge from the Pipe Leakage	RS_2: Recharge from the Sewage Originated Tap Water
DW: Discharge by the Existing Wells	
QB : Outflow of the Bedrock Aquifer	QL : Outflow of the Laterite Aquifer
ET : Evapo-transpiration	SR : Surface Runoff

Fig.5.5.1 Schematic Drawing Showing the Groundwater Flow System

Next formula is presented to show the groundwater balance in the Study Area.

$$Outflow = QL + QB + DW = Inflow = RL + RB + RP + RS_1 + RS_2$$

(2) Estimation of the Outflow Amount from the Aquifers

1) Outflow Amount from the Laterite Aquifer to the Oubangui River (QL)

The groundwater outflow amount to the Oubangui River from the laterite aquifer is estimated by the calculation of the seepage amount passing the section E-E (see Fig.5.1.2) which is located near to the Oubangui River and perpendicular to the groundwater flow. The groundwater flow amount passing the section is calculated with next formula.

$$QL = A \times P \times G \times 365$$

where, QL : Outflow amount from the laterite aquifer to the Oubangui River (m^3/year)

A : Area of the laterite aquifer, 460,000m^2

P : Permeability of the laterite aquifer at the section E-E, 0.5m/day

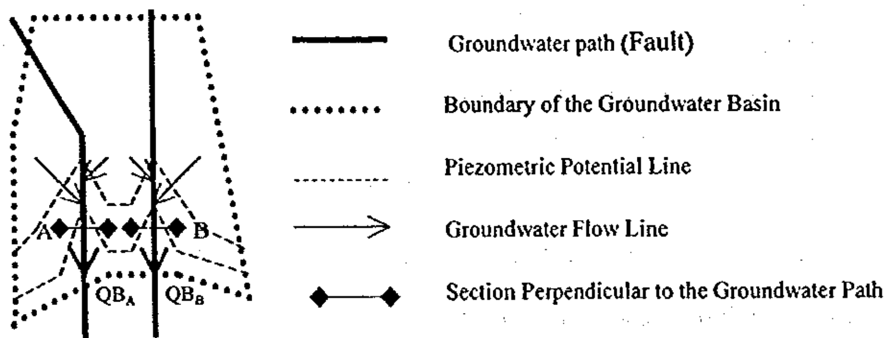
Note: The permeability of the laterite aquifer at the section E-E is supposed to be larger than that of the other areas because the laterite aquifer is very rich in sand and gravels around the section E-E as shown in Fig.5.1.2.

G :Groundwater gradient of the laterite aquifer at the section E-E, 10/2,500

Accordingly, QL = 335,800m^3/year ≒ 0.34 MCM/year

2) Outflow Amount from the Bedrock Aquifer to the Oubangui River(QB)

The groundwater outflow amount to the Oubangui River from the bedrock aquifer is also estimated by the calculation of the seepage amount along the groundwater paths (faults) which accumulate almost the groundwater of the bedrock aquifer in the groundwater basin. The groundwater flow amount flowing the faults is calculated with following manner and formula.



Note:For the detail, refer to Fig.5.1.1

$$QB = QB_A + QB_B$$

$$QB_A = L_A \times T_A \times G_A \times 365$$

$$QB_B = L_B \times T_B \times G_B \times 365$$

where, QB : Outflow amount from the bedrock aquifer to the Oubangui River (m^3/year)

QB_A, QB_B: Outflow amount passing the sections perpendicular to the groundwater paths A, B

L_A,L_B : Width of the groundwater paths, L_A =1,500m, L_B=1,300m

T_A,T_B : Transmissibility of the Groundwater paths, T_A= 500m^2/day, T_B= 500m^2/day

Note: The transmissibility of the bedrock aquifer along the groundwater paths is estimated based on the pumping test results.

G_A,G_B :Groundwater gradient along the groundwater paths, G_A=0.002,G_B=0.002

Accordingly, QB_A= 547,500m^3/year and QB_B=474,500 m^3/year

So, $QB = QB_A + QB_B$ ≒ 1,022,000 m^3/year ≒ 1.02MCM/year

3) Discharge Amount by the Existing Wells (DW)

a. Discharge Amount from the Deep Wells

Only twenty two deep wells are presently working in the Study Area and their total annual discharge amount of groundwater is some 0.24 MCM according to the well inventory survey. The discharge amount and served population of the deep wells are summarized as follows:

Table 5.5.1 Groundwater Discharge Amount by the Deep Wells

	Well number	Discharge amount (m3/day)	Served population	Consumption rate per Capita (lit/day/Capita)
Domestic	21	170(0.06 MCM/year)	24,000	7.1
Industrial	1	500(0.18 MCM/year)	--	--
Total	22	670(0.24 MCM/year)	24,000	--

Though a deep well for industrial use is located in the factory yard of Bangui SCB (MOCAF) in Bimbo district and this area is out of the target groundwater basin, the discharge amount from the SCB well is not taken into consideration in this examination.

Only one well is tapped the bedrock aquifer (Bangui FOYER CHARITE). As its discharge amount is estimated around 0.003MCM/year (3,000m^3/year), it is judged that the discharge amount from this well is negligible for the water balance examination. Accordingly, the groundwater dishrag amount from the laterite aquifer by the deep wells is estimated about 0.06 MCM/year (170 m3/day) in the target groundwater basin.

b. Discharge Amount from the Traditional Shallow Wells

There are numerous number of traditional shallow wells and many people still greatly rely on such traditional wells in the Study Area. Following characteristics in usage of the shallow wells were assumed through the the survey of fifty shallow wells:

- The shallow well is not used in District I because all houses and buildings are connected to water supply system.
- Shallow wells are chiefly used for washing, cleaning and bathing supplementing the tap water in the served area with public faucet.
- In the non-served area from the existing water supply system (Bimbo 4, Bimbo 5 and Bimbo 7), averages groundwater consumption rate per Capita from the

shallow wells is assumed about 30 Lit according to the resulta of the interview questionaire survey (refer chapter 3.2.3).

- In the served area with the public faucet, averages groundwater consumption amount per Capita from the shallow wells is assumed about 23Lit. accoding to the analysis of water use among the population discussed in chapter 3.2.3 (District I, DistrictII, DistrictIII, DistrictIV, DistrictV, District VI).
- In the area where served houses and no-served houses are mingled, average groundwater consumption amount per Capita from the shallow wells is assumed about 27Lit. in two areas (DistrictVIII and Bimbo 2).

Next table shows the estimated discharge amount from the laterite aquifer by the traditional shallow wells based on the conditions mentioned above.

Table 5.5.2 Assumed Groundwater Discharge Amount by the Shallow Wells

District	Population in 1998	Groundwater Consumption per Capita (lit)	Supposed Discharge Amount (m^3/day)
I	15,688	0	0
II	81,63	23	1,878
III	125,851	23	2,517
IV	44,005*	23	880
V	154,676	23	3,094
VI	78,275	23	1,566
VIII	66,279	27	1,790
Bimbo 1	2,750*	23	55
Bimbo 2	3,000	27	81
Bimbo 4	1,000*	30	30
Bimbo 5	1,500*	30	45
Bimbo 7	1,500	30	45
Estimated Rounded Total	620,000	--	13,197m^3/day

Note : For the population of each district, refer to Chapter 6.2.

* : Half of the population of the area

Based on the calculation shown above, it is expected that about 13,200 m^3/day (approximately 4.82MCM/year) of groundwater is being discharged from the laterite aquifer by the traditional shallow wells in the target groundwater basin.

c. Total Discharge Amount from the Existing Wells

As described in section "a" and "b", the total discharge amount from the existing wells in the target groundwater basin is summarized as follows:

Table 5.5.3 Total Discharge Amount by the Wells

Aquifer	Deep Wells	Shallow Wells	Total
Laterite Aquifer	0.06MCM/year	4.82MCM/year	4.88MCM/year
Bedrock Aquifer	Negligible	0	Negligible
Total	0.06MCM/year	4.82MCM/year	4.88MCM/year

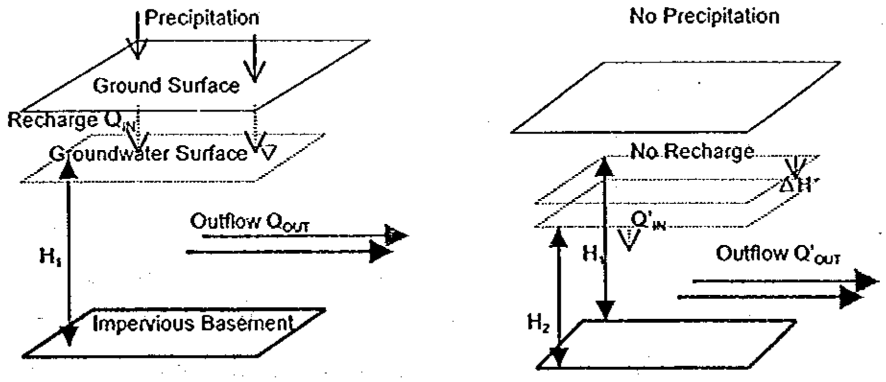
Consequently the existing groundwater development is concentrated on the laterite aquifer in the target groundwater basin and its annual amount is estimated about 4.88MCM/year as shown above table.

(2) Estimation of the Inflow Amount to the Aquifers (RL + RB, RP, RS_1 and RS_2)

1) Recharge Amount from the Precipitation (RL + RB)

As the laterite aquifer and the bedrock aquifer are hydraulically connected and both two aquifers can be regarded as one aquifer, the recharge amount of the both aquifers is examined using the groundwater level fluctuation pattern.

The groundwater level fluctuation pattern of the both aquifers bears resemblance which shows clear relation with the precipitation as shown in Fig.5.3.3. In such case, the recharge amount to the aquifers can be assumed from the natural drawdown rate during the no rain days (no recharge days). The theory of this estimation is as follows:



Outflow in rainy season, $Q_{OUT} = Q_{IN}$ Outflow in no rain days, $Q'_{OUT}=Q'_{IN}=\Delta h$ x storage coef.

Fig.5.5.2 Basic Concept for the Estimation of the Groundwater Recharge amount

As shown in Fig 5.5.2, the groundwater outflow amount (Q_{OUT}) is almost equal with the recharge amount from the precipitation (Q_{IN}) in the middle of the rainy season. On the contrary, the outflow is borne by reducing the storage of the aquifer in no rain days of dry season and its amount can be estimated from the decreasing rate of the groundwater level (ΔH) and the storage coefficient of the aquifer. As the depth of the decreasing groundwater level (H1-H2) is much smaller than the total aquifer height (H_1)

and it is judged negligible, the outflow amount is almost same in rainy season and no rain days in dry season. Therefore, the recharge amount can be estimated by following formula.

$$Q = Q_{IN} = Q_{OUT} = Q'_{OUT} \quad \text{(see Fig. 5.5.2)}$$
$$= \Delta H \times S \times A$$

where,

ΔH : Decreasing rate of the groundwater level

Q : Recharge amount to the aquifer from the rain water infiltration

S : Storage coefficient of the Aquifer

A : Area of the groundwater basin

The decreasing rate of the groundwater level in dry season (ΔH) is assumed 0.5m/month according to the continuous groundwater level observation at the exploratory wells (see Fig.5.3.4). The storage coefficient of the aquifer should be employed the value of the laterite aquifer as the groundwater level fluctuation part remains in this aquifer. The storage coefficient of the aquifer is given 1×10^{-2} because the laterite aquifer is rich in clayey materials. The area of the target groundwater basin located on the Bangui city area is 47km². Based on the condition mentioned above, the annual recharge amount to the aquifers (laterite aquifer and bedrock aquifer) in the target groundwater basin is estimated as follows:

$$Q = \Delta H \times S \times A = 0.5\text{m/month} \times (1 \times 10^{-2}) \times 47\text{km}^2 \times 12$$
$$= 2{,}820{,}000\text{m}^3\text{/year}$$
$$\fallingdotseq 2.82\text{MCM/year}$$

As the annual rainfall amount in the Bangui city area is about 1,400mm, approximately 4% of the precipitation is assumed to infiltrate into the ground and to recharge the groundwater in the target groundwater basin. It is judged that the value of 4% is reasonable as the infiltration ratio of the rainwater in the Study Area according to the surface condition because the area is covered with thick lateritic clay layer and many drainage channels are excavated in it.

2) Recharge Amount from the Leakage of the Existing Water Supply System

It is said that the leakage from the existing water pipes forms great part of the groundwater recharge in the urban area. It is also assumed that the leakage amount from the existing water supply might reach great amount in Bangui City.

Although the detailed information concerning the leakage amount from the existing water supply system cannot be available in Bangui City, it is expected that the leakage rate is around 35% referring the average leakage rate in the city area in the world.

As the produced water volume is estimated around 8.58MCM/year (23,500m^3/day) based on the actual record of the treat ment plant in 1988, it is expected that the leakage amount from the existing water supply system is around 3.00MCM/year.

3) Recharge Amount from the Sewage Infiltration (RS_1 and RS_2)

It is certain that the groundwater receives the recharge from the sewage because it is contaminated with coliforms and ammonia whose contaminant is obviously originated from the human activities.

As described in section a, the infiltration ratio of the rainwater in the Study Area is assumed about 4%, the same ratio is given to the infiltration ratio of the sewage. The calculation result is shown in next:

$$
\begin{aligned}
RS &= RS_1 + RS_2 \\
&= (WS_1 + WS_2) \times 0.04 \\
&= (4.88\text{MCM/year} + 5.58\text{MCM/year}) \times 0.04 \\
&= 0.20\text{MCM/year } (RS_1) + 0.22\text{MCM/year } (RS_2) \\
&= 0.42 \text{ MCM/year}
\end{aligned}
$$

where,

RS : Total annual recharge amount from the sewage

RS_1: Recharge from the sewage originated from the groundwater

RS_2: Recharge from the sewage originated from the tap water (from Oubangui River)

WS_1 : Groundwater consumption amount, 4.88MCM/year (see Table 5.5.3)

WS_2 : Tap water consumption Amount,

RS_2=Produced Water – Leaked Water=8.58MCM/year – 3.00MCM/year =5.58MCM/year (refer to section 2))

It is assumed that 0.42 MCM/year of the sewage annually infiltrated in the target groundwater basin.

(3) Groundwater Balance in the Target Groundwater Basin

The outflow amount and inflow amount of the groundwater calculated in section (1) and (2) are summarized in next table.

Table 5.5.4 Calcurated Inflow and Outflow amount of the Groundwater

Outflow Amount (MCM/year)		Inflow Amount (MCM/year)	
Outflow from the Laterite Aquifer (QL)	0.34	Recharge from the Precipitation (RL + RB)	2.82
Outflow from the Bedrock Aquifer (QB)	1.02	Recharge from the leakage of the Existing Water Supply System (RP)	3.00
Discharge by the Shallow Wells (DW)	4.88	Recharge from the Sewage Infiltration (RS_1+RS_2)	0.42
Total	6.24	Total	6.24

Sice the outflow amount is coincident with the inflow amount as shown above table, it is judged that the calculation results on the groundwater balance are almost acceptable. The groundwater balance in the target groundwater basin can be schematically shown in next figure.

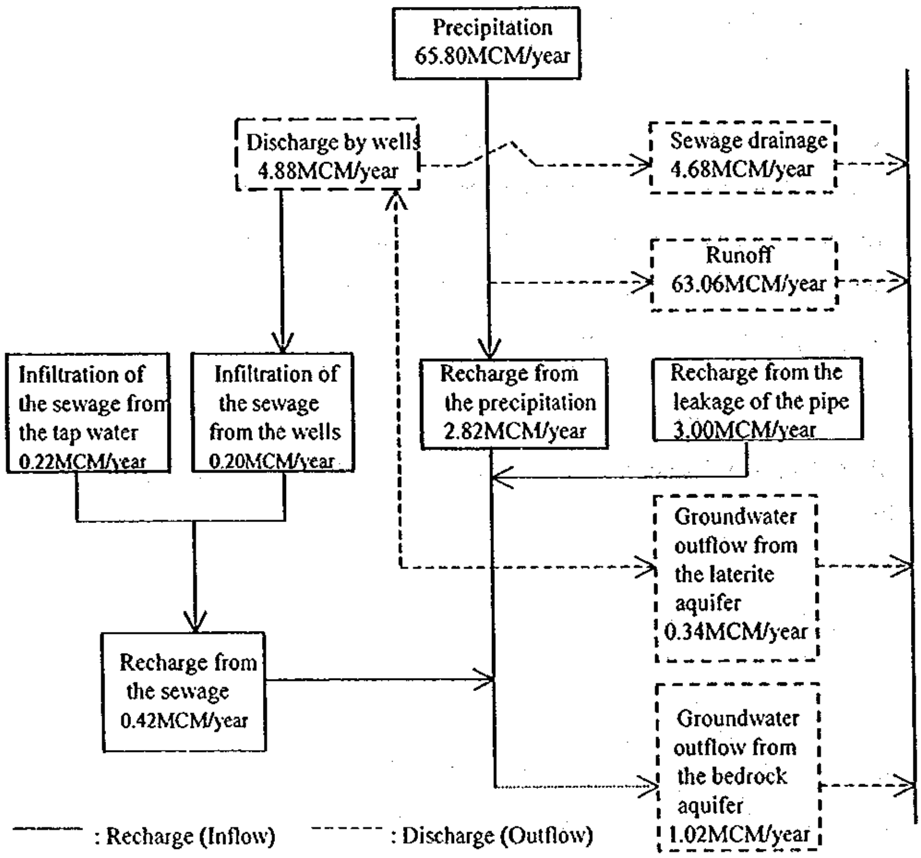


Fig. 5.5.3 Schematic Groundwater Balance in the Target Groundwater Basin

5.6 Numerical Groundwater Simulation

The purpose of the numerical groundwater simulation in this chapter is to formulate the hydrogeological model for the future simulation after the groundwater development. Reproduction simulation of the present groundwater level is done in this chapter for the formulation of the hydrogeological model of the target groundwater basin. The simulation of future status of the groundwater level will be discussed in chapter 7.1.1 for the estimation of the groundwater potential of the target groundwater basin.

The numerical groundwater simulation is conducted on the bedrock aquifer because the laterite aquifer is not adequate in terms of its low productivity and deteriorated water quality.

(1) Simulation Program

Modflow is employed for the numerical groundwater simulation. Modflow is constructed based on the differential element method and has been applied in various field concerning the groundwater seepage and contamination.

(2) Basic Conditions for the Numerical Simulation

1) Grid Model and Boundary Condition

Grid model is formed at the spacing of 160m as shown in Fig.5.6.1. Non-flow boundary condition is set along the boundary of the target groundwater basin and the head constant boundary is set along the Oubangui River as shown in Fig.5.6.1.

2) Recharge Amount

The outflow amount from the bedrock aquifer is estimated 1.0MCM/year based on the result of the groundwater balance examination (see Fig.5.5.3), the same value is given as the recharge amount to the bedrock aquifer.

3) Thickness of the Aquifer

Based on the results of the exploratory well drilling, 30m is given as the thickness of the bedrock aquifer.

4) Distribution of the Permeability

High permeability value is given along the groundwater paths (faults) and low permeability is given to another area according to the pumping test results.

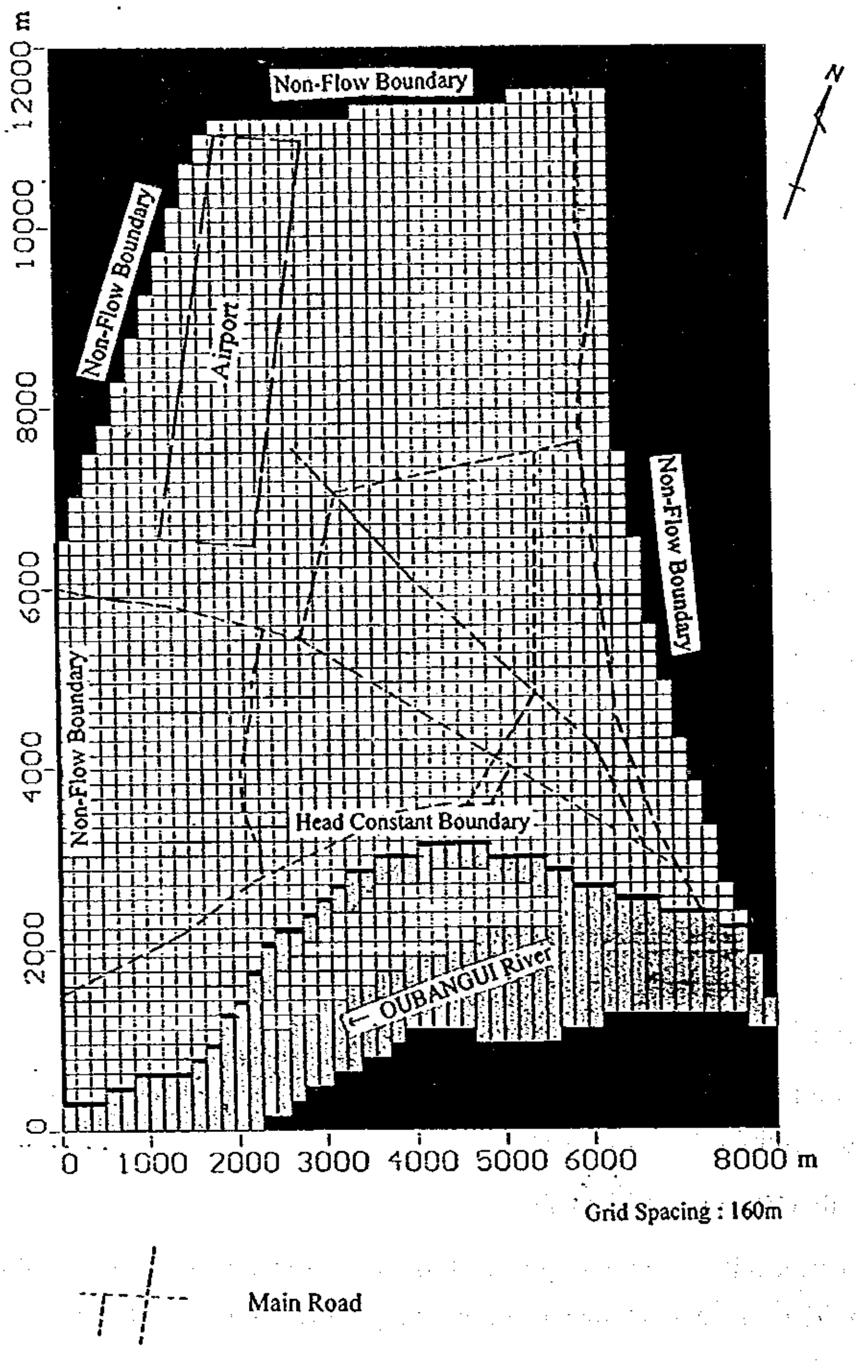


Fig.5.6.1 Grid Model and Boundary Condition For the Groundwater Simulation

(3) Trial of the Numerical Simulation

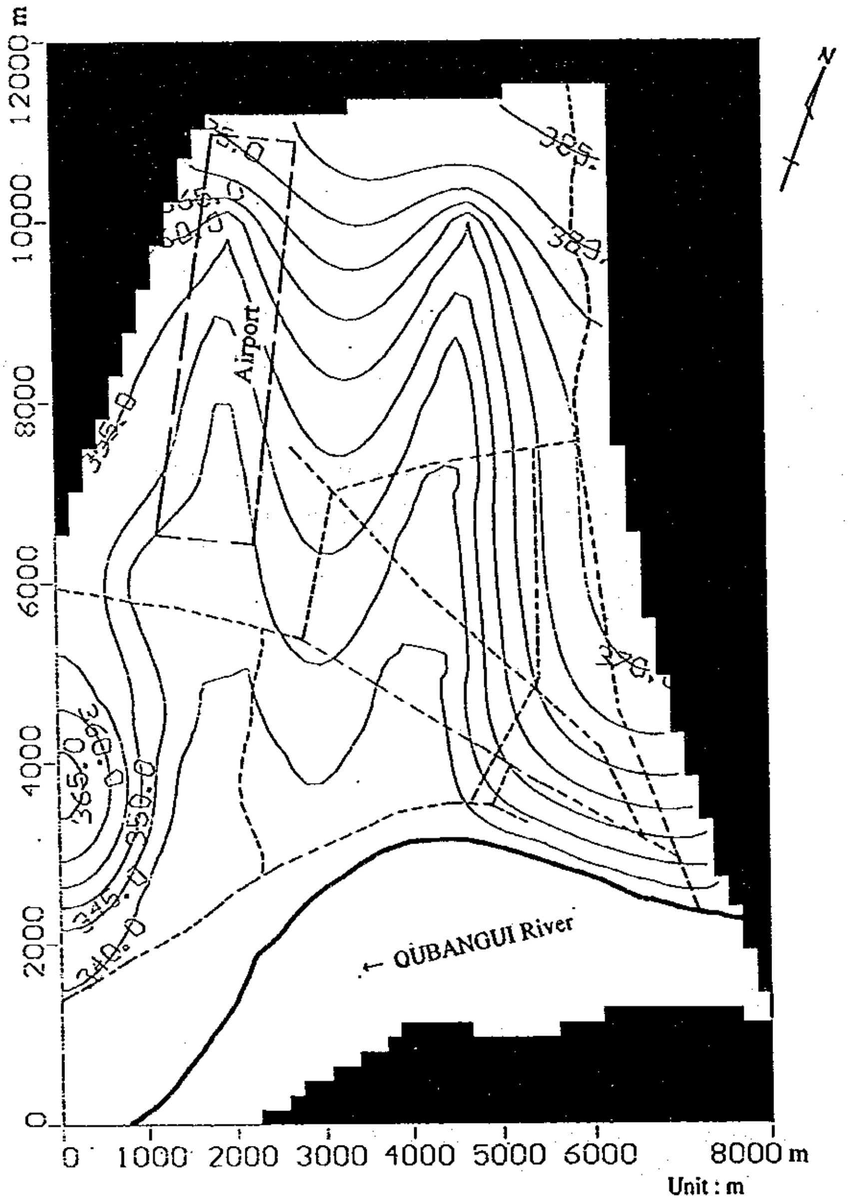
The groundwater numerical simulation was conducted through trial and error by changing the recharge amount and distribution of the permeability until the present groundwater level contour was reproduced in satisfactory accuracy.

(4) Results of the Reproduction Simulation of the Present Groundwater level

The finalizes reproduced groundwater level contour line is shown in Fig.5.6.2. Comparing the reproduced contour by the simulation with the actual line shown in Fig.5.1.1, it is assumed that the reproduced contour line is almost coincident with the actual one.

Final permeability distribution of the bedrock aquifer is shown in Fig.5.6.3 on which high permeability zones are appeared along the assumed groundwater paths (faults) . The final permeability distribution is consistent with the pumping test results mentioned in chapter 4.3.

The final recharge amount is 1.0MCM/year and the most resemble contour line to the actual one can be reproduced under this recharge amount.



Note : Recharge amount to the bedrock aquifer is $1,000,000m^3$/Year

—340.0— Re-appeared Groundwater Table Contour Line of the Bedrock Aquifer measured in Jannuary, 1999 in meter

Fig.5.6.2 Reproduced Present Groundwater Contour Line of the Bedrock Aquifer

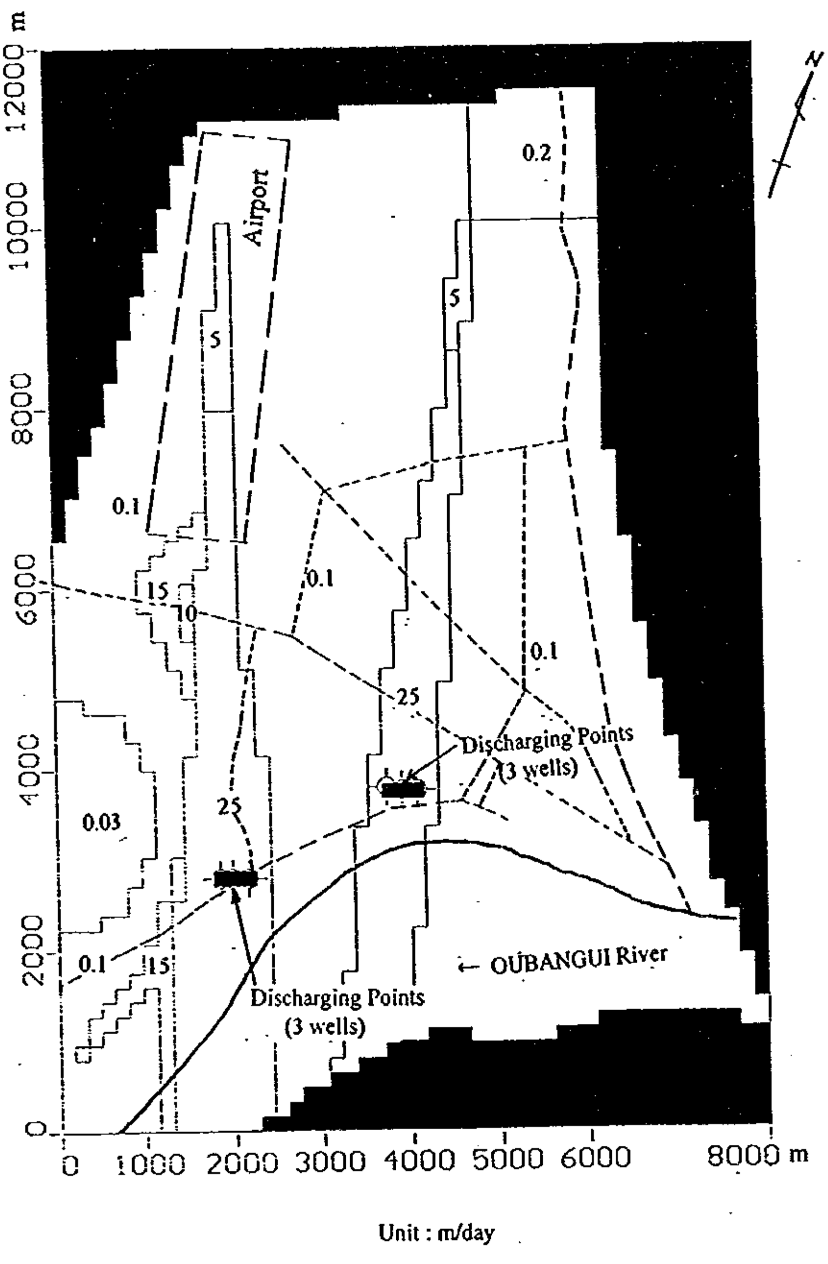


Fig.5.6.3 Permeability Distribution of the Bedrock Aquifer Obtained through the Trial of the Simulation

Chapter 6. Surface Water Potential for the Water Supply Plan

The OUBANGUI river and the M'POKO river can be a water source of water supply system for the Project area. The study area is surrounded by the M'POKO river on the north, west and south parts. While there still remains a lot of forest and farm lands around the river, the flow is being contaminated gradually by garbage, sewage and drainage which were brought through peoples lives. Urbanization will be the prime cause of contamination of the river in future. Of the M'POKO river system, the M'BALI river, one of major tributaries, joins the M'POKO near the west side of the study area. The M'BALI river is now free from contamination and there is no particular activity which causes to pollute the river water in future. Therefore, it is highly recommended that the M'BALI river shall be the source of water supply service for the study area in future. The location of the proposed intake facility was selected on the right bank of the MBALI river at about 1 Km upstream of the confluence of the both rivers.

1) OUBANGUI river

In 1964, the existing intake pump station was constructed on the right bank of the OUBANGI river, through which about 0.30 m^3/sec of water has been utilized for SODECA's water supply at present. The existing intake facility is composed of 4 centrifugal vertical pumps and a floating type pump. At the time of the minimum discharge of the river in April 1990 (227 m^3/sec, 40-year probability), the intake was maintained well in use by drawing water through the floating pump. A total intake volume of 0.87 m^3/sec proposed in the master plan of this study is negligibly small to the drought discharge of 227 m^3/sec. The OUBANGUI river, having sufficient water quantity and water level as the water source, can supply domestic water demand in future.

2) M'POKO river

In the M'BALI river, the BOALI dam was constructed in November 1990 in order to ensure a stable water flow of 20 m^3/sec to the existing BOALI hydraulic power plants I and II with total capacity of 18.85 MW, which located at about 5 km downstream from the dam. These power plants were founded in 1953 and 1976 respectively and have been sending energy to BANGUI City. The dam has a storage capacity of 258 million m^3, by which excess rainwater is possible to be stored in the rainy. After certain trial operational period, the dam was started normal operation from August 1991 and then 20 m^3/sec of discharge enabled to be released to the plants constantly in the dry season.

Of the BOALI dam, water balance or discharge control/adjustment function was studied. As the result of the dam water balance simulation for 35 years from 1964 to 1998, no water shortage occured in case of basic discharge of 20 m^3/s. In case of 25 m^3/sec basic discharge, the shortage happened in 2 years (106 days in 1988 and 37 days in 1990) and the recurrence interval was estimated 15-20 years. The results of the BOALI dam water balance are presented in Table 6.1.1, Fig.6.1.1 and Fig.6.1.2.

The annual minimum discharge at BOALI of the M'BALI river was also studied. Based on the dam inflow data (daily discharges at BOALI ICOT gauging station), the discharge calculation was carried out for a period from 1985 to 1998 in cases with dam and without dam. The annual minimum discharge and probability of non-exceedence were computed as below. In case without dam, probable minimum discharge of 5-year return period was 7.1 m^3/sec. In case with dam, the minimum value of 20-year probability was 20.4 m^3/sec.

From above, it was concluded that by the adjustment function of the BOALI dam the M'BALI river discharge should be stable. In case that the basic discharge of 20 m^3/sec be supplied from the dam to the power plants, water quantity problem shall not occur by taking water of 0.87 m^3/sec which estimated as the requirement of 2015 in the master plan of this study.

<u>The annual minimum discharge at BOALI of the MBALI river</u>

Year	with dam m3/sec	Without dam m3/sec
1985	36.9	24.6
1986	24.6	6.7
1987	23.9	5.7
1988	20.2	0.3
1989	27.0	10.2
1990	23.7	5.4
1991	35.1	22.0
1992	36.0	23.3
1993	29.6	14.0
1994	34.2	20.7
1995	42.3	32.5
1996	42.1	32.2
1997	44.3	35.4
1998	34.2	20.7

Return Period	with dam m3/sec	without dam m3/sec
50	17.9	0.8
30	19.2	1.6
20	20.4	2.4
10	22.8	4.3
5	25.8	7.1
2	32.0	15.1

Table 6.1.1 Summary of BOALI Dam Water Balance

Year	Qb = 25 m3/s						Qb = 20 m3/s			
	Vmin	WLmin	Vmin-r	Qo-min	Period when Qo<Qb	Insuffi-cient V	Vmin	WLmin	Vmin-r	Qo-min
	(MCM)	(m)	(%)	(m3/s)	(day)	(MCM)	(MCM)	(m)	(%)	(m3/s)
1964	216	570.72	84	25.0			240	571.64	93	20.0
1965	254	572.16	99	25.0			259	572.33	101	23.0
1966	249	571.96	96	25.0			259	572.31	100	20.9
1967	251	572.04	97	25.0			259	572.33	100	22.3
1968	260	572.36	101	26.1			260	572.36	101	26.1
1969	260	572.36	101	25.5			260	572.36	101	25.5
1970	262	572.42	101	32.3			262	572.42	101	32.3
1971	212	570.55	82	25.0			242	571.72	94	20.0
1972	165	568.52	64	25.0			216	570.72	84	20.0
1973	51	561.22	20	25.0			135	567.06	52	20.0
1974	68	562.74	26	25.0			160	568.27	62	20.0
1975	137	567.13	53	25.0			199	570.03	77	20.0
1976	249	571.95	96	25.0			259	572.31	100	20.7
1977	205	570.26	79	25.0			244	571.77	94	20.0
1978	154	567.99	60	25.0			214	570.63	83	20.0
1979	155	568.08	60	25.0			216	570.73	84	20.0
1980	145	567.57	56	25.0			199	570.04	77	20.0
1981	172	568.87	67	25.0			218	570.78	84	20.0
1982	171	568.81	66	25.0			218	570.78	84	20.0
1983	57	561.82	22	25.0			121	566.29	47	20.0
1984	63	562.35	25	25.0			141	567.36	55	20.0
1985	76	563.34	29	25.0			152	567.89	59	20.0
1986	19	557.17	7	25.0			100	565.01	39	20.0
1987	3	552.61	1	25.0			83	563.87	32	20.0
1988	3	552.67	1	0.1	106	179	6	554.15	2	20.0
1989	51	561.21	20	25.0			111	565.70	43	20.0
1990	3	552.80	1	4.8	37	47	53	561.45	21	20.0
1991	62	562.23	24	25.0			138	567.22	54	20.0
1992	125	566.47	48	25.0			174	568.93	67	20.0
1993	141	567.36	55	25.0			205	570.26	79	20.0
1994	129	566.70	50	25.0			195	569.85	76	20.0
1995	125	566.47	48	25.0			204	570.24	79	20.0
1996	162	568.40	63	25.0			217	570.75	84	20.0
1997	210	570.46	81	25.0			249	571.95	96	20.0
1998	138	567.19	53	25.0			205	570.27	79	20.0
average	143	566.20	55	24.0			191	569.19	74	20.9
min.	3	552.61	1	0.1			6	554.15	2	20.0

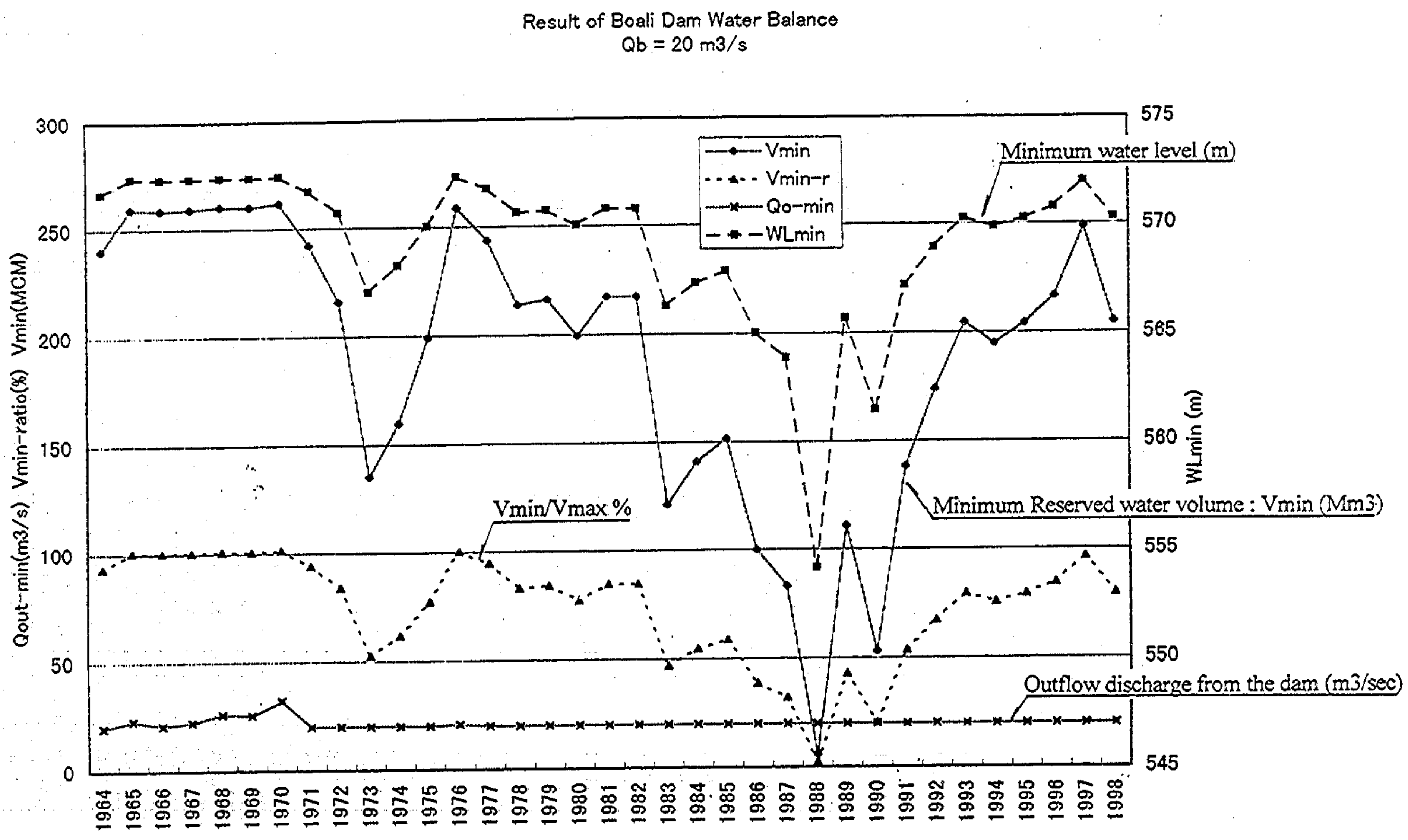


Fig. 6.1.1 Result of BOALI Dam Water Balance (Qb = 20m3/sec)

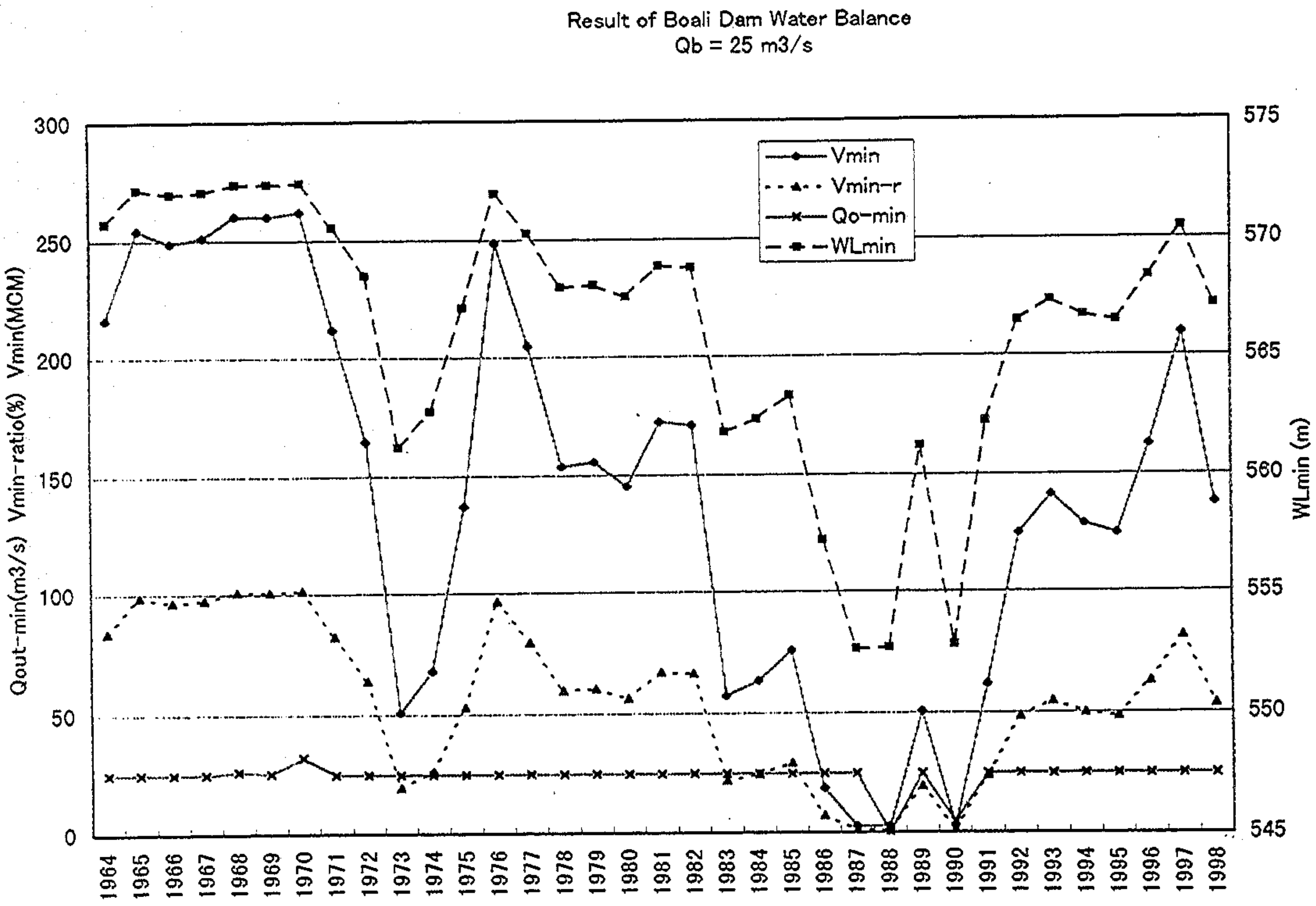


Fig. 6.1.2 Result of BOALI Dam Water Balance (Qb = 25m3/sec)

Chapter 7 Establishment of Master Plan

7.1 Formulation of Methodology for Master Plan

7.1.1 Flow of Master Plan Study

Master Plan Study is implemented accordance with the following flowchart.

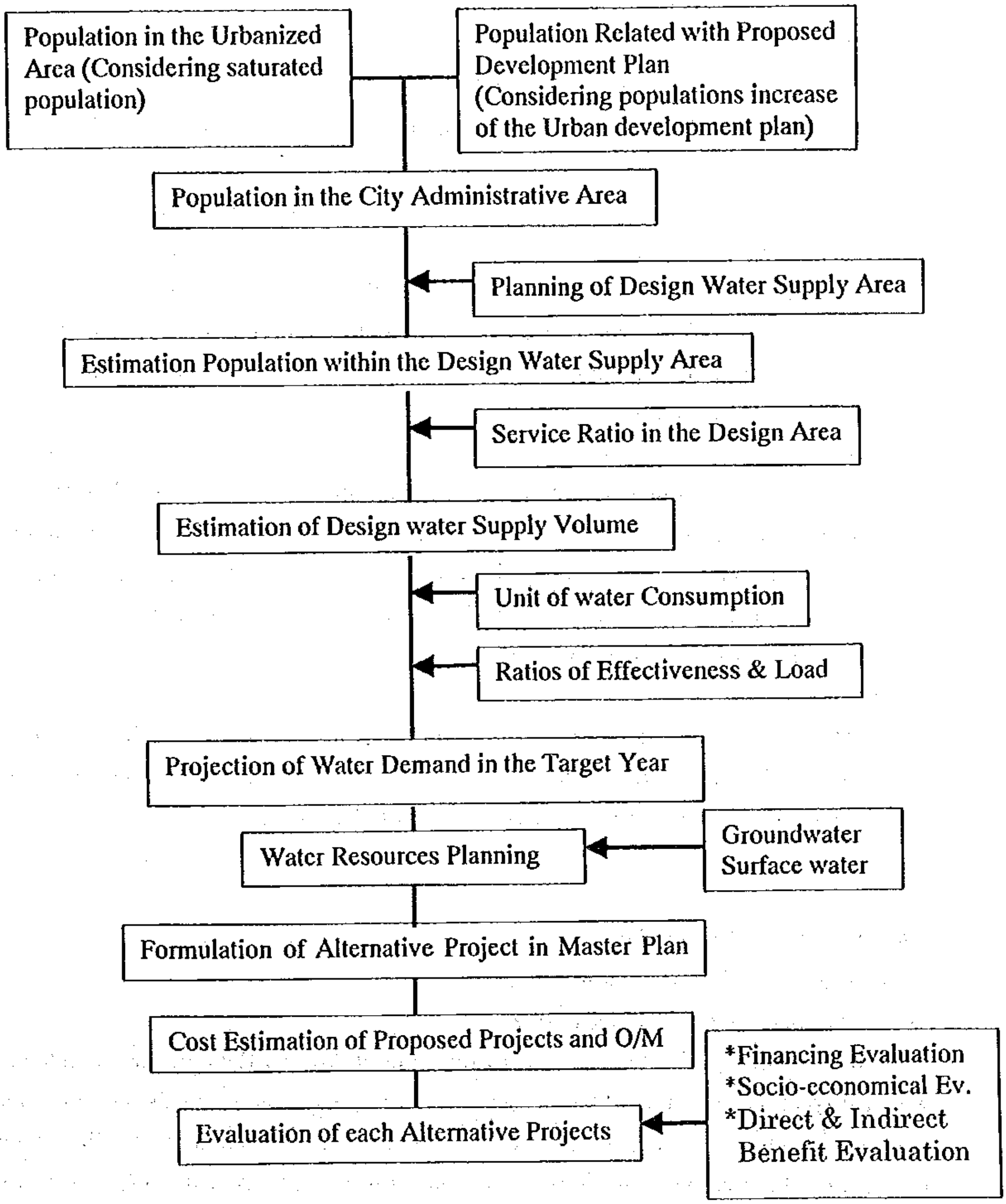


Fig.7.1.1 Flowchart of Master Plan

7.1.2 Policy of the Master Plan

As a basic policy of the Master Plan, the following condition shall be applied.

1) Target Year:

The final target year of Master Plan shall be 2015. A year of 2005 is the short ranged target which corresponds to the target of the Feasibility Study to be conducted in the next stage.

2) Source of water Supply

Water source is the groundwater and the surface water which have been analyzed and evaluated potential to be utilized in the First Stage of this Study. Quality of supply water shall satisfy with the international WHO guidelines.

3) Target Area

Main target area shall be peripheral zones of Bangui City where some are located outside of the existing water supply area and the others, even inside of the supply area, can not be supplied with adequate pressure and quantity. In case that the existing distribution pipeline can not cater to a future water demand, replacement of the existing pipeline nets shall be considered in the Master Plan.

4) Facilities to be Proposed

Water production facilities shall be applied to the type of the proposed water source. Each component of alternative plans shall be suitable to technical level of the local engineers and also be considered of from the easy and economical operation and maintenance point of view. Distribution facilities, house connections and public faucets, shall be designed in accordance with the criteria which are applied presently.

5) Materials for Construction

Materials to be utilized for construction of the project shall be selected among the locally produced ones as much as possible. In case imported materials are used, commonly distributed ones in the CAR shall be given priority.

7.2 Study of the Master Plan

7.2.1 Projection of Service Population

1) Present Population in the Study Area

In 1998 the third official census of the Central African Republic was conducted with a 10-year interval since 1988, the second. The census last year was successful but now aggregation / data classification by Ministére Délégué à l'Economie, au Plan et à la Cooperation Internationale are in progress and those procedures will finish around the end of this year, 1999.

The Statistical Center of the Ministry gave a worksheet in process for population estimates of Bangui City, Bimbo (city center and suburbs) and other districts in the country to the JICA study team. According to the census, annual population growth rate all over the country is estimated as 2.25%. This figure is not unrealistic while comparing to other estimates, such as by IMF (2.6% in 1977)[1] or CIA (2.05% in 1997)[2].

The design area consists of the whole of Bangui city, which is in a progress of urbanization except the hilly area located in the east part of Bangui, and three sub-districts of Binbo-center, Kokolo, Begoua in Bimbo District which belongs to Ombella Mpoko Prefecture. These three sub-districts are located next to the urbanized area of Bangui therefore these are categorized into the urban in the District. (See Fig.7.2.1)

The population of the design area is estimated as shown in Table 7.2.1 hereunder.

Table 7.2.1 Present Population of Study Area Based on Census

Area	Population by Census in 1988			Estimated Population in 1998			Population Increas Ratio
	Total	Urban Area	Rural Area	Total	Urban Area	Rural Area	
1. Bangui City							
D-I	10,724	10,724	-	15,688	15,688	-	3.88%
D-II	55,801	55,801	-	81,631	81,631	-	3.88%
D-III	86,029	86,029	-	125,851	125,851	-	3.88%
D-IV	60,162	60,162	-	88,011	88,011	-	3.88%
D-V	105,732	105,732	-	154,676	154,676	-	3.88%
D-VI	53,507	53,507	-	78,275	78,275	-	3.88%
D-VII	34,428	34,428	-	50,365	50,365	-	3.88%
D-VIII	45,307	45,307	-	66,279	66,279	-	3.88%
Total	451,690	451,690	0	660,776	660,776	0	
2. Ombella & Mpoko Prefecture							
Bimbo District	69,176	10,751	58,425	158,350	23,022	135,328	7.91%
Ombella & Mpoko pref.	150,865	10,751	140,114	291,792	49,390	242,402	7.91%
3. Other Pref.	2,085,871	524,095	1,110,086	1,746,349	655,049	1,091,300	
4. Public of Central Africa	2,688,426	986,536	1,701,890	3,359,693	1,365,215	1,994,478	2.25%

(Source: Ministère Délégué à l'Economie, au Plan et à la Coopération Internationale)

The Mayor of Bimbo District confirmed that a total population of the three sub-districts of Bimbo, which included in the study area, was 25,000 as of the end of 1998.

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[1] IMF, *Central African Republic: Statistical Annex*, (1998). P. 3

[2] The US Center Intelligence Agency, *World Factbook: Central African Republic 1998.*

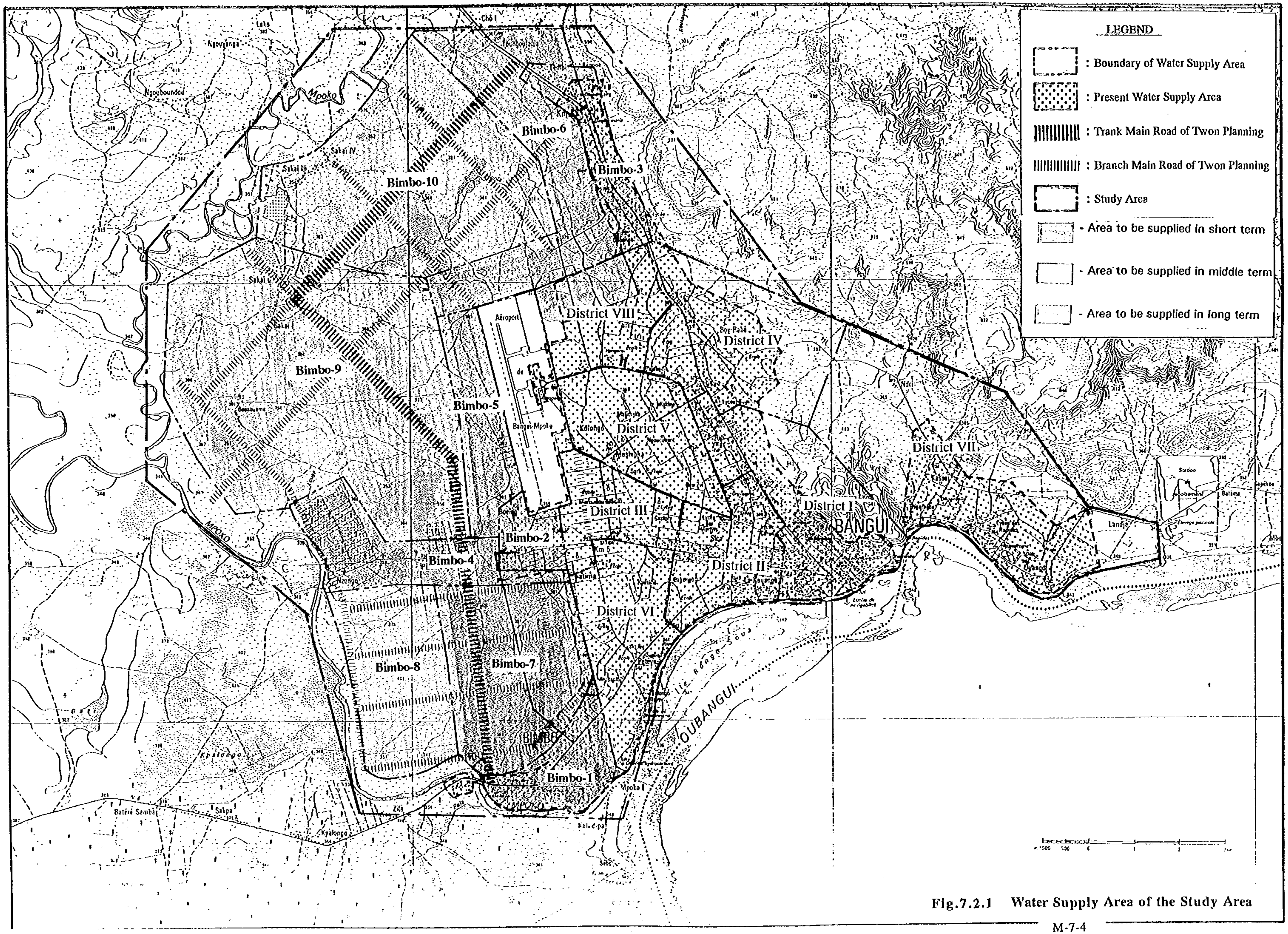

Fig.7.2.1 Water Supply Area of the Study Area

The Population growth rate of Bangui was estimated a little higher (3.88%/year) and Bimbo was much higher (7.91%/year) than other districts in the country. The exact reason why the Central African authority employed these rates was not theoretically explained, however, according to the interview to the Bimbo City Office or Ministère Délégué à l'Economie, au Plan et à la Coopération Internationale, population inflow to Bimbo has become drastically incremental in recent years (mainly because residential areas in Bangui have become almost saturated and people migrating from countryside cannot afford costs for living in the city)

2) Characteristic of the Study Area

The design water supply area consists of the Urbanized area of Bangui city, and the three sub-districts of Bimbo District located in the east of Mpoko river where are expected to be rapidly urbanized in near future. Bangui City is divided into eight administrative districts. And it is considered to be suitable for the estimation work that the sub-districts of Bimbo in the study area shall be divided into ten zones, from B1 to B10, considering progress of urbanization of each zone.

The characteristics of the each zone are as follows.

a) Existing Water Supply Area (presently urbanized area)

The existing water supply area of the public water service (SODECA) covers almost Bangui city area except hilly area which stretches in the east side of the city from north-west to south-east and some parts of sub-district of Bimbo where urbanization is rapidly under way. The Bangui City consists 8 administrative districts. Among them there are some districts where the population density is reaching to the limit. In these zones, without drastic renovation of policy of urban planning such as reconstruction to multi-story building from the present situation with mostly one-story houses, population density would not be expected to increase any more. The north half part of District VIII of Bangui is out of covering of the present water supply system. In the zone of B-1, B-2 and B-3 of Binbo, the water service is partly provided through the distribution laid in the main streets. However, the people in these zones are served water with poor quantity and pressure and the service is suspended sometimes in the dry season.

b) Non-water Supply Area

The west half of the study area except B-1, B-2 and B-3 of Binbo is out of the present water supply area. Depend on the locations of the existing main facilities such as a water treatment plant and reservoirs which are situated in the east part of Bangui city, expansion of the water supply area to west and north is facing to difficulties for lack of water volume and pressure. In some vicinity zones of

Bangui City without public water supply, the water demand is increasing quite rapidly according to the steep population growth. The whole of Bimbo area in the study area where is scheduled to be unified into Bangui City in near future, summarized as follows.

i) B4, B5 and B6 of Bimbo (Semi-urban zone):

In these zones population is increasing almost as same as Bangui City, and people rely water on unsanitary traditional shallow wells. Therefore, an installation of sanitary water supply system is highly needed.

ii) B7 of Bimbo (Pilot area of the urban developing plan)

In this zone a pilot project of urban developing plan is progressing. The objective of this urban developing plan is to absorb the rapid population increase that causes irregular settlement of people and expansion of a slum in the metropolitan of Bangui. While the Government of CAR and Bangui Municipality put the highest priority on realizing the plan, the progress of the project still remains at insufficient level because of difficulty of finding proper finance sources. Selling of lands and construction of houses are partly under way and new comers are starting to settle under lack of water supply service situation. Thus, there is a high need of water supply service.

iii) B8, B9 and B10 (Zone of Urban Developing Plan for Future)

These zones, where the urban developing plan covers, are left undeveloped with a few populations. And there is a potential for people's migration in future. While a timetable of realization of the plan is not clear for these zones, need of water supply service remains in the next to the zone B7.

3) Estimation of the Population in Study Area

Population shall be estimated in the following two areas.

a) Presently Urbanized Zone

For the existing urbanized zones, natural population increase and the population increase by small-scale housing development shall be considered. The population in these areas is projected by employing 3.88% as annual increase rates for Bangui and 7.91% for Bimbo, depend on the result of the two censuses in 1988 and 1998. Regarding the District III and V in Bangui City, the population can not be expected to increase, because these areas have been already developed and a potential to renovate into the area for multi-storied building is not foreseen. Therefore, the saturated population densities in these areas were assumed at 250 person/ha considering some marginal addition to the present population density in 1998.

b) Peripheral Area

In peripheral area of Bangui City, population increases by implementation of the proposed urban development plan shall be considered.

B7 is categorized into the high priority area for urgent developing, therefore the saturated designed population density shall be adopted in accordance with the urban developing plan as follows,

i) 20% of the design area is allocated for the road space

ii) 10% of the same is for public space of gardens, community centers, etc.

iii) Remaining 70% of the same is for residential area for selling.

iv) Design population density is 8 person per 600 m^2 (20 m x 30 m)

Accordingly, the design population density can be calculated at 100 person per hectare by the following calculation.

Resident area per hectare: 10,000 m^2 x 0.7 = 7,000 m^2

Design population density : 8 persons x (7,000 m^2 / 600 m^2) = 93 persons

= about 100 persons / ha

c) Estimation of the Population

In accordance with above conditions the conditions for estimation of the design population is summarized as follows.

* Time span of estimation : from 1998 to 2015
* Manner of estimation :

In the case that the population density reaches the saturated population density in each districts before 2015, It shall be provided that the density of the area will reach to the saturated density in 2015. Then the populations before 2015 can be calculated by adopting a linear increasing trend between 1998 and 2015.

* Saturated density of the study area:

The whole Bangui city & B1, B2, B3	: 250 person/ha
B4, B5 and B6	: 150 person/ha
B7, B8, B9 and B10	: 100 person/ha

The result of estimation of population is summarized in Table 7.2.2 and Fig. 7.2.2

Table 7.2.2 Estimation of Population in Study Area

1) Bangui City

District	Area	Population in the District (habitants)					
	Km2	Year 1988	Year 1998	Year 2005	Year2010	Year 2015	Saturated
D-I	5.46	10,724	15,688	20,478	24,771	29,965	136,500
			(28.7)	(37.5)	(45.4)	(54.9)	
D-II	5.47	55,801	81,631	104,327	120,539	136,750	136,750
			(149.2)	(190.7)	(220.4)	(250.0)	
D-III	5.10	86,029	125,851	126,530	127,015	127,500	127,500
			(246.8)	(248.1)	(249.0)	(250.0)	
D-IV	5.51	60,162	88,011	108,492	123,121	137,750	137,750
			(159.7)	(196.9)	(223.4)	(250.0)	
D-V	6.40	105,732	154,676	156,868	158,434	160,000	160,000
			(241.7)	(245.1)	(247.6)	(250.0)	
D-VI	6.69	53,507	78,275	102,175	123,597	149,975	167,250
			(117.0)	(152.7)	(184.7)	(224.2)	
D-VII	7.76	34,428	50,365	65,743	79,527	96,499	194,000
			(64.9)	(84.7)	(102.5)	(124.4)	
D-VIII(1)	3.20	22,307	32,624	42,586	51,514	62,508	53,000
			(102.0)	(133.1)	(161.0)	(195.3)	
D-VIII(2)	3.02	23,000	33,655	43,931	53,141	64,483	102,500
			(111.4)	(145.5)	(176.0)	(213.5)	
Total	48.61	451,690	660,776	771,131	861,658	965,430	1,215,250
			(135.9)	(158.6)	(177.3)	(198.6)	

2) Sub-districts of Binbo District

Zone	Area	Population in Zone (habitants)					
	Km2	Year 1988	Year 1998	Year 2005	Year 2010	Year 2015	Saturated
B-1	3.5	-	6,000	10,223	14,959	21,888	87,500
			(17.1)	(29.2)	(42.7)	(62.5)	
B-2	2.1	-	4,000	6,815	9,972	14,592	52,500
			(19.0)	(32.5)	(47.5)	(69.5)	
B-3	3.4	-	3,500	5,963	8,726	12,768	85,000
			(10.3)	(17.5)	(25.7)	(37.6)	
B-4	6.3	-	3,000	5,112	7,479	10,944	94,500
			(4.8)	(8.1)	(11.9)	(17.4)	
B-5	5.0	-	1,500	2,556	3,740	5,472	75,000
			(3.0)	(5.1)	(7.5)	(10.9)	
B-6	11.4	-	2,500	4,260	6,233	9,120	171,000
			(2.2)	(3.7)	(5.5)	(8.0)	
B-7	9.0	-	1,000	1,704	2,493	3,648	90,000
			(1.1)	(1.9)	(2.8)	(4.1)	
B-8	12.6	-	500	852	1,247	1,824	126,000
			(0.4)	(0.7)	(1.0)	(1.4)	
B-9	33.4	-	1,500	2,556	3,740	5,472	334,000
			(0.4)	(0.8)	(1.1)	(1.6)	
B-10	20.6	-	1,500	2,556	3,740	5,472	206,000
			(0.7)	(1.2)	(1.8)	(2.7)	
Total	107.3	10,751	25,000	42,596	62,328	91,199	1,321,500
			(2.3)	(4.0)	(5.8)	(8.5)	

Note : ( ) is Population density in each zone (Person/ha)

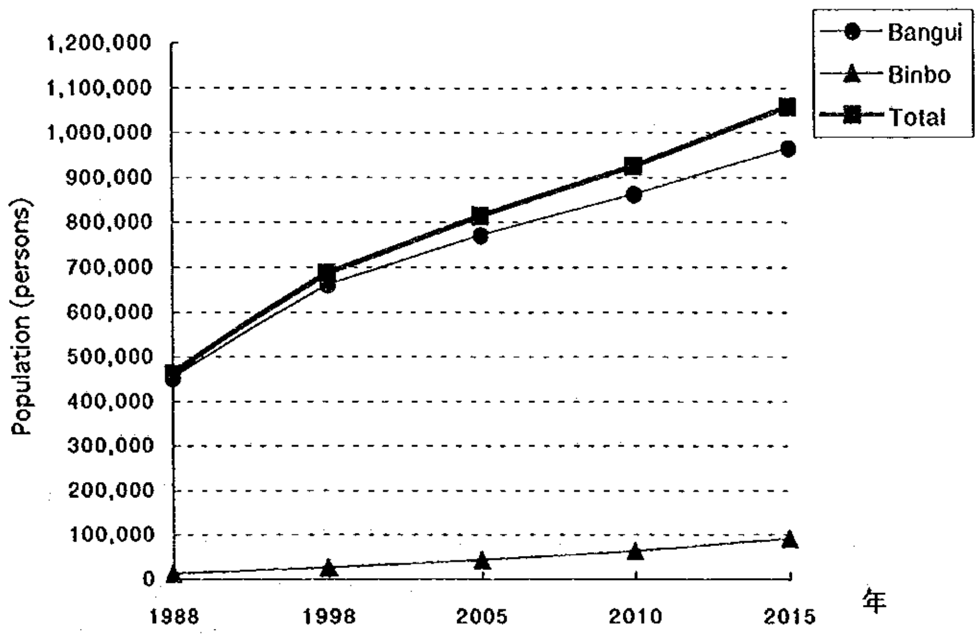

Fig. 7.2.2 Estimation of Population

7.2.2 Estimation of Water Demand

1) Condition for Water Demand Projection

Based on the above, conditions for water demand projection in future are provided as follows,

a) Study Target Year

The final target year is 2015 for the Master Plan. The year 2005, when it meats the halfway between 1998 and the final target year, is the short term target year.

b) Water Coverage Ratio

*The whole Bangui city and B1, B2 & B3:

According to the present condition of SODECA's water supply service into account, the water coverage ratio shall be assumed at 30% from 1998 to 2000. In 2005 the ratio is assumed to improve up to 50% by implementation of a project for repairing of the existing distribution pipe network which is expected to commence from 1999 by a financial assistance of AFD[1]. Considering the hard economic situation in Bangui area, it is difficult to anticipated that the water coverage ratio in Bangui City which is presently about 30% and much lower than in capital cities of the neighboring countries, would improve to so high level within only about 15 years.

Therefore it is assumed that the water coverage ratio would reach to 60% in 2015, which the Government of CAR once officially targeted in urban area to reach by 2000.

*B4, B5, B6 & B7:

Providing that a short-term project will be completed in 2004, then water service can be started. It is assumed that the water coverage ratio would be 30% in 2004 and increase linearly to 60% in 2015.

*B8, B9 & B10:

It is Provided that these areas would be gradually developed after the completion of the short team project and installation of distribution pipe network would be expected to expedite after 2009 depending on a possible program of the project implementation. Accordingly the water coverage ratio in 2009 and 2015 in these area are assumed at 30% and 60% respectively.

The water coverage ratios for each zone are summarized in Fig 7.2.3

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1) The Follow-up Study for 4th Project, see Chap. 3.2.5

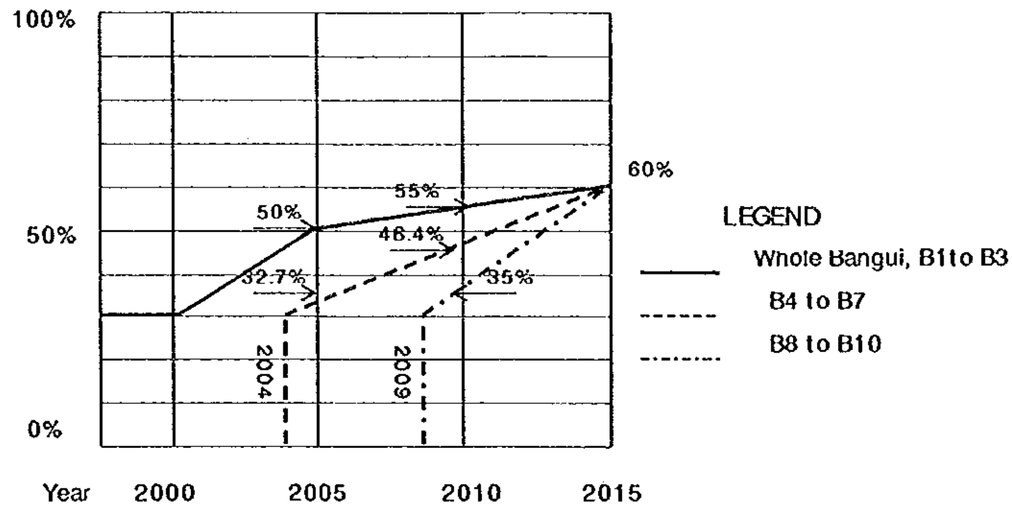


Fig. 7.2.3 Water Service Ratio for Each Zone

c) Proportion of Users of Public Faucet and Private Connection

According to an analysis done in Chapter 3.2.3 above about water service situation of SODECA, a 31% of service population can be supplied by private connection and a 69% of the same accesses to the public water faucet. Taking this result into consideration, water supply systems to the service population are assumed as follows.

* Bangui City: Proportion of users on private Connection and public faucet is same as it is for the future also.
* B1 to B7: In this area need of water supply is the highest and there is no public water service. Taking living level of the people point of view, proportion of user of public faucet shall be comparatively higher than the average in the initial stage of the project. Therefore, the rate of public faucet user is assumed at 85% and it shall be decrease gradually to 70% in 2010.
* B8 to B10: In accordance with less population in these areas, requirement of water supply service is lower in near future. Therefore, it is assumed that the potable water shall be commenced to supply in 2010 and people shall be served all the water through public faucets.

Accordingly the proportion of users of public faucet and private connection is summarized in Table 7.2.3.

Table 7.2.3 Proportion of Users of Public Faucet and Private Connection

year	Bangui city		B1 to B7 in Bimbo		B8 to B10 in Bimbo	
	Private connection	Public faucet	Private connection	Public faucet	Private connection	Public faucet
2005	30%	70%	15%	85%	0%	0%
2010	30%	70%	30%	70%	0%	100%
2015	30%	70%	30%	70%	10%	90%

d) Unit of water consumption

Depending on a guideline officially applied to water supply activities, units of water consumption are assumed as follows,

For private house connection user : 70 Lit./capita/day

For public faucet user : 25 Lit./capita/day

Taking these volumes into consideration, the units of water consumption for each area are assumed as follows.

* Bangui City: the unit consumption of private connection user is adopted at 70 lit/cpd (lit/capita/day) in 2005 then it is assumed to increase lineally to 100 lit/cpd in 2015. The one for public faucet user shall be as same as the present level until 2015.
* B1 to B7: Taking the high requirement of water supply service in this area, the unit consumption of private connection user is assumed to increase as same as the one in Bangui City. On the other hand the one in 2005 for public faucet user is assumed comparatively lower level than the present level taking a living standard of people into account. But it shall increase to the same of Bangui City by 2015.
* B8 to B10: Taking a progress of urbanization in these areas into consideration, it is difficult to expect that water demand of these areas would grow up to a enough level to install a public water supply system until 2005 from a managerial point of view. Since it can be expected that the water demand would reach the primary level by 2010, the units of the private connection user and the public faucet user in 2010 are assumed at 70 lit/cpd and 10 lit/cpd respectively. Then those values are assumed to increase to 85 lit/cpd and 17.5 lit/cpd in 2015.

Accordingly the unit consumption for each user are summarized in Table 7.2.4.

Table 7.2.4 Assumption of Unit Water Consumption

year	Bangui city		B1 to B7 in Bimbo		B8 to B10 in Bimbo	
	Private connection	Public faucet	Private connection	Public faucet	Private connection	Public faucet
2005	70 lit./cpd	25 lit./cpd	70 lit./cpd	10 lit./cpd	Non supply	Non supply
2010	85 lit./cpd	25 lit./cpd	85 lit./cpd	17.5 lit./cpd	70 lit./cpd	10 lit./cpd
2015	100 lit./cpd	25 lit./cpd	100 lit./cpd	25 lit./cpd	85 lit./cpd	17.5 lit./cpd

e) Ratio of Effectiveness

The present ratio of effectiveness of SODECA's water supply was estimated 65%. Taking renovation work of distribution pipe network to be commenced in 1999 by the financial assistance of AFD into consideration, the ratio of effectiveness in Bangui City and B1 to B3 can be expected to improve up to 75% in 2015. On the other hand water supply facilities such as distribution main, pipeline net work, and water meters to houses or kiosks shall be newly installed in the area of B1 to B7. In this case uncountable water of leakage or stolen water can be kept at minimum level. Therefore, it was assumed that the ratio of effectiveness for B4 to B7 areas was 90% in 2005 and be reduced to 85% in 2015.

Accordingly the ratio of Effectiveness for each area are summarized in Table 7.2.5.

Table 7.2.5 Assumption of Ratio of Effectiveness

year	Bangui city & B1 to B3	B4 to B7 in Bimbo
1998	65%	0%
2005	69.1%	90%
2010	72.1%	87.5%
2015	75%	85%

f) Ratio of Load of Water Supply

In general ratio of load of water supply is adopted by concerning seasonal fluctuation of supply volume. According to the present water service of SODECA, the ratio of load of water supply can be assumed at 80%. Therefore, this ratio is also adopted for this water demand projection.

2) Water Demand Projection in Target year

Taking the above assumptions into consideration, the water demand in target years were estimated as mentioned in Table 7.2.6 and Fig. 7.2.4

In Table 7.2.6 the Area 1 corresponds the zones of B1 to B7 and D-VIII(1) in Bangui City where the public water supply does not cover presently, Area 2 also corresponds to B8 to B10 in Bimbo and Area 3 covers zone where people can receive the public water service sufficiently .

Table 7. 2 .6 Water Demand Projection in Target Year

Year 2005

District	Population	Water	Water	Propotion of Supply Type		Population		Demand (lit/d/c)		Demand (m3/d)		Total	Ratio of	Av. Day	Ratio of	Max. Day	Area 1	Area 2	Area 3
	(habitants)	Supply Ratio %	Supply Population	Private Connect.	Public Faucet	Private Connect.	Public Faucet	Private Connect.	Public Faucet	Private Connect.	Public Faucet	Dimand (m3/d)	Effective -ness	Production (m3/d)	Load	Production (m3/d)	(m3/d)	(m3/d)	(m3/d)
1. BANGUI																			
D-I	20,478	50.0	10,239	0.30	0.70	3,072	7,167	70.0	25.0	215	179	394	0.691	570	0.80	713	0	0	713
D-II	104,327	50.0	52,164	0.30	0.70	15,649	36,514	70.0	25.0	1,095	913	2,008	0.691	2,906	0.80	3,633	0	0	3,633
D-III	126,530	50.0	63,265	0.30	0.70	18,980	44,286	70.0	25.0	1,329	1,107	2,436	0.691	3,525	0.80	4,406	0	0	4,406
D-IV	108,492	50.0	54,246	0.30	0.70	16,274	37,972	70.0	25.0	1,139	949	2,088	0.691	3,022	0.80	3,778	0	0	3,778
D-V	156,868	50.0	78,434	0.30	0.70	23,530	54,904	70.0	25.0	1,647	1,373	3,020	0.691	4,370	0.80	5,463	0	0	5,463
D-VI	102,175	50.0	51,088	0.30	0.70	15,326	35,761	70.0	25.0	1,073	894	1,967	0.691	2,846	0.80	3,558	0	0	3,558
D-VII	65,743	50.0	32,872	0.30	0.70	9,861	23,010	70.0	25.0	690	575	1,266	0.691	1,831	0.80	2,289	0	0	2,289
D-VIII(1)	42,586	50.0	21,293	0.30	0.70	6,388	14,905	70.0	25.0	447	373	820	0.900	911	0.80	1,139	1,139	0	0
D-VIII(2)	43,931	50.0	21,966	0.30	0.70	6,590	15,376	70.0	25.0	461	384	846	0.691	1,224	0.80	1,530	0	0	1,530
Total	771,130	-	385,565	-	-	115,670	269,896	-	-	8,097	6,747	14,844	-	21,207	-	26,508	1,139	0	25,370
2. BINBO																			
B-1	10,223	50.0	5,112	0.15	0.85	767	4,345	70.0	10.0	54	43	97	0.691	141	0.80	176	176	0	0
B-2	6,815	50.0	3,408	0.15	0.85	511	2,896	70.0	10.0	36	29	65	0.691	94	0.80	117	117	0	0
B-3	5,963	50.0	2,982	0.15	0.85	447	2,534	70.0	10.0	31	25	57	0.691	82	0.80	102	102	0	0
B-4	5,112	32.7	1,672	0.15	0.85	251	1,421	70.0	10.0	18	14	32	0.90	35	0.80	44	44	0	0
B-5	2,556	32.7	836	0.15	0.85	125	710	70.0	10.0	9	7	16	0.900	18	0.80	22	22	0	0
B-6	4,260	32.7	1,393	0.15	0.85	209	1,184	70.0	10.0	15	12	26	0.900	29	0.80	37	37	0	0
B-7	1,704	32.7	557	0.15	0.85	84	474	70.0	10.0	6	5	11	0.900	12	0.80	15	15	0	0
B-8	852	0.0	0	0.00	0.00	0	0	0.0	0.0	0	0	0	0.900	0	0.80	0	0	0	0
B-9	2,556	0.0	0	0.00	0.00	0	0	0.0	0.0	0	0	0	0.900	0	0.80	0	0	0	0
B-10	2,556	0.0	0	0.00	0.00	0	0	0.0	0.0	0	0	0	0.900	0	0.80	0	0	0	0
Total	42,597	-	15,958	-	-	2,394	13,564	-	-	168	136	303	-	410	-	513	513	0	0
														21,617		27,021	1,651	0	25,370

27,021

Year 2010

District	Population	Water	Water	Propotion of Supply Type		Population		Demand (lit/d/c)		Demand (m3/d)		Total	Ratio of	Av. Day	Ratio of	Max. Day	Area 1	Area 2	Area 3
	(habitants)	Supply Ratio %	Supply Population	Private Connect.	Public Faucet	Private Connect.	Public Faucet	Private Connect.	Public Faucet	Private Connect.	Public Faucet	Dimand (m3/d)	Effective -ness	Production (m3/d)	Load	Production (m3/d)	(m3/d)	(m3/d)	(m3/d)
1. BANGUI																			
D-Ⅰ	24,771	55.0	13,624	0.30	0.70	4,087	9,537	85.0	25.0	347	238	586	0.721	813	0.80	1,016	0	0	1,016
D-Ⅱ	120,539	55.0	66,296	0.30	0.70	19,889	46,408	85.0	25.0	1,691	1,160	2,851	0.721	3,954	0.80	4,942	0	0	4,942
D-Ⅲ	127,015	55.0	69,858	0.30	0.70	20,957	48,901	85.0	25.0	1,781	1,223	3,004	0.721	4,166	0.80	5,208	0	0	5,208
D-Ⅳ	123,121	55.0	67,717	0.30	0.70	20,315	47,402	85.0	25.0	1,727	1,185	2,912	0.721	4,039	0.80	5,048	0	0	5,048
D-Ⅴ	158,434	55.0	87,139	0.30	0.70	26,142	60,997	85.0	25.0	2,222	1,525	3,747	0.721	5,197	0.80	6,496	0	0	6,496
D-Ⅵ	123,597	55.0	67,978	0.30	0.70	20,394	47,585	85.0	25.0	1,733	1,190	2,923	0.721	4,054	0.80	5,068	0	0	5,068
D-Ⅶ	79,527	55.0	43,740	0.30	0.70	13,122	30,618	85.0	25.0	1,115	765	1,881	0.721	2,609	0.80	3,261	0	0	3,261
D-Ⅷ	51,514	55.0	28,333	0.30	0.70	8,500	19,833	85.0	25.0	722	496	1,218	0.875	1,392	0.80	1,740	1,740	0	0
D-Ⅷ(1)	53,141	55.0	29,228	0.30	0.70	8,768	20,459	85.0	25.0	745	511	1,257	0.721	1,743	0.80	2,179	0	0	2,179
D-Ⅷ(2)																			
Total	861,659	-	473,912	-	-	142,174	331,739	-	-	12,085	8,293	20,378	-	27,966	-	34,958	1,740	0	33,218
2. BINBO																			
B-1	14,959	55.0	8,227	0.225	0.775	1,851	6,376	85.0	17.5	157	112	269	0.721	373	0.80	466	466	0	0
B-2	9,972	55.0	5,485	0.225	0.775	1,234	4,251	85.0	17.5	105	74	179	0.721	249	0.80	311	311	0	0
B-3	8,726	55.0	4,799	0.225	0.775	1,080	3,719	85.0	17.5	92	65	157	0.721	218	0.80	272	272	0	0
B-4	7,479	46.4	3,470	0.225	0.775	781	2,689	85.0	17.5	66	47	113	0.875	130	0.80	162	162	0	0
B-5	3,740	46.4	1,735	0.225	0.775	390	1,345	85.0	17.5	33	24	57	0.875	65	0.80	81	81	0	0
B-6	6,233	46.4	2,892	0.225	0.775	651	2,241	85.0	17.5	55	39	95	0.875	108	0.80	135	135	0	0
B-7	2,493	46.4	1,157	0.225	0.775	260	896	85.0	17.5	22	16	38	0.875	43	0.80	54	54	0	0
B-8	1,247	35.0	436	0.00	1.00	0	436	70.0	10.0	0	4	4	0.875	5	0.80	6	0	6	0
B-9	3,740	35.0	1,309	0.00	1.00	0	1,309	70.0	10.0	0	13	13	0.875	15	0.80	19	0	19	0
B-10	3,740	35.0	1,309	0.00	1.00	0	1,309	70.0	10.0	0	13	13	0.875	15	0.80	19	0	19	0
Total	62,329	-	30,820	-	-	6,247	24,573	-	-	531	407	938	-	1,220	-	1,525	1,481	44	0
														29,186		36,483	3,222	44	33,218

36,483

Year 2015

District	Population (habitants)	Water Supply Ratio %	Water Supply Population	Propotion of Supply Type: Private Connect.	Propotion of Supply Type: Public Faucet	Population: Private Connect.	Population: Public Faucet	Demand (lit/d/c): Private Connect.	Demand (lit/d/c): Public Faucet	Demand (m3/d): Private Connect.	Demand (m3/d): Public Faucet	Total Dimand (m3/d)	Ratio of Effective -ness	Av. Day Production (m3/d)	Ratio of Load	Max. Day Production (m3/d)	Area 1 (m3/d)	Area 2 (m3/d)	Area 3 (m3/d)
1. BANGUI																			
D-Ⅰ	29,965	60.0	17,979	0.30	0.70	5,394	12,585	100.0	25.0	539	315	854	0.75	1,139	0.80	1,423	0	0	1,423
D-Ⅱ	136,750	60.0	82,050	0.30	0.70	24,615	57,435	100.0	25.0	2,462	1,436	3,897	0.75	5,197	0.80	6,496	0	0	6,496
D-Ⅲ	127,500	60.0	76,500	0.30	0.70	22,950	53,550	100.0	25.0	2,295	1,339	3,634	0.75	4,845	0.80	6,056	0	0	6,056
D-Ⅳ	137,750	60.0	82,650	0.30	0.70	24,795	57,855	100.0	25.0	2,480	1,446	3,926	0.75	5,235	0.80	6,543	0	0	6,543
D-Ⅴ	160,000	60.0	96,000	0.30	0.70	28,800	67,200	100.0	25.0	2,880	1,680	4,560	0.75	6,080	0.80	7,600	0	0	7,600
D-Ⅵ	149,975	60.0	89,985	0.30	0.70	26,996	62,990	100.0	25.0	2,700	1,575	4,274	0.75	5,699	0.80	7,124	0	0	7,124
D-Ⅶ	96,499	60.0	57,899	0.30	0.70	17,370	40,530	100.0	25.0	1,737	1,013	2,750	0.75	3,667	0.80	4,584	0	0	4,584
D-Ⅷ(1)	62,508	60.0	37,505	0.30	0.70	11,251	26,253	100.0	25.0	1,125	656	1,781	0.85	2,096	0.80	2,620	2,620	0	0
D-Ⅷ(2)	64,483	60.0	38,690	0.30	0.70	11,607	27,121	100.0	25.0	1,161	677	1,838	0.75	2,450	0.80	3,063	0	0	3,063
Total	965,430	-	579,258	-	-	173,777	405,481	-	-	17,378	10,137	27,515	-	36,407	-	45,509	2,620	0	42,889
2. BINBO																			
B-1	21,888	60.0	13,133	0.30	0.70	3,940	9,193	100.0	25.0	394	230	624	0.75	832	0.80	1,040	1,040	0	0
B-2	14,592	60.0	8,755	0.30	0.70	2,627	6,129	100.0	25.0	263	153	416	0.75	554	0.80	693	693	0	0
B-3	12,768	60.0	7,661	0.30	0.70	2,298	5,363	100.0	25.0	230	134	364	0.75	485	0.80	606	606	0	0
B-4	10,944	60.0	6,566	0.30	0.70	1,970	4,596	100.0	25.0	197	115	312	0.85	367	0.80	459	459	0	0
B-5	5,472	60.0	3,283	0.30	0.70	985	2,298	100.0	25.0	98	57	156	0.85	183	0.80	229	229	0	0
B-6	9,120	60.0	5,472	0.30	0.70	1,642	3,830	100.0	25.0	164	96	260	0.85	306	0.80	382	382	0	0
B-7	3,648	60.0	2,189	0.30	0.70	657	1,532	100.0	25.0	66	38	104	0.85	122	0.80	153	153	0	0
B-8	1,824	60.0	1,094	0.10	0.90	109	985	85.0	17.5	9	17	27	0.85	31	0.80	39	0	39	0
B-9	5,472	60.0	3,283	0.10	0.90	328	2,955	85.0	17.5	28	52	80	0.85	94	0.80	117	0	117	0
B-10	5,472	60.0	3,283	0.10	0.90	328	2,955	85.0	17.5	28	52	80	0.85	94	0.80	117	0	117	0
Total	91,200	-	54,720	-	-	14,884	39,836	-	-	1,477	944	2,421	-	3,069	-	3,836	3,562	273	0
			633,978											39,475		49,344	6,182	273	42,889

49,344

Water Production (m3/day)

Year	Area 1	Area 2	Area 3	Total
1998	950	0	22,550	23,500
2005	1,651	0	25,370	27,021
2010	3,222	44	33,218	36,483
2015	6,182	273	42,889	49,344

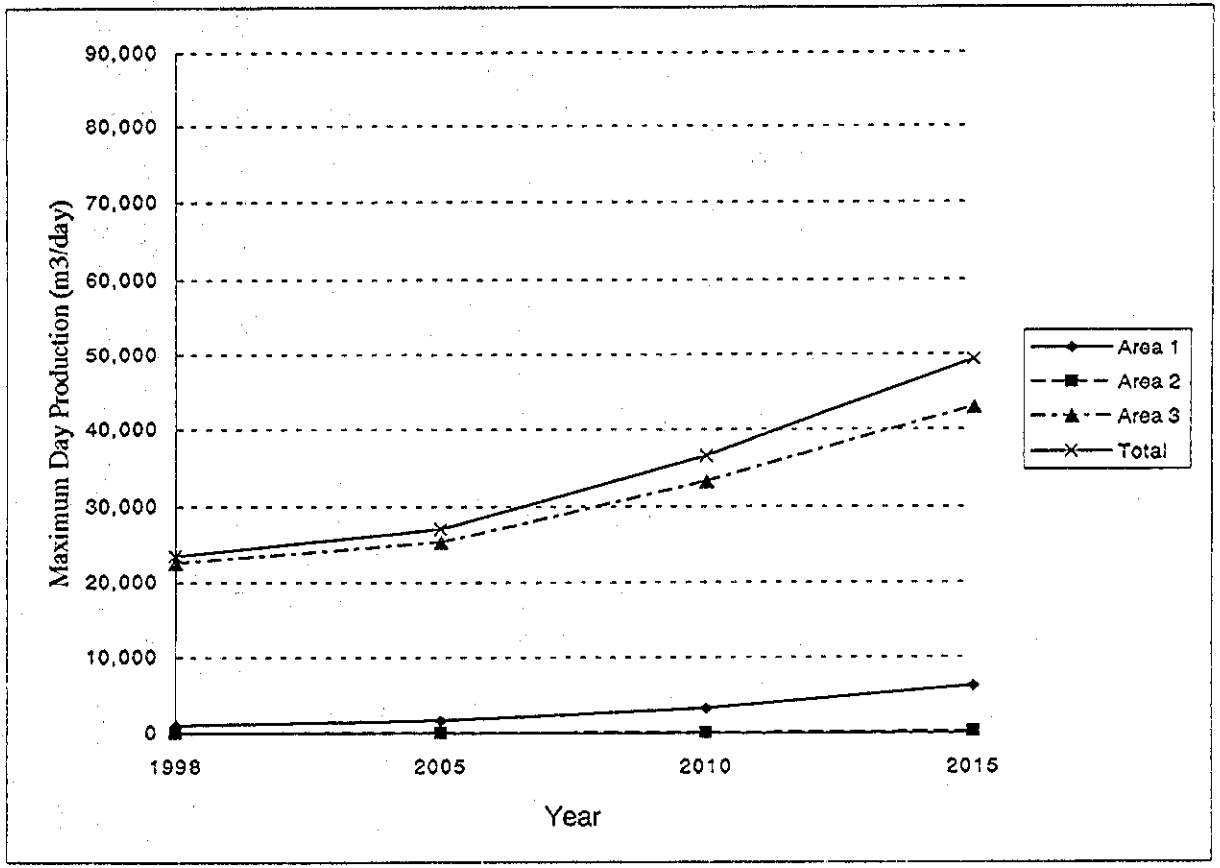


Figure 7.2.4 Water Demand Projection in Target Year

7.2.3 Concept of Proposed Master Plan

According to the water demand projection estimated in the former Chapter, various type of facilities with certain capacities can be proposed in the several steps to the final target year 2015. It is obvious that utilization of groundwater for the potable water source is more beneficial than surface water from less operational and maintenance cost point of view. For the short term target year 2005 a groundwater development project will be the most suitable for the peripheral areas of Bangui where population increase rate is rather high and public water service is not covered sufficiently. Then the water demand can be catered through the existing water treatment plant by the year 2008. Therefore after year 2009, the surface water shall be highly required in order to cover the future water demand because of limitation of the potential of usable groundwater which had been analyzed by this study. For utilizing the surface water, expansion of the existing water intake/treatment plant or construction of a new intake/treatment plant can be considered.

Considering the above conditions, it can be proposed as the applicable measures for the study area to combine facilities which shall depend the water sources on both the groundwater and the surface water. Therefore, the alternative plans can be composed of the following sub-idea plans in order to cater the estimated future water demand.

1) Deep well construction Project.
   To use the design maximum water volume of groundwater: 2,200 m^3/day.
   Proposed facilities are as follows,
   Several Deep wells, a water reservoir in the hill of Bimbo, transmission main between wells and the reservoir, distribution pipeline network and other facilities.
2) Expansion of the exiting water treatment plant, for which a space has been already obtained for 600 m^3/hrs-capacity plant next to the exiting facilities in the water treatment plant.
   Proposed facilities are as follows,
   Installation of an intake pump, a new water treatment plant with 600 m^3/hrs capacity, a reservoir and distribution pipe network.
3) Construction of new water intake and treatment plant. Proposed facilities are as follows,
   Water intake plant with pumping facilities on Mbali River, raw water transmission pipeline, a water treatment plant with a capacity of 14,100 m^3/day, a reservoir, and distribution pipeline network.

The timing of implementation of these projects can be drawn in Fig. 7.2.5 with relation to the estimated water demand in the study area.

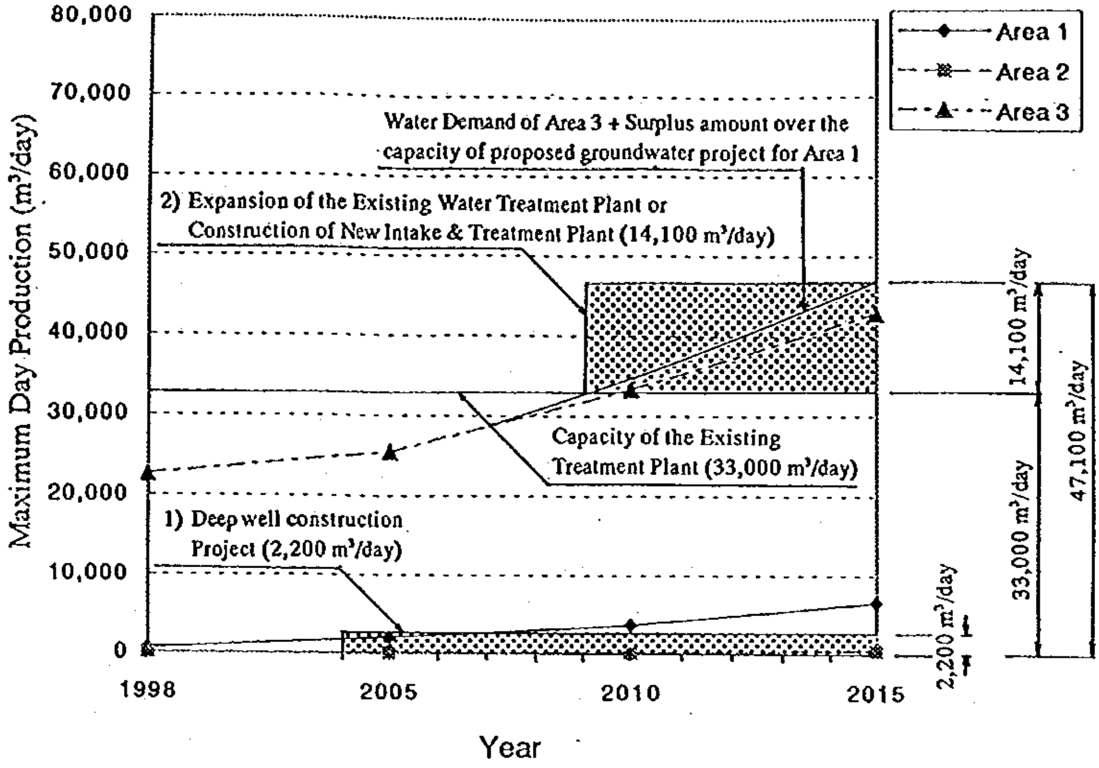


Fig. 7.2.5 Increase of Water Demand and Implementation of the Proposed Projects

A deep well construction project will be completed in 2004. The water production capacity of this project is 2,200 m³/day which will cover demand of Area 1 by 2007. After 2008 the water demand in Area 1 would exceed gradually the capacity of the groundwater system and such shortage of water should be supplemented from the existing distribution system.

Area 3 is almost the same of the current water service area in Bangui City. Water demand of this area is expected to increase as a project for reinforcing and rehabilitating of the existing distribution pipeline would be implemented by the assistance of the AFD. The existing distribution system should also cater the surplus amount of water over the capacity of the proposed deep well project for Area 1 after 2008. That water demand is anticipated to reach the capacity of water production of the existing water treatment plant by 2009 and a new water supply system with a 14,100 m³/day of water supply capacity should work then.

Accordingly, the total water supply capacity in the whole metropolitan area will be augmented by implementation of the above two sub-projects up to 35,200 m³/day by 2004 and 49,300 m³/day by 2009 which covers the total water demand in 2015.

7.2.4 Component of Alternative Plan

1) Sub-project 1

Considering requirement of water supply service, the highest priority shall be placed on the areas from B1 to B7 in Bimbo and Bangui VIII(1), because people's lives in these areas are exposed to unsanitary condition without safe and sufficient water. Moreover, prevailing population increase in these areas develops problem of living circumstance. Therefore, water supply planning shall be furnished to the areas from B1 to B7 as soon as possible. Taking the estimated population into consideration, groundwater can be suitable to cater these areas until around year 2005. A new distribution pipelines can be installed independently from the existing one by this year. After then it shall be interconnect between the new pipeline network and the existing one because the exploitable groundwater volume is not enough to cater the estimated water demand in this area. Facilities concerned are proposed as follows,

Intake facility: Well with 6' dia., Submersible pump Q=510 lit./min	6 sets
Transmission Pipeline: Dia. 150 mm to 200 mm	7,400 m
Service Reservoir: V= 1,900 m3 at Bimbo hill	1 unit
Distribution pipe net: Dia. 50 mm to 300 mm	30,100 m

2) Sub-project 2-1

By completion of sub-project 1, the capacity of the water production facility will increase to 35,200 m^3/day, which corresponds to the estimated water demand of year 2008. Then it shall be required that the water supply volume should be augmented by construction of a new water intake and treatment plant etc. The existing water treatment plant had been designed and constructed in consideration of future's expansion. It has already obtained a space for installation of a new pump in the existing intake house and an enough land for construction of a system of water treatment with a 600m^3/h capacity in the concession of the existing water treatment plant. By this expansion the capacity of water production will cover the water demand of year 2015 by a 24 hours operation a day. Facilities concerned are proposed as follows,

Source of water: Oubangui River

Intake facility: Installation of a new pump with a capacity of 11m^3/min. in the existing intake plant	1 unit
Treatment facilities: Construction of a new plant in the concession of the existing treatment plant. Capacity is 14,100 m^3/day (=600 m^3/hr)	1 unit

Transmission facilities: Installation of pump with a capacity of 59.8 lit./sec. — 2 sets

Service reservoir: Construction a reservoir at Bimbo hill and a reservoir at the Bangui side — 1 lot

Distribution pipe net: Dia. 50mm to 300mm — 64,400m

3) Sub-project 2-2

As an alternative to the sub-project 2-1 above, a system with a capacity of 14,100 m^3/day which composes of a intake plant on Mbali River and a treatment plant at Bimbo hill shall be constructed. And the existing distribution pipe network shall be renovated to augment in order to convey water which corresponds to the estimated water demand year 2015. Facilities concerned are proposed as follow,

Water source: Mbali River

Intake facility: Construction of a new intake plant at the south side of Mbali River, one of the tributaries of M'poko River — 1 lot

pump with a capacity of 3.7 m^3/min. — 4 sets

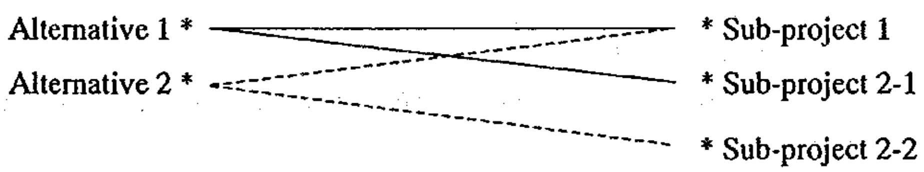
Raw water pipeline: Dia. 450mm — 11,400m

Water treatment plant: Construction of a new at Bimbo Hill with a capacity of 14,100 m^3/day — 1 unit

Service reservoir: Construction of a new reservoir in Bimbo Hill with a capacity of 7,400 m^3 — 1 lot

Distribution pipe net: Dia. 50mm to 300mm — 64,400m

Accordingly, the alternative plans for the target year 2015 in the study area were formulated by combination with the above sub-projects as follows.



The implementation plans of the above alternatives are shown in the Fig. 7.2.5. Concerning the stage by stage project implementation, Sub-project 1 shall be commenced in the first stage, and either Sub-project 2-1 or Sub-project 2-2 shall be done next. Master plan for the two Alternatives are shown in Fig.7.2.6 and Fig. 7.2.7.

7.2.5 Water Supply Facility Plan

1) Alternative 1 (Existing facilities + Sub-project 1 + Sub-project 2, see Fig. 7.2.6)
The facilities of Sub-project 1 and Sub-project 2 will be composed of the followings.

a) Sub project 1 (covered by the F/S of 2005)

i) Intake well facilities

- Intake amount: 2,200 m^3/day (Day maximum supply amount, approx. 25.46 lit/sec)
- Three wells per each group (one well for stand-by, well casing of 6") into two groups
- Operating hours of submergible pump: 18 hours
- Type of submergible pump: Single suction volute pump
- Total head: 30 m, Discharge amount: 8.49 lit/sec/well, Electric motor output: 3.7 kW, three phase/380 V/50 Hz
- Discharge water tank: 1place, effective capacity: 122 m^3, dimension: 3.0m (W) x 6.0m (L) x 3.5m(H) x 2
- Transmission pump: Water supply amount; 17.0 lit/sec/unit water tank
- Number of transmission pumps: three pumps (one stand-by), total head; 135 m
- Sterilisation device: one unit

ii) Raw water pipeline (from deep well to service reservoir)

- Discharge amount: 2,200 m^3/day (34.0 lit/sec)
- Day maximum supply amount
- Steel pipe: Diameter; 150 to 200 mm, length; 7,400 m
- Incidental equipment: Sluice valve, air valve, drainage valve, waterway crossing
- Construction of access road; width; 5.0 m, length; 3,600 m

iii)Service reservoir (on BIMBO hill)

- Effective capacity: Equivalent of 12 hours of day maximum supply amount; 1,900 m^3
- Dimensions: 25m (W) x 25m (L) x 3.5m (H)

iv)Distribution main

- Distribution amount: 4,400 m^3/day (Maximum day demand x time factor 2)

- PVC: diameter; 50 to 300 mm, total length; 30,100 m
- Equipment: Sluice valve, air valve, drainage valve, waterway crossing

v) Secondary distribution

- PVC: Diameter; 65 to 200 mm,
  In accordance with the model design based on the population density of 2005
- An elevated water tank shall be necessary at the location having the dynamic water pressure of less than 20m on the hydraulic estimation sheet.
- Equipment: Sluice valve, air valve, drainage valve, waterway crossing
- Private faucet at each house
- Public faucet

vi) Iron & Manganese removal facility (Idea for 2015)

- Pressure Tank Filter Type, Steel made, Diameter 2.6m x H 3.1m: 2 No.
- Air Compressor, 200 lit./min x 7 kgf/cm^2, 2.2 kw: 1set
- Caustic lime dosing equipment: 1 set
- Related piping arrangement : 1 lot.

b) Sub-project 2 (covered by the Master Plan of 2015)

i) Intake Facilities (Installation of additional pump)

- Installation of an additional pump(11.0 m^3/min, pump dia. 200mm, total head 55m, 190kW)

ii) Expansion of Existing Treatment Plant

- Planned water treatment amount 15,500m^3/day (maximum day demand 14,100 m^3/day x 1.1)
- Operating hours: 24 hours

iii) Transmission Facilities

- Installation of 2 sets of pump (including 1 standby),
  Centrifugal pump, dia. 300 mm, 59.81 liters/sec., total head 143m, 140 kW
- One Pumping Station House
- Transmission Pipeline
  Discharge 5,170 m^3/day(59.81 liters/sec), Ductile Iron Pipe, Dia.300mm

iv) Service Reservoirs

- 1 reservoir with the capacity of 5,500 m^3 at Bangui Hill (12 hours of maximum day demand, Dimensions 40m (W) x 40m (L) x 3.5m (H) at Bangui hill
- 1 reservoir with the capacity of 1,900 m^3 at Bimbo Hill (12 hours of maximum

day demand, Dimensions 25m (W) x 25m (L) x 3.5m (H) at Bimbo hill

- v)Distribution main (Area 1 & Area 2)
  - Distribution amount: 14,700 m^3/day (Day maximum demand x time factor 2)
  - Ductile Iron Pipe Dia. 350mm, PVC: Dia.50 to 300 mm, total length; 65,000 m
  - Incidental equipment: Sluice valve, air valve, drainage valve, waterway crossing

vi)Secondary Distribution
  - PVC: Diameter and length is in accordance with the model design based on the population density
  - An elevated water tank will be installed at the location having the dynamic water pressure of less than 20 m on the hydraulic estimation sheet.
  - Incidental equipment: Sluice valve, air valve, drainage valve, waterway crossing)
  - Private faucet at each house
  - Public faucet

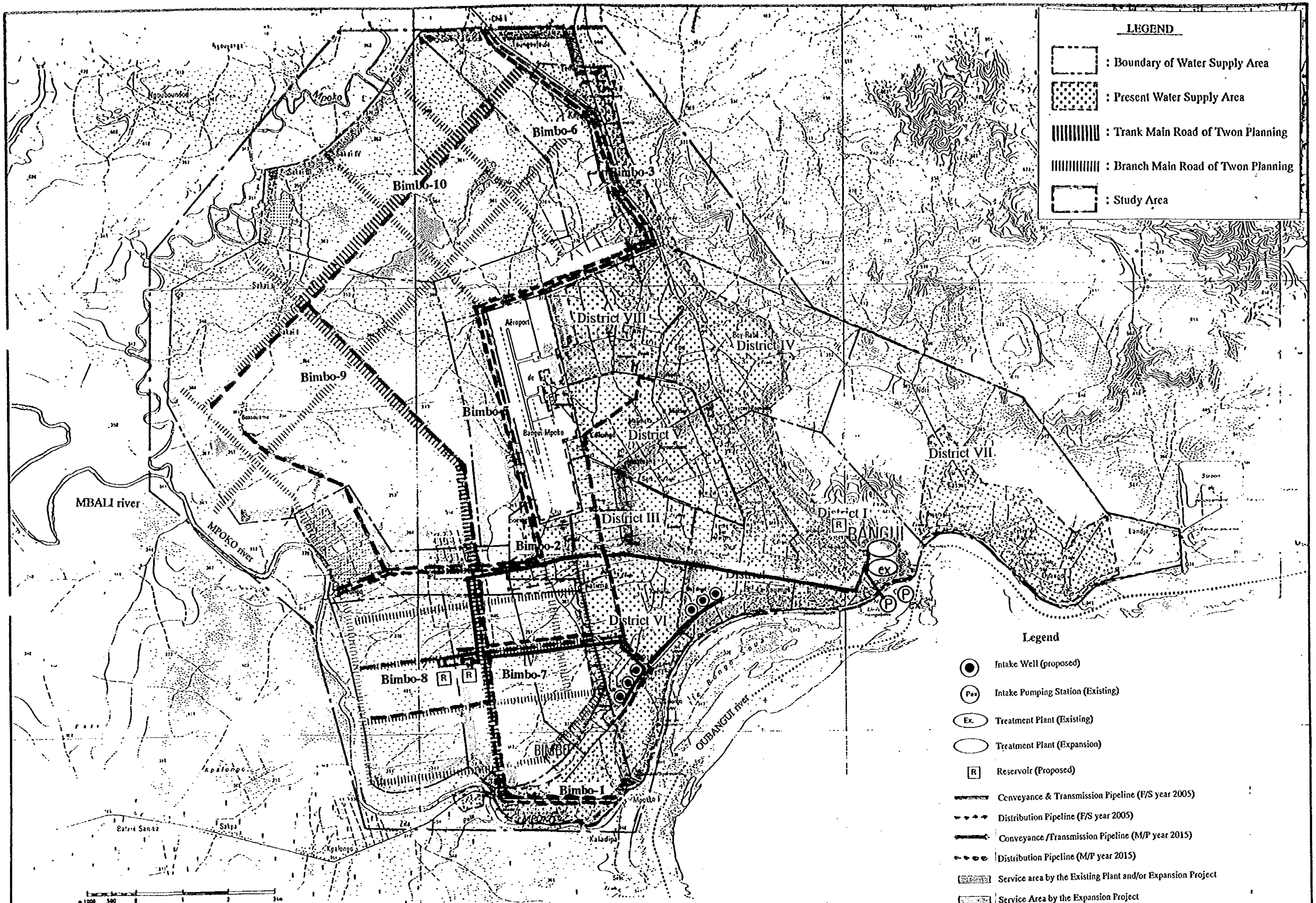


Fig. 7.2.6 Master Plan of Alternative Plan 1

2) Alternative - 2 (Existing facilities + Sub-project 1 + Sub-project 3, see Fig. 7.2.7)
The facilities of Sub-project 1 and Sub-project 3 will be composed of the followings.)

a) Sub-project 1
Same as Alternative 1.

b) Sub-project (covered by the Master Plan of 2015)

i) Intake pumping plant (MUBALI River)

- Planned intake amount 15,500 m^3/day (Maximum day demand x 1.1, operating hours: 24 hours)
- Installation of 3 sets of pimps (including 1 standby, single suction volute pump, pump dia.250mm, total head: 152m, 230 kW, attached with a flywheel for the prevention of water hammer
- Water intake: Pump shed
- Fencing and drainage work
- Power supply facilities
- Earth work

ii) Raw water pipeline (intake pumping plant to water treatment plant)

- Discharge amount: 15,500 m^3/day (Maximum day demand x 1.1)
- Steel pipe: Dia.400mm, length; 11,400 m
- Equipment: Sluice valve, air valve, drainage valve
- Access road:
- Waterway crossing of MPOKO River (bridge: length; 100m, width; 5 m)

iii) Water treatment plant (on BIMBO Hill)

- Planned water treatment amount: 15,500 m^3/day (Maximum day demand x 1.1)
- Discharge water tank: Effective capacity; 80 m^3 (Dimensions; 8m (W) x 5m (L) x 3m (H)
- Number of pumps: 2, total head; 40 m, 50 Hz

iv) Service reservoir (on the hill)

- 1 Reservoir with the capacity of 1,900 m^3 (12 hours of maximum day demand, Dimensions 25m (W) x 25m (L) x 3.5m (H)

v) Distribution main
same as Alternative 1.
vi) Secondary Distribution
same as Alternative 1.

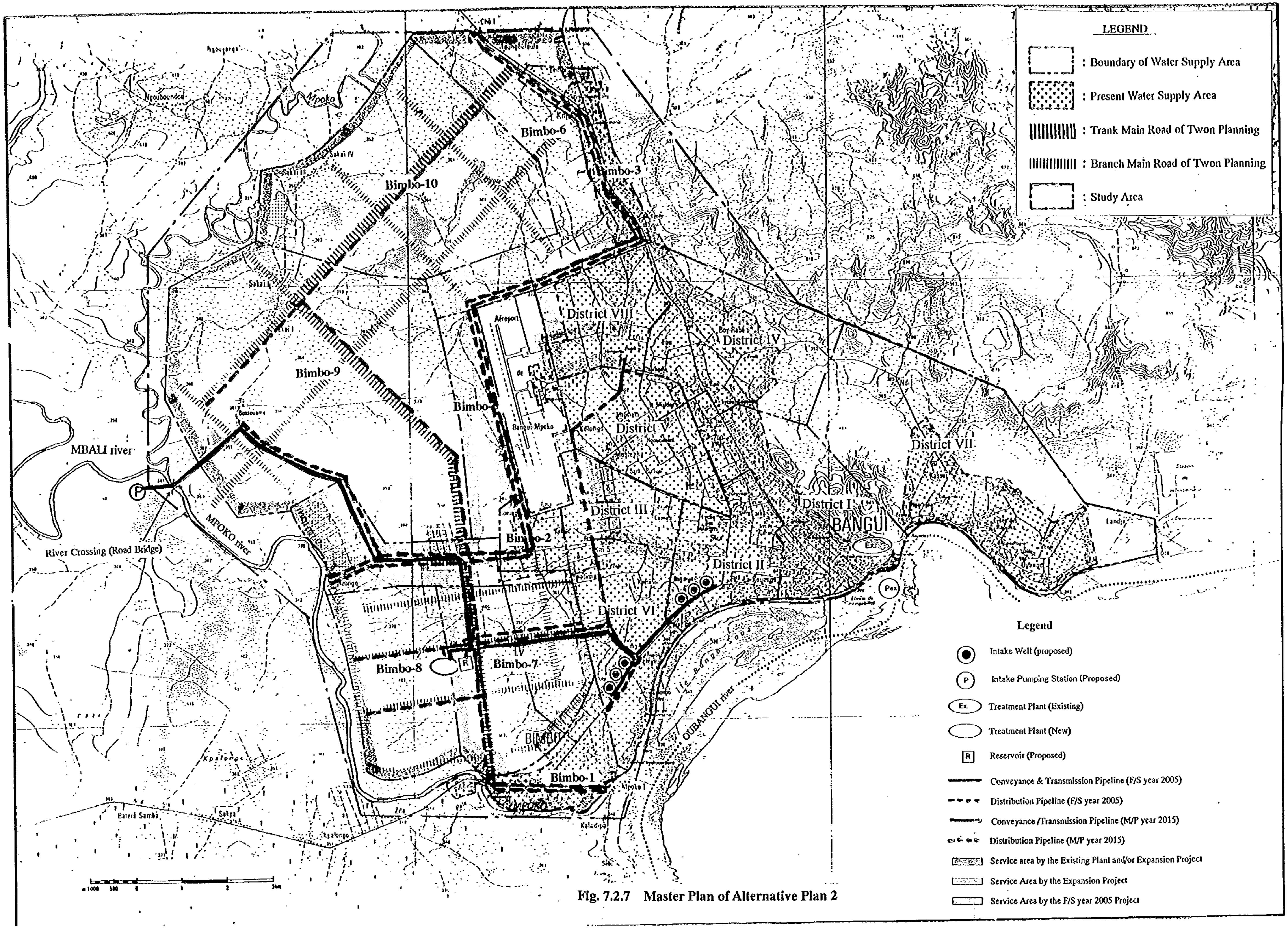


Fig. 7.2.7 Master Plan of Alternative Plan 2

7.3 Cost Estimation of Alternative Project

Project Costs were estimated for each alternative project formulated in the above Chapter. The Cost is summarized in Table 7.3.1. Breakdown of cost estimation are attached in Appendix in this report.

Table 7.3.1 Cost Estimation of Alternative Project (1,000 FCFA)

Alternative project	Specification	Q'ty	Cost
I. Alternative 1			
1. Groundwater Development Project			
1) Intake well Facilities	Intake capacity 510 lit. /min. x6 unit	1lot	396,120
2) Raw water transmission pipeline	Dia.150mm to 200mm, steel pipe	7400m	403,350
3) Water reservoir	1,900m^3	1 unit	262,100
4) Distribution network	Dia. 50mm to 300mm, PVC	30,100m	1,452,190
Indirect cost		1 lot	1,005,500
Sub-total			3,519,260
2. Expansion of the Existing Water Treatment Plant			
1) Installation of intake pump	11 m^3/mini.	1 no.	64,760
2) Water treatment plant	15,500 m^3/day capacity	1 unit	3,630,000
3) Transmission Facilities	59.81 liters/sec., Head 143m, 140kW, 2nos	1 lot.	1,057,680
3) Water reservoir	5,500m^3+1,900 m^3	1 lot	999,000
4) Distribution network	Dia. 50mm to 300mm	64,400m	4,313,300
Indirect cost		1 lot	4,025,900
Sub-total			14,090,640
Grand Total of Alternative 1	**1+2**		**17,609,900**
II. Alternative 2			
1. Groundwater Development Project (same as Alternative 1)		1 lot	3,519,260
3. New Water Treatment plant in Bimbo Area			
1) Intake facilities on Mbali river	5.38 m^3/min. x 3 units	1 lot	636,900
2) Raw water transmission main	Dia. 400mm, DCIP	11,400 m	1,844,000

3) Treatment plant	15,500 m^3/day	1 unit	4,065,000
4) Reservoir	1,900 m^3	1 lot	256,500
5) Distribution network	Dia. 50 to 300mm	64,400 m	4,551,800
Indirect cost		1 lot	4,541,600
Sub-total			15,895,800
Ground total of Alternative 2	**1+3**		**19,415,000**