Chapter 1. INTRODUCTION

1.1 Background

The hydrogeological survey, which carried out during the stage of Master Plan study, resulted that an exploitable volume of groundwater in the study area was 800,000 m^3 per year which corresponds to 2,200 m^3 per day. In order to utilize this limited resource effectively as a source of public water service, an idea was justified in the Master Plan study. The idea envisaged to serve potable water produced economically to the population who lived in the west or north outskirts of Bangui and were generally categorized into low-income class. And the idea was formulated into a project which was composed of 6 deep wells, a transmission main, a reservoir at Bimbo hill, and distribution pipelines.

In the Master Plan study two alternative plans were formulated to cater the water demand until 2015 in the metropolitan area of Bangui. The above project was adopted as a sub-project in the both alternative plans due to its financial and technical advantages such as a less cost for construction and operation, an easy maintenance skills etc.

The both alternative plans as a whole were not given a sufficient point to exploit by the financial and economic appraisals. However, the proposed project, which constituted an element of the alternative plans, were concluded that it would give a high benefit to the population who unavoidably faced to a hard sanitary condition. Therefore the project was highly recommended to implement from the BHN's point of view.

1.2 Study Area

The study area for the feasibility study is the west or north peripherals of present water service. The study area has generally been urbanized by sprawl phenomenon. Therefore physical and social infrastructures in the area can not be properly introduced as the population increase. Sanitary potable water service, drainage system, sewerage system, medical service, education for children etc. are lacking in the area. A steep increase of population drives up the requirement of these services, however, the Government of the CAR has not taken effective measures due to their hard financial condition. Many people depend water on unsanitary traditional shallow wells which are contaminated with coliform or bacteria. Accordingly the people in the area are exposed to a risk of sweep of various diseases. Safe water supply is therefore highly required to improve the sanitary condition in the area.

1.3 Basic Policy and Strategy for Feasibility Study

Basic policy and strategy used in compiling the feasibility study are as follows:

1) The objective of the Feasibility Study is to provide for the projected 2005 water demands of the areas where are eminently urgent need for improvement of sanitary conditions. Depending on site investigation the proposed water service area and its water demand for 2005 shall be reviewed.

2) Exploitable water source is the groundwater whose potential was analyzed in detail on the stage of Master Plan. Based on the result of the Master Plan and site survey production well sites shall be proposed. The exploitable groundwater volume shall be reviewed. And the necessary measures against deterioration of the water quality shall also be recommended.

3) Facilities to be designed should be suitable to technical level of the local engineer. Equipment and materials for the proposed facilities should be also used among ones generally distributed in the CAR as much as possible. Capacity of the facilities shall applied considering the present operational systems and level to be improved in future. Public water faucet, which play main role of supply water to the population, shall be designed in accordance with the present design criteria in the CAR.

4) In case the project would be implemented on grant aid basis, the CAR side should be obliged in various works on the construction and the operational stages of the project. The works include land acquisition for construction of the proposed facilities, installation of primary power cable to the proposed electrical facilities, arrangement of community road for distribution pipelines and proper operation and maintenance of the proposed facilities, etc. Considering the institutional capacity on project management of the counterpart of the CAR side, the program of project implementation should be formulated with a proper marginal time.

5) The water service shall be newly introduced to the major part of the project area. In these area people are used to utilize shallow wells despite of unsanitary quality. Although they have a primary knowledge of public water service system, it should be improved for customization of the public water use. Therefore operation and maintenance system shall be formulated in order to function properly in the project area.

Chapter 2. PRESENT CONDITIONS OF FEASIBILITY STUDY AREA

2.1 Water Use & Sanitary Condition

2.1.1 Water Use Condition

The areas for the feasibility study in general have been sprawling without proper regulation or restriction. Majority of the population in the study area is migrant form the provinces in seeking jobs in the capital or expecting better lives with their successful relatives. These people used to prefer to start their lives in out-skirt of the urbanized area by reason of easiness of space acquisition to erect their temporal houses. This phenomenon boosts population increase in these areas. Depending on a high potential of shallow groundwater in these areas, people enable to use easily groundwater from shallow wells dug inside their owned land or centers of small communities. The water of these shallow wells are contaminated by coliform and bacteria that implies intrusion of excreta to the groundwater from latrines which are dug in a corner of the concessions without a sufficient distance form the wells. The people have no option except access to these shallow wells due to lack of the public water service in these areas.

Depending on urbanization circumstance the following 3 zones have own situation as follows.

In Bimbo-1 to 3 zones the people can access the public water service. However, there are also many shallow wells in these areas and usage of the public water service was limited for mainly drinking and cooking purposes. As these areas are located in the far-ended of the present water service area, the people have a great difficulty to receive the service due to frequent suspension or low pressure especially in dry season. Fetching water from Kiosks depend mainly on women or children.

Only Bimbo-7 zone located in hill of Bimbo was commenced to develop under a program of urban planning in 1995. The plan, however, is faced with difficulty in looking for financial investors for project implementation and delay of arrangement of physical infrastructure especially potable water supply. Water service pipe is partly laid by the SODECA, but the service remains insufficient level with a low pressure and suspension because the location is beyond the limits of the existing facilities. The shallow groundwater is not available in this zone, therefore if the water service would suspend for long hours, people have to fetch water from the nearest kiosk whose distance is far more than 2km.

In Bangui VIII (1) the public water service does not cover yet because of its far distance from the existing water reservoir. The population density of this area is almost as same level as another districts of Bangui City. People depend water on kiosks in the neighbor district.

2.1.2 Sanitary Condition

Sprawl and population increase affects also sanitary condition in the study areas. There is no proper drainage system and sewage system. Many people flash wastewater away on the ground and let it dry out. Drain canals excavated in front of some houses are not maintained well. Especially in the rainy season inundation emerges here and there after a heavy rain. The inundation often covers some resident areas, houses as well as toilets and shallow wells. Because of the lack of distance from latrines, the sallow wells are highly contaminated by coliform and bacteria. Accordingly people are always exposed to a high risk of suffering from water born diseases like Parasite and Diarrhea. Therefore the potable water service is highly required in the study area.

The people expect that the water service would bring not only improvement of sanitary conditions but also modernization of their lives.

Education or workshops concerning sanitation or hygiene are often held at a community level by health workers of the local government or NGO, but still insufficient. UNICEF has been continuing to promote people's awareness on sanitation and hygiene on a project basis.

2.2 Socioeconomic Condition

2.2.1 Population

The population in the study area of feasibility study was estimated at about 54,000 as of 1998 in the Master Plan study (see Table 2.2.1). The population increase rate in Bimbo district was also estimated at 7.91% per year which marked more than twice larger than the one of Bangui City, 3.88% per year.

Table 2.2.1 Estimated Population of Study Area in 1998

Zone	Population
Bimbo-1	6,000
Bimbo-2	4,000
Bimbo-3	3,500
Bimbo-4	3,000
Bimbo-5	1,500
Bimbo-6	2,500
Bimbo-7	1,000
Bangui VIII(1)	32,624
Total	54,124

(Extractions from the Master Plan study)

2.2.2 Land Use and Economic Activities

Bimbo-1, 2 and 3 are categorized semi urban area where urbanization was started earlier than another study areas. In Bimbo-4, 5 and 6 there are still permanent residents who are generally involved in agriculture and a trend of migration is recently increasing in these zones. In Bimbo-7 an urban development plan is on progress and migration of people has been commenced partly. However, the developed area is quite limited. Insufficiency of water supply service is one of the obstacles to expedite the progress of the plan.

Bangui VIII (1) is categorized in urban area, however, population face difficulty of access to potable water service.

In general, the majority of families in these areas, who earn their lives by involving works or jobs in Bangui City, are categorized into a low income level.

2.2.3 Physical Infrastructure

1) Roads

Asphalt paved roads are limited only to the Bangui-Mbaïki road and the Bangui-Km12 road. In Bimbo-1, 2 and 3 community roads are arranged without pavement. In Bimbo-4 a route of Km 5-Nzongo is the trunk main and the most people live along this road in this area. In Bimbo-6 and 5 the main road is arranged along the fringe of the airport. Some lanes and paths are used as community level roads to link the local communities. In Bimbo-7 main roads were constructed without pavement in accordance with an urban development plan. Although community level roads are not sufficiently arranged yet.

2) Electricity

In Bimbo-1, 2 and 3 it is available to connect electric power supply as same as Bangui City where electrification ratio is reported at 6%. In another areas requirement of electric power supply is supposed to be far below than Bangui City. Electricity service lines are arranged along the main road in the study area with low-tension level.

3) Telephones

Telephone service is available in the limited area Bimbo-1, 2 and 3. In another areas the telephone line is not arranged yet due to the less requirement.

Chapter 3. WATER RESOURCES DEVELOPMENT PLAN

3.1 Proposed Well Field

The well field should be located in the area that meets the following conditions:

- High yield area of the groundwater (area of high permeability)
- Downstream area of the groundwater flow path
- Converging area of the groundwater in the groundwater basin
- Area where the groundwater quality is better

The suitable well fields which meet the above conditions are situated in the limited areas in the Study Area as shown in the hydrogeological map in Master Plan Report. Namely, there are two proposed well fields in the target groundwater basin. One of them is located in the Bakonngo area and another is Mbossoro area as shown below.

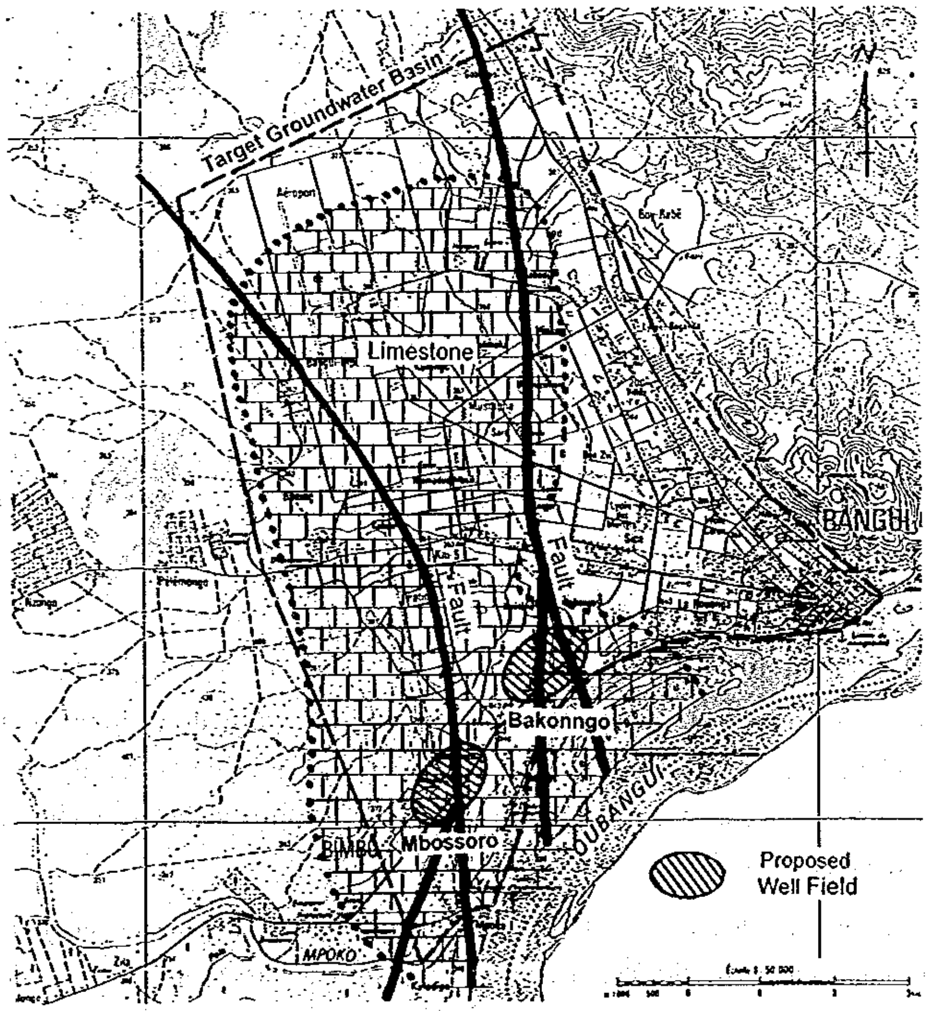


Fig.3.1.1 Proposed Well Fields

3.2 Groundwater Potential

(1) Numerical Simulation on the Future Status of the Groundwater Level

The groundwater potential is examined in the case that the groundwater development is done in the bedrock aquifer at the two well fields mentioned above with six production wells. The numerical simulation on the future status of the groundwater level was conducted for the examination of the groundwater potential based on the hydrogeological model described in Master Plan Report.

The simulation was conducted in the six cases of the development. The results of the simulation are shown in Fig.3.2.1(1) and Fig.3.2.1(2). The maximum regional draw-down of the groundwater level caused by the development is summarized in Table 3.2.1.

Table 3.2.1 Assumed Maximum Regional Draw-down Caused by the Development

Development Case	Development amount (MCM/year)	Maximum Regional Draw-down (m)
Case-1	0.6	1.0
Case-2	0.7	1.2
Case-3	0.8	1.4
Case-4	0.9	1.6
Case-5	1.0	1.8
Case-6	1.1	2.0

It is anticipated that the regional draw-down area of the groundwater level will widely spread in the hinterland of the well fields according to the simulation results shown in from Fig.3.2.1(1) and Fig.3.2.1(2).

It is also supposed that the drawing of the river water will start from the Oubangui river to the well fields incase that the development amount exceeds the recharge amount (1.0MCM/year) and make the draw-down smaller.

(1) Examination on the Groundwater Potential

The draw-down itself caused by the development is supposed small in every development cases and it may range from 1.2m to 2.0m. The draw-down in the production wells is also assumed small ranging from 2m to 3m. In such case, the draw-down depth in the production wells will not become a restriction factor against the groundwater development.

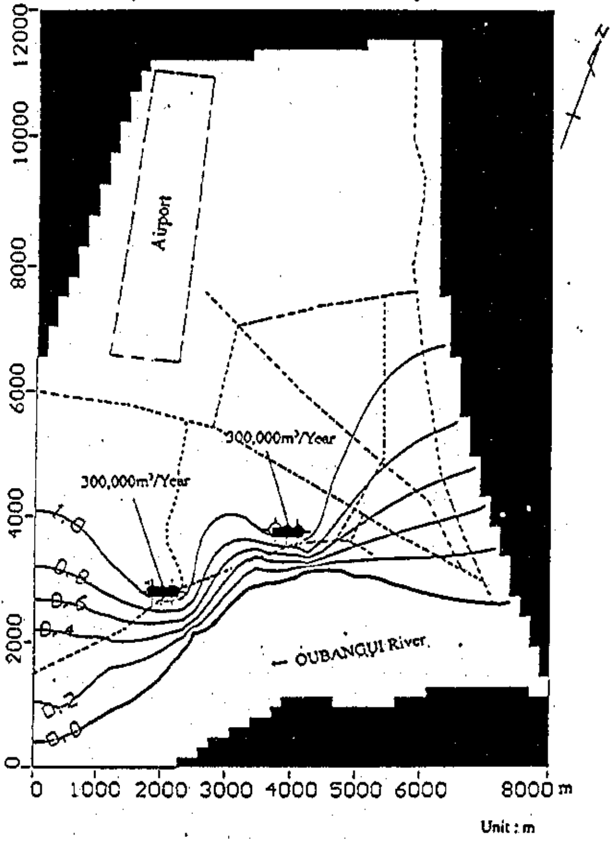
As mentioned in chapter 5.3 in Master Plan Report, the bedrock aquifer is hydraulically connected with the shallow laterite aquifer and the groundwater level of the shallow laterite aquifer will decrease in accordance with the groundwater level draw-down of the bedrock aquifer. There are many existing wells excavated in the shallow laterite aquifer and many people is dependant on the shallow wells. Even after the completion of the urban water supply system, the shallow wells will be still indispensable for the life of the people.

Therefore, the draw-down of the shallow wells should be employed as the criteria for the decision of the groundwater potential (the maximum exploitable groundwater amount).

The groundwater depth from the bottom of the shallow wells is assumed around 1.5m in the dry season according to the well survey. If the groundwater level draw-down of the bedrock aquifer exceeds 1.5m, almost all of the shallow wells will be dried up in dry season.

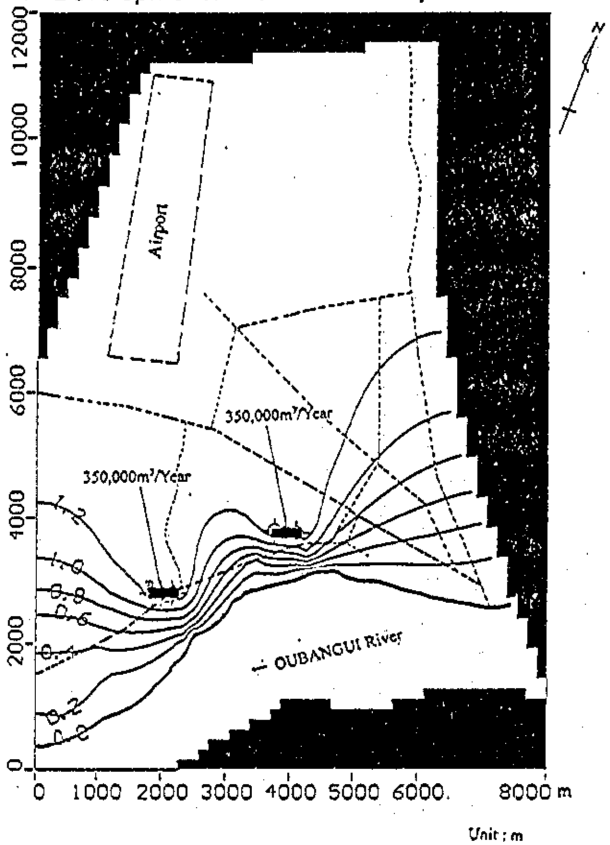
As the reason mentioned above, the regional draw-down to be caused by the groundwater development should be kept within 1.5m. Accordingly, the groundwater potential of the bedrock aquifer is 0.8MCM/year whose regional draw-down is assumed 1.4m.

Case-1
Development Amount:0.6MCM/year



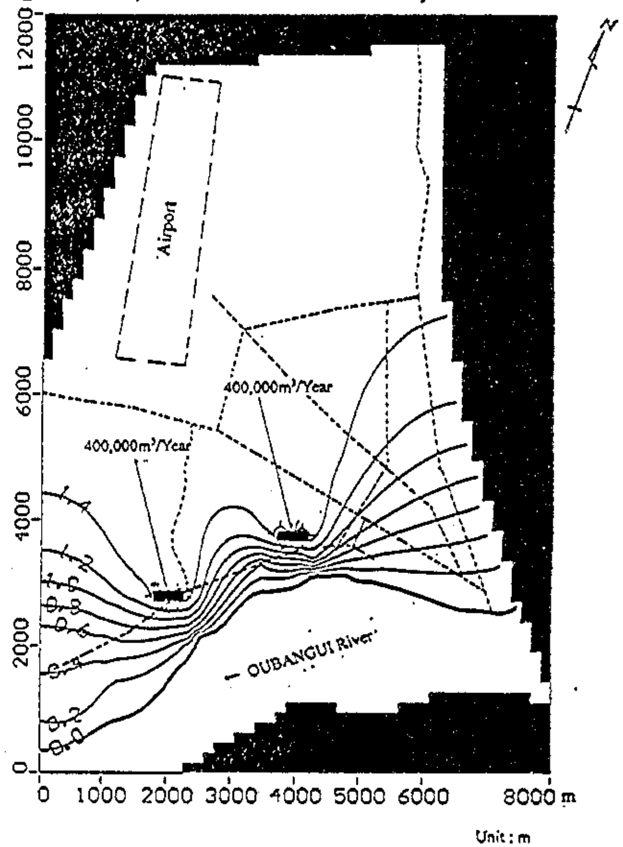
—1.0— Simulated Draw-down Depth of the Bedrock Aquifer in meter (Discharge Amount : 600,000m³/Year)

Case-2
Development Amount:0.7MCM/year



—1.0— Simulated Draw-down Depth of the Bedrock Aquifer in meter (Discharge Amount : 700,000m³/Year)

Case-3
Development Amount:0.8MCM/year



—1.0— Simulated Draw-down Depth of the Bedrock Aquifer in meter (Discharge Amount : 800,000m³/Year)

Fig.3.2.1(1) Simulated Draw-down Depth of the Bedrock Aquifer by the Development

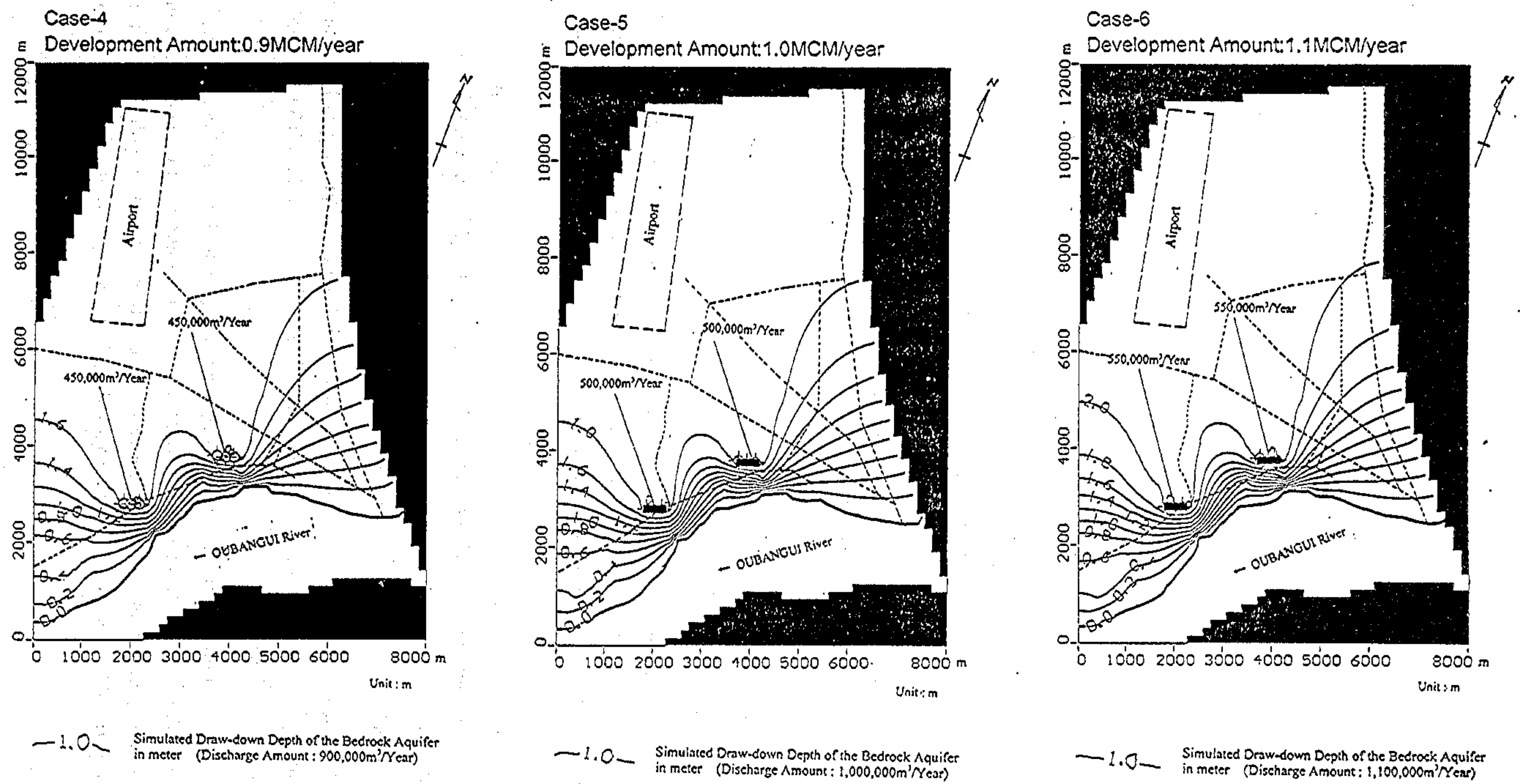


Fig.3.2.1(2) Simulated Draw-down Depth of the Bedrock Aquifer by the Development

3.3 Groundwater Quality

The groundwater quality is out of WHO standard for potable water in following items in the deep bedrock aquifer in the target groundwater located in the Bangui city area.

-Coliform, -Mn, -Fe, -NO3,

3.3.1 Present Groundwater Quality in the Target Groundwater Basin

(1) Coliform

Coliforms were found in all deep wells including the exploratory wells drilled in this Study. Moreover, Thermotorelant Coliforms were found in all wells including the deep wells tapped the bedrock aquifer. The density of the Thermotolerant coliforms directly relates to that of the Escherichia Coliform which exists peculiarly in the feces.

The findings mentioned above suggest that even the deep groundwater has been contaminated with pollutant from ground surface. Therefore, the sterilization facilities will be needed for the water supply system.

(2) Manganese ion (Mn)

The distribution of the Mn concentration in the groundwater is shown in Fig.3.3.1.

1) Shallow laterite aquifer

The Mn concentration in the shallow laterite aquifer exceeds WHO standard (0.5mg/lit) in nearly all area of the target groundwater basin and it seems that the Mn concentration gets lower in the northern area of the target groundwater basin as shown in Fig 3.3.1.

There is a tendency that the Mn concentration gets lower in rainy season. It is inferred that such change in concentration might be caused by the dilution with the abundant recharged water in rainy season.

2) Deep bedrock aquifer

Mn concentration of the deep groundwater in the bedrock aquifer gets lower along the high permeable zones in which the Mn concentration meets the WHO standard as shown in Fig.3.3.1.

It is inferred that as the fresh water is flowing along the high permeable zone, the Mn concentration gets lower than the other areas where the groundwater is stagnant because of the low permeability. It is concluded that the safe water can be gotten only in the high permeable zone where the proposed well fields are located in term of Mn concentration.

(3) Ferric ion (Fe)

The distribution of the Fe concentration in the groundwater is shown in Fig.3.3.2.

1) Shallow laterite aquifer

The Fe concentration in the shallow laterite aquifer exceeds WHO standard (0.3mg/lit) in nearly all area of the target groundwater basin excepting the area around the airport as shown in Fig 3.3.2.

The same tendency with the Mn concentration is also founded in Fe concentration in the shallow groundwater. That is, the Fe concentration gets lower in rainy season and it is also inferred the dilution of the groundwater in rainy season might be the main reason.

2) Deep bedrock aquifer

Fe concentration of the deep groundwater in the bedrock aquifer also gets lower along the high permeable zones in which the Fe concentration meets the WHO standard as shown in Fig.3.3.2. It is inferred that the same reason with the case of Mn concentration could be applied for the explanation of this phenomena.

Therefore, it is also concluded that the safe water can be gotten only in the high permeable zone where the proposed well fields are located in term of Fe concentration.

(4) Nitrate ion (NO_3)

The distribution of the NO_3 concentration in the groundwater is shown in Fig.3.3.3.

1) Shallow laterite aquifer

The NO_3 concentration in the shallow laterite aquifer is almost less than WHO standard (50mg/lit) excepting the northern area of the groundwater basin in rainy season as shown in Fig 3.3.3. Its average concentration is around 10mg/lit to 20mg/lit.

The reverse tendency to the case of Mn and Fe can be found in the seasonal change of the concentration. That is, the NO_3 concentration gets higher in rainy season. It is inferred that the change might be caused by the inflow of the contaminated surface water into the shallow wells because of the poor protection works of the well mouth.

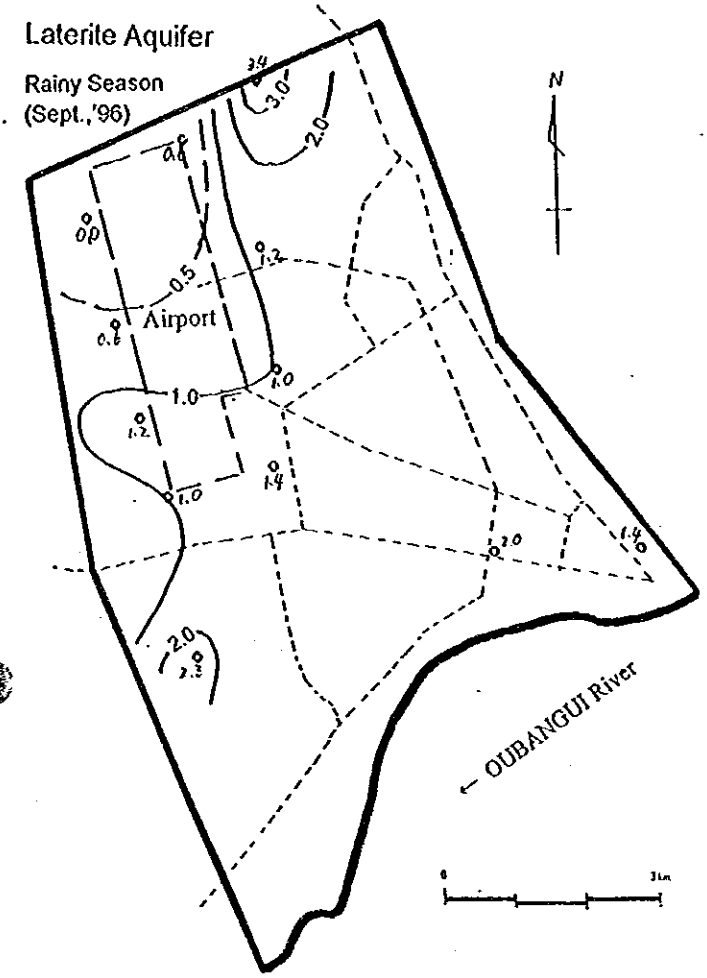
It is inferred that the NO_3 concentration in the shallow groundwater still remains in low level in spite of the abundance of the contaminant such as pit latrine.

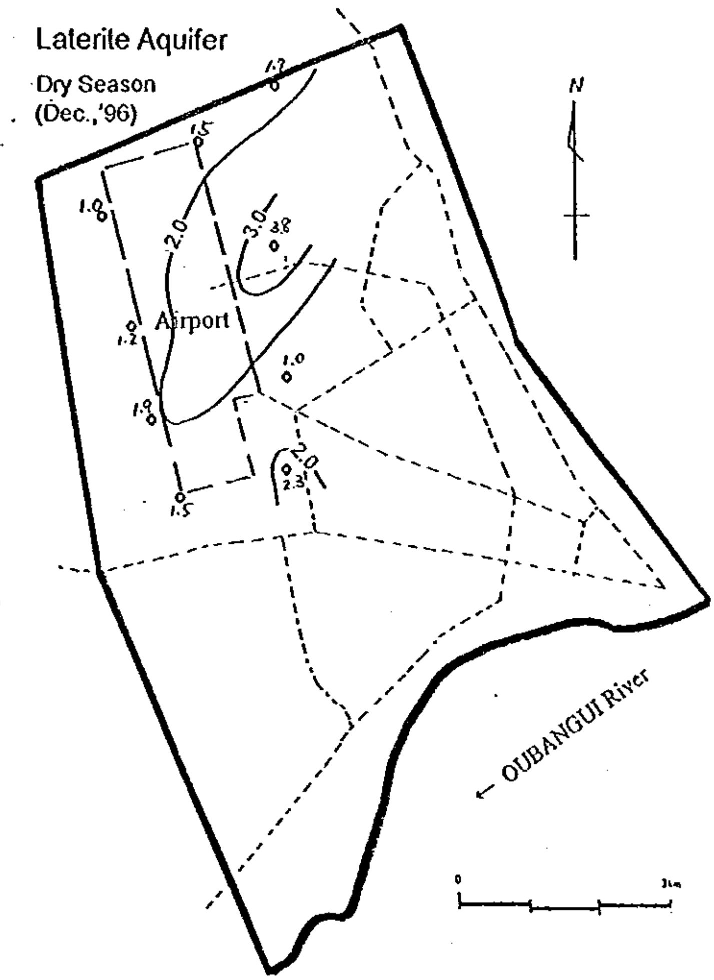
2) Deep bedrock aquifer

The distribution pattern of NO_3 concentration of the deep groundwater shows different characteristics from that of Mn and Fe concentration. That is, it seems that the NO_3 distribution is not controlled by the permeability of the aquifer and the concentration is almost constant ranging from 10mg/lit to 20mg/lit which meets WHO standard. It is clarified from this phenomena that the NO_3 derives from the contaminants made by the human activities such as pit latrine and sewage infiltration.

It is also inferred that the NO_3 concentration in the deep groundwater still remains in low level same as the shallow groundwater.

Mn CONCENTRATION (mg/L)





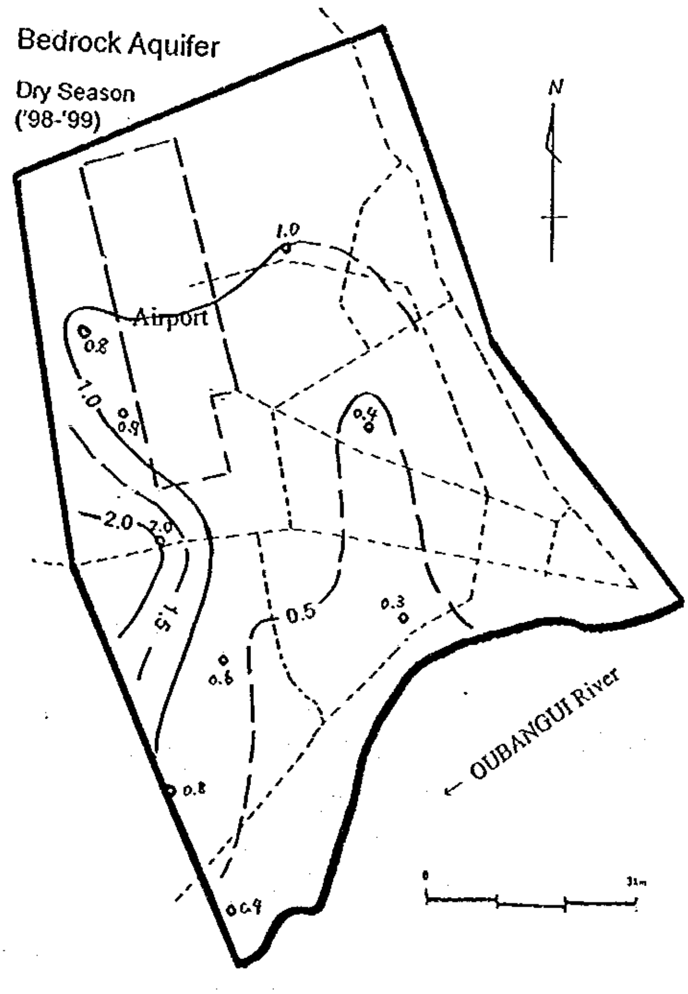
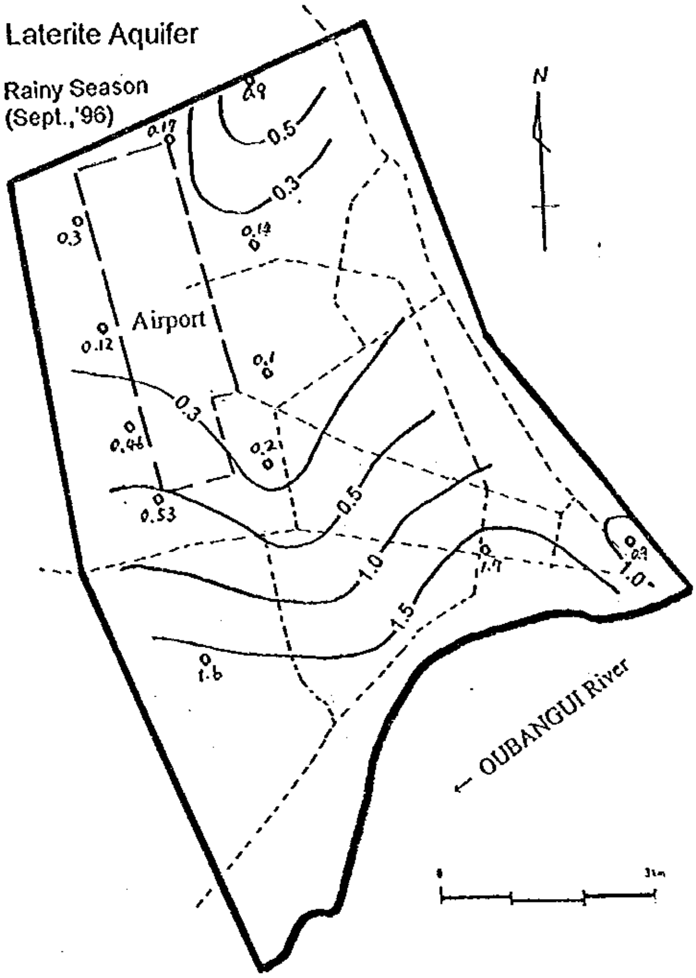
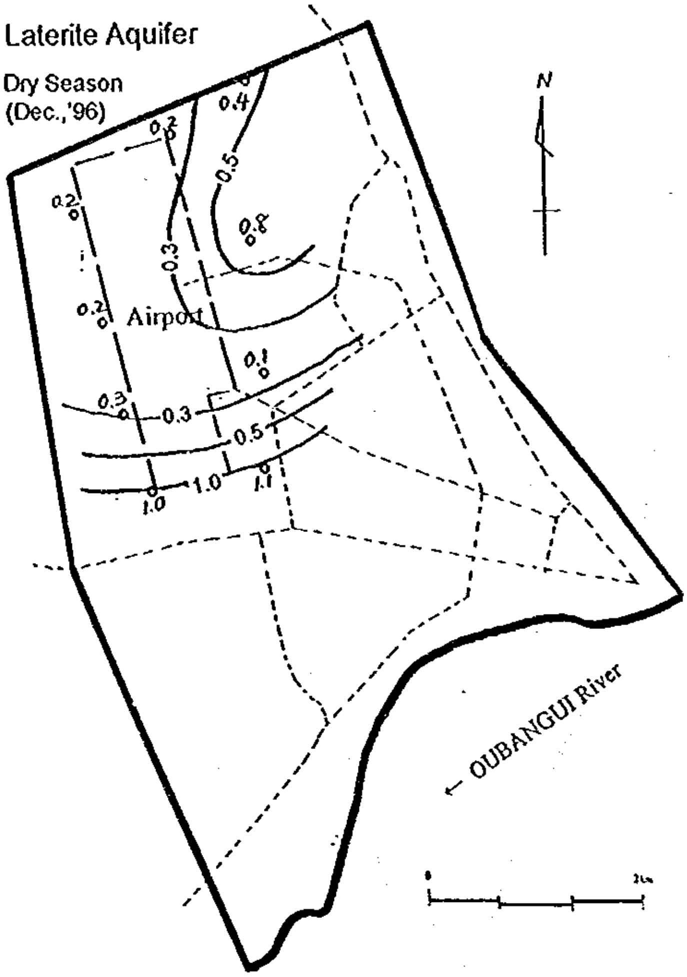


Fig.3.3.1 Distribution of Mn Concentration
in the Groundwater

Fe CONCENTRATION (mg/L)





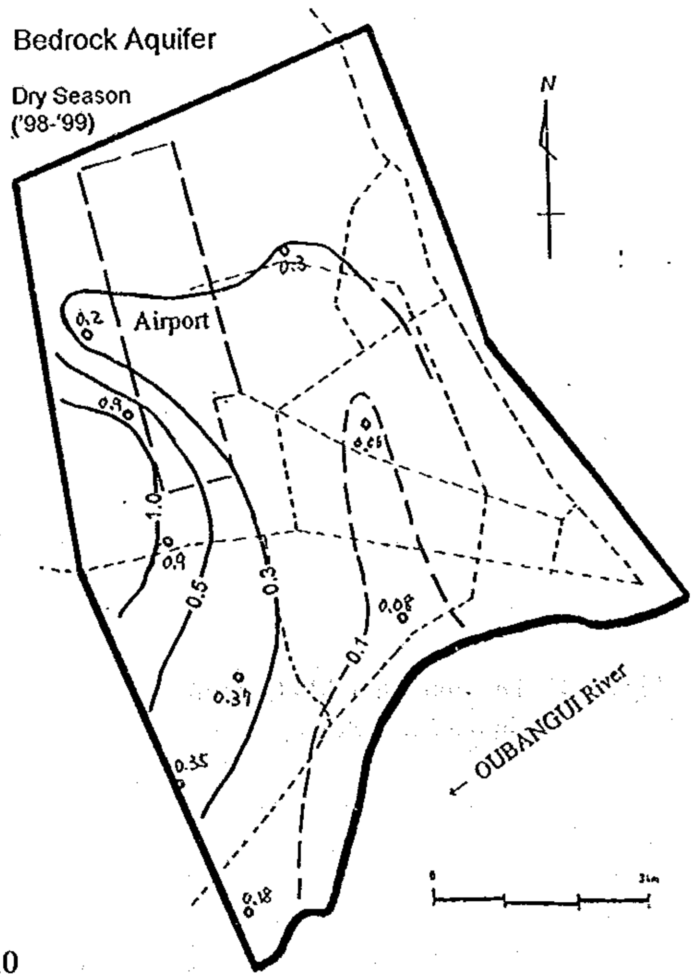


Fig.3.3.2 Distribution of Fe Concentration in the Groundwater

NO_3 CONCENTRATION (mg/L)

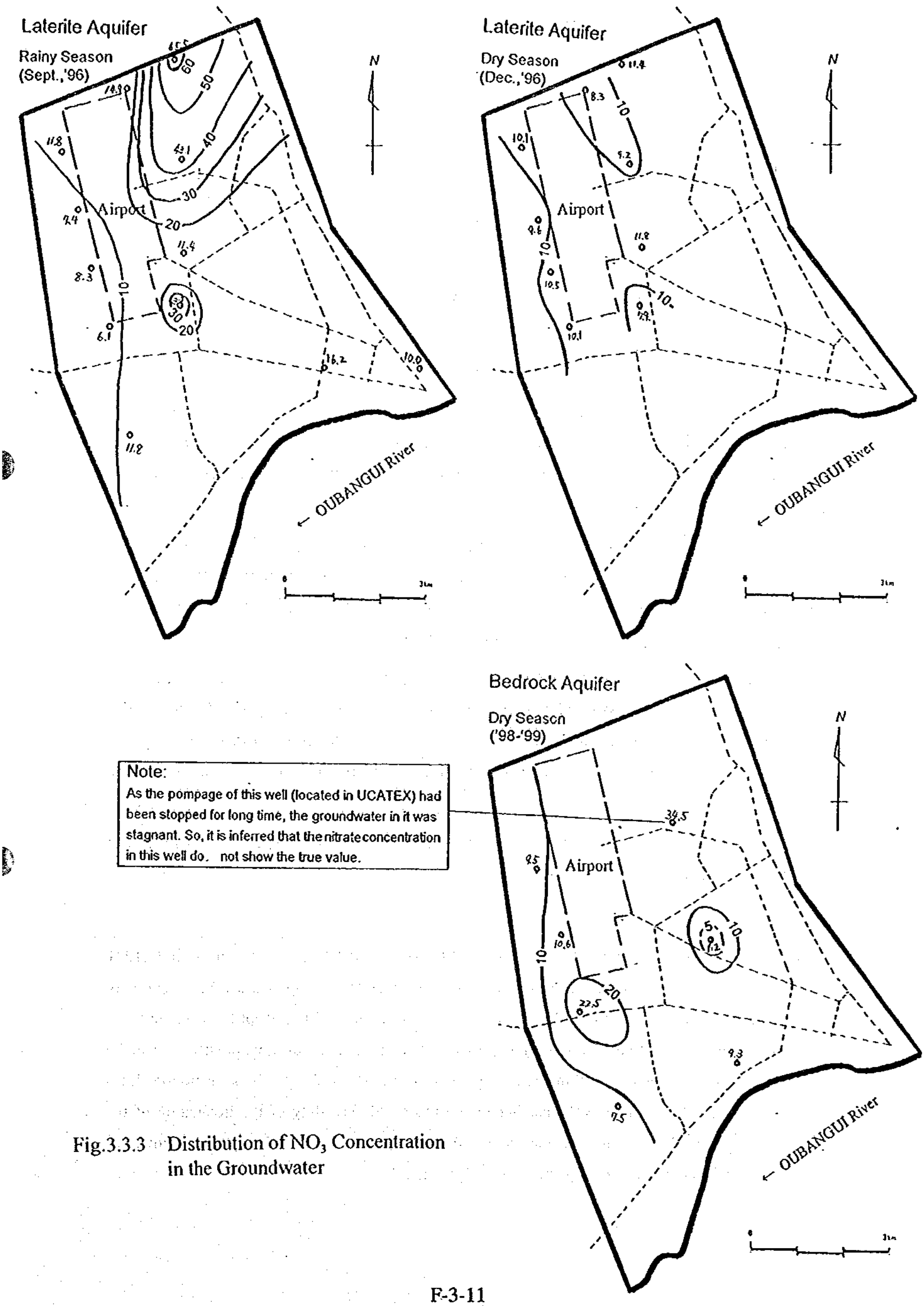


Fig.3.3.3 Distribution of NO_3 Concentration in the Groundwater

3.3.2 Contaminant Sources in the Target Groundwater Basin

(1) Contaminant source of Mn and Fe ion in the groundwater

As described in Master Plan Report, Mn and Fe ions are assumed to derive from the layers taking the distribution of the concentration of these ions into consideration.

However, the contamination mechanism which is chemical reaction between the groundwater and layers has not been clarified because of its complexity such as elution and adsorption.

(2) Contaminant source of coliform and nitrate (NO_3)

The offices and factories which consume large amount of water are selected from first to 20th rank based on the information from SODECA and their locations are shown in Fig.3.3.4. As shown in this figure, the large water consuming buildings are almost governmental offices, hospitals and factories.

Governmental offices and hospitals discharge normal sewage without any special toxic contaminants such as heavy metals and organic chloride (trichloroethirene etc.) and they do not become the contaminant source because all of these buildings are equipped with septic tanks according to the regulation[note].

For the factories (No.2 and No.15 in Fig.3.3.4), the sewage treatment plants are equipped too. It is also assumed that they will not contaminate the groundwater in the target groundwater basin even if the unforeseen accidents will happen in future because they located lower most reach of the groundwater flow in the groundwater basin.

Consequently, it is concluded that the contaminant sources of the coliform and NO_3 are the private houses without septic tanks and they widely spread in the target groundwater basin.

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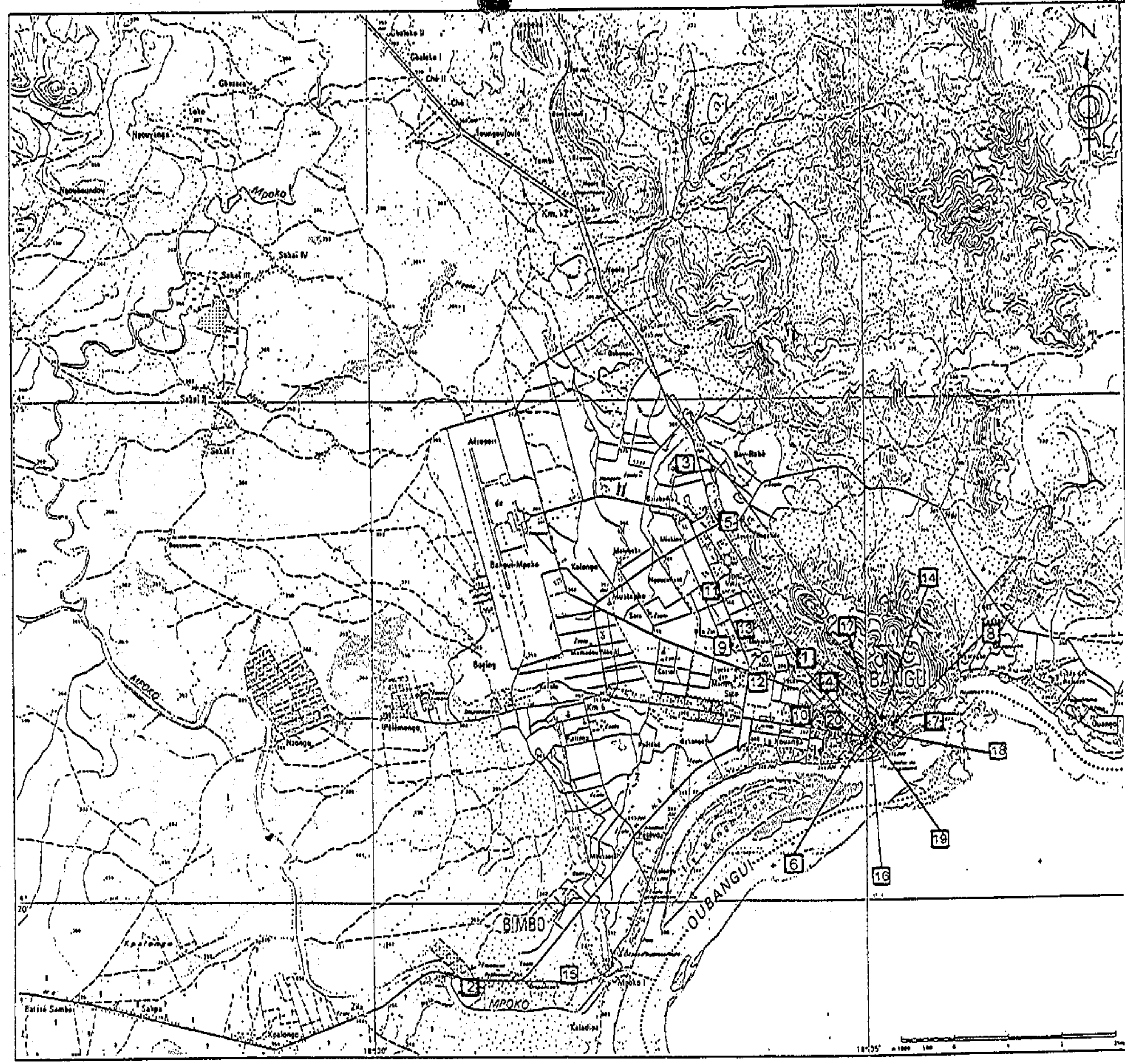
note : "REGLEMENT D'URBANISME DE LA VILLE DE BANGUI" established in April 3rd,1971 by the Ministry of Housing and Transportation. This regulation is applied for the Bangui City and regulated the duties in Article 5 that the sanitation facilities (septic tanks) must be installed in the newly constructed houses and buildings. The construction license can be canceled unless such sanitation facilities are constructed. The scale of the sanitation facilities is designated according to the number of the household. The duty of the installation of the sanitation facilities is imposed the hoses and buildings of more than four persons. However, the penal clauses are not designated in this regulation.



Buildings of Large Comsumption of Water

No.	Name	Com. Amount (m^3/day)
1	Min. of Difence	34,040
2	SCB (beer facto.)	31,434
3	Hospital Amitie	28,145
4	Min. of Sanitation	18,066
5	Diet Building	15,656
6	Min. of Information	8,493
7	Hotel Sofitel	5,936
8	President Residence	5,897
9	Hosp. Communautaire	5,413
10	Min. of Education	3,062
11	UDEAC(political party)	2.996
12	FATEB(religious party)	2.371
13	Min. of Foreign Affairs	1,882
14	Min. of Finance	1,865
15	HUSACA (soap facto.)	1.777
16	Hotel Central	1.632
17	Min. of Justice	813
18	Socati(Tel. company)	763
19	Min. of Forest	646
20	Min. of Mines and Ener.	619

Fig.3.3.4 Location of Buildings Consuming the Large Quantity of Water

3.3.3 Examination on the Groundwater Quality Change and Recommendation

Since the groundwater recharge area is located in the urban area under the development, the quality of the groundwater is anticipated to change according to the urban development in future. Namely, It is supposed that the groundwater quality will deteriorate by the increase of the infiltration amount of the sewage drained from the household and factories which will be extending every year.

1) Coliform and nitrate ion (NO_3)

The number of coliforms and NO_3 concentration in the groundwater will increase in future because of the reason mentioned above.

As the sterilization facilities are included in the groundwater development plan, the increase of the number of the coliforms will not be problem in future.

Present NO_3 concentration in the groundwater is around 10mg/lit to 20mg/lit as shown in Fig.3.3.3 and it can be concluded that the NO_3 concentration still remains low level so far comparing with WHO standard (50mg/lit).

As the contaminant source of NO_3 is human activities such as feces and sewage as mentioned in chapter 3.3.2, it is assumed that the NO_3 contamination of the groundwater will advance in accordance with the increase of the population. Namely, it is supposed that the human himself is the contaminant source of NO_3.

Based on this idea, it is anticipated that the NO_3 concentration will reach the WHO standard in case that the population will increase by 2.5 times of the present population. Supposing that the population of the Bangui City will constantly increase with the growth rate of 3.88%, it is anticipated that the population will increase by 2.5 times of the present population after about 25 years.

2) Mn and Fe ions

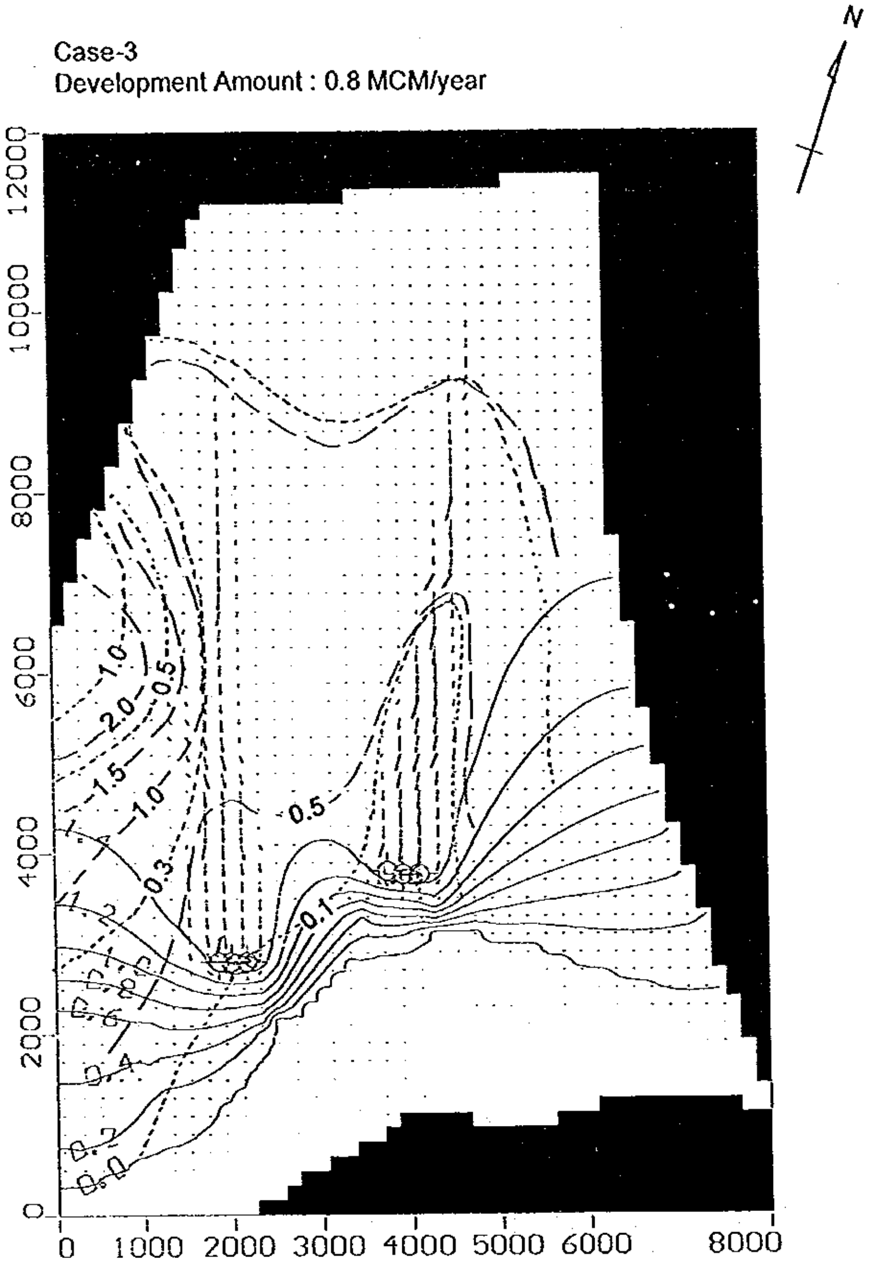
As the contamination mechanism which is chemical reaction between the groundwater and layers has not been clarified because of its complexity such as elution and adsorption, it is difficult to predict precisely the change of Mn and Fe concentration to be caused by the groundwater development.

It is inferred that the concentration of Mn and Fe may increase in the proposed well fields because the groundwater of high concentration of Mn and Fe may be forced to inflow to the well fields by the groundwater discharge from the high concentration area situated in the upstream of the groundwater basin (see Fig.3.3.1 and 3.3.2).

On the contrary, it is also inferred the Mn and Fe concentration may not greatly change in the proposed well fields because the groundwater inflow amount from the high concentration area will be small as shown in the map of groundwater flow vector after the groundwater development (see Fig3.3.5).

The prediction of the change of Mn and Fe concentration is difficult in either case at present.

Case-3
Development Amount : 0.8 MCM/year



Mn Concentration in the Deep Groundwater (mg/lit)

Fe Concentration in the Deep Groundwater (mg/lit)

Flow Vector of the Deep Groundwater after the Groundwater Development (0.8MCM/year)

Fig.3.3.5 Mn and Fe Concentration and Groundwater Flow Vector

Chapter 4. WATER SUPPLY PLAN

4.1 Water Supply Area and Population

The Master Plan study focused on a groundwater development project as recommendation for the Feasibility Study to save the people from the unsanitary and inconvenient life condition. The facilities necessary for groundwater development are comparably smaller in scale than utilization of the surface water. Therefore it has advantages of less construction cost and operation and maintenance cost as well. Therefore considering its merits, the study area was selected by the following viewpoints.

a) Non-water supply area
b) Area whose water service condition remains poor in pressure and quantity
c) Area where a rate of population increase is so high
d) Area where the population are exposed to a high risk of sweep of water born diseases.

Considering the above conditions as a whole, the west or north peripherals of the present water service area are corresponded. A few zones in Bimbo district next to Bangui City are now provided the public water service but it is unstable. Especially in dry season these zones have a great difficulty of frequent suspension or low pressure due to a much water consumtion inside Bangui City.

Accordingly, based on the field reconnaissance the study area was decided as mentioned in the Table 4.1.1. and also shown in Figure 4.1.1.

Table 4.1.1. Feasibility Study Area

Study Area	Community and zone	Reason to be selected
Bimbo –1	Banékola, Batalimon I, Batalimon II, Pala	Although the public water presently served, population has difficulty to receive it constantly.
Bimbo –2	Pélémongo, Boeing, Kokolo	Although the public water presently served, population has difficulty to receive it constantly.
Bimbo –3	Ngola I, Ngola II, Km 12	Although the public water presently served, population has difficulty to receive it constantly.
Bimbo –4	West side of Boeing, and Pelemongo, Nzongo	Non-water service area. Population is growing rapidly. Unsanitary shallow wells are used widely.
Bimbo –5	East side of Bangui-Mpoko	Non-water service area. Population is growing rapidly. Unsanitary shallow wells are used widely.
Bimbo –6	North of the Airport, , West of Bimbo-3	Non-water service area. Population is growing rapidly. Unsanitary shallow wells are used widely.
Bimbo –7	Pilot area of urban development plan	Non-water service area. Population is increasing by the commencement of the urban planning. No other water source is available except water service by the proposed project.
Bangui –VIII	North part of Ngongonon and Combattants	Non-water service area. Population is growing rapidly. Unsanitary shallow wells are used widely.

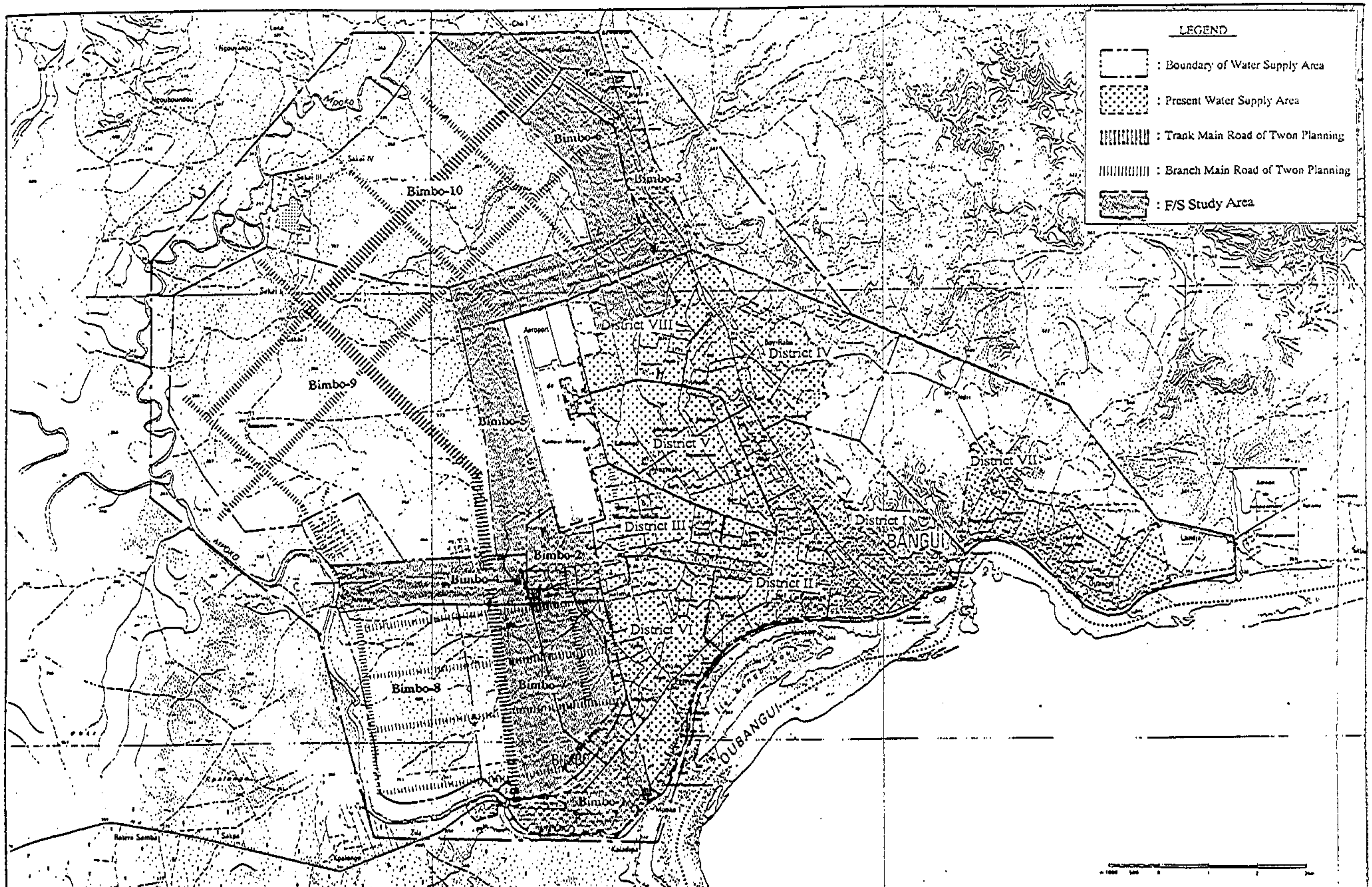


Figure 4.1.1. F/S Study Area

Population projection was analyzed in the Master Plan. As no other surplus data about the population projection were informed, the population of the target year 2005 on this Feasibility Study follows the result of the Master Plan. The population of study area in future are summarized as in Table 4.1.2.

Table 4.1.2 Estimated Population of Study Area

Zone	Year 1998	* Year 2005	Year 2010	Year 2015
Bimbo-1	6,000	10,223	14,959	21,888
Bimbo-2	4,000	6,815	9,972	14,592
Bimbo-3	3,500	5,963	8,726	12,768
Bimbo-4	3,000	5,112	7,479	10,944
Bimbo-5	1,500	2,556	3,740	5,472
Bimbo-6	2,500	4,260	6,233	9,120
Bimbo-7	1,000	1,704	2,493	3,648
Bangui VIII(1)	32,624	42,586	51,514	62,508
Total	54,124	79,219	105,116	140,940

Note: * Target year for the Feasibility Study, 2005

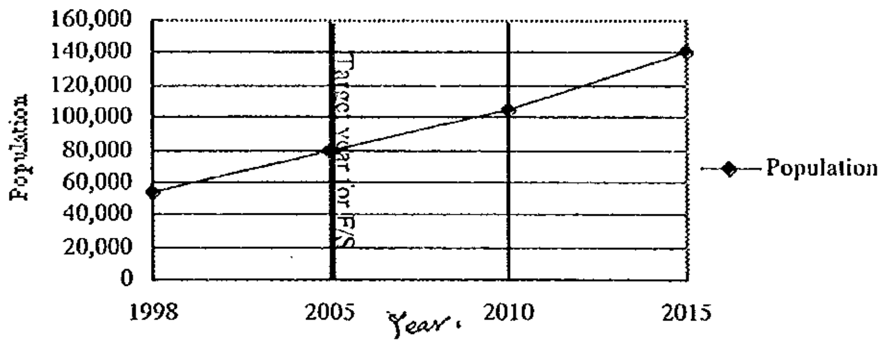


Fig. 4.1.2 Population Projection

4.2 Water Demand Projection

The factors for water demand projection were assumed in the Master Plan study. In accordance with the results of the Master Plan study, these factors are summarized as follows.

Water service population was estimated by assuming water coverage ratios of each zone. Water coverage ratios for the Feasibility Study area are summarized as following Table 4.2.1.

Proportions of the public faucet users and the private connection users are shown in Table 4.2.2.

Water consumption units were assumed taking the characteristics of urbanization in each zone into consideration. The water consumption units are shown in Table 4.2.3.

Ratio of effectiveness of water service corresponds that how much water would be supplied to the consumers out of the total water volume produced at the water treatment plant. The ratios of effectiveness are shown in Table 4.2.4.

Ratio of load of water supply is a percentage of the mean daily water supply volume against the maximum daily water supply. The maximum daily water supply is normally recorded in dry season. In accordance with actual data of SODECA, it was estimated at 80%.

Table 4.2.1 Water Coverage in the Study Area

Zone	Year 1998	* Year 2005	Year 2010	Year 2015
Bimbo-1 to 3	30%	50%	55%	60%
Bimbo-4 to 7	0	32.7%	46.4%	60%
Bangui VIII(1)	0	50%	55%	60%

Table 4.2.2 Proportions of Public Faucet and Private Connection Users

Zone	User	Year 2005	Year 2010	Year 2015
Bimbo-1 to 7	Private connection	15%	22.5%	30%
	Public faucet	85%	77.5%	70%
Bangui VIII(1)	Private connection	30%	30%	30%
	Public faucet	70%	70%	70%

Table 4.2.3 Unit of Water Consumption

Zone	User	Year 2005	Year 2010	Year 2015
Bimbo-1 to 7	Private connection	70 lit./cpd	85 lit./cpd	100 lit./cpd
	Public faucet	10 lit./cpd	17.5 lit./cpd	25 lit./cpd
Bangui VIII(1)	Private connection	70 lit./cpd	85 lit./cpd	100 lit./cpd
	Public faucet	25 lit./cpd	25 lit./cpd	25 lit./cpd

Table 4.2.4 Ratio of Effectiveness

Zone	Year 1998	* Year 2005	Year 2010	Year 2015
Bimbo-1 to 3	65%	69.1%	72.1%	75%
Bimbo-4 to 7 & Bangui VIII(1)	0	90%	87.5%	85%

Taking the above factors into account, water demand is estimated as shown in Table 4.2.5.

Depending on the above estimation, projection of water service population and water demand are shown in the following figures.

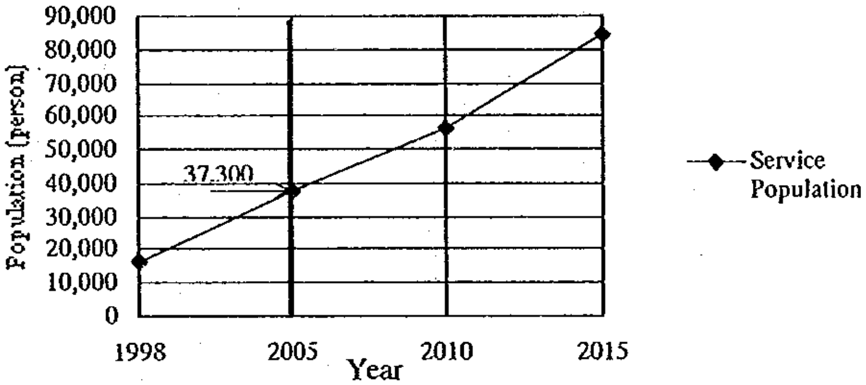


Fig. 4.2.1 Service Population

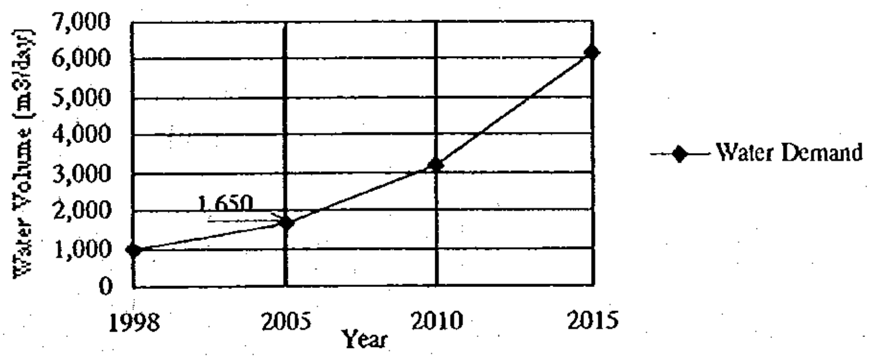


Fig. 4.2.2 Water Demand Projection

Table 4.2.5 Water Demand Projection in Future

Feasibility Study Target Year 2005

District	Population (habitants)	Water Supply Ratio %	Water Supply Population	Propotion of Supply Type		Population		Demand (lit/d/c)		Demand (m3/d)		Total Dimand (m3/d)	Ratio of Effectiveness	Av. Day Production (m3/d)	Ratio of Load	Max. Day Production (m3/d)
				Private Connect.	Public Faucet	Private Connect.	Public Faucet	Private Connect.	Public Faucet	Private Connect.	Public Faucet					
Bimbo-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
Bimbo-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
Bimbo-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
Bimbo-4	5,112	32.7	1,672	0.15	0.85	251	1,421	70.0	10.0	18	14	32	0.900	35	0.80	44
Bimbo-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
Bimbo-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
Bimbo-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
Bangui 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
Total	79,219	-	37,251	-	-	8,782	28,470	-	-	615	508	1,123	-	1,321	-	1,651
Year 2010																
Bimbo-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
Bimbo-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
Bimbo-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
Bimbo-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
Bimbo-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
Bimbo-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
Bimbo-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
Bangui D-VIII(1)	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
Total	105,116	-	56,099	-	-	14,747	41,351	-	-	1,254	872	2,126	-	2,577	-	3,222
Year 2015																
B-1	21,888	60.0	13,133	0.30	0.70	3,940	9,193	100.0	25.0	394	230	624	0.750	832	0.80	1,040
B-2	14,592	60.0	8,755	0.30	0.70	2,627	6,129	100.0	25.0	263	153	416	0.750	554	0.80	693
B-3	12,768	60.0	7,661	0.30	0.70	2,298	5,363	100.0	25.0	230	134	364	0.750	485	0.80	606
B-4	10,944	60.0	6,566	0.30	0.70	1,970	4,596	100.0	25.0	197	115	312	0.850	367	0.80	459
B-5	5,472	60.0	3,283	0.30	0.70	985	2,298	100.0	25.0	98	57	156	0.850	183	0.80	229
B-6	9,120	60.0	5,472	0.30	0.70	1,642	3,830	100.0	25.0	164	96	260	0.850	306	0.80	382
B-7	3,648	60.0	2,189	0.30	0.70	657	1,532	100.0	25.0	66	38	104	0.850	122	0.80	153
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	0.850	2,096	0.80	2,620
Total	140,940	-	84,564	-	-	25,369	59,195	-	-	2,537	1,480	4,017	-	4,946	-	6,182

4.3 Facilities Arrangement

Basic policies of facility arrangement are as follows.

1) In accordance with the water demand projection, in the target year 2005 the water demand was estimated at 1,650 m3/day. After then, the water demand was presumed to increase at steeper rate than before and reach the amount of exploitable groundwater, which was estimated at 2,200 m^3/day, by 2007. Since facilities proposed in this study are expected to complete in around year 2004, it would be reasonable to allow several years as the capacity of the system. Therefore 2,200 m^3/day, that corresponds to the exploitable groundwater volume, should be the design maximum day demand. In accordance with the projection of water service population, about 45,000 persons can be served with the water volume by 2007.

2) The proposed water supply system consists of intake wells, a transmission main, a reservoir and distribution facilities. From the intake well to the reservoir those facilities shall be the independent system form the existing ones. The distribution pipes, however, would partly cover the existing water supply area in Bimbo-1,2 and Bimbo-3. Though the proposed distribution networks can be operated independently from the existing ones, considering the following cases the main pipes should be connected between the new system and the existing one.

   Case 1: At the primary stage of operation of the new system the water demand in the target area would be smaller than the capacity of the system. From an efficient utility of the water point of view, the surplus amount of water can be conveyed to the existing water service area through connecting points.

   Case 2: When water service is suspended in an emergency, the service could be continued by supplying water through connecting points.

   Case 3: According to the water demand projection, water demand in the target area would increase the proposed production water volume in around 2007. After then water should be drawn from the existing distribution network through connecting pipes.

   However, from the easy operation point of view, it is recommended that the connection valves between the both pipe networks should be closed normally.

3) Although people would be served the water through the public faucets or the private connections, public faucets users shall be the majority. Generally the

private connection users would be categorized into a high income class. Therefore it is assumed that the private connection users can afford to pay to connection work by themselves. From the basic policy of BHN point of view the facilities of public faucet should be included in the scope of the project.

Chapter 5. DESIGN OF WATER SUPPLY FACILITIES AND EQUIPMENT

5.1 Design Criteria

5.1.1 Water Demand

(1)Maximum Day Demand

As mentioned in the report of Master Plan, the maximum day demand have worked out at 2,200 m^3.

(2)Peak Hour Demand

Peak hour demand is obtained with the following equation:

$$Qp = K \times Qm \times 1/24$$

Where, Qp: peak hour demand (m^3/hour)

Qm: maximum day demand (m^3/day)

K: peak hour factor (2)

(3)Fire Demand

Water demand is obtained with following equation:

$$Qf = (Qm \times 1/24) + \text{water demand at fire hydrant}$$

Where, Qf: fire demand (m^3/hour)

Qm: maximum day demand (m^3/day)

water demand at fire hydrant=60m^3/hour.

(4)Water Demand

Various water demands have worked out and summarized as shown in Table 5.1.1.

Table 5.1.1 Various Water Demand

Maximum Day Demand (m^3/day)	Peak Hour Demand (m^3/hour)
2,200	183.33

5.1.2 Intake Facilities

Intake facilities is composed of six deepwells and conveyance pipeline. Of these six wells, four deepwells are normally operated for 18 hours, and the remaining two deepwells are stand-bys. The discharge rate of a submersible pump is obtained as follows:

Table 5.1.2 Respective Discharge Rate of Submersible Pump

Maximum Day Demand (m^3/day)	Pump Numbers	Operation hours	Respective discharge rate (m^3/hour)
2,200	4	18	30.56

5.1.3 Transmission Facilities

(1) Collection Chamber

The storage volume of collection chamber will be provided for one hours of maximum day demand.

(2) Transmission Pump

Three units of transmission pumps have been proposed in this facilities, two transmission pumps are normally operated for 18 hours, and the remaining one pump is stand-by, as well as deepwells. In addition, a factor of 1.05 is considered in maximum day demand as a discharge rate for transmission pump.

5.1.4 Power Supply For Water Supply Facilities

Power supply for proposed water supply facilities in this study is provided from existing commercial electric line.

5.1.5 Pipeline

(1) Location and Depth

Pipeline, especially main, will be routed along the existing road and laid with a minimum depth of 1200mm from the ground surface to top of the pipe.

(2) Velocity

The maximum velocity of flow rate will be 2.5 m/sec.

(3) Pressure

The minimum pressure in the distribution pipeline shall be more than 1 kgf/cm^2.

(4)Material

Ductile Cast Iron Pipe will be adopted for raw water conveyance pipeline and transmission pipeline, and steel pipe is used for river crossing (aqueduct). Concerning distribution pipeline, Ductile Cast Iron Pipe (DCIP) is adopted for the diameter more than 300mm, and polyvinyl Chloride (PVC) for the diameter less than 250mm, from the viewpoint of the marketability of pipe materials in CAR.

5.1.6 Service Reservoir

The required storage volumes of service reservoir will be basically provided for 12 hours of maximum day demand, and the storage volume will be taken the efficiency for future arrangement of extra reservoir into account. In addition, the reservoir will be provided to meet the requirement of fire hydrants for a duration of two hours.

5.1.7 Public Fountain

A public fountain is located within a radius of 500 meters (medium distance) and the typical design of the fountain in CAR is adopted in this project

5.1.8 Fire Hydrants

2 fire hydrants will be taken into consideration to design calculation of distribution pipeline for fire fighting case and 1.0 m^3/mini. will be discharged from a fire hydrant.

5.1.9 Location of Flushing Device and Valves

Flushing device will be provided at the low point of the pipeline, and the valve chamber will be provided at major pipe junctions in order to ensure flexible operation. In addition, air valve will be provided at specific point, where necessary.

5.1.10 Dosage of Chlorine

A dosage of 2mg/lit. is required for disinfection alone, and residual chlorine in water shall be 0.1 to 0.2mg/lit. at the last tap in the distribution pipeline.

5.2 Facility Design

5.2.1 Deepwells

(1) Number and Location of the Production Wells

1) Number of the Production Wells

As the maximum discharge rate of the production wells are estimated around 100m^3/hour in the proposed well fields (refer to chapter 4 of the Master Plan Report),. 40m^3/hour is employed as the actual pumping rate of the production wells considering the safety pumping.

The annual working rate of the production wells is expected as 80% considering the regular maintenance. The daily working hour is scheduled 18 hours a day.

As the planned total discharge amount is around 800,000m^3/year, the necessary well number is estimated based on the conditions mentioned above as follows:

Number of necessary production wells = 800,000m^3/year ÷ (40m^3/hour x 18 hours x 365days x 0.8)
= 3.81→4wells

In addition to the minimum necessary wells, one spare well should be added to each well field providing against the unforeseen accidents. Therefore, it is consequently decided that the six production wells will be needed for the groundwater development project in Bangui City.

2) Location of the Production Wells

The spacing between the production wells should be kept more than 500m in order to prevent the well interference.

The suitable sites of the six production wells were selected in the proposed well fields shown in Fig.3.1.1 through the field reconnaissance taking the above condition into consideration. The location of the selected sites of the production wells is shown in Fig.5.2.1.

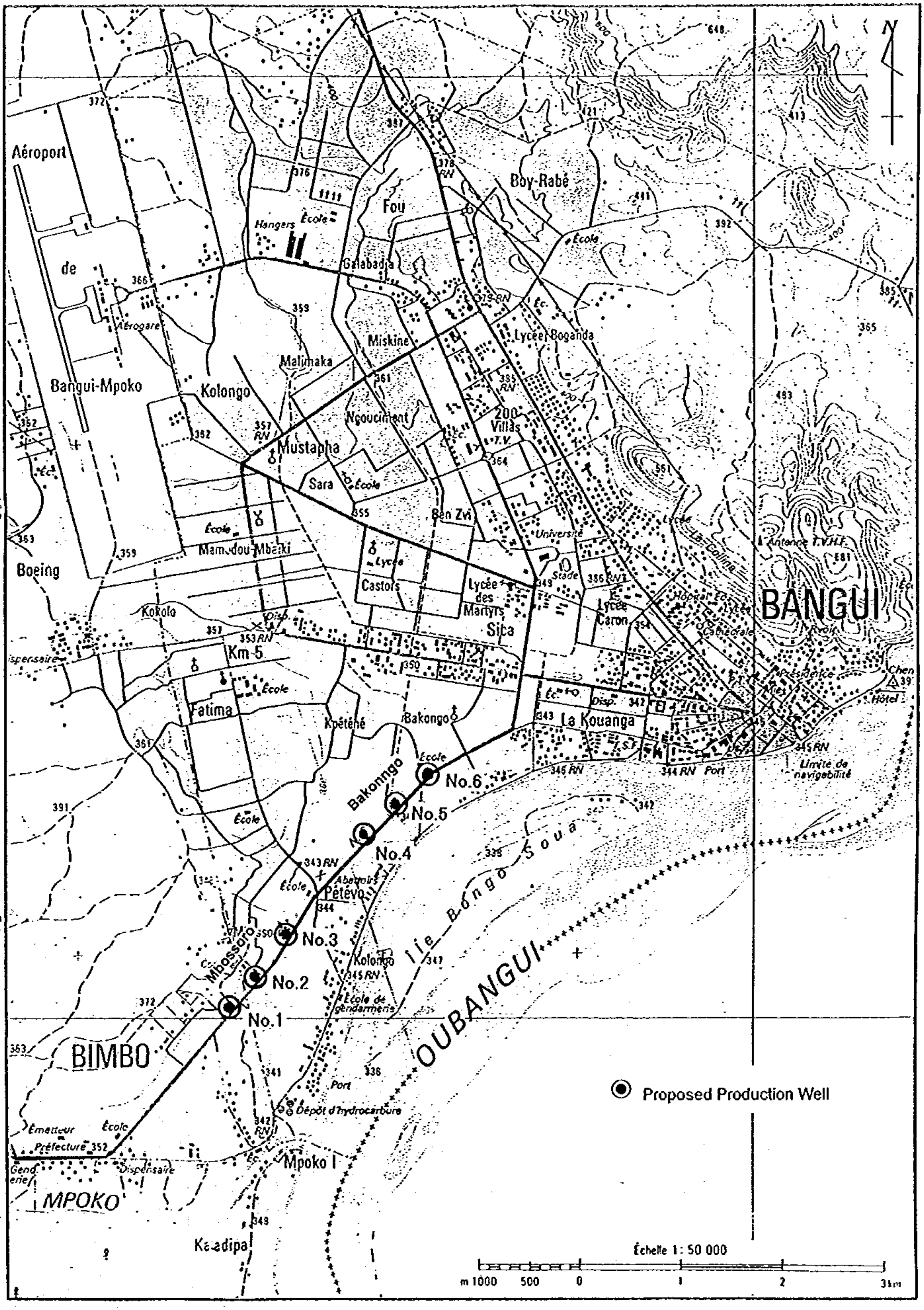


Fig.5.2.1 Location of Proposed Production Wells

(2) Design of the Production Wells

The well design and drilling specification are basically same with those of the exploratory wells drilled in this Study.

1) Depth of the Production Wells

The depth of the production wells is planned based on the hydrogeological profile E-E as shown in Fig.5.2.2. The production wells are scheduled to be completed after the 30m penetration to the bedrock aquifer.

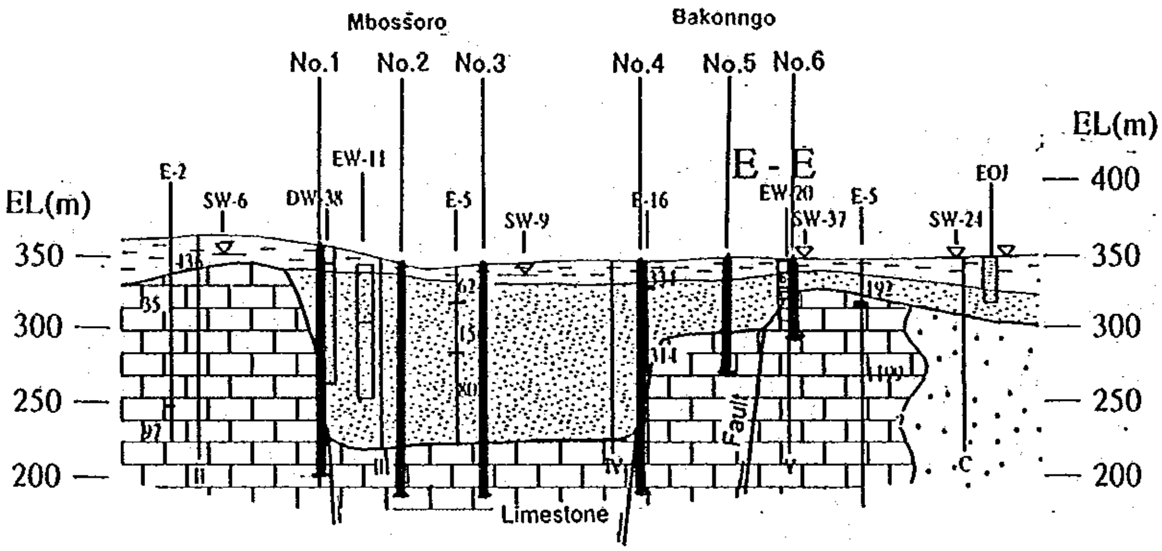


Fig.5.2.2 Hydrogeological Profile of the Proposed Well Field

The scheduled depth of the production wells is summarized in next table.

Table 5.2.1 Scheduled Depth of the Production Wells

Well No.	Overburden (laterite) (m)	Bedrock (limestone) (m)	Total (m)
No.1	120	30	150
No.2	120	30	150
No.3	120	30	150
No.4	120	30	150
No.5	50	30	80
No.6	20	30	50
Total (m)	550	180	730

2) Casing Program of the Production Wells

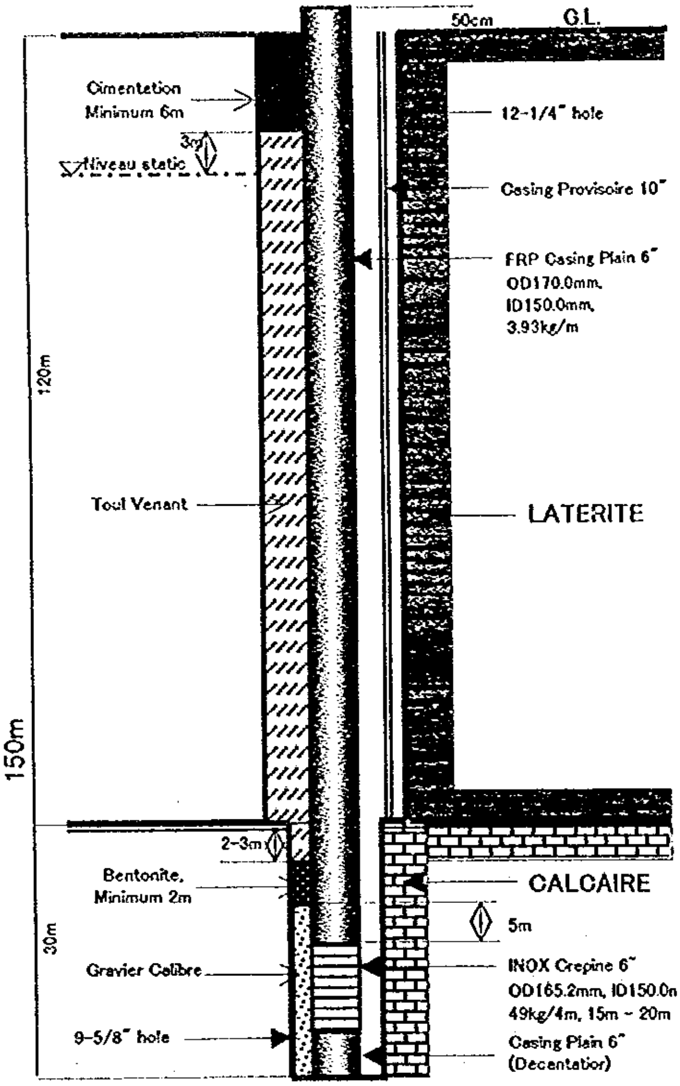
The minimum drilling diameter should be 9-5/8" and the completion diameter of the production wells is scheduled 6" with FRP casing and stainless steel screen (inox screen) as shown in Fig.5.2.3. The screen should be installed in the bedrock aquifer and upper overburden part (laterite) should be sealed with bentonite, clay and cement.

The quantity of the drilling work of the production wells is summarized as follows:

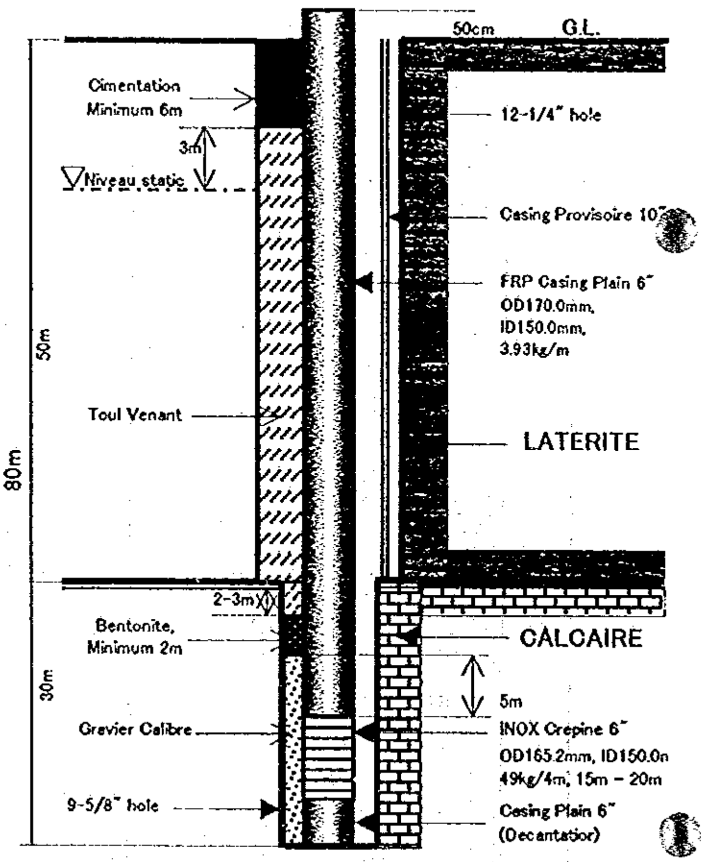
Table 5.2.2 Quantity of the Drilling Works of the Production Wells

	Item	Q'ty	Remarks
1	Drilling Work		
	(1) Mobilization, Demobilization	L.S.	
	(2) Shifting	5 times	
	(3) Drilling	–	
	1) 12-1/4" hole, 0-50m	270m	Laterite
	2) 12-1/4" hole, 50-100m	200m	Laterite
	3) 12-1/4" hole, 100-150m	80m	Laterite
	4) 9-5/8" hole, 0-50m	30m	Limestone
	5) 9-5/8" hole, 50-100m	30m	Limestone
	6) 9-5/8" hole, 100-150m	120m	Limestone
	(4) Casing Installation	–	
	1) FRP Casing	610m	FRP 6", O.D. 170.0mm, I.D. 150.0mm, 3.93kg/m
	2) Casing Installation Work	610m	
	3) Temporary Casing Installation	550m	Steel temporary casing, I.D. : around 10"
	(5) Screen Installation	–	
	1) INOX Screen	120m	INOX 6", O.D. 165.2mm, I.D. 150.0mm, 49kg/4m
	2) Screen Installation Work	120m	
	(6) Cementation	48m	8m x 6 holes
	(7) Clay Packing	520m	115m x 4 holes + 45m + 15m
	(8) Bentonite Packing	18m	3m x 6 holes
	(9) Gravel Packing	144m	24m x 6 holes
	(10) Well Development	6 wells	more than 24hours per one well
	(11) Well Logging (3 items)	730m	S.P., Resistivity, Caliper
	Total	–	
2	Pumping Test	–	
	(1) Field Pumping Test	–	
	1) Step Pumping Test	120 hours	One step is 4 hours, 5 steps per one test
	2) Continuous Pumping Test	288 hours	48 hours pumping per one test
	3) Recovery Test	144 hours	24 hours observation per one test
	Total	–	
3	Completion Report	3 copies	

Production Well No.1, No.2, No.3 and No.4



Production Well No.5



Production Well No.6

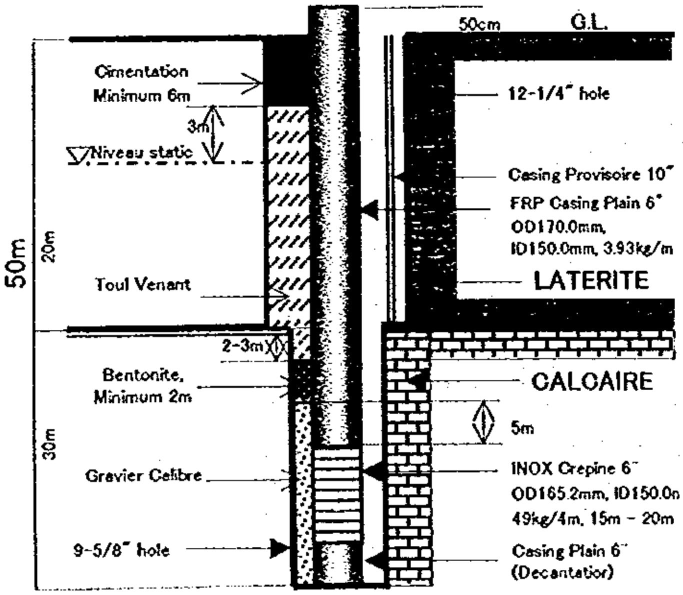


Fig.5.2.3 Casing Program of the Production Wells

5.2.2 Intake Facilities (Pipeline and Submersible Pump)

(1) Hydraulic Design

1) Friction Losses in Pipeline

Friction loss in pipeline is obtained by means of following Hazen-William's formula.

$$H=10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85} \times L$$

Where,

H: friction loss (m)

C: velocity coefficient

D: pipe diameter (m)

Q: discharge rate (m^3/sec)

L: distance (m)

2) Friction Losses in Various Valves, etc.

As friction losses in various valves such as check valve, sluice valve, etc., the rate of 0.2 is assumed.

(2) Friction Losses

1) Distance from the submersible pump to the beginning of conveyance pipe (H_1)

Based on above conditions, the friction losses have worked out as shown in Table 5.2.3.

Table 5.2.3 Friction Losses of Deepwell Facilities

Well No.	well Depth (m)	riser pipe length (m)	pipe	c	dia. (m)	discharge rate (m^3/sec)	hydraulic Gradient I	friction loss h1(m)	friction loss h2(m)	total friction loss H1=h1+h2 (m)	velocity (m/sec)
1	150.0	120.0	G.S.	110	0.075	0.0085	0.07896	9.48	0.20	9.68	1.92
2	150.0	120.0	G.S.	110	0.075	0.0085	0.07896	9.48	0.20	9.68	1.92
3	150.0	120.0	G.S.	110	0.075	0.0085	0.07896	9.48	0.20	9.68	1.92
4	150.0	120.0	G.S.	110	0.075	0.0085	0.07896	9.48	0.20	9.68	1.92
5	80.0	50.0	G.S.	110	0.075	0.0085	0.07896	3.95	0.20	4.15	1.92
6	50.0	30.0	G.S.	110	0.075	0.0085	0.07896	2.37	0.20	2.57	1.92

2) Distance from Deepwell Facilities to Junction Point of Conveyance Main (H_2)

H_2 is obtained by means of Hazen-William's formula as well as H_1, friction losses have worked out as shown in Table 5.2.4.

Table 5.2.4 Friction Losses from Deepwell to Junction

well No.	distance L (m)	pipe	dia. (m)	discharge rate (m^3/sec)	C	hydraulic gradient I	friction loss H2(m) L x I	velocity (m/sec)
1	0.0	DCI	0.100	0.0085	110	0.01945	0.00	1.08
2	5.0	DCI	0.100	0.0085	110	0.01945	0.10	1.08
3	5.0	DCI	0.100	0.0085	110	0.01945	0.10	1.08
4	5.0	DCI	0.100	0.0085	110	0.01945	0.10	1.08
5	5.0	DCI	0.100	0.0085	110	0.01945	0.10	1.08
6	5.0	DCI	0.100	0.0085	110	0.01945	0.10	1.08

3) Distance from Junction Point of Conveyance Main to Collection Chamber (H_3)

Friction losses from junction point of conveyance main to collection chamber (H_3) have worked out as well. The wellfield is composed of six deepwells, four deepwells will be basically operated, and the remaining two deepwells are stand-bys. For this reason, friction losses of H_3 in two cases have worked out as shown in Table 5.2.5, and 5.2.6.

Case 1 is the operation shift when Well No..3, 4, 5, and 6 are operated, and Case 2 is when Well No. 1, 2, 3, and 4.

Table 5.2.5 Friction Losses from Junction to Collection Chamber (Case1)

station	distance L(m)	accumulative distance(m)	pipe	dia. (m)	discharge rate (m^3/sec)	C	hydraulic gradient I	friction loss L x I H3(m)	accumulative friction loss (m)	velocity (m/sec)
Collection Chamber to Well No.1	12.0	12.0	DCI	0.20	0.0340	110	0.00866	0.10	0.10	1.08
Well No.1to No.2	534.0	546.0	DCI	0.20	0.0340	110	0.00866	4.62	4.73	1.08
Well No.2 to No.3	460.0	1006.0	DCI	0.20	0.0340	110	0.00866	3.98	8.71	1.08
Well No.3 to No.4	1080.0	2086.0	DCI	0.20	0.0255	110	0.00508	5.49	14.20	0.81
Well No.4 to No.5	605.0	2691.0	DCI	0.15	0.0170	110	0.00975	5.90	20.10	0.96
Well No.5 to No.6	455.0	3146.0	DCI	0.10	0.0085	110	0.01945	8.85	28.95	1.08

Table 5.2.6 Friction Losses from Junction to Collection Chamber (Case2)

station	distance L(m)	accumulative distance(m)	pipe	dia. (m)	flow rate (m^3/sec)	C	hydraulic gradient I	friction loss L x I H3(m)	accumulative friction loss (m)	velocity (m/sec)
Collection Chamber to Well No.1	12.0	12.0	DCI	0.20	0.0340	110	0.00866	0.10	0.10	1.08
Well No.1to No.2	534.0	546.0	DCI	0.20	0.0255	110	0.00509	2.72	2.82	0.81
Well No.2 to No.3	460.0	1006.0	DCI	0.20	0.0170	110	0.00240	1.10	3.92	0.54
Well No.3 to No.4	1080.0	2086.0	DCI	0.20	0.0085	110	0.00067	0.72	4.64	0.27

(3) Power Requirement of Submersible Pump

Power requirement of the submersible pump to be installed in this project is obtained by means of following equation (JIS: Japan Industrial Standards).

$$P=0.163 \times r \times Q \times H \times (1+a) \times 1/b$$

Where,

P: power required for pumping (kW)

r: specific weight of water (1.0 kg/liter)

Q: pumping rate (m^3/mini.)

H: Static head plus total friction loss (m)

a :allowance (15%)

b : pumping efficiency (0.65)

Power requirements have worked out and summarized in following Table 5.2.7.

Table 5.2.7 Power Requirement of Submersible Pumps

Well No.	water level difference (m)		pipeline friction loss (m)					submersible pump	
	HWL of collection chamber h1	groundwater level h2	$h1-h2=H_4$	H_1	H_2	H_3	total friction loss	discharge rate (m^3/mini.)	P (kW)
1	350.00	343.20	6.8	9.68	0.00	0.10	16.58	0.51	2.40
2	350.00	341.50	8.5	9.68	0.10	2.82	21.09	0.51	3.05
3	350.00	341.40	8.6	9.68	0.10	8.71	27.08	0.51	3.92
4	350.00	341.70	8.3	9.68	0.10	14.20	32.28	0.51	4.67
5	350.00	342.30	7.7	4.15	0.10	20.10	32.05	0.51	4.64
6	350.00	344.10	5.9	2.57	0.10	28.95	37.52	0.51	5.43

*30.56/60= 0.51

5.2.3 Transmission Facilities

(1) Collection Chamber

The storage volume of the collection chamber worked out at 122 m^3.

(2) Hydraulic Design on Transmission Pipeline

Friction loss in transmission pipeline is obtained with Hazen-William's formula, as well, and summarized in Table 5.2.8.

Table 5.2.8 Friction Loss from Transmission Pump to Service Reservoir

station	distance (m)	accumulative distance L(m)	pipe	dia. (m)	discharge rate (m^3/sec)	c	hydraulic gradient I	head loss L x I (m)	velocity (m/sec)	G.L (m)	hydraulic water level (m)	hydraulic head (m)
reservoir	0.0	0.0	DCI							425.0	425.0	
11+205	195.0	195.0	DCI	0.2	0.018	110	0.002622	0.51	0.57	405.9	425.5	19.6
10+820	385.0	580.0	DCI	0.2	0.018	110	0.002622	1.52	0.57	408.9	427.0	18.1
9+892.5	927.5	1507.5	DCI	0.2	0.018	110	0.002622	3.95	0.57	389.2	431.0	41.8
7+253.8	2638.7	4146.2	DCI	0.2	0.018	110	0.002622	10.87	0.57	351.4	441.9	90.5
6+620	633.8	4780.0	DCI	0.2	0.018	110	0.002622	12.53	0.57	347.0	454.4	107.4

(3) Power Requirement for Transmission Pump

Pump facility is composed of three sets of transmission pumps, normally two sets of boosting pumps is planned to be operated, and the remaining one pump is stand-by. Power requirement of transmission pump worked out as well as submersible motor pump, and summarized in Table 5.2.9.

Table 5.2.9 Power Requirement of Transmission Pump

water level difference (m)		friction loss (m)			transmission pump	
HWL of reservoir h1	pump level h2	$h1-h2=H_2$	H_1	total friction loss	discharge rate (m^3/mini.)	P (kW)
438.20	346.50	91.7	12.5	104.2	1.07	31.66

*2200x1.05x1/18x 1/2x1/60= 1.07

5.2.4 Distribution Facilities

(1) Service Reservoir

The required storage volume at the target years of 2005 and 2015 worked out as follows:

Table 5.2.10 Required Storage Volume

	Maximum Day Demand (m3/day)	12 hours of Maximum Day demand A(m^3)	Fire Demand B(m^3)	Required storage volume A+B (m^3)
2007	2,200	1,100	120	1,220
2015	6,182	3,091	300	3,391

In order to meet required storage volumes at the target years, two service reservoirs will be provided. Thus, the volume of the reservoir to be provided at the year of 2007 is more than 1,700m^3, which is equivalent to the half of 3,391 m^3.

(2) Pipeline

Branched distribution system is adopted in this project. Two cases of hydraulic design, namely ordinary case and fire fighting case, were carried out and summarized in Table 5.2.11 and 5.2.12.

Area No.	Peak Hour Demand
1	0.35
2	0.35
3	9.79
4	1.09
5	0.78
6	0.70
7	65.65
8	30.52
9	8.30
10	0.62
11	0.67
12	0.19
13	0.19
14	14.69
15	0.04
16	0.25
17	0.39
18	0.88
19	2.25

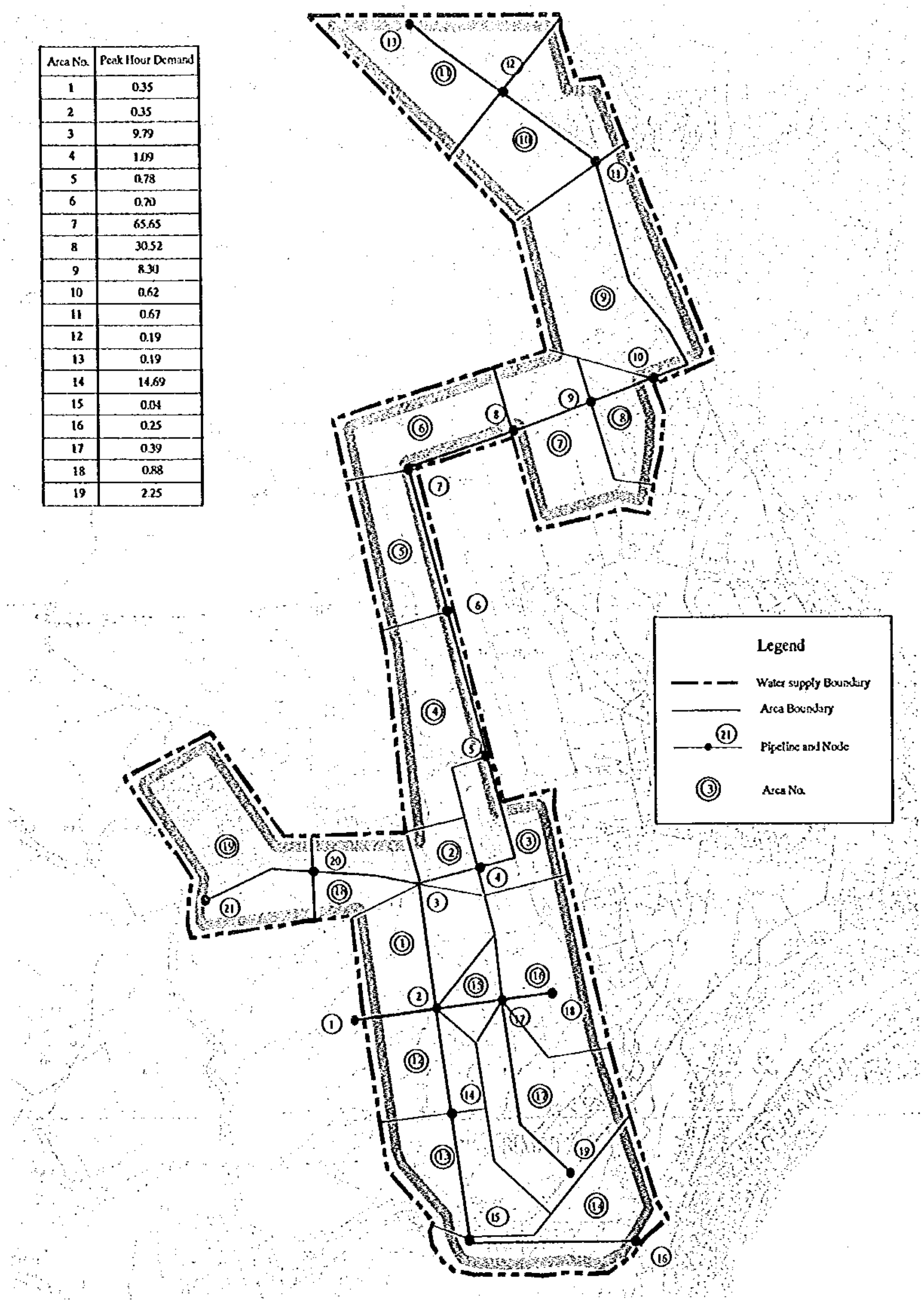


Figure 5.2.4 Area-wise Water Demand

Table 5.2.11 Design Calucuilation of Distribution Pipeline (Ordinary Case)

Node	water demand			distance L (m)	dia. (mm)	velocity (m/sec.)	hydraulic gradient I	friction loss L x I (m)	dynamic water level (m)	ground elevation (m)	hydraulic head (m)	static head (m)
	peak hour demand (m^3/hour.)	accumulative demand (m^3/hour)	accumulative demand (liters/sec.)									
1	0.00								438.20	436.0		
2	0.00	183.35	50.931	750	350	0.53	0.00120	0.90	437.30	410.0	27.3	26.0
3	0.47	162.34	45.094	1,650	350	0.47	0.00096	1.58	435.72	365.0	70.7	71.0
4	0.47	157.72	43.811	900	350	0.46	0.00091	0.82	434.90	365.0	69.9	71.0
5	13.00	157.25	43.681	1,850	350	0.45	0.00090	1.67	433.22	365.0	68.2	71.0
6	1.45	144.25	40.069	2,050	300	0.57	0.00163	3.35	429.88	365.0	64.9	71.0
7	1.05	142.80	39.667	2,000	300	0.56	0.00160	3.21	426.67	365.0	61.7	71.0
8	0.93	141.75	39.375	1,400	300	0.56	0.00158	2.21	424.46	372.0	52.5	64.0
9	87.45	140.82	39.117	1,300	300	0.55	0.00156	2.03	422.43	385.0	37.4	51.0
10	40.65	53.37	14.825	1,050	300	0.21	0.00026	0.27	422.15	401.0	21.2	35.0
11	11.01	12.72	3.533	3,200	300	0.05	0.00002	0.06	422.09	412.0	10.1	24.0
12	0.82	1.71	0.475	1,600	181	0.02	0.00001	0.01	422.09	400.0	22.1	36.0
13	0.89	0.89	0.247	1,300	127	0.02	0.00001	0.01	422.08	369.0	53.1	67.0
2									437.30	410.0	27.3	26.0
14	0.26	20.09	5.581	1,600	145	0.34	0.00147	2.35	434.95	382.0	52.9	54.0
15	0.25	19.83	5.508	1,750	145	0.33	0.00143	2.51	432.44	365.0	67.4	71.0
16	19.58	19.58	5.439	2,000	145	0.33	0.00140	2.80	429.64	355.0	74.6	81.0
2									437.30	410.0	27.3	26.0
17	0.06	0.92	0.256	900	45	0.16	0.00146	1.31	435.99	388.0	48.0	48.0
18	0.34	0.34	0.094	1,200	45	0.06	0.00023	0.28	435.71	365.0	70.7	71.0
17									435.99	388.0	48.0	48.0
19	0.52	0.52	0.144	2,500	45	0.09	0.00051	1.27	434.72	365.0	69.7	71.0
3									435.72	365.0		
20	1.17	4.15	1.153	1,500	45	0.72	0.02369	35.53	400.19	355.0	45.2	81.0
21	2.98	2.98	0.828	1,600	45	0.52	0.01284	20.54	379.65	352.0	27.6	84.0

Table 5.2.12 Design Caluculation of Distribution Pipeline (Fire Fighting Case)

Node	water demand			distance L (m)	dia. (mm)	velocity (m/sec.)	hydraulic gradient I	friction loss L x I (m)	dynamic water level (m)	ground elevation (m)	hydraulic head (m)	static head (m)
	peak hour demand (m^3/hour.)	accumulative demand (m^3/hour)	accumulative demand (liters/sec.)									
1	0.00								438.20	436.0		
2	0.00	211.67	58.797	750	350	0.61	0.00157	1.18	437.02	410.0	27.0	26.0
3	0.23	141.16	39.211	1,650	350	0.41	0.00074	1.22	435.80	365.0	70.8	71.0
4	0.23	138.85	38.569	900	350	0.40	0.00072	0.65	435.16	365.0	70.2	71.0
5	6.50	138.62	38.506	1,850	350	0.40	0.00072	1.32	433.83	365.0	68.8	71.0
6	0.72	132.12	36.700	2,050	300	0.52	0.00139	2.85	430.99	365.0	66.0	71.0
7	0.52	131.40	36.500	2,000	300	0.52	0.00137	2.75	428.24	365.0	63.2	71.0
8	0.46	130.88	36.356	1,400	300	0.51	0.00136	1.91	426.33	372.0	54.3	64.0
9	43.72	130.42	36.228	1,300	300	0.51	0.00136	1.76	424.56	385.0	39.6	51.0
10	20.33	86.70	24.083	1,050	300	0.34	0.00064	0.67	423.90	401.0	22.9	35.0
11	5.51	66.37	18.436	3,200	300	0.26	0.00039	1.24	422.65	412.0	10.7	24.0
12	0.41	60.86	16.906	1,600	181	0.66	0.00388	6.20	416.45	400.0	16.5	36.0
13	60.45	60.45	16.792	1,300	127	1.33	0.02149	27.94	388.51	369.0	19.5	67.0
2									437.02	410.0	27.0	26.0
14	0.13	70.05	19.458	1,600	145	1.18	0.01480	23.69	413.34	382.0	31.3	54.0
15	0.13	69.92	19.422	1,750	145	1.18	0.01475	25.82	387.52	365.0	22.5	71.0
16	69.79	69.79	19.386	2,000	145	1.17	0.01470	29.41	358.11	355.0	3.1	81.0
2									437.02	410.0	27.0	26.0
17	0.03	0.46	0.128	900	45	0.08	0.00040	0.36	436.66	388.0	48.7	48.0
18	0.17	0.17	0.047	1,200	45	0.03	0.00006	0.08	436.58	365.0	71.6	71.0
17									436.66	388.0	48.7	48.0
19	0.26	0.26	0.072	2,500	45	0.05	0.00014	0.35	436.31	365.0	71.3	71.0
3									435.80	365.0		
20	0.59	2.08	0.578	1,500	45	0.36	0.00660	9.90	425.90	355.0	70.9	81.0
21	1.49	1.49	0.414	1,600	45	0.26	0.00356	5.70	420.21	352.0	68.2	84.0

5.3 Equipment for Operation and Maintenance

The following equipment shall be required for the DGH in order to operate and manage the project's implementation. Procurement of these equipment shall be included in the scope of the project.

(1)Vehicles: 4WD Pick-up type -3 No.

There is a high requirement of vehicles for supervision of the construction and operation and management of the project. There is few vehicles remained in the DGH due to destruction by the mutiny occurred in 1996 to 1997.

(2)Radio communication set: HF 125 W -1 set. (Station 1 No. + Transceiver 10 No.)

The public telephone service is available in the study area. A few chiefs of the DGH carry cellular telephones with them. However, it is impossible to give more phones to the officers due to its utility cost. Therefore a radio communication system shall be most effective to communicate among the staff of the DGH.

(3)Computer, Printer and Software: Personal desk-top type 1 set

It is recommended to supervise and analyze the following data by computer.

Groundwater elevation record, Groundwater quality record, Accounting record, Financial record, Stock of materials, etc.

(4)Water Analysis Equipment and reagents

Water analysis equipment shall be necessary for monitoring of water quality of the groundwater to be conducted by the DGH. Main items of the equipment were supplied for conducting this Master Plan study by JICA. Therefore, spare parts or reagents should be mainly supplied after checking performance of each equipment.

Chapter 6 OPERATION AND MAINTENANCE PLAN

6.1 Background to be Considered in Formulating the Operation and maintenance Plan

Drinking water supply is an essential public service that supports social welfare of the people. The service should be financially self-supporting and sustained with good condition in order for all the consumers to be provided with sufficient drinking water.

In the City of Bangui, drinking water supply service is currently provided by a private company, SODECA, on the basis of the contract with the CAR Government. SODECA works as an operation body of water supply facilities that are built and owned by the state-owned water supply corporation (SNE), under the above contract.

The project subject to the current feasibility study plans to supply drinking water of around 2,200m^3 per day starting in 2004. The project aims at supplying drinking water to the peoples in danger of health due to limited access to safe water. It is of the most importance to build a reliable maintenance and operation system from technical, financial, and managerial viewpoints for the sake of these peoples.

Currently, SNE is in the process of organizational reform under the leadership of the Ministry of Mines and Energy (DGH), which is responsible for policies, plans, and development of water supply system in the CAR. This reform is a good opportunity to reexamine the current operation and maintenance system of water supply in the Central African Republic. The institutional feasibility of the project highly depends on how the reliable maintenance and operation system can be built under on-going organizational reform. The operation and maintenance plan of the project should be formulated in due consideration of the above institutional conditions in the Central African Republic.

In accordance with the above recognition of the background, the operation and maintenance plan is described below by the following components;

- Section 6.2 Basic Principles of Operation and Maintenance describes 4 principles of operation and maintenance of water supply facilities as a public service responding to the basic human needs,

- Section 6.3 Organizational Arrangement for Project Implementation firstly proposes the organization to be established for construction of groundwater supply facilities with its detailed tasks and human resources allocation. Subsequently, it proposes the organizational arrangement for operation and maintenance of the facilities after the construction. In this part, commissioning of O/M works to private sector is proposed on the basis of a comparative evaluation of organizational arrangement options. The role of DGH is proposed to be limited to supervising the private contractor. Thirdly, the organizational arrangement of DGH for supervising is recommended, which is followed by proposed tasks and human resources allocation. Fourthly, commissioning procedure, commissioned works, and supervising roles of the government is specifically described with the training needs of DGH to carry out duties.
- Section 6.4 Monitoring Plan provides technical details of groundwater level and quality monitoring in the project.
- Section 6.5 Basic Policies for Operation and Management of Public Faucets (KIOSKs), discusses the needs of present operation and management system of KIOSKS by individual entrepreneurs and recommends some improvement measures. It also discusses the possibility of experimenting a community-based management as an alternative of kiosk operation

6.2 Basic Principles of Operation and Maintenance

As a public service responding to the Basic Human Needs (BHN), the operation and maintenance plan should be formulated on the basis of the principles given below:

(1)Safety
Drinking water is essential for people to live his human life. It is the most importance for the drinking water supply service to maintain water quantity and quality in accordance with the determined criteria (e.g. drinking water quality standard by the World Health Organization). Regular inspection of the groundwater level and quality is a key part of operation and maintenance in the current project.

(2)Sustainability
To secure constant supply of drinking water, water supply service has to be sustained in good condition despite any predictable disturbance (e.g. seasonal flux of rainfall, calamity, etc.). Proper facility maintenance / operation and business management (inc.

human resource management, accounting, etc.) are fundamental factors of maintaining and sustaining the level of water supply services.

(3)Speed

Quick response is an essential part of facility operation and maintenance, especially in the public service such as drinking water supply. In case malfunction of the facility or water leakage from the distribution pipe is detected, repair works have to be done as soon as possible so as to minimize the inconvenience of consumers and loss of project benefit.

(4)Self-supporting

Drinking water supply project has to be self-supporting, meaning that the project be managed by collecting the water bill from subscribers. Unit price of drinking water has to be determined on the basis of proper calculation of unit cost of water under the efficient management of water supply services. It is also important that the level of services should be maintained in accordance with the principle of public service to contribute to the social welfare of the people. It has to be kept in mind that project profitability and maintaining the levels of services be balanced, and one of which never be sacrificed for another.

6.3 Organizational Arrangement for Project Implementation

Assuming that the construction of new drinking water supply facilities is carried out on grant aid basis, Government of the Central African Republic, need to bear the following undertakings as the recipient country:

- Site preparation for the facilities to be constructed, e.g. securing the land, obtaining public consensus regarding the use of land for facilities construction, etc.),
- Providing necessary utility services connection to the site, including electricity, telecommunication, and so forth,
- Securing the smooth custom clearance and land transportation of the machinery and materials for the construction, including exemption of import duties and relevant taxation,
- Exemption of taxes and other relevant charges for the enterprises and entities to be involved in the project execution under the contract with the CAR Government,
- Assignment of counterpart expert personnel for the transfer of operation and maintenance technologies and practices as well as for on-site confirmation of the

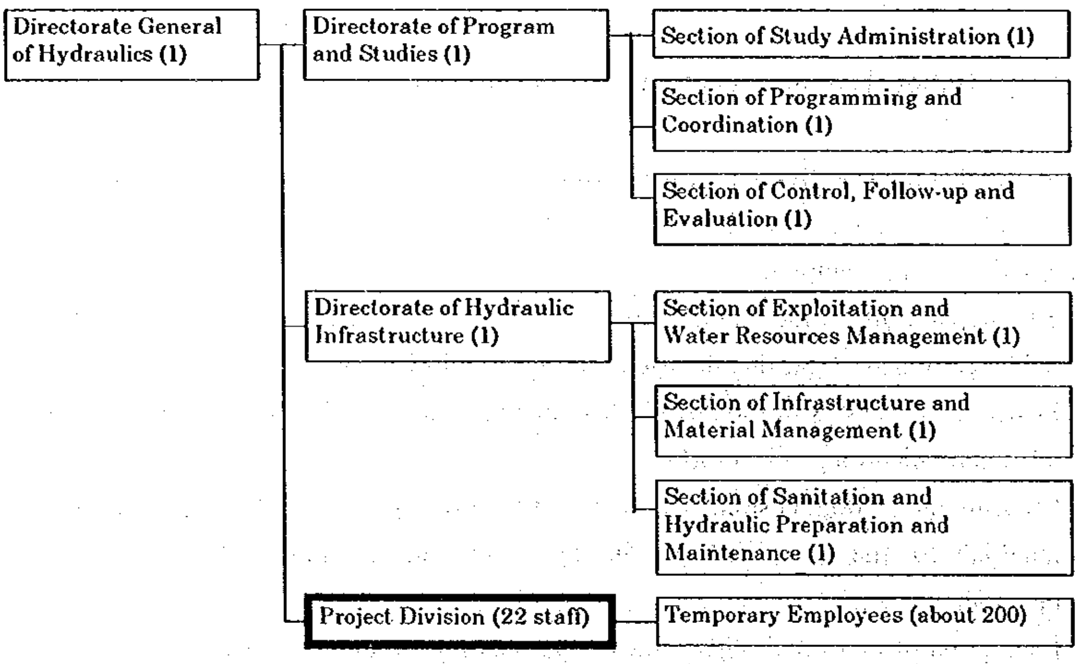
construction works,

- Catering salaries of counterpart staff assigned for project implementation and expenses necessary for their activities,
- proper and sustainable operation and maintenance of the constructed facilities, and
- other necessary undertakings.

The organizational arrangement for implementation of the project should be made in due consideration of the above undertakings of CAR. The proposed organization should have enough technical, managerial, and financial capacity of bearing them.

6.3.1 Organizational Arrangement for Study and Construction Stage

To cover the undertakings of the Government of Central African Republic for the construction of new drinking water facilities, the following organizational arrangement is proposed. Figure 6.3.1 indicates the present organization chart of DGH. The organization responsible for executing the undertakings of CAR during the construction period is to be built in the Project Division.



*Figures in brackets indicate the existing number of staff.

Figure 6.3.1 Present Organization Chart of DGH

Detailed organizational diagram and human resources allocation are given in Figure 6.3.2 and Table 6.3.1 below.

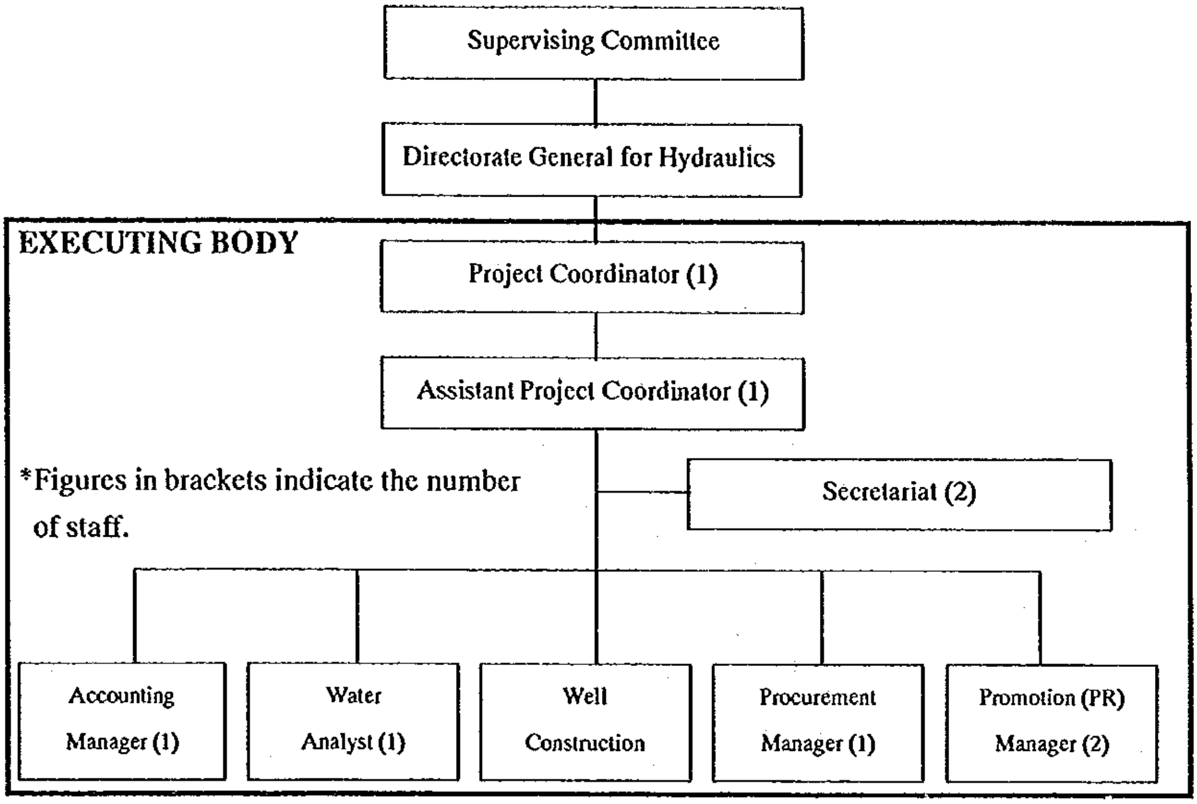


Figure 6.3.2 Proposed Organization during the Construction Period

Table6.3.1 Number of Staff in the Organization during the Construction Period

Position	Number of Staff
Project Coordinator	1
Assistant Project Coordinator	1
Secretariat	2
Accounting Manager	1
Water Analyst	1
Well Construction Supervisor	1
Procurement Manager	1
Promotion (PR) Manager	2
Total	10

The proposed tasks and resource persons in the organization above are given in Table 6.3.2 on next page.

Table 6.3.2 Proposed Tasks and resource persons in the proposed organization

Personnel	Tasks	Resource Persons
Project Coordinator	- Managing overall coordination for implementation of construction works. - Managing supervision of overall construction works - Preparing a report on supervising activities to be submitted to the Supervising Committee. - Informing the Committee of the progress of construction works and supervision results.	-DGH
Assistant Project Coordinator	- Supporting the Coordinator in executing overall works of the project - Acting as the deputy in the absence of the Coordinator and informing him all the deputized works when he returns. - Assisting the Coordinator in preparing reports and conducting all the preparatory works for meetings.	-DGH
Secretariat	- Supervising and managing all secretarial works	-DGH
Accounting Manager	- Overall accounting and bookkeeping of the organization	-DGH
Water Analyst	- Confirming and supervising the quality of water in compliance with the prevailing drinking water standard - Reporting regularly to the Coordinator of his activities	-DGH
Well Construction Supervisor	- Confirming and supervising construction works on site with the Japanese experts	-DGH
Procurement Manager	- Necessary arrangement for procurement of machinery and materials for construction works	-DGH
Promotion (PR) Manager	- Conduct necessary promotion and PR activities for dissemination of the project - Educating the community for community-based operation and maintenance of Kiosks - Operation and maintenance training of candidate kiosk owners - Health and sanitary education of the community to cultivate awareness of using safe drinking water	-DGH -Ministry of Health -NGO

The supervising committee is to be organized by the representatives from the ministries, government institutions, and other entities relating to the project, which may include Ministry of Mines and Energy, DGH, Ministry of Health, and so forth. The Committee has the primary responsibility for supervising the construction works and carrying out the undertakings of the Government of Central African Republic.

DGH is working as the implementing organization of the project in the CAR. DGH will dispatch necessary resource persons to the executing body to totally supervise and implement the project.

DGH have enough experience in groundwater supply facility construction in several districts. Some of the staff members who were directly involved in well construction works, have sufficient experience and know-how in selection and supervision of consultants and contractors. In addition, they also have dealt with 3 projects of Japanese grant aid and completed them successfully.

Therefore, as long as the existing human resources of DGH are properly appointed to the project, the organization above has enough capacity of implementing the construction works of the project.

6.3.2 Organizational Arrangement for Operation and Maintenance Stage

(1) Examination on Possible Options of Establishing the Operation and Maintenance Body

The JICA Study Team defines that the principal role of DGH for operation and maintenance of the project is to supervise operation and maintenance of the groundwater supply facilities while actual facility operation and maintenance are commissioned by contract to the private sector.

There are mainly two ways of organizational arrangement are assumed for operation and maintenance of the project; one is to establish a new operation and maintenance body by the CAR government while another is to commission the operation and maintenance works to private sector by contract, similar to the present operation and maintenance system run by SODECA.

To determine better way of organizational arrangement of operation and maintenance, the JICA Study Team made a comparative evaluation between the above two organizational arrangement schemes from the viewpoints of human resources allocation, technical, managerial, and financial capacity. Table 6.3.3 shows the results of evaluation.

Table 6.3.3 Comparative Evaluation of DGH's Organizational Arrangement Options for Operation and Maintenance of the Project

Evaluation Items	Establishment of a new O/M body by the CAR Government (DGH)	Commissioning the O/M to private sector by contract
Human Resources Allocation (Staffing) -Technical experts: 17 -Administration staff: 3 -Metering/bill collectors: 10 -Financial/Accountant: 2	-Very limited experience in O/M of the water supply system. -It is necessary to educate and train experts in the limited short-term. -Outsourcing may be needed.	**-The roles of CAR Government is focused on selection and supervision of private O/M contractor. -No need for major organizational reform or development.**
Technical Capacity		
1)Facility Operation (electromechanical technology)	-Because DGH is technology-oriented organization, it has enough capacity of dealing with facility operation.	-Private O/M contractors have enough capacity and experience in facility operation
2)Maintenance and Repair Works	Ditto	Ditto
3)Monitoring and Analysis (Groundwater level and quality)	-Some training may be needed, but enough capacity to deal with.	Ditto
Managerial Capacity		
1)Administration and Management	-Very limited experience and know-how in day-to-day management and administration of the organization.	**-Private O/M contractors usually have enough experience in administration and management**
2)Financial Management	-Because accounting method is totally different between government budget and private sector accounting, it is necessary to train staff or to recruit experts.	**-Private O/M contractors usually conduct strict financial management and have enough capacity and experience in financial management.**
3)Consumer Services Management	-Awareness of consumer services need be raised and cultivated by education and training	**-Private O/M contractors are well aware of the quality of consumer services because it is the key of business profit.**
Financial Capacity	-Due to limited budget and access to financial institutions, the financial capacity of DGH is weak.	**-Private O/M contractors have more financial capacity as well as more access to the financial institutions.**
Comprehensive Evaluation	-A lot of technical and financial difficulties are anticipated in establishing a new organization by the Government in the limited short-term. -No certainty whether the established organization works as expected because there is only limited experience in O/M of the system before.	**-Private O/M contractors usually have several experience in the above tasks. -Their capacity can be estimated from their former experience. -Private sector participation in public utility services is in compliance with the national structural adjustment policies.**

*The columns filled out with bold letters mean advantages of the commissioning of O/M to private sector by contract.

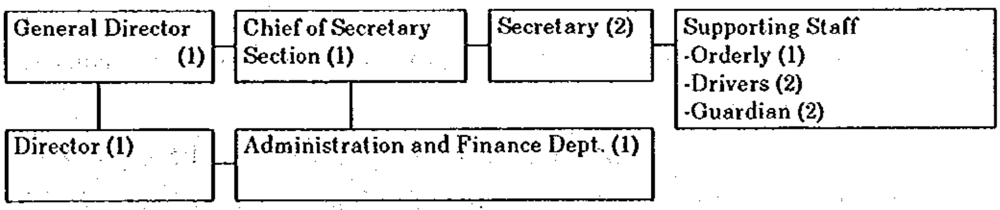
As indicated in the table above, commissioning of O/M to private sector by contract has a lot of advantages in comparison with the establishment of a new O/M body by the Government (DGH), while establishment of a new O/M body by the CAR Government within this short-term will face a lot of difficulties. In addition, private sector participation in public utility services is in compliance with the national structural adjustment policies. Therefore, the JICA Study Team decided to select O/M by commissioning to private sector.

(2) Organizational Arrangement for Conducting the Supervising Roles of the Government

The most important task of DGH relating to operation and maintenance of the facilities is to supervise operation and maintenance works carried out by the O/M contractor. DGH has to supervise whether operation and maintenance of the facilities are conducted in accordance with the principles (safety, sustainability, speed, and self-supporting) as described in 6.2 of this chapter. To do this, information and data on the conditions of operation and maintenance has to be regularly provided to DGH in the form of a report (preferably every month). DGH may need to prepare a checklist or criteria for supervising and evaluating the operation and maintenance works of O/M contractor. To secure the supervision process above, duties and responsibilities of DGH and the O/M body have to be provided in the contract as specifically as possible (e.g. what types of reports should be submitted by the O/M body to DGH monthly, quarterly, annually, what kind of data and information should be provided in the reports, etc.).

To accomplish the above tasks, supervising capacity of DGH need to be reinforced institutionally as well as individually. Until May 1999, SNE was in charge of supervising operation and maintenance of the water supply services run by SODECA. Therefore, SNE's experience should be utilized at its maximum in the organizational arrangement for conducting supervising roles of DGH.

The organizational structure and manpower of SNE is as given in the Figures 6.3.3.



Figures in brackets indicate the number of staff.

Figure 6.3.3 Organization Structure of SNE

Because there is no definitive function of supervising the O/M contractor in the current organization of DGH, such function need be defined in the new reformed DGH. The Figure 6.3.4 proposes the reformed organizational structure of DGH that reinforces the function of contractor management and supervision.

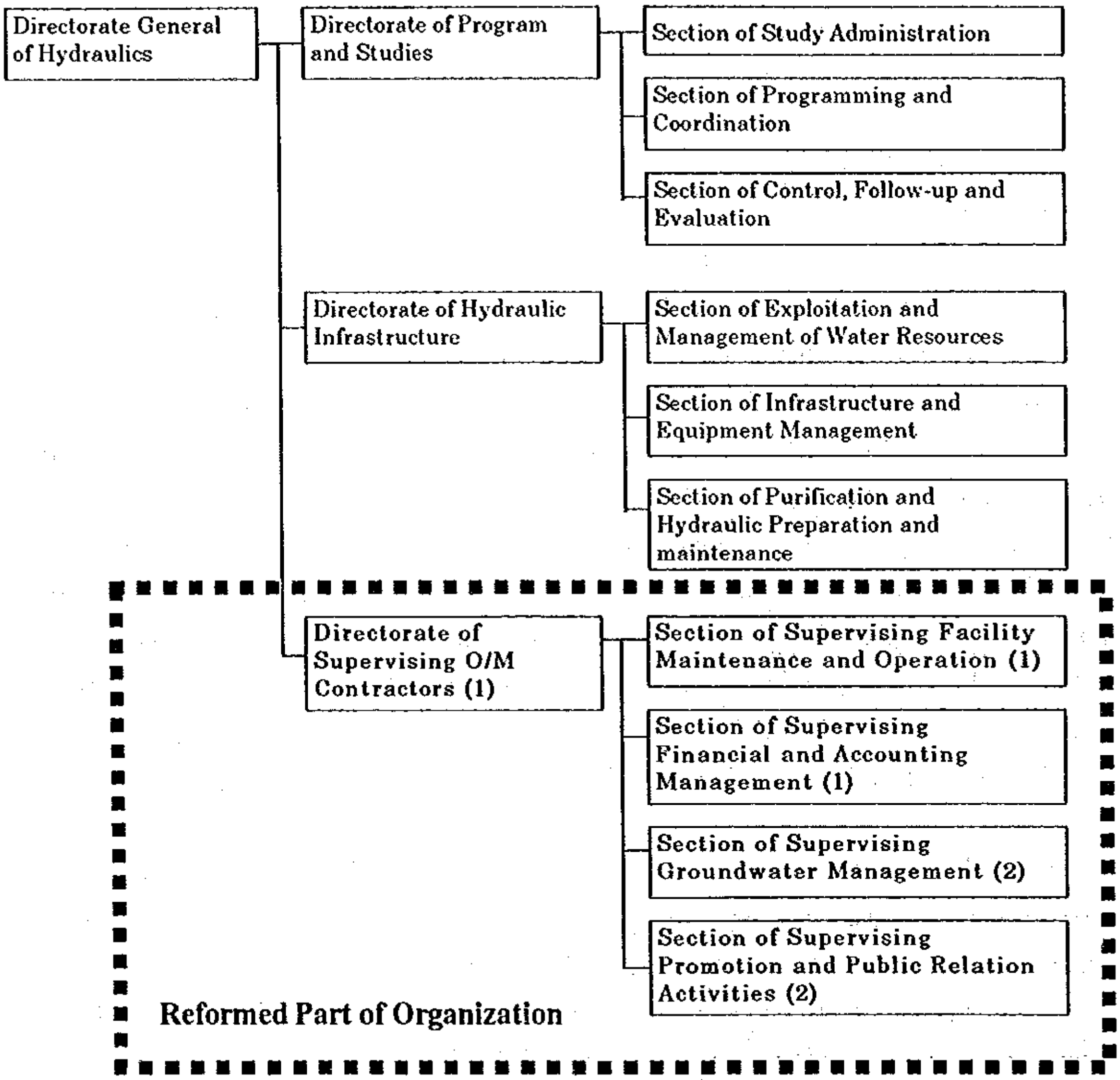


Figure 6.3.4 Proposed Organizational Reform of DGH

(3) Proposed Personnel Composition and Tasks of the Directorate of Supervising O/M Contractors

The Directorate of Supervising O/M Contractors (DSOMC) is to be organized by relocating the human resources from the organization established for facilities construction of the project. The proposed Personnel composition and tasks of DSOMC are given in Table 6.3.4 on next page.

Table 6.3.4 Proposed Personnel Composition and Tasks of DSOMC

Position/Section	Nos.	Tasks
Director	1	- Administrative responsibility for the Directorate - Formulation of policies, plans and programs of supervising O/M contractors
Section of Supervising Facilities Maintenance and Operation	1	- Examining and verifying facilities maintenance and operation records
Section of Supervising Financial and Accounting Management	1	- Auditing the O/M body's account - Examining and verifying billing related records
Section of Supervising Groundwater Management	2	- Examining and verifying groundwater level monitoring records - Examining and verifying water quality monitoring records - Cross-checking the amount of water supply and consumption (leakage identification)
Section of Supervising Promotion and Public Relation Activities	2	- Examining and verifying marketing and PR activities records - Examining and verifying customer management records. - Education and training of community-based and individual kiosk operators (See 6.5 for details)

To properly accomplish the above tasks, necessary budget should be annually allocated to the new directorate by the CAR Government. The facilities concession fee, which is to be annually paid by the private contractor, can be utilized for financial resources of the above budget.

(4) Commissioning Procedure, Commissioned Works, and Supervising Roles of the Government

1) Commissioning Procedure

The JICA Study Team recommends that the commissioning of operation and maintenance works be carried out by international tender. Although the drinking water supply system in Bangui is currently operated by SODECA as a sole agent, it will be preferable if there are other private contractors to compete with SODECA, which may increase the efficiency of O/M as well as quality of services. Taking into account such possibility, selection of a private contractor is suggested to be made by international tender.

To select a private contractor by international tender, DGH need to take the following steps;

a) Preparation of the tender document

To have an international tender for operation and maintenance of the project, DGH need to prepare a tender document. The tender document may specify the details of facilities, guidelines for facilities maintenance and operation (e.g. unit price of water, responsibilities and duties of the operation and maintenance body, etc.) and other information needed for clarification of the project.

b) Selection of the contractor by opening a bidding

Based on the tender document prepared above, an international tender is to be held by DGH to select a private contractor of the facilities. DGH has to carefully evaluate the proposals submitted by the candidate contractors from technical, managerial, and financial viewpoints.

DGH have enough experience and know-how of handling the above tendering procedure. The organization to be established for facilities construction may take a lead in conducting this procedure.

2) Commissioned O/M Works

In principle, all operation and maintenance works of facilities are commissioned to the selected private contractor. The contractor will conduct all the operation and maintenance works including metering and bill collection. The collected bills are the income of the contractor, some of which will be paid to DGH probably as facility leasing charges. Major Commissioned O/M works to the private contractor are:

a) Facilities Maintenance and Repair Works (groundwater pumping facilities, distribution pipes, electromechanic device, etc.)
b) Operation of Facilities (Operation, operation data processing and management of facilities)
c) Groundwater level and quality management (monitoring and analysis)
d) Metering, billing, and bill collection
e) Accounting and Financial Management (Expenditure control, bookkeeping, preparation of the company's financial reports –B/S, P/L, etc.)
f) Customer management (customer information processing and management, customer's complaint procedure, etc.)

g) Marketing and promotion activities (Water demand analysis, PR activities)
h) Other related activities

3) Supervising Roles of the Government

The following operation and maintenance works of the contractor may be subject to supervision and examination by DGH.

- facility maintenance and repair works records
- facilities operation records
- groundwater level and quality monitoring records
- metering, billing, and bill collection records
- the contractor's financial and accounting reports (B/S, P/L, etc.)
- customer management records
- marketing and promotion activities (water demand analysis, PR activities)

Since groundwater level and quality monitoring method is different from the case of surface water monitoring, details of monitoring plan is explained in the next section 6.4.

(5) DGH's Supervising Capacity and Training Needs

The present human resources of DGH have enough capacity of supervising the private contractors from technical and engineering viewpoints. It means that DGH have appropriate human resources to be appointed to technical and engineering sections in DSOMC i.e. Section of Supervising Facilities Maintenance and Operation as well as Section of Supervising Groundwater Management.

Meanwhile, DGH's capacity of supervising financial and accounting management as well as promoting and public relations activities is relatively limited. It will be enhanced through education and training by some well-experienced institutions and trainers.

Such education and training can be provided through various training programs of bilateral as well as multilateral aid agencies. The NGO's experience and capacity of community development and education can be utilized for capacity building of DGH in promoting and disseminating the use of safe groundwater, as well as in involving community for the management and operation of public faucets (kiosks), which is proposed as an option in this project later.

6.4 Monitoring Plan

The purpose of the groundwater monitoring is to make the groundwater development be sustainable by observing the groundwater level and quality. In case that the regional draw-down of the groundwater level will become greater than the expected value or the discharged groundwater quality will get worse, the countermeasures, which are for instance the reduction of the discharge amount or moving the well fields to other areas, must be done immediately.

Since the groundwater recharge area is located in the urban area under the development, both of the quantity and quality of the groundwater is anticipated to change according to the urban development in future. Namely, the recharge amount to the groundwater will decrease because of the non-infiltration area such as roads and buildings will expand as a result of urban development. It is also supposed that the groundwater quality will deteriorate by the increase of the infiltration amount of the sewage drained from the household and factories which will be increasing every year.

As the groundwater development in the urban area has disadvantage in terms of both of quantity and quality as stated above, the groundwater monitoring should be closely continued on the quantity (groundwater level) and quality of the groundwater.

(1) Monitoring Plan of the Groundwater Level

As discussed in chapter 3, the groundwater level of the traditional shallow wells will decrease by the deep groundwater development and the development amount is proposed to be restricted less than 0.8MCM/year so as not to make the existing traditional shallow wells be dried up. However, the proposed groundwater development amount in this Study is estimated through the numerical examination based on the limited study results and the recharge amount is anticipated to decrease in future as mentioned above, the groundwater level monitoring is indispensable for the sustainable groundwater development.

The groundwater level monitoring should be conducted not only on the deep wells but also on the traditional shallow wells. The monitoring wells of the groundwater level and monitoring frequency are proposed in Table 6.4.1.

Hearing survey concerning the groundwater level of the shallow wells and existence of dried wells should also be done in the vicinity of the monitoring wells simultaneously.

Table 6.4.1 Proposed Monitoring Wells for the Groundwater Level Observation

Well Type	Well No.	Monitoring Frequency, Method	Location, Coordinates
Deep Well	EW-3	Everyday by automatic recorder	Nzongo, N4° 22′ 20″ ,E18° 29′ 35″
	EW-4	-ditto-	Sakai East, N4° 24′ 28″ ,E18° 29′ 20″
	EW-9	-ditto-	Pelemongo, N4° 21′ 58″ ,E18° 31′ 28″
	EW-12	-ditto-	Plateau, N4° 20′ 25″ ,E18° 31′ 25″
	DW-18	Once a month by dip meter	Kpetencl, N4° 24′ 19″ ,E18° 34′ 04″
Traditional Shallow Well	SW-10	Once a month by dip meter	Nzangognan, N4° 21′ 18″ ,E18° 32′ 15″
	SW-24	-ditto-	Bakongo, N4° 21′ 47″ ,E18° 33′ 42″
	SW-29	-ditto-	Ramandow, N4° 23′ 10″ ,E18° 32′ 13″
	SW-30	-ditto-	Castors, N4° 23′ 20″ ,E18° 33′ 13″
	SW-31	-ditto-	Galabadja3, N4° 23′ 59″ ,E18° 32′ 33″
	SW-37	-ditto-	Bakongo, N4° 21′ 25″ ,E18° 33′ 12″
	SW-45	-ditto-	Boeing, N4° 22′ 53″ ,E18° 31′ 14″
	SW-47	-ditto-	Boeing, N4° 24′ 15″ ,E18° 30′ 51″

The results of the groundwater monitoring should be summarized in the table and groundwater fluctuation curves. The location of the proposed monitoring wells listed above is shown in Fig.6.4.1.

(2) Monitoring Plan of the Groundwater Quality

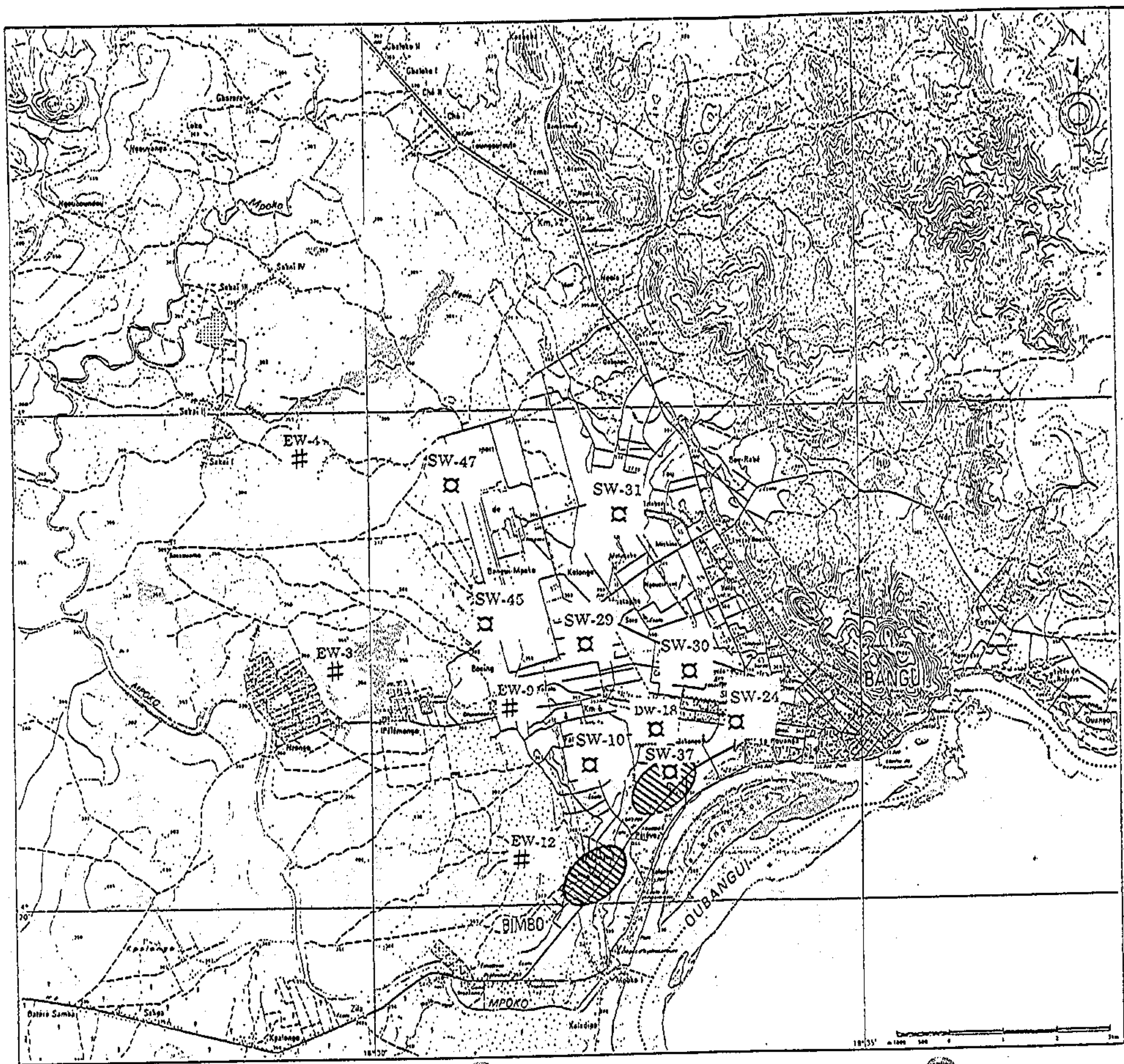
As discussed before, there is the possibility that the groundwater quality in the well fields will deteriorate in the course of the groundwater development because the recharge area of the groundwater is situated in the densely populated area where the urban development is still under the progress. Therefore, the groundwater quality monitoring must be regularly conducted on the discharged groundwater in the well fields.

The proposed monitoring frequency and monitoring items are as follows:

i. Subject wells for water quality monitoring : All of the production wells

ii. Frequency of the water quality monitoring :
- -During two months after the development-------------------------Once a week
- -From two months to six months after the development------------------Twice a month
- -From six months to the end of the project after the development-------Once a month

iii. Monitoring items : pH, Temperature, Electric conductivity, Hardness, NO_3, NH_4, SO_4, Mn, Fe, Cl, Ca, Mg, K, E. Coliform



LEGEND

\# : Groundwater Level Observation Well by the Automatic Recoeder

¤ : Groundwater Level Observation Well by the Dip Meter (by hand)

Proposed Well Field

Fig.6.4.1
Location of the Proposed Monitoring Wells for Groundwater Level Observation