JAPAN INTERNATIONAL COOPERATION AGENCY

DEPARTMENT OF HYDRAULIC
MINISTRY OF MINES AND ENERGY
CENTRAL AFRICAN REPUBLIC

THE STUDY ON GROUNDWATER DEVELOPMENT IN BANGUI CITY IN THE CENTRAL AFRICAN REPUBLIC

FINAL REPORT

SUMMARY REPORT

DECEMBER 1999

KYOWA ENGINEERING CONSULTANTS CO., LTD.
YACHIYO ENGINEERING CO., LTD.

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EXCHANGE RATE (as of June 1999)

US$ 1.00 = 627.23 FCFA

PREFACE

In response to the request from the Government of the Central African Republic, the Government of Japan decided to conduct the development study on Groundwater Development in Bangui City and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Masaaki Shindo of Kyowa Engineering Consultants Co., Ltd., and consisted of Yachiyo Engineering Co., Ltd. to Central Africa, seven times between March, 1996 and November, 1999.

The team held discussions with the officials concerned of the Government of the Central African Republic, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Central African Republic for their close cooperation extended to the team.

December, 1999

Kimio Fujita
President
Japan International Cooperation Agency

December, 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency (JICA)

LETTER OF TRANSMITTAL

Dear Sir,

We have please to submit you the final report entitled "The Study on Groundwater Development in Bangui City in the Republic of Central Africa".

The main outputs from the Study are broadly grouped into two components. One is the Master Plan Study on policy for arrangement of the water supply system that covers water demand projected for the target year 2015 for Bangui City and its peripheral area. The other is the Feasibility Study for the groundwater development project, which was selected as the preferred project among those proposed in the Master Plan Study.

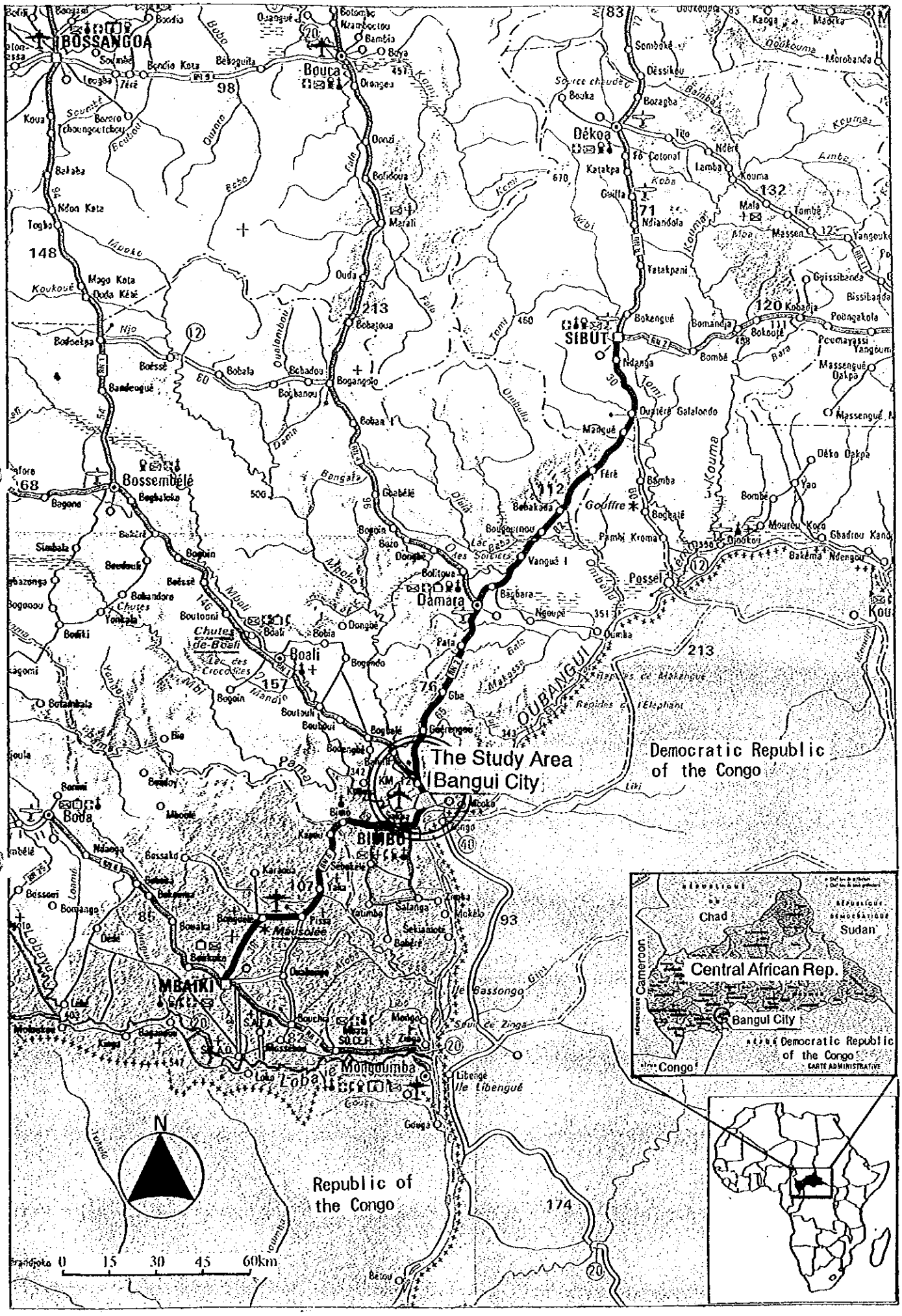
The report consists of the Summary Report, Main Report, Supporting Report, Data Book and Drawings. The Summary Report summarizes the results of all the studies. The Main Report contains the results of survey, analysis implemented at each step of the Study. The Supporting Report includes details of investigations and analyses for formulating the contents of the Master Plan and Feasibility Study. Data Book contains the data gained by analyses in the field survey. Drawings show each component of water supply facilities proposed in the Feasibility Study.

All members of the Study Team wish to express grateful acknowledgment to the personnel of your Agency, Ministry of Foreign Affairs and Embassy of Japan in Central Africa, and also to the officials of the Government of Central Africa for all assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the future water supply project in particular and to socioeconomic development of Central Africa.

Sincerely,

進藤昌明

Mr. Masaaki Shindo
Team Leader


BOSSANGOA
Bouca
Dékoa
SIBUT
Bossembélé
Damara
Boali
BIMBO
MBAIKI
Mongoumba
The Study Area
Bangui City
Democratic Republic of the Congo
Republic of the Congo
Chad
Sudan
Cameroon
Central African Rep.
Congo
0 15 30 45 60km
N

EXECUTIVE SUMMARY

INTRODUCTION

Metropolitan Bangui composed of Bangui City and 3 sub-districts of Bimbo District where are under urbanization. Total population is estimated at about 660,000 as of the end of 1998. The census of the population taken in 1998 indicates that population increase rates are 3.88%/year in Bangui City and 7.91%/year in Bimbo District within the last 10 years. This steep increase of the population causes serious social problems due to lack of installation of the urban infrastructure. The public water service covers almost Bangui City. The water distribution pipe network was installed densely in the downtown and expanded to Bimbo area that locates in the outskirts of Bangui City. The water service covers only about 30% of the population in the current water service area. There is no water supply facility in the most parts of Bimbo District, the people in these area can not help relying water on traditional dug wells, whose quality are normally bad. Therefore the residents have no choice but to live under the risks of water born disease and unsanitary circumstances. The Government of the Central Africa requested the Government of Japan a technical assistance on water resources development and water supply system arrangement in the Bangui metropolitan area. The main objectives of the Study are as follows,

- Formulation of Master Plan with the target year 2015
- Conducting Feasibility Study for the most preferential project for cover the water demand in 2005 selected in the Master Plan.
- Conducting technical transfer to the counterpart personnel of the Central Africa through the Study.

MASTER PLAN

1. Study Area and Characteristics

The study area covers 155 km^2 where includes the entire Bangui City and the 3 sub-districts which located in the north and the west of Bangui City. The study area belongs to the middle of the tropical rain forest climate and the savanna climate and has the dry season between December and March and the rainy season between March and November. The area is generally good for agriculture due to the climate with relatively high rainfall from 1,100mm to 1,700mm per year and high humidity.

The Study area is geomorphologically divided into 4 units such as Hill, Piedmont,

Alluvial Plain, and Plateau. A layer of lateritic clay or sandy silt covers almost the area over the pre-cambrian basement rocks such as chart, quartz schist, slate and so on.

2. Present Status of Water Supply Service

The source of the Bangui water supply system is Oubangui Rever. The water is purified by the treatment plant and distributed to Bangui City and some parts of Bimbo District located in the vicinity of Bangui. The system is the property of the central government. Operation and maintenance including water supply service and billing works, however, is carried out by a private firm, SODECA, on the contract basis with the Government since 1992. The water served population is estimated at about 204,000 out of the total population about 674,000 in the current water supply area. A 24 hour-water service was done in the center of the City. The distance from the water distribution reservoir reduces water pressure in the pipeline, in other words the water service steps down as the district shifts toward the outskirts of Bangui City. People living in the outside of the water supply area, almost Bimbo District, have no choice but to use traditional dug wells or river water.

3. Analysis of Groundwater Potential

In order to grasp characteristics of hydrogeological features, the Study team planed construction of exploratory wells based on the results of interpretation of the aerialphotos, geophysical prospecting, and survey of the existing wells, and field reconnaissance in the study area. The drilling work started from the beginning of September 1998 and completed at the end of January 1999. Total number of the drilled wells was 21 holes and total drilled depth reached to 1,599.4 m. After pumping tests, water quality analyses, monitoring of groundwater levels, the team conducted the simulation of groundwater balance and evaluated the potential of groundwater development in the study area. Through those analyses it was resulted that the groundwater potential would be 800,000 m^3 per annum in the Study area and the promising well fields were proposed.

4. Outline of Master Plan

Based on the results of projection of population, evaluation of progress of urbanization, and survey of water utility among people in the study area, the Study team hypothesized various factors for water demand projection such as the water supply coverage ratios, water consumption per capita per day, and the proportion of water users for each category of supply manners. Consequently the water demand projection was conducted until the final target year of 2015. The Study team formulated the basic policies for improvement of water supply system in the study area until 2015

considering water potential of groundwater and surface water in the study area. The Study team also planed the following 3 projects that were envisaged to improve the water supply service in the study area step-by-step.

1) To install urgently a water supply system, whose source should be the groundwater resulted to be reliable by the above analysis, for the poor water service area and non-water supply area located outside the present water service district.

2) To renovate and increase accessibility of the water distribution pipe networks in the present water service district and to make the existing water intake & treatment plant perform up to its maximum capacity which can meet the water demand of 2008.

3) To expand the existing water treatment plant or to construct a new system with water intake & treatment facilities until 2009. Since the water supply capacity of the above two projects would meet to only the water demand until 2008.

The Study team estimated the initial cost and operation & maintenance cost for the above projects. The financial and economic appraisals followed and resulted that it would face to a lot of difficulties to implement these projects on the loan basis. However, considering positive effects and the BHN point of view to be brought, the projects could be justified if the implementation would be carried out on the grant aid basis. In particular the groundwater development project can provide a significant improvement of sanitary condition for the area without sufficient and safe water currently by means of lower cost for construction and operation of the system than the others. Therefore the groundwater development project was consequently identified as the most suitable project to be formulated in the stage of the Feasibility Study.

FEASIBILITY STUDY

5. Basic Policy of Feasibility Study

The target year for the feasibility study was 2005. The study area was limited to the outside but near the present water supply area, where people had difficulties to access the public water service sufficiently. The source of the system should be the groundwater. The facility should be designed for local staff to operate and manage by their normal ability and manners. Equipment and materials for construction should be chosen from the local market as much as possible

6. Water Supply Volume and Served Population

The majority of populations in the study area are migrants from the provinces in seeking

jobs or expecting better lives in the capital. And almost of them are categorized into a low-income level. Many communities in the study area compose of various tribes and families that have different home villages. Almost people rely water on the traditional shallow wells whose water are contaminated by coliform and bacteria that implies intrusion of excreta from latrines which were dug without a sufficient distance form the wells. The total population in the study area was estimated at 54,000 as of 1998. Population increase rate was 7.91% per year, which was about double of the same of Bangui City. The designed water supply volume of the groundwater development project was estimated at 2,200 m^3/day, which corresponded to the water demand in 2007. Water served population was also estimated at 45,000 persons in the same year.

7 8. Project Component

The Table 1 bellow shows the project component proposed in the Feasibility Study and Figure 1 indicates the locations of the facilities.

Table 1 Proposed Facilities

Facility	component	Specification	No.
Well Facility	Deep Well	Dia. 12"1/4, Depth 50m to 150m, FRP Casing Dia. 6", INOX type screen Dia. 6"	6
	Submersible Pump	Q=0.51 m^3/min., 2.4 kw to 5.43 kw	6
	Raw water main	Dia. 100 mm to 200mm, DCIP	3,120 m
	Aqueduct	Dia. 150 mm, L=29m	1
Transmission Facility	Receiving tank	RC structure, V=122 m^3	1
	Transmission main	Dia. 200 mm, DCIP	4,780m
	Transmission pump	1.07 m^3/day, 31.66 kw	3
	Disinfection device	Hypochlorite dosing system	1
Distribution Facilitiy	Pipeline	Dia, 50 mm to 300 mm, DCIP / PVC	71,840m
	Distribution Reservoir	RC structure, V=1700 m^3	1
	Public fountain		40

The following equipment were recommended to procure for smooth implementation of the project.

- Vehicles: 4WD Pick-up type -3 No.
- Radio communication set: HF 125 W -1 set.
  (Station 1 No. + Transceiver 10 No.)
- Computer, Printer and Software: Personal desk-top type -1 set
- Water Analysis Equipment and reagents -1 set

The total cost of the project was estimated at about 62.27 million French Franc (= 9.93

million US$, converted by the exchange rate on June 2, 1999). The implementation was scheduled to begin in 2000, after studies for basic design and detailed design, a contractor for construction would be appointed through a tender procedure. The contractor would complete the construction works by the end of 2003.

8. Operation and Maintenance

The implementation organization of the project would be the General Department of Hydraulic (DGH) under jurisdiction of the Ministry of Mines and Energy. The DGH would build in the Project Division that has particular performances necessary to manage the progress of the project in the following 2 stages, Study & Construction and Operation &Maintenance. The Project Division has to perform works of public relations, land acquisition for construction of the facilities, supervision of consultants involved in the study and design works etc. on the Study & Construction stage. On the Operation and Maintenance stage the Division would fulfill different charges such as education and training for water users, monitoring of water resource potential, data compiling, and managing and controlling the private firm that would be entrusted to carry out actual operation and maintenance of the water supply system by the Government CAR. The annual cost for operation and maintenance of the system was estimated at about 391,000 French Franc (= 62,300 US$, converted by the exchange rate on June 2, 1999).

9. Assessment of Environmental Impact

The study area expands within the sphere of 30 minutes by car from the center of Bangui City. And the area has been generally under development for residence area or agricultural field. Therefore no scarce valued animal and plant is reported to exist in the study area. Since any large scale civil works is not anticipated for the groundwater development, impact for natural environment would be negligible. On the other hand, in the study area people have to rely their health on insanitary water from traditional shallow wells. In the resident area in particular many shallow wells are contaminated by intrusion of excreta from latrines. More over, dumping of rubbish and discharge of wasted water, those are found generally in the resident area, worsen sanitary condition around houses. Implementation of the project is expected to be one of the effective measures to improve the social environment to which people are exposed.

10. Project Appraisal

The financial and economic appraisals concluded that the project would be negative for the loan basis implementation. In case the project can be realized by the grant aid basis, however, the operation and maintenance cost could be recovered by the profit to

be gained by operating the system, even if costs for future renovation of the facilities was put into account.

The project was expected to provide the people positive social impacts such as decrease of work and time for wives and children to fetch the water, reduction of risk of water born diseases due to improvement of sanitary condition, correction of locational inequality for access to the public water service, production of job opportunity and labor demand by implementation of the project, etc.

There is no significant negative impact by implementation of the project.

11. Conclusion and Suggestion

It was expected that the project could sustain the O&M cost by the operational income in spite of the negative appraisal for loan basis implementation. There are already adequate engineering experience and capability for operation and maintenance on the proposed facilities in the CAR side. After completion of the facilities the Government of the CAR could provide a quality water service to people by entrusting the operation and maintenance works of the facilities to a private firm as it had been done. Therefore, from a BHN point of view, implementation of the project was concluded justifiable due to its grand impact for improving the social environment in which people had to manage their lives.

In order to guarantee more sustainability of the project's implementation, the following issues are recommended.

(1) Establishment of a monitoring system on groundwater level and water quality
(2) Formulation of counter measure for preservation of groundwater quality
(3) Reinforcement of organization of the DGH for the project's implementation
(4) Formulation and implementation of measures for increasing the water service ratio
(5) Pilot management of public faucet by a community oriented water committee system
(6) Thorough education for inhabitants about the utilization of water supply

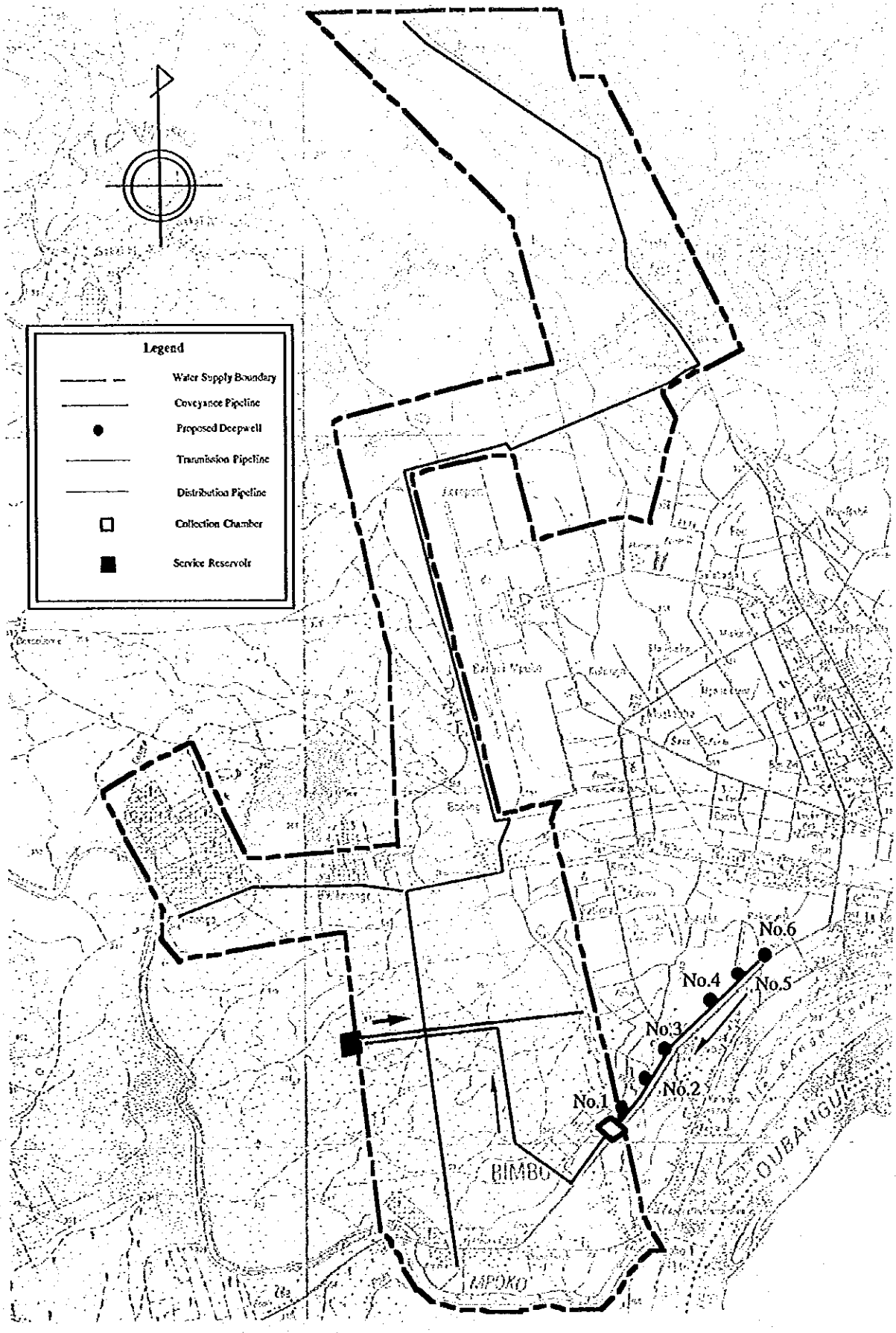


Figure 1 Layout Plan of Water Supply Facilities

LIST OF REPORTS

SUMMARY REPORT

VOLUME 1 MAIN REPORT
- MASTER PLAN REPORT
- FEASIBILITY STUDY REPORT

VOLUME 2 SUPPORTING REPORTS
1. SOCIOECONOMIC SURVEY
2. GEOPHYSICAL PROSPECTING
3. STUDY ON POTENTIAL OF SURFACE WATER
4. PRELIMINARY COST ESTIMATE ON F/S PROJECT
5. Fe & Mn ELIMINATION DEVICE
6. ANALYSIS OF WATER TARIFF

VOLUME 3 DATA BOOK
1. DRILLING REPORT
2. WELL INVENTORY SHEETS
3. GROUNDWATER QUALITY ANALYSIS RESULT
4. STUDY ON SURFACE WATER DISCHARGE
5. BOALI DAM WATER BALANCE CALCULATION
6. SOCIOECONOMIC ASPECT
7. DRAWINGS (FEASIBILITY STUDY)

THE STUDY
ON
GROUNDWATER DEVELOPMENT IN BAMGUI CITY
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SUMMARY REPORT

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MASTER PLAN

FEASIBILITY STUDY REPORT

LIST & FIGURE OF TABLES

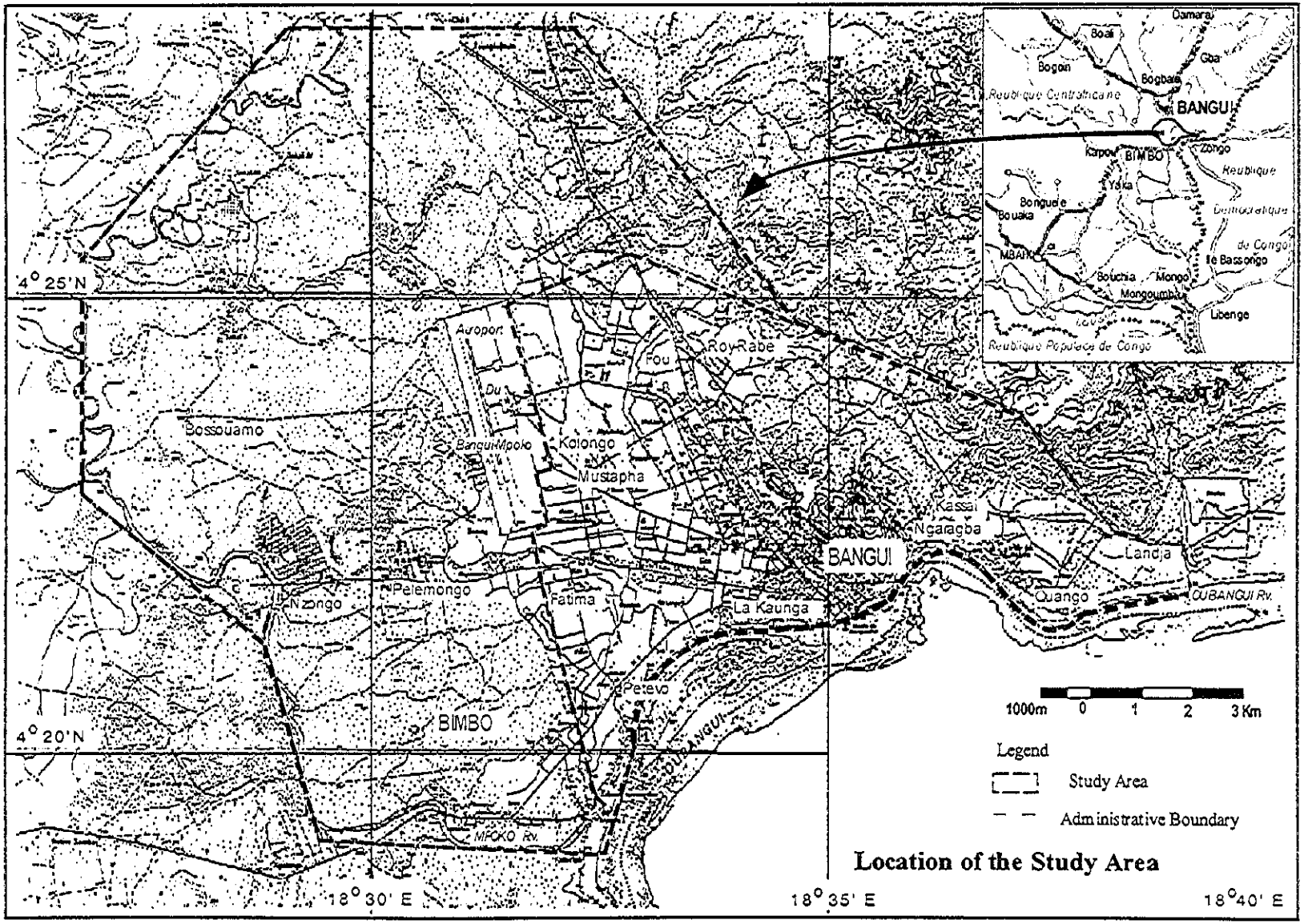
Mast Plan

Feasibility Study

ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
BHN	Basic Human Needs
CAR	Central African Republic
FCFA	Franc Communauté Financière Africaine
CFD	Caisse Francaise Development
DGH	General Department of Hydraulics
EIRR	Economic Internal Rate of Return
ENERCA	Energie Centrafricaine
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
GDP	Gross Domestic Product
IEC	Information Education Centre
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
MINURCA	Mission des Nations Unies en Republique Centrafricaine
MISAB	Mission interafricaine de surveillance des accords de Bangui
M/P	Master plan
MTAC	Ministry of Transportation and Aviation Civil
NGO	Non-Government Organization
ORS	Oral Re-hydration Solution
PHC	Primary Health Care
SCF	Standard Conversion Factor
SHE	Sanitation/Hygiene Education
SNE	Société Nationale des Eaux
SODECA	Société de Distribution d'Eau en CAR
S/W	Scope of Work
UNDP	United Nations Development Pogramme
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization

MASTER PLAN



Location of the Study Area

MASTER PLAN

CHAPTER 1. INTRODUCTION

1.1 Background of Study

The Central African Republic (CAR) has been considered as the one of African countries whose social infrastructure has been still developed at the lowest level. The water service coverage ratio in CAR is 18%. Even in urban areas only 20% of the population can access to the public water service. Therefore, the majority without water service relies on shallow wells or surface water. As the top priority has been given to the water supply infrastructure development by the Government of CAR in order to improve life conditions, some European donor agencies and the UNDP are now working on groundwater development in rural areas and provincial cities. Japan has been providing assistance in this regard through its Grant Aid program and by dispatching specialists to assist in these projects for more than 10 years.

Metropolitan Bangui, which consists of Bangui City, the capital of the CAR, and three urbanized sub-district of Bimbo District, has an estimated population of 660,000 in 1998. The annual population growth rate is estimated at 3.88% in Bangui and 7.91% in Bimbo in the past 10 years. As a result, insufficiency of social infrastructure becomes serious problem.

Bangui City has a water supply system whose source is the Oubangui River. Although the water distribution network has been furnished mainly in urbanized area of Bangui and also expanded toward the north and the west in the part of the sub-district of Bimbo. The current water service coverage is estimated at about 30%. Many of those without water service rely on unsanitary shallow wells for drinking water. This has often caused waterborne diseases. The French Government has mainly assisted CAR to construct and maintain the existing water supply system and to expand water distribution network by loan basis project in Bangui City and six main cities in the provincial. Presently, the rehabilitation of the existing water supply network in Bangui has been undertaken with financial assistance from the Agence Française de Dévelopment (AFD). However, specific plans have not been formulated for the development of new water resources and water service facilities in the west and the north areas which are located outside of the existing system.

Considering this background, in February 1995, the CAR Government requested the

Japanese Government for technical cooperation in order to develop new water resources and new water service facilities in the Bangui metropolitan area. Accordingly, in November 1995, JICA dispatched a delegation to the CAR to conduct a preliminary study of water supply conditions. Then the Scope of Work (S/W) was then agreed between the CAR and Japanese Government.

1.2 Objective of the Study

In order to ensure a stable and sustainable supply of sanitary drinking water to Bangui City and the peripheral areas where the water services do not currently exist, the following objectives were fixed.

- Master Plan (M/P) (target year 2015) would be created
- Feasibility Study (F/S) would be conducted for particular projects to be formulated by the M/P which would be deemed to be highest priority.

The target year of F/S which was originally aimed at 2000 then had been changed to 2005 taking suspension and delay of the progress of study into consideration.

In addition to the above, the Study Team intended to transfer technological know-how to their CAR's counterparts who would participate in the study meanwhile undertaking the study.

1.3 Study Area

The Study area has a total area of 155 km^2 and composes entire Bangui City, the capital of the CAR and the neighboring sub-district of Bimbo District. The Figure 1.1.1 shows the Study area.

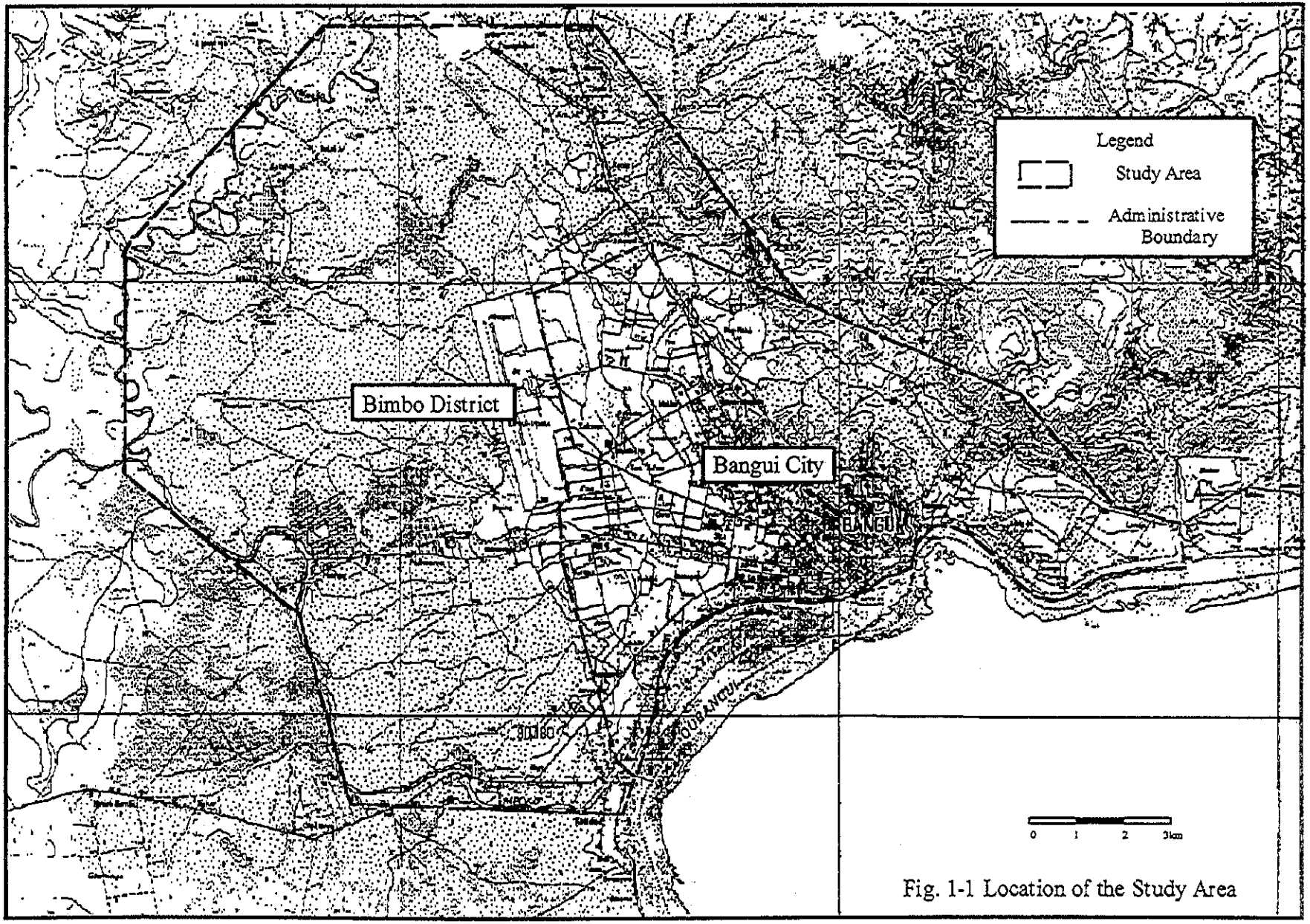


Fig. 1-1 Location of the Study Area

1.4 Scope of the Study

(1) Study of developing water resource

The development of groundwater resources is the main target in this Study. In order to make the potential of groundwater development obvious the following works were carried out in the study area.

- a landsat images and remote sensing methods
- an electrical and electromagnetic prospecting
- an evaluation the water yield capacity of the existing wells
- an estimation of the potential of groundwater based on the results of exploration wells drilled in the Study and a numerical groundwater simulation.

The main water source of the study is groundwater. However, if the region's groundwater resources would be found to be insufficient, the water source can be altered to the surface water. Oubangui River, which forms the borderline against the Democratic Republic of the Congo, and Mpoko River, which flows in the west boundary of the Study area and joins to the Oubangui, were analyzed hydraulically and hydrologically.

(2) Social Analysis/Study on Patterns of Water Utilization

In order to identify obstacles for improving overall sanitary conditions and to determine the best way cope with these matters, actual patterns of water utilization in the Study area would be investigated by means of questionnaire for residents. Based on the results of this part of the study, the Study Team envisaged to maintain social impartiality in the development of the region's water supply infrastructure.

(3) Formulating master plan and feasibility

The M/P consists a Water Resource Development Plan with the alternative of groundwater or surface water and planning of water supply facilities in the target year 2015. The M/P will be formulated based on the development plans of Bangui City, the population increases, the social environment and people's consciousness that would be grasped by the social analysis / the study on patterns of water utilization through interviews to the residents. The plan will also need to be flexible enough to meet the financial conditions and the level of technical capabilities of the relevant local organizations.

During the F/S stage schematic designs of the various water supply facilities, facility

maintenance plans, and operation cost estimations were conducted for priority projects that should correspond to the target year of 2005.

(4) Technology transfer

Technical skill concerning well drilling and the maintenance of equipment has already been attained by local specialists to certain level. This is the result of various on-the-job training implemented through the groundwater development projects sponsored by the Japanese Government. The training was also accomplished in the CAR through contact with JICA's long-term specialists. However it is necessary for them to improve their technological know-how such as methodology of planning and future projection corresponding to the social developments in the region. The technology of planning, investigation and analyze concerning groundwater development, etc. was transferred effectively to the CAR counterpart engineers through the Study.

1.5 Organization of Study Implementation

In order to arrange the implementation of the Study, The CAR Government established the Steering Committee as supreme organization which was composed of representatives of following 7 ministries and 7 organizations.

- Ministry of Mines and Energy
- Ministry Delegated to Economy, to Plan and to International Cooperation
- Ministry of Public works, of Habitat and Arrange of territory
- Ministry of Administration of territory and National security
- Ministry of Transportation and Aviation Civil (MTAC)
- Ministry of Women and Social Development
- Ministry of Health and Population
- National Committee of Water supply and Drainage
- Municipality of Bangui City
- Société Nationale des Eaux (SNE)
- Société de Distribution d'Eau en CAR (SODECA)
- Energie Centrafricaine (ENERCA)
- The Japanese Embassy
- JICA Study Team

Japanese side consists of JICA Study Team and Advisory Committee under supervision of the JICA head office. Members of the Study Team were as follows.

NAME	CHARGE TO BE TAKEN
Mr. Masaaki Shindo	Team Leader / Groundwater Development
Mr. Yosuke Sasaki	Sub-team Leader / Hydrogeology
Mr. Toshio Murakami	Topographic feature / Geology
Mr. Shigeo Otani	Hydrology
Mr. Hiroshi Nakamura	Electrical Resistively sounding
Mr. Satoshi Maruyama	Electromagnetic survey
Mr. Yoichi Harada	Supervision on Construction of Access Road
Mr. Takushi Matsunaga	Instruction of Well Drilling
Mr. Masayuki Taguchi	Sub-team Leader /Water supply planning / Facility plan
Mr. Naoki Hara	Economy / Finance /Organization
Mr. Keita Yonezawa	-do-
Mr. Satoshi Sugimoto	-do-
Mr. Serge Bouniatian	Social Analysis /Environment
Mr. Mutsumi Tsubouchi	-do-
Mr. Makoto Chiba	Interpreter

The member of Advisory Committee is:

Mrs. Keiko Yamamoto	Chairman of Advisory Committee

The principal members of the CAR side was composed mainly with engineers of General Department of Hydraulics (DGH) which is the executive organization of the Study under the Ministry of Mines and Energy. The key members of the Counterpart Team were as follows.

NAME	CHARGE TO BE TAKER
Mr. André Nalke Dorogo	Head of mission of Mineral Resources Ministry of Mines and Energy
Mr. Etienne M´peco	General Director/General Department of Hydraulics (DGH)
Mr. Barthélémy René Garama	Coordinator of Technical Project (DGH)
Mr. Desiré Ndemazagoa	Water Supply engineer (DGH)
Mr. David Tenguere	Well construction engineer (DGH)

Mr. Omar Chaib	Geo-physician (DGH)
Mr. Tean Ouaninga	Geo-physician (DGH)
Mr. Althanse Yambele	Hydrological engineer (MTAC)
Mr. Joachim Kozo	Water Supply engineer
Mr. Jonas Amakai Ibra	Chief

1.6 Report Organization

This report forms part of the final Report for the Study and is divided into two main sections : Master Plan and Feasibility Study. The Final Report comprises:

1) Summary Report
2) Main Report
3) Supporting Report
4) Data Book

CHAPTER 2. GENERAL CONDITIONS OF THE STUDY AREA

2.1 Natural Condition of the Study Area

2.1.1 Geomorphological and Geological Aspects

The Study Area can be geomorphologically divided into following four units based on the aerialphoto interpretation.

- Hill (Hl)
- Piedmont (Pd)
- Alluvial Plain (Al)
- Plateau (Pl)

a. Hill

The Hill is standing in the eastern side of the Study Area and its western edge is bounded by the steep escarpment running in NNW-SSE direction with relative height of around 300m to the Alluvial Plain. The Hill has flat top at the elevation of 600 to 650m showing the table land features. The hill is composed of Precambrian basement rocks such as chert, quartz schist, slate and so on and covered with the tropical rain forest.

b. Piedmont

The Piedmont lies on the foot of the escarpment in the eastern side of the Study Area. The Piedmont is gentle slope with inclination of 1/500 and its elevation ranges 370m to 400m. The piedmont extends in NNW-SSE direction with width of around 2 km. Many small towns and villages are distributed on the Piedmont and it is covered with cultivated land of cassava, mango and etc. The piedmont is covered with reddish brown lateritic clay.

c. Alluvial Plain

The Alluvial Plain distributes in the central part of the Study Area forming the low-land with the elevation of 340m to 360m. It shows almost flat plain feature with few undulation and dissection and it declines very gently toward the Oubangui River with the elevation of 370m to 440m. Many houses and farms are distributed on the Alluvial Plain with some forests. Pale gray sandy silt layer widely distributes on the Alluvial Plain.

d. Plateau

The Plateau has gently undulated land surface with many depressions and small valleys

and distributes in the west and north of the Study Area surrounding the Bangui City with the elevation of 360m to 400m. Some villages and farms are scattered on the Plateau and the tropical rain forest widely covers it. The plateau is covered with reddish brown laterite clay.

2.1.2 Climate

The Central African Republic (CAR) is located in between 2° to 12° of north latitude. The climate belongs to a mix of the Guinean forest climate and Sudano-Guinean climate which is characterized by a humid tropical equatorial.

In the study area the climate is composed of dry season, which is a comparatively short period form December to March, and rainy season from March to November. In August it has the heaviest rain in the year. In accordance with meteorological data of the last 19 years, a minimum annual rainfall occurred in 1989 with 1,103mm per annum. A maximum one, on the other hand, was recorded at 1,794mm in 1998. Accordingly the mean annual rainfall was calculated at 1,443mm. It was observed that the rainfall was decreasing between 1953 and 1987, however, it has a trend to increase of rainfall from then. The maximum monthly temperature was recorded between about 35°C in February and 30°C in July.

2.2 Socio-Economic Condition of the Study Area

(1) Economic Situations

According to estimates by the World Bank and IMF, CAR's gross domestic product (GDP) per capita at constant 1985 prices from 1992 through 1997 are respectively (unit: 1,000 CFA francs), 134.17, 131.65, 135.04, 140.03, 134.94, and 138.75. These figures tell not only that 1996 mutinies seriously affected the CAR's national production (-3.6% growth compared to the previous year), but also there have been no significant improvement in terms of people's living standard in recent 6 years. Since the early 1990s stagnating international markets of coffee and cotton products and a sharp increase in illegal trade across the border have damaged CAR's foreign currency earnings and tax / customs revenue. Although the CAR economy rejoiced a restoration of export competitiveness owing to the devaluation of the CFA franc (by 50%) in relation to the French franc in January 1994, the government lost control over a mounted budgetary deficit and failed once again in payment to public officials and eventually caused the mutinies in 1996.

(2) Social Situations

Social situations for the population in Bangui have not improved yet. Payment of salaries to employees of the public-sector has been still delayed for about 9 months. Pension for retired public officials, including veterans, has been frequently suspended. Although inflation rate is relatively low and consumer prices of bare necessities (e.g. market prices of food) have been stable within these two years, prices of imported goods in general are consistently uprising. As a result of the implementation of IMF rehabilitation programs, since the end of 1996, high percentage of public officials were laid off. Decaying economy created a serious extent of unemployment nationwide over the period, especially in urban areas. Closedown of several factories, such as of textile and cigarette industries, and decline of foreign direct investment seriously affected on it.

(3) Urban Infrastructure

Urban Population was stable at about 20% in 1950s. However, It started to increase in 1970s and in 1975 reached to 27% and in 1988 to 38%. This trend is not changed yet. Population increase raised by a natural factor due to a birth rate and a social factor due to transmigration from the rural area causes to multiply urban problems. Bangui City which has a 660,000 population as of the end of 1998, which corresponds to 20% of total population of the CAR, are facing a serious urban problems.

In Bangui City only 6% of household has modernized flush toilet. While 80% of the same has latrine type toilet which is made easily by digging in the concession, shallow groundwater is contaminated by intrusion of faeces or drained water from household. In Bangui City and its surrounding area there are many people rely on unsanitary shallow wells. Therefore, it is highly recommended that these shallow wells shall be closed and changed to utilize the public water service.

In the city there are a 24km of main canal of drainage and a 10km of the secondary canal. A 15km of these canals needs to be rehabilitated. The drainage system in the city is not sufficient. In the rainy season, because of luck of capacity of the drainage, not only many houses are inundated here and there but also all the dug wells are filled with the inundated water and faeces in the latrines flow away.

There are a 56km paved road and a 48km unpaved road in Bangui City. A 38% of the paved road and a 16% of the unpaved road are well maintained. In the outskirts of Bangui City a settlement of people from the rural area is disorderly spreading without

proper road arrangement. The poor road arrangement causes difficulty of construction of facilities of water supply drainage and electric supply etc.

The west and north areas of Bangui City, which belong to sub-district of Bimbo, are directly affected by urbanization of Bangui City and people in these areas are exposed to a high risk of sweep of diarrhea or water born diseases.

(4) Living Condition

The social services such as education and health sector are deteriorated both in quality and in quantity. It is almost impossible for the government to run social-affair programs due to shortage of fund. Several diseases strain socio-economic conditions in CAR. Parasite disease, malaria, diarrhoeal disease are most common diseases. Conspicuously AIDS becomes a very serious problem. Poverty remains an essential problem among the population. Their basement of lives has been fragile due to rising prices of some basic daily goods, high unemployment rate, shortage of social services and delayed payment of salaries.

People in CAR have generally large households. People have ' extended families' . That means there is core family and extended relative members living together. The number of inhabitants per household varies from place to place, 8.7 in urban area, 9.4 in sub-urban area, and 6.7 in rural area. In sub-urban area, there is slightly more than other area. In the sub-urban area, there is more space and it is relatively easier to access to urban service (water supply, electric supply employment and etc.) and life is still a little cheaper than urban area. Therefore they can maintain most number of habitants.

The electrification rate in Bangui is 6%. The extension of electrification is more than water supply. Most common fuel used is wood. Other type of fuel is very rare. Only 13% use improved stove. If the population increases as quick as now, there would be shortage of fuel wood around Bangui area.

CHAPTER 3. PRESENT SITUATION OF WATER SUPPLY SECTOR

3.1 Official Target of Sanitary Condition

The Government of the CAR placed a high priority on improvement of water supply and sanitary services to the nation in the National Policy in 1980s. And the Government is making effort to realize this policy by introducing foreign finances from the international aid agencies and the foreign countries. The policies aimed at year 2000 in the water supply and sanitary aspects are as follows.

1) To improve the rate of water supply coverage in the urban area to 60%
2) To improve the rate of water supply coverage in the rural area to 50%
3) To improve the rate of toilet coverage in the rural area to 100%

3.2 Organization of Water Supply Sector

The Ministry of Mines and Energy is a responsible in the Government of CAR to manage water supply policy. Under the ministry the General Department of Hydraulics (DGH) is the main organization which is responsible to realize the water supply policy of the Government and also in charge of development, planning, installation of water supply facilities and its maintenance in the whole Republic. The DGH has especially been dedicating to improve of sanitary condition in rural area by construction of deep wells for potable water. Under the DGH's there was an agency named the National Water Company (Société National des Euax de Centrafrique, SNE) whose responsibility was to introduce and improve of public water system in cities with more than 10,000 water service population. Therefore the SNE had been managing the public water supply system in Bangui. However, depending on a policy of restructuring on the governmental organizations or institutions, the SNE was dissolved in May 1999 and its responsibilities and roles were supposed to be taken over by the DGH in near future.

Operation and maintenance works on the water supply facilities including billing work has been entrusted to the Water Distribution Company of Central Africa (Société de Distribution d'Eau en Centrafrique: SODECA) since 1992. The SODECA is in charge of Bangui City and another 6 provincial cities.

3.3 Existing Water Supply Facilities

People in Bangui City and some parts of Bimbo next to Bangui City owe potable water to the SODECA, which purifies through the treatment plant. People in the peripheral area, the most area of Bimbo owe to traditional dug wells or river water without proper treatment. From the sanitary point of view, the traditional dug wells and river water are not recommendable to drink directly.

The facilities of water production are stationed in the mid slope of the hill which rises closely in the east side of the down town Bangui. The public water in Bangui was begun with being supplied in the center area of the present down town where a center of business and political activities was formulated. And as the city being developed the water supply area had been expanded through the distribution system with kiosks and house connections to the west and north. There is a separated water supply area behind the hill in the east part of the Bangui City. The components of the existing facilities are as follows,

1) Intake facilities

Resource: Oubangui river

Constructed: in year 1963

Pumping equipment: Vertical axis type, 510 m^3/hr x 54m head - 5 sets.

Transmission line: 3 lines are installed from the Intake to the Water Treatment Plant Dia. 300mm (steel pipe), Dia. 400mm (ductile iron pipe), Dia. 500mm (steel Pipe)

2) Water Treatment Plant

Total capacity of the water treatment systems: 1,500 m^3/h

There are 2 units of water treatment system with different capacity. The one with a capacity of 900 m^3/h was completed in 1963 and the other with 600 m^3/h was also constructed in 1976.

3) Distribution Facilities

Reservoirs : 7 reservoirs in Bangui system.

Total capacity of reservoirs : 13,880 m^3 (9.3 hour-capacity of the treatment system)

4) Distribution network

Almost the city of Bangui except the north east hilly area is covered presently by the present water supply area. The distribution pipeline net is being extended to some parts of sub-districts of Bimbo District where are located the next to Bangui City and the population is increasing. The total length of pipeline was 170 km (in 1985).

3.4 Present Status of Water Supply Service

In accordance with basic indices on water supply service done by SODECA, service population of the water supply system is estimated at about 204,000 persons as of December 1998. The estimated service population corresponds to 30 % of the total population which was estimated at 674,000. The mean daily consumption in the existing water supply area is estimated at 23,500 m^3/day which is delivered through 6,397 house connections and 117 kiosks, public water taps in 1998. A 31% of the service population is actually received the water through private house connection and the remaining 69% is supplied by the public faucet. Ratio of effectiveness of water supply service is equivalent to the rate of billing water in SODOECA's category. The average billing rates of SODECA in the last 5 years was calculated at 65.3%. Assuming that 82% of the billing can be paid actually from the consumers, "accounted-for water as percent of total" is estimated at 53%.

3.5 Water Quality Analysis on Piped Water and Groundwater

(1) Quality of Piped Water

The series of tests showed that water of the kiosks are almost kept enough level of residual chlorine. However, some of the tested waters showed nearly 0 level. It deduces that deterioration of pipeline may be highly progressed. SODECA is continuing to inject high level of chlorine at the water treatment plant in order to supply safety water to the population of Bangui. However, there are also peoples who do not appreciate to use the piped water. Especially residents who migrated recently from the rural area prefer to use well water because of unfamiliarity of smell of chlorine in the piped water. Almost all the in-house-stored water showed affection of coliform. It is assumed that coliform may be transferred from the hands of the dwellers by touching water when they scoop with bowls.

It is highly recommended that people shall use ladle with a long handle instead of bowls so as not for fingers to touch into water. And for storing water, diffusion of containers with faucet may also be effective for improve the present hygienic condition.

(2) Groundwater Quality in the Study Area

The result of water quality analysis conducted by the Study team showed that the aquifer in the shallow laterite layer was contaminated by coliform. The groundwater from this aquifer also showed higher level of Manganese (Mn), Iron (Fe), and Nitrate

ion (No_3) than the WHO standard for potable water. Therefore the groundwater in the shallow laterite layer was decided not suitable for drinking purpose. Another aquifer in the deep bedrock also showed generally as same tendency of water quality as the aquifer in the shallow laterite layer. However, the deep groundwater in the bedrock aquifer located along the high permeable zones fulfilled the WHO standard for potable water except coliform.

Coliform

Coliforms were found in all deep wells including the exploratory wells drilled in this Study. The density of the Thermotolerant coliforms directly relates to that of the Escherichia Coliform which exists peculiarly in the feces. This findings 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.

Manganese ion (Mn)

The Mn concentration in the shallow laterite aquifer exceeded WHO standard (0.5mg/lit). There was a tendency that the Mn concentration got lower in rainy season. Mn concentration of the deep groundwater in the bedrock aquifer got lower along the high permeable zones in which the Mn concentration met the WHO standard. It was inferred that as the fresh water was flowing along the high permeable zone, the Mn concentration got lower than the other areas where the groundwater was stagnant because of the low permeability. It was concluded that the safe water would be gotten only in the high permeable zone where the proposed well fields were located in term of Mn concentration.

Ferric ion (Fe)

Fe concentration in the shallow laterite aquifer exceeded WHO standard (0.3mg/lit) in nearly all area of the target groundwater basin except the area around the airport. The Fe concentration got lower in rainy. Fe concentration of the deep groundwater in the bedrock aquifer also got lower along the high permeable zones in which the Fe concentration meets the WHO standard. It is inferred that the same reason with the case of Mn concentration could be applied for the explanation of this phenomena.

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

Nitrate ion (NO_3)

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. Its average concentration is around 10mg/lit to 20mg/lit. The reverse tendency to the case of Mn and Fe was found in the seasonal change of the concentration. That was, the NO_3 concentration got higher in rainy season. It was 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 was inferred that the NO_3 concentration in the shallow groundwater still remained in low level in spite of the abundance of the contaminant such as pit latrine.

The distribution pattern of NO_3 concentration of the deep groundwater showed different characteristics from that of Mn and Fe concentration. That was, it seemed that the NO_3 distribution was not controlled by the permeability of the aquifer and the concentration was almost constant ranging from 10mg/lit to 20mg/lit which meets WHO standard. It was clarified from this phenomenon that the NO_3 derived from the contaminants made by the human activities such as pit latrine and sewage infiltration. It was also inferred that the NO_3 concentration in the deep groundwater still remained in low level same as the shallow groundwater. It was anticipated that the NO_3 concentration would reach the WHO standard in case that the population would increase by 2.5 times of the present population. Supposing that the population of the Bangui City would constantly increase with the growth rate of 3.88%, it was anticipated that the population would increase by 2.5 times of the present population after about 25 years.

CHAPTER 4. EXPLORATORY WELL DRILLING

4.1 Drilling Work

The exploratory well drilling was scheduled based on the results of the aerialphoto interpretation, existing well survey and field reconnaissance in order to grasp the comprehensive hydrogeological features of the Study Area. The drilling work started from the beginning of September 1998 and completed at the end of January, 1999. Total number of the drilled wells is 21 holes and total drilled depth is 1,599.4 m as shown in Table 4.1.1. Their locations are shown in Fig.4.1.1.

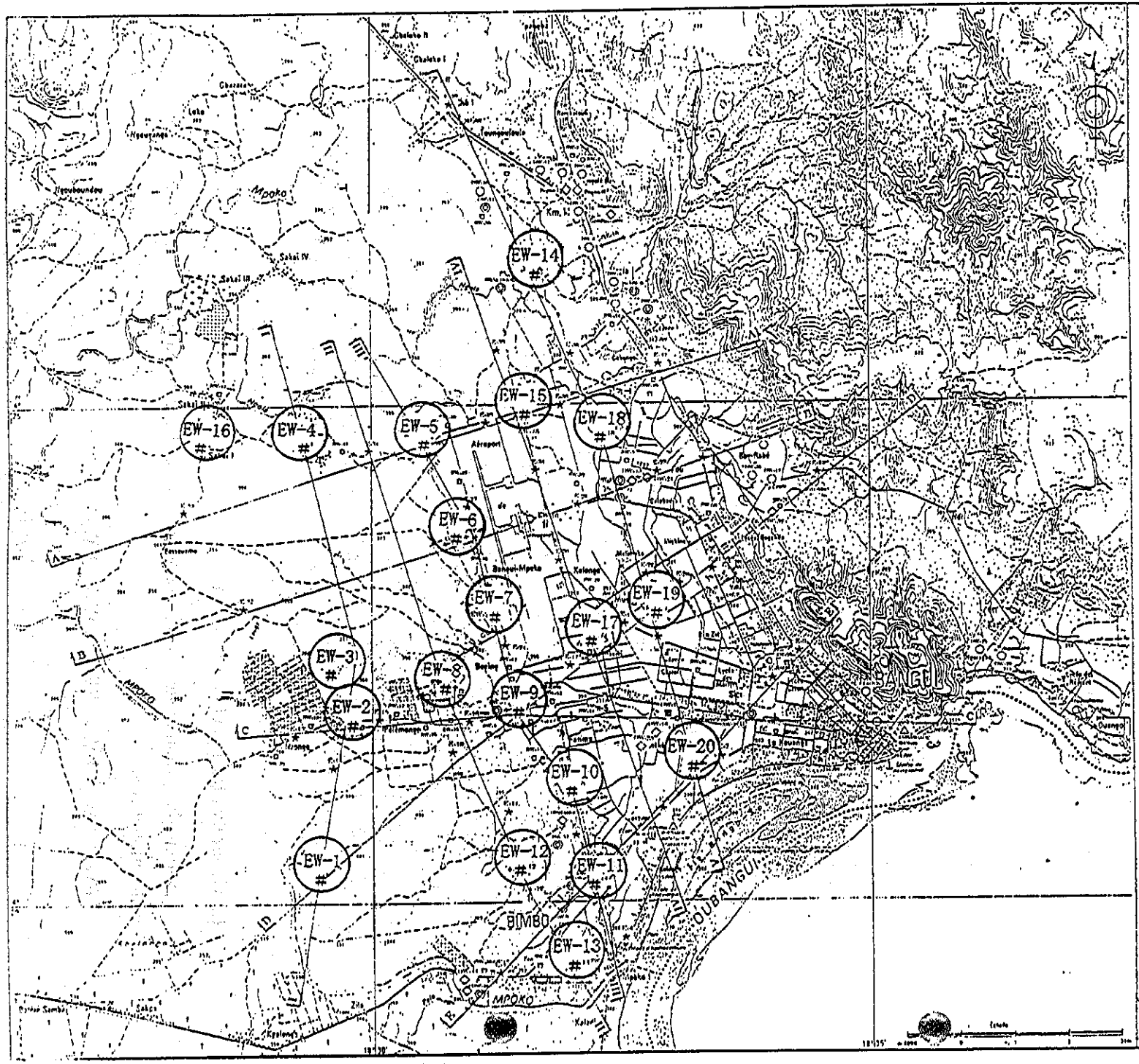
Table 4.1.1 Drilling Depth of the Exploratory Wells

Well Number	Main Geology	Drilling Depth (m)	Depth to Bedrock (m)	Remarks
EW-1	Lateritic clay	85.0	Not reached	Backfilled
EW-2	Lateritic clay	100.0	Not reached	Backfilled
EW-3	lateritic clay, Sandstone	70.0	52.0	Cased
EW-4	lateritic clay, Sandstone	43.0	22.0	Cased
EW-5	Lateritic clay	85.8	Not reached	Backfilled
EW-6	lateritic clay, Limestone	77.3	22.0	Cased
EW-7	lateritic clay, Limestone	51.5	24.5	Cased
EW-8	lateritic clay, Sandstone	37.0	20.0	Backfilled because of low discharge
EW-9	lateritic clay, Limestone	53.2	29.5	Cased
EW-10	lateritic clay, Limestone	92.0	56.0	Cased
EW-11	lateritic clay, Loose sand	89.0	Not reached	Backfilled
EW-12	lateritic clay, Limestone	80.0	32.8	Cased
EW-13	lateritic clay, Limestone	44.3	14.5	Cased
EW-14	Lateritic clay	95.4	Not reached	Backfilled
EW-15	lateritic clay, Sandstone	98.4	85.0	Backfilled because of low discharge
EW-16	Lateritic clay	128.0	Not reached	Backfilled
EW-17	Lateritic clay	123.5	Not reached	Backfilled
EW-18	Lateritic clay	125.0	Not reached	Backfilled
EW-19	lateritic clay, Limestone	56.0	49.0	Cased
EW-20	lateritic clay, Limestone	25.0	19.7	Backfilled because of collapsing
EW-20A	lateritic clay, Limestone	40.0	20.5	Cased, Re-drilled hole for EW-20
Total 21holes	--	1,599.4m	--	10 holes cased, 11holes backfilled

4.2 Groundwater Level Observation

Automatic groundwater level recorders have been installed at the following exploration wells.

EW-3, EW-4, EW-6, EW-9, EW-12, EW-20



LEGEND

EW-11 # : Exploratory Well

Fig. 4.1.1
Location Map of the Exploratory wells