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THE DEPARTMENT OF HYDRAULICS OF
THE MINISTRY OF HYDRAULICS AND ENERGY
AND
JAPAN INTERNATIONAL COOPERATION AGENCY

THE STUDY ON GROUNDWATER DEVELOPMENT FOR KIFFACITY

FINAL REPORT

MAIN REPORT

March 1999

Yachiyo Engineering Co., Ltd.

The Study on Groundwater Development
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Cost Estimate is based on
the following exchange rate

US$1.00 = ¥125.0
(averaged rate from Aug.1, 1998to Jan. 31, 1999)
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(as of the end of November, 1998)

PREFACE

In response to a request from the Government of the Islamic Republic of Mauritania, the Government of Japan decided to conduct a study on Groundwater Development for Kiffa City and entrusted the study to the Japan International Cooperation Agency (JICA).

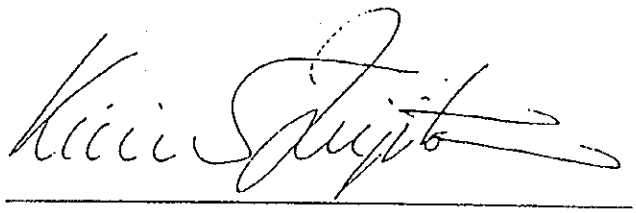
On four occasions between July 1997 and March 1999, JICA dispatched to Mauritania a study team headed by Mr. Noboru Saiki of Yachiyo Engineering Co., Ltd.

The team held discussions with the officials concerned of the Government of Mauritania, and conducted a field study at the study area. After the team returned to Japan, further studies were made, and as this result, the present report was finalized.

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 Islamic Republic of Mauritania for their close cooperation extended to the teams.

March 1999



Kimio Fujita
President
Japan International Cooperation Agency

March 1999

Letter of Transmittal

We are pleased to submit to you the study report on Groundwater Development for Kiffa City in the Islamic Republic of Mauritania.

This study was conducted by Yachiyo Engineering Co,. Ltd., under a contract to JICA, during the period from July 1997 to march 1999.

The present report clarifies the situation with regard to the extremely limited natural reserves of ground water in the area around Kiffa City, which is situated in the Sahel region (on the edge of the Sahara), and draws up plans for the development of the ground water on the basis of which are also drawn up plans for a water supply. The report also draws up plans for facilities to provide a safe water supply for residents who are at the present time forced to make use of the increasingly polluted shallow ground water within the city, as well as running and maintenance plans to allow the continued operation of the water supply service. In view of the importance of water reserves in this region, the report also suggests hygiene improvement plans to preserve and improve the quality of the water in the shallow ground water reserves within the city.

I would like to express my most heartfelt appreciation to JICA; the JICA offices in Senegal; the Ministry of Foreign Affairs and the staff of the Japanese Embassy in Senegal, as well as the Ministry of Water and Energy in Mauritania and those concerned in the City of Kiffa and the various government agencies, for the tremendous help and support we received throughout the whole period of the study. I sincerely hope that the results of the study will be of some help in improving the urban sanitary environment of Kiffa City in Mauritania, and in the social and economic development of the city.

Very truly yours,

Noboru SAEKI
Project manager,
Study team on
Groundwater Development for Kiffa City
Yachiyo Engineering Co,. Ltd.

The Study on Groundwater Development for Kiffa City
(Study period: July 1997 - March 1999)

SUMMARY

1. Background of the study

Kiffa, the second-largest city of Mauritania with a population of about 60,000 is located approximately 600 km east of Nouakchott, the nation's capital. It serves as an important relay point of material transport between the capital and the inland regions. Due to the drought in the 1970s, the nomads flowed into and settled in Kiffa, causing a sharp increase of population. On the other hand, the installation of infrastructure has been slow. The water supply facility, in particular, has not been in service, and people still depend on water wagons and water sellers with donkey-carts. Water sources are contaminated and insufficient in quantity.

2. Objective of the study

The objective of this study is to evaluate the potential of the groundwater resources of the study area, and to formulate the groundwater development plan and water supply plan for Kiffa City.

3. Study area

The study area for groundwater resources shall be the northern part of Kiffa City on the upstream of the city's groundwater basin (an area of approx. 1,260 km^2, covering a radius of 20 km from the center of Kiffa City), as shown on Fig. 1. The area subject to this water supply plan shall be the urban district of Kiffa City.

4. Outline of the development plan

4-1 Current situation of water supply

Currently, residents of Kiffa City depend entirely on the shallow groundwater in the city as the source of water for drinking and daily life use. They fulfill their needs either by drawing water from shallow wells in their neighborhood, or by receiving water from several municipal road tankers or from donkey cart water venders. However, the shallow

groundwater has become increasingly contaminated due to excessive pumping and wastewater discharge by the growing population. Apart from a very limited number of districts, the concentration of nitrate nitrogen (used as a contamination index: 0 - 1,400 mg/L) in the entire city is above the WHO guideline for drinking water (10 mg/L).

Water consumption remains around 15 liters per person per day. As shown by these data, water supply by the wells in the city has reached the limit in terms of both quantity and quality. The supply of safe water is an urgent issue for the sake of health and hygiene of Kiffa City.

4-2 Situation of groundwater reserve

As the result of a hydro-geological study of the study area, apart from the shallow groundwater in the city, the area approx. 15 km northwest of the city (Fig. 2 Overall development plan) was determined to be the only developable aquifer in the area, and its features were verified through 22 trial drillings. This aquifer is the weathered part on the surface of pelite (20 - 70 m deep) with many cracks along the fault located from northeast to southwest, and the water quality is good. The quantity of developable groundwater for which development can be sustained over a long period in the city and at the new water source in the northwestern area was evaluated as approx. 1,440,000 m^3 per year. See Table 1 for a breakdown. Although justifiable in consideration of natural conditions, the quantity of developable water is far from abundant. Taking into account future increase in population, strict control of the water supply quantity is necessary.

Table 1 Developable groundwater in the study area

District	Developable water per year (m^3)
Shallow groundwater in the city	240,000
Water source in the northwest area	1,200,000
Total	1,440,000

4-3 Water supply plan

Based on the identification of contamination of shallow groundwater in the city and new potential water sources, a priority project of the water supply plan was set up. Its aims are to develop safe and hygienic water in the new water source and to supply the minimum requirement of all residents as soon as possible. Meanwhile, a long-term overall plan

including a hygiene improvement plan was set up for the target year of 2015. Principal objectives of the water supply plan are as follows, based on the efficient use of water through restrictions on the quantity of water supply, and preservation and improvement of shallow groundwater in the city. The facility distribution plan is shown in Fig. 2 Overall development plan.

Table-2 Principal objectives of the water supply plan

1. Target population	Priority project (2005) 77,000 Long-term plan (2015) 100,000
2. Planned water supply quantity	Individual water supply 30 L/day/person. for drinking + 10 L/day/pers. for daily use Public water taps 20 L/day/person. for drinking + 10 L/day/pers. for daily use
3. Water sources	Drinking water Sources in the northwest Water for daily use Wells in the city
4. Facility plan (priority project)	Pumping facilities at the source (6 production wells) Water conveyance facilities (12 km) + drainage pond (1,000 m^3) City water distribution facilities (total 41 km) + 39 public water taps
5. Cost of water supply facility construction project	Priority project approx. UM2,000,000,000 Long-term plan approx. UM840,000,000

5. Project evaluation

5-1 Economic and financial evaluation

(1) Economic evaluation

Cost and benefit were analyzed by considering the cost that the residents of Kiffa City are willing to pay, i.e., the actual payment for water, as the economic benefit of execution of project under this water supply plan, and by considering the cost of water supply facility construction and financial cost of operation maintenance and management after installation as the economic cost of the project. The estimate indexes obtained from this analysis were as follows: economic interior revenue rate (EIRR) 14.0%, benefit/cost ratio (B/C ratio) 1.27, and net present value (NPV) UM440 million. As these indexes show that the economic interior revenue rate surpasses 10%, the project is judged to bring a positive impact to the economy of Mauritania. Therefore, this project should be executed from the viewpoint of the national economy.

(2) Financial evaluation

An analysis was made by considering water charge revenue as the income from the project under the water supply plan, and by considering the cost of water supply facility construction and financial cost of operation maintenance and management after installation as the financial cost of the operation. The result of this analysis shows that the financial interior revenue rate (FIRR) of this project is negative. This means that under the current charging system assumed for the analysis, it is not favorable to procure the investment cost for this project from government loans. On the other hand, judging from the current financial situation based on the balance sheet of SONELEC, it is barely possible to execute the project with the funds on hand. Therefore, grants from the government or from overseas are essential.

Another estimate made on profit and loss as well as financing in the case in which the project is executed with grants shows that the maintenance and management of the water service should face no problem under the current charging system, but it will be difficult to carry out the extension works in 2006 with loans. However, if these works can also be covered by grants, the profit is expected to grow steadily, enabling the accumulated fund to cover not only the maintenance and management cost but also the renewal of the facilities twenty years later.

5-2 Social evaluation

There is no fundamental problem regarding the social impact of this water supply project, except some of the practical issues that have been pointed out, including improvement of the management method of the public water taps to remove the unfair situation between the tap users and those who are supplied with water at home, and diversion or effective use of water sellers with donkey-carts who currently play a major role in water business.

5-3 Technological and environmental evaluations

This water development plan is highly praised from the technological point of view, as the following technological improvements are expected in the water resource development and water supply projects. In the water resource development project, considerations for water quality preservation and sustainable development have been given toward the groundwater environment.

- Water resource development: establishment of the method of production well development around Kiffa City, and preservation of the quality of the shallow

groundwater in the city

- Water supply plan: supply of safe water, application of appropriate technology, time-limited water supply

6. Recommendations

Based on the results of the project evaluation, the following recommendations are made as collateral conditions of this project.

(1) Early launching of water resource protection and water quality preservation measures
(2) Early launching of monitoring of groundwater level and water quality
(3) Trial operation of public water tap management with the participation of the residents
(4) Examination of revision of the water service charging system in Kiffa

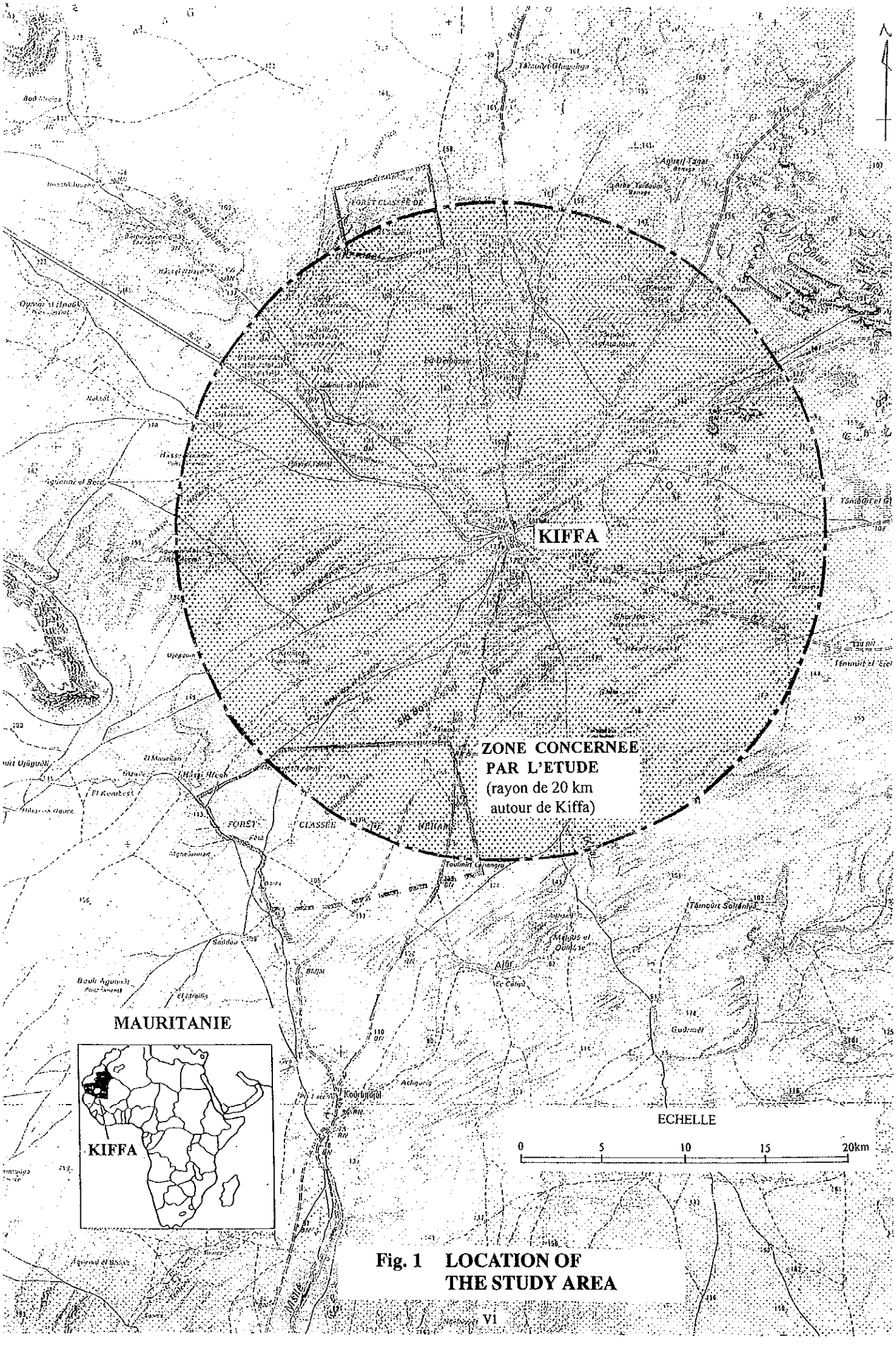


Fig. 1 LOCATION OF THE STUDY AREA

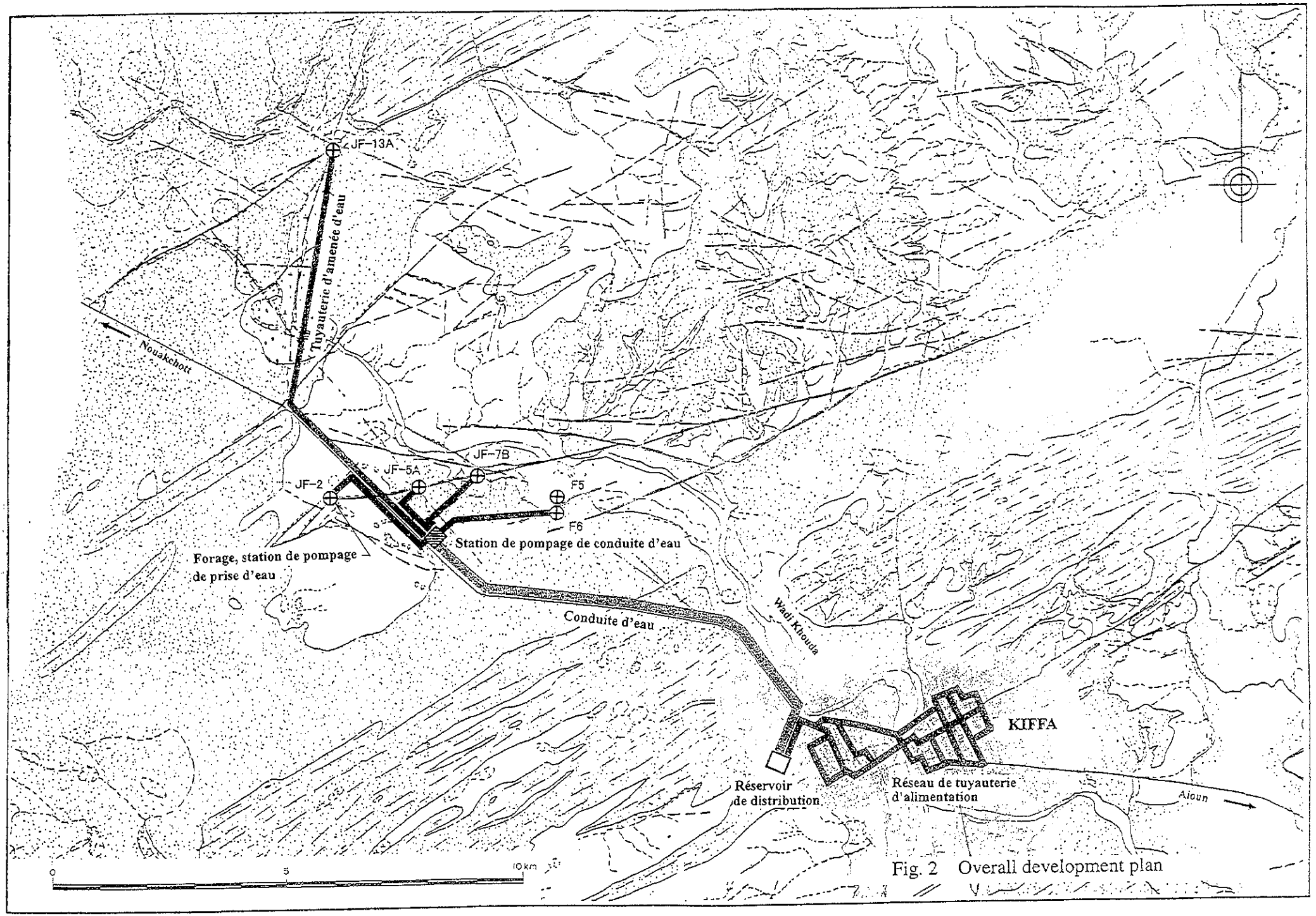


Fig. 2 Overall development plan

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Chapter 1 Outline of the Study

1.1 Background of the study

(1) The Islamic Republic of Mauritania (population: 2.14 million (1993), surface area: 1,030,000 km^2) is located on the northwestern coast of Africa. Due to drought and increased desertification, agricultural production has been in decline, and iron ore and marine products, which are the nation's major source of acquiring foreign currency, also are experiencing low international price. The GNP per capita is about 510 dollars (1993), which classifies Mauritania as an LLDC. Since the majority of land is covered by desert, and often experiences drought, the stable supply of hygienic water is regarded as the most critical issue facing the nation. As a cooperative action toward the water supply sector, Japan has provided two voluntary fund cooperation, i.e., "Water supply plan in the mid-southern region" (1993 Basic Design) and "Eradication of Guinea worm and drinking water supply plan" (1996 Basic Design).

(2) Kiffa commune (Kiffa city: population 61,000 (1996), and surface area of approx. 1,200 km^2), the target area of this study, is the second-largest city of Mauritania. Located 600 km east of Nouakchott, the capital, in an inland area of the southern part of the nation, its convenient location makes it an important transit point in the transport of supplies between the capital and inland areas. Following the serious drought, nomads started to settle in the southern region where rainfall is relatively abundant, resulting in a rapid increase in the local population. The annual rainfall in the region is 100 - 400 mm.

(3) The water supply network that had been constructed in Kiffa City during the French occupation was abandoned in the 1970s. The population now purchases water from municipal trucks or from private sellers who carry water drums on donkey-carts. In both cases, facilities at the source are contaminated, and the quantity of water is insufficient. Although studies have been conducted on the aquifer that has potential to serve as a new resource, the results remain insufficient and lacking in information.

(4) With this background, requests have been made to set up a water resource development plan on subterranean water and a water supply plan.

1.2 Objective of the study

(1) Evaluate the potential of subterranean water resources of the study area.

(2) Set up a subterranean water development plan to supply water to Kiffa City.

(3) Set up a water supply plan for Kiffa city.

(4) Based on this study, transfer our technology to counterparts in Mauritania.

1.3 Study area

The target area of this study shall be the urban district of Kiffa City in the south of Mauritania and the northern part of the commune at the upstream of the subterranean water vein (area covered by a radius of 20 km from the center of Kiffa, about 1,260 km^2).

1.4 Content of the study

Based on the Scope of Work and Meeting Minutes that were agreed upon, signed and exchanged between the Mauritanian government and Japan International Cooperation Agency (JICA) on March 26, 1997, field research of this study started in July 1997. During the 18 months that followed, field studies and analyses were compiled, the results of which are presented here as the draft final report. Works progressed in three phases. Principal working procedures were as follows.

Phase 1: Information gathering, fundamental study for site reconnaissance (July 1987 - December 1987)

- Explanation and discussion of the inception report
- Field research supervision congress
- Collection of existing documents and information and analysis
- Examination of existing water supply projects by the Hydroelectricity corporation
- Understanding of aerial photographs and site reconnaissance related to hydrology, hydraulic geology, topography and geology
- Social and economic research/ social and WID analysis
- Initial environmental evaluation (IEE)

Phase 2: Subterranean water reserve study (January - July 1998)

- Physical exploration
- Preparation and explanation of progress report (1)
- Rehabilitation of excavators owned by the water utilization office for trial drilling investigation
- Trial drilling investigation, hole logging and pumping test
- Preparation and explanation of progress report (2)
- Field research supervision congress
- Preparation of outlined analysis of water balance/hydraulic geological map
- Examination of overview of the subterranean water reserve

Phase 3: Set-up and evaluation of subterranean water development and supply plans (April - December 1998)

- Anticipation of demand for water
- Setting up of data and objectives for the plans
- Setting up of a subterranean water resource development plan
- Setting up of a water conducting facilities plan and water supply facilities plan
- Setting up of a hygiene improvement plan
- Preliminary examination of estimation of project cost and project execution plan
- Preparation, explanation and discussion of the interim report
- Field research supervision congress
- Setting up of outlined design of water conveyance and supply facilities/materials and equipment procurement plan
- Setting up of a management and maintenance plan, organization plan and monitoring plan
- Setting up of the project cost estimate and financing plan
- Project evaluation (for economic, financial, organizational, technological and social factors)
- Setting up of a project execution plan
- Preparation, explanation and discussion of the draft final report
- Field research supervision congress
- Preparation and submission of the final report

This study was realized thanks to the instruction of the study supervising congress chaired by Mr. Hisao Ushiki, expert on international cooperation, as well as valuable cooperation

from our counterparts represented by Mr. Ely Ould El Hadj, director of the water utilization office of the Ministry of Water and Energy of Mauritania and his successor Mr. El Houssein Ould Jiddou.

Chapter 2 Socio-Economic Factors

2.1 General description of Kiffa city

2.1.1 Development of the Kiffa city

When the French colonizers arrived in this region in 1906, Kiffa was only a salty pond visited by the neighboring Nomads to allow their animals to benefit from the specific characteristics of the pastures and the water in this site.

The French garrison post was installed on 1 February 1907 near the Hassi Babou well which belongs to the Ahl Sidi Mahmoud tribe. This post, located along the passage of caravans from Tagant to Nioro and Kayes, will become the future Kiffa.

At first, straw huts were built. The first administrative buildings were constructed only from 1914, following the inclusion of the Kiffa residential area to the civil territory of Mauritania, as an administrative department of the Assaba circle with M'bout as its county town.

However, from the installation of the post in 1907, families of Soninkes and Bambara merchants, connected to the African military auxiliaries of the French, established themselves in Kiffa, thus constituting the first inhabitants of the district now called Qadîma. Small groups of former Moorish slaves, benefiting from the protection offered by the French authorities, took refuge in this place. They were principally farmers, but also provided the labor force for the first "urban" jobs at the site (casual laborers, domestic workers, butchers, bakers, etc.). Little by little, the families of the Moorish merchants (mainly from the Idawali tribe) and the cavalry recruited by the colonial administration (the Jaavra group in particular) constituted the first core of Kiffa inhabitants. Nevertheless, they continued to leave the place with their animals, without going too far, during the rainy season.

In 1923, Kiffa became the county town of the Assaba circle replacing M' bout. In 1924, it only had 197 inhabitants (Villasante, 1994, p.850). Changes in the border with Sudan (future Mali) made it the principal border city with the Mauritanian area. The elimination of the "indigenous code" in 1946 increased its population: from 1,807 inhabitants in 1946, it reached 2,551 inhabitants in 1950.

The expansion of the village, which essentially only had an administrative and

commercial function, experienced the scarcity of water resources. In 1958, a water supply network with a motor pump and 6 water posts, was installed. It only survived for several months due to the exhaustion of the source of capture (see further down).

It was mainly due to the drought in the 70's when the Kiffa population experienced accelerated demographic growth. Most of the districts in the city were created after the arrival of rural people driven out from the hinterlands by poor climatic conditions. Arrival into the Nouakchott-Nema asphalted road ("the road to hope") where Kiffa constituted the halfway stage, contributed to the increase of its expansion movement.

Based on a questionnaire survey, 69% of households interviewed have resided in Kiffa for more than 10 years; 46%, are principally in the Qadima, Sagatar districts and the administrative Quarter, and have been living there for more than 15 years.

As a sign of a certain stabilization of the population, the immense majority (99.20%) of the partners of the household heads interviewed and who have responded to this question, have been living with their partners.

The residential choice of new arrivals to the city depend on considerations, among which family relations and the proximity of infrastructures (schools, etc.) play the most important role. This means that grouping through tribal affinity is common in the most recent districts of the city.

Table 2.1-1 Reason for choice of district

Reason for choice	Number of cases	Percentage
Presence of relatives	323	64%
Presence of an infrastructures	113	23%
Others	66	13%
Total	502	100%

Source: Water utilization office /JICA, 1997

2.1.2 Population increase

If data on the demographic evolution up to 1988 are more or less uniform, figures on the actual population volume in the city, considerably vary from one source to another.

Table 2.1-2 Estimates of the Kiffa population according to the source

Wilaya (prefecture) (1996)	Study of 10 cities (1992)	Kiffa PUR 1997
73,845	31,556	59,506

The Reference Urban Program (PUR) for Kiffa is the only document providing estimates per district based on density calculations applied to the occupation of space based on aerial photographs.

The most important densities were noted around the historical district of Qadima. More or less recent suburbs (Mseïguila, Seif, Dabaï, Tweïmirit, etc.) have a scarce and scattered population. However, in terms of volume, the distribution is more spread out since 53% of the Kiffa inhabitants reside in the districts of Qadima, Virdaws, Tweïmirit, Qlîg and Sagatar II. Districts with less inhabitants are those of Seif, Khwendy, and the administrative zone.

Table 2.1-3 shows the figures proposed by the Urban Reference Program.

Table 2.1-3 Distribution of the Kiffa population according to districts in 1997

Districts	Surface (ha)	Population	% Population	Density (persons/ha)
Qadima	56	7,129	12%	127
Jedida	50	3,095	5%	62
Q. administr.	19	795	1%	41
Gomez	33	2,170	4%	67
Khwendy	10	706	1%	68
Ntou	50	3,254	5%	65
Aleg	21	1,524	3%	73
Sagatar I	101	8,567	14%	85
Sagatar II	116	5,155	9%	44
Virdaws	88	6,899	12%	78
Seif	45	700	1%	16
Qlîg	143	5,748	10%	40
Timicha	70	2,250	4%	32
Tweïmirit	289	5,906	10%	20
El Hangar	66	1,547	3%	23
Debaï	67	1,116	2%	17
Mseïguila	239	2,945	5%	12
Total	1,463	59,506	100%	51 (average)

Source: Kiffa PUR, 1997

The sample of 502 households interviewed for the preparation of this report, showed that the Kiffa population is young (50% less than 20 years old), with a predominance of women,

particularly visible in the active age bracket (20-40 years old), probably due to the persistence of migratory flows in the direction of Nouakchott.

The IWACO report on Kiffa (cf. Bibliography) also shows the young population in the Assaba capital where 41.1% of the individuals were less than 15 years of age.

We also observed the same slight predominance of women as shown in our survey, indicating that migrations towards Nouakchott include around 10% of the Kiffa households.

Table 2.1-4 Distribution of the survey population according to age and sex

Age	Males	Females	Total	%
< 20 years	977	679	1,659	50%
20 to 40 years	330	750	1,080	32%
40 to 60 years	240	227	467	14%
> 60 years	82	43	125	4%
Total	1,629	1,702	3,331	100%

Source: Water utilization office /JICA, Survey in 1997

Based on data furnished by this survey, the Kiffa households are composed of an average of 6.6 persons, the majority of which have between 5 and 7 members.

The IWACO study included 5.9 persons, the average number of persons per household in Kiffa in 1996. Divorced persons and widows or widowers are slightly more numerous among the household heads interviewed in our survey. The IWACO study had 37% of the women in the city who were widows or divorcees, and therefore responsible for the management of their households.

According to this study, only 41% of the spouses were present in Kiffa during the survey. However, the survey conducted for this report revealed, as mentioned above, that 99.20% of the spouses (husbands) lived with their partners.

The survey sample for the preparation of the present report showed that the Kiffa population has a level of schooling much higher than the national average since illiteracy only included 38% of the individuals, as compared to close to 60% of the Mauritanians as a whole. However, education received often did not go beyond the first level (50% of the total persons interviewed).

Table 2.1-5 Distribution of family members interviewed according to their level of education

Level	Male	Female	Total	%
Illiterate	458	638	1,096	38%
Primary school	737	701	1,436	50%
Junior high school	149	85	234	8%
High school	31	79	110	4%
University	23	0	23	1%
Total	1,396	1,503	2,899	100%

Source: Water utilization office /JICA, Survey in 1997

The significant demographic growth in Kiffa from the beginning of the 70's, is mainly due as noted, to the migratory flows. The Assaba region alone holds half of the rural migrants who have settled in Kiffa since 1977. Among them, 13% have originated from the neighboring Wilaya of Tagant.

It must be noted that a huge fraction of the population, impossible to estimate due to lack of data, continues to leave Kiffa city for its neighboring areas during the rainy season (July - August - September). This seasonal exodus is mainly carried out by inhabitants of the districts of Sagatar, Jadida, Timiché, Tweïmirit, including those of Qadima, Khwendy, West Belemtar. However, it must be noted that these temporary migrants continue to avail of their daily supply, including water, from the city.

For the future evolution of the Kiffa population, projections established by the National Statistics Office (ONS) based on census data of 1977 and 1988, proposed the following figures:

Table 2.1-6 Projection of the Kiffa population up to the year 2015

Year	1999	2000	2005	2010	2015
Population	50,770	53,374	68,533	87,998	112,992

Source: ONS

According to these forecasts, by around 2015, Kiffa will become the third city in Mauritania, after Nouakchott and Noudhibou, and before Kaedi.

2.2 Socio-economic situation in Kiffa

2.2.1 Cultural environment and use of water

As the rest of the population in Mauritania, the Kiffa inhabitants are all Malikite Sunnite Muslims. In principle, their religion requires a state of precise ritual cleanliness which involves their own bodies, their clothes, and the place where they make their five daily prayers.

Ablutions using water with strict standards of purity are required before each of these 5 prayers. Likewise, an ablution of the entire body is obligatory after sexual contact or major amenorrhea in women. The preparation of dead bodies also requires the complete washing of the body of the deceased.

Canonists recommend the use of water in limited quantities for all ablutions which may sometimes be reduced to simple lustrations. Alternative forms of purification using water (tayarmmum or dry ablutions) are also allowed and most of the practictioners have to settle for it.

In fact, traditional rural people, especially Nomads which comprise the majority of the present Kiffa inhabitants, use water very moderately for hygienic purposes. Mobility requirements and the scarcity of water resources mainly explain this parsimony. However, these material constraints are sometimes combined with "medical" opinions which do not favor the hygienic use of water, reputed to propagate various pathologies linked to "cold humours".

We will see further on that these beliefs and behaviors appear to have evolved in the new urban context.

2.2.2 Social structures and social groups

The oldest inhabitants of Kiffa are those who settled in Qadima and its extensions (Khwendy and Debai). Even if these are composed of relatively heterogeneous groups, they have identified themselves with the important village created with the arrival of the French.

These first inhabitants were well united among themselves, in spite of the great diversity of origins which characterized them. The majority were poor, or very poor farmers, who

provided the essential urban labor force in the city.

Even if the tribal framework remains in their mentalities, and still exercises a significant influence in the local political field, the tribal organization is not acknowledged as such by the Mauritanian administrative authorities who do not wish to directly deal with it for the management of activities in the city. As such, even if the tribal parameter must be considered in the evaluation of cohesion and solidarity factors, this unit cannot be directly mobilized.

Several special ethnic characteristics remain (Soninké, Bambara, Peul) from the old inhabitants of Qadima. However, these black families are essentially assimilated into the surrounding Moorish cultural group. Old slaves who have broken their bounds, and who have more or less grouped themselves together, also tend to go back to their tribal origins. However, the "hrâtin" social level constitutes a very important portion of the Kiffa population, which constitutes the poorest groups in the Assaba capital.

2.2.3 Administrative framework and forms of population organization

The Wali and its specialized services (hydraulic, regional delegation of MDRE, health, education, etc.) represent the government at the regional level.

In particular, the Hakem, Wali and their administrative trusteeships who have the authority to allocate public land or to enforce expropriation for the public interest of spaces required for developments considered useful by the State (Decree 90 020 of 31 January 1990).

The official representation of the entire Kiffa population at present is exercised through the municipality which is the certified interlocutor of the administrative authorities and the exterior development operators working locally.

The municipality itself has established an administrative structure for the populations in the districts, with the heads of the zone to serve as the "transmission belt" and the agent to implement its policies. There are 10 zone heads for the city itself, and 5 for the peripheral areas.

Cooperatives also constitute a framework for discussion and decision making, also in relation with administrative authorities, the municipality and development organizations. These are principally women's cooperatives.

In 1995, an office was established for the cooperatives in the Kiffa city, composed of 9 members, all presidents of cooperatives. Their duty is to provide training for the organization and management of existing cooperative associations and encourage the creation of new structures at the residential level (district..) and/or at the community activity level.

Today, the principal promoter of this cooperative movement was recruited by the Integrated Development Project of Assaba, as the person responsible for the participation and management of this project. Sectors of interests for cooperatives principally involve the following areas: market gardening, industrial crafts, trade, agriculture, the manufacture of grills for fences, nurseries.

The Kiffa office for cooperatives was opened to all associations in the city who paid the required membership fee (1,000 UM). It was a unit recognized by the commune for interventions which it wanted to encourage or promote in areas such as the supply of seeds, the purchase of grills, water, training, etc. However, according to its former president, few cooperatives were recognized or had significant activities. These were often very temporary associations, conducted by one or two persons, and mainly oriented to seeking assistance.

Based on indications gathered in Kiffa, there were 56 women's cooperatives recorded in the State Department on Women's Conditions. There were a total of 1,269 members, or an average of 22.6 members per cooperative. The majority of these associations declare that they were organized for market gardening: 31 cooperatives out of 56 (55.35%) with 669 members (52.71% of the members). The following table summarizes these cooperatives according to their principal field of activity.

Table 2.2-1 Women's Cooperatives in Kiffa according to their field of activity

Field of activity	Number of cooperatives	Number of members
Industrial crafts	1	33
Beauty salons	1	30
Trade	5	83
Sewing/embroidery	5	104
Market gardening	31	669
Poultry raising	3	66
Dyeing	6	127
Weaving	4	157
Total	56	1,269

Source: Assaba program, 1998

We have previously mentioned that the Kiffa mayor's office associated itself with the Assaba project to assign 12 women's cooperative with the use of water carts allocated by the project to the commune. The goal of this operation, within the context of support to micro-projects initiated by the municipality, is triple: distribute cheaper water under the best hygiene conditions, using the self-organization capacities of the population. Tanks in the commune, as a priority, serve as basins to supply water to member cooperatives at 60 UM for 200 liters, who then sell it at 100 UM to the population, while its current price varies between 150 and 200 UM.

The only counter-service required of cooperatives benefiting from equipment, aside from the application of the above-mentioned charge, is to assure the cleanliness of the basins and tanks for the storage and transport of water, as well as maintenance of the equipment. Even if this equipment is considered only as temporarily provided, we can see that the sole community participation in the management and distribution of water in Kiffa city operates on the basis of an allocation without a counterpart in resources. However, it contributes to promote women's participation in a field which particularly concerns women: the distribution and supply of water.

2.3 Social infrastructures, urban infrastructures and economic activities

2.3.1 Social infrastructures

(1) Education

In 1997, the Kiffa city had 22 primary schools with 5,928 students trained by 226 teachers; 14 of these schools are in the Kiffa city perimeter, with a total school population of 5,346 students, under 131 teachers. Table 2.3-1 shows the distribution of these establishments according to the districts.

Table 2.3-1 Distribution of schools, classrooms and students in Kiffa

District	No. of schools	No. of classrooms	No. of students
Qadima	3	24	1,154
Jedida	-	-	-
Quartier adm.	-	-	-
Gomez	1	12	603
Khwendy	-	-	-
Ntou	1	9	552
Aleg	-	-	-
Sagatar I	4	23	1,105
Sagatar II	-	-	-
Virdaws	1	7	266
Seif	-	-	-
Qlîg	1	8	453
Timicha	-	-	-
Tweïmirit	2	17	949
El Hangar	-	-	-
Debaï	1	6	264
Mscïguila	-	-	-
Total	14	106	5,346

Source: PUR/Kiffa

Furthermore, there is one secondary establishment (junior high school + high school) with 800 students. There are also 30 Koran schools, most often associated with mosques, where the total number of visits is difficult to estimate.

(2) Health and hygiene

Kiffa has a regional hospital built, mainly managed by the Chinese cooperative (a team of 7 Chinese specialists). This establishment which will require serious restoration work, presently employs 45 Mauritanians.

The rest of the health infrastructures consist of a health center (11 employees) and 5 health clinics (10 employees).

Data on the number of hospitalized persons provide the only quantitative approach to health problems. These data are available at the Regional Department for Health and Social Activities (DRASS).

Table 2.3-2 Number of hospitalizations in the Kiffa hospital, 1996

Pathology	Medicine	Pediatrics	Total
Diarrhea	84	17	101
Bilharziasis	15	-	15
Neuro-malaria	93	18	111
Malaria	474	134	608
Broncho-pneumonia	104	32	136
Anemia	2	-	2

Source: DRASS, Kiffa

These pathologies requiring hospitalization in the Kiffa hospital are linked to more than 85% of water-borne diseases (diarrhea, bilharziasis, malaria, etc.). Most of the malaria cases occur during and immediately after the rainy season (July-January), malnutrition peaks during the summer period (May-July). The occurrence of diarrhea is not connected to any particular season.

Furthermore, close to 400 cases of cholera were noted in Kiffa (mainly around the Nazaha district) in June 1997. However, according to the health authorities, there was no incidence of Guinea worm in the Assaba capital. At present, there is no health education project being conducted in Kiffa city.

Based on estimates of regional health services, at least one fifth of the population is affected by malaria during the rainy season. Bilharziasis and skin diseases also affect a lower fraction of the population, which cannot be estimated. Manifestations of malnutrition, observed due to night blindness (vitamin A deficiency, etc.) are also regularly noted at the end of the dry season.

Hygienic habits associated with water consumption show that if the declarations recorded are an exact reflection of the effective practices of the population, body cleanliness is a problem since less than 72% of the subjects interviewed declared taking a shower everyday.

However, 100% of the household heads interviewed in the same survey declared that they wash their hands after using the toilet, and almost all (99%) washed their hands with water after meals.

2.3.2 Urban infrastructures

(1) Road system

The only asphalted road (deteriorated in the urban part) which crosses the city is the Nouakchott-Nema road which services the Southeast to Northwest districts of Virdaws, Mseïguila, Sagatar I and II, Debaï and Tweïmirit. It joins the city center (administrative district) through a road towards the South to the UNDP office and the airport, and serves as the border between the Qadima district in the South and the districts of Jedida, Khwendy and Ntou in the North.

Aside from these two roads, the Kiffa streets are only paths or dirt roads, running through the districts of Qadîma, Jedida and the administrative area, but whose contours must be specified in other parts of the city.

(2) Living quarters

Based on data from available documentation (cf. Bibliography), the residential area in Kiffa consists mainly of houses in banco (between 44 and 50% according to sources), followed by solid and semi-solid buildings (32.7 to 34%). The rest consists of huts and tents.

The recent development of these living quarters was first marked by a high growth in the proportion of flimsy lodgings (huts and tents) from the flow of drought migrants. This was followed by houses which reflect the intention of the new arrivals to settle more permanently, and probably, an improvement in their standard of living. Indications from the survey conducted for the present report include all types of houses, in higher proportions than those given in the study of the 10 cities cited above.

Table 2.3-3 Distribution of household heads according to the type of lodging

Type of lodging	No. of cases	Percentage
House	451	90%
Huts	23	5%
Tents	28	6%
Total	502	100%

Source: Water utilization office /JICA, Survey in 1997

The study of the 10 cities, evaluated as 80% of the Kiffa population occupying a poor parcel of land, and 83% of the number of households inhabiting a lodging which they owned.

The survey conducted by the Hydraulic Department and JICA in December 1997, provides a higher proportion of owners, with tenants representing a small minority:

The tents are mainly found in the districts of Verdouz and Mseïguila, the huts are more dispersed in the districts of Timicha and Kebba.

Most of the family lots visited (47%) in this survey, have a courtyard with a surface between 200 and 600 m^2; 20% of the courtyards are bigger than 600 m^2. The big lots are mainly found in the districts of Tweïmirit, Mseïguila and Sagatar. The small lots (less than 100 m^2) were observed in the Aleg, Qlîg districts, but also in Sagatar.

Houses with a garden belonged to only 2% of the sample interviewed. According to a survey data, these are mainly found in the districts of Mseïguila and Qadima.

In the results of this survey, houses with 2 rooms are slightly more than houses with 3 rooms. These 2 types of lodgings constitute a large majority of the homes surveyed.

The presence of big houses were mainly noted in the Sagatar and Ntou districts. One-room apartments or studios are more uniformly distributed in the districts of Mseïguila, Sagatar and Qlîg.

Distribution according to the total surface area shows a clear prevalence of houses with more than 60 m^2, which represent 60% of the homes surveyed. More spacious houses are principally found in Sagatar, Qadîma and Mseïguila districts.

Table 2.3-4 Distribution of Kiffa houses according to surface area

Surface	< 20 m^2	21 to 44 m^2	45 to 60 m^2	> 61 m^2	Total
%	5%	11%	15%	60%	100%

Source: Water utilization office /JICA, Survey in 1997

(3) Water, sanitation and electricity

1) Water

We already stated that a small water supply infrastructure was installed in Kiffa in 1958, but that it only functioned for a short period of time. There were 6 posts in the Qadima, Jadida districts and the administrative area, supplied through 6,000 m of mains from a small water tower with a height of several dozen m^3, still visible today not far from the governance offices.

At present, the Kiffa population is supplied from water tanks (2 out of 6 still running) from the municipality and wells.

According to the local administrative authorities, the wells provide around 80% of the water consumption of the city as compared to 20% from the tank trucks whose maintenance (spare parts, tires, etc.) and management pose serious problems.

According to the study conducted on the spot for the present project, there are 1,000 wells in Kiffa, almost all private.

Water is transported by carts to the homes. At present (January 1998) it is sold at 150 UM per 200 l tank. The cart load cannot go beyond this volume. One cart can carry out (at the most) around 10 deliveries per day, or a total daily delivery of 2,000 liters.

We still do not know the exact number of carts in the city, but based on estimates of the municipality and Wilaya, there may be around 300.

Water delivery cart drivers are mainly Mali seasonal workers who generally live in Kiffa between January to June (there are no precise data concerning them). If they work as employees, the drivers earn around 6,000 UM/month.

Cart drivers of local origin generally belong to traditionally poor social classes. More often, young boys rather than adults drive the carts.

The total cost of equipping a cart (body, wheels, donkey, tank, etc.) is presently around 40,000 UM. If we deduct the calculated amortization in constant prices for 5 years (666 UM/month), the salary of a cart driver (6,000 UM/month), the daily cost of feeding the donkey (3,000 UM/month), as well as a provision for miscellaneous expenses (taxes, small repairs, etc.: 4,500 UM/month), they may have a monthly net profit of 26,334 UM (based on 10 deliveries/day for 27 days). This represents a considerable income at the Kiffa revenue scale.

Furthermore, we should note that part of the local industrial crafts consist of the building and maintenance of carts. The transport of water is only one function among others (transport of merchandise, passengers, etc.).

Based on results of the survey by questionnaire conducted in December 1997 for the establishment of the present report, carts supply 65% of the interviewed household, as compared to 17% whose water is supplied by tank trucks from the commune. The rest of the inhabitants directly take water from the wells.

2) Sanitation

At present, there is no waste water evacuation infrastructure or any rain water drainage system in Kiffa. Solid waste is not systematically collected and pile up on the streets, sometimes in areas provided for this purpose, that is, dumpsites which are not regularly evacuated.

Results of the survey by questionnaire show that waste water and domestic waste are thrown in the street by all persons who responded to this question.

We know that the proximity of lavatories with water taps may generate contagion. To the question of distance between wells where water is taken and toilets, 81 households who felt they were affected responded in the following manner:

Table 2.3-5 Distance of toilets to water supply wells according to families

Distance	No. of cases	Percentage (%)
Less than 5 m	1	1.2
From 6 to 20 m	1	1.2
From 21 to 50 m	21	26.0
More than 50 m	58	71.6
Total	81	100.0

Source: Water utilization office /JICA, Survey in 1997

This information shows that in most cases, toilets are located at a reasonable distance from water supply points.

3) Electricity

Since 1996, Kiffa has had a thermal plant equipped with 4 sets of 800 KWA. According to data from PUR/Kiffa, more precise than those provided by the SONELEC local department, the city has 2,020 subscribers, for a total 3,125 branches installed. In fact, several "subscribers" are content with the installation provided free of charge by SONELEC, without using it. Based on the SONELEC officials, many of these "subscribers" have asked for connection to the electrical system, thinking that this will provide access to water. In any case, potentially there are 14,459 Kiffa inhabitants with electricity. Studies are being conducted to extend the network to 380 new subscribers. The average monthly consumption per household is 50 kW.

The following table shows the distribution of the subscribers according to "sectors" defined by the PUR study, and the percentage of the population in the sector with access to electricity.

- Sector I is composed of 4 districts: Qadima, Jedida, the administrative district, Gomez, Khwendy, Ntou, Aleg
- Sector II: Sagatar I, Sagatar II, Virdaws
- Sector III: Seif, Qlîg, Timicha, Tweïmirit, El Hangar, Debaï, Mseïguila

Table 2.3-6 Distribution of subscribers in Kiffa

Sector	% population with access	Number of subscribers	Average consumption	Total consumption (kW)
Sector I	42%	955		47,750
Sector II	11%	331		16,550
Sector III	22%	734		36,700
Total	24%*1	2,020	50kW	101,000

*1: from the total Kiffa population

Source: PUR/Kiffa, 1997

2.3.3 Revenues, consumption of households and economic activities

(1) Revenues

The capital of Assaba is essentially a rural community. Outside the administrative and commercial occupations, small industrial crafts and services for consumption and urban activities, these inhabitants are in agricultural and livestock breeding.

The study of the 10 cities evaluated the average monthly revenue of households in Kiffa at 21,113 UM. The survey conducted for the present report gives a lower figure of 7,826 UM. This difference may result from an attempt at dissimulation in order to receive assistance for water supply. Globally and in percentage terms, this revenue is distributed, as shown in the table 2.3-7, with respect to its sources:

Table 2.3-7 Annual average revenue of households based on sources

Source	Amount	Percentage
Salaries	64,988	69%
Agricultural revenue	266	0%
Livestock breeding revenue	527	1%
Other revenue	28,165	30%
Total	93,913	100%

Source: Water utilization office /JICA, Survey in 1997

This table shows both the important contribution of salaries and transfer revenue (the essential component of the "others" item) to resources of Kiffa households, and at the same time, the small contribution of agriculture to their budget input. Different from livestock breeding, this contribution is used mainly to satisfy self-consumption needs.

(2) Public employment

The administrative services employ around 450 persons according to the Wilaya, with an average net monthly salary of around 14,000 UM. We may note that this figure given to us significantly differs from that gathered by the authors of the study on the 10 cities, which evaluated the number of administrative employees to 200, but still representing 12% of the households heads employed in the city.

The survey conducted from a sample of 502 household heads gives the following

distribution of employment:

Table 2.3-8 Distribution of employment based on the survey

Employment category	No. of cases	Percentage
Administrative employees	65	12.9
Laborers in the modern sector	109	21.7
Laborers in the traditional sector	14	2.8
Farmers	17	3.4
Livestock breeders	17	3.4
Housewives	49	9.8
Trade	108	21.5
Unemployed	111	22.1
Others	12	2.4
Total	502	100.0

Source: Water utilization office /JICA, Survey in 1997

This table shows that aside from a big percentage of the unemployed (more than 30% of household heads, if the housewives are included), the salary resources of the Kiffa inhabitants are essentially derived from small employment in the modern sector, trade, and administrative employment.

(3) Trade and services

Based on the 10-cities study, in 1996, Kiffa had around 450 shops, 9 service stations, 115 bakeries, 150 laundry services, 18 pharmacies, and 19 hotels or restaurants. Laundry services refer to individuals or teams (often Mali seasonal immigrants) who wash and iron clothes with no equipment other than their 2 arms). In fact, there is only one hotel, but several small "restaurants/sheds" at the road station which can receive passengers for the duration of their stay.

There are several small businesses, and the city has 2 livestock markets and 2 general food markets. The building of a third one will soon be completed.

(4) Industries

The only industrial units in the city, a cold chain and a dairy unit, are no longer operating. However, industrial crafts (mechanical, electrical, metallic fittings, brickwork, etc.) occupies a significant fraction of the population. The only figure

estimate we were able to obtain from the above-mentioned study, is 8.5% of houschold heads. As we have seen above in the distribution of employment from our study sample, the industrial crafts sector holds a high percentage among the salaried activities in the Assaba capital.

(5) Agriculture

There is no specific data on Kiffa agriculture. The information elements available in the Regional Department of the Ministry of Rural Development (MDRE) refers to the entire Assaba region or to the Kiffa "mouqataa".

Indications provided by the MDRE department show that in 1988, there were 323 farmers in the "mouqataa". The following estimates are given for harvest volumes of the principal cereals cultivated ("dieri" or only rain-fed cultivation) within and around Kiffa in 1997.

Table 2.3-9 Cereal production in the Kiffa mouqataa in 1997

Type of product	Harvested volume
Sorgum	11,430 t
Millet	1,630 t
"Niebe"	6,300 t
Corn	2,400 t
Total	15,400 t

Source: MDRE department/Kiffa

In addition, the different surveys conducted and the documentation show that agriculture has always played a significant role in the activities and revenues of the Kiffa city inhabitants.

Introduced in 1925, the cultivation of date palms, which occupies a large portion of the Kiffa wadi, is declining at present due to deteriorating climate conditions. At present, the city has 20.4% of the Assaba palms (source: CIMDET, 1997), or a total of 20,262 units distributed on 245 hectares.

The harvesting of dates varies based on the type of cultivation (foot spacing) and the maintenance of the palms groves. If we consider the average provided by the technical services (30 kg/palm tree), the potential annual date harvest in Kiffa will be

607.86 tons.

Well before the introduction of palm trees, the Kiffa inhabitants cultivated cereal (millet, sorgum, corn, niebe, etc.) and some commercial plants (henna, tobacco, etc.), including peanuts. These are cultivated at the banks of Kiffa wadi from October to January.

We have no precise estimates of cultivated surface areas in Kiffa itself, nor the volume of harvest. We only know that cereal harvests have regularly diminished since the beginning of the 1970's due to the rainfall and changes in lifestyles.

Market gardening which is progressing since its introduction in the 1950's, tends to replace the above-mentioned cereal cultivation. In this area, there is no existing evaluation of cultivated surfaces in Kiffa city, nor of the production of carrots, cabbages, tomatoes, raddish, salad vegetables, potatoes, etc.

Aside from the water scarcity problem, the expansion of market gardening activities is limited because of the small market, the regular drop in prices during the high season (December-February) due to relative overproduction, and the absence of modern packaging and/or conservation means.

Cultivation is not practiced in the concessions, but only throughout the length of the surrounding area (Arâgîb) of the zone liable to flooding (Msîla) between Billamtar and Hsaï al-Bakkâi.

All land or individual properties known, and populations who recently arrived (Idaïboussât, Aghlâi, etc.) cultivate the depressions outside the city (Kraïkit, Maïssâh az-Zbil, Oum ech-Chgâg, etc.).

However, individual property titles are written in the land sections of the Msîla, clearly marked by predominant tribal customs. From East to West, the names of the principal locations of the Msîla and tribes can be seen:

Further on, we will see that under considerations for the organization of populations, many cooperatives have declared themselves as mainly agricultural cooperatives.

(6) Livestock breeding

Available data on livestock breeding covers the entire region of Assaba or the mouqataa, with no precise elements regarding the single city of Kiffa.

Livestock breeding services estimate that Assaba has 13% of the Mauritanian livestock with 210,000 cattle, 1,010,000 sheep-goats and 90,000 camels. According to the MDRE regional delegation, in 1997, the Kiffa mouqataa had 800,000 sheep-goats, 70,000 cattle, 25,000 camels, 500 donkeys and 100 horses.

In Kiffa itself, domestic animals are mainly composed of small ruminants, goats in particular, raised to provide milk. More well-off families sometimes also own a few cows, or more rarely, a few milk-producing female camels. Donkeys are strong draft animals, used in the city particularly to transport water.

However, results of the survey by questionnaire show the following figures for animals owned by the interviewed families:

Meat is the principal animal product commercialized. Butter (processed), and to a smaller extent, milk, are also marketed. Skins, not locally treated, are sold in Nouakchott, or transported by intermediaries to neighboring Mali.

2.4 External interventions and development projects

Several external contributors have provided or are still providing their assistance for the development of Kiffa city:

2.4.1 NGOs

(1) The French Association of Volunteers for Progress (AFVP) has participated, within the context of a financing granted by the Ile de France Regional Council, particularly for the construction of water storage basins (20 basins must be built, of which only 7 are presently functioning in the districts of Debaï, Kebba, Seif, Jedida, Timicha, Gomez) and the repair of the tank trucks in the municipality. This intervention was stopped due to the termination of financing.

(2) Since 1985, the World Vision International NGO has been conducting an Integrated Regional Program for the Development of Assaba (PIDA) which consists of drilling wells (outside Kiffa), the establishment of cereal banks, support for market gardening, training for cooperatives, and the granting of small credits.

(3) Since 1979, the World Lutheran Federation (FLM) has been conducting an activity affecting various economic and social sectors of the Assaba inhabitants, and more particularly Kiffa:

- assistance to an "appropriate technology cooperative" (mechanical construction craft industry);
- reforestation (green belt, etc.);
- a public secretarial office to support the handicapped;
- support for market gardening cooperatives
- building of classrooms, a mosque, etc.

At present, the FLM activities in Assaba have been suspended. Activities of this NGO are now deployed in the Brakna region.

(4) American Peace Corps Volunteers have a small unit in Kiffa, in particular to promote the use of a particular type of pump: the plug-type pump.

2.4.2 Bi- or multilateral assistance

(1) The Assaba Program of the United Nations Equipment Fund (FENU) presently working in the entire Assaba region, has planned the following activities in Kiffa where it is based:

- The rehabilitation and building of 20 classrooms and a junior high school,
- The sanitation of 2 unhealthy districts (an agreement to this effect was signed in April 1997 between the commune, World Vision and the Assaba Program for garbage collection in the Jedida district by an individual),
- The promotion of small productive and service enterprises,
- Support to the Kiffa municipality, particularly through the building in 1997 of 6 water storage basins of 12 m^3 (in the districts of El Hangar, Sonader, Qlîg, Qadima, Jadida and Garage). These basins are each provided with 4 carts equipped for water delivery and provided for management by women's cooperatives.

The activities of the Assaba Program started between March and April 1997 and are still continuing.

(2) The GIRNEM program (Integrated Management of Natural Resources in East Mauritania), launched in 1994, with German assistance, is planned for 3 years. Its activities, centered on survey and planning work on the environment, have scarcely covered Kiffa city at present.

(3) Other projects (OASIS, PARC, PDS, PRVA) attached to the Regional Delegation of the Ministry of Rural Development and the Environment, have developed or are still developing activities without major impact on Kiffa city.

Chapter 3 Hydrogeological Survey/Valuation of Recharge Storage

3.1 Weather and hydrology

In Kiffa city, there is a weather observation station governed by the Planning Ministry. Observation of atmospheric temperature, humidity, amounts of evaporation and precipitation, wind direction of a wind and the number of days per weather has been carried out since 1989. Because water doesn't stream in the Wadi Rhouda running through Kiffa city, the amount of flowing water in the Wadi is not observed.

Based on data observed over a period of 8 years, from 1989 to 1997, at the observation station in Kiffa city, the annual average amount of precipitation is 235.4 mm and the amount of evaporation is 3,062 mm. The average monthly amounts of precipitation and evaporation are shown in the following figure.

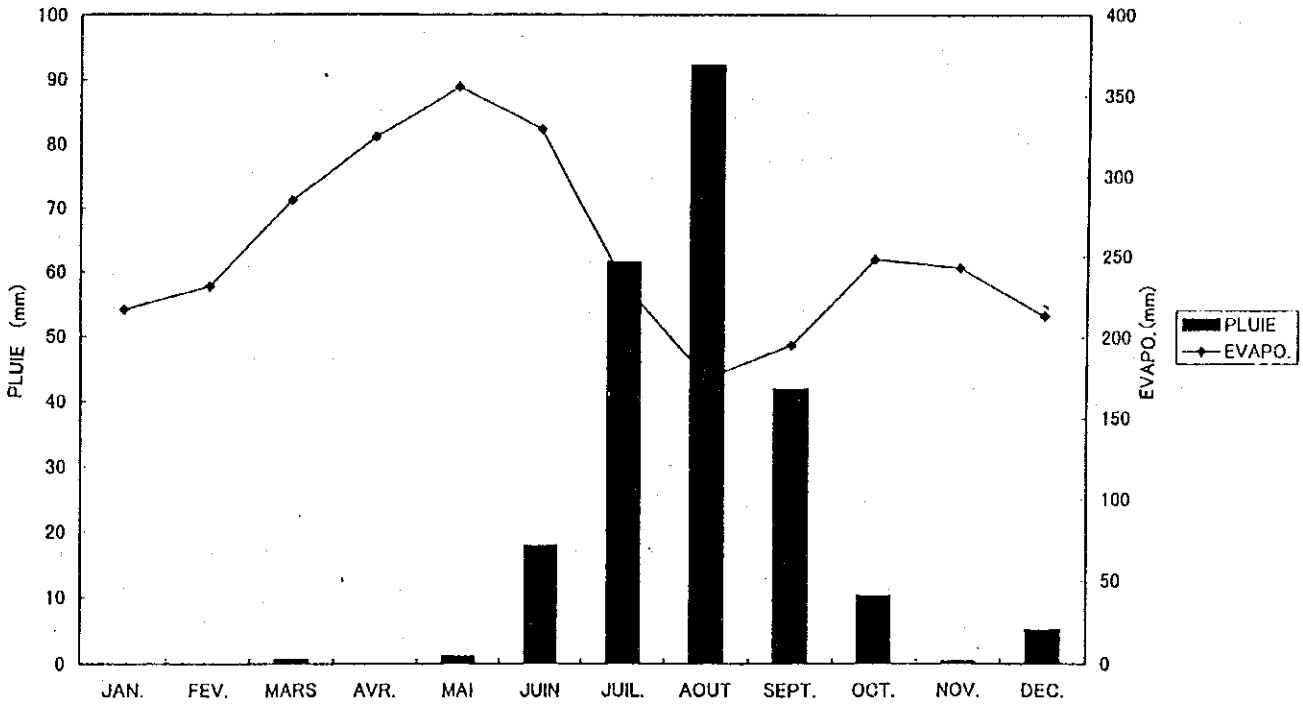

Fig. 3.1-1 Amounts of precipitation and evaporation by month in Kiffa city

As shown in the above figure, the length of the rainy season in the study area is 5 months, from June to October; August has the most rain. Precipitation is found in December in the above figure because there was a large amount in December 1995; precipitation was not observed in December in other years. On the other hand, the amount of evaporation is highest in May, and there is a decreasing tendency in the rainy season.

The amount of evaporation is much more than that of precipitation in every month. The amount of evaporation is twice that of precipitation even in August when it rains the most.

3.2 Geographical features and geology

3.2.1 Summary of geographical features and geology in the study area

(1) Summary of geographical features

Kiffa is located on a plain restricted by the Assaba Plateau in the west, by the Aouker sandhill-like mountainous region in the north, and by the Affole mountainous region in the east.

Around Kiffa, many places are covered by sandhills running parallel from northeast to southwest. In the bare-rock zone near Kiffa, jasper and/or pelite is folded moderately and forms soft hills and valleys. Many of the valleys distributed among hills are depressions without outlets of flows, and a lot of wadi come into them.

The Rhouda Wadi crosses Kiffa. It flows into the El Msîlé Wadi, which is a northern extension of the Karakoro River, one of branches of the Senegal River. In the Rhouda Wadi, ponds are formed intermittently along the wadi during the rainy season.

(2) Summary of geology

The geological map of the area near Kiffa is shown in Fig. 3.2-1.

In the area surrounding Kiffa, strata of sedimentary rocks from the infracambrian period to the Cambrian-Silurian period and Quaternary strata are seen. The order of the strata is as shown in Table 3.2-1.

Table 3.2-1 Order of layers around Kiffa

Quaternary Period		Clay of Sandhills, Alluvia and Bottoms of Lakes and Marshes
	Intrusive Rock Group	Dolerite
Silurian Period ~ Cambrian Period	Assaba Series	Sandstone and quartzite
		Upper dolomite
	Kiffa Series	Light-yellow and fine sandstone
		Pelite (mudstone, shale)
		Jasper(chert)
		Lower dolomite
	Cambrian base series	Upper tillite
		Dhar Taleb sandstone
		Lower tillite
Infracambrian period	Affole series	Fine sandstone at the top of the Affole mountain mass
		Ayoun sandstone

From east of Kiffa (Affolé mountain) to west (Assaba height), geological formations from the Cambrian period to the Silurian period are seen dipping gently towards the west. In the direction of the east of Kiffa, Ayuon sandstone of the Infracambrian period crops out widely on the Affolé mountainous district. Around Kiffa, the parts cropping out are of pelite (mudstone, shale), jasper (chert) and tillite, which were formed from the Cambrian period to the Silurian period. In the direction of the west of Kiffa, the top of the Assaba height is sandstone and quartzite, which were probably formed from the Silurian period to the Ordovician period.

The Ayuon sandstone forms is the base of the Affolé mountainous district, and fine sandstone forms its roof. These sandstones of the Affolé series are characterized by large-scaled slant lamina, and the thickness of a stratum is approximately 100 m. Lithology is soft, and their colors are white, yellow or rose pink. There are alternations of these rocks with thin clay strata in some places.

Sandstone of the Affolé series of the infracambrian period is unconformably covered by tillite of the Cambrian period. In the upper part of tillite, Dhar Taleb sandstones cropping out in northeast of Kiffa. It is covered by upper tillite. Selection of these tillites is remarkably bad, and they consist of clay, sand and breccia. Breccia in tillite consists of granite, and the size is diverse.

Upper tillite is covered by paleozoic strata of the Kiffa series, which mainly consists of pelite (mudstone, shale) and jasper (chert). One thin stratum of dolomite-limestone (thickness: approximately 15 m) is between tillite and jasper in some places. This series formed from the Cambrian period to the Silurian period is composed of jasper,

mudstone and light-yellow fine sandstone. Pelite and jasper are widely distributed near Kiffa and in the northern part of Kiffa. Pelite is very fine compact siliceous rock and clay in various colors (gray, green, beige, purplish color and black). Some are sandy. Thickness of a layer is over 200 m.

All of these sedimentary rocks of the Kiffa series are covered by siliceous sandstone of the Assaba series cropping out on cliffs of the Assaba height. In the base of this sandstone, probably there is one thin stratum of dolomitic limestone (thickness:15-20 m).

Generally, these paleozoic strata dip gently westward and are piled up conformably. Some of these strata have intrusive basic rocks (dolerite, diorite, etc.)