4. Groundwater development plan

4.1 Groundwater development plan in Kiffa city

The potential development capacity of groundwater in Kiffa city is 240,000 m^3/year, as discussed in Chapter 3. In contrast, the volume of water now pumped up is 330,000 m^3/year, far exceeding the volume contemplated by the development program.

When water is conveyed from the northwest well field in 2000, the potential development volume will increase to about 300,000 m^3/year, assuming that about 10% of the conveyed water may permeate through the ground. If sewer systems are built in Kiffa city by 2015, this groundwater permeation becomes unavailable. In view of these factors, it should be planned in Kiffa city to regulate the pumping of water step by step.

In consideration of the above, the groundwater development program should be implemented according to the timetable given in Table 4.1.

Table 4.1 Development plan of groundwater at shallow aquifer in Kiffa

Unit: m^3/year

	Present	2000	2005	2010	2015
Projects		Construction of water supply facilities	Regulation of water pumping -9%	Regulation of water pumping -17%	Building of sewage systems Regulation of water pumping – 27%
Recharge by rainfall	300,000	300,000	300,000	300,000	300,000
Water permeation of water conveyed from the northwest	0	73,000	73,000	73,000	0
Maximum available pumped water	240,000	298,000	298,000	298,000	240,000
Pumped water	330,000	330,000	300,000	274,000	240,000
Water balance	-90,000	-32,000	-2,000	24,000	0

4.2 Groundwater development plan in the northwest well field

(1) Volume of groundwater in the development program for the northwest well field

The potential volume of groundwater available from the development in this northwest well field totals 1,200,000 m^3/year as discussed in Chapter 3. The volume of water now pumped up in the northwest well field is estimated to be as little as 1.5% of the developable capacity, a practically negligible amount.

Given these facts and in consideration of the future water demand in 2005 and 2015 in Kiffa city, the groundwater development program in the northwest well field should be as shown in Table 4.2.

Table 4.2 The Groundwater development plan in the northwest well field

Unit: m^3/year

Groundwater basin	Built-up water volume	Volume available for pumping	Present pumped water volume estimated	Plan 2005	Plan 2015	Wells in use
Area A	800,000	640,000	5,000	560,000	600,000	JF-2,JF-5A, JF-7B,F-5,F-6
Area B	210,000	170,000	2,500	170,000	170,000	JF-13A
Area C	490,000	390,000	10,000	0	380,000	About 4 new wells
Subtotal	1,500,000	1,200,000	18,000	730,000	1,150,000	
Shallow wells in the city	---	---	---	300,000	240,000	
Total water supply				1,030,000	1,390,000	
Water demand				1,026,000	1,387,000	

As shown in this table, the planned volume of pumped water in the northwest well field is 730,000 m^3/year in 2005 and 1,150,000 m^3/year in 2015. This means that the groundwater development in this area will provide sufficient water supply to fill the water demand of Kiffa city through 2015.

(2) Groundwater development plan targeted for 2005

In the groundwater development program targeted for 2005, six wells producing a relatively large amount of pumped water will be chosen from the test-bored wells in this survey for conversion to production wells. The structural data of these six wells is shown in Table 4.3 and their location in Fig. 4.1.

Fig. 4.3 Structure of the production well

Groundwater basin	Well No.	Aquifer	Drilled length	Well diameter	Volume of pumped water	Section in which strainers are installed
A	JF-2	Pelite	58.0m	6 inch	9.5m^3/h	GL-23m～-39m
	JF-5A	Pelite	62.0m	6 inch	7.2m^3/h	GL-24m～-52m
	JF-7B	Pelite	46.0m	6 inch	18m^3/h	GL-11m～-40m
	F-5	Pelite	66.0m	6 inch	54m^3/h	GL-8m～-40m
	F-6	Pelite	42.0m	6 inch	70m^3/h	GL-11m～-39m
B	JF-13A	Pelite	58.0m	6 inch	37m^3/h	GL-19m～-47m

(3) Groundwater development plan targeted for 2015

1) Location of production wells

As stated in Chapter 3, the groundwater development program for the target year of 2015 needs the boring of new wells in the development area shown as C in Fig.4.1. The number of production wells depends on the volume of pumped water per well. If the volume is assumed to be 10 m^3/hour per well, the number of wells could be six.

2) Boring specification of the production wells

In the groundwater development program for the target year of 2015, the specification of the well is presumed to be the same as that of the test-bored well in this survey, that is, a well having a wellhead diameter of 8-5/8 inches with a 6-inch FRP casing and strainer fit inside and bored to a depth of 50 m to 60 m.

4.3 Groundwater management program

(1) Management program of groundwater at shallow aquifer in Kiffa

Groundwater of relatively good quality is distributed and available in the still underdeveloped area to the northwest of Kiffa city. In order to regulate development in this area, groundwater conservation measures are needed. Also, in order to alleviate today's excessive water pumping, it is desired that the city authority will take necessary actions including the regulation of water pumping from the wells of poor water quality.

(2) Management program of the northwest well field

In order to verify the dipping of the water level due to groundwater development,

five recording water gauges will be installed on the wells test-bored in this survey. Also, the production wells will be periodically checked regarding water quality at a frequency of twice a year or so.

In addition, the northwest well field will be designated as a water source conservation area, where pasturing and other agricultural activities as well as housing development will be strictly regulated or prohibited with a view to preserving the quality of groundwater.

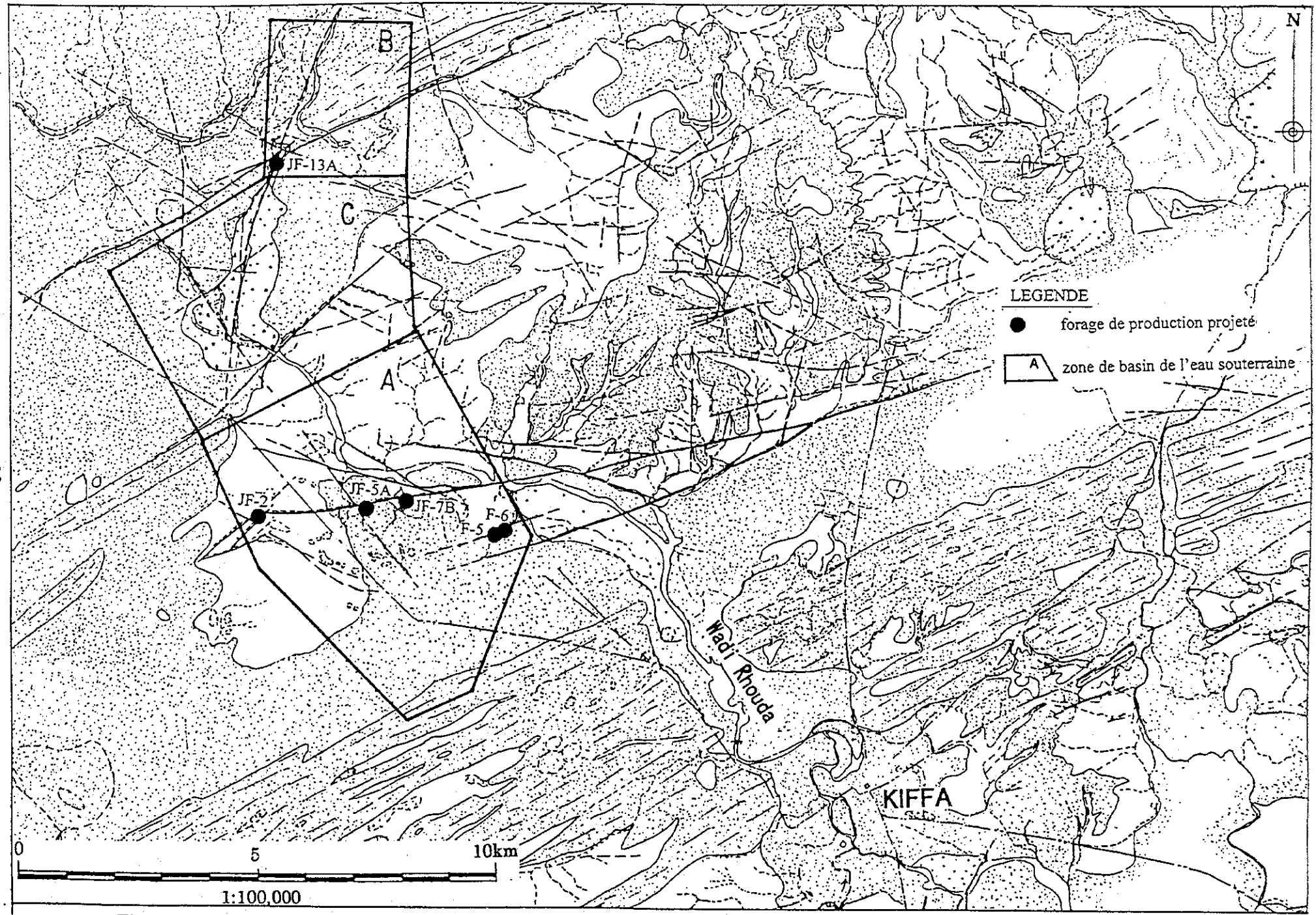


Fig. 4.1 Map of groundwater basin and the location of deep wells to be used for the water supply plan

5. Water supply plan

5.1 Contents of the project

The contents of the project in the water supply plan are as follows.

(1) Target years of the plan

a. Year 2005: Urgent improvement plan

b. Year 2015: Long-term improvement plan

(2) Potential development capacity of groundwater

a. Points of development as water sources

The northwest well field (a water source 12 - 20 km northwest of the city) and the groundwater in at shallow aquifer in the city

b. Potential development capacity (Unit: m^3/year)

Plan year	Northwest water source		Groundwater at shallow aquifer	Total
	Areas A and B	Area C		
2005	730,000	0	300,000	1,030,000
2015	770,000	380,000	240,000	1,390,000

(3) Area covered by the plan

The urban district of Kiffa city shall be the area to be covered by the water supply plan.

(4) Population served by the plan

The present populations (in 1997) in Kiffa city and populations in the plan are shown in the following table.

Year	Population (persons)	Population in each area	
		I and II groups	III group
Current (1997)	60,921	36,975	23,946
2005	77,000	50,000	27,000
2015	100,000	80,000	20,000

I : Old urban district

II : New urban district developed under the plan

III : Area where development has advanced spontaneously.

(5) Planned amount of water supply and demand

1) Planned amounts of water supply

The planned amount of water to be supplied in each target year is shown in the following table.

Target year	Water supply system	Population covered by water supply	Amount of water supplied (little/person/day)
2005	Water supplied to each house	50,000	40 (10 of which are groundwater at shallow aquifer)
	Public water tap	27,000	30 (10 of which are groundwater at shallow aquifer)
	Total	77,000	
2015	Water Supplied to each house	80,000	40 (10 of which are groundwater at shallow aquifer)
	Public water tap	20,000	30 (10 of which are groundwater at shallow aquifer)
	Total	100,000	

2) Planned amounts of water demand

Annual amounts of water demand in 2005 and 2015 are shown in the following table.

Target year	Water supply system	Population covered by water supply	Amount of water demand (m^3/year)
2005	Water supply for individual houses	50,000	730,000
	Public water tap	27,000	296,000
	Total	77,000	1,026,000
2015	Water supply for individual houses	80,000	1,168,000
	Public water tap	20,000	219,000
	Total	100,000	1,387,000

5.2 Water supply plan

5.2.1 Basic policies

(1) Development of water sources

Water sources to be developed are the aquifers at a depth of 50 - 100 m around pelite faults located at 10 - 15 km northwest of the city. Shallow wells with relatively good water quality that exist in the city now should be considered as water sources in the water supply plan. Measures to conserve water quality in these wells also should be developed in the plan.

(2) Water supply plan

There are areas where road arrangements required for laying of distributing pipes for water supply to individual houses have not been completed, or areas where the residents cannot afford the expense of water supply by house connection. Therefore, a system with both water supply to individual houses and use of public water taps should be considered. Restriction of water supply to certain hours should be introduced as a method to restrict the amount of water supply.

(3) Operation of water-supply facilities

The main water-supply facilities should be operated, maintained and managed by SONELEC. For public water taps, a method should be examined to strengthen the functions as a public service, including autonomous maintenance and management by a residents' organization.

5.2.2 Restriction of water supply to certain hours

The system of restricting water supply to certain hours is applied to this plan as measures for restricting the water consumption.

(1) Preconditions

Factors to be considered for restricting water supply to certain hours are as follows:

① Areas in which water supply will be restricted to certain hours, and what those hours will be, should be determined to ensure that proposed water-supply facilities will not be excessively large.

② The peak hours for water consumption (7 - 9 o'clock in the morning and 6 - 8 o'clock in the evening) should be taken into consideration when establishing water-

supply hours.

③ The manual opening and closing of valves will be necessary to restrict water supply to certain hours. Attention should be paid so that enormous effort and cost will not be required for operation and maintenance because the valves concerned will be many in number.

④ The pipe network should be planned so that a certain amount of water will be supplied to the whole service area even if a distribution main is damaged by an accident.

⑤ The pipe network should be examined on the assumption that residents will secure or consume the fixed amount of water supplied within the determined hours of water supply.

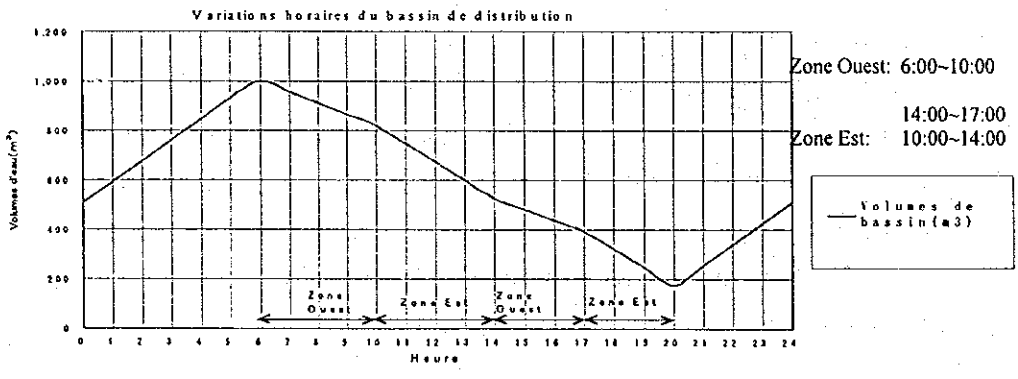
(2) Division of areas with restriction of water supply to certain hours

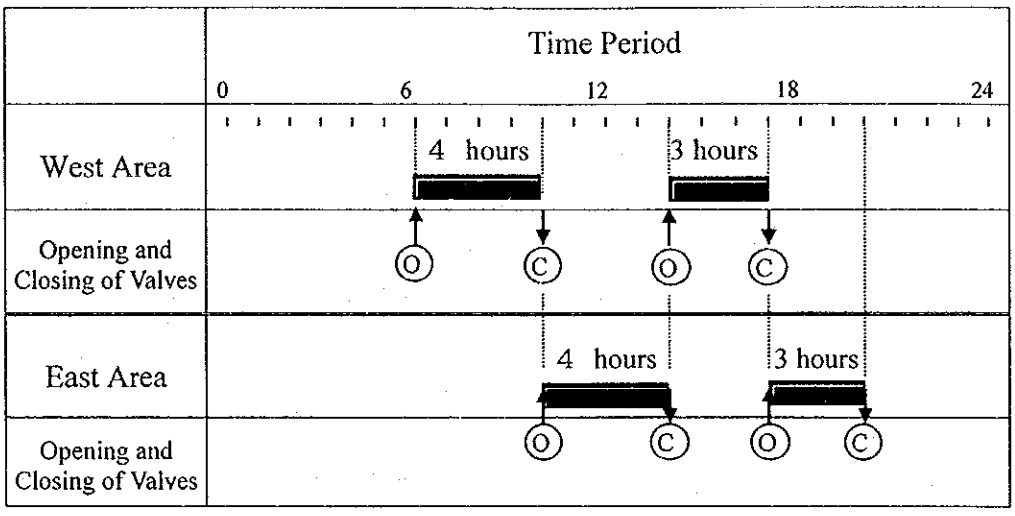
In Kiffa city, two urban districts spread out west and east of the Wadi Rhouda. Relatively independent distribution networks are formed in these western and eastern areas. Therefore, areas with restriction of water supply to certain hours are divided into two parts, eastern and western.

(3) Establishment of hours and time zones of water supply

In the case of restriction of water supply to certain hours, it is supposed that residents will use water simultaneously in the time periods of water supply so that a large amount of water will be used in a short period of time. There is the possibility that the amount stored in the distribution reservoir will be completely used during these periods, causing the inside of the distribution pipes to have negative pressure. Therefore, it is necessary to establish hours and time periods of water supply in order to prevent it.

In consideration of the above-mentioned preconditions, we will apply 7 hours of water supply to this plan. The results are shown in the following figures.





C=Close O=Open

(4) Contents of the water supply plan

The contents of the water supply plan are as shown in the following table.

Target year and population	Contents of the plan
Urgent improvement plan (year 2005, 77,000 people)	• Development of water sources in the northwest well field and Areas A and B • Construction of ducts for water conduction from the northwest well field to inside of the city • Supply of drinking water by water supply through ducts (2 systems: one in the northwest well field and one for wells in the city) • Conservation of quality of water at wells in the city (improvement of well structures and manually-operated pumps) • Use of groundwater at shallow aquifer in the city as non-drinking water
Long-term improvement and Completion plan (year 2015, 100,000 people)	• Development of water sources in Area C in the northwest • Increase in supply of drinking water by water supply through ducts • Improvement of groundwater quality at shallow aquifer in the city • Restriction and control of pumping-up of groundwater at shallow aquifer in the city

5.3 Facilities plan

5.3.1 Basic design policies

(1) Facilities specifications

The specifications of water-supply facilities should be determined based on a water per capita consumption of water (30 liters/person/day) in the urgent improvement plan

(2005), population in the plan, range of improvement and completion, etc. With an extension of facilities and equipment taken into consideration, a facilities plan should be made.

(2) Facilities plan

In consideration of the present situation of urban water supply systems in Mauritania, a facilities plan should be made so as to realize a water supply system featuring low construction cost and easy and low-cost maintenance and operation, and will not cost much and which will be able to cope with a future extension.

(3) Design conditions

The following table shows the summary of design conditions established according to the design frame of the project and the basic policies.

No.	Item	Design condition		Remarks
1	Target year	Year 2005	Year 2015	
2	Target population	77,000 persons	100,000 persons	Estimated with the results of the on-the-spot survey
3	Maximum water consumption per head per day			
	• House connection system	30 liters/person/day (65% of population)	30 liters/person/day (80% of population)	
	• Public water tap system	20 liters/person/day (35% of population)	20 liters/person/day (20% of population)	
4	Maximum water consumption per day	2,000 m^3/day	2,800 m^3/day	("3" stated above) x Population in the plan
5	Coefficient of hourly fluctuation (for water ducts)	2.0		To be determined according to the actual conditions in Mauritania
6	Minimum hydrodynamic pressure at the end of distribution branches			
	• House connection system	1.0 kg/cm^2		According to the SONELEC criteria
	• Public water tap system	0.5 kg/cm^2		According to the SONELEC criteria
7	Minimum water velocity	0.3 m/s		With reference to Japanese criteria
8	Capacity of reservoir	Portion for 12 hours of the maximum water consumption per day		To be determined according to the actual conditions in Mauritania
9	Pipe type			
	• Water conveyance pipe	Ductile cast iron		Common in Mauritania
	• Water transmission pipe	Ductile cast iron		Common in Mauritania
	• Water distribution main	Hardened polyvinyl chloride (PVC)		Common in Mauritania
	• Water distribution branch	Hardened polyvinyl chloride (PVC)		Common in Mauritania
	•Connection pipe for public water tap	Hardened polyvinyl chloride (PVC)		Common in Mauritania
10	Earth covering depth to pipe	1.0 m		According to the SONELEC criteria
11	Population covered by a public water tap	500 - 700 persons/tap		To be determined according to the actual conditions in Mauritania

5.3.2 Basic Design for Water Supply System

(1) Configuration of the Water Supply System

A water supply system is composed of the following facilities (Fig. 5-1). Basic design drawings of all facilities are as shown in the drawings.

① Well/lift pump station
② Water conveyance pipeline
③ Water transmission pump station
④ Water transmission pipeline
⑤ Distribution reservoir
⑥ Water distribution pipeline

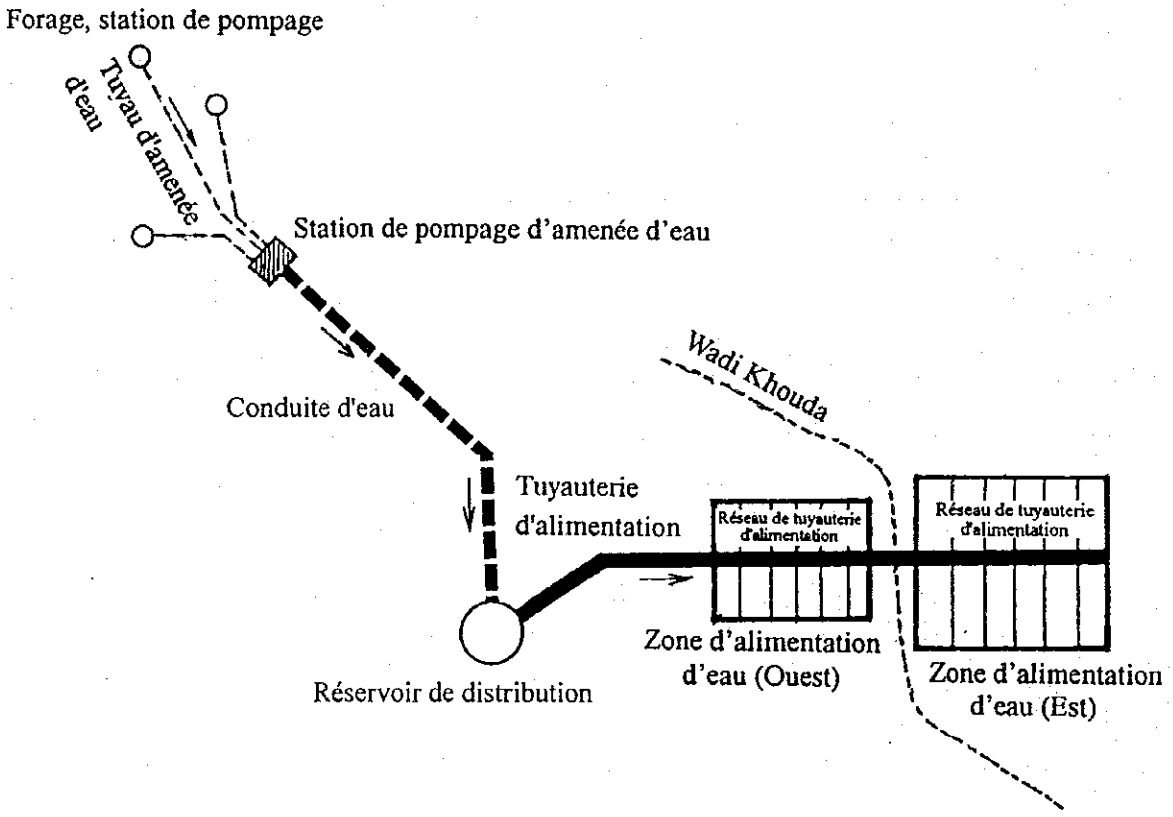


Fig. 5-1 Conceptual figure of water supply system

5.3.3 Establishment of facility specifications

(1) Well/lift pump station

1) Maximum water consumption per day

a. Urgent improvement plan: 2,000 m³/day

b. Long-term improvement plan: 2,800 m³/day

2) Planned water pumping rate

Safe yield, planned pumping rate, depth, and water level of each production well are as shown in the following table.

Well No.	Safe yield (m³/h)	Planned pumping rate (m³/h)	Depth of well (m)	Water level of well (m)
JF-2	11	10	58	14.3
JF-5A	5	5	62	13.6
JF-7B	18	15	46	7.7
JF-13A	30	25	58	4.1
F-5	35	25	66	8.0
F-6	35	25	66	8.0
Total	134	105		

3) Capacity of lift pumps

Well No.	Altitude (m)	Design pumping rate (m³/min)	Pump head (m)	Number of pumps	Specifications of pump	Depth of installation (m)
JF-2	137.1	0.2	50	1	Dia. 50 mm, 3.7 kW	30
JF-5A	135.8	0.1	45	1	Dia. 40 mm, 2.2 kW	30
JF-7B	128.3	0.3	50	1	Dia. 65 mm, 5.5 kW	20
JF-13A	120.4	0.5	70	1	Dia. 65 mm, 11.0 kW	25
F-5	129.2	0.5	45	1	Dia. 65 mm, 7.5 kW	20
F-6	129.2	0.5	45	1	Dia. 65 mm, 7.5 kW	20

(2) Water transmission pump station

Planned water transmission volume: 2,000 m³/day

Capacity of water transmission pump is as follows.

Target year	Planned water transmission volume (m^3/min)	Discharge volume (m^3/min/pump)	Pump head (m)	Number of pumps	Specifications of pump
2005	1.4	0.7	45	3 (2 for daily use + 1 spare)	Single suction centrifugal pump (Dia. 65 mm, 9.2 kW)
2015	2.0	0.7	45	4 (3 for daily use + 1 spare)	

(3) Water transmission pipe

The diameter of water transmission pipe is designed for the maximum water consumption per day in 2005.

The specifications of water transmission pipes in the target years, 2005 and 2015, are shown in the following table.

Target year	Water transmission pipe	water transmission volume (m^3/s)
2005	250 mm x 1 pipeline	0.023
2015	250 mm x 1 pipeline 150 mm x 1 pipeline	0.032

(4) Distribution reservoir

A distribution reservoir will be constructed on the heights (at 165 m height) on the west side of Kiffa city to distribute water by gravity. Capacity of the reservoir should be 1,000 m^3 equivalent to 12-hour operation for the maximum water consumption per day and, which is employed in various cities in Mauritania.

(5) Water distribution pipeline

A water distribution pipeline consists of a water distribution main to supply water throughout the service area, and water distribution branches diverging from a water distribution main and laid so that a service pipe can be connected to each house. Fig. 5-2 shows the drawing of the distribution network plan.

Water distribution mains shall be laid out to form a loop in order to ensure stable quantity and pressure.

The diameter of water distribution main is planned to cope with the future increase in demand for water, and to secure the minimum hydrodynamic pressure (house connection system: 1.0 kg/cm^2, public water tap system: 0.5 kg/cm^2) at the end of a water distribution branch at ordinary times.

As for the water distribution network, the following four cases have been studied for the eastern and western districts, considering the continued water supply upon application of restriction of water supply by hour and in the case of damage to the water distribution main (abnormality).

Case A: 7-hour water supply -- At ordinary times (amount of water supplied in 2005)
Case B: 7-hour water supply -- At abnormal times (amount of water supplied in 2005)
Case C: 7-hour water supply -- At ordinary times (amount of water supplied in 2015)
Case D: 7-hour water supply -- At abnormal times (amount of water supplied in 2015)

The diameter of a water distribution main is 63 mm - 300 mm, and the total length is about 41 km (including water distribution mains excluded from calculation for the pipe network).

The diameter of the water distribution branches, determined from the minimum pipe diameter, is 50 mm, which is commonly employed in Mauritania.

(6) Public water tap

Public water taps will be installed in Area III formed in such a way as natural generation, each public water tap will be installed within the range with a maximum radius of 300 m. It is determined that the population covered by the tap is 500 - 700 people. This number is the criteria of Mauritania. For structure/form, the tap should have 6 cocks of the kiosk type.

Connection pipes from a water distribution branch to the public water tap should be PVC pipes with a diameter of 32 mm.

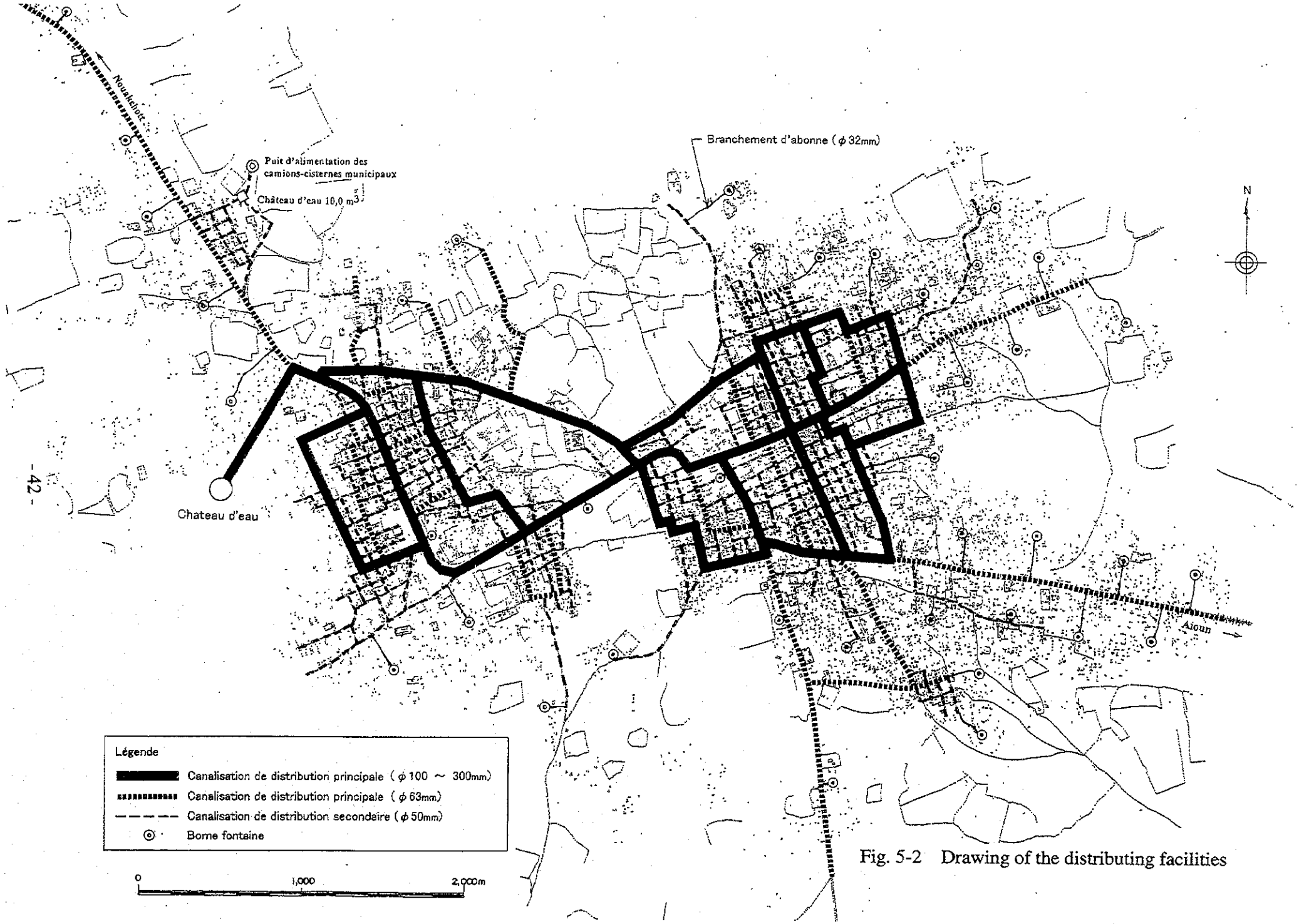


Fig. 5-2 Drawing of the distributing facilities

5.3.4 Plan of use of groundwater at shallow aquifer

Shallow wells that have good quality and will be able to be used as drinking water are 13 wells for public use, shown in Fig. 7.3-8. Among them, one well is used as a source of water for municipal water-supply trucks. The water pumping rate at this well is about 150 m³/day which is more than other wells. For the usage plan, this well is classified separately from other wells, most of which are sources of water for donkey-cart water venders.

① Shallow well for municipal water-supply trucks: water supply through distribution pipes to specified areas

② Other shallow wells: water supply by hand pumps

(1) Water supply through distribution pipe to specified areas

The well for this supply is located in the Belemtar East district. Therefore, the range of water supply by the well should be areas with higher population density and near the well, in the Belemtar East district. Service areas selected from these viewpoints are shown in Fig. 5-2.

The population subject to water supply in the area covered is 2,700. As the maximum water supplied per person per day is 30 liters/person/day, the maximum amount of water supplied per day is about 80 m³.

Water should be supplied as follows. Lift pump → Elevated water tank → Distribution pipe → Water supply by house connection and public water tap.

(2) Water supply by hand pumps

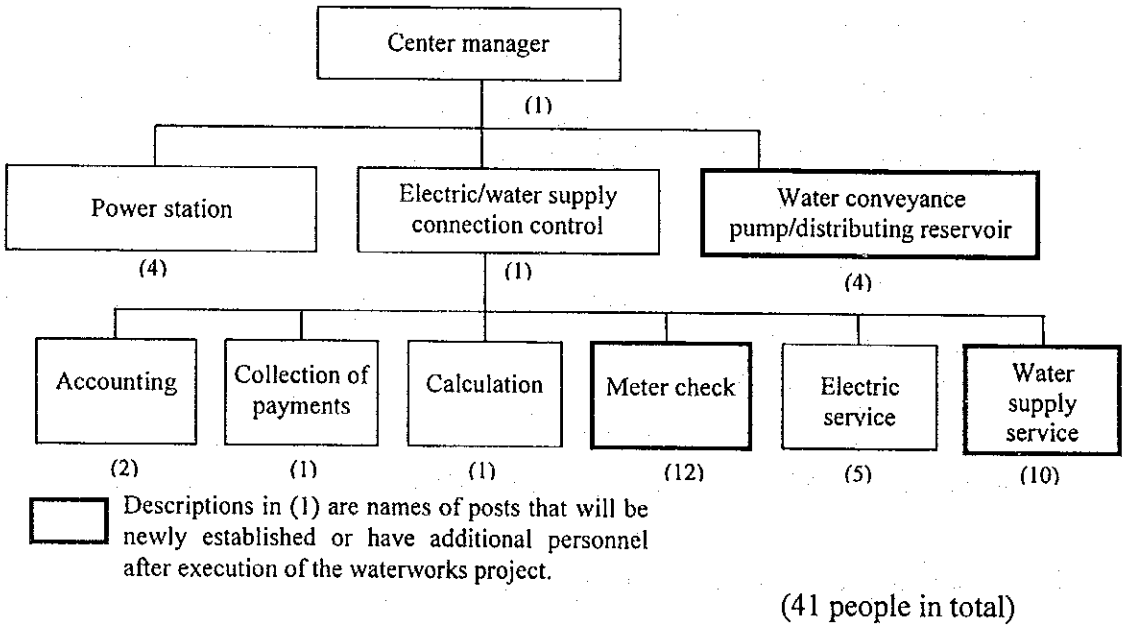
The wells concerned are now mainly used by donkey-carts water venders. Therefore, as to the structure of the wells, the foot of a well should be protected with concrete to keep the excrement of donkeys from permeating into the well, and sufficient measures for drainage should be taken. In addition, they should be equipped with hand pumps so that residents and water venders will be able to draw water easily.

5.4 Plan of operation and maintenance organization

Personnel required for operation, maintenance and management necessary for waterworks activities after execution of the waterworks project in Kiffa city are as shown in the following table, with consideration given introducing the restriction of water supply to certain hours.

Post name	Number of people	Remarks
Water conveyance pump station and distributing reservoir	4	One individual for each, one person in charge of maintenance and inspection for each
Control of water supply connection	0	Electrical division also holds this work.
Accounting	0	Electrical division also holds this work.
Collection of payments	0	Electrical division also holds this work.
Calculation	0	Electrical division also holds this work.
Meter check	6	
Water supply service	10	Two persons for maintenance and inspection, 8 for valve opening/closing
Total	20	

An organization chart (planned) of SONELEC after execution of the waterworks project is shown in Fig. 5-3.



(41 people in total)

Fig. 5-3 Organization chart (planned) of SONELEC Kiffa center after execution of the waterworks project

6. Hygiene improvement plan

6.1 Hygiene improvement activities

(1) Necessity of formulating a hygiene improvement plan

The result of the field survey of this study revealed poor hygienic conditions of Kiffa city.

In order to improve the situation, it is necessary to install water supply facilities through a groundwater development project, and to supply safe and hygienic drinking water that will meet the water quality standards. Installation of water supply facilities is expected to improve the hygienic conditions of Kiffa city, especially in terms of reduction of the number of water-related diseases.

It also has been revealed in this study that the potential of water resources to be developed is quite limited. Therefore, a water supply plan that also considers the use of shallow groundwater in the city shall be examined. In that case, prevention of contamination of the groundwater and conservation of water quality shall also be considered.

(2) Measures for conservation of water resources

Water sources to be conserved shall be new groundwater sources in the northwestern part of the city and the shallow groundwater in the city.

(3) Wastewater treatment

As the result of the groundwater development and construction of waterworks, procurement of water for daily use shall become more convenient, but the increase in water consumption shall also mean an increase in the discharge of sewage. However, there is no sewage facility in Kiffa city, and installation of such a facility is not included in the urgent improvement plan of this project. Therefore we propose household wastewater treatment measures that can be taken under the residents' own initiative, and simplified sewage treatment measures to be taken by the local authorities and neighborhood organizations.

Also, as a long-term improvement plan, we propose a full-scale sewage system plan to be completed in the year 2015.

(4) Hygienic improvement activities under the residents' initiative

To improve hygienic conditions, it is important to service the facility-related hardware, but it also takes awareness and effort by the entire population of Kiffa city to create a hygienic environment. We propose the following realization plan of hygienic improvement activities under the residents' initiative.

1) Disinfection of drinking water with chlorine-type bleaching agent
2) Prevention of nitrate nitrogen intake by infants
3) Improvement of water conveyance and storage facilities
4) Protection of wells for household use

(5) Hygiene education

The purpose of hygiene education is to provide the residents with hygiene-related knowledge including the relation between the living environment and human health, hygienic conditions of drinking water, and importance of water resource conservation, as well as technical details such as the method of dealing with facility problems as described in sections 8.1.2 - 8.1.4 above, and to call their awareness to the importance of hygiene improvement. As UNICEF and other NGOs develop various activities, it is recommended that the hygiene education be provided in liaison with these organizations. In particular, UNICEF activities for the formation of neighborhood organizations and diffusion of hygienic lavatories are directly related to our project. We hereby propose the following steps of hygiene education.

6.2 Conservation of shallow groundwater in the city

(1) Shallow groundwater conservation plan

In order to conserve the shallow groundwater in Kiffa city, it is necessary to conduct the hygiene improvement plan as follows for each service plan.

(2) Urgent improvement plan (target year: 2005)

1) Prevention of contamination of wells in the city through structural improvement of wells
2) Prevention of groundwater pollution by sewage
   ① Simplified household septic tanks and diffusion tanks
   ② Imhoff tanks and diffusion trenches for housing complexes

(3) Long-term improvement plan (target year: 2015)

① Promotion of preventive measures against contamination of wells in the city

Promote further the well structure improvement project carried out in the course of the Urgent improvement plan.

② Prevention of groundwater contamination by installation of sewage facilities

In the long-term improvement plan, the prevention of groundwater contamination from sewage shall be intended through development of sewage septic tanks and installation of conduits and simple sewage treatment facilities.

Fig. 6-1 shows the concept of sewage system servicing, and Fig. 6-2 shows the sewage facilities plan.

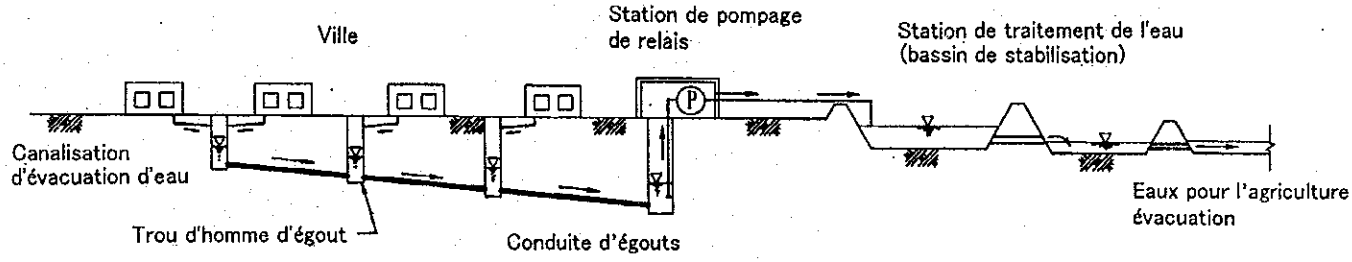


Fig. 6-1 Concept of sewage system servicing

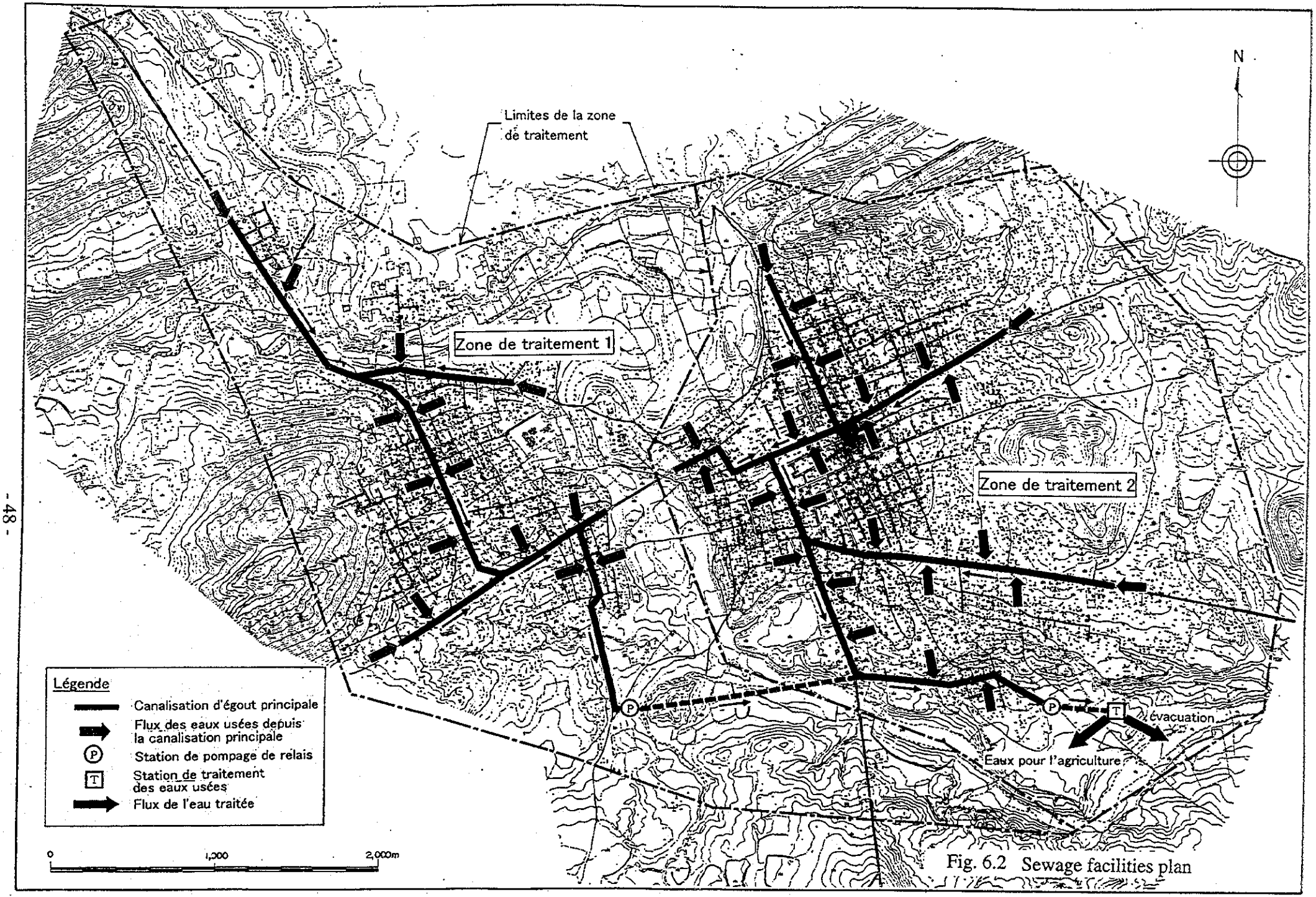


Fig. 6.2 Sewage facilities plan

7. Project evaluation and implementation plan

7.1 Project evaluation

(1) Economic evaluation

In this economic evaluation, costs and benefits are analyzed after estimation of economical costs and benefits. The economic internal rate of return (EIRR), the net present values (NPV) and the benefits-costs ratio (B/C) are estimated. Then, evaluation is made using these as indices. The discount rate for calculation of the NPV and the B/C and opportunity cost to be compared with the EIRR should be 10%. This is the same figure as is used in the master plan of waterworks improvement and completion in 10 cities in Mauritania.

1) Economic costs

The costs estimated in Chapter 6 are financial costs. They are the costs actually paid by an executor for construction and operation of the facilities when the project is executed. Economic costs are values for the national economy in Mauritania, regarding resources (material, manpower, land, etc.) invested for implementation plan of the project, and the calculated cost based on economic prices. Upon economic evaluation, the following points are considered and financial costs are converted into economic cost.

Table 7.1-1 Economic costs and financial costs

(Unit: UM. thousand)

Costs	A. Economic Costs	B. Financial Costs	A/B
Construction Costs (in the early stage)	1,506,140	2,084,000	72%
Operation, Maintenance and Management Costs (in 2005)	19,034	20,619	92%

2) Economic benefits

Economic benefits in the projects are as follows. They were obtained by calculating the difference in amounts if the project is executed and if it is not.

① Those that occur because the outbreak of diseases caused by water decreases as a result of supply of safe water.

a) Reduction in medical treatment costs

b) Increase in the production amount (or the value of decreased hours) because working hours increase as a result of decrease in hours required for medical

treatment, rest, recuperation and nursing

② Increase in the production amount resulting from reduction of hours/labor to secure water, or costs to purchase water

Based on limited information, the items stated above were roughly calculated and estimated. The results are covered in the Supporting Report. Here, Kiffa citizens' willingness-to-pay for water is estimated and will be considered as an economic benefit. The amount of money that is now paid for water by Kiffa citizens is the willingness-to-pay in this analysis, as in other analyses generally conducted in the field of water supply.

According to a household questionnaire survey, UM.25,174/household/year is paid on average to secure water for the home. As the average number of family members covered by the questionnaire is 6.6 per household, the cost per person is about UM3,800/person/year. Economic benefits are obtained by multiplying this unit price per person by population with water supplied. Since the number of such population is considered to be 77,000 in 2005, the result of calculation of economic benefits in this project is about UM.294 million in 2005. Costs paid by Kiffa citizens to secure water is now 7.4% of household income (estimated to be UM38,500 per household per year). Since it is said that their willingness-to-pay is generally 3% - 5% of household income, this is a considerably high figure. From another viewpoint, this figure shows a situation in which Kiffa citizens must pay expensive costs for water, i.e., where they are distressed about securing water for living, because the water is indispensable for human life.

3) Estimation of indices and evaluation

The following figures are obtained from calculation with the benefits and costs stated above: 14.0% for the economic internal rate of return, 1.27 for the benefit/cost ratio and UM440 million for the net present value.

Because the economic internal rate of return is over 10%, it is possible to judge that this project will produce a good impact on economy of Mauritania. Therefore, it can be said that this project should be executed in terms of national economy. As a result of sensitivity analysis, we found that economic propriety of this project would not be lost. This is because the economic internal rate of return will be maintained at 10% even if benefits decrease by 21% in all years in the evaluation period, or if construction costs increase by 30%.

(2) Financial Evaluation

The results of the economic analysis indicate the economic propriety of this project in the national economy. Therefore, for the government of Mauritania or SONELEC, which is a public organization, this project should be executed for economic development and improvement of the national welfare.

The financial internal rate of return is then estimated based on the incomes and expenses of SONELEC. With this rate, possible options for policies of financing, water rates, etc. are determined. Under these conditions, the profit/loss statement and the cash flow statement of this project are estimated, and sound operation is examined and verified.

1) Estimation of the Financial Internal Rate of Return

The financial internal rate of return (FIRR) of this project will be negative. This means that investment funds for implementation plan of this project should not be raised by a loan from the viewpoint of the existing rate system. In addition, judging from SONELEC's present financial conditions as shown in its balance sheet, etc., it is almost impossible for it to execute the project with its own funds.

From the examinations stated above, it is possible to conclude that the initial investment in this project should not be made with a loan. Therefore, a grant from a foreign country or the government is required.

The difference of the rates of return in the above-mentioned economic and financial analyses resulted from a difference between the costs of UM3,800/person/year, which is now used for water and considered as an economic benefit, and the supposed rate (the current water rate of SONELEC) of about UM700/person/year, which is considered as a financial income. On the other hand, if average willingness-to-pay for the water rate is estimated with answers to the question about it in the household questionnaire, it will be about UM1,100/month or UM2,000/person/year. This amount is approximately 2,8 times higher than the supposed rate. It is also 3.8% of the average household income. Since it is said that willingness-to-pay is generally 3% - 5%, this amount is considered reasonable. Therefore, we consider that there is enough grounds to discuss a rise in rates to this degree in the future.

2) Estimation of the Profit/Loss Statement and the Cash Flow Statement

In this financial analysis, as one of options for financing, grants are assumed for

projects with the priority suggested to be executed from 1999. On this assumption, the profit/loss statement and the cash flow statement of this project are estimated. Then, examination is carried out regarding methods of fund raising for expansion work and renewal of facilities to be required in and after 2006.

If the water rate is kept at the current one supposed, the accumulated fund until 2006 will remain small even if the initial work is carried out with a grant. In addition, as profitability of the expansion work will be low as the initial investment, it is difficult to conduct it with a loan. If the expansion work is also executed with a grant, we expect that renewal of facilities after 20 years will be affordable with accumulated funds.

In this water supply project plan, the amount of water supplied is restricted because of the limited water resources. Accordingly, water-rate incomes are small and there is an unbalance between water-supply costs and water rates. It is anticipated that the policy to establish special water rates only in Kiffa city will encounter political difficulties. However, in our opinion, this policy should be considered in terms of sound operation of the project as well, partly because the current rate is much lower than willingness-to-pay. Of course, the rise in water rates will be required to be accompanied by some policy in consideration of poor households. For example, water rates will be made equivalent to 3% of the household income on the whole by charging a low rate to people consuming the minimum amount of water and a higher rate to people consuming greater amounts of water.

(3) Social analysis

1) Grouping of the population

The question was raised regarding the "risk" of the increased attraction of Kiffa city once a water supply equipment as projected will be installed.

The explosion of the urban phenomenon was mainly observed with the drought which swept Mauritania in 1968. The very rapid growth of most of the existing towns and the emergence of many others started during this climatic crisis. The urban population of Mauritania therefore increased from around 3% in the beginning of the 50s to more than 41% today.

All new towns were built around water supply ports. However, neither the growth of the existing towns nor the emergence of new human settlements may be associated with this single factor. The potential settlers or rural migrants were looking for means of subsistence (assistance of any nature), health care, a place to educate their children, work, etc. They were and are still motivated by the need to affirm their particular identities, in particular, to group themselves based on tribal origins. Communication means, in particular the so called "road to hope" where Kiffa constitutes the midway stage, have contributed significantly to migratory movements. The maintenance of connections with the rural hinterlands where part of the family continued to lead a pastoral or agricultural existence, was another factor in the residential choice of the potential migrants or settlers.

To our knowledge, the improvement of potable water supply equipment has never played a specific role in the progression curve of the population in a Mauritanian town. In short, there is little need of apprehension that water-supply facilities in Kiffa will cause a great change in the rhythm of populational increase in the city. This rhythm will depend on a complicated combination of various other factors.

2) Impact of the building of water supply installations in villages surrounding Kiffa.

One of the questions regarding the building of water supply installations involves the supply of water in 6 villages surrounding Kiffa and which are part of its commune: Kendra, Kreikett, Wed Rodha, Meissah, Hassi Bekaye and Oum Echgag. Though these villages are not included in the water supply plan because they relatively far from the central part of the city (7 - 18 km), there is a fear of lack of social equity.

The two most important villages, Hassi Bekaye and Kendra, are equipped with solar pumps with a theoretical daily production capacity of 20 m^3 for Hassi Bekaye and 30 m^3 for Kendra. In other villages, water is supplied simply from shallow wells, which satisfies for the present demand. However, it is necessary to improve and complete independent facilities with pumping-up equipment such as a solar system

3) Price of water, management systems and social inequalities

Given the dimensions of the equipment to be installed in Kiffa and the advantages of including the management for electricity under SONELEC, it seems that the latter will be the best partner for managing the future water supply installation.

Benefits from the facilities should not be received only by lucky people who can lay branch pipes for water supply to individual houses, which is a system allowing water to be obtained at the lowest cost. Water supply to individual houses should be available to as many residents as possible and, therefore, costs for connection of these branch pipes should be examined. However, an idea that the costs will be adjusted according to areas or applicants' income levels doesn't seem very realistic.

The social cost of individual connections applied by SONELEC outside Nouakchott, which we have noted in a preceding report as amounting to 2,000 UM, may be considered for an increase based on the existence of a relatively well-to-do class in Kiffa city, which however cannot be pinpointed individually, based on the actual status of our data.

To avoid transport costs and the intervention of retailers, we can also suggest the installation of "cooperative water taps" to be managed by groups of neighbors composed of a small number of families (from 5 to 20) who will designate a head and who will organize themselves to assure the payment of charges. A more precise definition of the functions of these family groups, the dimensions and facilities required to benefit from facilities available in order to manage equipment, will require more investigation and specific training.

In any case, if the management unit applies "real prices", only a minor fraction of the population in the Assaba capital can avail of water through the easiest means, that is, through individual taps. In spite of the advantages which the water supply equipment may provide to the entire population, it may in this case, increase disparities between well-to-do and the poorer inhabitants of Kiffa.

4) Water selling carts

The question of the price of water is closely related to the function of water carts which presently constitute the essential means of water distribution in the city. Evidently, there is some contradiction between the maintenance of their activity and standardized access to water at basic rates proposed by SONELEC.

However, the following must be taken into consideration: the loss of profit for cart owners due to the loss or reduction of the distribution market, and the fact that part of this activity will remain useful for supplying water to the poorest inhabitants and those living farthest from Kiffa.

The carts are also often used to transport products other than water, and are even used as transport "taxis" by some of the Kiffa residents. We may consider assistance in the form of modifying the form of the carts to allow the owner to specialize in the transport of passengers and baggage (provision of seats, covered roofs, baggage holders etc.). Carts used to transport water may be equipped with a more hygienic container (water-proof, transfer of water from the tap and not through a plastic hose etc.).

(4) Technical evaluation

1) Development of sources of water

- Method to Select Sites for Excavation of Production Wells

Hydrogeology and aquifers around Kiffa city were clarified. Then, the method was established for development of water sources that would be necessary to be conducted by the Water utilization office and SONELEC to cope with future increase in demand for water.

As a result, sites and depth of excavation are determined as follows. It is possible to realize them with investigating equipment and materials currently owned by the Water utilization office and at their present technical level.

- Conservation of groundwater quality at shallow aquifer in the city

As a matter of course, the recharge storage of groundwater in the new well fields, found in this survey, is limited. Accordingly, it is necessary to use groundwater at shallow aquifer in the city in order to satisfy demand for water in Kiffa city. Groundwater at shallow aquifer in the city is a low-cost water resource that doesn't require long-distance transportation. Therefore, conservation of the groundwater quality at shallow aquifer in the city, which is being contaminated more and more, is important not only in the term of environmental quality but from the economical viewpoint.

As a method preserving the groundwater quality at shallow aquifer in the city, it will be finally necessary to improve and complete sewer systems. Based on the economic conditions in Kiffa city, step-by-step construction is possible from protection of existing wells to improvement and completion of sewer systems.

2) Water supply plan and water-supply facilities plan

- Supply of safe water

There is severe pollution of groundwater at shallow aquifer in the city, which is now used by residents in Kiffa city. The supply of safe water is an urgent problem. This plan will allow safe water to be supplied to all residents, although the amount is the required minimum, because hygienic groundwater will be developed at sources of water outside the city and conducted to the city. The hygienic environment will be improved in full measure.

- Appropriate technology

  In order to continuously maintain and operate the planned water supply project, it is important to adopt technology appropriate for social and economic conditions and for the technical level in the area covered by the plan. For determination of the water supply plan and the water-supply facilities plan, the following matters are considered.

  - Restriction of planned amount of water supplied
  - Public water taps
  - Configuration of an easy to maintain and manage water supply system

- Restriction of water supply to certain hours

  Throughout this water supply plan, effective use of poor water resources is a problem. Measures for restriction of consumption are considered, and employment of an escalating water rate is proposed for operation. On the other hand, in the facilities plan, water supply on the assumption of restriction of water supply to certain hours is included in the initial plan. It is not forecast that the planned daily amount of water supplied will increase much more than the initial plan in the areas concerned. Therefore, execution of restriction of water supply to certain hours is assumed in order to restrict consumption.

7.2 Project priority

As repeated in this report, the results of the surveys clearly show that, under the present situation of water supply in Kiffa city, pollution of groundwater at shallow aquifer being used by the residents now is advancing to the extent where the WHO's standards are greatly exceeded. We consider it is indisputable that supply of safe drinking water to residents should be the problem of the highest priority.

The following two methods, both of which are important, are possible for solution of this problem.

- To find new sources of water supply outside the city.

- To improve the groundwater quality at shallow aquifer in the city.

As a result of the hydrogeologic survey, it was found that promising aquifers are located around 15 km northwest of the city. This means that a source of water was identified. On the other hand, it was also confirmed that improvement of the groundwater quality at shallow aquifer would require long-term execution of measures. For these reasons, a water supply plan was made with this as the priority. In this plan:

- groundwater will be developed to satisfy short-term demand for water by the new source of water in the northwest, and
- water will be conducted to Kiffa city and supplied through a piping network.

On the other hand, from the long-term viewpoint, it is expected that demand for water will increase with the increase in population, and the new source of water naturally has a limited amount of water. Therefore, it is indispensable to execute activities for hygienic improvement and for improvement and completion of sewer systems in order to secure water sources by improvement of the quality of groundwater in the place close to the residents, i.e., at shallow aquifer in the city.

7.3 Implementation plan

Fig. 7.1 ("Implementation plan of the Kiffa city water supply project") shows an implementation plan in each fiscal year for the above-mentioned project with priority and the long-term-planned project until 2015.

1) Water supply plan with priority

As a project with priority, development of groundwater at the new water source in the northwest of the city, and construction of water-supply facilities will be executed as fast as possible in order to supply the required minimum amount of hygienic and safe water in 2005.

2) Second water source development and Construction of water-supply facilities

The second water source development will be carried out in the northwest water source to satisfy increased demand for water accompanying an increase in population in and after 2005. For this purpose, water-supply facilities (water-conducting and conveyance facilities and inside-the-city distributing facilities) will be also increased with 2006 as a target year. We judge that a limit of recharge storage in the northwest water source is such that it will cover demand for water in 2015. For other

developments after 2015, it is necessary to consider other measures for water sources.

3) Conservation of groundwater quality at shallow aquifer in the city

Measures for conservation of water quality will be immediately taken for essential wells where groundwater at shallow aquifer is used and whose water quality remains good now.

4) Control of pumping-up of groundwater at shallow aquifer in the city

In the water supply plan, groundwater to be newly developed will be supplied for drinking water. For a part of water for daily life, it is considered to use existing groundwater at shallow aquifer in the city. According to the forecast, this groundwater at shallow aquifer in the city will be excessively pumped up as a result of increase in demand for water in and after 2005 if its use is not controlled. These private wells also require measures for restriction of pumping-up and for control.

5) Improvement and completion of purification tanks

Treatment of home and raw sewage is the most effective measure for improvement of groundwater quality at shallow aquifer in the city. Though full-scale improvement and completion of sewer systems is expected, it is judged from Kiffa city's financial conditions that early implementation plan will be difficult. Therefore, purification tanks will be installed at each residence, as a measure before the improvement and completion stated above.

6) Improvement and completion of sewage ducts and treatment facilities

As a drastic measure for improvement of the groundwater quality at shallow aquifer in the city, real sewage facilities with ducts and treatment equipment will be constructed aiming at completion in 2015. In this plan, reuse of treated water for agriculture is taken into consideration. It is considered as help for development of water sources after 2015.

7.4 Fund plan

Fig. 7-1 ("Implementation plan of the Kiffa city water supply project") shows the summary of the required amount of investment based on the implementation plan of the water supply project until 2015.

Fig. 7-1 Implementation plan of the Kiffa city water supply project

Implementation	Implementation year																
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
(Water supply development plan)																	
Development of sources of water	■																
Construction of water-supply facilities	■	■															
Development of new sources of water								■									
Expansion of water-supply facilities									■	■							
Conservation of groundwater quality at shallow aquifer in the city		■	■	■	■	■	■										
Control and restriction of pumping-up of groundwater in the city								■	■	■	■	■	■	■	■	■	■
(Hygienic improvement plan)																	
Prevention against polluting wells in the city		■	■	■	■	■	■	■	■	■	■	■					
Installation of purification tanks		■	■	■	■	■	■										
Improvement and completion of sewage ducts and treatment facilities													■	■	■	■	■
Water supply amount (m^3)				336	389	450	521	605	632	661	691	723	756	791	827	865	905
Required amount of investment for the water supply project (million UM)	104.0	990.0	990.0					43.0	398.0	398.0							
Operation and maintenance cost (million UM)				17.5	18.4	19.4	20.6	22.0	22.5	23.0	27.0	27.5	28.0	28.6	29.2	29.9	31.0

7.5 Recommendations

(1) Protection of water sources and conservation of water quality

This survey found a promising source of groundwater northwest of the city. Some wells using groundwater at shallow aquifer in Kiffa were also specified as those with good water quality. We would like to recommend that measures be taken for protection of water sources and for conservation of their water quality, until full-scale construction of water-supply facilities based on the water supply plan will be implemented.

-Protection of water sources

In the well field in the northwest, no people are living and water quality is good. In order to conserve long term, protective measures such as prohibition of house construction and of land use for agriculture should be taken throughout the area of 5 km x 10 km.

-Conservation of water quality

Similarly, for the wells with good water quality in the city, urgent measures to prevent pollution around wells should be taken.

(2) Monitoring of ground water levels and water quality

As an assumption for implementation plan of the water supply plan, water levels and quality will be regularly monitored at the wells for the new water source and for groundwater at shallow aquifer in the city, and accumulation of data will be started.

For the contents of monitoring, see Chapter 6 (" Groundwater development plan ").

(3) Operation and management of public water taps

In the water supply plan, water supply with public water taps is suggested in some areas according to the conditions of urban development and economy. In the method to operate public water taps in other cities that has been employed by SONELEC, operation is entrusted as profit-making work to an individual. Some people point out that, as a result, users have social disadvantages such as payment of high water rates.

A possible measure to improve this is operation and management of public water taps by a regional residents' organization, such as a livelihood cooperative association. We expect that the city will prepare implementation plan of the project and give a guidance of concrete formation of such an organization.

(4) Discussion on establishment of water rates in Kiffa city

As pointed out in the financial analysis for evaluation of the project, in the planned project, the amount of water supply is restricted to the minimum to continuously use the limited amount of water resources in the area. As a result, water rate incomes are also limited and water-supply facilities are financially ineffective. On the other hand, residents now purchase water from water-sellers using donkey-pulled wagons, whose price is far higher than the water rate. It is considered that it is reasonable to specially establish water rates in the water supply project for Kiffa city in order to reduce this present amount paid by the residents by about the half. We recommend discussion of revision of water rates for the purpose of sound development of water service activities.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summary