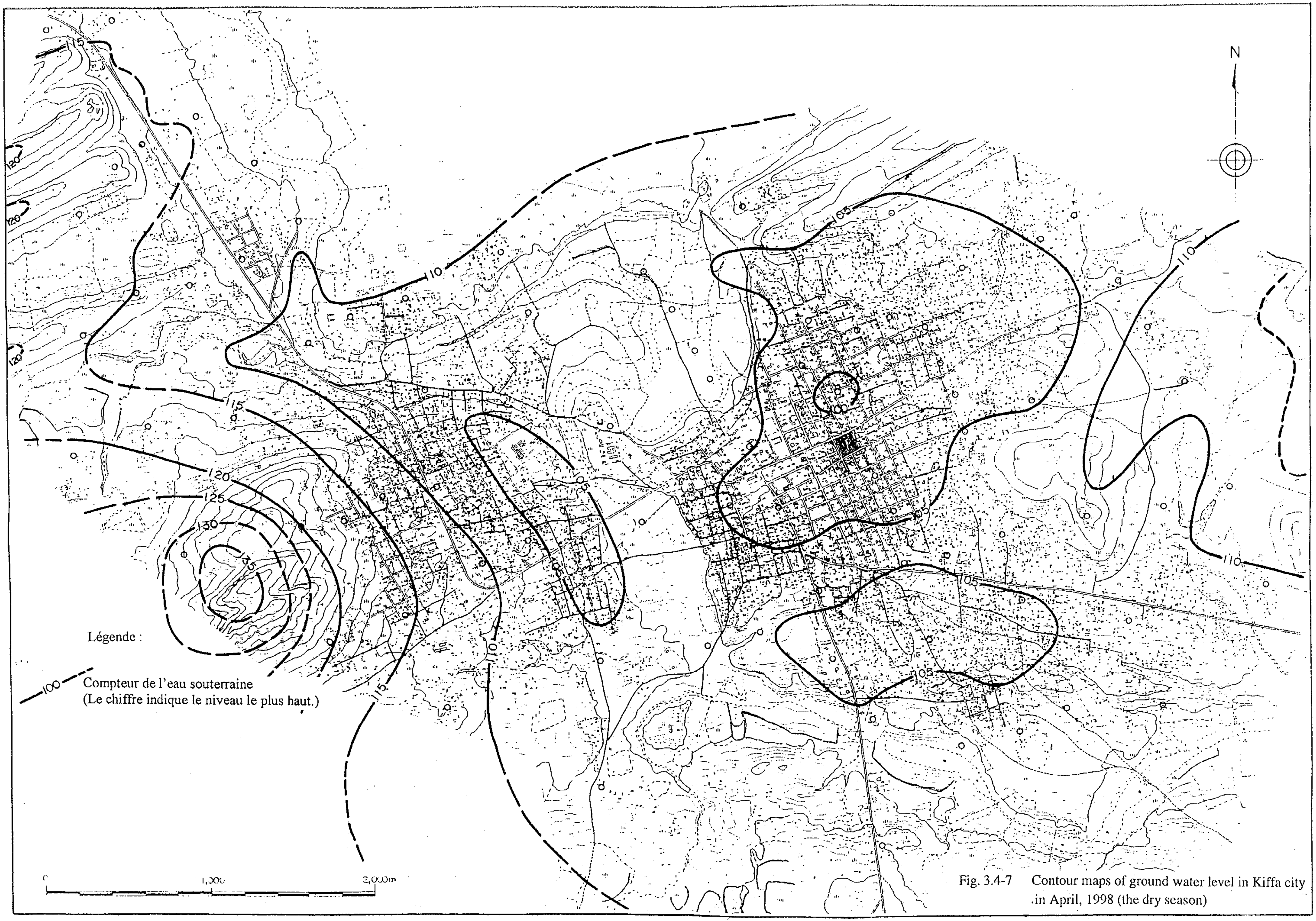



Fig. 3.4-7 Contour maps of ground water level in Kiffa city in April, 1998 (the dry season)

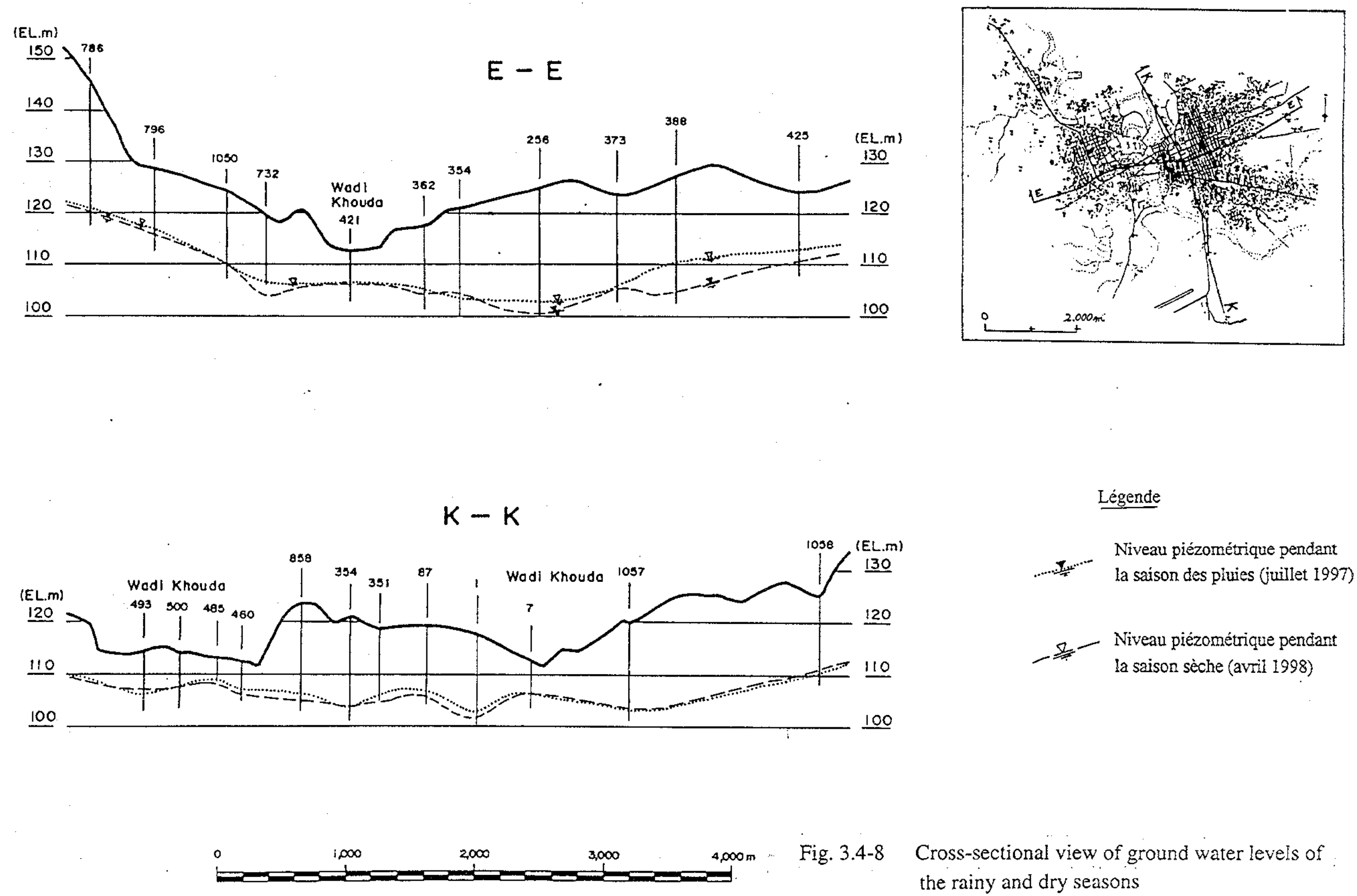



Fig. 3.4-8 Cross-sectional view of ground water levels of the rainy and dry seasons

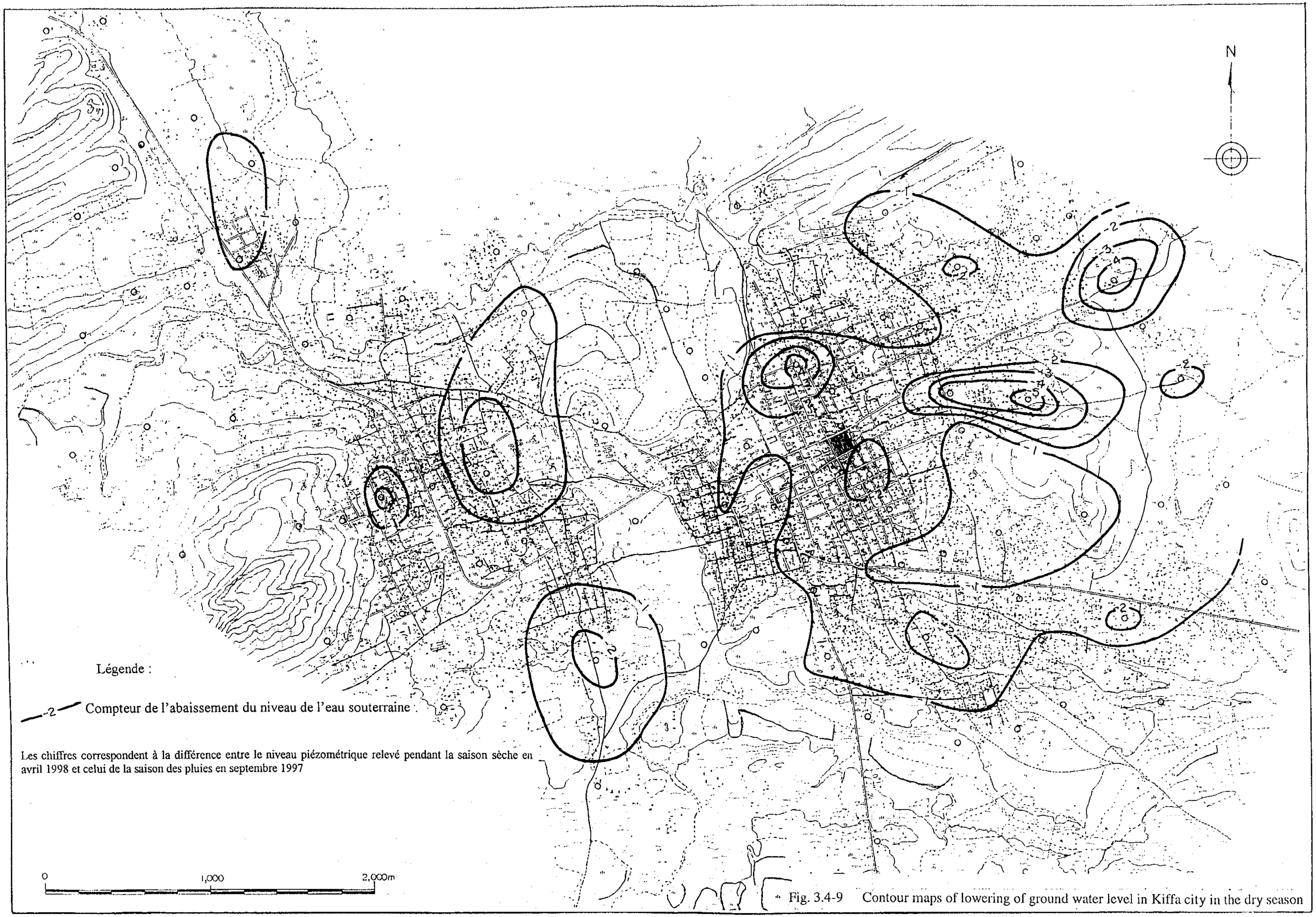



Fig. 3.4-9 Contour maps of lowering of ground water level in Kiffa city in the dry season

### 3.4.2 Hydrogeology in the area for ground water development

(1) Summary

Aquifers in the area around Kiffa are roughly the following three:

- Sand stratum of the Quaternary period
- Aquifer of pelite of the Kiffa series
- Aquifer of Ayuon sandstone

Among these, outcrops of Ayuon sandstone are distributed 40 km east of Kiffa and farther. Test pitting of 246 m was carried out in Kiffa city in order to confirm the existence of deep aquifers in Ayuon sandstone. However, this test pitting well didn't reach Ayuon sandstone and stopped in tillite. Therefore, aquifers made of Ayuon sandstone are not included in the aquifers in shallow wells both in the existing Kiffa city and in the new underground development area in the west-north part of Kiffa, which was confirmed as a result of these hydrogeologic and test pitting surveys.

The hydrogeologic map in the underground water development area is shown in Fig. 3.4-10, and its cross-sectional view is shown in Fig. 3.4-11. Tillite, limestone-dolomite, and pelite-chert crop out, in this order, from the east. These strata dip very gently towards the west and are widely covered by sandhill sand (fixed, moving).

(2) Hydrogeology in Kiffa city

1) Quaternary sand stratum

These are classified as aquifers in sandhills and those in alluvia. Aquifers in sandhills have not developed much because rainfall is low. As for those in alluvia, the condition of cultivation is good in the Rhouda Wadi where ponds exist intermittently in the rainy season. In alluvia in the Rhouda Wadi within Kiffa city, a number of 2 m-6 m shallow wells are dug manually in the dry season, and water in alluvia is used. However, because the water contains much silt and permeability is poor, the water is not pumped up much and is muddy.

2) Aquifer of pelite

Almost all the shallow wells in Kiffa city are dug down into pelite, and underground water in weathered zones made of pelite is used. Though pelite is impermeable in the unimpaired state, it forms an aquifer because, generally, there are many joints and permeability down to the place is influenced by weathering. The thickness of weathered zones made of pelite is mostly from 20 m to 30 m, as shown in "(2) Geophysical Prospecting" of the Supporting Report. The amount of water pumped up is as little as several hundred liters per day to several cubic meters per day. However, approximately 26 $m^3$ water is pumped up per day at a shallow well (No.1) in front of the Water utilization office, and approximately 180 $m^3$ water is pumped up per day at a shallow well (No. 127) for water-supply wagons operated by Kiffa city. Water permeability is good in places well fractured. The water level is usually 10 m - 20 m. In the dry season, the water level of these shallow wells falls and the amount of water pumped up decreases remarkably, which is a water problem in Kiffa.

(3) Hydrogeology in the northwest water source area

In this survey, 22 test pittings with total length of 1,321.5 m were made. This reveal that strata in the northwest water source in Kiffa mainly consist of tillite, sandy siltstone (a part with less gravel of tillite), limestone-dolomite, pelite and jasper, in order from the lower part. For details of the test pitting survey, see "(1)Test Pitting Survey" of the Supporting Report.

Tillite is widely distributed in the deep places, but the amount of water pumped up is little because the content of silt is great and cracks have not developed. Underground water in tillite is not good to drink because the concentration of salt is high. It seems that Taleb sandstone is also distributed in the lower part of tillite, but this could not be confirmed by 136 m test pitting this time.

According to the test pitting survey carried out this time, strata of the Kiffa series is composed of jasper (distribution chert), pelite (shale, mudstone and siltstone) and limestone-dolomite. Pelite is often siliceous or calcareous. Jasper (chert)is resistant to weathering because it is remarkable hard and crops out on the surface of the earth, while the thickness of the layer is as very thin as 2 - 6 m. Generally, limestone-doromite can be a good aquifer but the thickness of the layer in this area is as very thin as 2-10 m.

Pelite exists as good aquifers in the places with many cracks, such as a fracture zone. Several wells with a large amount of water pumped up are obtained, including Test Pitting Wells JF-7B (18 $m^3/h$), JF-13A (30 $m^3/h$) and JF-5 by SONELEC (75 $m^3/h$). Aquifers made of pelite have low water permeability, and there is danger of high concentration of salt in underground water if the amount of water pumped up is little. Test Pitting Wells JF-5 and JF-7 installed on the same lineament hit a dike made of dolerite. Although dolerite itself is an aquiclude, it intrudes into a fault, fractures pelite around dolerite and forms a good aquifer.

The following table summarizes the results of this test pitting survey. For locations of test pitting wells, see "3.5 Valuation of Recharge Storage."

Table 3.4-1 Summary of results of test pitting survey

| Well No. | Depth (m) | Amount of Water Pumped Up ($m^3/h$) | Hydrostatic Level (b.g.l) | Electrical Conductivity (μs/cm) | Aquifer |
|---|---|---|---|---|---|
| JF-1 | 136 | Very little | 7.09 | 5,730 | Fracture part of pelite, tillite |
| JF-2 | 58 | 11 (Pumping test) | 14.29 | 1,077 | Fracture part of pelite |
| JF-3 | 68 | 3.4 (Air lift) | 12.12 | 717 | Fracture part of pelite |
| JF-4 | 68 | 2.2 (Air lift) | 6.70 | 990 (26m)<br>2,560 (56m) | Fracture part of pelite<br>Tillite |
| JF-5 | 122 | 0.4 (Air lift) | 13.13 | 1,060 | Weathered part of dolerite (intrusion into a lineament) |
| JF-5A | 62 | 5 (Pumping test) | 13.56 | 816 | Fracture part of pelite |
| JF-6 | 74 | Very little | 21.11 | 611 | Pelite |
| JF-7 | 44 | 24 (Air lift) | 7.55 | 1,260 | Fracture part of pelite (abandoned due to breaking-down of well) |
| JF-7A | 58 | 3 (Pumping test) | 7.60 | 1,180 | Weathered and fracture parts of dolerite |
| JF-7B | 46 | 18 (Pumping test) | 7.69 | 1,421 | Fracture part of pelite |
| JF-8 | 74 | 4.2 (Air lift) | 16.65 | 1,360 (32m)<br>3,300 (68m) | Fracture part of pelite<br>Tillite |
| JF-8A | 36.5 | Very little | - | 2,110 | Weathered pelite |
| JF-8B | 41 | Very little | 8.85 | 1,405 | Weathered pelite |
| JF-9 | 50 | 2.0 (Air lift) | - | 2,840 | Tillite and sandstone |
| JF-10 | 56 | 1.0 (Air lift) | 5.80 | 851 | Pelite |
| JF-11A | 44 | Very little | 14.44 | 2,160 | Pelite, tillite |
| JF-11B | 56 | (7) | 10.28 | (800) | Fracture part of pelite |
| JF-12A | 50 | 0.5 (Air lift) | 11.36 | 531 | Pelite |
| JF-12B | 38 | 1.5 (Air lift) | 10.88 | 450 | Pelite |
| JF-13A | 58 | 30 (Pumping test) | 4.14 | 654 | Fracture part of pelite |
| JF-13B | 32 | 1.5 (Air lift) | 8.05 | 7,350 | Pelite |
| JF-14 | 50 | 0.5 (Air lift) | 6.18 | 3,000 | Pelite |

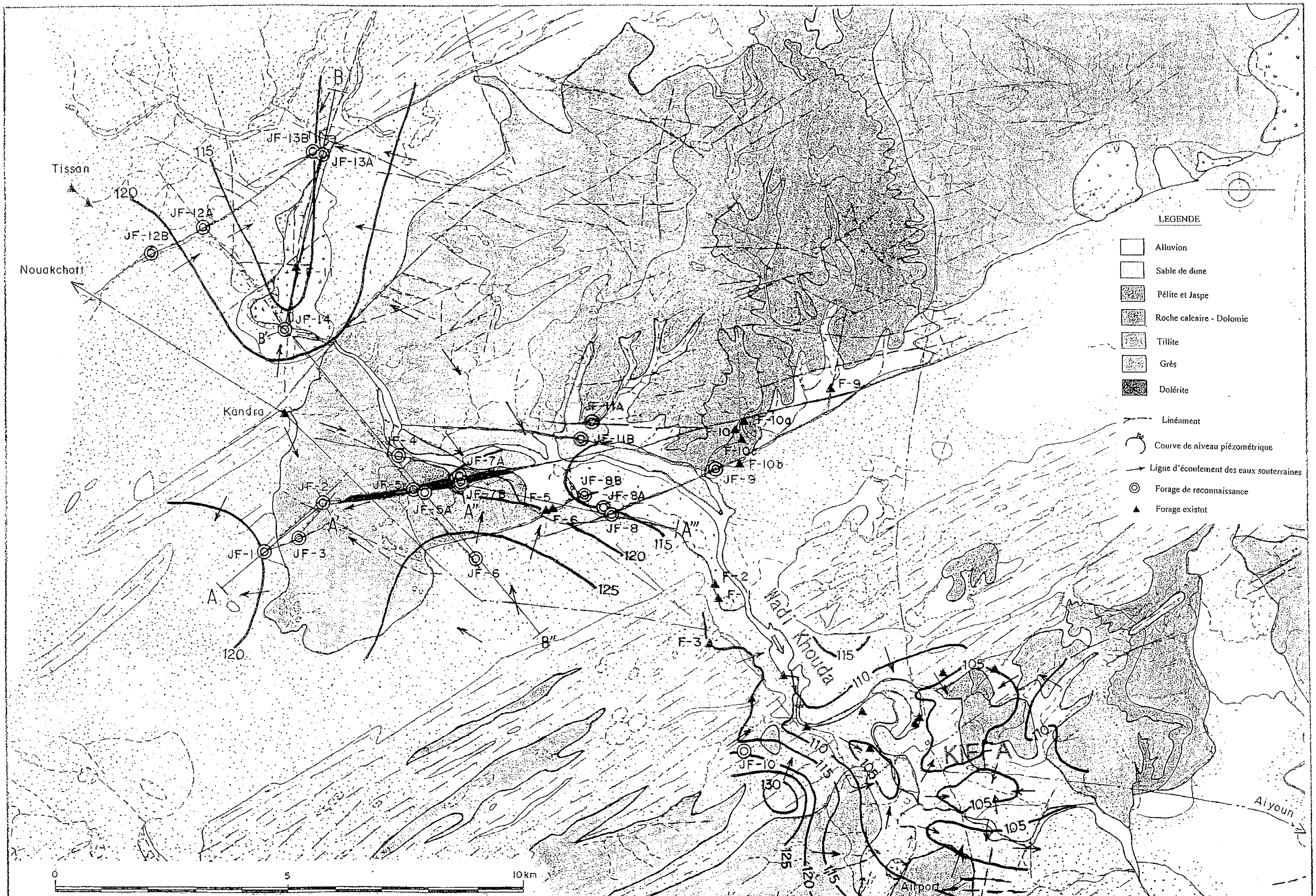



Fig. 3.4-10 The hydrogeologic map in the ground water development area

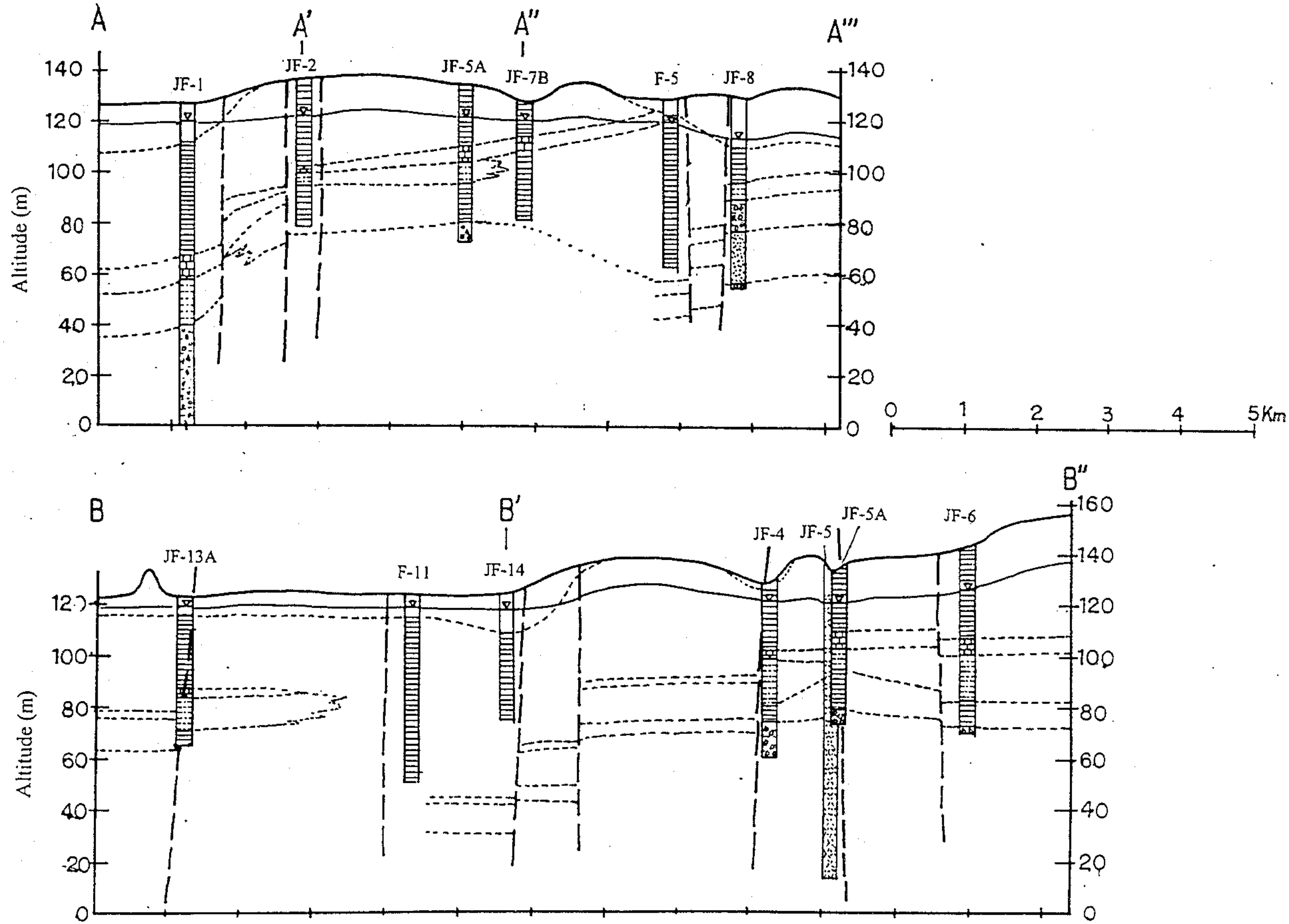



Fig. 3.4-11 The hydrogeologic cross-sectional view in the underground water development area

## 3.5 Valuation of recharge storage

### 3.5.1 Developable amount of groundwater at shallow aquifer in Kiffa

(1) Method to calculate the underground cultivation amount

As a method to calculate the cultivation amount of unconfined underground water, the following methods are generally proposed.

i. The amount of rain, surface runoff and the amount of evapotranspiration are calculated by hydrologic analysis, and, from them, the amount of permeation of rainwater into the underground (the cultivation amount) in the area is indirectly calculated.
ii. If hydrologic constants of an aquifer (a modulus of water permeability, layer thickness), the shape of the water table and environmental conditions (a water level-fixed border, a running-fixed border, etc.) are known in permeating flow analysis of underground water, the permeating analysis is carried out, and the cultivation amount in the area is calculated in this process.
iii. Runoff of underground water from the area is calculated with the rate of lowering of the water table in the time period without rainfall, and this runoff is considered as the cultivation amount.
iv. From the difference in water levels in the rainy and dry seasons and the effective porosity of an aquifer, the increase in storage of underground water resulting from permeation of rainfall in the area is calculated, and it is considered as the cultivation amount.

The method stated in "i" above is suitable for calculation of the cultivation amount of underground water in a wide area because underground water and surface flowing water are considered as one circulation system. This analysis is possible only if the results of observation of rainfall, results of observation of the amount of flowing water and so on are available. However, though there are results of observation of rainfall and the amount of evaporation, the amounts of flowing water in wadis are not observed. Therefore, this method can not be adopted.

By the method stated in "ii" above, it is possible to calculate the cultivation amount accurately in the area where hydrogeologic conditions such as distribution of permeability coefficients, underground water level contours, characteristics of changes in ground water level, etc., are known in detail. This method is applied in the narrower area but can't be done in Kiffa city because its detailed hydrogeologic conditions such as distribution of permeability coefficients for aquifers, etc., are not available.

The method stated in "iii" above is based on the view that runoff of underground water from the basin is almost fixed and equals the cultivation amount of underground water. It is a method to calculate runoff (=the cultivation amount) of underground water with lowering of the water table in the period without rainfall when there is no influence by water level changes resulting from rainfall. However, as mentioned above, underground water levels tend to be lower in a wide area, including the study area. Water level changes are added to this because all water level observation wells are used daily except Observation Well 126 (F-5). As a result, water level changes are greatly different among observation wells and reliability in accuracy is lacked. Therefore, this method cannot be adopted here.

The method stated in "iv" is a method to calculate the cultivation amount by the amount of increase in a water level on the assumption that underground water that has permeated stays in place nearly the same as initially. This is the simplest method, but can be applied because underground water runs to the side immediately after permeation in aquifers with higher permeability such as sand strata. Aquifers in the study area are weathered parts of the outer layer of base rocks, and the water level in a well lowers by several meters upon pumping up. Therefore, it is assumed that its permeability coefficient is much lower than that of a sand stratum. In addition, there is an observable tendency for difference between water levels in the rainy and dry seasons (in all areas in Kiffa except where a zone with lowering of the water table is formed as a result of excessive pumping-up). It is assumed from this that underground water replenished by rainfall generally stays in its initial location rather than running to the side. For the above-mentioned reasons, the cultivation amount of underground water in Kiffa city is calculated using the difference between underground water levels in the rainy and dry seasons. This method offers a rough calculation of the cultivation amount in an area for which hydrogeologic data is poor, but it is not a method that enables quantitative prediction as to in which area and by how much lowering of the water table will occur.

(2) Estimation of the cultivation amount of underground water in Kiffa city

The typical amount of lowering of the water table from the rainy season to the dry season in Kiffa city is shown in the following figure.

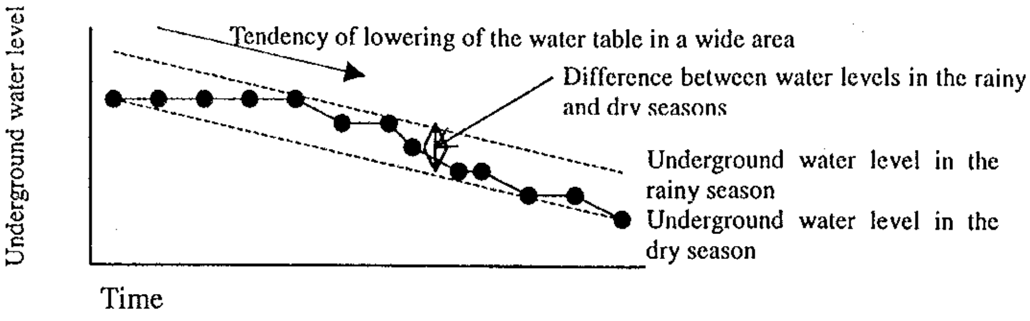
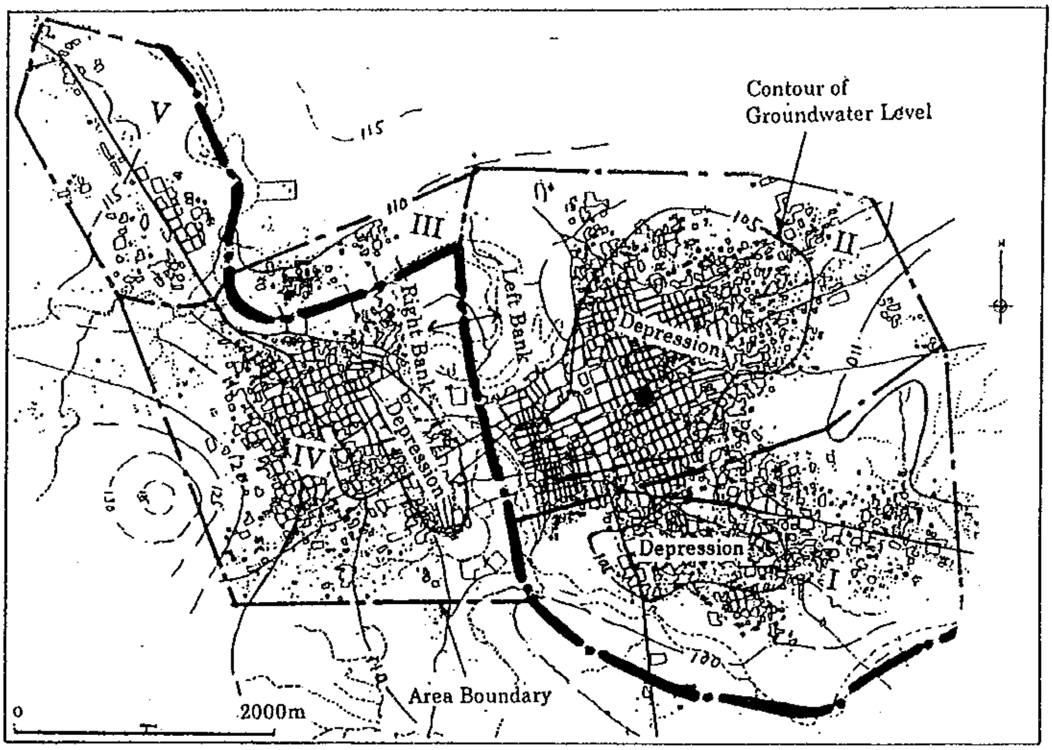



Fig. 3.5-1 Typical differences between water levels in the rainy and dry Seasons

As a result of simultaneous observation of underground water levels, as shown in Fig. 2.4-8 "Cross-sectional view of the underground water level" and Fig. 3.4-9 "Distribution of differences of underground water levels in the rainy and dry seasons," in Chapter 3.4.1, the difference of lowering of the water table between the rainy and dry seasons is 1 m or lower except in depressions due to excessive pumping-up. Based on the results of simultaneous observation of underground water levels, it is estimated that the average is around 70 cm.

Aquifers in Kiffa city are parts of the outer layers of a rock base (pelite) with cracks having developed. It is supposed that porosity in the weathered part of the rock base is generally from around 1% to 3%.

Based on the above-mentioned conditions, as shown in the following figure, Kiffa city is divided into a right-bank area and a left-bank area, with an area of underground water along a wadi as a boundary. Furthermore, the right-bank area is divided into two districts; the urban district and the surrounding district. The left-bank area is divided into three districts; two districts with lowering of the water table and one surrounding districts. Thus, the city is divided into 5 districts in total, and the cultivation amount of underground water is estimated for each area.




| Left Bank | Square Measure (km²) | Right bank | Square Measure (km²) |
|---|---|---|---|
| I Urban district in the south side | 6.0 | IV Urban district | 5.8 |
| II Urban district in the north side | 6.7 | V Surrounding district | 2.2 |
| III Surrounding district | 0.4 | | |
| Total | 13.1 | Total | 8.0 |

Fig. 3.5-2 Division of the area for calculation of the cultivation amount of underground water in Kiffa city

As mentioned above, the difference of underground water levels between the dry and rainy seasons is about 70 cm, and it is assumed here that the effective porosity of an aquifer is 2%. Thus the cultivation amount of underground water in Kiffa city is roughly calculated as follows.

Table 3.5-1 Estimated cultivation amount of underground water in Kiffa city

| Area Division | | Estimated Cultivation Amount of Underground Water ($m^3$/year) | Area Name |
|---|---|---|---|
| Left-bank | I | 84,000 | Entou, Kweindy, Siyassa, Nezaha, Arafat, Toueimirit, Taiba |
| | II | 94,000 | Khadima, Jedida, Toueimirit, Temicha, Qlig, Seif Cherif, Gomez, Admi. Dist., Aleg |
| | III | 6,000 | Boulenwar |
| | Sub-total | 184,000 | -- |
| Right-bank | IV | 81,000 | El Hanger, Edebaye, Segatar I, Segatar II, Kebata, M'sseigila |
| | V | 31,000 | Belementar East, Belementar West |
| | Sub-total | 112,000 | -- |
| Total | | 296,000 | -- |

(3) Water balance in Kiffa city

Surface run-off doesn't occur in Wadi Rhouda running through Kiffa city. A part of rain falling on both banks of the wadi permeates into the underground, and much of the remainder evaporates in the initial place. Though a little runs off to the wadi in the case of heavy rain, the rainwater forms small pools or damp ground intermittently and evaporates some time later without flowing down the wadi. A part of the rainwater permeates into the underground and becomes underground water. However, as will be mentioned later, developments of underground water greater than the amount of permeation is now carried out so that cultivated underground water doesn't run off from Kiffa city but evaporates as sewage there. It is considered that a hydraulic cycle is being formed in which eventually all of the rainfall in Kiffa city will evaporate in Kiffa city.

In the previous section, based on the changes in underground water levels from April 1997 to June 1998, the cultivation amount of underground water in Kiffa city (i.e., the amount of rain permeation into underground), is estimated to be approximately 300,000 $m^3$/year. The annual precipitation in Kiffa in 1997 was 150 mm. Assuming that the area of Kiffa city is 21.1 $km^2$, according to the figure of division of the area for calculation of the cultivation amount of underground water in Kiffa city, the total precipitation last year in Kiffa city was 3,165,000 $m^3$. From this, the value of around 10% is obtained as the rate of rain permeation underground. It is considered that approximately 90% of the remaining evaporates where it fell, or in pools and damp ground along wadis.

(4) Calculation of the developable amount of underground water in Kiffa

According to the results of the social/economic survey, the present population of Kiffa city is approximately 60,000, and it is estimated that the amount of water used per person is about 15 liters per day. Since all of the water for daily life in Kiffa city is supplied by underground water in the city, it is estimated that the amount of underground water pumped up in Kiffa city is around 330,000 $m^3$/year.

As shown in the table above, as it is estimated that the cultivation amount of underground water is around 300,000 $m^3$/year, it is considered that the amount of underground water pumped up under the present situation has already exceeded the cultivation amount of underground water by about 10%. As a result of observation of underground water levels, three areas were confirmed as those in which lowering of the water table is judged to result from excessive pumping-up. It was also found that all underground water in Kiffa city permeates into these areas and doesn't run off to downstream areas in the city. This also supports the conclusion that the amount of water pumped up under the present situation is greater than the cultivation amount. Simultaneous observation of water levels in 89 existing wells in the city, which was carried out in April (the dry season) 1998, showed that sufficient underground water existed in all observation wells and was used in November (in the middle period between the rainy and dry seasons) 1997, but, in the dry season, 15 of them went completely dry and at 26 wells water levels were lowered to a degree that made pumping-up impossible. Therefore, in the dry season, underground water levels are lowered at 41 of 89 existing wells to the degree that pumping-up is impossible. This rate, 46% of the whole, also indicates that the current amount of underground water pumped up in Kiffa city is excessive.

Existing wells located in the depression number 232 in the old urban district on the left-bank side, 67 in the south district on the left-bank side and 23 in the Sagatar I district on the right-bank side. It is conjectured from this that most of the excessive pumping-up is carried out in the old urban district on the left-bank side. The following is an estimate of the amount of excessive water pumped up in the areas with underground water levels lowering in this left-bank old urban district, based on the tendency of lowering of the water level at observation wells shown in Fig. 1.3-5, Chapter 1.3.

ED = D x A x P = 36,000 $m^3$/year

ED:Roughly calculated amount of excessive water pumped up in the areas experiencing lowering of the water table in the left-bank old urban district ($m^3$/year)

D : Rate of lowering of the underground water level (m/year)
It is assumed, from the observed tendency of lowering of water levels at observation wells and the cross-sectional view of underground water levels , that the average rate of lowering of the water table in the left-bank old urban district is 1.5 m.

A : Area of the locations with lowering of the water table
The area of the locations with lowering of the water table on the left-bank old urban district in November (the middle period) 1997, i.e., 1,200,000 $m^2$, is applied.

P : The effective porosity of an aquifer is assumed to be 2%.

As shown above, it is estimated from the tendency of lowering of the water table that the roughly calculated amount of excessive water pumped up is 36,000 $m^3$/year in the depression in the old urban district on the left-bank side. This almost corresponds to the amount of excessive water pumped up (approximately 30,000 $m^3$/year) calculated from the difference between the cultivation amount obtained from the differing water levels between the rainy and dry seasons, and the current amount of water pumped up estimated with the population and the source unit of water use.

As mentioned, it is certain that excessive pumping-up of underground water that exceeds the cultivation amount is being carried out in Kiffa city. It is expected that the source of underground water will dry up if current developments of underground water are continued without taking any responsive measures.

As shown in Fig. 3.4-3, there is, indeed, the possibility that, judging from the long-term precipitation trend, precipitation will increase because it is now a period of water shortage and the amount of underground water cultivation will increase accordingly. However, this is just a trend, and it is impossible to predict at what time period in the future and by how much rainfall will increase. Therefore, the cultivation amount is calculated with the present characteristics of changes in underground water and with the current precipitation.

From the viewpoint of the proper amount of water pumped up, as aquifers in Kiffa city are weathered strata of base rock with lower water permeability, the lowering of water levels at wells is great and efficiency of pumping-up is poor, in these kinds of aquifers it is generally considered that around 80% of the cultivation amount is the maximum sustainable amount of development. If the development of underground water exceeds this percentage, there is the possibility that reciprocal interference among wells will result in a remarkable lowering of water levels.

In order to continuously use underground water in Kiffa city, a major premise is to confine the amount of development to the cultivation amount or less. It is judged that an amount of around 80% of the cultivation amount is the upper limit. Therefore, it is estimated that the maximum sustained developable amount of underground water in Kiffa city is around 240,000 $m^3$ annually. It is considered that the actual amount of underground water pumped up (approximately 330,000 $m^3$/year) in Kiffa city exceeds the sustainable amount of water pumped up by around 90,000 $m^3$/year.

On the other hand, it is anticipated that, if approximately 2,000 $m^3$ per day or 730,000 $m^3$ per year of water is introduced from the northwest area to Kiffa city, the amount of around 73,000 $m^3$ per year, equivalent to about 10% of it, will permeate underground. That is, it is estimated that an amount of water near to the target amount of a large cut in pumping-up, will be cultivated. Therefore, it is expected that, if operations of water introduction to Kiffa city are carried out, the problem of excessive pumping-up will be reduced to some degree, apart from the problem of underground water quality.

However, if intensive development of underground water is continued in the three areas of lowering of the water table that were formed due to excessive pumping-up, there will be a possibility of considerable lowering of the water table occurring locally, and many well will go dry. Therefore, it is necessary to regularly monitor underground water levels in these areas. Measures, such as restriction of the amount of pumping-up in areas where remarkable lowering of the water table is observed, will be required.

Areas requiring watching of water levels are the old urban district on the left-bank side covering four areas (Gomez, Jedida, Qlig and Temicha), two areas of the south district on the left-bank side (Khadima and Entou)around existing wells of the Water utilization office, and the Segatar I area on the right-bank side.

### 3.5.2 Developable amount of groundwater in the northwest water source area

(1) Source of cultivation of underground water

1) Characteristics of groundwater basins in the northwest water source area

Underground water level contours in the northwest water source area obtained from results of the test pitting surveys are shown in Fig. 3.5-3. Characteristics of the shape of water tables shown in this figure are described below.

a. As shown in Fig. 3.5-3, two watersheds of underground water are observed along a trunk road from the north to the west from the underground water level contour to Nouakchott, and along a fixed sandhill extending in from the north to the east in Kandra and behind it. Three small groundwater basins are formed with these watersheds as a boundary. These basins are independent of each other, and it is judged that there is no movement of underground water among the ground water basins.

b. The groundwater basins in the southwest and north sides are obviously closed basins. There is the possibility that the basin in the southeast side is also closed without connection with ground water basins in Kiffa city. It was mentioned in Chapter 3 that water systems in the study area are the aggregate of small closed water systems. The groundwater basins show the same characteristics as these surface water systems. It is considered that the closed groundwater basins almost correspond to the closed water systems.

c. The tendency of lower water tables is observed along lineaments in each groundwater basin. It is considered that they gather along lineaments with high permeability of cultivated ground water.

2) Examination of the source of ground water cultivation

It was stated in "3.2.2 Results of Interpretation of Air Photos" that the lineament running through the northwest water source from the east to the west was estimated to be an eastern extension of the large lineament extending along Passe De Goussas in the Tarf Tintara height on the west side of the study area. This large lineament can be read even on a 1/200,000 topographical map. It is assumed that the width of its fracture zone is over 100 meters. This large lineament is considered to extend to the northwest water source across the Hassel Nkheile sandhill consisting of a number of small closed water systems.

As a result of digging of the test pitting surveys, it was found that areas with potential for development of underground water are distributed along lineaments. It is considered that underground water gathers and flows mainly along lineaments. From this, it is possible to build a hypothesis that underground water gathers along the large lineament as shown in Fig. 3.5-4 and flows into the northwest water source.

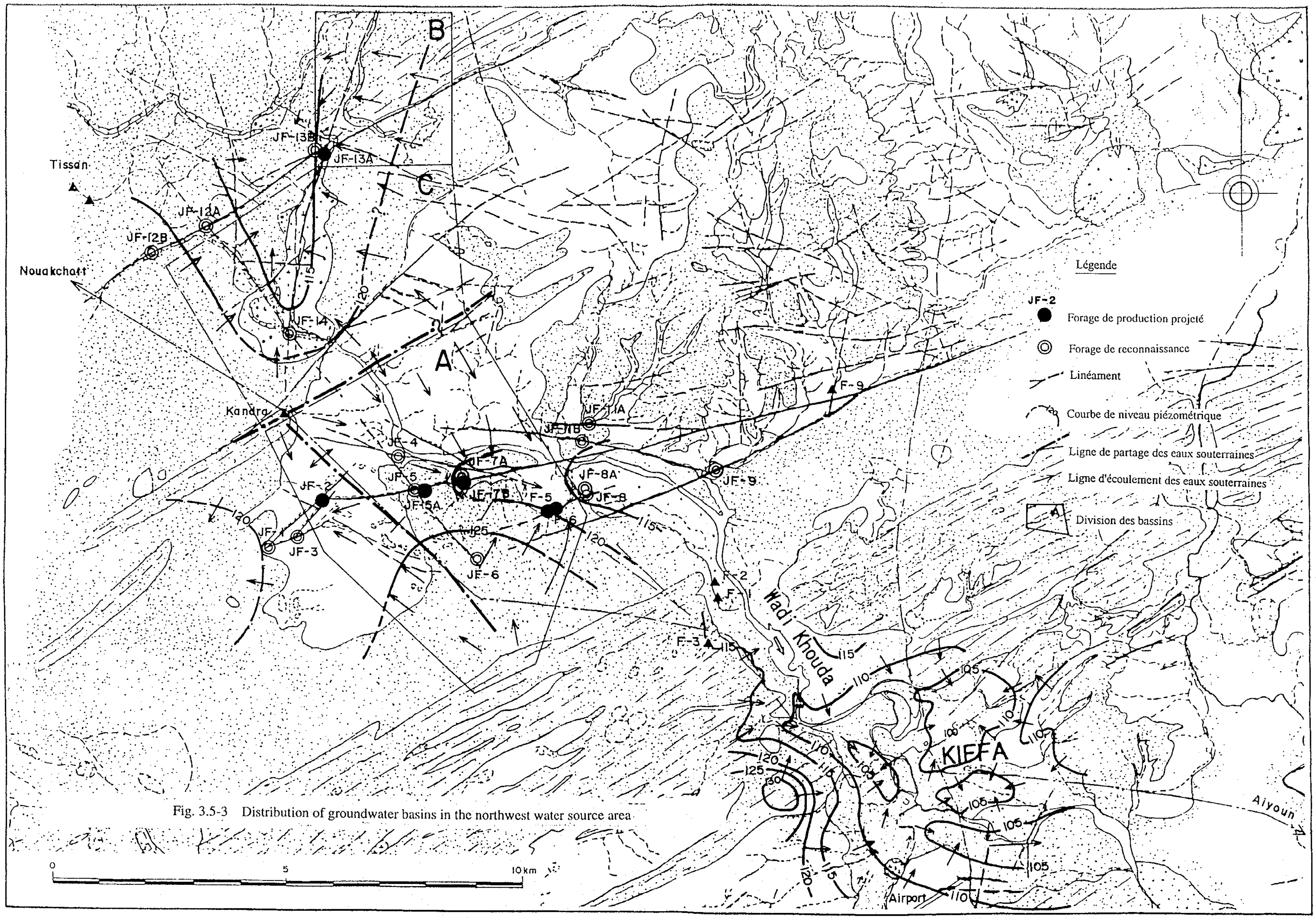



Fig. 3.5-3 Distribution of groundwater basins in the northwest water source area

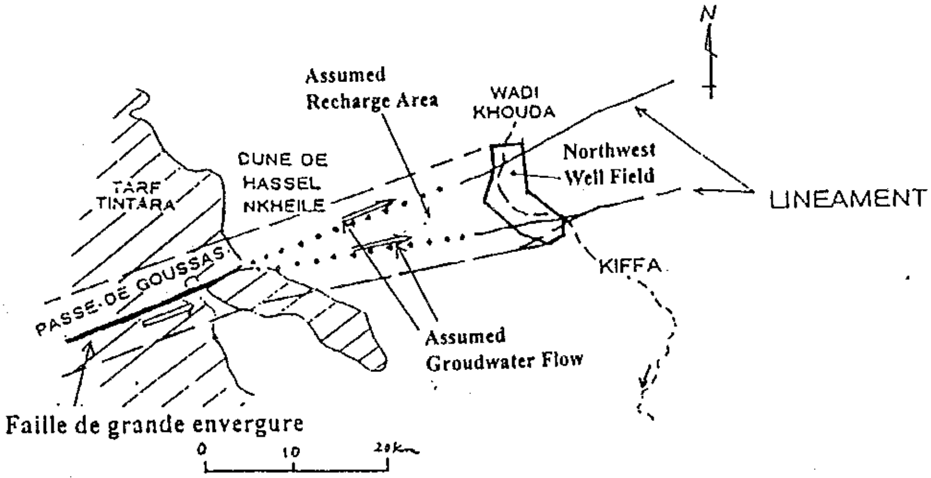



Fig. 3.5-4 Cultivation area assuming that underground water flows in along the large lineament on the west side

If the aforesaid is correct, as shown in the above figure, the cultivation area in the northwest water source area is extremely extensive and includes the Tarf Tintara height and the Hassel Nkheile sandhill on the west side. It is estimated that the area is over 5,000 $km^2$. This means that an enormous amount of underground water (roughly calculated to be more than 100 million $m^3$/year) flows into the northwest water source.

However, as mentioned in the previous section, the groundwater basin from the ground water level contour line to the northwest water source is divided into three smaller ones. It is supposed that these basins are independent of each other, and there is no movement of underground water among ground basins. It is considered from this that there is a low possibility that a large amount of underground water flows from the west side to the water source along the large lineament because this test pitting survey was carried out within a very limited range along lineaments. However the assumption mentioned above cannot be completely denied.

For the above-stated reasons, the premise of trial calculation of the developable amount of underground water here should be performed on the safe side. Then examination should be carried out based on the view that underground water in the northwest water source area is cultivated solely by permeation of rainwater from the ground surface.

(2) Water balance in groundwater basins

In the northwest water source area, the development of underground water is carried out. It is judged that the water balance is kept natural.

Rainwater in the closed groundwater basins in the northwest water source area gathers as surface run-off at the bottom of the surface closed water systems and forms marshland, damp ground and grassland. In our opinion, rainwater having permeated underground moves as underground water along the zone with high water permeability, such as lineaments, and eventually accumulates in marshland, damp ground or grassland (which is also the bottom of the groundwater basin, and where the rainwater evapotranspires). We think that all the precipitation evapotranspires in the closed water systems in the study area in this fashion.

In the northwest water source, underground water cultivation is carried out solely in the groundwater basins in this fashion. Therefore, cultivation systems in which additional underground water is supplied from distant places through lineaments, etc., are not taken into consideration.

(3) Method to calculate the amount of underground water cultivation

As mentioned in the previous section "3.5.1 Developable amount of groundwater at shallow aquifer in Kiffa," several methods to calculate the amount of underground water cultivation can be listed. However, in this study, only the test pitting surveys and the pumping-up tests were carried out in the northwest water source area. There was no long-term observation of water level changes or hydrogeologic observation due to time limitation. Therefore, the methods to calculate the amount of underground water cultivation stated in the previous section cannot be adopted.

From the result of examination of the amount of underground water cultivation in Kiffa city described in the previous section "3.5.1 Developable amount of groundwater at shallow aquifer in Kiffa," it was estimated that the rate of rainwater permeation underground (the rate of underground water cultivation by rainfall) was around 10% and the remaining 90% evapotranspired. The northwest water source area and Kiffa city are about 10 km apart and have almost same meteorological, hydrologic and hydrogeologic conditions. In addition, underground water cultivation in the both places is limited to permeation of rainfall in their own catchment areas, there is no supply of underground water from other catchment areas, as mentioned above. Therefore, it is possible to obtain the amount of underground water cultivation in the northwest water source from the areas of the groundwater catchment basins, the amount of annual precipitation at the source, and the rate of rain permeation underground (the rate of underground water cultivation by precipitation) in Kiffa. As mentioned in "3.5.1 Developable amount of groundwater at shallow aquifer in Kiffa," a limitation of this calculation method is that is cannot be used to qualitatively predict in which area or by how much lowering of the water table will occur in the case of future development of underground water. Rather the method roughly calculates the amount of underground water cultivation in an area with poor hydrogeologic information.

(4) Calculation of the developable amount of underground water in the northwest water source area

The developable amount of underground water cultivation in the northwest water source area was calculated with the condition that wells from which much water is pumped up should be selected from among the test pitting survey wells dug this time and existing observation wells, and then diverted to production wells. The number of wells to be diverted to production wells are the following six, and their locations are shown in Fig. 2.5-3.

- JF-2 (The test pitting survey well dug this time was converted to a production well.)
- JF-5A (The test pitting survey well dug this time was converted to a production well.)
- JF-7B (The test pitting survey well dug this time was converted to a production well.)
- JF-13A (The test pitting survey well dug this time was converted to a production well.)
- F-5 (The existing observation well was diverted to a production well.)
- F-6 (The existing observation well was diverted to a production well.)

1) Division of underground water catchment area for calculation of the cultivation amount

Based on flows of underground water (underground water flow lines) estimated from ground water level contours shown in Fig. 3.5-3 and on locations of watersheds of underground water, the three areas with underground water flowing in were set up on the said map.

Area A is a range where it is assumed that five wells located on two lineaments from the east to the west have the possibility of taking in underground water. Area B is a range where it is assumed that one well located on one lineament from the south to the north has the possibility of taking in underground water. A detailed study was not carried out this time in the extension part in the south of the lineament from the south to the north. However, it is supposed that this place has as high potential for development of underground water as Areas A and B. Therefore, Area C was established as a range of ground water flowing-in if production is installed on this lineament from the south to the north. This is shown in Fig. 3.5-3.

2) Underground water cultivation amount and developable amount of underground water in the northwest water source area

For each catchment area of underground water set up in Fig. 3.5-3, the cultivation amount is calculated with the area, annual precipitation and rate of rainfall permeation underground. For the annual precipitation, 235.4 mm/year, which is the 8-year average annual precipitation shown in "3.1 Weather and Hydrology," was employed. For the rate of rainfall permeation underground, 10%, which was obtained from examination of the water balance in Kiffa city, was employed.

As the maximum possible amount of underground water pumped up in the areas, 80% of the cultivation amount was set up. Upon planning of development of underground water, the amount of water pumped up in each area must be set up at or under this maximum possible amount.

The results of trial calculation of the amount of underground water cultivation and the maximum possible amount of water pumping up in each area are shown in the following table.

Table 3.5-2 Amount of underground water cultivation and the maximum possible amount of water pump-up in the northwest water source areas

| Division of Underground Water Catchment Area | Area ($km^2$) | Cultivation Amount ($m^3$/year) | Maximum Possible Amount of Water Pumped Up ($m^3$/year) | Production Well |
|---|---|---|---|---|
| Area A | 34 | 800,000 | 640,000 | JF-2, JF-5A,JF-7B,F-5, F-6 |
| Area B | 9 | 210,000 | 170,000 | JF-13A |
| Subtotal | 43 | 1,010,000 | 810,000 | - |
| Area C | 21 | 490,000 | 390,000 | To be newly developed |
| Total | 64 | 1,500,000 | 1,200,000 | - |

As shown in the above table, if underground water development areas in the northwest water source are determined to be two areas, A and B, it is estimated that the cultivation amount is around 1,010,000 $m^3$ per year and the maximum possible amount of water pumped up is around 810,000 $m^3$ per year. If development of underground water is carried out in Area C in the future, the total cultivation amount in these three areas is around 1,500,000 $m^3$ per year and the maximum possible amount of water pumped up is around 1,200,000 $m^3$ per year.

The storage amount of the groundwater is estimated about 25,000,000$m^3$ in the northwest well field, assuming that the thickness of the weathered surface part of the bedrock (aquifer) is around 40m and the porosity of the aquifer is about 1%.

# Chapter 4 Current Situation of Water Supply Project

## 4.1 Water resource and supply project in Mauritania

(1) Demographics

Demographically, Mauritania is characterized by rapid population growth, low population density and increasing concentration in cities. The estimated population of the nation in 1991 was two million, but due to urbanization led by development of a modern economy and by large-scale drought, half the population was concentrated in 24 cities of over 5,000 residents each. The rest of the population, dispersed in rural areas, is composed of 175,000 nomads and 825,000 settled stockbreeders, living in approximately 4,000 villages of less than 1,000 residents. The nation's average population density is the lowest in West Africa. The average national population growth rate is estimated at 2.9% per year.

The largest city of Mauritania is Nouakchott, with a population of 640,000. Other large cities with over 30,000 residents include Nouadhibou, Rosso and Kiffa.

(2) Water and sewage

Currently, only about 20% of the urban population receives water via hygienic conduits. The rest obtain water from water sellers who resell water taken from public water tap or private wells. On the other hand, only about 40% of the village population can obtain safe and secure water. As for sewage facilities, only 4% of the population of Nouakchott have access to sewage pipes.

(3) Water resources

In Mauritania, most of drinking water is obtained from subterranean water. In particular, Nouakchott, the capital, is situated above a layer of saline water, so the water is taken from a pumping zone about 60 km west of the city at great expenses. The quality of water is excellent, requiring no special treatment other than simple injection of chlorine. The quantity of the reserve of water in the zone is anticipated to be sufficient to satisfy the demand of the near future.

(4) Administrative organizations related to water and hygiene

In Mauritania, water and hygiene are administered by four organizations. The major roles and functions of each are shown in Table 4.1-1.

Table 4.1-1 Administrative organizations related to water and hygiene

| Organization | Principal roles and functions |
|---|---|
| Ministry of Water and Energy (MHE) | - Drafting and enforcement of policies related to national water resources<br>- Management/examination/planning/maintenance of water resources<br>- Basic responsibility for water supply to urban/rural areas<br>- Supervision of SONELEC |
| Hydroelectricity corporation (SONELEC) | - Production/distribution of water in urban areas |
| Ministry of Hygiene (MS) | - Planning and execution of sewage and waste disposal<br>- Drafting and enforcement of laws and regulations related to hygiene<br>(National hygiene center)<br>- Monitoring of water quality<br>- Research on public health |
| Ministry of Rural Development (MDR) | - Affairs related to water resources for farming and stockbreeding |

(5) Basic policies for water supply

The basic goal for urban areas is to satisfy all demand with individual water supply and public water taps by the year 2000. To achieve this goal, the following four policies were adopted: ① installation in each city of over 5,000 residents of a facility capable of supplying 40 liters per person per day, ② privatization of public water taps to ensure costs are borne by the beneficiaries, ③ settlement of plans to install water supply pipes and to set up a reasonable charging system for the destitute, ④ expansion of the scope of operation of SONELEC to supplement the insufficient capacity of local government.

In rural areas, local residents are invited to participate in planning and management of water resources to promote installation of a profitable system including recovery of investment cost. For this purpose, the structure of the Water utilization office shall be modified to adapt to rural needs, and construction of water supply facilities shall be gradually passed on to private corporations.

(6) Institutional system

Laws relative to the water supply project (water resource development and waterworks project) in Mauritania include the Water Code (Code de L'eau: law No.85-144) established on July 4, 1986, by the Ministry of Water and Energy. The law is constituted of the following 10 chapters and 141 articles.

Chapter 1 Basic disposition
Chapter 2 National property
Chapter 3 Restrictions on the use of water assets
Chapter 4 Rules on the exploitation of water
Chapter 5 Conservation of the quality of water
Chapter 6 Use of water and priorities
Chapter 7 Authorization system for water-related enterprises
Chapter 8 Infractions and penalties
Chapter 9 Transitory dispositions
Chapter 10 Abolition, promulgation and enforcement of the law

Articles closely related to the water resource development and waterworks project are found in chapters 3 through 6.

(7) Privatization policy

1) Water supply for urban areas by SONELEC

Since the late 1980s, the Mauritanian government has adopted various policies to improve the corporation's declining economic and financial situations, assisted by the IMF and the World Bank. As a part of such policies, the government established the Economic and Financial Recovery Plan (EFRP) in 1985. This plan includes reform plans to improve management of public corporations and to make more efficient use of private corporations. Within the framework of the plan the state-operated hydroelectricity corporation (SONELEC) is rapidly regaining financial independence and other functions, resulting in sufficient success as stated in the section 4.4.1.

With regard to the practical side of the water supply project by SONELEC, a type of privatization is under way in the management of the water supply by public water taps, which holds an important position of the current water supply in urban areas (about 40% of the population subject to water supply in Aioun city). It is achieved by inviting people to become agents to manage and operate the public water taps, and entrusts them with the resale of water to individual customers. SONELEC regards such agents as its ordinary customers and charges them the due amount for the quantity of water supplied.

Although this is a convenient method for the operation of SONELEC, as a public water supply system it cannot be qualified as a success. The number of public water taps is absolutely insufficient, the service hours depend on each agent, and customers are obliged to pay a higher unit price for water. In addition to institutional problems, there is also a technical problem of installation of public water taps that needs to be handled.

2) Water supply in rural areas by the Water utilization office

The Ministry of Water and Energy is responsible for water supply in rural areas including development of subterranean water and construction of water supply facilities. Following the government's privatization policy, management of wells after completion of the facilities and water supply operations are being entrusted to private corporations.

In the actual enterprise of the project, the Water utilization office calls for managing agents, among whom a concessionaire shall be selected and a management/maintenance contract concluded. The concessionaire shall sell water to villagers at a rate stipulated by the contract, and pay the cost of management/maintenance, depreciation cost and local taxes according to sales quantity to the National Treasury and local government as stipulated in the contract. The difference between the sales revenues and the payments shall be the concessionaire's profit. The system requires that the cost of management/maintenance and depreciation cost be deposited in a specific bank account and used only for rehabilitation and renewal of the facilities.

The fact is that, in this system, water supply is operated as a project in a very explicit way, thanks to the presence of agents who relieve the Water utilization office of its burdens and benefit from the profit as an incentive. Unlike in urban areas, water supply in rural areas is small in scale and independent in each village; therefore, management and maintenance are relatively easy. Management and maintenance by an organization of local residents may be possible. Since this is still a new system and has been starting in relatively wealthy villages, it is expected that application of this system may be difficult in poor villages with no cash revenue.

## 4.2 Current situation of water supply in Kiffa city

### 4.2.1 General situation of Kiffa city

(1) General situation of Kiffa city

1) Urban district and population

The population, number of households, surface area and categories of urban district of the Kiffa city are shown in Fig. 4.2-1. The administrative zone of the Kiffa city is stipulated to be within the radius of 20 km from the center of the city. Six communes exist in the surrounding areas (refer to 4.2-2).

Table 4.2-1 Population and surface area in each district of Kiffa city

| | | District/Sub-District | Population | No. of Household | Surface area ( ha ) | Category |
|---|---|---|---|---|---|---|
| 1 | | Belemtar East | 6,899 | 1,090 | 89.0 | II |
| | 1-1 | Belemtar East | | | | |
| | 1-2 | Boulenwar | | | | |
| 2 | | Belemtar West | 2,945 | 463 | 508.8 | III |
| | 2-1 | Belemtar West | | | | |
| | 2-2 | M'sseigila | | | | |
| | 2-3 | Kerkeb | | | | |
| 3 | | Sagatar I | 8,567 | 1,379 | 107.0 | II |
| | 3-1 | Sagatar I | | | | |
| | 3-2 | Kebata | | | | |
| 4 | 4-1 | Sagatar II | 5,155 | 811 | 118.6 | II |
| 5 | 5-1 | Edebaye | 1,116 | 199 | 135.6 | III |
| 6 | 6-1 | El Hanger | 1,547 | 218 | 66.9 | III |
| 7 | 7-1 | Aleg | 1,524 | 263 | 98.5 | I |
| 8 | 8-1 | Administration District | 795 | 140 | 23.7 | I |
| 9 | 9-1 | Seif Cherif | 700 | 100 | 90.7 | III |
| 10 | 10-1 | Gomez | 2,170 | 365 | 33.0 | I |
| 11 | 11-1 | Jedida | 3,095 | 482 | 53.8 | I |
| 12 | 12-1 | Khadima | 7,129 | 1,212 | 147.9 | I |
| 13 | 13-1 | Kweindy | 706 | 126 | 10.7 | I |
| 14 | 14-1 | Entou | 3,254 | 847 | 122.4 | I |
| 15 | 15-1 | Qlig | 5,748 | 903 | 160.6 | III |
| 16 | 16-1 | Temicha | 2,250 | 356 | 70.9 | III |
| 17 | | Toueimirit | 5,906 | 964 | 327.0 | III |
| | 17-1 | Toueimirit | | | | |
| | 17-2 | Arafat | | | | |
| | 17-3 | Nezaha | | | | |
| | 17-4 | Siyassa | | | | |
| | | | 59,506 | 9,918 | 2,165.1 | |
| 18 | 18-1 | Taiba | 1,415 | 212 | 50.0 | III |
| | | | 60,921 | 10,130 | 2,215.1 | |

Source: 1997 Study by Ministry of Planning and documents obtained from Kiffa city

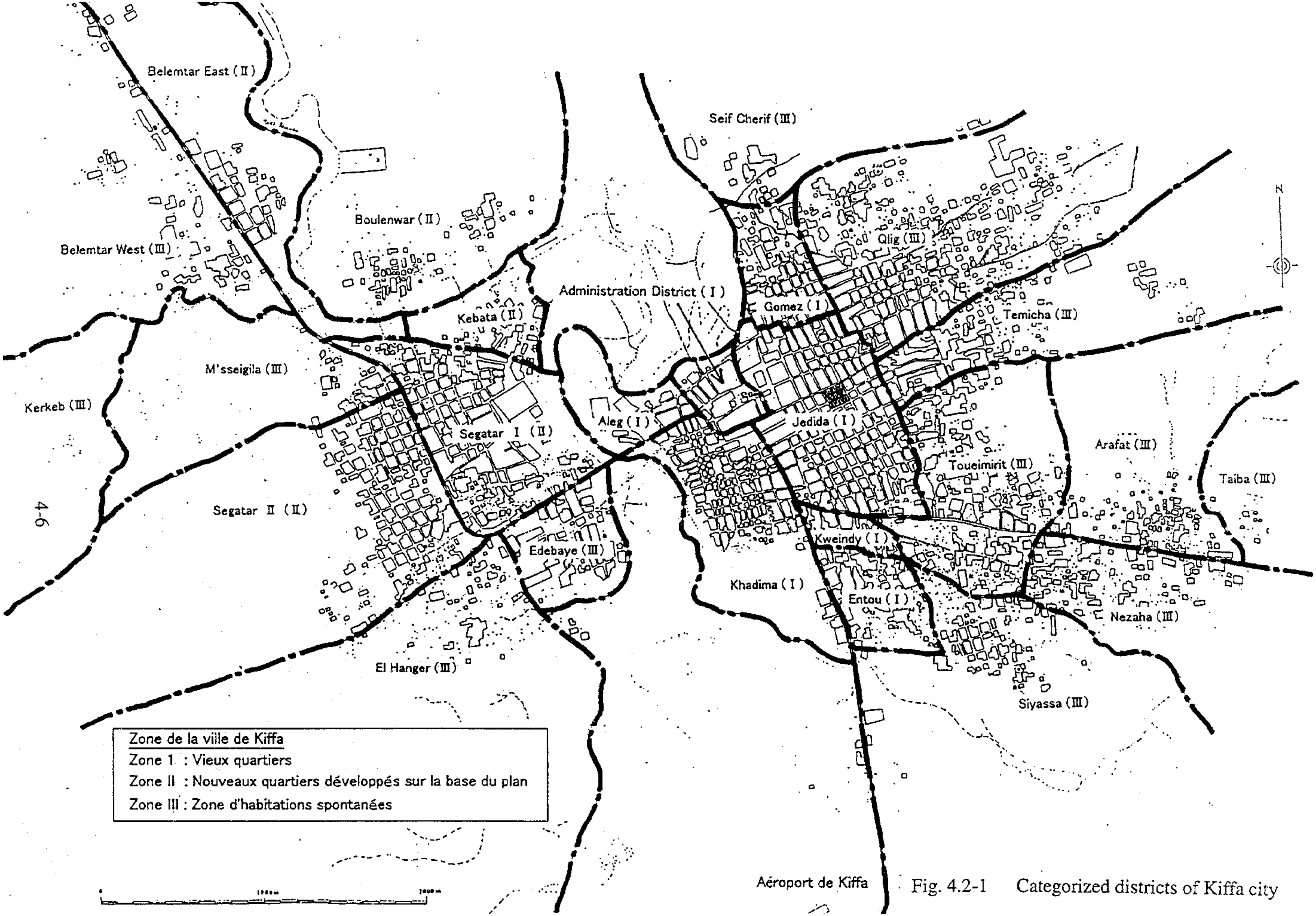



Fig. 4.2-1 Categorized districts of Kiffa city

In the statistical table (Table 4.2-1), "Taiba district" is added for this study plan to the study area designated by the Ministry of Planning. The district, situated at the east end of the urban district, has become rapidly modernized in recent years, and the city government recognizes this district as a part of its administrative zone. In addition, small districts shown in Table 4.2-1 and Fig. 4.2-1 exist under the administrative district, forming communes in the surrounding areas that are recognized as geographical places. As they often have racial/tribal features, they are used as units of category for study purposes.

Categories of districts used here are those shown in the study conducted by the Ministry of Planning.

I: old town

II: new urban district developed by the plan

III: naturally developed district

2) General situation of social infrastructure other than water supply

Of the details being examined by the social study team, only the general situation of basic features of social infrastructure shall be discussed here.

① Public facilities

- Assaba state agency (headed by the state governor)
- City office (administration under publicly-elected mayor; see organization chart)
- Police
- Army
- Schools (one junior-to-senior high school, eight elementary schools)
- Hospital (only medical institution in the city; constructed under Chinese aid in the 1960s and run by a group of Chinese doctors ever since)
- Health centers (two in the city)

② Roads

As shown in Fig. 4.2-1, roads in the city are not paved. The sole exception is National Route 3 connecting Nouakchott and Nema. The roads are not explicitly distinguished, and structures such as walls mainly constitute the division of roads between houses. In the surrounding areas (Zone III) where development took place in an unorganized manner, there is no distinct infrastructure that can be referred to as roads.

③ Sewage and waste

There is absolutely no drainage system for rainwater or household wastewater in the city. Rainfall is little, but reports say that in some districts, water pools after rain due to geographical conditions, mixes with residential wastewater and causes sanitary problems. Since only a little water is currently used (as mentioned below), wastewater from houses is either directly discharged on the ground or diverted into a ditch-type lavatory and disposed of through infiltration into the ground.

Waste disposal is also an unattended issue. The only concrete action taken is trial disposal by on handcarts through an NGO (World Vision) in the districts where shops are concentrated. In reality, vacant lands are used as a dumping ground without control. It is not yet a serious problem because there is little garbage due to the low level of consumer activity and also because of the dry climate. The problem is likely to become serious, however, together with sewage treatment, as the water consumption shall increase in relation to the success of the water supply project. A garbage collection improvement project in two urban districts within the framework of UNDP's Assaba program is planned for 1998.

④ Electricity

A power distribution network run by SONELEC (hydroelectricity corporation) has been installed. There is hardly any power failure. In Mauritania where cities are dispersed over a huge area, power distribution networks are independent in each city and not linked. In Kiffa, a diesel power plant (3,200 kW) was constructed in 1995. However, it supplies only about 2,300 households out of 10,000 because of the high initial cost for wiring. Although about 1,000 households have requested wiring, power generation in 1997 for the entire city was around 200 kW per an hour on average, and consumption per client remains very low. Therefore, it is an excessive facility for the city. The tariff for electricity is 24.6UM per 1 kWh, and there is a nationwide computing system for inspection of power consumption and collection of the tariff.

⑤ Gas

SONELGAZ supplies propane gas in cylinders. Although the government is promoting the use of gas as part of its policy to preserve the precious forest environment, wood and charcoal are used as fuel in the city in general.

⑥ Telephone

There are approximately 220 line contractors in the city. People generally use public telephone operated by shops. Connection outside of the city is ensured by satellite, but currently there are only six lines available. So long-distance and international calls may encounter connection problems during peak hours.

(2) Current situation of water supply

Currently, water used in Kiffa city is surface water of Wadi Khoda (normally, water is pooled due to the topography, and flows southward only when rainfall exceeds certain amount) that flows into low land, and groundwater at shallow wells installed all over the city.

Surface water is used for cultivation of palm trees on flood plain of Wadi and for small-scale irrigation gardening. However, the use of shallow wells is also necessary for irrigation gardening because the flooded area disappears in the dry season. Such gardening can be seen in the center of Wadi and at the southernmost part of the city.

As examples of the use of ground water at shallow aquifer, approximately 1,060 wells were spotted all over the city in this study. This is the number of the wells that are in use or that can be used, excluding some 300 old wells that are considered not in use. Wells are about 15 m deep and dug manually. In general, owners of the wells are individuals. Since there are approximately 10,000 households in Kiffa city as mentioned above, about 10% are equipped with a well. There are few public wells, only two or so.

When people use well water for daily use, stockbreeding or for a private garden, there are three methods of procurement in general.

- Drawing water directly from the well.
- Buying from a water seller carrying 200-liter drums on donkey-cart.
- Getting supplied from the city-owned water truck

Wells are not equipped with pumping devices, except for those with an engine pump for the municipal water truck, and a few windmills and solar-powered pumps. Therefore, water must be drawn manually. When people draw water from a well, they use their own well or go to the nearest well. Although wells are owned by individuals, it is tolerated in this society that people in the neighborhood use them freely, so there is no problem about using wells belonging to others. The cost of drilling of a well is about 30,000 - 40,000UM. Attention must be paid to the social custom that individuals bear this cost and offer well water to local residents.

The proportion of water directly drawn from the well among the total water consumption is estimated to be around 30% - 40% based on the immediate result of interviews conducted as a part of the water supply project. Naturally, the choice of method between direct drawing and buying from sellers with a donkey cart not only depends on the wealth of the residents but also on the quality of water in the region. Where the quality of water is not suitable for drinking, e.g., with a high saline concentration, even the poor must buy water from sellers. If the local water is good, people can use it from the well. It is noteworthy that the task of drawing water is assigned to women regardless the region.

Water supply by the municipal water truck is limited to large users, i.e., public facilities or the wealthy people having their own water tanks. They apply for the service to the municipal office at a specific charge and are supplied with water by turns.

There is no large consumer of water for commercial use. No restaurant with an important kitchen facility exists in the city. The only profession using a quantity of water is laundries, and although there are about a hundred small laundries, they make efficient use of a limited quantity of water, so the amount of water purchased from water sellers is sufficient.

As for irrigation gardening, the most common method in this region is relatively large-scale gardening, using the flooded area of Wadi during the rainy season and planting cereals while the land is dry, or a more active method of irrigating the land to diffuse water and nutrients into the soil for a certain period and then releasing the water for planting. There is also small-scale gardening to cultivate vegetables by pumping the subterranean water on the clay soil of Wadi . In both cases, it can be considered that water consumption depends largely on the annual rainfall, and that water is used up to the limit of the quantity available.

### 4.2.2 Water consumption per source and per purpose

An outline water consumption per source and per purpose is given based on the result of an actual water use study of the socioeconomic study and collected materials and interviews on the water supply project.

The population of Kiffa city fluctuates largely between seasons. In the summer (June through September) when the rainy season begins, numbers of people and animals drop because the settling nomads move to the south. However, individual consumption of water by residents increases in this season due to high temperature. From October through December when water is relatively abundant and the weather is moderate, people and animals return to the city, making the living population its largest. Water consumption per source and per purpose other than irrigated gardening in the winter in Kiffa city is estimated as follows.

Water consumption per purpose

| | |
|---|---|
| Daily life | 900 $m^3$ (including water for family garden) |
| Stockbreeding | 100 $m^3$ |
| Public water | 30 $m^3$ (entirely supplied by the municipal water truck) |
| Commercial and industrial use | 20 $m^3$ |
| Total | 1,050 $m^3$ |

Water consumption per source (To be accurate, the only source is the shallow wells in the city. This is a classification by means of procurement.)

| | |
|---|---|
| Municipal water truck | 150 $m^3$ |
| Water sellers with donkey carts | 500 $m^3$ |
| Drawing for oneself | 400 $m^3$ |
| Total | 1,050 $m^3$ |

This water consumption is an extremely small amount for a city with a population of 60,000, as it corresponds to less than 17 liters per person per day. The reason for such low consumption is undoubtedly the limited means of procurement due to insufficient water sources. Therefore, the consumption is expected to increase if appropriate water supply facilities become available.

### 4.2.3 Existing wells, water supply trucks and water sellers with donkey-carts

(1) Existing wells

Almost all existing wells in Kiffa city were identified in the course of the first field study, as the result of which the Well Register was compiled (attached document). From the viewpoint of the water supply project, the obtained data can be summarized as follows.

Age: 174 wells over 20 years old, 549 wells 10 to 20 years old, 512 wells less than 10 years old

Average number of wells drilled in a year: 50

Structure: Nearly 100% are shallow wells dug manually. The majorities are open-air type; there are an extremely few closed-type wells with pumping facility (underwater pump, manual pump or windmill).

Ownership: Mostly are owned by individuals, but 891 (84%) of such wells are for common use.

Quality of water (according to EC1500 standard):
869 wells (82%) are good, 192 wells (18%) are poor.

(2) Municipal water supply trucks

1) Operating system (person in charge at the city office: Mr. Brahim Mane)

Formerly, the city entrusted the operation to a private supplier by renting the trucks. However, it came under the city's direct management in November 1997 for an unknown reason. Therefore, no record of past operation is available, only from November 6, 1997.

2) Trucks in possession

| | | |
|---|---|---|
| a. Mercedes Benz | 12 $m^3$ | built in 1993 |
| b. Mitsubishi | 14 $m^3$ | built in 1996 |
| c. Belrace (Italian company) | 10 $m^3$ (out of service) | |

3) Price of water

12 $m^3$: 3,000UM

14 $m^3$: 3,500UM

Water is supplied to public facilities free of charge.

4) Services

Each truck makes 5 - 6 journeys daily, except on Friday.

2,560 $m^3$ of water supplied in 21 days between November 6 - 30, 1997 (average of 110 $m^3$/day).

5) Personnel

2 drivers

2 assistants

1 maintenance operator for the engine pump of the well

6) Hygiene

No particular sterilization treatment is given. No budget is allotted for this purpose.

(3) Water sellers with donkey-carts

1) Interview at the city office (person in charge of tax matters, member of City Council: Ahmed Ould Abeid)

Anyone can work in the business with no registration required, but a seller has the obligation to pay a tax of 2,000UM a month. Tax is collected once a month directly from the sellers on the streets, so it is unknown if all sellers have paid without fail. Tax was collected from 120 sellers in November, but the estimated number of sellers is approximately 500.

2) Interview at the study on existing wells conducted by the study team

About 30 wells in the city supply the water sellers. Three among them (Wadi , Gomez, and the Water utilization office) have an abundant discharge and a large diameter allowing 10 - 15 people to draw water at the same time. However, other wells are smaller in size, supplying only 5 - 10 people at a time. It is estimated that about 300 sellers work full time. A record of observation at the well belonging to the Kiffa branch of the Water utilization office showed that there were a total of 130 trips a day.

3) Interview with water sellers with donkey-carts (nine sellers, December 17)

- Initial cost of the business
  : donkey 5,000UM, cart and water tank 15,000UM
- Number of water sellers on the day of interview
  : 10 at Gomez, 8 at Wadi, 8 at the Water utilization office
- Experience : 8 months - 15 years
- Age : 20 - 59 years old (majority of Malians?)
- Number of trips to the well
  : 5 - 10 (average of 7 trips)
- Sales price : 150UM/200L
- Ownership/non-ownership of equipment
  : 7/2 persons
- Working hours : from dawn to dusk, even on Friday
- Sales method : Sellers do not collect water after receiving orders. They collect water first and peddle in the city. Water is not necessarily sold per 200 liters; poor people can buy a minimum quantity of 10 liters in a bucket for 5UM.

### 4.2.4 Outskirts of Kiffa

Kiffa city is stipulated to cover the zone extending 20 km from the office of the Assaba state governor at the center of the city. There are many small villages outside the central part of the city (8 km from east to west and 4 km from north to south) within the stipulated area of the commune. For administrative convenience, they are grouped into six villages as shown in Table 4.2-2 (List of villages in the outskirts) and in Fig. 4.2-2 (Locations of villages in the outskirts).

Table 4.2-2 List of villages in the outskirts

| Village | Distance from Kiffa | Population*1 | Water supply facilities | School | Electrification |
|---|---|---|---|---|---|
| Hassi Bekaye | 7km to the east | 2,000 | Solar/conduits | Yes | No |
| Wad Rodha | 10km to the west | 430 | Wells | Yes | No |
| Oum Echgag | 10km to the east | 472 | Wells | No | No |
| Kandra | 18km to the west | 1,200 | Solar/conduits | Yes | No |
| Kreikett | 14km to the south | 483 | Wells | Yes | No |
| Meisah | 11km to the north | 397 | Wells/dams*2 | Yes | No |

*1. Population obtained from interview with the villagers. Figures available at the city office are outdated.

*2. Dike dams for purely agricultural use built for expansion of flooded area and recharge of soil. Water is released in September for seeding.

Of these villages, four located along the national route running from east to west constitute a form in which houses are relatively concentrated, serving as a base for nomadic activities or for farming. The other two villages have poor access, as they are away from the national route north or southward at the distance shown in the above table. The inhabitants live on extensive cereal farming over the flood area of Wadi . Therefore, houses are dispersed in the village, not forming any distinctive colonies.

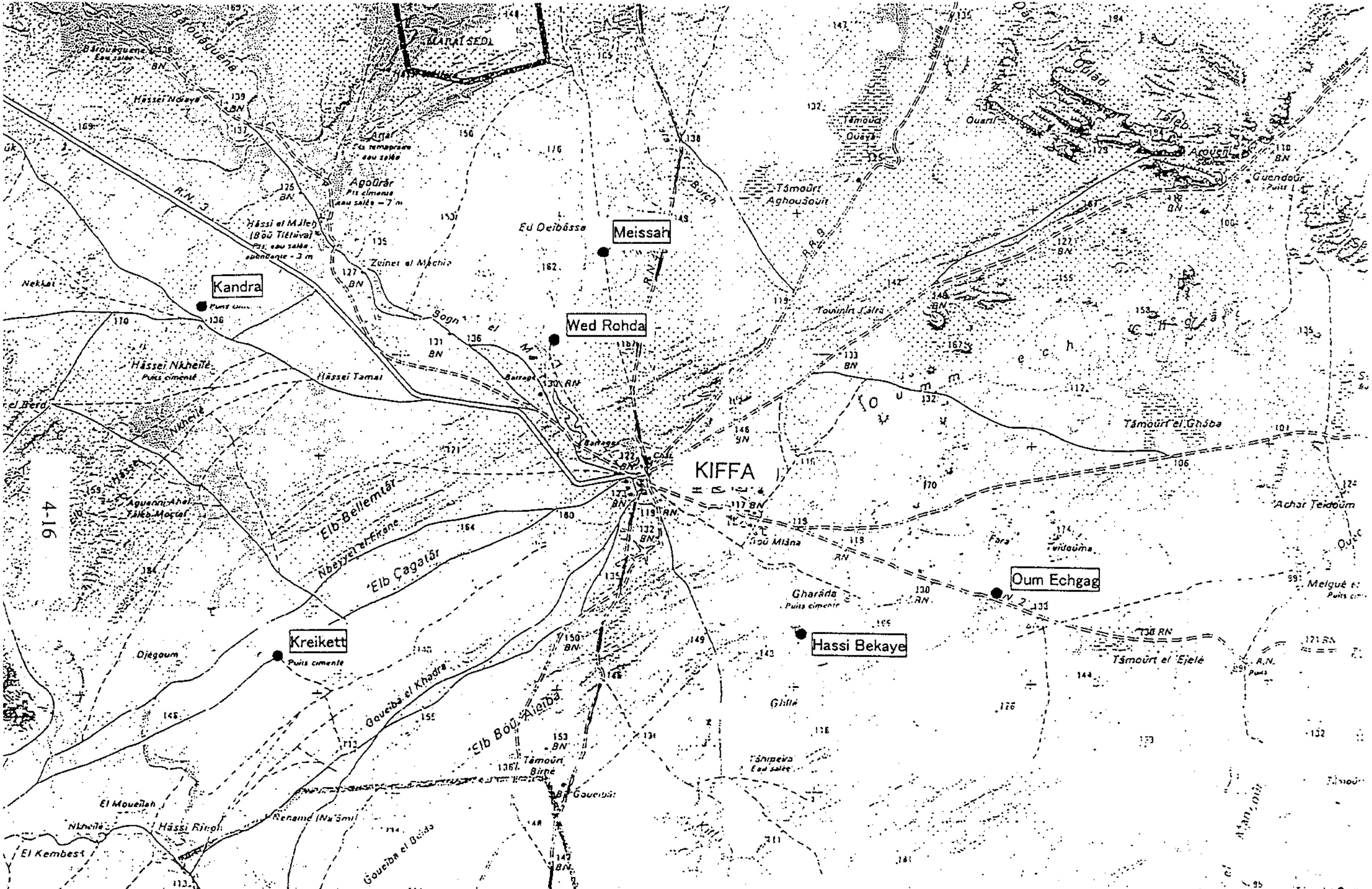



Fig. 4.2-2 Locations of villages in the outskirts of Kiffa

## 4.3 Water resource study and water supply project in rural areas by the Water utilization office

### 4.3.1 Details of the project

(1) Organization

In Mauritania, development of water resource and water supply is under the jurisdiction of the Ministry of Water and Energy, the organization of which is shown in Fig. 4.3-1. The local Water utilization office is directly in charge of the project.

The local Water utilization office has nine branches nationwide for construction, operation and management. The Water utilization office, our counterpart organization for this study, has the following functions: water resource policy planning, water resource examination/water supply plan for urban and rural areas, construction of wells, supervision of SONELEC (hydroelectricity corporation), etc. Fig. 4.3-2 is the organization chart of the Water utilization office of the Ministry of Water and Energy.

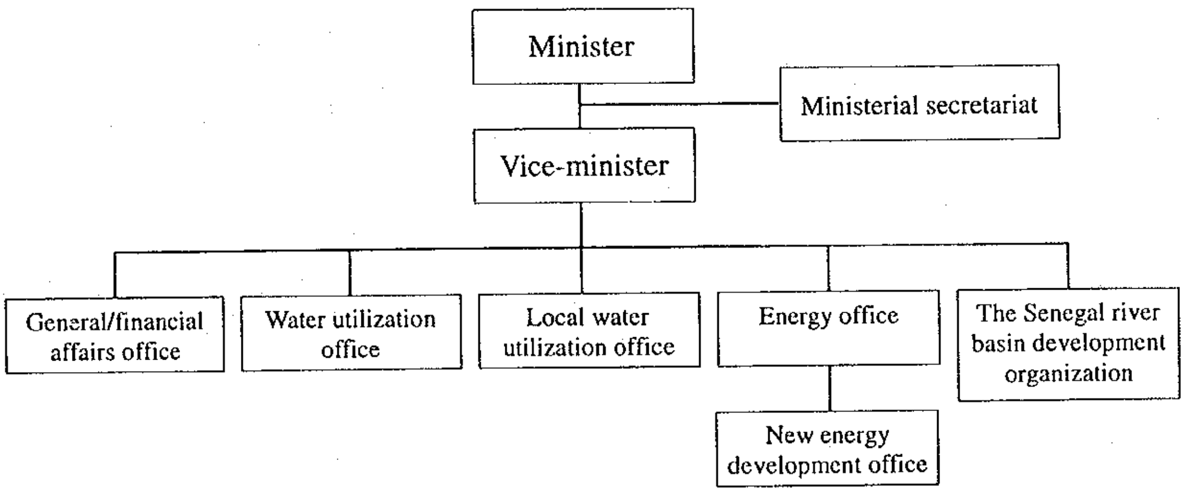



Fig. 4.3-1 Organization of the Ministry of Water and Energy

(2) Content of the project

Following the water-related policy of the above mentioned economic and financial rehabilitation plan (PREF 1985) and the general economic development plan (PCR 1989), the Water utilization office has been constructing water supply facilities for urban and rural areas, and conducting water resource examination including physical exploration. The Senegal River, the only river in Mauritania to have a permanent flow, is an international river running through three nations. Therefore, another office of the ministry joins the development organization. The Water utilization office is mainly involved in subterranean water development of water for daily use and for stockbreeding. The use of surface water in the rainy season in Wadi is only for agricultural use at the moment, and the Ministry of Rural Development is in charge of this work.

The Water utilization office settled on the nationwide construction plan for wells to supply rural areas in 1984, based on which development work is under way. Numerical details of the development plan are given in Table 4.3-1. The table shows that 7,053 wells eventually need to be completed throughout the nation, but the achievement rate as of the end of 1996 was 47.8%, with 3,370 wells completed. Considering the fact that 752 wells were built in the six years from 1990, the goal to build 3,683 wells by the year 2000 to achieve 50% of water supply by building 313 wells in the next three years seems fairly possible.

Table 4.3-1 Construction plan for wells to supply water in rural areas (1996)

| Region | Number of wells required in villages | | | Number of wells required for nomads | Number of wells required in large villages | Total number of wells required | Number of wells completed | Achieve ment rate (%) | Number of wells to be completed in 2000 |
|---|---|---|---|---|---|---|---|---|---|
| | Small villages | Medium villages | Nomads | | | | | | |
| TRARZA | 179 | 361 | 300 | 302 | 3 | 1,145 | 434 | 38 | 711 |
| INCHIRI | 5 | 7 | 22 | 19 | --- | 53 | 37 | 70 | 16 |
| BRAKNA | 140 | 360 | 140 | 207 | 5 | 852 | 239 | 28 | 613 |
| TAGANT | 34 | 110 | 120 | 266 | 3 | 533 | 157 | 29 | 376 |
| GORGOL | 229 | 436 | 46 | 176 | 12 | 899 | 145 | 16 | 754 |
| GUIDIMAKA | 153 | 259 | 25 | 176 | 8 | 621 | 332 | 53 | 289 |
| ASSABA | 236 | 284 | 120 | 176 | 5 | 821 | 450 | 55 | 371 |
| HODH GHARBI | 202 | 180 | 180 | 302 | 3 | 867 | 257 | 30 | 610 |
| HODH CHARKHI | 204 | 210 | 245 | 302 | 5 | 966 | 375 | 39 | 591 |
| ADRAR | 58 | 78 | 50 | 38 | 3 | 227 | 105 | 46 | 122 |
| TIRIS | 3 | 9 | 2 | 18 | 3 | 35 | 55 | (157) | 0 |
| NOUAHIBOU | 10 | 6 | --- | 18 | --- | 34 | 32 | 94 | 2 |
| Total | 1,453 | 2,300 | 1,250 | 2,000 | 50 | 7,053 | 2,618 | 37 | 4,415 |

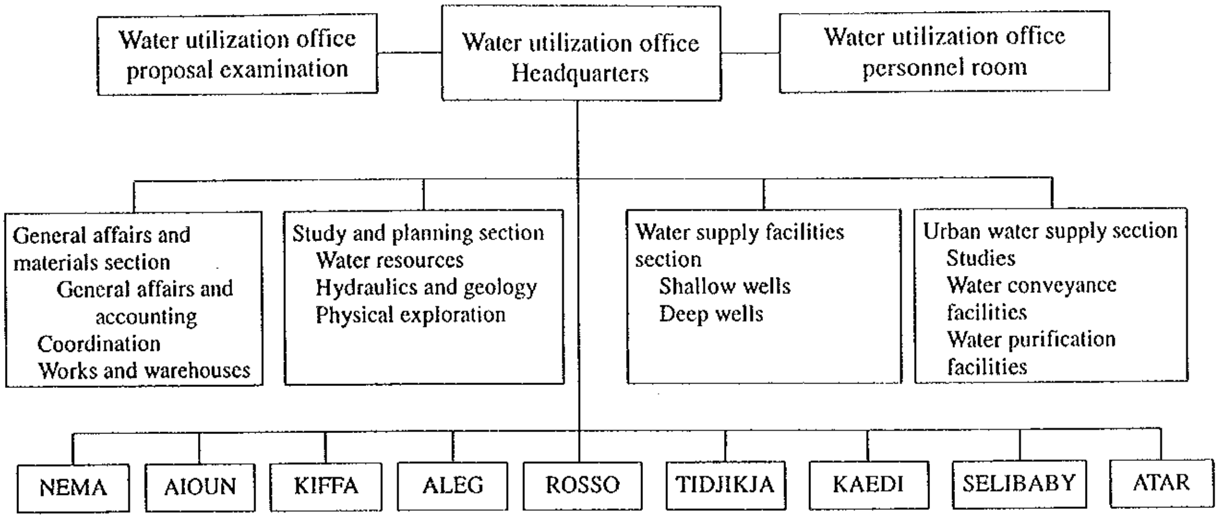



Fig. 4.3-2 Organization of the Water utilization office, Ministry of Water and Energy

Construction of wells within the framework of the construction plan for wells to supply water in rural areas began in the northern region in which damages by drought are great. However, following the rapid trend for nomads to settle in the urban areas around the axis connecting Nouakchott and Kiffa and Nema, development has been focused on the southern region.

A development program in the southern region has been executed under international assistance by Japan and Germany. Japan subsidizes the development of the states of Trarza and Brakna in the south-central region, and Germany the states of Assaba, Hodh Gharbi and Hodh Ech Chargui to the east of the above states. As a countermeasure for guinea warming, execution of a new development plan centered on the northern part of the Senegal River by Japan's voluntary fund cooperation assistance has been decided.

(3) Budget of the Water utilization office

The 1997 annual budget of the Ministry of Water and Energy (the fiscal year is January through December) was slightly less than 130 million yen (See Table 4.3-2 for budget evolution). As shown in Table 4.3-3, the budget consists entirely of the running cost of related offices and does not include the execution cost of projects. The budget allotted to the Water utilization office is 84 million yen, a far greater amount than the head office for energy, another major jurisdiction. However, this difference may be due to the fact that the head office for energy mainly operates in urban areas while the Water utilization office has branches throughout the nation, and the head office for energy is only directly involved in planning and execution of basic policies, leaving other issues to the three affiliated public corporations (gas, petrol refinery, and petrol sales).

As the breakdown of the budget for the Water utilization office in Table 4.3-4 shows personnel expenses take up 15%, administrative gales 60% and the rest goes to maintenance of vehicles and equipment. The content of administrative gales that occupy a large part of the expenditure is the cost of research, classified as various honoraria.

The project budget of each ministry is administered collectively by the prime minister's office as a "Support fund" in the governmental budget of Mauritania, and the content of a project is not yet decided at the beginning of the fiscal year. The Water utilization office has project plans ready before the fiscal year, and applies for approval of each plan in consideration of the situation of foreign assistance while the budget is being executed. The actual project budgets executed in 1996 and 1997 were 36 million UM and 23 million UM, respectively.

Table 4.3-2 Evolution of the budget of the Ministry of Water and Energy (1993 - 1997)

Unit: 1000UM

| Year | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|
| Budget for the Ministry of Water and Energy | 118,207 | 133,231 | 130,961 | 144,661 | 156,418 |

Conversion rate to Yen in the text: 1USD=160UM=130 yen, 1UM=0.81 yen

Table 4.3-3 Breakdown of the budget of the Ministry of Water and Energy (1997)

| | | |
|---|---|---|
| Chap-1 | CABINET SECRETARIAT FOR WATER UTILIZATION | 14,813,000 |
| Chap-2 | WATER UTILIZATION OFFICE | 103,626,000 |
| Chap-3 | LOCAL WATER UTILIZATION OFFICE | 26,802,000 |
| Chap-4 | HEADQUARTERS FOR ENERGY | 3,504,000 |
| Chap-5 | NEW ENERGY SERVICE | 530,000 |
| Chap-6 | DEVELOPMENT OF THE SENEGAL RIVER BASIN | 6,378,000 |
| Chap-7 | GENERAL AND FINANCIAL AFFAIRS OFFICE | 765,000 |
| | TOTAL | 156,418,000 |

Table 4.3-4 Breakdown of the budget of the Water utilization office (1997)

| | | |
|---|---|---|
| Chap-2 | WATER UTILIZATION OFFICE | 103,626,000 |
| Art. 7 | Salary and allowances | 4,533,000 |
| Art. 8 | Allotment, pensions and social security | 9,757,000 |
| Art. 9 | Office materials and expendable supplies | 10,084,000 |
| Art.10 | Expenses for business trips and administrative work | 60,361,000 |
| Art.11 | Public service maintenance cost | 18,891,000 |

### 4.3.2 Example of entrustment of a project for Guerrou village in the suburbs of Kiffa to private corporation

After development of subterranean water and construction of water supply facilities in rural areas, the Water utilization office, following the government's privatization policy, is pushing forward with entrustment of maintenance and management of wells and water supply facilities to private corporations.

In actual operation, after the completion of facilities, the Water utilization office calls for candidates as managing agent, and concludes a maintenance/management contract. The concessionaire sells water at a rate stipulated in the contract, and pays to the national treasury or local government the cost of management/maintenance, depreciation cost and local taxes according to the quantity sold. The difference between the sales revenues and the payments shall be the concessionaire's profit in this system. The cost of management/maintenance and depreciation cost shall be deposited in a specific bank account and used only for rehabilitation and renewal of the facilities.

The provisions of the contract are standardized throughout the whole nation, and details of operation, maintenance and management are provided in the "Specifications for general operations of entrusted projects" that is attached to the contract.

The project for Guerrou village, located 50 km west of Kiffa city, was entrusted to a private corporation, and just went through the regular annual audit by the Water utilization office. This case shall be studied as an example of execution of a project entrusted to a private corporation.

| | |
|---|---|
| Guerrou village | |
| Location: | 50 km from Kiffa toward Nouakchott, along the national route. |
| Construction: | Constructed with funding by the African Development Bank, completed and put into operation on October 30, 1995. |
| Outline of the village: | 500 households, population of 3,000 people, elementary school |
| Facilities: | Wells, elevated water tank (6 m above ground, capacity of 15 $m^3$), four public water taps (BF), diesel power generation facility, and storage pump |
| Management: | Enterprise by concessionaires under management contract with the Water utilization office. The concessionaire, Mr. Med El Moustapha O. Med Lemine is a shopkeeper in Kiffa. |

Conditions of the contract:

| | | |
|---|---|---|
| | Sales price of water via public water taps | 90UM/m$^3$ |
| | Sales price of water via individual water supply | 68UM/m$^3$ |
| | Tax due to the city | 5UM/m$^3$ |
| | Reserve fund for maintenance/management | 16UM/m$^3$ |
| | Reserve fund for renewal | 11.20UM/m$^3$ |
| | Security money: | 50,000UM |

Service: Public water taps are usually locked, and one of the four managers, agents of the concessionaire living near the tap unlocks it and sells the water as required. According to the report submitted to the Water utilization office in May 1997, the quantity of water sold in April and May was 3,407 m$^3$ and 3,952 m$^3$, respectively. These figures include the water used for vegetable gardens.

Water consumption in a year drops in June because it is the hottest season and the nomads take their livestock down to the Senegal River in the south. Water consumption rises sharply in October when the Nomads come back.

### 4.3.3 Operation of solar-powered wells

For villages forming groups of a certain size (around 500), the Water utilization office adopted a system such that water is supplied by several public water taps linked by water pipes. In this case, pumping of water up to the elevated water tank by a solar power generation is under way, and construction up to the seventh plan has been achieved, financed by funding of the European Development Fund (FED). There are three examples of a project executed within Kiffa city, and they are now in service as stated below. The advantages of solar power generation have led to a high working rate: It is sufficient to run the system only during the day, and to use the water pumped to the elevated water tank after the sunset. Hardly any maintenance/management procedure is necessary, and therefore no technical expertise is required for operation. Thanks to this system, the difficulty of fuel procurement due to a poor access route can be overcome. However, this strong facility also explicitly presents negative features including insufficient support system that needs to be attended to in the future: if there is a problem, it cannot be easily repaired.

(1) Hasibekay village

Location: 7 km from Kiffa toward Ayuon, 1 km further from the national route.

Construction: After construction of wells with funding from the African Development

Bank, an elevated water tank, solar power generation, pumps and plumbing (integrating flowmeter) were built with aid from the European Development Fund (FED) and Solar Project Regional Program (phase 6 and 7). The facilities were completed and put into operation on March 3, 1997.

Outline of the village:approx. 500 households, population of approx. 3,000, elementary school; 1,002 people over 18 years of age voted in the presidential election of December 9.

Facilities: Well, elevated water tank (6 m above the ground, capacity of 15 $m^3$), four public water taps (BF), solar power generation (28 sunlight collection panels, made by the German company Siemens)

Specification of a single panel

| | |
|---|---|
| Wp | 50 |
| V | 21.5 |
| A | 3.1 |
| Max. V | 600 |

Management: Enterprise by concessionaires under management contract with the Water utilization office. The stipulated sales price is 20UM/200L. The manager was appointed for having met the following conditions: native of the village, with high level of education (graduated from Faculty of Literature, University of Mauritania), and unemployed at the time of appointing.

(2) Kandera village

Location: 18 km from Kiffa along the national route leading to Nouakchott.

Construction: After construction of wells with funding from the African Development Bank, an elevated water tank, solar power generation system, pumps and plumbing (integrated flowmeter) were built with aid from the European Development Fund (FED) and Solar Project Regional Program (Phase 6 and 7). The facilities were completed and put into operation in February 1996.

Outline of the village: approx. 200 households, population of approx. 1,200. The village presents an impression of being fairly wealthy. However, two antagonistic tribes live in this village, and one of the tribes does not have access to these water supply facilities.

Facilities: Well (depth of water: 12 m, a number of residents do not use it because of high saline concentration in the water), water tank on the ground (height: 3.1 m above the ground, capacity: 30 $m^3$), four public water taps (BF), solar power generation (28 sunlight collection panels, made by the German company Siemens). Two of the panels are damaged but not repaired. There does not seem to be a problem for necessary power generation capacity. This year, a water conduit was installed to ten houses.

Management: Enterprise by concessionaire under management contract with the Water utilization office. Stipulated sales price of water: 20UM/200L (via public water taps), 85UM/$m^3$ (individual water supply).

Concessionaire: Ahmed Ould Mohamed Mahmoud

(3) Agohratt village

Location: Approx. 50 km from Kiffa toward Ayoun, along the national route. Not covered by the administrative zone of Kiffa city.

Number of households: 600

Population: 4,000

Facilities: Wells were constructed with funding from the African Development Bank, and a Panel-type elevated water tank, solar power generator, pumps and plumbing (integrated flowmeter) were built with aid from the European Development Fund (FED). Due to failure of the solar power generator, the facilities are run by an engine pump. Three public water taps were installed, partially with pipings for individual water supply.