Chapter 5

Water pumping / Desalination system powered by PV system

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The desalination system would be installed in Rasem Al Shikh at the initial stage. However, a lot of fresh water was provided by diesel generation pump from the new-well. Then, SSRC/HIAST and the study team selected suitable well or new welling site among existing wells considering following points.

①As water demand of the village is 20m³/day, the supplying ability of the well should be more than 4m³/hr. (This must be confirmed by test pumping)

②It is necessary to avoid the well having ineffective contaminants for desalination system through water analysis.

③ This system is demonstrative plant. It is necessary to execute periodical maintenance for desalination system, inverter and battery. Therefore, accessibility and easy execution of maintenance is taken into account to select the objective village.

④Electrification by grid extension is not expected within 10 to 15 years.

Outline of each facilities are shown below.

Water pumping system in Zarzita

Type of system	No. of system	Outline of main
Water pumping system (Mar 1998～)	1	PV array 6kW Submergible Pump 2 x 0.55kW Transfer Pump 1 x 0.55kW Water reservoir tank x 2 Water transfer line etc

Water pumping/desalination system in Kalif

Type of system	No. of system	Outline of main
Water pumping system (Aug 1998～)	1	PV array 1.9kW Inverter 1.5kW Submergible pump etc
Desalination system (Aug 1998～)	1	PV array 8.6kW Controller for Desalination system Inverter 10kW Battery 24kWh(20 x 12V-100Ah) Desalination unit Raw water tank Desalinated water tank Pre-fabricated house etc

5.1 PV water pumping system in Zarzita

Zarzita locates 35km to the north west of Aleppo City and its population 421, number of households 42. The site is on the top of small mountain about 600m above sea level.

Electrification policy of the government of Syria is large and important villages first, so this village is now out of national electrification plan. The water supply of this area is under control of the Aleppo Water Authority. The Authority once studied several wells for the water supply to this village, but all of them did not satisfy the facilitation standard of 15m³/hr, so the village is left without water supply from the Authority until now. It is very difficult to supply water for such a small and rural village because the cost for the facilitation becomes higher and the maintenance is not so easy. Same situation is often seen across the Syria so some new way of water supply is needed for such areas.

This project focused on utilizing PV water pumping system for supplying water for such villages. Zarzita was selected for installing pilot plant, and though the installation and operation, necessary information was transferred to Syria.

5.1.1 Water situation of the site and determination of system scale

(1) Water situation of Zarzita

In Zarzita, people have their own water tank under their houses and save rain water or purchased water in it. Purchased water is obtained from private water sellers come from other villages carrying water with lorries. In rainy season they can live with rain water but in dry season, this saved rain water runs short and they must buy water from them. Price of purchased water is very high, and the transportation of the water is very costly(refer Table 5.1-1). So people hope to have their water source in the village but for now they cannot get good water source.

Table 5.1-1 Water price

Source	Price
Private water seller	250SP for $4m^3$ (water 50SP, transportation 200SP)

(Aleppo Water Authority: $2SP/m^3$)

(2) Determination of system scale

Usually, a demand of water in the arid area is about 10 liter for one person per day. From our study, the demand has the range of 10-30 liter, and the priority of its use is ① drinking/cooking, ② washing body, ③ washing cloths, ④ cattle/plants. A family which has large water demand uses water for their livestock. That use is somewhat different from the use of human living but since there is no other available water around there and Zarzita, being near Dartazze, is likely to be affected by advanced life, only 10 liter/person x day is not enough to keep their life level. Therefore the water demand for this system is determined to be 20 liter/person x day.

In winter, rainy season, people can use rain water, so design of the system is based on the insolation of summer season. Considering village population of ~ 400, pumping system must pump up about $8m^3$/day in summer season.

Table 5.1-2 Water demand specification for the system

Per capita minimum water per day	20liter/day
Supply of water in the village	~8 m^3/day

Usually, this amount of water can be pumped with small power source, but since there is no electrification plan people used to live inconvenient life. Same situation can be seen across whole country. To electrify small and sparsely distributed villages is difficult from the point of economy and maintenance so they are put aside from electrification plan. On the other hand, PV system is feasible for small rural application in spite of high cost of modules because grid extension cost much higher for such application. Zarzita is a typical case of such application so PV water pumping can be considered to be economically and operationally feasible way.

5.1.2 System design and installation

(1) Design of PV water pumping system

①Design base

1) Submersible pump is considered and it is driven only in day time, therefore, system needs no battery.

2) Water is distributed by gravity using high tank locating in the village.

3) High tank has the quantity of 5 days water supply.

4) One spare pump should be provided.

5) Insolation data should be obtained at Aleppo measuring system.

Table 5.1-3 Insolation in Aleppo (kWh/m^2)

Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
3.4	4.3	5.0	5.4	6.1	6.3	6.5	6.6	6.5	5.8	4.9	3.4	5.35

6) Water demand for one person one day is 20 liter

7) Population of the village is 421.

②Well selection

Several wells are studied and the selection is done along its water quantity and water quality. Results are listed in Table 5.1-4.

Table 5.1-4 Results of well study

Well	Site	Initial level	Dynamic level	Quantity	Quality
Initial plan	4km north	Give up for the study because of the distance			
Z-1	800m north	156m	160m	1m^3/hr	○
Z-2	Village	160m	180m	0.2m^3/hr	

When the demanded quantity of water 8m^3/day is driven by PV water pumping, considering the 5.5 hours/day operation which is got from the insolation of annual average 5.5kWh/m^2/day, the estimated flow rate is about 1~2m^3/hr. So from the above Table, Z-1 can be used for the system. But possible total head of current available PV pump is 190m at most, so possible candidate well determined to be Z-1.

Therefore the water quality of Z-1 is tested and is indicated that it satisfies the drinking water quality standard of Syria.

The results of usable water quantity test and quality test are shown in the Fig.5.2-1 and Table 5.2-5 respectively. The parameter of Z-1 well is listed in the Table 5.2-6.

Time	Level	
	Flow $1m^3/hr$	Flow $2m^3/hr$
0.0	-141.0	-141.5
0.5	-145.0	-149.7
1.0	-147.0	-155.0
1.5	-148.5	-160.0
2.0	-150.0	-164.0
2.5	-151.0	-167.7
3.0	-152.0	-171.5
3.5	-153.0	-174.0
4.0	-153.8	-177.0
4.5	-154.1	-170.1
5.0	-154.5	-163.5
5.5	-154.8	-157.5
6.0	-155.2	-151.5
6.5	-155.3	-145.6
7.0	-149.5	-141.5
7.5	-143.0	
8.0	-141.5	

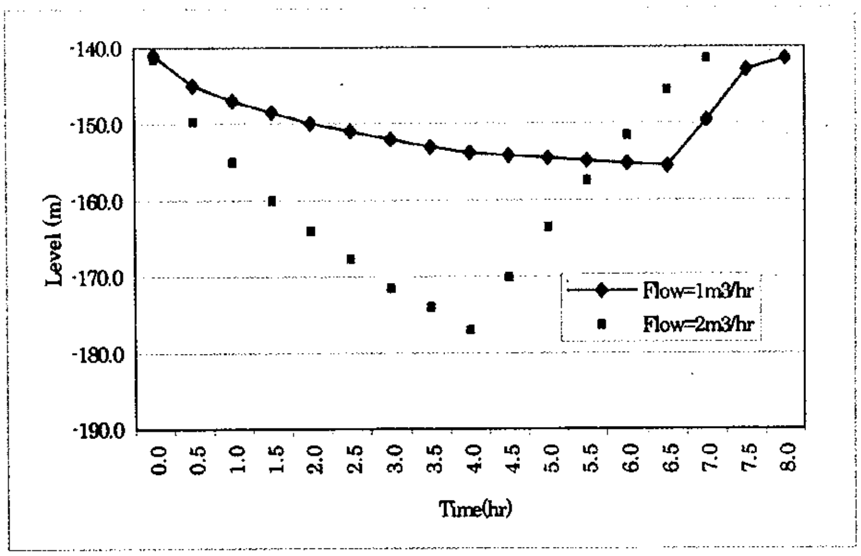


Fig.5.1-1 Results of water quantity test

Table 5.1-5 Results of water quality test

Test Items	Unit	Standards	Sample on Nov.7 1996	Sample on July 15 1996
Electric conductivity	Micro moh/cm	1500	492	476
pH		6.5-8.5	7.5	7.45
Total Alkalinity	HCO3 mg/ℓ		230	240
Hardness Ca	CaCO3 mg/ℓ		230	305
Hardness Mg	CaCO3 mg/ℓ		20	75
Total Hardness	CaCO3 mg/ℓ	500	250	380
Nitrate	NO3- mg/ℓ	(N) 15-40	28.73	4.5017
Ammonia	NH4+ mg/ℓ	0.05	0	-
Sulfate	SO4= mg/ℓ	250	2.5	8.6467
Chloride	CL- mg/ℓ	250	14	9.71
Phosphate	PO4 mg/ℓ	0.5	0.25	
Carbon dioxixide	CO2 mg/ℓ	500	8.8	
Carbonate	CO3 mg/ℓ		0	
Hydro-carbonate	HCO3 mg/ℓ		280.6	
M.O(Organics)			0.7	
Calcium	Ca++ mg/ℓ		92	
Magnesium	Mg++ mg/ℓ		4.86	
Sodium	Na+ mg/ℓ	200		3.7734
Potassium	K+ mg/ℓ			0.6471
Iron	Fe mg/ℓ	0.3	0.05	-
COD	O2 mg/ℓ	2-3		2.8
Total precipitated salts due to evaporation	mg/ℓ		246	
Turbidity	ppm	0.3	2	
Hydrogen sulfate	H2S mg/ℓ	-	-	

Table5.1-6 Parameter of Z-1 well

Diameter	12inch
Well depth	487m
Initial level	137～142m
Ground type	0～161m (calcium clay)
	161～260m (calcium sandy aquifer)
	260～487m (marl layer)

③Design of water pumping system

1) Pumping up quantity is 8.4m^3/day. Insolation is 5kWh/m^2/day(take less value than summer, for securing some margin)

2) Dynamic level of the well is -165m, piping loss is 5% of pumping head, so total head is 173m.

3) 2 pumps are used to secure flow rate, then the pumping-up quantity for each pump is 4.2m^3.

4) Flow rate and pumping capacity is

Flow rate 4.2m^3 ÷ 5 kWh/ m^2day ÷ 60min/hr = 0.014 m^3/min

Pump capacity 0.163 x 0.014m^3/min x 173m = 0.395kW

5) Pump efficiency is assumed to be 0.33 because of deep well and motor efficiency is 0.90.

Pump input 0.395 ÷ 0.33 = 1.197kW

Motor input 1.197 ÷ 0.90 = 1.330kW

6) Inverter efficiency and PV array efficiency is assumed 0.9 and 0.8 respectively.

Inverter input 1.330 ÷ 0.9 = 1.478kW

PV Array capacity 1.478 ÷ 0.8 = 1.847kW

7) Then 2 sets of 1.847kW array and 0.395kW pump will satisfy this demand. Usually standard pump rates 0.55kW for this requirement.

8) PV array is not determined only by the power but the voltage to meet the inverter input. For this system, it is 115V～175V. PV module used for this system is 60W and its open circuit voltage is 22V. Therefore four parallel of eight series PV modules will make one set of PV array.

9) Then the PV water pumping system becomes as below.

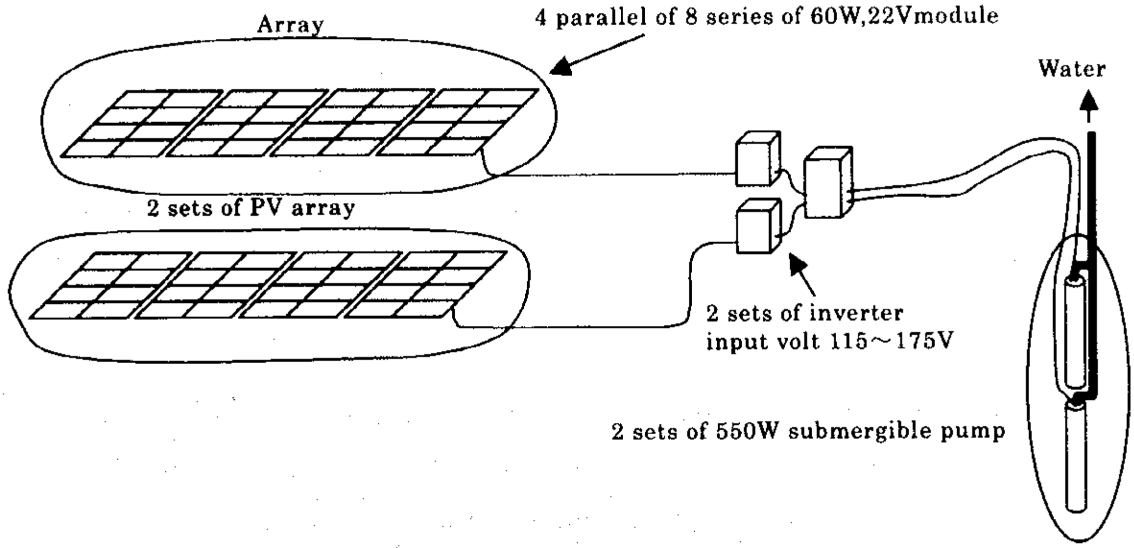


Fig.5.1-2 Configuration of PV water pumping system

(2) General configuration

①Location of the system

This village is also a village for PV electrification using centralized 35kW station in the south. Since as the well locates 800m north from the village, additional PV arrays for the water pumping system was installed around Z-1 well. Pumped up water is stored in the transit tank near the well, then it is transferred by another PV pump to the hi-tank in the village. It is sent to the water taps installed at the center of the village by gravity from the hi-tank. The location of Z-1 well and village is shown in Fig.5.1-3.

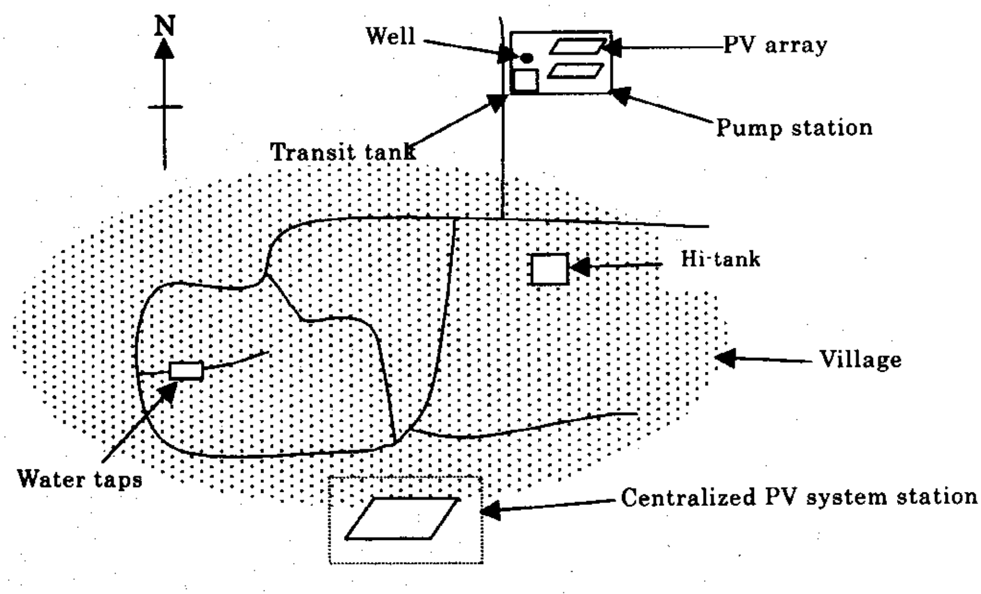


Fig.5.1-3 Location map of Z-1 well and village

a. Pumped-up water is stored in the transit tank near Z-1 well, then it is transferred to the hi-tank in the village. The water transfer pump is also powered by PV system. As a discharge head of this pump is about 20m, load is about one forth of the water lifting pump. Thus, PV array capacity of the transfer pump is also about same ratio of the water lifting pump. The configuration of PV array circuit for the transfer pump is two parallel of eight series PV module.

b. The capacity of the transferred tank is $10m^3$, which is enough to store one day pumped-up water quantity. On the other hand, the capacity of the hi-tank is $30m^3$, which can store 3 days pumped-up water for the villager's life.

c. Regarding water supply, as the villagers come to the point and get water, the one supply point is prepared in front of the mosque. However, to avoid confusion, four of water tap is installed for this point.

②System description

General view of this system is shown in the following Fig. 5.1-4. The capacity of pumps and PV arrays are designed to pump up more than $10m^3$/day in summer, and the capacity of transit tank and hi-tank are designed to be $10m^3$ and $30m^3$ respectively considering the fluctuation of load.

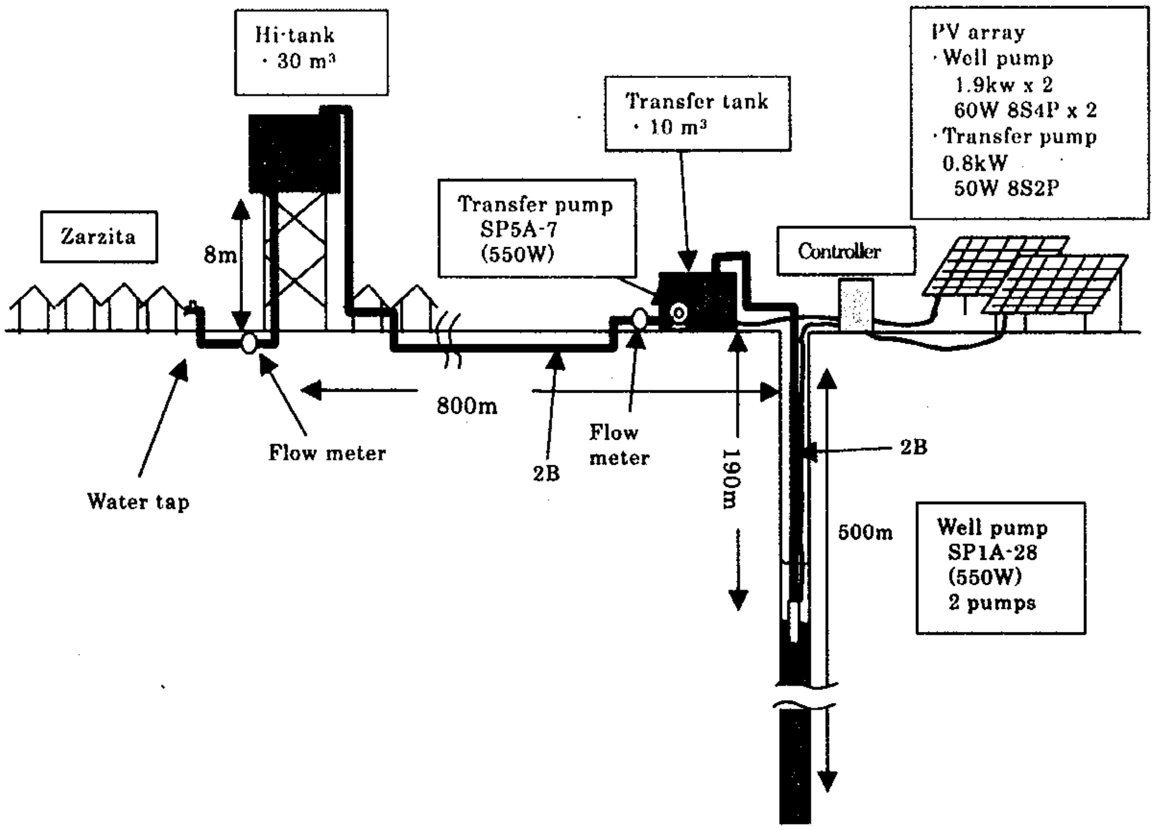


Fig.5.1-4 Overview of PV water pump system in Zarzita

(3) Features of the system

①Maximum Power Point Tracking (MPPT)

With regard to PV system, in order to utilize solar energy efficiently, MPPT technology is applied to get maximum output of PV system continuously by tracking a fluctuation of insolation. MPPT technology is also developed for the PV water pumping. This technology is that the rotation of pump is controlled continuously according to the intensity of insolation to keep maximum quantity of water pumped. To apply this technology, PV array is needed to install exclusively for the water pump. In this project, PV array is installed exclusively for the water pump and the operation of this pump system is controlled by the inverter which includes MPPT function. Moreover, as MPPT makes rotation control of the water pump, optimum control for both frequency and voltage is made using VVVF to meet the motor condition.

<VVVF : Variable Voltage and Variable Frequency>

②Security of pumped-up water quantity

There are some general products of PV pump by such as GRUNDFOS or TOTAL. But the capacity of these products is limited to pump up less than 150m depth. The dynamic level of this well is ~165m, so it was difficult to get enough water by single pump. In this case, it is available to get wider operation range by choosing option which combine plural pumps. Therefore, a controller for controlling two pumps operation to get required water quantity is provided by the manufactures.

The controller is called Flow Optimizer which is composed of Switch Box and Terminal Box, and operates according to the insolation as followings.

1) A pair of pump of maximum total head 190m/inverter/PV array is installed.
2) These systems are connected as illustrated below, and when the insolation is strong enough, the system operates under the connection of – – – .
3) When the insolation becomes weak, then connection changes to ·········, and the output of both PV arrays are put together into one pump, and secure more water quantity.

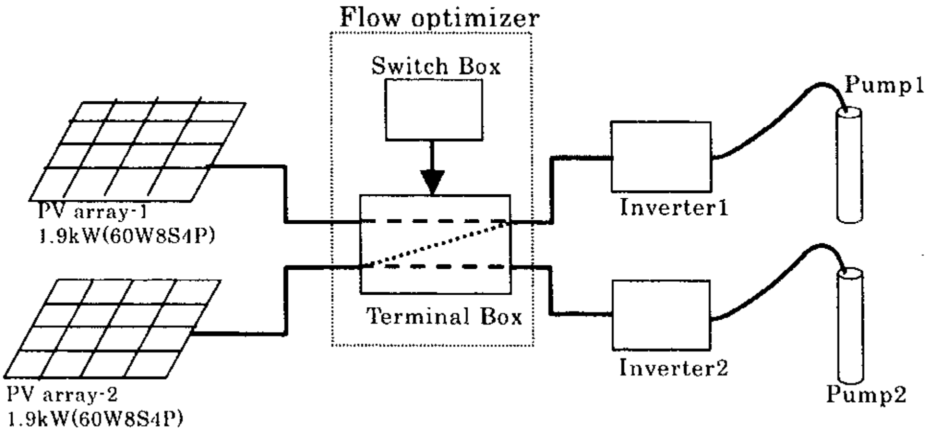


Fig.5.1-5 Connection of flow optimizer

③Automatic control

Start / stop is done automatically without manual operation except maintenance.

④Durability of pumps

In order to make long operation, whole parts of pump are made by SUS to protect corrosion.

(4) Assistance of installation

①Confirmation of delivery

Number of the delivered parts and their safeness are confirmed.

②Piping and wiring

Two inch dia. rise pipes were installed in the Z-1 well using a crane. Wiring for the pump was installed and fixed together with the rise pipe. The pump is suspended by the pipes. Casing is installed to upper 260m of the well, the lower 140m of the casing is slit type. The upper 10m of the well is fixed with cement.

③Wiring of PV system

The wiring of two sets of 8 series x 4 parallel interconnection was done and it was connected to inverters then to well pumps. The wiring of 8 series x 2 parallel interconnection was done and it was connected to an inverter then to transfer pump.

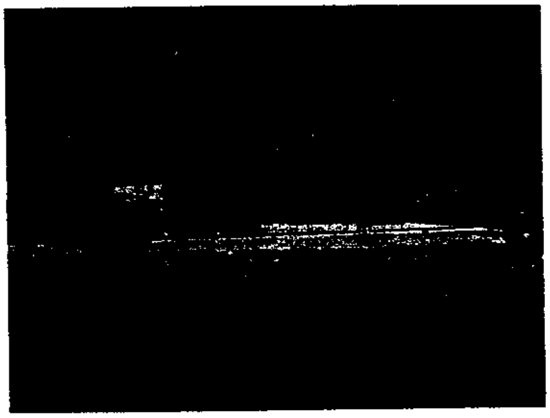


Fig.5.1-6 General view of water pumping system

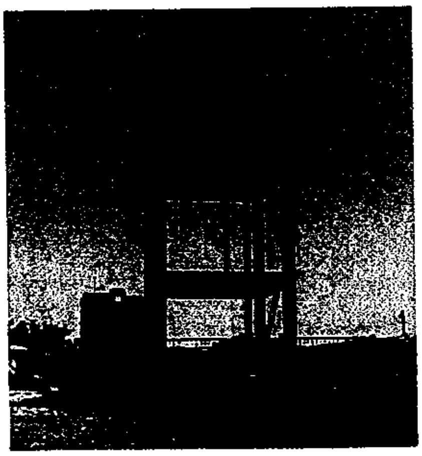


Fig.5.1-7 Water supply tank

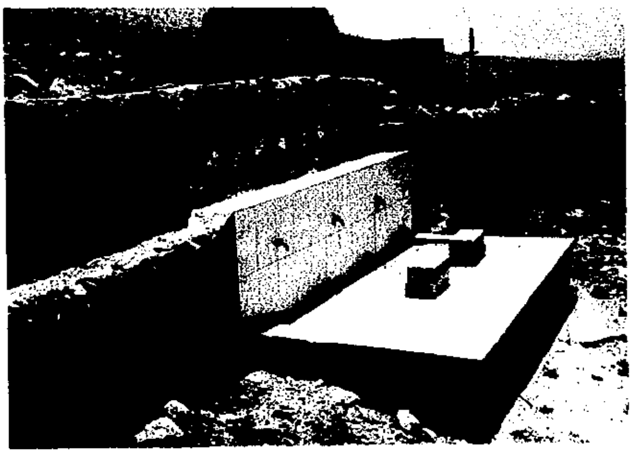


Fig.5.1-8 Water service taps

④Electrical test

Electric output of PV system was actuated. Proper operation of electric circuit and equipment was confirmed electrically and mechanically.

⑤Piping test

After cleaning the transit tank and high tank, water was flown into the pipes and design pressure is imposed whole piping system. Through this test, no leakage was observed.

⑥Trial operation

Trial operation of this pumping system was conducted and designed operation and flow rate was confirmed.

5.1.3 System operation and maintenance

(1) System operation

This system is installed on March/1998, and initially operated under control of SSRC/HIAST. Initially, there were two troubles of generation of bacteria and chattering of transfer pump operation. The bacteria generation was caused initial insufficiency of cleaning, and never happened again after disinfection. The chattering of pump operation is repaired by adding 30 minutes delay control for restarting transfer pump. After these troubles recovered, no trouble was observed, so the operation is transferred to the operator who was selected by the Water Authority and trained by SSRC/HIAST on september/1998.

(2) Maintenance

Since this system is totally operated automatically, there is no daily operation but only daily checking as listed below are needed. But since this is a pilot project, operation data recording should be done at least for a year.

- Normal maintenance(two or three times a week)
  - a. Cleaning of PV module surface
    It should be done when needed.
  - b. Recording the reading of integral flow meter
    When there is much decrease on flow, there is some possibility of Y-strainer plugging.
  - c. Recording of well water level

d. Recording of tank water level

e. Visual inspection of wiring

f. Visual inspection of piping

· Periodical maintenance

a. Water quality (once or twice a year)

The water quality is analyzed at the point before transfer tank and water tap in the village. If water quality before the transfer tank is turn to bad, fertilizers is considered to use around Z-1 well. If water quality of the water tap is bad, bacteria generation is considered in transfer tank and pipes. For bacteria generation occurring, disinfection for tank and pipe should be done.

b. Pumping test(once or twice a year)

Hourly flow should be measured on a sunny day and compared with the data before for checking any difference.

c. Deposition on tank internal surface(once or twice a year)

If there is much deposition, same situation will occur in the pump. In this case, submergible pump cleaning is needed.

(3) Operation results of water supply

Trial operation began on April 1998 under the control of SSRC/HIAST, and the operation was shifted to the operator selected by the Water Authority from September. From October, recording of flow meter and level meter is done by the selected operator every day. The operation goes fairly well without initial bacteria generation and transfer pump chattering caused by unbalance of transfer/well pump capacity. Both troubles are solved by disinfection and delay timer respectively. The selected operator can maintain the system well after the education by SSRC/HIAST. The operation management activity is under the control of the Aleppo Water Authority(Dartaze branch). The selected operator checks the system every day and records the reading of flow meter and well water level which are described below.

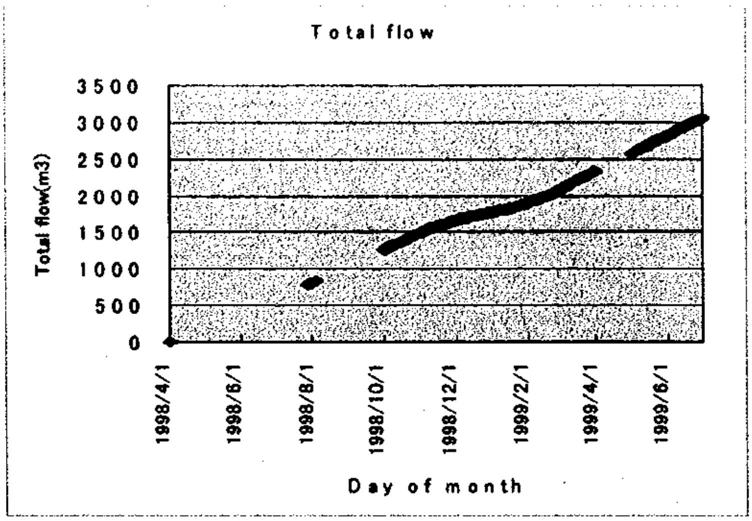


Fig.5.1-9 Transition of pumped-up water quantity

Transition of total amount of pumped-up water is shown in Fig.5.1-9. It is winter and rainy season in Syria from December to January, and number of sunny day is a few. In this season, pumped water quantity is less than other season.

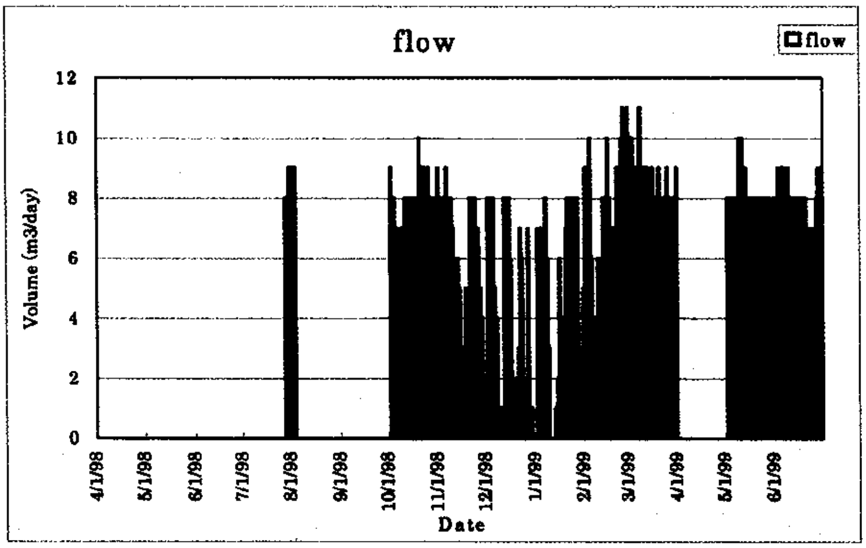


Fig.5.1-10 Transition of pumped-up water quantity per day

Fig.5.1-10 shows one day water quantity obtained by subtracting previous day's total quantity from totalizer. Data recording is done every day but recording time is not same, so this difference does not directly reflect the day's pumped up volume, but nearly same value is shown. From Fig.5.1-10, the water quantity in winter is small because of rain and short day time resulting only 4m³/day on average, and it becomes 8～10m³/day in the other seasons. In summer the water quantity becomes 10m³/day which is same with the design value.

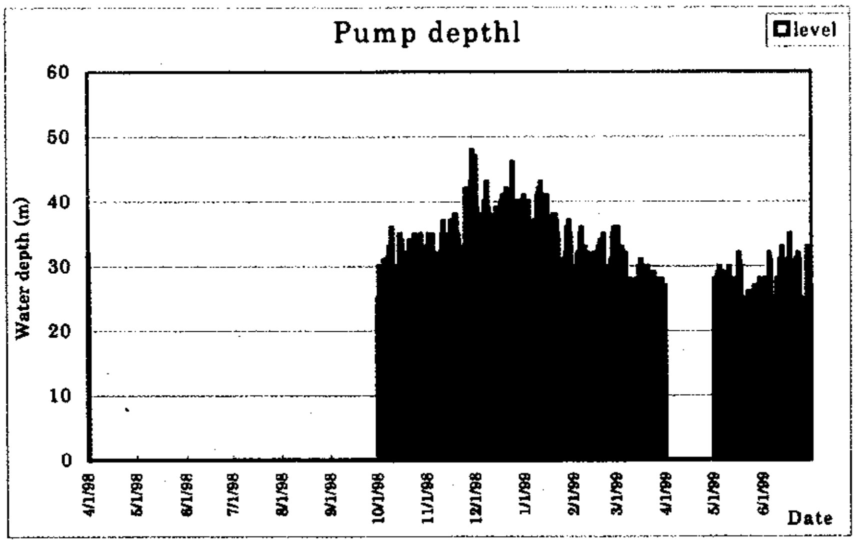


Fig.5.1-11 Transition of pump depth from well water surface

Pump depth which means length from water surface to the pump is shown in Fig.5.1-11. Since the pump is fixed at −190m from ground, it means the fluctuation of water level. The larger it goes, the higher the level goes up.

According to Fig.5.1-11, pump depth in winter is ～40m, that is ～150m under ground. On the other hand, the depth in the other season is ～30m, that is ～160m under ground. The reason of high level in winter season is that under ground water level goes up due to raining and that small pumping due to small insolation. Water quantity can be said to be enough because it is stable at 30m in summer season.

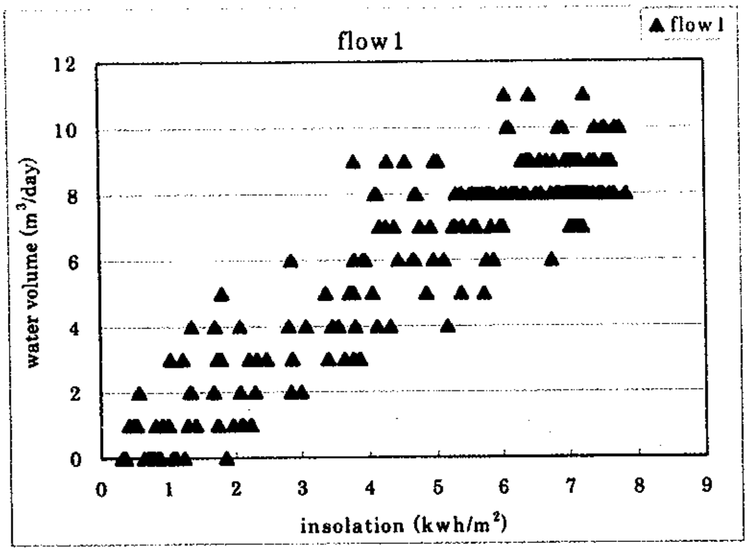


Fig.5.1-12 Correlation between water quantity and insolation

The correlation between insolation and one day water quantity is shown in Fig.5.1-12. The graph shows good correlation between the pumped up water quantity and insolation and no saturation observed. Maximum pumped-up quantity is $11m^3$/day.

(4) Way of water distribution

In Zarzita, the water taps are installed only one in the center of the village, so villagers must come all the way to there. Then following issues occurred.

①Before the system installation, water is delivered to the family tank by the water shop's lorry, but after the installation they must go to the taps to get water.

②It is difficult to know the each family's water consumption.

Villagers had discussions to solve these issues and got following solution.

①3 additional water tap stations around the village is prepared to distribute..

②Each family provide plastic hose which can connect from nearest water tap to their family tank.

③Make water tap schedule among villagers to connect their hose to tap, and get water while the scheduled time.

Water consumption is identified by the connection time, and average half day is assigned to a family. There are some errors in from the actual values, but there is consensus among villagers.

Water consumption of whole village is measured by the flow meter installed at the hi-tank, and this quantity is divided using scheduled time. This way of thinking is projected to fee system. For fee system, a contractor exists between the Water Authority and villager, and the contractor pays fee according to the reading of the meter at hi-tank, and villagers pay tariff according to the scheduled time as illustrated below.

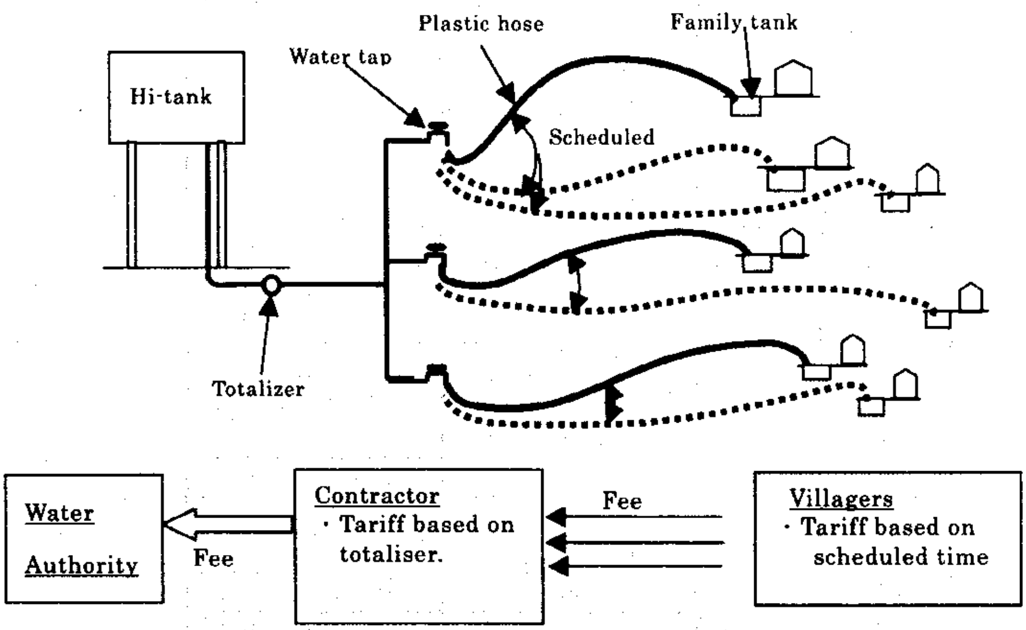


Fig.5.1-13 Water distribution management

Using above delivery system, water is always delivered to one of villagers, that is water is almost directly delivered from tank to one of family tanks without staying hi-tank. Number of household is 42, and current water assign is twice a day for every four tap stations, then villagers can get water at least once a week.

Now, the water fee between the Water Authority and the contractor is 6.5SP/m^3, and that between villagers and the contractor is 7.0SP/m^3. The former fee should be defined according to the Water Authority's regulation but the latter fee can be defined by the contractor independently. This management system (including scheduled connection of plastic hose) lessens cost of piping and shares the managing cost between the Authority and villagers. It will be a good example for future water supply in small rural villages.

(5) Effect of PV water pumping introduction

The difference of water purchased after the installation is questioned to villagers, and one third of villagers replied. The result is listed below. Originally there was little water purchase in winter because of seasonal rain, after the installation no purchase occurs. On the other hand, the water quantity by PV water pumping is not enough in summer season and they must purchase additional water from water shop. According to this study, the amount of water purchased becomes half of before as is shown in the following table.

Table 5.1-7 Change of water purchased (m^3)

House number	Family number	Summer		Winter	
		Before Purchase	After Purchase	Before Purchase	After Purchase
4	7	50	25	0	0
5	14	40	20	0	0
7	13	8	0	0	0
8	4	20	0	0	0
9	10	15	8	4	0
10	8	40	32	0	0
11	9	50	25	0	0
13	8	100	50	8	0
21	21	6	0	0	0
29	11	16	8	0	0
30	20	55	30	12	0
31	2	4	4	0	0
33	10	15	5	0	0
42	9	10	0	0	0
Total	**146**	**429**	**207**	**24**	**0**

From this table, decreased amount of purchase water is 222m^3. Since the replied family is one third of the village, total decreased amount is estimated to be 666m^3. On the other hand, the total quantity pumped-up by PV water pump is about 1,200m^3 that are double of decreased quantity of purchase water.

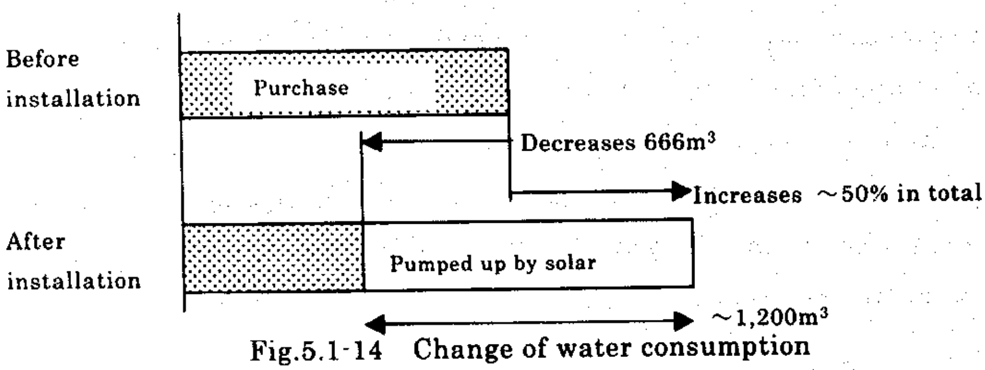


Fig.5.1-14 Change of water consumption

There are some reasons for the extra purchase of water after the system introduced. The washing machines are introduced about one third of the village because of introduction of the centralized PV system. In addition, during trial operation, as water is free of charge, it is difficult to understand reduction of water consumption. On the other hand, Zarzita is close to Dartazze and urban life-style affected to Zarzita easily. However, it is considered that road to Zarzita was paved and easy to get purchased water. The quantity of water pumped-up is almost same as the quantity which is before introduction of PV system. This extra use of water is considered to be initial fluctuation by not knowing how much water they can use from the system. It can be expected that the consumption will be decreased by the fees collection and appropriate education to utilize water and power.

5.1.4 Monthly change of pumped water and supplied water

Monthly change of the amount of pumped water and supplied water is shown in Fig. 5.1-15. It is shown that the amount of the pumped water meets 250m³ per month in summer. On the contrary, the amount of the pumped water declines 140m³ in winter, because of low insolation. The difference between pumped water and supplied water is that the water has been used for washing PV modules. The amount of pumped water in spring and summer in 2000 is small compared to that of the same time in last year. This is the reason why one out of two pumping controller broke and one pump was not working. However, the controller was repaired by SSRC/HIAST, after this repair, two pumps were working normally.

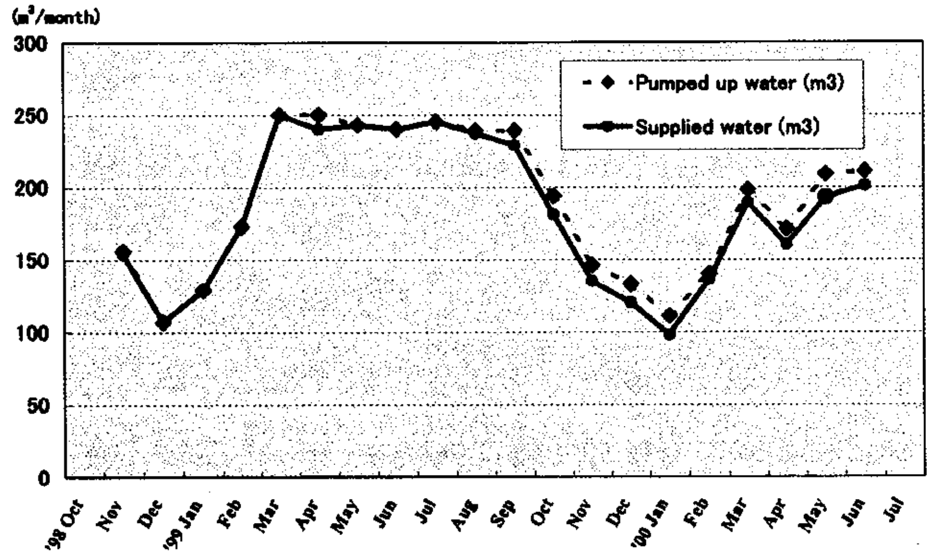


Fig. 5.1-15 Monthly change of the amount of pumped water and supplied water

5.1.5 Evaluation of the pilot plant

This system was designed by the study team, and the installation, operation and maintenance was done by SSRC/HIAST and the study team. Through all stages, technology was transferred completely to SSRC/HIAST. About the operation, initial troubles such as bacteria generation in the tank was solved only by Syrian staffs. Daily inspection was already transferred to the operator who was selected by the Water Authority and trained by SSRC/HIAST.

The reason of such smooth technology transfer is that the configuration is PV pumping system is very simple and the products are highly defined for rural use through a lot of experiences. Therefore their reliability, the way of operation and maintenance and the way of installation is highly improved and the design methods and manuals are also well defined by the manufacturers. Therefore, PV water pumping can be utilized for rural water supply by using these methods.

The water level of the well of Zarzita is very deep(-165m). Most wells in Syria are not so deep. This means for most wells PV water pumping is technically applicable.

From now on, the important thing is forming effective way of water use pumped by PV system and developing sound operation system. As for water distribution, a good management system using plastic hose was developed by the villagers of Zarzita. The introduction of PV system makes good solidarity among villagers and the method is good sample for future rural water supply.

Currently, it seems that water demand of the village exceeds the system ability but by reconsidering the use for cattles and plants and imposing charging, the demand will fall within the system ability. Accumulating such experiences in Zarzita and project them to the future rural water supply is the most effective way of PV water pumping dissemination.

5.2 Desalination System in Kalif

5.2.1 Water situation at installation site and system scale setting

(1) Water situation in Kalif

Kalif practices agriculture and livestock farming with 25 households and about 170 peoples. A lot of villagers depend on buy charged drinking water because well water in the village is too salty for drinking use. Such a villager owns a water storage tank made of concrete in the underground around the house for receiving charged drinking water which traders bring in by a tank lorry several times a month. The fees for such fresh water is extremely high as shown in the table below, though it includes transportation expense, compared with the fee for the water provided by the Aleppo Water Authority.

Table 5.2-1 Water fees

Water Supplier	Fees
Water Trader	50 (SP/m^3)
Aleppo Water Authority	2(SP/m^3)

The demand for fresh water had been investigated in Rasem Al Shikh before Kalif was chosen as the installation site, and found to be about 10 liter/person/day. Though there was no investigation data about Kalif, the fresh water demand for the village was thought to be similar to that of Rasem Al Shikh. Therefore, the requirement of the village for fresh water was assumed to be about 2m^3 per day because the population was about 170.

Table 5.2-2 Fresh water demand in Kalif

Per capita minimum water per day	10 liters /day
Water quantity for whole village	2.0 m^3/day

5.2.2 Design and installation of the system

(1) Design of desalination system

①Preconditions for designing the desalination system

a. Desalination unit

- The desalination rate of well water is set to about 35% aiming to prolong the reverse osmosis membrane life.
- Well water is pretreated by compulsive oxidation (aeration) and filtration, and not by chemical treatment method.
- The operation mode is both automatic and manual.

b. Power Unit

As for the design of the power unit of the desalination system, the basic idea of system concept was discussed with SSRC/HIAST PV group. According to the following items, the power unit was designed.

- When the power consumption of desalination system per day is balanced with the output of PV system at the minimum insolation, the capacity of PV array is designed.
- Power supply of the desalination system is AC220V-50Hz.
- Equipment such as PV module, controller and inverter etc is purchased in Japan.
- For the time being, Japanese batteries are introduced. These batteries are estimated to replace from Japanese to Syrian products after five to seven years.
- Minimum insolation of 3.3(kWh/m²/day) at Aleppo is chosen.

②Selection of system installation site

Table 5.2-3 shows the results of selecting the desalination equipment installation site.

Table 5.2-3 Results of the desalination system installation site selection

Candidate Well Site	Well Capacity	Water Quality	Note
Rasem Al Shikh			Out of consideration because of change of water situation.
Al Rahab		×	
Mazraat Al Rahab		×	
Shweiha	×		
Rasem Al Shikh Kalif (K-1)	○	○	Private well. Owner's disapproval.
Ditto (K-2)	△	○	Enough capacity could be secured by re-digging it to be arabic well.
Al Haunta	○	○	Private well. Owner's disapproval.
Jeb Alama	×		
Maizile	×		
Jafr Al Mansour	×		
Jeb Eles	×		
Al Rabeea	×		
Smereya	×		
Clayat Al Shik	×		

Based on the above-mentioned selection results, it was decided to secure enough well capacity for K-2 well by re-digging the well (K-2) which had been dug in Kalif to make it an Arabic type well so that desalination system could be installed there. The properties of the K-2 well are as shown in Table 5.2-4.

Table 5.2-4 Properties of K-2 well

Well Diameter	100 cm
Well Depth	60 m
Initial Water Level	22 m
Horizontal Tunnels	36 m and 44 m
Geological Features	0～17m (Soft soil)
	17～78 m (Chalky Limestone)
	78 m～ (Marl Layer)
Well Capacity	12 m^3/hr at 12 hour continuous pumping and dynamic water level of 45m.

The results of pumping test of the K-2 well and water quality test of the well water are shown in Fig. 5.2-1 and Table 5.2-5 respectively.

Elapsed Time	Well Water Level (m)	
	Pumping rate: 4m^3/hr	Pumping rate : 6m^3/hr
0	-24.0	-24.0
0.25	-33.5	-33.0
0.50	-34.5	-36.0
0.75	-35.5	-38.0
1.00	-36.5	-43.0
1.25	-37.0	-46.0
1.50	-38.0	-51.0
1.75	-38.5	-56.0
2.00	-39.0	-60.0
2.25	-39.0	-45.0
2.50	-39.5	-34.0
2.75	-40.0	-28.0
3.00	-40.0	
3.25	-40.5	
3.50	-41.0	
3.75	-41.0	
4.00	-41.5	
4.25	-42.0	
4.50	-43.0	
4.75	-44.0	
5.00	-45.0	
5.25	-45.5	
5.50	-34.0	
5.75	-30.0	
6.00	-28.0	

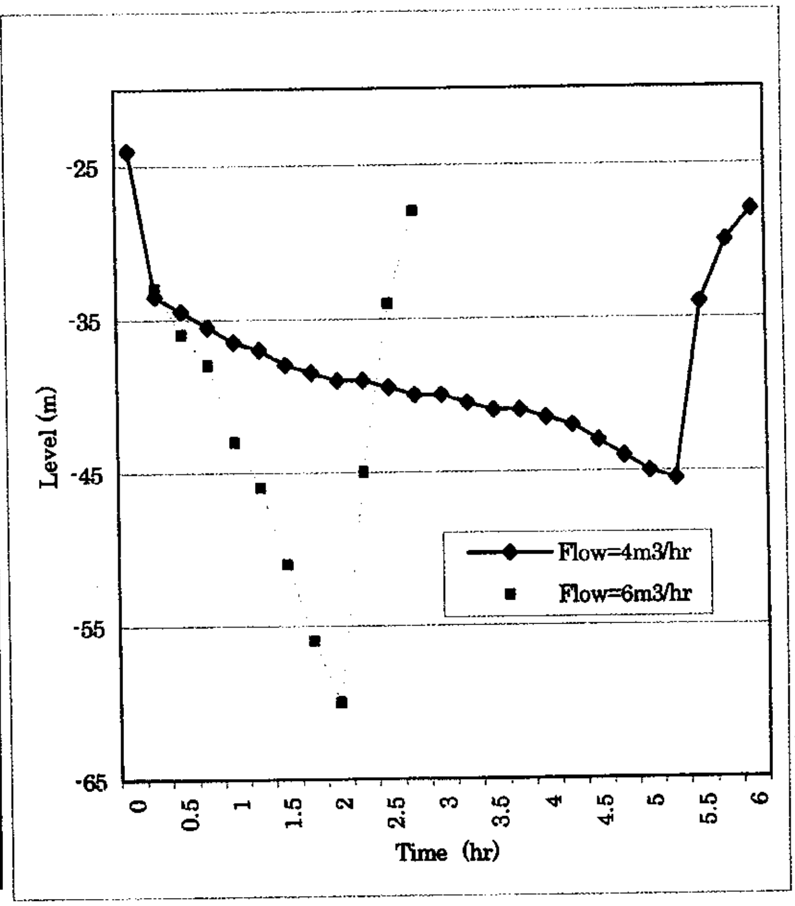


Fig.5.2-1 Pumping test results of K-2 well

Table 5.2-5 Water quality test result of K-2 well

Item	Unit	Syrian Code	Well water Analysis		
			SSRC	Aleppo Univ.	Aleppo Water Auth.
Turbidity	NTU	5			
Electric conductivity	μS/cm	1500*	3200	3690	
pH		6.5-8.5	7.75	7.34	7.5
Suspended Solid	mg/ ℓ	1000	17	<100	
Total Dissolved Solid	mg/ ℓ	1000	3091	2620	3066
COD	mg/ ℓ	3		0.031	
NO3	mg/ ℓ	40	83.49	143	101.66
NO2	mg/ ℓ	0.01		0	0.0492
Cl	mg/ ℓ	600	539.76	524	346
Residual Chlorine	mg/ ℓ	0.5		0	
CN	mg/ ℓ	0.1			
SO4	mg/ ℓ	400	928.74	841	1350
NH3	mg/ ℓ	0.5	0.053	0	0.516
Phosphate	mg/ ℓ	2		2.7	0.25
H2S	mg/ ℓ	0			
Total	mg/ ℓ	500	1500	1010	1120
Hardness(CaCO3)	mg/ ℓ	0.2			
Detargent	mg/ ℓ	0.5			
Phenol					
Cr	mg/ ℓ	0.05			
Cu	mg/ ℓ	1			
Mn	mg/ ℓ	0.2	0	0.034	0.25
Pb	mg/ ℓ	0.05			
Hg	mg/ ℓ	0.001			
Cd	mg/ ℓ	0.005			
Fe	mg/ ℓ	1	0.06	0.12	
Al	mg/ ℓ	0.2			
As	mg/ ℓ	0.05			
Se	mg/ ℓ	0.01			
Zn	mg/ ℓ	5			
Na	mg/ ℓ	200	284.38	390.0	
Ba	mg/ ℓ	0.1		0.5	
Ag	mg/ ℓ	0.01			
B	mg/ ℓ	1			
Aldrin,di-Aldrin	μg/cm	0.03			
Hexachloro Benzene	μg/cm	0.01			
Chlordene	μg/cm	0.3			
Dichloro Benzene-p	μg/cm	1			
DDT	μg/cm	1			
Hepta Chlor	μg/cm	0.1			
Hexa Chlorobenzen	μg/cm	0.01			
Methoxy Chlor	μg/cm	30			
Penta Chlorophenol	μg/cm	10			
Tetra Chlorophenol	μg/cm	10			
Benzene	μg/cm	10			
Tetra Chlorocarbon	μg/cm	3			
Chloroform	μg/cm	30			
Coliform	/100m ℓ	0		0	0
E.Coli	/100m ℓ	0			
Faecal Streptococci	/100m ℓ	0			

* The standard code of electric conductivity was originally 700 μS/cm.

③Selection of desalination method

As above mentioned, the well water in Kalif is of considerably low quality. Electric conductivity is more than 3,500 μ S/cm and contents of such compounds as nitrates, nitrites and sulfides far exceeds the drinking water quality standard in Syria. This is considered to be attributable to agricultural chemicals and drains from households (Table 5.2-5). In designing the desalination system, it is necessary to select the most suitable system considering the properties of well water, situations of the installation site, etc.

The reverse osmosis (hereinafter called RO) membrane method is so far the most widely used water desalination technology followed by electro-dialysis (hereinafter called ED) method. Moreover, while RO membrane method can be used to desalinate water of comparatively wide-range of salinity, ED method is suitable for brackish water of electric conductivity 3,000 μ S/cm level.

The electric conductivity of the well water of Kalif exceeds 3,000 μ S/cm, and the salinity is very likely to rise gradually in the future as pumping-up of ground water in Syria advances. In addition, RO membrane method has the following advantages.

- Composition of the equipment is simple and easy to handle.
- Maintenance is comparatively easy.
- Initial cost, maintenance cost and power consumption are comparatively low, and economical.
- Removal rate of harmful stuff such as bacteria is excellent.

Because of these reasons, RO membrane method was adopted as the desalination method.

④Design of desalination equipment

However, the following characteristics of RO membrane method are the difficulties encountered in desalination.

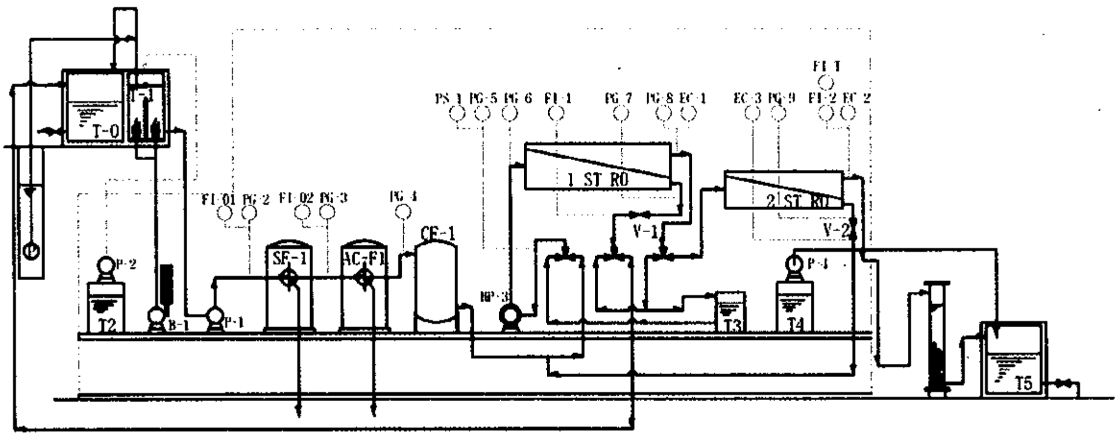
- The membrane performance decreases by accumulation of silica and other hard-to-dissolve stuffs such as calcium sulfides and calcium carbonates on the surface of the membranes and oxidation of the membranes by acidic materials.
- The removal rate of the nitrates and nitrites is lower to those of other impurities in well water.

Therefore, adequate pretreatment is required prior to the processing by membranes to make fresh water that meets Syrian drinking water quality standard for a long term.

Considering the above-mentioned, the desalination system is designed to include chloride oxidation system, sand filtration, activated carbon filtration, and RO membrane system. Table 5.2-6 shows the principal design specifications of the desalination system.

Table 5.2-6 Principal design specifications

Fresh Water Production Method:	Spiral RO membrane type
Properties of well water:	As shown in the water quality analysis result
Amount of desalinated water:	12.0 m^3 /day/ 24 hours
Amount of well water processed:	34.3 m^3 /day/ 24 hours
Amount of brine	22.3 m^3 /day/ 24 hours
Operating temperature range	5℃～45℃
System rejection rate	99.0 %
Maximum operating pressure:	25.0 kgf/cm^2
Design operating pressure:	13.0 kgf/cm^2



T-0	Multipurpose usage water tank	T-1	Feed water tank
T-2,T-4	Chemical tank	T-3	Chemical cleaning tank
T-5	Desalinated water tank	T-6	Mineral addition tank
B-1	Blower for aeration	P	Well water drawing up pump
P-1	Filtration pump	P-2	Chemical injection pump
SF-1	Sand filtration tank	ACF-1	Activated carbon filter tank
CF-1	Check filter tank	HP-3	High pressure pump
1ST RO	First stage RO membrane module		
2ND RO	Second stage RO membrane module		
V-1	Pressure control valve	FI-1	Brine flow meter
EC-1	Electric conductivity meter (1)	FI-3	Feedback flow meter
FI-2	Desalinated water flow meter	FI-T	Integrated flow meter
V-2	Pressure control valve	EC-2	Electric conductivity meter (2)

Fig.5.2-2 Flow of desalination system

The system is usually operated in an automatic mode, while for maintaining the system the operation mode is changed into a manual mode. In the automatic operation, a chlorine injection pump for pretreatment and a blower are set to begin operation at the same time as the electric power's being supplied, and a few minutes after the starting, a filtration pump and a high-pressure pump start to operate in sequence.

Pumped up well water is introduced into the well water tank as feed water to the desalination system. The water storage is designed so that the well water may automatically flow into the multipurpose usage water tank, which is next to the well water tank, when the water level of the well water tank gets to a preset position. Hypochlorite solution and air is injected into the well water tank while the system is in operation so that the unoxidized substances in the pumped-up well water may be oxidized compulsively. For getting the most of the oxidation, the well water tank is so designed as to make the water passage as long as possible. The oxidized well water is sent to the sand filter, the activated carbon filter and the check filter in series by the filtration pump. The element (residual suspension materials in well water, chlorine ion and organic matters) by which RO membrane is negatively affected is removed by the filtration. The oxidized well water is pumped by a high-pressure pump into pressure vessels, where RO membrane modules are housed. The abnormal- high-pressure cut-off switch (High-pressure switch) is installed on the intake side of the high-pressure pump. This switch activates when the operating pressure exceeds a preset pressure to stop the high-pressure pump. Three pressure vessels of RO membranes are set up, where the first and the second pressure vessels correspond to 1ST RO as shown in Fig.5.2-2, and the third pressure vessel corresponds to 2ND RO respectively.

The design standard of the desalination system in terms of the quality of the desalinated water is set as follows; the salinity is to be less than 100 μ S/cm by electric conductivity, and the content of harmful substances such as nitrates and nitrites are to be less than that of the Syrian standard for drinking water. In the original design, five RO membranes were to be used to meet the standard. However, there was a request from the Syrian side to produce as much desalinated water as possible as long as the water quality is within the value of Syrian regulation. In compliance with the request, it was decided to change the desalination process. Canceling the second stage desalination, the number of reverse osmosis membrane elements was reduced to three. As a result, no concentrated water from the 2ND RO is fed back to the inlet of the high-pressure pump.

In the revised configuration, two RO membrane modules are housed in the first pressure vessel, and one membrane module is in the second pressure vessel of the 1ST RO, with 2ND RO not used at all. The change resulted in about 20 percent increase in the desalinated water production volume.

In the finale stage of the process, the desalinated water come through RO membrane modules with decreased impurities is made potable by adding a suitable amount of minerals, mainly calcium, in the mineral addition tank, and is stored in the desalinated water tank. If storage period in the tank becomes long, the possibility of deterioration of the stored water by bacteria increases. To prevent the infection, a hypochlorite solution is dosed into the tank by chlorine injection pump as the post-treatment.

⑤Setting how to use water

The desalination system is designed to desalinate about 30% of water feed, or about $2m^3$/day of desalinated water out of about $8m^3$/day of raw water feed. Therefore, about $5.6m^3$/day of brine is produced as bi-product. The brine is planned to be mixed with raw water in the other use water tank to be used for various purposes, including irrigation and livestock feeding. The planned water use for the Kalif K-2 well is summarized as per Table 5.2-7.

Table 5.2-7 Planned water use (K-2 well)

①Well Water Pumping-up	20 m^3
②Desalination Feed water	8 m^3
③Desalinated Water	2 m^3
④Brine	6 m^3
⑤Water for Various Uses	18 m^3

⑥Design of power unit for desalination

The power for the desalination system is supplied by PV system and battery. The power of water pumping is directly from PV system and an amount of $20m^3$/day is pumping up in summer. For the desalination system, the batteries are installed for desalination system to ensure back up and stable supply of power.

The configuration of power unit is shown below.

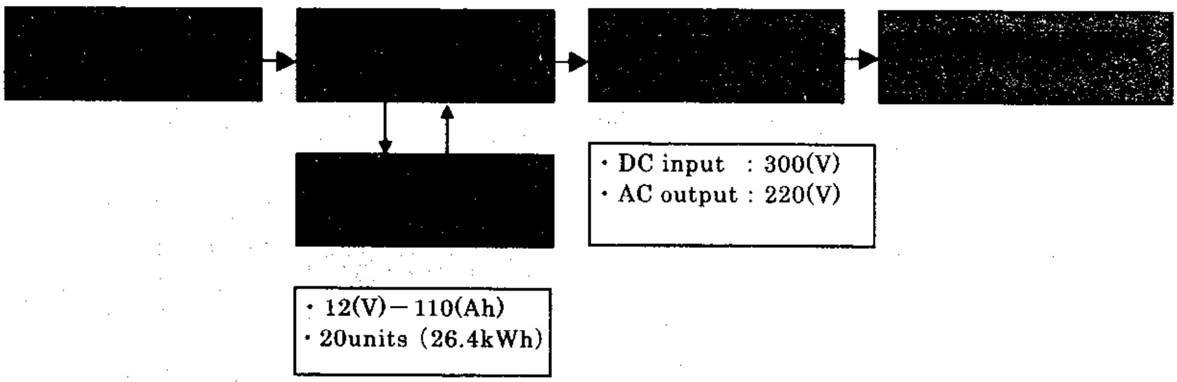


Fig.5.2-3 Configuration of power unit for the desalination

a. PV array

Capacity of PV array was designed based on the following condition.

Capacity of desalination system : 3.0(kW)

Operating hours of desalination system :6(hr)

Minimum insolation month / day : 3.3(kWh/m^2 · day)

Capacity of PV module are calculated to 8.6(kW) from these data.

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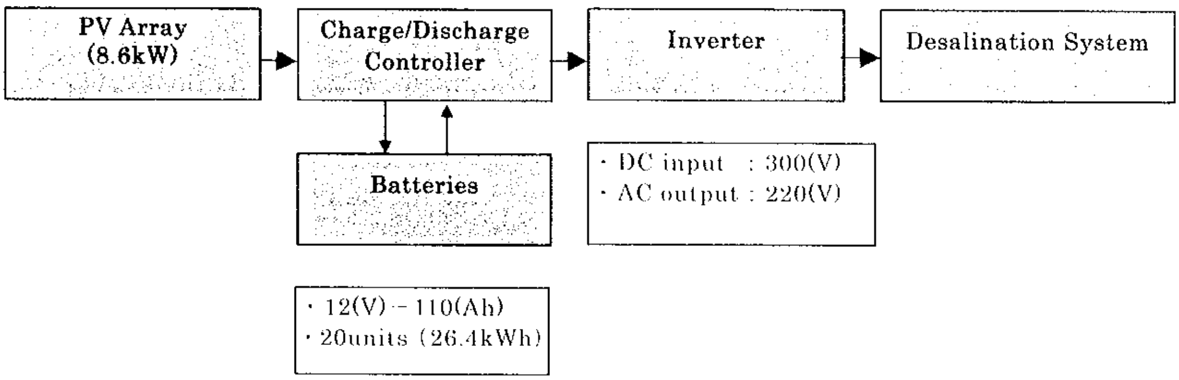

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Capacity of PV module are calculated to 8.6(kW) from these data.

Poly-crystal PV module was chosen for the power unit of desalination system. The terminal voltage of battery at full charge is about 300(V) and PV array configuration is 18 modules connected in series and 4 units are connected in parallel.

b. Battery

As for the battery capacity, the capacity is determined as 20 series and 1 parallel, 26.4kWh (12V-110Ah x 20 units).

The battery which is remodeled is lead-acid battery for PV system use. The unit capacity of it is 12V-110Ah and the weight is about 37kg. It has an advantage in durability for long-term charge/discharge use. For the time being, Japanese batteries are introduced. These batteries are estimated to replace from Japanese to Syrian products after five to seven years. Therefore, the introduced battery is compatible as the local battery.

c. Charge/discharge controller

- Batteries are under floating charge at normal time and discharged in response to the decrease of PV output.
- Starts and stops of the desalination unit and the inverter can be operated in both modes of automatic and manual by the control unit.
- Charge/discharge of batteries can be controlled by the terminal voltage.
- Capacity of charge/discharge controller shall be about DC300[V]-50[A].

d. Inverter

- CVCF (Constant Voltage Constant Frequency) type of inverter shall be purchased for the stable power supply to the desalination system.
- Capacity of the inverter is 10kW in consideration of the surge capacity at starts of the desalination unit.
- Input of the inverter is DC240[V], and output is three phase four wires ,AC220V-50Hz.

(2) General configuration of desalination system

①Arrangement of the system

Water pumping/desalination system was arranged as shown in Fig.5.2-4 which is located on 100m distance from the south of village and surrounded the new dug well. At first, the desalinated water from the system is stored in the feed tank. Then the inhabitants use the water from hydrant on the front of the tank.

②General configuration of the system

General configuration of the system is shown in Fig.5.2-5. The power souses of water pumping/desalination system are in dependent from each other respectively. The water pumping system has capability of $20m^3$ per day in summer and this water is partially used for raw water of desalination and the rest water is used for diluting water of drainage from the system. This system has capability of producing about $2m^3$ per day in summer.

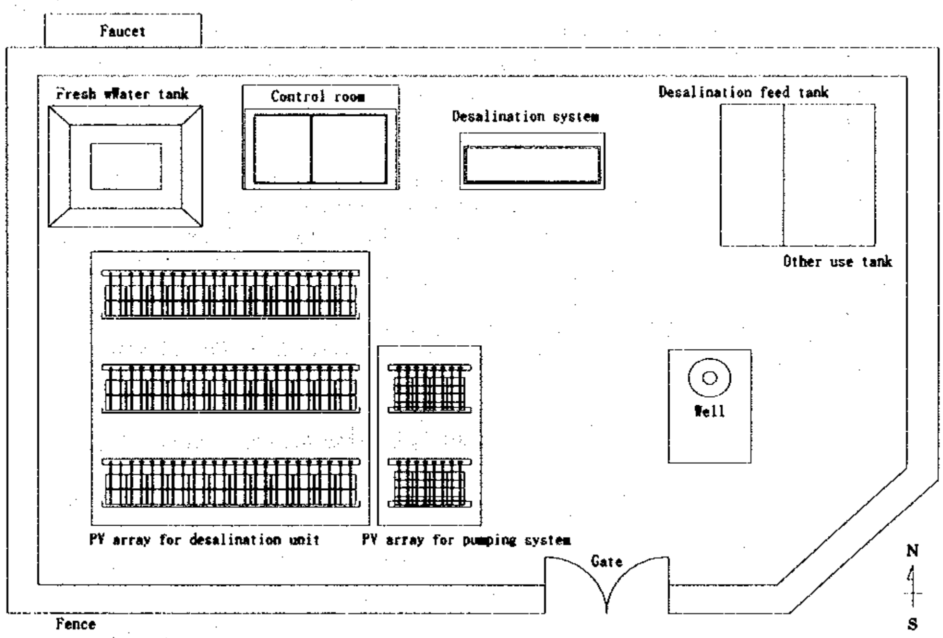

Fig. 5.2-4 Plot plan of desalination system

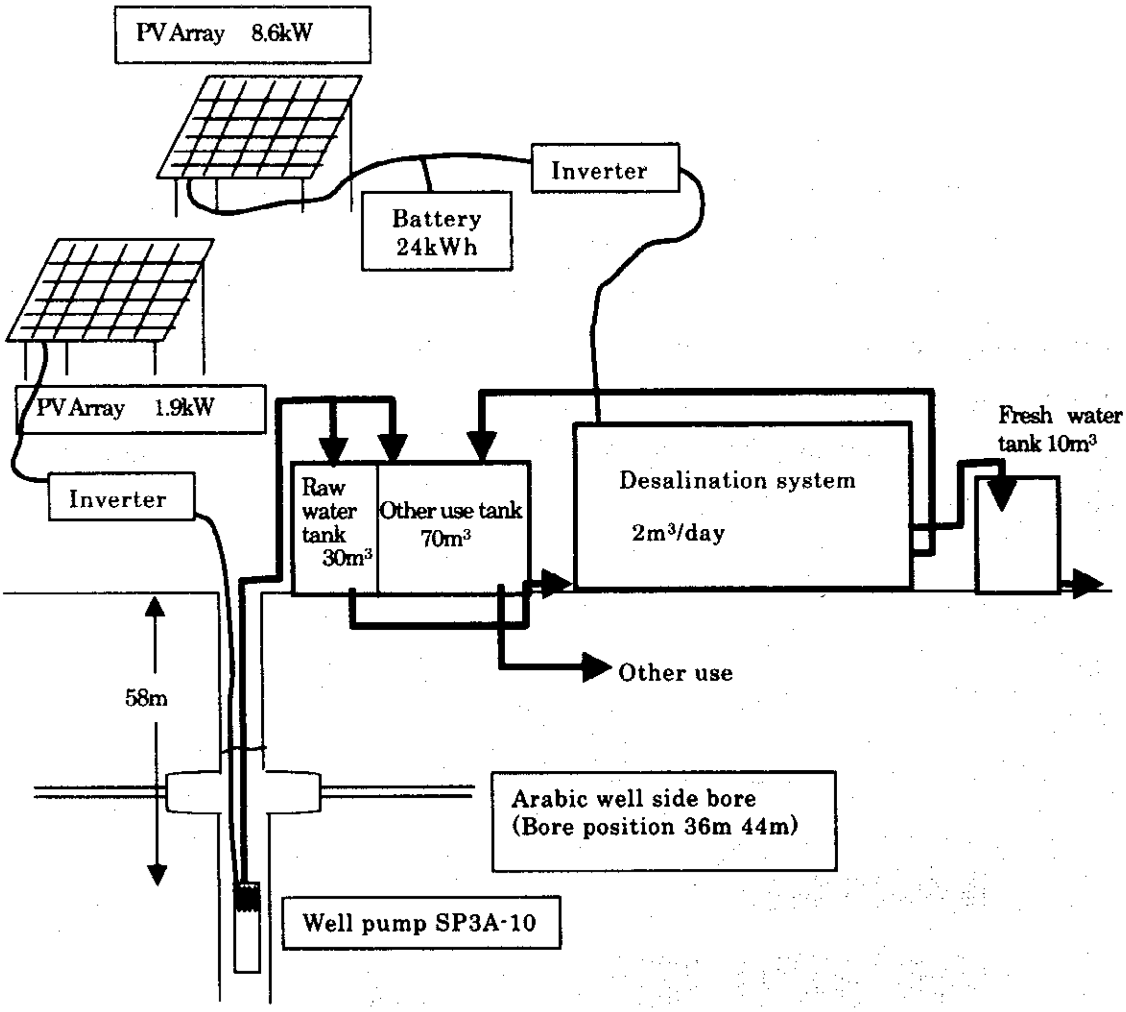

Fig. 5.2-5 General configuration

(3) Assistance for installation

①Desalination unit

The water desalination system was installed at Kalif in August 1998. The outline of the installation and commissioning of the desalination system is as follows.

a. Checking and confirmation of transported items

A set of the desalination equipment, which had been shipped from Japan and transported to the site, was unpacked and the amount for each item was confirmed. Main parts of the equipment including machines and pipes for connecting them had been mounted on a skid and housed in a container before shipping.

b. Installation

The container was lifted by a crane and placed on a concrete base, and was fixed onto the top of the base by chemical anchor bolts. Three shallow ditches were cut out of the top surface of the concrete base for draining.

c. Piping and wiring

All connecting pipes are of hi-impact PVC made in Japan. The pipes connecting the desalination equipment to the well water tank and the desalinated water tank were buried in a ditch of about 50cm deep wherever possible to prevent freezing of contained water. The unburied part of the pipes was insulated. The pipe for aeration was laid and fixed onto the center bottom of the well water tank all the way along the well water flow line. On the upper surface of the pipe are opened holes of 1.5mm diameter every 40cm apart.

d. Machine operation test

Using electricity from PV system, the machines of desalination system were checked on their operation.

e. Water leak test

After washing the sand filter and the activated carbon filter, the pipes, connectors, etc. were checked on water leakage by introducing pretreated well water into the process line.

f. Trial operation and adjustment

Trial operation of the desalination equipment was conducted and adjustments were made on water flow rates, operation pressures, etc. Also injection rate of hypochlorite solution for pretreatment and post-treatment of well water were adjusted.

g. Analysis of produced water

Analyzing the desalinated water, it was confirmed that the produced water is as good quality as designed and expected.

Fig.5.2-6 Unpacking of the desalination equipment and attachments

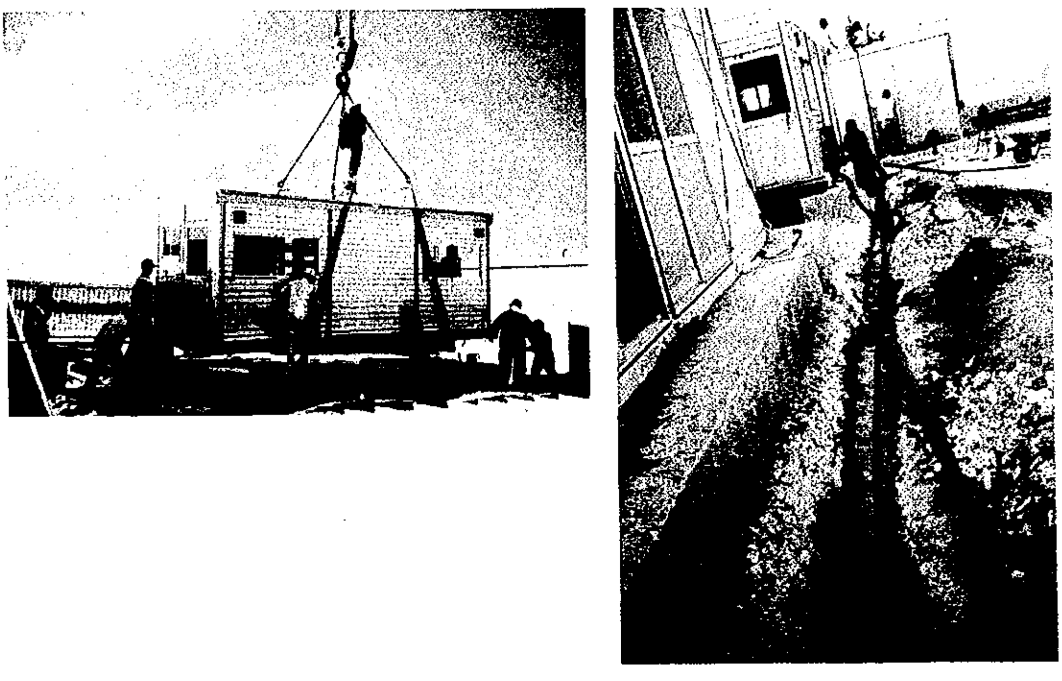

Fig.5.2-7 Installation of the main unit of the desalination system, piping and wiring

②Power sources

As for the power unit of desalination system in Kalif, the civil work such as ground leveling and foundation construction was started from March 1998. From July 1998, the installation of PV array, battery, inverter and controller etc was started. The all of installation, test and trial operation is completed in August 1998. In here, the state of installation, trial operation and continuous operation is mentioned. The maintenance and trouble is mentioned as well.

a. Material procurement

The material procurement for this system, the main components which is PV module, battery, inverter and controller was purchased in Japan and transported to Syria. These equipment had no damage based on the receiving inspection. Moreover, the material for array structure and foundation etc were purchased in the local market.

b. Installation

At the first phase, The civil work for the battery room and PV array structure was started from March 1998, and completed in May. On the second stage, from July 1998, the installation of PV array, battery, inverter and controller etc which was purchased in Japan was started. All of installation, test and trial operation is completed in August 1998. This installation was executed by SSRC/HIAST in cooperation with the mechanical and architectural section of SSRC/HIAST Aleppo and the Ministry of Agriculture Jabal Al Hoss office. The study team executed technical and managerial assist and transported these technology to SSRC/HIAST.

Fig.5.2-8 PV array overview

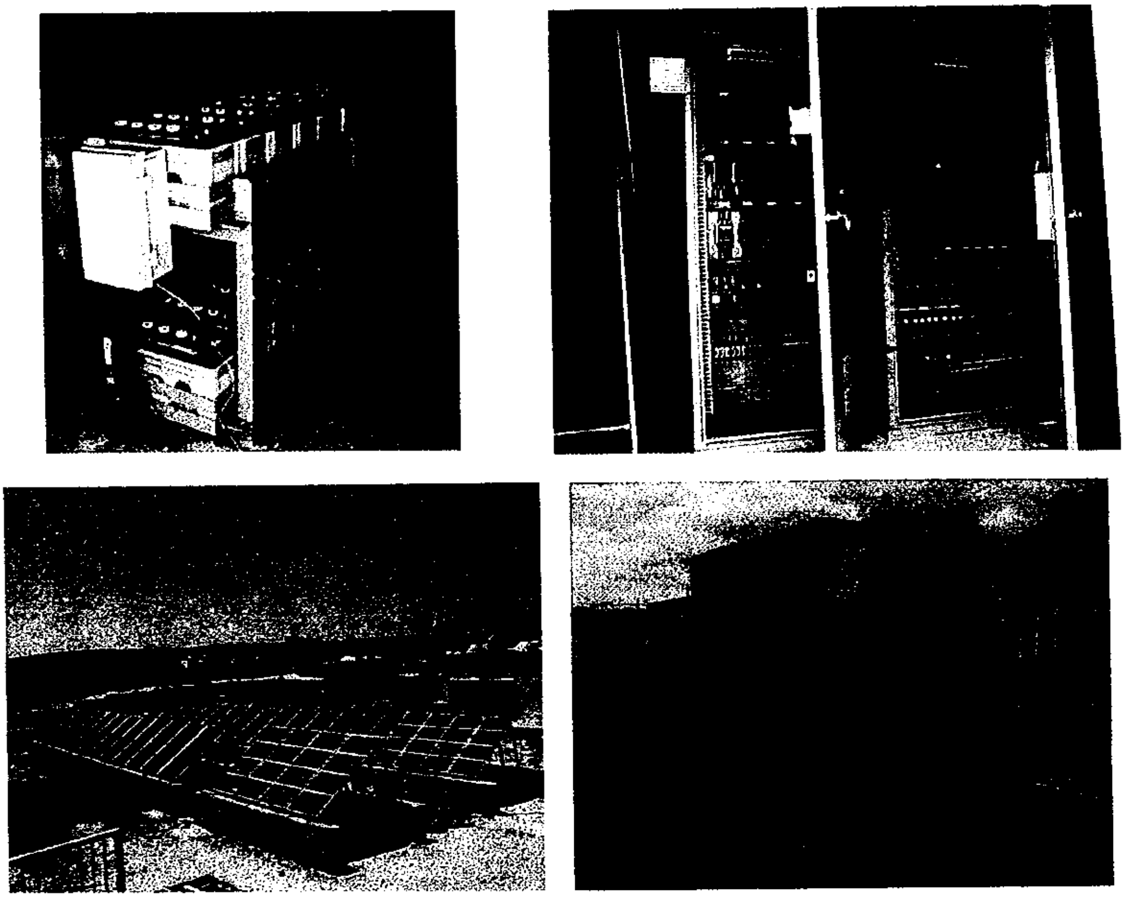

Fig.5.2-9 Installation of main equipment of power unit

c. Test and trial operation

Voltage, current of PV array, terminal voltage of battery and earth resistance etc was taken measure, and electric circuit was normal. After this, the battery solution was refilled and initial charging was executed to recover up to 100% of state of charge for battery. Sequence of controller was checked and the protection function, operation of charge/discharge and start/stop were confirmed. No load operation of inverter was done, and output voltage and wave shape was confirmed as well. All of inspection was completed, trial operation was started to supply power to the desalination itself. According to this trial operation, the detail set of voltage of charge/discharge and start/stop point were confirmed again. Some of set point were changed based on the actual operation condition.

These works were cooperated together with the study team and SSRC/HIAST. The engineer of the manufacturer who is the expert of inverter and controller etc was dispatched to Syria to assist the study team. The expert was instructed much precise technology about the operation management and maintenance. The careful guidance was executed because of the cooperation with the study team and the expert from manufacturer.

5.2.3 System operation and analysis of maintenance situation

(1) Situation of system operation

At the beginning of the operation, the salt rejection rate of the desalination system was 99% or higher as designed. However, the rejection rate decreased by 2-3% in about one year after commissioning. This earlier-than-usual performance decrease of RO membranes is considered to be attributable to the following facts;

(1)Operation was completely stopped for as long as two weeks after some water leaks were detected at the filter tank at an initial stage of the operation.

(2)Chemical cleaning of the RO membrane was inappropriate when the equipment was put into operation several times during the shutdown before the leaking tank was replaced by a substitute.

As long as a steady operation and maintenance system is assured, the machine parts of the desalination equipment including RO membrane could be used for a long term. Table 5.2-8 through Table 5.2-10 shows some of the operation records of the desalination system at Kalif.

The average desalinated water production rate is about 8.3 liter/min, about 20% more than that of original plan. This is because of a process change as above-mentioned. The operation records indicate that about $1m^3$ of fresh water was produced in winter season, whereas about $4m^3$ for summer.

Table 5.2-8 Operation records of desalination equipment

(The end part of October 1998)

Instrument \ Date	10/20/1998	10/23	10/24	10/25	10/26	10/27	10/28	10/29	10/30	10/31
FI-01 (cub.m/h) Sand Filter Inlet Flow rate	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-2 (kgf/sq.cm) Sand Filter Inlet Pressure	2.7	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
FI-02 (cub.m/h) A. Carbon Filter In. Flow rate	1.9	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-3 (kgf/sq.cm) A. Carbon Filter Inlet Pres.	2.6	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
PG-4 (kgf/sq.cm) Check Filter Inlet Pressure	2.8	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
PG-5 (kgf/sq.cm) High Pressure Pump In. Pres.	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.7	2.7	2.6
PG-6 (kgf/sq.cm) R.O. Membrane Inlet Pres.	12.0	12.0	12.0	12.0	12.5	12.0	12.5	12.0	12.0	12.5
PG-7 (kgf/sq.cm) R.O. Membrane Outlet Pres.	11.5	11.5	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
FI-1 (ℓ/min) Concentrated Water Flow rate	15.0	15.5	15.5	15.5	15.7	15.7	15.6	15.5	15.5	15.7
FI-2 (ℓ/min) Permeated Water Flow rate	8.4	8.3	8.2	8.2	8.2	8.3	8.3	8.4	8.2	8.2
EC-1 (μ S/cm) Permeated Water E. Cnduct'y.	50	50	50	50	50	50	50	50	50	50
Permeated Water Prod. Rate (m^3/d)										

Table 5.2-9(1) Operation records of desalination equipment (March 1999)

Instrument \ Date	3/2	3/3	3/4	3/5	3/6	3/7	3/8	3/9	3/10	3/11
FI-01 (cub.m/h) Sand Filter Inlet Flow rate	1.9		1.9		1.9	1.9	1.9	1.9	1.9	1.9
PG-2 (kgf/sq.cm) Sand Filter Inlet Pressure	2.7		2.8		2.8	2.8	2.8	2.8	2.8	2.8
FI-02 (cub.m/h) A. Carbon Filter In. Flow rate	1.9		1.9		1.9	1.9	1.9	1.9	1.9	1.9
PG-3 (kgf/sq.cm) A. Carbon Filter Inlet Pres.	2.7		2.9		2.9	2.9	2.8	2.8	2.8	2.8
PG-4 (kgf/sq.cm) Check Filter Inlet Pressure	2.9		2.9		2.9	2.9	2.9	2.9	2.9	2.9
PG-5 (kgf/sq.cm) High Pressure Pump In. Pres.	2.6		2.6		2.6	2.6	2.6	2.5	2.5	2.6
PG-6 (kgf/sq.cm) R.O. Membrane Inlet Pres.	14.5		14.5		14.7	14.4	14.5	13.5	14.5	14.5
PG-7 (kgf/sq.cm) R.O. Membrane Outlet Pres.	13.5		13.5		13.8	13.4	13.5	12.5	13.5	13.5
FI-1 (ℓ/min) Concentrated Water Flow rate	15.5		15.5		15.5	15.5	15.5	15.5	15.5	15.5
FI-2 (ℓ/min) Permeated Water Flow rate	8.3		8.5		8.5	8.7	8.7	8.8	8.4	8.7
EC-1 (μ S/cm) Permeated Water E. Cnduct'y.	58		58		57	58	58	63	58	58
Permeated Water Prod. Rate (m^3/d)	2.32		1.15		3.17	2.60	2.15	0.05	2.19	3.81
Remarks		Note 1		Note 1						

Table 5.2-9(2) Operation records of desalination equipment (March 1999)

Instrument \ Date	3/12	3/13	3/14	3/15	3/16	3/17	3/18	3/19	3/20	3/21
FI-01 (cub.m/h) Sand Filter Inlet Flow rate	1.9	1.9	1.9		1.9	1.9	1.9			
PG-2 (kgf/sq.cm) Sand Filter Inlet Pressure	2.8	2.8	2.7		2.7	2.7	2.7			
FI-02 (cub.m/h) A. Carbon Filter In. Flow rate	1.9	1.9	1.9		1.9	1.9	1.9			
PG-3 (kgf/sq.cm) A. Carbon Filter Inlet Pres.	2.8	2.8	2.7		2.7	2.7	2.7			
PG-4 (kgf/sq.cm) Check Filter Inlet Pressure	2.8	2.8	2.8		2.9	2.9	2.9			
PG-5 (kgf/sq.cm) High Pressure Pump In. Pres.	2.6	2.6	2.6		2.6	2.6	2.6			
PG-6 (kgf/sq.cm) R.O. Membrane Inlet Pres.	14.5	14.5	14.4		14.5	14.5	14.5			
PG-7 (kgf/sq.cm) R.O. Membrane Outlet Pres.	13.5	13.5	13.4		13.4	13.4	13.4			
FI-1 (ℓ/min) Concentrated Water Flow rate	15.5	15.5	15.5		15.5	15.5	15.5			
FI-2 (ℓ/min) Permeated Water Flow rate	8.7	8.5	8.7		8.7	8.2	8.6			
EC-1 (μS/cm) Permeated Water E. Cnduct'y.	57	57	57		57	53	56			
Permeated Water Prod. Rate (m^3/d)	0.92	0.15	3.52		4.95	2.60	1.93			
Remarks				Note 1				Note 1	Note 1	Note 1

Note 1: No operation due to cloudiness

Instrument \ Date	3/22	3/23	3/24	3/25	3/26	3/27	3/28	3/29	3/30	3/31
FI-01 (cub.m/h) Sand Filter Inlet Flow rate			1.9	1.9	1.9	1.9		1.9		
PG-2 (kgf/sq.cm) Sand Filter Inlet Pressure			2.8	2.8	2.7	2.7		2.8		
FI-02 (cub.m/h) A. Carbon Filter In. Flow rate			1.9	1.9	1.9	1.9		1.9		
PG-3 (kgf/sq.cm) A. Carbon Filter Inlet Pres.			2.8	2.8	2.7	2.7		2.8		
PG-4 (kgf/sq.cm) Check Filter Inlet Pressure			3	3	2.9	2.9		3		
PG-5 (kgf/sq.cm) High Pressure Pump In. Pres.			2.5	2.5	2.6	2.6		2.6		
PG-6 (kgf/sq.cm) R.O. Membrane Inlet Pres.			14.5	14.	15	15		15		
PG-7 (kgf/sq.cm) R.O. Membrane Outlet Pres.			13.5	13	14	14		14		
FI-1 (ℓ/min) Concentrated Water Flow rate			15.5	15.5	15.5	15.5		15.5		
FI-2 (ℓ/min) Permeated Water Flow rate			8.6	8.2	8.2	8.4		8.2		
EC-1 (μS/cm) Permeated Water E. Cnduct'y.			62	62	50	57		60		
Permeated Water Prod. Rate (m^3/d)				1.86	0.86	2.60		0.45		
Remarks	Note 1	Note 1					Note 1		Note 1	Note 1

Note 1: No operation due to cloudiness

Table 5.2-10(1) Operation records of desalination equipment (July 1999)

Instrument \ Date	7/1	7/2	7/3	7/4	7/5	7/6	7/7	7/8	7/9	7/10
FI-01 (cub.m/h) Sand Filter Inlet Flow rate	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-2 (kgf/sq.cm) Sand Filter Inlet Pressure	2.7	2.7	2.8	2.8	2.8	2.8	2.7	2.8	2.8	2.8
FI-02 (cub.m/h) A. Carbon Filter In. Flow rate	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-3 (kgf/sq.cm) A. Carbon Filter Inlet Pres.	2.7	2.7	2.8	2.8	2.8	2.8	2.7	2.8	2.8	2.8
PG-4 (kgf/sq.cm) Check Filter Inlet Pressure	3	2.7	2.8	2.9	3	2.9	2.9	2.9	2.9	2.9
PG-5 (kgf/sq.cm) High Pressure Pump In. Pres.	2.6	2.5	2.9	2.5	2.6	2.6	2.6	2.6	2.5	2.6
PG-6 (kgf/sq.cm) R.O. Membrane Inlet Pres.	13	12	13	12.9	13.5	13.5	13.5	13.5	13.5	13.5
PG-7 (kgf/sq.cm) R.O. Membrane Outlet Pres.	12	11	12	11.5	12	125	12	12	12	12
FI-1 (ℓ/min) Concentrated Water Flow rate	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
FI-2 (ℓ/min) Permeated Water Flow rate	8.5	8.9	8.7	8.7	8.6	8.6	8.6	8.7	8.6	8.7
EC-1 (μS/cm) Permeated Water E. Cnduct'y.	80	80	60	85	78	75	70	70	70	70
Permeated Water Prod. Rate (m^3/d)		1.86	3.98	0.93	1.15	5.72	5.25	4.11	5.57	4.24
Remarks										

Instrument \ Date	7/11	7/12	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20
FI-01 (cub.m/h) Sand Filter Inlet Flow rate	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-2 (kgf/sq.cm) Sand Filter Inlet Pressure	2.8	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.8	2.8
FI-02 (cub.m/h) A. Carbon Filter In. Flow rate	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-3 (kgf/sq.cm) A. Carbon Filter Inlet Pres.	2.8	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.8	2.8
PG-4 (kgf/sq.cm) Check Filter Inlet Pressure	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
PG-5 (kgf/sq.cm) High Pressure Pump In. Pres.	2.5	2.5	2.5	2.5	2.5	2.6	2.5	2.5	2.6	2.5
PG-6 (kgf/sq.cm) R.O. Membrane Inlet Pres.	13.5	13.4	13.4	13.4	13.2	13.2	13.5	13.2	13.2	13.3
PG-7 (kgf/sq.cm) R.O. Membrane Outlet Pres.	12	12	11.5	11.5	11.9	12	12	12	12	12
FI-1 (ℓ/min) Concentrated Water Flow rate	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.8	15.8
FI-2 (ℓ/min) Permeated Water Flow rate	8.7	8.7	8.7	8.7	8.5	8.5	8.6	8.5	8.3	8.3
EC-1 (μS/cm) Permeated Water E. Cnduct'y.	80	70	70	70	70	70	70	70	70	70
Permeated Water Prod. Rate (m^3/d)	5.15	4.70	4.69	3.47	5.00	4.50	7.93	5.80	3.84	10.15
Remarks										

Table 5.2-10(2) Operation records of desalination equipment (July 1999)

Instrument \ Date	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31
FI-01 (cub.m/h) Sand Filter Inlet Flow rate	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-2 (kgf/sq.cm) Sand Filter Inlet Pressure	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
FI-02 (cub.m/h) A. Carbon Filter In. Flow rate	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
PG-3 (kgf/sq.cm) A. Carbon Filter Inlet Pres.	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
PG-4 (kgf/sq.cm) Check Filter Inlet Pressure	2.9	3	2.9	2.9	2.8	2.9	2.8	2.9	2.9	2.9	2.9
PG-5 (kgf/sq.cm) High Pressure Pump In. Pres.	2.5	2.5	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
PG-6 (kgf/sq.cm) R.O. Membrane Inlet Pres.	13.9	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.5	15	15.5
PG-7 (kgf/sq.cm) R.O. Membrane Outlet Pres.	12	12.0	12.0	14	14	14.5	14.9	15	15	15.3	14
FI-1 (ℓ/min) Concentrated Water Flow rate	15.5	15.5	15.7	15.5	15.8	15.5	15.5	15.5	15.7	15.6	15.5
FI-2 (ℓ/min) Permeated Water Flow rate	8.5	8.2	8.2	8.9	7.5	7.9	6.9	8.2	8.3	8.3	8.2
EC-1 (μS/cm) Permeated Water E. Cnduct'y.	70	70	70	70	70	70	70	70	70	70	80
Permeated Water Prod. Rate (m^3/d)	5.29	4.05	5.86	4.29	4.50	5.64	3.70	5.56	4.38	6.21	6.21
Remarks											

The seasonal variation of the salinity of K-2 well is extremely large. The result of the water quality analysis is as shown in Table 5.2-12 and Table 5.2-13. The analysis results indicate the electric conductivity of K-2 well were 7,290 μS/cm in August and 4,540 μS/cm in October 1998, and 3,200 μS/cm in February 1997. The other water samples are desalinated water, water purchased from the Local Authority and stored in an underground storage tank in the village, and water purchased from private well and stored in an underground storage tank in the village. Most of the analyses were consigned to the Aleppo Water Authority.

It was found, however, the obtained desalinated water met all the drinking water standard of Syria. Because the internal coating was not applied to the desalinated water tank, alkaline materials in concrete melt into the desalinated water tank, and therefore, the desalinated water contained in the tank showed comparatively high pH value. However, the degree of alkalinity gradually decreased and reached a proper value in several months.

The amount of fresh water production of Kalf desalination system is shown in Table 5.2-11. The daily average production of desalinated water is shown in Fig. 5.2-10. This shows that about 1.5m^3 of fresh water was produced in water, whereas about 4m^3 for summer. The main reason for the water quantity decrease in winter is that cloudy weather hinders the operation of the desalination system.

Table 5.2-11 Monthly water production of Kalif desalination system

	Desalinated Water (m³)	Pumped Water (m³)	Working Days (day/month)	Average Water Production (m³/day)	Soled Water (m³)
'98 Sep	102	-	-	-	-
Oct	110	-	-	-	-
Nov	86	-	-	-	-
Dec	49	-	-	-	-
'99 Jan	33	-	-	-	-
Feb	48	-	-	-	-
Mar	64	282	21	3.05	-
Apr	87	861	28	3.11	-
May	32	-	13	2.46	-
Jun	63	-	21	3.00	-
Jul	109	817	31	3.52	-
Aug	110	929	31	3.55	-
Sep	71	882	27	2.63	-
Oct	85	854	29	2.93	-
Nov	66	672	27	2.44	-
Dec	50	644	28	1.79	-
'00 Jan	26	598	16	1.63	-
Feb	40	490	17	2.35	-
Mar	79	789	27	2.93	-
Apr	72	686	27	2.67	-
May	106	853	31	3.42	-
Jun	120	740	30	4.00	100
Jul	126	603	31	4.06	100
Aug	126	514	31	4.06	100
Sep	119	569	30	3.97	100
Oct	90	600	30	3.00	

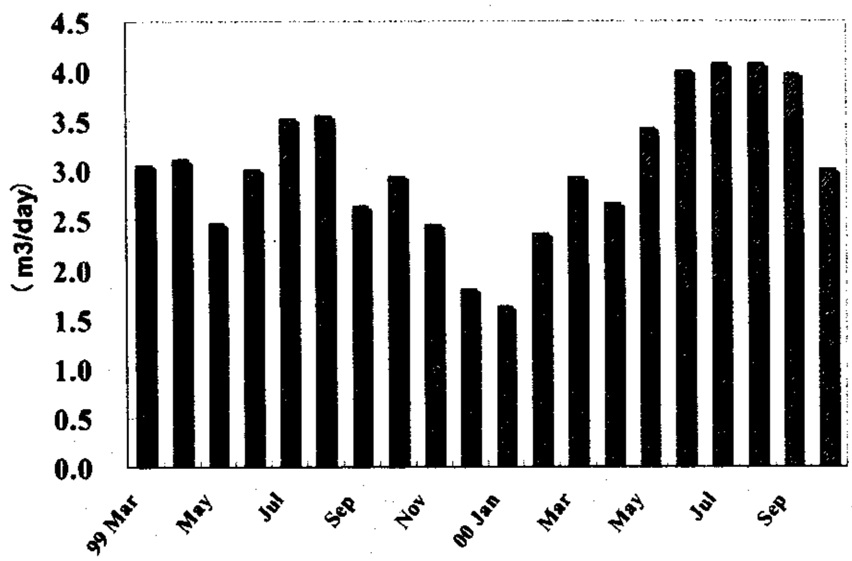

Fig. 5.2-10 Daily average production of desalinated water

Table 5.2-12 Water quality analysis result (1)

Item	Unit	Syrian Code	K-2 Well Water				Desalinated Water		
			Feb/23/1997	Aug/4/1998	Oct/29/1998	Oct/11/2000	Aug/13/1998	Oct/29/1998	Oct/11/2000
Turbidity	NTU	5		2.5	0.5	1.5	1.8	0.4	1.5
Conductivity	μ S/cm	1500	3200	7290	4540	4500	162.5	88.2	230
pH		6.5-8.5	7.75	7.47	7.24	8.1	7.35	8.4	7.4
Suspended Solid	mg/ ℓ	1000	17	—	—	0	—	—	0
Total Dissolved Solid	mg/ ℓ	1000	3091	5492	2345	—	108	45.2	—
COD	mg/ ℓ	3	—	—	—	—	—	—	—
NO3	mg/ ℓ	44	83.49	145	139.7	50	19	16.8	10
NO2	mg/ ℓ	0.033		0.033	0.011	—	0.0098	0.011	—
Cl	mg/ ℓ	250	539.76	1050	777	—	21	18.2	—
SO4	mg/ ℓ	250	928.74	1360	568	—	15	11	—
NH3	mg/ ℓ	0.05	0.053	2.09	2.06	—	—	0	—
Phosphate	mg/ ℓ	2		0.13	0.22		0.08	0.1	—
Total Hardness(CaCO3)	mg/ ℓ	500	1500	1700	1234	1200	162.5	16	14
Cr	mg/ ℓ	0.05	—	—	—	—	—	—	—
Cu	mg/ ℓ	1	0	—	—	—	—	—	—
Hg	mg/ ℓ	0.001	—	—	—	—	—	—	—
Cd	mg/ ℓ	0.005		—	—	—	—	—	—
Fe	mg/ ℓ	0.3	0.06	—	—	—	—	0.25	—
As	mg/ ℓ	0.05	—	—	—	—	—	—	—
Se	mg/ ℓ	0.01	—	—	—	—	—	—	—
Na	mg/ ℓ	200	284.38	390.0	—	—	—	—	—
Ba	mg/ ℓ	0.1	—	0.5	—	—	—	—	—
Coliform	/100m ℓ	0	—	0	—	15	—	—	0
E.Coli	/100m ℓ	0	—	3	—	—	—	—	—
Faecal Streptococci	/100m ℓ	0	—	0	—	—	—	—	—

Table 5.2-13 Water quality analysis result (2)

Item	Unit	Syrian Code	Chef. Kalif's Storage (Local Authority)	Chef. Kalif's Storage (Ramley Water)
Turbidity	NTU	5	0.5	46
Electric conductivity	μ S/cm	1500	574	453
PH		6.5-8.5	8.3	8.48
Suspended Solid	mg/ ℓ	1000	–	–
Total Dissolved Solid	mg/ ℓ	1000	335	202
COD	mg/ ℓ	3	–	–
NO3	mg/ ℓ	44	76.9	8.39
NO2	mg/ ℓ	0.033	0.011	0.0098
Cl	mg/ ℓ	250	58.8	28
SO4	mg/ ℓ	250	46	39
NH3	mg/ ℓ	0.05	0.03	0
Phosphate	mg/ ℓ	2	0.09	0.11
Total Hardness(CaCO3)	mg/ ℓ	500	176	13
Cr	mg/ ℓ	0.05	–	–
Hg	mg/ ℓ	0.001	–	–
Cd	mg/ ℓ	0.005	–	–
Fe	mg/ ℓ	0.3	–	–
As	mg/ ℓ	0.05	–	–
Se	mg/ ℓ	0.01	–	–
Na	mg/ ℓ	200	–	–
Ba	mg/ ℓ	0.1	–	–
Coliform	/100mℓ	0	–	8
E.Coli	/100mℓ	0	–	36
Faecal Streptococci	/100mℓ	0	–	0

Before the installation of the desalination system, the villagers in Kalif were buying fresh water from private trader in Ramley village and others. So, the water sampled from a storage tank in Kalif was analyzed for a reference. The water had been brought from a private well in Ramley and stored in the tank for several months. Little bit of bacteria was detected in biological analysis while the result of chemical analysis was fine. The Local Authority provides certain amount of fresh water per year for settlers in Kalif by application at about 6SP/m^3. Such water purchased from the Local Authority had been stored in an underground storage tank in the village. So, an analysis was made on the water and the result showed that the content of nitrates and nitrites are about twice the Syrian drinking water quality standard value. Although no biological analyses were made on the water, it seems that the water contains bacteria as in the case of the above-mentioned purchased water.

Well water, product water, and concentrated water of Kalif were analyzed to know how the performance decrease of RO membrane as mentioned above affects the product water quality. The result is as shown in Table 5.2-14. Though the salt rejection rate of the system has decreased to about 95%, the water quality of the product water is still satisfactory because the value for all the items analyzed clears a standard value of Syrian regulations.

Table 5.2-14 Water quality analysis result (3)

Item	Unit	Syrian Code	Product Water	Concentrate Water	Well Water
Turbidity	NTU	–	–	–	–
Electric conductivity	μ S/cm	1500	180	4540	3900
PH		6.5-8.5	6.54	7.57	7.22
Suspended Solid	mg/ ℓ	1000	0.0	0.0	0.0
Total Dissolved Solid	mg/ ℓ	1000	–	–	–
COD	mg/ ℓ	3	0.24	0.26	0.12
NO3	mg/ ℓ	44	0.62	94	96
NO2	mg/ ℓ	0.033	0.0	0.0	0.0
Cl	mg/ ℓ	250	34	873	731
SO4	mg/ ℓ	250	24	1123	883
NH3	mg/ ℓ	0.05	0.0	0.0	0.0
Phosphate	mg/ ℓ	2	0.10	0.14	0.13
Total Hardness(CaCO3)	mg/ ℓ	500	22	1450	1240
Cr	mg/ ℓ	0.05	0.014	0.017	0.013
Hg	mg/ ℓ	0.001	<0.01	<0.01	<0.01
Cd	mg/ ℓ	0.005	<0.01	<0.01	<0.01
Fe	mg/ ℓ	0.3	0.010	0.018	0.012
As	mg/ ℓ	0.05	0.019	0.024	0.016
Se	mg/ ℓ	0.01	<0.01	<0.01	<0.01
Na	mg/ ℓ	200	38	502	454
Ba	mg/ ℓ	0.1	–	–	–
Coliform	/100m ℓ	0	–	–	8
E.Coli	/100m ℓ	0	–	–	36
Faecal Streptococci	/100m ℓ	0	–	–	0

(2) Maintenance

The main matters to be checked on the maintenance of the desalination system are as follows.

①Daily maintenance

1) Pressure

(Feed water, permeated water, and concentrated water)

2) Flow rate

(Feed water, permeated water, and concentrated water), Integrated flow rate (Permeated water)

3) Water temperature (Feed water)

4) Amount of residual chlorine of chlorine-oxidized water and filtration water

5) pH of chlorine-oxidized water and filtration water

6) Liquid level in each storage tank and chemical tank

7) Electric conductivity
(Feed water and desalinated water)

8) Preparation and Replenishment of chemicals in the tank

9) Water leakage and overheating of motors

10) Operation situations of machines
(Vibration of the suction pipe of the high-pressure pump, etc.)

11) Tightness of V-belts for rotation machines

12) Reverse-washing of sand filter and activated carbon filter

13) Oiling of high-pressure pump

14) Water leakage from high-pressure pipes

15) Total operation hours

②Regular maintenance

1) Changing of activated carbon
(To be executed if necessary)

2) Replenishment of hypochlorite solution
(To be executed if necessary)

3) Exchange of check filter cartridges
(To be executed if necessary)

4) Oil exchange for rotation machines
(To be executed about once every two months)

5) Dismantling of high-pressure pump
(To be executed about once a month)

6) Chemical cleaning of the reverse osmotic membranes
(To be executed about once every two months)

7) Exchange of the machines or the parts
(To be executed if necessary)

③Monitor matters

The following matters should be monitored and be recorded at a daily maintenance or a regular maintenance.

1) Pressure for feed water, permeated water, and concentrated water

2) Flow rate for feed water, permeated water, and concentrated water
Integrated flow rate for Permeated water

3) Water temperature for Feed water

4) Amount of residual chlorine of chlorine-oxidized water and filtration water

5) pH of chlorine-oxidized water and filtration water

6) Electric conductivity for feed water and desalinated water

7) Operation time

8) Measures taken on occasion of system shutdown.
(Method of membrane cleaning, etc.)

9) Situation and measures when abnormality occurred

(3) Management, operation and maintenance, of desalination system

The Aleppo Water Authority is responsible for managing the operation and the maintenance of the desalination system. It seems necessary to entrust the management of daily operation and maintenance to someone who resides in the village because it is very difficult for the Aleppo Water Authority provide an technician to take charge in the daily maintenance. Also it is necessary that more than one person should be in charge to cope with an unexpected situation.

The person in charge reads various operation data while the operation is stable, about 1-3 hours after the start-up of the operation every day, records the data in a fixed form, checks the operation situation of the system overall, and does necessary maintenance work.

However, regular maintenance will have to be conducted by an engineer of the Aleppo Water Authority who is in charge of the management of the system.

(4) Fee collection and distribution of fresh water

The Aleppo Water Authority began fee collection for the fresh water supply in April 2000. Fee is 7.0SP/m^3 for the beneficiaries. A contractor executes the fee collection as a proxy, and 6.5SP/m^3 goes to the Aleppo Water Authority. This collection system is the same as that for Zarzita. The introduction of the desalination system and the water supply system are considered to give great benefit and convenience for the villagers. They can get fresh water much cheaper than buying it from fresh water well such as Ramley village, and they don't have to go all the way to purchase the fresh water with a tank lorry and a tractor.

The least necessary amount of fresh water for an adult each day for drinking and cooking use only was presumed to be about 6 liters in winter and 10 liters in summer. The actual amount of water to be distributed for each individual would be decided based on these figures. However, as mentioned above, the population of the village decreases to about 30 people in summer because many of the villagers have to be away from the village for pasturing and rising of sheep. Whereas the operation hours of the desalination system in this season is as long as 8 hours/day or more on the average per day and about 4m^3 of fresh water is produced on the average. Therefore, most of the fresh water would become surplus as long as the allocation is set on 10 liters/person. There seem to be the following three ways to utilize the produced fresh water effectively; ① Distribution to villagers other than Kalif, ② Storage in preparation for shortage of waters, ③ Increasing the allocation to the villagers of Kalif. However, first of all, ③ is too unrealistic because the amount of distribution for each individual would physically exceed the limit of common sense. As for ②, according to the Chef of Kalif, there are following villages in the vicinity of Kalif, and currently the villagers obtain most of the fresh water from private wells.

Village Name	Population in winter	Distance from Kalif
Nawara East	About 200	2 km
Talsabha West	About 200	3 km
Tel Ahamal	About 150	2 km
Alma Ezyre	About 100	5 km
Umhaan West	About 100	5 km

The population of these villages in summer is presumed to be about 20% of that in winter because all of the villages have the similar characteristics as Kalif or most of the villagers are not really settled. Assuming that is true, the fresh water demand in the Rasem Al Shikh and its vicinity area in summer would be equivalent to about 180 people, and comparatively good demand and supply balance would be expected.

On the other hand, the number of cloudy and rainy days increases in winter season, roughly November to March, and the operation rate of the desalination system remarkably decreases. For instance, according to operation results for March 1999 (Table 5.2-9), there were nine non-operation days in total out of which five days in a row, and the total amount of product water in 29 days was only 33.5m^3. In this season, the population of Kalif grows to about 170 because people who have been away during summer come back to the village. Therefore the amount of water allocated for one person would have to be about six liters per day at this time of the year.

In light of the circumstances, it seems reasonable to try to ease a disproportionate demand and supply between winter and summer even somewhat by the method of ②.

The desalinated water, which has not been used in summer, is saved in underground storage tanks in the villages as capacity permits to be used in winter. Because purchased fresh water has been actually stored in underground tanks in the village for as long as 5-6 months, no problem is foreseen in storing the desalinated water for such period.

Though the amount of the produced desalinated water can be measured with the integrated flow meter installed in the desalination equipment, the amount of consumed water cannot be directly measured because there is no flow meter at the outlet of the desalinated water tank. However, because the water delivered to other villages are measured by a flow meter installed at the desalinated water tank, the total quantity of consumed water can be indirectly measured. As for allocation to each household, for instance, such agreement could be made among the villagers as that certain number of buckets of water a day for each household is allocated for each household and the fee is collected based on actual amount of consumption.

(5) Emergency

The method to be taken when some abnormalities in the desalination system are detected is proposed as follows. In an emergency situation, a person in charge of daily maintenance goes to Taldaman, the distance being about 14km, by using a suitable transportation in the village, contacts by phone the person in charge of operation and maintenance of the desalination system in the Aleppo Water Authority, and explain the situation.

The person who receives the report gives necessary directions to the maintenance person and proceeds immediately to the site, depending on the situation. However, when the maintenance person has difficulty in securing suitable transportation, the Aleppo Water Authority is advised to consider appropriate means to cope with such situations.

5.2.4 Evaluation of the system

Though the desalination system encountered with some mechanical trouble at the early stage of operation, normal operation was established after removing the trouble. However, the quality of desalinated water has decreased somewhat more than expected because RO membranes got deteriorated earlier than schedule due to the aftereffect of the trouble. Nevertheless, the water quality still meets the drinking water standard of Syria.

Because the desalinated water production rate is greatly affected by the quantity of insolation, the discrepancy between the produced water quantity in summer and in winter was more than expected. However, the least necessary water was managed to supply in winter when the demand and supply gets tight.

Considering the local situation, the proposed on how to cope with normal operation and maintenance and emergency of the desalination system seems to be reasonable.

5.3 Technology transfer

5.3.1 PV water pumping

The technology of design, installation, operation and maintenance of PV water pumping is transferred to the staffs of SSRC/HIAST. The items of the technology transfer are listed below. Documents for the technology transfer such as manuals, design sheets, specification sheets, maintenance check sheets are prepared in English and they are passed to SSRC/HIAST in order for the staffs to be able to refer when needed.

The operation (daily inspection) is now done fairly well by the person selected among the villagers who was trained from SSRC/HIAST. Now the technology transfer from SSRC/HIAST to staffs of the Water Authority is planned and after that the management of the system is also transferred from SSRC/HIAST to The Authority.

Followings are items of technology transfer.

(1) Operation/Measurement

1) Inspection beers the systems start.

2) Start/ Stop sequence of the system.

3) Measuring method of flow rate.

4) Measuring method of water level.

5) Measuring method of one-day pumping quantity.

(2) Daily inspection

1) Confirmation of pump operation.

2)Condition of piping(Leakage, crack, scratch, bent, · ·)

3) Operation of flow meter

4) Indicator lamp of the inverter

5) Water level of the well/tank

6) Dust on the surface of PV module

7)Condition of wiring(Rust, connection, covering, · ·)

8)Any damages · ·

(3) Design

1) Design of PV water pump

2) Cost calculation of PV water pump

About (3)-2) Cost calculation of PV pump, a software using EXCEL is developed and it is passed to SSRC/HIAST. About the contents of the documents and software, refer the report of technology transfer.

5.3.2 Maintenance management of desalination system

(1) Maintenance management

Technical guidance and explanations on the following matters were provided to the engineers in charge of the desalination system in SSRC/HIAST. Also, technological instruction manuals of the desalination system written in English were provided to SSRC/HIAST and the Aleppo Water Authority. The manuals explain how to carry out the operation and maintenance of the desalination system so that the person in charge, etc. can refer them if necessary.

①Handling of the system

According to the manual, explanations on the following matters were provided while confirming the flow sheet as follows.

1) Purpose of blower for aeration of well water tank

2) Purpose of injecting hypochlorite solution as pretreatment and procedure of adjusting the solution

3) Procedure of operating filtration pump
(Air venting, valves operation, and switch operation)

4) Purpose and reverse-washing operation of sand filtration tank

5) Purpose and reverse-washing operation of activated carbon filtration tank

6) Exchange of check filter element

7) Method of adjusting pressures with pressure gauges and pressure adjustment valves

8) Method of adjusting flow rates with flow meters and valves

9) Situations of water flows in the process when each operation is conducted

10) Purpose of injecting hypochlorite solution as post-treatment and method of adjusting the solution

11) Purpose of adding mineral to desalinated water and method of replenishing the mineral

②Training

1) Adjustment, maintenance, and management of high-pressure pump

Oil injection into felt packing, oil exchange, V belt adjustment and dismantling of the manifold of high-pressure pump

2) Adjustment, maintenance, and management of blower

Oil injection and V belt adjustment

3) Taking out and re-insertion from pressure vessel of reverse osmotic membranes

4) Reverse-washing of sand filtration tank and activated carbon filtration tank,

Procedure of operation for five-way valve, etc.

5) Making of hypochlorite solution

Handling, measuring, etc. of sodium hypochlorite.

6) Adjustment of injection amount and maintenance of chemical injection pumps

7) Operation of switchboard

(Switching from automatic operation to manual operation, etc.)

8) Check points and record keeping in daily operation

9) Charging and discharging of contents for activated carbon filter tank

When the technological guidance to the engineers of SSRC/HIAST in charge of the system operation and maintenance was over, the engineers provided on-the-job training to persons who are chosen among the villagers for daily operation and maintenance. To avoid possible mistakes in operation and maintenance by those people, procedures of the operation and maintenance work written in Arabic were prepared and posted at places easy to be seen.

Details of the technology on the desalination system are as described in a separate cover, "Technology Transfer Report".

Chapter 6
Operating Management and Organization System

Chapter 6 Operation Management and Organization System

As for PV system (for power supply or water supply) installed in this project, a maintenance/operation system is established so that a consistent service can be provided after completing the project. Power supply and water supply with the attendant maintenance and management of those systems in this project are according to the principle of power/water supply in Syria, handled by the Aleppo Electric Authority and the Aleppo Water Authority, respectively.

6.1 Maintenance/management systems for the installed systems

PV electrification system and water supply system installed in this project are demonstrative systems for research and development and therefore it would be difficult to operate and maintain those systems as independent commercial plants. Under the technical assistance of SSRC/HIAST, the operation and management of these systems were committed to the Aleppo Electric Authority and the Aleppo Water Authority, which are public establishment in Syria, and the written agreement was submitted to them. The agreement was approved by the Aleppo Water Authority in July 1999, and was approved by the Aleppo Electric Authority in January 2000, respectively.

6.1.1 Outline of the agreement

The following is the outline of the agreement on maintenance/management of the systems:

- SSRC/HIAST and the both Authorities shall establish a management committee for maintenance/management of the systems, respectively.
- Management committees are responsible for operating the systems, analyzing the operation data, expanding the existing systems, approving the use of the equipment, and disclosing the appropriate technologies obtained through the experience during the operation of these systems.
- Both Authorities are charged with all responsibilities for operating and maintaining the systems.
- Fees shall be considered and set by the both Authorities and the fees shall be collected immediately after contracting with customers who need public services.
- For new customers who need electricity and/or water, the decision shall be made based on the opinion of the management committee.

6.1.2 Management of PV electrification systems by the Aleppo Electric Authority

(1) System management committee

The system management committee consists of the Aleppo Electric Authority and SSRC/HIAST:

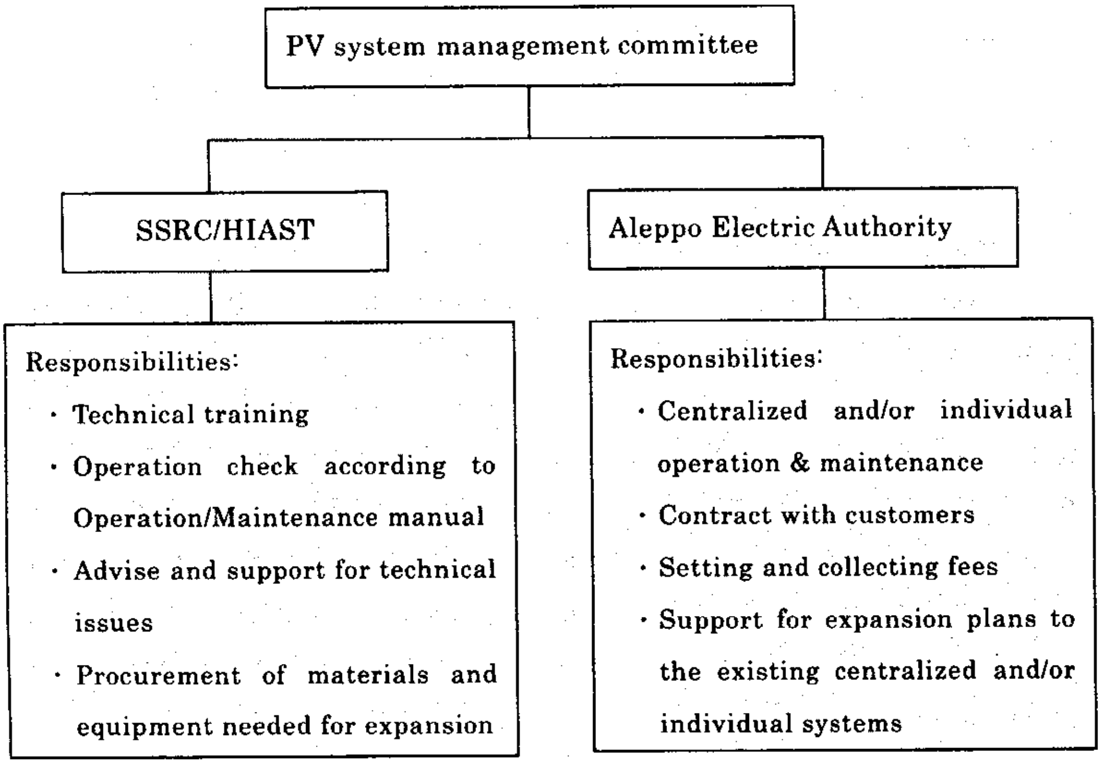

Fig.6.1-1 PV system management committee

Members of the management committee:

Chairman:	Eng.Mohamad SAAD	President of Aleppo Electric Authority
Member:	Dr.Riad SABOUNI	SSRC/HIAST, PV laboratory, Chief
Member:	Eng.Yasel SHAHEED	SSRC/HIAST, PV laboratory
Member:	Eng.Jamal Haj BAKRI	Aleppo Electric Authority, Dartazze Economy Unit, Chief

The committee consists of two members from the Aleppo Electric Authority, and two members from SSRC/HIAST. The chairman of the committee is the Director General of the Aleppo Electric Authority. The committee maintains and manages the systems located consistently for a long period of time through operating the PV electrification systems in four villages located by the inquiry commission and analyzing maintenance & operation data. As for the support to a new customer who needs public services, the committee should consider how to support the customer. If necessary, systems are expanded or added; the Aleppo Electric Authority bears the expenses for expanding or adding systems, and SSRC/HIAST procures necessary materials and equipment.

(2) Organization of the Aleppo Electric Authority for system management

Before the management of the village electrification system is committed to the Aleppo Electric Authority, it is necessary to get approval by PEDEEE (Public Establishment for Distribution & Exploitation of Electrical Energy), which controls electricity distribution businesses in Syria. The scope of PEDEEE includes setting fees for electricity supplied from the PV system.

In the Aleppo Electric Authority, all PV systems of four villages should be managed by Economy Unit in Dartazze. The Aleppo Electric Authority nominates engineers and/or technicians and educates them under the guidance of SSRC/HIAST.

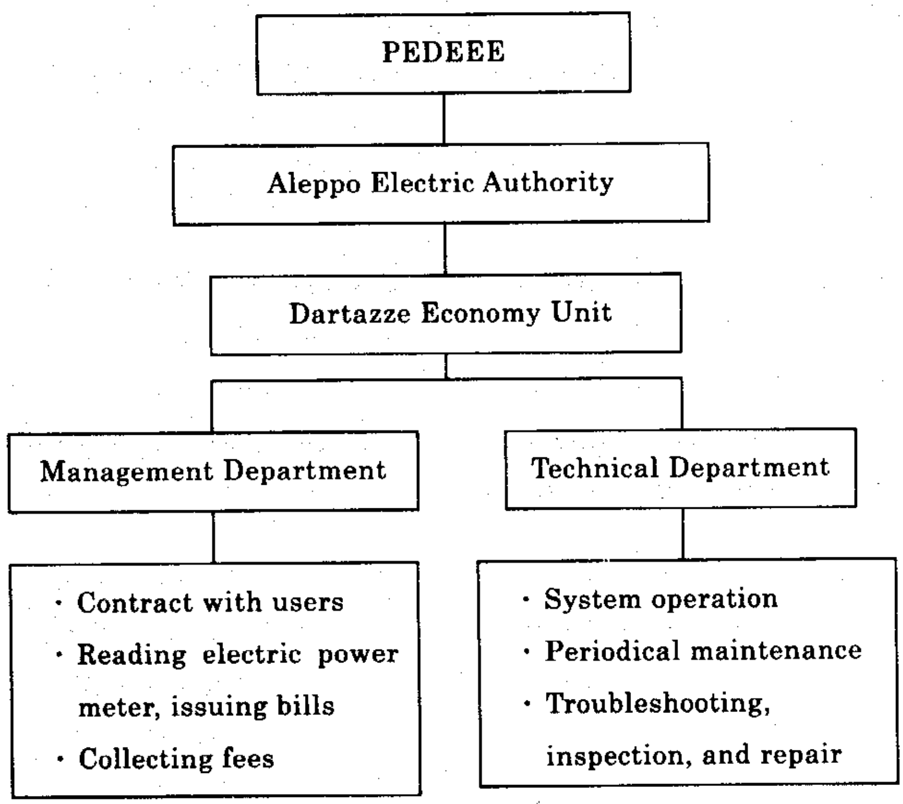

Fig.6.1-2 System management chart of the Aleppo Electric Authority

(3) Setting electricity fees

Originally, the electricity fees from PV systems introduced in this project were considered by PEDEEE and afterwards the consideration was committed to the Aleppo Electric Authority. The results of that consideration with SSRC/HIAST were reported to PEDEEE in September 2000 and fee was revised by PEDEEE as 0.75SP/kWh for all villages in January 2001.

In Zarzita, there is an electric power counter. So the reading of the counter is considered as the usage. For Fedre, Katoura, and Kalif, fixed fees are applied. The amount of power generated is calculated on the assumption of 10 hours of sunshine a day. According to this calculation, fee is charged for every two months. The results of calculations are:

Fedre:	200Wx10hours/dayx30days= 60kWh/month	= 45SP/month
Katoura:	300Wx10hours/dayx30days= 90kWh/month	= 67.5SP/month
Kalif:	500Wx10hours/dayx30days=150kWh/month	= 112.5SP/month

(Kalif: per system)

The total payment fee of a user is the above fee plus about 20% taxes.

For Zarzita, theoretical power consumption of design is 66kWh per day in the whole village. Per family, it is 1.65kWh/day. Per month, it is 49.5kWh. The fee is 37SP. The usage fee of the electric power counter is 25SP per month and therefore the total fee is 62SP per month. For Zarzita, the power consumption varies greatly with users and therefore the fees to each user is different.

6.1.3 Management of the water pumping/desalination system by the Aleppo Water Authority

(1) System management committee

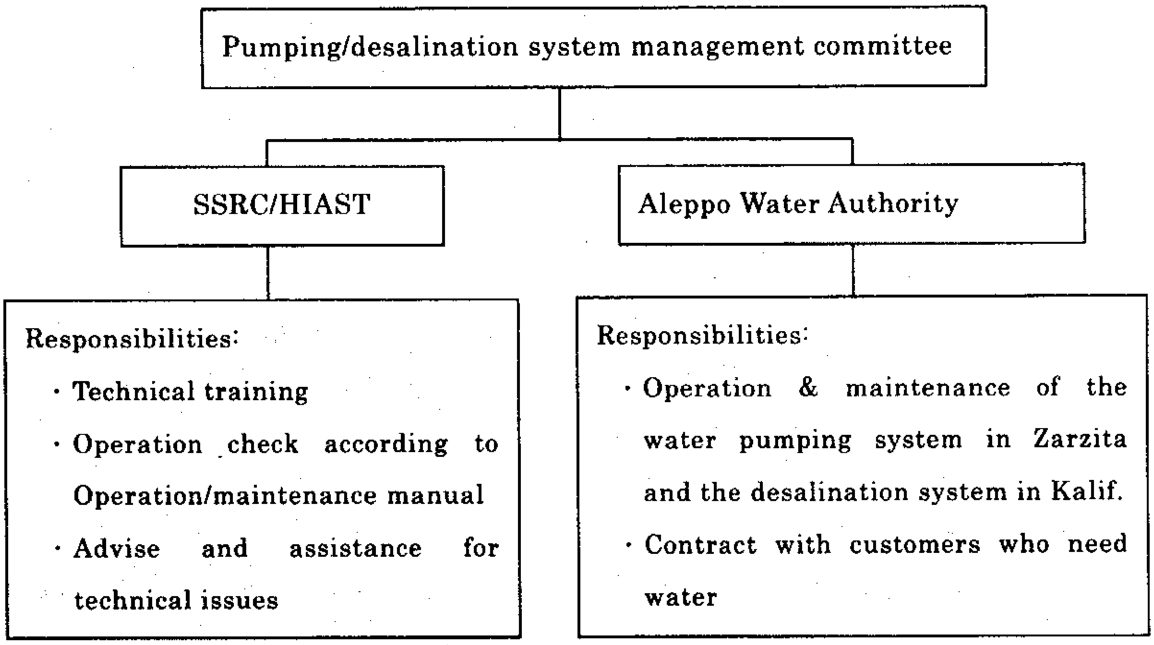

Fig.6.1-3 Water pumping/desalination system management committee

(2) Water pumping/desalination system management chart by the Aleppo Water Authority

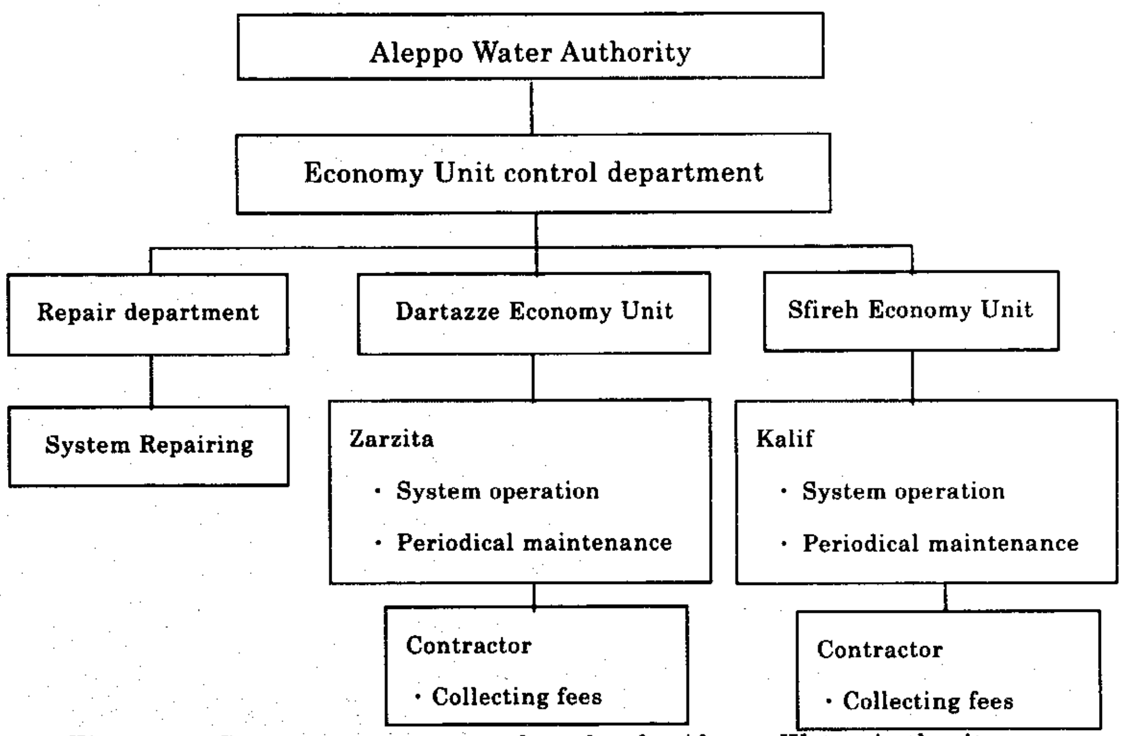

Fig.6.1-4 System management chart by the Aleppo Water Authority

(3) Training of technicians involved by the Authority

Training two persons of Economy Unit in Dartazze was completed in July 1999. One person is operating and maintaining the system as a dedicated technician. Training three persons of Economy Unit in Sfireh was started in February 2000. One of them is living in Kalif and has been trained since the test operation of the desalination system. Now, a dedicated technician executes operation and management of the system.

(4) Selecting contractors and setting fees

In Zarzita and Kalif, contractors were selected. The Aleppo Water Authority charges the contractors for water fees as 6.5SP/m^3 and the contractors charge the users for water fees as 7.0SP/m^3.

(5) Collecting fees

In Zarzita, Economy Unit charges the contractor for water fees before collecting the water fees from users. The users pay an equal share of expenses in a family.

In Kalif, water is distributed to each family using a water tank truck at present. The total water amount is measured when water is supplied into the tank truck. The water fees for each family are calculated and charged when the truck distributes water to the water tank of each family: a water fee of 7SP/m^3 plus usage fee of the tank truck.

6.2 Estimated income into the both authorities

6.2.1 Estimated income of electricity fees

(1) Zarzita

For the centralized system in Zarzita from September 1997 through October 1999, the average electricity demand of each family per month was calculated. As shown in Fig.6.2-1, the average demands vary widely from 10kWh/month or less to 120 kWh/month or more.

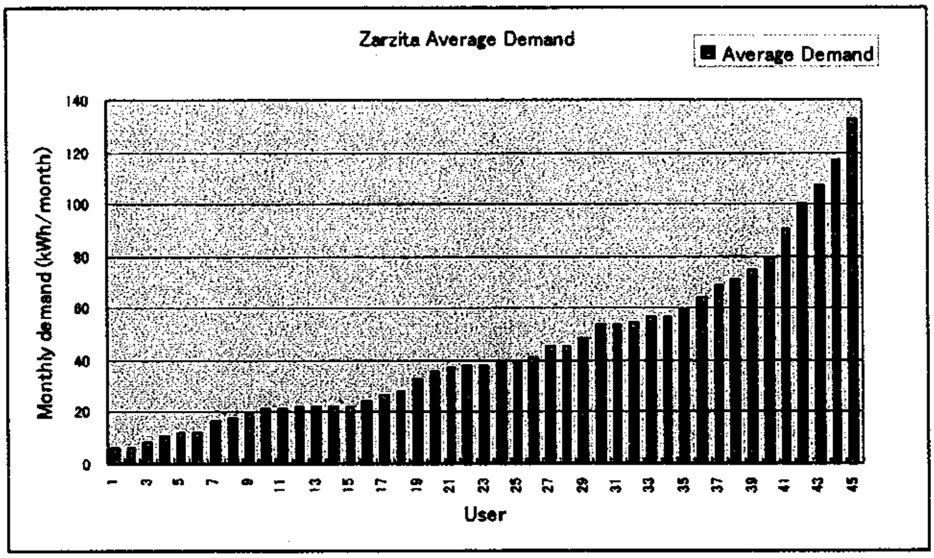

Fig.6.2-1 Monthly average demand of each family

The total amount of these averages is 1,800kWh per month and the total income from fees is calculated assuming that the distribution of the average demand is constant if the need of electricity becomes a designed amount of 66kWh/day x 30days=1,980kWh/month. Based on the newly decided electricity fee that the fee is 0.75SP/kWh for all villages the total monthly fee is 1,485SP. If a meter usage fee of 50SP/user is added every two month, the total monthly fee will be 2,535SP and the total year fee will be 30,420SP(661US＄). The fee per electric power consumption is 1.28SP/kWh (0.028US$/kWh) with counter tariff. The distribution of monthly fees per user is as low as 27.7SP/month and as high as 124.4SP/month (see Figure 6,3-2).

Note that this fee is an estimated fee at present. For example, if the income for next twenty years is estimated, it will be necessary to consider the rising of fees in the future. In test calculation of costs, it is assumed that the inflation rate is 3%/year and the discount rate to the present value is 6.5%/year. For electricity fee, if the inflation rate is 3%/year, the estimated average fee for twenty years will be 1.24 times of the present value.

That is to say, the total year fee will be 37,720SP(820US $). The fee per power consumption is 1.56SP/kWh (0.034US$/kWh) with counter tariff.

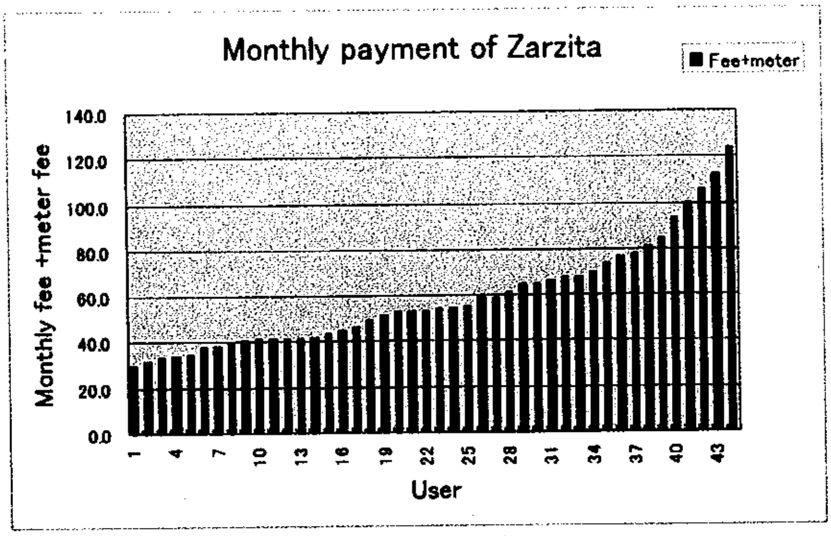

Fig.6.2-2 Distribution of monthly fee

(2) Present fees in Fedre, Katoura, and Kalif;

Fedre:	45SP/month x 13systems x 12 = 7,020SP/year
Katoura:	67.5SP/month x 27systems x 12 = 21,870SP/year
Kalif:	112.5SP/month x 15systems x 12 = 20,250SP/year

The average income estimated for next twenty years considering the inflation rate as 3%;

Fedre:	55.8SP/month x 13systems x 12 = 8,705SP/year
Katoura:	83.7SP/month x 27systems x 12 = 27,119SP/year
Kalif:	139.5SP/month x 15systems x 12 = 25,110SP/year

6.2.2 Estimated income of water fees

The estimated water supply amount;

Zarzita : If $8m^3$/day for May through October and $6m^3$/day for November through February are assumed, then the amount is $2,640m^3$/year.

Kalif: If $3m^3$/day for May through October and $1.5m^3$/day for November through February are assumed, then the amount is $900m^3$/year.

The year income from the present water fee;

Zarzita : 2,640 m^3/year x 6.5 SP/m^3 = 17,160 SP/year

Kalif : 900 m^3/year x 6.5 SP/m^3 = 5,850 SP/year

Total : 23,010 SP (500 US$) (Fee per water consumption is 0.14 US$/$m^3$)

The average income estimated for next twenty years;

Zarzita : 2,640 m^3/year x 8.1 SP/m^3 = 21,384 SP/year

Kalif : 900 m^3/year x 8.1 SP/m^3 = 7,290 SP/year

Total : 28,674 SP (637 US$) (Fee per water consumption is 0.18 US$/$m^3$)

6.3 Considering the operation costs of each system

It is assumed that the PV system and the water pumping/desalination system will operate for twenty years. In this case, the necessary expenses and incremental costs excluding initial investment costs per supply amount are calculated in order to estimate expenses for the Aleppo Electric Authority and the Aleppo Water Authority.

6.3.1 Assumptions before consideration

- Operation costs includes system operation/maintenance costs, repair costs, inspection costs, replacement costs and so on. Indirect costs such as general management costs are included in labor costs.
- Major equipment to be replaced such as inverters for the centralized system and the pumps of the water pumping system has been delivered as spare equipment. Therefore only replacement costs will be added up.
- It is assumed that the life of a battery made in Japan is seven years. The Japanese batteries installed will be replaced seven years later.
- Replacing batteries will be ones made in Syria. It is assumed that the life of Syrian batteries are three years or four years.
- Unit price of labor costs is 400SP/person·day, which is an average cost of one engineer (500 SP/day) and one assistant engineer (300 SP/day).

6.3.2 Break down of operation expenditure for each system

(1) PV electrification system

①Centralized system in Zarzita

a. Costs for updating equipment

✧ Replacing inverters, controllers, etc.

- Equipment costs: Expected life is 10 years. It was already delivered as spare equipment.
- Replacement costs: Labor costs (16 persons·day),

Unit price: 400 Sp/person·day	6,400 SP
Transportation costs (one truck per day)	3,500 SP
Total	9,900 SP

✧ Replacing batteries

- Equipment costs: Batteries made in Syria (200Ah)

140 units Unit price: 3,400 SP	476,000 SP

● Replacement costs: Labor costs (10 persons·day),

Unit price: 400 SP/person/day 4,000 SP

Transportation costs (two trucks per day) 7,000 SP

Total 487,000 SP

b. Maintenance and inspection costs

One periodical inspection every two month 10 persons·day

Unit price: 400 SP/person·day 24,000 SP/year

Battery supplement water (5 litter/year/units)

Unit price: 18 SP/litter 12,600 SP/year

Repair costs (20% of labor costs) 4,800 SP/year

Total 41,400 SP/year

②Individual systems in Fedre, Katoura, and Kalif

The expenses of the individual systems are added up in the same way as the centralized system.

a. Costs for updating equipment

Table 6.3-1 Costs for updating equipment in Fedre, Katoura and Kalif

Items		Fedre	Katoura	Kalif	Remarks
Number of systems		13	27	15(27)	( ) : Number of houses
Inverter		———	———	60,000	Unit price: 4,000 SP/unit
Controller		104,000	216,000	120,000	Unit price: 8,000 SP/unit
Replacement costs					
Labor costs (person·day)		(4)	(10)	(10)	Labor costs: 400 SP/person·day
Sum of money		1,600	4,000	4,000	
Total		105,600	220,000	184,000	
Battery	Capacity (Ah)	200	200	100	In Kalif, six 100Ah batteries per system.
	No. of units	13	27	90	
	Unit price	3,400	3,400	1,900	
	Sum of money	44,200	91,800	171,000	
	Replacement				
	Labor costs (person·day)	(4)	(8)	(8)	Labor costs: 400 SP/person·day
	Sum of money	1,600	3,200	3,200	
	Costs for Transportation	3,500	3,500	3,500	A truck is used.
	Total	49,300	98,500	177,700	

b. Maintenance and inspection costs

Table 6.3-2 Maintenance and inspection costs in Fedre, Katoura, and Kalif

Items	Fedre	Katoura	Kalif	Remarks
Inspection:				One inspection per two month
Number	6	6	6	Labor costs:
Persons・day	4	8	8	400 SP/person・day
Cost	9,600	19,200	19,200	
Battery water	1,170	2,340	4,860	5 L/year/units, Cost : 18 SP/L Kalif : 3 L/year/units
Repair costs	1,920	3,840	3,840	20% of labor costs
Total	12,690	25,380	27,900	

L : litter

(2) Water pumping/desalination system

At water pumping system in Zarzita and the desalination system in Kalif, the dedicated technicians are located for daily operation and management.

①Water pumping system in Zarzita

a. Costs for updating equipment

✧ Replacing inverters for submergible and transfer pump

- Equipment costs: Expected life is 10 years. It was already delivered as spare equipment.
- Replacement costs: Labor costs (eight persons・day)

Unit price: 400 SP/person・day	3,200 SP
Transportation costs (one truck per day)	3,500 SP
Total	6,700 SP

b. Maintenance and inspection costs

✧ Daily operation and management: One person

Unit price x 4,000 SP/month	48,000 SP/year

*Unit price of labor : 4,000 SP/month

✧ One periodical inspection per six month 4 persons/day

Unit price: 400 SP/person・day	3,200 SP/year
Repair costs	640 SP/year
Total	51,840 SP/year

②Desalination system in Kalif

a. Costs for updating equipment

✧ Replacing inverters and controllers

- Equipment costs: Expected life is 10 years. It was already delivered as spare equipment.
- Replacement costs: Labor costs (16 persons·day),

Unit price: 400 SP/person·day 6,400 SP

Transportation costs (one truck per day) 3,500 SP

Total 9,900 SP

✧ Replacing batteries

- Equipment costs: Batteries made in Syria (100Ah)

20 units Unit price: 1,900 SP 38,000 SP

- Replacement costs: Labor costs (2 persons·day),

Unit price: 400 SP/person·day 800 SP

✧ Transportation costs (one truck per day) 3,500 SP

Total 42,300 SP

b. Maintenance and inspection costs

✧ Daily operation and management: 1 person

Unit price: 4,000 SP/month 48,000 SP/year

RO consumption article costs (See Table 6.3-3) 22,800 SP/year

✧ One periodical inspection per two months 3 persons*day

Unit price: 400 SP/person·day 7,200 SP/year

Repair costs 1,440 SP/year

✧ Pump-hanging inspection: One inspection per year

8 persons·day 3,200 SP

Total 82,640 SP

Table 6.3-3 Consumption article costs relating to the RO system (SP)

Items	Monthly costs	Annual costs	Remarks
Cartridge filter	414		It is assumed that the system operates 5.5 hours a day by average.
RO cleaner	32		
Pre-processing (chlorine)	129		
Pre-processing (activated carbon)	1,118		
Post-processing	37		
Replacement parts	170		
Total	1,900	22,800	

(3) Summary of operation costs

The summary of operation costs including equipment replacement costs and maintenance/inspection costs for each system is shown is Table 6.3-4.

Table 6.3-4 Summary of operation costs

①Equipment replacement costs (SP)

Systems	Inverters & controllers for replacement	Batteries for replacement
	Life: 10 years	Life: 3 or 4 years
Zarzita (centralized)	9,900	487,000
Fedre (individual)	105,600	49,300
Katoura (individual)	220,000	98,500
Kalif (individual)	184,000	177,700
Zarzita pumping system	6,700	
Kalif desalination system	9,900	42,300

②Maintenance/inspection costs (SP/year)

Systems	Annual maintenance & inspection costs	Labor costs within maintenance & inspection costs
Zarzita (centralized)	41,400	24,000
Fedre (individual)	12,690	9,600
Katoura (individual)	25,380	19,200
Kalif (individual)	27,900	19,200
Zarzita pumping system	51,840	51,200
Kalif desalination system	82,640	55,200

6.3.3 Incremental costs of power generation and water supply

Based on the above assumptions and breakdown, incremental costs of power generation and water supply are calculated for each system. In the calculation, equipment replacement costs are calculated and allocated to each investment year on an annualized basis at an interest rate of 6.5% and an inflation rate of 3%. Maintenance and inspection costs are also included in each year at an inflation rate of 3%.

The costs per unit are calculated by converting costs for each year into the present value at a discount rate of 6.5% and adding up all the costs, converting the amount of power generation and the amount of water supply into the present value and are adding up them, and dividing the total cost present value by the total power generation present value or the total water supply present value.

(1) Incremental costs of PV electrification

Incremental costs were calculated for both three years and four years of each battery life. The results are shown in Table 6.3-5. The cost of the centralized system in Zarzita is the lowest one because of its large power generation capacity and using the delivered spare equipment such as inverters and controllers for replacement.

The cost of individual system in Fedre is the highest one because of its small power generation, although the replacement costs of batteries and controllers and the maintenance and management costs per system are equal to the system in Katoura.

Table 6.3-5 Incremental costs of PV electrification systems by villages

Items	Zarzita	Fedre	Katoura	Kalif
Expected amount of power generation (kWh/day/system)	66	0.323	0.436	1.09
Number of systems	1	13	27	15
Expected amount of power generation (kWh/year)	24,090	1,534	4,293	5,970
Total present value of power generation amount (SP)	282,689	18,001	50,377	70,056
Total present value of equipment replacement costs (SP)				
Battery life 3 years	1,597,805	160,893	509,361	737,087
Battery life 4 years	1,225,710	124,081	435,812	604,400
Total present value of maintenance & inspection costs (SP)	614,038	188,216	376,432	413,808
Total present value of expenses (SP)				
Battery life 3 years	2,140,616	341,990	851,413	1,108,378
Battery life 4 years	1,773,171	305,557	778,621	977,056
Incremental power generation costs (SP/kWh)				
Battery life 3 years	7.6	19.0	16.9	15.8
Battery life 4 years	6.3	17.0	15.5	13.9

Estimated costs in the future are shown in Fig.6.3-1 for Zarzita. In this figure, the variable cost is maintenance/inspection cost, and the fixed cost is equipment replacement cost. The fixed costs are actually paid every three years for batteries, and every 10 years for inverters and controllers. However, in the calculation of necessary costs, they are treated as annualized costs for three years or 10 years.

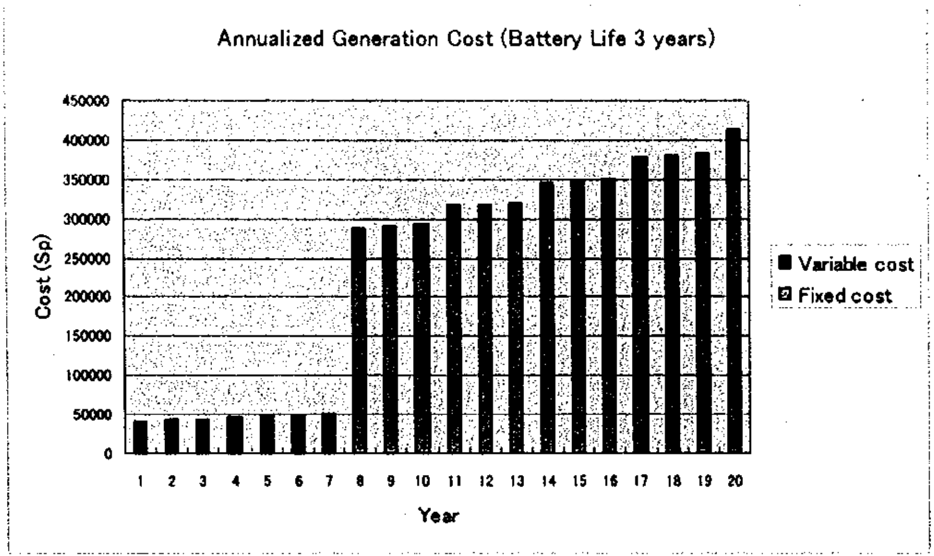

Fig.6.3-1 Annualized generation cost in Zarzita
(Battery life three years)

(2) Incremental costs of PV water pumping/desalination system

The result of similar calculation for the water supply system is shown in Table 6.3-6.

Table 6.3-6 Incremental costs of water supply by villages

Items	Zarzita	Kalif
Expected water supply amount (m^3/year)	2,640	900
Total present value of water supply	30,980	10,561
Total present value of equipment replacement costs (SP)		
Battery life 3 years	3,801	139,489
Battery life 4 years		108,229
Total present value of maintenance & inspection costs (SP)	768,882	1,225,702
Total present value of expenses (SP)		
Battery life 3 years	772,683	1,365,191
Battery life 4 years		1,333,931
Incremental costs of water supply (SP/m^3)		
Battery life 3 years	25	129
Battery life 4 years		126

6.3.4 Costs of power generated and water supply and collected fee

(1) Power generated cost and collected fee (SP/kWh)

For running costs excluding initial costs, costs of power generated are calculated assuming that the life of the battery is 3 years or 4 years. The average collected fee rates to power generated costs estimated for 20 years are calculated: In case of a battery life of 3 years, 20.0% for Zarzita, 29.3% for Fedre, 35.8% for Katoura and 25.6% for Kalif; In case of a battery life of 4 years, 24.0% for Zarzita, 32.8% for Fedre, 39.2% for Katoura, and 29.0% for Kalif. (Collected fee is an average amount of money for 20 years at a fee rising rate of 3%/year.)

Table 6.3-7 Costs of power generated and collected fee (SP/kWh)

Items	Zarzita	Fedre	Katoura	Kalif
Incremental power generated costs				
Battery life 3 years	7.6	19.0	16.9	15.8
Battery life 4 years	6.3	17.0	15.5	13.9
Collected fee	1.56*	5.68	6.31	4.20

*A fee with meter tariff.

To collect all running costs, estimated costs for each user are; 357SP/month (battery life 3 years) or 297SP/month (battery life 4 years) for Zarzita, 191SP/month (battery life 3 years) or 171SP/month (battery life 4 years) for Fedre, 233SP/month (battery life 3 years) or 214SP/month (battery life 4 years) for Katoura, and 545 SP/month (battery life 3 years) or 482SP/month (battery life 4 years) per system for Kalif.

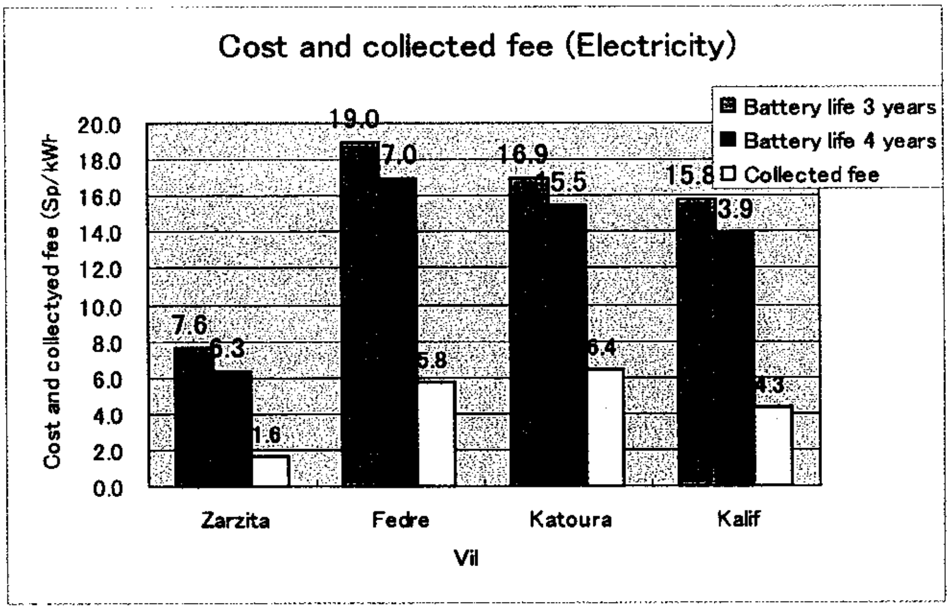

Fig.6.3-2 Power generated cost and collected fee

The balance of power generated cost and the collected fee to be paid by the Aleppo Electric Authority is shown in Table 6.3-8 (average amount of money for 20 years).

Table 6.3-8 Balance to be paid by the Aleppo Electric Authority (SP/year)

Village	Battery life 3 years	Battery life 4 years
Zarzita	144,053	112,740
Fedre	20,263	17,159
Katoura	44,937	38,733
Kalif	68,873	57,682
Total	278,126	226,315

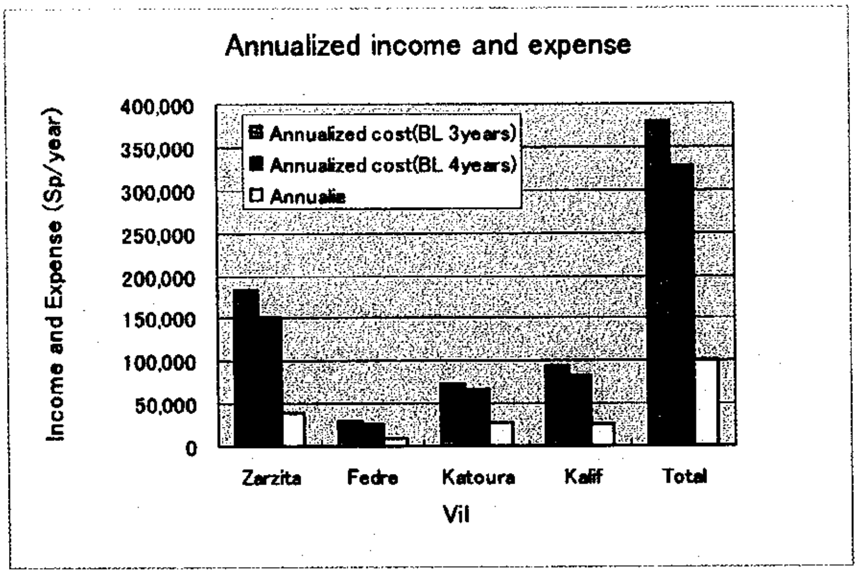

Fig.6.3-3 Adverse balance to be paid by the Aleppo Electric Authority

(2) Water supply cost and collected fee (SP/m^3)

The average collected fee rates to water supply costs estimated for 20 years are 32.4% for the water pumping system in Zarzita and 6.2% and 6.4% for the desalination system in Kalif.

The cost of water supply in Kalif is about five times as much as the cost in Zarzita, and the water amount supplied in Kalif is about one third of the water amount supplied in Zarzita because the cost of consumption articles needed for the operation of the desalination system and the cost of replacing batteries are added.

Table 6.3-9 Water supply cost and collected fee (SP/m^3)

Items	Zarzita	Kalif
Incremental water supply cost		
Battery life 3 years	25	129
Battery life 4 years		126
Collected fee (average for 20 years)	8.1	8.1

*As water pumping system in Zarzita does not use a battery, the cost does not depend on the life of a battery.

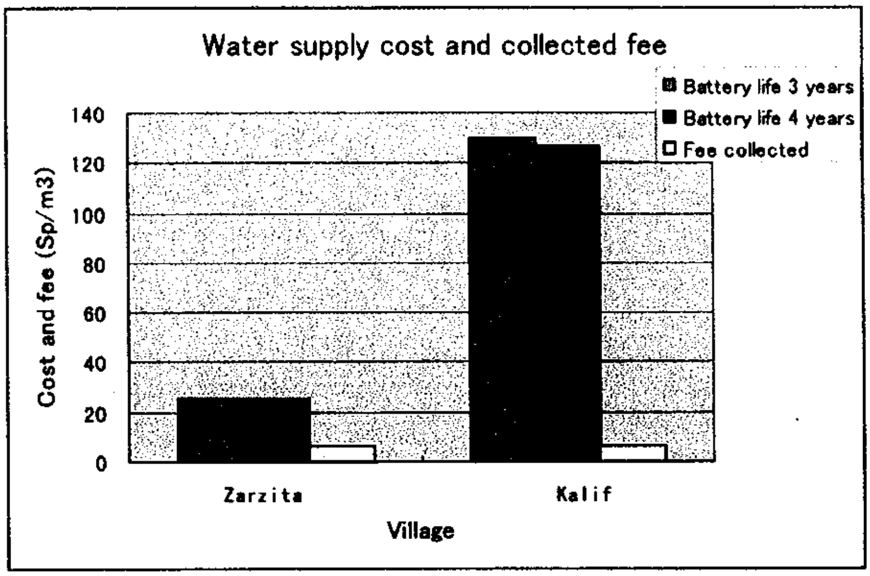

Fig.6.3-4 Cost of water supply and collected fee

The balance of water supply to be paid by the Aleppo Water Authority is shown in Table 6.3-10 (average for 20 years).

Table 6.3-10 Average balance to be paid by the Aleppo Water Authority

(SP/year)

Village	Battery life 3 years	Battery life 4 years
Zarzita	44,157	44,157
Kalif	108,944	106,280
Total	153,101	150,437

6.4 Summary

(1) Management organization

PV systems introduced in four villages are operated and managed by the dedicated persons for maintenance and management of those systems under the guidance of SSRC/HIAST. The Aleppo Electric Authority appointed the person responsible for operation and management of electricity, and the Aleppo Water Authority appointed the person responsible for operation and management of water, respectively. As dedicated organizations, Economy Unit of the Aleppo Electric Authority in Dartazze is responsible for PV electrification systems located in Zarzita, Fedre, Katoura, and Kalif; Economy Unit of the Aleppo Water Authority in Dartazze is responsible for PV water pumping system in Zarzita; and Economy Unit of the Aleppo Water Authority in Sfireh is responsible for the desalination system in Kalif. For the water supply systems, the selected contractors collect water fees.

(2) Fees of electricity and water

a. Electricity fee

For electricity fee, the unit price of 0.75SP/kWh was applied for all of the introduced PV systems. For Zarzita, the reading of the electric power counter is applied to fix collecting fees. For individual systems in Fedre, Katoura, and Kalif, same unit price as Zarzita and fixed rate service is applied assuming 10 hours per day power generated. For Zarzita, power consumption varies greatly with users and therefore the charges to each user is different.

Table 6.4-1 Fee of electricity (SP/kWh)

Item	Zarzita	Fedre	Katoura	Kalif
Supply amount (kWh/year)	24,090	1,534	4,293	5,970
Electricity fee (SP/kWh : present fee)	1.26*	4.58	5.09	3.39
Average monthly fees (SP/user)	62	45	67.5	62.5
Electricity fee (SP/kWh) (Assumed average for 20 years)	1.56*	5.68	6.31	4.20
Average monthly fee (SP/user)	77.2	55.8	83.7	77.5

* Fee of electricity in Zarzita is a fee with counter tariff (25 SP/month).

b. Water fee

According to the consumption, the contractor charges water fee to the users as an unit price of 7.0 SP/m^3. Then the contractor pay water fees as an unit price of 6.5

SP/m^3 to the Aleppo Water Authority. Based on the assumed water supply quantity, annual income for the Water Authority using a unit price of 6.5SP/m^3 is calculated.

Zarzita 2,640m^3/year x 6.5SP/m^3 = 17,160SP/year

Kalif 900m^3/year x 6.5SP/m^3 = 5,850SP/year

Total 23,010SP(500US$)(Fee per water consumption is 0.14US$/m^3)

(3) Estimated incremental costs

Incremental costs without initial investment costs were calculated on the assumption that costs for system replacement and periodical maintenance/inspection are required for 20 years. In the calculation, it is assumed that the life of the batteries made in Japan is seven years, the life of replacing batteries made in Syria is three years or four years, the estimated inflation rate is 3%/year during these periods, and the discount rate to the present value is 6.5%/year.

Table 6.4-2 Estimated incremental cost of electricity (SP/kWh)

Item	Zarzita	Fedre	Katoura	Kalif
Supply amount (kWh/year)	24,090	1,534	4,293	5,970
Battery life 3 years	7.6	19.0	16.9	15.8
Battery life 4 years	6.3	17.0	15.5	13.9

Table 6.4-3 Estimated incremental cost of water (SP/m^3)

	Zarzita pumping-up	Kalif desalination
Supply amount (m^3/year)	2,640	900
Battery life 3 years	25	129
Battery life 4 years		126

(4) Outlook for the future

The electricity fee and the water fee collected from users are not sufficient to maintain, manage, and operate the system and therefore the support from the Aleppo Electric Authority and the Aleppo Water Authority is necessary.

Both PV electrification system and PV water supply system are important as Syrian electrification/water supply systems in rural areas. Therefore it is necessary for the both Authorities to learn and establish those technologies. In other words, the supporting effort of the Aleppo Electric Authority and the Aleppo Water Authority is a prior investment.

The major part of incremental costs is battery replacement costs. The quality and price of a battery have a great effect on the future operational costs. As for the quality of a battery, UNDP researched as one of the cooperative investigation in this project. Technical training to improve the quality of batteries made in Syria is carried out under the guidance of UNDP foreign technical expert and the fruits of such an effort will be expected.

The other parts of system except battery such as charge controllers and inverters for individual systems will be supplied by Syrian domestic producers. The costs of them are also expected to be reduced by development of PV market in Syria. But its effect on the incremental cost of electricity will be not so large as their life of use is expected as 10 years long.

For maintenance and inspections, technicians of the Aleppo Electric Authority and the Aleppo Water Authority will go to the site to perform those tasks. By training local staffs for maintenance in the located villages in order to make periodical maintenance and inspections, the number of visits to the site and the traveling costs could be cut down. This would result in reduced costs for maintenance.

(5) System sustainability

- PV electrification and PV water pumping/desalination system have been managing under the Aleppo Electric Authority and the Aleppo Water Authority respectively. Those are specific technology for both Authorities, therefore, management activity is carried out without any technical difficulty by both Authorities in the future.
- There are large difference between collected fees and substantial maintenance. Both Authorities subsidize to fill this difference.
- According to the system management activity by the both Authorities, sustainability of the introduced PV systems could be kept during their life.