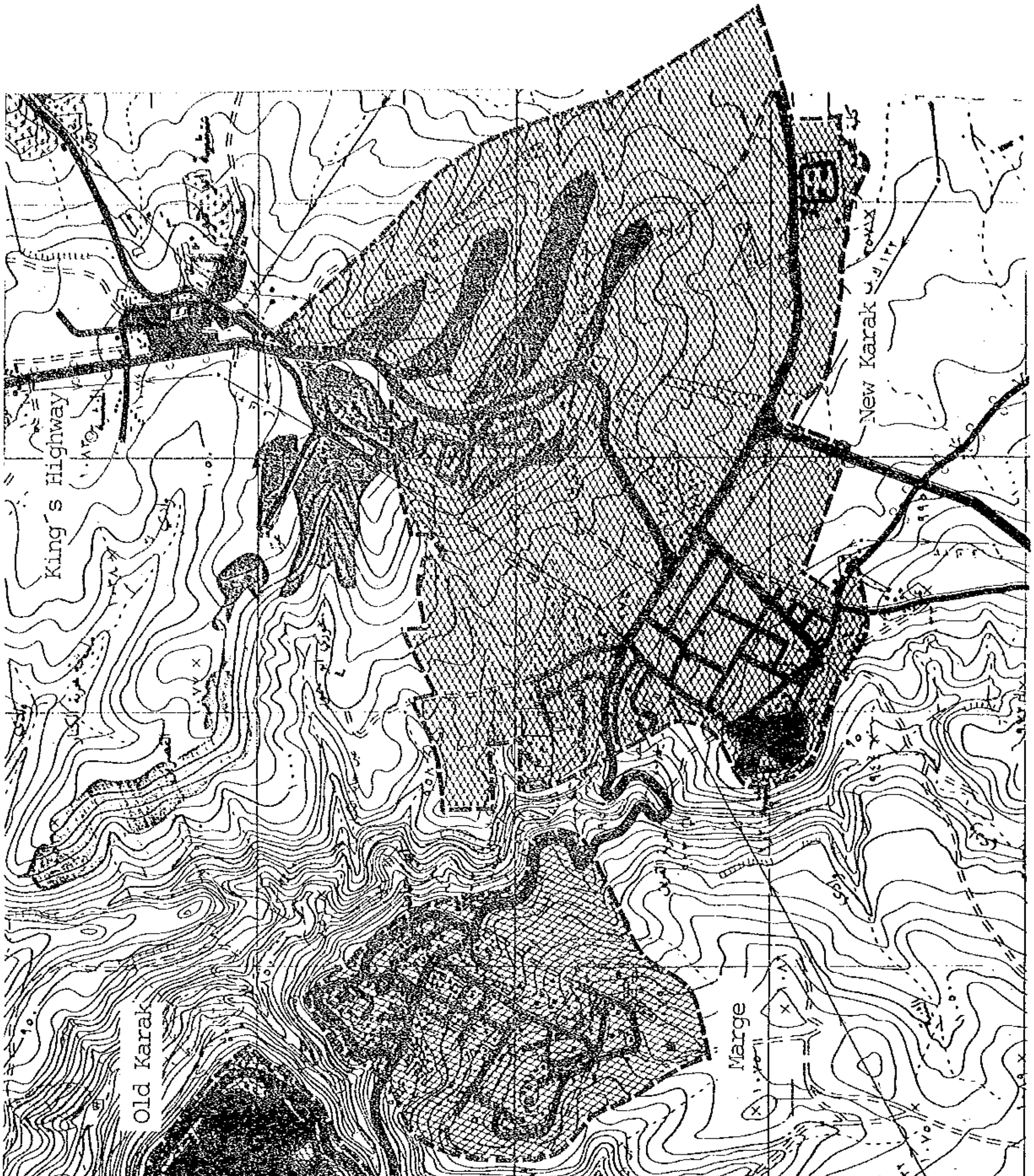


Fig. H-2 Planning Area of Karak Municipality

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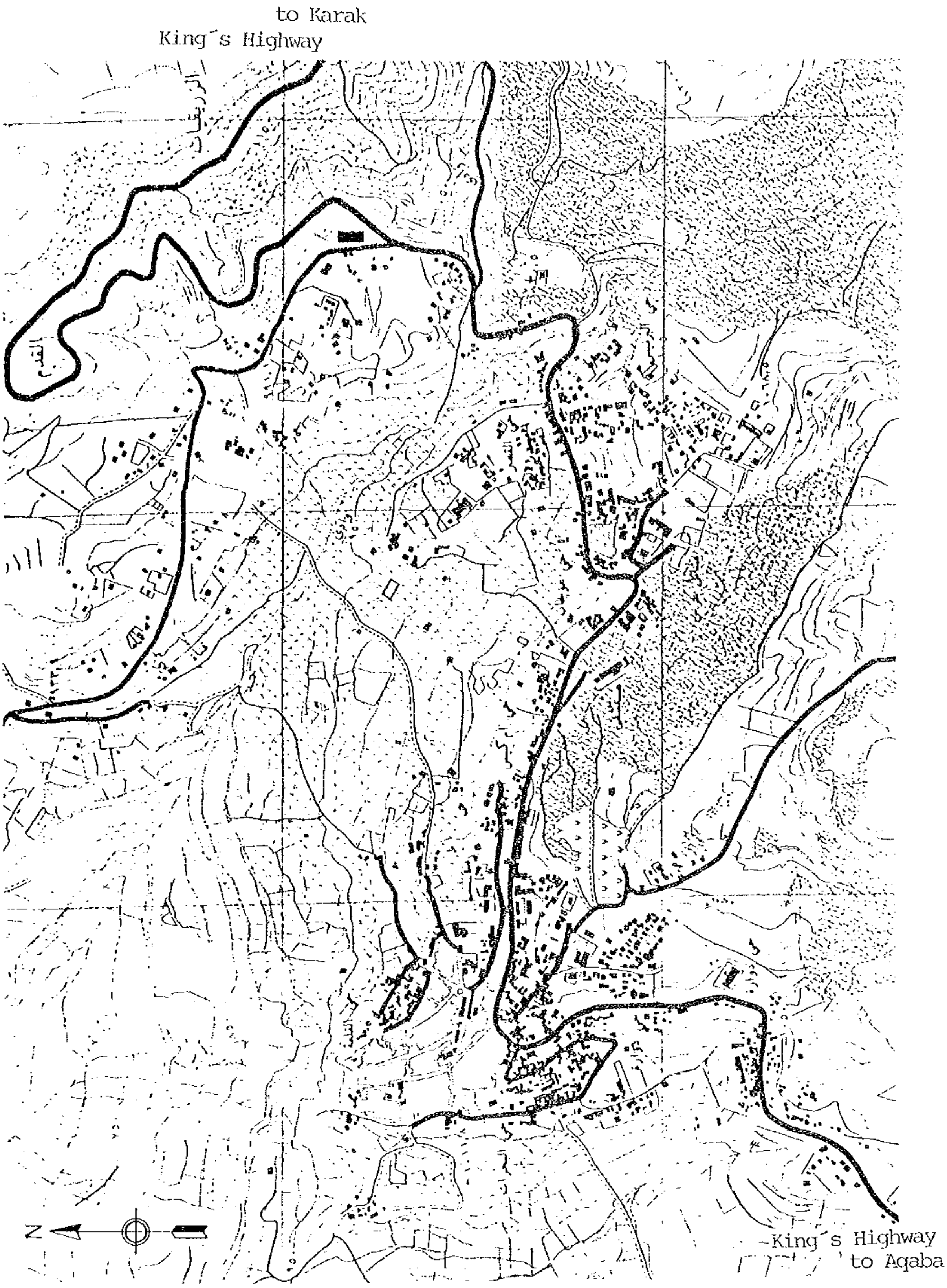


Fig. H-3 Tafila Municipality

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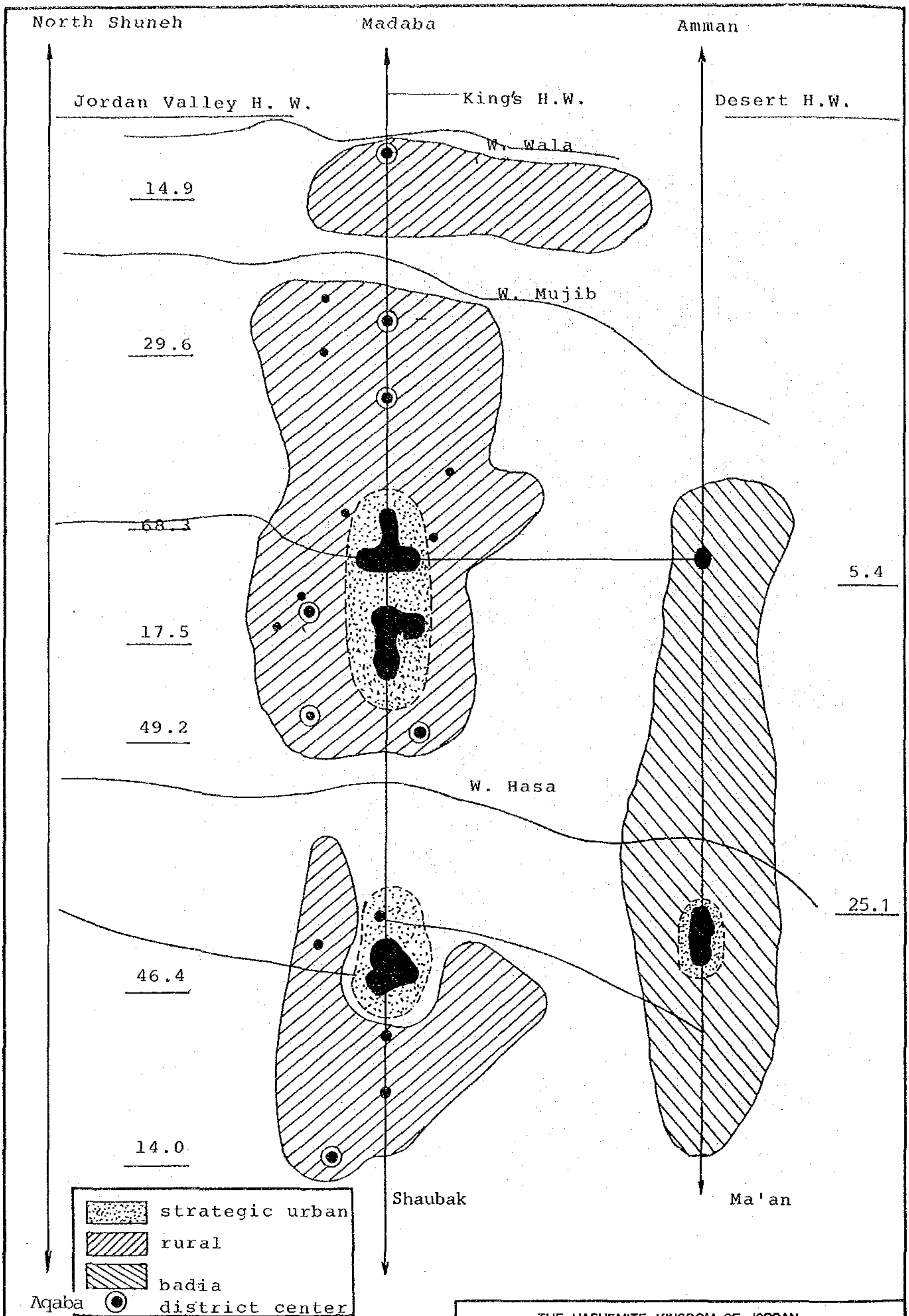


**Fig. H-4 Planned Distribution of Major Settlements (2005)**

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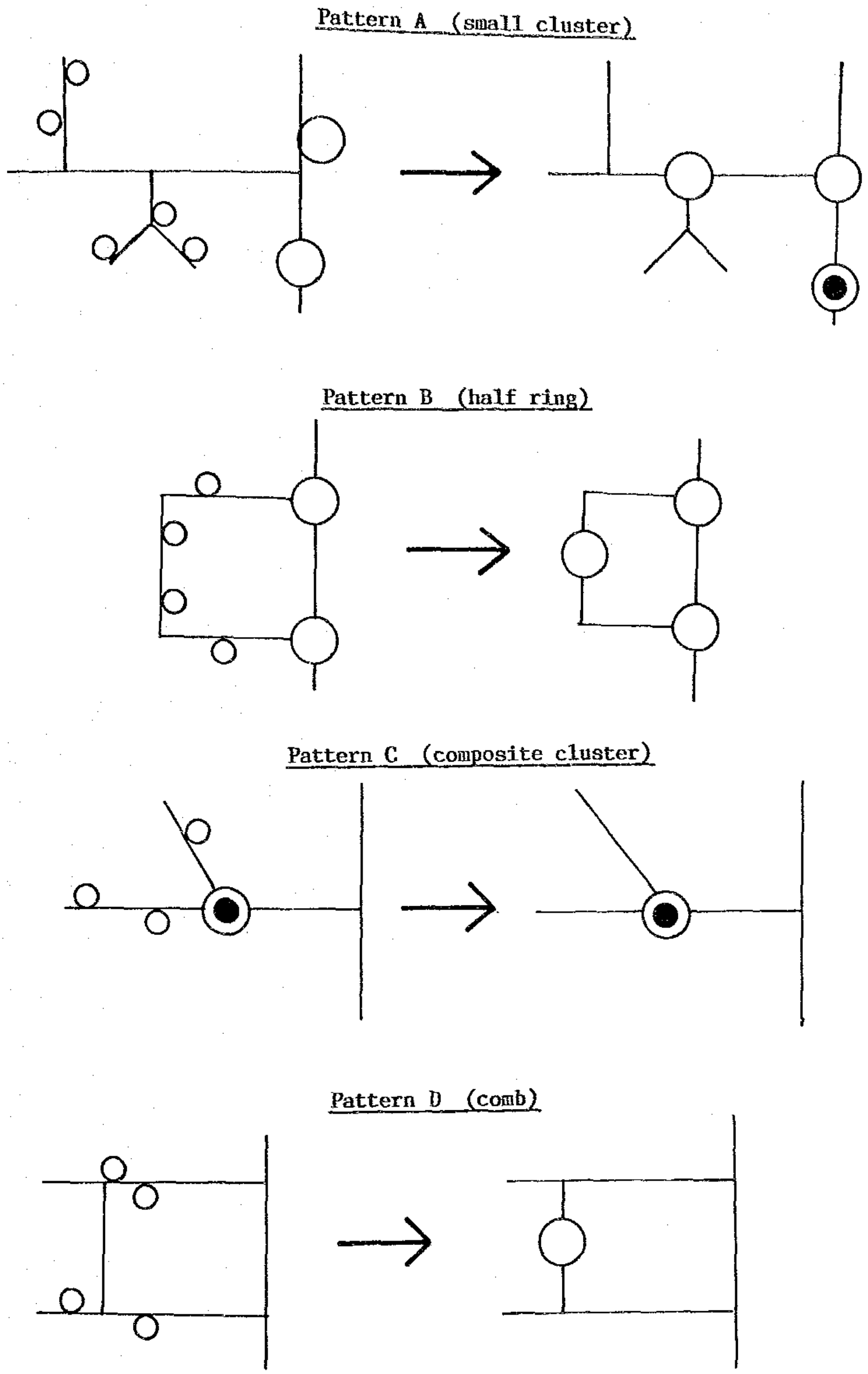


Fig. H-5 Typical Patterns for Village Consolidation

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# ANNEX-I SOLAR AND WIND ENERGY UTILIZATION

THE STUDY ON
INTEGRATED DEVELOPMENT MASTER PLAN
FOR THE KARAK-TAFILA DEVELOPMENT REGION

VOLUME 4: SUPPORTING REPORTS

**ANNEX-I: SOLAR AND WIND ENERGY UTILIZATION**

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# 1. INTRODUCTION

The development potential of solar and wind energy utilization in the Study Area was indicated in previous studies.

The primary objectives in this study are to evaluate the possibility of new energy utilization through comparison with the conventional energy utilization system, and to propose the most appropriate system for new energy application in the Study Area.

This sector study was carried out at a master plan level from July 14, 1987 to August 31, 1987 including a 16-days site survey in Jordan. The result described below should be scrutinized at a further study level.

# 2. BACKGROUND

## 2.1 Current Situation of Electric Power in Jordan

Jordan is one of electrified countries and has been modernized with latest technology in the power system.

Peak load demand in Jordan was abut 560 MW in 1986, including 70 MW of exported power to Syria.

In order to meet the growing power demand, power stations consisting of Hussein Thermal Power Station (390 MW), Aqaba Thermal Power Station (236 MW), some other small thermal power stations, gas turbine power stations, diesel power stations and hydropower stations have been installed. Most of the required power are supplied by the thermal power stations. Jordan imports almost all the required fuel.

The above situation shows that a generation cost of electric power in Jordan will be influenced by fuel price in the international market.

The 400 kV and 132 kV power transmission systems have been established to transmit generated power to consumers, and the 230 kV and 66 kV systems for international interconnection.

Operating power stations in Jordan and their installed capacities are shown in Table I-1. The national grid and its single line diagram are shown in Figs. I-1 and I-2 respectively.

For the ratio of electrification, 95.4 per cent of the total population in Jordan was under electricity service in 1986. This ratio is high in comparison with the ratios for other developing countries.

Even for a rural electrification base, 93.8 per cent of the total rural population has an electricity supply. However, in terms of of the number of villages only 66.5 per cent has been electrified. In Karak and Tafila, the above electrification ratios in number of villages are

63.6 per cent and 60.0 per cent respectively.

Those villages that have large population and are located close to electrified areas can be easily and effectively electrified, while small villages that have small population and are isolated from electrified areas have remained unelectrified due to inefficiency of their electrification with the conventional system.

Information and data on these were obtained from the Jordan Electricity Authority (JEA), and are shown in Tables I-2 and I-3. The overall electric consumption in 1986 is shown in Table I-4 for each sector. Consumption in the domestic sector accounts for 30 per cent of the total power consumption.

## 2.2 Distribution of Population

Population in Jordan was about 2.8 million in 1986. About 60 per cent of the total population lives in Greater Amman, where plentiful urban services are available.

The rural area constitutes approximately 80 per cent of Jordan's land. Population in the rural area was about 1.1 million in 1986, or about 40 per cent of the total. Karak and Tafila Governorates have populations of 112,000 and 37,000 respectively. Fig. I-3 shows location and population size of villages in the Study Area.

## 2.3 Present Conditions of Small Isolated Villages

Some small isolated villages having population of less than 100 inhabitants are not connected with the telephone network, the electricity grid and the water network. These villages have few clinics or hospitals.

It is important to electrify these villages to improve living conditions. The Government intends to electrify these settlements by the end of this century.

## 2.4 Current Situation of Bedou and Settlement

Most of the Bedou in Jordan have nomadized accompanying a great number of sheep, goats and/or camels.

In compliance with the Government policy to settle the Bedou, some Bedou changed their life style from the nomadic life to the settled life. Some of them changed their profession and some of them pastured their livestock around their houses. Other Bedou are nomadizing with tent houses for their camp in the vast area in and around Jordan.

In order to improve the living conditions of the Bedou and to increase the production of livestock, watering stations are needed to provide water at convenient locations in their nomadizing area.

## 2.5 New Energy Development in Jordan and Government Policy

Jordan is dependent on imported fuel and is affected by the world energy situation. Due to the high cost of importing oil and the increasing energy demand, the energy requirements become a real burden on the national economy.

The Government has the following policy to overcome these situation:

- Reducing national energy dependence on the imported oil
- Reducing the imported oil bill through development of domestic resources
- Introducing legislative measures and incentives in the direction of energy conservation

In relation to the policies above, it is important to develop new indigenous energy resources.

Solar and wind energy resources are one of the indigenous and renewable energy resources of Jordan. Jordan is blessed with the most plentiful solar and wind energy in the world.

The solar radiation rate in Jordan is as high as two times if compared with that in Japan, and the number of continues cloudy day is only 2-3 days and is limited only to winter.

Also the wind energy of 150-250 W/$m^2$ is available in the whole Kingdom except the Jordan Valley.

In order to research the application potential of these new energy resources, Royal Scientific Society (RSS) has constructed some experimental pilot plants in cooperation with the German Agency for Technical Cooperation (GTZ) Ltd. of West Germany, and with agencies of EEC, USA, etc.

**2.6 Meteorological Data in the Study Area**

Meteorological data in the Study Area were obtained from Jordan Meteorological Department (JMD) and RSS, and are shown in Tables I-5 to I-9 and in Fig. I-4.

**2.7 Application Effect of Renewable Energy Resources in the Study Area**

The Study Area is a rural area located in the Highlands to the south of Amman. Many young workable people have migrated to Greater Amman to obtain job opportunities. For development of the Study Area, it is important to stop the out-migration.

Electrification is one of the essential factors for development of the rural areas. It will produce the following advantage for development of the Study Area:

- Increase of agricultural production including livestock. The area has extensive and underutilized land.
- Promotion of settlement of the Bedou
- Improvement of living conditions in isolated small villages

Although the Government has a plan to electrify all villages in Jordan with the conventional commercial power system by the end of this century, it is attractive if the new energy resources can be applied for supplying electricity to small isolated villages.

# 3. DEVELOPMENT PLAN IN THE STUDY AREA

## 3.1 Optimum Application System of New Energy

Initial costs of solar and wind energy applications are presently higher than costs of the conventional power supply system which uses distribution lines etc., although running cost of the new energy applications is minimum.

The initial cost of the necessary equipment for the new energy applications such as photovoltaic battery and windmill generator is presently high although the technology innovation has been progressing. For instance, photovoltaic battery equipment presently costs about JD 2.3 per Watt, and the total investment cost will increase in proportion to the design load.

To electrify a small village with the conventional power supply system, construction of a distribution line will inevitably be required, and the distribution line will cost about JD 10,000/km regardless of a scale of the design load.

As for electrification of such an isolated area as requires a long distance distribution line but has small power demand, new energy application would be feasible even at present.

These new energy applications would be expanded widely in the future if the present high equipment cost of photovoltaic battery will become down to a suitable cost, i.e. not more than US$ 1.0/Watt.

As the result of the site investigation and some information obtained from relevant organizations such as RSS, JEA and the Ministry of Energy, the following applications are recommendable:

(1) Electrification of small isolated villages: For example, a case of small villages having less than 45 houses and isolated more than 10 km away from the nearest electrified area is considered.

Assumed demand for a small isolated village is:

(A) Lighting and basic domestic use equipment

- 40 W x 6 persons x 24 hr ≈ 0.58 kWh/day/house

Where, electrification load such as lighting and for basic domestic equipment is assumed at 40 W per person in accordance with the information from RSS. A family size is assumed at 6 person in the rural areas in Jordan.

(B) Water pumping

- $0.163 \times 40 \times 10^{-3}\ m^3$/day/person) x 1/24 x 1/60 x 100 m
  = $4.5 \times 10^{-4}$ kW/person
- $4.5 \times 10^{-4}$ kW/person x 6 persons x 24 hr
  = $6.5 \times 10^{-2}$ kWh/day/house

Where, unit drinking water demand is assumed at 40 litre per capita per day (lcd), and an average depth of wells is assumed at 100 m in static head for calculation of pump in accordance with the information from RSS.

(C) Refrigeration

- 200 W x 8 hr = 1.6 kWh/day/village

Where, provision of one refrigerator with 200 W is required to keep medicines in a clinic which will be established in villages (RSS information).

The total demand for electrification of a small isolated village with 45 houses will then be:

$$P = 1.6 + (0.58 \times 45) + (6.5 \times 10^{-2} \times 45)$$
$$= 31 \text{ kWh/day}$$

(2) Watering Station for Bedou camps: For example, small Watering Stations in the Badia isolated more than 5 km away from the nearest electrified area are considered.

Establishment of the Watering Stations is proposed to supply drinking water necessary for human and domestic animals raised by the Bedou. The number of the Bedou camps per Watering Station is assumed at not more than 10 groups, consisting of 6 persons, 200 sheep and 20 camels per group.

These applications are being extensively studied and developed by RSS through construction of some experimental pilot plants.

The water demand for one Watering Station is assumed as follows:

(A) Water pumping for life of the Bedou family

- $6.5 \times 10^{-2}$ kWh/day/family

Refer to item (B) above for the assumed demand of a small isolated village.

(B) Water pumping for drinking water of sheep and goats

- $0.163 \times 5 \times 10^{-3}$ $m^3$/day/sheep) x 1/24 x 1/60 x 100 m

  = $5.7 \times 10^{-5}$ kW/sheep

- $5.7 \times 10^{-5}$ kW/sheep x 200 sheep x 24 hr

  = $2.7 \times 10^{-1}$ kWh/day/group

Where, average consumption of the drinking water is assumed at 5 litre per sheep per day.

(C) Water pumping for drinking water of camel

- $0.163 \times 40 \times 10^{-3}$ $m^3$/day/camel) x 1/24 x 1/60 x 100 m

  = $4.5 \times 10^{-4}$ kW/camel

- $4.5 \times 10^{-4}$ kW/camel x 20 camels x 24 hr

  = $2.2 \times 10^{-1}$ kWh/day/group

Where, average consumption of the drinking water is assumed at 40 litre per camel per day.

The total demand of one Watering Station for 10 Bedou camps will then be:

$$P = (6.5 \times 10^{-2} + 2.7 \times 10^{-1} + 2.2 \times 10^{-1}) \times 10$$

$$= 5.6 \text{ kWh/day}$$

System diagrams for the above new energy application are shown in Figs. I-5 and I-6. Before implementation of every cases, a study should be made whether the new energy application is economically feasible in comparison with the conventional power application.

Figs. I-7 and I-8 are the result of study for application of new hybrid energy consisting of photovoltaic system and windmill system, to the small isolated village electrification. Fig. I-7 shows cost comparison between the conventional power and the new energy application for the variable size of settlement at an assumed distance of 10 km from the nearest electrified area. Fig. I-8 shows comparison for the variable isolated distance from the nearest electrified area on the assumed size of settlement at 45 households.

Fig. I-9 shows a feasible range of the new energy application which is obtained by integrating Figs. I-7 and I-8. Every cases shown with arrows in the figure are feasible if the new energy system is applied for small isolated village electrification. For instance, for a village having 30 houses and is away more than 8 km from the nearest electrified area, the new energy application is feasible in comparison with the conventional energy supply.

Meanwhile, Figs. I-10 to I-12 are for an isolated Watering Station. Three kinds of new energy application such as a windmill with AC-generator, photovoltaic, and a hybrid system (windmill with DC-generator and photovoltaic) are illustrated.

Fig. I-12 shows a feasible limit of new energy application to an isolated Watering Station for 10 groups of the Bedou. Stations which are away more than 1.0, 1.2, and 1.8 km from the nearest electrified area are feasible to apply the windmill system with an AC-generator, the hybrid system and the photovoltaic system respectively in comparison with the conventional energy utilization.

Fig. I-12 shows that the photovoltaic is most suitable among the three new energy applications. It is due to the reason that the rated power to pump up the water is required during summer season and is not necessary during winter because most of the Bedou will go back to their settlements. The photovoltaic system has such characteristics as two times of energy is available in summer than in winter and is, therefore, most suitable and effective for these utilizations.

3.2 Project Site

As shown in Tables I-5 to I-8, the Study Area has an excellent solar radiation and wind power. However, among three locations in the Study Area; Hasa, Tafila and El Rabba small differences are seen.

(1) Annual mean solar radiations at Tafila and El Rabba are 6.75 $kWh/m^2/day$. That of El Hasa is 5.44 $kWh/m^2/day$, being a little smaller than at Tafila and El Rabba.

(2) For theoretical power of annual mean wind energy, Hasa has large potential of 247 $W/m^2$. On the other hand, Tafila and El Rabba have 155 $W/m^2$ and 184 $W/m^2$ respectively. Therefore, wind energy in Hasa is approximately 160 per cent of those in other locations.

(3) Wind energy variation in seasons is large only at Hasa, where the wind energy is large in summer and small in winter having the similar variation trend to that of solar radiation. Tafila and El Rabba have small variations of wind energy in seasons.

To apply the photovoltaic system which has such a tendency that available power is large in summer and small in winter, certain compensation will be required to supplement the shortage of power in winter. The hybrid system consisting of the photovoltaic system and windmill system can, in general, meet this requirement.

El Rabba and Tafila except Hasa are suitable for the hybrid system application, because there is a tendency that the wind energy in winter is large and constant while the solar radiation is small, and that the wind energy is small in summer while the solar radiation is large and constant adversely. Therefore, for electrification of an isolated small village where constant power supply is required in every season, the hybrid system is applicable particularly to such areas as El Rabba and Tafila.

Regarding the Watering Station for Bedou camps, the required power supply can be reduced in winter but should be increased in summer because water could be obtained from wadis in winter and some Bedou will go out of the area to other warmer places or to their settlements in winter. Therefore, a Watering Station for some Bedou can be installed at Hasa where the power supply will drop in winter.

As indicated in Table I-2, numbers of non-electrified villages in Karak and Tafila were 43 (10,000 in total population) and 22 (6,000 in total population) respectively in 1986. Most of these villages could be electrified by the hybrid system. Villages for the hybrid system application should be selected and decided through a further economic study and taking account of the JEA's future electrification plan.

An extensive area located to the west of the Desert Highway is considered to be suitable for locating the Watering Station because the area has a higher potential as a grazing land for livestock than the land to the east of the Desert Highway, and is isolated from the existing electrified areas. The number of required Watering Stations and their locations should be decided through a further study.

### 3.3 Necessity of Experimental Pilot Plant

Preceding installation of application plants, a pilot plant should be installed and experimented for the reasons below:

(1) Through operation of the pilot plant, the actual natural conditions, to which the plant will be exposed, should be clarified and confirmed such as irradiation, duration of insolation, wind velocity, wind energy, etc. These data in the actual planned area are important to review and improve the design of the new energy application system, which is first worked out on the basis of the meteorological data obtained by JMD.

(2) An optimum composition ratio between photovoltaic battery capacity and windmill generator capacity should be examined through the pilot plant for design of the hybrid application system.

(3) Deterioration ratios of equipment should be examined through actual operation.

(4) The effect of the new energy application systems should be demonstrated to people so as to encourage them towards development of the Badia.

### 3.4 Scale and Location of Experimental Pilot Plant

(1) Mini Pilot Plant in the Hasa Oasis Park: It is proposed to install the pilot plant in the Hasa Oasis Park together with other park facilities such as solar street lights and a solar-driven fountain for demonstration purposes in view of:

(A) Higher demonstration effects for the proximity to the Desert Highway

(B) Possibility to obtain suitable and strong wind energy in comparison with Karak or Tafila (refer to Fig. I-4)

(C) Easy approach from Amman to the experimental site

(D) Easy mutual check and review through obtained data of the existing Darawish pilot plant having a similar system and similar meteorological conditions

The following mini models are recommended as a pilot plant in order to minimize a required investment within the scope for obtaining necessary data:

(A) A small Watering Station for a Bedou camp having a 1.0 kW windmill generator (assumed as a load for two groups of the Bedou)

(B) - do -, having a 0.7 kWp photovoltaic battery (- do -)

(C) - do -, having the hybrid system consisting of 0.3 kW windmill generator and 0.5 kWp photovoltaic battery (- do -)

(D) A small isolated village electrification system having the hybrid system of 1.0 kW windmill generator and 1.0 kWp photovoltaic battery (assumed as a load for one isolated house and one isolated clinic).

(2) Actual level pilot plants for the Watering Station: In addition to the Mini Pilot mentioned above, it is proposed to install three actual

level pilot plants for the Watering Station; one each for three types of the new energy application system. Through the experimental operation of the actual level pilot plants, the followings can be obtained:

(A) The most probable number of the Bedou groups which will utilize the Watering Station

(B) Confirmation if the equipment is withstandable to a site environment such as the desert etc.

(C) Actual help for the Bedou

Their prospective locations are shown in Fig. I-14. Final location, however, should be restudied in consideration of such factors as the relation with isolated distance from the electrified area, potential as grazing land, an economical depth of a well, and so forth.

The scale of the actual level pilot plants is proposed as follows:

(A) Watering Station for the Bedou camp having a 4.5 kW windmill generator (assumed as a load for 10 groups of Bedou)

(B) - do -, having a 2 kWp photovoltaic battery (- do -)

(C) - do -, having the hybrid system consisting of 1.0 kW windmill generator and 2.5 kWp photovoltaic battery (- do -)

## 3.5 Main Facilities and Equipment for Experimental Pilot Plants

The facilities and equipment are recommended to be provided as shown below at the proposed pilot plant sites; Hasa Oasis Park and the three locations for Watering Stations.

### 3.5.1 Hasa Mini Pilot Plant

(1) <u>Facilities</u>

- Model local house .................................. 1 house
- Pump house .......................................... 1 house
- Well (assumed as 100 m of head) ...................... 1 well
- Drinking water distributor for livestock ............ 1 set
- Others (water supply pipe, gate and fence
  guard house, parking lots, foundation, etc. ........... 1 lot

A room to install the measuring instruments for the experimental plant, a showroom for demonstration, a guestroom, etc. will be provided in the model house. A deep well will be utilized in common for three kinds of Watering Station mini pilot plant.

(2) Equipment

(A) Mini Pilot Plant for the Watering Station utilizing windmill generator

- Windmill with AC generator (propeller upper deflection type, 1.0 kW) .................................. 1 set
- Tower structure to mount the windmill with generator ............................................ 1 set
- Deep well water pump (0.6 kW, electric motor driven) .......................................... 1 set
- Water storage tank (for 3 days) ......................... 1 set
- Control panel ........................................... 1 set
- Measuring instruments and automatic recording equipment with a personal computer ........... 1 set

(B) Mini Pilot Plant for the Watering Station utilizing photovoltaic system

- Solar battery (0.7 kWp) ................................. 1 set
- Array structure for solar battery ...................... 1 set
- Inverter (0.6 kVA) ...................................... 1 set
- Deep well water pump (0.3 kW, electric motor driven) .......................................... 1 set
- Water storage tank (for 3 days) ......................... 1 set
- Control panel ........................................... 1 set
- Measuring instruments and automatic recording equipment with a personal computer ..................... 1 set
  (The measuring instruments and recording equipment may be applied in common for every mini pilot plant in the Hasa Oasis Park.)

(C) <u>Mini Pilot Plant for the Watering Station utilizing hybrid system</u>

- Windmill with DC generator (propeller upper deflection type, 0.3 kW) .......................... 1 set
- Solar battery (0.5 kWp) .................................. 1 set
- Tower structure to mount the windmill with generator ..... 1 set
- Array structure for solar battery ....................... 1 set
- Inverter (0.8 kVA) ....................................... 1 set
- Deep well water pump (0.4 kW, electric motor driven)...... 1 set
- Water storage tank (for 3 days) .......................... 1 set
- Control panel ............................................ 1 set
- Measuring instruments and automatic recording equipment with a personal computer ...................... 1 set

(D) <u>Mini Pilot for the small isolated village electrification</u>

- Windmill with DC generator (propeller upper deflection type, 1.0 kW) .............................. 1 set
- Solar battery (1.0 kWp) ................................. 1 set
- Tower structure to mount the windmill with generator .... 1 set
- Array structure for solar battery ...................... 1 set
- Storage battery (12 kWh for 2 days of non-sun shine and non-wind)..................................... 1 set
- Inverter (1 kVA) ........................................ 1 set
- Lighting fixture (40 W fluorescent lamp) ................ 2 pcs
- Basic domestic use equipment (Television set-100W, ceiling fan - 60 W) .................................. 1 lot
- Refrigerator for clinic (200 W) ......................... 1 set
- Control panel
- Measuring instruments and automatic recording equipment with a personal computer ..................... 1 set

As mentioned in Paragraph (1) of Section 3.1, a pump for supplying drinking water will be required in the actual station. However, the pumping equipment is not included in the above list for the mini pilot plant because it is very small.

### 3.5.2 Three Prototype Pilot Plants for Watering Station

(1) Facilities

- Pump house .................................... 1 house/station
- Well (assumed as 100m of head) ............... 1 set/station
- Drinking water distributor for livestock ..... 1 set/station
- Others (water supply pipe, gate and fence, parking lot, etc.) ........................... 1 lot/station

(2) Equipment

(A) A Watering Station utilizing windmill generator

- Windmill with AC generator (propeller upper deflection type, 4.5 kW) ................................ 1 set
- Tower structure to mount the windmill with generator .... 1 set
- Deep well water pump (3 kW, electric motor driven) ........................................... 1 set
- Water storage tank (for 3 days) ......................... 1 set
- Control panel ........................................... 1 set
- Measuring instruments and automatic recording equipment with a personal computer ..................... 1 set

(B) A Watering Station utilizing photovoltaic system

- Solar Battery (3.0 kWp) ................................ 1 set
- Array structure for solar battery ...................... 1 set
- Inverter (3.0 kVA) ..................................... 1 set
- Deep well water pump (1.5 kW, electric motor driven ) ......................................... 1 set
- Water storage tank (for 3 days)........................ 1 set
- Control Panel .......................................... 1 set
- Measuring instruments and automatic recording equipment with a personal computer .................... 1 set

(C) A Watering Station utilizing hybrid system

- Windmill with DC generator (propeller upper deflection type, 1.0 kW) .................................. 1 set
- Solar battery (2.5 kWp) .................................. 1 set
- Tower structure to mount the windmill with generator .... 1 set
- Array structure for solar battery ...................... 1 set
- Inverter (3.5 kVA) ...................................... 1 set
- Deep well water pump (1.7 kW, electric motor driven) ........................................... 1 set
- Water storage tank (for 3 days) ........................ 1 set
- Control panel ........................................... 1 set
- Measuring instruments and automatic recording equipment with a personal computer ..................... 1 set

## 3.6 Cost for Experimental Pilot Plant

Approximate costs of the pilot plants are estimated as follows:

(1) Hasa Mini Pilot Plant

(A) Facilities JD 42,200

(B) Equipment

- Mini pilot plant for the Watering Station utilizing windmill generator including JD 34,100 for measuring instruments and recording equipment JD 39,500
- Mini pilot plant for the Water Station utilizing photovoltaic generator JD 5,800
- Mini pilot plant for the Watering Station utilizing hybrid system JD 6,500
- Mini pilot for the small isolated village electrification JD 12,900

Total for Hasa Mini Pilot Plant ............... JD 106,900

(2) Three Prototype Pilot Plants

| | | |
|---|---|---|
| (A) | Facilities (JD 25,600 x 3 plants) | JD 76,800 |
| (B) | Equipment | |
| | - Actual level pilot plant utilizing windmill generator | JD 54,900 |
| | - Actual level pilot plant utilizing photovoltaic generator | JD 48,900 |
| | - Actual level pilot plant utilizing hybrid system | JD 50,700 |
| | Total for three local site pilot plants ........ | JD 231,300 |

| | | |
|---|---|---|
| (3) | Guidance service for operation including assist of data analyzing (2 engineers for 6 months...total 12 man months) | JD 63,800 |

### 3.7 Implementation Schedule

As seen on the time schedule in Fig. I-15, manufacturing of the equipment will take 3.5 months. Consequently, 13 months will be required from the start of the work to the inauguration of the project.

In addition, Fig. I-16 shows the time schedule up to implementation of the actual plants. After completion of the pilot plant, the experiment should be carried out for at least 1 year to obtain actual meteorological data and data for matching an expected output from the new energy application systems with a connected load.

Through the experiment on the basis of the above pilot plants, it should be judged whether the actual project is feasible or not, and some adjustments and modifications would be made on the system and equipment design.

### 3.8 Organization

Through the overall stage from construction of the pilot plant up to completion of the actual plant as shown on the time schedule in Fig. I-16, the project should be supervised by the governmental organization in cooperation with MOP, MMRAE, RSS, JEA, JMD, NRA, Mu'tah University and so forth.

Especially, in design and operation stages including measurements of data in the pilot plants, assistance of RSS which has plentiful experiences for new energy systems will be required. Cooperation of consultants may be needed to lead to the success.

# 4. CONCLUSIONS AND RECOMMENDATIONS

One of the major advantage of the new energy application is that both solar and wind energy is available at a site of demand (decentralized energy production and supply systems). For example, windmill and solar systems for water pumping can be installed at a point of water source.

Another major advantage is that the new energy application systems do not require frequent maintenance; "maintenance free".

However, its practical utilization has not spread until now in the world due to such constraints as its high equipment cost at a present level of technology innovation and insufficient meteorological data for its design.

The cost of the new energy system will decrease towards the future owing to the continuing technology innovation made worldwide. While the cost of the conventional energy system would adversely increase along with price of the fossil fuel in the international market. It will be effective and attractive to develop the new energy application systems in the Study Area where solar and wind energy is abundant.

Both the proposed new energy applications, a small isolated village electrification and a small Watering Station in the Badia for the Bedou are feasible even at a present level of the equipment cost. They do not need to transport fuels, but they are maintenance free, which is an important factor for application to those areas which are not connected with roads.

The economic viability and unexpectable problems for actual applications should be examined and solved through operation of the pilot plants.

It is, therefore, strongly recommended that, preceding the installation of actual plants, the pilot plants should be constructed and experimented to avoid such risks as a shortage of the power output against the expected output.

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Volume IV : State of the Art Survey on Solar and Wind Energy related to Jordan's Needs

Volume V : Possible Applications of Solar Energy in Jordan

# TABLES

Table I-1 OPERATING POWER STATIONS IN JORDAN AND THEIR INSTALLED CAPACITIES

(MW)

| | Hydro | Steam | Gas | Diesel | Total |
|---|---|---|---|---|---|
| 1. JEA | 3 | 623 | 182 | 56.5 | 864.5 |
| HTPS | - | 3x33 | 1x14 | - | 395 |
| | - | 4x66 | 1x18 | | |
| ATPS | 3 | 2x130 | - | - | 263 |
| Marka P.S. | - | - | 4x18 | 30 | 102 |
| Amman South G.T. | - | - | 2x30 | - | 60 |
| Aqaba Central P.S. | - | - | | 2x3.5 | 22 |
| | | | 1x18 | 3x5 | |
| Karak P.S. | - | - | - | 3x1.5 | 22.5 |
| 2. Other Organizations | 4 | 73 | - | 37.5 | 114.5 |
| IDECO | - | - | - | 6 | 6 |
| Central Factory (Fuheis) | - | - | - | 9 | 9 |
| Petroleum Refinery Co. | - | 14 | - | 2 | 16 |
| Arab Potash Co. | - | 15 | - | - | 15 |
| Fertilizer complex | - | 44 | - | - | 44 |
| El Hassa Phosphate Mine | - | - | - | 12 | 12 |
| King Talal Dam | 4 | - | - | - | 4 |
| Municipalities & Others | - | - | - | 8.5 | 8.5 |
| Total | 7 | 696 | 182 | 94 | 979 |

Source: JEA

Table I-2 RURAL ELECTRIFICATION IN JORDAN AS OF 1986

| Area | Total Villages | | Electrified Villages | | No. of Villages Electrified as% of the total in Each Area | |
|---|---|---|---|---|---|---|
| | Villages | Pop. (000's) | Villages | Pop. (000's) | Villages | Pop. |
| Amman & Balqa | 333 | 348 | 180 | 313 | 54.1 | 90 |
| Irbid | 345 | 495 | 287 | 489 | 83.2 | 98.7 |
| Jordan Valley | 65 | 96 | 55 | 95 | 84.6 | 98.9 |
| Karak | 118 | 102 | 75 | 92 | 63.6 | 90 |
| Ma'an | 69 | 49 | 26 | 37 | 37.7 | 75.5 |
| Tafila & Shaubak | 55 | 35 | 33 | 29 | 60 | 82.8 |
| Total | 985 | 1125 | 656 | 1055 | 66.5 | 93.8 |

Source: JEA

Table I-3 NUMBER OF VILLAGES TO BE ELECTRIFIED IN 1987

| Area | No. of Villages | Population (000's) | % of the total in Each Area |
|---|---|---|---|
| Amman & Balqa | 28 | 17 | 4.7 |
| Irbid | 20 | 3 | 0.6 |
| South Area | 17 | 4 | 1.4 |
| Total | 65 | 24 | 2.1 |

Source: JEA

## Table I-4 ELECTRICAL ENERGY CONSUMPTION BY SECTOR

(GWh)

| | Domestic | Industrial | Commercial | Water Pumping | Street Lighting | Others | Total |
|---|---|---|---|---|---|---|---|
| JEA | 72 | 12 | 41 | 67 | 9 | 5.6 | 206.6 |
| JEPCO | 520.5 | 208.5 | 173.8 | 125 | 31.6 | 38.6 | 1098.1 |
| IDECO | 110.2 | 9.7 | 16.6 | 68.7 | 14 | 17.8 | 237 |
| Industrial Companies | - | 676 | - | - | - | - | 676 |
| Other Companies | 1.8 | 0 | 39 | 65 | - | - | 105.8 |
| Total 1986 | 704.5 | 906.2 | 270.4 | 325.7 | 54.6 | 62 | 2323.4 |
| 1985 | 655 | 903 | 268 | 215 | 46 | 64 | 2151 |
| 1984 | 604 | 851 | 233 | 151 | 38 | 67 | 1944 |
| 1983 | 539 | 715 | 177 | 108 | 28 | 56 | 1623 |
| 1982 | 455 | 488 | 160 | 98 | 25 | 48 | 1274 |
| 1981 | 382 | 349 | 140 | 84 | 20 | 53 | 1028 |

Source: JEA

## Table I-5 MONTHLY MEAN WIND SPEED

(m/s)

| No. Station | Elev. (m) | Lat. (° ′) | long (° ′) | Jan. | Feb. | Mar. | Apr. | May. | Jun. | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Er Rabba | 920 | 31 16 | 35 45 | 6.38 | 6.47 | 6.6 | 6.55 | 5.29 | 5.95 | 5.99 | 5.64 | 5.34 | 5.19 | 5.6 | 5.76 |
| 2. Tafila | 1200 | 30 47 | 35 43 | 5.76 | 5.66 | 6.96 | 5.15 | 5.42 | 5.33 | 5.44 | 5.1 | 4.33 | 4.76 | 5.16 | 5.12 |
| 3. El Hasa | 865 | 30 49 | 35 58 | 5.49 | 6.1 | 6.15 | 6.95 | 6.77 | 7.42 | 7.76 | 7.57 | 6.25 | 5.17 | 5.14 | 4.82 |

Source: JMD

Table I-6 MONTHLY MEAN THEORETICAL POWER OF WIND

($W/m^2$)

| No. Station | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Er Rabba | 246 | 252 | 265 | 261 | 199 | 199 | 206 | 176 | 152 | 141 | 176 | 185 | 184 |
| 2. Tafila | 185 | 177 | 202 | 220 | 157 | 151 | 159 | 134 | 91 | 113 | 139 | 136 | 155 |
| 3. El Hasa | 163 | 216 | 218 | 305 | 283 | 364 | 410 | 384 | 230 | 139 | 138 | 166 | 247 |

Source: JMD

Table I-7 MEAN SUNSHINE DURATION

(hr/day)

| No. Station | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Er Rabba | 6.93 | 7.74 | 8.45 | 9.08 | 11.27 | 12.15 | 12.35 | 11.82 | 10.61 | 9.52 | 8.15 | 6.82 | 9.58 |
| (S.D.) | 1.1 | 0.6 | 0.7 | 0.6 | 0.6 | 0.2 | 0.2 | 0.2 | 0.4 | 1.1 | 0.6 | 0.9 | 0.18 |
| 2. Tafila | 6.93 | 7.74 | 8.45 | 9.08 | 11.27 | 12.15 | 12.35 | 11.82 | 10.61 | 9.52 | 8.15 | 6.82 | 9.58 |
| (S.D.) | 1.1 | 0.6 | 0.7 | 0.6 | 0.6 | 0.2 | 0.2 | 0.2 | 0.4 | 0.5 | 0.4 | 0.9 | 0.18 |
| 3. El Hasa | 6.07 | 6.95 | 7.7 | 7.97 | 10.58 | 11.91 | 12.27 | 11.7 | 10.41 | 9.11 | 7.67 | 5.91 | 9.05 |
| (S.D.) | 0.8 | 1 | 0.7 | 0.9 | 0.6 | 0.5 | 0.3 | 0.3 | 0.4 | 0.7 | 0.9 | 0.7 | 0.26 |

Source: JMD
Note: S.D. means standard deviation.

Table I-8 ESTIMATED MEAN SOLAR RADIATION

($kWh/m^2/day$)

| No. Station | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Er Rabba | 4.67 | 5.55 | 6.51 | 7.49 | 8.73 | 8.55 | 8.73 | 7.99 | 7.19 | 6.1 | 4.98 | 4.38 | 6.75 |
| 2. Tafila | 4.67 | 5.55 | 6.51 | 7.49 | 8.73 | 8.55 | 8.73 | 7.99 | 7.19 | 6.1 | 4.98 | 4.38 | 6.75 |
| 3. El Hasa | 3.06 | 3.98 | 5.25 | 5.92 | 7.41 | 7.99 | 7.93 | 7.44 | 6.21 | 4.73 | 3.43 | 2.68 | 5.44 |

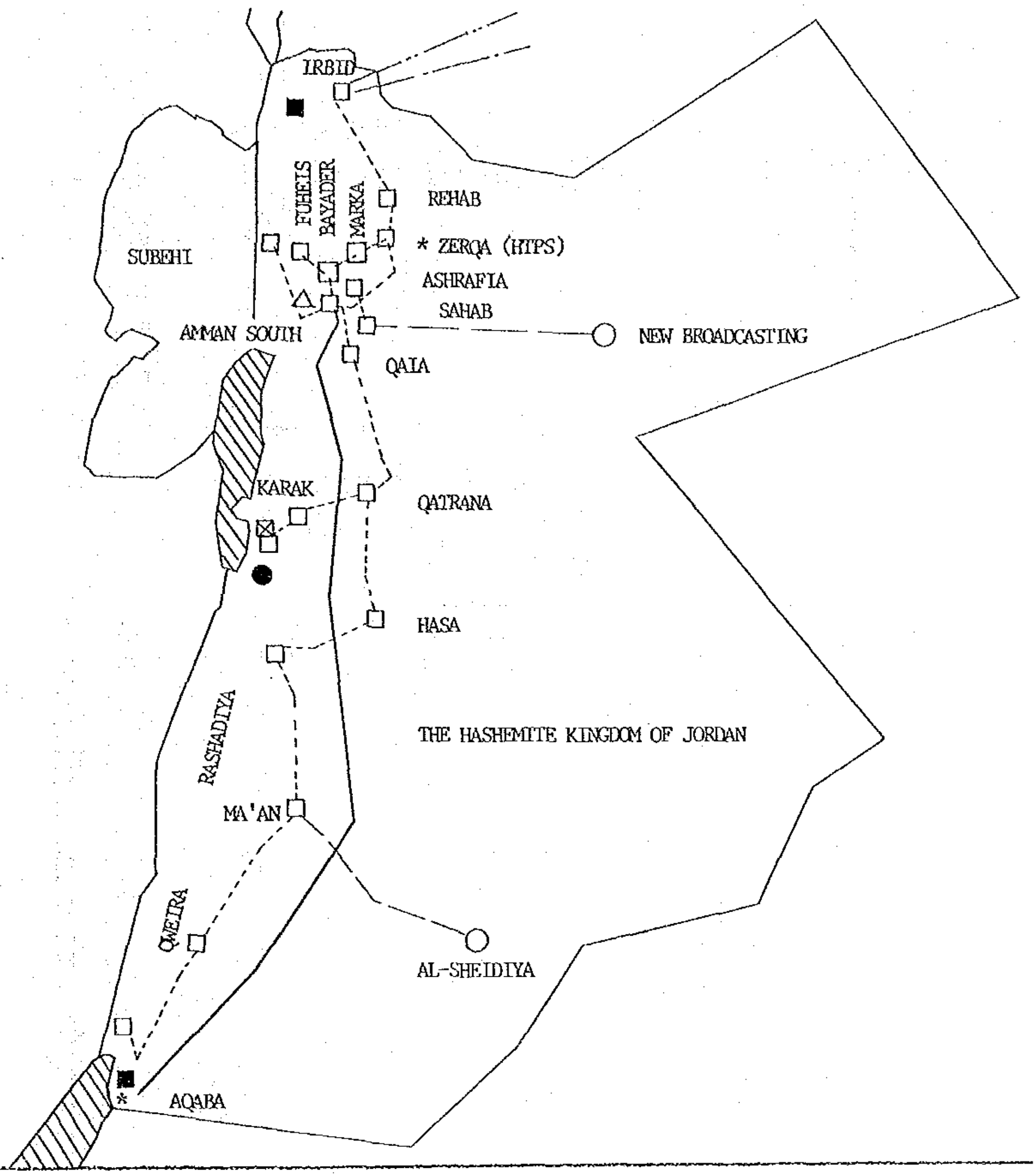
Source: JMD

Table I-9 MONTHLY AND ANNUAL MEANS OF CLOUDY DAYS

| No. Station | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Er Rabba | 6.7 | 3.7 | 5.3 | 3.4 | 0.7 | 0 | 0 | 0 | 0 | 0.3 | 3.1 | 6.2 | 29.4 |
| 2. Tafila | 4.8 | 3.8 | 4.6 | 3.4 | 0.5 | 0.2 | 0 | 0 | 0 | 0.3 | 3.8 | 5.7 | 27.1 |

Source: JMD

# F I G U R E S




* Thermal P.S. in Operation

□ Substation in Operation

● Private Thermal P.S. in Operation

○ Substation Under Construction

■ Diesel P.S. in Operation

⊠ Diesel & Gas Turbines P.S. in Operation

△ Gas Turbines in Operation

---- 132 kV T.L. in Operation

—— 400 kV Interconnection Line

—--— 66 kV T.L. in Operation

—·— 230 KV T.L. in Operation

—— 132 KV T.L. Under Construction.

Fig. I-1 National Grid

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

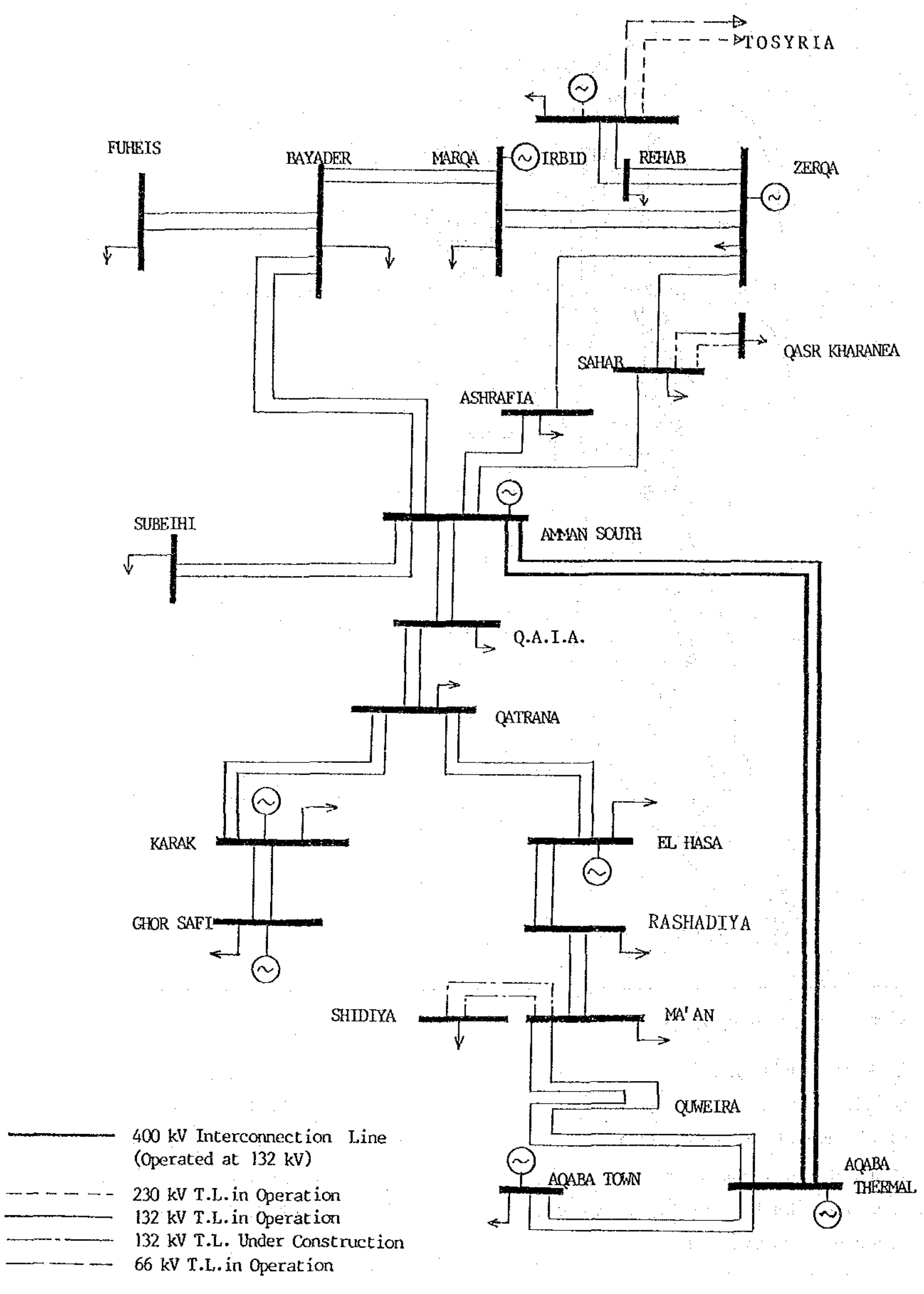



**Fig. I-2 Single Line Diagram of National Grid**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

## Number of inhabitants (1985)

| | | | | | |
|---|---|---|---|---|---|
| 1. | Karak | 14935 | 80. | Abiad | 283 |
| 2. | Lajjun | 200 | 81. | Um El Ghozlan | 169 |
| 3. | *Samra* | 531 | 82. | Juweir | 52 |
| 4. | Izra | 60 | 83. | Noaymeh | 170 |
| 5. | Shehbiyyeh | 2231 | 84. | Hadabeh | 41 |
| 6. | *Adir* | *2714* | 85. | Rojem Ennawayseh | *234* |
| 7. | Ainun | 543 | 86. | El Manshiya | 515 |
| 8. | Eththnniya | 1174 | 87. | El Jauza | 121 |
| 9. | *Mikkein* | *664* | 88. | Edabbaka + Isawiya | 103 |
| 10. | Adnaniyyeh | 1237 | 89A. | Wadi Ennwayseh | 105 |
| 11. | Mirwid | 846 | 89B. | Rashediyyeh | |
| 12. | *Qatrana* | *2315* | 90. | *Tafila* | 15626 |
| 13. | Mumya | 385 | 91. | Aima | 1230 |
| 14. | Abdaliyyeh | 134 | 92. | Sinifha | 995 |
| 15. | *Kamnah* | 33 | 93. | Alyeh | 87 |
| 16. | Gmuweir | 1331 | 94. | Essile | 891 |
| 17. | El Baqei | 436 | 95. | Almitan | 72 |
| 18. | *Zahum* | 564 | 96. | Abur | 100 |
| 19. | El Musheirifa | 276 | 97. | Elis | 424 |
| 20. | Manshiyat Abu Hammur | 2142 | 98. | Abil | 285 |
| 21. | Badhdhan | 908 | 99. | Shaedham | 63 |
| 22. | Sakka | 454 | 100. | An-Namata | 211 |
| 23. | Raudhah | 262 | 101. | Dhiba'a | 109 |
| 24. | *Mraighah* | 54 | 102. | Rhab | 408 |
| 25. | El Ma'muniya | 234 | 103. | Afra | 104 |
| 26. | Batir | 823 | 104. | El Burbeita | 159 |
| 27. | *Wadi Ben Hammad* | 567 | 105. | Jurf Ed Darawish | 646 |
| 28. | Um Rummanah | 72 | 106. | El Hasa | 4077 |
| 29. | Damekhi (Siwaqa) | 120 | 107. | El La'ban | 288 |
| 30. | *Qureifilla* | 41 | 108. | Arafah | 336 |
| 31. | Zugheiriya | 48 | 109. | Abu Banna | 260 |
| 32. | Saahoor | 39 | 110. | Ain Al Beida | 2880 |
| 33. | *Bawwab* | 19 | 111. | Ruweim | 805 |
| 34. | El Hawiya | 140 | 112, | El Harir | 399 |
| 35. | Sad Essoltan | 480 | 113. | Swaimie | 24 |
| 36. | *Rakin* | *1994* | 114. | *Majadil* | 1 |
| 37. | Judaiyida | 1958 | 115. | Zhaigah | 115 |
| 38. | Ai | 4545 | 116. | Bsaira | 3618 |
| 39. | *Kathrabba* | *2191* | 117. | *Rashadiyyeh* | 5 |
| 40. | Jauza | 1486 | 118. | Dhana | 504 |
| 41. | El Iraq | 2028 | 119. | Gharandal | 1531 |
| 42. | *El Qasr* | *1929* | 120. | *Kadiesyyeh* | *2898* |
| 43. | El Rabba | 3026 | 121. | Lahdhah | 48 |
| 44. | Simakiya | 1335 | 122. | Um Essarab | 81 |
| 45. | *Humud* | *406* | 123. | *Sail Ria* | 88 |
| 46. | Wasiyyeh | 36 | 124. | Qar Qoor | 23 |
| 47. | Faqu | 3024 | 125. | Janien | 30 |
| 48. | *Imra* | 890 | 126. | *Dhiban* | *3020* |
| 49. | Sirfa | 2263 | 127. | Falha | 253 |
| 50. | El Yarut | 1005 | 128. | Alyeh | 809 |
| 51. | *Ariha and Abu Turaba* | 810 | 129. | *Dhaibeh* | 291 |
| 52. | Mesar | 296 | 130. | Barza | 350 |
| 53. | Shihan | 348 | 131. | Shaqaiq | 689 |
| 54. | *Jada* | 1338 | 132. | *Mathlootheh* | 199 |
| 55. | Mughaiyir | 383 | 133. | Qbaibeh | 48 |
| 56. | Zahra | 419 | 134. | Um Shjaireh Gharbiyyeh | 105 |
| 57. | *Mujib* | 861 | 135. | *Um Shajarah* | 54 |
| 58. | Eddimna | 471 | 136. | Qasymieh | 104 |
| 59. | Majdalein | 117 | 137. | Mesherfeh | 193 |
| 60. | *El Mazar* | 5099 | 138. | Ara'er | 16 |
| 61. | Mauta | 3432 | 139. | Um Shjaireh Sharqiyyeh | 82 |
| 62. | Tayybeh | 3325 | 140. | Um Zabarah | 43 |
| 63. | *Sarara* | 204 | 141. | Alaqi | 27 |
| 64. | Um El Khanazir | 30 | 142. | Hano Allebbarah | 8495 |
| 65. | El Baqa | 48 | 143. | Wadi Rmail | 128 |
| 66. | Amashiyyeh | 87 | 144. | Jmayyel | |
| 67. | Dabbeh | 227 | 145. | Mzayyer Alia | |
| 68. | Khauka | 6 | 146. | Elayyan | |
| 67. | Juhra | 349 | 147. | Msaitbeh | |
| 70. | El Amaqa | 123 | 148. | Salyeh | |
| 71. | Sul | 1502 | 149. | Um Rsas | |
| 72. | Moab | 5974 | 150. | Ramah | |
| 73. | That Ras | 2780 | 151. | Abu Hlaileefeh | |
| 74. | Mhiyy | 1354 | 152. | Mshairfet Slait | |
| 75. | El Hashimiya El Janubiya | 757 | 153. | Toar Hashash | |
| 76. | El Shariffeh | 21 | 154. | Thrayya | |
| 77. | Majra | 284 | 155. | Yahoon | |
| 78. | Hamdiyyeh | 156 | 156. | Rojom Fhaid | |
| 79. | Um Al Yanabee | 56 | 157. | Rojom Igab | |
| | | | | Total | 152,105 |

Note : *Above figures are slightly defferent from the data given by MOP*
Source : Regional Planning Department, MMRAE

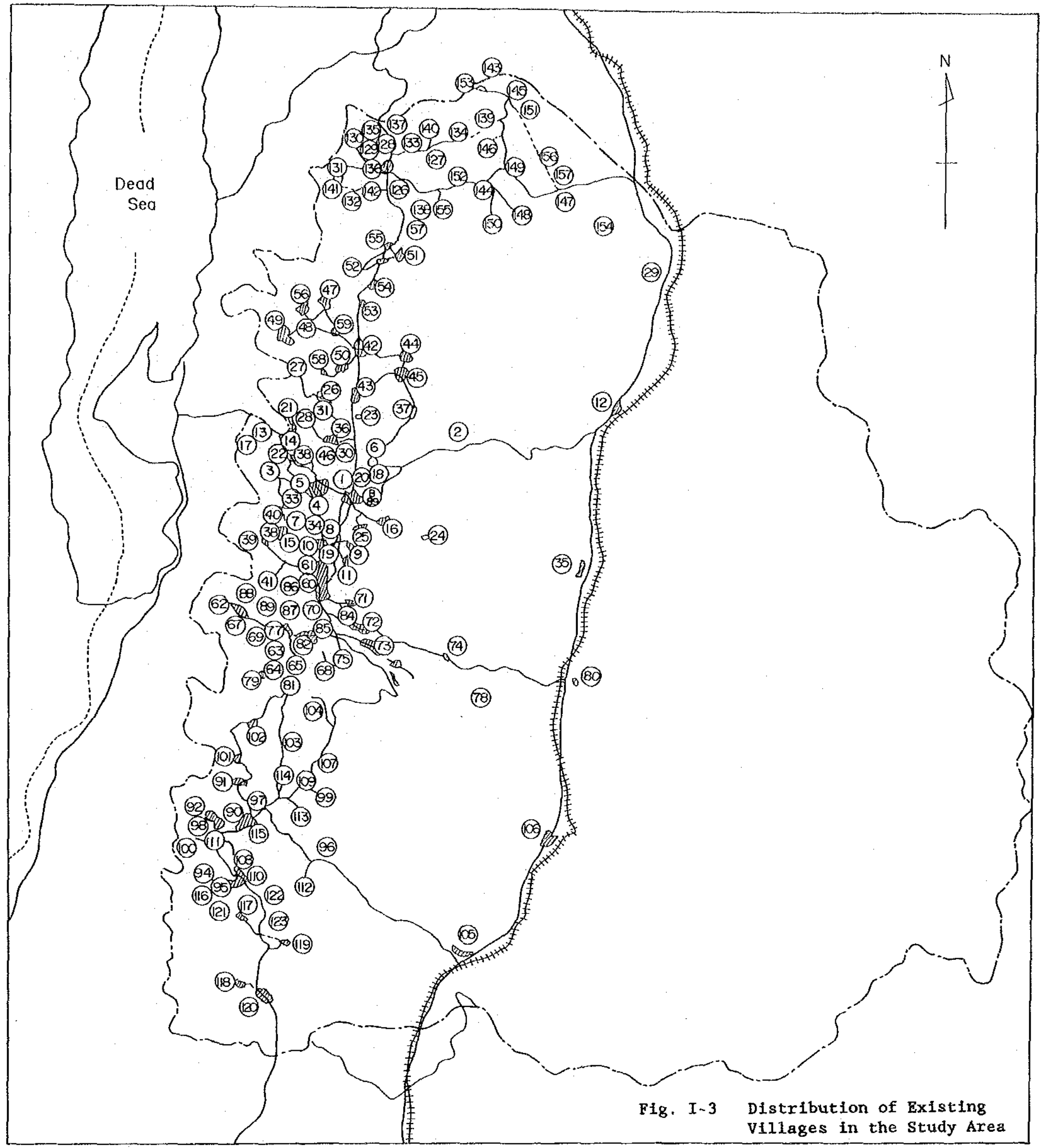
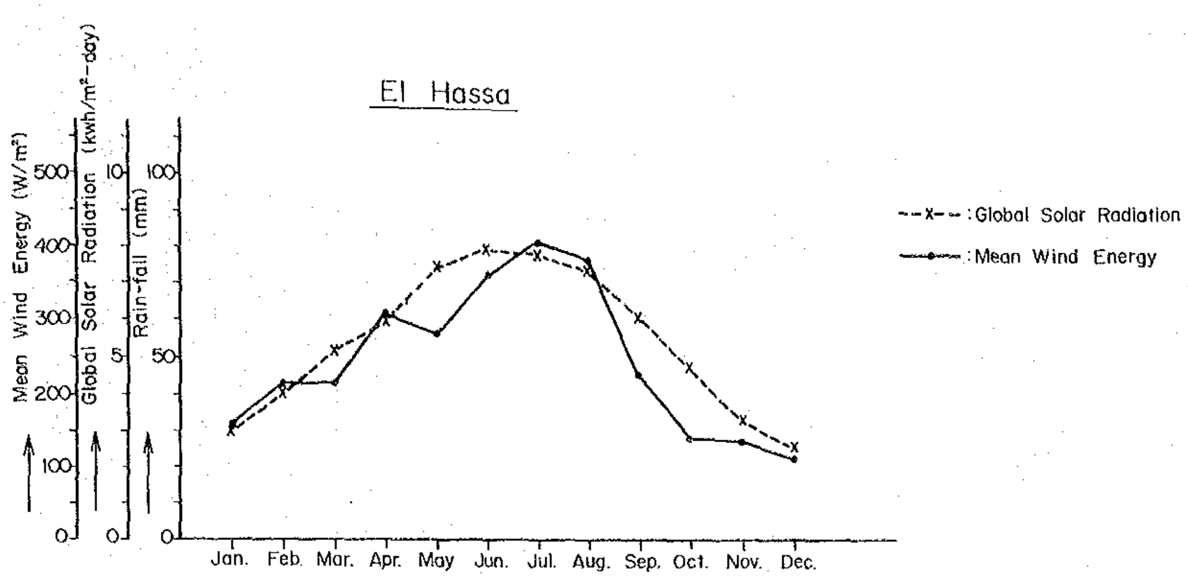
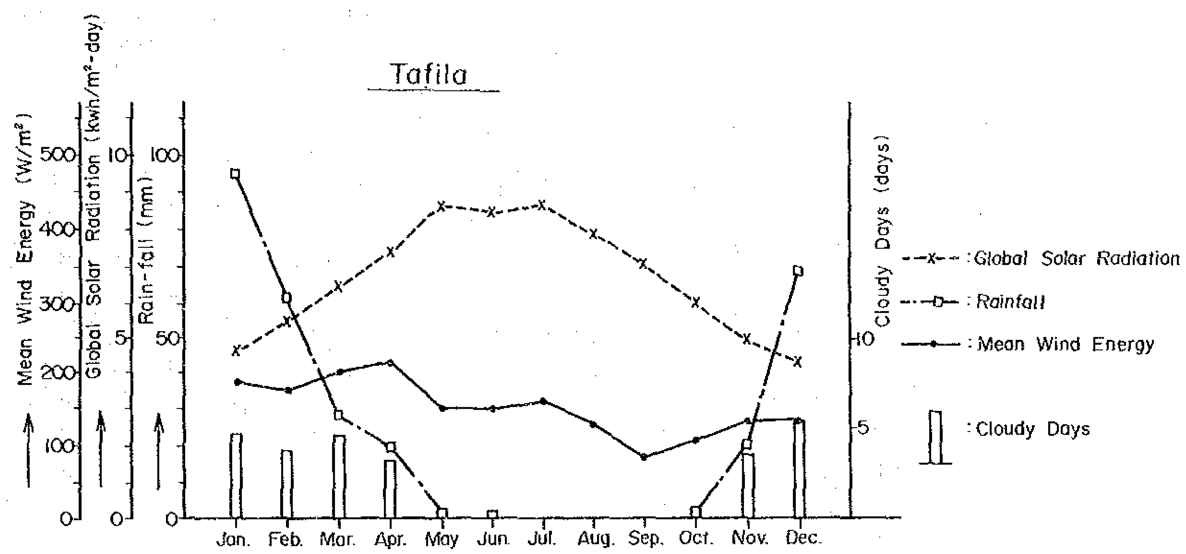



Fig. I-3 Distribution of Existing Villages in the Study Area

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION
JAPAN INTERNATIONAL COOPERATION AGENCY



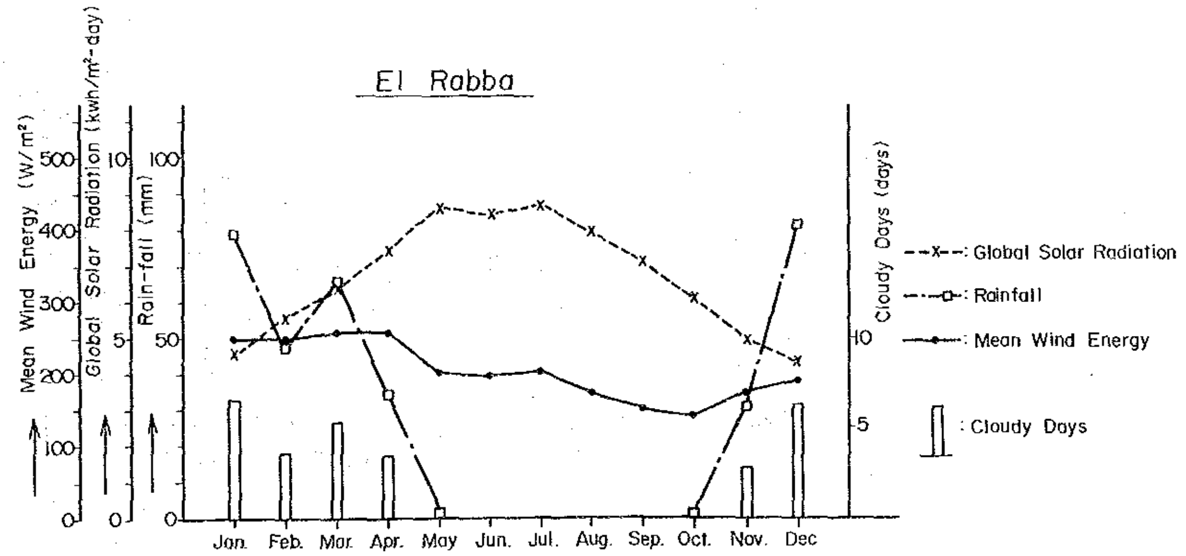




**Fig. I-4 Rainfall, Solar Radiation and Wind Energy in the Study Area**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

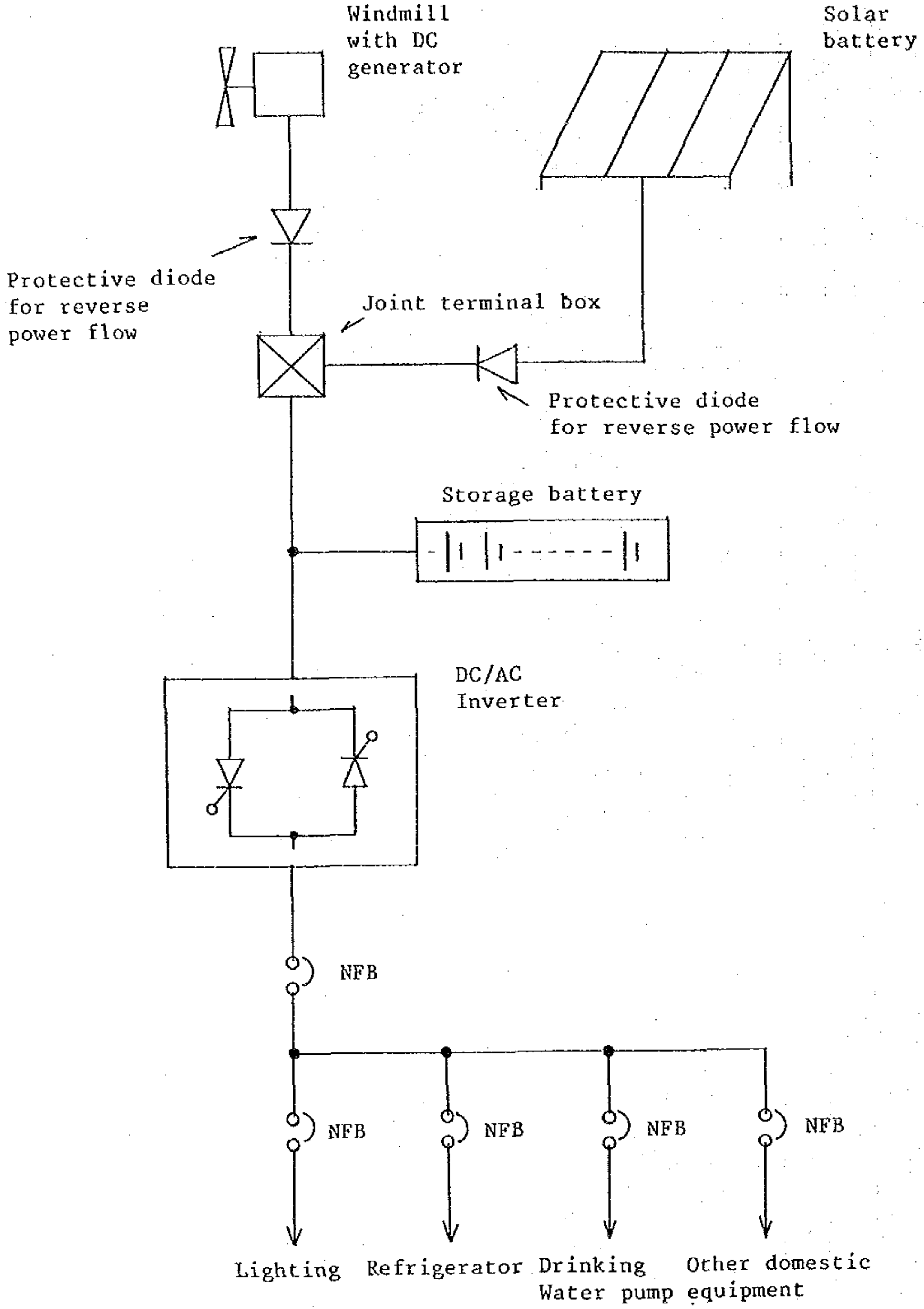



**Fig. I-5 Schematic Plan of New Energy Application to Electrification of Small Isolated Villages**

| |
|---|
| THE HASHEMITE KINGDOM OF JORDAN<br>THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION |
| JAPAN INTERNATIONAL COOPERATION AGENCY |

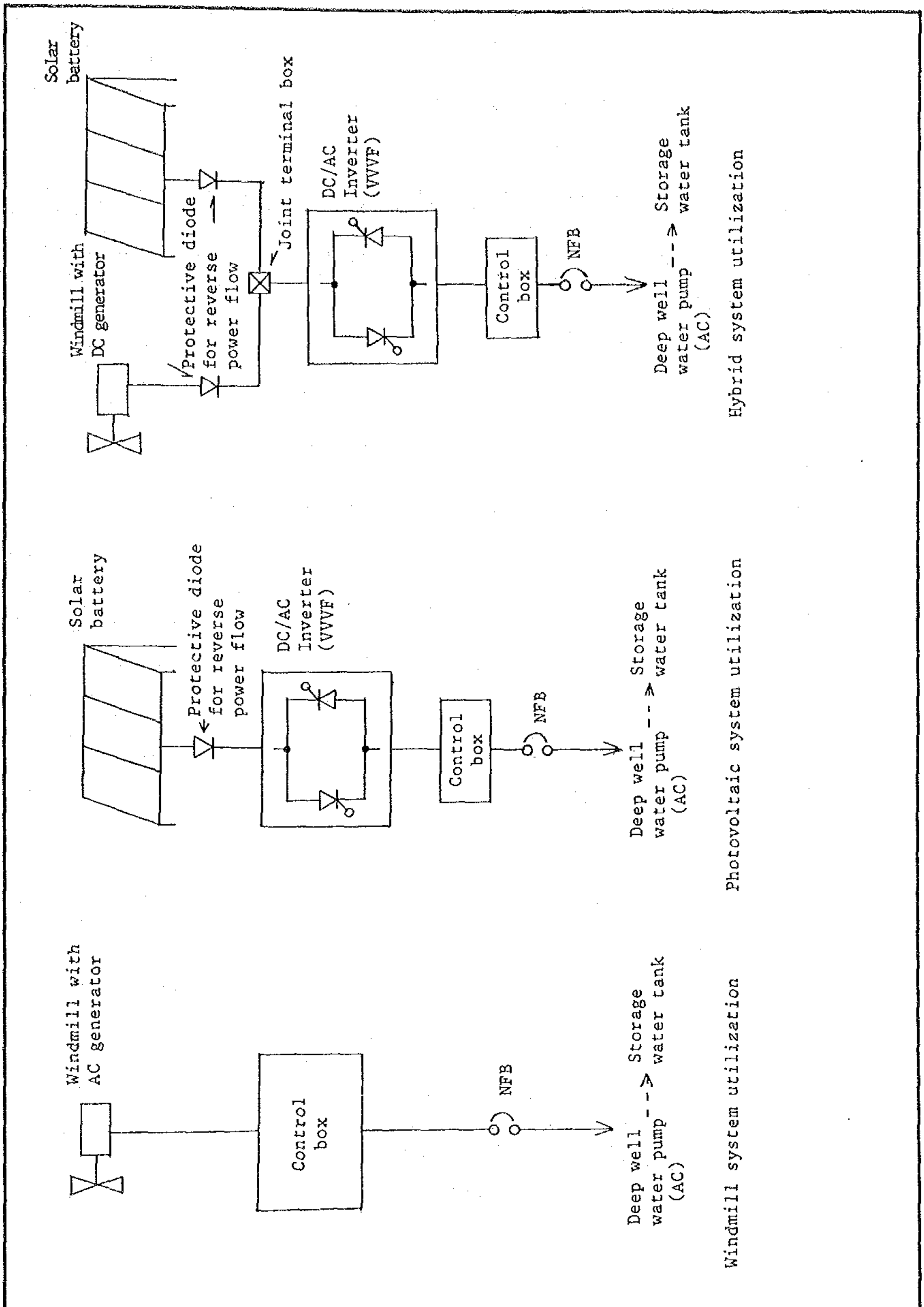



Fig. I-6 **Schematic Plan of New Energy Application to Watering Station**

| THE HASHEMITE KINGDOM OF JORDAN<br>THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION |
|---|
| JAPAN INTERNATIONAL COOPERATION AGENCY |

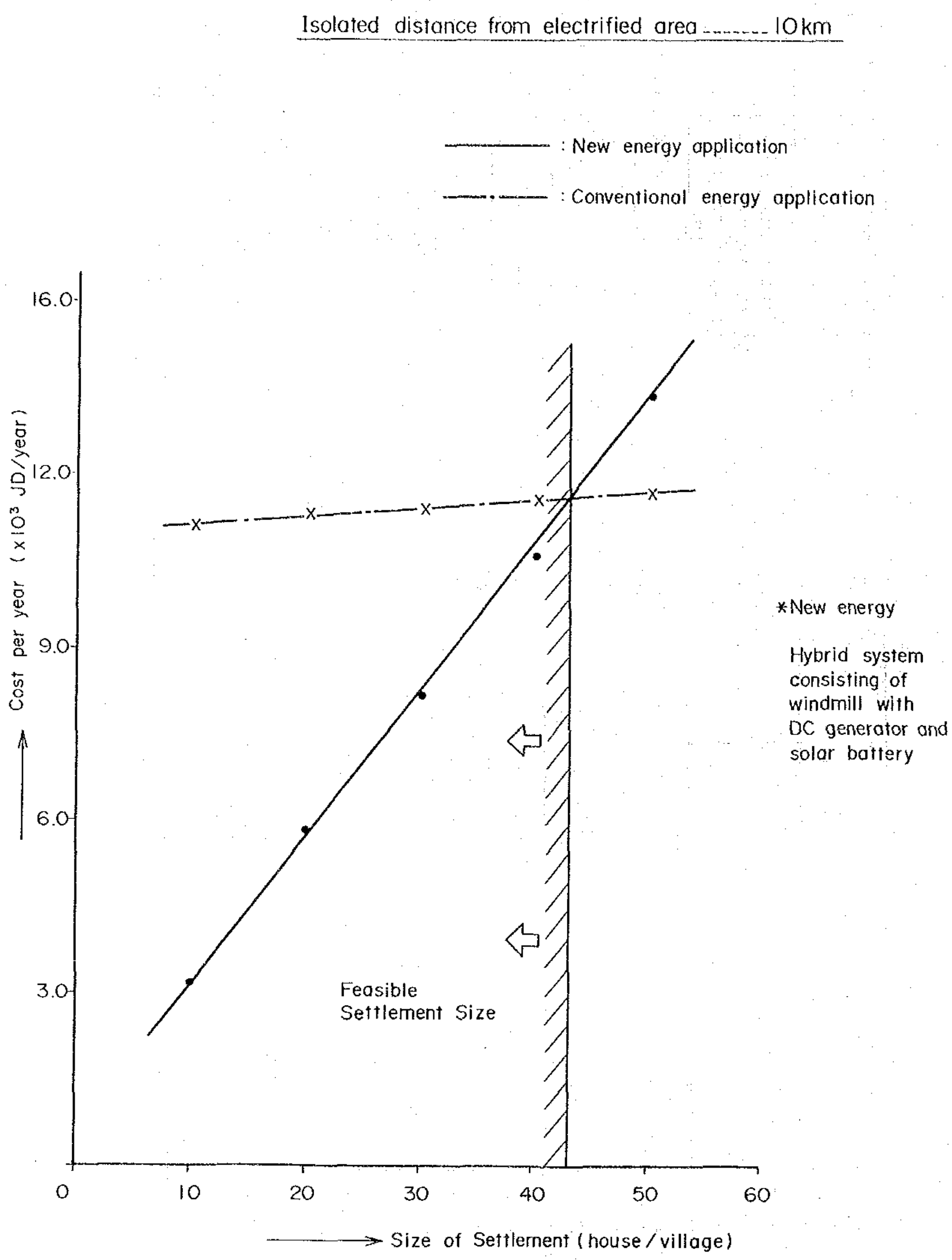



**Fig. I-7 Maximum Settlement Size for Electrification by New Energy**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK-TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

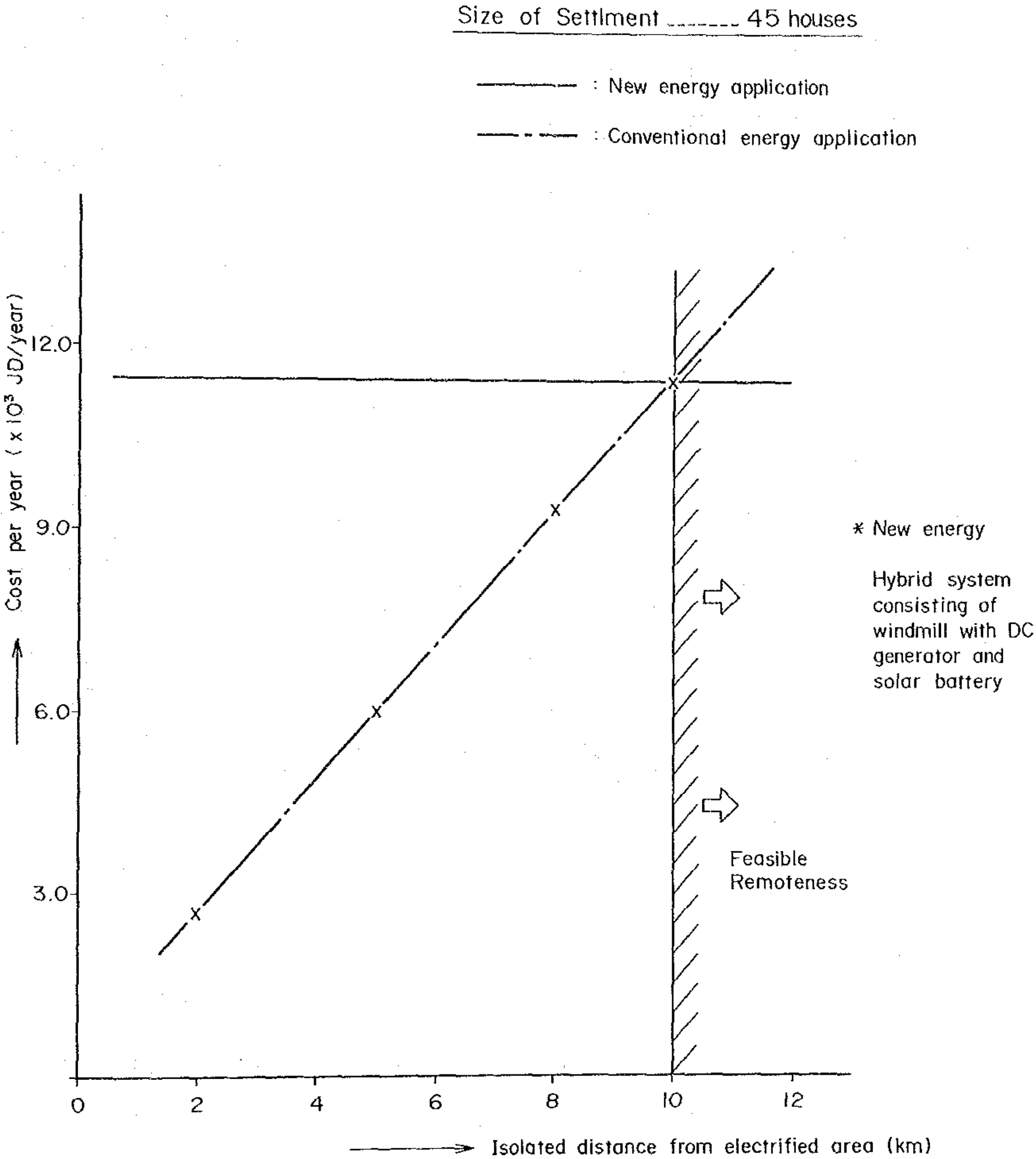



Fig. I-8 **Minimum Remoteness for Electrification by New Energy**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

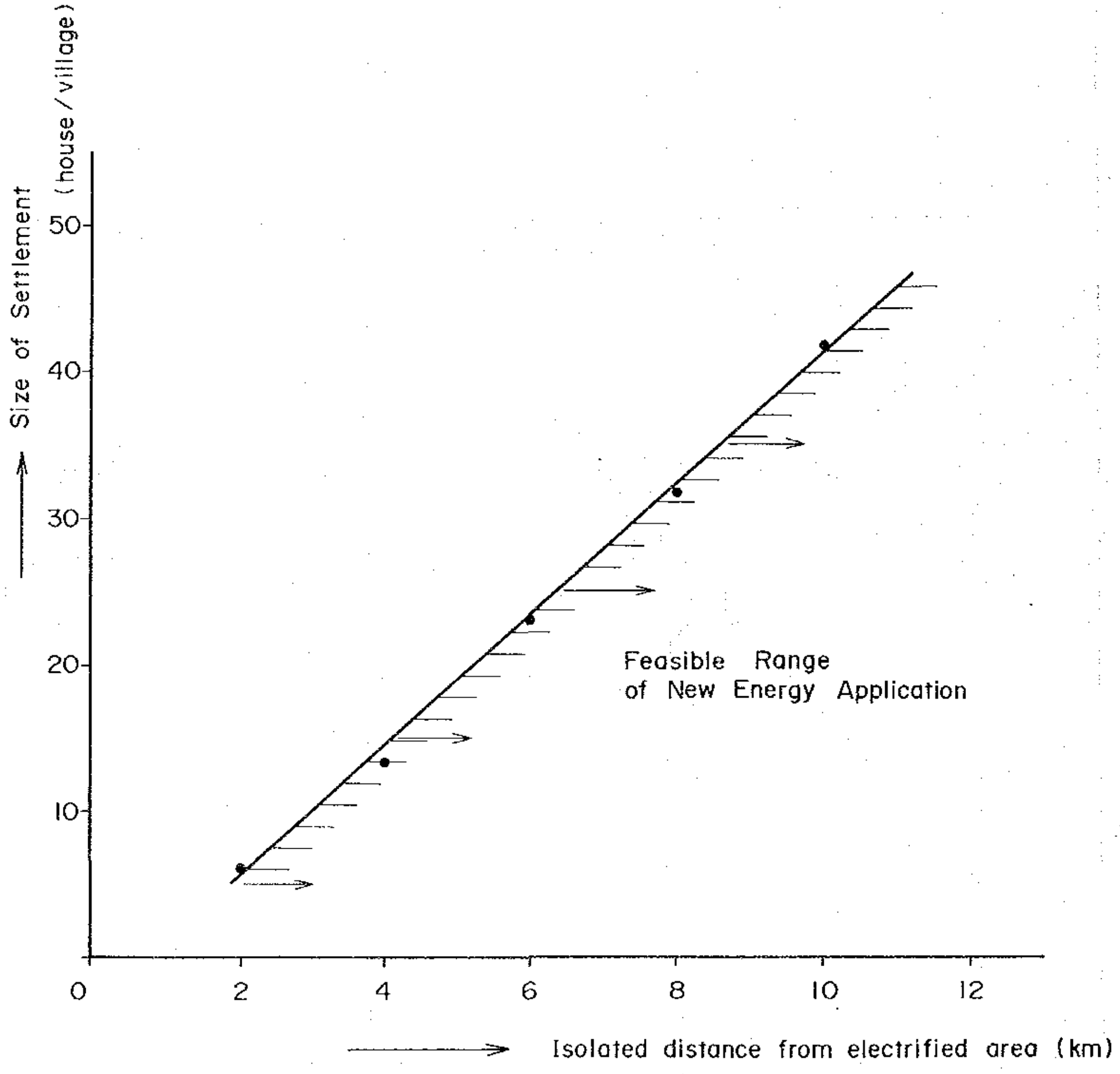



Fig. I-9 **Feasible Range of New Energy Application for Electrification of Small Isolated Villages**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION
JAPAN INTERNATIONAL COOPERATION AGENCY

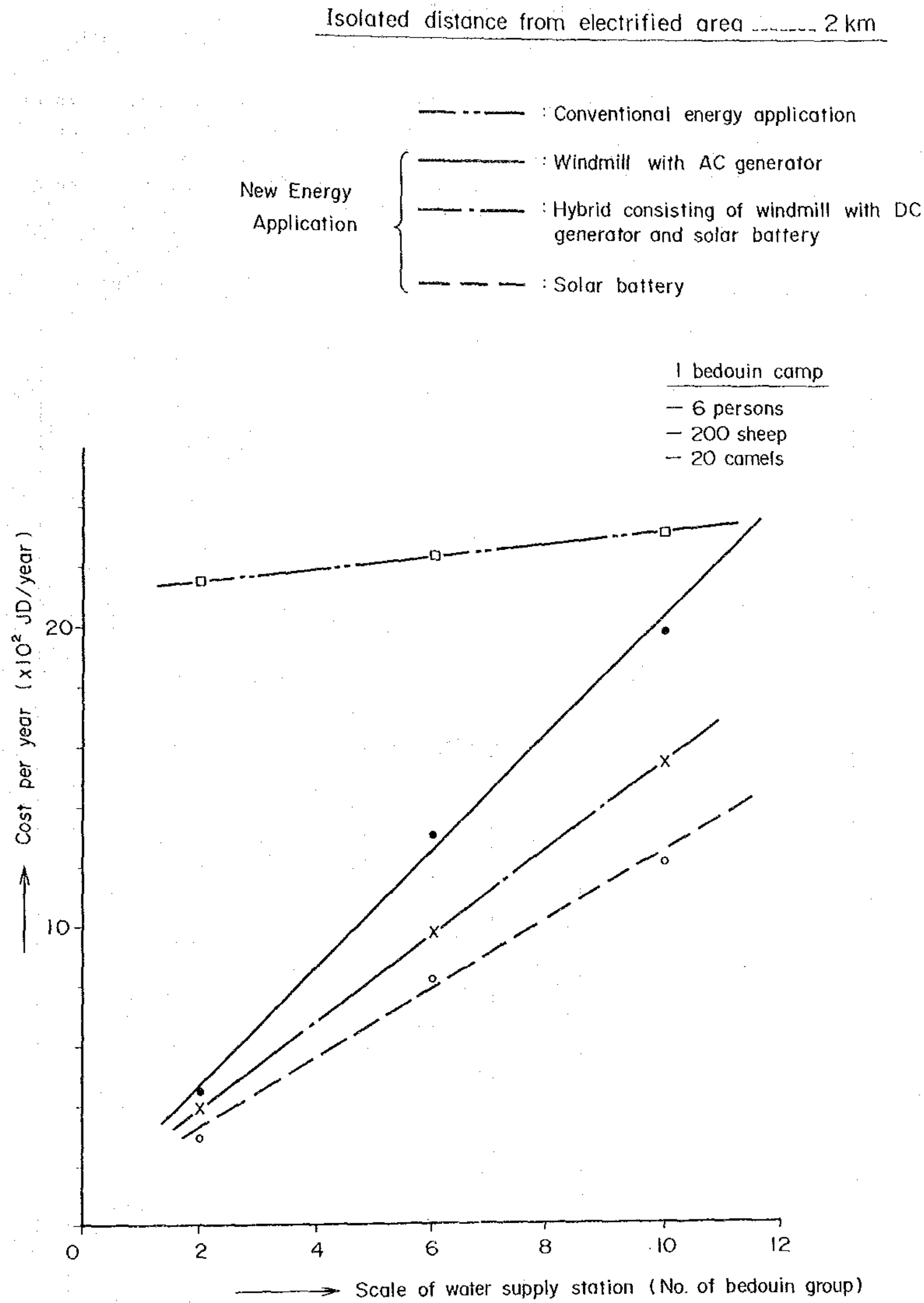



**Fig. I-10 Maximum Scale of Watering Station for New Energy Application**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION
JAPAN INTERNATIONAL COOPERATION AGENCY

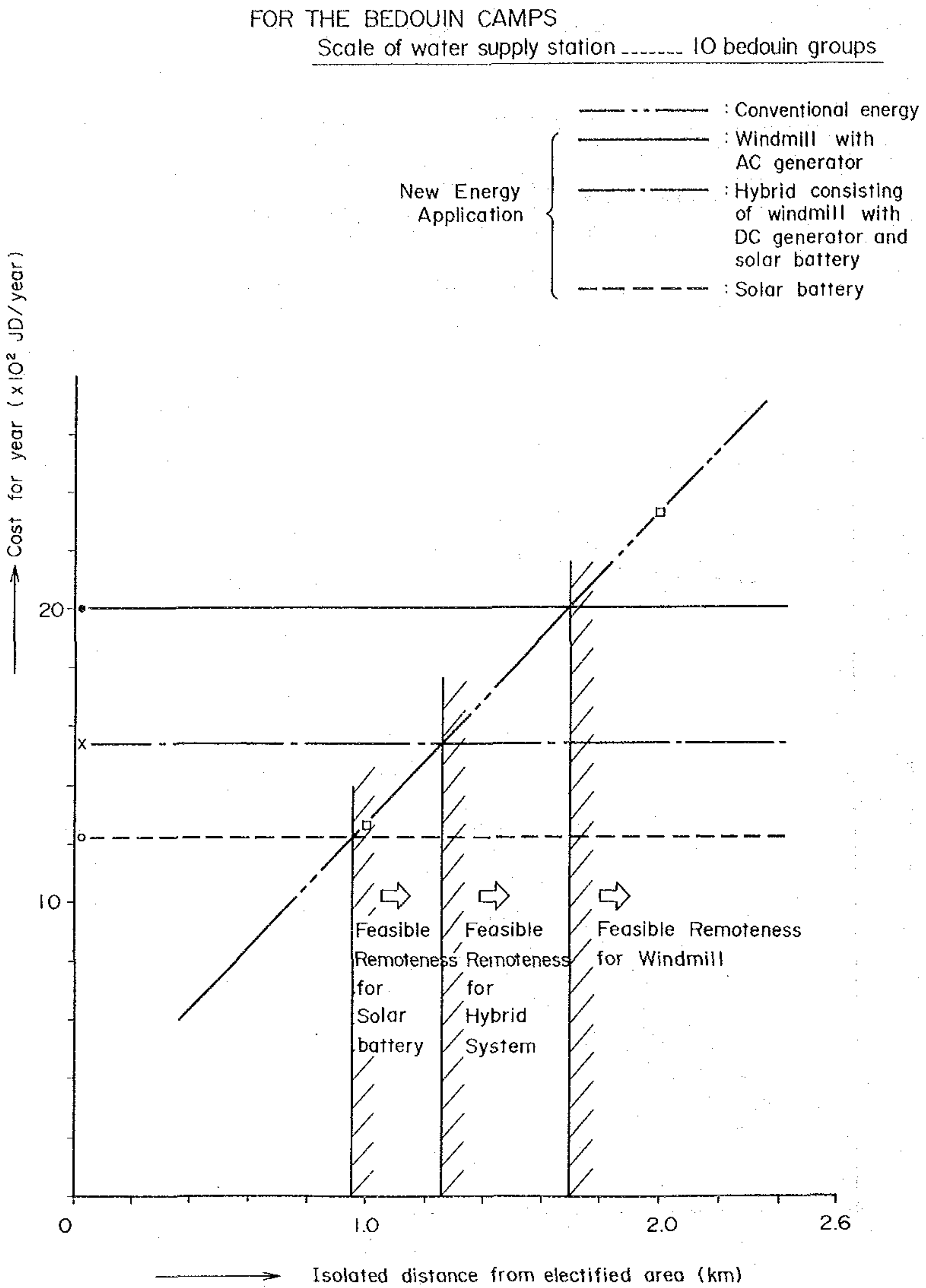



**Fig. I-11 Minimum Remoteness of Watering Station for New Energy Application**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

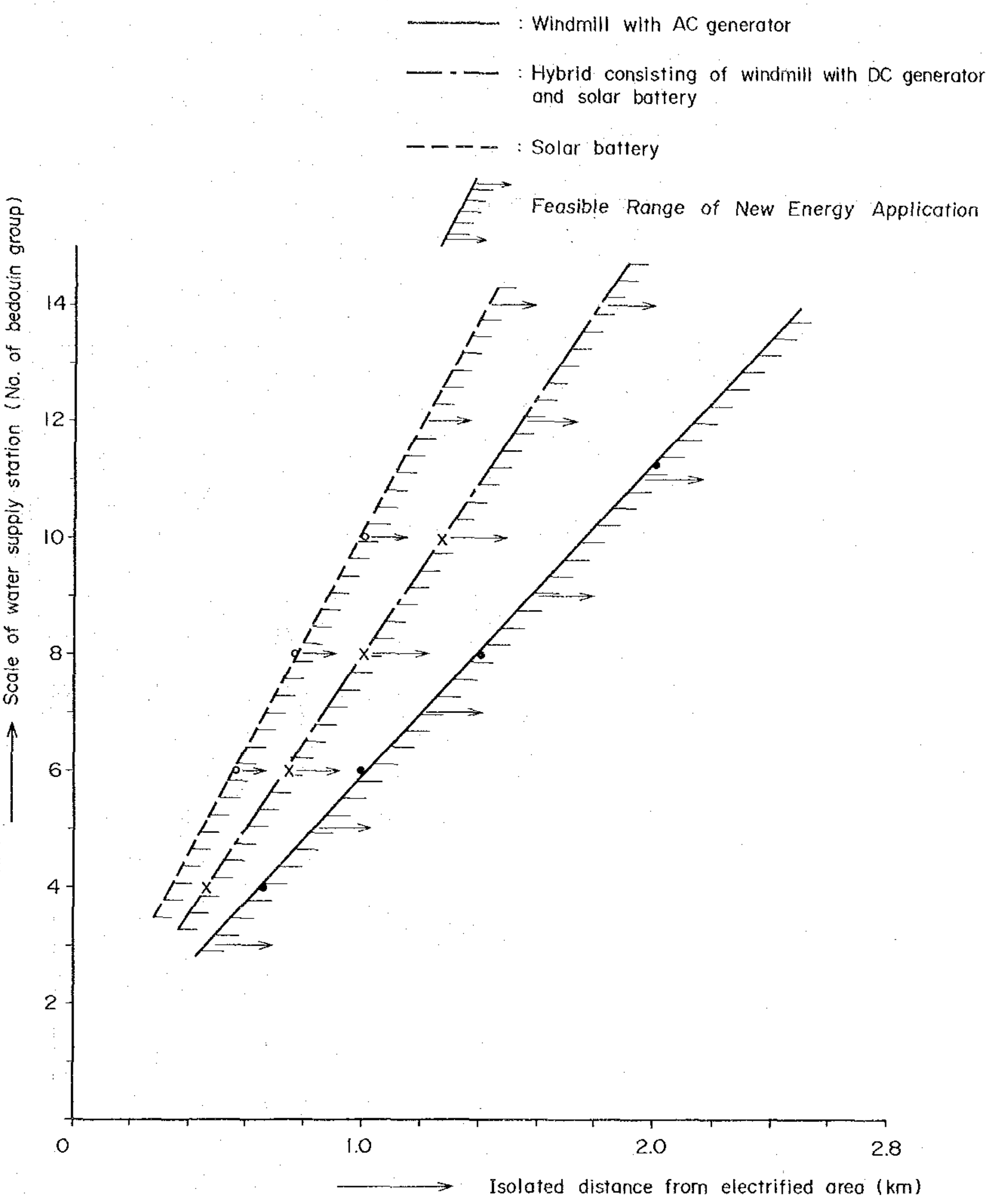



**Fig. I-12 Feasible Range of New Energy Application for Watering Station**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

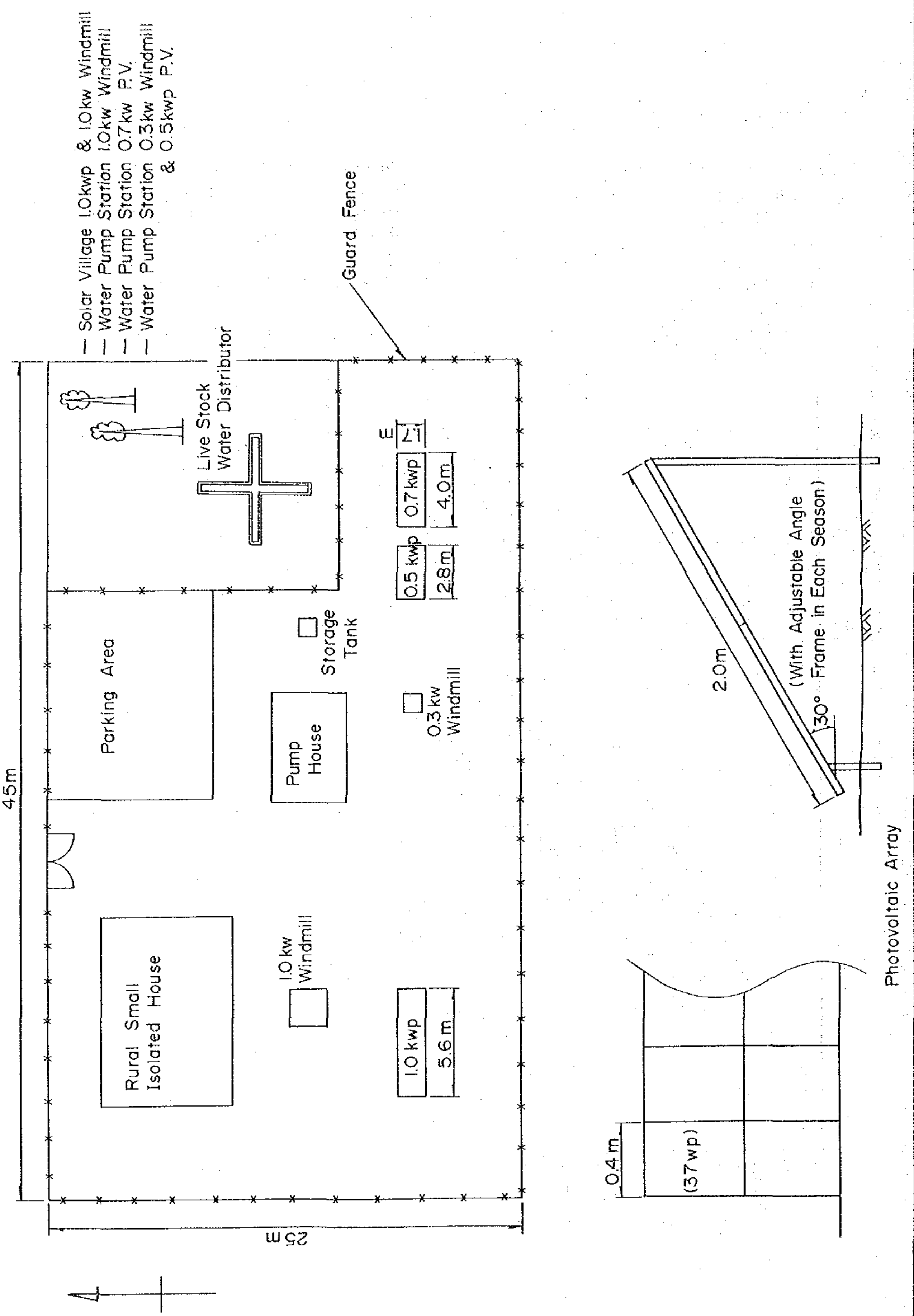



Fig. I-13 Preliminary Layout of Hasa Mini Pilot Plant

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

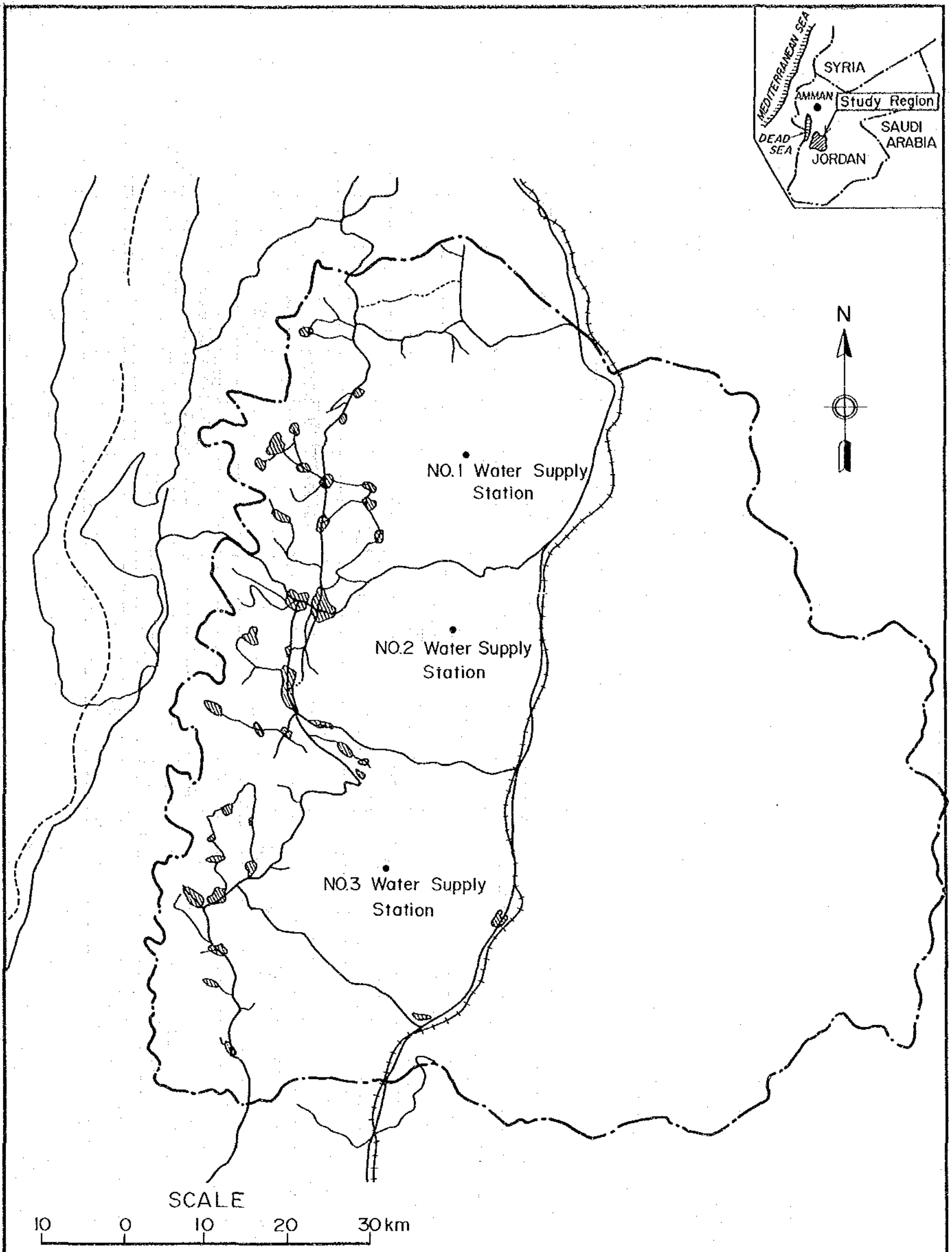



Fig. I-14 Prospective Location of Prototype Watering Stations

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

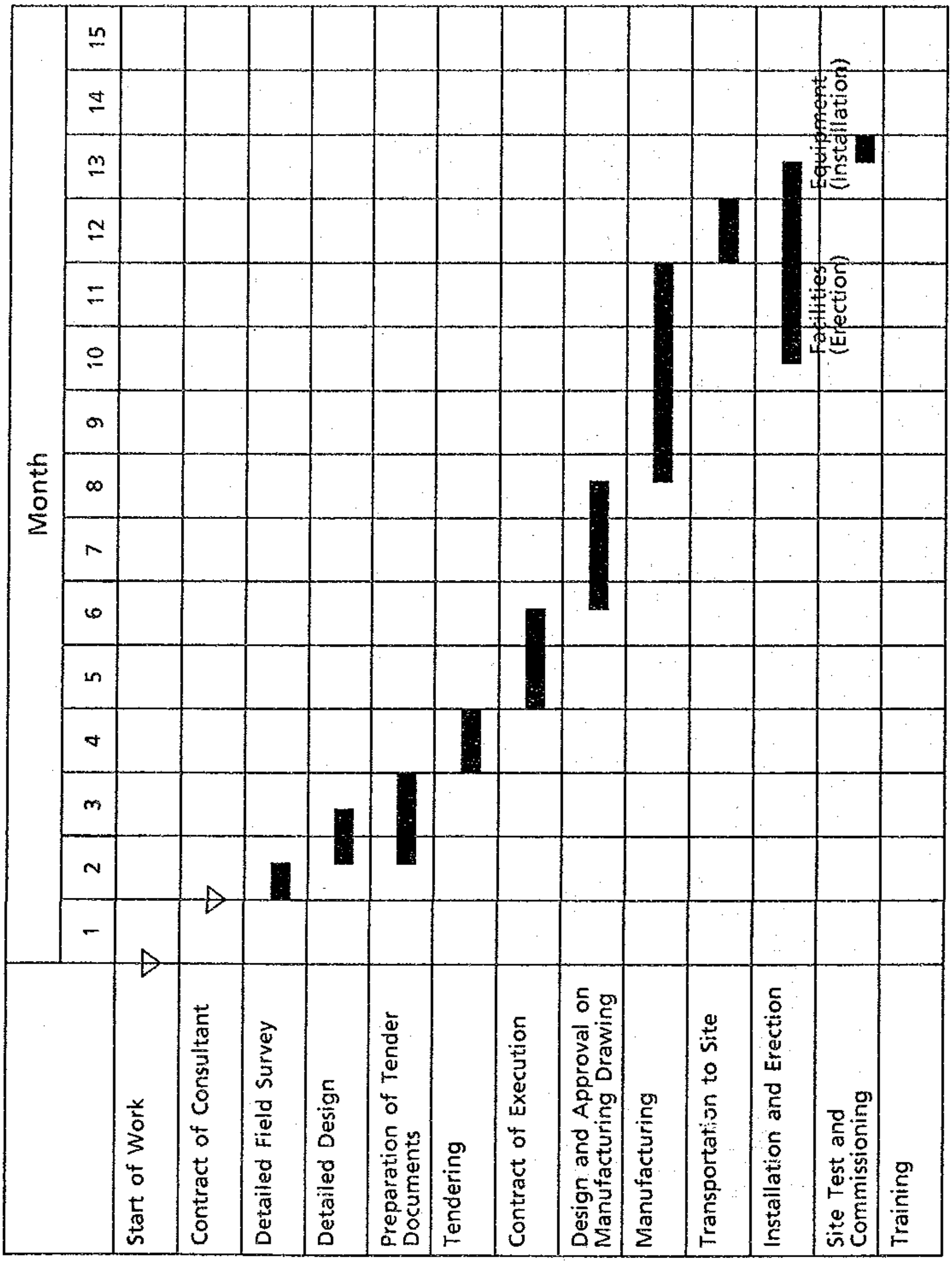



Fig. I-15 Implementation Schedule for Pilot Plants

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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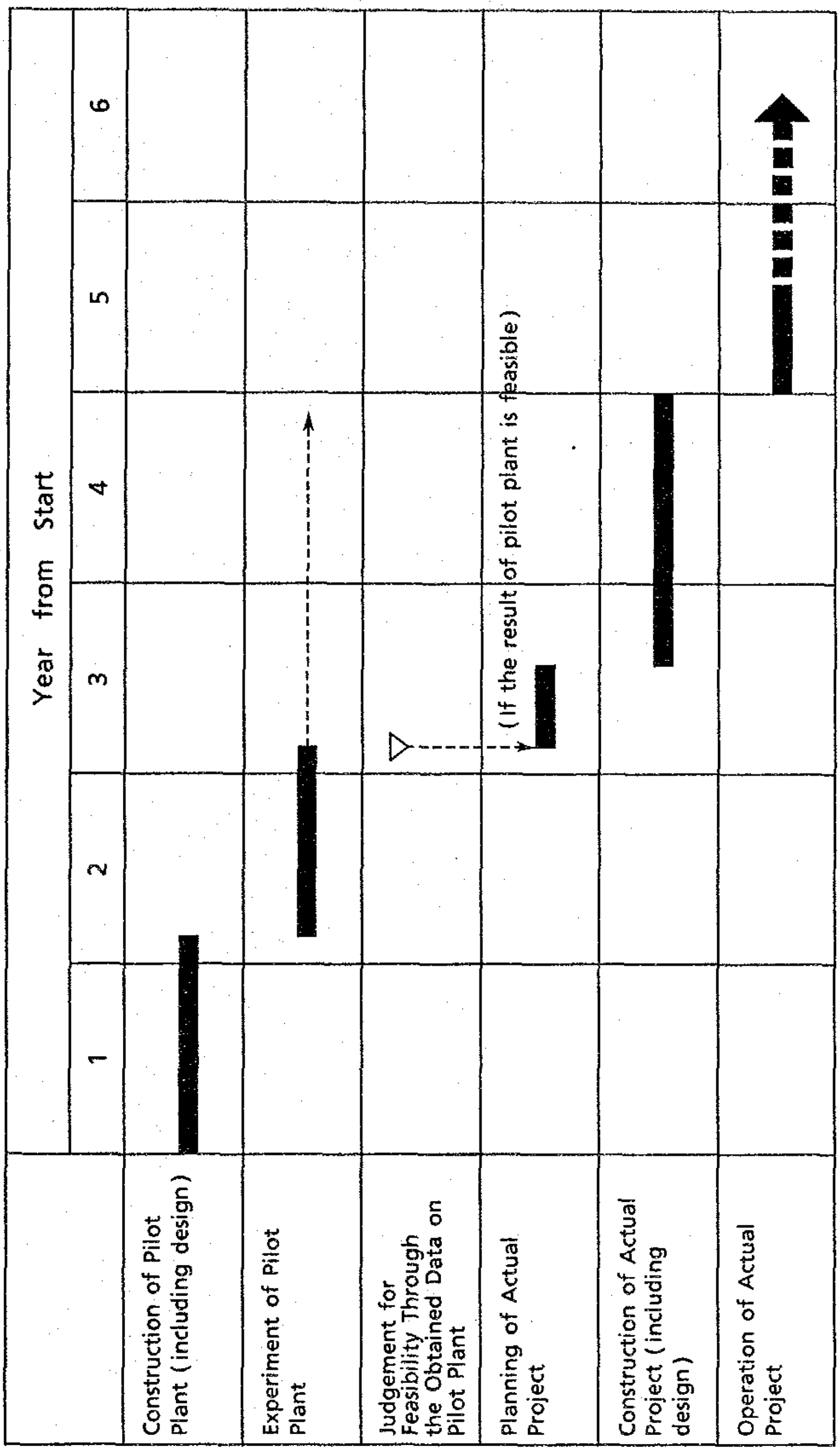


Fig. I-16 Overall Implementation Schedule

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

# ANNEX-J AQUACULTURE

THE STUDY ON
INTEGRATED DEVELOPMENT MASTER PLAN
FOR THE KARAK - TAFILA DEVELOPMENT REGION

VOLUME 4: SUPPORTING REPORTS

**ANNEX-J AQUACULTURE**

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## LIST OF TABLES



## LIST OF FIGURES

# 1. INTRODUCTION

The potential of aquaculture development in Jordan including the Study Area using a hot spring was indicated in previous studies.

The objective of this Study is to further examine aquaculture development plans based on the investigation of present fisheries and aquaculture activities in Jordan and the reconnaissance of several potential project sites.

The Study was carried out from July 14, 1987 to August 31, 1987 including a 16-days survey in Jordan.

## 2. BACKGROUND OF AQUACULTURE

### 2.1 Fish Production

Domestic fish production of the Kingdom has been quite limited because of its land-locked nature and semiarid climate. Although Jordan has a coast of about 20 km in length along the Gulf of Aqaba, marine fish catch was limited and continued to decline from 56.2 tons in 1980 to only 1.5 tons in 1984 as shown in Table J-1. Inland fish catch is apparently negligible, while leisure fishermen occasionally enjoy fishing in the Jordan River and some wadis where small carp species can be caught.

The only important source of domestic fish production is from inland aquaculture. Although presently there are no published statistics for aquaculture production in Jordan, it is estimated that more or less 50 tons of culture fish mainly tilapia were produced in 1985.

Development of national food resources would give a valuable effect on the economic growth and improvement of external trade position of Jordan. Possible effects were duly considered in the Third Five-Year Plan (1986-1990) for reducing food import costs and improving the national food security. The Ministry of Agriculture plans to expand the freshwater fish production to 1,000 t/yr during the Plan period.

### 2.2 Demand and Supply

In order to meet the domestic demand of fish, a considerable fish import has been made as shown in Table J-2. The net fish import reached 4,256 tons in 1975, 4,452 tons in 1980, and 6,249 tons in 1985. The average annual growth rate of net import was only 0.9 per cent during 1975-1980 but it increased to 6.9 per cent during 1980-1985. The main imported items are frozen fish and canned fish, which correspond to 40-50 per cent and 50-60 per cent of the total fish import respectively. Jordan imported frozen fish mainly from Arab countries: Oman, Saudi Arabia, Kuwait and South Yemen. The value of these imports in 1985 was estimated to be about JD 2.35 million.

Despite the recent increase of imported fish, the per capita fish consumption did not show a marked increase. It reached only between 2.0 to 2.6 kg during 1980 to 1985 whereas 12.0 kg worldwide and 20.3 kg in Oman on an average during 1979-1981 (FAO statistics).

One of the reasons for the low per capita fish consumption is the fact that the supply of favoured fresh fish is limited. According to the interview survey (Ref. J-1), 32 per cent of the interviewees prefer fresh fish to fresh sheep. The survey also indicated that they are ready to spend JD 5.6 - 7.8 a month for fresh fish, when the retail price is about JD 2.0/kg. Assuming the fresh fish is marketed constantly and the retail price is at JD 2.0/kg, a family of six in size would consume monthly about 3-4 kg of fresh fish. This could be converted into a potential per capita demand for fresh fish of 6-8 kg per year.

The total fish demand in 2000 is estimated to be 11,250 tons based on the projected national population of 4.5 million and present per capita fish consumption of 2.5 kg/yr. The demand for fresh and frozen fish is estimated to be 4,500-5,000 tons or 1.5-2.0 times of the present imported quantity. If the potential per capita fish demand of 6-8 kg per year mentioned above is considered as real figure, the demand of fresh fish would be 27,000 - 36,000 tons by the year 2000.

## 2.3 Marketing Conditions

There is no fish market or store selling fresh fish in Amman or in other big cities except in the retail stores where live tilapia is delivered from the Arab Fish Company (AFCO) in the Jordan Valley. At present consumers buy frozen or canned fish at supermarkets. The supply of frozen fish was controlled by the Government and retail price was fixed till 1985. Since August 1985, frozen fish has been imported by private traders following the instruction of the Ministry of Supply (MOS). The retail price of frozen fish is set according to the following formula:

$$\text{Retail price (fils/kg)} = (\text{CIF price} \times 115)/100 + 101.3$$

At the time of this Study, there were several wholesale traders in Amman. These traders usually import both frozen fish and meat, and distribute to supermarkets. Retail prices of frozen fish imported from neighbouring countries are around JD 0.6 - 0.8/kg, while the imported luxury fish such as fillet of plaice, salmon or headless shrimps are sold at higher prices of more than JD 6.0/kg. The retail price of cultured live tilapia, which is not controlled by the Government, is currently JD 1.5/kg irrespective of fish size or colour. The commercial size of tilapia is over 250 grams.

## 3. PRESENT AQUACULTURE ACTIVITIES IN JORDAN

### 3.1 Aquaculture by Public Sector

The promotion of aquaculture and fish production industry is entrusted to the Department of Animal Production and Health under the Ministry of Agriculture (MOA). At present two veterinary doctors who have acquired aquaculture experience in Europe and USA are assigned as officers in charge of fishery, and they monitor the existing aquaculture activities in Jordan. Since Jordan is not familiar with the aquaculture industry, it appears that the Government has not organized their own staff properly. MOA acts as an administration and implementing authority while the planning work is carried out under the responsibility of the Ministry of Planning (MOP). Recently MOP executed two feasibility studies for fish farming at Wadi Hisban and at South Azraq by hiring a foreign consulting company.

In the Third Five-Year Plan, aquaculture projects are denoted at South Azraq by use of spring water and at Al Rameh using water from artesian wells containing the salinity of 3.0-4.0 ppt. The annual production of 300 tons is planned for each project with an investment of JD 1.2 million. According to this plan, the fish production in the Kingdom for the period 1986-1990 is expected to increase to 1,000 t/yr from that of the previous period 1981-1985 at 20-50 t/yr, and the self-sufficiency ratio may reach 21.7 per cent.

### 3.2 Aquaculture by Private Sector

There are several fish farms in the Jordan Valley which culture tilapia and some carps. However, only the Arab Fish Company (AFCO) produces significant quantity of fish using the water from Jordan River.

(1) <u>Arab Fish Company (AFCO)</u> was established in 1983 as a private share holding firm by the Pension Fund, the Social Security Cooperation, the Jordanian and Social Organization for Retired Servicemen (JESORS), and an European engineering firm with the equity of JD 650,000. Since there was no commercial scale fish farm before the establishment of AFCO, it

is recognized as a pilot fish farm company of the Kingdom.

The AFCO farm is now producing mainly Red Tilapia, which is a mixed hybrid through selective and cross breeding of ablino strain of tilapia species, Oreochromis mossambica and O. nilotica in FRP tanks utilizing the running water system. The chief aquaculture technician has been hired successively from Europe and Asian countries. The production in 1986 was still as low as 34 t/yr compared to the planned target production of the facility of 400 t/yr.

In its early stage the farm introduced fry and broodstock of Red Tilapia and ordinary gray-coloured tilapia, O. nilotica from several countries such as USA, England, Taiwan and Singapore. The farm encountered many technical problems related to the acclimation of imported broodstock and fry to local water and low water temperature of Jordan River in winter. Taking into consideration these experience in operation for about three years, AFCO has changed the production target as 200 t/yr which should be realized by 1988 if the rearing condition is well maintained.

The fish is distributed alive to the retail stores and restaurants in Amman, Zarqa, Jerash and Irbid in their own transportation vehicle equipped with aerated fish container. The retail stores are managed by JESORS. At the time of this study (July 1987), the retail price of live tilapia was JD 1.5/kg, while it was JD 2.0-2.5 kg in 1986. The farm-gate price was JD 1.0/kg. The management board of AFCO is considering to offer reasonable price so as to increase consumption of cultured tilapia.

(2) Other Aquaculture Activities: As explained earlier, all the other existing fish farms are small in scale and do not operate commercially. Besides these small fish farms, recently several new inland aquaculture projects have been planned as indicated below:

| No. | Site | Source of Water | Executing Body | Culture Method | Target Production |
|---|---|---|---|---|---|
| 1. | South Azraq | Spring | Cooperative | Gravity based fish pond | 14 t/yr (for the year 1988) |
| 2. | South Azraq | Spring | Village Council | Water re-circulation | 300 t/yr |
| 3. | Ain Zara | Hot spring (near Dead Sea) | JESORS | Gravity based raceway | 400 t/yr |
| 4. | Al Rameh | Well | Not decided | | 300 t/yr |

The species to be cultured at South Azraq is tilapia, O. nilotica, while at Ain Zara it is mainly Red Tilapia. In July 1987, the fish ponds in South Azraq with total areas of about 5.2 ha were under construction.

# 4. AQUACULTURE DEVELOPMENT PLAN

## 4.1 Basic Concept

There is a significant demand for fresh fish. Both the public and private sectors have recognized its importance, and they are venturing into new projects, although the aquaculture development is relatively new in Jordan.

The total production of cultured tilapia delivered from the Jordan Valley and Azraq will increase to several 100 tons, though it may take time to achieve the target production as seen in the existing fish farm. It is anticipated that the retail price of tilapia will be controlled by that time by demand and supply balance, and different marketing prices will be applied depending on the quality, size and the preference of fish colour through the competition among fish farms. Taking these conditions into consideration, the basic concepts for the introduction and promotion of aquaculture industry in the Study Area are proposed as below:

(1) Project sites which have advantageous conditions comparing to existing fish farms should be selected as high priority in order to produce competitive crops in the market.

(2) A practical culture system operated successfully in other places should be applied for the first project in the Study Area before the introduction of any advanced system requiring complex equipment.

(3) New potential species applicable to the Study Area should be considered as one of the special products in addition to tilapia.

## 4.2 *Selection of the Priority Project Site*

Based on the information from the regional offices in Karak and Tafila, nine potential aquaculture sites were identified as shown in Fig. J-1. These sites were examined during the site reconnaissance, and their appropriateness was evaluated as follows:

According to the results of water quality analysis, harmful features of water such as abnormal pH value or high content of $SO_4$ ion were not found among the samples from Afra Hot Springs, Burbeita Hot Springs and Wadi Mujib as shown in Table J-3. The dissolved oxygen (DO) at the source of springs seems to be nearly zero, however, the spring water is aerated in the downstream flow. The field measurement of DO at Wadi Hasa downstream from Burbeita Hot Springs indicated more than 6 ppm, and water insects and fish were observed. A laboratory test showed a DO concentration of 8.0 ppm for the water taken from Wadi Afra near the box-culvert on August 24, 1987, and 7.0 ppm for the water taken from Wadi Hasa at the Burbeita road crossing.

On the radioactivity of the springs, Burbeita Hot Springs contained relatively high activity of radon 222, particles at 29.0 nCi/litre in comparison to 5.1-5.4 nCi/litre in Afra Hot Springs and 5.9 nCi/litre in Wadi Ibn Hammad (Ref. J-2). It is known that the concentration of radon at present level is good for health care of human body, and fish does not accumulate radon 222 in their body. Consequently the water quality of examined wadi and springs is judged to be suitable for fish culture. The other spring water is also preliminarily judged to be suitable based on the site survey and existing information.

The results of evaluation of the potential aquaculture sites are summarized in Table J-4. The advantageous conditions are clearly found in Afra and Burbeita which have hot springs to ensure high growth rate of fish. Despite several constraints like unavailability of electricity at present, these sites have suitable natural conditions, and should be given high priority. The sites located beside the Desert Highway namely Qatrana, Sultani and Hasa have good accessibility to ensure smooth marketing. However, a heating system is indispensable in winter because of the typical cold weather in the Highlands. The sites at Wadi Mujib, Wadi Ibn Hammad, Ain Sara and Lajjun have general potential conditions for aquaculture to be examined in future.

There are many hot springs that originate underneath Wadi Hasa and converge near Wadi Afra and Burbeita. The characteristics of two hot springs are summarized as follows:

| Items | Afra | Burbeita |
|---|---|---|
| - Water temperature at source of spring | 47-60°C | 40-42°C |
| - Approximate water temperature of main stream flow (estimated) | 40°C | 28-38°C |
| - Spring flow (litre/min) | 7,500 | 4,800 |

The source of Afra Hot Springs is located in the deep valley of Wadi Afra, a tributary of Wadi Hasa. There are few land areas for the fish farm in the vicinity of Afra Hot Springs up to about 1 km downstream. In summer people from Karak and Tafila regions, and also from Amman and neighbouring countries gather in Afra for hot spring care. People also go to Burbeita Hot Springs. However, Afra Hot Springs are popular because of its right temperature and volume for health care. Considering the optimum water temperature for tilapia and other warm water species at 26-30°C, Burbeita Hot Springs may be more suitable as a source of rearing water than Afra Hot Springs.

Burbeita Hot Springs emerge and gush out from the riverbed of Wadi Hasa. There are several small hot springs parallel to the main stream of Wadi Hasa. The project site can be found on the left bank of Wadi Hasa, which would be free from inundation by floods if provided with some bank protection dikes.

At present electric line has not been extended to both springs sites, however, it will be furnished by the year 1990 according to the Five-Year Plan of Tafila (1986-1990).

Based on the above discussion, Burbeita is selected as the most suitable aquaculture project site in the Study Area.

### 4.3 General Conditions of the Project Site

The suitable project site in Burbeita was found on the left bank of Wadi Hasa with an area of about 4 ha as shown in Fig. J-2. The greenhouse project is also planned in this site introducing hot water from Afra (refer to Chapter 3 of Volume 3 for details). When the warm water is required for aquaculture in winter it can be brought from greenhouses or be supplied directly from a hot water pipeline from Afra Hot Springs. The access to the site is easy by paved road of about 8 km long from the King's Highway connecting about 35 km with Karak, 20 km with Tafila and 150 km with Amman. The broad wadi basins in the vicinity have agriculture fields growing various vegetables and fruits with the irrigation water from Wadi Hasa. There are several houses and Bedou tents distributed in the Hasa Valley.

Meteorological conditions at the site with EL 260 m are estimated based on the data from two nearby stations at two different altitudes: Tafila with EL 1,200 m AMSL; and Wadi Wala with EL 450 m AMSL. The results are shown in Table J-5 and Fig. J-3. A significant climatic contrast is seen between summer and winter which is common throughout the Kingdom.

In summer the temperature may reach up to 35°C in the day time and drop to 18°C in the night showing daily difference of 17°C. In winter the temperature may drop to 5°C in the night while it goes up to 17°C in the day time. However, an extreme temperature of 40°C was observed during the field survey. The intensive rainfall causes seasonal flood in the wadi. The wind speed may be as moderate as 5-6 knots or 2.8-3.1 m/s throughout the year.

The proposed Tannour damsite is located on the main stream of Wadi Hasa at about 8 km upstream from the site for irrigation and control of floods (Ref. J-3).

As indicated in Section 4.2, electricity is not supplied to the site at present. A power distribution line will be extended to Burbeita under the Five-Year Plan of Tafila (1986-1990).

4.4 **Culture Species**

According to the natural conditions and the Jordanians' preference, tilapia species are suitable for aquaculture in the Kingdom. The culture species should be selected from either tilapia, O. nilotica or Red Tilapia. Both the species grow well and breed well in temperature between 24-32$^{o}$C.

In comparison with their characteristics, tilapia shows higher growth and reaches bigger size than Red Tilapia. However, Red Tilapia is preferred in the market because of its colour and taste.

In this study both Red Tilapia and tilapia are found to be suitable culture species, since the same culture method can be utilized.

As a new potential species, the Giant Freshwater Prawn, Macrobrachium rosenbergii may be nominated firstly. This prawn can be bred in a hatchery and requires similar rearing temperature as tilapia. The Giant Freshwater Prawn was found originally in Southeast Asia and has been introduced to many countries including the Middle East for aquaculture. During the larval stages for about 20 days, a certain amount of seawater is required. Seawater may be brought from Aqaba, and the transportation of seawater to the project site would be easier than the existing and planned aquaculture project sites located in the Jordan Valley and Azraq.

Consequently, Red Tilapia, tilapia and Giant Freshwater Prawn are selected and proposed as the culture species for the project.

4.5 **Availability of Fry, Feed and Skilled Manpower**

(1) Broodstock and Fry: The initial broodstock or fry of Red Tilapia can be purchased from AFCO farm, and those of tilapia from Azraq cooperative fish farm. Giant Freshwater Prawn has been imported for experimental work by AFCO. However, fry production has not been carried out. The initial broodstock of the prawn will have to be imported. The fry can be easily produced at the farm once the initial broodstock or fry is transferred and acclimatized.

(2) Feed: There are few feed materials for fish in Jordan. Presently AFCO purchases pellet feed from a meal company in Amman which produces mainly crumble feed for poultry. The feed materials consisting of fish meal, corn, soya bean, wheat and so forth are all imported except wheat bran. The pellet feed produced these days contains about 30-35 per cent of protein and sold at JD 125-130 per ton. Although the quality of pellet needs improvement, the sufficient quantity of feed could be procured in Jordan at low price than the imported pellet which was marketed at JD 350 per ton. Since the production of tilapia has been carried out without significant nutrient problems, the domestic pellet feed can be used as the major feed source of this project.

In future by-products from slaughter houses and wastes from restaurants should be examined as sources of feed materials.

(3) Skilled manpower: Unfortunately it seems that there is no Jordanian aquaculture technician at present. Even in AFCO the chief aquaculturist has been hired successively from Europe or Southeast Asia. At the initial stage of operation the assistance by a foreign expert for at least two years will be needed.

**4.6 Recommended Production System**

The recommendable production system both for tilapia and Giant Freshwater Prawn are discussed based on the site conditions and recent advance of aquaculture techniques. The production scale is proposed based on the available water quantity.

(1) Production system of tilapia: Tilapia species are cultured worldwide and the culture methods vary depending on site conditions and management policy. The outline of the methods is summarized in Table J-6. Since the construction of broad culture ponds is rather difficult in the vicinity of Afra-Burbeita, recently-developed intensive culture methods represented by a running water system and a water recirculation system are recommended for the project.

In general the running water system is a flow through system where the water is introduced and discharged, and the daily operation is easy though water intake is costly at those sites where water pumping head is high. While in the water recirculation system, the water is recirculated, and the required volume of make up water is low. In addition, the discharge of waste organic product can be controlled though construction cost is high as it requires complex equipment. And once fish disease sets in, it is difficult to control. The running water system is applied practically for various culture species including tilapia. The water recirculation system supported by biofiltration techniques has been advanced for limited culture species such as eel, trout and plaice.

In the project site the base flow of Wadi Hasa including discharge of Burbeita Hot Springs amounts to about 4,800 litre/min, and the water pumping head will not require more than 5 m. Hence the running water system is more recommendable comparing to the water recirculation system.

When the aquaculture is conducted in the project site in which climatic conditions show much difference between summer and winter and between daytime and night time, the maintenance of rearing water temperature might be one of the most important factors to achieve target productivity. The temperature in rearing tanks fluctuates due to various environmental conditions and running water input. These are roughly estimated by the calculation of thermal calorie balance as follows:

- Calorie gain ($Q_g$ in kcal/hr)

  $$Q_g = V (T_2 - T_1)$$

- Calorie loss ($Q_l$ in kcal/hr)

  $$Q_l = [20 (T_1 - t) + 70 w] A k$$

Where,
$V$ : Volume of input water (litre/hr)
$T_1$ : Water temperature of tank ($^oC$)
$T_2$ : Water temperature of input water ($^oC$)
$t$ : Air temperature ($^oC$)

$w$ : Wind speed (m/s)
$A$ : Surface area of tank ($m^2$)
$k$ : Coefficient

When $Q_g = Q_1$, $T_1$ is calculated as below:

$$T_1 = \frac{V\,T_2 + A\,k\,(20\,t - 70\,w)}{20\,A\,k + V}$$

The average water temperature in a 100-ton rearing tank is estimated as shown in Table J-7 for two cases; with and without pretreatment of water. Although tilapia can be grown under these water temperatures without any artificial adjustment, it is recommended that the optimum water temperature be maintained by supplying the water through cooling tower in the day time of summer and by introducing the warm water from greenhouses or directly from the Afra Hot Springs pipeline in winter.

The semi-transparent roof covering the tanks is recommended to avoid strong sunshine in summer and cold rainfall in winter. The wind should also be prevented to maintain rearing water temperature in winter by providing vinyl sheet to sides of the roof. Applying these facilities and operation, the water temperature can be controlled at an optimum level throughout the year.

A schematic production system of Red Tilapia using 100-ton tanks is summarized in Fig. J-4. Under the proper management three crops per year in grow-out tanks can be realized, and the annual productivity to the unit volume of water supply will be 60 kg/litre/min. In the case of tilapia, O. nilotica the productivity will increase in relation to its high growth rate and high fecundity to about 72 kg/litre/min of water.

(2) Production System of Giant Freshwater Prawn: The Giant Freshwater Prawn is usually cultured in freshwater ponds of 1,000 $m^2$ to more than 10,000 $m^2$ (1 ha). Its annual productivity is 3-5 t/ha or 0.3 - 0.5 $kg/m^2$ even in so-called intensive ponds.

The intensive production method in the small scale tank has not been developed well because of the difficulty in stocking prawn in high density due to their benthic and cannibalistic behaviours and also the inefficient and unstable production of fry.

Recently a Japanese expert who has 15 years experience in aquaculture of Giant Freshwater Prawn in Southeast Asia and Japan reported high productivity in new type of a nursery and grow-out tank as shown in Fig. J-6. Styrofoam plates are floated in the tanks to increase the area of settlement for prawn to provide shade for prevention of cannibalism. The principle of this method is to rear the batch of larvae hatched from one spawner without mixing with other batches up to commercial size prawn, and to market them constantly throughout the year based on the successive production. The optimum scale of unit rearing facilities has been studied for the rearing of one batch of larvae or young prawn.

This culture system is now applied on a commercial basis in one Japanese farm, and several farms are carrying out the practical rearing tests. Based on the progress in culturing prawn in tanks, this system seems to be reliable from technical point of view. Since it is difficult to produce commercial size prawn in high density using the existing system and there is no prawn farm operated on small scale grow-out tanks, this culture system and facility are recommended for the project site.

The schematic production system of Giant Freshwater Prawn is shown in Fig. J-5. During the larval rearing in the hatchery, certain volume of seawater is required for culturing zoea in brackish water at a salinity of about 10 ppt. The nauplii of zooplankton, Artemia salina is commonly used for the feed of zoea and early postlarva. Artemia nauplii is hatched out from dry eggs which are packed in can and sold commercially. These can be hatched artificially in 1-1.5 days and fed to larvae using a pipet or fine mesh net. After larval stages, prawn can be fed either animal or plant feed according to their omnivorous feeding habit. These can also be fed with pellet diets of tilapia.

The rearing water temperature is also very important for prawn culture, and is estimated in the same manner as for tilapia: with and without water pretreatment; and in addition under the indoor condition as shown in Table J-8. It is rather difficult to produce prawn in an outdoor tank in winter without introduction of warm water. Accordingly, it is recommended that tanks be kept in a simple house as in poultry. If the affect of wind is completely checked by construction of the house, the water temperature can be maintained at an optimum level throughout the year and two crops per year in grow-out tanks will be possible under the proper management. The annual productivity in terms of the unit volume of water supply will be 16 kg/litre/min. About 30 litres per year of seawater will be required to produce prawn fry to meet this productivity.

(3) Production scale: Based on the above discussion on the productivity of the recommended production system, the relation between annual production and quantity of water supply can be represented as shown in Fig. J-7.

Assuming that about 3,000 litre/min of water are available for aquaculture out of 4,800 litre/min of the total water flow in the project site and considering the balance of facilities, the production scale for both the species is proposed as follows:

| | Production Scale (t/yr) | Volume of Water Supply (litre/min |
|---|---|---|
| Red Tilapia ................. | 150 | 2,500 |
| (tilapia) | (180) | |
| Giant Freshwater Prawn ...... | 8 | 500 |
| Total | 158 | 3,000 |
| | (188) | |

(4) Water supply and discharge system: A schematic diagram showing the water intake, pretreatment and distribution flow to rearing facilities is shown in Fig. J-8. The base flow of Wadi Hasa which includes discharge of Burbeita Hot Springs will be pumped up to a reservoir tank at a rate of about 3,000 litre/min. The water stored in this tank will be

siphoned to the pretreatment tank provided with aeration, and be distributed to rearing tanks of tilapia and prawn using submersible pumps. Water for the hatchery will be drawn from the main distribution pipe. During the daytime in summer, water will be cooled in the cooling tower and in winter water will be warmed by mixing with hot water from greenhouses or the Afra Hot Springs pipeline. The control of water temperature in these manner will be realized automatically by applying a relay system between pumps.

During the flood of wadi in winter that may occur 2 to 8 times a year, it is anticipated that water can not be drawn directly from Wadi Hasa for about three days. At this time most of the water will have to be supplied from greenhouses or the Afra Hot Springs pipeline. Considering the quantity of discharge of greenhouses at about 1,200 litre/min, the rearing operation can be continued without any serious damage even during flood time.

The BOD load of discharged water from rearing tanks is estimated to be about 10 ppm at the maximum based on the calculation of daily feed input and feed consumed by fish. Assuming that the BOD in Wadi Hasa is less than 1 ppm, total BOD load would increase to 6.6 ppm at the immediate downstream of the facility, however it will decrease to less than 3.1 ppm by mixing with the Wadi Afra flow (7,500 litre/min) at about 2 km downstream from the site and the increasing base flow of Wadi Hasa. The actual BOD load will be much reduced by the wadi's self-purification effect. Consequently a simple biofiltration facility is recommended instead of full-scale water treatment facility.

### 4.7 Necessary Facilities and Equipment

The major facilities and equipment necessary for operation of the production system discussed above are as follows. A preliminary layout plan of the facilities is shown in Fig. J-9.

(1) Facilities

| | Facility unit | | Major facilities to be included |
|---|---|---|---|
| 1. | Administration building | : | Office, meeting room, service room, Rest room for workers, store room |
| 2. | Residence | : | Bed room, lavatory, shower room, dining room, kitchen, recreation room |
| 3. | Electric supply facility | : | Transformer and generator room, control panel, generator, oil tank |
| 4. | Hatchery | : | Broodstock and reserve tanks, larval rearing tanks and seawater reserve tanks for prawn, reserve tanks for tilapia, wet laboratory, store room, aeration facility |
| 5. | Tilapia rearing facility | : | Rearing tanks (24 units 10 m dia.), roof |
| 6. | Prawn rearing facility | : | Rearing tanks (20 units 8 m dia.), rearing house |
| 7. | Water supply facility | : | Reservoir tank, pretreatment tank, cooling tower, water pumps, supply pipe line, and valves |
| 8. | Water discharge facility | : | Drainage pipe line and canal, water treatment facility |
| 9. | Shipping facility and others | : | Shipping space, road in site, gate and fence, watchman box, lamppost, parking lot |

(2) Equipment

| | Equipment unit | | Major Equipment included |
|---|---|---|---|
| 1. | Equipment for hatchery and wet laboratory | : | Breeding tanks for prawn, Artemia incubation tanks, electric heater, aeration equipment, laboratory table, dissecting microscope, weight and balance, equipment for water quality check, portable water pump, refrigerator, cabinet, hand nets |
| 2. | Rearing and shipping equipment | : | Water puddle, automatic feeder, transportation container, screen net, scoop net |
| 3. | Office equipment and furniture | : | Telephone, office desk sets, meeting table and chairs, cabinet and other office tools, kitchen utensils, bed and furniture, etc. |
| 4. | Vehicles | : | Transportation trucks (2), pick-up truck, fork-lift |

4.8 Preliminary Financial Analysis

(1) Construction costs are estimated at the current prices of 1986 based on the following conditions and assumptions:

(A) Import duties and taxes are not included.

(B) Land acquisition cost is not included.

(C) Cost of each facility includes installation cost.

(D) Indirect construction cost is estimated at 7 per cent of the direct construction cost.

(E) Overhead and miscellaneous cost is estimated at 15 per cent of the direct and indirect costs, equipment cost and transportation cost.

(F) Construction supervision cost is estimated at 10 per cent of the total construction cost except for basic design and detailed design cost.

The construction costs are estimated to be JD 576,000 as shown in Table J-9. It may be approximately divided for the two culture species using the cost of rearing facilities: JD 325,000 for tilapia; and JD 251,000 for prawn.

(2) Operation and maintenance costs: The annual operation and maintenance costs are estimated based on the following assumptions:

(A) Grow-out feed cost for tilapia is calculated for production of 150 t/yr of Red Tilapia.

(B) Maintenance cost is estimated at 2 per cent of the total construction costs.

(C) Marketing cost is estimated at 10 per cent of the revenue.

(D) Administration and miscellaneous cost is estimated at 10 per cent of the operation cost.

(E) Temporary costs at the initial stage of operation such as a cost for hiring a foreign company or an expert, a cost of procuring initial stocks, are not included.

The annual operation and maintenance costs are estimated to be JD 121,000 as shown in Table J-10. The estimate of personnel expense is summarized in Table J-11. The annual operation and maintenance cost may be approximately divided for the two species using water supply ratio:

JD 100,000 for tilapia; and JD 21,000 for prawn.

(3) Revenue: The annual revenue is estimated to be JD 150,000 for Red Tilapia or tilapia and JD 52,000 for Giant Freshwater Prawn, and in total JD 202,000 based on the following farm-gate prices:

- Red Tilapia : JD 1.00/kg (present farm-gate price of AFCO)
- Tilapia : JD 0.83/kg
- Giant Freshwater Prawn: JD 6.5/kg

The price of Giant Freshwater Prawn is estimated by using a unit price ratio of imported frozen shrimp to imported frozen tilapia. Usually the ratio is about 8. When the price of fresh tilapia is 0.83 JD/kg, that of fresh prawn will be 6.5 JD/kg.

(4) Financial viability: The estimated costs and revenue are summarized by species in Table J-11. The annual profit before interest, tax and temporary costs at the initial stage of operation is estimated to be JD 29,000 for tilapia, JD 15,000 for prawn, and JD 44,000 in total which are equal to about 20 per cent of the revenue for tilapia and 30 per cent for prawn. It is suggested that when the total investment is provided by the Central Bank of Jordan at the maximum current interest rate of 10 per cent, the project will not show financial viability. However, if the interest rate is less than 7 per cent and the temporary cost is excluded, the project will financially be viable.

### 4.9 Implementation Schedule

The implementation schedule of the project is shown in Fig. J-10. Since the preliminary framework of the project has been presented in this study, basic design and detailed design can be implemented successively.

After basic and detailed design for about 4-5 months and construction work for about one year, the pilot operation will be started with assistance of experts from a foreign company. The technical transfer should be done during this period. The marketing strategy of live and fresh fish should also be developed through marketing promoting activities.

The production system should be evaluated and developed from both technical and management points of view by the end of the pilot operation stage.

When the initial stage is completed successfully in about 5 years from the basic design stage, the full-scale operation will be commenced.

## 4.10 Organization

As aquaculture requires 24-hours operation, management should be conducted by private firms. However, in the case of implementation by a private organization only, the project may not be financially viable and there would be several constraints in the marketing of large quantity of live or fresh fish especially in the initial operation.

This project will bring economic benefit through creation of new industries in the Project Area, supply of domestic fresh fish in the Kingdom to stabilize the potential demand and to save foreign currency by import substitute.

Considering the above characteristics of the project, it is suggested that the project should be implemented by the initiative of the public sector but practical operation be carried out under private management during the pilot stage till the suitable marketing structure will be formulated for live and fresh fish in the Kingdom. Then the project may be transferred to the private sector.

With regard to the public organization, the regional government of Karak and Tafila should take leadership besides the semi-governmental organizations which have acquired experience in aquaculture such as the Pension Fund, the Social Security Cooperation and JESORS, which are recommended to support its management. The central government such as MOA, MOP and MOS should play a role as one of financing sources for hiring a foreign company or expert either for basic design and detailed design or pilot scale operation. In this case the foreign company can also offer consulting services for other aquaculture-related industries.

In the private sector formulation of cooperatives among the local people will be more effective in terms of enhancement of technical transfer and promotion of aquaculture industry. In this case the operation should be carried out by the cooperative members from the initial stage of the operation. The rotation of workers can be considered among the cooperative members. When the cooperative members have acquired experience in the operation of the facilities and handling of fishes, and when the fresh fish market is established, the local cooperatives will be able to take leadership as one of the indispensable operating bodies.

*The organizational structure of the project is shown in Fig. J-11.*

## 5. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have been obtained through the study:

(1) The high demand for fresh fish supply was confirmed in the Kingdom.

(2) The project site in Burbeita where base flow and hot spring water are available was identified to be most recommendable for aquaculture in the Project Area.

(3) Under proper management of the recommended production system, 150 t/yr or JD 150,000/yr of Red Tilapia and 8 t/yr or JD 52,000/yr of Giant Freshwater Prawn can be produced with a water supply of 3,000 litre/min.

(4) The total construction cost is estimated to be 576,000 and the annual operation cost JD 121,000 excluding the temporary cost at the initial stage.

(5) The preliminary analysis suggested that the project will be financially viable, if it is financed with an interest rate of less than 7 per cent and adequate cooperation of public organizations provided.

(6) The public sector should organize and manage to some extent the project until a suitable marketing system for live and fresh fish will be formulated and established.

The project is recommended to be proceeded to basic and detailed design stages as soon as possible focusing on the following subjects:

(1) Determination of an adequate production scale based on the marketability of the product

(2) Detailed estimation of construction and operation costs

(3) Financial analysis of the project

There are several problems to be solved for development of aquaculture in Jordan, particularly on the poor marketing conditions for live and fresh fish.

So, besides implementation of the proposed aquaculture project, a study on the marketing and transportation of fresh fish should be made to clarify the following points:

- Potential demand for fresh fish by region
- Suitable retail price of cultured fish species based on marketing analyses
- Necessary facilities and equipment to realize a marketing network of fresh fish: ice plant, cold storage, processing plant, transportation vehicles, etc.
- Organizations to implement smooth fish marketing

At present the following actions are recommended for the short-term strategy to stimulate the fresh fish demand in the Kingdom by both the public and private sectors:

- Opening of a demonstration fresh fish market in downtowns of Amman and other major cities
- Opening of demonstration fresh fish restaurants at tourist spots especially in the Study Area
- Promotion of new fish recipes or methods of cooking through an advertisement by mass media

## REFERENCES


J-1 Feasibility Study for Fish Farming at Azraq (1986), Ministry of Planning

J-2 National Radioactivity and Hydrochemistry of Some Jordanian Groundwater Resources (1987), Water Research and Study Center, University of Jordan

J-3 Further Updated Feasibility Study Report on Mujib and Southern Ghors Irrigation Project - stage II - 1987

# TABLES

Table J-1 QUANTITY OF FISH CAUGHT IN AQABA BY MONTH DURING 1979-1984

(t/month)

| Month | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|---|
| January | 0.8 | 2.0 | 0.8 | 1.4 | 0.2 | 0.12 |
| February | 4.6 | 2.2 | 0.3 | 1.7 | 0.9 | 0.12 |
| March | 2.2 | 2.1 | 1.6 | 2.2 | 1.3 | 0.12 |
| April | 1.3 | 4.7 | 1.8 | 1.7 | 3.1 | 0.12 |
| May | 5.3 | 5.1 | 3.8 | 2.2 | 4.7 | 0.17 |
| June | 2.6 | 7.5 | 5.7 | 1.2 | 1.7 | 0.12 |
| July | 3.6 | 5.7 | 7.1 | 1.2 | 1.8 | 0.12 |
| August | 3.6 | 1.6 | 2.9 | 1.1 | - | 0.12 |
| September | 1.1 | 6.0 | 3.1 | 2.5 | 1.2 | 0.13 |
| October | 5.6 | 5.1 | 3.6 | 3.0 | 2.1 | 0.12 |
| November | - | 7.0 | 2.3 | 1.2 | - | 0.12 |
| December | 5.5 | 7.0 | 2.3 | - | - | 0.12 |
| Total | 36.2 | 56.2 | 35.3 | 19.4 | 17.0 | 1.5 |

Source: Ministry of Agriculture

Table J-2 SUPPLY OF FISHERY PRODUCTS IN JORDAN

| | 1975 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 1/ |
|---|---|---|---|---|---|---|---|---|
| Imports (t/yr) | 4281 | 4481 | 4879 | 5154 | 6467 | 5613 | 6249 | 5340 |
| 1. Fresh, frozen or chilled | 3210 | 1849 | 2517 | 1402 | 2750 | 2233 | 3225 | 2301 |
| 2. Dried, salted or smoked | 40 | 143 | 172 | 141 | 283 | 76 | 61 | 211 |
| 3. Canned | 1031 | 2489 | 2208 | 3511 | 3434 | 3304 | 2963 | 2828 |
| Re-Exports (t/yr) | 16 | 27 | 99 | - | - | 43 | 17 | |
| Net Imports (t/yr) | 4256 | 4454 | 4798 | 5154 | 6467 | 5570 | 6232 | |
| Local production 2/ (t/yr) | N.D. | 56 | 35 | 19 | 17 | 2 | N.D. | |
| Total Consumption (t/yr) | 4256 | 4510 | 4833 | 5179 | 6484 | 5572 | 6232 | |
| Population (million) | 1.82 | 2.23 | 2.32 | 2.42 | 2.51 | 2.60 | 2.69 | |
| Per Capita Consumption (kg/yr) | 2.3 | 2.0 | 2.1 | 2.1 | 2.6 | 2.1 | 2.3 | |

Source: Ministry of Agriculture
1/: Preliminary data
2/: Excluding freshwater fish

Table J-3 **WATER QUALITY OF AFRA HOT SPRINGS, BURBEITA HOT SPRINGS AND WADI MUJIB**

| | | Afra Hot Springs (18/7/87) | Burbeita Hot Springs (20/7/87) | Wadi Mujib (18/7/87) | Burbeita (16/8/87) |
|---|---|---|---|---|---|
| E.C. | (mS/cm) | 0.71 | 0.81 | 1.41 | 0.55 |
| T.D.S. | (mg/l ) | 454 | 518 | 902 | 352 |
| pH | (meq/l) | 7.80 | 7.85 | 7.72 | 6.7 |
| $Ca^{++}$ | (meq/l) | 3.61 | 3.57 | 4.08 | 2.15 |
| $Mg^{++}$ | (meq/l) | 1.29 | 1.84 | 4.80 | 1.37 |
| $Na^{+}$ | (meq/l) | 2.10 | 2.50 | 5.60 | 1.9 |
| $K^{+}$ | (meq/l) | 0.11 | 0.16 | 0.19 | 0.19 |
| $Cl^{-}$ | (meq/l) | 2.33 | 2.79 | 6.42 | 2.18 |
| $SO_4^{-}$ | (meq/l) | 1.75 | 1.47 | 3.62 | 0.9 |
| $CO_3^{-}$ | (meq/l) | 0.0 | 0.0 | 0.0 | 0.0 |
| $HCO_3^{-}$ | (meq/l) | 2.93 | 3.81 | 4.55 | 2.32 |
| $NO_3^{-}$ | (meq/l) | 0.97 | 0.53 | 1.99 | 0.0 |

Source: The Study Team

Table J-4 PRELIMINARY EVALUATION OF THE POTENTIAL AQUACULTURE SITES

| Sites | Major source of water | Climate | Water | | | Availability of land | Electricity | Accessibility |
|---|---|---|---|---|---|---|---|---|
| | | | Temp. | Qly. | Qty. | | | |
| Karak Region | | | | | | | | |
| 1. W. Mujib | Spring | 0 | # | 0 | 0 | 0 | 0 | 0 |
| 2. W. Ibn Hammad | Spring | 0 | # | 0 | 0 | 0 | 0 | 0 |
| 3. Ain Sara | Spring | # | # | 0 | 0 | # | 0 | 0 |
| 4. Lajjun | Spring | # | # | 0 | - | 0 | 0 | 0 |
| 5. Qatrana | Reservoir & well | # | # | - | - | 0 | 0 | 0 |
| 6. Sultani 1/ | Reservoir | # | # | - | - | 0 | 0 | 0 |
| Tafila Region | | | | | | | | |
| 7. Afra | Hot spring | 0 | 0 | 0 | 0 | # | X 2/ | # |
| 8. Burbeita | Hot spring & wadi | 0 | 0 | 0 | 0 | 0 | X 2/ | 0 |
| 9. Hasa | Well | # | # | - | - | 0 | 0 | 0 |

1/: During site survey in July 1987, no water was impounded in Sultani Dam.

2/: A distribution line will be extended by the year 1990.

Notes:

(1) Means of relative evaluation marks are as follows:
0: Good #: Fair X: No Good -: Unknown

(2) Criteria for the above evaluation are as follows:

(A) Climate: Whether relatively moderate temperature in winter is expected or not

(B) Water

(a) Temperature: Whether suitable water temperature of over 24°C (for tilapia and prawn) can be realized annually or not

(b) Quality: Whether the content of harmful substance such as $SO_4$ is low enough or not

(c) Quantity: Whether perennial and adequate volume of water can be drawn or not

(C) Availability of land: Whether adequate land area for fish farm can be obtained in the vicinity or not

(D) Electricity: Whether a distribution line extends near the sites or not

(E) Accessibility: Whether an access road condition is good or not

Source: The Study Team

Table J-5 ESTIMATED METEOROLOGICAL CONDITIONS IN BURBEITA

| | Summer (July and August) | Winter (January) | Annual Ave./Total |
|---|---|---|---|
| Temperature ($^oC$) | | | |
| Ave. Max. | 35 | 17 | 27 |
| Ave. Min. | 18 | 5 | 12 |
| Mean | 26 | 11 | 20 |
| Rainfall (mm) | 0 | 70 | 270 |
| Wind Speed (Knot) | 5.5 | 6.0 | 5.5 |
| (m/sec) | 2.8 | 3.1 | 2.8 |

Source: The Study Team

Table J-6 *PRODUCTIVITY OF TILAPIA IN VARIOUS CULTURE METHODS*

| Culture Method | Water Change (times/day) | Aeration | Water Recirculation (times/day) | Filtration | Productivity ($kg/m^3$/crop) | Present Condition |
|---|---|---|---|---|---|---|
| 1. Extensive | < 0.1 | No | No | No | < 5 | Practical |
| 2. Semi-intensive | < 0.1 | Yes | No | No | 5-10 | Practical |
| 3. Intensive | | | | | | |
| a. Running water | 1.5-2 | Yes | No | No | 30-40 | Practical |
| b. Running water + recirculation | 2 | Yes | 6 | Yes | ≥100 | Experimental |
| c. Recirculation | < 0.1 | Yes | 24-36 | Yes | 30-40 | Practical |

Note: Applied commonly for some species: eel, trout and plaice but rarely for tilapia
Source: The Study Team

## Table J-7 ESTIMATED WATER TEMPERATURE IN A 100-TON REARING TANK FOR TILAPIA

(1) Without pretreatment

| Water change (times/day) | Summer 1 | Summer 1.5 | Summer 2 | Winter 1 | Winter 1.5 | Winter 2 |
|---|---|---|---|---|---|---|
| V (litre/hr) | 4200 | 6300 | 8400 | 4200 | 6300 | 8400 |
| $T_2$ (°C) | 38 | 38 | 38 | 28 | 28 | 28 |
| t (°C) | 26 | 26 | 26 | 11 | 11 | 11 |
| w (m/sec) | 2.8 | 2.8 | 2.8 | 3.1 | 3.1 | 3.1 |
| A ($m^2$) | 78 | 78 | 78 | 78 | 78 | 78 |
| k | 2 | 2 | 2 | 2 | 2 | 2 |
| $T_1$ (°C) | 28.7 | 30.8 | 32.1 | 16.1 | 18.8 | 20.5 |

Note: k = 2 is applied considering the effect of water puddling to be equipped in the tank.

(2) With pretreatment

| Water change (times/day) | Summer $T_2$=30°C 1 | Summer $T_2$=30°C 1.5 | Summer $T_2$=30°C 2 | Winter $T_2$=34°C 1 | Winter $T_2$=34°C 1.5 | Winter $T_2$=34°C 2 |
|---|---|---|---|---|---|---|
| $T_1$ (°C) | 24.1 | 25.4 | 26.3 | 19.6 | 22.8 | 24.8 |

Note: (1) In summer water is supplied through a cooling tower.
(2) In winter water is supplied after mixed with hot water from greenhouses or from the Afra Hot Springs pipeline.

Source: The Study Team

Table J-8 ESTIMATED WATER TEMPERATURE IN A REARING TANK FOR GIANT FRESHWATER PRAWN (1/2)

(1) Without pretreatment ($T_2$ - 38°C in summer, 28°C in winter)

Case 1: Outdoor

| | Summer | | | Winter | | |
|---|---|---|---|---|---|---|
| | Inner tank | Outer tank | | Inner tank | Outer Tank | |
| Water change (times/day) | 7 | 1 | 2 | 7 | 1 | 2 |
| V (litre/hr) | 1200 | 1200 | 2400 | 1200 | 1200 | 2400 |
| $T_2$ (°C) | 38 | 38 | 38 | 28 | 28 | 28 |
| t (°C) | 26 | 26 | 26 | 11 | 11 | 11 |
| w (m/s) | 2.8 | 2.8 | 2.8 | 3.1 | 3.1 | 3.1 |
| A ($m^2$) | 13 | 50 | 50 | 13 | 50 | 50 |
| k | 1 | 1 | 1 | 1 | 1 | 1 |
| $T_1$ (°C) | 34.1 | 28.1 | 31.6 | 23.0 | 15.3 | 19.8 |

Case 2: Indoor (w = 0)

| | Summer | | | Winter | | |
|---|---|---|---|---|---|---|
| | Inner tank | Outer tank | | Inner tank | Outer Tank | |
| Water change (times/day) | 7 | 1 | 2 | 7 | 1 | 2 |
| $T_1$ (°C) | 35.9 | 32.5 | 34.5 | 25.0 | 20.3 | 23.0 |

Source: The Study Team

Table J-8 ESTIMATED WATER TEMPERATURE IN A REARING TANK FOR GIANT FRESHWATER PRAWN (2/2)

(2) With pretreatment ($T_2$ = 30°C in summer, 34°C in winter)

Case 1: Outdoor

| | Summer | | | Winter | | |
|---|---|---|---|---|---|---|
| | Inner tank | Outer tank | | Inner tank | Outer Tank | |
| Water change (times/day) | 7 | 1 | 2 | 7 | 1 | 2 |
| V (litre/hr) | 1200 | 1200 | 2400 | 1200 | 1200 | 2400 |
| $T_2$ (°C) | 30 | 30 | 30 | 34 | 34 | 34 |
| t (°C) | 26 | 26 | 26 | 11 | 11 | 11 |
| w (m/s) | 2.8 | 2.8 | 2.8 | 3.1 | 3.1 | 3.1 |
| A ($m^2$) | 13 | 50 | 50 | 13 | 50 | 50 |
| k | 1 | 1 | 1 | 1 | 1 | 1 |
| $T_1$ (°C) | 27.5 | 23.7 | 25.9 | 28.0 | 18.6 | 24.0 |

Case 2: Indoor (w = 0)

| | Summer | | | Winter | | |
|---|---|---|---|---|---|---|
| | Inner tank | Outer tank | | Inner tank | Outer Tank | |
| Water change (times/day) | 7 | 1 | 2 | 7 | 1 | 2 |
| $T_1$ (°C) | 29.3 | 28.2 | 28.8 | 29.9 | 23.5 | 27.2 |

Source: The Study Team

Table J-9 ESTIMATE OF CONSTRUCTION COSTS

| Description | | Cost (JD) | |
|---|---|---|---|
| Total Construction Cost | | | 576,000 |
| 1. | Detailed Design | | 35,000 |
| 2. | Direct construction cost | | 308,000 |
| | 1) Site preparation | 12,000 | |
| | 2) Administration Building | 13,000 | |
| | 3) House for engineer | 11,000 | |
| | 4) Electric supply facility | 29,500 | |
| | 5) Hatchery | 15,000 | |
| | 6) Tilapia rearing facility | 85,500 | |
| | 7) Prawn rearing facility | 66,000 | |
| | 8) Water supply facilities | 40,000 | |
| | 9) Water discharge facilities | 18,000 | |
| | 10) Shipping facility and others | 18,000 | |
| 3. | Indirect construction cost | | 22,000 |
| 4. | Equipment cost | | 90,000 |
| | 1. Equipment for hatchery | 18,000 | |
| | 2. Rearing and shipping equipment | 30,000 | |
| | 3. Office equipment and furniture | 12,000 | |
| | 4. Vehicles | 22,000 | |
| | 5. Installation of equipment | 8,000 | |
| 5. | Transportation cost | | 8,000 |
| 6. | Overhead and miscellaneous cost | | 64,000 |
| 7. | Construction supervision | | 49,000 |

Source: The Study Team

Table J-10 ESTIMATE OF OPERATION AND MAINTENANCE COSTS

| Description | | Cost (JD) |
|---|---|---|
| Total Operation and Maintenance Cost | | 121,000 |
| 1. Personnel expense | | 29,000 |
| 2. Feed Cost | | 34,000 |
| 1) Grow-out feed for tilapia (FCR 65%) | 30,000 | |
| 2) Grow-out) feed for prawn (FCR 60%) | 1,800 | |
| 3) Artemia and larval feed | 2,200 | |
| 3. Utility cost | | 15,000 1/ |
| 4. Maintenance cost | | 12,000 |
| 5. Marketing cost | | 20,000 |
| 6. Administration and miscellaneous | | 11,000 |

1/: Utility cost is estimated to be JD 15,800 before electricity is supplied.

Source: The Study Team

Table J-11 ESTIMATE OF PERSONNEL EXPENSES

| Position | No. | Monthly Salary | Annual Total |
|---|---|---|---|
| Director | 1 | 350 | 4,800 |
| Vice Director | 1 | 250 | 3,000 |
| Mechanic engineer | 1 | 250 | 3,000 |
| Clerk | 1 | 200 | 2,400 |
| Driver | 2 | 150 | 3,600 |
| Workers | 8 | 100 | 9,600 |
| Watchman | 2 | 100 | 2,400 |
| Total | 15 | | 28,800 |

Source: The Study Team

Table J-12 PRELIMINARY EXAMINATION OF FINANCIAL VIABILITY

(JD)

| | Tilapia | Prawn | Total |
|---|---|---|---|
| Production Cost | 121,000 | 37,000 | 158,000 |
| 1) Operation Cost | 100,000 | 21,000 | 121,000 |
| 2) Depreciation | 21,000 | 16,000 | 37,000 |
| Revenue | 150,000<br>(100%) | 52,000<br>(100%) | 202,000<br>(100%) |
| Profit before interest, tax and temporary cost at initial operation stage | 29,000<br>(19%) | 15,000<br>(29%) | 44,000<br>(22%) |

Note: Depreciation period was assumed to be 20 years for 70 % of construction works and 10 years for the remaining 30 %.

Source: The Study Team

# F I G U R E S

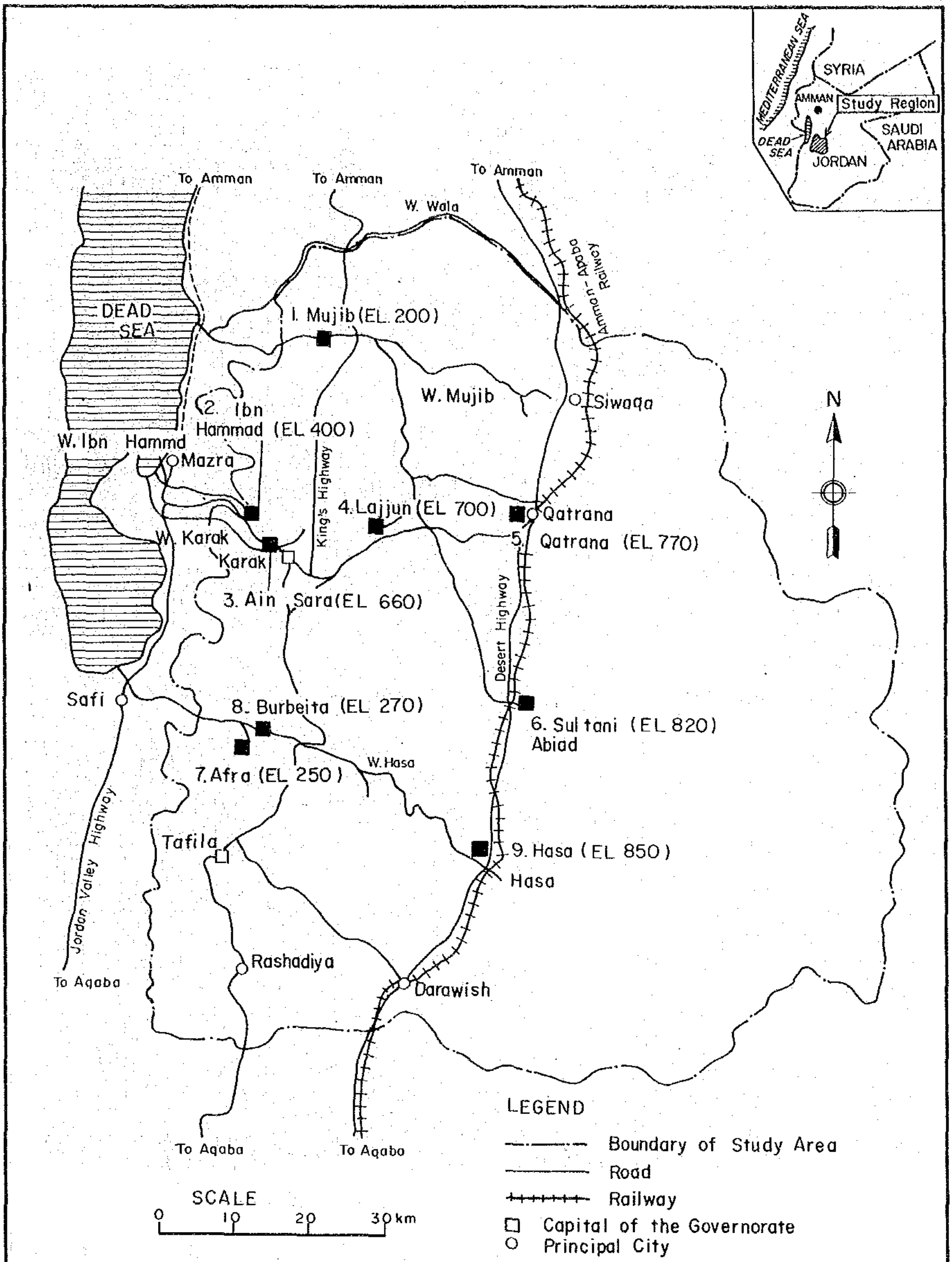


Fig. J-1 Potential Sites for Aquaculture in the Study Area

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

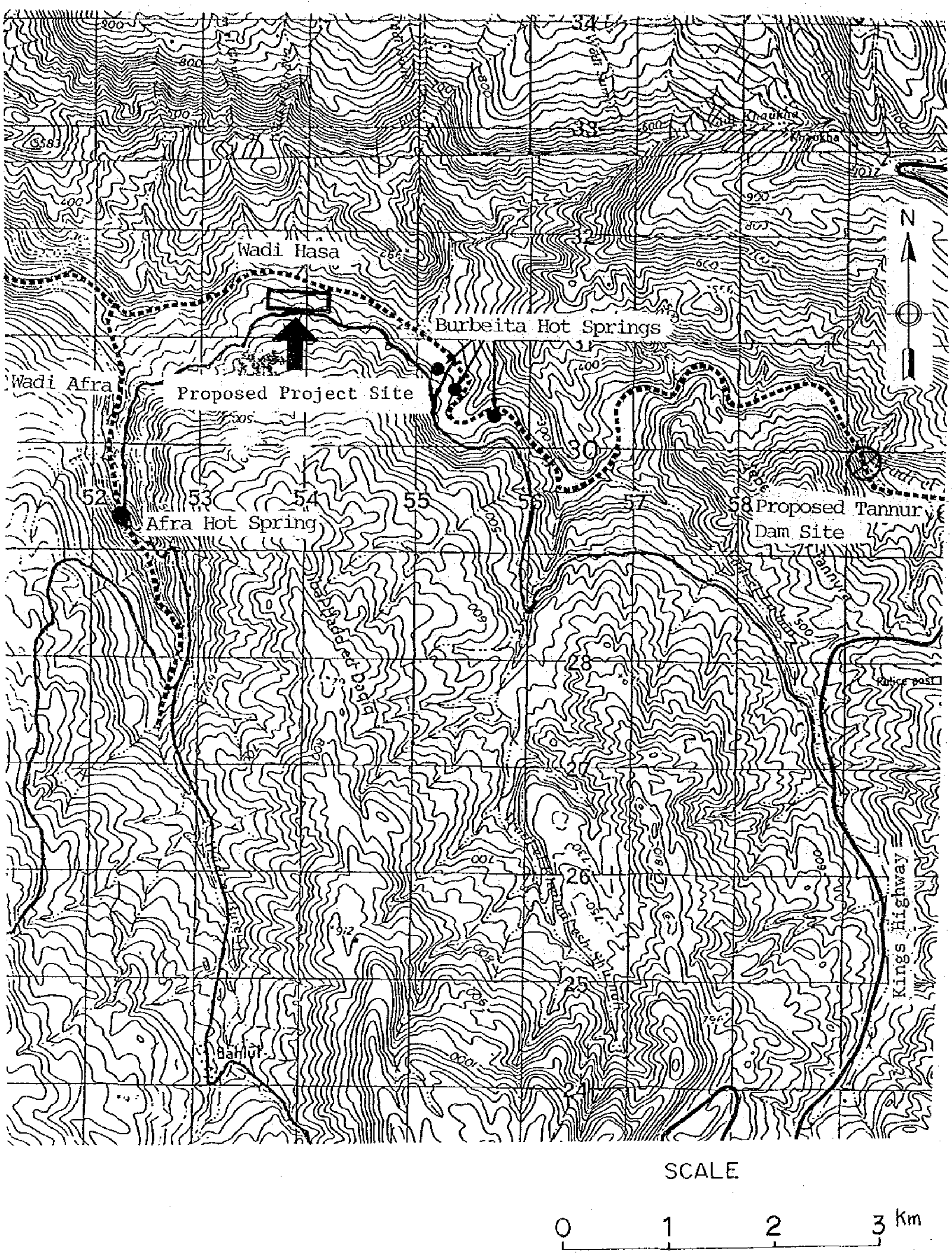


Fig. J-2 Location Map of Proposed Aquacultural Project

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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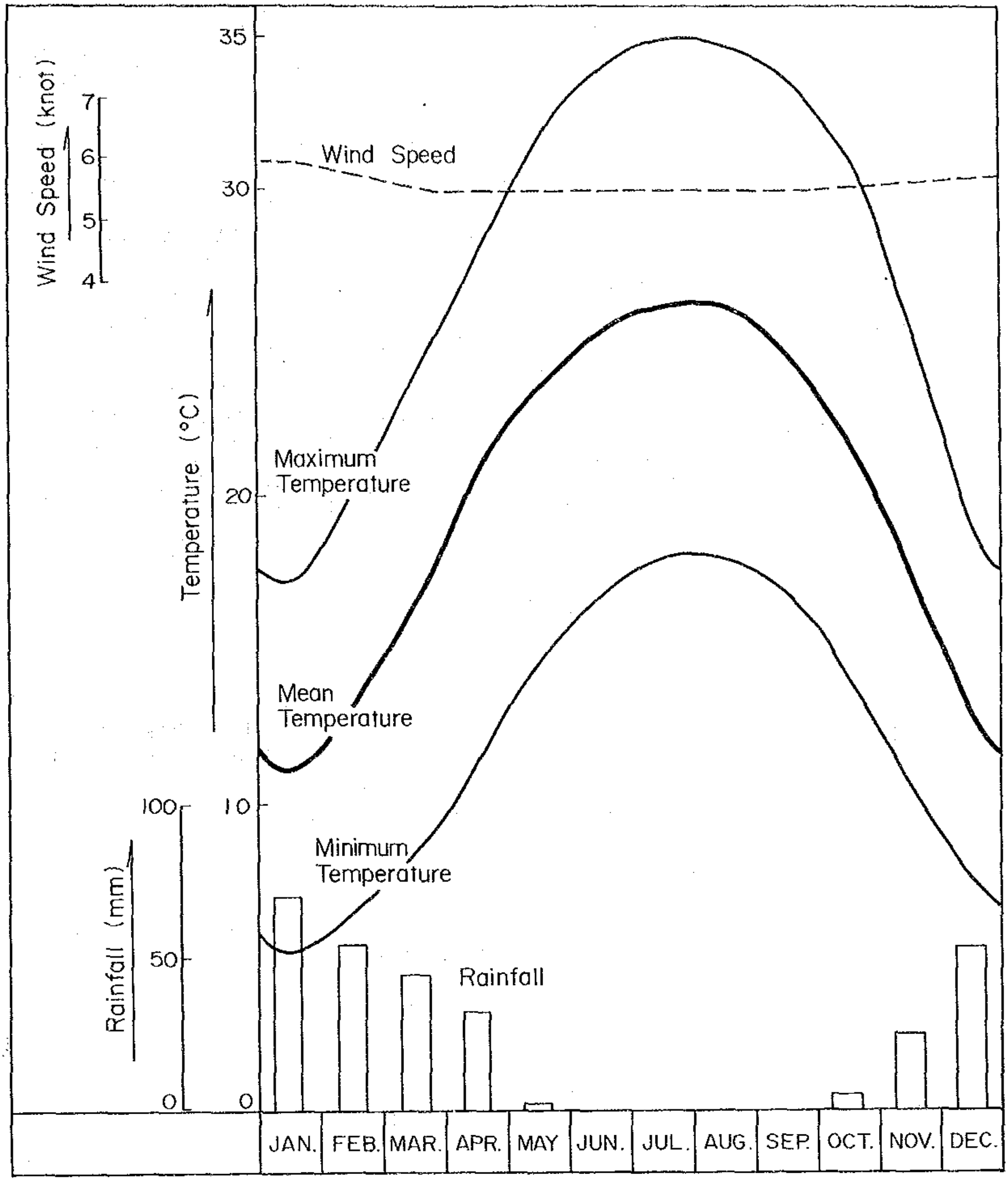


Fig. J-3 **Estimated Meteorology at Project Site**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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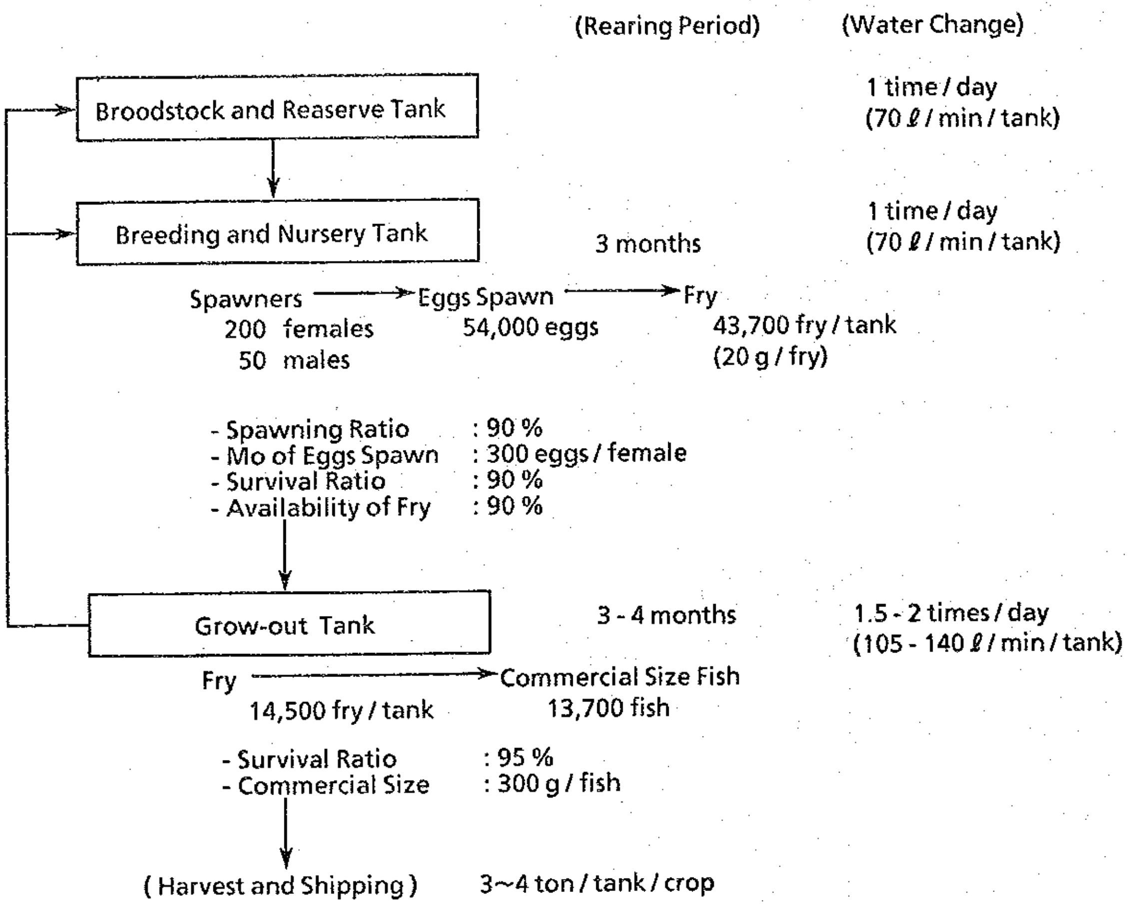


Fig. J-4 Schematic Production System for Red Tilapia (for 100-ton Tank)

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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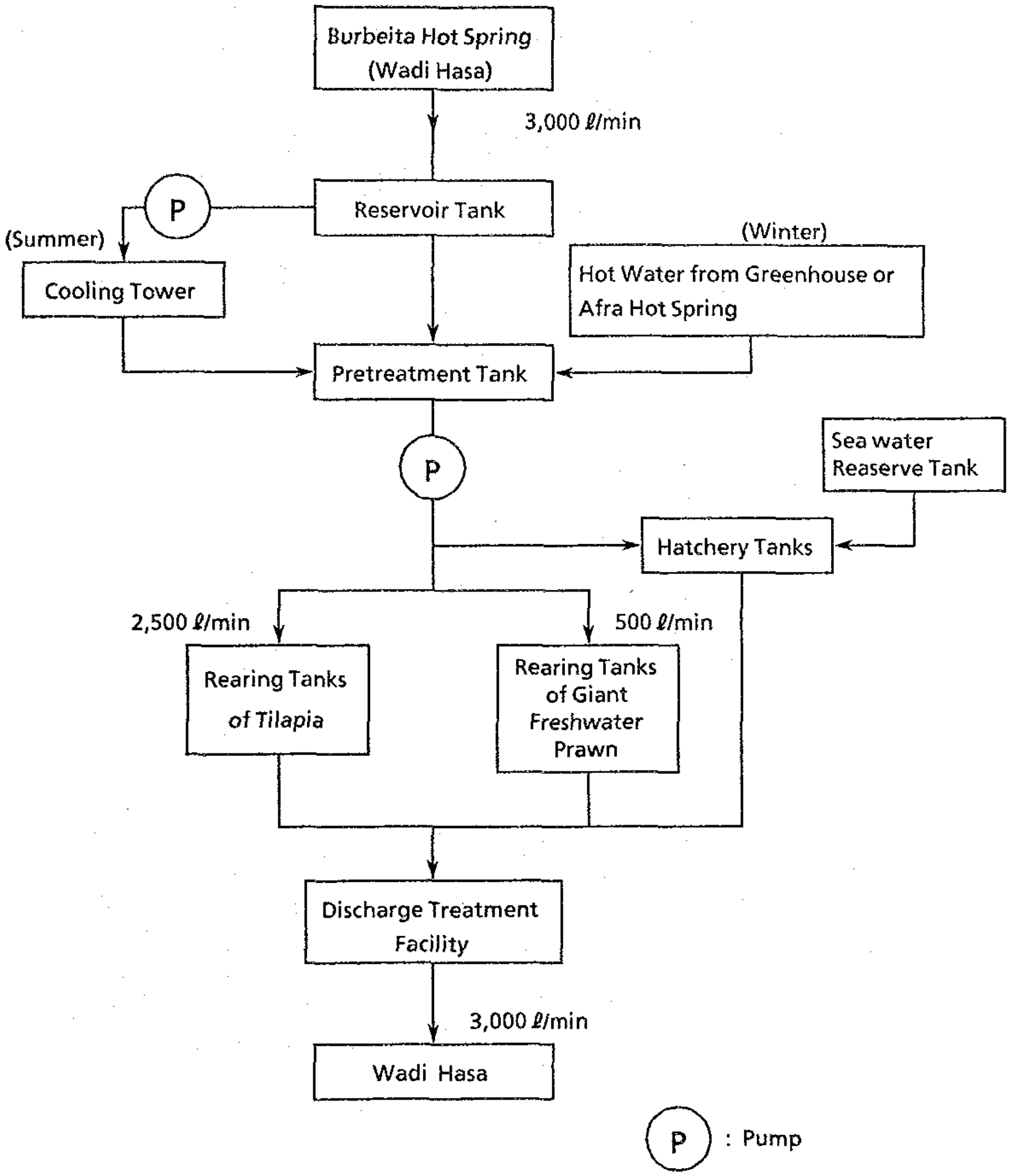


Fig. J-5 Schematic Production System for Giant Freshwater Prawn

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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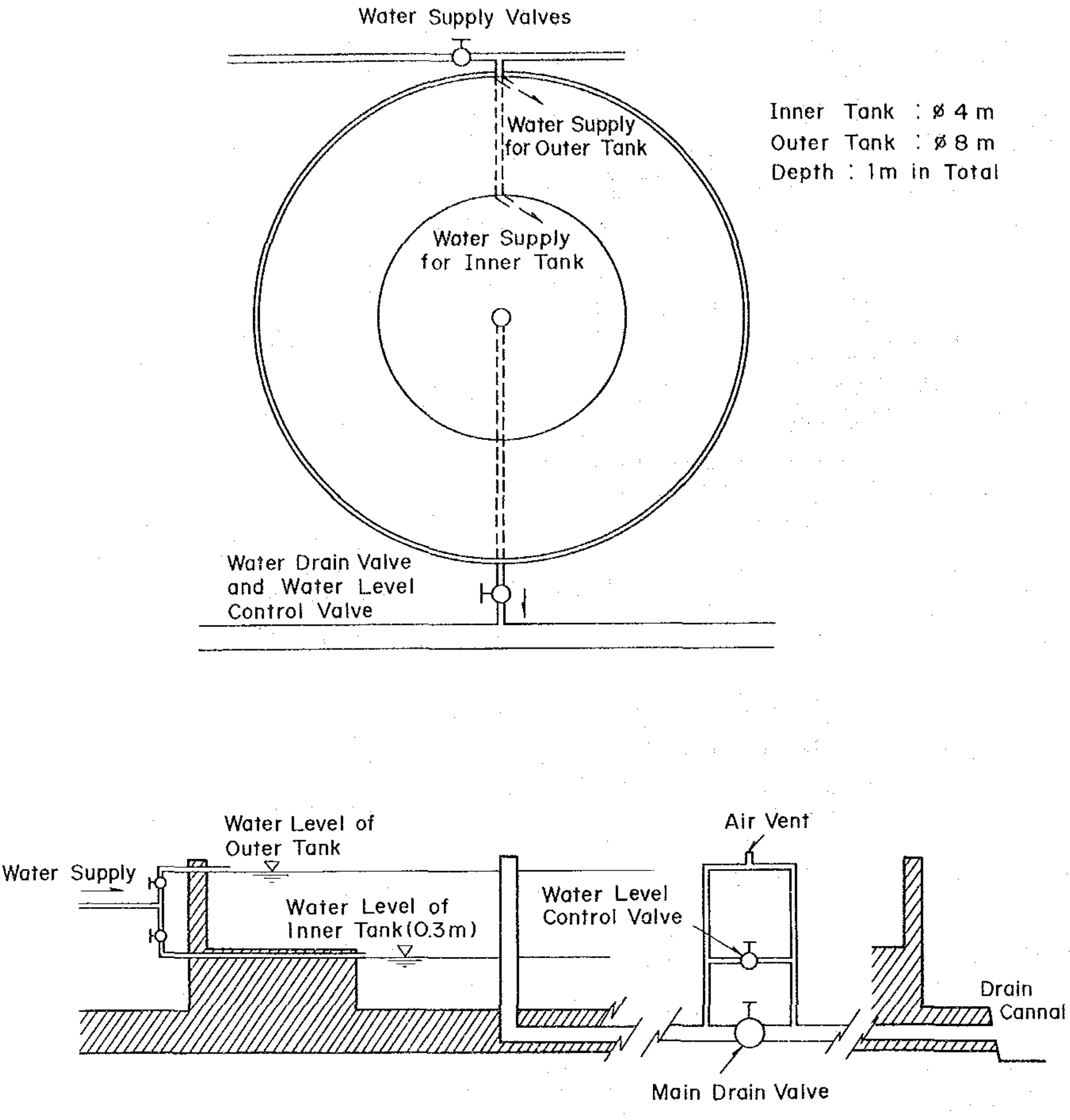


Fig. J-6 Layout of Nursery
and Grow-out Tank
for Giant Freshwater Prawn

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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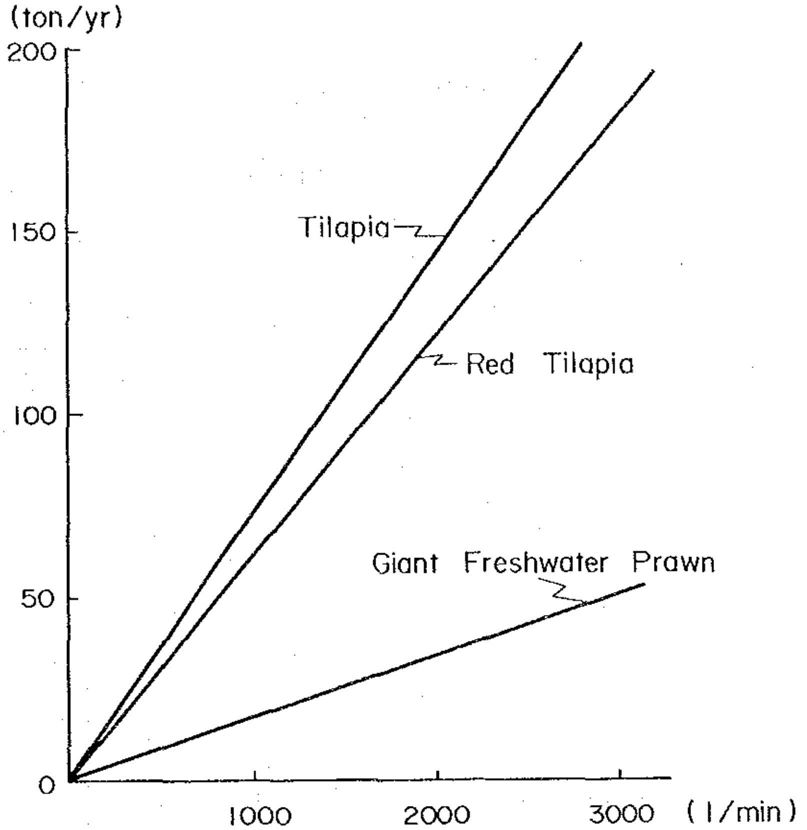


Remarks 1) Water Temperature : 26 ~ 30°C
2) No. of Crop per year :
- 3 times for Tilapia and Red Tilapia
- 2 times for Giant Freshwater Prawn

**Fig. J-7 Relation Between Unit Water Flow and Annual Production**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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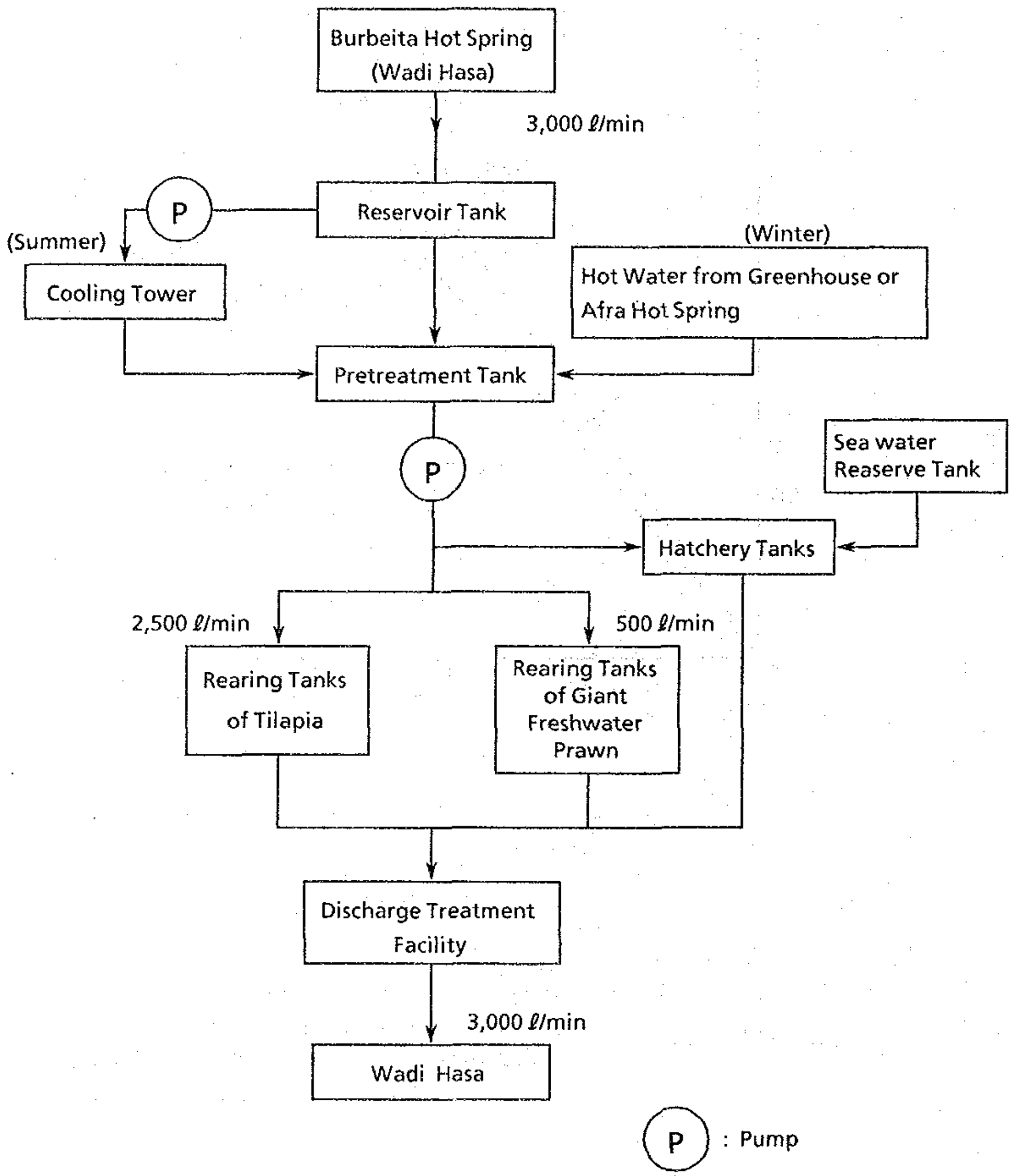


Fig. J-8 Water Flow Diagram

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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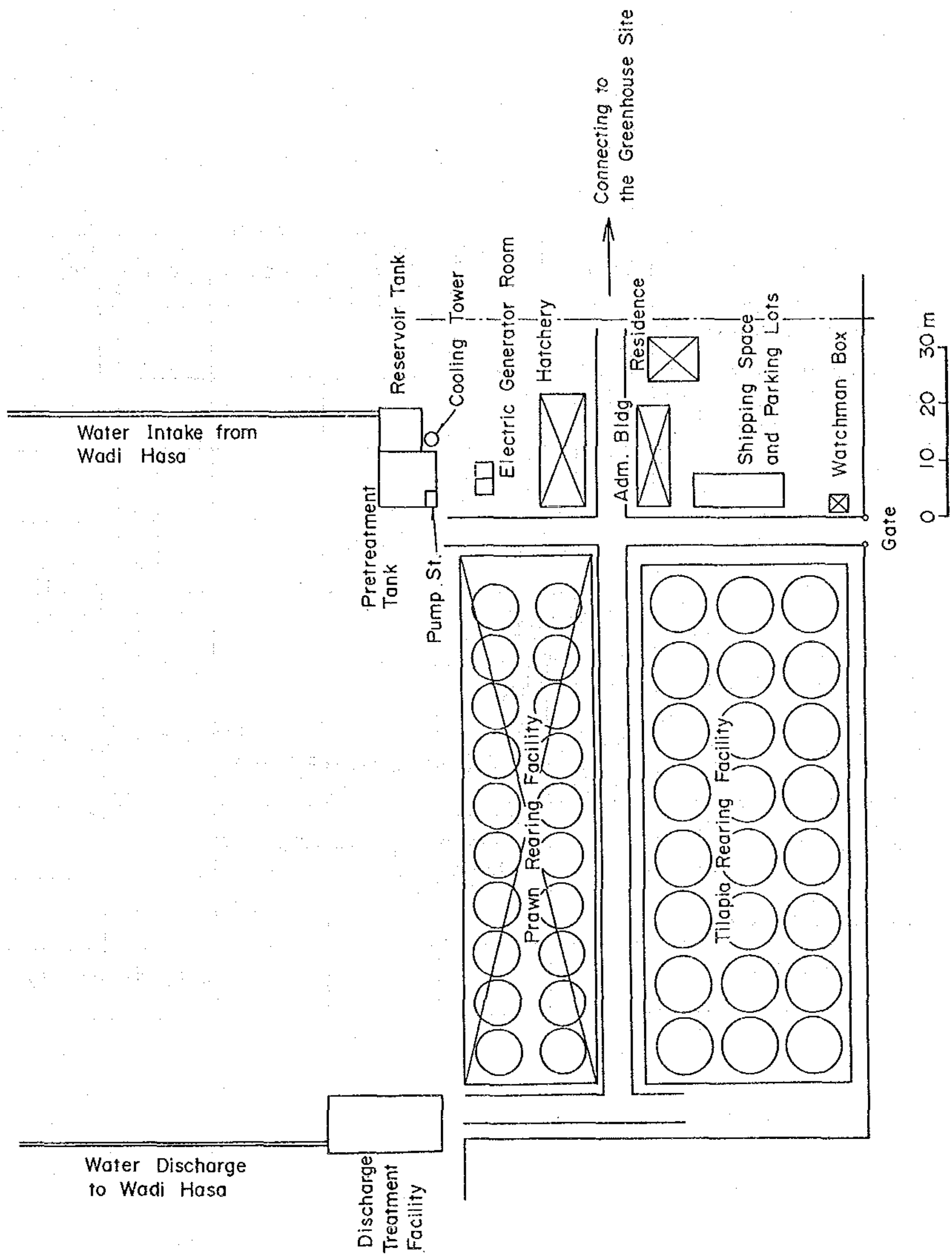


**Fig. J-9 Preliminary Layout of Proposed Fish Plant**

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

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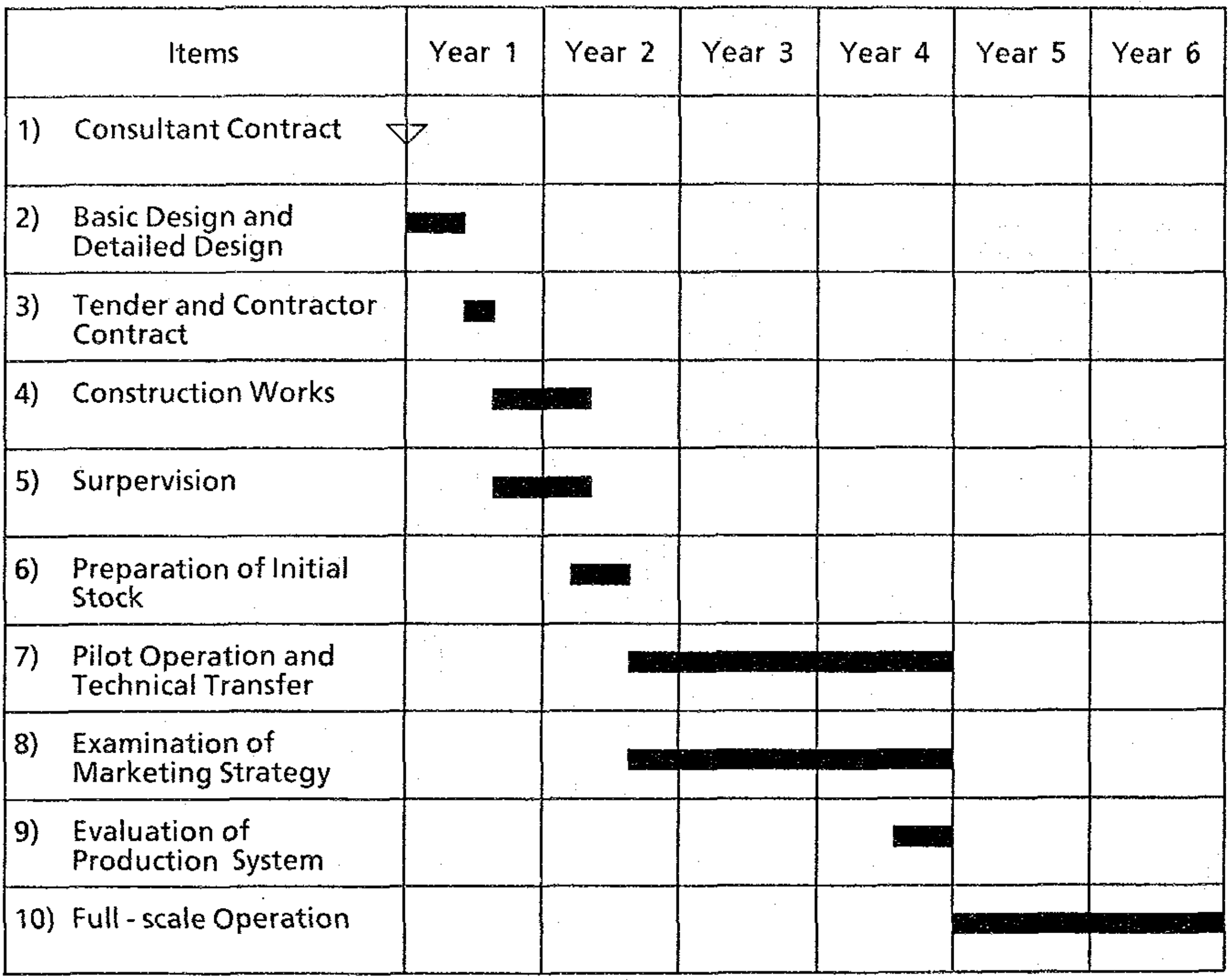


Fig. J-10 Implementation Schedule for the Project

THE HASHEMITE KINGDOM OF JORDAN
THE STUDY ON INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE KARAK - TAFILA DEVELOPMENT REGION

JAPAN INTERNATIONAL COOPERATION AGENCY

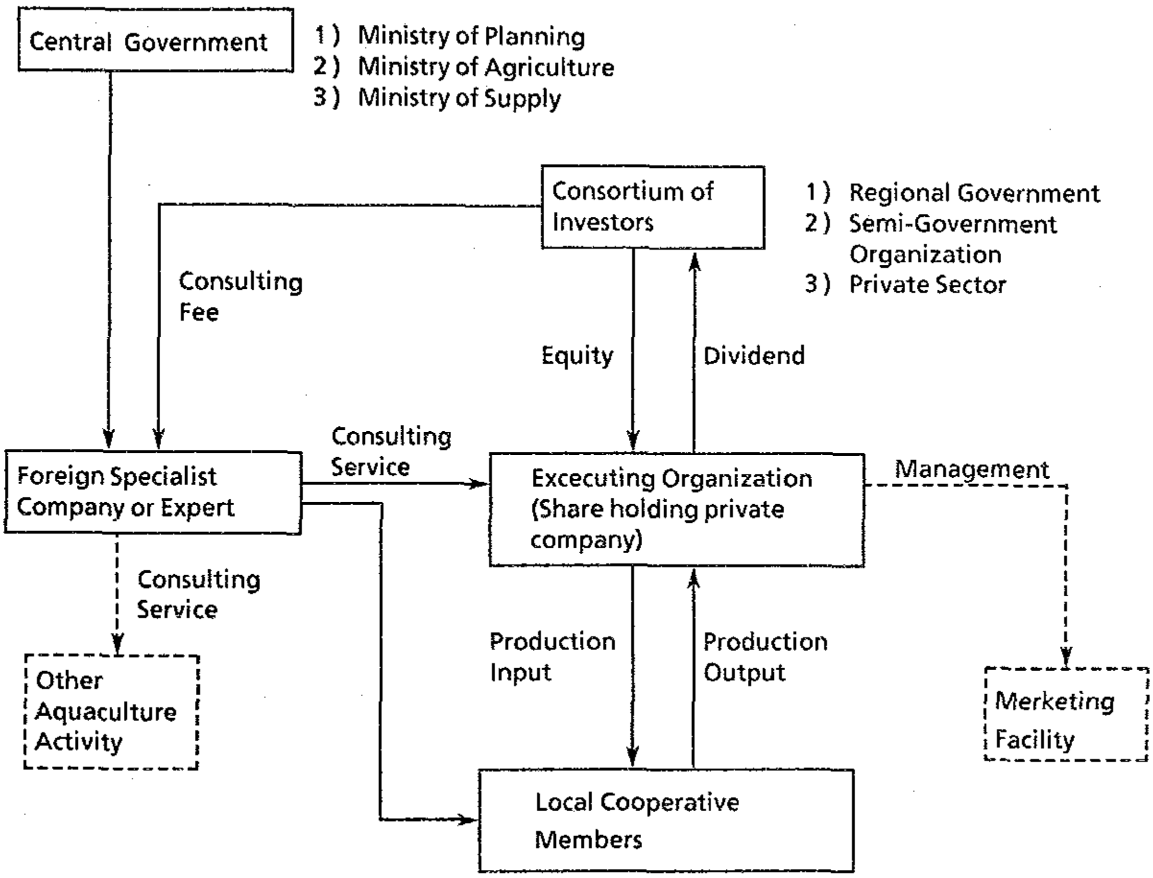


Fig. J-11 Organization Chart for the Project

THE HASHEMITE KINGDOM OF JORDAN
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