

SULTANATE OF OMAN
THE STUDY
ON
AGRICULTURE DEVELOPMENT PROJECT
IN
THE NEJD REGION
SUMMARY

OCTOBER 1989

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JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a response from the Government of Sultanate of Oman, the Japanese Government decided to conduct a study on Agriculture Development Project in the Nejd Region and entrusted the study to Japan International Cooperation Agency (JICA).

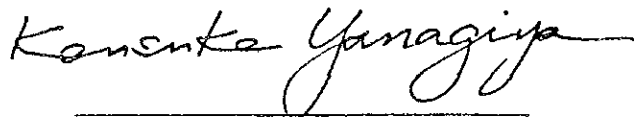
JICA sent to Oman a Study Team headed by Mr. Makoto TANAKA, Pacific Consultants International, five times in the period from October, 1987 to September 1989.

The Study Team held discussions with concerned officials of the Government of Sultanate of Oman and conducted field surveys (Phase I and II) in the Nejd of Southern Region. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Sultanate of Oman for their close cooperation extended to the Study Team.

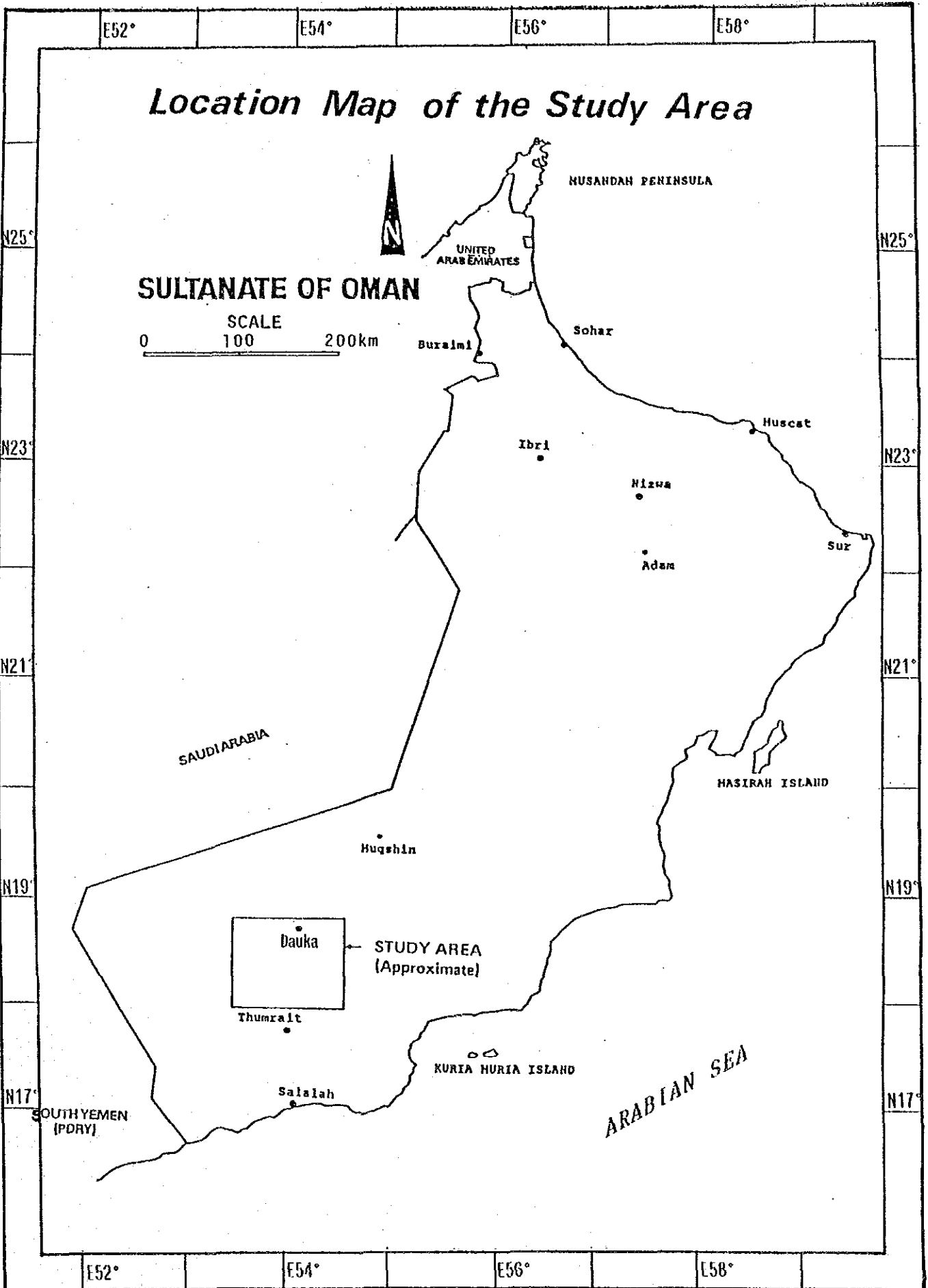
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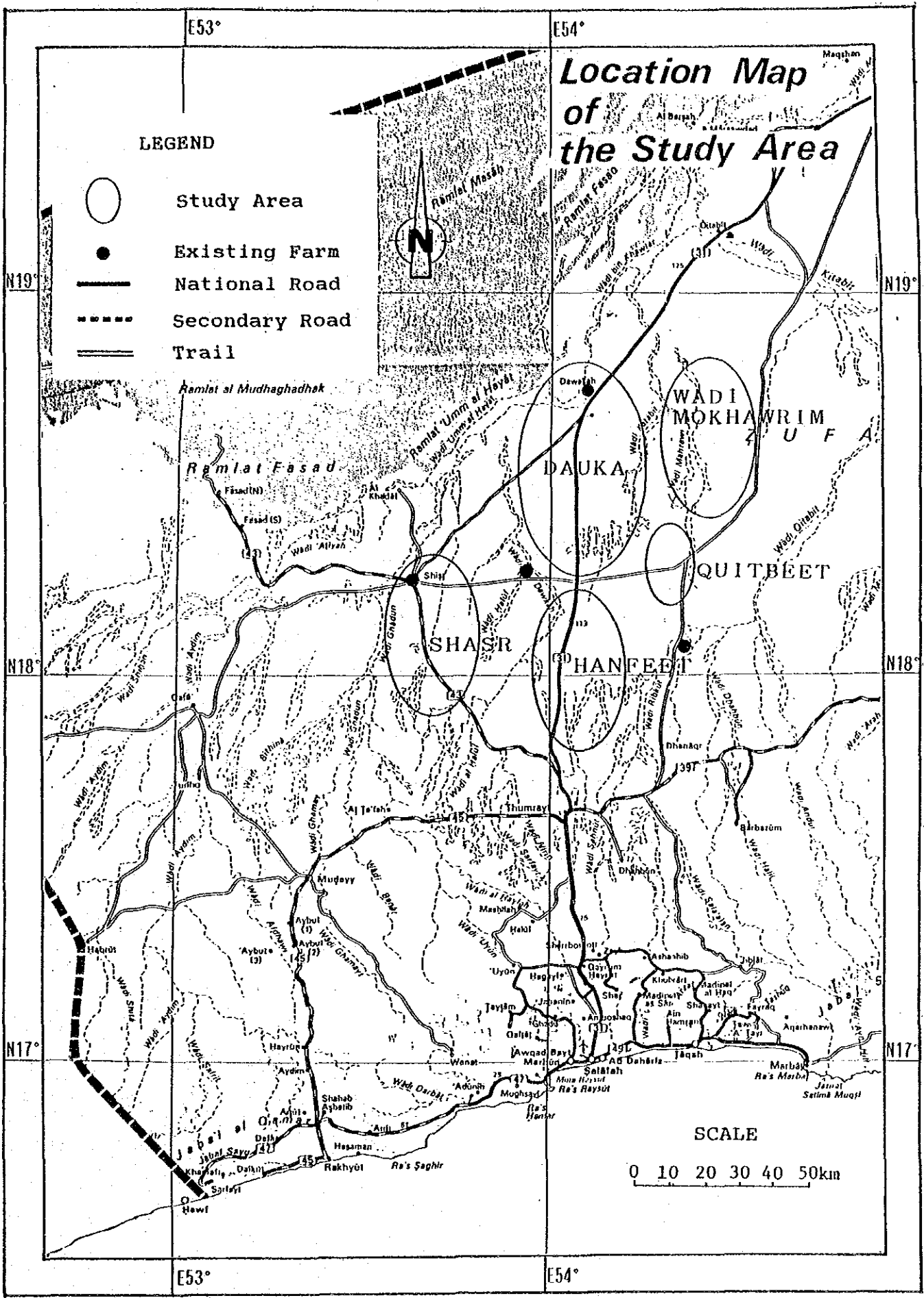


Kensuke YANAGIYA

President

Japan International Cooperation Agency





Location Map of the Study Area

LEGEND

- Study Area
- Existing Farm
- National Road
- Secondary Road
- Trail

N19°

N19°

N18°

N18°

N17°

N17°

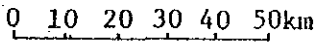
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SCALE



Ramlat al Mudhaghathak

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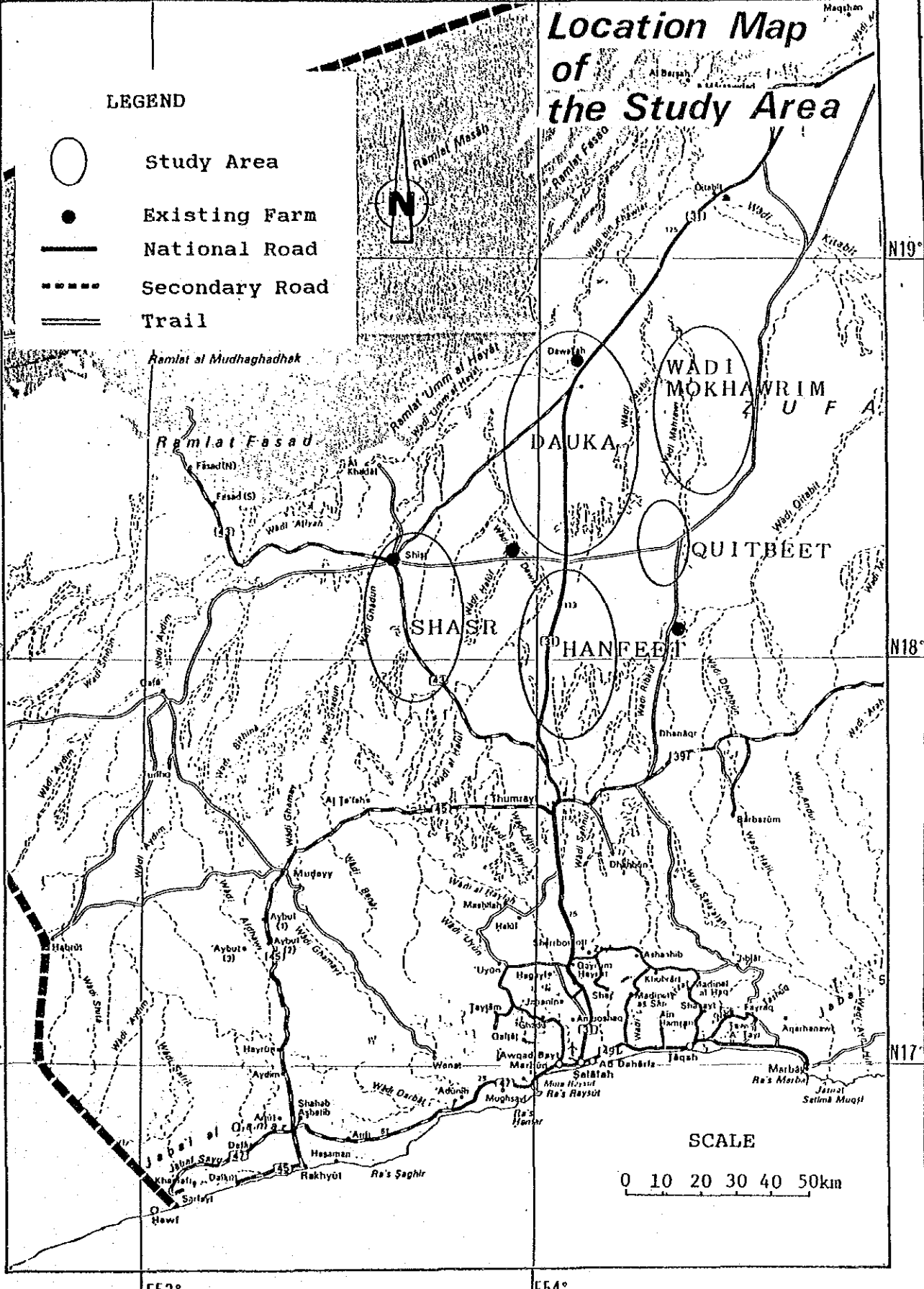
SHASHR

DAUKA

QUITBEET

HANFEET

WADI
MOKHAWRIM
U F A



SUMMARY AND RECOMMENDATIONS

Summary and Recommendations

This is a summary of "The Agriculture Development Project in the Nejd Region". The report of this study consists of the following two volumes:

Volume I : Main Report

Volume II : Appendix

1. Objectives of the Study

In this study, surveys were conducted on the groundwater and soil resources in the five areas of the Nejd from the view point of agriculture development.

Based on the results of the survey, a guideline for agriculture development in a promising area and a plan for a pilot farm, are formulated. Applicable farming system and appropriate utilization of groundwater and soil are elaborated.

2. Background of the Study

2.1 The Sultanate of Oman gives a high priority to the promotion of agriculture development and water resources development, since the Government wishes to achieve economic independence from oil and self sufficiency in the supply of food, a goal since the first five-year plan (1976 - 1980). Furthermore, agriculture is planned to be developed intensively in a 10-year plan.

2.2 Salalah plain is situated on the coast and is the main populated part of the southern region with a major farming area. In this plain, a little room is left for the additional large scale agriculture development, since there has been a rapid utilization of land and water resources caused by the rapid increase of population accompanying with the urbanization.

In this regard, the agriculture development in the Nejd which has a development potential, becomes important for the development of the southern region.

2.3 Critical natural conditions and poor infrastructure facilities had restricted the agriculture development with only some small scale farms doing cultivation in the Nejd. However, the groundwater and soil investigations show the availability these resources and the agricultural development scheme was started in the Nejd.

A PDO desert farm was established as a pioneer to experiment the crops suitable for the desert area.

2.4 However, the condition and the potential of the groundwater resources have not been clarified, since only a partial investigation of the groundwater resources was made in the past. In the above conditions, the effective method is to establish a pilot farm as the first stage of the development and proceed with the appraisal of groundwater resources in order to plan an agriculture development project for the effective conservation of precious groundwater resources.

2.5 For the purpose of carrying out this study on agriculture development in the Nejd, the government of the Sultanate of Oman requested for the technical cooperation of the Government of Japan.

In response to the request, the Government of Japan agreed to carry out the study through the Japan International Cooperation Agency (JICA) which then despatched a preliminary study team to Oman. The team held a series of discussions with the Omani officials concerned and in December 1986 agreed upon the scope of the work.

The survey was carried out from October, 1987 to September, 1989.

3. Current Situation of the Study Area

General Outline of the Area

3.1 Nejd is located in the southern region and has an area of approx. 40,000 km².

The study area consists of five target areas; i.e, Dauka, Wadi Mokhawrim, Shasr, Hanfeet and Quitbeet. These target areas extend over 100 km both from east to west and from north to south.

- 3.2 Infrastructure facilities are undeveloped in the study area, except a National Highway of 1,000 km length which connects Muscat and Salalah.

There are some settlements surrounding the study area, i.e, Thumrait which is the major settlement for both administration and commerce, Shasr which is an oasis from the ancient days, Quitbeet and Hailat Al-Rakah.

- 3.3 Population density in the Nejd is quite low with approx. 7,300. The population of Thumrait is approx. 2,100 and the other areas is approx. 5,200. Most of the people are nomads who don't have their own permanent residences, and therefore the population varies seasonwise.

Natural Conditions

- 3.4 The terrain of the Nejd is moderately sloping towards north from mountains at the southern fringe. The mountains at the southern fringe is not only the northern limit of monsoon rain, but also the watershed between the coastal area and the Nejd. The northern margin of the Nejd is bordered by the great sand desert, Rub' Al-Khali at 190 km from the coast.

- 3.5 In the southern region, southwestern monsoon blows against the southern slope of the 1,000 m high Dhofar Mountains. The monsoon produces rainfall from June to September and for this reason summer is referred as rainy season. However, the rainfall area is limited only to the coastal plains and the southern slope and the summit area of the mountain range. Aridity increases in the inland area, forming parallel climatic zone to the coastline.

According to the meteorological data in Thumrait, diurnal range of atmospheric temperature in the study area is very large and a range of 20°C is common throughout the year. The maximum annual temperature of 43 to 45°C is observed in June. The minimum is 2 to 6°C in January. Annual precipitation is highly variable, ranging from 0 mm to 150 mm. Major rain is caused by cyclone. Large scale cyclones are supposed to occur at the Nejd once in every five years.

Soil Survey

3.6 The Soil Classification Map and the Land Suitability Classification were already prepared by Harza (1985) and GDC (1986). In this study, Soil Classification Map and Land Suitability Classification Map of the same scale (1:60,000) are prepared for an area of 418,100 ha based on the soil information collected around the proposed pilot farm site, in confirmation with the previous data.

3.7 Most of the soils in the study area occur on limestone and marl of Tertiary System. These soils are constituted of the eolian and aqueous sediments of the weathered material of these rocks.

The shallow soil (about 30 cm depth) is dominant in the study area, while the deep soil (more than 100 cm depth) is distributed only in a small area of wadi, alluvial fan and toeslope.

The land unsuitable for cultivation covers an area of 363,125 ha (about 87% of the study area), and the land suitable for cultivation covers an area of 54,975 ha (about 13%). Highly suitable land of 'S1' class and moderately suitable land of 'S2' class cover only an area of 18,905 ha (about 4.5%).

3.8 Some farms were established around the study area without considering the soil conditions. Problems of poor drainage and salt accumulation occur in these farms with shallow soil depth.

At the proposed pilot farm site, an impermeable layer (hard limestone) is located at a depth of 4 - 5 m and therefore the natural drainage potential should be high.

Agriculture

3.9 The agriculture development in the Nejd started at the beginning of 1980's with the development of hand-dug well and flowing well by the local people. Small scale farms are established recently and the agriculture development progressed rapidly.

3.10 There are 54 farms in the study area with a total area of 390 ha, excluding the PDO farm of 100 ha area.

Among these farms only 20 farms of 128 ha area are registered. The total cultivated area is only 95 ha and other area is in developing stage. At present some of these farms are unsuitable, because of poor soil conditions caused by salinity hazard.

Major crops cultivated are fodder grass, fruits and vegetables with an average planted area of 52.1%, 25.0% and 21.3% respectively.

3.11 There is a high demand of fodder grass for the cattle grazing at the Jabal next to the Nejd. Although there is a plan to reduce the cattle population in Jabal by the livestock destocking program, a stable supply of the fodder grass is indispensable if the rangelands are to be preserved in the Jabal.

Most of the fodder grass cultivated in Nejd is Rhodes grass. Rhodes grass is the most suitable crop to improve the soil structure and is highly tolerant for drought and salinity. Therefore it is widely cultivated at several farms in the Nejd.

Rhodes grass of high quality and high yield was experimented at PDO farm and was found that it can be harvested 10 times a year with the yield of 40 - 45 ton/ha/year as dry matter.

3.12 PDO farm was established in 1985 by the instruction of H.M. Sultan Qaboos with the prime objective of rapidly evaluating the possibility of irrigated agriculture in the Interior desert. Originally the farm size was 40 ha and a 60 ha area was added with a centre pivot irrigation system and at present the total area is 100ha.

Water is pumped with six deep wells of 450 - 590 m depth and the water level is about 60 m depth below the ground level. Forage crop cultivation, mainly Rhodes grass, shares 95% of the total farm land, and vegetables and fruits are also cultivated. Rhodes grass hay is sold to nomads and some amount is sent to market. Other products are mainly consumed by the people who live in Marmul oil camp.

3.13 The agricultural technology such as cropping pattern has not been established in the area. Crop cultivation period of vegetables is much different between each farmer. However, cropping season trials of vegetables, such as tomato and cucumber have been started by the PDO farm and the experimental cultivation is still under progress.

3.14 According to the experimental cultivation results at the PDO farm, the appropriate seeding time of vegetables in the area is from October to November. If the seeding time is delayed, the crop will be damaged by low temperature in the seeding period and yield will be much decreased. Crop cultivation is very difficult in the summer season of July and August and the crops are affected by the high temperature. However, a few crops such as Okra and water melon are cultivated during the summer season.

4. Groundwater Resources

Review of Preceding Groundwater Surveys

4.1 Groundwater survey in the Nejd is still at the preliminary level. Surveys of restricted scale and accuracy were carried out by Sir W.Halcrow and Partners (1976), Sir A.Gibb and Partners (1984) and Harza (1985). These surveys were followed by two significant surveys carried out by PDO (1985) and PAWR (1986). The survey carried out by PDO was a compilation work of the water resource surveys, which were carried out as an auxiliary part of oil exploration. In this report, eastern portion of the Nejd is covered, but most of the central and all of the western Nejd are excluded.

PAWR drilled groundwater exploration bore holes at 13 points, over an area of 15,000 km² of the Nejd in almost the identical area of the present project. Almost in the same period, PAWR had conducted environmental isotope studies on the groundwater in nation wide scale. According to the study, the lower UER aquifer, the target aquifer of the present project, bears groundwater of low level carbon-14 throughout the area and the groundwater ages were computed as more than 10,000 years. Also it was discovered that the oxygen and hydrogen isotope ratios of the lower UER aquifer is different from those of rain and groundwater of the Dhofar Mountains. These facts strongly suggested that the Nejd groundwater is disconnected from the present hydrologic cycle. Eventually the groundwater resources are believed to be finite without any current recharge.

Hydrogeology

- 4.2 The basement of the Nejd is Pre-Cambrian, but most of the outcropping rocks are sedimentaries of Hadhramaut group from Palaeocene to Eocene in geologic age.

The tertiary formations are divided into the following four formations from the lower to the upper horizon.

1. Umm Er Radhuma (UER) formation

Lower UER formation

Upper UER formation

2. Rus formation

3. Dammam formation

4. Aydim formation

Remarks : PDO classified UER formation into three subformations in which Shammar Shale of the lower UER of this report is termed as Lower UER and the overlying part as middle UER.

4.3 As the aquifer develops mainly in the carbonate rocks, it is presumed that some fracture structure may be related. Fracture could be caused by faults and/or synclinal structures. These structures may produce lineaments at the ground surface.

In the survey area lineaments of SW-NE trend was recognized to be prevailing.

Groundwater Hydrology

4.4 Four aquifers were discriminated for the project area in the Nejd by PAWR and the present survey.

Zone A: Dammam formation and Rus formations, 0-140 m

Generally good water quality of EC less than 2,000 $\mu\text{S}/\text{cm}$, except for some high salinity water of more than 10,000 $\mu\text{S}/\text{cm}$ is available in the Rus formation. However the total resource amount is not appreciable. Some waters are in confined condition.

Zone B: Upper part of upper UER formation 140-270m

Large transmissivity can be encountered. There are some good quality waters but the water quality of the marly part of the formation is degraded, more than 2,000 $\mu\text{S}/\text{cm}$. Mostly in confined condition.

Zone C: Top of lower UER formation, 270-310 (?) m

This aquifer develops extensively in the Nejd. Quality is good with EC around 1,500 $\mu\text{S}/\text{cm}$. The aquifer is confined and produces flowing wells in the north.

Zone D: Lower UER formation, 310 (?) m -

Both quality and quantity is poorer than Zone C. EC exceeds 2,000 $\mu\text{S}/\text{cm}$. and tends to increase with the depth.

4.5 Potentiometric groundwater heads and EC values of Zone C were measured by the observation wells drilled by PAWR and this project. The contour patterns indicate prevailing flow direction of SW-NE in the project area.

By the analysis for Zone C waters, it is anticipated that the groundwater in the Nejd agrees with the flow zone system. These Nejd waters are different from Salalah Plain groundwaters which are currently recharged by the rains on the Dhofar Mountains. Consequently Zone C waters do not seem to contain any recharge waters from the Mountains.

Electric Prospecting

- 4.6 Two prospecting methods, i.e. ELF-MT and Schlumberger, were applied in stages to cover the widespread area of the Nejd within a limited period.

For the first stage, the ELF-MT method, was selected as the regional mapping method. This method can be easily practiced to determine the general trend of the local ground resistivity.

For the second stage, the Schlumberger method was applied to analyse vertical components of resistivity anomalies which were detected by the first stage.

Exploration Drilling Works

- 4.7 In order to evaluate groundwater with a view of developing agriculture in the Nejd and secure the water source for the planned Pilot Farm, two observation wells and two test wells were drilled as specified in the following table.

Specification of Exploration Drilling Works

Study Phase	Well No.	Well type	Depth (m)	Borehole Dia. (mm)	Casing Dia. (mm)
Phase I (1987)	NJD-1	Observation Well	400	152-444	178-245
Phase II (1988)	NJD-2	Test Well	350	216-610	245-340
	NJD-3	Observation Well	350	152-444	178-245
	NJD-4	Test Well	350	216-660	245-340

4.8 Based on the result of drilling works, it is found that the groundwaters except for the lower UER formation have low water level with low quality. Lower UER formation has groundwater whose level is merely the same as ground level and it is pressurized under approx. 30 atm with relatively good quality. As per each pumping test, its transmissivity is 4,000 m²/day and its storage coefficient is 4 x 10⁻⁵.

Groundwater Resources Evaluation

4.9 Three models of regional groundwater systems are formulated based on the field results and previously published data, namely,

1. Isolated confined aquifer model
2. Residual gradient model without groundwater recharge
3. Residual gradient model with groundwater recharge

The most suitable groundwater model for the regional groundwater system should be verified by further groundwater observation and survey. However, the "residual gradient model without groundwater recharge" seems to be adequate at this stage.

The drawdown proceeds in two stages. In the first stage it occurs mostly in the piezometric loss. Then in the second stage it involves decline of phreatic level.

Based on the results of the analysis, the following two main points are remarkable.

1. For a development area of 300-500 ha, the life time is generally fairly long, i.e. in the order of thousands years.
2. Initial drawdown puts a limitation to the reclamation scale, i.e. reclamation scale of 1,000 ha is critical.

Development and Conservation of Groundwater Resources

4.10 Lower UER formation is the major water resource for the agriculture development in the Nejd. Based on the characteristics of this formation, the following directions are proposed for the groundwater conservation and development.

1. Optimization of pumping site disposition.
2. Decide the rate of groundwater development based on continuous and systematic groundwater observation.
3. Administrative system for groundwater conservation.
Under this system, groundwater monitoring, routine groundwater exploration, development and control of the resources shall be executed.

5. Guideline for Agriculture Development in the Nejd

5.1 A guideline is proposed for the agriculture development in the Nejd, based on the potential of groundwater resources and soil conditions in the study area. However there are a lot of constraints to be settled so as to make agriculture in the Nejd as a prime industry of the area.

Particular attention should be paid to the fact that the groundwater in the Nejd is categorized as fossil water and is a limited water resource like oil. Therefore, while utilizing this scarce resource, suitable and appropriate methods should be adopted based on the resource life time and its contribution for the prosperity and development of Oman.

Phased Agriculture Development

5.2 A phased agriculture development plan is proposed in this study, based on the actual conditions and limitations of the Nejd. Because of high uncertainties of groundwater and other resources, it is not advisable to introduce a large scale development project.

The three phases of phased agriculture development plan are as follows:

1. Phase I

- Establishment of pilot farm; experimentation at pilot farm and collection of data.

2. Phase II

- Development of upto 500 ha area based on the results of phase I.

3. Phase III

- Further development based on the results of phase II.

Tentative Scale and Pace of the Development

5.3 The following two items should be clarified for the successful implementation of the agriculture development project.

1. Project development pace (Suitable development pace)
2. Limitation of the project area (Maximum development area)

In the phase II of the phased development plan, the development area is assumed temporarily as 500 ha and the prosperity of this development scale should be verified at first. If the expected results can not be achieved, the development scale should be revised and the prosperity should be studied once again.

Evaluation Items to Step Up from One Phase to Next Phase

5.4 The phased agriculture development plan in the Nejd is divided into three phases. The problem points of each phase should be clarified properly before shifting from one phase to the next phase.

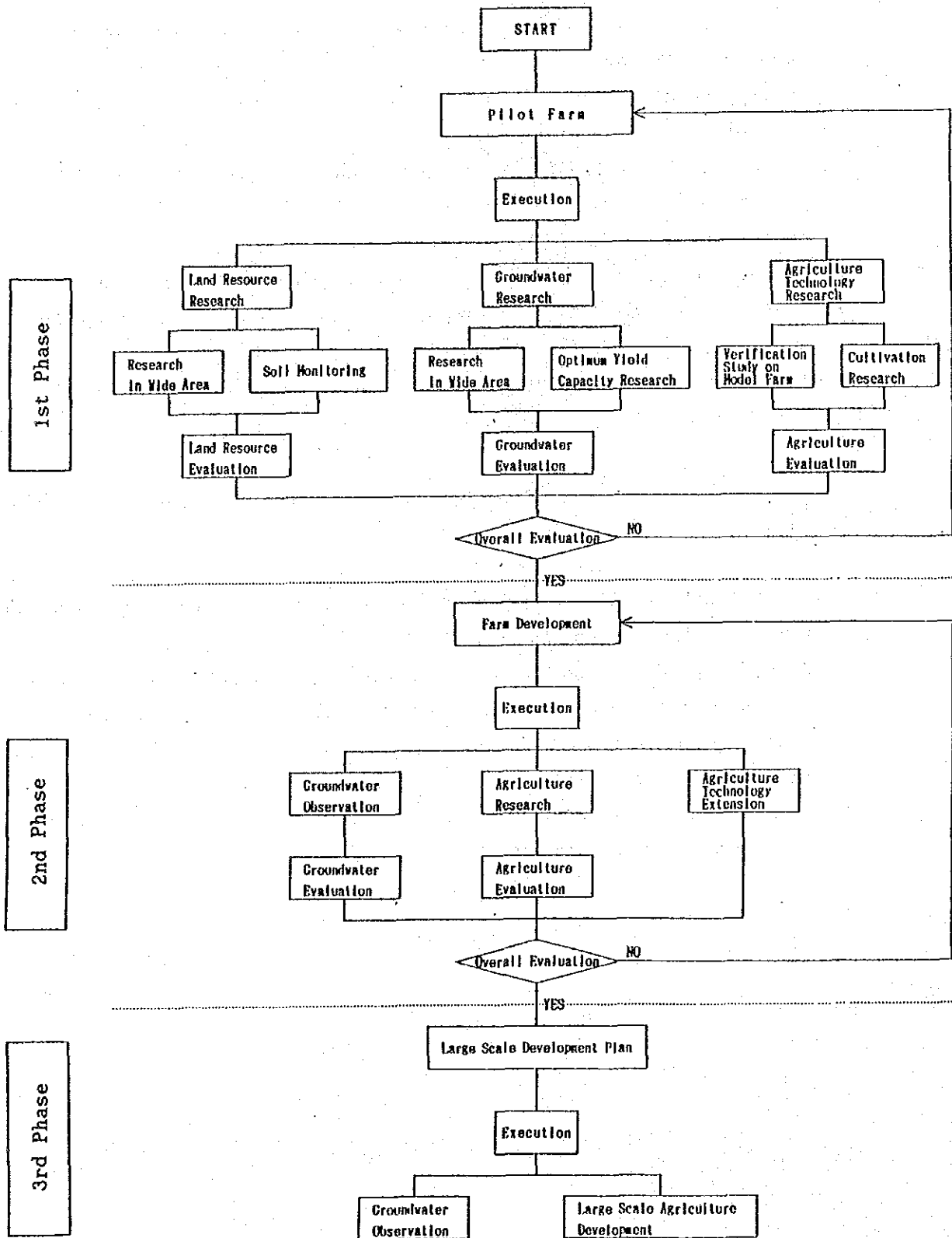
The following items should be evaluated before shifting from phase I to phase II.

1. Groundwater drawdown accompanying with pumping up should be within the reasonable value.
2. The quality of groundwater should not become worse because of the pumping up operation.
3. There should not be any problems regarding the cultivation technology for fodder grass.
4. Marketability of fodder grass should not be decreased remarkably.
5. Supporting systems to proceed with farm management under commercial base should be clarified.
6. Systematic control system of groundwater should be established.
7. Soil survey for the development area should be carried out in detail.
8. Training and extension system should be established for the farmers.

Items to be evaluated for shifting from phase II to phase III are as follows:

1. Clarification of groundwater condition by the groundwater investigation in the whole area.
2. Confirmation of the suitable project development pace and the limitation of the project area based on the groundwater condition.
3. Confirmation of the cropping pattern, cultivation technology, and marketability for different crops.
4. Establishment of marketing system for the fodder grass and the other crops to be introduced.

Phased Agricultural Development Diagram



Proposed Site for Agriculture Development

5.5 Based on the natural and socioeconomic conditions, the selection is recommended to the following four areas for introducing agriculture development project. The advantage of each area is shown below.

1. Nagha area (Area around the proposed pilot farm site)
 - Adjacent to national highway and located at the centre of the existing development area
2. Dauka area
 - Adjacent to national highway and can expect high pressurized groundwater
3. Shasr area
 - Adjacent to local road and can expect high pressurized groundwater next to Dauka Region
4. Wadi Makhawrim area
 - Adjacent to local road and can expect enough area of 'S2' soil class. At present there is no residence in this area.

Project site selection should be done carefully by considering the conditions mentioned below.

1. Soil condition

The site selection should be made in the area where the soil class is 'S2' more and the area of this soil class in this study area is 18,900 ha.

2. Static groundwater level

The pumping area should be selected in a site where the static groundwater level is at a higher level or level equal to the ground surface so that the primary investment, pumping cost and operation and maintenance cost will be cheaper.

3. Socioeconomic Conditions

The project site selection should be done in an area where it has good access to the national highway and local gravel roads.

Groundwater Development Plan

- 5.6 Top of the lower UER formation should be developed as a groundwater resources for agricultural development in the Nejd.

It was found that the groundwater with good quality ($1,500 \mu\text{S}/\text{cm}$ - $2,000 \mu\text{S}/\text{cm}$) spreads in the project area from the result of this study.

- 5.7 The target groundwater resources is a strongly pressured confined one and store stagnant fossil water.

Since any extraction of water causes inevitable decline of water level, it is necessary to envisage the limited availability of groundwater both in terms of volume and span for its agricultural use.

It impractical to pump up the groundwater from 300 meter depth from the view point of farm management. Farming can be done upto a groundwater depth of 100 m, since the pumping head of the ordinary pump for farming is within 100 meters.

- 5.8 For the minimum interference of water levels between the production wells, the mutual distance should be kept beyond the radius of influence.

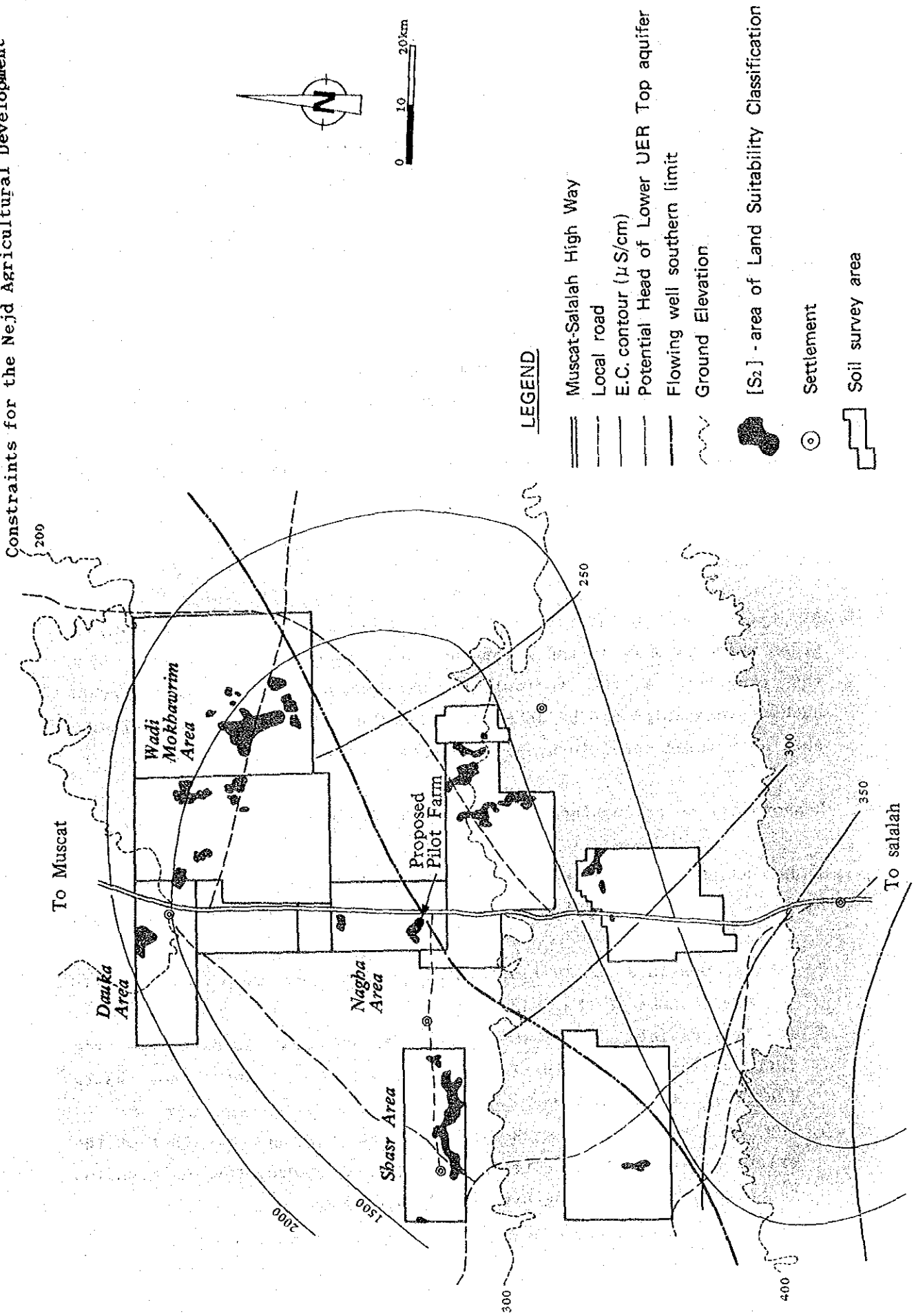
The distance between the production wells should be low enough which will cause low interference in groundwater level and should be close enough to the farms. Hence the distance between the production wells of two 50 ha farms is proposed as 10 km which will cause an acceptable draw down of 100 mm over an area of 50 ha for a discharge of $5,900 \text{ m}^3/\text{day}$.

Farm Arrangement Plan

- 5.9 From the viewpoint of soil and groundwater conditions, two types of farm arrangement are considered.

1. Scattered type

- In this type, the farms will be located at separate locations close to their production wells



LEGEND

- ▬▬▬ Muscat-Salah High Way
- ▬▬▬ Local road
- ▬▬▬ E.C. contour (µS/cm)
- ▬▬▬ Potential Head of Lower UER Top aquifer
- ▬▬▬ Flowing well southern limit
- ▬▬▬ Ground Elevation
- [S₂] - area of Land Suitability Classification
- ⊙ Settlement
- ▭ Soil survey area

2. Concentrated type

- In this type, the farms will be located together at one location although they are separated from their production wells

Among these two types concentrated type is proposed and the reasons are as follows:

1. Concentrated type creates a concept of community which is very much essential for the development project
2. Farm machineries can be purchased and maintained together by farmers' association
3. The infrastructure facilities such as roads, electricity etc. can be developed in common, at one location.

Crop Selection Plan

5.10 At first, it is advisable to grow fodder grass, especially Rhodes grass which is more suitable for the Nejd. Later, in accordance with the progress of the agriculture development, the commercial crops such as vegetables can be added based on the crop selection criteria such as natural conditions, yield benefit, marketing potential etc.

Reasons for selecting fodder grass are as follows:

1. Rhodes grass which has high tolerance for drought and salinity can be cultivated as the reclamation crop to improve the soil structure.
2. It is possible to cultivate high quality grass in a whole year in the dry weather of the Nejd.
3. It is possible to minimize the manpower requirement by the introduction of machineries and it doesn't require any extra facilities for marketing.
4. The cultivation and marketing of Rhodes grass are done at the existing farms and PDO farm in the Nejd and hence the cultivation techniques and marketing are already practiced.

5. There is a demand of fodder grass for cattle grazing at the Jabal with a market price of R.O.100/ton.

In future even if the cattle population of the Jabal is destocked to half by the introduction of the destocking programme, a stable supply of the fodder grass will be indispensable for the conservation of the Jabal grasslands.

6. In the southern region, the farm products are assigned in three areas i.e., Salalah Plain, the Jabal and the Nejd for the effective utilization of available resources in each area. In this regard, the farming in the Nejd is proposed as "fodder grass supply area", to supply grass for the cattle population in the Jabal and Salalah plain.

5.11 Crop selection plan for the commercial crops such as vegetables must be decided based on the experimental cultivation at the pilot farm, considering the following factors:

1. Natural conditions
2. Yield benefit
3. Appropriate cultivation technology
4. Marketing potential

Organizational Set-up for Project Development

5.12 The agriculture development project starting with the establishment of pilot farm necessitates the coordination of different organizations for the effective management of the project.

The various activities to be performed in course of introducing the agriculture development project are as follows:

1. Technical guidance/extension service to the farmers
2. Procurement of production materials and services for storage and marketing of farm products
3. Financing for farming
4. Operation and maintenance of farm roads, electricity, etc.

Hence coordination of different organizations becomes necessary to perform all these activities, "Project appraisal and advisory committee" with the representatives of different organizations is required for this purpose. Besides, a project office which will be responsible for the execution and management of the development project and a pilot farm which will be responsible for the experimental investigation and training will also be established.

Settlement Plan

- 5.13. The pace of development project mainly depends upon the groundwater condition. The government should decide the number of families/enterprise which will settle at the area to maintain the new developed farms. Policies of land tenure, owning of machineries, facilities, prices etc. should be decided by the government in accordance with government policy.

The main objective of agriculture development project is to introduce agricultural development through the "Omanization" concept. This means that an innovative group of Oman people should take the full responsibility for complete management of the farms and this group will act as the pioneers for the future generation who will shoulder the responsibility of Oman's future agriculture.

Hence a suitable farming group of local people should be selected to take this responsibility. Before the settlement, the farming group should be given enough training at the proposed pilot farm.

6. Pilot Farm Plan

- 6.1 In the project area, data necessary for planning and implementing of the agriculture development is highly insufficient. Especially data such as groundwater potential, meteorological data, type of crops suitable, appropriate cultivation technology etc. are lacking which restrict the planning of suitable development project. For this purpose a pilot farm project should be executed as the first phase of the phased development plan. The major objectives of the pilot farm are summarized as follows:

1. Experimental cultivation by introducing locally appropriate technology
2. Demonstration of these techniques to the local people and the others through on farm training
3. Extension of these techniques to the Nejd through agricultural extension work
4. Evaluation of groundwater potential and observation of soil and meteorological conditions.

Area of the Pilot Farm

- 6.2 The farm size is planned as 50 ha, considering the pumping rate of two test-wells which were drilled during this study. Three types of farm will be operated at the pilot farm, and the following allotment will be made in order to achieve the target.

Experimental farm	5 ha x 1 ea. = 5 ha
Small scale verification farm	6 ha x 1 ea. = 6 ha
	9 ha x 1 ea. = 9 ha
Large scale verification farm	30 ha x 1 ea. = 30 ha

Farm Management Plan

- 6.3 Based on the objectives of pilot farm, the farm management plan can be divided into the following four categories.

(1) Crop cultivation plan

After establishing the pilot farm, at first it is necessary to improve the soil condition by applying organic matter, fertilizers etc. Fodder grass will be grown for some period till the soil is cultivated enough and become suitable for the other crops. Hence the crop cultivation plan is divided into two stages:

1. Soil reclamation stage

- At this stage fodder grass will be cultivated in the whole pilot farm area to improve the soil condition.

2. Crop cultivation stage

- After the soil condition is improved and become suitable for the other crops, experimental cultivation should be started using the appropriate technology for the Nejd.

(2) Agriculture Training Plan

To succeed in agriculture in a virgin land, several cultivation techniques and knowledge are required. Continuous technical guidance and education is necessary for the farmers of the existing farms and for the new comers who will be engaged in agriculture in the near future.

Hence it is planned to establish an agriculture training center within the pilot farm, where the farmers and agriculture students can learn and experience the actual farming techniques.

(3) Agricultural Extension Plan

As a primary step towards the agriculture development of the Nejd, the pilot farm is obliged to diffuse the agricultural technology and knowledge to the farmers of the existing farms and to the new comers who will be engaged in agriculture in the future.

The results obtained from these extension activities will be fed back to the pilot farm and will be analyzed by carrying out the consecutive activities at pilot farm.

The main extension works are as follows:

1. Guidance of appropriate farming techniques
2. Publicizing technical informations
3. Investigating and collecting informations

(4) Groundwater, Meteorology and Soil Observation Plan

Continuous observation of groundwater level is necessary to evaluate the hydrogeological features and properties of the Nejd. Therefore after the establishment of pilot farm, the groundwater level at the two observation wells of the pilot farm and the other observation wells around it should be measured continuously and systematically.

Continuous observation of meteorological and soil conditions are necessary since these data can be used in planning the future agriculture development.

Irrigation Plan

6.4 Irrigation methods such as centre pivot sprinkler system in large scale verification farm and rain gun and side wheel sprinkler systems in small scale verification farm and experimental farm will be introduced. Drip irrigation system will be adopted in a part of experimental farm.

The daily water requirements for the 50 ha farm is 7750 cu.m/day as the maximum and 3900 cu.m/day as the minimum. Total annual requirement is 2.16 million cu.m.

The irrigation water requirement for the two pumping cases is summarized as follows:

Pumping Time	MAX	MIN	MEAN
18 hrs	7.1 cu.m/min (118 lit/sec)	3.8 cu.m/min (63 lit/sec)	5.5 cu.m/min (91 lit/sec)
24 hrs	5.3 cu.m/min (89 lit/sec)	2.8 cu.m/min (47 lit/sec)	4.1 cu.m/min (68 lit/sec)

The maximum requirement is 118 lit/sec and the pump capacity required for one production well in case of 18 hrs of pump operation is 59 lit/sec.

Irrigation Facilities Plan

6.5 Irrigation facilities proposed for the pilot farm are summarized as follows:

1. Water supply facilities

Production well : 2 Nos. (Test well drilled during this study)

2. Water distribution facilities

Farm pond : 1 No. (2,400 m²)

Distribution pump : 1 place (Booster pump: 5 Nos.)

Distribution line : Pipeline network

3. Drainage facility

Pipe drainage : 1 ha (Experimental farm)

4. Irrigation facilities

Irrigation Method	Type of Farm
Center pivot sprinkler	: 30 ha (Large scale verification farm)
Side-wheel sprinkler	: 6 ha (Small scale verification farm)
Rain gun irrigation	: 9 ha (Small scale verification farm)
	: 4 ha (Experimental farm)
Drip irrigation	: 1 ha (Experimental farm)

5. Road

Trunk road : 5.1 km (width 10 m)

Branch road : 3.3 km (width 7 m)

Cultivation passway : 2.3 km (width 3 m)

6. Windbreak facilities

Windbreak trees : 9.7 km

Windbreak fence : 4.4 km

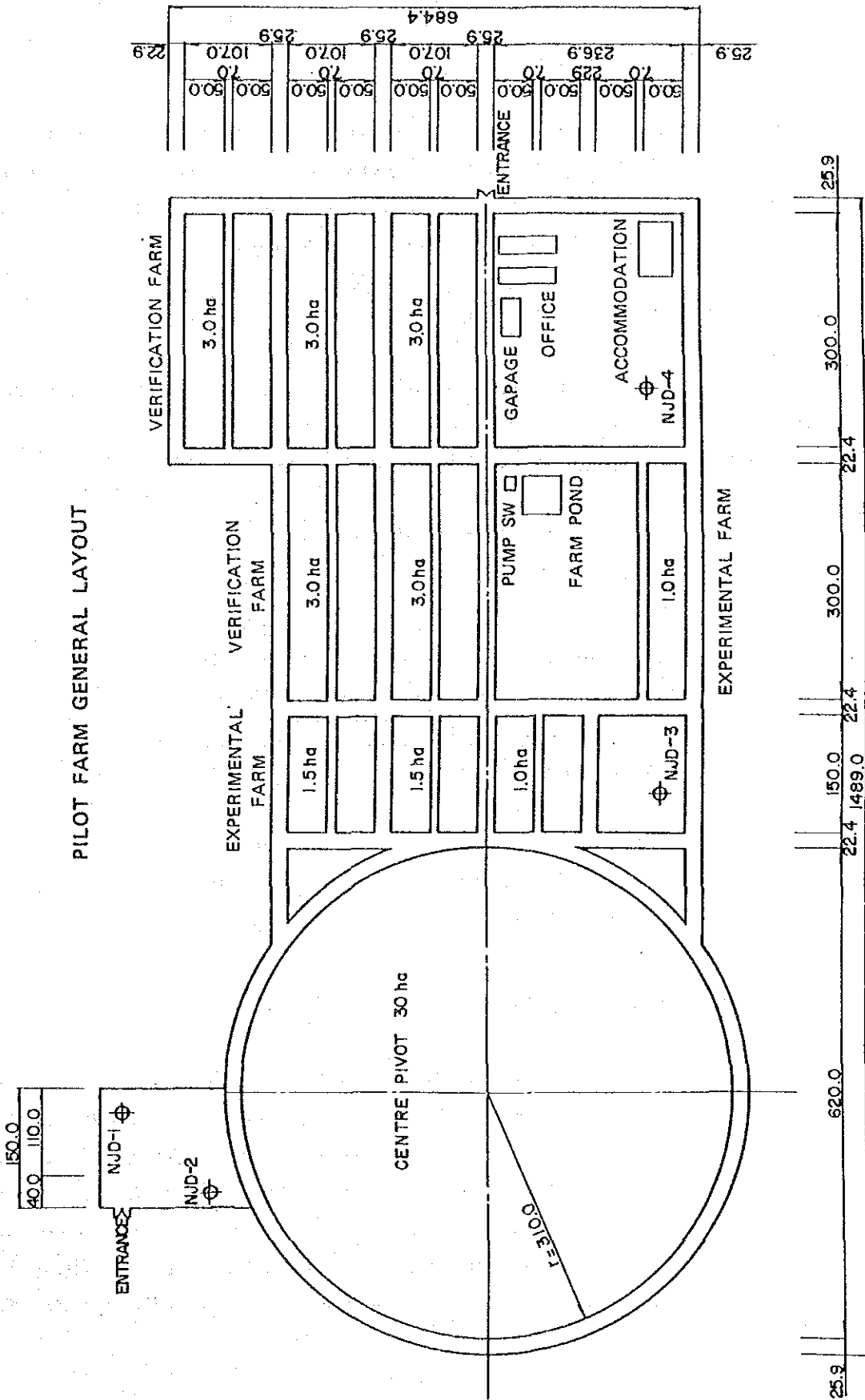
7. Power facility : 500 kVA (100 KVA x 5 Nos.)

8. Buildings : 1,420 m² (Office building, training building, Dormitory, staff quarter, etc.)

9. Agro-meteorological observation station : Temperature, Rainfall, Humidity, Wind, Evaporation, etc.

10. Farm machineries : 16 Nos. (Tractor, Harrow, Truck, etc.)

PILOT FARM GENERAL LAYOUT



Pilot Farm Execution and Maintenance Plan

Project Execution Agency

- 6.6 The DGAFS (MAF) is recommended as the project execution agency for the pilot farm project. Groundwater monitoring should be technically supported by PAWR which is executed in parallel with operation/maintenance work after its construction.

Project Cost for the Pilot Farm

- 6.7 The total project cost is estimated as R.O.1,698,500 (US\$4,423,200) under prices in January 1989.

The summary of the project cost is shown in the following table.

Summary of the project cost

Item	unit: R.O. Cost
1. Construction cost	1,193,951
2. Machineries & equipments cost	149,040
Sub Total	1,342,991
3. Project facilities cost	9,400
4. Administration cost	5,700
5. Consultation service cost	186,000
6. Physical Contingency	154,409
Grand Total	1,698,500

Operation and Maintenance Plan

- 6.8 The pilot farm office takes care of operation/maintenance of several facilities in the pilot farm. This office is composed of 20 staffs including experts of agronomy and irrigation, agricultural extension workers, operators and mechanics. Observation workers should be included for monitoring of groundwater/soil and maintenance of meteorological observation equipments. If the activity of the pilot farm goes well, the experts from outside should also be invited for training.

A Case Study of Agricultural Development in the Nejd

Background and Purpose of the Project Plan

6.9 In order to proceed the agriculture development in the Nejd systematically, the phased development which begins with the pilot farm establishment must be practiced.

In case of proceeding with the development project after the pilot farm construction, the appraisal of the project enlargement pace for farm development and limitation of the project scale is quite important.

A case study of the project proposed from the guideline is discussed in order to understand the problems to be expected at the project execution stage as the second phase of the agriculture development plan.

Main items to be studied are as follows.

1. Rough estimation of the project cost
2. Appraisal of the project
3. Governmental subsidy for the project

Presumptions of the Project Plan

6.10 The presumptions of the project plan of the case study are as follows.

1. Accomplishment scale of the project

The accomplishment scale for the project is presumed as 500 ha based on the groundwater conditions obtained from the survey results.

2. Phased development

Development area will be expanded step-by-step, based on the evaluation of the groundwater.

3. Crop selection

Rhodes grass will be cultivated.

4. Project starting period

The project will be started after the confirmation of development potential by monitoring/management at the pilot farm for two years.

Development Area

6.11 Among the four areas selected in the guideline, Nagha area and Dauka area are selected as the development areas in this project plan. By selecting these two areas, the mean project cost are estimated, since the project cost is different between these areas.

Construction Plan

6.12 The project plan presumes that the area of farms is 50 ha and the development unit is expanded step-by-step in Nagha area and Dauka area. It presumes that the 50 ha farm is constructed as ten units and the development area reaches to 500 ha in total.

Facilities Plan

6.13 The facilities, materials and machineries required for the 50 ha farm is detailed as follows: Five sets of these items will be required both in Nagha area and Dauka area.

<u>Item</u>	<u>Details</u>
1. Land reclamation	: 50 ha area should be the unit of development and it will be irrigated by a centre pivot irrigation system.
2. Distribution line	: Same as the pilot farm plan
3. Windbreak facilities	: -- ditto --
4. Farm road	: Construct new trunk roads and cultivation pass way.
5. Farm pond	: One farm pond is designed per 50 ha area.
6. Booster pump	: Arrange two booster pumps of 65 KW
7. Irrigation facility	: Introduce a centre pivot irrigation system for 50 ha area
8. Production well	: Wells are designed assuming their depths as 330 m in Nagha area and 430 m in Dauka area
9. Monitoring well	: -- ditto --

10. Submersible pump : Submersible pump should be installed at Nagha area only. 45 KW
11. Storage line : Storage line is installed from production well to farm pond to deliver water
12. Power facility : Power facility is designed for both submersible pump and booster pump
13. Connecting road : Connecting road is designed to connect the national highway and development area
14. Operation and Maintenance Road : This road is designed for operation and maintenance of production well and storage line
15. Farm machineries : Necessary farm machineries are introduced
16. Vehicles : Vehicles are provided for operation and maintenance of the farm
17. Residences and accommodations : Residences and accommodations for settlers are provided

Project Cost for the Case Study

6.14 The project cost for 50 ha farm is shown in the following Table. The mean values of the 10 farms of the Nagha and Dauka area are shown in this table. The total project cost for 500 ha farm area is estimated as 10 times of the 50 ha farm.

Item	Mean value of 50 ha unit farm
1. Construction cost	R.O.1,296,500
2. Machinery cost	R.O. 84,500
Sub-total	R.O.1,381,000
3. Construction facilities cost	R.O. 7,400
4. Administration cost	R.O. 5,700
5. Consultation service cost	R.O. 110,700
6. Physical contingency	R.O. 150,500
Total	R.O.1,655,300

Operation and Maintenance Cost

- 6.15 Operation and maintenance cost includes depreciation, repairing cost and fuel consumption cost.

The mean annual operation/maintenance cost of 50 ha unit farm is R.O.128,500 (\$334,600) although it is different for each farm with respect to water resource conditions of the area. The following three costs are the main items of operation maintenance cost.

O/M cost of intake facilities	28%
O/M cost of on farm facilities & housing	48%
O/M cost of farm machineries	23%

7. Appraisal of the Nejd Agriculture Development Plan

- 7.1 Based on the case study of agricultural development as the phase II of the phased agriculture development scheme, a financial appraisal is prepared in order to examine the policy of governmental subsidy to support the project.

Financial Internal Rate of Return (FIRR)

- 7.2 Financial Internal Rate of Return (FIRR) of the project is estimated for the following three cases of governmental subsidy for the unit price of Rhodes grass of R.O.100/ton and the unit production rate is set at 40 ton/ha.

CASE	Governmental Subsidy	FIRR (%)
1.	Without any subsidy	+1.1%
2.	Construction of observation well, storage line (with O/M road) and connecting road	+6.9
3.	Construction of production well, observation well, storage line (with O/M road) and connecting road	+11.6%

Presumptions: Project life is set to 30 years
Project price is calculated as of Jan., 1989

FIRR of the project for all the three cases of Governmental subsidy is positive for the unit price of Rhodes grass of R.O.100/ton. In addition to this FIRR of the project is estimated with the unit price of R.O.70/ton for the three cases of Government subsidy and it was found out that FIRR is negative for the unit price of R.O.70/ton. Consequently, it can be concluded that this high cost project will be economical only if the revenue of Rhodes grass will be equal to or above 4,000/ha (= R.O.100/ton x 40 ton/ha).

Debt Service Schedule, Financial Statement and Government Expenditure

7.3 The financial statements tell us that, with generous doses of government subsidies, which is set to cover the interest cost of investment to the farm facilities, to bear the investment and operation/maintenance cost to the rest of the facilities except to installing the production wells with its pumps which is to be charged to the farm operators, the annual sale of fodder grass with the unit price of R.O.100/ton will not only cover the direct production cost including water cost, the O/M cost, depreciation cost and repayment of the long term loan but also be able to allow the farmers to retain the remuneration of R.O.720 per year per hectare.

With the level of remuneration mentioned above, the periodical replacement cost of machinery can be paid without raising any extra short term loan.

The following items of the government expenditure are required for obtaining the remuneration.

1. Interest

The government is supposed to bear the interest (1.5%) of the long term loan for the project provided by the OBAF.

2. Monitoring Well with Observation Equipment

It is supposed to bear the cost of installation of the facilities and its maintenance and operation. The latter cost may be borne by the PAWR, as the operation may appropriately fall within its jurisdiction.

3. Storage line with O/M Roads.

Construction costs and O/M cost are supposed to be borne by the government. The latter may be maintained by the MAF.

4. Connecting Roads

Construction costs and O/M cost are supposed to be borne by the government. The latter may be borne by either the MOC or the Wali of Dhofar.

Project Impacts

7.4 In addition to the project benefit that can be quantified and valued in monetary terms, every project entails cost and benefit that are intangible and do not lend themselves to evaluation. Because these cost and benefit are a factor for project selection, it is important that these are identified.

Probable impacts are as follows:

1. Agriculture development in the Nejd facilitate the development of southern region as a whole.
2. Development of basic industries creates new employment opportunities in the area.
3. Pilot farm project contributes for the development of human resources through its training and extension program.
4. The project will supply fodder grass for the cattle population in the nearby Jabal.
5. The project will facilitate to improve the social infrastructure of the area.

However sparsely they may be, people have been living in the frontier desert of the Nejd. It is important for the government to provide them with infrastructures not only for living but also for production and transport, because they give the local people self-esteem. But beyond the level of purely financial appraisal, ranking of the project in the priority schedule would be left entrusted to the perspective of the policy makers.

Recommendations

At present, the socioeconomic conditions of Oman highly depend on the petroleum industry and the agriculture development is highly essential for stabilizing post-oil economy. However, the informations regarding the Nejd such as natural environment, soil, groundwater and socioeconomic conditions are not sufficient enough. Hence the scale and details of the agriculture development project in the Nejd should be decided carefully.

Based on the study of groundwater and soil, and agricultural conditions the following recommendations are made for the agriculture development in the Nejd.

- (1) The agriculture development project should be established in confirmation with the groundwater and soil conditions of the area. The groundwater and soil conditions in the Nejd can not be clarified until the detailed investigation is carried out further in the whole area. Hence the accumulation of the informations regarding all the relevant parameters should be carried out under a suitable investigation system.
- (2) The development project should proceed with a systematic development plan in order to obtain good results fitting with proper investment. It is hoped that the establishment of the project appraisal and advisory committee with the coordination of concerned governmental offices will be helpful in order to manage and control groundwater, land and manpower resources and for the planning and promotion of suitable agriculture development project.
- (3) The phased agriculture development project plan should be established based on the guideline for the agriculture development proposed in this report.
- (4) The pilot farm project which will be carried out as the first phase of the phased agriculture development project is the most important phase to confirm the development potential of the Nejd. In this regard, the early execution of the pilot farm project is strongly recommended.

It is necessary to collect the following data which are indispensable for developing the agricultural project in the Nejd.

1. Continuous observation of groundwater conditions
 - Groundwater level
 - Groundwater quality
2. Continuous observation of soil conditions
 - Physical and chemical properties of the cultivated soil
 - Tests of fertility status and salt concentration
3. Continuous observation of meteorological data
4. Crop cultivation experiments which include type of crops to be introduced, cropping pattern and cultivation techniques.
5. Irrigation tests which include the selection of irrigation method and analysis of water requirement for each crop.

(5) The groundwater resource is the most important factor which influences the promotion of the agriculture development project in the Nejd. For the further development and conservation of the groundwater resource, the investigation of groundwater condition in the whole area should be carried out systematically and in detail in parallel with the phased agriculture development project. The following investigations should be carried out.

1. Exploration of groundwater
 - Drilling of new exploration wells and new observation wells
 - Exploration of aquifer distribution by the electro-magnetic prospecting
2. Groundwater monitoring
 - Continuation of groundwater observation and improvement of its observation network.
 - Establishment of groundwater observation system and securing of staffs for its observation.

3. Administrative system for groundwater resource conservation

- Establishment of administrative system for groundwater development and conservation
- Desirable drilling procedure and well structure
- Optimization of well arrangement
- Determination of suitable development speed and limitation of project area based on the groundwater appraisal.

(6) Although a detailed soil survey was carried out in the pilot farm site, only a preliminary soil survey was done in the other areas and the information of soil condition is not sufficient enough. In case of selection of further development area the following detailed soil survey is required in the target area proposed in this report.

- Air photo survey
- Topographical survey
- Definition of land suitability and description of soils

(7) The results of the financial appraisal make it clear that the large scale governmental subsidy is required to implement the project with proper remuneration under the assumption of the unit price of Rhodes grass as R.O.100/ton and the yield as 40 ton/ha. The high cost of groundwater irrigation project will be economical only of the high yielding crops, which can make the revenue of R.O.4,000/ha/year should be grown in the newly developed area.

(8) It is hoped that the concerned governmental offices should review the project plan periodically during the promotion of the project and revise its contents if necessary, so as to reflect the socioeconomical conditions of Oman.

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