SULTANATE OF OMAN

DEVELOPMENT OF NEW LAND FOR IRRIGATED AGRICULTURE

Soil Consultant's Report
July-November 1977

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

SULTANATE OF OMAN

Ministry of Agriculture, Fisheries, Petroleum and Minerals
Directorate of Agriculture

Development of New Land for Irrigated Agriculture in Oman
Soil and Land Classification

A Soil Consultant Report
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By

Dr. Hatim El-Attar
Associate Professor of Soils
University of Alexandria

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Mr. G.M. Baily	- Laboratory Director
Mr. Mohamed Suleman	- Chemist
Mr. Abdul Malek Abdul Aziem	- Agronomist
Mr. Mostafa Ali Mostafa	- Agronomist
Mr. Osma Ahmed Foda	- Lab. Assistant
Mr. Hassan Ali Ossman	- Lab. Assistant

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I - INTRODUCTION

The original terms of reference were to review, summarize and to assemble soil maps according to the FAO system of soil and land classifications for the Sultanate of Oman.

Upon arrival to Oman on July 1977, the Omani Government Officials asked for urgent consultancy:

- to carry out a comprehensive soil study of the existing government production and experimental farms in the Batinah region;

- to select a suitable area to initiate a new experiment and research farm in the Interior region near Nizwa;

- to select suitable areas at the Sharqiya region in the vicinities of Ibra-Ad Dariz, Al Kamil - Al Wafi and Bani Ali - Bani Hassan.

The consultant was asked and advised by Dr. M. Hosni, the FAO Project Manager, to review the earlier soil survey reports that have been recently completed by several Consulting Agencies as a guide to proceed in this mission.

The following three reports were consulted comprehensively during the work:

- water resources development project of Northern Oman, International Land Development Consultants (ILACO) 1975;

- water resources survey of Northern Oman, Sir Alexander Gibb and Partners and ILACO 1975;

- water resources survey in Northern East Oman, Renardet Sauti ICE Consulting Engineers 1975.

The general information presented in this report is extracted from these reports.

The Omani Government provided the consultant with 1974-1975 aerial photographs of the scale 1:20000.

All soil and water analysis data presented in this report were made at the soils laboratory at the Rumais Experiment Station.

The full cooperation between the FAO Water Resources experts and the soil consultant made this work possible.

2 - SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

During this short consultancy mission the following activities were completed as best as the time, facilities and available data permit:

- A review of previous soil surveys of Northern Oman.
- A detailed soil survey and evaluation of the Governmental farms in the Batinah region.
- Selection and survey of the new projects at Sohar - Saham vicinity.
- Selection and survey of a site for an experiment station farm in Manah area near Nizwa of the Interior region.
- Selection of some project areas at Ad Dariz and Al Kamil-Al Wafi of the Sharqiya region.

2.1 General Findings and Recommendations

- Out of a total area (5.900 ha) surveyed by the consultant, about 2 900 ha were found to be suitable for irrigated agriculture as shown in the following table. This means that the present cultivated area (135 ha) within the surveyed regions could be expanded by 25 times, subject to the availability of irrigation water and the other inputs. The percentage distribution of the suitable soils for irrigated expansion within the surveyed regions is 100, 50, 33 and 60% in Southern Batinah, Northern Batinah, Sharqiya and Interior Regions, respectively.
- A training center - affiliated to the Agriculture Institute at Nizwa - should be able to provide the Sultanate with technically qualified agronomy, and agricultural engineering assistants.
- Technical land and soil survey department teams should be administrated through the Directorate of Agriculture. Suitable tools and equipments for both field and office as well as for mapping cartograph should be furnished.
- The soils laboratory has to be completed and strengthened to carry out essential types of soil, water, plant and fertilizer analyses that may be required for all the above needed assessments.
- An irrigation expert or consultant is needed, to help in establishing proper water distribution and management practices and in disseminating this information to users.

2.2 Rumais Farms

- The soils of Rumais farms are considered of very marginal types. Very coarse, very shallow and gravelly soil profiles are dominant. No further irrigated agriculture extension is recommended in this area.
- Water distribution and management should be improved through:

  i) maintaining water pumpage hours and well intensity low to prevent sea water intrusion, due to large draw-down;

  ii) development of sprinkler or much better drip irrigation for different crops, if they can be technically and properly managed;

  iii) collection and precise assessment of evapotranspiration, water consumption, water utilization, water quality, soil moisture and soil temperature as well as other meteorological data;

  iv) evening and perhaps night irrigation may be required to reduce evaporation losses.

Areas in hectars of cultivated, suitable for irrigated agricultural expansion and surveyed lands.

Region	Area - ha. Cultivated	Suitable	Surveyed
Southern Batinah Region:			
Farm 1	10	50	50
Farm 2	15	100	100
Farm 3	15	100	100
Nursery Farm	10	50	50
Experiment Station Farm	15	100	100
Northern Batinah Region:			
Sohar Production Farm	20	-	-
Sohar Dairy Farm	20	200	500
Sohar New Project	-	750	1500
Saham New Project	-	750	1500
Shargiya Region:			
Ad Dariz vicinity	-	100	500
North Al Kamil	20	300	500
South Al Kamil	10	100	500
Interior Region:			
Manah vicinity	-	300	500
Total:	135	2900	5900

- Soil management should be improved through:

  i) use of shallow and light ploughs and cultivators to avoid bringing gravel from subsurface;

  ii) under plough and mixing of green manures with surface soil using disc-harrow ploughs. Green manure should be periodically introduced to increase the organic matter status to improve soil and nutritional conditions.

- Fertility management should be highly considered through:

  i) regular introduction in the crop cycle of legumes inoculated with the proper Rhizobium organism. This will improve legume production, biological nitrogen fixation, and soil nitrogen content.

  ii) preparation of inoculants, under local conditions. A soil microbiology expert may be consulted. A competent laboratory or specialized firm would be contracted to supply strains adapted to Oman conditions;

  iii) minimizing the use of ammonium fertilizers. Urea is recommended as a substitute nitrogen source. Diammonium phosphate may be another alternative which will supply both N and P;

  iv) foliar fertilization to reduce fertilizer leaching and enable use of micronutrient fertilizers;

  v) assessment of macro - as well as micro-nutrients (N, P, K, and Fe, Zn, Mn, Cu and B) in soil, plant and water.

2.3 Sohar-Saham Farms and Projects

- The soils of this general area have better properties than those at Rumais. There is a good soil potentiality to extend irrigated agriculture. The soils have deeper soil profiles with coarse to medium texture and with low gravel content.

- Salt hazards are found in the Sohar Production Farm which should be leached as soon as possible using high water applications during the winter season and at regular short intervals during the summer.

  i) water pumpage hours from wells No.4 and 2 should be reduced because of their relative high boron and salt contents.

- Over and above the Rumais recommendations for water, soil and fertility practices, the following factors are very important to consider:

  i) development of the water resources should proceed as soon as possible and precede any reclamation plans;

  ii) heavy irrigations have to be applied for reclamation and during the early cultivation period to ensure salt leaching and to improve soil structure;

  iii) Clover should be cultivated for at least the first two years and to be underploughed to improve organic matter content, the soil structure, and soil nutritional conditions.

2.4 Sharqiya Region

The reconnaissance and semi detailed surveys show that good soil and water potentials are found near Al Kamil, but medium to marginal ones are found near Ad Dariz. No good water potentials are expected near Bilad Bani Hassan and Bani Ali. Other areas near Al Wasil and Al Zahir are sandy and rough but with good water resources.

To develop the selected project areas in this region the following should be noted:

i) water resources investigations should proceed to provide certain data indicating the availability of water of suitable quality;

ii) provided that suitable water is found, a soil survey team should follow a land (topography) team, both being provided with adequate facilities, to prepare land and soil maps at proper scale;

iii) since the selected areas are subject to flood hazards it is essential to prepare engineering water conservation plans to prevent flood hazards. One important action is to adjust the wadi courses;

iv) the selected areas are subject to blown sand hazards. Wind breaks should be initiated early during the reclamation period, i.e. prior to cultivation. These wind breaks should be several lines thick. A Forestry expert should be consulted to decide on the suitable plants, direction and spacing of the wind breaks.

- Sand dune stabilization is highly important in Sharqiya region.

- Precise land levelling and high rates of water applications should be practiced on sandy soils to provide as even a water distribution as possible. Drip or sprinkler irrigation may help.

- Small private farm holdings, at the rate of one for each well, may be suitable in Sharqiya region. Avoid establishing governmental farms as much as possible. Only demonstration farms would be governmentally managed.

- A rest-house should be built in Sharqiya region to facilitate the living conditions of experts and teams of workers required for the extensive studies.

2.5 Interior Region

- The soils of the project area are well developed. Deep soil profiles with a calcic B horizon are found. The textures are medium to fine. The area is hot. The water is limited. The possibility of soil salinization is great.

- Soil, water and fertility management have to be very carefully studied and practiced.

- The falaj systems have to be maintained, specially falajs Khatum and Messarag, to increase their flow rate and to secure water availability for new irrigated land.

- Furtherground water development should be investigated and some wells may be developed to add another source of irrigation water.

3 - SUMMARY OF AVAILABLE INFORMATIONS

3.1 General

The Sultanate of Oman covering an area of 300 000 sq. km consists of five main regions:

a) Musandum - the northern peninsula at the Strait of Hormuz;

b) Batinah - (north east coast), the north central of Oman parallel to the Gulf coast to the east of Jebel Akhdar;

c) Interior - the north central of Oman to the west of Jebel Akhdar;

d) Sharqiya - the north east central of Oman. This region includes the central east coast of Oman including Masira island and the Wahiba Sands which is a desert region stretching about 600 kms south west of northern Oman ;

e) Dhofar - the southern most region which is hilly (500-1000 m) and famous for its summer rains.

3.2 Geomorphology and Parent Materials

3.2.1 Mountains

The Oman mountain range, some 50-75 kms wide with peaks of 2000 meters above sea level, is directed NW-SE and runs parallel to the coast of the Gulf of Oman.

The major and central part of the mountain consist of igneous and metamorphic rocks. Gabbros, peridotites and serpentines are the dominant (ultra basic) rocks.

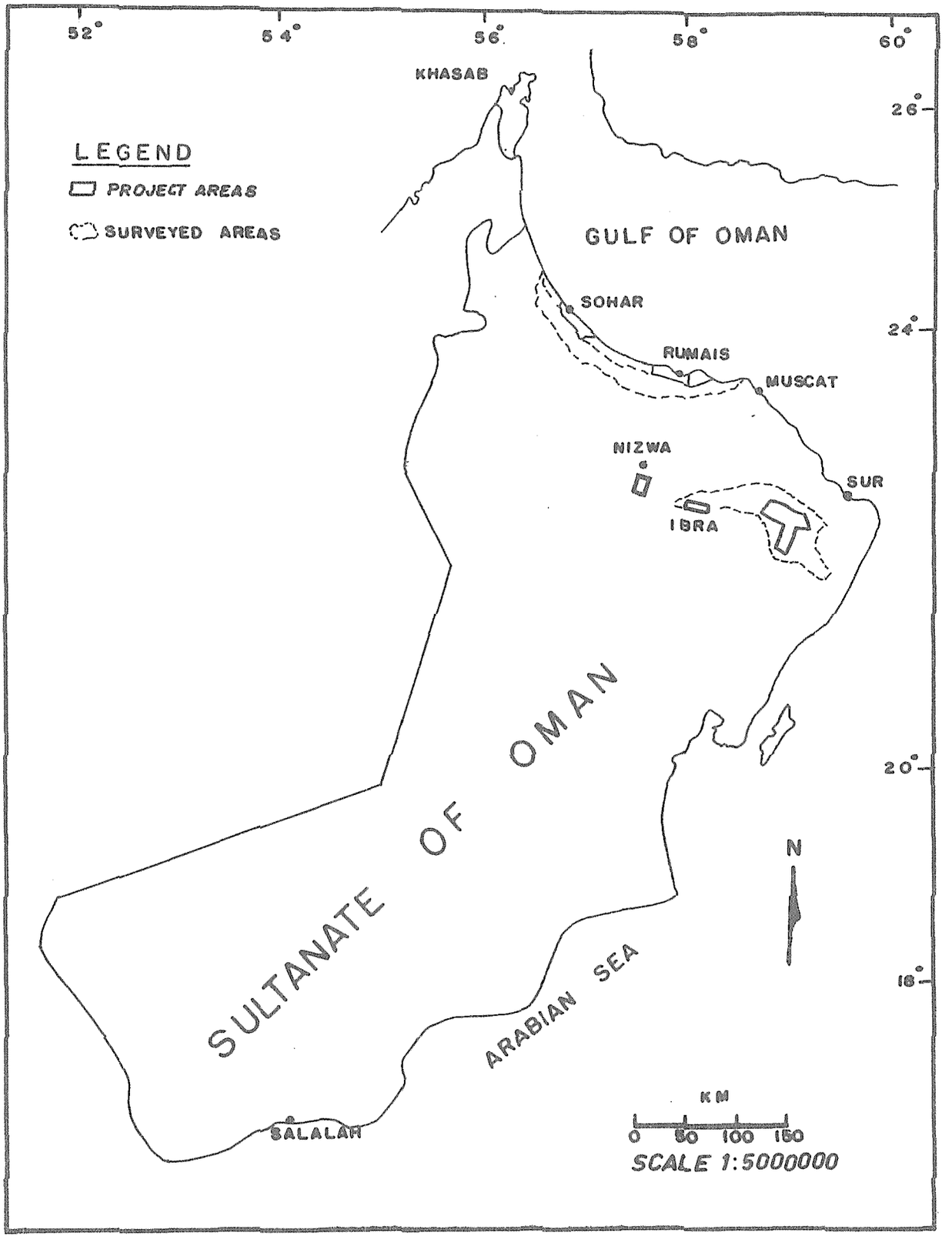
Along the edges of the mountains, sedimentary rock formation, mainly of limestones and marls are found.

On all sides of the mountains a large system of alluvial fans spreads out. The wadi-fan complex and the flood plain are mixed with a coastal complex in the east side (Batinah). On the west side (Interior and Sharqiya) the alluvial complex is affected by the sand seas formations of the Rube' Al-Khali (unpopulated region).

3.2.2 Wadi-fan Complex

This is a system of older and younger alluvial fans built up of coarse detritus. Different levels of terraces are recognized. The older formations are generally conglomerated in the deeper-lying layers and cemented by carbonates in the upper layers.

The wadi deposits consist of coarse sand, gravel and boulders.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3.2.3 Accumulation Plain (flood plain)

The plain formations are very flat. The sediments deposited in the plain are principally of alluvial origin, transported by wadis and also by sheet floods.

In some places, dried up wadi beds, old terraces, sand dunes, and lagoons have become sources of wind-borne deposits. A great deal of these materials have been reworked. Thus, aeolian and alluvial processes are strongly mixed up. Aeolian sands and loams are interbedded with wadi sands and gravels.

Near the coast, aeolian sediments such as fine loamy sand, sandy loam and loam are dominant. In land the alluvial sediments are generally coarser (sands and gravels).

Local dune formation occurs mainly near and along the main wadi channels. The wadi sands were deflated and redeposited.

Low mounds or small micro-dunes (Nebkhas) developed around herbs and grasses are a common characteristic feature of the accumulation plains.

The surficial layers of some deposits or formations are often deflated, leaving a surface covered with gravel (desert pavement).

3.2.4 Coastal Complex

Generally, the coastal complex is composed of the following:

- a long-shore sandbar, emerging 5-10 m above sea level. It consists of marine sands mixed with shell fragments. It has been built up by wave action. It has been reworked by wind into low dunes in many places;

- a large flat saline area (coastal Sabkha) which has originated from coastal lagoons. Strong stratification of fine sands with medium and fine textured marine and coastal sediments is a characteristic of the coastal Sebkha;

- older sand bars and Sebkhas, these are found more inland, often covered with recent aeolian deposits of older materials reworked by winds. Low sandy dunes are moving inland (unstable) over the flat clayey or loamy surfaces of the older saline flats. The presence of shells in these areas confirms the marine origin of these sediments.

3.3 Climate

The existence of a high mountain range near the coast greatly influences the climate of the Sultanate of Oman. While the rainfall on and near the mountains is sufficient to support irrigated agriculture in small areas where there is aquifer storage, much of the country remains arid.

- The climatic year could be divided into two distinct periods. The winter months are from November to April. The predominant air flow is from the north west during the winter.

- The summer months are from June to September with a mansoon air flow from the south west.

- May and October are the months of transition between the winter and summer conditions.

Winter conditions arise from a general area of low pressure over the Indian Ocean extending over the low coastal region of Oman. A modified polar through from the eastern Mediterranean can migrate in a south easterly direction to encounter the Jabal Akhdar or moist air moving inland from the Gulf of Oman.

Summer conditions are strongly influenced by the formation of the inter-tropical convergence zone (ITCZ) is the junction between two main air streams, the north westerlies (on the Arabian Gulf) and the south west monsoon which is deflected to a south easterly by the Arabian land mass.

Normally the monsoon flow is shallow giving little rain inland. Inputs of more humid air from the east or through crossing the Gulf of Oman from Iran trigger local storms.

In summary, the major factors governing the amount of rainfall and its geographical distribution and frequency of occurrence would appear to be the number of cold fronts crossing the area in the winter months, and the position of the ITCZ in the summer.

Generally, May, June, October and November would be expected to have little rainfall. Despite high variability from year to year there is a distinct seasonal pattern shown by the records.

At Muscat, (Batinah), rainfall tends to occur in the winter months from December to April. Only occasionally are there summer storms.

At Nizwa, (Interior), the winter rainfall appears to occur mainly in February and April, less often in January and March, and rarely in December. There is rainfall in July in most years of the record (Gibb's) with less frequent falls in August and September.

At the desert region of Sharqiya there is an erratic rainfall.

At Dhofar, summer rains are famous.

The following summary of temperature and evaporation records is after Mr. P. Horn, FAO water resources expert.

Temperature and Evaporation	Winter		Summer
Mean max °C	28		40
Mean min. °C	18		30
Mean annual °C		28	
Evaporation rate mm/day	3-4		8-9

In the interior plain as well as in the Sharqiya plain the relative humidity is much lower than in the Batinah (coastal plains), and the mean wind velocities are much higher resulting in higher evaporation rates in the Interior and Sharqiya.

3.4 Rainfall and Water Resources

Rainfall is more regular but highly variable in quantity over northern Oman but of low dependability over the eastern desert region (Sharqiya) and Dhofar (southern region).

Few short periods of heavy showers of short durations in northern Oman cause surface run off.

The gravel-filled wadi courses and the alluvial plains on all sides of the mountains serve to capture most of the surface flow from the hard rock areas and some part of the rainfall on the plains.

Typical annual median values are 100 to 115 mm on the coast and 50-100 in the interior of northern Oman, rising to 300-400 mm in the mountains and only 70-100 mm in the Dhofar region.

In the coastal plain there is a ground water basin with permeable formations saturated with fresh water. The sea water/fresh water interface is at a greater depth in the area south of Saham (north Batinah) than to the north. The falaj systems are not common in this reach.

In the Interior and Sharqiya the ground water seems to be bound to certain channels of limited depth. Several falaj systems are common in these two regions.

The total water resources could be estimated at around 1000 M cu m/year ending up as ground water and around 300 M cu m/year surface water flowing to waste.

The present cultivated areas are estimated (1975) to be as follows:

	17000	ha	Batinah
	6000	ha	Interior
	2500	ha	Sharqiya
	3000	ha	Dhofar
Total	28500	ha	

It is estimated that this area would consume 800-900 M cu m/year, therefore, around 100-200 M cu m/year could appear feasible for further irrigation developments.

3.5 Vegetation

The vegetation is strongly influenced by the source rainfall, the salt content of the soil and the availability of water.

Xerophytic or halophytic types of vegetation are dominant.

The vegetation pattern can be broadly correlated with physiographic position of the land forms. Little or no vegetation could be found on desert sandy land form. Halophytic types (Zygophyllum sp. and Haloxylon salicornium) are grown on salt affected land forms of Sebkha near the coast or on low lagoonal type formations in the flood plains. Xerophytic types (Acacia sp. and Tamarix indica) could be recognized in all land forms that may experience some rainfall or run off. The growth pattern of xerophytic type plants reflects the availability of moisture in the formation being

well developed on moist conditions. Grasses could be recognized after rainy seasons and its growth is much affected by the rain quantity, intensity and duration.

3.6 Soil and Land Resources

There are considerable amounts of information available on land and water resources. For some reason, these regional survey reports are not properly co-ordinated. These reports followed different patterns, system and detail levels of classifications.

From the point of view of soil and land use classification the report by ILACO is the most comprehensive. This report followed the internationally accepted systems of soil and land classification and to a great extent the FAO-UNESCO system. Both the ILACO and Gibb's reports give very reasonable reconnaissance survey of the Northern (Batinah and Interior) regions. These two reports included some semi detailed surveys of selected areas or farms.

- The Gibb's report, however, slightly used the FAO system of soil classification and mostly followed the natural classification systems with some correlation to the USDA (American) system without being very specific.

- The third report of Renardet Sauti ICE gave only a fair reconnaissance survey of land resources. This report followed the French natural system of land classification.

- All three reports did not give enough or complete and clear data. Their presented data in certain cases do not support their diagnosis of the different characteristic horizons. In effect, their reported soil types or classes sufferred some ambiguity. The following points may make this clear.

The cambic horizons and classes are reported without presenting any characteristics except in some cases as the texture property.

The calcic horizons or classes were reported while the given $CaCo_3$ percentages do not fulfill the requirements of calcic horizons. The soils of Oman are generally calcareous and sometimes highly calcareous, therefore, calcaric classes "calcaric fluvisol".

- The aridic moisture regime of Oman leads to a great confusion in the reported soil classes. While a great deal of weight was given to the Yermosols or desert soil formations, Xerosols were reported in the coastal flood plain of northern Oman.

- The fluvisols were given much smaller weight than they should have. The wadi, fan, and flood plain formations with their stratification property as well as the weak development of the soil profiles were appreciated in all reports. Many fluvisols however were classed as Yermosols in both ILACO and Gibb's reports.

- The saline phases were sometimes wrongly classified as Solonchalk classes.

These confusions were further repeated in the reports of Dr. Hesse that had to be based on the ILACO and Gibb data without being checked with further field and laboratory studies.

The estimated most suitable or potential extension areas in the surveyed regions are summarized in the following table.

It can be concluded that about 75,000 ha are of the suitable classes 1 to 3, from which 55,000 ha are in the Batinah region. Only about 15,500 ha are in the Interior and 3,500 ha are potentially in Sharqiya region.

Distribution of Suitable and Potential Land

Land Class	Area (ha)	Location	Reference
Suitable	23,000	Batinah	ILACO
2-3	31,500	"	Gibb
5	4,600	"	"
2-3	4,400	"	"
		Possible in Wadi Bani Kharus	"
Suitable	7,900	Interior	ILACO
1-3	0,675	"	Gibb
1	0,120	Wadi Quriyat	"
2	2,120	" "	"
3	1,360	" "	"
5	0,750	" "	"
6	3,020		"
1-3	2,900	Possible in "	"
Potential	3,500	Sharqiya	Renardet

4 - WORK PLAN AND METHODS

4.1 Field Work

The existing governmental production or experimental station farms at Rumais were visited. Soil and water potentialities were examined. Observations on the existing cultivated areas, the crop production, the soil and water as well as the fertility managements were carefully considered.

Detailed soil survey was completed for these farms. Several soil bores to the depth of 120 cm or to the gravel or rock layer were examined and sampled for laboratory analyses. Representative soil pits were carefully examined, described and sampled.

A cross section representing the detrital fan-wadi complex, the flood plain and the coastal complex was examined and results are reported. This cross section study and analyses made it possible to understand and to make some adjustments to the earlier surveys to fit the FAO system of soil and land classification.

The Sohar-Saham new projects that are suggested to be financed by the World Bank Fund have been given a special priority. These project areas represent the northern Batinah region which has greater soil potentiality than the Rumais vicinity. The water resources seem to be good for further irrigation development, however, we feel the necessity of further water resources studies in this region. The water studies should include both the capacity of the aquifers and quantity and the quality of the ground water available for irrigation developments.

In this area also the Sohar production farm, the Dairy Farm (FMC) as well as some private farms were surveyed on the observation (reconnaissance) and the detailed levels according to the facilities available and as much as time permits.

Some observations of water level in wells and water samples were collected during field work. The analyses of water samples help to correlate the water quality with the plant growth and soil conditions.

Somewhat between detailed and semi-detailed soil and land use classification maps were prepared. These maps represent the production farms 1, 2 and 3 as well as the nursery farm and the experiment station farm at Rumais. Also similar maps of the production farm and the dairy farm as well as the two new project areas at both Sohar and Saham were prepared.

In Sharqiya region, our task was most difficult. Only a general reconnaissance soil and water resources map was available (Renardet, 1975).

With hard field work in co-operation with Mr. David Read the FAO water expert and his associate Mr. B. Blasco from the water resources department, we were able to review the earlier works by the above French Consultant Agency and to identify their previous pointed out areas of good water potentialities. Mr. B. Blasco records of the existing wells in these areas guided us to the most suitable areas of good water possibilities. Accordingly the areas south of Al Wafi i.e. Bani Ali and Bani Hassan were excluded from our soil survey because of the high salinity of the well water in these areas. Other areas such as No. 7, 8, 9 and 10 which were shown on the water resources maps (Renardet, 1975) were excluded from soil surveys because of their topography, stonyness, or being subject to wind erosion or wind blown sand hazards.

In Ad Dariz area near Ibra only small areas (40-50 ha) could be located in between wadi courses or beds. These are of medium to marginal suitability for irrigated farms.

In between Al Kamil and Al Wafi an area of reasonable suitability for irrigated agriculture could be developed. This area is subject, however, to wind blown sand hazards and further water resources studies have to be developed.

At North and north east of Al Kamil which is generally north of the new road to Sur there are several hundreds of hectars that could be put under irrigation. More detailed soil survey to exclude dunes and wadi courses should be carried out before a final development plan is decided. Also area is subject to flood hazards and erosion as well as wind blown sand hazards. Engineering of the wadi Khalid watershed could conserve soil erosion. An initiation of wind breaks would combat wind hazards.

A semi detailed soil survey of the suggested new project areas to be developed by the Kuwait Bank funds is presented.

In the Interior Region, the FAO soil consultant and the water resources expert of the FAO were asked to select an area that could be suitable to establish an experiment farm in this region in Nizwa vicinity.

The Regional Director of Agriculture Mr. M. Mahfouz suggested an area in Manah vicinity in which several falaj systems are used.

Our field observations showed that the falajs in this area are active. The water quality and quantity are suitable and there are several abandoned farms in this vicinity. The water resources expert, Mr. Horn and his associates, carried out a systematic measurements of water flow in these falajs and their preliminary study show that an experiment station farm could be initiated using Al Khatum falaj around which some farmers used to rent the land owned by the Government for a winter rain-fed crop only.

Semi detailed soil survey in the area was carried out and priorities are shown on maps to indicate the extension possibilities according to the water resources development in the future.

4.2 Soil Analysis

The following laboratory analyses were made by the staff of the soils laboratory at Rumais Experiment Station under the supervision of the soils consultant.

4.2.1 Particle Size Distribution

The abundance of gravelly soils in the surveyed areas made it very important to report the gravel content of each sample. Gravel distribution both vertically and horizontally varies very much from one site to the other. The gravel percentage in each sample is reported.

The percentages of the coarse and fine sand size fractions as well as the silt and clay size fractions were determined in the fine earth portion of the samples. The pipet method is used for this analysis. Soil textural classes are reported according to both the USDA and the FAO systems.

4.2.2 Carbonate Content

The soils of Oman are generally calcareous. The diagnosis of the calcic horizon is very important for both soil classification and land use interpretation.

The calcium carbonate equivalent percentage was calculated from the results of back titration method of sample portion.

4.2.3 Organic Matter Content

The organic matter content is a useful parameter for soil classification as well as for plant nutritional potentiality and fertility management.

The organic carbon content of the sample portion was chemically oxidized. The organic matter content was calculated using proper factor.

4.2.4 Available Phosphorus Content

The concentration (ppm) of phosphorus in a bicarbonate extract (Olsen method) is used to indicate the availability level of phosphorus in soil samples. The following parameters (Chapman, 1965) are used to estimate the response to phosphate fertilizers:

Av. P(ppm)	Degree of response to phosphorus fertilizers
5	expected response
6-10	probable response
11	unlikely response

4.2.5 Salinity Analyses

Soluble salt content in both soils and water is a critical parameter that should be periodically determined to avoid salinity hazards. This analysis is more important in hot and dry regions where salt accumulation is usually expected. It is more crucial under irrigation practice specially when well or ground waters are used for irrigation. The ionic assemblage is as important as the total concentration, specially to avoid a specific ion hazards.

The electrical conductivity of the saturated paste extract (ECe) is used as the salinity index of soils. Because of practical benefits several laboratories, however, determine the electrical conductivity (EC_5) of 1:5 soil/water extract. A correlation has to be done in every laboratory between EC_e and EC_5 local values.

In this report only the EC_5 values are reported. The works of the previous consultants showed the following correlations between EC_e and EC_5 values for the soils of Oman:

Salinity Class	EC_5 m.mhos/cm at 25°C	EC_e m.mhos/cm at 25°C	Salt %
Non saline	< 0.75	< 4.7	< 0.25
Slightly saline	0.75 - 1.50	4.7 - 8.9	0.25 - 0.50
Saline	1.50 - 3.00	8.9 - 16.0	0.50 - 1.00
Very saline	3.00 - 5.00	16.0 - 25.0	1.00 - 1.65
Highly saline	> 5.00	> 25.0	> 1.65

After Gibb's report.

4.2.6 Boron in Soils and Water

Boron is one of the essential elements for plant growth. The narrow margin between its required and its toxicity levels in soil, plant and irrigation water requires very careful and periodical boron analyses. This is specially true when well water is used for irrigation in dry hot regions and when boron-sensitive plants such as citrus and many vegetable crops are cultivated.

Boron level in hot water soil extract should not be less than 0.3 and 0.6 ppm for sandy and clayey soil, respectively, to prevent boron deficiency (Chapman, 1965).

Boron level in irrigation waters should not be more than one ppm (Richards, 1954) for sensitive crops.

4.2.7 Cation Exchange Capacity

The ammonium acetate method is used to determine the cation exchange capacity.

4.3 Facilities and Equipment

The reported field work herein would be more appreciated if the reader will bear in mind the following points.

- The consultant arrived at Oman on the first day of July to start a five months mission.
- Unplanned and unexpected task of field work was suggested and very urgent data have to be collected, analyzed and reported as soon as possible.
- Every possible help was offered by both Omani officials and FAO experts.
- Tools and equipments are scarce, some are misplaced but the consultant is expected to find a solution.
- Only topographic maps of the scale 1:250,000 are available, but recent aerial photographs (1974-1975) of the scale 1:20,000 are available.

- Three main soil and water resources reports are available and could be used as a guide.

- The consultant is expected to prepare detailed soil and land use maps of scattered areas in the previously surveyed regions.

- A soil laboratory with a limited capacity and very limited facilities and equipments is available and can help in soil and water basic analyses.

- Although available, not a single one of the official project cars can run steady for more than one week in field work.

- Counterparts, associates or even technical assistants were not available.

- There is no technical field staff that can carry out any field survey specially during the most hot and humid regions and months, respectively.

- The FAO soil consultant had to dig at least 75% of the auger bores, therefore, several road cuts and hand dug wells were used to complete this field work.

- Many of the above mentioned conditions seem normal and would be expected, however, the magnitude and frequency of occurrances were unexpected.

5 - SOIL AND LAND SUITABILITY CLASSIFICATION

- The FAO-UNESCO system of the soil map of the world (UNESCO-Paris, 1974) is applied for soil classification in this report.

- Land use classification for irrigation purpose is used in this report. The proposed system herein is guided by the FAO Soils Bulletin No. 32 and a modified ILACO system.

Few necessary adjustments were needed to make the symbols more cannotative to the property or the limitation factor. In our system subclasses are only used to indicate the conditioned class (C) that was used in ILACO report. The not suitable class is given proper symbol (N) rather than (U) used in ILACO report

The following land suitability system is adopted.

- Two land suitability orders are designated by:

  i) (S) for suitable;

  ii) (N) for not suitable.

- Three suitability classes are designated by their respective arabic numbers:

  i) (S_1) for highly suitable;

  ii) (S_2) for moderately suitable;

  iii) (S_3) for marginally suitable.

- Six suitability subclasses are designated by a suffix small letter and a number which represents the critical soil property and its degree of severity, respectively.

- The suffix letters are connotative to the soil property as follows:

  i) t for soil texture of the plough layer;
  - t_I for gravelly sands
  - t_2 for sands
  - t_3 for clays

  ii) p for soil profile depth to gravel, cemented layer or rock
  - p_1 for a depth of less than 90 cm;
  - p_2 for a depth of less than 60 cm;
  - p_3 for a depth of less than 30 cm;

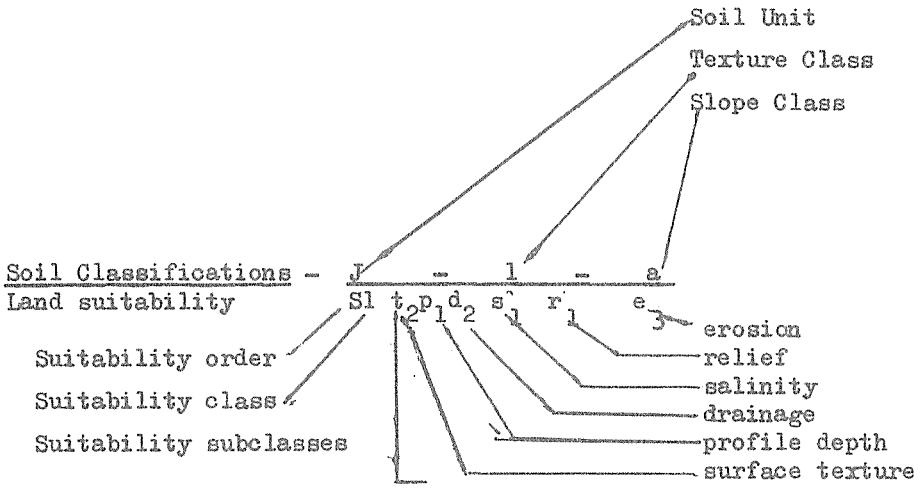
  iii) r for microrelief
  - r_1 for variations of less than 50 cm;
  - r_2 for variations up to 100 cm;
  - r_3 for variations of more than 100 cm;

iv) s for soil salinity
- s_1 for slightly saline
- s_2 for moderately saline
- s_3 for very saline

v) d for internal drainability
- d_1 for good drainage
- d_2 for poor drainage
- d_3 for excessive drainage

vi) e for erosion
- e_1 for slight probability
- e_2 for moderate probability
- e_3 for high probability

Legend for soil and land suitability classifications



5.1 The Southern Batinah Region

5.1.1 Rumais Farms

a) Location

The Rumais Governmental farms are located in the southern reach of the Batinah region. These farms are within 60-65 kms from the capital area. All of them are located within few hundred meters from the main road to Muscat. These farms could be developed to supply the capital area with vegetables.

Farm Nos. 1 and 2 and the Nursery are located to the south side of the road (see map 1). Farm No.2 being further south in the wadi fan complex. The Experiment Station Farm as well as Farm No.3 are located north to the main road being more close to the accumulation plain position. Their area may represent the transition between the wadi fan complex and the accumulation plan formation. Most of the accumulation plain is populated and old date gardens are common.

b) General Soil Properties

The field work reveals that the soils in this area of collovia-alluvial type. They are very recently formed of very shallow soil profile with very little development. The recent thin (10 to 30 or 40 cm) blanket of fine earth is gravelly in most cases and stones are not uncommon at soil surfaces (pavement like). This latter appearance may indicate either a thin sheet of running water or of medium type winds that carried out the fines leaving the gravel covered on the top.

There is relatively thick (60-80cm) gravelly and sometimes stony subsurface, overlying a partially cemented transitional thin layer to the parent sand stone type rock or conglomerate of calcareous composition at a depth varying between 70-120 cm.

This type of stratification indicates cycles of deposition processes on the top of an old terrace formation which had experienced stages of deformation and cementation.

These are calcareous type soils of an ochric thin epipedon followed by either pure gravel layer or very weakly developed cambic - or calcic-like B horizons. These two types of B-like horizons do not satisfy the requirements of their types. The cambic-like horizon is of coarser texture than loamy fine sand, the color requirements are difficult to decide; the only criteria that may be recognized is the rusty spots or powdery surface of some primary minerals. The spotted effervescence is common all over the profile which indicates a diffuse distribution of carbonates. Also the variation in the strength of HCl reaction with carbonates may be due to the particle size distribution rather than to the percentage of carbonates. Also the percentage increase in carbonate from one layer (I reject "horizon" for the case) to the other does not fulfill the requirements for a calcic horizon in most cases.

The soils are thin or very shallow and of course texture. The land has a level topography except some shallow Wadi channels that coule be avoided or adjusted for future emergency surface drainage.

The organic matter is not detectable. The natural vegetation is scattered Acacia sp. and shrubs of weak growth which had been subject to draught and being up rooted (Acacia) because of the shallow and weak mechanical support of this type of soil for such medium size trees. Also the very dry and hot climate of desert or semi-desert type reduces organic matter accumulation to the minimum.

The drainage is good. The high permeability of these soils is of good concern when irrigation systems have to be developed. Soil salinity is low or medium and little leaching may be required during the first year only. The resalinization process is not anticipated because of the excessive drainage capacity of the subsoil gravel.

The available phosphorus is very low specially in the subsoil (see tables). Nutritional conditions are not good because of the coarse texture, low organic matter, high carbonate contents (50%) and low exchange capacity (5 meq/100 gm). These soils are marginal (low) or medium suitable for forage and vegetable crops, respectively. The vegetable crops are of short growth period and of shallow root zones which suit the soil shallowness and the need for frequent irrigations.

1) Farm No. 1

a) General

This farm is used for vegetable crop production. Only the northern part of this farm is successful. The soils are of deeper (layer) root zone and of less gravel content at surface than farm No.2.

The common practices of in furrow or on ridge cultivation of most types of vegetable crops lead to the accumulation of salts on crests of ridges.

The southern area of this small farm is located in a gravelly shallow type soils which made vegetable production poor and difficult. More frequent irrigation and fertilization are required on these coarse and shallow soils with very permeable subsoils.

Drip irrigation system could be tried and developed if proved practical. Foliage fertilizer should be used. Green and manure fertilization will improve soil condition. Biological fertilization specially for legumes has to be regularly practiced.

Soil and Land Classification

The farm is located in the fan-wadi complex formation. The soils are classified as being calcaric regosols (Rc) or Calcaric Fluvisols (Jc) of coarse texture and of level topography. Sometimes it is difficult to distinguish between Regosols and Fluvisols in two different map units because of the small size of the farm and the complex system of the wadi fan formation. In such case the two types are mapped as an association.

The soils are coarse, shallow to medium shallow, and some part of this farm has saline conditions. For irrigation classification, these soils would be in the marginally suitable class S_3 with the appropriate sub-class to its properties asit is indicated on the classification map of this farm. Analyses and description of profile 8 will provide an example.

ii) Farm No. 2

a) General

This is the Animal Production Research Farm. Forage production is the main plant production for feed purpose. The farm is located deep in the Wadi-fan complex. Two small wadi courses border it from the east and west. The area is relatively flat but also very gravelly. The soils are of very coarse texture and structureless. Organic matter content is very low even in the manured field (see profile 1).

The plant growth for both Alfalfa and Sorghum plants is very poor. Zinc and nitrogen deficiency symptoms are clear on Sorghum. There are no developed nodules on the alfalfa roots indicating the need for Rhizobium innocule.

Five wells are supplying irrigation water for this farm. Only one well (ADG 10) has good water quality that has an EC of 800 u mhos/cm at 25°C. Another well (ADG 18) has an EC value of 4700 u mohs/cm. An irrigation expert should be consulted.

b) Soils and Land Use Classification

Since the soils are very shallow on the top of gravel or cemented old terrace surface they are classified in the Regosols (Pit 1). Being of calcareous parent material and containing more than 50% carbonates they become Calcaric Regosols (Rc).

The irrigation development of this farm will be one of the most difficult cases to be handled. Very careful studies have to precede any irrigation developments. Evapotranspiration, infiltration of water and permeability of subsurface soil, and water quality studies are very essential to assist the design of a suitable system. Sprinkler type irrigation is the only foreseen system that is suitable for forage crops. The soils are very marginally suitable for such crops.

Very coarse texture and very shallow soil profile with excessive internal drainage make these soils almost not suitable but we classified them as S_3 with three conditional subclasses. This type of classification will be criticized. Only this will be appreciated when the reader will see how the soils in this area are very limited but have to be developed.

During our consultancy mission we surveyed the area to the west of the existing farm because it was suggested as an extension. The survey showed that only an association of Lithosols of poor properties is found in this area. The only possible extension was found to be on land, similar to the existing farm, to the north. The soil may be of deeper profile because it belongs to the transition to the accumulation plain (similar to farm 1).

iii) Nursery Farm

a) General

This farm is used to produce mainly ornamental plants. The soils are of coarse to very coarse textures and gravelly in most cases. Shallow or very shallow profile depth to gravel is common. Salinization of the best soil class occurred after short period of irrigation. Leaching practice is required and sprinkler irrigation could be very helpful.

b) Soil and Land Use Classification

The southern reach is an association of Calcaric (75% carbonate) Regosols and Fluvisols of coarse texture and level topography. The soils to the north become of more deeper profiles (p_3 to p_2), hence only Calcaric Fluvisols (Jc) are reported.

For irrigation development the soils of this farm will be marginally suitable (S_3) similar to farms 1 and 2).

Farm No. 3

General

This is called the vegetable production farm. Only less than one third of the area is cultivated. Four wells with pumps are supplying irrigation water of high salinity. Electrical conductivity values of 2000-3000 u mhos/cm at 25°C are reported (Rumais Soils Lab.) for the wells water in this farm.

Salt effect was not found at the time of this survey in areas close to wells, but far at the end of their reach salinity was gradually increasing (Pit 18). This means that salt leaching is possible close to the original of water (plenty water is available) but at the end of the irrigation canal (less water is available) salt are accumulating.

An irrigation system should be developed for this farm similar to the cemented canal system of the experiment station. A drip irrigation system may be more suitable for vegetable crop production.

The soils are calcarous, coarse, structureless, poor in organic matter and low in available phosphorus. The excessive internal drainage with shallow soil profiles make it necessary to improve soil-water and fertility managements.

Alfalfa, clover and legumes should be cultivated for green manure purpose after being innoculated with the suitable Rhizobium organism.

Disc ploughing should not be used on these shallow with gravelly subsoils. Only dis-harrow plough or shallow cultivators should be used to avoid bringing gravel to the surface.

b) Soil and Land Use Classification

Only small area is classified as an association between Calcaric Regosol and Calcaric Fluvisol (R-Jc). The soils in this farm are stratified with relatively deeper soil profiles (60 cm). This area represents the transition to the accumulation plain (see Rumais cross section B 22-P 24).

Coarse flat calcareous Fluvisols of different profile depth are found in this area. These Calcaric Fluvisols are classified for irrigation purpose according to the depth of or the shallowness of the root zone mainly. Salt effect and internal drainability along with soil texture were also considered to define the subclasses (see soil map).

v) The Experiment Station Farm

a) General

This farm is similar in physiographic position to Farm 3. Being experiment station, the farm is provided with better management. Cemented cannals saved water losses through the very permeable soil material of the area, hence, higher water efficiency increased the cultivated area and produced better crops.

b) Soil and Land Use Classification

The Gibb's report gave a map which was assumed to be a reconnaissance map for this farm. In my opinion, their map is a detailed survey. Only it was not properly prepared as a soil classification map. It may have been more useful if a more internationally accepted system was applied.

The soil survey work on this farm was not as conclusive as the Gibb's report. It is hoped, however, that the following classification system will be more useful.

Flat Calcaric Fluvisols of coarse texture (Jc - 1a) and variable profile depths and salinity levels are found. The soil suitability for irrigation is very much affected by the soil profile properties. Accordingly, the soils of this farm are considered marginal for irrigation development (S_3 subclasses).

5.1.2 Rumais Cross Section

This cross section study was planned to help in the soil and land use classification of Omani soils. Since the wadi-fan complex soils were covered in the Rumais Farms survey, this cross section starts from the end (northern end) of the Experiment Station Farm. (See Rumais farms figure).

The soils along this cross section represent the accumulation plain, the old sebkha-dune complex, the coastal sabkha (saline low lands) and the coastal ridge-complex.

Bore No. 6 represents the sandy loam (finer than the loamy sands of the wadi-fan plain complex) accumulations. This type of soil is fully cultivated. It is one of the best soil types under old cultivation. The plant growth on this type is excellent. The Omani farmers succeeded to manage simple irrigation and fertility practices which suit these soils. The improvement of the irrigation and fertility methods will save water and improve fertilizer efficiency. These will reduce the input cost, hence revenue will increase.

This soil type could be classified as Calcaric Fluvisols of coarse to medium textures and of level to undulating micro-relief (Jc-1-2-ab). Being of coarse texture and with high internal drainage and sometimes are not very flat they could be classified as (S_1 d_2 r_{1-2}) for irrigation development.

Bore 22 and Pit 22 may represent another soil type found in the flood (accumulation) plain. These soils are of loamy sand texture and of fairly deep profile. The water quantity is less available and of low quality in this area. Only date gardens are successful under these conditions.

This type of soils could be classified as Calcaric Fluvisols (Jc-1-ab) but of limited (shallower) soil profiles than the above group. For land use classification this soil group will be of medium suitability for irrigation development (S_2 t_1 p_{1-2} r_{1-2}).

Bore 23 and Pit 23 represent the accumulation plain-dune complex. Pit 23 shows three different phases of developments. On the top there is about 50 cm of wind blown material of loamy sand texture. This saline material is a normal product of the deflation process of the flate very saline (coastal sebkha of Bore 24 and Pit 24) soils adjacent to this area.

The underlying gravelly material represents the product of high flood period which covered the old sabkha underneath this gravelly layer.

This soil type was previously classified as Regosols. This classification was based on ignoring the other two sequences underneath the wind blown material and also ignored its salt content.

Since the wind blown materials are sometimes of 1 meter thickness or more, and do not satisfy the salinity levels of solonchaks we prefer to classify them as Albic Arenosols (Ca). They are of different relief conditions (Cabc). These soils are not suitable for irrigation development (N) because of the texture and topography, being of small areas and being very close to the coast.

Bore 24 and Pit 24 represent the coastal sabkha formation. These flat low land areas are confined between the sand dune complex and the coastal ridge. Textures of loamy or silty sands are common. Very high salinity with a salt crust formation during the summer was found. Water table level is shallow Gleyed sub-soils are common.

These soils are classified as Gleyc Solonchaks (Zg). These are not suitable for agriculture development, therefore, they belong to the N order of the land use classification.

No bores or pits were sampled from the coastal ridge. It is formed of unconsolidated sandy material (beach sands) with high percentage of shells and shell fragments. These are also not suitable for agriculture development.

5.1.3 Remarks and Recommendations

The soils in Rumais vicinity are of coarse texture, shallow, highly calcareous, poor in available nutrients (both macro and micro), with gravelly and very permeable subsurface. The soils are recently deposited with least profile development.

Water for irrigation is mainly ground water of medium to high salinity. Being in the coastal region sea water intrusion is expected with continuous pumping and increasing well intensity.

Being close to the capital area. Rumais vicinity is attractive for development. Agricultural productions such as vegetables seem very promising business.

Irrigation, fertility and soil managements have to be developed carefully. Water is very expensive to pump and its quality has to be carefully assessed. Water application methods have to be well developed. Usually sprinkler and drip irrigation are accepted to be suitable.

The maintenance and management of such systems are difficult and technical training has to be provided locally or abroad.

Several meteorological data have to be provided to decide the evapotranspiration rate and hence the consumptive use for different crops at different seasons.

In Oman it is expected to avoid high evaporation losses during evening and night.

Poor nutrient availability is reported for Omani soils generally. This can only be economically corrected through better farm management. Green manuring should be given more attention. Forage fertilizers are highly recommended. Biological fertilizing for both nitrogen and phosphorus (being developed) has to be considered. A soil microbiology staff and laboratory has to be developed. Producing national innoculates is much cheaper and saffer than to importing them.

Urea should substitute ammonium fertilizers because of the probable high loss of ammonia during storage periods under hot-humid conditions. Ammonium phosphate fertilizer may be more suitable than ammonium sulphate.

Micro-nutrients studies should be developed in the Experiment Station. Plant tissue analyses should start at the soils laboratory. Nitrogen analyses equipment should be added to the soils laboratory as soon as possible.

Disc-harrow plough should substitute the disc-plow ploughs commonly used in Rumais. This practice will avoid bringing gravels from subsoil to its thin surface layer. Very light cultivators should be used for cultivating these coarse texture soils.

Soil temperature and soil moisture could be measured through a battery of thermometers and tensiometer to be installed in Experiment Farms. Soil temperature has to be recorded to select Rhizobium organisms that are adapted to soil temperature. There is a claim that Rhizobium innoculation cannot survive the soil temperature specially during the summer season. Irrigation frequency should be designed to suit the moisture characteristics at different soil dephts in different soil types. This will be known through the tensiometer readings.

5.2 The northern Batinah Region

5.2.1 Sohar Production Farm

This production farm had been cultivated for long period. The conditions of mango and citrus trees in this farm are bad. Haplic Xerosols, Calcaric Fluvisols could be better class for these stratified undeveloped soils. There are similar to those of Sohar Dairy Farm and Sohar new project area. Soils of this region are subject to salinization (Bores 27 and 28) after being put under irrigation for some period.

The source of salt could be from the irrigation water (see water analyses of the four wells presented in this farm). Also bad soil levelling and poor irrigation practices may cause spotted salinization. The high levels will accumulate more salt than low levels which will be subject to leaching every irrigation.

The soil analyses showed that pH values as high as 8.5 are found. The soils are highly calcareous (20% carbonate) and rich (relatively) in magnesium. Also the water analyses are rich in magnesium. Ammonium fertilizers are commonly used as a source of nitrogen. The irrigation water quality should be assessed carefully for this farm because one of the wells water (well 4) showed a boron content of more than one part per million.

Zinc deficiency was noticed on citrus leaves and new citrus orchard was sprayed for amendment. This may indicate the need for more green and manure fertilizers to develop nearby areas in the region. Micronutrients fertilizer management should be considered.

The organic matter content as well as the phosphorus availability is very low for a fertilized field.

Salt leaching is most important to improve this farm. Less pumpage hours should be practiced for wells 2 and 4 which are of high salinity and boron levels.

SOHAR PRODUCTION FARM

Well-water analyses

	Well 1	Well 2	Well 3	Well 4
pH water	7.9	7.9	7.9	7.9
EC mmhos/cm at 28°C	1.10	2.07	1.07	2.61
Soluble salts meq/l				
Ca	0.7	0.8	0.8	0.8
Mg	4.6	6.1	5.6	7.3
Na	6.0	13.7	4.8	18.4
K	0.1	0.1	0.1	0.2
HCO_3	4.0	4.6	3.7	5.5
Cl	4.8	11.0	4.6	12.5
SO_4	1.9	4.2	2.2	
B ppm	0.3	0.65	0.2	1.2

5.2.2 Sohar Dairy Farm (FMC)

This farm is recently put under a developing programme. The soils are of coarse texture and are classified in the Haplic Yermosol group (see map). It is preferable to classify these soils as Calcaric Fluvisol. The soils are stratified with least development. The area is subject to fresh deposition by floods. It is calcareous (15-20% $CaCO_3$), subject to salinization because of high evaporation rate and poor irrigation practice (Profile 40). The soils are subject to wind erosion when it is ploughed, levelled and left for long time without irrigation. The soils are of very poor structure and of very low organic matter content.

The nutritional conditions are poor. The availability of phosphorus in a cultivated area is very low (see tables). The zinc deficiency symptoms were noticed on new citrus plantation.

Urgent need for better soil and water management is advised. Intense fertility programme should be established with the new proposed modern systems of irrigation (sprinkler and drip irrigation systems are planned).

5.2.3 Sohar-Saham New Projects (SSP)

Two project sites were inspected with Mr. Jack Schnider, the farm Manager of the Dairy Farm (FMC) at Sohar.

The consultant was provided with aerial photograph of 1974-1975 at the scale of 1:20000. Being this the only reference material, the main physical land features that were considered in the project area are as follows:

- The main paved road Muscat-Sohar is taken as the north-eastern border for the project areas.

- The gravel road to Heeb (north-south) is taken as the eastern reference line, while an army camp with its facilities are the western border to the Sohar site.

- The Saham site is located between a gravel road to Alflaye village which is taken as the eastern reference line, while wadi Mahmum represents the western limit.

The project sites were previously surveyed by ILACO and a semi detailed soil survey of the general area was included in their report.

a) Topography

The project area is gently sloping from the collovial fans at the foothills of Oman mountains to the Gulf Coast. Undulating to level land surface is the dominant feature. Several wadi courses cut through the generally levelled flood plain causing very rough surfaces. Wind blown material may be accumulated around dry desert shrubs forming mounds that may be considered an obstacle for land reclamation.

b) Parent Material and Soil Formation

The weathered products of the generally basic rocks of Oman mountains in the form of collovial (alluvial fans and flood plain represent the parent material of the highly calcareous soils of the Batinah region. The parent material of northern Batinah is relatively rich in serpentine type rocks.

c) Natural Vegetation

The natural vegetation is composed of scattered Acacia trees and several dry desert shrubs. Few scattered areas of very short grass of weak growth could be traced. The most dense vegetation follows the water courses as are found in relatively deep soils where relatively high water holding capacity exists. In spite of the very dry desert climate that prevails, green plants are found everywhere, however, very low organic matter could be accumulate due to the very hot climate, specially during the dry season.

d) Water Resources

The only expected water resource is the gound water (well water). Several manual dug wells were located within one km (Sohar) and 2 km (Saham) from the Muscat - Sohar main road. The water level in the inspected wells ranged between 9 and 12 meters from the land surface. Quantitative assessment of the water resources has to be developed to decide how large areas could be irrigated.

Soil Common in the Project Area

The flood plain lands are the best soils for agricultural potential. These are soils of medium to fine textures. The soil profile is fairly deep to very deep. The fan area as well as the wadi areas are generally shallow to very shallow soils. These are also characterized by rough topography and may be also stony or gravelly.

- The soils of the fan or wadi courses were excluded from this field survey. The soils of the flood plain were studied in detail to select the most potential soils for irrigation development.

- The soils are generally calcareous of medium texture, weak structure, very low organic matter contents, and of well drainage conditions. The soil sample analyses showed the presence of low to medium salt content in some profiles. This is specially true for the deep soils that were previously under cultivation.

i) Sohar New Project Area

The soils in this new area is of coarse to medium stratified type soils. Fluvisols are the most common soils with good irrigation potentiality. Calcaric Fluvisols (Jc) is the reported class because in spite of the observation of some carbonate accumulation in some profiles, a calcic horizon was not proved from the chemical analyses.

The presence of small or micro-mounds around shrubs may seem an obstacle but this was ignored since shrub clearance and land reclamation is necessary to develop this land.

The most important properties that were taken into consideration are:

i) the salinity in subsoil which may become effective if poorsoil management occurs;

ii) the depth of the soil profile to the gravel layer defines the effective root zone and brings to attention the excessive drainage of the subsoil;

iii) the soils are generally of loamy sand or sandy loam textures with very poor structure and organic matters content. This requires the need for frequent irrigation, fertilization and manuring.

Other shallow to medium deep soils which were classified as Fluvisols of the calcareous types are also found. These are mainly confined to wadi courses or close to them. These are also subject to flood hazards.

The project area is surrounded with Regosol-Fluvisol association. These are wadi-fan complex formation with very shallow, very gravelly and rough topography. These are also subject to sheet floods which made their surfaces gravelly and sometimes stony.

It is not recommended to develop any land from other classes than the relatively deep Fluvisols.

ii) Saham New Project Area

The soils in this project area are of medium texture. The area which seemed to have been under irrigation but were abandoned in the last 100 years were of saline subsoils and were classified as Xerosols. Other very similar type of soils were classified as Haplic Yermosols.

The most important soil properties that may influence the irrigation development of this project area are:

i) the presence of mounds from the micro size 75 cm to the large or medium sizes of 1-3 m. These mounds are of coarse texture (sands);

ii) some soils are of medium depth to gravel layer which reduces the root zone size and the soil water holding capacity;

iii) the soils are subject to salinization as could be seen from the previous experience.

5.2.4 Remarks and Recommendations

The soils of Sohar-Saham project area are calcareous, of medium texture and weak structure, of low organic matter content and contain some soluble salts.

The reclamation process may include some soil levelling speicially in wadi areas and wherever mounds are present in large number and close together.

Therefore the following should be carefully considered:

i) land levelling operation should be kept at minimum, and light machinary equipment should be used. This is recommended to preserve the soil surface in as natural cinditions as possible for nutrient conservation and to preserve the soil structure which is already weak;

ii) irrigation should be intense and more frequent for the purpose of salt leaching;

iii) The reclaimed areas should be cultivated with Berseem (Alfalfa or clover types) for at least one year. This crop could be ploughed under using a disc-harrow. This green manure is essential to improve the soil structure and the fertility potential of these soils;

iv) Inoculation of both legume seeds and soil should be always practiced. The specifica Rhizobium sp. should be used repeatedly to build up a strain adapted to the local conditions such as high temperature and high carbonate contents.

Inoculation of soils under Lucerne or Clover should be done annually at the beginning of the growing season. The inoculant could be mixed with soil or sand and spread in a similar manner to any other chemical fertilizer.

This biological fertilizer practice should improve the nitrogen deficiency of legume crops and also will improve nitrogen availability of the soils for other crops.

This practice will save in the consumption of chemical nitrogen fertilizers which were proved to be of low efficiency in Oman.

v) The low efficiency of the ammonium and nitrate salts is due to high temperature, coarse texture of soils, and excessive use of irrigation water. Therefore, we recommend urea as a nitrogen source. Also ammonium phosphate should substitute ammonium sulphate. This substitution will improve the availability of phosphorus which is found to be low in the Omani soils of the Batinah region.

vi) The spraying of green plants (foliar) with sulphate solutions of iron, zinc, manganese, and copper should be regularly practiced specially for tree and vegetable crops.

Zinc deficiency symptoms are common on almost all citrus and corn plants in the Batinah region.

It is common to find low availability of iron, zinc, copper and manganese in soils of high pH and specially in calcareous or coarse texture soils. Therefore, it is considered that the availability of the other three elements. (Fe, Mn and Cu) is also low, but their particular deficiency symptoms are not clearly observable because they often appear only at the end of the growth cycle or they may be also similar to symptoms of other defects.

It is always a good practice to spray sulphate solutions or preferably chelated forms of these elements to improve yields.

vii) Irrigation water quality should be watched carefully. Water analyses for both total salt content and different ion species should be regularly performed and reports prepared showing any variations.

Special attention should be given to the content of chloride and boron ions in the water samples. Leaf burn has been noticed on many crops in the Batinah region. This symptom could be a physiological one due to high temperature specially at Zenith. Also it may be due to an excess of both or one of B and/or Cl ions. This could only be verified from leaf tissue analysis which are not presently available.

The boron content of irrigation water of one particular well (in the oldest mango garden) at Sohar production farm was found to be about one ppm. This level is considered critical for plants sensitive to this element.

Also it was noticed that magnesium ion content in well waters of this farm is six to nine times the calcium ion content. This phenomenon should be carefully studied as it indicates the intrusion of magnesium source possibly sea water. Soil water ion balance should be studied to verify this problem.

High magnesium in this area may be due to the presence of serpentine type minerals and rocks in parent material.

5.3 Sharquiya Region

5.3.1 Reconnaissance Survey

Guided by the synthesis of the hydrogeological results (Renardet, 1975) the water resources expert, Mr. Read and myself visited Wadi Al Batha plain of the Sharqiya region. Out of eleven areas, namely No. 2, 7, 8, 9, 10 and 11 were carefully looked at for soil resources.

Areas 7, 8 and 9 were considered to have little or no potential for agricultural development. These areas are:

- Covered with sand dunes or ridges.
- Subject to further wind blown material from the Whiba Sand body.
- Tracks to Az Zahir (through area No. 7) were found covered with at least 50cm of recently blown sands which made out trip to visit area No. 6 very difficult.

The soils of area No. 7 for example, are covered with deep sandy material, but has good levelled land forms with very scattered or rare low acacia and desert shrubs. The ground water has fair amount of salts (well No. 401 has an EC of 720 u mohs/cm) but the water level is at 34 m below surface.

Area No. 10 has very rough topography and is stony at surface. Boulders are not uncommon.

Area No. 2 in Ad Dariz-Al Izz vicinity was carefully surveyed.

Near Ad Dariz and very close to Ibra-Sur main road there is a flat area that looks very promising for agricultural development. A well very close to the main road was examined and its water was of very poor quality. The water resources expert and his associate did not expect any further water resources development in this area.

South Ad Dariz and to the west of Al Izz several wadi courses are found. Several wells of relatively shallow (10-16 m) water level and of reasonable salt contents (EC of 800-1400 u mohs/cm) were located. These wells were hand dug for bedouin domestic use. Those wells close to wadi courses have lower salt content and could be developed for irrigation water supply for small size farms. The size of farms in this area would be small because of the general roughness of the area. The wadi course meanders and branches leaving only island type areas or turtle back shape lands. Some of these areas are shallow and covered with gravels. There are some low level lands but these are subject to floods. Other areas are covered with sandy material which made them look suitable. The subsoils of these areas were found very gravelly. Very shallow auger bores were possible indicating very shallow soil profiles.

Finally two small areas south west of Al Izz are reported possible for small farms project area for this vicinity. Further detailed soil survey would be required if water resources could be developed.

Area No. 11 is in Al Kamil vicinity. Our visit to the regional agriculture office at Al Wafi lead us to a long discussion and field inspection for several areas that were suggested by the local personnel.

At Al Wafi a new farm with its new well and pump were inspected. The soils have a sandy texture with gravelly subsurface. It is subject to wind blown sand and slight erosion but soil water management can prevent these hazards. The water quality does not seem to be promising. The EC of well No. 601 is 3050 u mhos/cm. Further to the south and south east and west of Al Wafi wells 602 and 603 gave similar salt content. These findings were in agreement with earlier findings (Renardet, 1975). The field team decided that the area down stream near Bilad Bani Bu Hassan and Bu Ali should not be inspected at present. Water quality is expected to be of lower class downstream.

Attention was given to the relatively flat area between Al Kamil and Al Gadeed. Sandy soils are common with medium vegetation intensity of Acacia and other dry desert trees and shrubs. Water salinity was measured in a farm well at Sooque Al Imam which is very close to Al Kamil. The vegetables and alfalfa growing plants showed very good conditions. An EC value of 1200 u mhos/cm was found. It was decided to further study the soil and water resources of this area.

North of the main Muscat-Sur road an area of large size and good soil profile properties was located. Several small farms supplied by ground irrigation water were found and inspected. Water EC values in the range of 800 u mhos/cm were found. It was decided to concentrate our field work in this area expecting it to be most promising from both the water and soil resources points of view.

5.3.2 Ad Dariz-Al Izz Vicinity

The suggested two small areas to be developed if suitable water is found, are at the south west of Al Izz. The wells close to the wadi in this area have low salt contents (wells 610, 611 gave EC values of 660 and 500 u mohs/cm, respectively. Well capacity has still to be tested.

The complex wadi system of this area accounts for its rough topography. The low lands are subject to floods and sometimes form saline flates with shallow and gravelly soils. Relatively higher lands (island-like or turtle back-shaped forms) could be developed for small private farms to which government may provide wells for irrigation water. Other sandy soils of this region are excluded from irrigated agriculture.

Soil and Land Use Classifications

The soils (to be developed) are calcareous with dominant loamy (medium) textures. Secondary carbonate accumulation in the subsoil was noticed in field, however, calcic horizons were not well proofed from the carbonate analyses (Pit 50).

Soil profile depths between 60 and 80 cm (P_1) were accepted for irrigation development, but shallower than this class was not recommended for development.

Moderately saline subsoils were found (Bore 71). Many other areas (nearby) showed salt crust and dense halophitic plants were excluded for irrigation development.

The soils could be classified as Calcaric Fluvisols (Jc - 2 ab) of medium texture and variable topography from level to undulating. They are stratified calcareous material in a wadi complex formation.

If calcic horizon will be proofed during the details survey prior to development plan, these soils could be classified as Calcic Yermosols (Yk - 2ab).

For irrigation development soil salinity, profile depths as well as land levelling are critical properties. These soils will be considered marginally suitable (S_3 p_1 r_1 s_2).

5.3.3 South Al Kamil New Project

This project area starts south of Al Kamil near Sooq Al Imam farms and could be extended to the west and east of the road to Al Wafi up to Al Gadeed. The soil profile is generally covered with sandy blowm material for depths between 40-80 cm, followed by gravel layers of different depths which lie on a very old terrace surface of limestone-like material (Pits 51 and 52).

The sandy accumulation gets thinner towards Al Wafi and also water quality gets poorer downstream towards Bilad Bani Hassan and Bani Ali.

Larger area of this type of soil formation is found in this site. However, it is only recommended to develop only suitable small farmers according to ground water availability. The falaj systems of the area are barely sufficient for domestic use.

This area is subject to wind blown hazards and of coarse to very coarse texture material, therefore could be easily eroded. Subsoils may suffer some salinity conditions but it is not expected to be hazardous.

Soil and Land Use Classification

This soil could be classified as Albic Arenosols with undulating to level soil surface (Qa - 1 - ab). For agriculture use these soils are very coarse with excessive internal drainage, with medium soil profile depth and subject to erosion (S_3 t_1 p_1 e_2).

5.3.4 North Al Kamil new Project

This site is located parallel to Muscate - Sur road north of Al Kamil. It is extended for about 5 kms along the road with a width of 1 to 2 kms to the wadi.

Several hand dug wells for drinking water were found. Some small farms were recently developed on well water of relatively low salt contents. Some farmers, however, complained from quick draw down upon starting pumping their wells. This may indicate low transmissibility of the recent shallow sediments (aquifers). Deeper wells should be investigated in the near future to decide water availability for further irrigation developments.

The area is subject to both flood and wind blown sands hazards. Flood hazard could be avoided through engineering designes to adjust wadi course and it's water flow away from the project area. Wind breaks as well as sand dune stabilization practices will reduce the wind hazards.

Sand dunes as well as rough wadi land forms should be excluded from the future development plan. Flat areas of 25 to 50 or 100 ha could be suitable sizes for irrigated farms in this area.

All the good lands are a part of the flood plain of wadi Bani Khalid which is only locally affected by wind blown sand or being reworked by irregular floods.

The soils are highly calcareous, stratified, of medium textures to fine texture in some cases. The topography of the land is verying from one place to the other. Some subsoils are slightly salinized. As it was mentioned before the area is subject to erosion and wind blown hazards.

These soils could be classified as calcaric Fluvisols (Jc-2-ab).

For irrigation land use classification they could be considered very suitable (S_1) with different subolasses according to their local limitations of relief, erosion and salinity hazards. ($S_1\ r_{1-2}\ e_{1-2}\ s_1$).

5.3.5 Remarks and Recommendations

To develop the selected project areas in this region the following should be noted:

- Water resources investigations should proceed with further studies on the availability of water of suitable quality.

- Provided that suitable water is found, a soil survey team should follow a land (topography) team, both provided with suitable facilities, to prepare suitable size land and soil maps.

- Since the selected areas are subject to flood hazards it is essential to prepare engineering conservation plans to prevent flood hazards. One important action is to adjust the wadi courses.

- The selected areas are subject to blown sand hazards, wind breaks should be initiated early during the reclamation period, i.e. prior to cultivation. These wind breaks should be several lines thick. A Forester expert should be consulted to decide the suitable plants and directions and spacings of the wind breaks.

- Generally, sand dune stablization is highly important in Sharquiya region.

- Precise land levelling and high rates of water applications should be practiced on sandy soils to provide as even as possible water distribution. Drip or sprinkler irrigation will help.

- Small private farm holdings, one for each well, may be suitable in Sharquiya region. Avoid governmental farms as much as possible. Only Agriculture Extension Farms would be governmentally managed.

- Fertility management should be highly considered specially on sandy and highly calcareous soils.

- Green manure is very essential to improve soil conditions specially during the reclamation and improvement period.

5.4 Interior Region

5.4.1 Reconnaissance Survey

An agriculture experiment station is suggested to be initiated near Nizwa. Early August of this year (1977) Mr. Horn, FAO water expert and the consultant accompanied Mr. Mahfuz, Regional Director of Agriculture to inspect the proposed site.

The proposed area lies in Manah vicinity at about 6 kms from the Nizwa-Muscat main road on a well graded road to Manah.

- There is a wide area (about 400 ha) of abandonned farms which had been (canalized) under cultivation. Both the winter rains as well as the water of falaj Khatum should have been utilized by these farms.

- A 65 liters/second rate of flow of this falaj was measured. The water salinity was found relatively low (EC) of 630 u mhos/cm at 35°C.

- The right on this falaj belongs to the Government, however, it is diverted to join falaj Mesarag at present.

- There is little previous information on this site. The general area is very briefly mentioned in the Gibb report.

- Auger bores showed that there are fairly deep soil profiles with medium to fine texture materials. The soil surface is compacted and hard when dry which breaks to soft sticky and plastic when moist. Strong effervescence was noticed all over the soil profile and secondary carbonates may be concentrated in the subsoil. The subsoils are well drained with apparent good soil structure in the subsoil. Some gravelly surfaces were noticed.

- The Mesarag falaj was inspected. Its flow rate was found 85 1/sec., but its EC value was 1330 u mhos/cm at 32°C.

- Some wells are used to irrigate small farms of good green vegetables and alfalfa plants.

- In general the soils seemed to be very suitable for all types of crops if proper water and soil managements are provided.

- It looks that there are about 200-300 ha which could be potentially suitable for irrigation in this area if enough water is available.

5.4.2 Manah Project Site

The project site begins at about 6 kms from Nizwa Muscate road on a good gravel road to Manah.

Several abandonned farms that were irrigated from the Khatum falaj about two generations ago are found. The water rights on this falaj belong to the government but it is diverted to join Mesarag falaj which is used by other farms near the site area.

The water flow and salt contents are suitable to irrigate an area which could be assumed to be the experiment station farm in Nizwa area.

The soils are flat very calcareous, has medium to fine textures. The soil profiles are deep and well developed. A plowed Ochric, "A" horizon overlies a well developed Calcic horizon of blocky to prizmatic structures. The C horizon is highly cemented and hard.

The natural vegetation is moderately dense and is composed of Acacia sp. and other desert shrubs, with halophytes being dominant in open lands. Wheat straw residues are common on previously cultivated areas.

The soils are Calcic Yermosols, Yk-2-a, (pit 57) which develop to Calcic Xerosols Xk, under irrigation (pits 58-59-60). At areas very close to the jebel (pit 56) shallow soils with gravelly properties are found. These soils are excluded from development. This latter group is classified as Calcaric Regosols (Rc-1-ab).

The soils of the project site are highly suitable for irrigation development (S_1). The area may be subject to salt hazards if irrigation practices or irrigation water quality become low.

5.4.3 Remarks and Recommendations

It was noticed that some parts of this area is rented for a rainfed wheat crops. This wheat may get late or little rains in early winter and suffers an early dry season. This late germination as well the deficit water during seed formation and maturity reduce the crop or may destroy it. Initiating some wells or developing the falaj system (maintain it) may be able to supply two irrigations. One irrigation early (November) in the season and another at the end of the wheat growth stage (April-May) will get reasonable production in this area.

The soils of the project area are well developed with a calcic horizon and of deep soil profile of medium to fine texture material. The area is hot and the water is limited, hence possible soil salinization may occur.

Soil, water and fertility managements have to be very carefully studied and practiced.

Small farms similar to the type of small private holdings could be developed nearby the suggested experiment station. Mutual benefits to the station and these farms will be an ideal system.

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APPENDIX
List of Tables

Pit 8

Location: Vegetable Crop Production Farm (Farm 1 at Rumais). According to diagram it is located in the north east side of the farm (N.E. quarter).

0-25 cm 10 YR 6/3 D, 4/3 M loamy sand of very weak granular structure. Very soft, friable, non sticky and non plastic. Porous and calcareous with dominant medium roots. A gradual increase of gravel to

25-35 cm Ditto but with more gravel.

35-100 cm 10 YR 4/3 M sandy gravel and stones of dark colors are dominant which are stained due to partial weathering but does not fulfill being a cambic horizon yet. Clear boundary. Very fine roots to 80 cm. Diffused carbonates.

100-120 cm 10YR 4/4 M sandy gravel and stone with powdery carbonate gives strong effervescence. This may represent the surface of an old terrace rather than being a pedagenic horizon.

SOIL PROFILE No. 8

Location: Farm 1 at Rumais

Analyses	Sample depth cm		
	0-20	20-35	35-100
Clay %	16	16	14
Silt %	7	11	5
Fine sand %	48	42	16
Coarse sand %	29	31	64
Gravel %	25	28	63
$CaCO_3$ equivalent %	37	37	40
Org.matter %	0.29	0.17	0.02
Available P ppm	23	9	3
CEC meq/100 gm	5.8	5.9	4.4
pH water	8.0	7.2	7.9
EC 1:5 ext.u Mhos	1441	373	445
Soluble salts meq/1			
Ca	2.6	-	-
Mg	3.8	-	-
Na	5.2	-	-
K	0.9	-	-
HCO_3	7.6	-	-
Cl	3.8	-	-
SO_4			
Bppm			

Pit 1

Location: Animal Production Research Farm at Rumais.

- South of the Goat shed just at the edge of the best sorghum in the farm which is irrigated from the electric power supplied well.

0–10 cm	10 YR 6/3 D, 4/3 M pale brown sandy loam of very weak crumby structure breaks to loose dusty material. Common affervescence indicating diffuse carbonate is noticed all over.
10–20 cm	Gravelly sandy loam.
20–70 cm	Stratified sands with gravells of black to white colors. Very loose material with diffused carbonates.
70–80 cm	Partially cemented gravelly sandy loam with strong effervescence.
80 + cm	10 YR 7/2 to 7/3 light gray to very pale brown highly cemented material of sands, gravells and some stones. Very hard when dry but only hard when wet. Strong effervescence.

SOIL PROFILE No. 1

Location: Animal Production Research Farm 2 at Rumais.

Analyses	Sample depth cm		
	0–20	20–70	70–110
Clay %	14	14	14
Silt %	7	5	6
Fine sand %	50	33	29
Coarse sand %	29	47	50
Gravel %	12	30	10
$CaCO_3$ equivalent %	44	50	73
Org.matter %	0.24	0.1	-
Available P ppm	7	3	3
CEC meq/100 gm	5	4.5	3
pH water	7.1	7.8	8.0
EC 1:5 ext.u Mhos	202	118	118
Soluble salts meq/1			
Ca	0.7	0.4	0.4
Mg	0.9	0.7	0.7
Na	0.2	0.2	0.2
K	0.2	0.08	0.04
HCO_3	1.0	1.0	1.0
Cl	0.6	-	-
SO_4	-	0.3	0.3
B ppm			

Pit 10

Location: Nursery Farm at Rumais.

- East the farm gate at about 50 meters east of the eastern well.

- Bare - plowed after mellon, gravel and some stones at surface.

0.30 cm	10 YR 6/3, 5/3 D, 4/3, 4/4 M loamy sand with some gravel, very weak platy followed by weak granular, very soft, friable, non sticky and non plastic. Few very fine roots. Very porous with strong effervescence.
30-40 cm	Ditto with more gravel. Medium effervescence.
40-60 cm	Gravelly sand, spotted effervescence.
60-75 cm	Sandy loam with some gravel. Medium efferverscence.
75-100 cm	Gravelly sand that is partially cemented. Powdery white carbonate could be seen on gravel surfaces with a very strong effervescence. Black gravels are dominant.
100 + cm	Partially weathered sand stone-like material; compacted cemented and strong effervescence.

SOIL PROFILE No. 10

Location: Nursery Farm at Rumais

Analyses	Sample depth cm			
	0–30	30–75	75–100	100+
Clay %	14	13	14	11
Silt %	9	6	6	6
Fine sand %	54	33	32	25
Coarse sand %	23	49	48	58
Gravel %	5	19	34	45
$CaCO_3$ equivalent %	60	48	50	49
Org. matter %	0.02	0.03	0.02	0.01
Available P ppm	4	3	3	3
CEC meq/100 gm	6	5	5	4
pH water	7.9	7.6	7.9	8.0
EC 1:5 ext.u Mhos	146	534	623	391
Soluble salts meq/1				
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 19

Location: Production Farm 3 at Rumais.

- See sketch map.

- Weak vegetable growth-Okra.

0-30 cm	10 YR 6/3, 4/3 M, loamy sand, weak granular, soft, friable, porous, few roots, strong effervescence.
30-60 cm	10 YR 6/3 D, 4/3 - 4/4 M loamy sand.
68-85 cm	10 YR 6/3 D, 4/4 M gravelly loamy sand with increasing gravel with depth, very strong effervescence.
85-120 cm	Stony gravelly loamy sand.

SOIL PROFILE No. 19

Location: Production Farm 3 at Rumais.

Analyses	Sample depth cm		
	0–30	30–60	60–90
Clay %	10	12	16
Silt %	7	14	14
Fine sand %	46	34	30
Coarse sand %	37	40	40
Gravel %	9	22	40
$CaCO_3$ equivalent %	43	47	39
Org. matter %	0.2	0.1	0.05
Available P ppm	10	3	4
CEC meq/100 gm	5	6	7
pH water	7.8	8	7.9
EC 1:5 ext.u Mhos	605	638	925
Soluble salts meq/1			
Ca	1.2	1.6	2.8
Mg	2.1	3.4	5.2
Na	2.6	1.3	1.5
K	0.3	0.3	0.5
HCO_3	1.0	0.8	0.8
Cl	3.4	1.4	1.4
SO_4	1.8	4.8	8.0
B ppm			

Pit 21

Location: Production Farm 3 at Rumais

- See sketch map. (10 meters west of the well).

- Plowed for vegetable crop.

0-35 cm Plowed 10 YR 6/3 D, 4/3 M loamy sand to loamy, dusty, friable, non sticky and non plastic. Very strong effervescence.

35-55 cm Gravelly loamy sand of granualr structure. Slightly hard, friable, non sticky and non plastic. Powdery white spots of carbonates with very strong effervescence. Common fine roots are found to 80 cm.

55-80 cm Very gravelly with some stones loamy sand. Single grains with strong spotted effervescence.

80-120 cm Gravelly coarse loamy sand.

SOIL PROFILE No. 21

Location: Production Farm 3 at Rumais.

Analyses	Sample depth cm			
	0-35	35-55	55-80	80+
Clay %	13	13	9	10
Silt %	13	10	6	9
Fine Sand %	37	40	19	22
Coarse sand %	37	37	66	56
Gravel %				
$CaCO_3$ equivalent %	43	41	31	55
Org.matter %	0.3	0.08	0.01	0.01
Available P ppm	2	2	3	3
CEC meq/100 gm	6.1	6.1	4.2	4.2
pH water	8.7	7.8	7.9	8.0
EC 1:5 ext.u Mhos	276	207	202	225
Soluble salts meq/1				
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 25

Location: Experiment Station at Rumais.

- About 15 north east the central well in the citrus orchard.

- Good growth of Orange trees.

0-30 cm 10 YR 6/3 D, 4/3 M gravelly loamy sand, very soft, very friable, fine roots and pores are common. Strong reaction with HC1 indicates diffused carbonates.

30-60 cm 10 YR 5/4 M loamy sand massive, friable, slightly sticky. Medium roots are common with fine roots. Porous with strong effervescence.

60-100 cm Ditto gravelly loamy sand.

100 + Ditto stony gravelly sand. Cemented with diffused carbonate giving very hard structure.

SOIL PROFILE No. 25

Location: Experiment Station at Rumais.

Analyses	Sample depth cm			
	0–25	25–60	60–100	100+
Clay %	10	12	12	10
Silt %	3	12	7	10
Fine sand %	39	46	25	30
Coarse sand %	48	30	56	50
Gravel %	16	3	27	37
$CaCO_3$ equivalent %	45	46	56	48
Org. matter %	0.07	0.09	0.02	0.03
Available P ppm	4	3	5	3
CEC meq/100 gm	-	-	-	-
pH water	7.3	7.8	7.8	7.7
EC 1:5 ext.u Mhos	310	308	177	177
Soluble salts meq/1				
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
Bppm				

Pit 26

Location: Experiment Station at Rumais.

- About 100 m north-west of central well in a mellon field with meidum growth and production.

0-20 cm 10 YR 6/3 D, 4/3 M loam, granular, soft, friable, non sticky, non plastic with very strong effervescence.

20-35 cm Ditto, gravelly loam sand, loose.

35-50 cm Ditto, loamy sand with common fine roots.

50-100 cm Ditto, gravelly loamy sand. Spotted effervescence.

100 + cm Cemented loamy sand with very strong effervescence.

SOIL PROFILE No. 26

Location: Experiment Station at Rumais.

Analyses	Sample depth cm				
	0–20	20–35	35–50	50–110	110 +
Clay %	10	12	10	13	13
Silt %	7	4	5	12	10
Fine sand %	48	60	32	31	23
Coarse sand %	35	24	54	44	54
Gravel %	11	3	5	8	25
$CaCO_3$ equivalent %	41	41	49	53	57
Org.matter %	0.2	0.1	0.02	0.05	0.03
Available P ppm	26	8	2	10	10
CEC meq/100 gm	–	–	–	–	–
pH water	7.3	7.1	7.9	7.8	7.8
EC 1:5 ext.u Mhos	620	257	168	266	292
Soluble salts meq/1					
Ca					
Mg					
Na					
K					
HCO_3					
Cl					
SO_4					
B ppm					

Pit 22

Location: Rumais Section.

- About 700-800 north the Experiment Station.

- Acacia sp. some date, some alfalfa, all of medium and average growth.

0-60 cm	10 YR 6/3 D, 4/3 M loamy sand with sand band at about 30 cm of 5 cm thick. Granular to sub-angular blocky very soft at surface, soft at some depth then slightly hard at about 40 cm. Friable in general and slightly sticky below 20 cm except at the sand band. Very few fine roots at surface with tree roots (big) at about 40 cm. Porous with very strong diffused effervescence.
60-90 cm	Ditto, partially cemented (by carbonates) loamy sand of sub-angular blocky or coarse granular structure. Very strong effervescence indicating diffused carbonates.
90 + cm	10 YR 7/3 D, 4/3 M cemented, very hard sandstonelike material with very strong effervescence.

SOIL PROFILE No. 6

Location: Rumais cross section.

Analyses	Sample depth cm			
	0-30	30.60	60-90	90-120
Clay %	21	20	21	20
Silt %	8	11	12	8
Fine sand %	62	59	55	64
Coarse sand %	10	10	12	8
Gravel %	2	2	1	17
$CaCO_3$ equivalent %	45	47	48	48
Org.matter %	0.48	0.27	0.17	0.10
Available P ppm	-	-	-	-
CEC meq/100 gm	-	-	-	-
pH water	7.6	7.8	7.9	7.8
EC 1:5 ext.u Mhos	0.4	0.4	0.3	0.8
Soluble salts meq/1				
Ca	1.0	0.8	0.9	1.0
Mg	1.6	1.5	1.7	1.9
Na	0.14	0.1	0.08	0.1
K	1.1	1.0	1.2	1.1
HCO_3	1.0	0.9	1.3	1.3
C1	0.8	0.8	0.6	0.6
SO_4				
B ppm				

SOIL PROFILE No. 22

Location: Rumais cross section.

Analyses	Sample depth cm			
	0-30	30-60	60-90	90-120
Clay %	15	12	15	9
Silt %	16	9	11	7
Fine sand %	57	36	29	16
Coarse sand %	12	42	45	67
Gravel %	4	6	22	9
$CaCO_3$ equivalent %	37	52	56	28
Org. matter %	0.8	0.2	0.1	0.05
Available P ppm	21	3	4	3
CEC meq/100 gm	-	-	-	-
pH water	7.9	7.9	7.9	7.7
EC 1:5 ext.u Mhos	156	414	524	408
Soluble salts meq/1				
Ca				
Mg				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 23

Location: Rumais Section.

- About 1700 m north of the Experiment Farm.
- Dates, halophites (scattered) and other small shrubs.
- Dunes type topography of more than 3% slope.

0–50 cm 10 YR 6/3 D fine loamy sand of massive structure. Very soft, very friable, non sticky. Diffused carbonates gave very strong effervescence. Wind blown type material.

50–70 cm Ditto but gravelly.

70–80 cm Fine loamy sand.

80–87 cm Another layer of gravelly loamy sand.

87–140 cm Fine loamy sand with few gravel.

140+ cm 10 YR 7/3 Partially gleyed sand clay loam with very strong effervescence and salty taste.

See bore 24, and pit 24 for comparison.

SOIL PROFILE No. 23

Location: Rumais cross section.

Analyses	Sample depth cm				
	0–20	20–25	50–80	80–140	140+
Clay %	13	9	9	9	36
Silt %	13	5	2	3	35
Fine sand %	67	67	20	34	23
Coarse sand %	12	19	69	54	5
Gravel %	2	2	44	3	11
$CaCO_3$ equivalent %	38	43	40	45	59
Org. matter %	0.3	0.2	0.01	0.04	0.3
Available P ppm	29	4	3	3	7
CEC meq/100 gm	6.3	5.2	3.9	4.5	-
pH water	8.0	8.0	7.9	7.9	8.0
EC 1:5 ext.u Mhos	2960	2636	1711	598	2590
Soluble salts meq/1					
Ca	9.0	2.2	6.2	-	1.3
Mg	4.2	3.2	2.4	-	3.2
K	15.8	18.2	8.0	-	19.3
HCO_3	0.4	0.3	0.2	-	0.2
Cl	0.8	0.8	0.8	-	2.8
SO_4	17.0	19.0	7.6	-	17.6
B ppm	17.8	1.8	9.0	-	5.0

Pit 24

Location: Rumais Section.

- At about 2500 m north of the Experiment Farm.

- Low and known as "Sabkha" or very salt affected wet soil. Haloyphites are the most common vegetation. Dates are grown on relatively high levels and of coarse texture material on both the coast line ridge and the sand dunes.

0-20 cm Salt crust followed by 10 YR 5/3 M compacted sand or loamy sand. Slightly hard but very friable, non sticky and non plastic. Strong effervescence.

20-55 cm 10 YR 5/3 M loamy sand with some fish shell fragments. Slightly hard, very friable with very strong effervescence.

55-110 cm 10 YR 3/4, 4/4 M loamy sand, gleyed and stained (spots of iron oxides and hydroxides). Some shell pieces. Moist, slightly sticky when wet. Dead (decomposed) tree-shrub roots.

110 + cm 7.5 YR 2/0 Beach sand mixed with fish shell fragments. The dark color is dominant with the white fish shells all over. Very soft and wet. Friable and non sticky. Strong effervescence is noticed.

See bores 24 and 25 and pit 23 for comparison.

SOIL PROFILE No. 24

Location: Rumais Cross Section.

Analyses	Sample depth cm			
	0–20	20–25	59–110	110–150
Clay %	10	11	13	9
Silt %	22	5	8	2
Fine sand %	39	50	44	35
Coarse sand %	29	34	35	54
Gravel %	5	3	3	-
$CaCO_3$ equivalent %	42	52	41	48
Org.matter %	0.5	0.08	0.1	0.5
Available P ppm	12	4	7	5
CEC meq/100 gm	7.6	-	-	-
pH water	7.9	7.9	8.0	8.0
EC 1:5 ext.u Mhos	16465	2035	2821	4070
Soluble salts meq/1				
Ca	47.2	1.3	1.6	9.8
Mg	38.2	3.0	4.6	15.4
Na	110.0	15.2	19.6	15.0
K	3.6	0.3	0.4	0.3
HCO_3	0.8	1.0	1.2	1.6
Cl	142.0	15.6	21.6	17.8
SO_4	52.0	3.2	3.6	30.8
B ppm				

SOIL PROFILE No. 27

Location: Sohar Production Farm.

Analyses	Sample depth cm				
	0–20*	20–40	40–70	70–100	100–120
Clay %	27	26	17	22	20
Silt %	30	33	14	22	19
Fine sand%	40	38	41	51	55
Coarse sand %	3	3	28	5	6
Gravel %	5	1	10	4	2
$CaCO_3$ equivalent %	18	21	13	20	19
Org. matter %	0.1	0.3	0.3	0.2	0.2
Available P ppm	16	6	3	6	2
CEC meq/100 gm	–	–	–	–	–
pH water	8.5	8.4	8.5	7.9	7.9
EC 1:5 ext.u Mhos	381	381	266	399	354
Soluble salts meq/1					
Ca	0.2	0.2	0.3	0.1	0.1
Mg	0.5	0.3	0.2	0.4	0.3
Na	3.0	3.0	2.2	3.4	3.0
K	0.1	0.08	0.04	0.02	0.02
HCO_3	2.2	2.2	2.0	2.2	2.2
Cl	1.4	1.0	0.8	1.6	1.2
SO_4					
B ppm					

* Furrow crest sample showed high salinity.
The EC 1:5 = 6447 u mhos/cm at 28°C.
NaCl being the most dominant salt.

SOIL PROFILE No. 28

Location: Sohar Production Farm.

	Sample depth cm			
	0–20	20–50	50–90	90–120
Clay %	23	31	27	22
Silt %	27	38	26	14
Fine sand %	44	31	45	61
Coarse sand %	7	1	2	4
Gravel %	9	1	1	-
$CaCO_3$ equivalent %	19	20	19	19
Org.matter %	0.7	0.3	0.3	0.2
Available P ppm	2.4	5	3	3
CEC meq/100 gm	-	-	-	-
pH water	7.5	7.2	7.4	7.3
EC 1:5 ext.u Mhos	939	2763	1980	1169
Soluble salts meq/l				
Ca	1.2	2.0	1.4	1.0
Mg	1.6	5.8	4.4	3.6
Na	5.2	18.2	13.8	6.8
K	1.3	1.3	0.1	0.06
HCO_3	1.2	1.0	1.2	1.2
Cl	2.6	12.0	10.4	7.9
SO_4				
B ppm				

Pit 39

Location: Dairy Farm at Sohar.

- Uncultivated area in the south east corner (see sketch).

0-25 cm 10 YR 6/3 D, 4/3 M loamy sand weak platy to granular, slightly hard, slightly sticky and slightly plastic calcareous material of very strong effervescence. Common fine and medium roots.

25-40 cm Ditto silty loam of platy structure, hard friable, slightly sticky and slight plastic.

40-55 cm Ditto, silt loam, soft, friable, slightly sticky and slightly plastic massive to weak granular structure. Calcareous.

55-70 cm Ditto, sandy loam.

70-110 cm Ditto, clay loam, hard, friable, sticky and plastic calcareous material of platy structure. Strong effervescence may indicate relative accumulation of diffused carbonates.

110-140 cm Ditto, silty loam.

140+ cm Gravelly stony, loam.

SOIL PROFILE No. 39

Location: Sohar Dairy Farm.

Analyses	Sample depth cm				
	0-25	25-40	40-55	55-70	70-110
Clay %	10	13	10	10	14
Silt %	9	31	12	7	28
Fine sand %	74	50	70	76	51
Coarse sand %	7	6	8	7	7
Gravel %	2	-	-	-	-
$CaCO_3$ equivalent %	13	16	15	11	17
Org.matter %	0.2	0.2	0.2	0.2	0.2
Available P ppm	2	1	3	1	2
CEC meq/100 gm	9	13	9	8	13
pH water	-	-	-	-	-
EC 1:5 ext.u Mhos	99	122	132	127	207
Soluble salts meq/1					
Ca					
Mg					
Na					
K					
HCO_3					
Cl					
SO_4					
B ppm					

Pit 40

Location: Dairy farm at Sohar.

In a new citrus orchard that had been sprayed for Zn deficiency. Very close to the first well in the north east corner of the farm. (See Sketch).

0-20 cm 10 YR 6/3 D, 4/4 M; silt loam to clay loam, granular, soft, friable, sticky and plastic. Common roots to 30 cm. Strong effervescence.

20-50 cm Ditto. Silty clay loam of granular structure except a band of platy structure is about 40 cm.

50-100 cm Ditto, sandy loam of massive structure. Calcareous porous material.

100-150 cm Ditto silty loam of massive structure. Moist calcareous material.

SOIL PROFILE No. 40

Location: Sohar Dairy Farm.

Analyses	Sample depth cm			
	0-20	20-50	50-100	100+150
Clay %	16	14	10	12
Silt %	29	15	6	18
Fine sand %	52	62	70	55
Coarse sand %	3	9	14	15
Gravel %	-	-	-	-
$CaCO_3$ equivalent %	21	21	13	16
Org.matter %	0.5	0.3	0.1	0.1
Available P ppm	23	5	4	4
CEC meq/100 gm	11	7	5	10
pH water	7.0	8.0	8.0	8.0
EC 1:5 ext.u Mhos	1084	462	150	264
Soluble salts meq/1				
Ca	3.4			
Mg	4.3			
Na	1.9			
K	0.2			
HCO_3	1.0			
Cl	3.1			
SO_4				
B ppm				

Pit 41

Location: Dairy Farm at Sohar.

The center of the area at which the proposed center pivot irrigation system will be installed.

Undulating topography.

0-10 cm 10 YR 6/3D, 5/4 M, sandy loam, platy, soft, friable slightly sticky and slightly plastic. Few roots of fine and very fine size. Strong effervescence.

10-50 cm Ditto, but of granular structure.

50-90 cm Ditto, loam blocky, hard, friable, sticky and plastic. Mottles of carbonate of powdary nature giving very strong reaction with dilute cold acid. Dense fine roots are present.

9-140 cm Ditto silty loam, granular; hard friable; slightly sticky and slightly sticky and slightly plastic. Strong effervescence.

140+ cm Ditto with gravells and strones.

SOIL PROFILE No. 41

Location: Sohar Dairy Farm.

Analyses	Sample depth cm			
	0–10	10–50	50–90	90–140
Clay %	17	16	20	15
Silt %	14	17	28	35
Fine sand %	55	53	47	45
Coarse sand %	14	4	5	5
Gravel %	2	–	–	–
$CaCO_3$ equivalent %	18	17	19	15
Org.matter %	0.2	0.3	0.2	0.3
Available P ppm	4	3	2	4
CEC meq/100 gm	10	10	15	16
pH water	–	–	–	–
EC 1:5 ext.u Mhos	113	113	310	603
Soluble salts meq/1	–	–	–	–
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 45

Location: Dairy Farm at Sohar.

- South west area of the farm (see sketch).

- Undulating uncultivated area. More than 1% slope to the north east.

0-20 cm 10 YR 6/4 D loamy sand platy, soft, friable non sticky, non plastic. Few roots of fine and medium sizes. Strong effervescence.

20-42 cm 10 YR 6/3 D loamy sand with some gravels.

42-60 cm 10 YR 6/4 silty loam hard, compacted or cemented by some diffused carbonate with very strong effervescence. Slightly sticky and plastic material.

60-110 cm 10 YR 6/3 fine loamy sand, slightly compacted friable, non sticky and non plastic calcareous material.

110-150 cm 10 YR 6/4 D silty clay loam, blocky to angular blocky, hard, friable, sticky, plastic, and calcareous material.

SOIL PROFILE No. 45

Location: Sohar Dairy Farm.

Analyses	Sample depth cm				
	0–20	20–42	42–60	60–110	100+
Clay %	10	10	13	1	17
Silt %	6	5	19	6	31
Fine sand %	78	57	60	76	48
Coarse sand %	6	28	8	7	4
Gravel %	–	–	–	–	–
$CaCO_3$ equivalent %	15	11	20	16	21
Org.matter %	0.12	0.1	0.15	0.1	0.1
Available P ppm	9	3	2	2	3
CEC meq/100 gm	7	6	9	8	–
pH water	–	–	–	–	–
EC 1:5 ext.u Mhos	65	91	127	122	182
Soluble salts meq/1					
Ca					
Mg					
Na					
K					
HCO_3					
Cl					
SO_4					
B ppm					

Pit 31

Location: Sohar New Project.

- 2500 m west of Heeby gravel road at about 900 m south to Muscat Sohar main road. North west boundary.

- Undulating to rough relief because of several wadi intersections in this area.

0-40 cm 10 YR 6/3 D, 5/4 M, clay loam, coarse granular to sub-angular blocky, slightly hard, friable, sticky and plastic. Strong reaction with dilute acid.

40-70 cm Clay loam blocky, compacted, hard sticky and plastic.

70-110 cm Sandy loam, loose and soft, slightly sticky and non plastic.

110-120 cm Sand band.

120-150 cm Loamy sand - strong effervescence.

SOIL PROFILE No. 31

Location: Sohar New Project area.

Analyses	Sample depth cm		
	0–40	40–70	70–110
Clay %	25	23	16
Silt %	32	24	13
Fine sand %	38	47	51
Coarse sand %	5	6	10
Gravel %	–	–	–
$CaCO_3$ equivalent %	20	22	15
Org.matter %	0.4	0.3	0.1
Available P ppm	10	7	6
CEC meq/100 gm	14.5	14.5	11
pH water	7.8	7.7	7.9
EC 1:5 ext.u Mhos	14.1	38.1	31.0
Soluble salts meq/1			
Ca	0.4	0.4	0.2
Mg	0.4	0.6	0.3
Na	0.6	2.6	2.2
K	0.2	0.02	0.02
HCO_3	0.2	0.02	0.02
Cl	–	1.6	1.0
SO_4	1.3	2.0	1.8
B ppm			

Pit 35

Location: Sohar New Project.

About 850 m west of Heeby gravel road at about 2700 m south of Muscat - Sohar main road.

Undulated topography. Scattered desert shrubs with scarce Acacia sp. and short weak grass.

8-20 cm	10 YR 6/3, 6/4D stratified (layered) loam of platy structure. Slightly hard, friable, sticky and plastic. Strong reaction with HC1. Common very fine roots.
20-35 cm	Ditto but more compacted with very strong effervescence with a wavey boundary to
35-60 cm	Gravelly plus stone layer.
60-100 cm	Stratified loam with gravel and stone.
100-120 cm	Sandy loam of granular structure.
120-140 cm	Stratified loam with gravel and stone.
140 + cm	Loam, fairly compacted, granular to blocky structure. Strong effervescence.

SOIL PROFILE No. 35

Location: Sohar New Project area.

Analyses	Sample depth cm				
	0-20	20-35	35-60	60-100	100-120
Clay %	17	17	6	Gravel	16
Silt %	30	28	5	"	6
Fine sand %	48	47	17	"	41
Coarse sand %	5	7	72	"	37
Gravel %	-	2	21	"	3
$CaCO_3$ equivalent %	19	16	5	-	8
Org.matter %	0.4	0.4	0.01	-	0.3
Available P ppm	19	2	2	-	1
CEC meq/100 gm	15	12.5	4.5	-	7
pH water	-	-	-	-	-
EC 1:5 ext.u Mhos	132	518	150	-	113
Soluble salts meq/1					
Ca					
Mg					
Na					
K					
HCO_3					
Cl					
SO_4					
B ppm					

Pit 46

Location: Saham New Project.

- At about 2 km south of Sohar - Muscat road on the South East boundary.
- Scattered desert shrubs on a relative flat area with nekhas. Acacia is the most common shrubs.

0-20 cm	10 YR 6/3 D, silty loam of platy structure, soft friable, slightly sticky and slightly plastic.
20-75 cm	Gravelly sand with stones.
75-90 cm	10 YR 6/3 silty loam layer.
90 + cm	Gravelly sand layer.

SOIL PROFILE No. 46

Location: Sohar New Project area.

Analyses	Sample depth cm			
	0-20	20-75	75-90	90-
Clay %	20	9	12	Gravelly
Silt %	39	2	23	sand
Fine sand %	36	31	46	
Coarse sand %	6	58	20	
Gravel %	-	19	-	
$CaCO_3$ equivalent %				
Org. matter %				
Available P ppm				
CEC meq/100 gm				
pH water				
EC 1:5 ext.u Mhos	142	85	114	
Soluble salts meq/1				
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 47

Location: Saham New Project.

- At about 300 m south of Sohar - Muscat road at about 2500 m west of Saham Shell gas station, near the western boundary of the project.

- An open, levelled area which seemed to have been cultivated in the past.

0-20 cm 10 YR 6/3 D, 4/3 M, silty loam of weak platy structure, soft, friable, slightly sticky and slightly plastic. Calcareous.

20-50 cm Ditto, sub-angular blocky breaks to large granular structure. Calcareous.

50-80 cm Ditto, more stable structure, more compacted and hard, friable, slightly sticky and plastic.

80-100 cm Ditto, blocky structure with stronger effervescence which may indicate some accumulation of secondary carbonate.

100-130 cm Ditto, but relatively softer.

130-200 cm Ditto, but more compacted and strong effervescence.

SOIL PROFILE No. 47

Location: Saham New Project area.

Analyses	Sample depth cm				
	0-20	20-50*	50-80	80-100	100-130
Clay %	25	27	24	26	34
Silt %	52	43	37	33	50
Fine sand %	22	29	37	39	16
Coarse sand %	1	1	2	2	-
Gravel %	-	-	-	-	-
$CaCO_3$ equivalent %					
Org.matter %					
Available P ppm					
CEC meq/100 gm	12	13	15	15	16
pH water					
EC 1:5 ext.u Mhos	7.4	8.0	8.0	7.9	7.8
Soluble salts meq/1	200	2759	1806	1710	1996
Ca	-	7.2	3.4	3.0	2.4
Mg		7.8	6.4	6.0	7.6
Na		12.0	8.6	7.8	9.4
K		0.1	0.1	0.2	0.3
HCO_3		1.2	1.2	1.2	1.2
Cl		16.0	9.5	10.0	12.5
SO_4		10.1	7.9	6.3	5.8
B ppm					

*Saline sub-soil, also bores 41 and 50.

SOIL PROFILE No. 71

Location: Ad Dariz - Sharqiya.

Analyses	Sample depth cm		
	0-20	20-40	40-70
Clay %	14	23	25
Silt %	16	36	30
Fine sand %	43	28	32
Coarse sand %	27	23	13
Gravel %	13	7	8
$CaCO_3$ equivalent %	26	39	37
Org. matter %	0.16	0.15	0.12
Available P ppm	13	5	2
CEC meq/100 gm	-	-	-
pH water	7.6	7.6	7.6
EC 1:5 ext.u Mhos	280	1800	2500
Soluble salts meq/1			
Ca	-	54	6.0
Mg	-	3.6	4.6
Na	-	10.6	15.2
K	-	0.2	0.2
HCO_3	-	1.2	0.8
Cl	-	7.2	14.6
SO_4	-	11.4	10.6
B ppm			

Pit 50

Ad Dariz - Sharqiya

- Undulated topography - scattered desert shrubs and low Acacia sp.

0-10 cm	10 YR 6/3 gravelly loam, granular, loose, friable slightly sticky, slightly plastic and very calcareous.
10-30 cm	Ditto with more gravel and better structure. Spots of powdery calcium carbonate.
30-60 cm	10 YR 7/3 silty loam with carbonate soft concretions.
60 + cm	Gravel layer.

SOIL PROFILE No. 50

Location: Ad Dariz-Sharqiya.

Analyses	Sample depth cm		
	0-10	10-20	20-60
Clay %	23	24	21
Silt %	28	23	20
Fine sand %	26	20	41
Coarse sand %	24	33	18
Gravel %	14	31	11
$CaCO_3$ equivalent %	33	30	33
Org.matter %	0.06	0.07	0.03
Available P ppm	5	2	2
CEC meq/100 gm	-	-	-
pH water			
EC 1:5 ext.u Mhos	110	120	120
Soluble salts meq/1			
Ca			
Mg			
Na			
K			
HCO_3			
Cl			
SO_4			
B ppm			

Pit 51

Location: Al Kamil - Al Gadeed New Project.

- At about 200 m south of Soak Al Imam farm and at 800 m from the southern end of Al Kamil.

- Acacia shrubs and trees are common on a level land which is subject to wind blown sand.

0-40 cm 10 YR 6/4 D, 7.5 YR 4/4 M loamy sand. Highly calcareous.

40-75 cm 7.5 YR 6/4 D, 4/4 M gravelly loamy sand. Roots are common to the depth of 50 cm.

75-90 cm Ditto, highly gravelly loamy sand.

90-110 cm Highly calcareous loamy sand. Secondary carbonates show in soft mottles.

110-160 cm Gravelly loamy sand plus stones.

160 + cm Highly calcareous stone or rock, chalky color rock.

SOIL PROFILE No. 51

Location: Al Kamil - New Project area.

Analyses	Sample depth cm				
	0-40	40-75	90-115	115-160	
Clay %	11	17	14	17	13
Silt %	2	5	4	6	5
Fine sand %	74	61	44	60	59
Coarse sand %	14	17	38	18	24
Gravel %	-	5	20	10	29
$CaCO_3$ equivalent %	30	30	31	25	24*
	0.2	0.07	0.09	0.1	0.2
Org. matter %	18	10	24**	42**	20**
Available P ppm	-	-	-	-	-
CEC meq/100 gm					
pH water	-	-	-	7.8	7.8
EC 1:5 ext.u Mhos	510	330	400	660	1180
Soluble salts meq/1					
Ca				2.8	7.6
Mg				3.2	5.0
Na				1.2	1.5
K				0.08	0.08
HCO_3				1.4	1.1
Cl				1.0	1.2
SO_4				5.0	12.0
B ppm					

* The old terrace sub-strata contained 35% $CaCO_3$ at the depth of more than 160 cm.

** This area was used to discharge wastes of gravel grinding for the main road.

Pit 53

Location: North - Al Kamil New Project.

- At about 1000 m Muscat - Sur new road or north of Al Kamil new police station. Near well No. 626 which is about 300 north of well No. 625.

- Undulating topography. Affected by recent flood. Subject to wind blown sands. Medium cover of desert shrubs. Halophites are common in this area.

0-30 cm	10 YR 6/4 D, 4/4 M loamy fine sand of massive to laminar or platy structure. This type of formation indicates a mixed origin of this material. It could be a mixture of colluvium alluvial material (water movement) mixed by wind blown material.
30-80 cm	10 YR 6/3 D, 5/4 M clay loam of granular structure that develops to weak sub-angular blocky with depth. This may represent a flood plain deposit.
80 + cm	Cemented and compacted gravelly material. This may represent an old terrace surface.

SOIL PROFILE No. 53

Location: North Al Kamil new project area.

Analyses	Sample depth cm	
	0-30	30-80
Clay %	17	10
Silt %	5	24
Fine sand %	67	58
Coarse sand %	11	8
Gravel %	5	7
$CaCO_3$ equivalent %	38	41
Org. matter %	0.03	0.12
Available P ppm	5	26
CEC meq/100 gm		
pH water	2.3	7.3
EC 1:5 ext.u Mhos	180	2800
Soluble salts meq/1		
Ca	-	28.0
Mg		6.0
Na		2.3
K		1.6
HCO_3		0.7
C1		1.0
SO_4		35.0
B ppm		

Pit 54

Location: North Al Kamil New Project.

- At about 500 m north west of the new police station. At about 500 m from the main road Muscat - Sur (Near well, Tim 82).

- Undulating topography, low sandy dunes are scattered in this reach. Small farms irrigated from hand dug wells on the east and west of this pit.

0-20 cm 10 YR 7/3 D, 4/4 M silt loam of dusty or massive structure. Very calcareous. Common fine roots of halophites are present.

20-25 cm Ditto silt loam of granular structure. Very calcareous. Hard, friable, slightly sticky and slightly plastic.

50-80 cm 10 YR6/3 D, 3/4 M silt loam of strong granular to sub-angular blocky. Very strong effervescence which may indicate a relative accumulation of secondary carbonate.

80-100 cm Ditto but gravelly.

SOIL PROFINE No. 54

Location: North Al Kamil New Project area.

Analyses	Sample depth cm			
	0-20	20-50	50-80	80-100
Clay %	15	15	24	19
Silt %	8	14	15	19
Fine sand %	73	63	51	52
Coarse sand %	5	8	10	11
Gravel %	5	9	10	9
$CaCO_3$ equivalent %	62	37	65	35
Org.matter %	0.25	0.20	0.24	0.22
Available P ppm	7	3	4	4
CEC meq/100 gm	-	-	-	-
pH water	-	-	-	-
EC 1:5 ext.u Mhos	120	100	160	240
Soluble salts meq/1				
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 55

Location: North Al-Kamil New Project.

- At about 4000 m from Al Kamil new police station and at about 800 m east of the main road. West to old village remnant.

- Undulated topography. Acacia of medium dense cover. Some sand dunes are observed.

0-20 cm 10 YR 7/3 D, 4/4 M, loam, fine granular, loose to very soft, slightly sticky and slightly plastic. Very calcareous. Medium and fine roots are common.

20-50 cm Ditto loam to clay loam or silty clay loam. Sub-angular blocky to blocky structure. Hard, friable, sticky and plastic.

50-90 cm 10 YR 6/3 D, 3/4 M, clay loam to silty clay loam. Sub-angular blocky to blocky. Hard, firm, sticky and plastic. Calcareous.

90-110 cm 10 YR 6/2 D, 3/4 M clay loam of blocky structure. Hard, firm, sticky and plastic. Calcareous.

SOIL PROFILE No. 55

Location: North Al Kamil New Project area.

Analyses	Sample depth cm			
	0-20	20-50	50-90	90-110
Clay %	20	31	45	44
Silt %	27	26	33	39
Fine sand%	52	42	21	16
Coarse sand %	2	2	1	1
Gravel %	10	3	5	15
$CaCO_3$ equivalent %	41	41	41	41
Org. matter %	0.37	0.35	0.41	0.38
Available P ppm	10	4	5	3
CEC meq/100 gm	-	-	-	-
pH water	7.9	7.9	7.9	7.8
EC 1:5 ext.u Mhos	140	290	820	1800
Soluble salts meq/1				
Ca			1.4	2.0
Mg			2.2	2.6
Na			4.7	12.6
K			0.4	0.5
HCO_3			1.2	1.4
Cl			1.9	4.3
SO_4			5.1	12.1
B ppm				

Pit 57

Location: Manah Project.

- A well pit near Al Sagereen falaj close to Mehmed village.

- Vegetable farm irrigated from the well.

0-15 cm 10 YR 6/5 silty loam of very soft hardness. Very weak platy structure which breaks to dusty, very calcareous and viscular.

15-50 cm 10 YR 6/2 loam of granular structure. Soft, friable, slightly sticky and slightly plastic. Very calcareous and viscular.

50-130 cm 10 YR 6/2 clay loam of sub-angular blocky structure which is also viscular or very common pores of different sizes are present. Soft, friable to very friable, slightly sticky and slightly plastic. Very calcareous.

130 + cm Crute calcare of very compacted and cemented nature. This may represent an old terrace surface.

SOIL PROFILE No. 57

Location: Manah Project.

Analyses	Sample depth cm			
	0-15	15-50	50-130	130-
Clay %	19	29	32	22
Silt %	16	24	26	54
Fine sand %	61	40	35	19
Coarse sand %	5	7	6	4
Gravel %	2	2	4	6
$CaCO_3$ equivalent %	47	47	46	65
Org.matter %	0.88	0.47	0.85	0.12
Available P ppm	12	4	4	3
CEC meq/100 gm				
pH water	7.3	7.4	7.3	7.4
EC 1:5 ext.u Mhos	170	220	220	190
Soluble salts meq/1				
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 58

Location: Manah Project.

- West of the gravel road Nizwa-Manah at about 1250 m to the west. This area lies between the Khatum and Masara falaj. (See map).

- An abandoned farm. After wheat.

0-30 cm 10 YR 6/2 to 6/3 silty loam to clay loam of sub-angular blocky to blocky structure at few centimeters from the plowed layer. Slightly hard, firm, sticky and plastic. Very calcareous. Roots are common.

30-50 cm 10 YR 5/3 clay loam of blocky structure. Hard, firm, sticky and plastic. Very calcareous with carbonate micilia and small nodules common.

50-100 cm 10 YR 4/2 clay loam to clay of prizmatic structure. Powdery or soft carbonate nodules common. Pressure faces with very thin clay films could be noticed. Hard, firm, very sticky and very plastic.

100 + cm 10 YR 4/2 clay loam to clay of very cemented or compacted structure. Very hard, very firm, slightly sticky and slightly plastic.

SOIL PROFILE No. 58

Location: Manah Project.

Analyses	Sample depth cm		
	0-30	30-50	50-100
Clay %	30	43	48
Silt %	31	36	29
Fine sand %	37	21	22
Coarse sand %	2	-	-
Gravel %	12	13	14
$CaCO_3$ equivalent %	47	41	41
Org.matter %	0.7	0.9	0.3
Available P ppm	6	2	3
CEC meq/100 gm			
pH water	7.6	7.7	7.3
EC 1:5 ext.u Mhos	530	850	1200
Soluble salts meq/1			
Ca		2.4	1.2
Mg		5.7	3.4
Na		3.1	7.1
K		0.2	0.1
HCO_3		0.9	1.1
$C1^3$		4.3	6.0
SO_4		6.2	4.6
B ppm			

Pit 59

Location: Manh Project.

- West the gravel road Nizwa-Manah at the northern reach at about 1 km from the small Mosque near Al Khatum falaj.

- Abandoned farm, or a rain-irrigated farm, part of which was recently sawed with wheat.

0-20 cm 10 YR 6/3 viscular silty loam at surface develops to strong blocky at 10 cm. Very soft at surface becomes slightly hard with depth. Friable, sticky and plastic when moist. Very calcareous. Common fine and medium roots are found.

20-40 cm 10 YR 4/3 clay loam of blocky structure that breaks down to sub-angular blocky showing carbonate powdery nodules between grains or on peds surfaces. Very hard, firm, sticky and plastic. Very strong effervescence. Some tree roots or big roots are found.

40-100 cm 10 YR 3/4 to 3/6 clay loam of weak to good prizmatic structure. Pressure faces with very weak clay films could be observed. Obvious carbonate nodules of grain size are common.

100 + cm Cemented very hard material breaks to gravelly which may indicate the surface of an old terrace.

SOIL PROFILE No. 59

Location: Manah Project.

Analyses	Sample depth cm			
	0-20	20-40	40-100	100-150
Clay %	26	34	24	26
Silt %	23	32	22	17
Fine sand %	45	29	26	27
Coarse sand %	6	5	28	29
Gravel %	12	13	22	15
$CaCO_3$ equivalent %	44	39	35	48
Org.matter %	0.36	0.55	0.31	0.07
Available P ppm	4	2	2	2
CEC meq/100 gm	-	-	-	-
pH water	7.6	7.3	7.9	7.4
EC 1:5 ext.u Mhos	180	320	430	300
Soluble salts meq/1				
Ca				
Mg				
Na				
K				
HCO_3				
Cl				
SO_4				
B ppm				

Pit 60

Location: Manah Project.

- West of the gravel road Nizwa-Manah near the southern reach of this flats open land.

- Vegetation is scattered and composed of mainly halophites. Some low acacia is also present.

0-20 cm	10 YR 6/3 silty loam, viscular at the top granular underneath this crust. Very loose, friable, slightly sticky and slightly plastic. Very calcareous. Only few fine roots are present.
20-40 cm	10 YR 6/2 silty loam to clay loam of sub-angular blocky to weak blocky develops to blocky with depth. Hard, friable, sticky and plastic. Very strong effervescence.
40-90 cm	10 YR 3/4 clay loam of blocky to weak prizmatic structure. Very hard, sticky and very plastic. Very strong effervescence. Some salt crystals (gypsum) are present.
90 + cm	Very hard and cemented material or perhaps the parent rock of limestone or sand stone mixture.

SOIL PROFILE No. 60

Location: Manah Project.

Analyses	Sample depth cm			
	0-20	20-40	40-90	90-140
Clay %	27	31	25	-
Silt %	34	37	23	-
Fine sand %	36	30	43	-
Coarse sand %	3	2	9	-
Gravel %	7	14	11	9
$CaCO_3$ equivalent %	32	37	38	26
Org.matter %	0.38	0.2	0.1	0.2
Available P ppm	3	2	2	3
CEC meq/100 gm	-	-	-	-
pH water	7.3	7.3	7.2	7.0
EC 1:5 ext.u Mhos	290	850	1150	370
Soluble salts meq/1				
Ca	-	1.5	3.6	29.5
Mg		1.3	2.6	6.5
Na		5.4	5.2	3.1
K		0.1	0.1	0.1
HCO_3		0.8	0.7	0.5
Cl		4.5	3.8	2.0
SO_4		2.9	7.0	36.0
B ppm				

APPENDIX

List of Maps

Rumais farms General location

Rumais farm No. 1

Rumais farm No. 2

Nursery farm - Rumais

Rumais farm No. 3

Experiment Station farm - Rumais

Sohar production farm

Sohar dairy farm

Sohar new project

Soham new project

Ad Dariz - Al Izz General area

Al Kamil - Al Wafi General area

Manah general area