# REPORT ON PRELIMINARY SURVEY OF OMANI AGRICULTURAL DEVELOPMENT

AUGUST 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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# PREFACE

It is with great pleasure that I present this report entitled Preliminary Study for the Agricultural Development Project to the Government of the Sultanate of Oman.

This report embodies the result of a preliminary survey which was carried out in the Batina Coast and Dohar area, Oman from June to July, 1980 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of the Sultanate of Oman.

The survey team, headed by Mr. Resaburo Nasu, had a series of close discussions with the officials concerned of the Government of the Sultanate of Oman and conducted a wide scope of field survey and data analyses.

I sincerely hope that this report will be useful as a basic reference for development of the project.

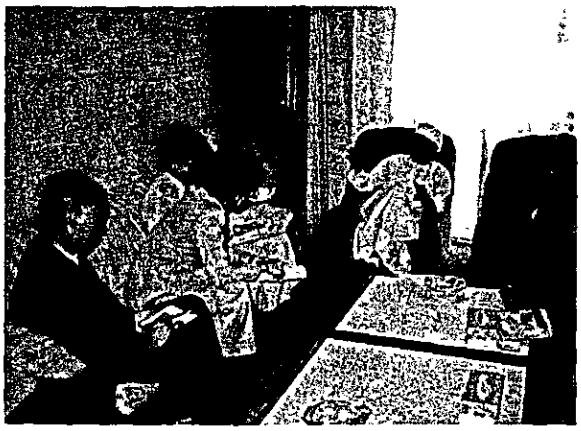
I am paticularly pleased to express my appreciation to the officials concerned of the Government of the Sultanate of Oman for their close cooperation extended to the Japanese team.

September, 1980

A. Arimatsu

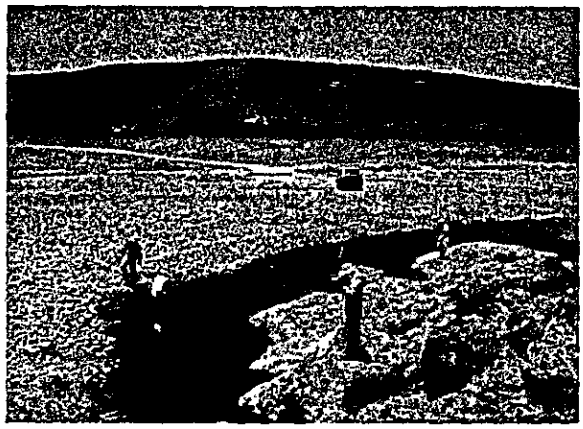
Akira Arimatsu
Executive Director

Japan International Cooperation Agency

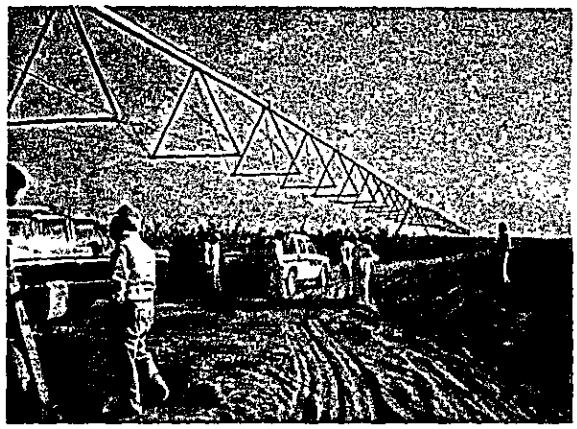


Negotiation with Staff of Oman
Ministry of Agriculture & Fisheries

Muscat City

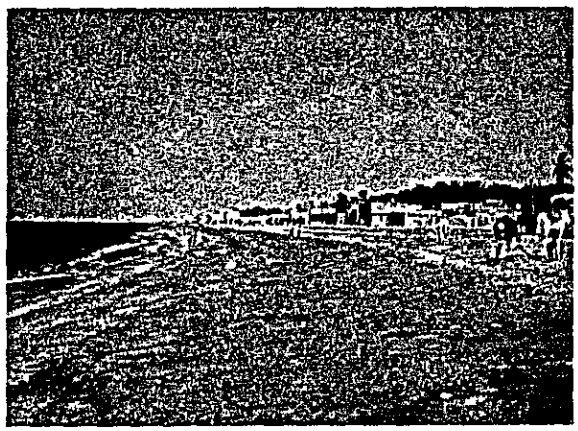


Wadi Jizzi

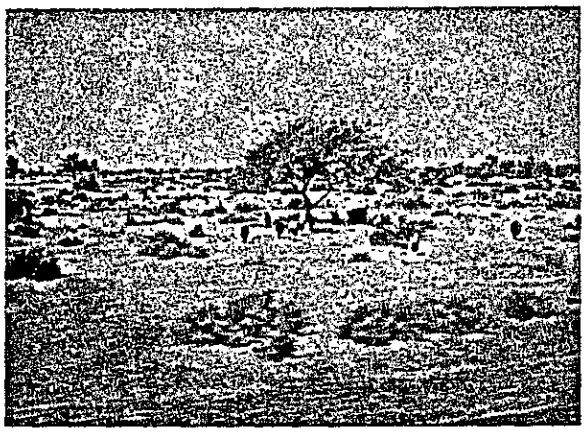


Oman Sun Farm

Renovation of Falaj near Rustaq



Batinah Coast



Sharqiya

Misfar, Interiors

Dates

Open Falaj at Nizwa

Darbat at Wadi in Salalah

Quiroon Heirithi Fruit Tree
Exp. Sta. in Salalah Highland

Contents

# I. SUMMARY OF SURVEY

## 1. Process of Preliminary Survey

Following the negotiation on the water resource development project under our cooperation to Oman, which took place when Mr. Sonoda, a Prime Minister's special envoy, paid a visit to King Kaboos, our project finding mission visited the nation in April 1980. At the meeting with this mission, the Omani government urged our cooperation to the water resource (agriculture) development project.

## 2. Purpose & Process of Survey

The Omani government is planning its 2nd 5-year project (1981 to 1985), and the said water resource (agriculture) development project is given the top priority in order to promote the employment and to increase the national income. To study the feasibility of the said agricultural development, the survey team selected the survey areas, discussed the survey techniques and acquired the associated information and data.

## 3. Outcome of Survey

The survey team has reached the conclusion for the Omani water resource (agriculture) development project, as shall be described hereunder, from the study of diverse data provided by the Omani government as well as the surveys conducted on 13 local areas of Oman.

### (1) Batina Coastal Area

The existing irrigation system on the cultivated lands along the Batina coast seems to increase the pump-up volume, and thereby raise the saline concentration. It is therefore recommended that the water supply points in the lands to be newly developed or to be reconditioned in future be located as much upstream as possible, and that the natural watering system be given priority, considering the running cost, and further that the ground water system be employed jointly, which may induce the surface water into the ground and store underground. The existing water supply by wells should be changed to be taken from as many wells as allowed, and proper water level observation network must be set up to conduct as appropriate water control. The present Falaj

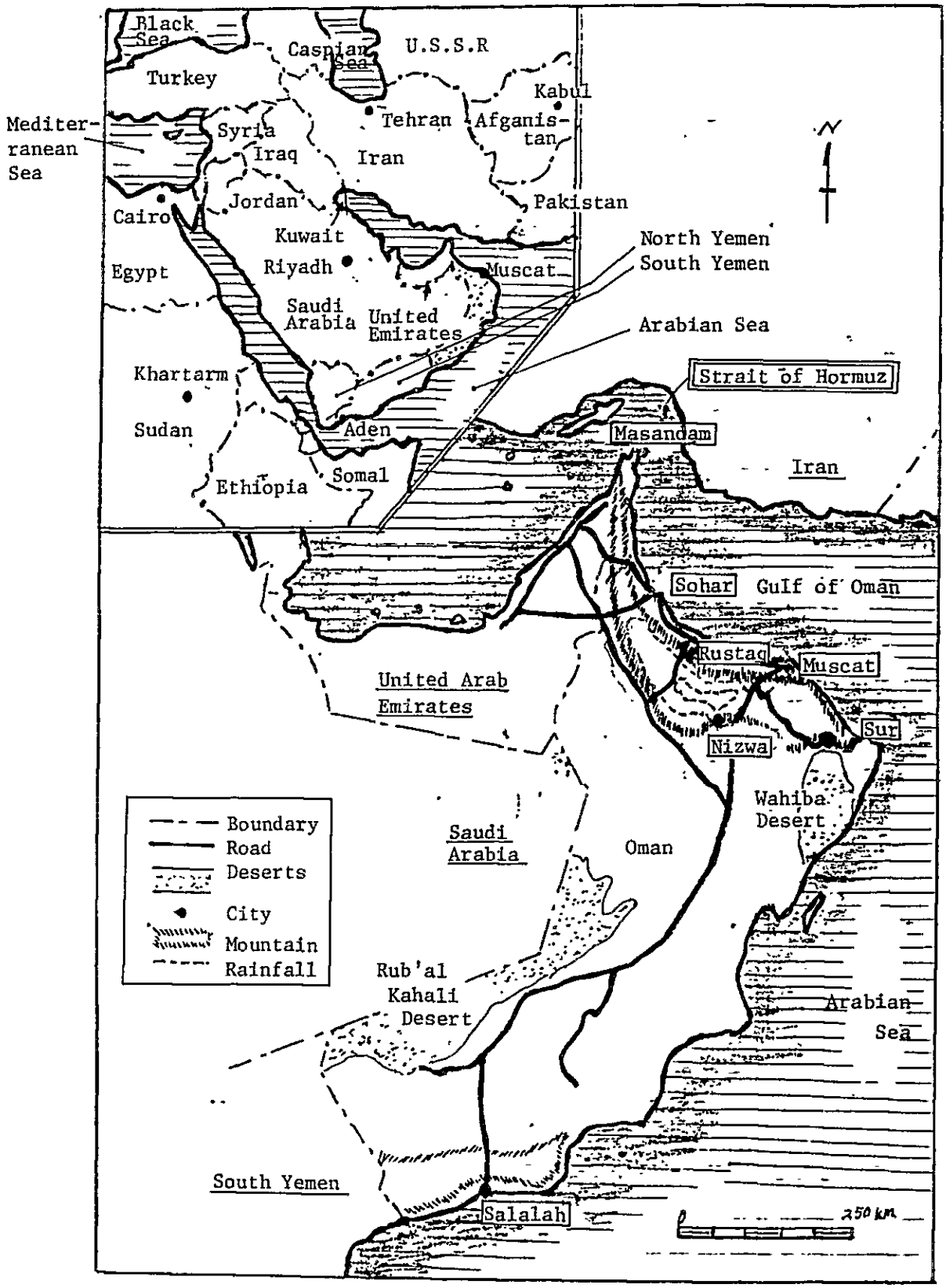



Fig. 1 Map of Oman

water supply system should be integrated by means of concrete weirs or at least it needs an improvement of the existing facilities and a reorganization by installing the pipelines. The cultivated lands should also be readjusted to expand the lands for agricultural to such an extent as the surplus water may well irrigate them.

(2) Interiors

Similar improvements are required for the inland areas to those of the Falaj and pump-up water supply systems. The water supply system should be definitely separated into the irrigation, drinking and miscellaneous use, and study should further be made on the settlement reorganization and the high-level use of water.

(3) Shargiya Area

The government-sponcered development is under way in this area. Considering a broad basin of Wadi Al Batha and the existing Falaj systems downstream of Waji Bani Khalid and further the adjacent Wahiba Sands, it is concluded that a hydrological and geological survey be conducted over the whole water system as well as the analysis and study on the sand arrestation be likewise performed.

(4) Salalah Area

For the skirts of this area the irrigation may be provided either by the upstream intake system that catches the spring water, or by the ground water pump-up system. It is however essential, since the topographical maps, geologic structures, soil distribution and analyses are not properly provided, that the surveys on these factors be conducted at an earlier stage to set up the overall development plan for this area.

(5) Others

Various studies and experiments on the Omani agriculture are being undertaken step by step; however, more planned studies and experiments should be promoted particularly for the fertilized cultivation management and plant breeding. Another consideration should be given to the placement of irrigation engineers and the organization of these staffs in the local bureau for the future projects. To promote the future

water resource development, it is essential to analyse the hydrological data as well as to upgrade and extend the present hydrological observation system. It is now concluded as the most urged theme that the development in the Wadi Jizi area be given priority, for this area is relatively easy to start up the project.

Note:

A strong request has been made by the Omani government on the following points of our interim report:

(1) The selection of preliminary survey areas is not objectionable, but the impact of preliminary survey must be proven at an earlier stage.

(2) Equal to the Batinah coastal area, the Salalah area is the top priority area whose development should be proveeded as quickly as possible by the Japanese consultant(s) under the control and supervision of Japanese Government (the incidental costs are to be borne by the Omani government)

## II. NATURE & ECONOMY OF OMAN

### 1. Natural Conditions

#### 1) Weather conditions

Oman belongs generally to the dry weather zone, and its weather conditions vary remarkably with the districts due to its oceans, configuration and other various factors. Quite characteristics are the variation between its southern and northern districts as well as the changes from the coasts to the interiors.

The most variable between the southern and northern areas is the rainfall patterns. The rainfall concentrates in the winter over the northern Oman surrounding Muscat while it is centered in the summer over the southern district of Salalah and its surroundings. The coastal areas are high in the humidity because of the oceans, but the interiors are much severe in the dry weather.

#### i) Rainfall

The rainfall is characterized by its concentration on a few days during the rain season, and the annual changes are quite large. Such characteristics are more apparent in the northern Oman, and without penetrating into the ground and becoming the ground water, most of rains flow into the seas. The annual fluctuation of rainfall in Muscat ranges from several millmeters to 250mm, and it prevents the implementation of agricultural development as well as the plannings to a considerable extent.

The rainy season over the northern Oman prevails in the winter from December to March; and the rainfall accumulates to about 100mm a year in the Batinah area and about 130mm in Nizwa and its surrounding interiors. The rainfall is said to increase in the mountain areas, and it almost reached 300mm or more on the highest peak of Oman Mountains, Jabbel Al Akhdar (sea level about 3,000m, it means a green mount).

In the southern Oman the rain concentrates in the summer of June to August, and the rainfall is about 110mm a year in the plains or 500 to 750mm in the mountains. While visiting the Southern Area just after the rain season started, the survey team had a almost cloudy weather during the sojourn, and experienced frequently with rains like drizzles.

ii) Temperature

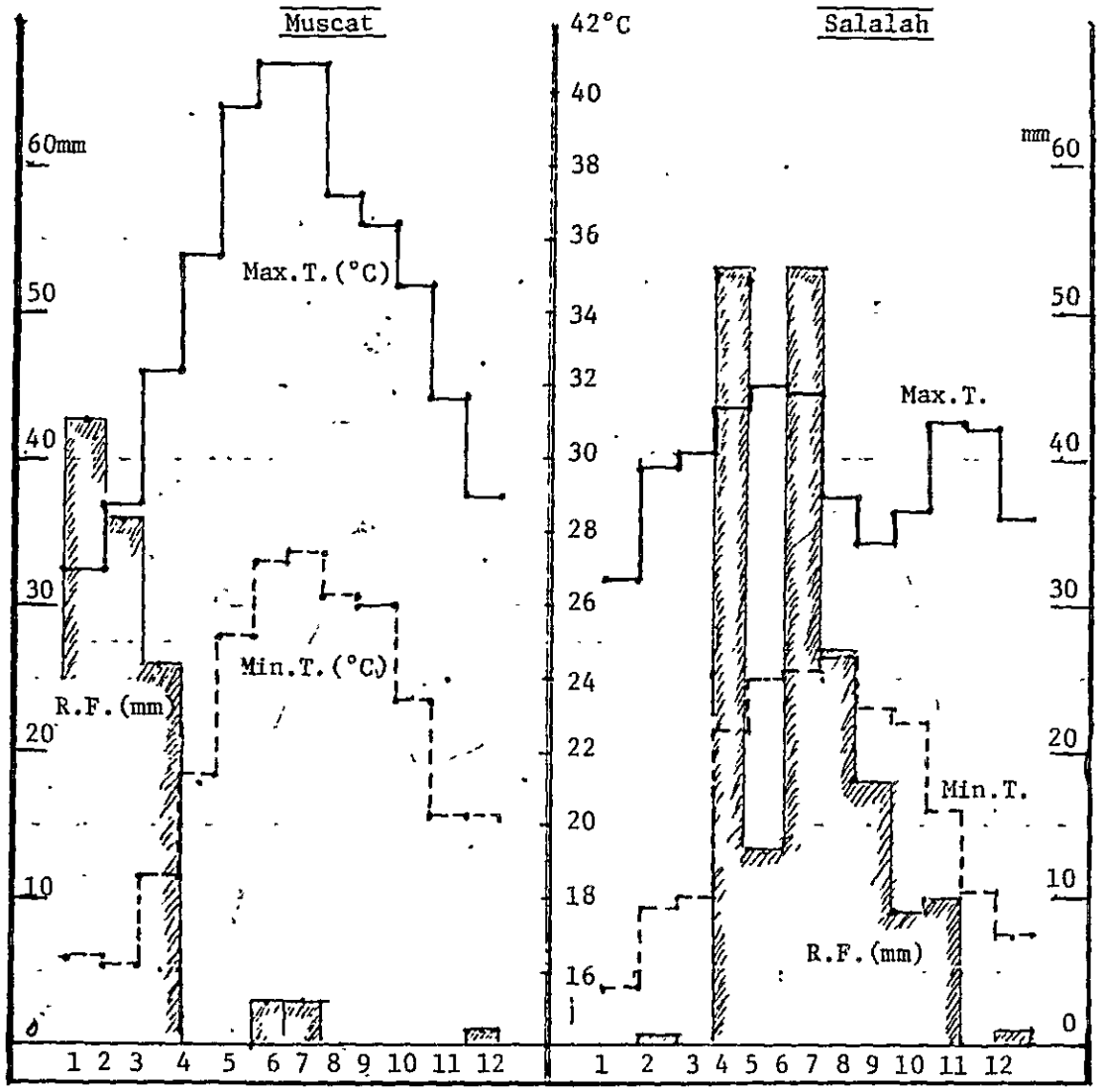
A maximum temperature over 40°C continues in the summer season of June to July in the northern area, and the daily fluctuation reaches 10-odd°C. The annual temperature fluctuation between the winter and summer is as severe as reaching almost 15°C (Fig. 2)

The daytime air temperature of the summer season in the southern district does not raise so much because of the cloudy weather, and it does not as much vary from that of the winter season as the northern areas. The climate can be said much moderate.

iii) Humidity

Unlike the neighboring desert land, Yemen, the Omani coasts has the relatively high humidity due to its oceans. The highest humidity is usually experienced in August where the temperature is rather lower than that of June where it is highest. Salalah is particularly higher in the humidity than Muscat.

The humidity over Muscat is similar to our Niigata Prefecture along the Japan Sea, as both have the equal trend of two peaks in a year. While Salalah is equal to our Kochi Prefecture having the same peak (in August), and the average humidity of a year is around 71% (Basic Data).




° Temperature averages from 1952 to 1961 & rainfall averages from 1976 to 1978 (Yearly fainfall averages = 153mm)

° Temperature averages from 19[illegible] to 1977 & rainfall averages from 1975 to 1977 (Yearly rainfall averages = 185mm)

Fig. 2 Maximum/Minimum Temperature Averages & Rainfall Averages

2) Geology

The lands of Oman are on the base of Precambrian bed and Paleozoic bed. Depending on the geology overlying on these beds, the Omani land can be grouped into the northern and southern groups. The northern group indicates the Oman Mountains and its surroundings where vastly developed are the sedimentary rocks and basic volcanic rocks of Mesozoic as well as sedimentary rocks of Quarternary. Widely distributed on the other hand in the southern district are mainly the limestones of Tertiary and other sedimentary rocks. The boundary of both groups is almost equal to the line linking Duqm and Lekkwair west of Ibra.

The Northern base is distributed over Musandam, Oman Mountains and Masira coast, and it is formed by the phyllites, schists, quartzites, limestones, conglomerates, sandstones and shales. Sedimented over the bed in a depth of several thousands meters are the sedimentary rocks of Mesozoic, represented by the Hawasina beds composed of cherts, sandstones, silts and shales. Still above those rocks are the Semail ophiolites formed by the Mesozoic basic volcanic rocks and superbasic rocks, which are unevenly overlapped. The Oman Mountains reaching from Musandam to Sur are mainly formed by these Mesozoic rocks; and the Tertiary limestones and marls are distributed over the east half of Oman Mountains from Muscat to Sur and the district extending from Qabil to Ibri.

Gravels, sands and silts generated from the aforementioned rocks are widely distributed over the Batina coastal plain, the interiors and Shargiya area, forming the main geology of Quarternary. It also forms the fluival and marine terraces, alluvial fans and wadis, the older of which are turned into lithosols by the carbonates. Thus gaps are narrowed. A wide Wahiba dune desert is developed southeast of Al Kamil.

The southern base is locally distributed east of Mirbat, and formed by gneiss and igneous rocks. Its Mesozoic bed is distributed in a small scale over the northwestern end of the base and north of Rakhyut. Most of the southern land is formed mainly by the Tertiary limestones, cretoceous, marls, etc., and the limestones distributed over the Salalah plain are inclined towards the sea and porous, thus developing caves in the order of multiple layers and making the

permeability quite excessive.

(3) Water Resource

Any country on the Arabian Peninsular lacks the rains, except Oman who is richest in the greens and whose agriculture dates back some 2,000 years.

Since the present King's accession to the throne in 1970, it is more deeply appreciated that the water resource is the most significant factor for Omani social and economical development to be successfully achieved. Every exertion has been taken since the last half of 1970s to the development of water resource, and the international bidding was under way for the 2nd seawater conversion plant during the survey team sojourn.

The supply of water resource by this seawater conversion plant may be used for a quite limited use such as the drinking water, and it may supply only a few percents of the nation's total demand even in the future. Nobody ever dares to doubt the importance of natural water such as the surface water or ground water brought by rains. The use of natural water is historically applied almost all to the irrigation except the Capital area, and it is incidentally used for the drinking water. The water resource for agricultural development should naturally be depend on the natural water in the sense of the volume of water required.

i) Rainness & Water Resource

Various changes are shown by the rainfalls over the northern Oman, Batina, interiors and Sharqiya, according to its topographical and meteorological conditions. The annual average rainfall is as small as 100 to 200mm, and the duration of each rain is about 6 hours. Each rainfall therefore has a considerable rain intensity, but such occurs generally several times a year (a maximum of 10 rains a year). The rains are characterized by the seasonal concentration, and the rainy seasons are in the winter and summer. The winter rains are wide in the range but low in the intensity, since they are brought by the cold

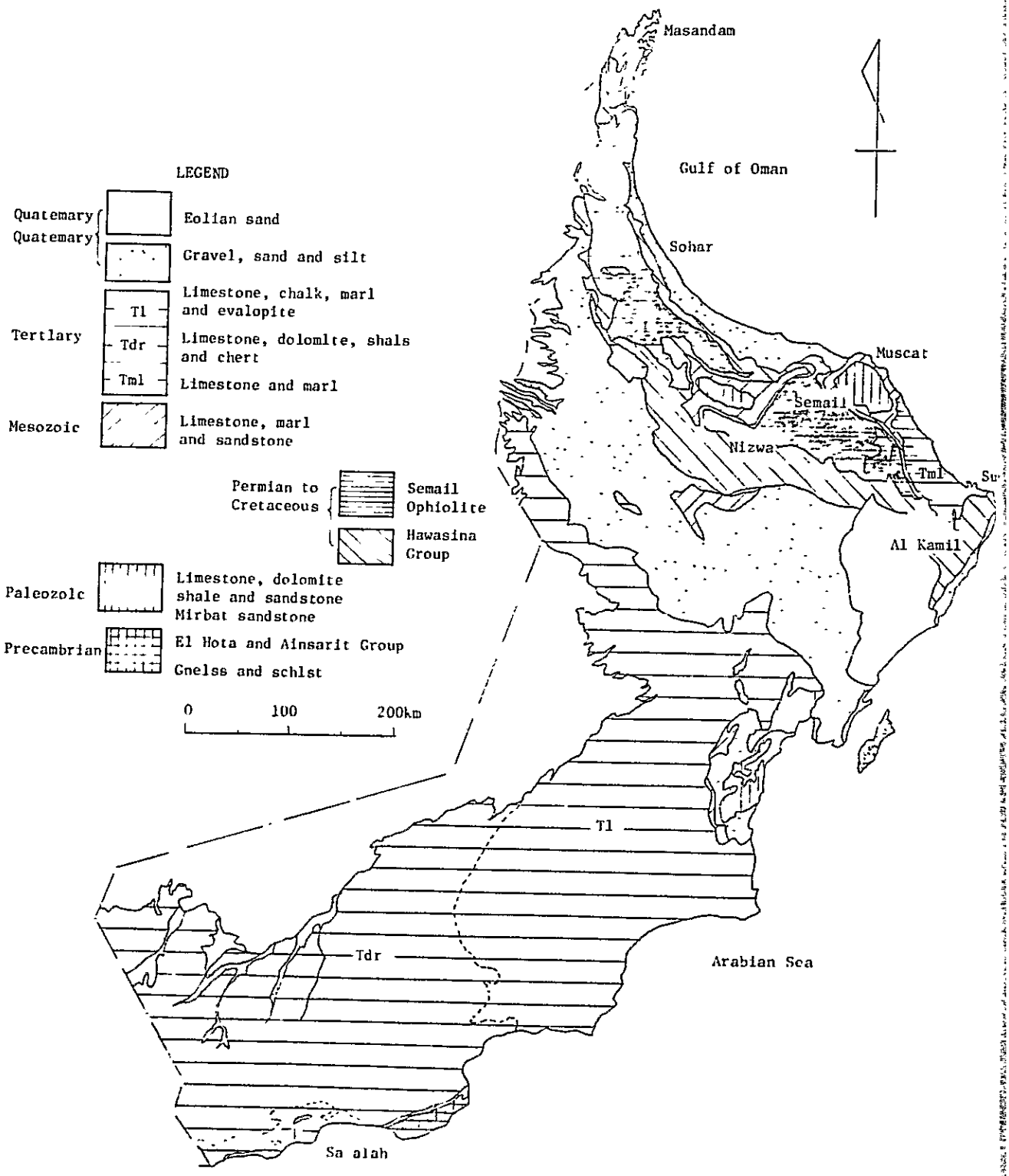



Fig. 3 Geologic Map of the Sultanate of Oman (after JICA, 1979)

front extending from the Mediterrainean Sea; its maximum intensity is 12 to 24 hours. The summer rains are intensive and local as brought by the shower clouds, which emerge over the southeast area of the mountains and from the mountains; the maximum is somewhat below the hourly intensity. The rains fall over the mountain sides, which are not yet mature in the soil formation, and over the plans. The overland flow, although some flows over a short period may cause floods, does not maintain any stable flow, and it cannot be used as a stable intake source. The rains turn into the ground water, only if they penetrate into cracks or gaps of the exposed rocks, or if they accumulate on the bottoms of valleys or within the sandy layers of plains; the flow characteristics show by far longer flow time than the overland flow.

Unlike the northern Oman the southern Dohar district receives the rains brought by the monsoons and typhoons. The southeast monsoons bring rains over about 2 months from the end of June to the beginning of September every year. The rainness is similar to the Japanese wetty rainly reason, and the total rainfall over 2 months is about 50mm in the plain Salalah and much smaller in the mountains, particularly its southeastern district. The rains brought by monsoons can be a stable water resource, as the origin is quite reliable. Another reason is that the rain intensity is low so that most of rains flow over the land; and such may help increase and develop the ground water.

The rains brought by typhoons occurs generally from April to May and October to November; if the country is located along their routes, it can be expected to have the rainfall of about 400mm. The frequency of typhoons is once or twice a year, and most of the rains flow over lands.

The efficiency of its use is therefore low and this kind of rans lack the wide coverage. Thus the main water resource should be provided by the ground water.

*1 According to the rainfall data of the mountaineous Rastaq, Saig and Nizwa from 1974 to 1978, the recurrence period of the rain intensity of 31mm/h is calculated to be 2 yeras; the rain intensity over the plans should be considerably lower than the above.

FAO "Short Period Rainfall Intensities in Oman Project, OMA/77/001 (Appendix A to Field Document No. 11).

ii) Rainfall & Groundwater to Argrarian Area

A research was made by P. M. Horn*[1] on the water income and outgo on the points extending from the mountain sides of 19 wadis in the Batina district to its plains (the basin area varies from 250km$^2$ to 1,615km$^2$; average 454km$^2$). According to his study, the groundwater recharge rate after rains is estimated from 9 to 15% with an average of 13%.

The water consumption per ha. by the main groundwater users, agriculture, is estimated to be an annual average of 0.6ℓ/s[*2], or it is equivalent to about 5.2mm a day (or 1,892mm a year). To irrigate an farm land of one hectare needs the rain of 14,554mm/ha (1,892÷0.13); it indicates the area with an annual average rainfall of 100mm needs an area about 145 times that of the farm land to collect the rains.

A statistics[*3] shows the areas of Omani coastal plains and mountain sides (sea level over 450mm) are 9,000km$^2$ and 45,000km$^2$ respectively. Presuming now the annual average rainfall over these two districts to be 100mm, the land of 37,000ha (54,000ha÷145) can be well irrigated, or its is close to the present agrarian area of the nation. For the Batina area, however, the water consumption is estimated as small as 0.42ℓ/sha[*4] based on which the above available land of 37,000ha will be increased to 53,000ha. It is generally known that the rainfall increases along with the higher sea level, and it is proven by the rainfall distribution map of Fig. 4. If an annual average rainfall of 200mm is presumed for the mountain sides, the cultivatable land should be 68,000ha, even based on the water consumption of 0.6ℓ/s/ha. Table 1 below summarizes the above assumptions.

Table 1 Agrarian Area & Water Resources

| Case | Rain Gathering Area | | Rainfall | | | Groundwater Volume | Water consumption | Agrarian Land Area |
|---|---|---|---|---|---|---|---|---|
| | Mountains km$^2$ | Plain km$^2$ | Mountains mm | Plains mm | Total MCM | MCM | ℓ/s/ha | ha |
| 1 | 45,000 | 9,000 | 100 | 100 | 5,400 | 702 | 0.60 | 37,000 |
| 2 | 45,000 | 9,000 | 100 | 100 | 5,400 | 702 | 0.42 | 53,000 |
| 3 | 45,000 | 9,000 | 200 | 100 | 9,900 | 1,287 | 0.60 | 68,000 |

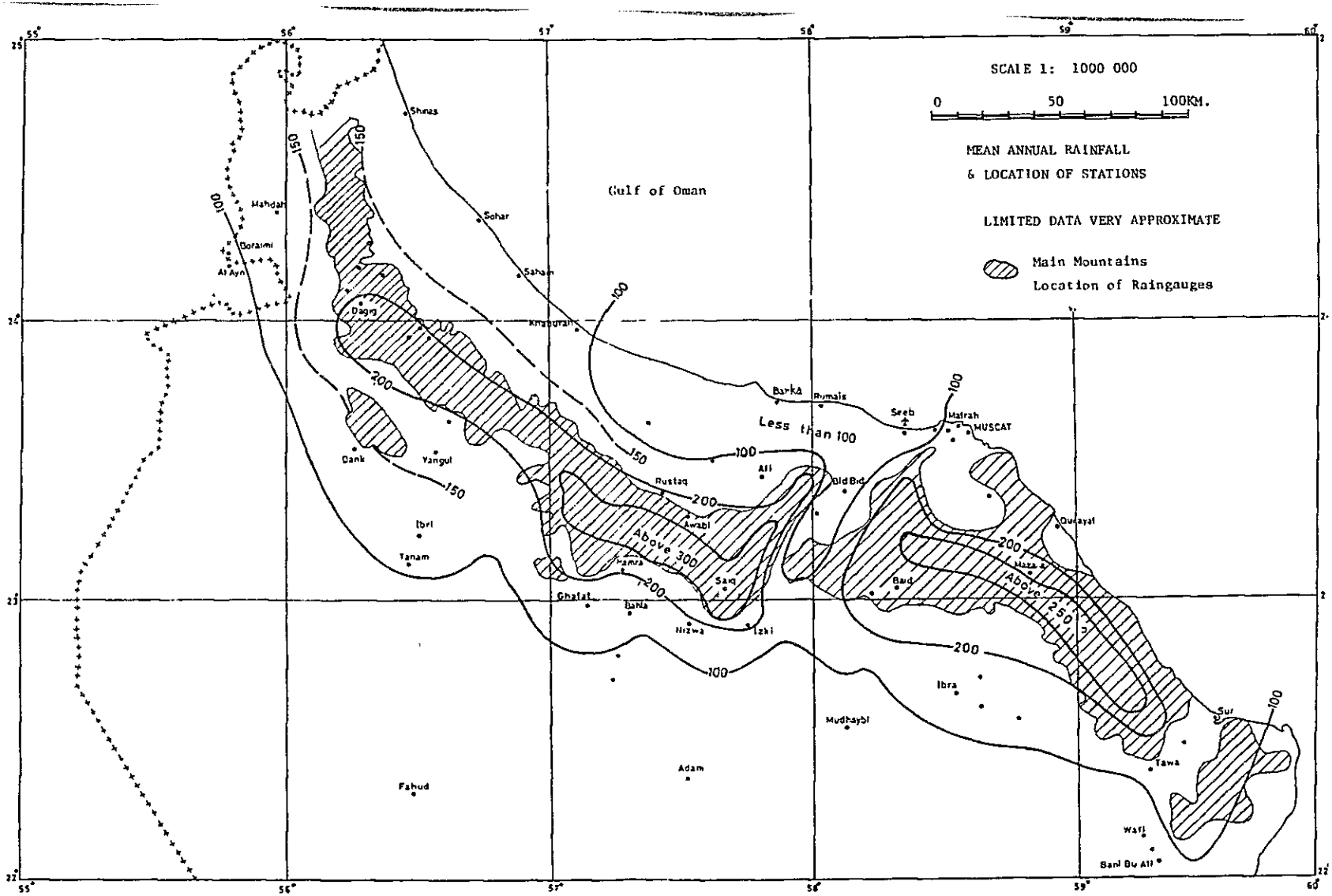



Fig. 4 Northerm Oman

*1. F. A. O., 1979 "Water Resources of the Batinan' M.M. Horn, Hydrologist, Project OMA/77/001 (Field Document No. 10)

*2. The water consumption of 0.6ℓ/s/ha is generally accepted by any agricultural development project, e.g.

F. A. O. May 1980 "Groundwater Development in the Kamil/Wafi District, Shargiya Region. Report On Phase I Study" Project OMA/77/001 (Field Document No. 15) P. 43

*3. Development Council, 'Sultanate of Oman' Statistical Year Book, 7th Issue, 1978 P. 3

*4. F. A. O. 'Development of the Water Resources in Oman for Agriculture' Project OMA/77/001 (Field Document No. 14) Jan. 1980, P. 5

265MCM/year÷365 day/year÷8640 sec/day÷20,000 ha=0.42ℓ/sec/ha.

*5. F. A. O. "Rainfall in Oman (1974-1978)
Project OMA/77/001 Fig. 1

2. History

As a marine nation, Oman is quite long in the world history. It emerged first in the ancient Sumer-accadian era (B.C. 3,000 to 1,750); The northern Oman in this era played an important role as a transit base linking Mesopotamia and Indus as well as the origin of copper and diorite. Over the Wadi Jizi basin, which was picked by the survey team as a site of the development, there remain the traces of the ancient copper mining and refining, and we can see a huge volume of refinery slags.

In the years of B.C. 100 circa, the southern Oman was properous with the transit port of perfumes (particularly the frankicense) as the perfume trade atrophied, entering into the Islamic era, Sohar of the nothern Oman was flouring as an international port. In the period of 9th to 10th centuries where Sohar was most properous, it was estimated that the neighboring farmlands were 3 to 4 times that of the present year; there were operated the irrigated agricultures by a small to large-scaled Falajs. These farm lands were abandones with the atrophy of Sohar, and now remain as a low-density shrubbery zone on both sides of the national highway.

Then Oman was formed into a power marine nation, and grew into such

an active trading country as extending over the East Africa and Indean Ocean in the 14th century. From 1507 when Muscat was occupied by Portugal, its land was kept under the domination of Portugal almost over 150 years.

Taking back Muscat in 1650 from Portugal, Oman started a steady step into the Eastern Indian Ocean, and with the advent of the present Bin Saeed dynasty in the middle of the 18th century, the existing land was almost established, and further the dynasty predominated Zinzibar and other eastern African coasts.

Oman who relied on the sailing boats had to slow down its activities because of the steamboat trade, which took over the Omani trade routes, after the Suez Canal was opened; the nation had no choice but to be under the protection of Britain, who was then expanding her power over the Arabian Gulf coasts.

Until 1970 Oman Closed her gates towards foreign nations other than Britain, U. S. A. and held its severe seclusion polocy. The former head took the traditional seclusion polocy against the foreign countries, and the extremely severe policies against his nation. Without turning to the development investment, the oil revenues started from 1967 have been kept inside, thus the national economy has stayed at a medieval level. Responding to the activities the Dofar liberation front intensified in the southern Oman, the present King Kaboos, who was educated in England, succeeded in bloodless court revolution in 1970, and initiated the modernization approach.

The people of Oman refer to this royal revolution in the term of "restart" rather than the revolution. After this restart, Oman has shown a remarkable growth within the last 10 years thanks to its steady oil production. In 1975 the subjugation over the southern districts was announced, and Oman is now one of the stablest Arabian nations, politically and socially.

3. Society

The statistical data of Omani population are all estimated values, for the national population census has never been conducted. As a postulate for planning the long-term projects and other policies, the Omani government employs the population of 1,500,000 while the World Bank presumes 800,000 as of 1978. Out of this population 34% are the

agriculture and fishery workers, and it indicates that the agriculture is still predominant in the Omani society.

The composition of population can be divided into the Omanis and foreign workers except about 30,000-odd Bedouins, who are nomads.

In line with the rapid national development after the so-called restart in 1970, scores of foreigners are flowing into this nation, either as simple workers or as engineers.

A survey based on the issued number of labor permits tells about 12,000 foreigners working in the government organizations (about 40% of all) and about 100,000 foreigners in the private firms. About 90% of those foreign workers are Indians and Pakistanis, both holding the mainstay of simple working force. Not only into the simple labors on the construction sites, but those emigrants are flowing into the agrarian zones from which the fundamental labors have reversely run into the urban areas; and these alternative labors become the factor to change the production structure in the agrarian districts. This phenomenon is more visible in the Batina area, which is the advanced agricultural district. On the other hand, certain effluence of labors from the interiors and Sharqiya districts into the urban districts is seen, yet the labor supply by foreigners seems not to have stepped up so deeply.

Besides those simple workers, most of the high-level engineers, who should be responsible for the project planning and implementation, regardless of the government or private firms, are foreigners, whose nationalities range from the European & Americans to the Near Eastern nationals, chiefly Egyptians and Lebaneses.

The intra-government staff organization is made up by Omanis, who hold the high-level administrators under the Group I (ministers and vice-ministers) and Group II (superintendents and vice-superintendents), except some of the privately-contracted advisory group to the chief executives. While about 60% of Group III (administrative workers) are held by foreigners, but the Group IV contains more Omanis than foreigners. The foreign dependency is quite notable in the high-level engineers group. The immigration of scores of Omanis was made in the seclusion years into the historically-linked Eastern Africa and India; as these overseas Omanis are educated with professional knowledge, they returned

home after the 1970 restart, and form the lower technical groups in the present Omani government and private firms.

Table 2 Governmental Staff Organization (%)

(As of the end of 1978)

| | Private contract | Group I | Group II | Group III | Group IV | Total |
|---|---|---|---|---|---|---|
| Omanis | 0 | 100 | 74 | 39 | 79 | 61 |
| Foreigners | 100 | 0 | 26 | 61 | 21 | 39 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

From: Statistical Year Book,
Sultanate of Oman, 1978

4. Economy

(1) Economy

In the seclusion years under the previous head the Omani economy was mostly maintained by the agriculture, but it turned to the petroleum-dependent since 1967, as the crude oil production started to grow. Then the products of its agriculture and fishery are showing a steady growth, yet the percentages of such outputs in the gross national product dropped abruptly from 15% in 1970 to 3% in 1978, reflecting the oil production.

From 1967 where the oil production started to 1976, the production was smoothly increasing, but a sign of drying-up appeared in the northern oil fields in 1977. The oil products then hit the ceiling, and at the present moment the crude oil production is estimated to be lower than the daily output of 300,000 barrel. The share of the petroleum and mining in which the former is predominant holds 56% (500 million rials) out of the GDP (gross domestic products) in the amount of 892.8 million rials of 1978, although the share is gradually dropping after 1974 (Table 3). Nonetheless active development efforts are being paid to the southern oil fields, and, when the preparation for practical operation is set up in a near future, it is estimated to keep up a stable daily production over 300,000 barrels.

Table 3 105 Gross Domestic Product, classified by Industrial Origin

Million Rials Omani

| Sector | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|---|---|---|---|---|
| Agriculture and Fisherics | 16.6 | 16.8 | 17.0 | 16.7 | 17.4 | 20.2 | 21.4 | 24.0 | 27.1 |
| Petroleum and minerals | 71.6 | 73.9 | 76.4 | 94.5 | 389.0 | 486.8 | 530.4 | 534.8 | 498.4 |
| Manufacturing | 0.2 | 0.2 | 0.3 | 0.6 | 2.0 | 2.1 | 4.0 | 8.3 | 11.2 |
| Construction | 10.6 | 20.4 | 22.6 | 24.0 | 58.0 | 70.8 | 83.0 | 84.2 | 85.3 |
| Transport and Communication | 0.7 | 2.1 | 3.2 | 4.4 | 12.3 | 23.5 | 25.5 | 28.2 | 33.2 |
| Electricity and water | 0.1 | 0.3 | 0.7 | 0.9 | 1.2 | 1.8 | 5.0 | 6.3 | 8.0 |
| Internal Trade | 1.6 | 2.8 | 3.8 | 8.3 | 27.2 | 38.5 | 50.3 | 65.5 | 72.2 |
| Banking | 0.6 | 0.7 | 0.8 | 0.9 | 3.5 | 9.8 | 11.2 | 13.3 | 14.5 |
| Ownership of dwellings | 1.5 | 2.1 | 2.5 | 2.9 | 4.8 | 9.3 | 13.8 | 18.3 | 21.8 |
| Public administration and defence | 2.3 | 4.1 | 11.0 | 13.1 | 46.4 | 53.0 | 71.0 | 83.4 | 105.9 |
| Other services | 1.0 | 1.7 | 2.5 | 3.1 | 6.7 | 8.4 | 11.4 | 13.8 | 15.2 |
| G.D.P. at market prices | 106.8 | 125.1 | 140.8 | 169.4 | 568.5 | 724.2 | 827.0 | 880.1 | 892.8 |
| Less: indirect taxes | -1.1 | -1.1 | -1.6 | -1.7 | -2.3 | -2.5 | -4.5 | -4.6 | -4.6 |
| G.D.P. at factor cost | 105.7 | 124.0 | 139.2 | 167.7 | 566.2 | 721.7 | 822.5 | 875.5 | 888.2 |

Note: The estimates relating to 1970 - 1974 are IBRD estimates. From 1975 the estimates are made by the Development Council, Oman. Hence the two series are not strictly comparable.

(2) Trade

The nation's crude oil export shares the large part of her total export volume, and in 1978 the oil export reached 521.8 million rials or 95% of her total export values.

Out of the said exported oil about 57% were shipped to Japan, and 16% to USA (Table 4). Japan is Oman's No. 1 importer. Oman does not belong to the Organization of Petroleum Exporting Countries (OPEC), and is one of a few oil producting countries who independently determine the oil exporting prices.

Except the crude oil other exporting goods are mostly agricultural and marine products, which totalled in 1978 to 3.3 million rials. The major export goods are dry limes for the United Arab Emirates, and other principal goods to be exported are dry dates and marine products.

The international balance of trade is excessively in black in the recent years thanks to the crude oil exports; yet the foodstuffs and most of the industrial products, including the construction facilities and materials for the national development projects, depend on the import.

While locally the nation has no modern oil refinary facilities, gasoline and other petroleum products are imported from the United Arab Emirates.

The amount of imported agricultural and marine products reached in 1978 54 million rials or 16% of the total import values. The imported products are mostly fruits and vegetables, and they are imported from the nearby Near Eastern and South Asian countries in the dry season where the vegetable breeding is hard to success. The next largest import is held by the staple foods, rices, cereals and dairy products. The export from Japan holds 15.5% of the total imports, ranking at the 3rd position, following Britain and United Arab Emirates; particularly 70 to 80% of the automobiles and household electric products are said to be imported from Japan.

Table 4 80. Directions of crude oil exports

Million Barrels

| Country | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|---|---|---|---|
| Japan | 35.9(33.8) | 43.7(42.3) | 38.0(35.5) | 37.5(35.4) | 46.8(37.5) | 58.2(43.3) | 62.7(51.4) | 65.8(56.9) |
| U. S. A. | - | 3.0( 2.9) | - | 3.2( 3.0) | 1.2( 1.0) | 21.2(15.8) | 18.8(15.4) | 18.3(15.8) |
| Notherlands | 12.2(11.5) | 4.8( 4.7) | 8.7( 8.1) | 1.9( 1.8) | 25.6(20.5) | 19.6(14.6) | 11.1( 9.1) | 7.3( 6.3) |
| Curacao | - | - | - | - | 4.1( 3.3) | 10.1( 7.5) | 11.1( 9.1) | 6.8( 5.9) |
| France | 10.7(10.1) | 15.4(14.9) | 18.6(17.4) | 12.7(12.0) | 8.6( 6.9) | 8.6( 6.4) | 4.7( 3.8) | 2.1( 1.8) |
| Canada | - | 2.2( 2.1) | 6.1( 5.7) | 12.4(11.7) | 4.8( 3.8) | 8.0( 6.0) | - | - |
| U. K. | 5.7( 5.4) | 3.7( 3.6) | 4.8( 4.5) | 5.7( 5.4) | 8.3( 6.6) | 1.7( 1.3) | 1.3( 1.1) | 0.8( 0.7) |
| Singapore | 5.2( 4.9) | 8.6( 8.3) | 6.8( 6.3) | 0.9( 0.9) | 7.4( 5.9) | 1.4( 1.0) | - | - |
| W. Germany | - | - | - | 0.6( 0.6) | 0.7( 0.6) | 1.6( 1.2) | 1.3( 1.0) | 2.8( 2.5) |
| Italy | - | - | - | 8.6( 8.1) | 0.6( 0.5) | 1.2( 0.9) | 1.3( 1.1) | 3.2( 2.8) |
| Sweeden | - | - | - | - | - | - | 4.1( 3.4) | 1.0( 0.8) |
| Norway | 9.4( 8.8) | 10.7(10.4) | 4.8( 4.5) | 3.2( 3.0) | 1.5( 1.2) | 0.6( 0.4) | 3.8( 3.1) | 7.5( 6.5) |
| Portugal | - | - | - | - | - | - | 2.1( 1.0) | - |
| Others | 27.2(25.5) | 11.1(10.8) | 19.1(18.0) | 19.1(18.1) | 15.2(12.2) | 2.1( 1.6) | 0.6( 0.5) | - |
| Total | 106.3(100.0) | 103.2(100.0) | 106.9(100.0) | 105.8(100.0) | 124.8(100.0) | 134.3(100.0) | 122.0(100.0) | 115.6(100.0) |

Note: Figures in parentheses are percentage of the total exports.

## III. AGRICULTURE IN OMAN

### 1. Current Agricultural Situation

#### 1) Agricultural Production

##### i) Agrarian Area

The nation's agrarian areas can be divided into the northern Oman extending over the both sides of Oman Mountains and the southern Oman centered at Salalah by the nation's metrological and geographical conditions. The sesear areas at the nation's center and along the Saudi Arabian boundary are used by the Bedouins in small scales for their nomad life, and mostly ignorable from the agricultural viewpoint. The northern Oman contains the Batina coastal area extending northward from Muscat thinly along the coastline, the interiors east of Oman Mountains and centered at Nizwa, the Boraimi area near the boundary with the United Arab Emirates and the Sharqiya area north of Wahida Desert.

The southern Oman can be split into the Salalah Plains centered at Salalah and its northern mountains.

##### ii) Products in Cultivation

An estimated total area of Oman's farm land is 36,000ha as of 1971, or about 40,000ha according to the interim report of the 1978 sampling survey. In any sense, farm lands shares only 0.1% of the total land area.

The dates palms are cultivated over 13,340ha or 37.1% of the total area (according to the 1971 estimate), and this basic agricultural product of Oman quite matches the nation's weather conditions. The Omanis therefore took the dates as their staple foods for long, either eating raw or after drying under sun. The dates were in the recent year took over by rices, which must be imported, and this fruit is now cultivated either for the side dishes or candies, and some are even exported to India, etc. Everywhere in the northern Oman we can see the dates, but quite rare in the southern Oman; the dates are generally cultivated at such a density as 150 to 200 trees per hectare, bringing out an output of 10 tons per featare. The modern dates process plants are installed in Rustaq and Nizwa, and operated by the government.

Table 5 Area under crops, 1971*

| Crops | Area under cultivation | |
|---|---|---|
| | Hectares | Percentage |
| Dates | 13340 | 37.1 |
| Luceme | 5560 | 15.4 |
| Limes | 3560 | 9.9 |
| Onions | 3680 | 10.2 |
| Wheat | 1200 | 3.3 |
| Tobacco | 1000 | 2.8 |
| Bananas | 880 | 2.4 |
| Mangoes | 380 | 1.1 |
| Coconuts | 200 | 0.6 |
| Others** | 6200 | 17.2 |
| Total | 36000 | 100.0 |

* Estimated.

** Includes chickpeas, sorghum, sweet potatoes and fallow land.

The working rate of these plants are by far below the processing capacities, and it is therefore necessary to shake up the product gathering system and to make contracts prior to the crops, thereby avoiding any risks to be caused by the unsteady natural condition as well as raising the working efficienty.

The dates palms not only brings fruits, but they also provide suitable shadows for vegetables cultivated under trees, and thus play an important role in the agriculture in the high temperature and dry lands, including Oman.

Lucerns (or alfalfas) are widely cultivated on the whole Oman land, and they are the most indispensable feed grains to supply the shortage of pastures. The 1971 estimate indicates the planting acreage of 5,560 ha next to the dates. Since it is possible to continue the crops nearly 10 years and the breeding does not take too much hands, the planted areas should brow in future, considering the labor shortage

in the agrarian districts. It, however, needs the promotion plans in conjunction with the stock raising development.

The lime is likewise cultivated in the whole Omani land. More are cultivated particularly in the mountain areas, and the inland Misfa area is famous for the lime production. Limes are mostly dried under the sun after crops, and shipped as the dry limes, which are widely used as the seasoning and which are the most important export product next to the oil.

The wheat cultivation is limited to the interiors around Nizwa, and the acreage is said to slightly exceed 1,000 ha with a crops of 2 to 3.5 tons per ha, which is however varying much with diseases. A surplus land is said to be available for expanding the acreage near Wadi Quriyat, but the time did not permit the survey team to visit there. Onions and other vegetables are cultivated nationwide mostly in the rain season, and some are exported. In the dry season aggplants, water melons and bumboos are cultivated in a small amount, and most of them are imported. And the need is estimated to upstep in future along the increasing urban population.

Bananas (small-type) are more cultivated in the southern Salalah neighbourhood, and the custom duty is imported to the imported bananas to promote the local production. While the acreage is rapidly growing, it is hard to say the cultivation technique and measures against diseases and insects are enough, and the yellowed leaves due to the lack of K and other troubles in the breeding are frequent y seen in various places. A process and packing plant is schedules to complete within 1980.

Coconuts in the southern district and grapefruits in the mountain sides are some of the fruit cultivations being processed.

Table 6 Acreage by Products of Crops

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Crops pen ha(ton) Oman A | Japan B | A/B % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Perennial | Dates | ● | — | — | — | — | — | — | — | — | — | — | ● | 10.0 | - | - |
| | Lime | ● | — | — | — | — | — | — | — | — | — | — | ● | 15.0 | - | - |
| | Mango | ● | — | — | — | — | — | — | — | — | — | — | ● | 20.0 | - | - |
| | Banana | ● | — | — | — | — | — | — | — | — | — | — | ● | 15.0 | - | - |
| | Alfhalpha | ● | — | — | — | — | — | — | — | — | — | — | ● | 90.0 | - | - |
| Annual | Wheat | ● | — | — | ● | | | | | | | ● | ● | 2∿3.5 | 3.6 | 76 |
| | Cotton | ● | — | — | — | — | ● | | | | | | | 2.5 | - | - |
| | Corns | ● | — | — | — | ● | | | | | | | | 3.5 | - | - |
| | Peanuts | | ● | — | — | — | ● | | | | | | | 3.0 | - | - |
| | Sunflower | ● | — | — | — | ● | | | | | | | | 1.5 | - | - |
| | Tomato | ● | — | — | ● | | | | | | | ● | ● | 30.0 | 53.4 | 56 |
| | Eggplant | ● | — | — | ● | | | | | | ● | — | ● | 20.0 | 30.5 | 66 |
| | Water Melon | | ● | — | — | — | ● | | | | | | | 20.0 | 33.9 | 59 |
| | Cucumber | | ● | — | — | — | ● | | | | | | | 10.0 | 42.1 | 24 |
| | Cabbage | ● | ● | | | | | | | | ● | — | ● | 25.0 | 36.2 | 69 |
| | Onion | ● | — | — | — | ● | | | | | | ● | ● | 15.0 | 36.9 | 41 |
| | Potato | ● | — | ● | | | | | | | | ● | ● | 15.0 | 27.8 | 54 |
| | Corns for feedling | ● | — | — | ● | | | | | | | | | 40.0 | 52.8 | 75 |

Note: Acreage is based on Batinah of Interiors,
Crops for Japan in 1978/1979.

iii) Agrarian Management

Any independent farm can obtain uncultivated lands at an extremely low price (or even free), when he wants to develop a new farm, by applying for the Ministry of Land. The major issue for the new development is how to secure the water resource, and any attempt to drill new wells in the Batina area or other advanced irrigation lands by wells should be first approved by the Ministry of Agriculture & Fishery (bureau of water resource irrigation). An average farming scale in the agricultural center like the Batina and Nizwa districts is around 1.0ha; a large-scale operation can be seen in Wadi Quriyat where each farm has an average of 30ha or more (by the 1975 sampling survey).

2) Soil

The world soil maps are prepared by American, Russian and other pedologists; yet their basic concepts of drawing the pedological maps vary with their nations and survey organizations, and it is hard to compare them evenly. The pedological map (1/16,000,000) prepared by Germany's Ganssen divides the pedological types of Oman into four groups; In the northern Oman it is divided into: i) the brown and red brown soil, ii) mountaineous dry forest soil, iii) dune soil (transitional soil) and iv) desert soil; In the southern Oman, i) desert soil and ii) dune soil only. This pedological map is classifying quite rough, and certain parts do not coincide with the soil types actually surveyed. For instance, the mountain soil found east of Salalah in the southern Oman is indicated as the desert soil.

The survey team failed to acquire the more minute pedrological maps of Oman, and it is presumed that any advanced soil surveys never were done to such an extent as the pedrological maps can be prepared. It is, however, expected that the land development project now under way includes the soil surveys at various places, and in a near future the new version of Omani pedological map is introduced.

This report, therefore, debriefs the soils by various agrarian areas based on the reports of regional pedological surveys, which were conducted previously by a number of consultants and FAO for the Omani land development. FAO names the major pedological types distributed over Oman as follows:

Yermosols (desert soil), Regosols (gravel soil), Lithosols (scoria soil), Fluvisols (alluvial soil), etc.

1) Southern Batina Region

This region is centered at Rumais where the national farmland, agricultural laboratory and seedling plant are set up. The soils are calcaric regosols and calcaric fluvisols; the survace soil is shallow, and its nature is coarse grains, containing gravels. Harmful lithosols are sometimes contained.

The soil fertility is generally low, and small in the content of organic substances and effective phosphor. The exchange capacity is as low as 5mg/100g while the carbonate is as high as 5%, and the permeability is fair.

The chloradization of uncultivated soil of this region may be overlooked, but the effect of soil salinity tends to appear, as the salinity of irrigation water is high if the irrigation is provided in the region. Considering good drainage of soil, the salinity can be easily removed from the irrigation water by desalting with low saline irrigation water. Since the bottom layer is composed of gravels, the resalinization by water rising through the capillaries is considered less.

Applying the FAO classification, the irrigated land falls into S3 or unsuitable; yet within the range of our survey, more lands available for agriculture seem to be distributed to certain extent if the gravels can be removed.

2) Northern Batina Region

This region is an agricultural areas around Sohar, and more emphasis is placed on this land by the Omani government for its agricultural development, and the Sohar Production Farm, Sohar Sun Farm, etc. are established here.

The soil distribution contains the haplic xerosols (dry soil) and calcaric fluvisols, both are based on the serpentinites.

The soil pH is high at 8.5, highly caricareous and contains substantial Mg. The organic substances and effective phosphor are quite small, showing the lack of zinc. The soil nature is mostly ranging fron the medium to fine grains.

The land classification of flat land falls into the rather suitable, S2, and the soil layer has the medium thickness. Yet the soils over wadis and fans have shallow surface soil, more likely to expose the gravels, and it falls into the classification, unsuitable S3. This region is close to the coast, and the sea level of suitable lands for agriculture is low at 50m only; the salinization by irrigation water should become an issue.

3) Dahira Region

This region is located northeast of Oman Mountains, and most are mountaineous soils. Buraimi, Ibri and other agrarian settlements are formed around the mountaineous oasis.

The soil is mostly calcic yermosols, and calcic regosols are distributed over a small area. The agricultural development being restricted by the capacity of water supply, the soil survey is not yet conducted nor any reports on farm land are available.

4) Interior Oman Region

The center of this region is Nizwa, and the soil survey around this town is now under way. The soil belongs to the calcic yermosols, and it may turn into the calcic xerosols when the land is irrigated; the calcic regosols are distributed sporadically.

The agricultural development here is being under taken in the Manah district with the water supply from the Khatum Falaj. The soil is of loam, and the nature is good; the soil layer is thick, and the land classification falls under the suitable Si. Depending on the way or irrigation, therefore, the effect of salinity may be given to the soil, and the lime accumulation layer appears in the depth around ±30 to 90cm.

5) Sharqiya Region

The center of the region's agriculture development is Al Kamil where an agricultural development project is under way. The soil north of Al Kamil is said to be the albic arenosols, and its topography has many undurations; the land is composed of coarse grain gravels but good in the internal drainage. The land classification is the unsuitable S3.

Yet the soil north of Al Kamil is the calcoric fluvisols, and the land classification of most suitable, Si can be estimated. This Si classification is attributable to the land being free of corrosions and much less in the saline troubles.

Then main soil of Wadi Quriyat is the brown calcarous soil with much advanced structure. The soil nature ranges from the loam to silty clayed loam; the saline accumulation may be caused by poor discharge of surface layers.

6) Dhofar Region

Salalah is the center of this region, and small suitable lands are available also at Jebel and Negd.

The soil of Salalah plain is of gravels, and bad soils are widely distributed, thus limiting reportedly the cultivatable lands to 1,300ha after certain agricultural land reformation by gravel removings.
The Garziz Farm is set up in the Salalah suburb as a large-scale farm where the dairy production is steadily operated. The soil is sandy soil, its pH is suitable, both the electric conductivity and exchange capacity are good. There are no needs for further improvement. Over the mountains (Jebel) and its wadi basin east of Salalah plain the well-structured silty clays and sandy clay soils are distributed. Over the skirts of Jebel on its moderate slope a number of high anthills are scattered, providing the good soil nature. The rainfall of 500 to 600mm is concentrated in July to September over the south slope of Jebel, and the soils washed by rain become acid, and the fertility thus high enough. Quiroon Heirithi Farm on the Jebel's breast, about 1000m above the sea level, is now conducting the tests of various fruits, cereals and pastures. The soil of this area is the mountaineous soil distributed with the silty clays. The surface layer is rich in the organic substances, and the fertility is relatively high.

The rainfall of Dohar is large as a whole, but it is quite uneven at locations. Thus its soil type varies quite much, ranging from the desert soil to the wet subtropical soil.

A summary of the local surveys of the pH, EC and soil nature of the soils sampled by our survey is shown in Table 7. Each of the sample soils does not show high pH or EC, but EC of the cultivated lands along

the coast appears rather high, and indicates a sign of the saline accumulation.

The soil salinity map os related to the soil of Batinah plain. Generally speaking, the soil of low level and coastal land is high in the salinity, and the regions 50m or lower above the sea level should be considered with the desalinization with irrigation water.

According to the FAO report on the acreage of lands suitable for Omani agricultural development, the lands under the agrarian aptitude Class 1 to 3 of the land classification (US Exploitation Bureau standard) are estimated with 55,000ha in the Batinah region, 15,500ha in the interiors, and 3,500ha in the Sharqiya region.

Another Omani data indicates the class 1 land by the land classification as shown in Table 8. More definite and detailed data can be attained in the process of future soil surveys.

Source:
F. A. O. of the United Nations:
Development of New Land for Irrigated Agriculture, Soil Consultant's Report, July - November, 1977.

Table 7 Oman's Pedological Characteristics
(local survey)

* 1:5 suspension

| | Location | PH* | ECmv/cm | Composition | Sampled form |
|---|---|---|---|---|---|
| Batinah and Interior | Rumais | 8.6 | 0.72 | Sandy loam | Agricultural Laboratory |
| | Sohar | 8.0 | 1.70 | Sandy clay loam | Farm |
| | Sun Farm | 8.5 | 0.46 | Loamy sand | Corn farm |
| | Barka | 8.6 | 0.46 | Clay loam | Coastal banana farm |
| | Dahira | 8.3 | 0.47 | Stylty loam | Nizwa |
| Dhofar | Taqa | 7.8 | 2.50 | Loamy sand | |
| | An Garziz | 8.4 | 0.31 | Silty loam | Hill at Ant |
| | Salalah | 8.7 | 0.41 | Sandy loam | Near Salalah |
| | Quiroon Heirithi Farm | 8.4 | 0.31 | Clay loam | |
| | Garziz Farm | 8.2 | 1.04 | Loamy sand | Corn farm |

Table 8 Cultivatable Acreage by Regions

| Location | Cultivated | Cultivable | Equivalent to flat land | Remarks |
|---|---|---|---|---|
| North Batina | 6,580 | 2,100 | 1,050 | |
| South Batina | 8,480 | 3,150 | 1,050 | |
| Dahira | 8,190 | 1,050 | - | By falaj |
| Interior | 6,470 | 1,050 | - | " |
| Sharqiya | 11,040 | 2,100 | 1,680 | |
| Dohar | 3,030 | 735 | 735 | |
| Total | 43,790 | 10,185 | 4,515 | |

Note: Acreage of cultivatable lands are those falling under Class 1 of Suitable land

Table 9 Fertilizers distributed by Extension to Private Farmers (1978)

Unit: Ton

| Agriculture Region | Ammonium Sulphate (21% - N) | Complex Fertilizers (N:P:K 15:15:15%) | Super Phosphate Calcium |
|---|---|---|---|
| North Batinah | 256.0 | 365.0 | 112.1 |
| South Batinah | 98.3 | 241.2 | 7.7 |
| Oman Interior | 184.7 | 287.5 | 6.9 |
| Dahira | 48.2 | 167.2 | 2.2 |
| Sharqiya | 116.7 | 244.4 | 2.6 |
| Janubiya | - | 25.9 | 1.4 |
| Musandam | 0.3 | 1.6 | - |
| Capital Area | 12.4 | 23.9 | - |
| Total | 716.6 | 1,256.7 | 132.9 |

3) Irrigation

As near as 100% of the use of natural water are held by the agricultural water in Oman. The natural water is mostly supplied by the ground water, which is taken in various forms depending on the district concerned. In the Batina coastal area all the irrigation is supplied by wells, and they are the artesian shallow wells (20m or less) in the traditional farms while the bore-holed deep wells are used by the large-scaled corporate forms, which are growing in the recent 10 years. In the districts over the mountains or over its skirts even in the same Batina region (e.g. Ar Rustaq), the ground water is located near the farms, and has a relative throw so that the Falaj systems are more effectively utilized. The interiors use the Falajs, but the pump system is currently diffusing in this area; the same system is also applied by the Sharqiya district. In the Salalah plain in the Dohar region the groundwater is taken by wells except some that uses the waterway from the mountaineous spring water.

The Omani history of irrigation started with the manual or animal scoop-up from the shallow wells, and gradually changed from the last half of 1960s to the dieselengine driven pumps. Even the Falaj district are developing the wells and expanding the farm lands, since the pumps are relatively economic, and the labor is short. The Omani government subsidized the purchase of diesel pumps, starting from 1975, and the diesel engines were diffused in the nationwide farms from 1979 to 1980 at the pace of 400 to 600 units per year. It does not only indicate the government is promoting the change from the Falaj system to the pump system, but the Omani government has drawn up the plans to render the technical assistance and financial aids to the maintenance and repairs of Falajs; this project has been undertaken in 20 to 25 settlements over the years from 1979 to 1980.

The irrigation system, either the Falaj or the pump-up system, generally leads the water into the farm through the lining-less soil ducts, and sprays water over the farms with ridges; it is a sort of the basin irrigation. This irrigation system applies to the 20 to 50$m^2$ oblong farm land in a quite small sector.

The frequency of irrigation is generally once for 7 days in the summer and 7 to 15 days in the winter season; the total irrigation

efficiency is said to be 45%, including the losses in the transmission and distribution. Comparing with the recent level of irrigation technique having an efficiency over 70%, it is considered certain improvement (e.g. the lining of water ducts within the farm land) can be achieved.

The water consumption, as the basis of irrigation, is generally estimated to be 0.6ℓ/s/ha; the irrigation is conducted in the large-scale farms (e.g. Oman Sun Farm) by controlling the water content in soils according to the type of soil and the breeding condition. In the government farms and private enterprise farms an efficient irrigation technique of the bore-holed deep wells (it prevents an excessive lowering of groundwater level by continued operation and the pump-up operation almost needs not be stopped) is used, and the labor-saving drip irrigation, spinkler irrigation or various types of the automatic apraying systems (center pivots, dolfin or side roll) are employed to bring out an excellent result. In the local agricultural laboratores studies are conducted to determine the required water amount fro crops, and to test and evaluate various kinds of irrigation technique; the intermittent irrigation is already installed for sol gum of wheat and feedlings, and experimental drip irrigations are also started for oranges.

The crops of this nation consist of the annual fruits, as dates and lime, and the perennial crop of alphalphas in general; the study on the amount of irrigation water and the irrigation system for each crop is quite significant for the nation's water consumption, and it is expected to come up with good results.

2. Position of Agriculture in Long-Term Project

The Omani government has proceeded its national buil-up since the 1970 restart, particularly for the reorganization of its social basis. The 1st 5-year plan (1976 to 1980) was enacted from 1976, and under this project an overall national development effort has been exerted mainly by the National Development Council.

Over 5 years from 1970 to 1975, the roads, ports, airports, communication facilities and other fundamental social and economic basis were reorganized; and from 1976 the Omani government proceeded with the promotion of economical activities, including the commerce and industry, in parallel with the shake-up of social infrastructure. The progress of implementation of these projects is highly appreciated by various international aid organizations and those in charge of foreign aids of various countries as quite sound and steady-going. The 1st 5-year plan principally aims at the economic diversification through efficient uses of non-oil resources from the oil-dependent economy; and agriculture in particular is ranked high with the mining and fishery.

Included in this 5-year project is the agricultural project, most of which have been implemented. The Oman Sun Farm and Sharqiya projects in Sohar and Salalah to which the survey team visited are among the proposed operations. For the moment, the agriculture has grown up, and gained an increase of 18.8% above the project target for the 1975 basic year.

The 2nd 5-year plan is under way to start from 1986, and in this project the agriculture and fishery are allocated with 35 million rials against the agriculture, 40 millions for the water resource and irrigation, and 25 millions against the fishery, totalling to 100 million rials. More substantial plans were under way shile the survey team stayed in the nation. The fishery plan has been drafted by the FAO consultants, and those for agriculture, water resource and irrigation were pending for the final report from an American consultant (Arther D. Little International Co.), which would be presented to the National Development Council.

The basic policy of agricultural development, as considered in planning the 2nd 5-year project, involved the up-bringing of private farmers, prevention of agricultural population from emigration into the

urban districts and promotion of their settlement in the farms, aids to the study and diffusion and promotion of agricultural machines and fertilizers by the government subsidies. Together with the large-scale water resource development, an emphasis is placed on the reformation of the existing Falajs in the project of water resource and irrigation.

3. Test, Research & Diffusion

The approach to further development of Omani agriculture may be found in the upgrading of land productivity of the present farmers, or in the improvement of production through the expansion of lands by new farm development. The latter land expansion largely depends on the water supply through the water resource development while the former relies on the advanced agricultural techniques and their diffusion into private farmers, and it further requires to reinforce the agricultural promotion plans from the agricultural administration.

The development of agricultural techniques can be slowly achieved through a number of individual tests and researchs on the breedings, fertilization, control, prevention and extermination of diseases and insects, all of which must be suitable for individual climate of region concerned.

Some may be well achieved by foreign agricultural techniques, but it is more important, since the agriculture is a production activity largely dependent on the natural environment, to upbring the agricultural techniques that are rooted in the independent regional environment.

The Omani government has made every exertion to assist and promote the tests and researches of agricultural techniques every year, yet more efforts are required to reinforce and extend the test and research institutions in future, considering the nation's agriculture development, which faces severe weather conditions and poor land conditions.

A total of 45 agricultural research stations are located in Oman, viz, at Rumais, Wadi Quriyat and Salalah, including and animal husbandry station. In July 1970 these agricultural research stations were set up at the instruction of M. M. The Sultan Kaboos.

The Rumais station started in 1971, containing the research centers of vegetables and fruits within the premise of 12.5ha, and the test rooms were also set up for the soil, water and plant protection. As the station

has just started, it seems that the research facilities are not sufficiently provided, the research workers are few and the station itself is still in the process. The test is fairly organized, but the setup of indoor observation and measurement instruments should be re-considered. The Wadi Quriyat station started in 1971, and it is expected to develop as the center of wheat breeding in the nation's interiors. The rate of self-supply of wheat is rather low, and the Omani government is planning to expand the acreage; but this plan is prevented by a large bottleneck as the crops are not much expecting excepting except the high level interiors. The wheat is said to be not suitable for any land under a mean temperature of 18°C or higher, and it seems difficult to breed wheat on such a high temperature region as Batina plain. For future production it must be considered to study the wehat troubles caused by high temperature and to promote the reformation of wheat kind, thus improving its productivity. The test and guide of fruit plantation are carried out by the fruit research station at Saiq of Jebel Akhdar. The agricultural research station at Garzaiz of Salalah mainly works on the study of fruits, vegetables and cereals. It sets up the laboratory of soil, water and plant protection, which will start the operation from 1980. The Salalah district in particular has a relatively large rainfall, and the prevention and extermination of diseases and insects are its important research items; the test and research of storage of agricultural products, particularly bananas, are likewise promising.

On the mountain sides of Dhofar the plantation of crops suitable for high level location is undertaken by the Qairoon Haith Station; this location has a large rainfall and the prevention and extermination of diseases and insects are its important research items; the test and research of storage of agricultural products, particularly bananas, are likewise promising.

On the mountain sides of Dhofar the plantation of crops suitable for high level location is undertaken by the Qairoon Haith Station; this location has a large rainfall from July to September, and good results have been attained from the non-irrigation breeding of wheat. To summarize the major research themes of these agricultural research station.

① Selection and introcution of crops suitable for the Omani climate.
② Efficient use of irrigation water for major crops,
③ Establishment of prevention and extermination techniques of diseases and insects on crops,
④ Setup of soil reformation and fertilizing techniques for improvement of land productivity

To upgrade the cultivation techniques of private farmers, the Omani government has set up the extensive centers or like facilities in the nation; there are four facilities now available for promotion and guide of agricultural techniques:

① Nine production farms, nationwide
② Two extension farms, nationwide
③ Thirtyfive extension centers/sub-centers, nationwide
④ Four nursery gardens, nationwide

The above nationwide facilities conduct the model plannation of major crops for each district concerned, and they are well managed. Most of the Omani agricultural workers are said to be hired on daily basis; to prevent their retirement from the farming, it is an urgent issue how to improve the agricultural productivity.

The extension centers in particular are active in the distribution of improved seeds, farming service by tractors, and diffusion of prevention of diseases and insects as well as the fertilization. Table 9 shows the amount of fertilizers distributed by the extension centers to the farmers; the amount of fertilizers used is quite low, and its is hoped to advance the diffusion of the fertilization technique.

Two animal husbanding station are installed, and as the rate of self-supply of dairy products and meats is so low that an increased production of livestock products is urged. The Dhofar district in particular has a considerable rainfall after monsoons, and the plantation of fodders and breeding of milch cows and beef cattles are being carried out. The grazing of milch cows is seen along the Salalah coast, and the Garziz Farm has succeeded in the large-scale planation of fodders and breeding of milch cows. Another grazing of beef cattles is seen on the mountains where the stock raising is operated quite in contrast

to the grazing of sheep in the northern Oman. In the Sun Farm of the northern Batina the production of fodders and breeding of milch cows are getting into gear.

The Omani stock raising is considered to be a sheep grazing by the Bedouins as a traditional form, yet the government has taken up serious measures to promote the form of stock raising management in conjunction with the dairy farming and poultry farming.

Judging from the present level of Omani stock raising, however, we cannot be too optimistic to see a rapid growth. It is said there are a few veternitians in Oman, and it is far from providing proper measures to take care of the cattle diseases. There are more technical issues to be solved before promoting the Oman's future stock raisings, such as the introduction of various kinds of grasses to self-sustain the fodders, improvement of good milch cows, reorganization of slaughterhouses and meat freezing facilities. The husbandry station is not only expected to solve the technical problems as mentioned above, but it also is assigned to the upgrading of farmer's technical levels.

## IV. HISTORY & ORIENTATION OF WATER RESOURCE DEVELOPMENT

### 1. Falaj

No one can talk about the water resource development in Oman by overlooking the Falaj. It originally means "a system to distribute water to the persons who have the water rights". Generally it indicates now the channel system to draw water from the water source for irrigation (including the drinking water for public). The water sources of Falajs occasionally include the springs and surface water, but mostly they are groundwater. An example of spring source the survey team has seen is located in the mountaineous settlement, Misfar, on the Jabel Akhdar Mountains north of Al Hamra. The Ayn Sahalnawt spring water development*1, which has been conducted to develop the Salalah Plains, is one of this type of water source.

Fig. 5 shows the model falaj of groundwater intake type.

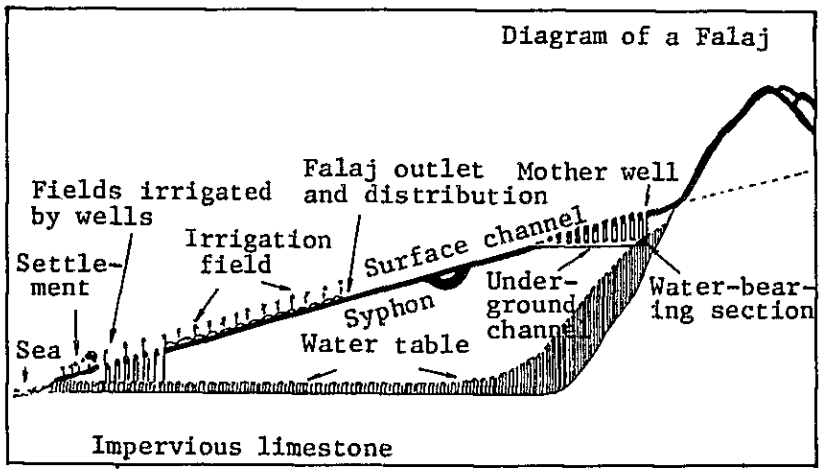



Fig. 5 Ministry of Information, 'The Oman Museum' Handbook for Visitors

Compared with the irrigated farmland, this type gathers water at much higher legel point, and lead it to the surface through the underground channels, and finally distributes to the farm lands of its final consumption points. In certain cases the inverted syphones and aqueduct bridges may be provided to cross over the wadis. A small-size aqueduct bridge is noted by the survey team on the trip. The catchment duct at the water source is provided in the sandy gravel layers of a wadi basin, but it is hard to discriminate the catchment ducts and the underground tunnels. The latter is formed in such a way, regardless of it being a catchment duct or a driving tunnel, that the shafts are digged in an appropriate intervals, and the lateral channels are then digged from the bottom of the shaft, and finally the lateral channels are interconnected. The shaft remains for the maintenance and repair until after the tunnel is completed (either the levee or a concrete cofferdam is provided to arrest sands around the shaft in a wadi basin). The spacing of shafts is 20 to 50m, and its depth is about 10m or occasionally it reaches 30m deep.

It is imagined a huge amount of expenses and high-level civil engineering techniques were required to dig up the ground and surface water ducts so deep in the wadi basin and construct the channels in some occasion by boring hard rocks. The Falaj is not a public property, but it is a private asset belonging to a particular person; the water rights are allocated according to the amount of investment on the construction.

The use of Falaj is separated into the public use and private use, and in the latter case the water rights are applied. Accordingly, the water rights is defined to be a right to freely dispose of the total flow of a particular Falaj for certain hours a day. An average hourly unit is 30 minutes every 8 days. The privileged person irrigates his land during this time, and in certain occasion he can sell the water right to any who does not have it.

Generally the privileged person makes his income by selling his allocated time partially or wholly, and maintain the Falaj by this income.

As suggested by the existence of public hours, the whole community along the Falaj receives benefits, although it is a private property,

and the Falaj is in a sense one of the social presence.

The Falaj at Al Kamir of Shargiya the survey team has observed specifies the intake point for drinking water, the laundry point and those for funeral and other ceremonies.

Around the Falaj there are various rules prescribed for the community, and it is easy to anticipate its stand in the community. The present's most difficult problem of Falaj is how to maintain and repair, partially for the labor shortage due to the emigration of agricultural population, leaving only a few technicians for maintenance and repairs, and partially because the privileged persons tend neglect their duty of Falaj maintenance and repair. The present decrease of Falajs from the old record of 10,000 can be accounted for by the variation of groundwater.

Worrying about such a phenomenon, the Omani government started a program to give the technical guidance and financial aids to the repairs.

The water right of each Falaj is considered from the viewpoint of an efficient use of the water resource to be a system more likely to cause the irrigation either excessive or wanting. In other words, the volume of water available changes with each year and each season, and it does not guarantee the said amount coincides with the required amount for crops, although the irrigation water can be secured for certain hour to particular farm lands. Use of auxiliary wells is already achieved in certain regions, but it is only effective for scarce irrigation; and it still leaves the excessive irrigations unsolved, which may cause the damages of overdamping.

* 1 Refer to IV. 3, Summary of Water Resource Survey

2. Well

By closing observing Fig. 5, we can find a farm land irrigated by well at its left side. The invention of wells should naturally preceed the development of Falaj, but it is not for sure whether the Falaj has been developed in advance of the wells for irrigation use. Considering the pump-up efficiency and cost of well, it is not hard to imagine that the irrigation from wells a few meters deep by men or animals would be quite hard, and particularly in the summer time the work to scoop up water should be quite laborious.

The irrigation is still supplied fully from the shallow wells (in some cases as deep as 10m or more, although) in the Batina coastal agricultural district, and the number of those wells are said to be over 10,000 from Seeb to Shinas. The trace of a well, which the survey team observed at Wadi Jizi, proves that once water was drawn by Falajs into wells, and the irrigation was done by the rizing well.*1 It is, however, not clearly known for what reasons the Falaj was changed to the well and when it took place.

The existing hand-bored wells are equipped with the diesel centrifugal pumps or the suction heads, and for large wells the pumps are installed far deep, and water is pumped up to the ground. The pumps have been rapidly diffused after 1960s, and the amount of water suction is thus increased more voluminously and quickly from the animal scoop-up years.

The well development is being diffused not only in the Batina coastal district, but also into the Interiors and Shargiya district where most of the irrigations have been supplied by the Falaj. Hence the rate of irrigation by wells there is rapidly going up, and proportionately the dependency on Falaj is decreasing (the new wells are to be constructed either to supply water into the Falaj or to develop a new far land). The above fact may be attributed to the well being self-perfecting, large in the degree of freedom, and being subsidized*2 for its pump purchase as well as relatively cheap for the agricultural economy.

Besides the traditional hand-bored wells, the machine-bored wells are diffusing for the urban water supply and for the irrigations in

the farm lands, which substantially exceed the traditional scale of Omani agriculture (an average acreage of 1 ha or less), in line with the large development projects for past 10 years. Generally this type of well is planned and developed after the available water amount of well and the required number of wells are theoretically estimated based on the pumping tests. The depth of groundwater suitable for well is generally up to 100m, and it is the groundwater which forms part of hydrological cycling.

The Public Authority of Water Resources, which was set up in December 1979, *3 starts the survey work to locate the water mining or the groundwater with an extremely low recharge, and already prepares for the operation of wells as deep as 100m, which is expected to start in a near future.

The malign phenomena of the present wells are the penetration of salt water and rise of saline concentration caused by the excessive pump-up in the Batina coastal district and Salalah area. The resultant drop of agricultural productions and the destruction of farm lands by the excessive residual salinity are another problems. Around Sohar, Saham, Al Khaburah and Seeb in particular, there are certain spots with the electric conductivity of wells reaching 17,000MM/cm (1975 data), and they are considered the negative-balanced areas. *4

The Interiors have enough water at present, including Shargiya, but it is worried that the water rights of Falajs may be infringed by the drop of groundwater level, which may be well caused by the diffusion of wells there. The bore-holed wells are installed apart from the shallow wells, and they pump up the different water sources. The interferences between the shallow and bore-holed wells in the Batina and Salalah districts are more likely to deteriorate both the shallow well capacity and the quality of water, since both districts are concentrated with large-scaled developments.

*1 In the 9th to 10th centuries it is said there were the farmlands, which were about 3 to 4 times larger than the present farmlands (14,500ha), and they were irrigated mainly by the falajs and partially by the shallow wells. The then falajs are confirmed at about 20 places.

Data form: Wilkinson, J.C. (1977) Water and Tribal Settlement in South-East Arabia
A study of the Aflag in Daman, Oxford

*2 The pump facilities are offered to the private farmers with the loans after 1975, and the number of pumps installed adds up to 971* for the period of 1975 to 1978, and in 1979 it is said to be about 500 pumps. The pumps are mostly the centrifugal diesel pumps with the capacity of 5 to 6HP, the diameter of 4", and the suction capacity of 7,000 gal/hour (head:22'). The pumps are now given free of charge.

* ... Development Council, "Sultanate of Oman", Statistical Year Book, 7th issue, 1978, p77.

3. Summary of Water Resource Survey

Prior to its 1st 5-year plan, the Omani government conducted on the available amount of water and lands. It was the nation's first survey of this kind, and it covered mainly the northern Oman and Salalah in the south. The survey was intended to gather the basic data of weather, hydrology, pedology, soils and other fields as well as to make the primary estimation of the water resources and available land areas for development. It did not help plan any substantial development projects, yet it contributes to the later surveys for development projects, such as the weather and hydrological observations currently conducted by the Ministry of Agriculture & Fishery, which is founded by this initial survey. The survey area of Northern Oman is divided into three parts, the northwest (Sohar, Buraimi, etc.), the center (Barka, Nizwa, etc.) and the southeast (Muscat, including Salalah independently, Ibra, Suru, etc.); and these areas were surveyed independently by four consulting firms, ILACO[*1], GIBB[*2], REMARDET[*3] and HALCROW[*4].

The groundwater surveys were conducted after 1975, and mainly the feasibility of well development and the characteristics of the groundwater zones, which were made at Jebel Al Qura[*5], Buraimi[*6], Negd[*7], Sohar-Saham[*8], Sharquiya[*9] and the Capital area[*10] (Wadi Al Khaud). The similar surveys on the quality of groundwater were performed in the Batina

coastal[*11] district and the Salalah plains[*12] mainly to check the saline problems.

The feasibility studies were also conducted in the last half of 1970s in several basins; some are already completed like the project[*13] of drawing water from Ayn Sahalnaut, one of four large spring water sources on the foot of Jabal Al Qara Mountains. Most of the projects were, however, suspended after the local surveys, as seen in the cases of Wadis Daygah[*14], Al Khawd/Samail[*15] (groundwater recharge) or Far[*16] (flood control), without being even implemented. One of the inhibitive factors is the fact that the accuracy of any feasibility study becomes inevitably low, for the basic hydrological data are insufficient for starting up a large-scale water resource development.


*1 ILACO (1975) 'Water Resources Development Project, Northern Oman', Final Report.

*2 GIBB (1975) 'Water Resources Survey of Northern Oman' Draft Final Report on Phase I Soil & Agriculture Studies with an Interim Water Resources Assessment.
GIBB: Sir Alexander GIBB and Partners.

*3 RENARDET SAUTI ICE, (1975) 'Water Resources Survey in North-East Oman', Interim Report.

*4 HALCROW (1975) 'Survey and Investigations for Land & Water Resources Development in Dhofar', Main Report
HALCROW: Wilcrowand Partners.

*5 TETRA TECH INTERNATIONAL INC. (1978) 'Ground Water System of Jebel Al Qura & Its Relation of Ground Water in Adjacent Salalah Coastal Plain and Negel'.

*6 Public Authority for Water Resources (1989) 'Buraimi Area Ground Water Resources Appraisal'.

*7 HALCROW, (1977) 'Jebel and Negel Summary Test Pumping'.

*8 International Research Institute (1978) 'Draft of Preliminary Report, Sohar-Saham Well Drilling and Pump Installation Study'.

*9 FAO, (1980) 'Ground Water Development in the Kamil/Wafi District, Shargiya Region'
Project OMA/77/001 (Field Document No. 15)

*10 Sir MacDonald and Partners, (1980) 'Capital Area Well Field Refurbishing - Al Khawd Wellfield'.

*11 Tetra Tech International Inc., (1978) 'Ground Water Salinity Survey of Southeast Batinah Coastal Plain'.

*12 Tetra Tech International Inc., (1978) 'Effect of Ground Water Use on Quality and Availability in Salalah Coastal Plain'.

*13 Development Consultants LTD, (1977) 'Irrigation Water from Sahalnaut'.

*14 Sir MacDonald and Partners, (1979) 'Wadi Daygah Feasibility Study'.

*15 Public Authority for Water Resources, (1980) 'Preliminary Engineering Design for Wadi Al Khawd'
Corps of Engineers, (1979) 'Report on Water Resources Study Phase 2 and Technical Proposal for Construction of Water Recharge Projects'.

*16 Scott Wilson Killpatrick (1977) 'Rostag Flood Protection & Reclamation Proposal for Design Consultancy'.

4. Future Development of Water Resources

It is to be basically understood that, in regard to the development of this nation's water resources, the relations between supply and demand in water differ in every region. That is to say that there are three regional classifications; 1) where the volume of water, which is obtained for use from surface and ground water through the current technology (a part of hydrologic cycle), does exceed the demand; 2) where the relations are on balance and 3) where the demand exceeds supply. To be specific, in inland regions and Shargiya it's well above demand, and in the coast of Batina and the Salalah plain it's kept on balance, and in the Capital area, there is insufficient water supply.

In the regions where there are rooms for further development, pumping and other equipment will generally be used for development works, and currently the Ministry of Agriculture and Fisheries[*1] is undertaking the work in Al Kamil and Al Wafi. In the regions where demand and supply are on balance, temporary restrictions should be

carried out on further agricultural development, in order to keep balance in water situations, which new water resources are to be sought out. In the regions of short supply, all possible efforts are being made on acquiring new water resources along with the adoption of distillation system.

As one of the new development in water resources, the method of turning salt water into fresh water is being utilized, and in the future it is expected to become a major means of water supply in Capital area, the Musandum Peninsula or Masira Island where there is shortage even in the daily necessity of water. In those critical areas, recycling use of water should also be taken into consideration.

Furthermore, there is a method under speculation, which would conduct water into short-supply areas from other areas, and as good examples in such projects, there are the water conveyance program[*2] from Wadi Daiga to the Capital area, and the moving[*3] of the well field of the capital to Wadi Al Khawd. In the past few years, an[*4] idea of utilizing flood water has been seriously examined, and the basic conception is to build one or few checking from dams against surface running water caused by a flood in a place, a little close to inland from coastline, surrounded by the strata, which could become groundwater zones. And, by conducting such waters into the spreading area and getting them infiltrated, it plans to cultivate ground waters. Ultimately, it will pump up the waters, stored underground, as necessity occurs, in the lower side of the spreading area, and send them to the consuming regions.

As sites proposed[*5] for the program, there are Wadis Semail and Daiga, intended for the Capital area, and Wadis Bani Kharus, Far, Ahin, Bani Ghafir and Al Jizzi in Batina region, but it is only in Wadi Semail that any concrete investigations are conducted.

For such programs, there still remain a few problems like insufficient data base, and the lack of proper research on the efficiencies of cultivation of ground water, or of wells. Therefore, at the present stage, it is only taken as a pilot project with two objects of some utilization and a data collection.

The utilization of underground water in deep stratum should be considered, not as permanent resources, but as water resources in a limited nature, and the ideas include the development of limestone stratum, more than 300m deep, which is assumed to exist under alluvium in the coast of Batinao, and the development of another underground water inside the limestone stratum estimated to be 300 - 1,000m deep under the Salalah plain. Such development plans are strategically understood as provisional measures to fill in the gap until the utilization of surface running waters of flood comes to be stabilized.

It is easy to refer to the maximum use of water resources by raising the efficiency in the existing facilities, but actually the realization is quite difficult. Along with the improvement of irrigation technology and the lining of waterways in fields, a following proposal, based on hydraulics of groundwater, connotes some interesting points.

That is, in shallow wells and Falaj, water-extracing rate from groundwater zone is low, and the loss by evaporation out of groundwater surface is not small as water is obtained from shallow, groundwater stratum. Also, as water level is preserved high, possible stogate territory is narrow despite the cultivation of groundwater, and, resultingly, while the volume of cultivation is small, the flowing loss from the surface will be bigger. Furthermore, in coastal areas, in seek of shallow groundwaters, wells tend to be established not far from the coast, little above the sea level, and due to the lowering of groundwater surface, there easily occurs the infiltration of salt waters. In order to improve those defects, the proposal insists that wells should be moved to more inland areas where groundwater level is relatively deeper. Putting aside social influence, it has some worthwhile hint for us to take note of.

Among the above substituting ideas on the development of natural water, it is expected that, within the next 10 years or so, the pilot project of the cultivation of groundwater and the utilization of groundwater in deeper stratum may be actively promoted.

Government organizations which are related with the development of water resources are listed up in Table 10.

References

*1 IV-3 *9

*2 IV-3 *14

*3 IV-3 *10

*4 IV-3 *15

*5 Water Resources Council, (1979), "Water Resources Prospect in Oman"

Table 10 Government organizations relating with the development of water resources

| Name of Ministry | Division of Duties |
|---|---|
| Ministry of Agriculture & Fisheries | Falaj, Land Reclamation Irrigation Project<br>Data .. Precipitation (60 gauges)<br>Flux (25 " )<br>Wells (400 " )<br>Falaj flux (150 " ) |
| Ministry of Electricity & Water | Drinking Water |
| Ministry of Health | Water Supply & Sewage (sanitary) |
| Ministry of Land Affairs & Municipalities | Sewage |
| Ministry of Defence | Its own Water Supply & Sewage |
| Water Resources Council | General administrative activities on water resources<br>Political plans, development planning and water system |
| Public Authority for Water Resources | Surveys on allotment of water resources. |

## V. SURVEY AREA

### 1. Batinah Coastal Area

#### 1) Wadi Jizi basin

##### a. Topology & geology

Wadi Jizi is a small-scale, waterless river which is originated in the northern part of the Oman mountains and, through the east-northeast route, reaches the Gulf of Oman in a spot about 7km north of Sohar. The basin spreads about 860km$^2$ and the length of route is 80km. The river has no running water usually and only in rare occasions when there is a big rainfall, it will be filled with water. As a FAO data shows, rainfall in Sohar is mostly seen in winter time, and in the period between 1974 through 1978, annual rainfalls were recorded as 44 - 252mm.

In this basin, low and flat coastal plain extends 10 and odd km to the west from the coastal line, and a few steps of terrace (ILACO, 1975) of river and sea layers and alluvial fans are developed, gently leaning to the east. They are composed of the gravel of the quaternary period, and it is expected to be thick more than 200m in the maximum (ILACO, 1975).

The deposit of the terrace is concreted with carbonates, and is generally made up of pebbles which, in the alluvial fan, become bigger in the upper stream and clearly turn smaller in the lower stream. Farming in the coastal area is conducted upon such granule heaps.

Going further to the upperstream, Wadi Jizi reaches the mountain range make up of Semail ophiolite, and the slope of the riverbed becomes comparatively sharper. Ophiolite and sedimentary rocks in the lower part are shown with a number of fissures. And due to the advanced stage of weathering in general, even with a little rainfall, earth and rocks are to be easily carried away. In the mountain riverside, the terrace which is composed of concreted gravel could be observed. In the area about 25km inside from the mouth of the river, ophiolite is exposed in the riverbed as well as toward 3 - 4m up in the ravine wall, and, along its upper line in the riverbed, groundwater is seen welling up and flowing.

b. Current agricultural situation

In the basin of the Wadi, farming is conducted in long and narrow area, 2 - 3km in width, which is located near the coast of Sohar and Majis, and placed between the coastal line and the national road. Recently, in the western side of the national road, big-scale farms like Garden Farm and Sun Farm are being established in scales like 1 - 2km in width.

The farming regions in the coastal line have a long history of agriculture, and big date trees, more than 10 years old, are growing thickly, filling the fields endlessly. The tree crowns create comfortable shadows and send cool airs even under flaming sunshines, making favorable environment.

Under those trees, the field is divided in small squares like a checkerboard, each 2 - 3 square meters, and they are allotted for the farming of vegetables, corns and pasture. It's the customary method of cultivation in so-called dry land agriculture.

Using this method of mixed farming, not only winter planting, but summer planting becomes possible, but vegetables are cultivated mainly in winter season.

One of the advantages in those small, divided fields seems to lie in the easiness in irrigation. In the center of the agricultural fields, a well for irrigation is set up and the pumped-up waters are supplied through curved, narrow irrigation channels, into the small divisions. Therefore, irrigation method is simple and takes the style of either ridge or basin irrigation. The volume of irrigation is decided by eye measure, and has been taken care of properly through long-term experience.

As the main fruit tree in this area, dates occupy 50% of the farming fields. There are several kinds of dates, and in the coastal area of Sohar, a rareripe kind, called Salti, is prevalent. Also, cultivated are lime, mango, coconut and orange.

As a feed grass, alfalfa is most popular and both in winter and summer plantings, stabilized cultivation is observed. Sorghum is also cultivated. The cultivation of vegetables has helped in the supply to big cities like Muscat, and it provides various kinds of vegetables.

Among them, the cultivation of onions takes the biggest space. The planting season for onion is between November and May, and it boasts the highest production. Other vegetables include tomato, watermelon, cabbage, bean, potato, carrot, peanut, and eggplant.

For grain cultivation, wheat, rye and corn are chosen. But wheat is especially susceptible to high temperature and the crop is very poor, less than the half of the amount expected in inland areas.

As an industrial cultivation, tobacco growing is done in Majis, and it's being exported to U.A.E. and other places. Average yield is said to be 3 tons/ha.

For the advancement of crop productivity in this region, the problems of irrigation, fertilization and damage by blight and noxious insects should be taken into consideration.

The Extension Center, aiming at the increase in productivity, assists the farmes by distributing fertilization, giving guidance in the method of fertilization or providing farm tractors and water pumps, as well as helping in the prevention of damage by blight and noxious insects.

The livestock farming, meanwhile, is mostly dependent on nomadic farming as in the past, and fixed stock farming is yet to see any advancement. But, as seen in the Sun Farm in Sohar, big scale dairy farming may come to be developed as a new farming method in the future. In ordinary farm-houses, only a few cattles, sheep or poultry are raised, and securing feed grains will be an important problem in the future agricultural development.

c. Development concept

(1) About the basic plans

A restricting factor in agricultural development in the basin of Wadi Jizi or the vicinity of Sohar, or in all the coastal regions of Batina, is the problem of water. The current utilization of shallow wells for water resources is said to be reaching the limit, as explained in Chapter 2 - Wells, and in some of the regions, the occurence of salt damage is being feared. Besides the shallow wells, the country is speculating on two plans, as mentioned in IV-4, in order to develop

new water resources in the area. One of them is to get and utilize ground water in limestone stratum by digging into the stratum of tertiary period which is considered to be under alluvium. And another plan is to use the surface water, flown into the sea as a result of floods, for the cultivation of groundwater by any conceivable means, or utilize such waters after storing them in dams.

This survey team's plan is to utilize the basal flowing volume of Wadi, as a stage to advance into the utilization of floods.

It is to build a low dam in a boundary spot where the Wadi Jizi comes to flow into the plain after passing through the sharp decline of deep mountain slopes of so-called hard rock zone, or else in a valley slightly in upper stream. By building a water catchment facilities beside the dam, which would store sub surface flow in the gravel of Wadi, it will store the basal flow of the river. Those waters will be led through the waterways by the action of gravity, into the area near the coast, and help to develop new location suitable for agriculture.

This idea is intended to revive the method of Falaj which is presumed to have been greatly utilized in the coast of Batina in the past, in a modern way. It will fill in a time in the process of the development of water resources, and at the same time has an advantage in expecting systematic collection of data for the big-scale development of Wadi by the use of the flood flows. Also this plan seems to have appropriate nature to be widely utilized in neighbering riversm which have similar water conditions, like Wadis, Sarami and Hawashina.

(2) About the facilities for water resources

The survey team conducted investigations in a spot about 1km in downstream from the bridge which initially crosses the Wadi Jizi on the road running from the coastal road toward Braimi, and where we observed a flow of spring water. In another spot, about 400m in upper stream from the bridge, there is a similar spring water, and the Ministry of Agriculture and Fisheries continues the observation of the basal flow volume. In that observation spot, water catchment area covers about 650km$^2$, and is considered to be the place where there is

the biggest surface running water in the Wadi Jizi. But also the volume of underflow is expected to be considerably big. In a spot about 300m in upper stream from the spot where the survey team made observations of the spring water, and there no surface flows were seen, there remained an observatory to check on the amount of water flow, which was formerly used by ILACO. At this observation spot, only the data of 1975 on the water flow was kept in record. Data on the volume of the water flows at those two observatories are shown in Table-10. The chart of the rain gauge sites in Wadi Jizi is shown in Chart-6, and the data at those observatories are included in Table-13.

Table 11 Volume of Surface Outflow in Wadi Jizi

Module: ℓ/sec.

| Date of observation | Volume | Note | Date of observation | Volume | Note |
|---|---|---|---|---|---|
| 1975. 2.11 | 30,000 | ILACO observatory water catchment area A = 670km$^2$ | 1978. 9.12 | 152 | |
| " 2.12 | 4,900 | | " 11.22 | 81 | |
| " 2.14 | 1,530 | | " 12.12 | 79 | |
| " 2.16 | 960 | | 1979. 2.8 | 125 | |
| " 2.23 | 280 | | " 3.25 | 91 | |
| 1977. 6.9 | 228 | Below are at the observatory of the Ministry Agriculture A = 650km$^2$ | " 4.4 | 140 | |
| " 7.14 | 273 | | " 5.12 | 79 | |
| " 8.23 | 93 | | " 6.10 | 77 | |
| " 9.28 | 136 | | " 7.11 | 54 | |
| " 10.13 | 565 | Small flood in the previous night | " 8.12 | 97 | |
| " 11.28 | 157 | | " 9.6 | 76 | |
| " 12.21 | 137 | | " 10.14 | 77 | |
| 1978. 1.21 | 99 | | " 10.27 | 262 | Small flood |
| " 2.12 | 2;916 | Flood in the previous day | " 11.13 | 119 | |
| " 3.19 | 145 | | " 12.5 | 103 | |
| " 4.18 | 84 | | 1980. 1.23 | 172 | |
| " 5.25 | 79 | | " 2.26 | 177 | |
| " 6.28 | 63 | | " 3.26 | 205 | |
| " 7.12 | 62 | | " 5.28 | 55 | |
| " 8.16 | 1,637 | | | | |

Table 12 Monthly Volume in Outflow

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Ordinary average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | - | - | - | - | - | 228 | 273 | 93 | 136 | 565 | 157 | 137 | 171 |
| 1978 | 99 | 2,916 | 145 | 84 | 79 | 63 | 62 | 1,637 | 152 | - | 81 | 79 | 94 |
| 1979 | - | 125 | 91 | 40 | 79 | 77 | 54 | 97 | 76 | 77 | 119 | 103 | 85 |
| 1980 | 172 | 177 | 205 | - | 55 | - | - | - | - | - | - | - | 152 |

* ... Average figures excepting the ones in flood

References: FAO Runoff Measurement of Oman
Project OMA/77/001 Water Resources
Field Document No. 7 and Data file of the M.O.F.

Table 13 Data of Observation on Volume of Rainfall within the Basin of Wadi Jizi (mm)

1) Annual rainfall

| Name | Type | Lat | Long | Alt. | 1974 | 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|---|---|---|---|---|
| Sohar | D & R* | 24°21 | 56°43 | 15 | 78 | 53 | 252 | 160 | 47 |
| Haylal Hayl | D | 24°18 | 56°20 | 430 | 67 | 71 | 392 | 160 | 54 |
| Farfar | D | 24°12 | 56°21 | 568 | 83 | 120 | 412 | 223 | 154 |
| Hayl | D | 24°12 | 56°14 | 500 | 51 | 81 | 375 | 107 | 91 |
| Kitnah | D | 24°08 | 56°13 | (700) | 55 | U | 348 | U | U |
| Daqiq | D | 24°06 | 56°15 | (840) | 87 | 154 | 483 | 161 | 166 |

D = Daily gauge R = Recorder U = Reliability is uncertain

The R in Sohar was used since Feb. 6, 1977

2) Monthly rainfall, 1978

| Name | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sohar | - | 34.2 | 6.5 | 2.0 | - | - | 3.6 | - | - | - | - | 0.3 | 46.6 |
| Haylal Hayl | - | 31.0 | 2.3 | 4.0 | - | - | T | 16.5 | - | - | - | - | 53.8 |
| Farfar | - | 54.5 | 3.0 | 6.0 | - | 5.0 | 12.0 | 73.0 | - | - | - | - | 153.5 |
| Hayl | - | 31.2 | 4.3 | 0.5 | - | 2.0 | 22.5 | 30.5 | - | - | - | - | 91.0 |
| Kitnah | - | 25.2 | 5.0 | - | - | - | 18.8 | 4.5 | - | - | - | - | 53.5 |
| Daqiq | - | 60.5 | 16.2 | - | - | - | 63.5 | 26.0 | - | - | - | - | 166.2 |

T = Trace rainfall or drops

Reference: FAO 'Rainfall in Oman (1974 - 1978)'
FAO Project OMA/77/001
Field Document No. 11

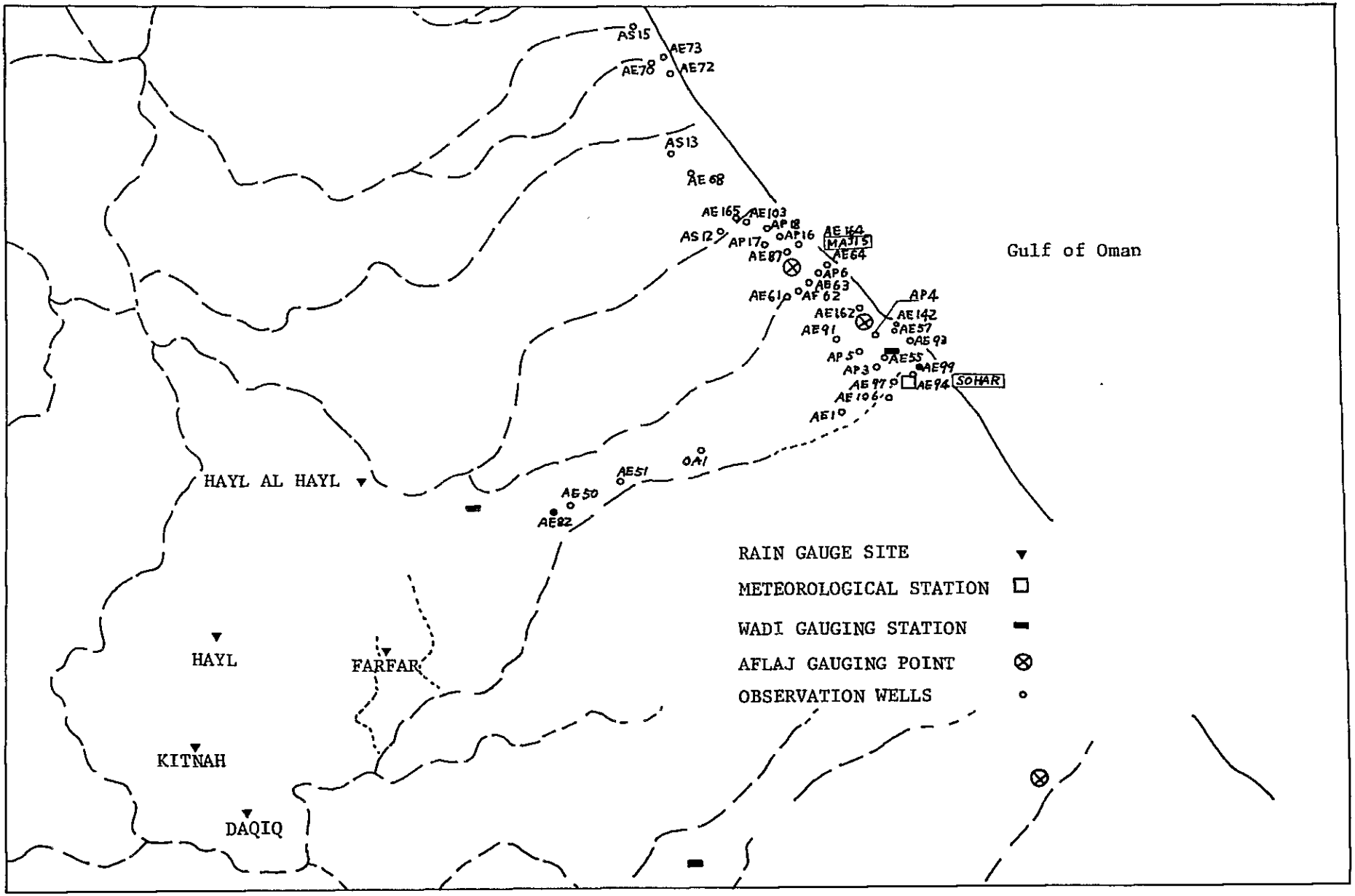



Fig. 6 The rain gauge sites

In reference to the Tables, the amounts of annual precipitation are under average, either in 1975 or in 1978. Nevertheless, the data of the flowing amount on Feb. 11, 1975 shows the biggest figures in observation. At those observation spots, data on hourly rainfall in 1975 are not recorded, but as we looked into the similar records of rainfall in Rustaq, Saiq and Rumains, there was an observation of more than 40% of the entire rainfall within an hour on the date of Feb. 11, 1975, averaging 10 mm/ha in intensity.*1 Therefore, there is no denying that in the basin of Wadi Jizi there was a rainfall high in intensity which resulted in the maximum water flows. (The reason for the big figure is assumed that the observation was carried out near the peak of the maximum overflows.) But such rainfalls, in high intensity and in flowing peak, are commonly observed in northern Oman, as already mentioned in II-I-(1), and at least more than a few times a considerable volume of water flows are expected to be seen, even temporarily. M.V. Johnson shows a peak volume of water flows at the ILACO observation spot, as calculated from channel geometry.*2

According to his data, it is 316$m^3$/sec in probability of 10 years and in 100 years it's 654$m^3$/sec.

As to the possible construction site for the water facilities, the survey team holds a view that the spring-water spot where the team conducted observations is not suitable for the buildup of an intake dam as the valley is more than 200m wide in a spot which changes into the plain from the U-shaped valley, and also, even with the road toward Burami which is situated in a higher position, it runs through the inside of the valley. Therefore, the area in the vicinity of the ILACO observatory, facing the upperstream, is considered for recommendation as the valley width measures less than 100m, and geographically favorable to the construction. Floods by heavy rainfall tend to accompany a big flow of earth and rocks, depending on riverbed slope of the Wadi and geological situations. Riverbed stones in the spring-water spot in the down stream of the ILACO observatory, are mainly pebbles about 10 - 20cm big, or 30cm at most, and there were no kinds of big rocks. Those pebbles are mixed with small, granular gravel and sands, and judging from the fact that surface running water goes in and out of the sight, it is

assumed that there is enough aeration rate for the infiltration of the underflow water.

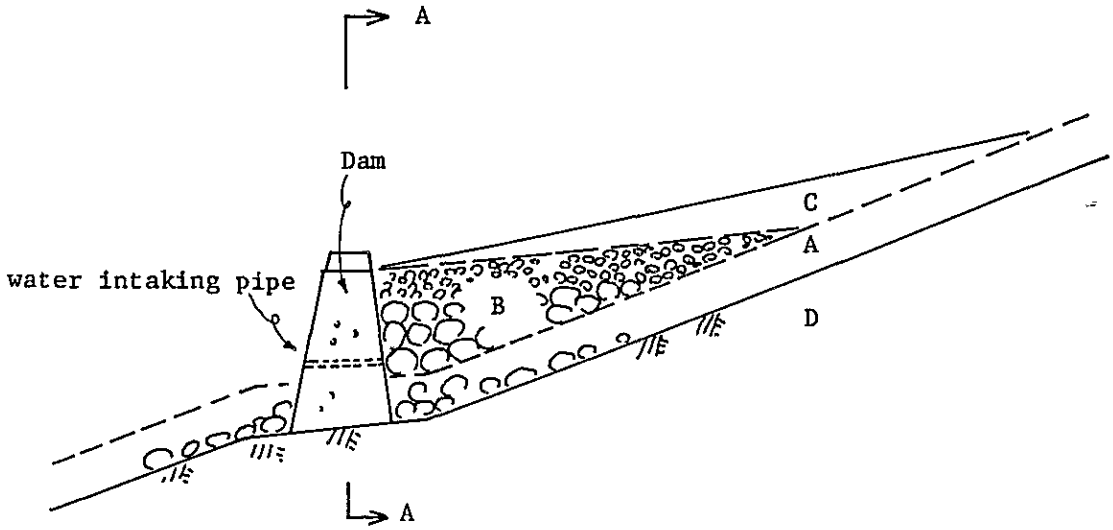
But, each time flood occurs, the accumulative positions and forms of sands, gravel and pebbles may be varied. So, in taking water from Wadi's basal flows, there is an apprehension that the weir for the intaking of surface water may be buried with flooding earth and sands. Therefore, another method is to be employed, which would collect water from under the riverbed without forcibly exposing the underf-ow water upto the surface of the riverbed, and it's considered favorable to let the flowing earth and sands from the upper stream go naturally to the lower stream. As to the collection method of the underflow water, there are two methods under consideration, and one of which is to utilize the current riverbed as in Falaj, and another is the method to establish a low dam and by creating artificial permeable bed in upper-stream side and to collect water from the permeable bed.

In case of this Falaj method, the extention of the waterway in underground is to be further prolonged, and if it's applied in the riverbed, there may be a variation of riverbed, as well as a problem of maintenance. If it's set up in the foundation rockbed, there now occurs a problem of extremely bigger construction expense. In the dam method, meanwhile, as the intaking of underflow water is possible, it's easy to build the waterways in the downstream, higher than above the sea level of the current riverbed. Also the maintenance of the waterways will be easier.

About the excessive volume of water which flows over the dam, the measurement of water flows will be done easily and correctly by applying V-shaped cut in a proper place and letting water flow downward. Resultingly, it is expected to make great contributions toward the collection of basic data for the future big programs.

For the reasons mentioned above, the water intaking will be done in a dam method. Fig. 7 shows the conception of the intaking of under-flow water by the dam method. (This dam does not aim at water storage, but is intended as an intake dam for the purpose of obraining the under-flow water. So, on the assumption of that the artificial permeable bed would function well, there is no need for constracting plural number of

dams, as there would be only one place near the coast, which is in need of water. Building debris barriers in the upperstream, or in the downstream of the dam, in order to control the variation of the riverbed, does not necessarily lessen the main functions of the dam. But, if the construction of the dam is equipped with the durability strong enough to cope with flowing down of earth and sands, there is little necessity for the construction of debris barriers. If there is a proper storage site which is geologically safe, the dam could be intended for the water storage.)




A: Drift layer of the current riverbed.

B: Artificial permeable bed to be built along with the dam construction. Take note of the granular pebbles.

C: Drift bed, formed as a result of downflows after the construction of the dam and B. If, by any chance, the layer should be impermeable, the water collecting function won't be affected as the underflow water infiltrate through A.

D: Rock bed.

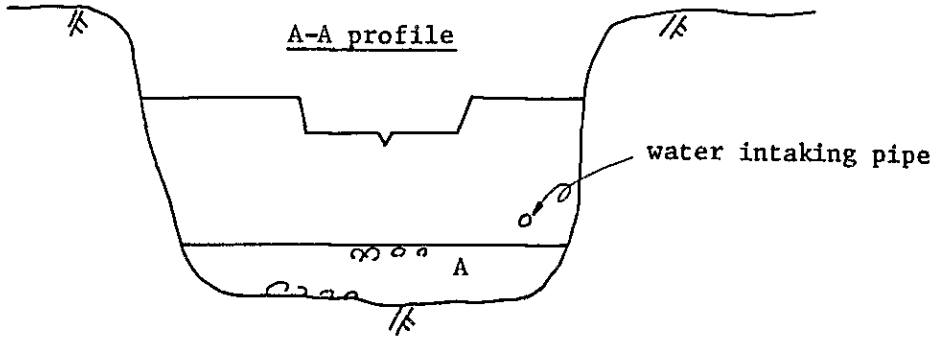



Fig. 7 Conception of water intake

(3) About the developable amount of water and agricultural development

According to P.M. Horn, annual cultivation volume of ground water at the observation spot of the basal waterflows is estimated to be 21.7 million $m^3$, which is 14.5% of 150 million $m^3$ (230mm) in the average annual rainfall. This cultivation volume of ground water is recorded at 0.688 $m^3$/sec, and has potentiality of irrigating farm lands more than 1,100 ha, assuming the daily water consumption on the fields as 0.6 ℓ/s/ha. But the water flow is somehow consumed in the upperstream of the observation spot, and the remaing volume turns for the cultivation of ground water in shallow wells in the coastal regions. Supposing that the situations of water resources in the vicinity of Sohar are acknowledged to be in negative balance*4, new developments won't be allowed in view of balance in water, even if it becomes possible to get water from water collecting facilities.

In such case, therefore, the development program will be two stages, and in the initial stage, the water collecting facilities and the raceways are to be constructed to get 0.688$m^3$/sec, or else the water.

For agricultural development, farmers who are affilicted with inferior water quality like salt damage, or the ones with a zest for improvement are to be invited to settle in, and the development should be gradually achieved in small scales. And these farmers are placed under an obligation to engage in irrigation farming by economical use of water. In return, two times more of the farm land than in the former location are to be allotted to them for agricultural development. It means that the water resources are to be changed and the same amounts of water as in the former farm land should be required through development. Also the hydrologic data should be recorded along with the agricultural development, and the balance in water resources must be checked while the propriety of the cultivation program of underground water is being examined. If situation of water resources are better than expected, the surplus is to be used for new development. And in the second stage, a new plan is to be formed for the cultivation project of ground water.*5

Meanwhile, from the standpoint of an idea that there is potential water volume for development a plan for water collecting facilities and raceways should be speculated to get the necessary volume, and along

with the advancement in plan, agricultural development must be taken into consideration. Whichever position one is to choose, it's undeniable that a big point lies in how you grasp potential water volume for development in the basin of Wadi Jizi.

*1

| Name | Date | Amount of rainfall | Amount in peak hour | Peak percentage |
|---|---|---|---|---|
| Rumais | 10-11/2/'75 | 24.0 mm | 10.3 mm | 43% |
| Rostaq | 8/2/'75 | 18.5 | 9.9 | 54 |
| | 9/2/'75 | 12.8 | 4.2 | 32 |
| Saiq | 11/2/'75 | 35.9 | 15.0 | 42 |
| Average | | | 10.0 | 43 |

FAO 'Short Period Rainfall Intensities in Oman',
Project OMA/77/001
(Appendix A to Field Document No. 11)

*2

| Location | Jizi (Mulajijinah) | |
|---|---|---|
| Water catchment area | 669 $km^2$ | |
| Peak flow at | 2 years | 113 $m^3$/sec |
| Recurrence Interval | 5 years | 226 |
| | 10 years | 316 |
| | 25 years | 445 |
| | 50 years | 589 |
| | 100 years | 654 |

FAO 'Runoff Measurement in Oman' Project OMA/77/001
Field Document No. 7 p.37

*3 FAO "Water Resources of the Batinah"
P.M. Horn, Hydrologist, Project OMA 77/001
Field Document No. 10

*4 IV-2 References

*5 Ministry of Agriculture & Fisheries "Agriculture Regions" Draft p.2

2) Rustaq area

a. Configuration and geology

Rustaq is a village situated in spot where Wadi Far is about to depart from the Oman mountains. According to the FAO data, in Rustaq it recorded 92 - 277mm for annual rainfalls in the period between 1974 - 1978. In 1978, there were about similar amounts of rainfalls both in winter and summer periods. The main stream of Wadi Far had Wadi Bani Kharus as the basin (about 300km$^2$) in the past, which was in the upper stream past Al Awabi, and is estimated to be one of the biggest rivers in the coastal plain of Batina. It is assumed that Wadi Bani Kharus has taken over the basin as it kept infiltrating from the side of the lower stream. The ravine plain extends more than 15km from Rustaq to Al Awabi and has a big width and the basin of about 130km$^2$. Therefore, Rustaq is situated in the big riverbed of the old Wadi Far, and possesses a ravine plain comparatively bigger for a mountain area. The valley is composed of Hawasina stratum in the mountain area on the left bank, and of Semail ophiolite on the right bank.

Hawasina stratum is made up with hard rocks, but cracks are observed and they are crushed into breccia form in some places. Semail ophiolite has becomes frail through the weathering. In the ravine bed, the drift which includes the conglomerate of cobbles and boulders is accumulated to more than 15m. For the accumulation of those big conglomerate in large quantity, it is estimated that the quality of bedrocks and the localized rainfall played an important factor. The drift in the ravine bed makes up a favorable water layer and in there wells and Falajs are constructed.

b. Current agricultural situation

The region is surrounded by the mountains of Jabal Akhdar, forming a basin, and, with the rainfall on those mountains turning into water resources, is blessed with comparatively plentiful water supply. Moreover, it's 500m above the sea level and good for cultivating fruits and grain, for the range of temperature is big.

The main agricultural product in this area is dates and the whole town is covered with a sea of dates trees. In the suburbs, there is a dates factory, which is solely undertaking the processing of dates in this region, using automation system for selection, drying and finishing. The processed dates, as the only agricultural product to obtain foreign money, are shipped to the cities and abroad. Besides dates, other fruit trees like lime and orange are cultivated, taking advantage of the mountaneous geographical location and the weather.

For grain, wheat and rye are extensively cultivated, and the average crop is 2 - 3.5 tons/ha. The Extension Center conducts guidance on the introduction of proper kinds and the control on fertilization, and makes efforts for the improvement of productivity. Feed grain cultivated most is alfalfa, with the average crop as 90 tons/ha. Vegetables are cultivated in mixed forming under the tree crowns of dates and lime, boasting a variety of kinds.

In Al Awabi, 20 kilometers southeast of the Rustaq area, there are seen the steep ravine of Wadi Bani Karus. In the ravines, no oasis village is spotted, but in the downstream area of Wadi, there are some villages of dates. In Wadi Far, running the north of Rustaq, some oasis villages are scattered, but they are in small scales, and don't seem to have good water resources.

c. Existing irrigation

The farm land scattered along Wadi Bani Karus and Wadi Far are mostly irrigated by Falaj system, and the pumping-up waters from the wells are only used for drinking in some of the area.

In the riverbeds of the both Wadis, there are Fajajs running in all directions and in every 100 - 200m, the openings of the pit for repair work are seen. The Falaj comes up to the surface in the upper

stream near the farm land, and through the open channel at the side of Wadi, water is led into the farm land.

The farm land in Rustaq district is developed long and narrow where there are accumulations of soil along Wadi, excepting the city area of Rustaq. Therefore, in most of the farm land, dates palms are cultivated, and under the trees, field is divided by ridges into about 5 square meters, and water is irrigated by the water channels of Falaj. This irrigation system, resembling a small-scale, underdeveloped irrigation method observed in Japan's paddy fields, could be taken as a big basin irrigation system.

The Rustaq district does not have a big Falaj like in the districts of Nizwa and Wadi Semail, but middle and small Falajs are developed for utilization of water.

d. Development concept

In Rustaq, following four methods are under consideration for the development of agricultural water, from the standpoint of the geographical and geological features, weather and the existing water usage:

(i) Improvement of the existing Falaj.
(ii) Discovery and development of new aqueous stratum
(iii) Construction of dam
(iv) Construction of underground dam

(i) The improvement of the existing Falaj will help in securing ground water to some extent, but requires a huge expense and maintenance fee. Also there are problems of scarce technicians for the improvement work. Therefore, recommended as a new measure, it is, not to carry the improvement in the nature of maintenance of the old facilities, but to remodel them into a complete water collecting type by a low dam, about 3m high, or other means, and all the water should be conducted through pipelines.

(ii) In this region, the discovery of a new aqueous stratum could not be possible as the bedrock itself is made up of Semail ophiolite and Hawasina layers. That is, in hard rock area, ground water could be

obtained through wells only in the location of crushed and cracked rock layers which do not include much of clayed soil of mountain lowlands.

(iii) There is a method of storing flood water by constructing a dam, but in this district, rainfalls mostly occur in limited periods of winter and summer and the quantity is small. Also the evaportation rate is very high and the foundation ground for dam site is expected to be deep. There is a fear for the occurance of an avalanche of earth and rocks at the time of torrential rainfalls. Judging from the observations of corroded cliff at the mountainside, and earth and stones mixed with boulders in the riverbed, and from the words of the people concerned, storage system by a dam seems to be difficult.

(iv) An underground dam has advantages of avoiding the danger of burying by avalanche of earth and rocks, and the remarkable controlling of evaporation rate. Fortunately, the bottom of the ravine, from Rustaq to Al Wadi, is composed of thick gravel and is judged to be favorable for the construction of an underground dam in geographical and geological conditions.

But if the underground dam would be constructed, the ground water flowing toward the downstream will be stopped, and it seems unavoidable that it would greatly affect the existing Falajs and wells. For that reason, in constructing the underground dam, there occurs a necessity to consider some measures to make up for the existing water-collecting facilities by securing the due of water to them. And there will be more problems to be solved, like the blocking of the aeration of gravel by granular objects brought by floods, or how to intercept water in gravel.

Either way, the construction of the underground dam should be carried out under the concensus of the people in the region, to say nothing of the need for geographical, geological, hydrological, technological and economical studies.

2. Interiors

1) Nizwa area

a. Current situation

The town of Nizwa is positioned in a plateau about 1,000m above the sea level. The town is developed long and narrow on the riverbank of Wadi Al Abyad which runs at the foot of Jabal Akhdar. Nizwa is the central city for agriculture and commerce in the inland areas, as it surrounded by Izki, 25km to the east, Bahla, 25km to the west and Manah, 20km to the south. Population, therefore, is concentrated in this Nizwa region.

National organizations, which are related with agricultural development, do mostly exist in Nizwa. They include the Agricultural Bureau, the Extension Center, National Production Farm, dates factories, a veterinary clinic, etc.

Also an agricultural school was established through the assistance of UNESCO, and it has 1-year and 3-year courses, devoting for the promotion of agricultural education.

In Wadi Quriyat, the east of Nizwa, there is an agricultural research station which engages in the experimental study of corn, feed grain and vegetables. For the breeding of sheep and goat, animal husbanding station is established and works for the promotion of stock-breeding.

Weather in this region is tropical arid climate of desert and the temperature is high, and it has a small rainfall. But the range of temperature is conspicuous between day and night, and floods would occur after intensified rainfalls. There are summer rains, as well as winter rains, and Nizwa is blessed with rain waters. The Falaj, built along Wadi Al Abyad in Nizwa, measures about 2 meters in width and the openings are made in trigonal linings of round stone concrete. It provides an excellent water flows in good quality.

Mainly cultivated are date, lime, banana, alfalfa, mango, wheat and onion. Wheat in this area is a staple product in Oman and the quality is very good.

Generally, in regions where the temperature rises to over 18°C, wheat is susceptible to the heat. But as this area positions high above the sea level, it is suitable for wheat. Also the production of dates is comparatively high, and there is a dates processing factory. One of the noxious insects for dates is Dubas and it is said to be most active in the periods March - May, and October - November, during which insecticides like Malachin are sprayed. In Nizwa, sugar canes and other fruit trees like grapes and peaches are extenstively cultivated, and with the engagement in a variety of agriculture, the region is filled with activities.

2) Misfa area

a. Current situation

Misfa is positioned in halfway up the southwestern slope of Akhdar, the highest peak of the Oman mountains. The inclination of the slope resembles the one of the stratum which forms the mountain mass, exposing hard rocks and gravel. The village is developed inside the steep valley walls which deeply infiltrated into the calcareous sedimentary rocks of paleozoic strata and a Mesozoic formation. From there one could enjoy grand, extensive views of the mountains.

The residents obtain groundwater, flowing out of the valley walls, through water channels, 30 - 40cm in width, and after utilizing it for daily needs, lead the water into the field in the ravine for the irrigation of dates and lime.

Due to the mountainous location of the village and the agricultural field, there seems to be inconveniences in the circulation of agricultural products and the traffic.

b. Renovation concept

Water resources in this area are comparatively abundant, and from the ancient past, various means of improvements have been conducted as to the utilization of water, and we observed them helping in the betterment of the regional like. So that not to be left behind in the development of this country's social economy, there seems to be a need

for preparing some courses for the future water use.

Plans for the improvement in this area are listed up as follows:

i) Securing water passage into the village.

ii) For the efficient use of water resources, the loss in the supply route should be eliminated.

iii) Total adjustment of the orders in water usage and the utilizing location, to meet variety of needs for water.

iv) Introduction of power plant enterprise, using a head of water.

v) Securing electricity by introducing a solar cell, along with the above plan.

vi) Rational positioning of the houses in rocky area.

As a tentative plan, the securing of water passage should be considered first. Especially, the part, which comes into the village from a ridge, is considered to be in extreme danger and should be taken care of urgently.

As a permanent plan, it is recommended to establish a program for an appropriate water passage and its enforcement.

Efficient use of water resources is currently being pursues, but it seems the loss is very big and it is advised to use pipes for the water channeling, aiming at lessning the water loss. Also, with the possibility of big water head, it should be utilized for power generation and be used for the lighting in households. Currently, the divided use of water in washing and other daily needs, is conducted, but it is assumed to be based on habitual judgement. Therefore, an adjustment plan of the whole region in the use of the efficient usage of water may be necessary. Also, it is judged that reexaminations are required in the matter of divisions of each field in the valley and water distribution system.

3. Sharqiya Area

1) Current situation

The Oman mountains are largely shifted to the northeast on the southeast side of the line (Semail gap tectonic line) which connects As Sib and Izki. The southeast side of the Oman mountains and the vicinity are called as the district of Sharqiya.

In Sharqiya, Wadi Al Batha, about 190km long and 5,500km$^2$ in basin space, runs nearly in a straight course toward the northwest-southwest direction. On the way, in the north of Al Kamil, it merges into Wadi Bani Khalid, a tributary stream which accompanies a lot of villages. The Wadi is originated from the Oman mountains which are more than 1,800m above the sea level, and along the basin, there are villages like Ibra, Al Mintirib, Al Kamil and Bani Bu Ali down from the northwest. According to the observations in Ibra, the annual rainfall is about between 50 - 200mm and the rainfalls occur mainly in winter and summer seasons.

Along Batha and its tributary stream, river terrace of the quaternary period and an alluvial fan are widely developed, and composed of pebbles and sands. The gravel is thick 40 - 50m according to a boring data and, underneath, an unspecified layer, which is composed of limestone and marl, is spreading. (FAO, 1980. The details about the layer are not known.) The bedrock of Sharqiya district is composed of Semail ophiolite and Hawasina stratum (JICA, 1979).

The gravel of the alluvial fan makes an important aqueous stratum in this area, and according to Renardet Sauti Ice (1975), ground water exists in the deep of 10 - 25m in Al Batha plain, 30 - 50m in the mid-stream and 5 - 10m in the lower stream of Al Kamil. The water levels are mostly unchangeable throughout the seasons. For the reason of sudden lowering of ground water level in a spot slightly to the upper-stream, where Wadi Bani Khalid merges with the main stream, there are some explanations in consideration like the existence of buried valley corroded in limestone, or the dislocation, or the unevenness of the bedrock. (Renardet Sauti Ice, 1975; FAO, 1989).

Water generally contains a slight Cl, and in the area where ground water is frequently utilized, there are some places which records 100 - 3,000 μΩ/cm in electric conductivity. Ground water is obtained through Falaj. The Falaj in this area generally measures 5 - 10km in water passage and one Falaj conducts 0.5 - 155 ℓ/s of underground water, according to a survey in 1974. (Renardet Sauti Ice, 1975).

In recent years, well drillings are frequently conducted and aqueous stratum is sought out in the underneath of the gravel or in the limestone. Farm land are largely seen near the village and dates, lime, alfalfa, banana, mango, and vegetables are cultivated. Rainfalls are small, and the irrigation water, of which more than 3,000mm are evaporated annually, is mainly obtained through the above mentioned Falajs.

2) Summary of Sharqiya development project

The survey of development in this area started with the research on water resources conducted by consultants (Renardet-Sauti-ICE, 1974 - 75). In the survey, an interim report[*1] was prepared in March, 1975, and it recommended a few suitable sites for the developing program within the basin of Wadi Al Batha which has an area of 5,500km for water catchment, the biggest in Sharqiya district. Based on the findings, soil specialists of FAO were sent to the area in 1977 and they conducted reinvestigations of the results of the soil survey in Northern Oman, as well as seeing sites for development works of agriculture in Sharqiya district. As a result, the vicinity of Ad Dariz and Al Kamil had come up as the most likeliest sites. And preliminary research was conducted as to the soil and water resources. It was judged later[*2] that in Ad Dariz quality of ground water was bad, and even though a good quality ground water could be obtainable in a spot far down to the south, the soil seemed not suitable for agriculture.

Meanwhile, the district of Kamil Wafi was recommended as quite suitable for the development both in quality of water and the soil, with the area of 900 ha. Furthermore, with those findings, FAO started a close inspection of ground water in the recommended site, about 3km to the northwest of Al Kamil.

They digged seven observation wells and six test/production wells, and at the same time carried out compiling an aerial survey map covering the two districts in Kamil Wafi region. According to the survey reports*3 (compiled in May, 1980), the summary of the development program is read as follows.

The amount of the influx into the underground water layer in Kamil Wafi region, was estimated in annual average (assumed on the basis of 50% of rainfall in excess probability) to be 10,000,000$m^3$ in total, that is 320 ℓ/s, of which 8,000,000$m^3$ comes annually from Wadi Bani Khalid in the north and 2,000,000$m^3$ comes from Wadi Al Batha. The module amount of water the assumption that irrigation loss would later be restored and be ultimately utilized, potential area for development was calculated as about 500 ha, after dividing 320 by 0.6. The amount of the influx, 320 ℓ/s, however, the one which should be utilized in all the area of Kamil Wafi region. In the survey, the existing agricultural area was estimated as 150 ha, and the area for individual development field was also assumed as 150 ha. For a development project by the Ministry of Agriculture and Fisheries, about 200 ha of development is assumed to be possible.

Furthermore, the survey calls for an attention that development works, besides the above mentioned ones, in Kamil Wafi region should not be permitted until; 1) new water resources are developed, or 2) it could be proved that the situations of water resources was better than the estimation in the survey.

In the allocation of the area, planned for the development by the Ministry of Agriculture and Fisheries, 150 ha was taken by the first priority district where the survey of the ground water preceded, and 50 ha to the second priority district, located between Al Kamil and Al Wafi.

The scale of an agricultural block in each district was to be limited under 50 ha each, in order to avoid unnecessary lowering of ground water or mutual interference of pumps. The first priority district has 3 blocks of each 50 ha, and in the second priority district, there are 2 blocks, 25 ha each.

The next stage of the development programs will be to build new wells needed in the first priority district, and in two blocks, A and B, of the three, the program should be promoted in each 50 ha until it reaches the stage of actual agricultural production.

Also, for the advancement of development works in the remaining block in the first priority district and the two blocks in the second priority district, necessary research on ground water must be conducted. For the achievement of production program, a developing system should be decided whether the districts be placed under the government control, or farmers be allotted with certain divided portions. It is needed to decide on matters of agricultural operations, like selected rotation of crops or cultivation system. While the positions of A and B blocks are to be clearly defined and lines be drawn on the forbiden area for development.

*1 IV-3 *3 Reference

*2 FAO, (1977), 'Development of New Land for Irrigated Agriculture'. Soil Consultant's Report - Dr. Hatim El-Attar

*3 IV-3 *9 Reference

3) Cooperation concept

If Japan is going to cooperate technically in the development project in Shargiya, it is considered that cooperation would be made in the survey of ground water in the second stage of the formerly mentioned development works, or in deciding a development plan for A and B blocks, as well as to cooperate in the designing of distribution pipes in fields or making an irrigation plan.

Possibly Japan could help in agricultural technique including irrigation skills which are certainly be needed at the time of designing terminal facilities, by sending Japanese specialists. Another possibility lies in technical cooperation in the cultivation of feed grain.

Otherwise, in case that the developed agricultural fields or water would be placed in the responsibility of individual farmhouses, with the adoption of the agricultural development system, Japan could co-operate with technical advice, at least on the irrigation technology of water saving method.

4. Salalah Area

1) Configuration & geology

A plain, called as Salalah, is developing 15 - 20km wide and 50km long at the southern foot of Al Qara mountains. The plain has the largest precipitation in Oman, that is, 133mm of annual average. The rainfall at the mountain area is said to reach 500 - 750mm. A number of small wadis 15 - 50km long are developing on this plain. They start from Al Qara mountains and flow down to N-S - N-E. Bases of Al Wara mountains and Salalah plain are widely composed of the tertiary limestones, which porous are and contain a large quantity of shell and trece fossils. It is accompanied with caves in multi-horizons. Well developed terraces are seen at the plain with formations of many small alluvial fans at the foot of Al Qara mountains intersecting these terraces. Some of the terraces have flat tops, suggesting they are marine deposits. The terraces are composed mainly from medium sizes gravels and their dimensions are sharply reduced as approaching to the shore. Basement racks are frequently exposed under gravel layers, which are supposed to be thin. The gravel layers of terraces at the mountain foot, red weathering crust is clearly shown. Since springs are found and trees are growing fainly well, formation of soils are possibly high.

2) Current agricultural situation

Salalah and its surrounding areas in the south are tropical mostly up to the mountain tops, being governed with the south-western monsoon in summer. This region is also strongly affected by thick fog of special characteristics in summer which covers mountains as well as plains. The temperature of Salalah plain is relatively stable with the maximum 31.8°C in May and minimum 15.7°C in January. The precipitation is highest at the Dhofar mountains, and decreases so sharply at the northern area of the mountain that the desert climate dominates. The coastal plain, spreading from Raysut at the West and crossing Salalah, is composed of sand and soils. It is favored with rich rainfall of monsoon from June to September. Behind the coastal plain are hills with well grown forests reaching to altitudes near 1,500m. Total

cultivated area is approx., 3,000 ha. The traditional products are coconut, banana, papaya, guava, alfalfa, corn, and vegetables such as tomato and eggplants. Its climate is best suited for the growing of coconuts, whereas dates cannot grow due to the high humidity. The Dhofar mountains are an area for cattle rearing, having approx. 500,000 ha of natural grass land, where more than 5,000 cattles are reared (Pasture of cattles are seen only in Dhofar mountains) The cultivation area is broken down by products as follows:

| | |
|---|---|
| Fruit-tree | 966 ha |
| Vegetables | 378 " |
| Upland crops | 336 " |
| Forage crops | 1,344 " |

The agricultural development activities in the south Oman supported by the Department of Agriculture and Fisheries include:

1. Establishment of the Exhibit Field at Qairoon Harithi, where the cultivation of fruit-trees in the mountain areas are to be experimented.

2. Development of water resources at Sahanooth Spring.

3. Construction of the banana processing plant.

4. Production of milk and fattening cattles at the Oman Sun Farm, which is jointly supported by the Government and SIAH.

In addition to the above, agricultural experiment stations, extension centers and livestock hospitals are constructed or planned. The cultivation of coconuts, which is limited in the Salalah plain, is estimated to be carried out in area of approx. 210 ha., with an annual production of 1 million fruits from 50,000 grown-up trees. This plant has no preference of soils but requires the irrigation, and is reported to be saline resistant.

3) Existing irrigation

The coastal plain arround Salalah is only area with the possibility of agricultural development within Dhofar. The plain is spreading along the coastal line and the ground water is continuously distributed in relatively thick layer beneath the plain. Water is taken from base rock layers of calcium carbonate or conglomerates. Generally the water quality is poor, except in the middle area of plains north behind Salalah city. Developable areas were confirmed by previous soil surveys, most of which were found not to be favorable since they are adjuscent to sea which give the possibility of attack of saline water and ground water recharing is insufficient. The ground water in the mountain area is contained in the calcium carbonate aquifer layers and springs out from fountains scattered over the area. Some of fountain water is utilized for part of plains by Falaj. Recharing of water to the plains are made with water from mountains and fountains.

Recent study of the balance in water resources gave an estimation the annual demand and supply of water as follows:

(Unit: Million Cubic Meters)

| | | |
|---|---|---|
| Amount of water taken from underground | | |
| Farms currently in use | 12.5 | |
| Drinking water for urban area | 2.5 | 24.0 |
| Possible to be taken in future | 9.0 | |
| Amount of water which flows out from fountains | | |
| Used for farms | 7.0 | |
| Amount of lost surface water | | |
| Lost into sea as flood | 11.5 | |
| Amount of flowing-away ground water | | |
| Amount required to prevent penetration of saline water | 6.0 | |

The most important task for the development of this area is the water resources development. Most care shall be taken for maintaining

the water quality of the "fresh water area" in the central part of Salalah plain, and for the selection of the agricultural planning area in future. Irrigated agriculture in the mountains is not planned at present since soils in highland areas are generally sterile.

The rainfall in summer is contributing to grow the grass at ranges by supplying water adequately. Water for household and liverstocks are supplied from deep wells.

No detailed information has been obtained on ground water conditions in internal highlands reaching to the margin of Rub Al Hal desert.

It is reported that there are wide aquifers of calcium carbonate in this area and artesian flows are frequently seen. The water quality, however, is generally poor and generation of soils are slow. Water penetration is high and soils are parren.

4) Summary of survey area

Several fountains are found at the foot of Al Qara mountains, some of which is led to Salalah plain for irrigation. The study team visited four fountains of them. ("Ayn" is an arabic word meaning fountain. Flow rates of these fountains are taken from materials by FAO.)

Ayn Garziz: Water is running from a cave formed in prous lime stones of the tertiary period (Pliocene epoch). A small pool was seen in which little fishes were swimming when we visited there. According to an officer of the Oman government, the water level rises after rain and is drained in continuing droughts the flow rate was 2 - 90 ℓ/s in 1977 - 1978. Water level is generally high in winter in this area. Caves were developing in a number of horizons and notches had been formed in multi-horizons of limestones.

Any Sahalnawt: Water is flowing out from a cave in porous limestone. A small dam of 3m high and 20m wide is constructed in its immediate downstream. Water leakage was found at the bottom of the dam and the storage was not high. Observations in 1977 - 1978 showed flow rates 31 - 305 ℓ/s, which was the one of the highest in this area. Fountains were found at the foot of limestone cliffs and small wadis were formed in their downstreams. A number of tree fossils were found in the limestones.

Any Anzat: A group of small fountains were seen at the foot of limestone walls. The flow rate was 100 - 182 ℓ/s according to observations made in 1976 - 1978. The rate was most stable among the four fountains. Its water was led to the plain through a duct. Clearly developed caves were observed several meters high along present wadi.

Wadi Darbat: Overhanging walls of several tens meter wide and several hundreds meters high are developing which would have been possible formed by fault. It was told that running water of the wadi forms a fall at the wall under record-breaking heavy rain. Rocks around here were porous limestone. Two wells of 80m deep had been digged for survey. The ground water level was about 26m and the electric conductivity was approx. 1,000 μv/cm.

5) Cooperation concept

Investment for the development has been heavily hampered by activities of the Dhofar Liberation Front in the southern region centered with Salalah, the second biggest city of Oman. Differences in development levels from the northern Oman are increasingly widened. The subjugation was issued in 1975 along with the restoration of security. Since then, the Oman Government is advancing the integrated development of the southern region including agriculture as one of the important policies, along with the development of oil fields in the southern region. Networks of highways are being constructed at accelerated speeds now. A fully paved highway is expected to be completed in 1982 to connect the southern and northern regions.

Emphasis would be placed on the agricultural development of Salalah plain along with the development of oil fields since this region has mild climate with plenty of rainfall, making it suited for the agriculture. Cooperation of Japan in the development of the southern region, which is highly significant for Oman, would have a very important and effective role in the promotion of harmonized development of the whole country.

The study team examined on the possibility of a variety of cooperations during sojourn in the Salalah region, and obtained conclusions as follows.

The study team investigated the possibility of cooperation in the redevelopment of four fountains, the water resources development of the Wadi Darbat, and the development of lagoon, all of which were surveyed on-site, and found that the most urgent problem in advancing development of the southern regions was serious lack of basic data compared with those of the northern region. Establishment of these basic materials and data are highly significant for the long term, integrated development of the region. Therefore, it is most adequate that Japan would cooperate in the establishment of an integrated agricultural development plan (master plan) through preparation of basic maps (topography, geology, soils, vegetation, etc.), survey of water resources and hydrographic analysis.

## VI. VIEWS & RECOMMENDATIONS

### 1. Areas Nominated for Field Survey

For the first place of water resources development aiming at agricultural development, various requirements for the priority of the agricultural development should be examined. Its implications to the internal and external social and economic conditions must be clearly understood including; the improvement of domestic food supply based on its increased agricultural production, expansion of exports of agricultural products, increased national economic benefits brought up by the expanded and stabilized opportunities for the agricultural employment, and improved regional differences during domestic regional developments. The water resources development for agricultural development is transferred from mere possibility to actuality only when the abundance of unutilized water resources suitable for agriculture based upon the hydrographic balance, and the existence of available soil for agriculture are equal or the latter is larger than the former. The study team made quick, short-time on-site surveys on the status of private or corporational agriculture, collection of agricultural products, processing plants, a number of agricultural experiment stations and local authorities with the aforementioned point of view, at the following locations:

① Wadi Zizi area
② Rustaq area (Wadi Banikarus, and Wadi Far)
③ Misfar area
④ Nizwa area
⑤ Wadi Small area
⑥ Sharqiya area
⑦ Ayn Sahalnawt
⑧ Ayn Aarziz
⑨ Ayn Arzat, and
⑩ Wadi Darbat

The specialists of the team drew conclusions for each area as follows.

③ Misfar area is hardly included in the developmental survey by survey by Japan because of it small scale although an agricultural reshaping is conceptually feasible.

④ No places are found to be suited for new development in Nizwa area, which had been developed since earlier time and redevelopments including unification of water supply systems, improvement of water distribution, and reconditioning of farm lands would be important tasks in future, though.

⑤ Wadi Semail area is not adequate for including in an agricultural development plan since a water resources development plan has been established by the Department of Water Resources, and the water resources is anticipated to be converted for water supply to urban use.

⑥ Sharqiya area is best suited for agricultural development provided that water resources are possible because it has a vast area of agricultural soils. However, it was excluded from candidate areas for the developmental survey because the Department of Agriculture and Fishery had selected it as a target of investigation and its developmental survey by wells had been entered the second stage.

In view of the above findings, the survey team selected the following three areas as possible areas for Japanese cooperation in development:

① Development of water resources for agriculture in Wadi Zizi area.

② Development of water resources for agriculture in Rustaq area.

③ Fundamental agricultural survey and master planning for the agricultural development in Salalah plain.

A. Wadi Ziai area

Batina has mountain areas and numerous highly developed wadis. It is highly probable that a large amount of water runs down several times in a year. Therefore, reliable underflows surely exist in beds of Wadis and a concept to take this water effectively is drawn. Accordingly, the hydrographic cycle is to be clarified, and investigations are to be made for the planning of surplus water development and conversion of water resources in a limited drained area under the survey of the Batina area in order to promote development in more advanced form of water utilization than previous ones relying upon wells or Falajs.

Advantages of the area:

① It is estimated that its topography and geology is compatible with installation of underground structures for water resources development.

② Areas suitable for development are found around Sohar area (particularly along the west side of the National Highway).

③ Paved roads have been completed reaching to survey sites.

④ No Falajs is being in use at present in the adjascent area.

⑤ Branch offices of the Bureau of Agriculture and the Bureau of Water Resources and Irrigation are located in the vicinity, facilitating cooperative actions.

⑥ Proliferating effects are evaluated as a model for the development of numerous wadis existing in the area.

Problems of the area:

① No particular problem is pointed out. However, the water balance is estimated to be negative.

② Influence to shallow wells on the coast.

B. Rustaq area

Similarly to the Wadi Zizi area, countless wadis develop in its lower draining area, which inevitably cause floods many times. Doubtlessly, amount of underflow at the river bed is larger than that of Wadi Zizi because Falajs are developing over the viciority. However, the investigation shall be done with sufficient care since troubles will unavoidably arise between Falajs due to increased consumption of water resources. Advantages of the area:

① It is anticipated that the topography and geology is best suited for the construction of underground dam.

② It is located near the Capital and this is advantageous for the development of suburban type agricultural development based upon vegetables.

③ The location near the Capital is also convenient for the transportation of major equipments and materials for construction.

④ Paved road is scheduled to be completed soon.

Problems of the area:

Plenty of time and cost would be required to estimate and investigate influences from the construction of underground dam in Wadi Banikals and Wadi Far where many Falajs exist.

② Compensation issues will be possibly raised for presently existing water collecting equipments.

③ Land suitable for agriculture near the dam site has already been developed.

C. Salalah area

Surveys of Salalah area is characterized in fundamental development investigation in which conditions of ground water are clarified based upon the structural analysis of ground water flow of the Salalah plain and its background mountains, the quantity of developable water resources development plan of Baina area which is based upon water balance

of each water system divided by each wadi.

Advantages of the area:

① The climate is the most favorable for agriculture in this country.

② Effectiveness of the cooperation is high as few regional survey has been made.

③ Large quantity of ground water supply is expected as indicated by actual conditions of springs.

④ Possibility of water conservation work exists in mountain area which are utilized as grasslands.

⑤ Cooperation is ready in Salalah area as branch offices have been established by the Bureau of Agriculture and the Bureau of Water Resources and Irrigation.

⑥ The area can be divided into mountains, foot of mountains and plain as there is no large wadi. The possibility of establishing a large scale development plan depends upon the abundance of water resources.

⑦ The government strongly requests.

Problems of the area:

① The area is located far from the capital.

② The area is significant for the security and restrictions are anticipated on the survey.

The priority is in the order of A, C, B, although they are almost equally evaluated.

2. Views on Agricultural & Water Resource Development

(1) Improvement of agricultural production and agricultural labor force.

Fruits and vegetavles have large shares in food imports to Oman. Particularly, vegetables are imported in large quantity in the dry season because its growing periods are limited except a few crops, and preservation life is also short. Price differences of vegetables are as high as 10 times between the dry and rain seasons. This is a serious problems for the national economy as well as for the household.

The northern and southern regions of Oman have different patterns of climate. Therefore, it is possible to improve the import-export balance as well as the agricultural productivity by producing vegetables in winter in northern area and in summer in southern area. Fortunately, the highway between Salalah and Muscat is nearly completed as one of activities promoted by the first 5 year plan, and urgent needs are felt for survey and establishment of distribution and transportation systems of vegetables.

A trend to leave agriculture is seen among people of this country as the social development has been remarkably advancing. Accordingly, mechanization of agricultural operation is becoming an important and immediate task together with the establishment of farms designed for the mechanization. Since the mixed farming is especially in progress as a feature of tropical agriculture, the mechanization would be accelerated by adequate selection of farm dimensions, and by adoption of systematic cropping.

(2) Improvement and promotion of agricultural technology.

Research and tests shall be strengthened for soil improvement, fertilization technology, pests and insect control, breed improvement and products conservation in order to increase the productivity of cultivated land. Since the current agricultural work is mainly a production under tropical environments, the experimental study shall be accomplished in accordance with these local climates. Expansion and reshaping of agricultural experiment stations are necessary for this purpose. It would be worth to examine technical assistance in

similar ways Japanese experimental stations and technical aid centers are utilizing.

(3) Expansion of livestock industry and productivity improvement of forage crops.

The Beduins' grazing had been common practices of livestock industry in deserts from earlier times, and this trends still remain today.

On the other hand, large scale cattle rearing is well promoted under the Government operations with considerable achievements. The most urgent requirements at present are establishment of animal husbandry stations and training of veterinary surgeons to cope with animal diseased control effectively. Major tasks to be performed for the planned promotion of livestock industry based upon grazing include the adjustment of animal population, systematic securing of grasslands, and increased feed production by improvement of grasslands.

(4) Water resource development.

Topographic maps (1:50,000) of the country shall be immediately prepared to accelerate the development of water resources. Particularly needed are to establish or improve flow rate and precipitation observation stations (which shall measure underflow, too) equipped with recording devices for all of these data, to prepare annual reports on hydrographic data, and to establish training organizations for personnel to collect and analyze these data.

(5) Flood reservoir

| Items | Batina | Dofahl |
|---|---|---|
| Utilization of ground water (Including those to be developed) | 303 million $m^3$ | 24 million $m^3$ |
| Fountain | - | - |
| Lost underground water | 32 " | 7 " |
| Lost surface water | 56 " | 115 " |
| Total | 391 " | 485 " |

Emphasis should be placed on the use of ground and surface water for the water resources development in future. The share of surface water utilization is 15.4% of total amount. It would fully contribute to the water resources development of this country depending extent of its utilization.

We propose four easiest methods for the practical utilization of it as follows:

① To stop the water with a low dam and construct large scale bare side ditches to facilitate penetration into the ground.

② To construct network of large scale side ditches without timber along wadis to facilitate penetration into the ground.

③ To install penetration cubes at a right angle to wadi at many locations to cause underground penetration.

④ To block water with mattress cages and construct large scale side ditches for the underground penetration.

Relationship between the above construction methods and floods of Wadi Zizi is presented as follows:

As mentioned above, floods are caused about 10 times a year at Wadi Zizi, and their flow rate is normally 152 ℓ/s. Assuming its duration is 1 day, then,

Flow rate in a day

$V = 152 \times 86,400 \times 1/2 \fallingdotseq 6,566\ m^3/day$

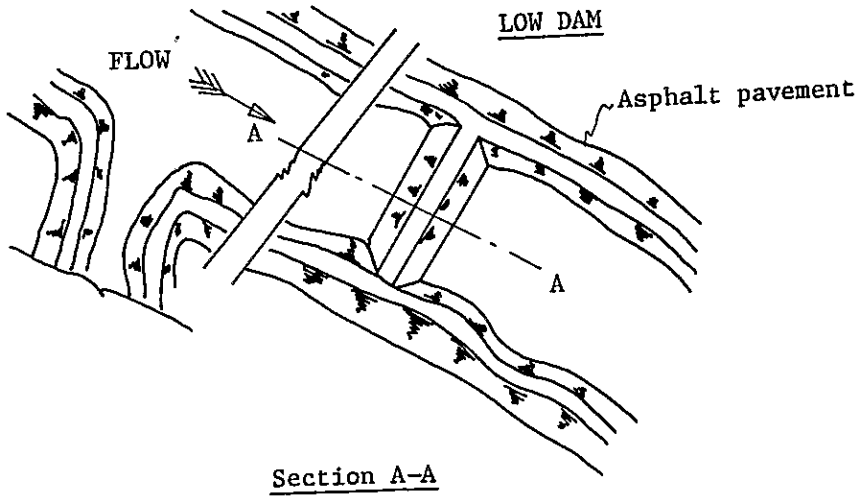
For the diffusion and underground penetration of this water, large water reserving channels (cross section 24 $m^2/n$) with total length of 274m is required for the underground penetration in cases ①, ②, and ④.

Taking 1-10 for service life of timberless ditches and 1/40 for others, construction cost per $m^3$ of reserved water is lowest in Case ③. As it is possible that the ditches may be burried with sands flowing down from upstreams, the construction work of Case ④ on the upstream of Case ③ would accomplish safe and effective water reservation and penetration.

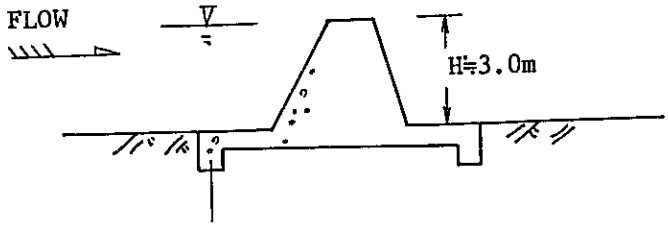
The above considerations are tentative since they are based upon incomplete apprehension of river behaviors and geology, as well as insufficient pertinent data. Optimum construction method in actual work plan should be determined in accordance with the conditions of site.

The evaporation during reservation was neglected since annual evaporation would be only 3,000$m^3$ with an assumption of the penetration coefficient $K = 6 \times 10^{-3}$

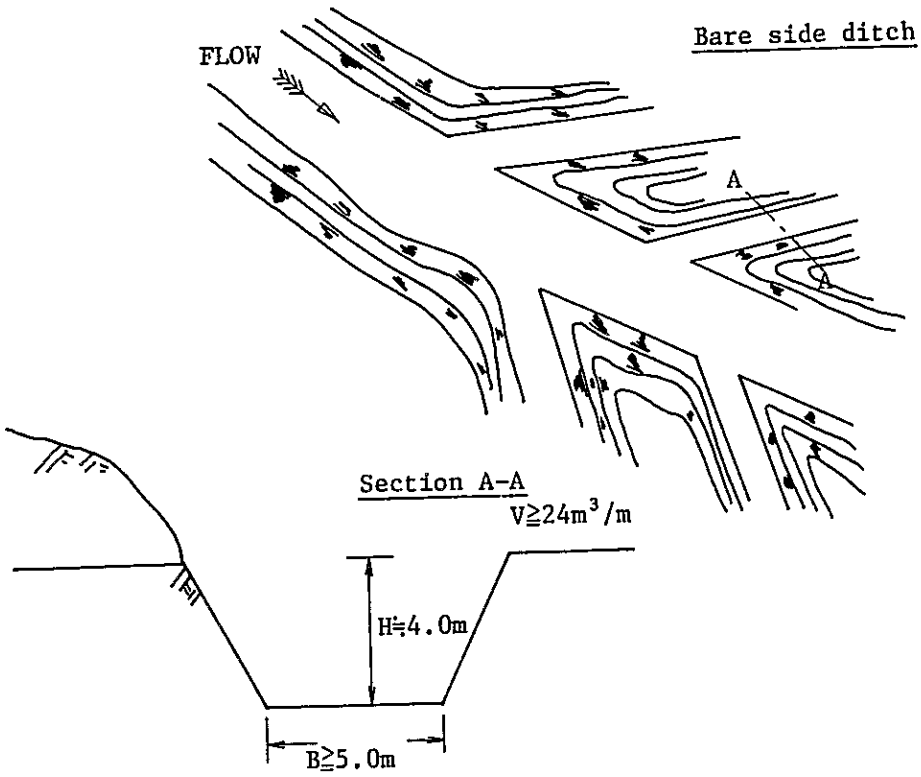
Case 1



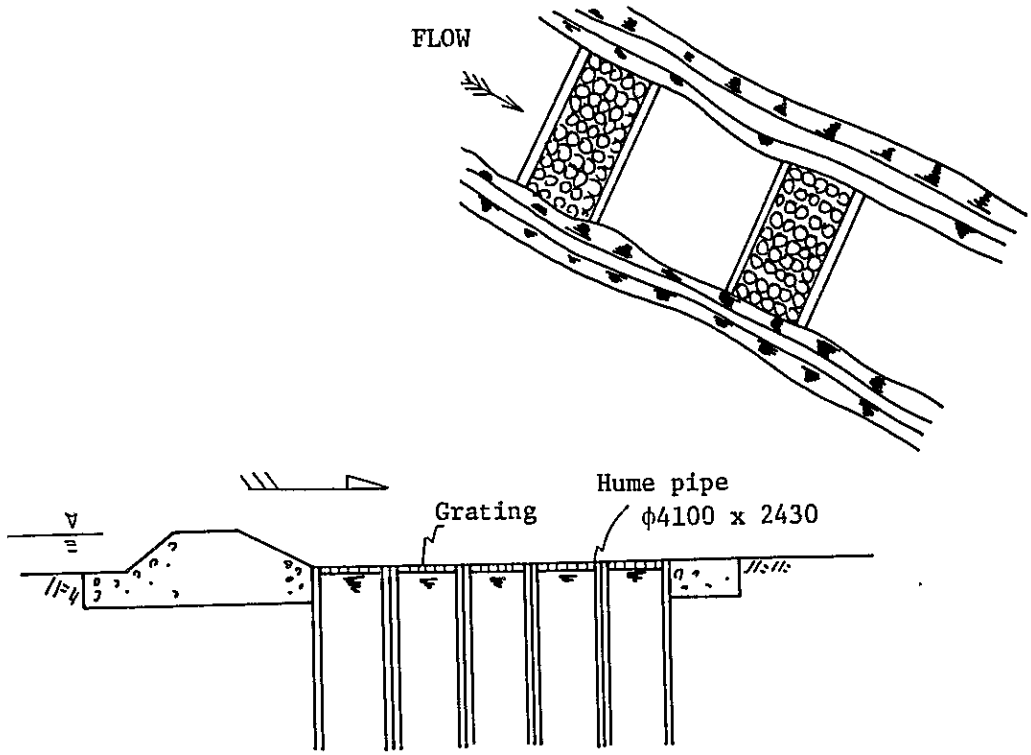

Section A-A



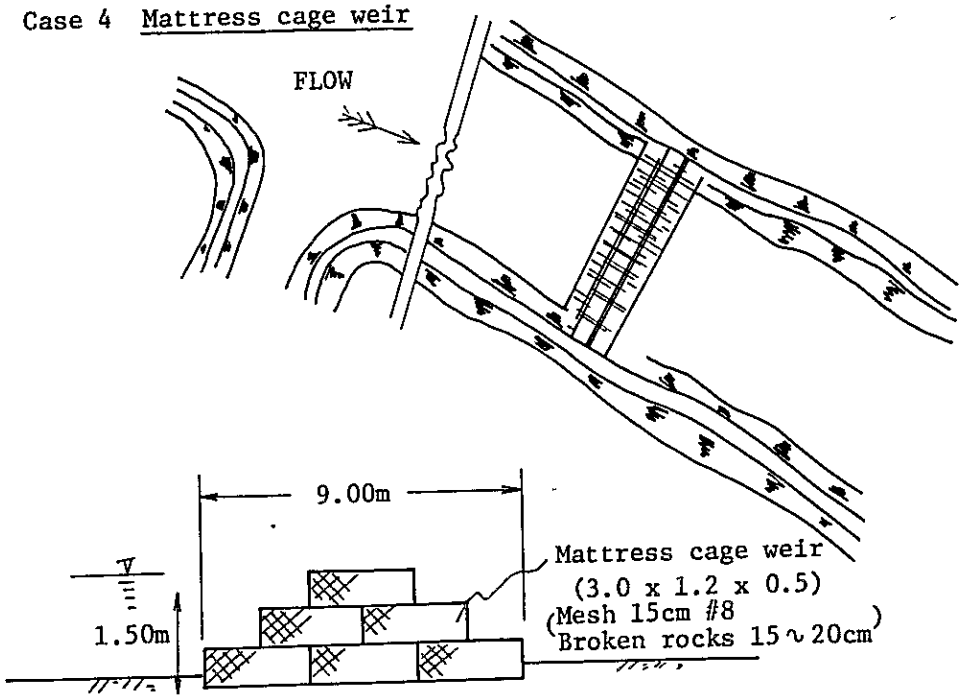

Case 2

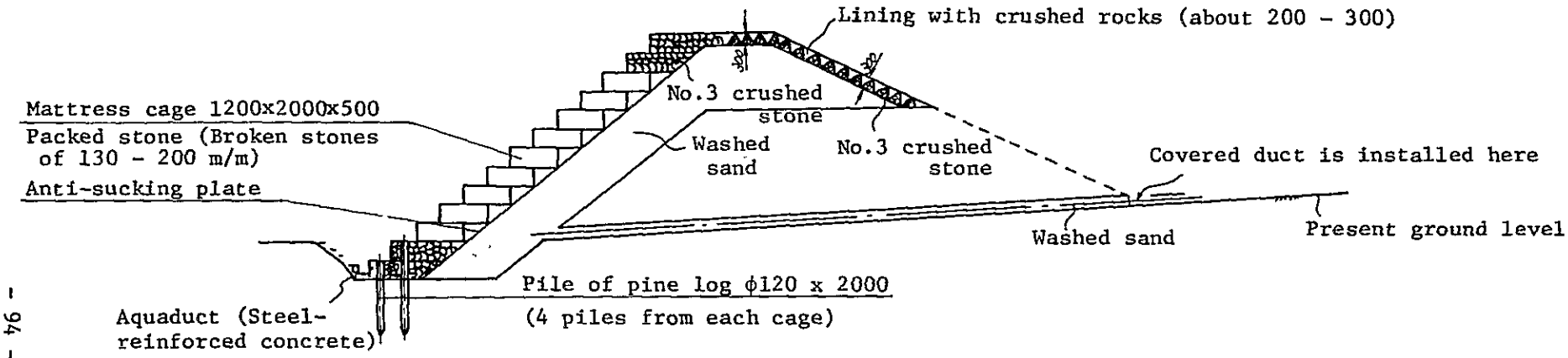


Case 3 Penetration cube




Case 4 Mattress cage weir






Example of structure of sand breaking dam
(Mattress cage type dam)

(6) Establishment of the water conservation forests.

The vegetating operation in this country seems to be limited only to households, highways and public installations. Nothing has been implemented on the vegetation of mountains and plains.

It is estimated that high possibility exists on the forestalization for water conservation in southern mountains, since deciduous bushes are highly developed with partial vegetation of ever-green trees there. Therefore, establishment of nursery farms, forest vegetation technology, and organization for them are urgently needed.

Vegetation should be started at southern mountains immediately, and then it shall be promoted gradually to northern area (where vegetation is seen around wadis).

# APPENDIX

## 1. List of Survey Team Members

| | | |
|---|---|---|
| Team Leader: | Risabudo Nasu | Vice Chief<br>Construction Department<br>Hokkaido Agricultural Administration Bureau<br>Ministry of Agriculture, Forestry and Fisheries<br>(General Manager) |
| Member: | Shuhei Seyama | Assistant Chief<br>Hakodate Construction Department<br>Hokkaido Development Bureau<br>Hokkaido Development Agency<br>(Irrigation) |
| Member: | Hoshimitsu Nakama | Geological Survey Official<br>Planning Department<br>Tohoku Agricultural Administration Bureau<br>Ministry of Agriculture, Forestry and Fisheries<br>(Geology) |
| Member: | Shiro Terasawa | Head of Pedological Science Laboratory<br>Chemistry Department<br>Agriculture Technology Institute<br>Ministry of Agriculture, Forestry and Fisheries<br>(Agriculture) |
| Member: | Takafumi Tawara | International Technical Cooperation Official<br>Economic Department<br>International Division<br>Ministry of Agriculture, Forestry and Fisheries<br>(Cooperation Planning) |

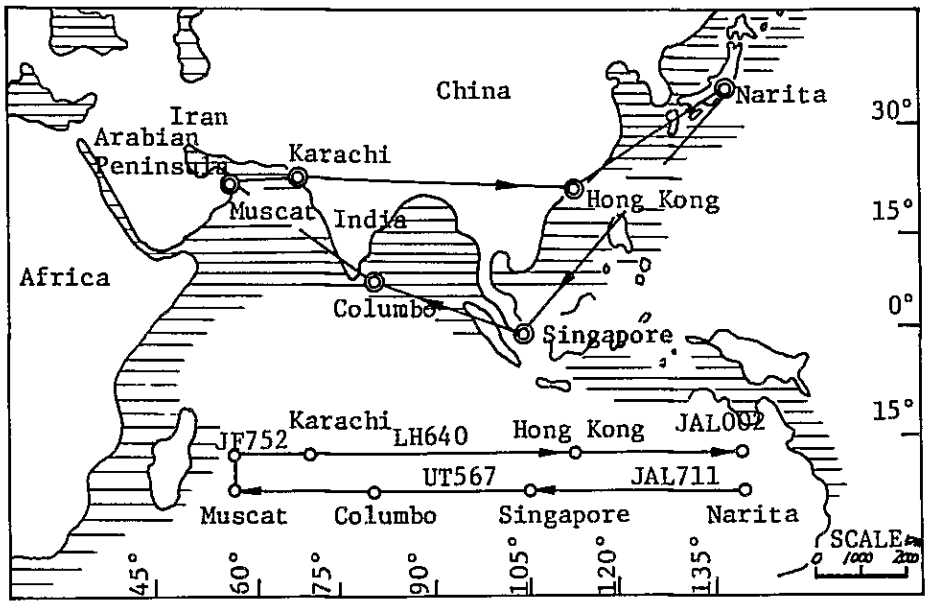
| | | |
|---|---|---|
| Member: | Heizo Kito | Development Cooperation Division<br>Economic Cooperation Department<br>Ministry of Foreign Affairs<br>(Cooperation Policy) |
| Member: | Yzo Shozaki | Special Part-time Employee<br>International Cooperation Agency<br>(Operational Adjustment) |

2. Schedule & Route of Survey Team

| Day | Date | Itinerary | Survey Details |
|---|---|---|---|
| 1 | June 21 (Sat.) | Departure from Tokyo | |
| 2 | 22 (Sun.) | Arrival at Muscat | Visit to Agriculture and Fisheries and Meeting |
| 3 | 23 (Mon.) | Muscat<br><br>Muscat Round Trip to Rumais | Meeting with Information Department, Ministry of Agriculture and Fisheries<br>Meeting with Planning Unit<br>Inspection of Rumais Agricultural Experiment Station |
| 4 | 24 (Tue.) | Muscat | Meeting with Water Resources Public Corporation, Agricultural Chemical Department and Water Resources, Irrigation Department |
| 5 | 25 (Wed.) | Muscat | Meeting with Information Bureau, Ministry of Agriculture and Fisheries |
| 6 | 26 (Thur.) | | Collecting Materials at the Library of Water Resources Public Corporation and Ministry of Agriculture and Fisheries |
| 7 | 27 (Fri.) | Muscat | Survey of the City |

| Day | Date | Itinerary | Survey Details |
|---|---|---|---|
| 8 | June 28 (Sat.) | Muscat | On-the-spot Survey of Sohar Area<br>Visit to the Office of Sohar Agriculture Department, Inspection of Oman Sun Farm, Wadi Jizi |
| 9 | 29 (Sun.) | Round Trip to Rustaq | On-the-spot Survey of Rustaq Area<br>Visit to Rustaq Diffusion Office<br>Inspection of Date Factory, Wadi Bani Khauss |
| 10 | 30 (Mon.) | Muscat | Meeting with Water Resources Public Corporation and Water Resources Irrigation Department |
| 11 | July 1 (Tue.) | Round Trip to Nizwa | On-the-spot Survey of Nizwa Area<br>Inspection of Wadi Samail, Wadi Coriyat and Misfar<br>Visit to the Office of Nizwa Agriculture Department |
| 12 | 2 (Wed.) | Round Trip to Sharqiya | On-the-spot Survey of Sharqiya Area<br>Inspection of Wadi Al Kamil<br>Visit to the Office of Ibra Agriculture Department |
| 13 | 3 (Thur.) | Muscat | Visit to Ministry of Petroleum and Minerals |
| 14 | 4 (Fri.) | Muscat to Salalah | |
| 15 | 5 (Sat.) | Salalah | Visit to Water Resources Department<br>Visit to Agriculture Department<br>On-the-spot Survey of Salalah Area<br>Inspection of Ayn. Garziz, Ayn. Sahal Nawt, Ayn. Arzat, and Wadi Darbat |

| Day | Date | Itinerary | Survey Details |
|---|---|---|---|
| 16 | July 6 (Sun.) | Salalah<br><br>Salalah to Muscat | On-the-spot Survey of Salalah Area<br>Inspection of Quinroon Heirithi Farm and Garziz Farm |
| 17 | 7 (Mon.) | Muscat | Visit to Development Council<br>Writing Reports<br>(Reception under the auspices of Ministry of Agriculture and Fisheries) |
| 18 | 8 (Tue.) | Muscat | Visit to Ministry of Agriculture and Fisheries<br>Submission of Interim Reports<br>Visit to Ministry of Foreign Affairs, Third Department<br>(Reception under the Auspices of Survey Team) |
| 19 | 9 (Wed.) | Muscat to Karachi | Exchange of Reports |
| 20 | 10 (Thur.) | Karachi to Hong Kong | |
| 21 | 11 (Fri.) | Hong Kong to Tokyo | |




Itinerary Map

3. List of Persons Visited by Survey Team

MINISTRY OF AGRICULTURE & FISHERIES

| | |
|---|---|
| H.E. Hassan Muraza | The Undersecretary |
| Dr. Khanfar | Act. Director General of Agriculture |
| Mr. Talib Harib | Asst. D.G. of Irrigation & Water |
| Dr. Alem | Head of Planning Unit |
| Dr. Akalal | Water Wapert |
| Mr. Khakid Al Zubaidy | Director of Information Unit |
| Mrs. Aliya Salim S.Al Busaidy | Director of Public Relation |
| Mr. Mohamed Muktar | Acting Director of Public Relation |
| Miss Hind S.N. Al Abry | Head of Public Relation |

PLANNING UNIT

| | |
|---|---|
| Dr. Mohamed F. Sharaf | F.A.O. Officer in Charge |
| Mr. M. Vazir Hassan | Agriculture Expert |
| Mr. Mohamed Tasnif | Fisheries Expert |
| Mr. Hassan Shehata Hassan | Economic Expert |

MINISTRY OF AGRICULTURE & FISHERIES

| | |
|---|---|
| Mr. Mahfuz H. Mahfuz | Director of Agriculture |
| Mr. Salim Ali Al Fawahy | Acting Director of Agric. Research |
| Mr. Mohamed Abo Khantwa | Agric. Extention Expert |
| Mr. Ahnaf O. Zubaidi | Acting D.G. of Agriculture |
| Mr. Abdul Saltar Kota | Agriculture Expert |
| Mr. Magid Bilarab | Irrigation Section |

M.A.F. (SOHAR)

| | |
|---|---|
| Mr. Ali Sulayim Rashid | Director of Agriculture, Sohar |

M.A.F. (SHARQIA)

| | |
|---|---|
| Mr. Ali Mohamed Salim | Director of Regional Shaqia Area |

M.A.F. (RUSTAQ)

| | |
|---|---|
| Mr. Moud Abdulla Salim | Director of Extension Center, Rustaq |

M.A.F. (NIZWA)

| | |
|---|---|
| Mr. Mohamed Ahmed Mahfodh | Director of Agriculture, Nizwa |
| Mr. Suleiman Rashid | Finance & Administration Section |

M.A.F. (SALALAR)

| | |
|---|---|
| Mr. Salem Alawi Babood | In Charge of Water Resource |
| Mr. Salem Salam | Hydrologist |
| Mr. Kohred Zeazouh | Water Engineer |
| Mr. Ali Tahar Moqabil | Director of Agriculture, Salalah |
| Mr. Ali Oman Mahfooz | Assistant Director of Agriculture |
| Mr. Mohamed Soukkary | Assistant Adviser of Agriculture Dept. |

MINISTRY OF FOREIGN AFFAIRS

| | |
|---|---|
| H.E. Mushtak Abdulla | Director of Third Department |
| Mr. Salim Mohamed Al Riyami | Japan Bureau, Third Dept. |

DEVELOPMENT COUNCIL

| | |
|---|---|
| Dr. Sherif Lotfy | Technical Secretary |

PUBLIC AUTHORITY FOR WATER RESOURCES

| | |
|---|---|
| Dr. Robert H. Dale | Technical Secretary |
| Mr. Abu Bakr Waziri | Chief of Administration |
| Mr. J.P. Rousseuv | Data Analysis Dept. |
| Mr. A.J. Taylor | Field Data Acquisition Manager |
| Mr. Chol C. Kim | Civil Engineer |

MINISTRY OF PETROLEUM & MINERAL

| | |
|---|---|
| Mr. S.P. Burden | Senior Geological Advisor |
| Mr. Ali Bathashi | Director of Economic Regal Affairs |

OMAN SUN FARM

| | |
|---|---|
| Mr. Omen Alwi | Operation Manager, Salalah |
| Mr. Laan | Farm Manager, Salalah |
| Mr. Abdul Kader O. Baabbad | Sohar |
| Dr. Steiner | Farm Manager, Sohar |

4. List of Data & Other Information Obtained

1. Agriculture in Oman
2. Agricultural Development Programme 1975
3. Sultanate of Oman (Quarterly Economic Review)
4. Development of new land for irrigated Agriculture
   (Soil consultant Report)
5. Agricultural Research and Development Report on Agricultural
   Development in Oman
6. Supply of Irrigation Water
7. Development Projects
8. Farm Household
9. Oman Sun Farm
10. Potencial Crops, their yields and their growing seasons
11. Ground-water Development in the Kamil Wahi District, Sharqia Region
12. Development of the Water Resources of Oman for Agriculture
13. Rainfall in Oman (1974 - 1978)
14. Short Period Rainfall Intensities in Oman
15. Climate of the Batinah (1973 - 1977)
16. Rainfall in Dhofar (Salalah Area)
17. Runoff Measurements in Oman
18. Statistical Year Book
19. Oman '79
20. Oman: Facts and Figures
21. The Journal of Oman Studies: Volume 1, 1975
22. The Journal of Oman Studies: Volume 2, 1976
23. Omani Silver
24. The Oman Museum
25. Oman: A history
26. Oman & Its Renaissance
27. Unknown Oman
28. Map of the Capital Area
29. Map of Sultanate of Oman

| | |
|---|---|
| BC-4 | Water resources survey Wadi Lansab Area - May '75. |
| BC-6 | Water resources survey Wadi Sansab Area<br>Report on the construction and testing of production wells - Aug. '76. |
| CE-2 | Report on water resources study phase 2 and technical proposal for construction of water recharge projects - Nov. '79. |
| DC-2 ∿ 6 | Statistical year book (2nd - 6th) '74 - '77 |
| DC-7 | The five year development plan '76 80 |
| DC-10 | Patterns of investiments and growth trends before and during the five year plan |
| DU-1 | Wells in the Dhafora-Dec. '74 |
| DU-2 | Research & Development Survey in Northern Oman, 1978 |
| DCL-1 | Water gaining & irrigation plants in Oman, 1978 |
| DCL-2 | Protection bank for Rostaq-Feb. 1977 |
| DCL-3 | Irrigation water from Ayn Sohannoot Dhaofar-April, 1977 |
| DCL-5 | Irrigation water from Sahalnaut cost comparison of the water carried-Jun., 1977 |
| DCL-6,7 | Project maps, drawings |
| FAO-4,5 | A summary of water resources and agricultural development reports in the Sultanate of Oman - 1975, 1976 |
| FAO-6 | National standards of soil and water analysis on Oman<br>Soil and water management, Field document No. 1, 1976 |
| FAO-7 | Relationship between conductivity values and salt concentrations in soils and waters of Oman, Field document No. 2, 1976 |
| FAO-9 | Development of new land for irrigated agriculture in Oman, soil and land classification, field document No. 4 |
| FAO-10 | The assessment of rainfall in North-eastern Oman through its integration of observations from conventional and satellite sources, Jun., 1977 |
| G-1 3 | Geology of the Oman mountains, part 1-3, Dec., 1974 |
| GO-1 | Thermal-inertia mapping form satellite descrimination of geologic units in Oman-VSGS Jour. Res. - Vol. 2 No. 2, pp. 147-158 |

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|---|---|
| GO-2 | A comparison of Landsat images and nimbus thermal-inertia mapping of Oman - Vol. 4, No. 6, pp. 661-665 |
| GO-4 | Ophioliite obduction and geologic evolution of the Oman mountains & adjacent areas - Geo. Soc. America, Aug. 1977, Bull Vol. 88 pp. 1183-1191 |
| GO-6 | Techtonics of the western gulf of Oman, Jour, Geophys, Res. pp. 3479-3489, Vol. 84, No. 137, Jul. 1979 |
| GO-7 | The geology and mineral resources of Dhufar province, Muscat and Oman, 1974 |
| GO-8 | The tectonic setting for phiolite obdiction in Oman Coleman, G. & Bailey, Edgar H. |
| HC-1 3 | Wadi Samail Aquifer studies including Bait Al Barakah Royal Palace water supply. Main report, summary report Feb. 1978 |
| HTS-1 | Pro-feasibility study to investigate alternative means of establishing commercial farming in interior Oman, final report, Oct., 1976 |
| HTS-2,3 | Livestock sector review and project identification Draft final Vol. 1-2 March, 1978 |
| I-8 11 | Water resources development project, northern Oman Final report Vol. 1-2, supporting documents, maps July, 1975 |
| IRI-1 | Draft of preliminary report Sohar-Saham well drilling and pump installation study, April, 1978 |
| JI-1 | Rostaq flood control project, May, 1977 |
| JTS-3 | Salalah water supply assessment of Salalah plain water resources, January, 1977 |
| JTS-4 | Salalah water supply contract W3 78/79 Well field completion report presenting information collected on the water resources of the Salalah plain, Sept., 1979 |
| K-1 | Reconnaissance survey of northern Oman water resources and development projects, August, 1975 |
| MC-1 | On the establishment of a national metrological service in the sultanate of Oman, Advisory report, 1976 |

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| MAF-1 | Proposed frame of the 5 year Agricultural Development plan, summary of highlights, July, 1976 |
| MAF-2 | Water in Oman, 1977 |
| MAF-3 | Dhofar land and water resources development Water development projects, Oct., 1975 |
| P-3 | Proposal for consulting engineering series of its design of a protection bank for Rostaq, Feb., 1977 |
| P-4 | Wadi Samail irrigation project proposal for consulting services, Dec., 1977 |
| P-5 | Mirbat water supply report on alternative supply schemes, Feb., 1978 |
| P-6 | Taqa water supply report on alternative supply schemes, Feb., 1978 |
| P-7 | Sudh water supply report on alternative supply schemes, Feb., 1978 |
| P-11 13 | Water well drilling in the Jebel and Dhofar-final report Vol. 1-4, May, 1979 |
| PAWR-1 | Preliminary engineering design for wadi alkhawd recharge scheme, May, 1980 |
| PAWR-2 | Ground water recharge alternative for wadi al khawd, May, 1980 |
| PAWR-3 | Buraine area ground water resources appraisal status report-Phase 1, June, 1980 |
| PBI-1 | Wadi Samail Project, June, 1978 |
| PBI-2 | Wadi Samail Phase 1 report, Aug, 1978 |
| PSI-1,3,4, 6,7 | Water resources Survey in North-east Oman, Interim report. March, 1975<br>Annex B: Geophysical Survey<br>C: Hydrogeology<br>E: Pedology<br>F: Agriculture |
| SI-9 | City of Rustaq - project for defence against wadi Far flood - final design report |
| SAG-9 | Water resources survey northern Oman, April, 1975<br>Draft final report on Phase 1 soil and agriculture studies with an int water resources assessment |

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| SAG-18 | Water resources survey of northern Oman - summary, June, 1976 |
| SAG-24 | Main report, rainfall, surface flow, geology, water chemistry |
| SMP-8 | Wadi Dayqah feasibility study - immediate recommendation, April, 1979 |
| SMP-9 | Consulting services poweranl urban water development programme, 1977-1995 |
| SMP-11 | Capital area wellfield refurbishing - al khawd wellfield, Jan., 1980 |
| SWK-1 | Rostaq flood protection & reclamation proposal for design consultancy, Feb., 1977 |
| TTI-1 | Demonstration of rockfill flood-retarding structures Sept., 1977 |
| TTI-2 | Channel geometry and wadi flows- Batinah coast, Sept., 1977 |
| TTI-3 | Satell imagery interpretation and brief techtonic history of Oman, Sept., 1977 |
| TTI-4 | Landsat land use mapping lower Dhofar, Jan., 1978 |
| TTI-5 | Model of shallow aquifer Salalah plain, Aug., 1978 |
| TTI-6 | Ground water salinity survey of its southeast Batinah coastal plain, Dec., 1978 |
| TTI-7 | Ground water system of Jebel al Qara and its relation of ground water in adjacent Salalah coastal plain and Negd., Dec., 1978 |
| TTI-8 | Effect of ground water use on quality and availability in Salalah coastal plain, Dec., 1978 |
| TTI-9 | Evaluation of alternative ground water development schemes for the wadi samail aquifer, March, 1980 |
| TWP-1 4 | Report on 3 year plan for development of irrigation Dec., 1977 |
| V-1 | Ayn Arzat Falaj - Aug., 1977 |
| VC-1 | Review of existing studies - Jan. 1979 |
| WHP-5,6 | Survey and investigations for land and water resources development in Dhofar, summary, main report, Aug., 1975 |

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| WHP-18,19 | Summary of water resources, water resources & irrigation - June, 1977 |
| WHP-22 | Jebel & Negd summary test pumping - June, 1977 |
| WHP-23 | Salalah plain Borehole elevations & logs - June, 1977 |
| WRC-1 | Water resources assessment & appraisal - March, 1979 |
| WRC-2 | Review of wadi Dayqah dam feasibility study - June, 1978 |
| WRC-3 | Water resources prospect in Oman - Aug., 1979 |
| WRC-4 | Flood hydrology of northern Oman - April, 1978 |
| WRD-1 | Rainfall in Muscat area - 1976 |
| WRD-2 | Climate of Jabel Akhdar (Saiq) - 1977 |
| WRD-3,6 | Rainfall in Oman - 1974 1976, 1977 |
| WRD-4 | Climate of the Batinah - 1977 |
| WRD-5 | Rainfall in Dhofar |
| WRD-7 | Runoff measurement in Oman - March, 1978 |
| WRD-8 | Water resources of Salalah plain an interim re-appraisal - April, 1978 |
| WRD-8A | " " |
| WRD-9A | Wadi Samail surface water balance (74-78) - April, 1979 |
| WRD-10 | Water resources of the Batinah - Feb., 1979 |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| BC | BRIAL COLQUHOUN |
| C | CANSULT |
| CE | CORPS OF ENGINEERS |
| CES | CONSULTING ENGINEERING SERVICES |
| CIC | COLORADO INTERNATIONAL CORPORATION |
| DC | DEVELOPMENT COUNFIL (OMAN) |
| DAC | DEVELOPMENT ASSISTANCE CORPORATION |
| DCL | DEVELOPMENT CONSULTANTS LTD |
| DU | DURHAM UNIVERSITY |
| FAO | FOOD AND AGRICULTURAL ORGANIZATION |
| G | GLENNIE |
| GO | GEOLOGY OF OMAN (MIS.PAPERS) |
| GME | GEOLOGY OF THE MIDDLE EAST (MISC.PAPERS) |
| GPP | GIBB PETER MULLER AND PARTNERS |
| HC | HYDROCONSULT |
| HTS | HUNTING TECHNICAL SERVICES |
| HWP | HAROLD WHITEHEAD AND PARTNERS |
| I | ILACO |
| IRI | INTERNATIONAL RESEARCH INSTITUTE |
| JI | JORDAN INTERNATIONAL |
| JTS | JOHN TAYLOR AND SONS |
| K | KONTEATIS |
| LD | LEWELLYER DAVIS |
| MC | MINISTYR OF COMMUNICATIONS (OMAN) |
| MH | MINISTRY OF HEALTH (OMAN) |
| MP | MANDERSTAM AND PARTNERS |
| MAF | MINISTRY OF AGRICULTURE AND FISHERIES (OMAN) |
| MAF (UAE) | MINISTRY OF AGRICULTURE AND FISHERIES (U.A.E.) |
| MDC | MUSANDAM DEVELOPMENT COMMITTEE |
| MEW | MINISTRY OF ELECTRICITY AND WATER (OMAN) |
| MLM | MINISTRY OF LAND AND MUNICIPALITIES (OMAN) |
| MPM | MINISTRY OF PETROLEUM AND MINERALS (OMAN) |
| OCM | OMAN MINING COMPANY |

| | |
|---|---|
| P | TENCOL |
| PAWR | PUBLIC AUTHORITY FOR WATER RESOURCES |
| PBI | PARSONS BRINCKERHOFF INTERNATIONAL INC. |
| RSI | RENARDET SAUTI ICE |
| SI | SAUTI ICE |
| SAG | SIR ALEXANDER GIBB AND PARTNERS |
| SMP | SIR MACDONALD AND PARTNERS |
| SWA | SIMPSON WEATHER ASSOCIATES |
| SWK | SCOTT WILSON KILPATRICK |
| SMAW | SAUDI MINISTRY OF AGRICULTURE AND WATER |
| SMPM | SAUDI MINISTRY OF PETROLEUM AND MINERALS |
| TTI | TETRA TECH INTERNATIONAL INC. |
| TWP | TURNER WRIGHT AND PARTNERS |
| TWT | TAILOR WOODROW TOWELL |
| USBR | UNITED STATES BUREAU OF RECLAMATION |
| USGS | UNITED STATES GEOLOGICAL SURVEY |
| V | VALTOS |
| VC | VADIS COMPANY S.A. |
| WB | WORLD BANK |
| WHO | WORLD HEALTH ORGANIZATION |
| WHP | WILLIAM HALCROW AND PARTNERS |
| WRC | WATER RECOURCES COUNCIL |
| WRD | WATER RESOURCES DEPARTMENT |

NOTE: BOOK BY THE FOLLOWING AUTHORS ARE NOT PRESENTLY AVAILABLE IN THE PAWR LIBRARY, AS OF 27 MAY 1980:

1) CANSULT (C)
2) U.S. BUREAU OF RECLAMATION (USBR)
3) MINISTRY OF ELECTRICITY & WATER (MEW)
4) OMAN MINING COY (OCM)
5) MUSANDAM DEV. COMMITTEE (MDC)
6) MINISTRY OF LAND & MUNICIPALITIES (MLM)

5. Summary of Discussion

1) The Government of Japan sent a preliminary survey team for an agricultural development project in the Sultanate of Oman. During the visit of the team in Oman from 22nd June to 9th July, 1980, the team held the discussion with the officials of the Ministry of Agriculture and Fisheries and carried out field surveys in Batinah, Oman Interior, Sharqiya and Southern Region: Wadi Jizi, Wadi Far, Wadi Bani Kharus, Nizwa, Al Kamil and Salalah.

2) Based of the results of the field surveys the team selected three areas which have high potentialities of agriculture development and put the following order of the priorities on each area for the feasibility study.

The order of the priorities:

1. Sohar - Wadi El Jizi
2. Salalah Plain
3. Rustaq - Wadi Far, Wadi Bani Kharus

3) The team submitted an interim report to the Ministry of Agriculture and Fisheries in which conceptions of the developments and priorities were described for each area.

4) The Ministry of Agriculture and Fisheries agreed in principle on the conceptions of the developments and the order of the priorities.

5) The Government of the Sultanate of Oman requested the Government of Japan to send a follow-up mission for consultations with the Government of Oman on the scope of works for the feasibility study in the area of Wadi El Jizi (Sohar)

6) The Ministry of Agriculture & Forest equally requested the Government of Japan to help for full study of Agriculture Development in the Southern Region "Salalah".

| | |
|---|---|
| H.A. Al-Morazza | Risaburo Hasu |
| Undersecretary | Team Leader |
| Ministry of Agriculture & Fisheries | Japanese Preliminary Survey Team |
| Sultanate of Oman | for Agricultural Development Project |

DATE: 9th July, 1980

PLACE: Muscat

6. Interim Report

H.E. Hassan Murraza
The Under Secretary
Ministry of Agriculture & Fisheries
MUSCAT
SULTANATE OF OMAN

Your Excellency,

Submission of Interim Report on
Preliminary Survey of
Agricultural Development Project

I have a great pleasure to submit herewith an Interim Report on Preliminary Survey of Agricultural Development Project, carried out by the Survey Team dispatched by the Government of Japan.

The Team carried out the survey throughly and sufficiently and had a series of discussions every now and then with officials concerned.

The contents of the report are, however, tentative and subject to revision on the occasion of making the final report after our return to Japan.

I expect that the Government of Japan will make necessary actions and procedures for the next step of the project as soon as possible.

In this occasion, I would like to express to you my hearty thanks for sincere cooperation, convenience and hospitality extended to us by you and your staff during our stay in Oman.

I remain,

Respectfully yours,

RISABURO NARU
Team Leader
Japanese Preliminary Survey Team
for Agricultural Development Project

THE SULTANATE OF OMAN

MINISTRY OF AGRICULTURE AND FISHERIES

# INTERIM REPORT

ON

# PRELIMINARY SURVEY OF AGRICULTURAL DEVELOPMENT

JULY 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

TABLE OF CONTENTS

# INTRODUCTION

In response to the request of the Government of Oman, the Government of Japan dispatched the Preliminary survey team for Agricultural Development Project in Sultanate of Oman hereafter mentioned as the team) through Japan International Cooperation Agency. The team headed by Mr. Risaburo Nasu stayed in the Sultanate of Oman from June, 22nd to July, 9th 1980.
(List of members is shown in Annexe)

The teams of reference of the team are to select and delineate the project area, to study technical skill of the survey and to collect the relevant existing data and information.

During the stay of nineteen days in the Sultanate, the team made a quick review of existing reports and studies on water resources and agricultural development. Discussions were held with the Government Officials concerned on these subjects. The team made field surveys arranged by the Ministry of Agriculture and Fisheries in four main agricultural areas - Batina Coast, Interior Sharfiya and Salalah area - and collected information at farmers level.

Due to the positive cooperation extended by the Government of Oman, the survey was carried out satisfactory obtaining the following findings and conclusions.

## I. - GENERAL REMARKS ON THE AGRICULTURE OF THE SULTANATE OF OMAN

The Sultanate of Oman is the greenest country of Arabia and the majority of the population is engaged in agriculture, the Sultanate, moreover, has a strong potentiality for agricultural developments. Prospective areas for development are identified on both sides of the mountains in the Northern Oman and on the Salalah Plain. The estimated acreage of lands in those areas is believed to around 20,000 acreas provided that the water is available for irrigation.

In the second five-year plan (1981-1985) currently under preparation, the agricultural section is said to continue to be one of the highest priority sectors. The agricultural sector, which has attained higher growth rates than anticipated, still has much to go in order to meet the local demands for food because the diversification in demands is due to continue as a result of the improvements in the quality of life and the rapid progress of the urbanization. The desire to export surpluses of the food is urgent in order to diversity the economy. The agriculture, therefore, is considered to be one of the most strategic industries of the Sultanate of Oman.

Dates and limes are traditional Omani crops for export, and still are the most important crops. Research into the production of fruits and vegetables is extensively carried out in every agricultural region of the country and the value added on those crops has shown remarkable increases. A large amount of vegetables, however, is imported in summer because the production of vegetables is limited to the winter time in the Northern Oman. The Salalah Plain could be a great source of vegetable supply to the Capital area if the next work of roads is completed because the Salalah Plain is suitable for vegetable, production even in summer due to the monsoon rains from June to September.

Erratic occurrences of intense storms with sporadic distribution, combined with impermiable steep terrains of the mountains, largely determine unique hydrological characteristics of the Sultanate of Oman. Most of the rain water runs, in only a matter of hours, to waste into the sea along the coastal side of the mountains and into desert sands on the other. Floods and unsteady "Wadi" (dry rivery channel) beds, not to speak of an unreliable nature of surface flow, are few of the problems associated with the runoff characteristics.

Because of those characteristics of surface flows, the people in the Sultanate used to rely exclusively on ground water. It should be noted that the ancient irrigation system called "Falaj", rooted in the unknown past, has been handed down from generation to generation. A Falaj is a system for the distribution of water and it means a hand-dug tunnel, in some cases, extending as far as 20km. The water tapped in the gravels of a Wadi is brought to the surface through Falaj tunnels by the gravity.

With the introduction of diesel pumps, beginning in 1950, abstractions of ground water from shallow wells, largely dug in aluvial deposits, provided ubiquitous opportunities for inexpensive developments of farm lands. Overpumping, however, has caused deterioration of the water quality, mostly a salinity problem, in some places along the coastal plains. As for the interior regions, ever-increasing abstractions from the wells might induce subsidences of water tables and eventually might arouse controversies over the water among the Falaj users and the well pumpers. Water has been, and would continue to be the basic constraint on agricultural developments in the Sultanate of Oman.

## II. - AREAS STUDIED

1. Sohar (The Wadi Zizi)

A short reconnaissance survey was made on the Wadi Zizi about 30km south-west of Sohar.

The Wadi meanders through a U-shaped valley (approximate width and depth: 150m, 10m), but it still seems to have the gradient of 1:200 on average. The Wadi bed is composed of aggregates with boulders (diameters: 20 30 cm) scattered.

There is a pool (approximate width and depth: 30 × 10m 30 50cm) with some fish in it. A stream runs from the pool but infiltrates back into the Wadi bed about 200m downstream of the pool.

The bed rock under the Wadi bed is supposed to be a member of Ophiolites and it could be less permiable.

Conceptualization of Agricultural Development

Water tapped in upstream Wadi beds should be conveyed to the land lying along the coastal road.

Series of diversion dams with adequate intervals should be built in a Wadi valley perpendicular to the stream line. The dams should serve to stabilize the Wadi bed as well as to raise the water levels. The water should be collected through tunnels/shafts especially designed for tapping the water in the gravels of the Wadi. The abstracted water should be converged into a conveyer conduit. A system of conveyance of the water should be an open or semi-open type which necessiates pressure release stands.

In the latter stages of the developments, the supply of water should be increased by detention dams and/or ground water re-charging facilities.

2. Rustaq (The Wadies Far, Bani Kharus, )

A one-day reconnaisance survey was made across the three wadies.

Mountains with steep slopes are just beyond the both sides of the Wadi beds. Rocks are of ophiolite and of ultra basic with clear

evidence of major and minor faults.

The width of wadi beds is more than 200m on average. The composure of the wadi beds is almost the same as the Wadi Zizi, i.e., aggregates, although the depth of aggregates is observed to be deeper.

There are several oasis villages, along the cruised course, the Falaj serving each one of the villages has its origin in the gravels of a wadi - a measured depth to a horizontal tunnel is 6 times as deep as an average height of man.

Conceptualization of Agricultural Development

Water withdrawn is to be used in the existing villages while the balance could be utilized for new lands.

Topography and Geology of the area allow the construction of underground reservoirs. Series of low dams floating on the gravels with an extensive grout curtain under each one of them should also stabilize wadi beds.

Methods of tapping the water and of conveying the water are essentially the same as the Wadi Zizi, although cares should be taken for the local farmers.

Surface detention of the water on recharge to the ground water should also be considered in the latter stages of the resources developments.

3. Salalah Plain

A three-day field trip to the Salalah Plain was arranged through the courtesy of the Ministry of Agriculture and Fisheries.

The monsoon and the limestones give the area a natural environment clearly different from that of the Northern Oman. The aquifers in the Plain currently in use are in the limestones as well as in the aluvial deposits and relatively shallow (up to 60m). The water from the aquifers is replied to be of good quality and sufficient in quantity with little seasonal fluctuations in the water levels.

Two development schemes utilizing the spring water are completed, and the results are very instructive from a hydrogeological point of view. A complemental scheme of ground water development is now ready

for implementation. Another large scale development is going to take off whenever the coordination of the pumping wells is finished.

Conceptualization of Agricultural Development

Water may or may not be available for further developments if the projected schemes are completed to the full extent. It should be necessary to identify the current state of development and to assess the potential for the developments in the future. A master plan for the Plain should be prepared on the stronger data base and should be approved by those who are concerned in order to control the unexpected deterioration of the water.

A mathematical model of the Plain with an emphasis on the ground water should be constructed and be simulated on the alternatives for the future. Accuracy of the information on the geological structure of the plain is crutial although land classification based on a soil survey cannot be missed.

4. Comments on other area

Al Kamil

A long one-day trip to the pumping cite of the Ministry of Agriculture and Fisheries was made from Muscat.

The project area is extensive and the soils of the area are good. The wadies flowing into the area have large watershed areas compared to the wadies on the coastal plains.

A master plan for the development should be formulated based on a solid estimation of an over-all hydrological cycle, because there are a fairly large number of Falajes and wells in the water sheds. Any idea about tapping and conveying the water from the Wadi Bani Khalit should be scrutinized while recharging schemes are to be studied on the latter phase of the developments.

Misfar

The village is located in a deep detached valley gauged in ultra basic rocks about 1500m above the sea level. The cultivated lands of the village are on different levels of the terraces on the walls of the

valley. The water flowing from the higher location of the valley is channeled down to the cultivated lands.

It should be possible to enhance the quality of life in the village by taking the following measures:

1. Building a pipeline system for drinking water.

2. Equipping a small size hydrogenerater in order to take advantage of the gravity head of the water.

3. Constructing a rope way system with auxiliary roads extending from terminals of the rope way.

## III. CONCLUDING REMARKS

The proposed concept for the Rustaq area needs coordination with the on-going project and with the local users of the existing Falajes. The studies on the Rustaq area, thus, should be placed in the lowest echelon.

The intensity of the developments on the Salalah Plain may abruptly cause water problems in the foreseeable future. Estimated costs for the areal studies, however, may be far beyond the reach of the Japanese Government if the requirements for the studies are extensive as well as intensive. The studies on the Plain, therefore, should not be given a first priority, although the urgency of the studies should not never be under-estimated.

The concept for Sohar is essentially in the nature of a pilot project and it should be applied to similar areas if the results of the project would be acceptable. Furthermore, the area is now experiencing a large scale agricultural development project, of which effects should be assessed anyhow. A top priority, accordingly, is to be given to the area of Sohar.

## ANNEX LIST OF MEMBERS

| Assignment | Name | Position |
|---|---|---|
| Leader | Mr. Risaburo NASU | Vice-Director,<br>Construction Dept.,<br>Hokuriku Regional Agricultural<br>Administration Office,<br>Ministry of Agriculture,<br>Forestry and Fisheries |
| Agriculture | Mr. Shiro TERASAWA | Chief,<br>Soil Physics Laboratory,<br>National Institute of<br>Agricultural Science,<br>Ministry of Agriculture,<br>Forestry and Fisheries |
| Irrigation | Mr. Shuhei SEYAMA | Deputy Director,<br>Assabe Agricultural<br>Development Office,<br>Hakodate Construction Dept.<br>Hokkaido Development Agency |
| Geology | Mr. Norichika CHUMAN | Geologist,<br>Resources Div.,<br>Planning Dept.,<br>Tohoku Regional Agricultural<br>Administration Office,<br>Ministry of Agriculture,<br>Forestry and Fisheries |
| Cooperation<br>& Planning | Mr. Takafumi TAHARA | Senior Official,<br>International Cooperation Div.,<br>Economic Affairs Bureau<br>Ministry of Agriculture,<br>Forestry and Fisheries |

| Assignment | Name | Position |
|---|---|---|
| Cooperation & Policy | Mr. Heizo KITO | Senior Official,<br>Development Cooperation Div.,<br>Economic Cooperation Bureau<br>Ministry of Foreign Affairs |
| Coordinator | Mr. Yzo SHOZAKI | Technical Adviser,<br>Japan International<br>Cooperation Agency |

7. Scope of Works (Draft)

Materials to be researched before commencement of survey operation

| Survey Items | |
|---|---|
| Purposes | Oman's intentions concerning acceptance of trainees |
| Recipient Government Body Water Resources Irrigation Bureau, Ministry of Agriculture and Fisheries | Relations with Agriculture and Water Resource Authority |
| I. Collection and Review of Existing Survey, Study and Observation Results | Referring to the list of reference materials and data collected by previous survey team |
| II. Survey in the Field | |
| II.-1 Natural Conditions | |
| a. Metrological Observations | Problem of main operation body (Japan or Oman?) Necessity of observing actual rainfall and the run-off. Necessity of observing seasonal changes |
| b. Geographical Survey | Scope of survey and method of assembling the results |
| c. Water Survey | |
| d. Agronomical Survey | Scope of survey and method of assembling the results |
| e. Plant Ecology Survey | Necessary? |
| f. Underground Water Survey | |

| | |
|---|---|
| II.-2 Agricultural Production Activity | |
| a. Present Land-use Situation | |
| b. Production of Crops | |
| c. Present Irrigation Situation | |
| d. Survey of Farm-household Management | Might be unnecessary because of Oman's intentions to farm form |
| e. Survey of Products, Inputs and Distribution Sector | |
| f. Other | |
| III. Making of Topographical Map | |
| III.-1 Taking Air Photographs | Regarding the existence of already-taken photos (ex. possibility of using photos the coastal area). Permission to take photos. Especially about using our country's airline. |
| III.-2 Diagramming Topographical Map on the Scale of 1:50,000 Area, Contour Lines | Permission to take photos abroad |
| III.-3 Diagramming Topographical Map on the Scale of 1:5,000 Location, Contour Lines | Point: How to deal with surveying and diagramming area along the pipe line |

| | |
|---|---|
| IV. Collection of Analysis of Data | |
| V. Preparation of Water Resources and Agricultural Development Plan | What form of farm management and crops being considered? |
| VI. Calculation of Construction Costs and Economic effect Analysis | |
| VII. Submission of Reports and Maps | |
| VII.-1 Inception Reports | |
| VII.-2 Interim (Progress) Report | |
| VII.-3 Draft of Final Reports | |
| VII.-4 Final Reports | |
| VII.-5 Submission of Topographical Map Originals | |
| VIII. Itinerary | s/w discussion<br>f/s (dry season and rainy season)<br>Air photograph |
| IX. Respective Responsibility Share of the Two Countries | |
| IX.-1 Responsibility Share of Oman | |

| | |
|---|---|
| (1) Offer Office Space<br>(2) Counterparts<br>(3) Completion of Necessary Procedures for Obtaining Permission for Air Photographing and Taking the Photos abroad<br>(4) Permission for Perusing and Copying Materials and Data (Especially Water Resource Authority)<br>(5) Permission for Taking Collected Materials abroad<br>(6) Offer of Maps for On-the Spot Survey (1/100,000) | Point: place-Muscat or Sohar<br>Residence place Field |

8. Fundamental Data

(1) Geographical Features

(2) Rainfall Situation

(3) Rainfall Statistics

(4) Moving of Actual Rainfall (Muscat Area)

(5) Monthly Temperature, Humidity and Evaporation

(6) Companies Registered Classified by Economic Activity

(7) Crude Oil Production

(8) Summary of Recorded Imports and Exports

(9) Recorded Imports Classified Under Broad Categories

(10) Government Revenue and Expenditure

(11) Government Medical and Public Health Establishments and Beds

(12) Governmet Schools, Pupils and Teachers

(13) Area under Cultivation and Area under Crops

(14) Government Production Farms, Research Stations, Extention Farms and Centers and Nursery Gardens

(15) Crops by Regions and Area under Cultivation

(16) Prices of Various Materials in Oman

(1) Geographical features

The Sultanate of Oman occupies most of the south-eastern corner of the Arabian Peninsular and has a coast line stretching almost 1,700km from the Straits of Hormuz in the north to the frontier with the People's Democratic Republic of Yemen. The Muscandam Peninsular, the north-most point of Oman, is separated from the main body of the Sultanate by a strip of territory which is part of the United Arab Emirates (UAE).

Oman is located between latitudes 16°40'N and 26°20'N and longitudes 51°50'E and 59°40'E.

| Land Area | sq.km. | sq.milles |
|---|---|---|
| Total | 300,000 | 120,000 |
| of which, regions: | | |
| Dhofar | 100,000 | 40,000 |
| Musandam | 2,000 | 800 |
| Other | 198,000 | 79,200 |
| and, type of terrain: | | |
| Mountains (450m + ) | 45,000 | 18,000 |
| Coastal plains, inhabited | 9,000 | 3,600 |
| Wadi and desert areas (450m - ) | 246,000 | 98,400 |

- Population

No population census has so far been carried out in Oman and precise population figures are not available. For planning purposes the population is assumed to be 1,500,000 (for 1974)

(2) Rainfall situation

Yearly Rainfall Averages by Regions

(rainfall in millimeters)

| | High above sea level | 1974 | 1975 | 1976 | 1977 | 1978 | Average of five years |
|---|---|---|---|---|---|---|---|
| Sohar | 15 | 78 | 53 | 252 | 160 | 47 | 118 |
| Wadi Jizi | 500 | 51 | 81 | 375 | 107 | 91 | 141 |
| Rostaq | 350 | (142) | 166 | 277 | 249 | 92 | 185 |
| Nizwa | 350 | ( 39) | 215 | 180 | 190 | 149 | 155 |
| Al Wati | - | ( 42) | 52 | 150 | 110 | 150 | 101 |
| Muscat | 5 | ( 25) | 80 | 203 | 181 | 74 | 113 |
| Salalah | - | 21 | 42 | 74 | 394 | - | 133 |
| Medinat Al Haq | - | 123 | 223 | 286 | - | - | 211 |

Monthly Rainfall Averages by Regions (1977 & 1978)

(rainfall in millimeters)

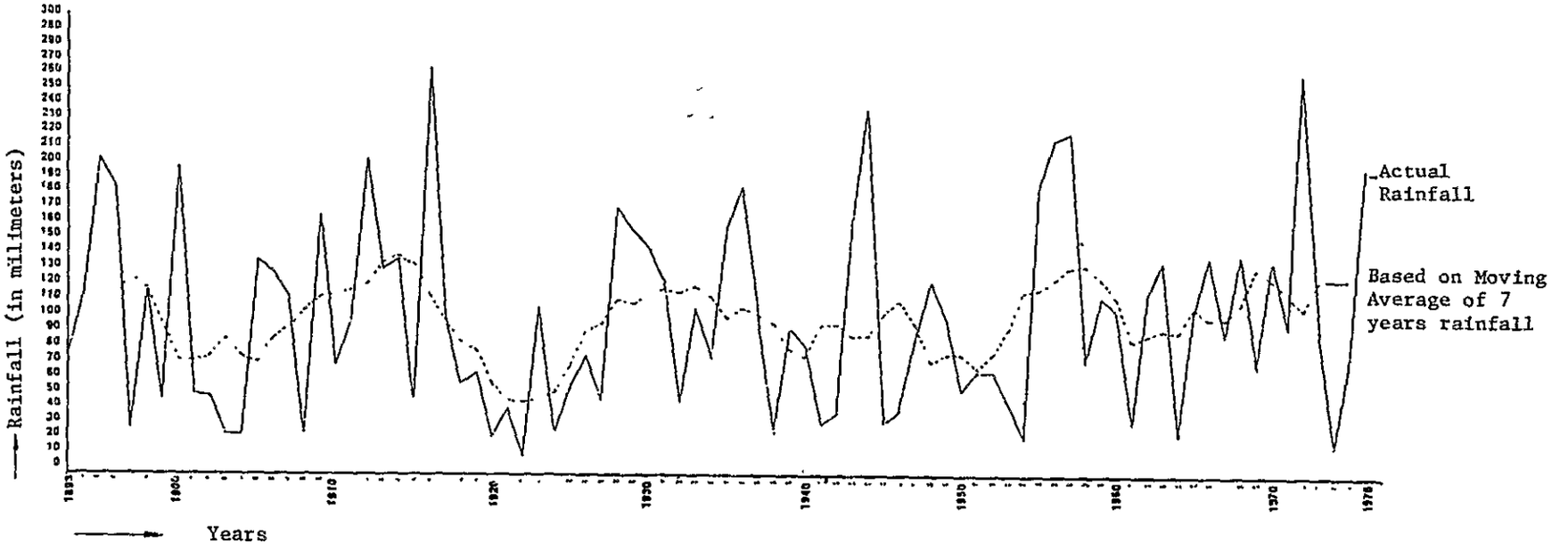
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sohar | - | 34.2 | 6.5 | 2.0 | - | - | 3.6 | - | - | - | - | 0.3 | 46.6 |
| Wadi Jizi | - | 31.2 | 4.3 | 0.5 | - | 2.0 | 22.5 | 30.5 | 13.8 | - | - | - | 91.0 |
| Rostaq | 9.5 | 19.5 | 19.5 | 4.8 | - | - | 13.0 | 19.7 | - | - | - | - | 91.8 |
| Nizwa | 31.8 | 3.3 | 42.5 | 3.4 | - | 0.2 | 54.4 | 13.0 | - | - | - | - | 148.6 |
| Al Wati | 10.5 | 28.5 | 2.5 | 22.0 | - | 16.5 | 64.5 | - | - | - | 5.5 | - | 150.0 |
| Muscat | 29.5 | 24.5 | 17.2 | 1.5 | - | - | 1.0 | - | - | - | - | - | 73.7 |
| Salalaj | 0.7 | - | - | 122.5 | 59.8 | 124.0 | 28.7 | 23.9 | 0.9 | 33.7 | - | - | 394.2 |
| Medinat Al Haq | - | - | - | 74.1 | 206.0 | 482.3 | 152.8 | x | x | 9.6 | - | - | 1100 |

Note: The averages of Salalah and Medinat Al Haq are based on 1977 data.

(3) Rainfall statistics

| Month | Muscat | | | | | | | Rostaq | Nizwa | Al Wafi | Salalah | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Monthly average | | | | Monthly actuals | | | Actuals | Actuals | Actuals | Monthly average | Monthly actuals | | |
| | 1893-1920 | 1921-50 | 1951-76 | 1893-76 | 1976 | 1977 | 1978 | 1978 | 1978 | 1978 | 1942-72 | 1975 | 1976 | 1977 |
| January | 28.3 | 25.2 | 33.7 | 29.0 | 44.5 | 54.0 | 29.5 | 9.5 | 28.9 | 10.5 | 1.0 | - | - | - |
| February | 21.3 | 14.5 | 19.1 | 18.7 | 59.5 | 23.7 | 24.5 | 11.5 | 3.3 | 28.5 | 1.0 | - | 1.8 | - |
| March | 15.5 | 5.1 | 11.7 | 11.2 | 53.0 | 6.8 | 17.2 | 19.5 | 42.5 | 2.5 | 6.4 | - | - | - |
| April | 10.5 | 3.7 | 10.4 | 8.5 | 35.3 | 16.5 | 1.5 | 3.8 | 2.3 | 22.0 | 4.6 | - | 75.2 | 83.2 |
| May | 0.1 | 0.1 | 6.7 | 2.3 | - | Tr. | - | - | - | - | 13.7 | - | - | 40.3 |
| June | 2.9 | Tr. | 1.7 | 1.7 | - | 8.1 | - | - | 1.0 | - | 4.0 | - | - | 159.0 |
| July | 0.4 | 0.2 | 4.1 | 1.6 | 8.0 | Tr. | 1.0 | 8.0 | 51.1 | - | 27.0 | 28.0 | 27.5 | 25.1 |
| August | 0.9 | Tr. | 4.6 | 1.9 | - | 0.5 | - | 24.0 | 10.0 | - | 26.7 | 21.0 | 10.2 | 23.3 |
| September | - | - | - | - | - | - | - | 12.0 | Tr. | - | 3.4 | 22.0 | 2.2 | 2.8 |
| October | 2.3 | 2.8 | Tr. | 1.7 | - | - | - | - | - | - | 7.6 | - | - | 30.5 |
| November | 8.3 | 7.7 | 6.8 | 7.6 | - | 74.7 | Tr. | - | - | 5.5 | 8.7 | - | - | - |
| December | 15.0 | 28.5 | 17.4 | 19.5 | 3.0 | Tr. | - | - | - | - | 3.8 | - | - | 3.5 |
| Total | 105.5 | 87.8 | 116.2 | 103.7 | 203.3 | 181.3 | 73.7 | 88.3 | 139.2 | 69.0 | 107.9 | 71.0 | 116.9 | 367.7 |

(4) Rainfall in Muscat Area
1893 - 1976

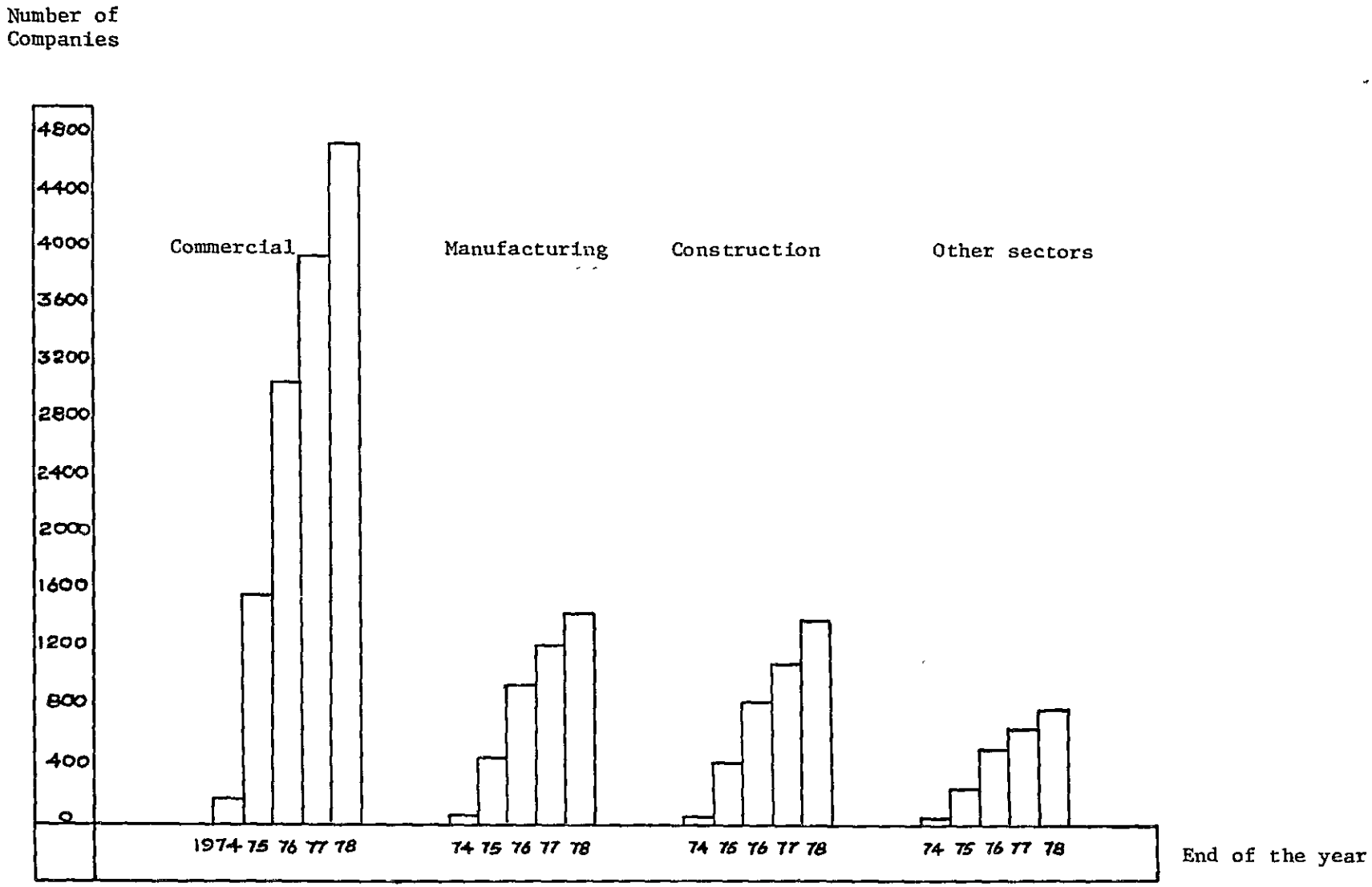


(5) Monthly temperature, humidity and evaporation

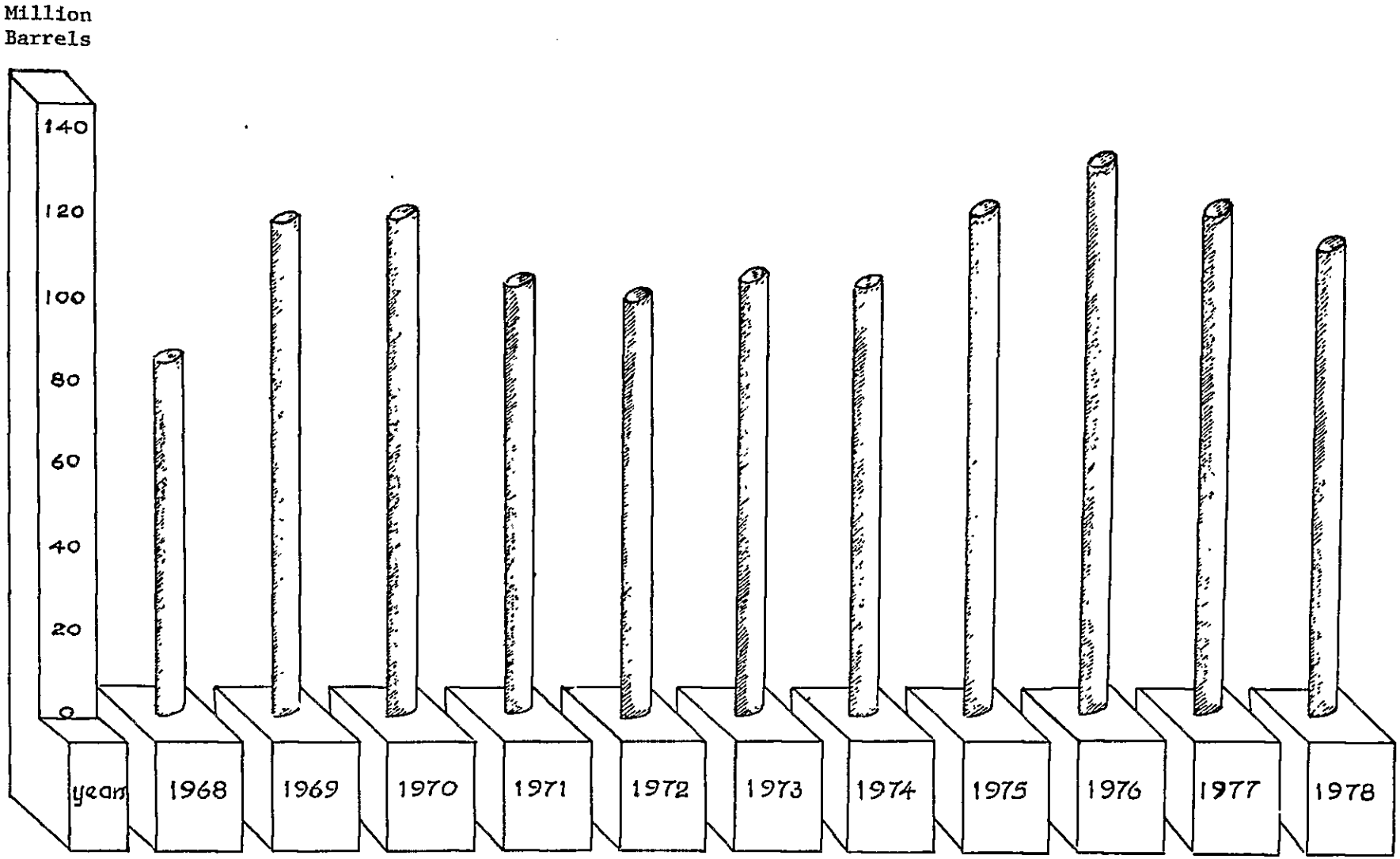
| Regions | Items | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sohar | M.max. | 23.8 | 23.9 | 28.5 | 31.3 | 38.3 | 39.1 | 37.3 | 36.6 | 36.1 | 33.7 | 28.9 | 26.0 | 32.0 |
| | M.min. | 12.0 | 12.8 | 15.8 | 17.8 | 23.2 | 25.5 | 27.3 | 27.1 | 23.9 | 18.8 | 14.0 | 12.7 | 19.2 |
| | R/H | | | | | | | | | | | | | |
| | Er. | 80 | 91 | 139 | 172 | 222 | 239 | 241 | 216 | 192 | 145 | 102 | 82 | 1919 |
| Rostaq | M.max. | 24.7 | 25.8 | 30.7 | 34.5 | 41.3 | 43.0 | 41.5 | 40.7 | 39.1 | 35.1 | 30.4 | 26.9 | 34.5 |
| | M.min. | 11.0 | 12.1 | 15.1 | 17.5 | 22.3 | 25.1 | 27.6 | 24.9 | 23.7 | 20.0 | 15.3 | 14.0 | 19.1 |
| | R/H | 65 | 72 | 64 | 53 | 50 | 52 | 75 | 52 | 55 | 55 | 53 | 65 | 59 |
| | Er | 90 | 108 | 185 | 210 | 265 | 270 | 236 | 222 | 203 | 172 | 122 | 91 | 2174 |
| Al Wati | M.max. | 28 | 29 | 34 | 38 | 42 | 42 | 43 | 40 | 39 | 37 | 33 | 29 | 36.2 |
| | M.min. | 14 | 15 | 17 | 23 | 25 | 27 | 27 | 24 | 23 | 21 | 17 | 16 | 20.8 |
| | R/H | 70 | 66 | 57 | 57 | 60 | 62 | 64 | 72 | 69 | 58 | 64 | 72 | 64 |
| | Er. | 132 | 178 | 270 | 247 | 350 | 369 | 403 | 334 | 256 | 289 | 252 | 190 | 3270 |
| Muscat | M.max. | 25.0 | 25.0 | 28.3 | 32.2 | 36.7 | 37.8 | 36.1 | 33.3 | 33.9 | 33.9 | 30.0 | 26.1 | 31.5 |
| | M.min. | 18.9 | 19.4 | 22.2 | 25.6 | 30.0 | 31.1 | 30.6 | 28.9 | 28.3 | 26.7 | 22.8 | 20.0 | 25.4 |
| | R/H | 72 | 73 | 71 | 64 | 58 | 72 | 77 | 82 | 75 | 69 | 69 | 70 | 71 |
| | Er. | | | | | | | | | | | | | |
| Salalah | M.max. | 26.8 | 29.5 | 29.4 | 31.5 | 31.8 | 31.4 | 28.9 | 28.1 | 28.5 | 30.7 | 30.3 | 28.2 | 29.6 |
| | M.min. | 15.7 | 18.1 | 18.9 | 23.1 | 24.5 | 25.6 | 24.6 | 23.5 | 22.8 | 20.4 | 17.8 | 16.7 | 21.0 |
| | R/H | 59 | 59.5 | 66.2 | 70.0 | 82.0 | 83.9 | 85.2 | 87.7 | 82.0 | 69.8 | 57.5 | 62.2 | 72.1 |
| | Er. | | | | | | | | | | | | | |

Note: Sohar average from 1974 to 1975 (Ev: 1973 to 1975)
Rostaq average from 1974 to 1975
Muscat average from 1973 to 1976
Al Wati average from 1974 to 1975

(6) Companies registered in Oman classified by economic activity



(7) Crude oil production (1968 - 1978)



(8) Summary of recorded imports and exports

Value in million Rials Omani

| Year | Total recorded imports | Exports | | | |
|---|---|---|---|---|---|
| | | Oil | Re-export | Other | Total |
| 1971 | 13.8 | 87.6 | | 0.4 | 88.0 |
| 1972 | 18.7 | 88.2 | | 0.4 | 88.6 |
| 1973 | 40.7 | 114.3 | | 0.6 | 114.9 |
| 1974 | 135.6 | 418.7 | | 0.4 | 419.1 |
| 1975 | 264.3 | 488.1 | | 1.1 | 489.2 |
| 1976 | 250.5 | 543.8 | | 1.4 | 545.2 |
| 1977 | 302.1 | 545.9 | | 1.5 | 547.4 |
| 1978 | 327.2 | 521.8 | 26.9 | 3.3 | 552.0 |

Note: 1. Figures for 1970, 1971 and 1972 are based upon dutiable imports and do not include imports by Government departments, contractors on Government projects, the oil companies and other duty free clearances.

2. From 1st July 1973 figures include all imports except some imports by Government departments. This accounts for part of the larger increases in recorded imports between 1972 and 1973.

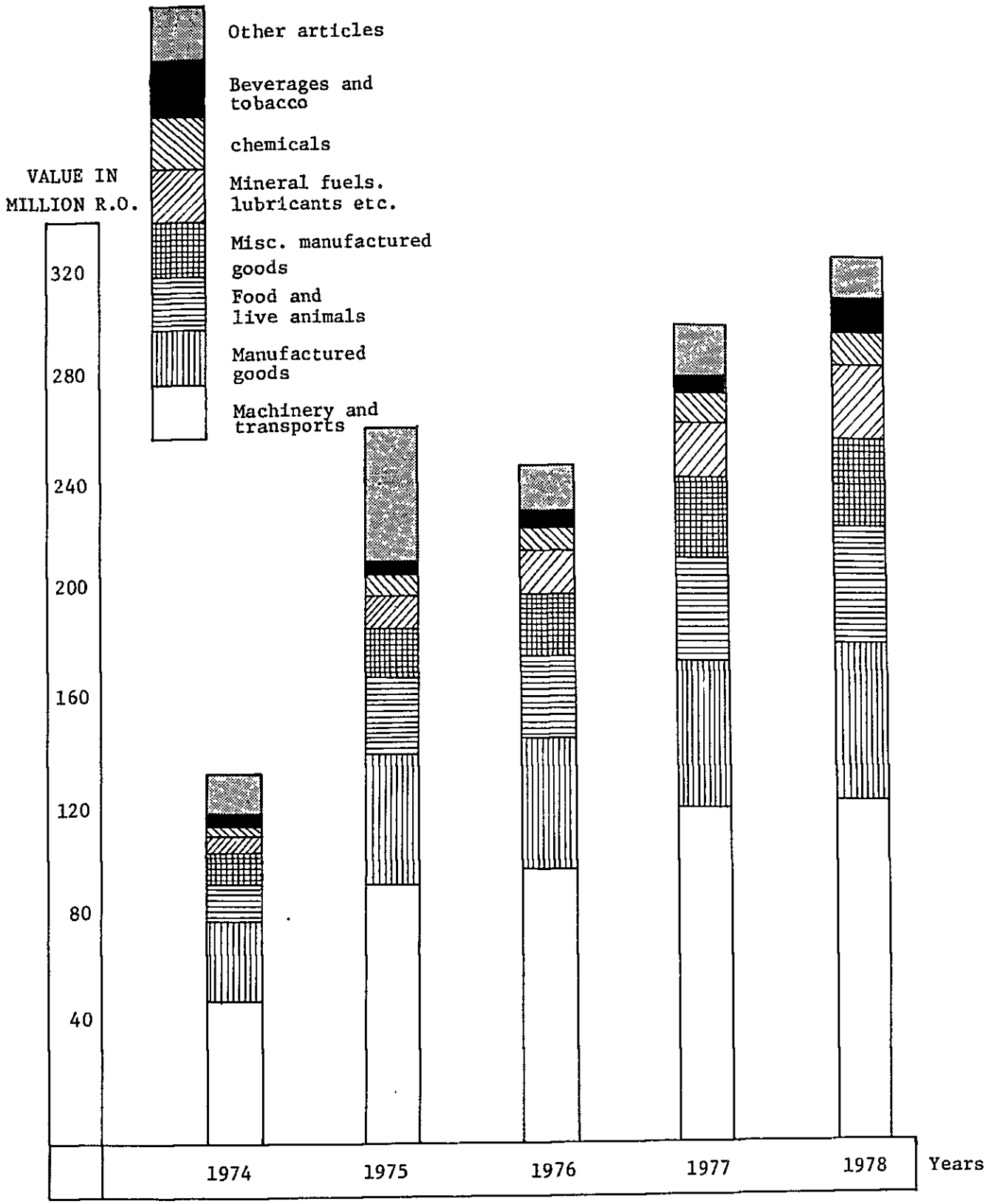
3. Gold imports are excluded.

4. The value of re-export is available for 1978 only.

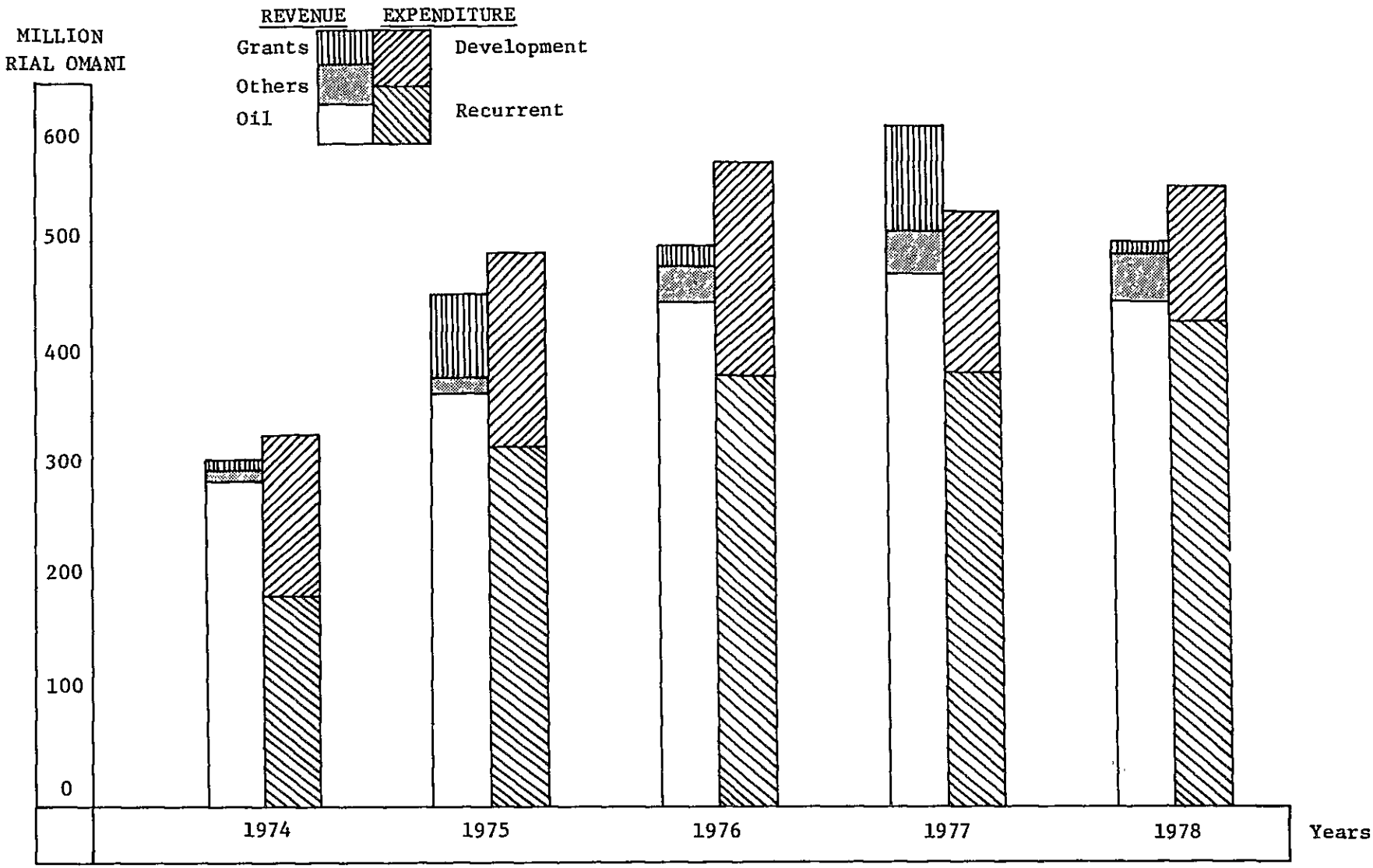
5. The rate of exchange for Omani currency against the US$ was fluctuating before July 1974.
Average rates for 1970 - 1978 are given below.

1970/71 ..... $ = R.O. 0.4167
1972 ..... $ = R.O. 0.3838
1973 ..... $ = R.O. 0.3460
1974/78 ..... $ = R.O. 0.3454

(9) Recorded Imports Classified Under Broad Categories



(10) Government revenue and expenditure



(11) Government medical and public health establishments and beds

Number at the end of

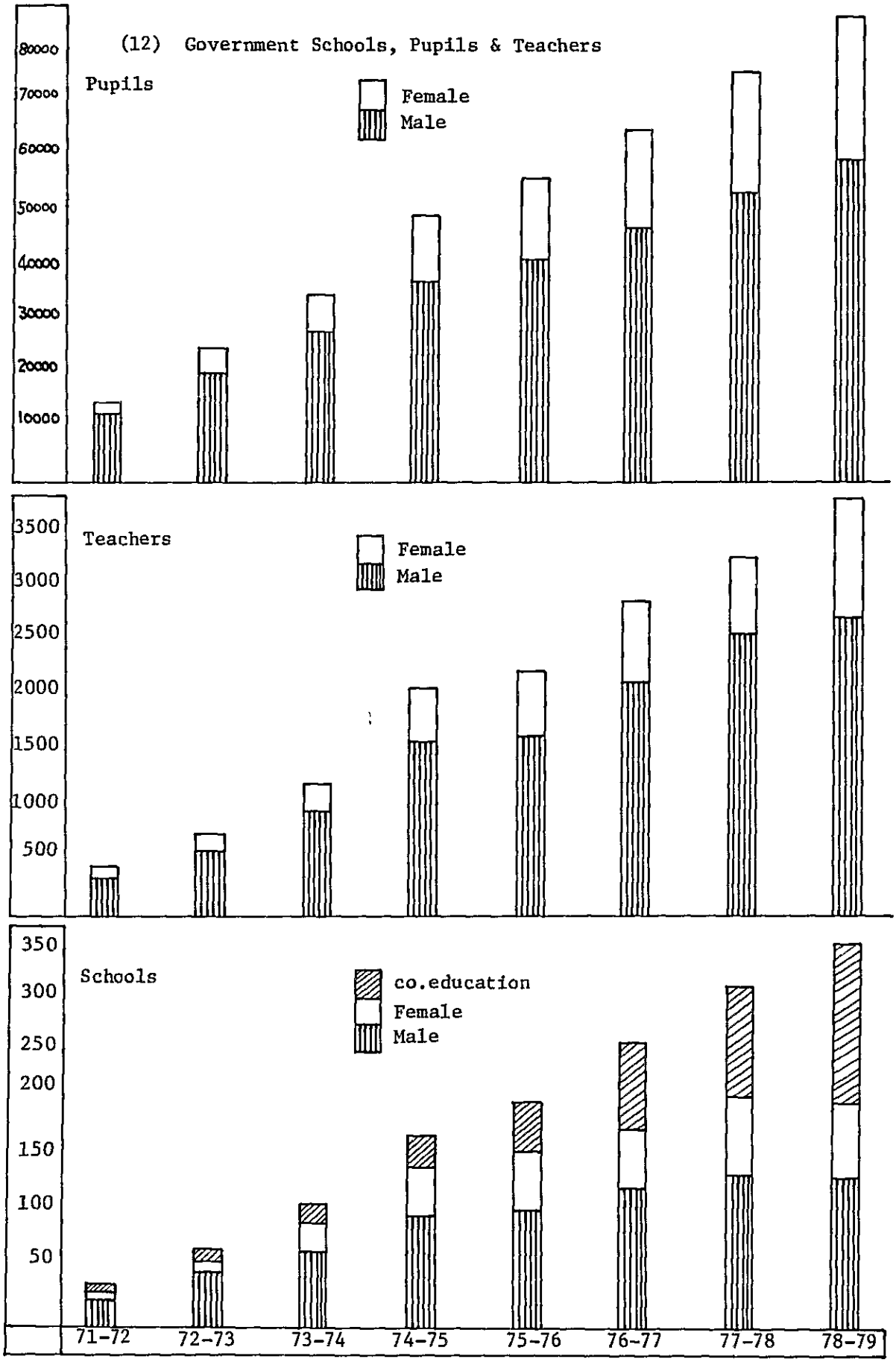
| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|---|---|---|---|---|
| Hospitals | - | 5 | 10 | 12 | 13 | 13 | 13 | 13 | 13 |
| Health Center | 9 | 10 | 7* | 5* | 11 | 11 | 11 | 12 | 12 |
| Dispensaries | 10 | 13 | 27 | 30 | 32 | 40 | 42 | 45 | 47 |
| Public Health Compounds | - | - | - | 2 | 2 | 4 | 4 | 5 | 5 |
| Public Health Units | - | - | - | - | - | 6 | 9 | 9 | 13 |
| Quarantine Units | - | - | - | - | - | 6 | 6 | 7 | 7 |
| Public Health Central Centers (Capital area) | - | - | - | - | - | 11 | 12 | 11 | 12 |
| Beds | 12 | 216 | 526 | 664 | 934 | 1000 | 1252 | 1409 | 1409 |

Location of Government (Civil) medical and public health establishments and beds, regionwise during 1978

Hospitals : Sumail (50), Tanaam (50), Arrahma-Mutrah (118 of which 25 TB and 29 mental), Assada-Muscat (16), Muscat (24) Nizwa (50), Sohar (50), Al Nahda-Ruwi (178), Salalah (300) Sur (50), Buraimi (50), Khoula-Mina al Fahal (185), Rostaq (50).

Health Center : Quriyat (6), Masnaa, Ibra (24), Bukah (16), Saham (8), Bahla (24), Sinaw (24), Bilad Bani Bu Ali (24), Bilad Bani Bu Hassan (24), Bayah (24), Khasab (24), Masirah (24).

Dispensaries : Sib, Barka, Shinas, Khabura, Afi, Nakhl, Adam, Dank, Kamil, Mudaibi, Ibri, Al Khod, Suwaiq, Fanja, Izki, Hamra, Manah, Ghafat, Birkat al Mawz, Dariz, Mudairib,* Taqa, Marbat, Mudhai, Thamrait (Midway), Abu Baqra, Shelim, Aiga, Wafi, Muhdah (4)** Hibi (4),** Mamur, Wadi Bani Ruwaha, Awabi, Hail-Ghaf, Madha (4),** Sadha, Yanqal (4),** Taiwi, Dhalkoot, Jebel Al Akhdhar, Bidiya, Dagmar, Rekhut, Hask, Kuria Muria, Al Ashkharah.


(12) Government Schools, Pupils & Teachers
Pupils
Female
Male
80000
70000
60000
50000
40000
30000
20000
10000
Teachers
Female
Male
3500
3000
2500
2000
1500
1000
500
Schools
co.education
Female
Male
350
300
250
200
150
100
50
71-72
72-73
73-74
74-75
75-76
76-77
77-78
78-79

Public Health
Compounds : Sumail, Nizwa, Saham, Salalah, Buraimi.

Public Health
Units : Sib, Bahla, Sohar, Mudhairib, Masirab Sur Dhank, Al Hamra, Quriyat, Khasab, Bilad Bani Bu Ali, Bilad Bani Bu Hassan, Al Ashkharah

Quarantine Units: Mina-Qaboos, Mina-Raysut, Mina-Al Fahal, Sib Airport, Salalah Airport, Khatmat Al Malahah, Wadi Hiti.

* Three health centered were upgraded to hospitals during 1972 and two more during 1973.

** Maternity centers.

Notes: 1. Figures in brackets show the number of beds.

2. Civil hospitals outside capital area also undertake public health work where there are no separate public health facilities.

(13) Area under cultivation and area under crops

- Area under cultivation by regions, 1971*

| Regions | Area under cultivation | |
|---|---|---|
| | Hectares | Percentage |
| Batinah | 13800 | 38.3 |
| Jau and Buraimi | 600 | 1.7 |
| Dhahirah | 3600 | 10.0 |
| Western Hajar | 3800 | 10.6 |
| Eastern Hajar | 3400 | 9.4 |
| Oman Proper | 6800 | 18.9 |
| Sharqiya and Jaalan | 2800 | 7.8 |
| Musandam | 400 | 1.1 |
| Dhofar | 800 | 2.2 |
| Total | 36000 | 100.0 |

- Area under crops, 1971*

| Crops | Area under cultivation | |
|---|---|---|
| | Hectares | Percentage |
| Dates | 13340 | 37.1 |
| Lucerne | 5560 | 15.4 |
| Limes | 3560 | 9.9 |
| Onions | 3680 | 10.2 |
| Wheat | 1200 | 3.3 |
| Tobacco | 1000 | 2.8 |
| Bananas | 880 | 2.4 |
| Mangoes | 380 | 1.1 |
| Coconuts | 200 | 0.6 |
| Others ** | 6200 | 17.2 |
| Total | 36000 | 100.0 |

* Estimated

** Includes chickpeas, sorghum, sweet potatoes and fallow land.

(14) Government production farms, research stations, extension farms and centers and nursery gardens

| Type of Farm/Station | Department of Agriculture Region | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | North Batinah | South Batinah | Interior | Dharhirah | Sharqiya | Janubiya | Musandam | Capital area | |
| Production farms | 1 | 2 | 5 | - | - | 1 | - | - | 9 |
| Research stations | - | 2 | 2 | - | - | 1 | - | - | 5 |
| Extension farms | 1 | - | 1 | - | - | - | - | - | 2 |
| Extension centres/ sub-centres | 7 | 4 | 9 | 3 | 4 | 4 | 1 | 3 | 35 |
| Nursery gardens | - | 2 | - | - | - | 2 | - | - | 4 |

Geographical situation:

Production farms:

Sohar (agriculture), Rumais (1) (3 agriculture), Nizwa (3 agriculture), Tanoof (agriculture), Akhdhar (agriculture)

Research stations:

Rumais (agriculture), Rumais (animal husbandary), Wadi Quriyat (agriculture) Wadi Quriyat (animal husbandry), Salalah (agriculture)

Extension farms:

Bahla, Buraimi.

Extension centres:

Al Mareer, Shinas, Liwa, Sohar, Saham, Al Khabura, Buraimi, Seeb, Barka, Masnaa, Rostaq, Nizwa, Manah, Izki, Hamra, Wadi Quriyat, Jebel Al Akhdahr, Sumail, Ibri, Sur, Al Wafi, Ibra, Sinaw, Khasab, Quriyat, Al Oqdain, Al Dahaleez, Taqa, Al Rabat.

Extension sub-centres:

Adam, Bahla, Dank, Yunqal, Al Khafigi, Bustan

Nursery gardens:

Rumais (fruits), Rumais (gardens) Rabat (fruits), Al Jebel (fruits)

Note: The Dairy farm in Sohar and Garwiz cow farms were excluded in this table while they appeared in last year issue of the Year Book 1977, since then it has been placed under the management of the Sun Farm Company (Oman).

(15) Crops by regions and area under cultivation

| Regions | Cities with regional bureau | Area under cultivation and % | Area under crops (ha.) | | | | Farm household number | Area per household | Main crops |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fruits | Vegeta-beles | Non-vegetable plant | Grass | | | |
| North Batinah | Sohar | 6,594 ha. 15% | 4,914 | 672 | 294 | 714 | 13,000 | 0.59 ha. | dates, lime, mango, guava, radish, tomato, melon, onion, tobacco |
| South Batinah | Ramais | 8,484 19% | 5,166 | 2,184 | 630 | 504 | 10,991 | 0.84 ha. | date, lime, mango, banana, radish, tomato, melon, onion |
| Dhahirah | Ibri | 8,190 19% | 5,166 | 882 | 924 | 1,218 | 5,865 | 1.39 ha. | date, lime, radish, tomato, garlic, onion, wheat, sorgham |
| Oman Interior | Nizwa | 6,468 15% | 4,788 | 630 | 126 | 924 | 9,772 | 0.59 ha. | date, lime, mango, banana, pulse, coriander, radish, tomato, garlic, onion, wheat, pea |
| Sharqiya | Ibra | 11,046 25% | 5,712 | 588 | 2,814 | 1,932 | ? | 0.84 ha. | date, lime, mango, banana, radish, tomato, melon, onion, garlic |
| Dhofar | Salalah | 3,024 7% | 966 | 378 | 336 | 1,344 | ? | ? | coconut, papaya, banana, guava, tomato, eggplant, onion, corn |
| Total | | 43,806 10% | 26,712 | 5,334 | 5,124 | 6,636 | | | |

(16) Prices of various materials in Oman (approximate estimate)

1 Ro = 640 yen

① Cement 32 Ro/ton

② Concrete 27 Ro/ton (1 cu.m = 45840 yen)

③ Pipe 4350mm pipe is difficult to obtain

a. Vinyl pipe (100mm dia.) 4.00 Ro/meter

b. Steel pipe (100mm dia.) 6.50 Ro/meter

c. Asbestos cement pipe (100mm dia.) 6.00 Ro/meter

d. Hume concrete pipe (difficult to obtain)

④ Unit Cost for Excavation

Unit cost for ditch, 30cm wide and 1m deep, is 4.0 Ro/meter

Note: Minimum wage for non-expert workers is 30 Ro/month.