FEASIBILITY REPORT

ON

WADI JIZZI AGRICULTURAL DEVELOPMENT PROJECT

IN

THE SULTANATE OF OMAN

(MAIN REPORT)

JANUARY 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

FEASIBILITY REPORT

ON

WADI JIZZI AGRICULTURAL DEVELOPMENT PROJECT

IN

THE SULTANATE OF OMAN

(MAIN REPORT)

JANUARY 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Sultanate of Oman, the Japanese Government decided to conduct a survey on the Wadi Jizzi Agricultural Development Project and entrusted it to the Japan International Cooperation Agency (JICA).

The JICA sent to Oman the first stage survey team headed by Mr. Yasushi Miyazaki from March, 1981 to May, 1981 and the second survey team headed by Mr. Shigekatsu Watanabe from November, 1981 to March, 1982.

The teams exchanged views with the officials concerned of the Government of the Sultanate of Oman and conducted a field survey in Sohar area in the north Batinah region, Oman.

After the teams return to Japan, further studies were made and the present report has been prepared.

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

I wish to express my deep appreciation to the officials concerned of the Government of the Sultanate of Oman for their close cooperation extended to the teams.

January, 1983

Keisuke Arita
President
Japan International Cooperation Agency

Mr. Keisuke Arita
President
Japan International Cooperation Agency (JICA)
Tokyo, Japan

January, 1983

LETTER OF TRANSMITTAL

Dear Sir,

We are very pleased to submit herewith the Final Report on the Feasibility Study for Wadi Jizzi Agricultural Development Project in the Sultanate of Oman.

The team has completed the feasibility study of the Project involving the water resources and agricultural development components in the Wadi Jizzi basin, located on the north Batinah region.

This report consists of three volumes: Volume I - Main Report, covering the summary of the results of the study including the conclusion and recommendations; Volume II and III - Appendix, providing the detailed technical information.

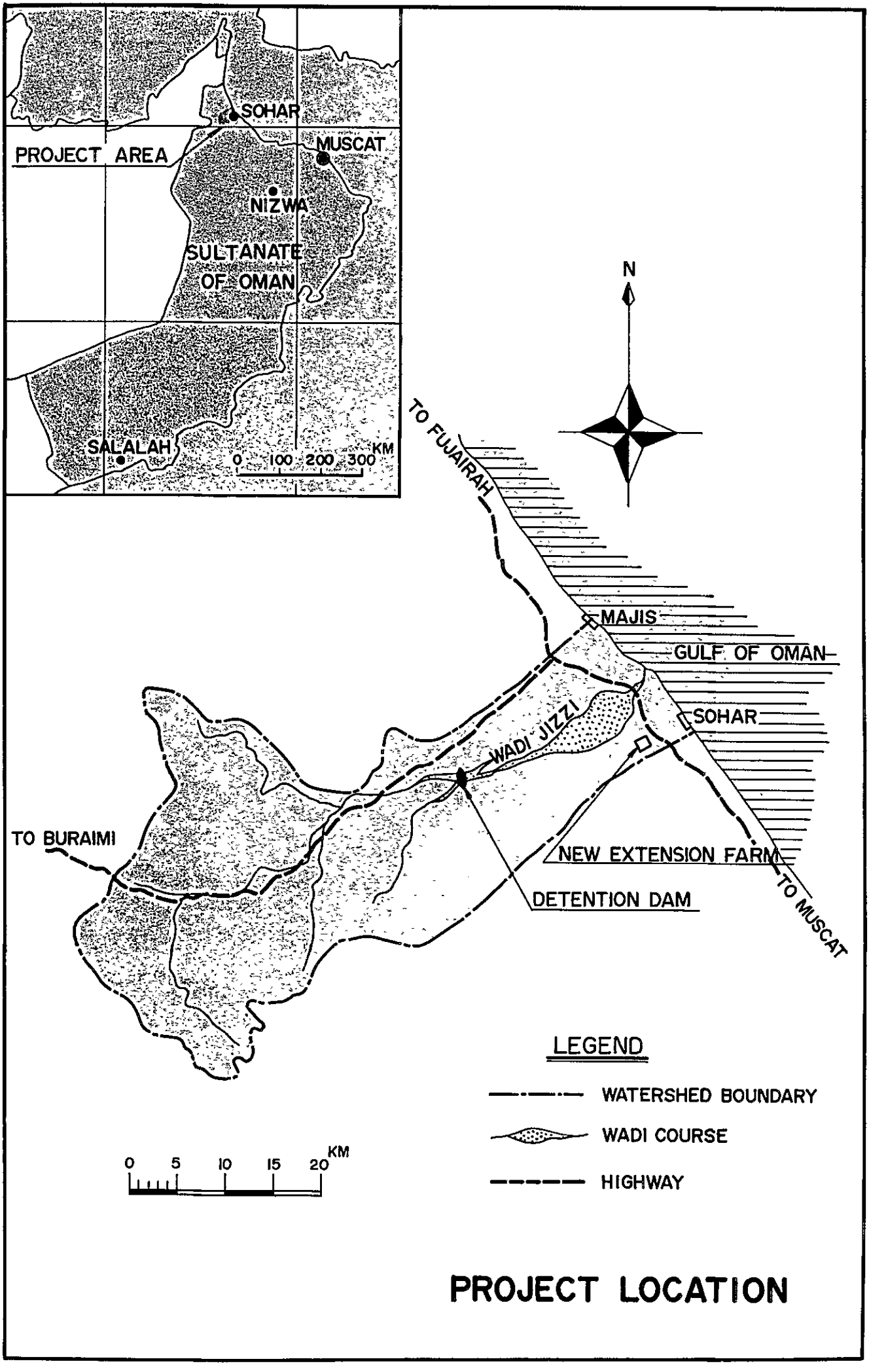
We hope that this agricultural development project can be a good example and greatly contribute to the social and economic development in Oman.

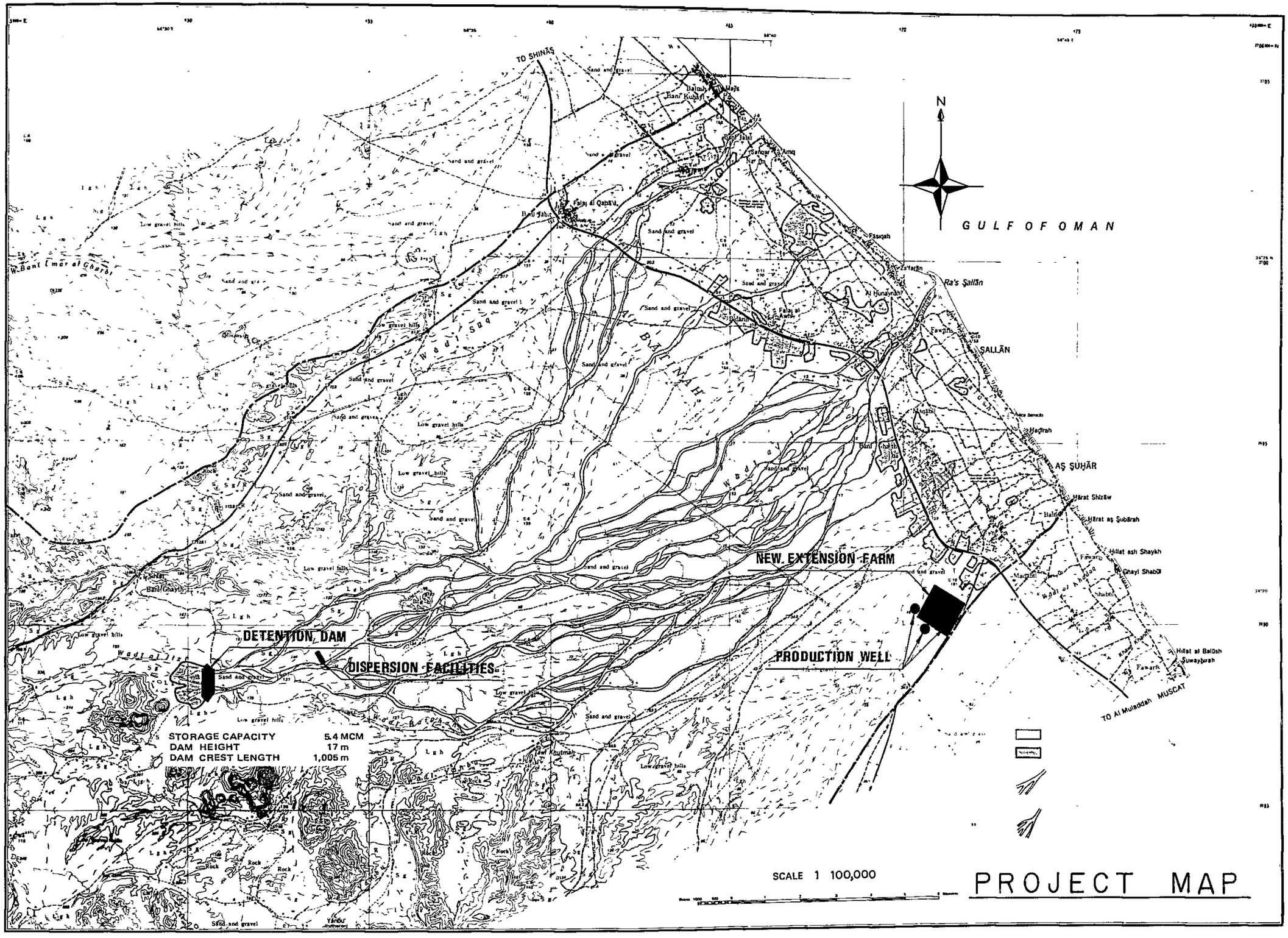
Finally, we take this opportunity to express our sincere gratitude to the Ministry of Agriculture and Fisheries of the Government of Oman, the Ministry of Foreign Affairs, the Ministry of Agriculture, Forestry and Fisheries of the Government of Japan, and the Japan International Cooperation Agency (JICA), especially for the Japanese Embassy in Oman, and the advisory group which gave useful advices to the survey team from time to time so as to smoothen the study.

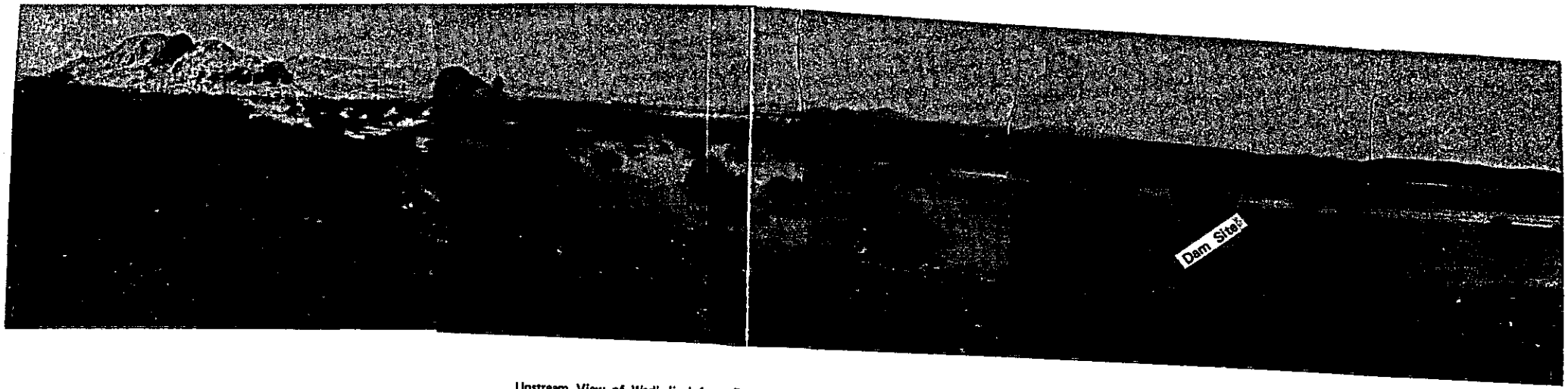
Respectfully yours,

Watanabe

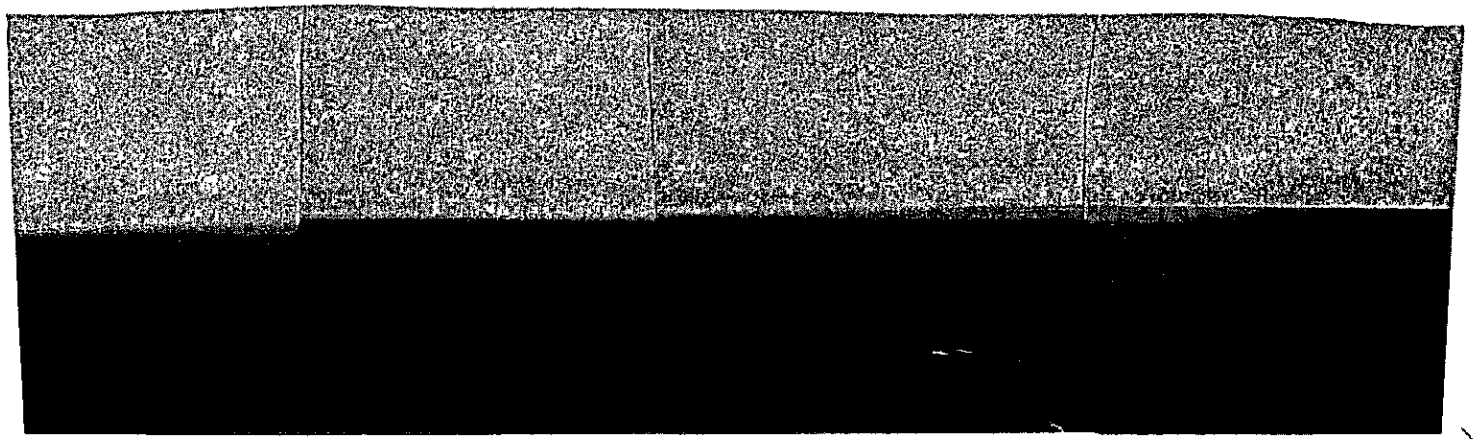
Shigekatsu Watanabe
Team Leader for the Wadi Jizzi
Agricultural Development Project


SOHAR
PROJECT AREA
MUSCAT
NIZWA
SULTANATE OF OMAN
SALALAH
0 100 200 300 KM
N
TO FUJAIRAH
MAJIS
GULF OF OMAN
SOHAR
WADI JIZZI
TO BURAIMI
NEW EXTENSION FARM
DETENTION DAM
TO MUSCAT
LEGEND
WATERSHED BOUNDARY
WADI COURSE
HIGHWAY
0 5 10 15 20 KM
PROJECT LOCATION

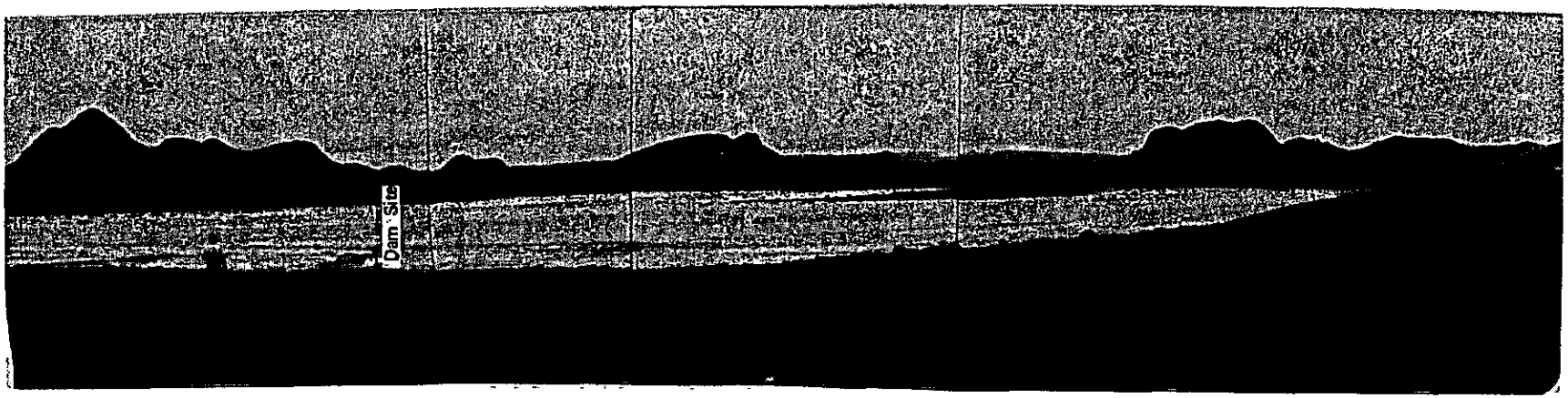

TO SHINĀṢ
N
GULF OF OMAN
Ra's Şallān
ṢALLĀN
AṢ ṢUḤĀR
NEW EXTENSION FARM
PRODUCTION WELL
DETENTION DAM
DISPERSION FACILITIES
STORAGE CAPACITY 5.4 MCM
DAM HEIGHT 17 m
DAM CREST LENGTH 1,005 m
TO Al Muladdah MUSCAT
SCALE 1 100,000
PROJECT MAP



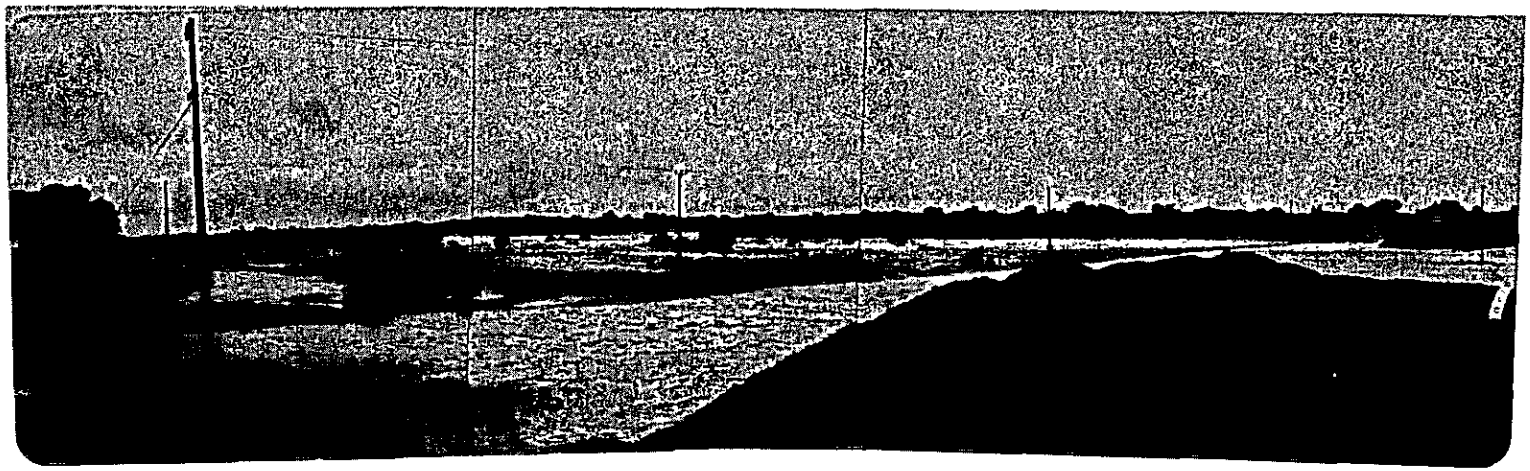
Upstream View of Wadi Jizzi from Proposed Detention Dam Site



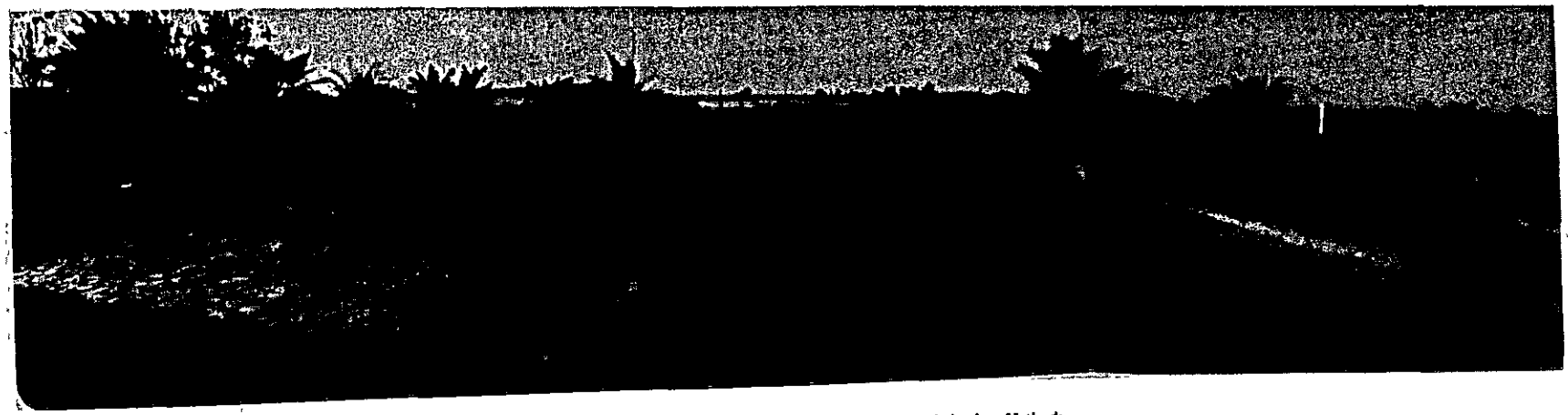
General View of Downstream Wadi Jizzi Plain



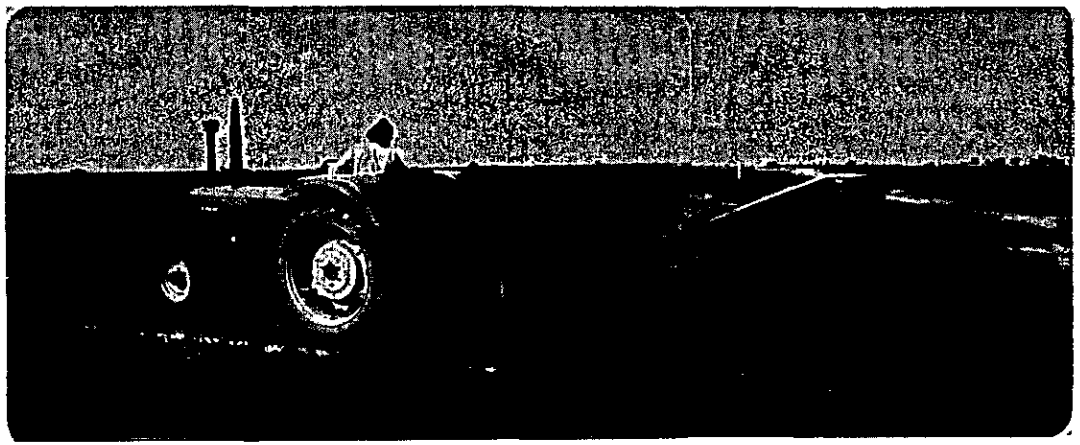
Flood Discharge at Proposed Detention Dam Site (14, February 1982)



Flood Discharge at Wadi Sallan (14, February 1982)

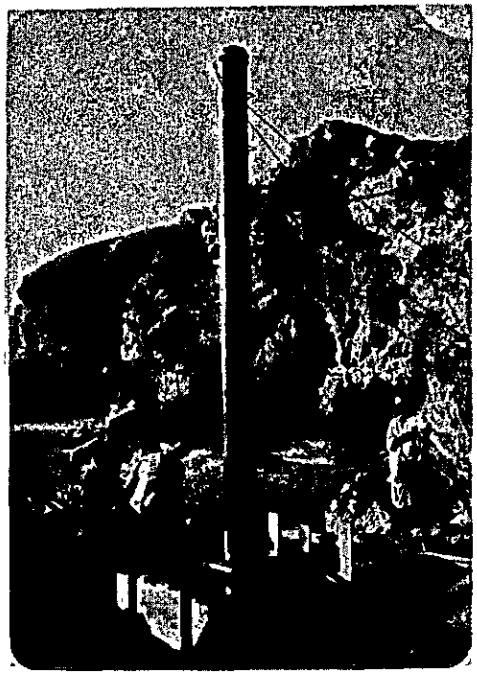


Present Cultivated Area Irrigated by Border - strip and Furrow Irrigation Methods

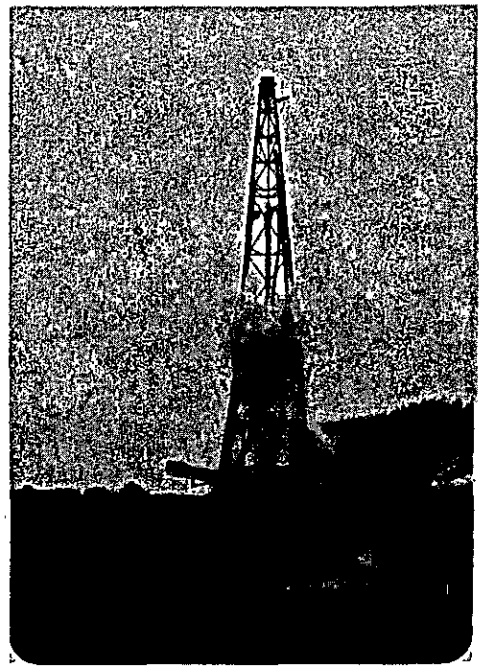


Harvesting of Fodder Crops in Oman Sun Farm

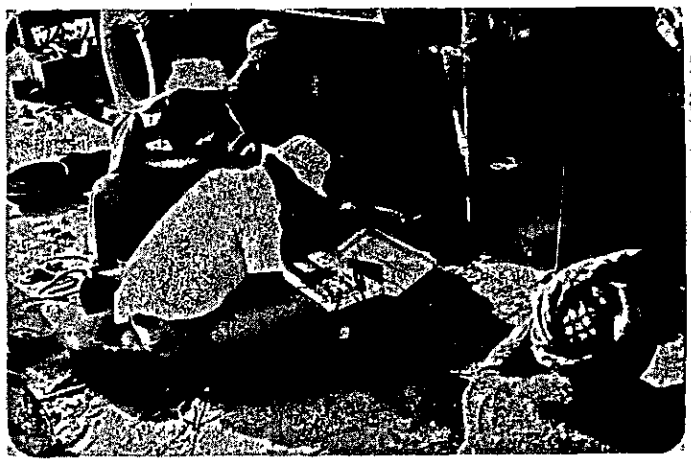
Marketing of Agricultural Products in Sohar



Installation of Water Level Gauge

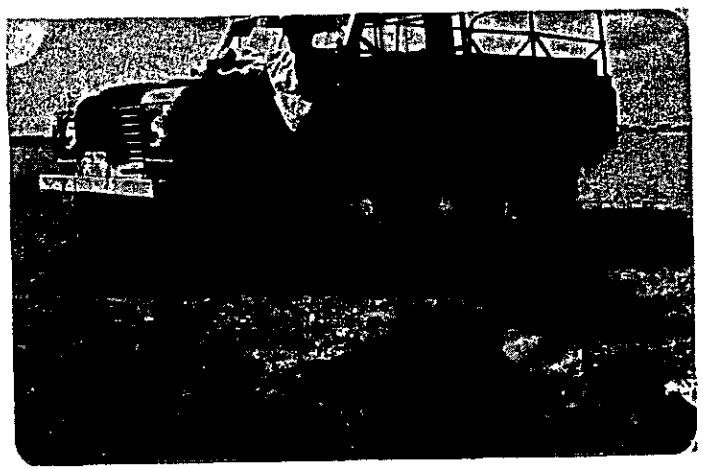


Construction of Observation Well (Cleaning of Constructed Well)

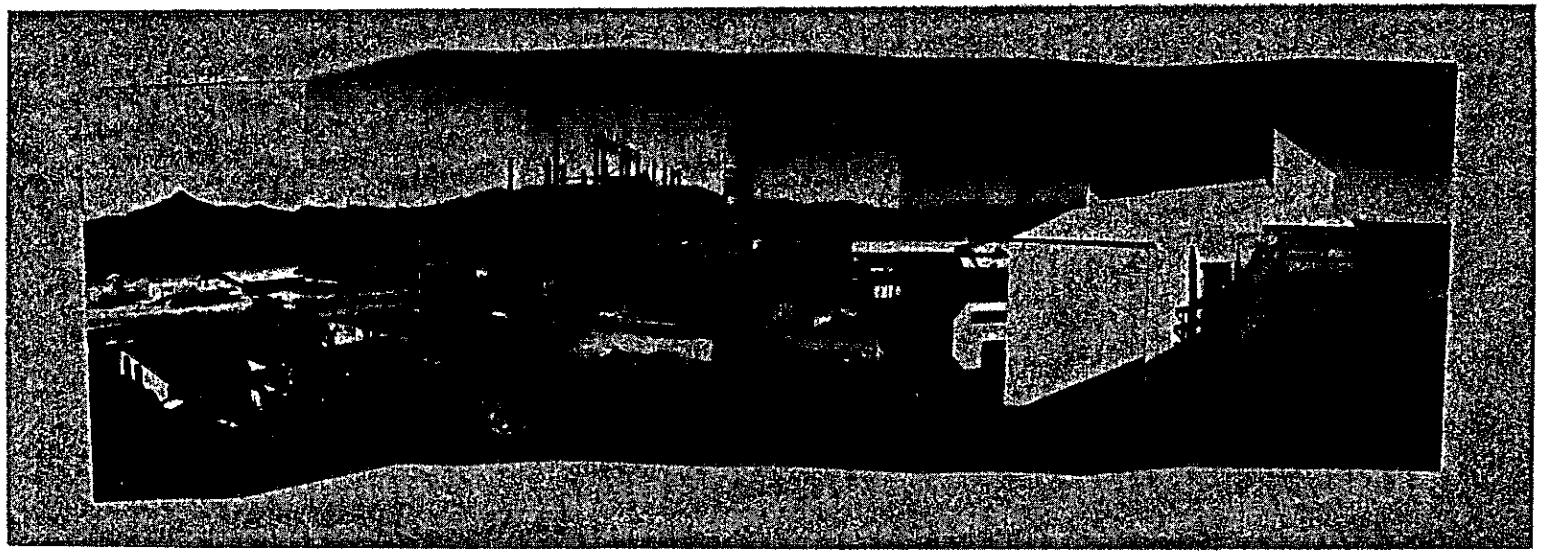


Bore Hole Logging at Constructed Well (JA–3)

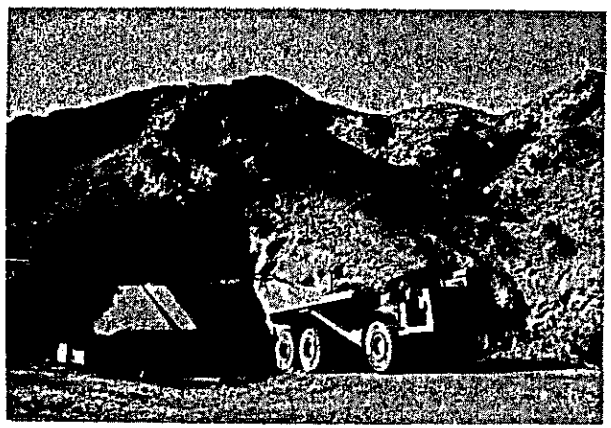
Geo-Electric Survey at Lower Wadi Jizzi Plain



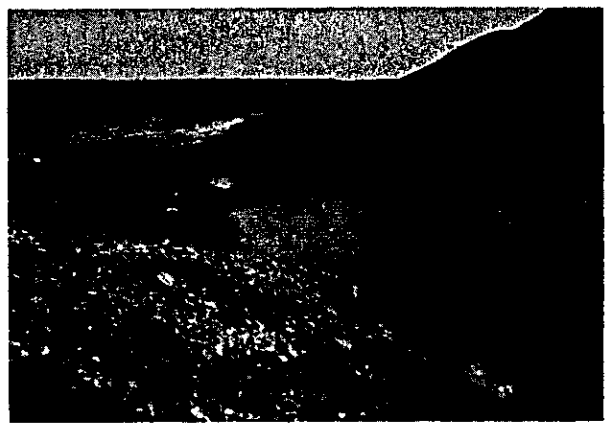
Intake Rate Test at Proposed New Extension Farm



Oman Copper Mining Process Plant (under Construction)



Entrance of Lasail Mining



Disposal Pond for Wasted Water from the Mine

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIES

ABBREVIATION AND GLOSSARY

MEASUREMENTS

Length

mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer

Area

sq.cm, cm^2	Square centimeter
sq.m, m^2	Square meter
sq.km, km^2	Square kilometer
ha	Hectare
MSM, 10^6 m^2	Million square meter

Capacity

1, lit	Liter
cu.m, m^3	Cubic meter
MCM, $10^6 m^3$	Million cubic meter
barrel	31.5 gallon (U.S.) = 36 gallon (U.K.)
gallon	3.785 1 (U.S.) = 4.546 1 (U.K.)

Weight

g	Gram
Kg	Kilogram
ton, m.t	Metric ton

Others

EL	Elevation above mean sea level
FWL	Full water level
HWL	High water level
mamsl	Meter above mean sea level
mbmsl	Meter below mean sea level
mbgs	Meter below ground surface
sec	Second
min	Minute
hr	Hour
min	Minimum
max	Maximum
°C	Degree Centigrade
°F	Degree Fahrenheit
EC	Electric Conductivity
mho	Reciprocal ohm
mmho	Millimho
µmho	Micromho
mg/lit	milligram of solute per liter of solution
ppm	Parts per million
%	Percent
FY	Fiscal Year

Conversion

R.O.	Omani Rial, R.O. = 2.924 USD. = 1,000 Baiza
U.S.D.	Dollar, USD. = 0.342 R.O.
Feddan	Oman unit of area measurement = 0.42 ha

GLOSSARY

ADB	Asian Development Bank
FAO	Food and Agricultural Organization
IBRD	International Bank for Reconstruction and Development
JICA	Japan International Cooperation Agency
MAF	Ministry of Agriculture and Fisheries
MEW	Ministry of Electricity and Water
MLAM	Ministry of Land Affairs and Municipalities
MPM	Ministry of Petroleum and Minerals
MPW	Ministry of Public Works
Ain	Spring
Aflaj	Plural form of Falaj
Falaj	Water distribution system under or above ground
Wadi	Dry river valley
Wali	Local Governor of an area
Wilaya	Local Governorate
Wilayat	Plural form of Wilaya
Project Area	Existing cultivated area in the alluvial plain extending from Majis to Wadi Khadaq
New Extension Farm Land	Area to be developed by the recharged water resources in the Project

SUMMARY AND CONCLUSION
RECOMMENDATIONS

SUMMARY AND CONCLUSION

The Study and Report

1. The Report has resulted from the feasibility study conducted by the JICA Study Team on Wadi Jizzi Agricultural Development Project. In preparing the Report, a comparative study was made on the two alternative water resources development plans; the Storage Pond Plan and the Groundwater Recharging Plan, and the latter has been selected as the Project plan.

2. The feasibility study has revealed that the Project plan is technically sound and economically feasible. Furthermore, this plan satisfactorily conforms to the national development policy of the Sultanate of Oman. A high priority is given to this pioneer water resources development project for increasing the agricultural production in Oman. It is also noted that groundwater recharging is an urgent need in the Wadi Jizzi basin since the sea water intrusion into the coastal strip has already taken place due to the overdraft of groundwater in the coastal plain.

Economic Background

3. The Sultanate of Oman occupies the major portion of the southeastern Arabian peninsula. Its territory covers some 300,000 sq.km. The Project Area is located at Wilaya Sohar in the North Batinah region, one of the most populous areas in Oman. No population census has been carried out so far in this country. Therefore, the population of Oman is assumed to be 1,500,000 persons for the planning purpose.

4. Since July, 1970, the Sultanate of Oman has been undertaking the socio-economic structural improvement, and made a rapid economic progress. For five years of 1970 to 1974, the country

acquired the basic requirements as a modern state. The Development Council of Oman adopted, in February, 1975, the definite strategies for the economic development.

5. The first five-year development plan (1976-1980) was successfully implemented, resulting in the averaged annual growth rate of 20.3 percent of Gross Domestic Product (GDP). Based on the achievement in the first five-year development plan, the second five-year plan (1981-1985) has been launched aiming at the annual GDP growth rate of 13.1 percent.

6. About 60 percent of the total population of Oman belong to the agriculture and fishery sectors. In other words, agriculture and fishery are the major sources of income for the majority of Oman people. However, the contribution of these sectors to GDP is almost negligible. The major constraints in agriculture in Oman are the lack of water resources for irrigation, the insufficient extension services, and the absence of agricultural credit system. Under the circumstances, the Wadi Jizzi Agricultural Development Project has been taken up as one of the pioneer water resources and agricultural development projects in this country.

The Project Area

7. The Wadi Jizzi basin for which the JICA Study Team conducted a study on water resources development is located about 180 km from Muscat, the capital of the country. Having the catchment area of about 1,300 sq.km at the Wadi mouth, the Wadi Jizzi runs down the course of some 75 km towards the northeast from its origin, and empties itself into the Gulf of Oman. The wadi slope is fairly steep; 1/100 in the upstream and 1/150 in the downstream. The averaged annual runoff at the proposed dam site was estimated at 11.3 MCM with an average annual rainfall of 130 mm.

8. The Project Area, located in the downstream Wadi Jizzi basin, has a rectangular shape of about 3,830 ha, lying between the coastal line and the inland line of about 17 km long that runs in parallel with the coastal line and connects Majis with Wadi Khadag. The distance between the two lines is about 9.5 km.

9. In the Project Area the construction of a new extension farm of 100 ha has been proposed. The farm land is located near the Oman Sun Farm. In determining the location of this farm, a careful study was conducted on i) groundwater discharge to be recharged in the Wadi Jizzi Plain, ii) irrigation water requirements based on the proposed cropping pattern, iii) soil conditions, and iv) socio-economic conditions.

Land Conditions

10. A soil survey was conducted by the Study Team in the coastal and alluvial plains. The survey area was about 13,800 ha. The soils of the Project Area are classified into ten soil types with respect to their textures and salinity. A land suitability classification was made based on the soil survey results. It has revealed that the most promising areas for agricultural development extend in the two soil groups near Amq and the Oman Sun Farm. These areas of about 1,300 ha in total are covered by fairly fine-textured soils with less salinity and few gravels. As mentioned above, a land of 100 ha adjacent to the Oman Sun Farm has been selected as the new extension farm land out of the above-mentioned promising areas of 1,300 ha.

Water Use Conditions

11. The water resources available in the basin are classified into the surface water and the groundwater. A flood discharge, which is the surface water, mostly takes place in winter from November

to March. It runs down the Wadi course to the sea in a short time, and its effective use is difficult at present. On the other hand, the groundwater in the basin is the major water source for irrigation, domestic and industrial water use. The annual consumption of the groundwater in the basin was estimated at 22.4 MCM, comprising 21.1 MCM for irrigation, 1.0 MCM for domestic use, and 0.3 MCM for industrial use.

12. The Wadi Jizzi basin for which a groundwater survey was carried out by the Study Team is composed of the impervious formations, terrace deposits, and alluvial deposits. The alluvial deposits are mainly developed in the coastal strip, forming an excellent unconfined aquifer thicker than 100 m and about eight kilometers wide. The aquifer extends from Majis in the north to the Wadi Hilti in the south along the coastal strips.

13. Taking the course consistent with that of the Wadi Jizzi, groundwater flows towards the sea with a hydraulic gradient of 1/2,000. The maximum height of groundwater is five meters above mean sea level.

14. A groundwater balance study of the coastal plain was made by the Study Team. The study has revealed that the shortage of groundwater will amount to 0.6 MCM per annum on an average based on the data of the past eight years. A sign of sea water intrusion was detected in the EC logging at Well OA-2 which is located in the coastal strip. The EC logging results show that the interface of fresh water and brackish water has shifted five meters upwards (16 m below mean sea level) since 1974. Furthermore, the conductivity of groundwater in the aquifer has increased from 18,000 to 50,000 micro mho/cm in the past eight years.

Agricultural Conditions

15. Presently the Project Area of 3,830 ha is roughly divided into 2,340 ha of orchards, 300 ha of upland fields and 1,190 ha of non-farm lands.

16. The number of farm households in Wilaya Sohar totals some 3,500. The typical farm family and farm size are 7.1 persons and 1.8 ha, respectively.

17. Almost the entire cropping in the Sohar area is from groundwater through wells. Dates are the major crops in the Project Area, and other tree-crops such as lime, banana, mango, etc., are also grown. The major upland crops are vegetables and fodder crops. Upland crops such as onion, garlic, tomato, etc., are raised in the dates farm as the inter crops of dates trees. The livestock breeding in Wilaya Sohar is ranked high in this country.

18. Irrigation in the Project Area depends on the groundwater pumped up through wells. The prevailing irrigation methods applicable hereto are classified into i) basin irrigation, ii) border-strip irrigation, and iii) furrow irrigation. An annual irrigation demand in the area of 2,640 ha was estimated at 21.1 MCM as mentioned above.

19. Overdraft of the groundwater in the coastal plain for various purposes has recently caused sea water intrusion into the aquifers in the coastal strip. Some existing cultivation areas have suffered from the high salinity in irrigation water. Under the circumstances, the water resources development through groundwater recharging is a vital and urgent requirement in the Wadi Jizzi basin.

20. Individual farmers, state farms, and importers bring agricultural products to the market. The marketing system has not been systematized yet, which is the cause of the stagnation of farming in Oman. Sohar has retail markets for agricultural products. Farmers in the Project Area bring their products to the market by vehicles.

21. The agriculture in Wilaya Sohar faces such constraints as a decrease in the number of full-time farm households, a malfunctioning marketing system, and a low cropping intensity. The gross income from a cropping area of 1.24 ha, typical farm size in the area, was estimated at 1,860 R.O., and the net farm income at 1,070 R.O.

Objectives and Components of the Project

22. The Project directly aims at i) water resources development through groundwater recharging and ii) agricultural development through the construction of a new extension farm land, and indirectly at iii) improvement of agricultural production in the existing land and of living environment through flood control and prevention of sea water intrusion into the coastal strip and iv) stabilization of groundwater production for the domestic and industrial water use.

23. The Project components consist of i) water resources development in the Wadi Jizzi basin through the construction of a flood detention dam for groundwater recharging and ii) agricultural development through the construction of a new extension farm land equipped with water source facilities, irrigation system, road networks, etc., together with strengthening of agricultural extension services, and prevention of salt damages in the existing land.

Study on Two Alternative Water Resources Development Plans

24. Prior to the formulation of the Project plan, two alternative water resources development plans were drawn up as mentioned above, and a comprehensive comparative study was carried out on these two plans from the technical and economic points of view.

25. In the Storage Pond Plan, the water resources development would be made in two stages; the surface storage stage and the groundwater recharge stage as follows;

° Surface Storage Stage

Part of flood discharges would be temporarily stored by a detention dam, and conveyed to a storage pond that would be constructed like moats surrounding the new extension farm land. Thus conveyance facilities are necessary to connect the dam with the pond. The storage pond should have a sufficient storage capacity to meet the annual irrigation water requirements on the extension farm.

° Groundwater Recharge Stage

The above-mentioned detention dam would have a function to detain flood discharge and recharge groundwater even in the surface storage stage. The groundwater potential and yield in the Wadi basin would be elaborately studied during the surface storage stage. Based on the study results, the intake facilities such as production wells and pumps could be planned to irrigate the new extension farm land with the groundwater to be recharged by the detention dam.

26. A detention and recharging dam would be also constructed in the Groundwater Recharge Plan. The water retarded by this dam would be released in proportion to the groundwater recharging capacity

of the downstream basin. The groundwater so recharged would be pumped up for the farm land through production wells.

27. The major dimensions of the required facilities are shown below;

Descriptions	Storage Pond Method	Groundwater Recharge Method
a) Proposed Structures:		
° Dam		
Function:	Detention dam	Detention dam
Capacity:	5.4 MCM	5.4 MCM
° Water Supply Facilities:		
Stage-1:	Conveyance facilities L=21.1km, Q=3.0cu.m/sec Storage pond, V=1.1MCM	3 Wells and pumps Farm pond, V=4,700 cu.m
Stage-2:	3 wells and pumps	
° Farm and Related Facilities:		
	New extension farm 100ha (Net: 85ha)	New extension farm 100ha (Net: 85ha)
b) Project Evaluation:		
° Technical Aspects:		
	Average irrigable area; 46ha. Accurate flood water to be diverted in the dry year cannot be determined.	Irrigable area; 85ha. Sufficient ground-water is available throughout the year

° Cost and Economic Aspects:

- Project Cost	27.7 million R.O.	10.0 million R.O.
(Index)	(277)	(100)
- IERR	2.9%	11.5%

As seen in the above table, the Groundwater Recharge Method is recommended from both the technical and economic points of view. This method of water resources development is, therefore, adopted in the Project.

Water Resources Development (Surface Water)

28. Stormy rainfalls cause the flood once or twice a year. However, the flood runs down the Wadi course in a short time, and only a limited water infiltrates into aquifers under the present conditions. In order to augment the natural infiltration, the construction of a detention dam has been proposed. The proposed dam site is located in the middle reaches of the Wadi Jizzi. The reservoir of this dam would have a function to reduce the peak discharge of floods and store it temporarily for recharging groundwater. The storage capacity of the reservoir has been determined at 5.4 MCM to regulate a flood with 20 percent exceeding probability.

29. The construction of dispersion facilities is proposed in the downstream reaches of about 3.3 km from the dam for maximizing the utilization of flood discharge larger than the design storage capacity of the detention dam.

30. The expected water resources to be developed by the proposed detention dam and the dispersion facilities are as follows;

° The maximum volume of a single flood to be regulated:	5.4 MCM
° Maximum rate of released flow:	14 cu.m/sec
° Annually regulated flood volume:	5.73 MCM
° Expected water volume to be developed:	3.6 MCM

Water Resources Development (Groundwater)

31. The groundwater recharge plan with the detention dam and the dispersion facilities is recommended. The potential groundwater recharge capacity of the gravel plain was estimated at 15 cu.m/sec based on its actual measurement in flooding time. In addition, the dispersion facilities would have a function to recharge groundwater at the rate of 7 cu.m/sec.

32. The flood discharge presently flowing uselessly into the sea could be converted into the exploitable water resources for the Project. The water volume to be recharged was estimated at 3.6 MCM per annum based on the water balance computation. The groundwater would be effectively recharged if the reservoir water is released in proportion to the recharging capacity of the downstream gravel plain.

33. Allocation of the above-mentioned groundwater to be recharged in the Project would be as follows;

° Groundwater to be recharged;	3.60 MCM
Supplemental water to cover the shortage of the present water balance;	0.10 MCM
Domestic and industrial water;	1.26 MCM
Irrigation for the new extension farm;	1.34 MCM
Water balance surplus;	0.90 MCM
° Groundwater to be used (total)	3.60 MCM

Agricultural Development

34. As a first step of formulating the agricultural development plan for the selected new extension farm land, a study was conducted on i) farming type, ii) farm size, iii) selection policy of settlers, iv) marketing system, and v) layout of farm land and related facilities.

35. The size of the new extension farm land has been determined at 100 ha taking into account the groundwater to be recharged in the Project. Eighty five hectares out of 100 ha are the net irrigable area. The remaining 15 ha will be allocated to residential lots, roads, a sorting and packing center with a farm office, windbreak zones, farm ponds, etc. The pipeline irrigation networks by a link system could be proposed for the farm land as a result of the comparative study of this and the open system.

36. After the construction of necessary facilities, 20 farm households will settle in the farm land. Therefore, the land holding per household is determined at 5 ha in gross and 4.25 ha in net. The net area of 4.25 ha will consist of 2.5 ha of orchards, 0.75 ha of upland fields, and 1.0 ha of fodder crop fields.

37. The proposed crops are; fruit-crops such as dates, limes and bananas; vegetables like tomatoes, cabbages, watermelons, eggplants and red peppers; and fodder crops like alfalfa. The five-year rotational cropping system would be introduced for vegetable cropping. The cropping intensity will be 120 percent. As for the irrigation method, a drip irrigation will be practised for fruit-crops and vegetables while a sprinkler irrigation will be introduced for fodder crops.

Farm Management and Farm Economy

38. The settlers would start farming in the new extension farm land from 1986 with the cooperation of the Sohar Office of Agricultural Department, North Batinah. These farmers will be given guidance and orientation for successful private farm management on crop growing and irrigation by the extension agents of Sohar Office.

The collative works, however, will be required for operation and maintenance services of the equipment to pump up the water from the proposed farm ponds and pipelines, and for collection of the water charges.

The public Authority of Marketing of Agriculture Produce will supervise the marketing of farm products by 20 settler farmers. To carry out these works smoothly, the settler farmers should undergo trainings and education.

39. Plowing will be made with tractors with disk plows owned by the Office of Agricultural Department. One tractor, one disk plow, and five sprayers shall be purchased for the farmers by the above-mentioned Agricultural Department. Such farm machinery as tiller, redger, and cultivator would be purchased by individual farmers.

40. Each farm household has to invest, in the initial stage of farm management, the fixed capital in farm land, housing, irrigation, and farm facilities, etc. It is recommended that the initial capital would be loaned by the Bank of Agriculture and Fisheries to the farmers.

41. The farm economy has been assessed by applying the financial prices. The net farm income of 2,140 R.O. in 1986 would increase to 14,420 R.O. in 1995.

Proposed Facilities

42. The facilities to be constructed under the Project consist of the detention dam, dispersion facilities, intake facilities including production wells and pumps, and farm facilities.

43. The major features of the detention dam and dispersion facilities are summarized below;

Detention Dam

° Catchment area:	812 sq.km
° Detention capacity:	5.40 MCM
° Specific sediment volume:	100 cu.m/sq.km/year
° Full water surface (F.W.S)	EL 163.90 m
° Reservoir water surface area at full water level:	1.25 MSM
° Design flood discharge:	1,890 cu.m/sec
° Water level at design flood discharge (H.W.L.):	EL 167.20 m

Dispersion Facilities

° Location:	3.3 km downstream of the detention dam
° Structure:	Gabion dike
Crest length:	112 m
Dam height:	2.0 m (max.)

44. The intake facilities consist of three existing production wells equipped with deep well pumps and conveyance pipelines to connect the wells with the farm pond for the new extension farm land as explained below;

Production Wells

Three production wells have been constructed for Sohar Expansion Farm by the Ministry of Agriculture and Fisheries. These wells are located near the eastern boundary of the Wadi Jizzi plain. It is expected that sufficient groundwater could be pumped up through these production wells, due to the detention effect of the proposed dam, for the irrigation of new extension farm land.

The design yield of groundwater through these three wells to meet the irrigation water requirement in the new extension farm is planned to be 70.1 lit/sec at maximum. The drawdown of groundwater due to the pumping was computed with the non-equilibrium equation to be around 0.3 m which is equivalent to 2.1 meters above mean sea level. The major dimensions of the three production wells are tabulated below;

Wells	Potential Yield (cu.m/hr)	Diameter of well (mm)	Depth of Well (m)
SE-1	134.0	260	56
SE-2	47.0	260	50
SE-3	106.0	260	55
Total	287.0		

45. The dimensions of production pumps and conveyance pipes are as follows;

Production Pumps

	No.1	No.2	No.3
Peak discharge (cu.m/min)	2.21	0.77	1.49
Total head (m)	29.9	22.9	22.1
Motor capacity (KW)	18.5	7.5	7.5
Pump type	Vertical turbine pump		

Conveyance Pipes

Well	Pump	Conveyance Pipe Diameter (mm)	Length (m)	Type
SE-1	No.1	ϕ200	730	VP
SE-2	No.2	ϕ150	240	VP
SE-3	No.3	ϕ200	120	VP

Note) VP: Vinyl chloride pipe

46. The new extension farm will be provided with the following farm and irrigation facilities under the Project;

Farm Facilities

Farm area:	100 ha (net area: 85 ha)
Settler's house:	20 houses
Sorting and Packing Center:	1 building

Irrigation Facilities

Farm pond:	2 places (V_1 = 3,100 cu.m V_2 = 1,600 cu.m)
Delivery pumps:	2 units (Q = 5.72x2 = 11.44 cu.m/min)
Distribution pipe:	Link system (L = 3,470 m, Dia. = 75-300 mm, VP)
Terminal irrigation facilities:	Drip and Sprinkler

Cost Estimate

47. The total Project cost inclusive of the contingency and probable price escalation was estimated at 10.0 million R.O. or US$29.2 million based on the unit prices as of January, 1982. The

breakdown of the Project cost into the foreign and local currency portions is as follows;

° Foreign currency portion	:	8.5 million R.O.
° Local currency portion	:	1.5 million R.O.
Total		10.0 million R.O.

48. The Project involves the water resources development and the agricultural development. However, as an alternative, the agricultural development plan might be cancelled and only the water resources development plan would be implemented for the Project. The Project cost in this alternative plan was estimated at 7.6 million R.O. or US$ 22.2 million (see Table 4-16).

Project Implementation

49. The Directorate General of Water Resources and Irrigation which is fully responsible for overall planning, programming, and execution of the major water resources and irrigation projects in the Sultanate of Oman would be the executing agency of the Project. Assistance and cooperation would be rendered to this executing agency from other Governmental agencies concerned during the implementation period of the Project.

50. The construction period of three years from FY 1983 to 1985 is proposed inclusive of about one-year of detailed design in FY 1983 so that farm management in the proposed extension farm land could start in 1986.

Economic Evaluation

51. The direct and indirect benefits could be expected from the Project after its completion. The measurable direct benefits will be derived from the incremental agricultural production in the new extension farm land (net area: 85 ha), the prevention of

flood damages, the protection of dates from salt damage, and the domestic and industrial water supply to Sohar and to the copper mining industry.

52. The internal economic rate of return (IERR) is computed at 11.5 percent. This rate corresponds to an interest of commercial bank in Oman.

53. Besides the direct benefits, the Project would create the indirect benefits, and give the socio-economic impacts on the farm economy as well as the regional and national economy.

Environmental Pollution Caused by Mining Development

54. Based on the analytical results of ores, rocks, sand, gravel, and waste water sampled at Lasail mine, the quality and nature of waste water and smoke were forecast. Based on the predictable pollution process of water and air, the scale and characteristics of pollution were studied. As a result, it has been revealed that the public nuisance would be brought about from acidic water, heavy metals contained in acidic water, alkaline water, various minerals in tailings, salt, and gas and fume in smoke.

55. Heavy metals injurious to agricultural crops are Cu, Pb, and Zn. The major metallic materials contained in tailings are $FeSO_4$, $CuFeS_2$, ZnS, and PbS. The concentration of SO_2 in exhaust gas from the ore sample was estimated to be more than 10 percent. SO_2 is deemed as the major factor of exhaust gas that causes the environmental pollution.

56. The prevention of environmental pollution should be made through i) chemical and physical treatment of exhaust water and smoke and ii) organizational arrangement for monitoring the treatment methods and consequent effects.

RECOMMENDATIONS

Surveys and Investigations

1. Prior to the commencement of the final design, the following surveys and investigations should be completed;

° Dam and Structure

a) Surveys

Detention Dam:

Topographic survey:	250 ha (Scale: 1/2,000)
Longitudinal survey:	L = 2,700 m
Cross sectional survey:	L = 5,390 m

Dispersion Facilities:

Longitudinal survey:	L = 11,300 m
Cross sectional survey:	L = 400 m

b) Geological surveys

Bore-hole drilling:	L = 230 m (7 holes)
Penetration test:	50 times
Permeability test:	16 times
Material investigation:	3 samples

° New Extension Farm Land

Topographic survey:	200 ha (Scale: 1/1,000)

Soil Management

2. The salinity problem of soil has occurred in the coastal plain where most of the existing farm lands are located. Some appropriate measures, therefore, should be taken for the soil

improvement such as proper irrigation or leaching with additional water. Otherwise, the relocation of farm lands to the inner area would be required. From physiological point of view, the application of acidic fertilizers and organic matters like composts is recommended. Frequent cultivation of deep-root crops like legume or grasses would be also effective for this purpose.

Water Management

3. The groundwater in the Wadi Jizzi basin will be utilized in various ways for irrigation, domestic and industrial use. Therefore, the Governmental organizations and agencies like the Ministry of Agriculture and Fisheries (MAF), the Ministry of Electricity and Water (MEW), the Ministry of Petroleum and Minerals (MPM), and so forth will be involved. For effective and efficient water utilization in the basin, it is recommended that a committee be established in charge of the administration of water utilization in the basin. The committee could be temporarily named "Water Utilization Committee (WUC)". The members of this committee would be selected from the above authorities concerned.

4. The annual water demand covering all the aforesaid sectors was estimated at 22.4 MCM, and the breakdown is as follows;

Sector	Water Demand (MCM)
Agriculture (irrigation)	21.1
Domestic water	1.0
Industries	0.3
Total	22.4

The demand for domestic water was estimated on the assumption of i) average population growth rate of three percent and ii) execution of the water resources development including the construction of new facilities, exclusively for domestic use, within several years(by 1987) after the construction of the pipe conveyance facilities.

Monitoring Systems

5. In parallel with the Project implementation, the monitoring systems of soils, groundwater, and environmental pollution in the Project Area should be established for adequate operation and maintenance of the Project facilities as well as groundwater management in the basin.

6. As for the soils, their salinity and alkalinity should be kept below the critical level through the control of groundwater extraction when necessary.

7. As for groundwater, the monitoring system aims at i) assessment of the effect of groundwater recharging and ii) groundwater quality control at each production well. The works to be performed for these are outlined below;

a) Assessment of the Groundwater Recharging Effect

To analyze the hydrograph of groundwater based on the observation data of groundwater tables at observation wells constructed for the Project Study and at the existing production wells, to assess the groundwater recharging effect to be brought about by the Project, and to control the lifting of groundwater, when necessary.

° Monitoring wells JA-1, JA-2, JA-3, JA-4, JA-5, EA-1, EA-2, OA-1, OA-2, SP-0

the observation well of Sohar Expansion Farm production well No. 1 (SE-1), WSI-26.

° Observation interval .... Once a month in the dry months and at ten-day interval in the wet months

° Commencement of monitoring .... January, 1983

b) Groundwater Quality Control at Production Wells

To prevent the sea water intrusion into the aquifer and to prevent groundwater from the chemical contamination caused by copper mining.

° Wells for EC logging JA-1, JA-2, JA-3, JA-4, JA-5, EA-1, EA-2, SE-0, SP-0, OA-1, OA-2, AE-62, AE-91, AE-93, AE-101, AE-142

° Chemical analysis JA-1, JA-2, JA-3, JA-4, JA-5, SE-0, SP-0, OA-1, OA-2, AE-49, AE-93, AE-101, AE-159

° Monitoring interval ..... EC logging, twice a year in dry and wet seasons
Chemical analysis, once a year

° Items of analyses ..... Agricultural purposes:
PH, EC, TDS, Na^{+}, K^{+}, Ca^{++}, Mg^{++}, $CO_3^{=}$, HCO_3^{-}. CI^{-}, $SO_4^{=}$
Ordinary analyses:
Cu, Pb, Zn, Fe, As, Cd.
Special analyses:
Mg, Cr, Hg.

° Commencement ..... The end of 1982 (to obtain the back data on groundwater quality)

CHAPTER I. INTRODUCTION

CHAPTER I. INTRODUCTION

1.1. Background of the Survey

The Sultanate of Oman has achieved a steady economic development since launching the Five-Year Development Plan in 1976. The Gross Domestic Product (GDP) at current prices amounted to 1,823 million Rial Omani (R.O.) in 1980, or 724 million R.O. in 1975. The average annual growth rate during the period between 1975 and 1980 was 20.3 percent. Of the total growth in GDP, some 754 million R.O. (68.6 percent of the total) was derived from the oil sector, and 345 million R.O. (31.4 percent) from other sectors.

Apart from the above, since about 60 percent of the total Omani employment belongs to the agriculture and fisheries, this sector is the main source of income for the majority of the Omani population, but its contribution to the Gross Domestic Product is almost negligible. The major problem in agriculture is the lack of water resources for irrigation, insufficient extension services, and absence of agricultural credit system, though particular attention has been given to the development and management of water resources by the Government.

Under the situation, the Government of Oman made a request in February 1980 to the Government of Japan for technical cooperation to formulate the agricultural development project through water resources development. Upon the request, the Government of Japan dispatched the preliminary mission to make a survey of projects as well as to have deliberate discussion and the Scope of Works for the Feasibility Study on the Wadi Jizzi Agricultural Development Project in North Batinah was agreed between the two governments.

The Japan International Cooperation Agency (JICA), an official agency responsible for implementing the technical cooperation programs of the Government of Japan, has carried out this study in close cooperation with the Ministry of Agriculture and Fisheries of the Government of the Sultanate of Oman. The Feasibility Study comprises two different stages, viz., the First Stage Survey which was carried out from March till May, 1981, and the Second Stage Survey for five months from November, 1981 through March, 1982.

1.2. Objectives of the Survey

The objectives of the survey were as follows:

i) to formulate an agricultural development project in Sohar in the Batinah Area through the development of water resources in the Wadi Jizzi basin and to verify the feasibility of the Project; and,

ii) to transfer the knowledge and technology to the Government's officials of the Ministry of Agriculture and Fisheries during the course of field survey and study.

1.3. History of the Survey

The history of the survey is as follows:

a) Preliminary Surveys (April and June, 1980)

Upon the request of the Government of Oman, the Government of Japan dispatched a Preliminary Survey Team to Oman. The Survey Team discussed with the Oman Authorities concerned the basic guidelines for a future survey and conducted relevant data collection.

b) First Stage Survey (16 Mar., 1981 - 14 May, 1981)

The Government of Japan sent a ten-member First Survey Team to the Sultanate of Oman for 60 days, from 16 March till 14 May, 1981. The Survey Team concentrated its effort on conducting the fundamental survey for the Project such as relevant data collection and observation and preparing the aerial photo-map at a scale of 1:50,000 covering the Wadi Jizzi basin.

c) Second Stage Survey (20 Nov., 1981 - 31 Mar., 1982)

A sixteen-member Second Survey Team was sent to the field for 132 days from 20 November, 1981 to 31 March, 1982. The main tasks of the second stage survey may be summarized as follows:

i) to collect, review and evaluate all the data and information available,

ii) to select optimum detension dam site with alternatives,

iii) to carry out the topographic survey at the proposed dam site and farm land,

iv) to undertake the geological survey on the following items;

- bore hole drilling at the proposed dam site
- geo-electric survey at the proposed dam site and the coastal area,

v) to drill six wells with a maximum depth of 60 m and perform a step-capacity pumping test,

vi) to install five automatic rain gauges, four flood gauges and six well water level gauges for continuous observation,

vii) to formulate the basic plan of the agricultural development project according to the results obtained from the above-mentioned survey and study, and

viii) to prepare and submit the Interim Report at the end of the field works.

Following are the Supervisory Group Members, Team Members and Counterparts personnel assigned to the Project.

Supervisory Group assigned to the Project

1.	Chief Advisor (Mr. Risaburo NASU) (15 Mar., 1981 - 19 May, 1981) (6 Nov., 1981 - 31 Mar., 1982)	Deputy Director, Construction Department, Hokuriku Regional Administration Office, Ministry of Agriculture, Forestry & Fisheries (MAFF)
2.	Chief Advisor (Mr. Takeshi INOUE) (1 Apr., 1982 - 10 Oct., 1982)	Deputy Director, Construction Department, Kinki Regional Administration Office, MAFF
3.	Advisor (Dr. Shiro TERASAWA)	Head, Laboratory of Soil Physics, Department of Soils and Fertilizers, National Institute of Agricultural Sciences, MAFF
4.	Advisor (Mr. Kanya OWADA)	Division Chief, Disaster Prevention Division, Construction Department, Agricultural Structure Improvement Bureau, MAFF

Team Member assigned to the Project (Period in the field)

First Stage:

1.	Team Leader (Mr. Yasushi Miyazaki)	15 Mar., 1981 - 13 May, 1981
2.	Hydrogeology (Mr. Hisao Ando)	15 Mar., 1981 - 19 May, 1981
3.	Geology (Mr. Haruhiko Nakamura)	15 Mar., 1981 - 30 Apr., 1981
4.	Soil (Dr. Yasuo Takijima)	15 Mar., 1981 - 29 Apr., 1981
5.	Irrigation (Mr. Kazuki Muta)	15 Mar., 1981 - 15 May, 1981
6.	Agronomy (Mr. Yoshiharu Musashino)	15 Mar., 1981 - 15 May, 1981
7.	Topographic Survey (Mr. Akira Yoshikawa)	16 Mar., 1981 - 27 Apr., 1981
8.	Topographic Survey (Mr. Michizo Ochiai)	16 Mar., 1981 - 27 Apr., 1981
9.	Topographic Survey (Mr. Yutaka Nakata)	16 Mar., 1981 - 27 Apr., 1981
10.	Topographic Survey (Mr. Shigeru Ichikawa)	16 Mar., 1981 - 27 Apr., 1981

Second Stage;

1.	Team Leader (Mr. Shigekatsu Watanabe)	20 Nov., 1981 - 4 Dec., 1981 25 Feb., 1982 - 11 Mar., 1982
2.	Hydrology (Mr. Toshinobu Nakano)	20 Nov., 1981 - 31 Mar., 1982
3.	Hydrology (Mr. Hironori Takahashi)	20 Nov., 1981 - 31 Mar., 1982
4.	Geology (Mr. Haruhiko Nakamura)	2 Dec., 1981 - 31 Mar., 1982
5.	Hydrogeology (Mr. Hisao Ando)	20 Nov., 1981 - 17 Dec., 1981 1 Feb., 1982 - 31 Mar., 1982

6.	Irrigation and On-farm (Mr. Seiji Takeuchi)	12 Dec., 1981 - 11 Mar., 1982
7.	Agronomy (Mr. Hirokazu Koriki)	1 Feb., 1982 - 28 Feb., 1982
8.	Dam (Mr. Takezo Nishida)	11 Jan., 1982 - 11 Mar., 1982
9.	Construction Planning (Mr. Takao Kume)	11 Jan., 1982 - 11 Mar., 1982
10.	Agro-economy (Mr. Shoji Yamada)	11 Jan., 1982 - 11 Mar., 1982
11.	Environment Assessment (Mr. Jiro Uchida)	1 Feb., 1982 - 28 Feb., 1982
12.	Specifications Specialist (Mr. Kazuki Muta)	20 Nov., 1981 - 17 Dec., 1981
13.	Geo-electric Survey (Mr. Izumi Kato)	2 Dec., 1981 - 30 Jan., 1982
14.	Geo-electric Survey (Mr. Makoto Uotani)	2 Dec., 1981 - 30 Jan., 1982
15.	Topographic Survey (Mr. Akira Yoshikawa)	11 Jan., 1982 - 11 Mar., 1982
16.	Topographic Survey (Mr. Junichi Nakagawa)	11 Jan., 1982 - 11 Mar., 1982

Counterpart Personnel assigned to the Project

1.	Mr. Mohamed Nasser Musabbah	Technical Assistant, Water Resources Branch in Sohar, Ministry of Agriculture and Fisheries, (MAF)
2.	Mr. Hussain A. Rahim	Technical Assistant, Water Resources Branch in Sohar, MAF
3.	Mr. Majid Bilarab Al-Batashi	Technical Assistant (in charge), Department of Water Resources and Irrigation, MAF
4.	Mr. Hilal Malik Mohamed Al-Batashi	Technical Assitant, Department of Water Resources and Irrigation, MAF

5.	Mr. Abdulla Saud Al-Hosni	Soil Engineer, Rumais Agricultural Research Station
6.	Mr. Abdulla Nasir Al-Khaduri	Agronomist, Sur Agricultural Research Station

CHAPTER II. BACKGROUND

CHAPTER II. BACKGROUND

2.1. National and Regional Economy

2.1.1. Location and Geography

The Sultanate of Oman occupies most of the south-eastern corner of the Arabian Peninsula covering an area of 300,000 sq. km and has a coast line stretching almost 1,700 km from the Strait of Holmuz in the north to the boundary with the People's Democratic Republic of Yemen in the south-west.

The national land area of 300,000 sq.km consists of Dhofar of 100,000 sq.km, Musandam of 2,000 sq.km and others of 198,000 sq.km.

The type of topography is classified into mountains of 45,000 sq.km with elevation over 450 m, inhabited coastal plains of 9,000 sq.km, and wadi and desert areas of 246,000 sq.km below 450 m in elevation.

The Project Area is located in Wilaya Sohar in the Batinah area. The Batinah plain extends some 270 km south-east from Muscat to the boundary with the United Arab Emirates (UAE). It is situated between the coast and the Western Hajar, varying from 10 to 30 km in width. The Batinah is one of the populous areas of Oman and the major municipalities are Barha, Masnaa, Suwaiq, Khabura, Saham, Sohar, Liwa, and Shinas.

2.1.2. National Population

According to the statistical year book, no population census has so far been carried out in Oman and precise population figures are not available. In 1974 the government made an estimate of the national population to be 1,500,000, of which approximately 80,000

live in the capital area of Muscat, Mutrah, and Ruwi. Nizwa and Salalah have a population of around 10,000 each. The remainder is found mostly in small villages and towns dotted along the coast and in the interior.

2.1.3. National Economy in 1970 - 1974

Prior to the commercial exploitation of oil in 1967, the Omani economy was at a subsistence level based entirely on agriculture and fisheries. Since July, 1970, Oman has been undergoing major structural socio-economic changes and the economy made a rapid progress. In the five years of 1970 - 1974, the country provided herself with the basic conditions of a modern state.

The Gross Domestic Product at current prices increased from 104.7 million R.O. in 1970 to 568.5 million R.O. in 1974, an increase of 443 percent. The greatest proportion of this increase resulted from the oil price hike in 1974.

2.1.4. Long-term Targets, Policies, and the First Five-Year Plan

The Development Council adopted, on the 9th of February in 1975, a decision defining the strategy of economic development in Oman. This presents a broad outline of the long-term targets and policies to be followed in preparing the consecutive five-year development plans. This strategy was published in the form of the first-five year plan.

The development strategy can be summarized in the following items;

i) to develop new sources of income to supplement and eventually to replace oil revenues,

ii) to increase the capital investment in income-generating projects, particularly in the sectors of manufacturing, mining, agriculture, and fisheries,

iii) to realize wider geographical distribution of investment in order to bridge the disparity in the regional income distribution and reduce the rate of migration to major urban centers,

iv) to meet the basic requirements of a free market economy with the private sector playing a leading role,

v) to pay more attention to the development of water resources, which is of vital importance to economic progress,

vi) to develop the local human resources in order that they may be able to play a more active role in the national economy,

vii) to continue the development of basic infrastructure, and

viii) to improve the efficiency of the government administration.

2.1.5. National Economy in 1976 - 1980

The first five-year development plan (1976 - 1980) was successfully implemented as follows:

- The Gross Domestic Product at current prices increased from 724 million R.O. in 1975 to 1,823 million R.O. in 1980, showing an increase of 1,099 million R.O. or 251.8 percent. The average annual growth rate at current prices was 20.3 percent.

- Of the total growth in GDP some 754 million R.O. (68.6 percent of the total) was derived from the oil sector.

- Non-oil sectors continued to grow annually and achieved an average annual growth rate of 19.7 percent at current prices.

- Total investments during the period of the first five-year plan amounted to 1,670 million R.O., i.e. 23.3 percent more than the target. This figure represents a gross capital formation ratio of 29.8 percent of the GDP.

- The financial position had also been improved for these five years.

- Employment grew substantially. The employment in the Government civil service increased from about 19,000 in 1975 to 38,359 in 1980, an increase of 101.9 percent, while the employment in the private sector also increased and the number of expatriate labor in that sector increased from about 65,000 persons in 1975 to about 130,000 persons in 1980, a 100 percent increase.

2.1.6. The Second Five-Year Plan

The successful implementation of the first five-year plan resulted in enhancing the capacity of the national and private economy. The following table shows such successful results.

Quantitative Development of Essential Sectores

Item	Units	1970	1975	1980
Oil production	'000 b/day	332	341	282
Electricity produced in the Capital Area	m. KWh	8	122	642
Water produced in the Capital Area	m. gallons	14	359	2,459
Asphalted Roads	kilometer	10	708	2,173
Graded Roads	kilometer	1,817	5,495	14,703
Telephone lines installed	number	557	3,701	15,044
Schools	number	3	176	363
Students	number	909	49,229	94,823
Hospital Beds	number	12	1,000	1,772
Cargo Unloaded at Port Qaboos	'000 shipping tons	71	1,038	1,623

Source: Oman Facts and Figures, 1980
Development Council, Technical Secretariat, Directorate General of National Statistics, August 1981

Based on the achievements of the first five-year plan, the second five-year plan aims in particular to achieve the following goals:

- to continue to maintain a sound financial position,
- to establish a State General Reserve Fund,
- to curb the latent pressure of inflation,
- to increase the rate of economic growth to the extent that the economy does not over-strain the manpower situation,
- to increase the crude oil production to 330,000 barrel/day and to maintain the level of production for five years,
- to attain a gross capital formation ratio to GDP, amounting to an average 23.8 percent for five years, and of which about 65 percent is envisaged to be carried out by the Government and the remaining 35 percent by the private sector,

- to give a strong and stimulating push to the private sector engaged in productive activities in agriculture, fisheries, manufacturing, mining and handicrafts,

- to expand the low-cost housing, program,

- to expand the network of vocational training centers,

- to give top priority to water resources projects, particularly for irrigation and agricultural purposes, and

- to achieve an average annual GDP growth rate of 13.1 percent.

The following table shows the relative importance of the various sources of the GDP.

Relative Importance of the Sources of GDP

Item	1980	1985	Average Annual Rate of Growth (1980-1985) (%)
Agriculture & Fisheries	2.0	2.2	15.6
Petroleum	67.2	65.8	12.6
Natural Gas	0.9	1.8	31.2
Mining	-	0.1	-
Manufacturing	0.9	2.3	34.2
Construction	6.1	5.6	11.0
Transport & Communication	2.2	2.1	12.0
Electricity	0.5	0.7	22.0
Water	0.2	0.3	21.5
Trade	5.5	5.2	12.0
Banking	1.4	1.5	15.0
Ownership of dwellings	1.8	2.2	18.0
Government administration	10.3	9.4	11.0
Other services	1.0	0.8	9.0
	100.0	100.0	13.1
Gross Domestic Product at current prices (million R.O.)	1,823	3,375	

Source: The Second Five-Year Plan

2.2. Investment in Agriculture and Water Resources Development

2.2.1. Development of the Water Resources Sector

The water resources represent a vital element in the economic development of Oman. They are relatively limited since the rainfall ranges only from 100 mm to 200 mm per annum on an average. The agriculture in Oman does not rely on direct rainfall, but rather on underground water. For this purpose the Falaj systems were developed some hundred years ago.

Recently, an increasing number of farmers has been using the wells with pumps to meet the local conditions. This tendency has resulted in the over-pumping of water beyond the level that the water table permits.

The rapid development and dramatic improvement in the standard of living in the countries of the region have contributed to a very substantial increase in water consumption. Such an immense increase in consumption has required the construction of large-scaled desalination plants in the capital areas.

The Government of Oman carried out several water resources surveys in the past years. However, it was found that in order to determine the best means to develop the natural water resources, further surveys and continuous monitoring of water resources as well as the nationalization of the water use would be needed. The said study envisages that a part of the water discharging into the ocean can be controlled to be utilized for extending agricultural activity. Small recharge and flood control dams are proposed as the most appropriate technical solution for this problem.

2.2.2. Important Projects in the Water Resources Sector

The water resources sector with regard to irrigation in the country is supervised by the Ministry of Agriculture and Fisheries.

The second five-year plan includes the following projects under the Ministry of Agriculture and Fisheries.

- A program of assistance in the maintenance and repair of privately-owned Aflaj, wells, and canals.

- Irrigation projects in the areas of Dank, Ibri, Buraimi, Wadi Quariat, Al-Kamel, Al-Wafi, Shinas, Nizwa, and other area.

- A program of surveys and studies of the availability of water resources in specific areas where arable land is available.

- The construction of small flood-control dams in various areas.

- The construction of small recharge dams in various areas.

CHAPTER III. THE PROJECT AREA

CHAPTER III. THE PROJECT AREA

3.1. Location and General Features

3.1.1. Geographic Location and Road System

The Wadi Jizzi basin, the objective area to be studied for water resources development in this plan, is located in the north Batinah region, forming one of the large alluvial fan near Sohar with the catchment area of about 1,300 sq.km. Sohar is one of nine Wilayat in Batinah region, and Sohar town lies on the Batinah coast of northern Oman, some 180 km north-west of the Muscat capital area.

The Muscat-Musandam road along the Batinah coast is the only main road only leading to Sohar and is now being widened into the four-lane paved road from two-lane road. The Qabail-Buraimi road branching off from the above main road at Qabail is constructed at the left border line of the Wadi Jizzi gravel plain, and connected with the road leading to the United Arab Emirates at Buraimi.

3.1.2. Social Environment

In the 10th century, Sohar was called "the emporium of the Whole World"[1/]. The then Sohar was about four times as big as what it is now, and so was the then farmland.

Nowadays, although Sohar is relegated to a minor fishing port, its importance as an administrative center of the coastal populous agricultural region and also the headquarters of Wilaya Sohar has resulted in considerable interaction between Sohar and its hinterland.

The area under Wilaya Sohar administration extends about 35 km along the coastline from Majis to Khadaq with a width of about 50

1/ Source: Integrated Development of Sohor Urban Region, Consulting Engineering Services, India, July, 1975.

km inland. Industry of Wilaya Sohar consists of agriculture, fisheries, manufacturing, mining, and commerce.

The landscape of two-four kilometer wide green belt developing along the coast is rarely seen in the Arabian Peninsula, and symbolizes an importance of agriculture as the main industry.

There is no large manufacturing industry in Sohar. The industrial development is limited to workshops for carpenters, metal workers, and car repairs. Small retail shops, some banks and offices, though limited, contribute to the local commercial development.

The national Sohar copper ore smelting project is currently under construction in the basins of Wadi Jizzi and Wadi Suq and its operation started in June 1982. Three mines are located in the Wilaya Sohar.

The town of Sohar is confined to a narrow coastal strip of about seven kilometer long and some 400 m wide from the beach. The governmental agencies including the police headquarters, hospital, school, and power station, are located in the southeast part of the area.

There is no water supply system in Sohar. The domestic demand is covered largely by the use of private and communal wells and Falaj system at Al-Awhi and Al-Qabail and to a lesser extent by water wagons. A water consumption for drinking, cooking, and washing is estimate to be 10 - 15 litres/head/day. But, the improvement in living standards will increase its consumption gradually.

The Wadi Jizzi and Wadi Al-Khadaq form the western and eastern boundaries of the area for the integrated Sohar urban development plan, and the plan, has been prepared for the year 2000 by the Ministry of Land Affairs and Municipalities.

3.2. Physical Conditions

3.2.1. Wadi Jizzi Basin and Its Topography

The Wadi Jizzi basin of about 1,300 sq.km is located in the North Batinah region within a range from lat. 24°03' N to lat. 24°27' N and from long 56°06' E to long. 56°45' E, and lies in the watershed of the Wadi Jizzi which flows from the mountains in the southwest to its outfall into the Gulf of Oman in the northeast, forming one of the large alluvial fans near Sohar.

In terms of topography the basin is roughly divided into two, i.e., the hilly areas and the alluvial plain areas. The hilly areas extend to the mountains of the southwestern part of the basin with an elevation up to 800 m and to the divide of the mountains on the northwest and the southeast with an elevation of 1,400 m to 1,600 m. The alluvial plain areas stretch along the downstream reaches of the Wadi Jizzi and along the Batinah coast.

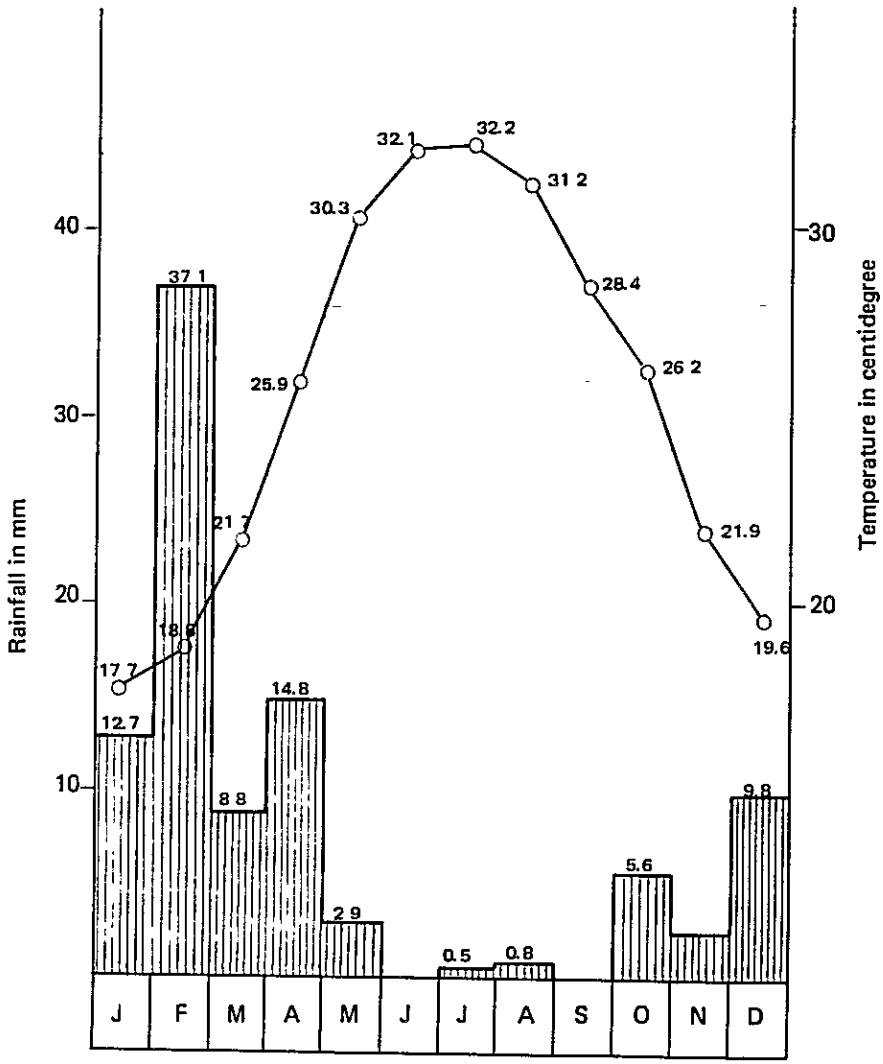
The Wadi Jizzi, originating in Al-Hajar Al-Gharbi, runs down to the northeast with a length of about 75 km and a total catchment area of about 1,300 sq.km, emptying itself into the Gulf of Oman. The slope of the Wadi is considerably steep. The average slopes are 1/100 and 1/150 in the upper and lower stream reaches, respectively (see Figure A-1, Appendix A-1).

3.2.2. Meteorology and Hydrology

a) Meteorology

The Project Area is situated in the arid zone. There are two distinct seasons in a year, i.e. the winter (November to March) and the summer (May to September). April and October are transitional period between the two seasons. A greater part of the annual rain falls during the winter (see Figure 3-1).

FIGURE 3-1 RAINFALL AND TEMPERATURE IN SOHAR



Rainfall

In the basin, there are six rainfall stations for water resources development that have been operated since 1974 (see Figure 3-2), whereas Muscat station since 1893 (See Appendix A-2). The correlation coefficient of annual rainfall between Sohar and Muscat is 0.78. Taking the overlapping moving average of annual rainfall observed at Muscat, the wet and dry years appear every five to six years and the year 1981 tends to approach the dry year (see Figure A-4, Appendix A-3).

Annual rainfall at each station is as follows.

Summary of Annual Rainfall

(Unit: mm)

Station	Annual Mean	Range	Note
Dam Site	130	47 to 421	areal rainfall
Sohar	95	37 to 253	
Muscat	101	4 to 266	

Temperature

The annual mean temperature observed at Sohar Meteorological Station is 25.5°C. July is the hottest month with a mean average of 32.2°C and January the coldest with that of 17.7°C.

Relative Humidity

The annual mean relative humidity is 72.8 percent. The minimum relative humidity is 58.0 percent in the winter season, while the maximum is 78.6 percent in the summer.

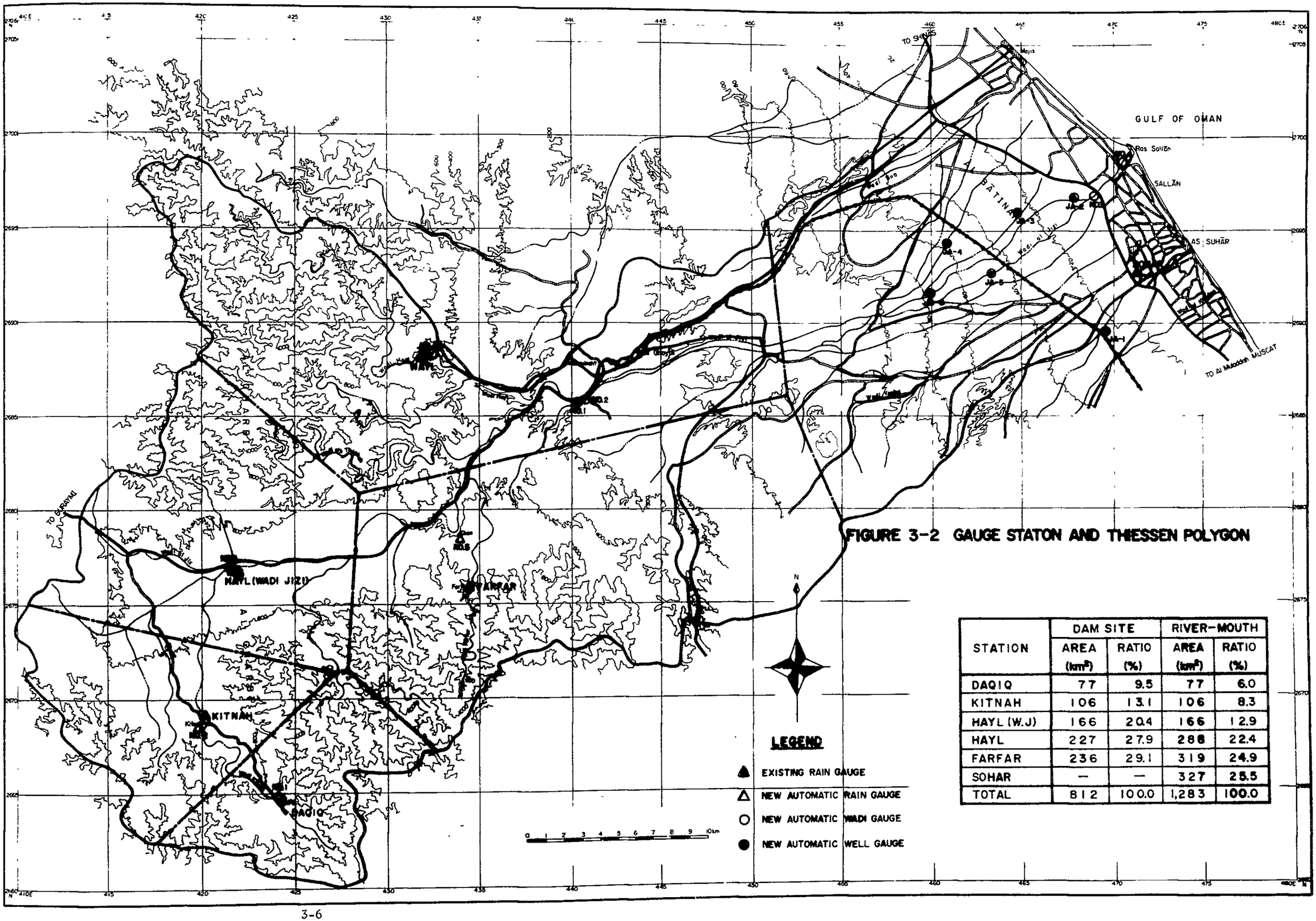


FIGURE 3-2 GAUGE STATON AND THIESSEN POLYGON

STATION	DAM SITE		RIVER-MOUTH	
	AREA (km^2)	RATIO (%)	AREA (km^2)	RATIO (%)
DAQIQ	77	9.5	77	6.0
KITNAH	106	13.1	106	8.3
HAYL (W.J)	166	20.4	166	12.9
HAYL	227	27.9	288	22.4
FARFAR	236	29.1	319	24.9
SOHAR	—	—	327	25.5
TOTAL	812	100.0	1,283	100.0

Wind

In winter the northwesterly wind prevails, whereas in summer prevails the southwesterly wind. The monthly mean wind velocity ranges from 45.8 to 90.1 km/day.

Evaporation

The annual mean evaporation (Class A Pan evaporation) is about 2,060 mm. The monthly mean maximum evaporation is 273 mm (8.8 mm/day) in May, while the minimum 93 mm (3.0 mm/day) in December. As for the estimated amount of evaporation in the reservoir, 75 percent of pan evaporation has been employed.

Sunshine Hours

The annual mean duration of sunshine hours is about 8.63 hours/day. The monthly minimum is 7.11 hours/day in January, while the maximum 10.28 hours/day in May.

The above-mentioned meteorological data are summarized in Table 3-1.

b) Surface Water Hydrology

The perennial flows are observed in the upper stream reaches and the tributaries where the river deposits are shallow and the hard rocks reach as far as the riverbed. Several floods are caused by the storm in a year. Those floods make the plain in a state of emergency, although gradually infiltrate into the aquifers of the alluvial fan.

Small floods subside before reaching the coastal road, excepting a few large floods, and a considerable amount of water is wasted into the sea.

Table 3-1 Summary of Meteorological Data in Sohar Station

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Air Temperature (C°)	17.7	18.8	21.7	25.9	30.3	32.1	32.2	31.2	28.4	26.2	21.9	19.6	25.5
Relative Humidity (%)	74.3	75.0	73.4	67.3	58.0	71.1	75.1	78.6	77.2	70.0	75.0	78.8	72.8
Evaporation (mm/day)	3.3	3.9	5.1	7.4	8.8	7.9	7.3	6.8	6.1	5.2	3.7	3.0	5.72
Sunshine Hours (Hrs/day)	7.17	7.68	8.07	8.68	10.28	9.91	8.73	8.54	9.34	9.14	8.43	7.60	8.63
Wind Velocity (Km/day)	57.0	61.8	67.8	72.1	76.5	78.8	90.1	88.8	75.6	60.1	51.3	45.8	68.8

Source: Sohar Meteorological Station

Air temperature : 1973 - 1980
Relative humidity : 1973 - 1980
Evaporation : 1976 - 1980
Sunshine hour : 1973 - 1979
Wind velocity : 1973 - 1980 (observed at 2 meter height)

The surface discharge of the Wadi Jizzi has been observed every month since 1977 by Water Resources Department at Mulayyinah point (CA = 654 sq.km). On the other hand, automatic level gauges have been operated since 1977 by the government, but no reliable records are available (refer to 3.3.1, Surface Water).

Area rainfall at the proposed dam site (CA = 812 sq.km) has been calculated by the Tiessen Polygon Method. The probability of annual rainfall is as follows;

Probable Annual Rainfall

(Unit: mm)

Location	80 Percent	50 Percent	20 Percent	Average
Dam Site	58	90	167	129
Sohar	31	72	150	95

No records are available on the sediment load of wadis in the Sultanate of Oman. According to the FAO Field Document No.7, 1/ the waters of the small floods of less than 5 cu.m/sec remain remarkably clear. The large floods cause the waters dirty but subside underground rapidly. During the field survey period, there occurred a big flood on February 14, 1982, in the north Batinah region, including the Wadi Jizzi basin, and the characteristics similar to the river flow mentioned above have been observed in the Wadi Jizzi floods. In qualitative terms, it is considered that silt transport in the Wadi Jizzi is not very different from that in the most flash rivers of the arid zone.

However, the designed sediment volume for the Project was set at 100 cu.m/sq.km/year, in considering that the figures commonly employed in the arid zone of the United State, are 50 to 150 cu.m/sq.km/year for the Projects. After the completion of the dam in the project, this figure would be revised depending on the sediment

---

1/: P.M. Horn and J.B. Nielson Run-off Measurement in Oman, FAO.

volume removed annually.

c) Groundwater Hydrology

The hydrologic system in the Area is divided into the following two systems; groundwater system and surface water system. The surface water system has mainly developed in the catchment as a base flow except flood times and the groundwater system has developed mainly both in the gravel and the coastal plains.

The surface water system is represented by sporadic flood discharge heavy rains occurring once or twice a year. The caused by perennial base discharge could be found on the river beds where the impervious rocks outcrop near the beds.

The groundwater system developing in the plains is divided into the two categories in terms of their flow conditions; flowing sub-system and stored sub-system. The former has developed in the buried terrace deposits in the west part of the gravel plain with eight kilometer width and 1:100 hydraulic gradient. The groundwater tables at the outlet and the end of the basin are about 10 meter below ground surface and 20 meter below ground surface, respectively. It is recharged by the base flow and flows into the stored sub-system. The estimated flow to the downstream is 6.7 MCM/annum on an average for the last seven years, and 10.9 MCM of flood flows can be added to it.

The stored groundwater sub-system has developed in the coastal plain with eight kilometer width and 80 m thickness in the recent wadi deposits. Hydraulic gradient of groundwater in the system is 1:2,000, taking the main sources by recharging from the flowing sub-system. The total groundwater run-off to the sea by 1:2,000 hydraulic gradient was estimated at 8.0 MCM/annum in terms of the water balance equation.