BASIC DESIGN STUDY REPORT
ON
THE RURAL WATER SUPPLY PROJECT
IN
THE YEMEN ARAB REPUBLIC

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

P R E F A C E

In response to the request of the Government of the Yemen Arab Republic, the Government of Japan has decided to conduct a basic design study on the Rural Water Supply Project and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to the Yemen Arab Republic a study team headed by Mr. Junzo SAGO, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs, from October 24 to December 22, 1986.

The team had discussions on the Project with the officials concerned of the Government of the Yemen Arab Republic and conducted a field survey in the areas related to this project. After the team returned 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.

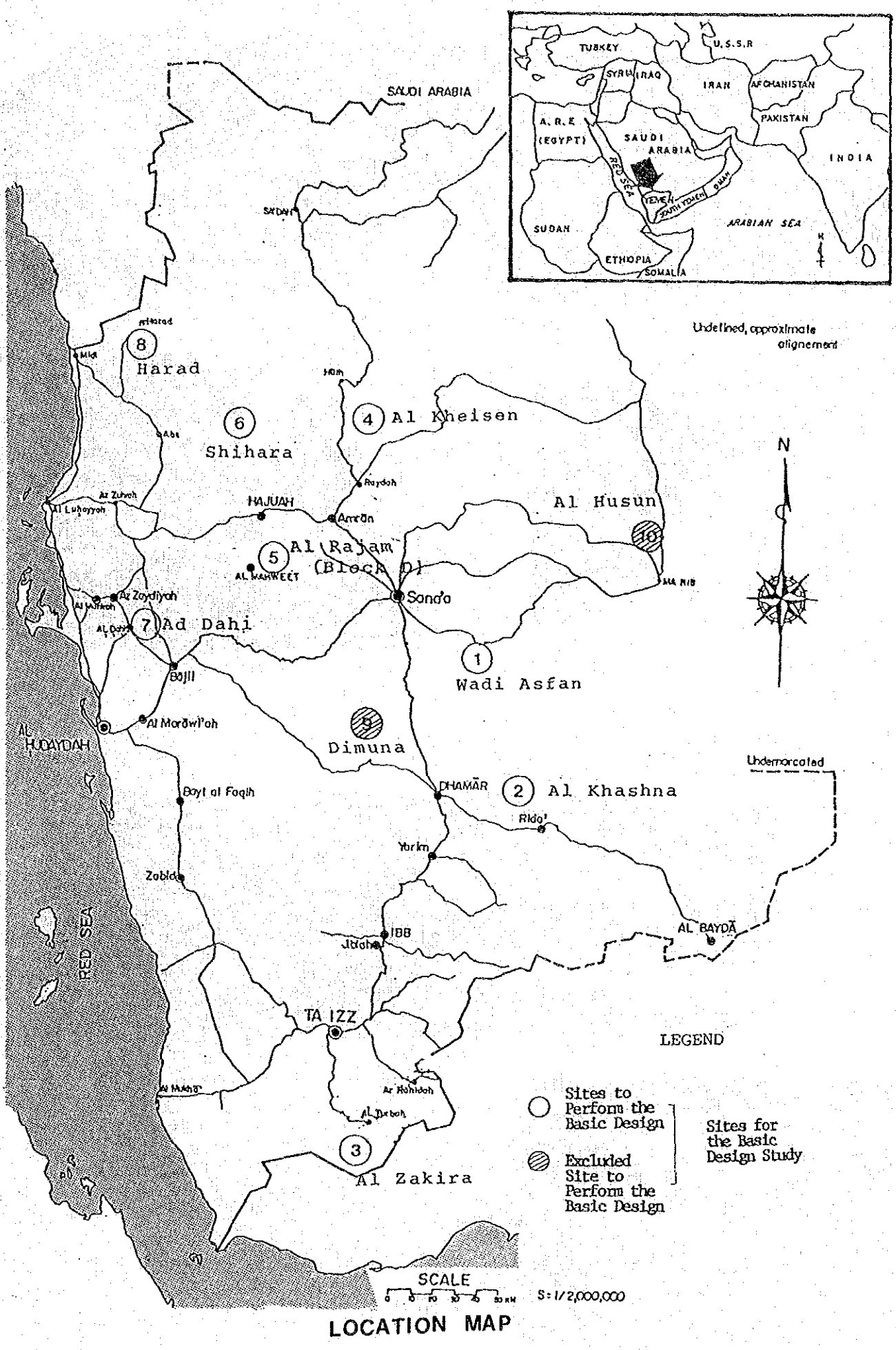
I wish to express my deep appreciation to the officials concerned of the Government of the Yemen Arab Republic for their close cooperation extended to the team.

March, 1987.

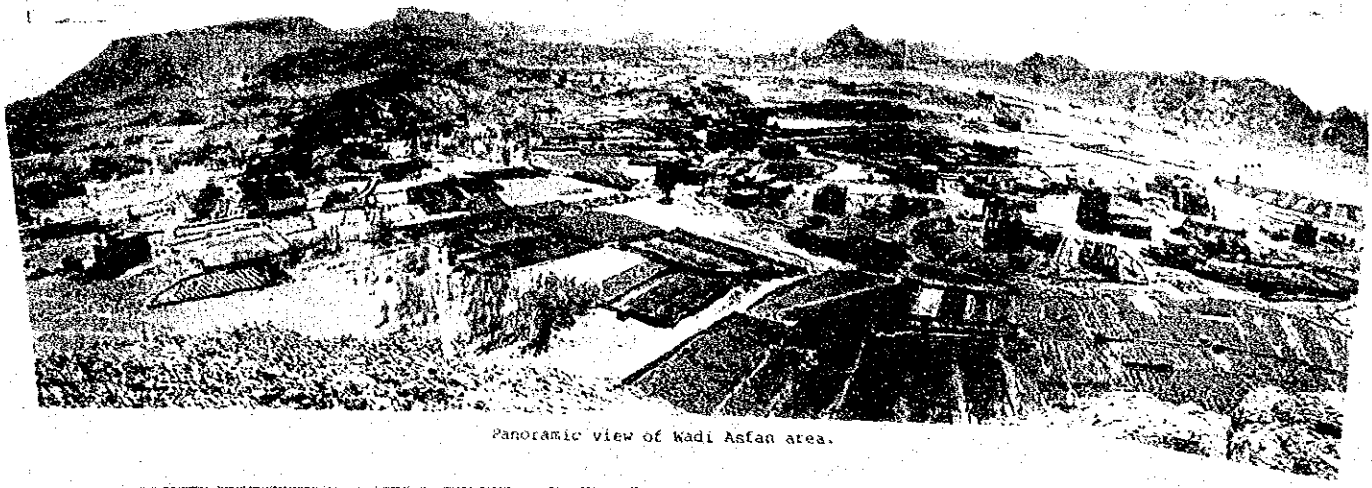
Keisuke Arita

Keisuke Arita

President
Japan International Cooperation Agency



LOCATION MAP

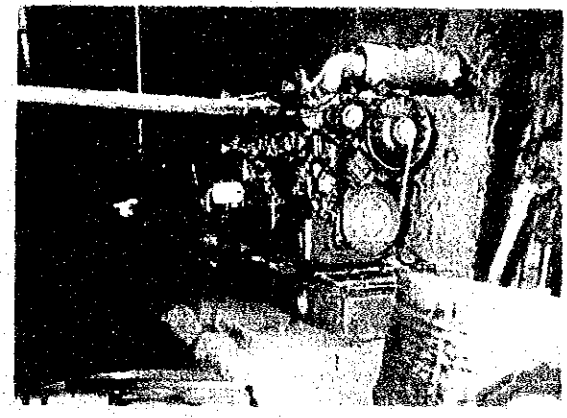


Panoramic view of Wadi Asfan area.

Private well (Wadi Asfan).

Manual extruction from hand dug well.

Panoramic view of Al Khashna area.



Borehole-pump and engine of private well.

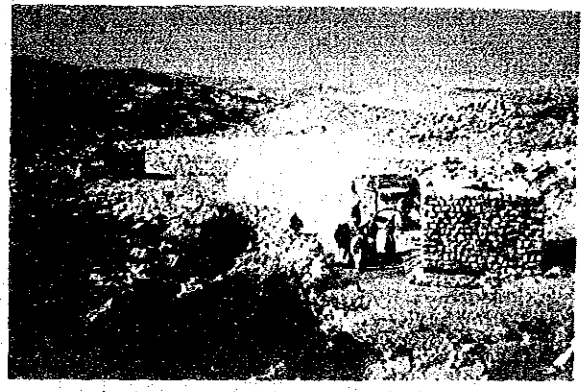
Reservoir tank and carriage water by donkey.

A view around the proposed well from Al Khashna village.

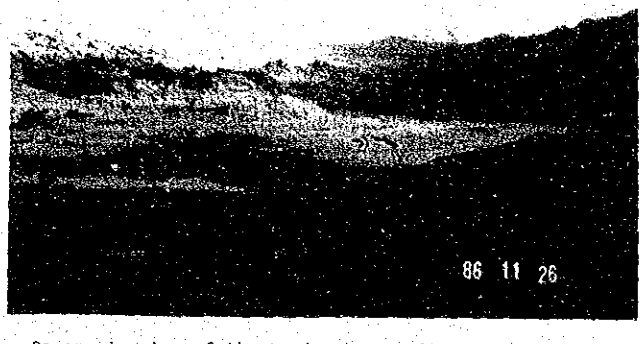
Access road to proposed distribution tank site.

A view to Al Kadra from Goré (Al Zakira).

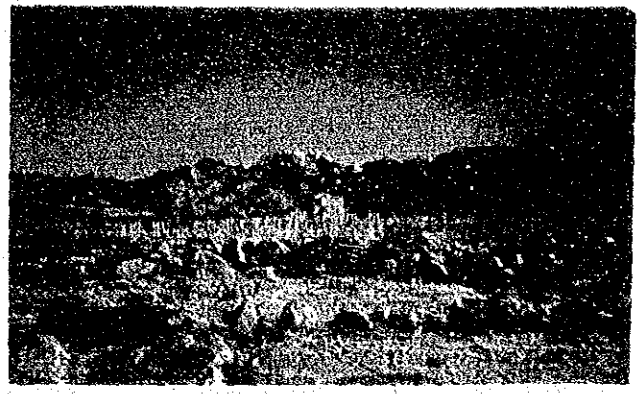
Panoramic view of Al Kheisen area.



Existing pump facilities in Al Kheisen.



Panoramic view of the basin where wells are proposed.

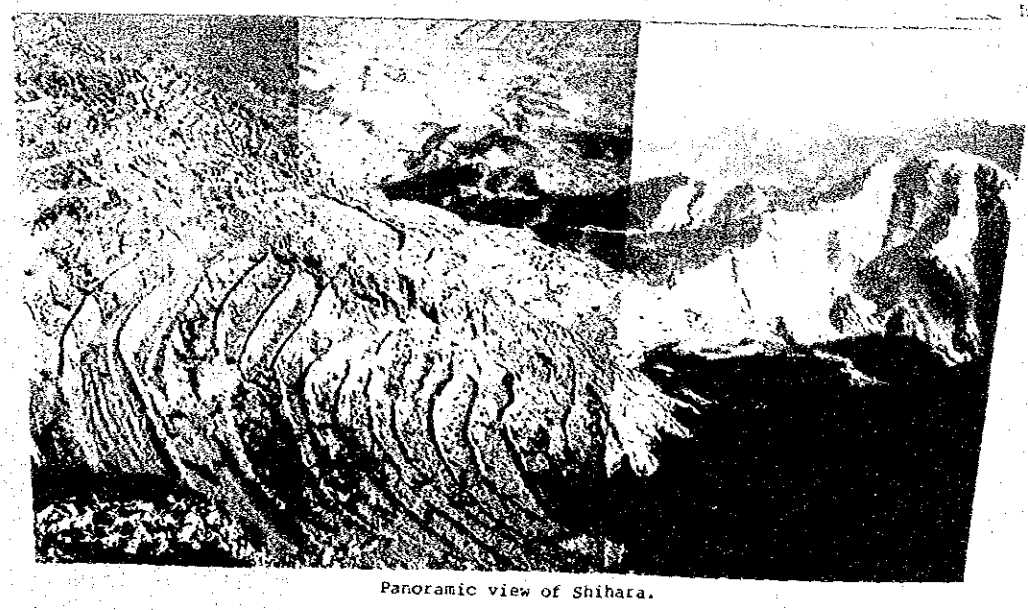


A view to the project area from the proposed well site.

Al Rajam area (Block D).

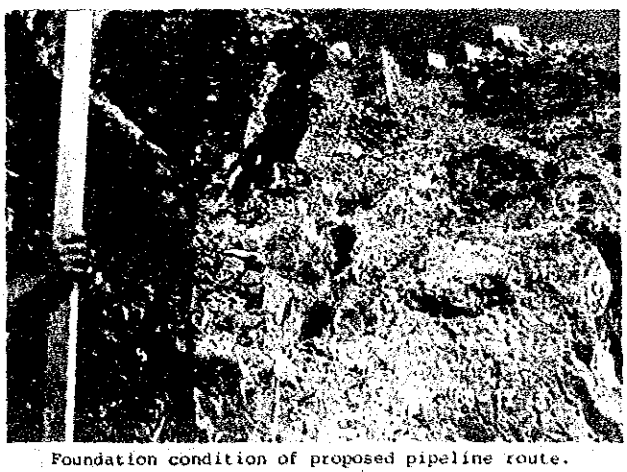
A situation of The Colony

E ←



Panoramic view of Shihara.

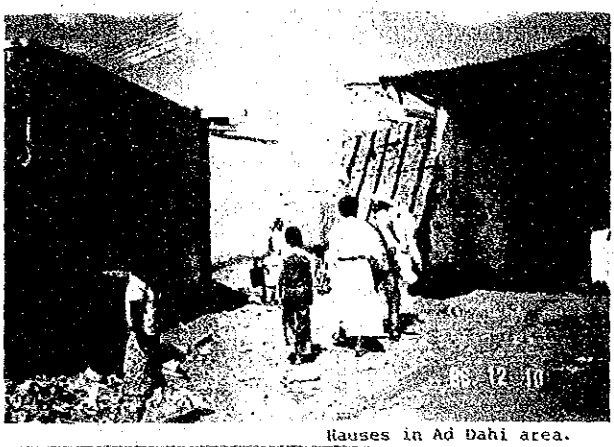
Cistern in Shihara.



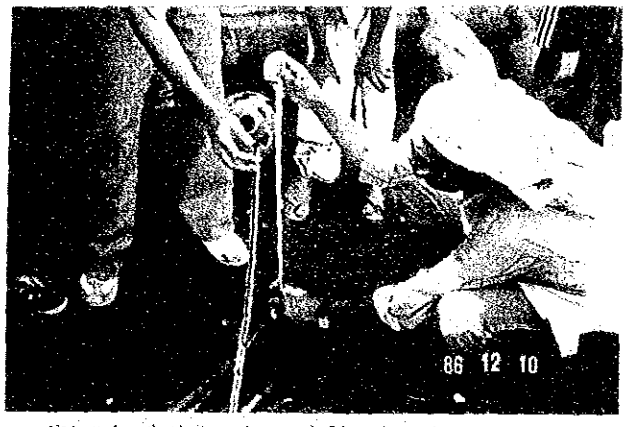
Foundation condition of proposed pipeline route.

Surface water in Shihara Area where well is proposed.

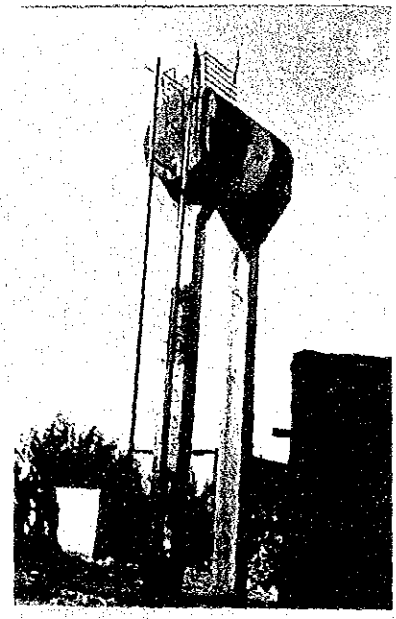
Hand dug shallow well in Shihara Area.



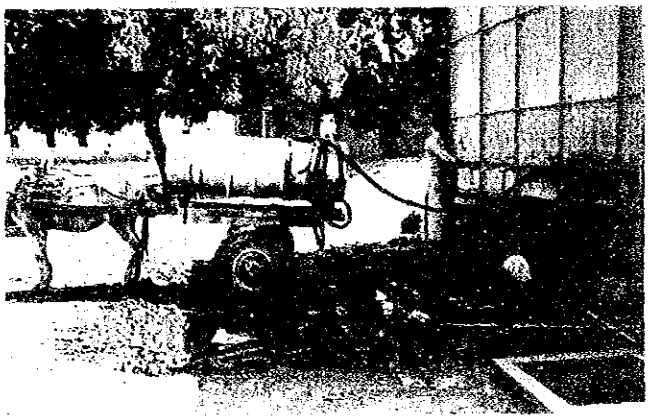
Hauses in Ad Dahi area.



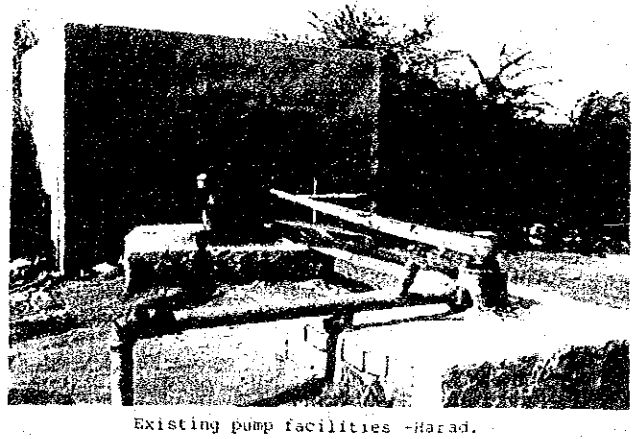
Water Head at tap (around 50 cm) -Ad Dahi Area.



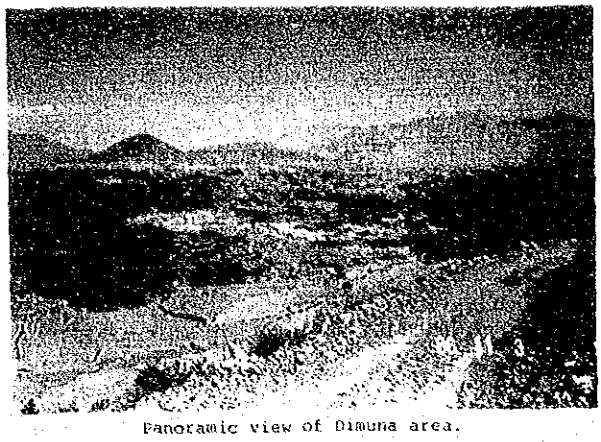
Existing elevation tank in Ad Dahi Area.



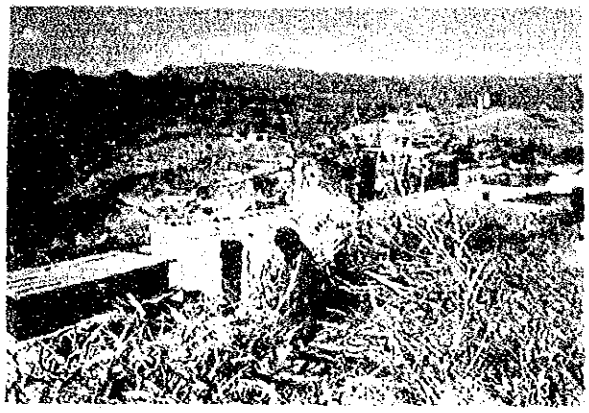
Existing reservoir tank -Harad.



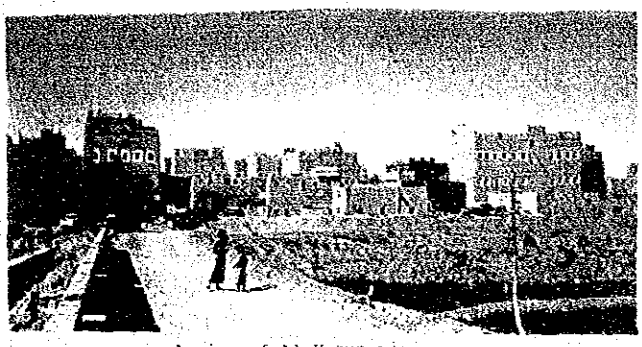
Existing pump facilities -Harad.



Panoramic view of Dimuna area.

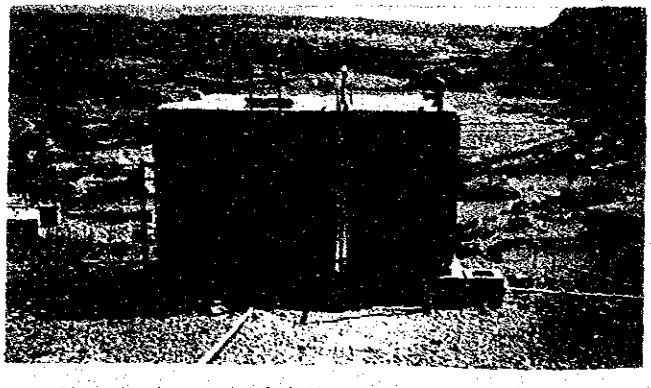


Village in Dimuna.

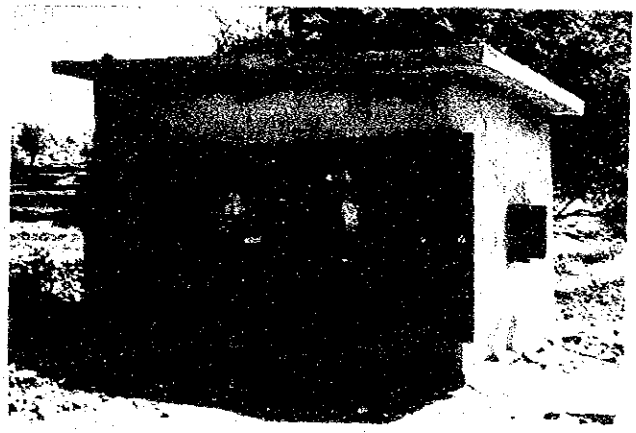


A view of Al Husun area.

Existing water supply facilities, constructed by Japanese Grant Aid Program.

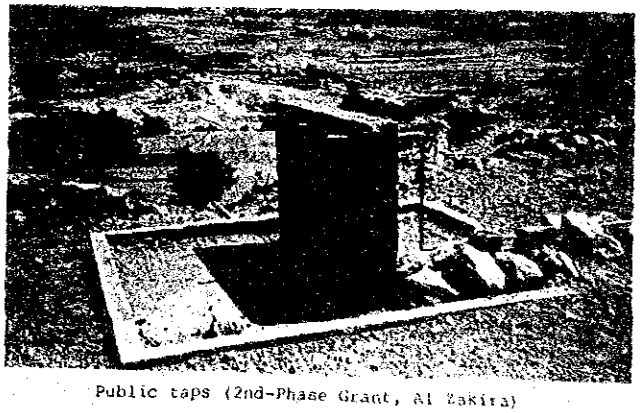


Distribution tank (2nd-Phase Grant, Al Zakira)



Pump facilities (2nd-Phase Grant, Al Zakira)

Pump and reservoir tank (1st-Phase Grant, Harad).



Public taps (2nd-Phase Grant, Al Zakira)

SUMMARY AND CONCLUSION

The Yemen Arab Republic (YAR) is situated in the southwest fringe of Arabian Peninsula, covers the area of about 200,000km^2 (about 50% the size of Japan), and has a population of about 9.3 million (in 1968). Most of the country consists of highlands and mountains at an altitude exceeds 2,000m, where sandy or rocky deserts are found. Owing to relatively abundant rainfall in the Arabian Peninsula, YAR's economic basis are agriculture in which more than 80% of the population are engaged. Traditionally, the people have adapted their way of life to suit these natural conditions. However, YAR suffers from an unstable domestic water supply due to the dry climate prevailing in the whole country. In particular, the inhabitants in the agricultural zone is still forced to use labor and cash in order to obtain drinking water.

In 1972, YAR established the Rural Water Supply Department in the Ministry of Public Works to improve such water supply conditions in rural areas. Since then, water facilities have rapidly improved through the two 5-year plans started in 1976. However, emphasis has been placed particularly on the urban areas, and only 22.1% of total rural population was being supplied with water supply facilities as of 1985. For this reason, further promotion of water supply improvement is required for the inhabitants in the rural areas where there is a shortage of domestic water. Although the Rural Water Supply Department is energetically developing the rural water supply improvement projects, the Government of YAR has requested foreign countries including Japan to provide assistances to improve the water supply because of financial difficulties the country faced. In fact, YAR is dependent on the foreign countries for about 30% of the water supply budget.

The international cooperation of Japan for the water supply of YAR started with the study carried out by Overseas Economic Cooperation Fund of Japan (OECF) in 1976. After that, the Japan International Cooperation Agency (JICA) performed a feasibility study for social development in 1979 and 1980 and as a result the Japanese Government provided the grant aid cooperation in 3 phases. The present basic design study corresponds to the 4th grant in succession to the above grants.

In 1986, the Government of YAR requested the Japanese Government to provide a grant for the construction of water supply facilities in the areas where urgent improvement is necessary, considering the satisfactory results of the previous grant aid projects of Japan.

In response to the request, the Japanese Government made a decision to start the basic design survey of the project for the grant aid cooperation.

Accordingly, JICA despatched a basic design study team to YAR from October 24, 1985 to December 22, 1985 to perform a field survey, which included discussions with YAR authorities concerned, collection of data on water supply and groundwater for the plan of water supply facilities, topographical surveys of distribution pipelines and other related facilities, pumping tests of existing wells, surveys of the water supply area and number of beneficiaries, studies of construction materials for wells, etc.

The project is formulated on the basis of the basic design study as shown below.

1) This project covers 8 sites out of 10 surveyed sites.

Mountainous Village	Semi-urban Area in Plain
Wadi Asfan	Ad Dahi
Al Khashna	Harad
Al Zakila	
Al Kheisen	
Al Rajam (Block-D)	
Shihara	

ii) Design Conditions

Item	Mountainous Villages	Semi-urban Area in Plain Zone
Design Target Year	2007	2007(1997 for water tanks)
Population Served	Population calculated on the basis of annual growth rate 1.7%.	Population calculated on the basis of the growth rate during the last five years.
Unit Consumption	401/capita/day	701/capita/day
Daily Demand	Design population served x unit consumption + water demand for public use (ex. hospital) Maximum daily water consumption = Daily demand x 1.5	
Water Head	at taps of public fountains: 5m as minimum at Distribution pipeline : 10m as minimum	
Water Supply Facilities	The water supply facilities of improved system is planned so that pumping water will be transported to elevated distribution tanks and distributed to surrounding villages. One public fountain will be installated in each village at the rate of 200 persons/1 tap.	

iii) Content of project

The project area covers a wide range of water supply facilities in the following sites. Proposed figures and facilities are as follows.

Site	Design Population (person)	Design Capacity (m^3/day)	Facilities	Description
Wadi Asfan	990	39.6	Deep Well	1 well, 200m deep, ϕ8" - 20"
			Intake Facility	1 lot
			Water Tank	1 tank, 50m^3
			Supply and Distribution Pipeline	3,475m, ϕ40 - 80mm
			Public Fountain	6 nos
Al Khashna	490	19.6	Intake Facility and Water Tank	1 lot 1 tank, 30m^3
			Supply and Distribution Pipeline	1,464m, ϕ32 - 65mm
			Public Fountain	1 nos

Site	Design Population (person)	Design Capacity (m^3/day)	Facilities Planned	Description
Al Zakira	820	32.8	Water Tank	1 tank, $50m^3$
			Supply and Distribution Pipeline	3,270m, ϕ40 - 50mm
			Public Fountain	3 nos
Al Kheisen	1,170	46.8	Pumping Facility	1 lot
			Water Tank	3 tanks, $20m^3$, $30m^3$, $50m^3$
			Supply and Distribution Pipeline	5,077m, ϕ40 - 80mm
			Public Fountain	5 nos
Al Rajam (Block-D)	6,070	242.8	Deep Well	2 wells, 200m deep ϕ8"
			Intake Facility	2 lots
			Pumping Facility	2 lots
			Water Tank	3 tanks, $50m^3$ x 2, $150m^3$ x 1
			Pumping and Distribution Pipeline	14,178m, ϕ40 - 100mm
			Public Fountain	11 nos
			Electric Facilities	1 lot
Shihara	8,440	337.6	Deep Well	1 well, 200m deep, ϕ8" - 20"
			Intake Facility	1 lot
			Water Tank	7 tanks, $30m^3$ x 1, $50m^3$ x 4, $60m^3$ x 1, $100m^3$ x 1
			Pumping Facility	5 lots
			Pumping and Distribution Pipeline	14,871m, ϕ50 - 150mm
			Public Fountain	8 nos
			Electric Facilities	1 lot
Ad Dahi	9,030	634	Intake Facility	2 lots
			Elevated Water Tank	2 tanks, $100m^3$ x 15m high
			Pumping and Distribution Pipeline	7,200m, ϕ40 - 150mm
			Public Tap	10 nos
Harad	6,920	488	Intake Facility	1 lot
			Elevated Water Tank	1 tank, $100m^3$ x 15m high
			Pumping and Distribution Pipeline	6,595m, ϕ40 - 100mm
			Public Fountain	6 nos

This project is planned to be implemented in the following 3 phases in consideratin of the work schedule, project scale, etc. The total implementation period of the Project requires 23 months for local construction.

Phase	Project Site
1st Phase	Al Khashna Al Zakira Al Kheisen
2nd Phase	Wadi Asfan Al Rajam (I) Shihara (I) Ad Dahi Harad
3rd Phase	Al Rajam (II) Shihara (II)

The local portion of the Project to be borne by YAR government is estimated at about 12 million Yemen Riyal.

The executing agency of this Project is the Ministry of Public Works, Rural Water Supply Department, whose Foreign Project Office is directly responsible for the Project implementation. In implementing the Project, the Ministry is requested to appoint between 4 and 7 counterparts to cooperate with the consultant and contractor from Japan.

The implementation of the project has the following effects. First, domestic water is stably supplied, and water quality and public health environment can be improved. Improvement of public health conditions results in reduction in the incidence of water-borne and digestive organ diseases, contributing greatly to the improvement of health of the inhabitants in the areas. Second, the completion of water supply facilities reduces the distance between the water source and service areas, and saves labor otherwise to be spent to obtain water, which would be utilized for other productive activities.

On completion of the Project, water is supplied to the present population of 21,470 (water supply volume: 1,130m^3/day), which is expected to rise to 33,920 in 20 years. In addition, this Project is expected to contribute greatly to transferring techniques to YAR counterparts.

Finally, this basic design study brings a conclusion that the project is feasible to be implemented by the grant aid cooperation of the Japanese Government.

TABLE OF CONTENTS

LOCATION MAP
SUMMARY AND CONCLUSION

Page

I. INTRODUCTION ..... 1 - 1
II. BACKGROUND ..... 2 - 1
2.1 Brief Description of Natural Conditions ..... 2 - 2
2.1.1 Topography and Geology ..... 2 - 2
2.1.2 Hydrology and Meteorology ..... 2 - 6
2.1.3 Land Use and Vegetation ..... 2 - 9
2.2 Social Background ..... 2 - 10
2.2.1 General ..... 2 - 10
2.2.2 Administration System ..... 2 - 10
2.2.3 Socioeconomy ..... 2 - 11
2.3 Outline of Development Plan ..... 2 - 12
2.4 Present Condition of Water Utilization ..... 2 - 16
2.4.1 Water Supply Condition ..... 2 - 16
2.4.2 Water Supply Project ..... 2 - 17
2.4.3 Present Condition of Water Resources Development ..... 2 - 23
2.5 Necessity of Local Water Supply ..... 2 - 24
2.6 Prior Work by Japan Assistance ..... 2 - 24
2.7 Content of Request ..... 2 - 28
III. PRESENT CONDITION OF THE PROJECT SITES ..... 3 - 1
3.1 General ..... 3 - 2
3.1.1 Location ..... 3 - 2

3.1.2 Social Situations ..... 3 - 3
3.1.3 Population ..... 3 - 5

3.2 Water Utilization ..... 3 - 7

3.3 Hydrogeology ..... 3 - 9
3.3.1 General ..... 3 - 9
3.3.2 Hydrogeological Characteristics ..... 3 - 11

3.4 Water Quality ..... 3 - 12

3.5 Present Conditions of the Project sites ..... 3 - 15
3.5.1 Wadi Asfan Area ..... 3 - 15
3.5.2 Al Khashna Area ..... 3 - 18
3.5.3 Al Zakira Area ..... 3 - 19
3.5.4 Al Kheisen Area ..... 3 - 21
3.5.5 Al Raham (Block D) Area ..... 3 - 22
3.5.6 Shihara Area ..... 3 - 24
3.5.7 Ad Dahi Area ..... 3 - 27
3.5.8 Harad Area ..... 3 - 29
3.5.9 Dimuna Area ..... 3 - 31
3.5.10 Al Husun Area ..... 3 - 32

3.6 Water Rights and Land Acquisition ..... 3 - 34
3.6.1 General ..... 3 - 34
3.6.2 Water Rights and Land Acquisition Problems ... 3 - 35

IV. THE PROJECT PLAN ..... 4 - 1
4.1 Objectives ..... 4 - 2

4.2 Study of the Request ..... 4 - 2

4.3 General Features of the Project ..... 4 - 5
4.3.1 General Features of Planned Facilities ..... 4 - 6
4.3.2 Executing Agency ..... 4 - 11
4.3.3 Operation and Maintenance ..... 4 - 11
4.3.4 Supply of Equipment .... 4 - 11

4.4 Examination of Basic Design Concept ..... 4 - 12
4.4.1 Basic Design Concept ..... 4 - 12
4.4.2 Relation to Projects Implemented ..... 4 - 15
4.4.3 Comparison of Water Supply Plans ..... 4 - 19
4.4.4 Examination of Water Source ..... 4 - 19
4.4.5 Target Year for the Project ..... 4 - 23
4.4.6 Planned Water Supply Sites ..... 4 - 25
4.4.7 Design Population ..... 4 - 26
4.4.8 Unit Consumption for Planning ..... 4 - 27
4.4.9 Design Demand ..... 4 - 28
4.4.10 Service Hours ..... 4 - 32
4.4.11 Design Capacity of Water Tanks ..... 4 - 33
4.4.12 Service Pressure ..... 4 - 34

4.5 Water Supply System ..... 4 - 35

4.6 Relation and Evaluation on Existing Facilities ..... 4 - 36

4.7 Relation to Future Plans ..... 4 - 37

4.8 Characteristic Features of Basic Design ..... 4 - 38

V. BASIC DESIGN ..... 5 - 1

5.1 Water Source Facilities ..... 5 - 2
5.1.1 Pumping Rate ..... 5 - 2
5.1.2 Number of Wells ..... 5 - 3
5.1.3 Study on New Wells ..... 5 - 3
5.2 Intake Facilities ..... 5 - 10
5.2.1 Pumping Facilities ..... 5 - 10
5.2.2 Pumping Duration ..... 5 - 10

5.3 Booster Pump Facilities ..... 5 - 11
5.3.1 Booster Pumps ..... 5 - 11
5.3.2 Control System of Pumping Facilities ..... 5 - 12

5.4 Pipelines ..... 5 - 13
5.4.1 Type of Pipelines ..... 5 - 13
5.4.2 Kind of Pipes ..... 5 - 13
5.4.3 Diameter of Pipes ..... 5 - 14
5.4.4 Additional Facilities of Pipelines ..... 5 - 14

5.5 Water Tanks ..... 5 - 15
5.5.1 Materials of Water Tanks ..... 5 - 15
5.5.2 Capacity of Water Tanks ..... 5 - 15

5.6 Public Fountains ..... 5 - 16

5.7 Water Supply Facilities of Sites ..... 5 - 17
5.7.1 Wadi Asfan ..... 5 - 17
5.7.2 Al Khashna ..... 5 - 18
5.7.3 Al Zakira ..... 5 - 19
5.7.4 Al Kheisen ..... 5 - 23
5.7.5 Al Rajam ..... 5 - 24
5.7.6 Shihara ..... 5 - 27
5.7.7 Ad Dahi ..... 5 - 31
5.7.8 Harad ..... 5 - 33

5.8 Estimated Project Cost ..... 5 - 35

VI. IMPLEMENTATION PLAN ..... 6 - 1
6.1 Organization for Implementation ..... 6 - 2

6.2 Construction Plan ..... 6 - 4
6.2.1 Construction Situation ..... 6 - 4
6.2.2 Description of Construction Works ..... 6 - 7

6.3 Procurement of Equipment and Materials ..... 6 - 8

6.4 Scope of Construction Works ..... 6 - 10
6.4.1 Responsibilities of the Yemen Arab Republic . 6 - 10
6.4.2 Responsibilities of the Japanese Government . 6 - 12

6.5 Implementation Schedule ..... 6 - 12

6.6 Detailed Design and Construction Suprevision ..... 6 - 13

VII. OPERATION AND MAINTENANCE ..... 7 - 1

7.1 Present Operation and Maintenance System of YAR ..... 7 - 2
7.1.1 Outline of Present Operation and Maintenance System ..... 7 - 2
7.1.2 Routine Operation and Maintenance ..... 7 - 3
7.1.3 Treatment of Problems ..... 7 - 3
7.1.4 Training System of RWSD ..... 7 - 4
7.1.5 Present Water Fee System ..... 7 - 5

7.2 Operation and Maintenance System ..... 7 - 6

7.3 Operation and Maintenance Plan ..... 7 - 8
7.3.1 Personal Plan for Operation and Maintenance .. 7 - 8
7.3.2 Equipment and Materials ..... 7 - 10
7.3.3 Management ..... 7 - 11

7.4 Operation and Maintenance Cost ..... 7 - 12

VIII. PROJECT EVALUATION ..... 8 - 1

IX. CONCLUSION AND RECOMMENDATIONS ..... 9 - 1

9.1 Conclusion ..... 9 - 2
9.2 Recommendations ..... 9 - 2

FIGURES

Fig. 1. Topographic Division of The Yemen Arab Republic ..... 2 - 3
2. Schematic Geological Column of The Yemen Arab Republic ..... 2 - 4
3. General Hydrogeological Map ..... 2 - 5
4. Isohyet Map ..... 2 - 7
5. Administration System of YAR ..... 2 - 11
6. Organization of the Ministries ..... 2 - 19
7. Schematic Columnar Section(Wadi Asfan) ..... 3 - 17
8. Schematic Columnar Section(Al Rajam) ..... 3 - 23
9. Schematic Columnar Section(Shihara) ..... 3 - 26
10. Outline of Water Supply System ..... 4 - 7
11. Diagram of Water Supply System ..... 4 - 15
12. Design Population Versus Hourly Peak Ratio ..... 4 - 29
13. Daily Water Consumption Pattern ..... 4 - 32
14. Basic Flow of Improved Water Supply System ..... 4 - 35
15. Proposed Well Structure ..... 5 - 9
16. Implementation System ..... 6 - 3
17. Operation and Maintenance System ..... 7 - 7

TABLES

Table 1. Annual precipitation ..... 2 - 8
2. Hydrogeomorphological Division in YAR ..... 2 - 9
3. Investment Plan Based on Five-Year Plan(1982-1986) ..... 2 - 15
4. Population of Safe Water Supplied ..... 2 - 17
5. Rural Water Supply Schemes ..... 2 - 20
6. Existing Production Capacity and Targeted Expantion(1982-1986).. 2 - 22
7. Rural Water Supply Projects Assisted by Foreign Aids ..... 2 - 22
8. On-going Rural Water Supply Schemes by Aids ..... 2 - 26
9. Requested Sites and Contents of the Request ..... 2 - 29
10. Distance between Sana'a and The Project Site ..... 3 - 2
11. Social Infrastructure in the Project Site ..... 3 - 4
12. Major Disease in the Project Site ..... 3 - 5
13. Rural Population Growth Rate at Each County(1986) ..... 3 - 6
14. Population Growth Rate of Each Site ..... 3 - 7
15. Water Price in the Project Site ..... 3 - 9

Table 16. Hydrogeological Parameter ..... 3 - 12
17. Water Quality of Study Area ..... 3 - 14
18. Amount of Design Facilities ..... 4 - 6
19. Equipment to be Supplied ..... 4 - 11
20. Comparison of Water Supply Plans ..... 4 - 17
21. Water Source and its Feasible Yield ..... 4 - 21
22. Existing Water Source ..... 4 - 22
23. Target Year of Water Supply Project ..... 4 - 23
24. Number of Villages Composing a Supply Area ..... 4 - 25
25. Design Populations ..... 4 - 26
26. Criteria for Unit Consumption ..... 4 - 27
27. Standard of Water Tank Capacity ..... 4 - 33
28. Pumping Rate ..... 5 - 2
29. Critical Velosities ..... 5 - 5
30. Planned Pumping Duration ..... 5 - 11
31. Valves and Their Purpose ..... 5 - 14
32. Capacity of Water Tank ..... 5 - 15
33. Local Portion of the Construction ..... 5 - 35
34. Operation and Maintenance Cost between with & without Project ..... 7 - 13
35. Comparison of Domestic Water Supply between with & without Project ..... 8 - 3

APPENDIX

A-1 FIELD SURVEY

a. Study Team

b. Schedule of the Site Survey

c. Minutes of Meeting

d. List of Person Contacted

A-2 ACTUAL CONDITION

e. Socio-ecnomic Condition

f. Completed Water Supply Projects under the Assistance of the Government of Japan

g. Population

h. Site Map

i. Water Quality

j. Water Rights and Land Acquisition

k. Existing Water Supply

A-3 WATER SOURCE

l. Water Source Condition

m. Geoelectric Prospecting

n. Examination of Possible Groundwater Yield

A-4 WATER SUPPLY FACILITIES

o. Disinfecting Facilities

p. Considerations on Pipelines

q. Considerations on Water Tanks

r. Examination of Pumping Facilities

s. Water Supply Plan for Al Husun

t. General Feature of Existing Large Water Supply Projects

A-5 OPERATION AND MAINTENANCE

u. Items of Operation and Maintenance Costs

v. Specification of Supplied Equipments

A-6 OTHERS

w. Design Criteria for Facilities of Rural Water Supply

x. List of Collected Information

ABBREVIATIONS

YAR	=	Yemen Arab Republic
CPO	=	Central Planning Organization
CYDA	=	Confederation of Yemen Development Association
LDA	=	Local Development Association
MPW	=	Ministry of Public Works
MEWS	=	Ministry of Electircity, Water and Sewage
OECF	=	Oversea Economic Cooperation Fundof Japan
RWSD	=	Rusal Water Supply Department
TDA	=	Tihama Development Authority
IBRD	=	International Bank for Reconstruction and Development
IDA	=	International Development Association
UNDP	=	United Nations Development Programme
USAID	=	United State Agency for International Development
WHO	=	World Health Organigation
JICA	=	Japan International Cooperation Agency
JIS	=	Japan Industrial Standard
GNP	=	Gross National Product
GDP	=	Gross Domestic Product
ℓ	=	liter
YR	=	Yemen Riyal (YR1.0=¥)
¥	=	Japanese Yen (¥1.0=)
m.s.l	=	Mean Sea Level
μS/cm	=	Micro Siemens per Centimetre
ppm	=	Part per Million

I. INTRODUCTION

I. INTRODUCTION

Since the revolution in 1962, the Government of the Yemen Arab Republic (YAR) has spent much effort to improve agricultural and social infrastructure such as roads, electric power, and rural water supply in order to accelerate the social and economic development. In particular, YAR suffers from insufficient domestic water supply and requires rapid improvement in rural water supply because about 90% of the nation is engaged in agriculture sparsely scattered over a wide range in the rural areas under a dry climate.

In YAR, the Ministry of Electricity, Water and Sewage has responsibility over urban water supply service, while the Ministry of Public Works, Rural Water Supply Department takes care of rural water supply service at present.

Established in 1972, the Rural Water Supply Department started the service with the construction of wells using 5 drilling machines supplied by USAID. However, vast services and investment are required to improve water supply facilities to support the rural population which accounts for about 90% of the whole population, and Rural Water Supply Department finds it extremely difficult to acquire the necessary budget at present, although many private well drilling companies have been engaged in the business as demand for well construction increases.

With this background, the Rural Water Supply Department reorganized the departments and sections and commenced their activities for rural water supply schemes with the government budget, with the technical cooperation provided by WHO. At the same time, the Department is dependent for about 30% of the annual budget on foreign financial aids, including USAID, Japan, West Germany, Holland, Saudi Arabia, the Arab Fund, and UNICEF. About 400 sites for water supply have been constructed or improved by these foreign financial sources.

The sites built with the assistance of Japan are summarized in Appendix A-2-f. In 1978, "The Rural Water Supply Project, Part I" was implemented by the financial assistance of DECF from Japan whereby rural water supply facilities were constructed in 42 sites. In 1979, the additional survey was made for a feasibility study on 26 sites as "Rural Water Supply Project, Part II", which required urgent improvement of water supply. This survey was followed by the implementation of the rural water supply improvement project for 9 sites, which were implemented in 3 phases by the grant aid cooperation of Japan.

In YAR, 1,273 deep wells were drilled as water sources for rural communities during the period of two five-year plans from 1976 to 1986, including the above two rural water supply schemes. However, the rate of water supply is still a little more than 20% of total rural population. This means that new water sources are further required to supply water to the rest of population accounting for about 80% of the whole rural population.

The Government of YAR requested the Japanese Government for the grant aid cooperation for the Water Supply Schemes for 15 sites, among which 5 sites had been surveyed as a part of the previous feasibility study and the other 10 sites had been planned independently by the Government of YAR.

In response to the request, the basic design study was carried out for 10 sites out of the proposed 15 sites because they require urgent improvement and are suitable for the grant aid cooperation of Japan. The basic design study was made from October 24 to December 22, 1986. Of 10 sites surveyed, 5 are those included in the previous Feasibility Study, and the other 5 are those separately planned by the Government of YAR.

The purpose of the basic design study is to determine the basic design of the rural water supply schemes in compliance with the request of the Government of YAR, including preparation of specifications on required equipment and materials, estimation of the project budget, and the maintenance and operation plan, and prepare the optimum implementation plan for the grant aid cooperation of the Japanese Government.

The study team selected 8 sites out of 10 proposed sites to perform the basic design, and discussed on the conditions of these sites with the YAR Government officials concerned, mainly with those of the Ministry of Public Works.

Appendix A-1 in the end of the Report summarizes information on the site survey and items discussed.

II. BACKGROUND

II. BACKGROUND

2.1 Brief Description of Natural Conditions

2.1.1 Topography and Geology

1) Topography

The Yemen Arab Republic is located at the southwest fringe of the Arabian Peninsula and extends from longitude 42°30' to 46°10' east and latitude 13°00' to 17°30' north. Its continental area is bounded by Saudi Arabia on the north, South Yemen on the south, Red Sea on the west, and Rub Al Khali desert on the east. The country consists of a plain area in the coastal region of the Red Sea, central highlands, which ocuppies the majority of the country with an average altitude of 2,400 m above mean sea level (m.s.l.) and eastern desert region at about 1,000 m m.s.l. The country's size is about 195,000 km^2. The Yemen Arab Republic has a population of about 9.3 million (1986). Sana'a is the capital of the country located in central highlands.

Topographic feature is divided into the four north-south zone belts according to altitudes and topographical characteristics as shown in Fig. 1: Tihama low zone, Central Highlands zone, Mountains zone, and Rub Al Khali desert zone from the west to the east.

The Central Highlands, where the peaks are over 3,000 meters m.s.l., rise from Tihama low zone with steep cliffs of about 2,000 meters in height. On the other hand, the eastern sector of the Central Highlands is gradually transformed to plateau desert. Therefore, general topographic feature shows asymmetrical character.

The Country's rivers are clearly distinguished into two types; eastward and westward streams flowing from the Central highlands. Westward streams, which flow to the Red Sea, are short and fast flowing, and eastward streams are large and slow flowing. The river system is called "Wadi", which has only seasonal intermittent water flow except for some westernward streams.

(Swiss Technicorl Co-operation 1978)

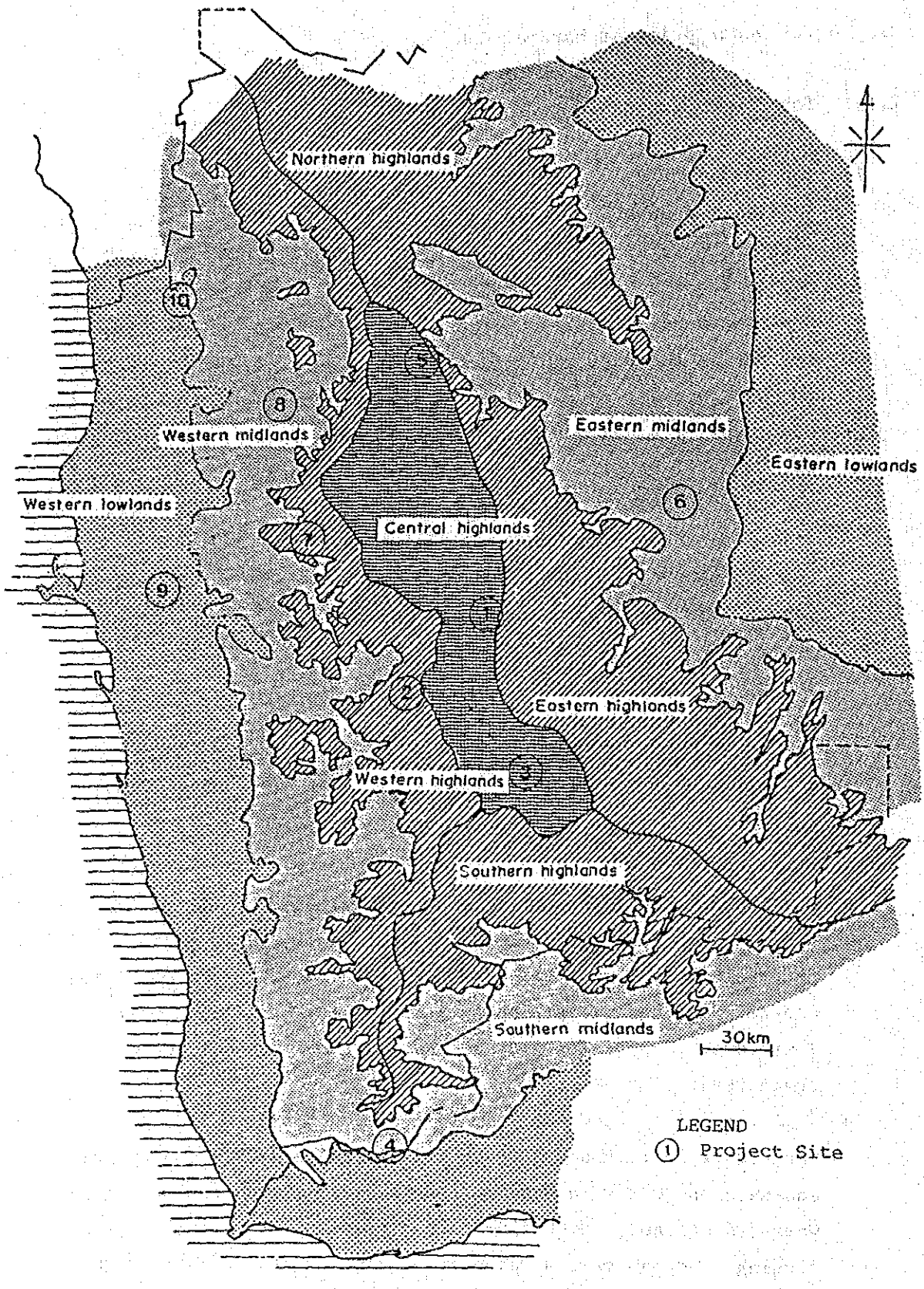


Fig. 1 Topographic Division of The Yemen Arab Republic.

2) Geology

The land of The Yemen Arab Republic principally consists (in upward sequence) of Precambrian bed, which is composed of gneiss, schist, and granitoids, as basement complex, Paleozoic bed (Ordovician), Mesozoic bed (Jurassic and Cretaceous). The most characteristic geological event is large intrusions of volcanic rocks with tectonic movement after Tertiary. These volcanic rocks are named Trapp series or Yemen volcanics and show wide distribution in central, western and southern zones. Eolian sand originated from these volcanic rocks is distributed in some sectors around Sana'a, Dhamar and Taizz.

Geologic Column in the Yemen Arab Republic

Geological Age	Log	Formation & Lithology	Thickness	Area
Quaternary		Alluvial deposits	20 - 300^{m}	Tihama Coastal Plain
		Basalt Lava	100 - 500^{m}	Central Highland
Tertiary		Yemen Volcanics	2000^{m} +	Central Highland, Western Highland, Southern and South-eastern Highland
		Basalt, Andesite, Trachyte, Diorite, Tuff		
Upper Cretaceous				
Upper Cretaceous		Tawilah Group & Medj-Zir Series	300^{m}	Sana'a Region
		Sandstone, Conglomerate	350^{m}	Western Highland
Upper Jurassic		Amran Series Limestone shale, Marl	600^{m} +	Central, Northern and Eastern Highland
Lower Jurassic		Kohlan Series Shale, Sandstone	300^{m}	Northern Highland
Ordovician		Wajid Sandstone	250^{m}	Sa'adah and Ma'reb Area
Pre-Cambrian		Basement Complex Granite, Gabbro Gneiss, schists	Unknown	Northern, Southern and Eastern Yemen.

Fig. 2 Schematic Geological Column of The Yemen Arab Republic

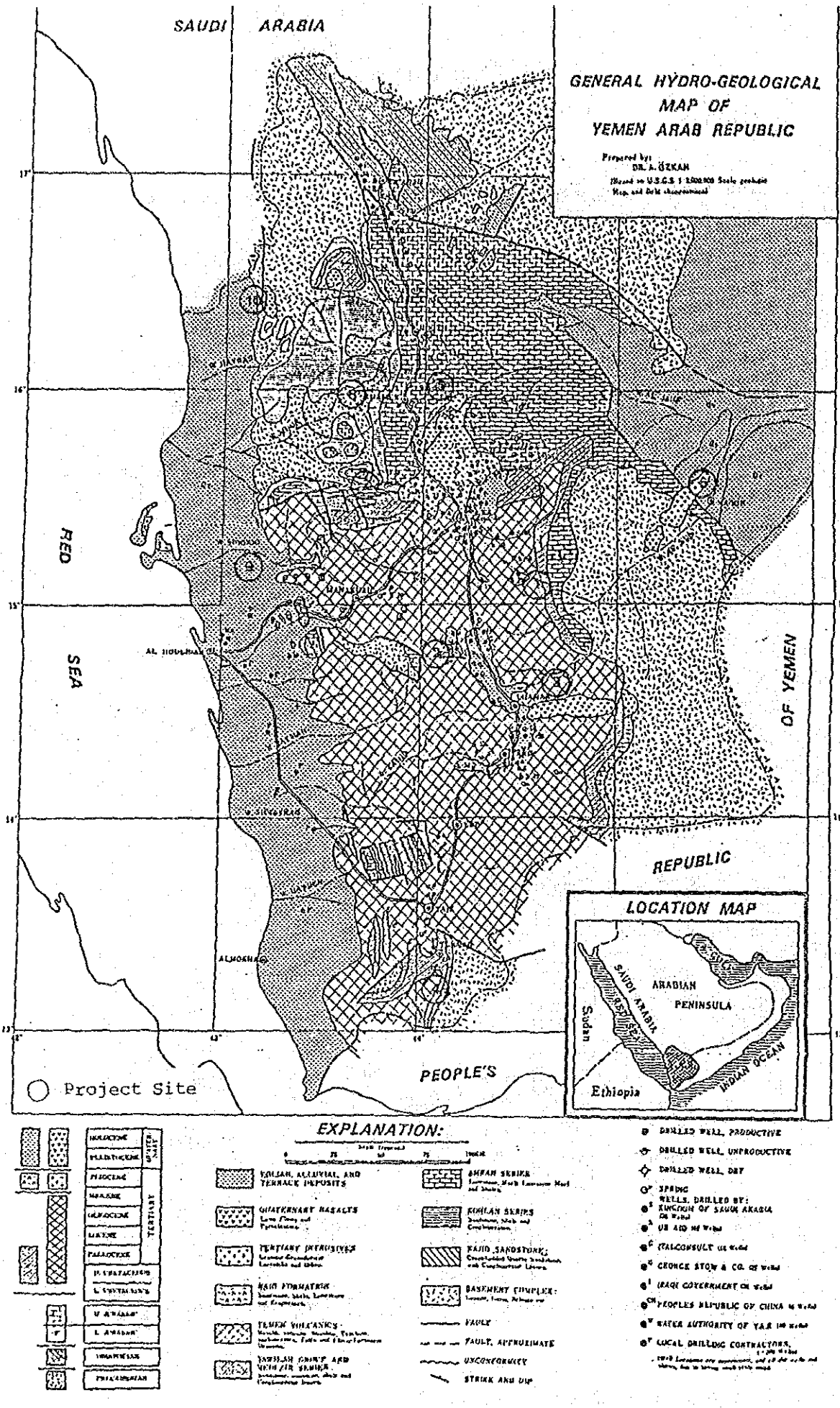


Fig. 3 General Hydrogeological Map.

Tectonic movement mentioned above ocurred in almost all the Arabian Penisula forming mountain ranges and block movement. This movement brought about faulting with over 1000 m of throw and folding, accordingly formed the mojority of actual inter-mountain collapse basins and fault cliffs.

Schematic geological column and hydrogeological map of the Yemen Arab Republic are shown in Fig.'s 2 and 3.

2.1.2 Hydrology and Meteorology

The country's climate can be distinguished: highland climate and desert climate. Rainfall is not so much, but its volume is rather heavy in comparison with other countries of the Arabian Penimsula. It is assumed that heavy rainfall and fog occur where the humid wind from the Red Sea hits the western slopes of the Central Mountains. Moreover, heavy rainfall occurs in the Southern Highlands where the seasonal winds from the Indian Sea hits the wall of the Central Mountains. There is a southern zone of 1,000 mm/year precipitation encircling Ibb City. On the eastern slopes of the Central Mountain zone, there is a little rainfall in the Eastern Highland appearing even desert climate in the central lowland due to foehn (Fig. 4).

Climate at Tihama low zone along the Red Sea shows high temperature and humidity. Rarely does it mark the monthly mean maximum temperature less than 30°C in Hudaydah throughout the year, rising as high as about 40°C between June and August. Monthly mean minimum temperature varies between 19°C and 35°C, even 19°C between November and February. Monthly relative humidity is about 72% throughout the year with the wide variation between 48% and 100%. The monthly relative humidity has a tendency to be high during summer season (from June to August). There has been little rainfall for many years.

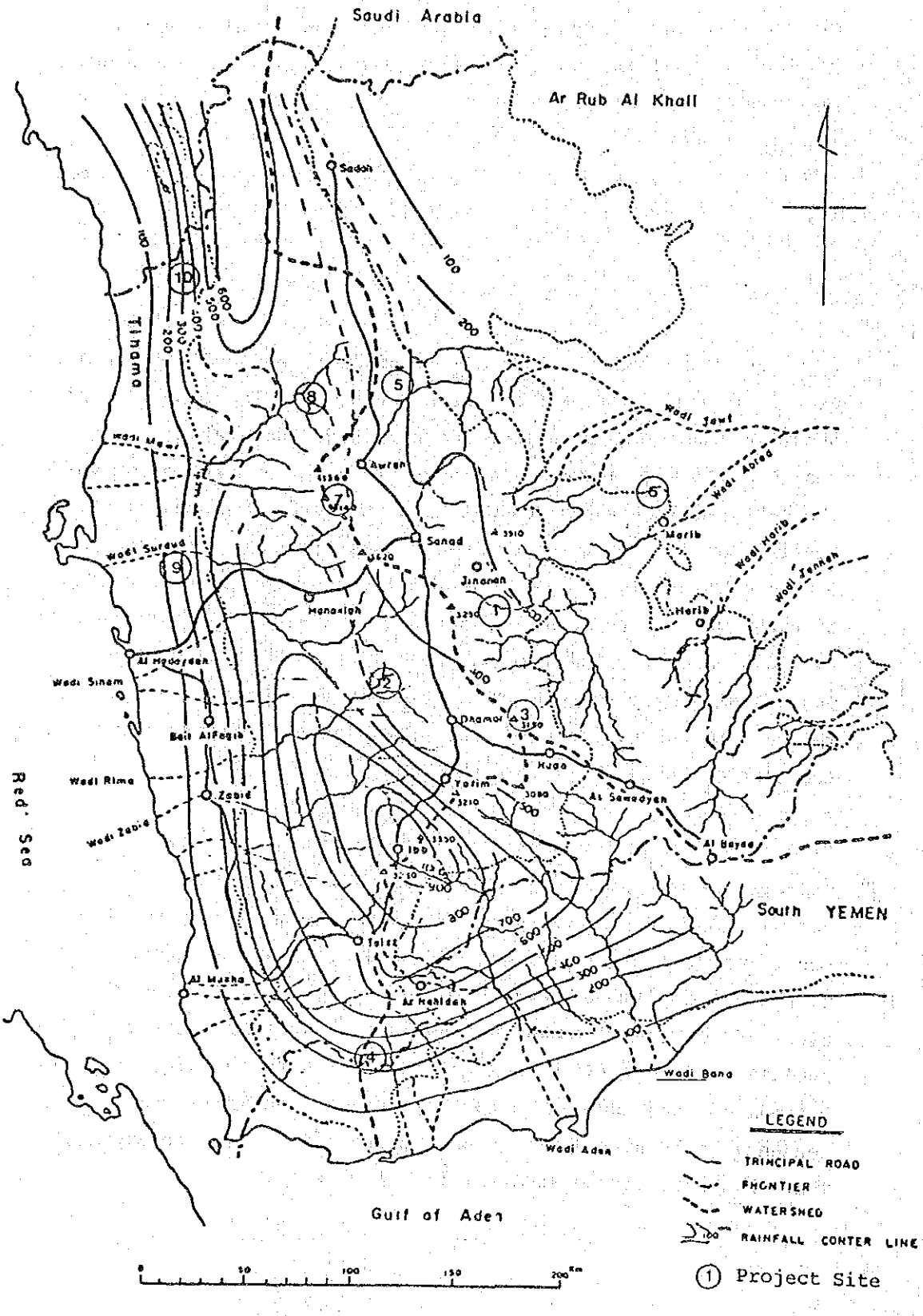


Fig. 4 Isohyet Map.

Climate of the Central Mountains is generally mild even at low latitudes due to its altitude over 2,000m m.s.l. In Sana'a, the monthly mean temperature shows between 13°C and 23°C throughout the year, with the maximum from 29°C to 33°C and from -1°C to 7°C during summer season from June to August and winter season from December to January, respectively. Daily difference of temperature is from 15°C to 20°C throughout the year, which shows clearly a charater of highland climate. Monthly mean relative humidity varies between 30% and 77% marking the maximum value in March and April. Many sand pillars happen in basin due to an ascending current in hot day. Annual mean rainfall is about 300mm but is subject to large temperature variations depending on the year. Drought occurs in case of little rainfall during rainy season (from April to September). Winter rainfall is rarely transformed into hailstorm.

Desert zone shows high temperature and low humidity, marking monthly mean temperature from 18°C to 36°C and monthly mean relative humidity from 12% to 52%. Especially, it is so hot between April and September with monthly maximum temperature of 32°C - 39°C and little rainfall.

Although climate of Highland zone has the same character of both Central Mountain and Desert zones, it generally classified as highland climate.

Table 1 Annual Precipitation

Unit : mm

Station	1974	1975	1976	1977	1978	1981	1982	1983
SANÀA	215.4	350.6	154.2	335.6	167.1	166.8	263.8	50.1
TAIZZ	—	—	357.6	—	—	269.8	320.3	235.9
HUDAYDAH	—	—	16.3	78.5	78.0	0.0	0.0	41.2
MAREB	—	—	—	—	—	—	0.0	2.0

Consequently, hydrogeomorphological division is carried out in accordance with altitude, climate, temperature, precipitation, vegetation, irrigation method, and agricultural products as shown in Table 2.

Table 2 Hydrogeomorphological Division in YAR

The major climatic zones of Yemen with the mean monthly temperature and the average annual rainfall

A TROPICAL TIHĀMAH ZONE	ALTITUDE	CLIMATE CHARACTER.	MEAN MONTHLY TEMP.°C	AVERAGE ANNUAL RAINFALL
Coastal Tihāmah plain with high atmospheric humidity and irregular low precipitation	0-50m	tropical	25-35	0-80 mm
Central Tihāmah plain with low atmospheric humidity and irregular, low precipitation	50-300m	tropical	24-32	0-150 mm
Eastern mountain near Tihāmah plain with low to medium precipitation	300-500m	tropical	22-32	0-300 mm
B TROPICAL TO SUBTROPICAL ZONE OF THE LOWER WESTERN ESCARPMENT ZONE				
Lower mountain slopes, frost-free zone with low precipitation	500-1,400m	tropical	22-26	200-400 mm
Upper mountain slopes with medium rainfall	1,400-2,100m	sub-tropical	16-24	300-600 mm
C TEMPERATE HIGHLAND ZONE				
Western, mountainous Highlands, with medium to abundant rainfall	2,100-3,700m	temperate	10-18	600-1,800 mm
Central Highlands, with medium rainfall	1,800-2,400m	temperate	12-18	200-1,000 mm
D SUBTROPICAL ZONE OF THE EASTERN ESCARPMENT				
Eastern mountain slopes with low, periodical rainfall	1,800-1,200m	sub-tropical	16-24	100-400 mm
Eastern desert zones	1,200-800m	sub-tropical	22-28	0-200 mm

2.1.3 Land Use and Vegetation

Alluvial plain is not distributed in the Central Mountains and Highland zones except narrow belts along wadis. Consequently, agriculture is carried out in terraced fields on slopes and narrow wadi lowlands. Village and population distributions are well correspond to the distribution of farm field.

Major crops are sorghum, millet, corn, wheat, potato graps, coffee, cotton, tobacco, and curt.

In relation with natural vegetation, thorny bushes which are typical in sub-tropical and desert climates are widely distributed. Furthermore, cactus are grown in colonies from one place to another and alpine plants are distributed in the highlands. Evergreen trees are found around wadis, where water is available.

2.2 Social Background

2.2.1 General

The majority of people is Yemeni, and minority is descendants of immigrants from Somalia and Ethiopia, and settled along the Red Sea. Only Arabic is spoken, and they are Muslims in Islam. The Government is of a republican system under President, and YAR is a member of the Non-Allied Nations. President, Ali Abdrah Saleh is the third President, and is in the second term of President's tenure of office after the first tenure of 5 years.

2.2.2 Administration System

The local administration system of YAR is as shown in Fig. 5.

In the local administration system, YAR is divided into 11 Mohafathats (governorates): Sana'a, Taizz, Ibb, Al Hudaydah, Sa'dah, Majjah, Al Mahweet, Marib, Dhamar, Al Baydah, and Al Jawf. Each state is subdivided into Nahiyas (county).

The Central Government is composed of Ministries and Department under the direction of a Prime Minister. The Central Planning Organization (CPO) plays an important role of accepting assistance from foreign countries. The CPO exercises jurisdiction over development and planning, and coordinates development plans proposed by ministries and other departments.

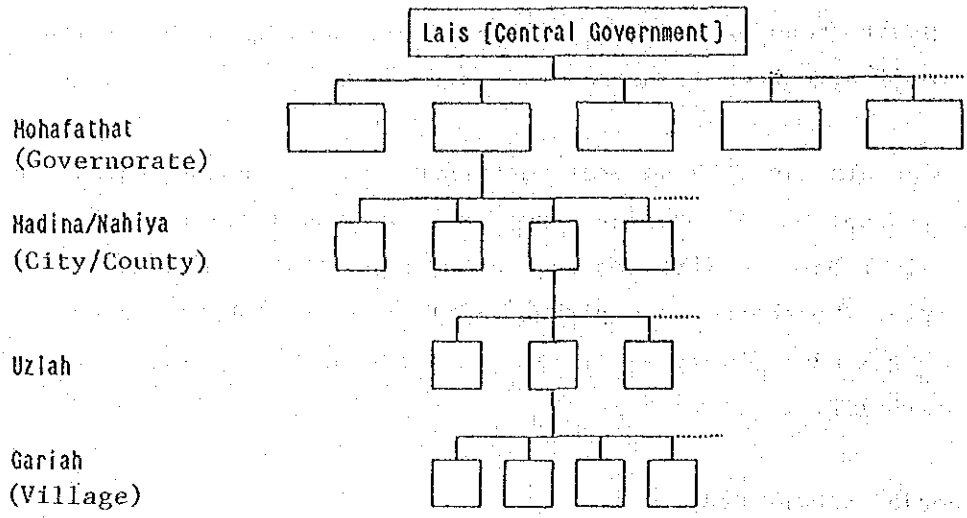


Fig. 5 Administration System of YAR

The Mahafathat (Governorate), Madina (City), and Nahiya (County) are governed by governors appointed by the President. The local organization under Madina/Nahiya is under the control of the tribe leader called Shaykh.

2.2.3 Socioeconomy

Infrastructure has recently made marked progress owing to stable administration. Traffic has improved to the extent that most major cities are connected with each other through paved roads. Electricity, water supply, and communications have been almost completed in major cities: Sana'a City, the capital of YAR (population: about 400,000), Hudaydah city, a trade port along the Red Sea (population: about 160,000), and Taizz City, a southern old city (population: about 180,000). However, such utilities are still under construction in local districts.

Economy in YAR depends mostly on agriculture, other primary industries, and wages earned in and remitted from foreign countries, but the scale of economy is limited. The GDP per capital in YAR was US $500 in 1984. More than 80% of the population depend upon agriculture, which depends on rainfed cultivation.