villages accounting for 70% of the entire area.) However, after the completion and delivery of the Project by the Japanese side, the RWSD further responded to the inhabitants' request to extend additional lines to remote villages which had not been included in the initial planning.

Compared to the preceding projects, most of the sites involved in the basic design study this time present planning areas of a larger scale, where many villages are dispersed. The facilities for transmission and distribution, therefore, must be designed to have the most practical effects through a close coordination with the RWSD.

2.7 BACKGROUND AND CONTENTS OF THE REQUEST

The great majority of people in the Republic of Yemen dwell in rugged mountainsides where water resources are scarce and the installation of water supply facilities entails a great deal of difficulty. Since the 1970s after the end of the revolution, the Yemen government has been struggling to promote the development of the agricultural sector as the first-priority policy in its national development planning, under which the improvement of welfare for the rural population accounting for more than 80% of the entire nation have been among the government's key strategies. Anticipated effects remains yet to be achieved, hampered by harsh natural and social conditions of the country, and the national economy has long been kept stagnant. Under such circumstances, the development of rural water supplies has been left lagging behind with its national coverage currently hovering around 50%, to the dismay of agencies concerned with the promotion of the WHO's program of International Drinking Water Supply and Sanitation Decade.

In view of such a situation, Japan has kept contributing to the rural water sector, and facilities constructed with its aid have been in service in various parts of the county. The number of beneficiaries under the loan and grant aid projects counts 212,000 in 62 sites, and the performance of the preceding projects have been appreciated by the Yemen government as well as those who directly received benefits.

The rural development is growing more important after the unification, with increasing demand from inhabitants for the improvement of water supply facilities. To meet such needs, the Yemen government has sent a request for a new planning for the construction of water supply systems in 14 sites suffering from shortages of water. The summary of the request is described as follows:

1) To make the survey of 31 sites located in 8 governorates of the country, and to implement the construction of planned facilities in 14 sites with higher priorities.

2) To procure material and equipment necessary for the said construction work.

3) To provide technical service for supervising the implementation of the project.

The 14 sites with higher priorities among 31 sites in the request are listed in the following table.

Table 2.8 Sites with Higher Priorities under the Request

Site No.	Site Name	Governorate	Population	Water Source (D=Well Depth)
1.	Iyal Qasim	Sana'a	4,000	No. source
2.	Mahalat Najr	Sana'a	2,000	Private well(D=260m)
3.	Khamis Bani Hajaj	Sana'a	5,000	Private well(D=270m)
4.	Bani Afif	Taizz	2,000	Public well (D=270m)
5.	Al Husha	Taizz	20,000	Public well, 2 Nos.
6.	Al Usfyn	Taizz	10,000	No description
7.	Al Jabub	Ibb	3,500	Public well (D=185m)
8.	Najid Al Majmaa	Marib	1,000	Public well (D= 10m)
9.	Al Ghudu	Marib	1,500	No source
10.	Ash Sharaqi	Hajjah	2,500	No source
11.	Aflah Al Yaman	Hajjah	3,000	No source
12.	Bait Al Sultan	Al Mahweet	3,000	Public well (D=102m)
13.	Al Thaiah	Sa'dah	800	Public well (D= 85m)
14.	Al Mallaheeth	Sa'dah	2,500	Public well (D= 75m)

Prior to the survey, the discussions were held between the RWSD/MEW and the survey team to confirm the contents of the request, and the contents of the discussions agreed by both parties are summarized as follows:

1) The survey shall be confined to 14 sites with higher priorities among the requested sites.

2) The sites which have been judged to have difficulty in the development of water sources through the survey shall not be included in the planning. The replacement of such sites for another ones shall not be allowed.

3) The scope of facilities planned for the respective sites shall be discussed between both parties after the survey.

4) The Najid Al Majmaa site (Site No. 8) cannot be located exactly, seemingly due to an incorrect site name. For this site, details shall be negotiated during the survey with the governor of Marib where this site is to be included.

The RWSD was found to have some additional data about the sites which had been obtained through the preliminary survey of their part or the whole by its engineering staff, expatriate experts in its office and staff of other bilateral projects. However, the details were considered to be confirmed through the survey and analysis this time. The comparison of data in the request with that obtained through the survey by the study team shows pronounced difference in the populations and the water source conditions. This probably comes from the difference in the areas of the respective sites covered during the previous survey and the one this time, due to complex natural and social conditions in the country's rural areas.

Concerning the water source conditions confirmed during the discussions, the survey has revealed that three sites out of fourteen are not likely to be able to secure feasible water sources due to their adverse hydrogeological conditions. Consequently it has been agreed with the representatives of the Yemen government after the survey that these three sites be canceled from the study. The outline of the three sites are summarized as follows:

a. Site No. 8: Majzal (Marib Governorate)

This site was chosen as an alternative for the Najid Al Majmaa site through the discussion with the governor of Marib. However, groundwater all over this area contains an intensively high concentration of chloride. Since this site has no other sources, planning for this site was given up.

b. Site No. 10: Ash Sharaqi (Hajjah Governorate)

The whole area of this site is scarce in water resources, and has been judged to be unable to secure stable water sources.

c. Site No. 13: Al Thaiah (Sa'dah Governorate)

Groundwater in this site is under the influence of an anomalous geothermal zone running through this area. Hot water over 50°C is not suitable for a source of the rural water facilities.

The details on these three canceled sites are referred to in Appendix III-c.

CHAPTER III

FEATURES OF THE PROJECT SITES

CHAPTER III. FEATURES OF THE PROJECT SITES

3.1 OUTLINE OF THE PROJECT SITES

3.1.1 Project Sites

The field survey for the basic design study for the Project was carried out in the fourteen (14) sites dispersed in the seven (7) govenorates of the country, based upon the request by the Yemen government, concentrating on such technical details as the environmental circumstances of the sites, hydrogeological conditions and water supply planning, etc. Prior to the commencement of the field survey, the discussions had been held on the contents of the request between the representatives of the Yemen government and the survey team, and it had been confirmed between them to exclude the sites where appropriate water sources were not likely to be secured, as one of basic policies on the Japanese side. After the survey following this confirmation, it has been agreed between both parties that the basic design study should be made for the eleven (11) sites out of 14, which are judged to be able to develop stable water sources. This chapter, therefore, deals with the general features of these 11 sites, focusing on their environments and hydrogeological conditions, based upon the results of the survey. The names of the 11 sites thus determined are listed in Table 3.1 along with their present populations. In addition, the names of the three sites canceled are shown in the attached table for reference.

3.1.2 Locations of the Project Sites

The eleven (11) Project sites are scattered in an extensive area covering 7 governorates among 11 of the former North Yemen, including the one bordering with Saudi Arabia in the north and another with the former South Yemen in the south. The main roads linking these sites to the capital of Sana'a have already been paved by the Highway Authority under the charge of the Ministry of Construction (the Ministry of Public Works before the unity, which completed the construction of paved roads reaching 2.396 km in the total length by the end of 1988). On the other hand, feeder roads connecting the

villages to main roads have constantly been under maintained by the responsible LCCDs). Transportation to the sites, therefore, raises no problems, although distances may vary. The distances from Sana'a to the respective sites with details on the types of roads are listed in Appendix for reference.

Table 3.1 List of the Project Sites

Site No.	Site Name	Governorate	Population
1.	Iyal Qasim	Sana'a	1,500
2.	Mahalat Najr	Sana'a	2,000
3.	Khamis Bani Hajaj	Sana'a	5,400
4.	Bani Afif	Taizz	7,300
5.	Al Husha	Taizz	13,000
6.	Al Usfyn	Taizz	28,500
7.	Al Jabub	Ibb	2,000
9.	Al Ghudu	Marib	1,770
11.	Aflah Al Yaman	Hajjah	4,500
12.	Bait Al Sultan	Al Mahweet	3,600
14.	Al Mallaheeth	Sa'dah	3,180
	Total:		72,750

List of the Canceled Sites

8.	Majzal	Marib	Unknown
10.	Ash Sharaqi	Hajjah	5,000
13.	AL Thaiah	Sa'dah	1,445

3.1.3 General Characteristics

(1) Planned Supply Area

One of the distinguished features of the Project sites is that each of the Project sites except for one comprises many villages dispersed in mountainous and hilly area, forming an extensive supply area for the planning. With the country's administrative divisions ranging from the smallest units of villages (*Qariah*) to

the sub-districts (*Uzlah*), to the districts (*Nahiya*), to the sub-governorates (*Qada*) to the largest ones of governorates (*Luwa*) in the order of an increased size of the area, **Al Husha** and **Aflah Al Yaman** among the Project sites fall under the division of the districts, and other six sites including **Al Usfyn**, under that of the sub-districts. The dimensions of these sites, therefore, are huge, involving villages constituting these large units extending in the mountainous areas. Such sites with vast supply areas were included in Japan's previous grant aid projects as well, but were usually combined with the ones of small size. The past grant aid projects from the phases IV to IV covered two such sites, while the 8 among 11 sites under this Project are composed of more than 9 villages.

The trend for such expansion of the supply area is suspected to derive from the LCCDs' recent activity after they have officially been established as the representatives of rural inhabitants by the elections. Since the promotion of the rural water supplies is one of their main duties, their initial planning naturally tends to involve as many villages as possible, even remote villages of smaller size. There are 3 sites in this Project for which the new water sources are to be installed at the locations beyond the limits of planned supply areas, which have been coordinated and settled through the LCCDs during the field survey this time. Such arrangement between villages had extremely been difficult before, and is considered to show another evidence of increasing influence of this organization among rural communities for the coordination and promotion of their rural life.

(2) Social Conditions

The inhabitants in the Project sites are largely dependent on agriculture for their living. Main cereals such as sorghum, millet, wheat, maize, etc. are popular in all the sites. Furthermore, in places the cultivation of *qat* is thriving, reflecting unceasing demand from the customs prevailing among the grownups in this country as well as several African countries across the Red Sea.

The Project sites exhibit typical rural scenes of this country, where inhabitants' average monthly incomes range from YR1,600 to

YR3,000. In many sites, dependence on remittances from migrant workers to the Gulf states are found to account for a large share of their incomes. As a result of the Gulf crisis/war, however, each site are receiving an increasing number of such workers returning from abroad.

(3) Health and Sanitation

The medical facilities in the Project sites are mainly the primary health centers installed in the centers of the districts by the Ministry of Health with support from WHO. Those having no facilities are relatively close to the cities or the district centers and can easily attend hospitals and/dispensaries there. Some of these facilities were contacted by the study team for the interview. The most striking fact obtained through the interviews is that bilharzia has grown one of the most threatening epidemics among the water-related diseases both in the north and the south. The statistics of infectious diseases reported by the Ministry of Health also indicates the spread of this disease among the public, as shown in Appendix III-4. While the Japanese species mainly live in intestines, the one in this part of the world intrudes into the veins of the bladder, but frequently attacks digestive organs as well. The widespread use of stagnant water in hand-dug wells during the dry season as well as contaminated water in cisterns or surface water has resulted in the chronic incidence of this disease, involving the sites under this Project. Under such circumstances, stable and safe water supplies are urgently needed.

(4) Water Supply Conditions

The current situation of water supplies in the respective sites is described separately in Clause 3.4. The general features are summarized as follows:

1) Every site has so far experienced the drilling of deep well(s) whether successfully or unsuccessfully, within its limits, to acquire safe and stable water sources. These operations were carried out by either the RWSD, or the LCCD or its inhabitants for themselves. This fact indicates that drilling has now grown a common undertaking in rural communities, as described in Clause 2.4.

2) However, where the hydrogeological conditions are unfavorable for the development, these efforts have turned out unsuccessful and the drilled wells have been abandoned.

3) On the other hand, the successful wells are located in the low-lying lands of the wadis far from the dwelling areas of inhabitants on the mountains, and all of them lack facilities to send water up to the mountainous area. Some communities, therefore, serve water to the inhabitants at the pump station, charging them fees compensating the operation and maintenance costs. Most of them, however, have been left closed and unused.

4) Under such circumstances, the inhabitants in the 11 Project sites have been compelled to buy water transported by tankers from the distant sources up to the mountains by tankers.

5) In a part of the sites, hand-dug wells are important water sources in the surroundings of dwelling areas to supplement their demand. Most of them, however, tend to dry up during the dry season, and remain out of service during 3 to 5 months of the year.

Water prices at the pump stations in wadis are usually YR10 to YR20/m^3, but soar up more than ten times to a range of YR200 to 250 in the dwelling areas on the mountains, causing a heavy economic burden on the inhabitants there. Since their monthly income is at most YR3,000, a family can only afford to buy 1 cubic meter of water every 10 days or two weeks to cover drinking and cooking water for its 7 to 10 members. An average per capita per day consumption is, therefore, estimated to be at a rate of 10 to 15 liters. The water use practice in the surveyed sites including 3 ones canceled is more or less similar to one another, all depending mainly upon water for sales. This situation is judged to urge the immediate improvement of water facilities in the Project sites.

The results of the survey on the environments of the respective sites are shown in the tables attached to the descriptions in Clause 3.4.

3.2 POPULATION OF THE PROJECT AREA

In the wake of the Gulf crisis, the Yemen Government announced on November 23, 1990 that 817,000 Yemeni migrants have been deported by the government of Saudi Arabia. Most of them thus repatriated now pack in the country's major cities such as Sana'a, part of them returning to the countryside. The Project sites involve two communities near the border with Saudi Arabia one of them, the canceled Al Thaiah (No. 13), which have obviously been affected by such a situation. Other sites are also receiving the repatriated. The following table shows the results of the interviews with the LCCDs or other representatives in the respective sites concerning the current situation of the expatriates:

Table 3.2 Current Situation of Returnees in the Project Sites

Site No.	Site Name	Governorate	Present Population	No. of Repatriated	No. of those living abroad
1.	Iyal Qasim	Sana'a	1,500	-	100
2.	Mahalat Najr	Sana'a	2,000	100	5
3.	Khamis Bani Hajaj	Sana'a	5,400	-	100
4.	Bani Afif	Taizz	7,300	700	300
5.	Al Husha	Taizz	15,000	-	100
6.	Al Usfyn	Taizz	28,500	2,000	10,000
7.	Al Jabub	Ibb	2,000	700	50
9.	Al Ghudu	Marib	1,770	20	500
11.	Aflah Al Yaman	Hajjah	4,500	1,000	200
12	Bait Al Sultan	Al Mahweet	3,600	-	-
13.	(Al Thaiah) Canceled site	Sa'dah	1,445	350	100
14.	Al Mallaheeth	Sa'dah	3,180	1,200	500

The further increase of the returnees in the villages would critically affect the population projection. However, since such a trend is judged to have settled with the termination of the war in February 1991, it is considered relevant to take the present populations as the basic figures for the forecast for this Project.

Information about the growth rate was not available in the sites. The population censuses in 1981 and 1986, therefore, are employed, on the basis of an average annual growth rate of the domestic population, which was 2.55% between that period. This rate roughly corresponds with 2.5%, obtained through the survey by the United Nations during the years of 1982 and 1983 and employed in the design criteria of the RWSD. The same rate was applied to the RWSD's report in 1990 to the meeting of the WHO's Eastern Mediterranean Region Advisory Committee for the International Drinking Water Supply and Sanitation Decade, in which the North's rural population in 1990 is estimated at 8 million with a growth rate 2.5% from 7.8 million in 1989.

3.3 NATURAL ENVIRONMENT

The 11 Project sites are dispersed across the whole area of the former North Yemen's territory, with their environments reflecting nearly every aspect of the country's diverse natural conditions. This chapter, therefore, deals with the grouping of general characteristics of the country's nature in relation with the features of the respective sites.

3.3.1 Topography and Geology

(1) Topography

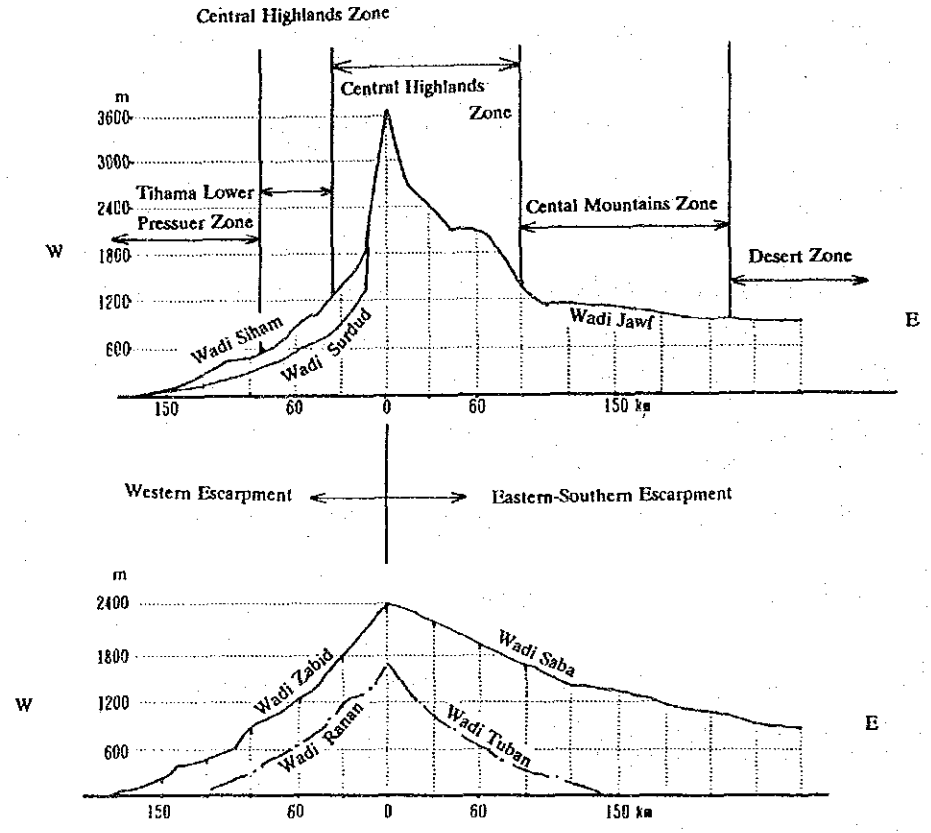
The Republic of Yemen is composed of the most elevated lands of the Arabian peninsula, and is largely divided into four (4) topographical regions aligning north to south, based upon such elements as the elevation and the land form. The groups thus divided are listed from the western side (the Red Sea) to the eastern side (the Rub Ar Khali Desert) as follows:

1) Tihama Lower Pressure Zone
2) Central Mountains Zone
3) Central Highlands Zone
4) Desert Zone

The Tihama Lower Pressure Zone is divided from the Central Mountains Zone with a steep escarpment as high as 2,000 m, while the eastern flanks of the Central Mountains Zone gently slope down

into the plateau area and then merge into the Desert Zone. The country's topographic profile, therefore, represents an extreme asymmetry, as shown in Fig. 3.1 where the representative profiles along the main wadis are illustrated.

Fig. 3-1 Profiles along Main Wadis



Most of the Project sites are located in the Central Mountains Zone and in the Central Highlands Zone. However, **Aflah Al Yaman** (No. 11) and **Al Mallaheeth** (No. 14) are at the base of the western escarpment of the Central Mountains Zones, the former at 440 m and the latter at 500 m above sea level, where the eastern edge of the Tihama Zone merges, and their climates are mainly influenced by the Tihama tropical weather with hot temperature and high humidity. Meanwhile, **Al Ghudu** (No. 9) is in the hilly area on the western edge of the Desert Zone. The locations of the respective sites related to the topographical divisions are indicated in Fig. 3.3.

The rivers are largely divided into ones draining eastward and the others draining westward, with the former having a long, gently-

sloped channel and the latter, a contrastingly steep short channel, eventually discharging into the Red Sea. They are called the *wadis* (dry valleys), usually having no surface flows through the major part of the year, except some of them draining westward.

(2) Geology

The stratigraphical profile of the country's geology is represented in Table 3.3. In the Project sites of the country's northernmost and southernmost part, ancient rocks such as granite and schist of the Precambrian age are widespread, while the groundwater development in other sites will have to deal with various geological features including the youngest Quaternary volcanic rocks. The nationwide geological map with the locations of the respective sites is shown in Fig. 3.2. Its general features related to groundwater development is presented below, with the details in the respective sites described later in Clause 3.4.

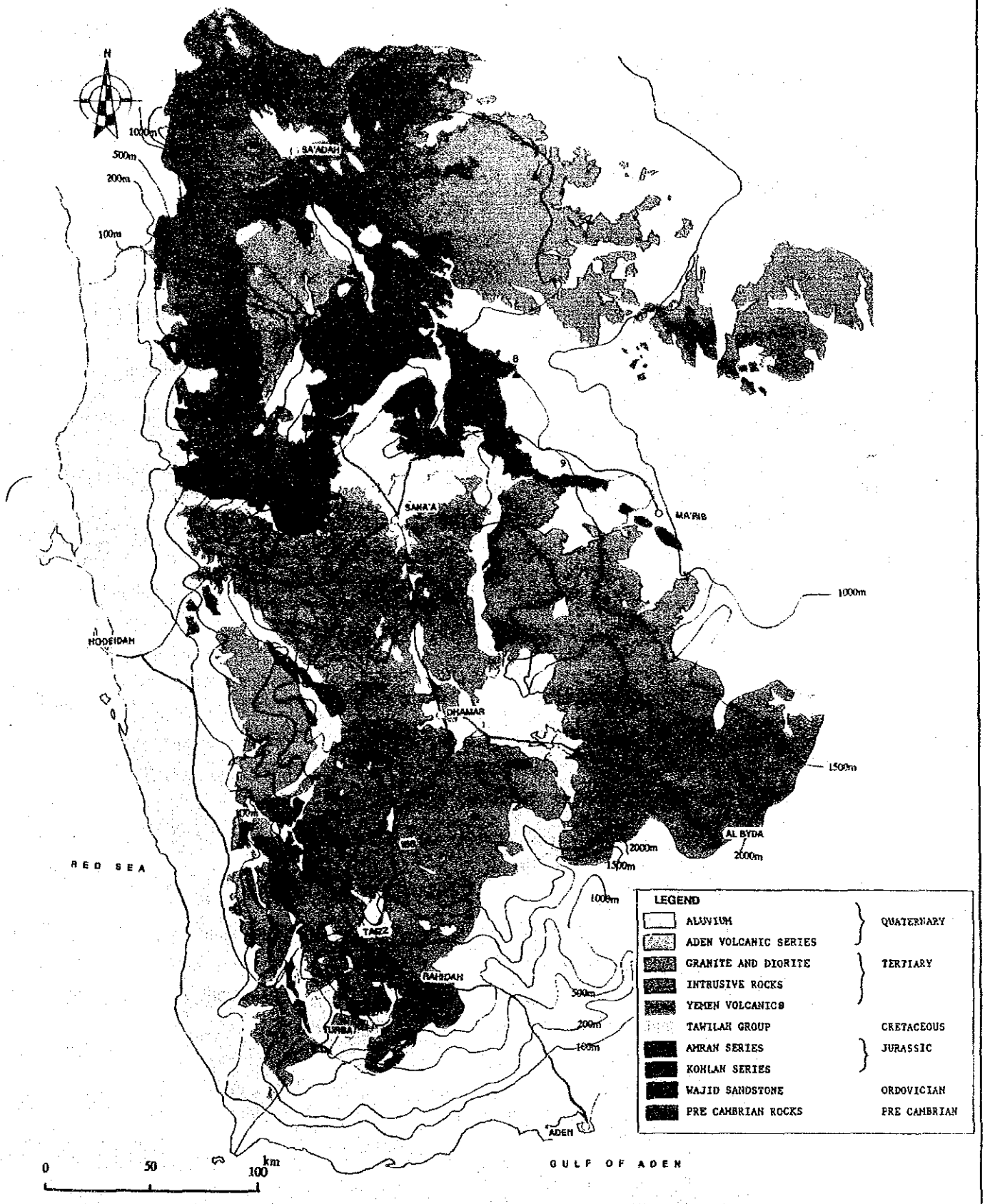
The country's basement complex consists of gneiss, granite, schist, etc., of the Precambrian age, overlain by various younger rocks. One of the youngest rocks, basalt produced in the Quaternary volcanic activities, forms an extensive lave plateau along the northern edge of the Sana'a basin in the central part of the country where the capital of Sana'a is situated. The similar patterns of lava plateaus have been formed farther down the south around Dhamar, Taizz and Aden. These Quaternary lava regions shows a pronounced characteristic of volcanoes created through fissure eruptions with most of their cinder cones keeping their primary forms untouched. Another Quaternary group is sedimentary formations including eolian sand broadly spreading in the Tihama Lower Pressure Zone and the Desert Zone. These deposits have developed alluvial fans more than 100 m thick along the fringe of the Central Mountains Zone, while belts of alluvium along wadis are usually thin, with their thicknesses mostly ranging from 5 to 10 m.

The *Yemen Volcanics* broadly distributed in the mountainous area south of Sana'a have a thickness exceeding 2,000 m. Since this group of rocks was discharged by volcanic activities through numerous fissures, it has been quite difficult to sort them in

Table 3.3 Geological Features of Republic of Yemen

AGE		Log	Lithology	Thickness	Description
Quaternary	Holocene		Quaternary deposits	5-100m	Eolian sand, Sand-Gravel
	Pleistocene		Quaternary volcanics	100-500m	Basalt flows and dyke with scoria
Tertiary			Yemen Volcanics	+2000m	Basalt, Rhyolite, Trachyte, Andesite (lave, dyke, sheet, pyroclastic rocks and tuff)
	Lower Miocene Eocene		Tawilah Group	300m	Coarse crossbedded sandstone with lenses of conglomerate, interbedded with shale
Cretaceous					
Jurassic	Upper		Amran Seris	+600m	Limestone, Marl and Shale with sandstone
	Lower		Kohlan Series	300m	Green shale with sandstone and conglomerate
Ordovician			Wajid Sandstone	250m	Crossbeded, locally conglomeratic sandstone
Precambrian			Precambrian system	unknown	Granite, Gneiss, Schist, Quartzite, Shale, Meta-andesite with pegmatite, Quartz dyke

FIG.3.2 GEOLOGICAL MAP OF REPUBLIC OF YEMEN



No.	Project Site	No.	Project Site	No.	Project Site
1.	Iyal Qasim	6.	Al-Usfyn	11.	Aflah Al-Yaman
2.	Mahalat Najr	7.	Al-Jabub	12.	Bait Al-Sultan
3.	Khamis Bani Hajaj	8.	Majzar	13.	Al-Thaish
4.	Bani Afif	9.	Al-Ghudu	14.	Al-Mallsheeth
5.	Al-Husha	10.	Ash Sharaqi		

details, but the study is now underway to divide them into six categories. It is an undeniable fact that the volcanism which brought forth these rocks had a close tie to a pan-Arabian tectonic movement from the end of the Mesozoic age over the Tertiary period, which created the alignment of depressed basins in the NW10° direction amidst the mountains, including those of Sana'a, Dhamar, Yarim, Ibb and Taizz from north to south. The fact that the direction of this alignment corresponds with that of the Red Sea may shed light on the study about the evolution of the country's geological structure and geomorphology as well as the hydrogeological features. In this context, another distinguished feature is demonstrated in the **Bab Al Mandab** region called the *Horn of Africa* facing the mouth of the Red Sea, where the Quaternary fissure volcanoes run in the directions of NS to NW20° in parallel with the alignment of the inland Quaternary volcanoes. The occurrence of the lineaments that produced chains of these volcanoes may be said to be one of evidences supporting the theory the ancient continent was separated into the Arabian peninsula and the African continent, forming the Red Sea in-between.

3.3.2 Hydrogeology

Groundwater occurrence in this country is largely divided into the following two types:

(1) Confined Groundwater

Most of the geological formations composing the country were produced during or before the Tertiary period, with all of them having been turned into tightly-cemented hard rocks. Accordingly groundwater occurrence in these rocks is not a *stratiform water*, as is the case with the unconsolidated formations, but mostly so-called *fissure water* flowing through the network of cracks or fissures formed in them. However, the cracks and fissures does not always pass a groundwater flow. Groundwater can move only through those which were formed in the younger geologic period, keeping pores from being plugged or clogged with clayey materials. The study of the successful deep wells in this country reveals a significant fact that most of them were drilled through the lineaments running in the directions of NS to NW20°, in parallel

with the Red Sea. This fact is considered to be a useful guide for the future development of confined groundwater in the country. It goes without saying, however, that yields may vary to a great extent with the scales of lineaments, rainfall, the catchment areas, and other elements.

Concerning the Quaternary rocks, there are spots in the low-lying lands from Tihama to Aden where the Quaternary sedimentary formations have been deposited with thicknesses over 100 m. They are loose unconsolidated formations, rich in permeability, containing stratiform water in ample quantities, although high salinity is frequently encountered. To develop this type of groundwater effectively, therefore, an elaborate survey including the extensive hydrogeological reconnaissance, the geophysical survey and the water analysis is required.

(2) Shallow (Unconfined) Groundwater

Shallow groundwater mainly occurs in belts of the Quaternary deposits consisting of sand and gravel along the wadis. Although they form unconfined aquifers rich in permeability, these deposits are usually thin, 3 to 5 m in thickness, though occasionally exceeding 10 m. Hand-dug wells installed into them, therefore, are frequently forced to remain idle during the dry season due to the sharp decline of the water level. Many of them also tap the weathered crack zone over the horizon of basement rocks underlying the Quaternary deposits. However, this type of wells frequently gets dry as well in the dry season.

In this Project confined groundwater is the main target of development for the new sources. In **Al Usfyn** (No. 6), however, the development of underflow through the Quaternary deposits in the wadi basin will be aimed, since confined groundwater available in the site has a problem in its quality.

3.3.3 Climate

The country is at 12°37" to 17°30" in North Latitude, with its climate grouped in a tropical to sub-tropical zone. However, since a large part of the land rises over 2,000 m above sea level, the climate is

generally cool and pleasant for its lower latitude, although it strikingly varies with the topographical divisions within a narrow limit of the country no more than 300 km wide from east to west. In general, the rainy season extends from May to September when the climate is mainly influenced by moist air masses which flow from the west or the southwest against the Central Highlands and cause heavy precipitation on the mountain slopes exposed to the west. In a sharp contrast, from October to February, dry air masses come on from the Central Asia to the country.

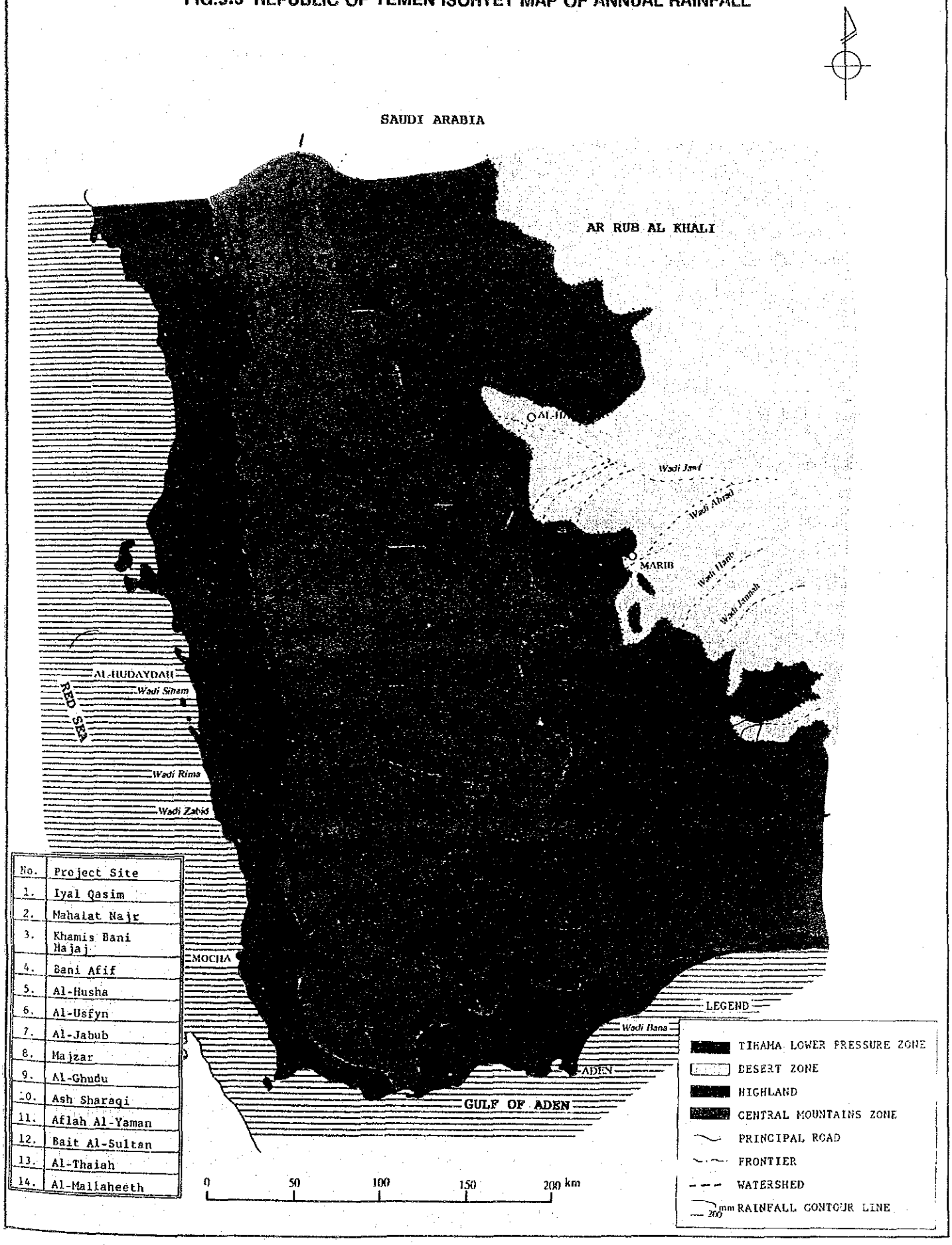
The distribution of annual precipitation rates in the country is illustrated in Fig. 3.3, in relation to the topographic divisions explained in the previous section. Groundwater occurrence in this country is largely affected by rainfall. Compared to other countries in the Arabian peninsula, Yemen receives by far a larger volume of rainfall, with its small rainy reason during April and May and the full-scale one extending from June to September. The main precipitation occurs in the area of **Ibb** which yearly receives over 1,000 mm. Another heavy rainfall belt of 600 mm a year is located around the border of the **Sa'dah** and **Hajjah** governorates, encircling part of the western slope of the Central Mountains Zone. On the other hand, the Tihama Lower Pressure Zone, the Aden plain and the Desert Zone present a striking contrast to those rainfall belts, with their mean annual rainfall less than 100 mm. In the areas with a higher rate of precipitation, groundwater can receive an appreciable rate of recharge, while those with a low rate tend to lose its storage, with a rate of evapotranspiration exceeding that of rainfall.

The characteristics of the climate in the respective topographical divisions are summarized in the following table 3.4:

Table 3.4 Climate in the Topographical Divisions

Topographical Division	Mean Annual Temperature (°C)	Mean Annual Precipitation (mm)
Tihama Lower Pressure Zone	22 - 35	0 - 200
Western Central Mountains Zone	16 - 26	200 - 600
Central Highlands Zone	10 - 18	200 - 1,200
Eastern Central Mountains Zone	16 - 24	100 - 400
Desert Zone	22 - 28	0 - 200

FIG.3.3 REPUBLIC OF YEMEN ISOHYET MAP OF ANNUAL RAINFALL



No.	Project Site
1.	Iyal Qasim
2.	Mahalat Najr
3.	Khamis Bani Hajaj
4.	Bani Afif
5.	Al-Husha
6.	Al-Usfyn
7.	Al-Jabub
8.	Majzar
9.	Al-Ghudu
10.	Ash Sharaqi
11.	Aflah Al-Yaman
12.	Bait Al-Sultan
13.	Al-Thaiah
14.	Al-Mallaheeth

The Project sites fall within the climate groups of the Central Mountains and Highland Zones except **Aflah Al Yaman** (No. 11) and **Al Mallaheeth** (No. 14), which are located in the foothills area of the Western Central Mountains Zone around the border with the Tihama Lower Pressure Zone, and their climates are mainly governed by the latter throughout the year. In addition, **Al Ghudu** (No. 9) is in the Desert Zone where the arid climate is dominant.

For reference, the data on the mean annual precipitation and temperature at the countrywide meteorological stations are listed in Appendix to this report.

3.3.4 Water Quality

There is a special type of traditional water source in this country called a *cistern*, an artificial reservoir of a large pond-like structure to collect rainfall. The great majority of local inhabitants used to utilize it as their main water sources until very recently. Even nowadays it still remains a precious water source for numerous villages not only in the remote mountains but in ordinary localities, although water for drinking and cooking has mostly shifted to the fresh one from local wells for which they frequently pay money. To install it, they dig a big artificial pond in a lower location of the village and finish the surrounding wall with stones, bricks and concrete. Whenever rain comes, surface runoff flows into it, washing human wastes as well as animals', as the villages still have no sewerage facilities. There still exist many villages chiefly depending upon this type of unhealthy water sources. Hand-dug wells, another conventional sources, are quite popular as well, but the use of stagnant water from them during the dry season has been causing health hazards throughout the country, as indicated by the statistics of infectious diseases, in which the cases of water-related ones are strikingly increasing, represented by bilharzia. (Refer to the diseases statistics until 1987 in Appendix.)

Compared to water from these traditional sources, groundwater from deep wells has been regarded by the inhabitants as clean and safe, and its chemical qualities have hardly been heeded to. However, the quality of groundwater from deep wells in this country is known to have the following trend, partly revealed through the study on the

data in the previous Japanese projects.

(1) Hardness

Hardness is usually high in content in most of groundwater in this country, seemingly due to the broad distribution of limestone areas.

(2) Chloride Ion

High rates of chloride iron are encountered not only in the coastal areas affected by the intrusion of sea water, but in the places where low precipitation and high evapotranspiration cause the intensive concentration of salinity underground. Under this Project, part of **Al Usfyn** (No. 6) and **Majzal** (No. 8) fall within this category, with groundwater in the latter having high contents ranging from 600 to 800 ppm.

(3) Fluoride

Fluoride tends to increase in groundwater where the Precambrian rocks are prevalent. In the Taizz governorate, the broad area is seen to have this trend.

During the field survey for the Project, water sampling was carried out in the respective sites to obtain data on the expected water qualities. The samples were tested on the spot with a simple analysis kit as well as by an authorized public laboratory back home in Japan with the results listed in Table 3.5. Hardness in the majority of the samples falls within the permissible range of WHO drinking water standards, indicating the new sources could have similar characteristics. A high rate of fluoride is seen in a sample from the deep well in Al Usfyn, but in general this item does not pose a question on the development of new sources under the Project. However, the high concentrations of chlorides in Al Usfyn (No. 6) and Majzal (No. 8) have been taken into account for the planning; for the former, the location for the development of new sources has been moved to an area outside the site, since it has been judged to be difficult to find a location within the site where a new source could meet the requirement both in quantity and quality, while the planning for the latter has been canceled

Table 3.5 Water sampling data in project sites

Site No.	Site name	Place	Well No.	Water Source	Water temperature c°	pH (mg/l)	Cl (mg/l)	Total Hardness (mg/l)	Ca (mg/l)	F (mg/l)	Electric conductirity (μs/cm)
1.	Iyal Qasim	Al Shutbah Private well	W-12	Ground-water	26.0	7.1	25.1	265	159	0.5	597
2.	Mahalat Najr	Private well	W- 7	Ground-water	26.8	7.3	80.9	366	244	0.5	885
3.	Khamis Bani Hsjaj	Public water well	W- 4	Ground-water	27.1	7.2	24.1	266	111	0.5	546
4.	Bani Afif	Shallow well	W- 7	Ground-water	28.0	7.1	41.1	357	167	0.5	805
5.	Al-Husha	Wadi Saela Sanagir	W-15	Ground-water	30.0	7.3	80.1	450	252	<0.8	1,006
6.	Al-Usfyn	Rahidah city well	W-15	Ground-water	28.0	7.7	121.0	473	255	<0.8	4,128
		Wadi Al Wabirah	W-19		32.0	7.1	574.0	460	356	2.3	3,292
		Ash Sarraj	W-11		32.0	7.4	630.0	875	470	<0.8	2,946
		in Rahidah hospital well	W- 1		28.0	7.4	485.0	975	575	0.8	2,064
7.	Al-Jabub	Public Deep well	W- 2	Ground-water	37.0	7.5	76.2	71.6	66	0.8	808
8.	Majzar	Darbu Al shraf	W- 1	Ground-water	30.0	6.9	640.0	1,580	1,050	1.5	4,324
		High way authrity well	W- 4		30.0	7.0	864.0	1,620	1,250	<0.8	3,293
		Ar-Fardah	W- 5		31.0	7.6	280.0	410	175	0.8	1,634
		Wadi Maraha	W- 3		30.0	7.5	625.0	975	775	0.8	2,072
9.	Al-Ghudu	Source for Public Existing well	W- 1	Ground-water	26.6	7.0	88.3	578	289	<0.8	1,546
10.	Ash-Sharaqi	Wadi water	-	Surface water (spring)	18.0	7.2	11.8	160	100	0.5	330
11.	Aflah Al-Yaman	Public water well	W- 3	Ground-water	31.0	7.2	111.0	499	219	0.5	1,064
		Suq Ar Rubu	W-10		32.0	7.4	68.6	185	90	0.5	953
12.	Bait Al-Sultan	Ar Rajam Public water well	W- 7	Ground-Water	21.0	7.0	8.6	112	81	<0.8	285
13.	Al-Thaiah	Wadi water	-	Ground-water	26.3	7.1	25.7	243	130	<0.8	719
14.	Al-Mallaheeth	Public water well	W- 1	Ground-water	35.0	7.2	73.4	461	210	0.5	1,148
Standards		W H O				7.0--8.5	400.0	500	75	1.0--1.5	2,000
		Japan				5.8--8.6	200.0	300	-	0.8	-

because a suitable new source will have to be located close to the mountain some 30 km south of the site lying in the desert. (For the details, refer to the descriptions on the features of the respective sites in Clause 3.4 and Appendix.)

3.4 FEATURES OF PROJECT SITES

3.4.1

Site Number	1	Site Name	IYAL QASIM

Administrative Division	Sub-district : Iyal Qasim District : Dhi-Bin Governorate : Sana'a				
No. of Villages	9	No. of Houses	245	Present Population	1,500
Planned Area	7.5 km²	Population Density		200 persons/km²	
Income Sources	Rank 1: Agriculture (75%) Rank 2: Remittances (25%) Rank 3: -			Average Monthly Income	YR3,000
Medical Facilities	Hospitals /Clinics	None	Educational Facilities	Primary School	1
	Medical Staff	None		Intermedi-ate School	None
	No. of Beds	None		Secondary School	None
Shops/Restaurants		9 shops	Mosques		11

Water Purchase Practice	Quantity	3,000 lit/10 days/15 persons: 20 lit/d/c
	Price	YR600/3,000 liters : YR200/m³
	Source	Khamer City and others
Average Consumption		20 lit/day/capita

(1) Water Practice and Existing Sources

Iyal Qasim consists of 9 villages composing a sub-district(*Uzulah*) scattered on an undulating elevated area at 2,450 to 2,500 m above sea level. In the vicinity of the villages, seven wells of 30 to 250 m in depth were drilled by the **Dhi-Bin** LCCD in the past, but all of them turned out substantially dry. Yet two of them have been in use by the villagers, although each one yields no more than 1 to 2 m^3 a day, and runs dry in some twenty minutes after the pumping starts in the morning and the afternoon. Accordingly the villagers are mainly dependent on selling water transported up to the mountain from the sources in **Qa Shams** and **Ash Shutbah**, a nearby village some 5 km away from the site. One cubic meter of water costs as much as YR200 in Iyal Qasim, causing a heavy burden on the families with an average monthly income of YR3,000, since they must spend YR600 or so a month for refilling their water tanks every two weeks or ten days. Paying such, each member of the family is allowed to use a daily share of only 20 or less liters of water. That's the reason even the wells producing trickles of water have been well attended in this site.

(2) Hydrogeological Features

At the eastern base of the uplands, on the top of which Iyal Qasim is situated, stretches a broad valley called Qa Shams which have dissected the lineament running roughly toward the southeast with three paralleled alignments of the Quaternary volcanoes. The Project site, up on the mountain at a level some 600 m higher than this valley, has little chance to develop groundwater since its drainage area is quite small.

The area is composed of the Upper Jurassic *Amran Series* mainly consisting of limestone interbedded with marl and thin layers of shale and sandstone. Layers strike from NW-20° to NW-10° in general, dipping at 6° to 15° westward, but due to the gently folded structure, the strikes and dips vary with places. Cracks in the directions of NS and EW are widespread in the area. An east to west structural line crossing the three villages of **Bitan**, **Bait Al Nafish** and **Al Agla'a** is a normal fault depressed to the south, while a lineament in the NW-10° direction seemingly runs along the wadi west of **Bait Daghar**. In the neighboring village, Ash Shutba, which is located about 5 km west of Iyal Qasim at a level some 100 m lower, is a NS to NW-10° lineament as well. The hanging cliff on the western edge of the mountain east of Ash Shutba is suspected to be a fault scarp, along the course of which the three deep wells were drilled at an interval of about 50 m distance, each well producing about 200 to 300 m^3 a day. One of them is a source of the public water system for this village installed by the RWSD, while the other two are private ones for water selling for

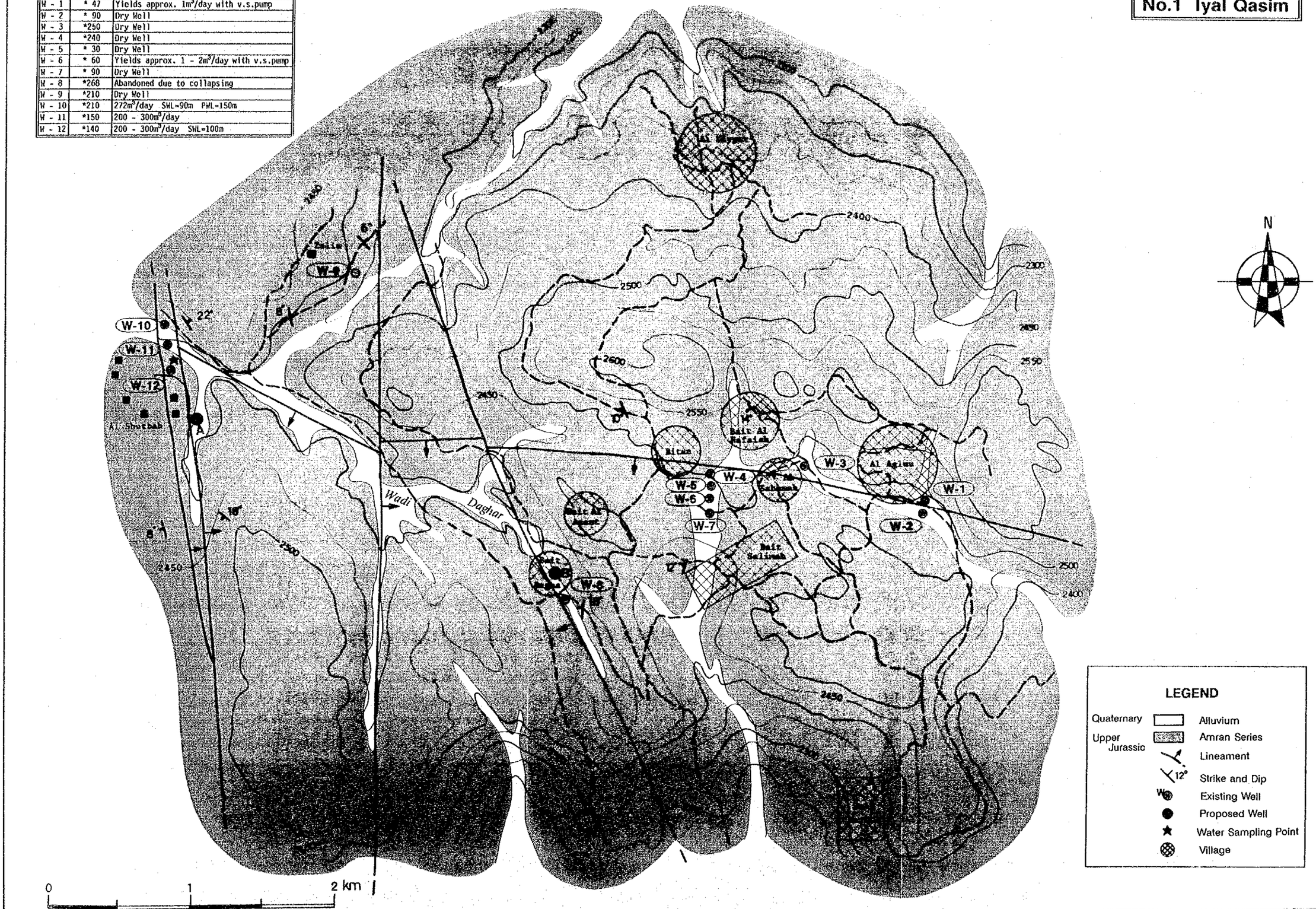
nearby villages.

Judging from the conditions of the existing wells, the lineaments in the EW or similar directions are suspected to have been formed in the older geologic ages, producing little or no water with effective porosity now growing definitely poor in their fractured zones. On the other hand, those of NS directions are young, providing the courses of groundwater passage in their fractured zones. Accordingly, the development of groundwater in this area is recommended to be located in the area of Ash Shutba, although this village is situated outside the Project site. Within the site, the NW-10° lineament near Bait Daghar is another candidate for the location of a new source for the Project. The existing deep well in this village is 268 m in depth, but has been abandoned, reportedly due to collapsing.

REFERENCE

Abbreviations in the Tables of the Hydrogeological Maps for the respective Sites
*W-1 •••••• Drilled deep well Drilled deep well
W-1 •••••• Hand-dug well
SWL •••••• Static Water Level
PWL •••••• Pumping Water Level
EC ••••••• Electric Conductivity
T •••••••• Water Temperature
v.s. pump• Diesel driven vertical shaft pump
s. pump •• Submersible motor pump
WC ••••••• Height of water column in hand-dug well

Well No.	Well Depth (m)	Remarks
W - 1	* 47	Yields approx. 1m³/day with v.s.pump
W - 2	* 90	Dry Well
W - 3	*250	Dry Well
W - 4	*240	Dry Well
W - 5	* 30	Dry Well
W - 6	* 60	Yields approx. 1 - 2m³/day with v.s.pump
W - 7	* 90	Dry Well
W - 8	*268	Abandoned due to collapsing
W - 9	*210	Dry Well
W - 10	*210	272m³/day SWL=90m PWL=150m
W - 11	*150	200 - 300m³/day
W - 12	*140	200 - 300m³/day SWL=100m



3.4.2

Site Number	2	Site Name	MAHALAT NAJR

Administrative Division		Sub-district : - District : Amran Governorate : Sana'a			
No. of Villages	1	No. of Houses	200	Present Population	2,000
Planned Area	3 km²	Population Density		667 persons/km²	
Income Sources	Rank 1: Wages/Salaries (60%) Rank 2: Agriculture (35%) Rank 3: Remittances (5%)			Average Monthly Income	YR5,000
Medical Facilities	Hospitals /Clinics	None (Going to nearby Amran City)	Educational Facilities	Primary School	None
	Medical Staff			Intermediate School	None
	No. of Beds			Secondary School	None
Shops/Restaurants		None	Mosques		7

Water Purchase Practice	Quantity	2,000 lit/10 days/15 persons: 27 lit/d/c
	Price	YR200/2,000 liters : YR100/m^3
	Source	Amran City and others
Average Consumption		40 lit/day/capita

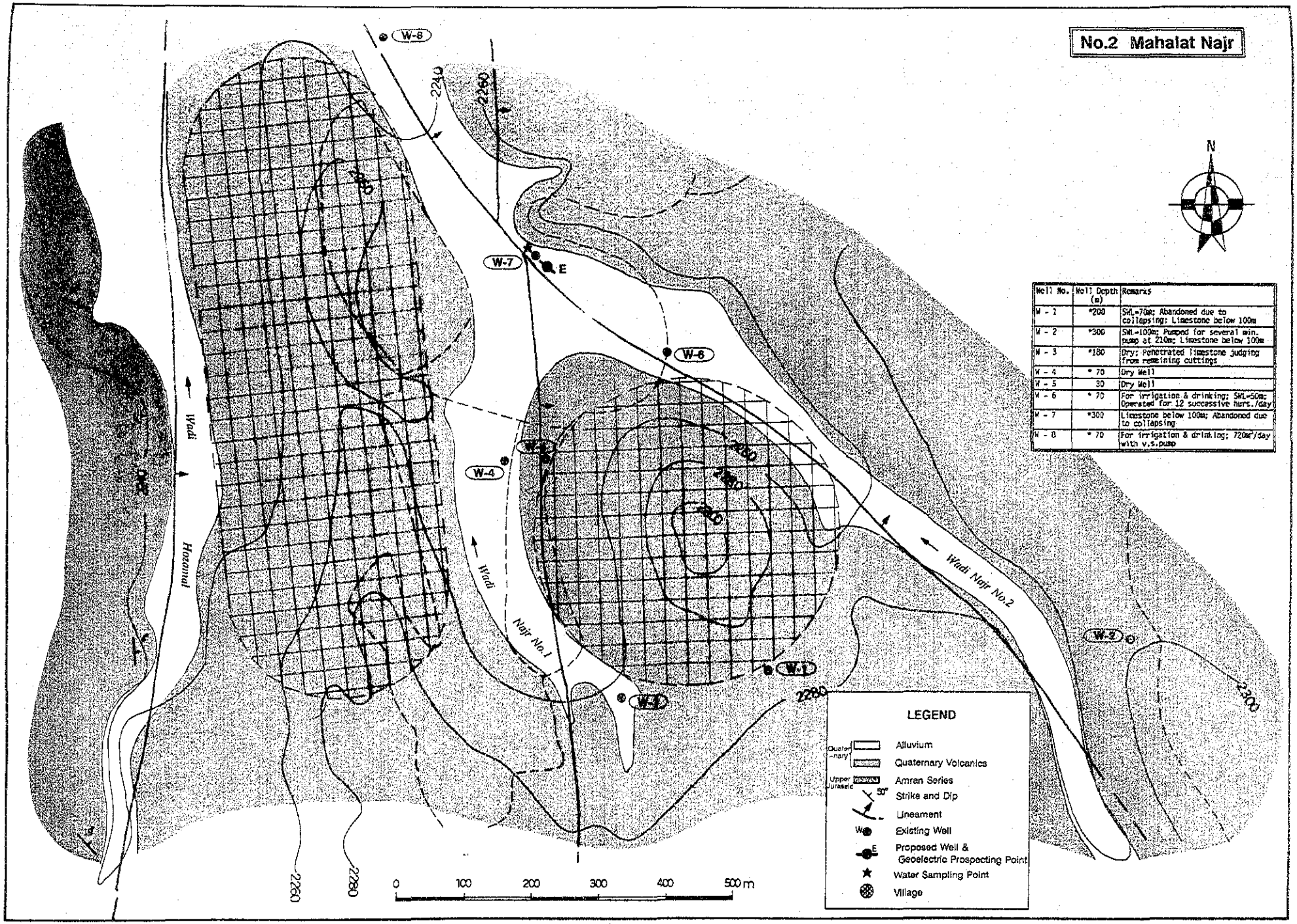
(1) Water Practice and Existing Sources

The Project site is in a close proximity of **Amran** City, one of the most thriving cities in Sana'a governorate located some 50 km north of the capital of Sana'a. At the foot of a limestone hill about 3 km west of the site stands the *Amran Cement Plant* installed with Japan's technology. Limestone created in the Upper Jurassic age is distributed extensively in this country, particularly from the surroundings of this area up to the north, and has been labelled *Amran Series* after the name of this region. The Project site lies on a volcanic hill of the Quaternary period overlying this Amran Series. As its location is quite close to the big city, many residents earn their living from various jobs there rather than agriculture, making a sharp contrast with the other mountainous sites in this Project.

Electricity reaches the village from Amran City, but water remains yet to do so, since the city itself currently has no surplus, depending upon only three deep wells. Up to now, well-off villagers of the site drilled eight wells with their own funds, out of which the two installed in the **Wadi Najr** (No. 2) have turned out successful. These wells have been operated with vertical shaft pumps for irrigation as well as for domestic use. The villagers buy water from those wells or the private ones in Amran City for YR100 per m^3, a half price, compared to those in other mountainous sites, due to the short distances from the sources.

(2) Hydrogeological Features

The Project site is a volcanic hill composed of the Quaternary volcanic rocks, faced on the western side with the **Wadi Hosermel** and the mountains formed of Amran series limestone. Within the site, the Wadi Najr (No. 1) and its tributary (No. 2) flow northward. The Quaternary volcanic material consists of basalt lava flow issued during the early stage of volcanic activities in that period, showing a pronounced unconformity with the underlying Amran Series. The basalt lava flows consist of alternated beds of hard black basalt lava and rather porous one, in places including autobrecciated lava beds. In addition, they contain an interbed of scoria of some 2 m in thickness with a couple of thin layers of volcanic ash several centimeters thick. Cracks in the NS or EW directions abound, and the Wadi Najr (No. 1) and (No. 2) are techtonic valleys in the directions of NS to NW20°. According to the performances of existing wells, groundwater occurs in the lineaments running in the NS to NW20° directions, but does not in those of the EW directions, as indicated by the locations of the two successful wells in the Wadi Najr which have daily been pumped continuously for 12 hours at a rate of 400 to 500 liters per minute. The new source for this Project, therefore, should be located in the course of the same lineament.



Well No.	Well Depth (m)	Remarks
W - 1	*200	SWL=70m; Abandoned due to collapsing; Limestone below 100m
W - 2	*300	SWL=100m; Pumped for several min. pump at 210m; Limestone below 100m
W - 3	*180	Dry; Penetrated limestone judging from remaining cuttings
W - 4	* 70	Dry Well
W - 5	30	Dry Well
W - 6	* 70	For irrigation & drinking; SWL=50m; Operated for 12 successive hurs./day
W - 7	*300	Limestone below 100m; Abandoned due to collapsing
W - 8	* 70	For irrigation & drinking; 720m³/day with v.s.pump

3.4.3

Site Number	3	Site Name	KHAMIS BANI HAJAJ

Administrative Division	Sub-district : Khamis Bani Hajaj District : Thila Governorate : Sana'a				
No. of Villages	7	No. of Houses	510	Present Population	5,400
Planned Area	8 km²	Population Density		675 persons/km²	
Income Sources	Rank 1: Agriculture (50%) Rank 2: Wages/salaries (40%) Rank 3: Remittances (10%)			Average Monthly Income	YR2,000
Medical Facilities	Hospitals /Clinics	None	Educational Facilities	Primary School	1
	Medical Staff	None		Intermediate School	None
	No. of Beds	None		Secondary School	None
Shops/Restaurants		None	Mosques		15

Water Purchase Practice	Quantity	3,000 lit/30 days/15 persons: 7 lit/d/c
	Price	YR130/1,000 liters : YR130/m3
	Source	Deep wells in the surrounding wadi
Average Consumption		7 lit/day/capita

(1) Water Practice and Existing Sources

The Project site comprises 7 villages scattered on the gently undulating uplands of the *Amran Series* limestone, 4 km north of **Thila** city, center of this district (*Nahiya*) about 50 km northwest of the capital of Sana'a. The Thila district is composed of 75 villages, including a subdistrict (*Uzlah*) of **Khamis Bani Hajaj** consisting of 12 villages, out of which 7 are planned to be covered under this Project. Thila city itself has no appropriate water sources, and receives the supply from the municipal water facilities for **Shibam** city about 10 km to the south, which were constructed by the RWSD. Due to its elevated position, the Project site also has not been able to develop any water sources except the cisterns to store rainfall for domestic use. Even hand-dug wells have been unsuccessful. The inhabitants have no choice but to buy water for drinking and cooking.

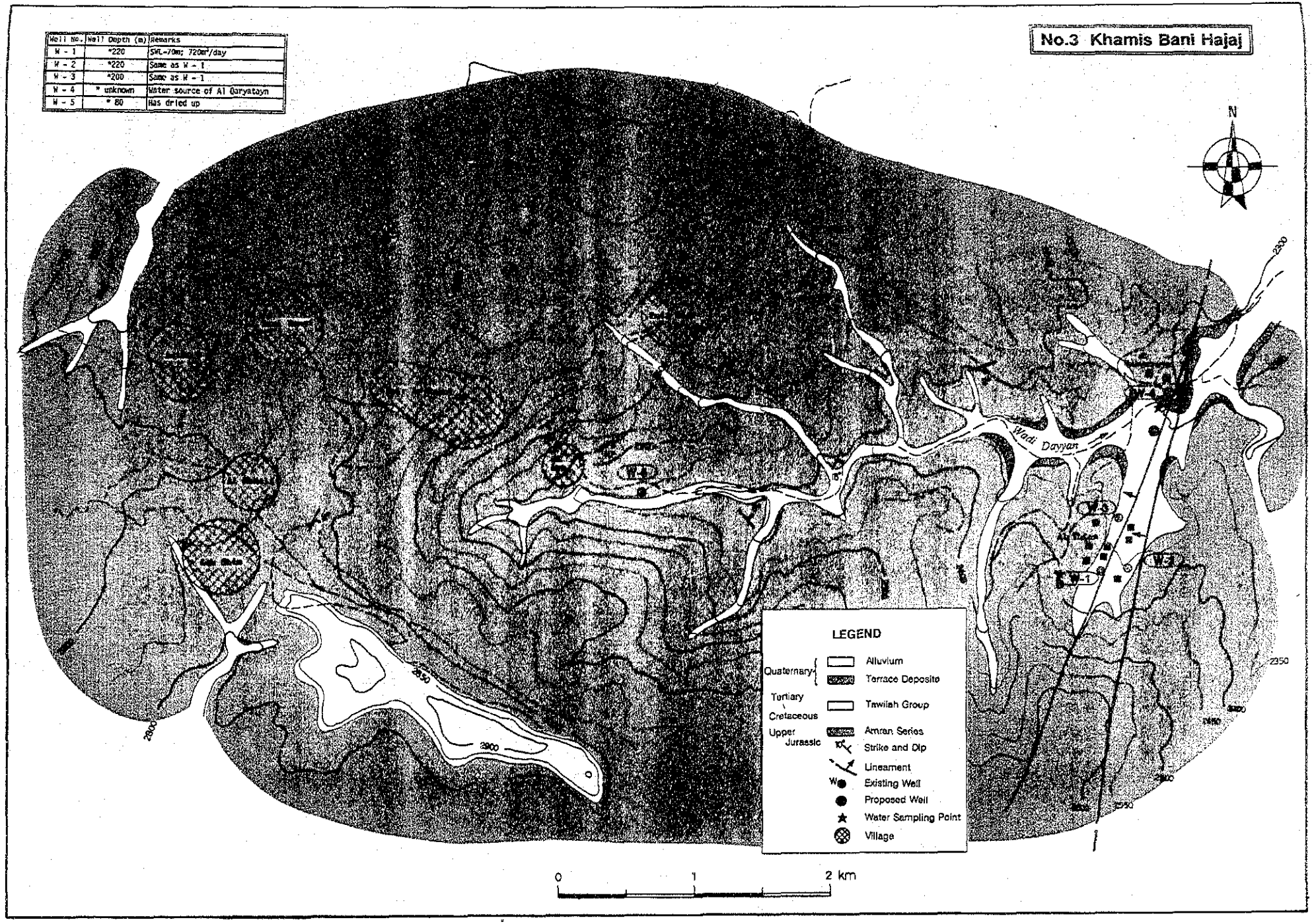
Appropriate water sources are not likely to be obtained within the Project site under its natural conditions unfavorable for the development. To find an alternative, it is necessary to go beyond the boundary of the Project site into a neighboring sub-district, about 10 km downstream the **Wadi Dayyan**, where the two villages, **Dayyan** and **Al Qaryatayn**, have successfully developed groundwater, with 4 deep wells producing sufficient yields, one of them for the public water supply for the former village which was drilled five years ago to a depth of 220 and yields about 500 liters/min through 3" pipeline with a vertical shaft pump installed at 170 m in depth. Other wells in this basin display a similar performance, and their rich yields have helped the inhabitants successfully launch the cultivation of fruit trees such as plums.

To fix a location of a new source for this Project in this promising basin, arrangement is required through the coordination of the concerned LCCD. During the survey, however, an agreement has already been reached on this point among the concerned parties.

(2) Hydrogeological Features

The Project site lies on the undulating uplands gently tilting eastward on the left side of the Wadi Dayyan, composed of the Amran Series limestone. In the northwestern part of the site, small patches of sandstone belonging to the *Tawilar Group* in the Cretaceous to the Tertiary periods are distributed, unconformably overlying the Amran Series. Limestone in this area shows a gently undulating, slightly folded structure, lacking faults and cracks. Accordingly no existing wells have been available within the site, and the inhabitants are entirely relying upon selling water for drinking use.

An exceptionally promising zone for groundwater development is encountered in the basin downstream the Wadi Dayyan east of the site where a lineament is developed in the direction of NE10°, allowing the successful drilling of 4 wells with their yields reaching about 700 m^3 a day. This lineament has a fracture zone 50 to 60 m wide, providing a good passage of groundwater flow. There are no other candidates for groundwater development in and around the Project site.


No.3 Khamis Bani Hajaj
Well No. | Well Depth (m) | Remarks
W - 1 | *220 | SWL=70m; 720m³/day
W - 2 | *220 | Same as W - 1
W - 3 | *200 | Same as W - 1
W - 4 | * unknown | Water source of Al Qaryatayn
W - 5 | * 80 | Has dried up
N
Wadi Dayqan
W-1
W-2
W-3
W-4
W-5
2800
2850
2900
2950
LEGEND
Quaternary
Alluvium
Terrace Deposits
Tertiary
Cretaceous
Tawilah Group
Upper Jurassic
Amran Series
Strike and Dip
Lineament
Existing Well
Proposed Well
Water Sampling Point
Village
0
1
2 km

3.4.4

Site Number	4	Site Name	BANI AFIF

Administrative Division		Sub-district : Bani Hammad District : Turba Al Mawasit Governorate : Taizz			
No. of Villages	9	No. of Houses	990	Present Population	7,300
Planned Area	14 km²	Population Density		521 persons/km²	
Income Sources	Rank 1: Agriculture (50%) Rank 2: Wages/salaries (45%) Rank 3: Remittances (5%)			Average Monthly Income	YR2,200
Medical Facilities	Hospitals /Clinics	PHC (1)	Educational Facilities	Primary School	4
	Medical Staff	Doctors (2) Nurses(3)		Intermediate School	1
	No. of Beds	30		Secondary School	None
Shops/Restaurants		None	Mosques		10

Water Purchase Practice	Quantity	2,000 lit/15 days/15 persons: 19 lit/d/c
	Price	YR200/2,000 liters : YR100/m3
	Source	Wells in the nearby wadis
Average Consumption		50 lit/day/capita

(1) Water Practice and Existing Sources

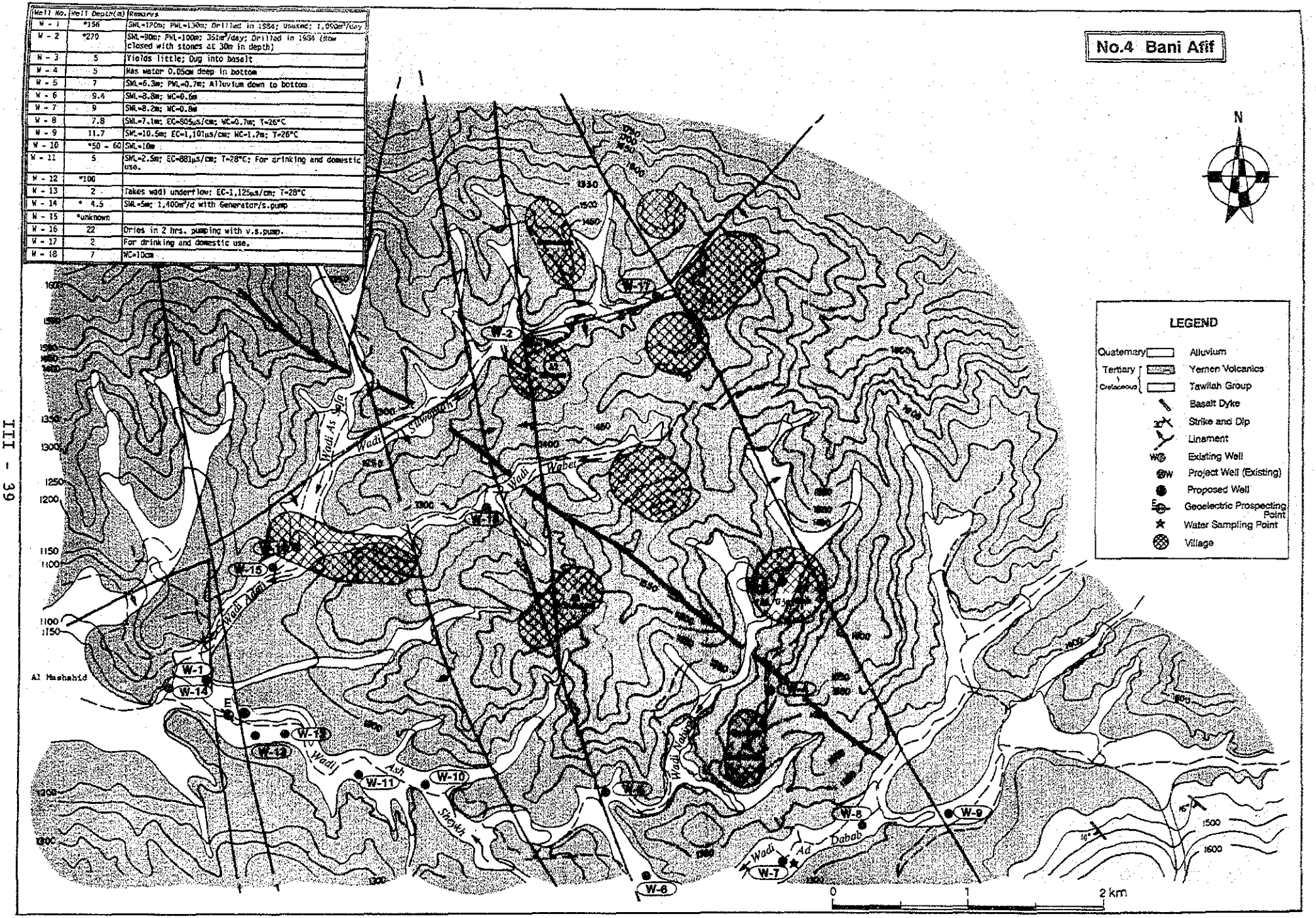
The Project site presents a complicated mountainous terrain composed of the *Yemen Volcanics*, with many wadis cutting down and fringing the mountainous body. Along the courses of wadis are numerous hand-dug wells as well as some deep wells in service for inhabitants' domestic water and irrigation use. Yet the existing deep wells drilled by the RWSD 9 years ago remain closed because of the lack of fund to install the facilities to convey water to the dwelling areas up on the mountain.

In the **Wadi Ash Shaykh**, one of the main wadis in the area, are 4 drilled wells including one public water source for the Project, out of which the only one is now in operation mainly for irrigation, yielding over 500 liters/min continuously for 16 to 20 hours a day. The public water source was drilled in a location close to this well in operation, reportedly having produced a yield of about 1,000 liters/min at the time of construction. The other public water source is in the **Wadi Bani Suwamah** upstream the **Wadi Adan** which joins the *Wadi Ash Shaykh*. During the field survey by the team, however, it was revealed that the inside of this well had been closed by stones thrown down by the unknown after it underwent the pumping test two years ago by the *Southern Highlands Development Authority* belonging to the then Ministry of Agriculture and Fisheries. To employ this well as a source for the Project, stones must be removed by the rehabilitation work.

The main water source for the inhabitants in the mountainous area is a hand-dug well several meters deep, installed upstream the public deep well in the Wadi Ash Shaykh. The water quality of this well has proved acceptable, and the well is said to remain serviceable even during the dry season. Most of existing hand-dug wells, however, can not perform like this one, frequently experiencing drastic falls of water levels during the dry seasons. Therefore, buying drinking water down from the wadi is a must for the inhabitants in the mountainous area.

(2) Hydrogeological Features

Most of the site is composed of the Yemen Volcanics produced during the Cretaceous and the Tertiary periods, consisting dominantly of basalt and rhyolite lava flows interbedded with andesite lava. In places interbeds of pyroclastic flows are recognized along with rare cases of mudstone interbeds. The rocks include a characteristic interbed of olivine basalt lava dotted with pronounced phenocrysts of feldspar of 2 to 5 m in thickness, which is traceable as a key bed. Moreover, a chain of basalt dikes extends across the area, some of them continuing for a distance of 6 km, probably having intruded in the latter part of the Yemen Volcanic activities. Lineaments in the directions of NE20° to 30° and NE50° are widespread, some of them accompanied with fractured zones 30 m wide. Groundwater, however, is judged to occur in the former types in the NE20° to 30°, based upon the existing drilling records. Among them, the most distinguished one runs in the NE20° direction, along the western boundary of the district adjacent to the **Al Mashahid** village in the neighboring district, where one of the existing public deep well was drilled.
In addition, unconfined groundwater occurs in belts of alluvial deposits along the wadis and through the weathered zones of volcanic rocks with numerous cracks, where many hand-dug wells have been installed to depths of 5 to 10 m. Many of them, however, reportedly suffer the sharp decline of the water level during the dry season.



Well No.	Well Depth(m)	Remarks
W - 1	*156	SWL=120m; PWL=130m; Drilled in 1984; Usable; 1,000m³/day
W - 2	*270	SWL=90m; PWL=100m; 350m³/day; Drilled in 1934 (Now closed with stones at 30m in depth)
W - 3	5	Yields little; Dug into basalt
W - 4	5	Has water 0.05cm deep in bottom
W - 5	7	SWL=6.3m; PWL=0.7m; Alluvium down to bottom
W - 6	9.4	SWL=8.8m; WC=0.6m
W - 7	9	SWL=8.2m; WC=0.8m
W - 8	7.8	SWL=7.1m; EC=805μS/cm; WC=0.7m; T=26°C
W - 9	11.7	SWL=10.5m; EC=1,101μS/cm; WC=1.7m; T=26°C
W - 10	*50 - 60	SWL=10m
W - 11	5	SWL=2.5m; EC=881μS/cm; T=28°C; For drinking and domestic use.
W - 12	*100	
W - 13	2	Takes wadi underflow; EC=1,125μS/cm; T=28°C
W - 14	* 4.5	SWL=5m; 1,400m³/d with Generator/s.pump
W - 15	*unknown	
W - 16	22	Dries in 2 hrs. pumping with v.s.pump.
W - 17	2	For drinking and domestic use.
W - 18	7	WC=10cm