over the country demands the government to accelerate the development of this sector, but its limited financial and human resources have resulted in the slowdown of its progress.

The Project sites are typical mountainous villages without any stable water sources where inhabitants have no choice but to buy costly water conveyed up to their dwelling areas on tankers from deep wells installed far down in the wadi lowlands. It costs them as much as YR100 to YR300 per cubic meter, limiting their average consumption to 10 to 20 liters per capita per day. Domestic water, therefore, must be supplemented by sources such as unsanitary hand-dug wells and cisterns available near their dwelling areas. Such a current practice in water use is far from easing women and children's painstaking labor for fetching water every day. Furthermore, it has led to the spread of epidemics related to water in places among the sites, urging the government to take immediate steps for improving their water environment. Taking this situation into account, the respective LCCDs responsible for the local development now view the water projects as their top-priority undertakings. As a result of the field survey and subsequent analysis for the study on the Project, which are presented hereafter, every site has proven to urgently necessitate water supply facilities, and the Project is judged to be feasible for the implementation with Japan's grant aid.

4.2.2 Review of Planning for the Respective Sites

(1) Site No. 1 **Iyal Qasim** (Sana'a)
Population: 1,500 No. of Villages: 9

1) Water source

Having no stable existing sources, this site needs a new one for the Project. However, since drilling within its territory has little chance of resulting in a successful well, the most feasible arrangement is to secure a location in the neighboring village of Al Shutba, for which negotiations have already been concluded between the concerned communities through the coordination of the LCCD which is in charge of local development projects for this area.

2) Water Supply Facilities

The shift of the water source location to the area outside the villages has resulted in the increased scale of transmission facilities with the length of transmission line reaching about 6,300 m. Other water facilities, however, can be located effectively within the villages with one distribution tank installed near the top of the hill at the back of the villages.

(2) Site No. 2 **Mahalat Najr** (Sana'a)

Population: 2,000 No. of Villages: 1

1) Water Source

A new source is necessary, but can be developed within the village.

2) Water Supply Facilities

Among the 11 sites for the planning, Mahalat Najr is the only one site composed of a single village located on a hill close to an urbanized area of a big city. Its area is relatively small allowing an effective water supply plan. However, urgency for facilities is judged to be less than that in other sites, since its location allows relatively easy access to the necessary water.

(3) Site No. 3 **Khamis Bani Hajaj** (Sana'a)

1) Water Source

This site has no existing water sources, and the development within its limits is judged unfeasible. Consequently, a location beyond its limits is proposed as for Iyal Qasim (Site No. 1). The arrangements by the LCCD has been completed as well.

2) Water Supply Facilities

The location of a new water source is far down the wadi from the site, and the transmission facilities are required to constitute two booster stations along the course. A part of villages, however, can receive the supply from these booster stations. The total length of transmission line is 15,800 m.

(4) Site No. 4 **Bani Afif** (Taizz)

1) Water Source

This site has two existing wells installed by the RWSD 9 years ago, and can be judged to be employed for this Project. However, one of them needs rehabilitation work, because its inside has been closed with stones. Further it is proposed that an additional new well be planned to protect against possible decrease in their yields in such a long period of neglect.

2) Water Supply Facilities

Due to the distribution of villages in a complex mountainous terrain as well as separate locations of the existing wells, this site is proposed to be divided into the two service areas with an independent system. Booster pump stations are required to overcome intensive topographic change. The total length of transmission lines for the two systems is 13,550 m.

(5) Site No. 5 **Al Husha** (Taizz)

Population : 13,000 No. of Villages: Over 30

1) Water Source

Two deep wells were drilled by the LCCD in 1986, having since been left unused due to lack of funds for facilities construction. The planning of additional wells is necessary to cover a large demand in its extensive area constituting a district (Nahiya).

2) Water Supply Facilities

The plan for this site involves such difficulties as an oversized planning area of about 120 km² with villages scattered on the rugged mountainsides and slopes, limited areas for possible groundwater development, etc. To overcome these difficulties for effective supply, the entire area is proposed to be divided into three supply zones to be installed with an independent system as follows:

a. Eastern Zone (Population: 5,000)
This zone includes villages dispersed on the southern-southwestern slopes of Mt. Al Husha, the highest peak of the area. A water supply system for the zone is of the largest size of the three, with its source located at the two existing wells in the northern wadi, which had been installed by the LCCD for the supply to this zone. Its execution is not judged to be feasible at present, since it entails a great deal of difficulty in the construction work in respect of access and other conditions.

b. Central Zone (Population: 5,000)
The system for this zone reaches the center of the district, Zuran city, located in the middle part of the mountain. The planned facilities are not likely to cause such a great deal of difficulty in construction as those for the Eastern Zone, and can produce effective results. In this view, this zone is judged to be the most suitable for the execution under this Project. Water sources, however, are required to be newly developed. The planned transmission line totals 13,400 m.

c. Western Zone (Population: 3,000)
This zone has an existing supply system installed by the Southern Highlands Development Authority belonging to the Ministry of Agriculture and Water Resources, which has at the moment been left idle because the water source has run dry. For this zone, the RWSD has proposed to make a necessary measure for the rehabilitation of facilities by means of drilling a new deep well with its own fund.

It is noted that the LCCD responsible for the district is strongly pressing for the implementation of the project for the Eastern Zone as it is the most suffering area. Accordingly, the final arrangements between the RWSD and the LCCD seem indispensable prior to proceeding to the execution of the aforementioned plan.

(6) Site No. 6 **Al Usfyn** (Taizz)

Population: 28,500 No. of Villages: 20

1) Water Source

Despite a broad stretch of the site constituting a sub-district (Uzlah) there are no existing wells to be employed for the Project, and most of the areas are dominated by groundwater with inferior quality of high chloride concentrations as well as fluoride unfitted for drinking. Accordingly the development of new sources in a location beyond its limits is planned, and the LCCD has made arrangements for a promising area along the wadi running 7 km north of the northern fringe of the site, where three wells are planned to be drilled to cover a large population.

2) Water Supply Facilities

Groundwater occurring in this area cannot be employed for the Project due to its high salinity, and a location for the new sources should be determined in an area along the Wadi Warazan, which flows across another district beyond the limit of this site. However, the location of this source poses a problem in water supply planning since it takes over 20 km from there just to the base of the mountainous area where villages are mainly located. With inhabitants there thoroughly depending upon costly water for sale, the absolute lack of water in the site demands urgent necessity of facilities, but the whole size of the project for this site amounts to by far more than what the Project can afford. One of possible measures for this site is a scheme to develop stable and safe water sources in view of the crunch of the site where there are no such ones existing, along with appurtenant service facilities at a point where most villagers

can make easy access. A candidate for this service station is proposed to be located near Al Rahidah city along the highway connecting Taizz and Aden. Such facilities are planned to be composed of a large reservoir attached with a public fountain and a hosepipe feeder to fill water tankers. Even this system necessitates a transmission line of about 9 km.

With this measure, public water facilities are to be installed relatively close to the dwelling areas of villagers. An efficient and effective operation of facilities with proper selling price is recommended to be established through the arrangements of the LCCD so that inhabitants can get sanitary water for far less expenses, which is sure to contribute to the significant improvement of health and sanitation in the whole region.

(7) No. 7 **Al Jabub** (Ibb)

Population: 2,000 No. of Villages: 6

1) Water Source

This site has an existing water source facility in service for inhabitants as follows:

Components: Deep well x 1 No.
Diesel engine driven vertical shaft pump x 1 No.
Pump house x 1 No.

Position in this Project:
The deep well is a public source drilled by the LCCD, and can be used for the Project. The pumping unit is, however, a private property to be returned to its owner after removal. In addition, the existing pump house is a temporary structure, and must be replaced by a new one under the Project.

The existing well, however, has turned out to yield only 100 liters/min according to the field measurement. To supplement the yield, an additional new well is planned in this Project.

2) Water Supply Facilities

Villages are located on mountains rising on both sides of the wadi in which the existing well was drilled. This site, therefore, is planned to be divided into the two zones with the individual supply systems, respectively using the existing well and a new one for their sources. Transmission lines for both systems are 8,300 m long in total.

(8) Site No. 9 **Al Ghudu** (Marib)

Population: 1,770 No. of Villages: 14

1) Water Source

This site owns the existing water source facility as follows:

Components: Deep well x 1 No.
Diesel engine driven vertical shaft pump x 1 No.
Pump house x 1 No.

Position in this Project:
The entire facility was constructed by the RWSD. In this Project, the existing pump and the pump house should be replaced by new ones.

2) Water Supply Facilities

Villages are dispersed in a flat wadi lowland surrounded by hills, on one of which a water tank is planned to be installed for the effective supply. The transmission line from the well to the hill is about 1,000 m.

(9) Site No. 11 **Aflah Al Yaman** (Hajjah)

Population: 4,500 No. of Villages: 22

1) Water Source

This site has an existing public well drilled by the LCCD, remaining closed. Judging from the condition of another well nearby, the existing one is estimated to be usable for the Project. In addition, a new well is recommended to cover a wide area composing the site.

2) Water Supply Facilities

Aflah Al Yaman is one of the districts (Nahiya) in Hajjah, and the planned area occupies about a half of its entire area. For the effective water supply, it is planned to be divided into the two zones with independent supply systems respectively using the existing well and a new one for their sources. The total length of transmission lines is 7,400 m.

(10) Site No. 12 **Bait Al Sultan**

1) Water Source

The site owns an existing deep well drilled by the RWSD, which is judged to be a suitable source for the Project as a result of the field survey.

2) Water Supply Facilities

The distance from the existing deep well to villages in the mountain is about 9 km, and a booster station is necessary on the way. This booster station is planned to be located in an area where several villages can receive supply.

(11) Site No. 14 **Al Mallaheeth**

Population: 3,180 No. of Villages: 9

1) Water Source

This site an existing water source facility as follows:

Components: Deep well x 1 No.
Diesel engine driven vertical shaft pump x 1 No.
Pump house x 1 No.
Reservoir of reinforced concrete, 30 m^3 x 1 No.

Position in this Project:
The existing source is a public water facility constructed by the RWSD. The pump has already been repaired 15 times and needs replacement. The pump house has a solid structure, and can be used for the Project, along with the reservoir attached

with facilities for feeding water tankers.

The existing deep well has been found to have decreased its initial discharge to 100 liters/min. An additional well is necessary to cover a demand in this Project.

(2) Water Supply Facilities

The water supply planning for Al Mallaheeth, the central community of the site, is relatively simple, with water to be pumped directly from the two wells to a reservoir on one of the hills surrounding the site. The transmission lines from the two sources are 1,370 m in total.

4.2.3 Review of System Components

The water supply systems for the respective sites are composed of the following facilities:

Water Source Facility	Deep well
↓	
Intake Facility	Deep well pump facilities, pump station
↓	
Transmission Facility	Transmission pump, booster line, booster pump station (include booster tank)
↓	
Distribution Facility	Distribution tank, Distribution line
↓	
Service Facility	Public fountain, Hosepipe feeder

Most of the sites included in the plan are extended clusters of settlements with a large planning area, with six (6) of them located more than 5 km from water sources, some of them requiring two or more water sources. In three (3) sites, their water sources are to be located outside the limits of their areas thanks to the coordination of the local LCCDs, indicating their growing influence on regional cooperation. These arrangements, however, have resulted in lengthy transmission lines, expanding their project sizes.

The clusters of settlements are so broadly dispersed in massive mountainous areas that it is practically difficult to extend distribution lines to every settlement composing the respective sites. The basic strategy of this planning for the composition of facilities, therefore, is first to secure the water sources adequate enough to meet the planned demands in the target year in the respective sites, then to design transmission facilities and reservoirs for distribution consistent with such demands and reflecting specific features of the respective sites, and finally to determine the extent of distribution lines to the central parts of the communities, in most cases to the villages near the reservoirs, with service facilities such as public fountains connected to the line ends. Facilities for feeding water tankers are to be installed at the same locations for the convenience of villages relatively distant from servicing points. In addition, it is proposed to supply piping materials for the extension of the distribution lines from those installed by the Japanese side for the purpose of meeting the inhabitants' needs as much as practicable. The installation work of those supplied piping materials shall be undertaken by the RWSD and/or the LCCDs, which are responsible for the Project for and on behalf of the Yemen government.

Compared to the currently prevailing water practice through the sites such as buying costly water, fetching water from sources away down by women and children, collecting unsanitary water from nearby sources, etc., the planned facilities in this Project allow inhabitants easy access to safe and stable water supply near their dwelling areas in the mountains and can contribute to curtailing a great deal of burden caused by their expenditures for water, even though they may share the costs of the operation and maintenance of facilities. One cubic meter of water at present costs inhabitants YR200 on the average, while the estimated maintenance and operation costs covering both operators' salaries and the fuel costs are at a level of one eighth or tenth that price.

Special arrangements are proposed, however, for the two large-scale sites, Al Husha (No. 5) and Al Usfyn (No. 6), in view of their extraordinary sizes and specific conditions; an individual water supply system is planned for one supply zone of the former site; and facilities focused on the water source development is planned to be installed for the latter.

4.2.4 Project Administration and Management

The operation and maintenance of the completed facilities are to be managed by the LCCDs responsible for the local development enterprises in the respective districts to which the Project sites are attached. One unit of the LCCDs is constituted of 7 to 10 members elected by popular votes from the entire district, with its management consisting of a chairman, a deputy and an accountant. Its main duties are usually focused on the construction, maintenance and repair of feeder roads within the limits of the district, based upon the allocation of the budget from the government. Further, it is in a position to administer local schools and hospitals/dispensaries, respectively installed by the Ministry of Education and the Ministry of Health. The improvement of water supplies falls within its scope of work, and each unit involved in the Project intends to take over the facilities upon completion and to administer their operation and maintenance. The setup is managed by chairman with the deputy or the accountant engaging in practical work, and the daily operation is planned to be attended by newly employed full-time operators basically consisting of one chief operator and one or two assistants. Normal operations of the facilities are concentrated on power drives based upon diesel engines as well as pumps and it is not difficult to recruit an expertise familiar with these types of equipment in the regional labor market, who is to be assigned to a chief operator. Assistants could be recruited within villages of the Project sites. In Al Mallaheeth and Al Ghudu where the existing facilities have long been in operation, the incumbent operators already have a lot of experience, and only assistants are needed to be recruited for attending to newly extended facilities. Expenditures for such operation and maintenance are to be collected from beneficiaries of the respective sites, including operators' salaries from YR1,500 to 2,500 per person in general as well as costs of fuel and lubricant. This type of rural water management is common across the country, as is the case with the rural communities where the previous Japanese projects were executed. Under this Project, since water is served at public fountains and feeders for tankers, water billing for such O/M cost is based upon fixed water rates allocated to villages or households receiving benefits. It varies with the facilities and the sizes of the communities. (In case of Al Husha (No. 5) planned to have transmission facilities of large extent, the O/M cost is estimated at YR18 per one cubic meter. In comparison to current water prices as much as YR400

to 600 per m^3 there, expenses to be borne by inhabitants are anticipated to be pronouncedly decreased to a level they would be willing to pay for.

The planned water systems for the respective sites except Al Mallaheeth and Al Ghudu include transmission facilities of a large scale with pipelines and pumping units withstanding high pressure exceeding 20 kg/cm^2. Since these materials and equipment are hard to obtain in this country, it is deemed necessary to provide spare parts and standby equipment under the Project for the sustained operation and maintenance by the LCCD.

With daily operations undertaken by the LCCDs in the respective sites, the role of the RWSD after the transfer of facilities is mainly to provide technical service to the LCCDs, including the dispatch of engineering staffs in case of troubles or damages with equipment, along with the supply of spare parts. However, since the larger part of the sites lack experience in a full-scale management of water supply system, the RWSD will have to extend relevant direction and support to the LCCDs from time to time through the initial stage of their operations. Such support is to be undertaken by the RWSD's staffs assigned to full-time counterparts during the execution of the construction work.

4.2.5 Priority of the Sites for Execution

Priority of the sites for the execution of the Project was discussed with the RWSD, mainly focusing on the necessity and urgency of facilities due to extreme difficulty in obtaining domestic water. The priority order of the eleven sites proposed by the RWSD is shown in Table 4.1.

As to the details of the planning, it has been agreed between the RWSD and the study team that distribution lines shall basically be extended to the center of the villages located close to reservoirs in the respective sites, and that the planning for the two large-scale sites, Al Husha (No. 5) and Al Usfyn (No. 6) shall be based upon different schemes from those for other sites, with the former planned to be provided with one individual supply system for a single area of the Central Supply Zone and the latter to be provided with facilities focused on new groundwater development.

Table 4.1 Priority of Sites Proposed by the RWSD

Order	Site No.	Site Name	Governorate	Population (1991)
1.	(14)	Al Mallaheeth	Sa'dah	3,180
2.	(1)	Iyal Qasim	Sana'a	1,500
3.	(3)	Khamis Bani Hajaj	Sana'a	5,400
4.	(6)	Al Usfyn	Taizz	28,500
5.	(5)	Al Husha (Central Zone)	Taizz	5,000
6.	(11)	Aflah Al Yaman	Hajjah	4,500
7.	(9)	Al Ghudu	Marib	1,770
8.	(12)	Bait Al Sultan	Al Mahweet	3,600
9.	(4)	Bani Afif	Taizz	7,300
10.	(7)	Al Jabub	Ibb	2,000
11.	(2)	Mahalat Najr	Sana'a	2,000

Taking all this into account, this report has made a further analysis on each of the sites ranking higher in the proposed priority listing, based upon such factors as the implementation, operation and maintenance and the project cost. As a result, five (5) sites, where facilities are judged to be most urgently needed and the execution can produce higher effects for investment than others, have been determined for the basic design study as follows:

1. Al Mallaheeth (Sa'dah Governorate)
2. Iyal Qasim (Sana'a Governorate)
3. Al Usfyn (Taizz Governorate)
4. Aflah Al Yaman (Hajjah Governorate)
5. Al Ghudu (Marib Governorate)

The reasons for the selection of these five sites are: (a) they all rank higher in the priority listing of the Yemen government; (b) the facilities for those sites can produce higher cost-effectiveness with a less construction cost per person; and (c) the operation and maintenance costs of those facilities are moderate, enabling sustained operation of facilities without difficulty. The planning for the remaining six (6) sites, however, is presented in this report with details on facilities and equipment for reference.

4.2.6 Necessity of technical cooperation

As a view of the government of Japan represented by the study team, technical assistance for the execution of the project is not required. However, to promote the rural water supplies in this country, the following comments should be taken into account:

The government of Japan dispatched two experts in water administration to the RWSD as an advisor to its director general during the periods of 1988/1989 and 1990/1991. The first expert carried out the follow-up survey of the previous Japanese projects with a loan and grants, and prepared a report on the results of the survey, in which he made reference to technical assistance as a necessary measure to assist in fostering human resources for this sector in this country as follows:

(1) Dispatch of an expert in groundwater development and hydrogeology
(2) Dispatch of an expert in operation and maintenance of water facilities, particularly for fostering and training engineers/technicians in the field of electrical engineering
(3) Continued dispatch of an expert in water administration tied with the dispatches of the above specialists
(4) Provision of comprehensive technical cooperation for water supply technology to promote water supply projects in this country

The RWSD currently assigns some staffs at its workshop to operation and maintenance work, but mainly due to lack of fund stemming from the official demarcation between this office and the LCCD on this job, the function of the RWSD in this line remains inactive. Therefore, it is deemed necessary that the RWSD should initiate a positive action by defining its function and securing an allocation of budget. As the first step, an organization of a operation and maintenance team in the RWSD is recommended to be formulated, not only for the dispatching on the occasion of unexpected trouble with facilities at the sites, but for the periodical patrolling. With such reform and improvement of organization of the RWSD, technical assistance from Japan could produce fruitful results under the cooperation of specialists in various fields including those in mechanical and electrical engineering along with the water administration expert.

4.3 PLANNING OF THE PROJECT

4.3.1 Framework of the Project

(1) Project Sites for the Planning

This Project is planned to undertake the construction of facilities for the five (5) sites out of eleven (11), where its execution is judged to be urgently required and the resultant effects related to investment are expected to turn out higher than those in others. For the remaining six (6) sites, details on their facilities are presented in this report for reference. The names of the sites in these two categories are listed as follows:

Table 4.2 List of Sites for the Project

1) Sites for the Basic Design Study

No.	Site Name	Governorate	Population (1991)	Planned Population (2006)
1.	Al Mallaheeth	Sa'dah	3,180	4,600
2.	Iyal Qasim	Sana'a	1,500	2,200
3.	Al Usfyn	Taizz	28,500	41,600
4.	Aflah Al Yaman	Hajjah	4,500	6,600
5.	Al Ghudu	Marib	1,770	2,600
	Total:		39,450	57,600

2) Other Sites for Facilities Designing

No.	Site Name	Governorate	Population (1991)	Planned Population (2006)
6.	Khamis Bani Hajaj	Sana'a	5,400	7,900
7.	Al Husha	Taizz	5,000	7,300
8.	Bait Al Sultan	Al Mahweet	3,600	5,300
9.	Bani Afif	Taizz	7,300	10,700
10.	Al Jabub	Ibb	2,000	2,900
11.	Mahalat Najr	Sana'a	2,000	2,900
	Total:		25,300	37,000

(2) Outline of the Project

1) The water supply systems to be installed under the Project include facilities for the water source (s), transmission facilities and distribution tanks with capacities to meet the planned supply rates in the target year in the four (4) sites except Al Usfyn among six. The one or more distribution tanks in the respective sites are designed to be installed at elevated locations which enable the future extension of distribution network on the Yemeni side to supply water by gravity to all the villages composing the respective sites.

2) Distribution pipelines for these four sites will basically be extended to the central areas of the sites nearest to the locations of the tanks. (These design principles shall be applied to other 6 sites for the planning for reference.)

3) In addition, to assist further extension of distribution lines from the end of those installed by the Japanese side in the four sites other than Al Usfyn, piping materials are proposed to be supplied to the respective sites under the Project for a portion of trunk mains for distribution which have been judged to be useful and effective, based upon the survey results. The installation work of such distribution mains shall be undertaken by the RWSD and/or the LCCDs responsible for the Project.

4) Al Usfyn is separately planned from the above 4 sites due to its extensive scale: it shall be provided with facilities concentrating on the water source development with appurtenant supply facilities.

4.3.2 Implementation Schedule

The implementation of the Project is largely affected by such features as the locations of the sites dispersed countrywide, construction environment in the rugged mountainous terrains, vast supply areas involving facilities of large scale, etc. Taking them into accout, it is relevant to divide the implementation schedule of the five sites into three (3) phases, with reference to the previous grant aid projects.

Each phase, based upon the rules of Japan's grant aid system, includes a routine process starting with the exchange of notes between both governments, followed by the consultancy contract, the detailed design survey, tendering, the procurement of equipment/materials, their shipping and the field construction in the final stage. Taking the priority order of the sites and their volumes of work into consideration, the most relevant phaseing of the whole Project involving the five sites is proposed as follows:

Table 4.3 Implementation Schedule of the Project

Phase	No.	Site No.	Site Name	Governorate	Population
First Phase	1.	(14)	Al Mallaheeth	Sa'dah	3,180
	2.	(1)	Iyal Qasim	Sana'a	1,500
Second Phase	3.	(6)	Al Usfyn	Taizz	28,500
Third Phase	4.	(11)	Aflah Al Yaman	Hajjah	4,500
	5.	(9)	Al Ghudu	Marib	1,770
			Total:		39,450

4.3.3 Planning of Facilities

(1) Composition of Facilities

The water supply systems in the Project are composed of the following facilities:

1) Water Source: New and/or existing deep wells

2) Intake Facilities: Deep well pumps with power drive units including pump stations housing equipment. Types of pumps are either a submersible motor pump operated by a diesel engine generator or a vertical shaft pump driven by a diesel engine.

3) Transmission Facilities: Booster pumps of horizontal volute type driven by diesel generators, pump stations, booster tanks and pumping main pipelines. Pipelines are either

galvanized steel pipes for ordinary service or galvanized steel pipes for high pressure service with both ends flanged.

4) Distribution Facilities:
Distribution tanks and distribution mains.

5) Service Facilities: Public fountains (6 taps or 4 taps) and hosepipe feeder for filling water tankers with connecting pipes.

(2) Facilities for the Respective Sites. The water supply systems for the respective sites are composed of the facilities outlined in the following list:

Table 4.4 Facilities for the Respective Sites

1) Project sites for implementation under the Project

Serl. No.	Site No.	Site Name (Governorate)	Water Source	Intake Facilities	Transmission Facilities	Distribution & Service Facilities
1.	14	Al Mallheeth (Sa'dah)	New Well ×1 No.	V.S.Pump × 2 Nos.	Pumping Main ø 2" --2-1/2" × 1,395m	Distribution Tank 120m^3 × 1 No.
			Existing Well ×1 No.	Pump Station × 1 No.		Distribution Line ø 2"-- 4" × 2,143m
						Public Fountain 1 No.
2.	1	Iyal Qasim (Sana'a)	New Well × 1 No.	S.Pump × 1 No.	Booster Pump × 1 No.	Distribution Tank 90m^3 × 1 No.
				Generator × 1 No.	Booster Tank 24m^3 × 1 No.	Distribution Line ø 1-1/2"--4" × 1,235m
				Pump Station × 1 No.	Pumping Main ø 2" --2-1/2"× 6,335m	Public Fountain 1 No.
						Hosepipe Feeder 1 No.
3.	6	Al Usfyn (Taizz)	New Well × 3 Nos.	V.S.Pump × 3 Nos.	Booster Pump × 1 No.	Distribution Tank 120m^3 × 1 No.
				Pump Station × 3 Nos.	Generator × 1 No.	Distribution Line ø 1-1/2"--6" × 30m
					Pump Station × 1 No.	Public Fountain 1 No.
					Booster Tank 48m^3 × 1 No.	Hosepipe Feeder 1 No.
					Pumping Main ø 4"--6" × 9,060m	
4.	11	Aflah Al Yaman (Hajjah)	New Well × 1 No.	S. Pump × 2 Nos.	Booster Pump × 2 Nos.	Distribution Tank 120m^3 × 2 Nos.
			Existing Well × 1 No.	Generator × 2 Nos.	Booster Tank 24/48m^3 ea. 1 No.	Distribution Line ø 1-1/2"--4" × 1,402m
				Pump Station × 2 Nos.	Pumping Main ø 3" × 7,465m	Public Fountain 3 Nos.
						Hosepipe Feeder 2 Nos.
5.	9	Al Ghudu (Marib)	Existing Well × 1 No.	S.Pump × 1 No.	Pumping Main ø 2-1/2"× 1,150m	Distribution Tank 75m^3 × 1 No.
				Generator × 1 No.		Distribution Line ø 1-1/2"--4" × 3,025m
				Pumping Station × 1 No.		Public Fountain 1 No.
						Hosepipe Feeder 1 No.

NB: V.S.Pump...Diesel driven vertical shaft pump
S.Pump.....Submersible motor pump

2) Project sites for planning (for reference)

Serl. No.	Site No.	Site Name (Governorate)	Water Source	Intake Facilities	Transmission Facilities	Distribution & Service Facilities
6.	3	Khamis Bani Hajaj (Sana'a)	New Well × 1 No.	S.Pump × 1 No.	Booster Pump × 3 Nos.	Distribution Tank 48/75m^3 ea. 1 No.
				Generator × 1 No.	Generator × 2 Nos.	Distribution Tank 120m^3 × 1 No.
				Pump Station × 1 No.	Pump Station × 2 Nos.	Distribution Line ø 1-1/2"--4" × 1,378m
					Booster Tank 24m^3 × 1 No.	Public Fountain 1 No.
					Pumping Main ø 3"--6" × 15,845m	Hosepipe Feeder 1 No.
7.	5	Al Husha (Taizz)	New Well × 2 Nos.	S. Pump × 2 Nos.	Booster Pump × 3 Nos.	Distribution Tank 90m^3 × 1 No.
				Generator × 2 Nos.	Generator × 2 Nos.	Distribution Tank 180m^3 × 1 No.
				Pump Station × 2 Nos.	Pump Station × 2 Nos.	Distribution Line ø 1-1/2"--6" × 1,145m
					Booster Tank 36m^3 × 2 Nos.	Public Fountain 2 Nos.
					Pumping Main ø'2-1/2" --4" × 13,390m	Hosepipe Feeder 1 No.
8.	12	Bait Al Sultan (Al Mahweet)	Existing Well × 1 No.	S.Pump × 1 No.	Booster Pump × 2 Nos.	Distribution Tank 120m^3 × 1 No.
				Generator × 1 No.	Generator × 1 No.	Distribution Tank 48m^3 × 1 No.
				Pump Station × 1 No.	Pump Station × 1 No.	Distribution Line ø 1-1/2"--4" × 394m
					Booster Tank 24m^3 × 1 No.	Public Fountain 2 Nos.
					Pumping Main ø 2-1/2"--4" × 9,141m	Hosepipe Feeder 1 No.
9.	4	Bani Afif (Taizz)	New Well × 1 No.	S.Pump × 3 Nos.	Booster Pump × 4 Nos.	Distribution Tank 75/90m^3 ea. 1 No.
			Existing Well × 2 Nos.	Generator × 3 Nos.	Generator × 2 Nos.	Distribution Tank 36/144m^3 ea. 1 No.
				Pump Station × 3 Nos.	Pump Station × 2 Nos.	Distribution Line ø 1-1/2"--4" × 2,619m
					Booster Tank 24m^3 × 2 Nos.	Public Fountain 5 Nos.
					Pumping Main ø 2"--4" × 13,575m	Hosepipe Feeder 1 No.
10.	7	Al Jabub (Ibb)	New Well × 1 No.	S.Pump × 2 Nos.	Booster Pump × 2 Nos.	Distribution Tank 48m^3 × 2 Nos.
			Existing Well × 1 No.	Generator × 2 Nos.	Booster Tank 36m^3 × 1 No.	Distribution Line ø 1-1/2"--4" × 2,300m
				Pump Station × 2 Nos.	Pumping Main ø 2"--2-1/2" × 8,330m	Public Fountain 3 Nos.
						Hosepipe Feeder 1 No.
11.	2	Mahalat Najr (Sana'a)	New Well × 1 No.	V.S.Pump × 1 No.	Pumping Main ø 3" × 3,300m	Distribution Tank 48/75m^3 ea. 1 No.
				Pump Station × 1 No.		Distribution Line ø 1-1/2"--3" × 1,310m
						Public Fountain 1 No.
						Hosepipe Feeder 1 No.

NB: V.S.Pump...Diesel driven vertical shaft pump
S.Pump.....Submersible motor pump

(3) Relation with Existing Facilities

1) Existing Deep Wells

Part of the sites already have deep wells as their sources -- three (3) sites among five intended for the implementation of the Project and also three (3) sites among six for facilities designing. These wells can be employed as part of facilities in the Project. The following measures are recommended to be taken about these existing facilities under the Project:

Existing wells tend in general to gradually decrease their yields due to clogging of well screens as years pass by. During the field survey, some of the existing wells including the one in Al Mallaheeth displayed such tendency. Therefore, it is planned to carry out cleaning of the wells to be employed for the Project. The direction for the operation of this work should be included in the tender specifications.

In addition, most of the existing pumping units were found to have been deteriorated, and are required to be replaced by new ones under the Project. The existing pump house of temporary structure in Al Ghudu is also recommended to be replaced.

2) Existing Water Facilities

Existing water supply facilities is owned only by Al Husha, but they have now been left idle since the water source has dried up. For these facilities, the RWSD has an intention to carry out rehabilitation work. Details of the survey on the facilities are described in Appendix IV-b.

(4) Relation with the Future Plan

The distribution tanks for the respective sites are designed to be installed in elevated locations in the sites suitable for supplying water by gravity to most of villages composing the sites, through the distribution trunk mains installed by the Japanese side and the extension of trunk mains and connection of service lines in the future by the Yemeni side. A rough estimate of pipeline lengths required for such extensions in the respective

sites except Al Usfyn ranges from 8,000 to 10,000 m, and piping materials for a major portion of such trunk mains are planned to be supplied to the respective sites under this Project, on condition that the installation will be undertaken by the responsibilities of the RWSD and/or the LCCDs.

For the future plan for the two especially large-scale projects of Al Husha and Al Usfyn, some details based upon the survey results are described in Appendix IV-b.

4.3.4 Operation and Maintenance Scheme

(1) Ongoing O/M System

The management, operation and maintenance of water facilities in rural areas in Yemen are currently entrusted to the responsibilities of the LCCDs installed in the respective districts (*Nahiyas*). Among the five sites where facilities are to be constructed in this Project are three communities having already operating the existing facilities for inhabitants, based upon the ongoing O/M system, as follows:

1) Al Mallaheeth (Sa'dah)

This site has been conducting a sustained operation of a water source facility constructed by the RWSD in 1984 under the responsibility of the LCCD of the *Al Dhaher* district. As it is a public facility, the LCCD offers water free of charge to such public institutions as schools, mosques, a dispensary and an army garrison in the central area of this site, but ordinary inhabitants must pay to cover the expenditure for its operation and maintenance including a salary for a full-time operator. (Refer to Clause 3.4.11 for details.)

2) Iyal Qasim (Sana'a)

In its strenuous efforts to provide stable water sources to this site, the LCCD of the *Dhi-Bin* district responsible for this site has so far drilled 7 deep wells in this area, which have all turned out virtually unsuccessful. However, two out

of these 7 wells can produce water at least, though the productions are confined to trickles of 1 to 2 m^3 a day, and the pumping facilities are now being operated by operators from the community to distribute bucketfuls of water to inhabitants suffering from the shortages of water. Such experience in sustained operation of facilities in this site is considered to be of help for the management of new facilities to be constructed in this Project.

3) Al Ghudu (Marib)

This site owns a water source facility installed by the RWSD in 1982, and has since been engaging in its sustained operation by the village operators under charge of the LCCD of the *Sirwah* district. Since the site and the facility is relatively small in scale, the operation has so far been continued without any problems.

Meanwhile measures for possible troubles after the commencement of operations in the respective sites are helped by technical service of the RWSD. Full-time counterparts assigned to the implementation of this Project are planned to organize a team supporting the LCCDs' operation of facilities. This team will arrange to dispatch the RWSD's engineering staff such as drilling engineers for the trouble with deep wells and mechanics for the damages to equipment, according to notices from the LCCDs on the nature of troubles. However, since the RWSD at present does not have sufficient staff in its Mechanical Division, the strengthening of this division is urgently needed. In Fact, it happened before that when a shaft of the deep well pump in Al Mallaheeth had once been broken during its operation, the LCCD repaired it by itself without help of the RWSD, with its expense compensated by the incomes from selling water to inhabitants.

(2) Operation Scheme

Full-time operators for daily operation and maintenance of facilities are planned to be employed by the LCCDs in the districts and/or sub-districts. Since the facilities in this Project employ power driving units such as diesel engines or diesel generators quite popular all over the country, it is not

difficult to recruit experts in the operation and simple repair of this type of equipment, as is suggested by the operation of water source facilities in many places and the recent development of rural electrification with diesel generators. (As a example, the facilities for the preceding project for the Ar Rajam Block C area is now being operated by three full-time staff members all recruited within the district.)

Based upon the facilities composing the water supply systems in the respective sites, the staffing program for the O/M scheme is planned as follows:

1) Al Mallaheeth

This site is designed to have two water source facilities, which can be operated by a skilled operator and an assistant. An additional staff member is planned to be posted at the service facility in the central part of the site. The total staff members are three (3).

2) Iyal Qasim

In this site, a booster pump is designed to be installed in the deep well pump station. The same staff members as those in Al Mallaheeth can manage the operation. The total is three (3).

3) Al Usfyn

The facilities for this site are composed of three deep well stations and one booster pump station at the water source site and a reservoir with a service facility near the planned supply area. The water source site needs two skilled operators with one assistant, while the service station, two assistants. Two shifts of these staff members are required to manage a daily operation in this site continuing for long hours to meet a huge demand. The total number of staff is, therefore, ten (10).

4) Aflah Al Yaman

This site has two individual supply systems, each of which can be operated by one skilled operator supported by one assistant. The total staff members are four (4).

5) Al Ghudu

Thanks to a simple composition of its facilities, this site needs to employ only one skilled operator and one helper.

These new employees cannot be expected to have expertise in the systematic operation of the systems involving high-grade equipment such as high-pressure horizontal pumps. In this view, it is arranged to provide them technology transfer during the periods of the test operation and the delivery of facilities concerning the fundamental operation and periodical maintenance of facilities and equipment. Small instruction manuals in Arabic are to be delivered to them. The RWSD is required to take prompt steps whenever requested by the LCCD in case of damages and troubles with facilities and equipment.

In the past the local operators were given an opportunity to attend the training course offered by the RWSD at its headquarter in Sana'a, which had been established with sponsorship of the WHO and support of the USAID. It has been suspended for these two years because of lack of fund. The RWSD eagerly wishes to resume this course as earlier as possible, with its reorganization plan for the authority including a training division specially intended for the improvement of local operators' capability. The previous courses used to give lessons on the mechanism of pumps and engines as well as exercise in their operation, including even a lesson for the concept of sanitation and health, for the period of one month, and at the end of the course, trainees were given certificates. When the course is resumed, the operators to be involved in this Project will have a chance to receive training through the application by the LCCDs (The draft report mission confirmed in November 1991 that the RWSD had been able to restart the training course in August 1991 with the assistance of the WHO and the government of the Netherlands. The first session ended in September with a successful result of 22 graduates of trainees

dispatched by the LCCDs from various part of the country. The next course is scheduled to be held in December. As a result, the chance to operators to be involved in this Project later stand a good chance to participate in this course.)

(3) Equipment and Materials for the O/M of Facilities

The local market has long been running short of equipment and materials for water supply facilities due to the country's severe shortages of foreign reserves. In view of such situation, it is indispensable to provide spare parts and standbys for main equipment composing the facilities as well as some O/M equipment for their sustained operation and maintenance as follows:

1) Deep Wells

In the preceding grant aid projects, a flow meter was installed at each of the deep well pump stations for the control of its operation, but daily measurement of yields does not seem to be observed in the sites. It is necessary to underscore again the necessity of exercising a regular operation of measurement to the representatives of the LCCDs as well as responsible operators on the occasion of the delivery of facilities under this Project. In addition, it is planned this time to provide a potable equipment for water level measurement at each of deep well pump stations in the respective sites, along with arrangements to install a tube line inside the deep well for lowering a measuring tape with an electrode. In this country, a damage to a deep well is frequently caused through overpumping, resulting in the drastic fall of water level and eventually leading to the decrease of its yield. Since the regular measurements of both the water level and yield help operators to get signs of any critical changes in the wells, technology transfer during the test operation is aimed at inspiring their attention to the relation between the water level and the yield for the sustained control of essentially important water source in their facilities.

2) Pumps

The types of deep well pumps to be employed in the Project include both a submersible motor pump and a vertical shaft pump. Concerns arise with the former, since some cases of overloading during its operation caused by unexpected reasons may result in burning of a submersible motor. Since a prevailing type of a submersible motor is of water-sealed one, this accident necessitates a complete replacement of this part. To safeguard against such a situation, it is recommended to include a standby supply for the part of motor. The vertical shaft pump is quite popular in this country, most of them imported from European countries, and the best way is considered to employ one of these models with spare parts for the Project.

High pressure volute pumps to be used as booster pumps are practically very hard to get in this country, with the same trend anticipated to remain in the near future. This type of pumps is required to be supplied with standbys.

3) High Pressure Plumbing Materials

Valves for high pressure service are not found in the local market, requiring extra ones as follows:

a. Air vent valves : One or two pieces of 1" in size shall be provided, according the site conditions.
b. Slow closing check valves: This type of valves is used with both deep well pumps and booster pumps for protecting against possible water hammering. Each extra piece of different sizes employed in the system shall be provided.
c. High pressure cast steel gate valves: This type of valves shall be supplied in the same manner as for check valves.

4) Power Drives

Power drives including diesel engines and diesel generators are planned to be delivered with spare parts in an amount equivalent to 20% of the equipment price, which are normally sufficient enough for the operation of 2 to 3 years.

(4) Operation and Maintenance Cost

The rural water supplies in this country is administered by means of water billing to inhabitants to cover operation and maintenance cost of facilities. The same process has been applied to the water facilities completed under the preceding loan and grant projects. According to the results of the follow-up survey in 1989 by the Japanese expert assigned to the RWSD, an average monthly spending of a household was less than YR50 in 84% of 26 sites included in the loan project. (At that time, in 63% of these sites, an average consumption was less than 30 liters per capita per day.) These water incomes were used mainly for salaries of full-time operators and fuel costs, with some sites collecting installments for reserves for probable repair costs of equipment.

The LCCDs involved in this Project employ a similar method for their management of facilities. There are two types of charging systems in practice in this country; one is based on a consumed water volume which is measured at a meter installed on each household connection; and the other is a fixed rate charging method allocating a fixed amount to each household. Since under this Project water is served at public fountains and feeders for tankers on vehicles, management must employ the fixed rate charging system.

The operation and maintenance cost in the Project is made up of the following components:

1) Operators' Salaries
   Based upon the results of the expert's follow-up survey and the inspection of previous projects this time, an average salary for a chief operator is fixed at YR2,500/month and that for an assistant, at YR1,500/month.

2) Fuel Cost
   This cost includes expenses for fuel required for driving all the equipment composing the facilities. At present, diesel cost is an officially fixed rate of YR4.0/liter.

3) Lubricant Cost

Ten (10) percent of the fuel cost is allocated to the expense for lubricants for equipment.

4) Equipment Repair Cost

Although spare parts and standbys are supplied for the main equipment, this item is included for a reserve fund for repairing unexpected damages and troubles with equipment. An appropriate level is assumed to be 10% of the total of the above items from (1) to (3).

Based upon this assumption, the operation and maintenance costs of facilities for the respective sites are estimated, as shown in Table 4.5. Such factors as an average number of household members and the average monthly incomes in the respective sites are based upon the results of interviews carried out by the survey team, with the former set at 8.5 persons/household (mostly from 7 to 10), and the latter as reported by the LCCD's representatives (ranging from YR1,600 to YR3,000).

Table 4.5 Estimated Maintenance and Operation Costs in Five Sites

No.	Site Name	O/M Cost per 1 m^3 of water (YR)	O/M Cost per household per month (YR)	Ratio of O/M Cost Share to Income(%)
1.	Al Mallaheeth	4.0	41	1.6
2.	Iyal Qasim	13.0	99	3.3
3.	Al Usfyn	3.6	28	1.6
4.	Aflah Al Yaman	7.7	79	2.4
5.	Al Ghudu	6.5	50	1.5

At present inhabitants in the sites are paying YR100 to YR300 for one cubic meter of water, while the facilities completed under the project will be able to serve them at an expense less than one tenth of what they are now respectively paying. The ratios of

water costs to household incomes are seen to be less than 5% in all the sites involved in the Project, indicating the compliance to the recommendation of the IBRD/IDA to rural water authorities in developing countries to manage to formulate a water billing system in which that ratio is less than 5%. As a result, the new facilities can help to save much of economic burden inhabitants are now bearing on their shoulders. The details of the calculation for these costs can be referred to in Appendix IV-e.

CHAPTER V

BASIC DESIGN STUDY

CHAPTER V. BASIC DESIGN STUDY

5.1 DESIGN POLICY

The basic design study for the Project deals with the five (5) sites based upon the results of the field survey and their analyses to formulate the planning of facilities and equipment/materials as well as to establish the implementation schedule, the project cost, the phasing of the schedule and other necessary details. The remaining six (6) sites are also treated in this study on the planning of facilities for reference.

Taking into account various characteristics of the Project sites such as the natural conditions of the rugged mountainous terrain in which villages are dispersed etc., the design policy for the Project is aimed at establishing the effective and efficient water supply systems in the respective sites in line with the principles of Japan's grant aid system, concentrating on such features as the selection of suitable equipment and materials, determination of relevant construction method and establishment of practical implementation schedule.

Since the operation and maintenance of the completed facilities are to be undertaken by the local administrative bodies of the LCCDs, the establishment of properly working systems, enabling them to carry out sustained and stable operation, is conceived to be of essential importance.

5.2 STUDY ON DESIGN CRITERIA

5.2.1 Water Sources

(1) The water sources shall be groundwater which is commonly employed in the rural water supply scheme of this country. To ensure stable and sanitary water supplies, new deep wells are basically planned to be drilled in the sites. In the sites where the existing deep wells are judged to be productive enough for planned demands, they are incorporated into the Project as its water

sources. Wherever it is necessary, the combined water sources of new and existing wells are employed.

(2) The yields of deep wells are examined through the analysis of the results of hydrogeological survey including the field tests, review of existing pumping records, etc. The numbers of deep wells in the respective sites are determined, based upon such examination of the yields of wells to meet the planned supply rates for the respective sites in the target year. The locations of new deep wells shall be based upon the results of the field survey.

(3) The structures of new deep wells are determined, based upon the hydrogeological characteristics of the respective sites clarified by the field survey, conditions and distributions of aquifers, types and sizes of pumping equipment to be installed, etc., with reference to the design in the preceding projects.

(4) Groundwater in this country mainly occurs as fissure water through lineaments. The characteristics of this type of water are required to be reflected in the determination of the numbers of wells based upon the examination of yields so that the planned yields can be obtained in sustained and stable condition.

5.2.2 Target Year of the Plan

The target year for the water supply scheme commences from the date of the planning. It should be neither too short nor too long, since the shorter one is likely to result in a risk of necessitating an expansion of the plan before it is reached and the longer one, in an excessive investment. While most of plans for municipalities and communities in Japan range from 10 to 15 years, those in Yemen generally extend from 15 to 20 years. The 20 years are mainly applied to relatively small-scale rural projects where changes tend to take place slowly with a scarce possibility of needing an immediate expansion of facilities. In contrast, since this Project needs urgency in its implementation, covering extensive planning areas, the target year of 15 years should be employed for its planning.

5.2.3 Planned Service Areas

The planned service areas in the respective sites shall basically be those including all the villages confirmed among the concerned parties including the LCCDs during the field survey. The names of the villages constituting the planned service areas are referred to in the attached lists for the respective sites in Appendix III-f, with their locations based upon the topographic survey during the filed survey shown in the basic design drawings in Appendix V.

5.2.4 Planned Served Population

The planned served populations shall be the numbers of residents in the planned service areas in the planning target year. The present populations in the respective sites are based upon the results of the field survey, and the planned populations are projected with a population growth rate examined in Clause 3.2 of this report. The summary of such projected populations in the respective sites are shown in Table 5.1, with their details shown in the lists of Appendix III-f.

Table 5.1 Planned Served Populations in the Sites

Category	No.	Site Name	Present Population (1991)	Planned Served Population (2006)
Sites for the Basic Design Study	1.	Al Mallaheeth	3,180	4,600
	2.	Iyal Qasim	1,500	2,200
	3.	Al Usfyn	28,500	41,600
	4.	Aflah Al Yaman	4,500	6,600
	5.	Al Ghudu	1,770	2,600
Total:			39,450	57,600

Other Sites for Reference	6.	Khamis Bani Hajaj	5,400	7,900
	7.	Al Husha (Center Zone)	5,000	7,300
	8.	Bait Al Sultan	3,600	5,300
	9.	Bani Afif	7,300	10,700
	10.	Al Jabub	2,000	2,900
	11.	Mahalat Najr	2,000	2,900
Total:			25,300	37,000

5.2.5 Unit Supply Rate

A unit supply rate for the Project should be determined, with reference to the real performance of other similar projects. The design criteria of the RWSD have a guideline to indicate that a per capita per day consumption for a project serving at public fountains in mountainous areas should be 45 liters, while the preceding Japanese projects put it at 40 liters. For determining a pertinent supply rate for this Project, the results of the field survey this time and those of the follow-up survey for the preceding projects have been analyzed as follows:

(1) Follow-up Survey of the Preceding Japanese Projects

The follow-up survey of the preceding Japanese projects was conducted in 1989 by the Japanese expert dispatched in 1988 to the RWSD as an advisor for water administration, concentrating on studying the working conditions of the facilities constructed with a loan from the government of Japan, which had started operation around 1985. This project involved various types and scales of communities all over the country, and most of installed facilities were under management of the LCCDs. The survey found that the 26 sites under this project had already installed house connections and that the facilities had been run by means of water billing system by the LCCDs. Since no sites kept operation records of facilities, real consumption rates were estimated during the survey by the expert, based upon the conditions of operation, water rates incomes, etc., as shown in Table 5.2

Table 5.2 Consumption Rates in the Loan Project Sites (Surveyed in 1989)

Range of Consumption Rate (l/c/d)	10 - 20	21 - 30	31 - 45	Over 45
No. of Sites	7	6	4	6

In this table, the sites where the consumptions exceeded 46 liters per capita per day include those located in the Tihama coastal plain where an average consumption is normally quite high due to its heat and humidity as well as a local city of relatively large scale. After the exclusion of these sites having such special conditions, a unit consumption rate less than 30 liters per capita per day accounts for 62% of the sites with house connections. Further, during the survey the expert visited some of the sites in the Japanese grant projects, where the residents had still been using public fountains installed under the projects with their consumptions ranging from 10 to 20 liters per capita per day. Therefore, a prevailing unit consumption is suspected to be normally under 30 liters in the public-fountain service systems.

(2) Field Survey on Consumption for This Project

Average consumption rates surveyed for this study are listed in the following table:

Table 5.3 Consumption Rates in the Project Sites (1991)

Range of Consumption Rate (l/c/d)	10 - 20	21 - 30	31 - 40	Over 41
No. of Sites	3	4	3	1
Name of Sites	K.B. Hajaj Al Husha Al Usfyn	I. Qasim Al Jabub A.A.Yaman A.Mallaheeth	M. Najr Al Ghudu B.Sultan	Bani Afif

In comparison with the results of the aforementioned survey, a strikingly similar pattern of consumption can be recognized in the list, although the inhabitants of these sites are currently in practice to buy water as costly as more than ten times those in the preceding projects. This situation may be interpreted to suggests the fact that nowadays rural communities in mountainous areas absolutely necessitate water at a level of 30 liters per capita per day for sustaining their lives. Another example in the survey in Al Rajam this time shows that an average consumption of residents in the Al Rajam city is about 20 liters per capita per day, even though house connections are now prevalent in that area.

Taking the results of these surveys into account, it is proposed that a unit supply rate be determined to be 30 liters per capita per day as an essential need of inhabitants in the mountainous areas. However, in the three sites of Aflah Al Yaman (No. 11) and Al Mallaheeth (No. 14) influenced by a hot weather of the Tihama plain and Mahalat Najr (No. 2) close to an urban area, a higher rate of 40 liters per capita per day is proposed.

5.2.6 Planned Supply Rates

For the formulation of planning for facilities and equipment, various supply rates are designated as follows:

(1) Planned Daily Average Supply Rate

This rate is the total volumes of daily water supply for the respective sites in the target year, calculated as follows:

(Planned served population in the target year) x
(Unit per capita per day consumption = 30 or 40 l/c/d)

(2) Hourly Maximum Supply Rate

This rate is employed for the calculation of the size of distribution lines intended for the house connection system. Although the installation of distribution lines in this Project is

confined to part of the villages composing the sites, this unit rate is required for selecting proper sizes of lines, since the distribution systems in the respective sites will be expanded by the Yemen side, using the piping materials supplied under the Project, and service lines are expected to be connected to those extended distribution lines with inhabihants' expenses in the near future. However, since the RWSD has no relevant criteria for this rate, the authorized standards for Japan's rural water facilities have been referred to for this study. Although the current water consumption in Yemen's mountainous areas is typically concentrated during 10 hours of the daytime, the completion of house connections in the sites in the future is expected to result in gradually shifting to a pattern of water consumption similar to the one under 24-hour service. Since the aforementioned standards are based upon actual cases of water supplies through house connections for a similar range of populations as those in this Project, its application is judged to be relevant. The calculation of the hourly maximum supply rate is made, using the following formula:

(Hourly maximum supply rate) =
{(Planned average daily supply rate) x 1.5 x
(Ratio of hourly maximum rate based upon village population)}
÷ 24 hours

5.2.7 Comparison of Criteria with Preceding Projects

The comparison of various factors for the planning, along with features of main facilities are shown in Table 5.4.

Table 5.4 Comparison of Water Supply Planning

No.	Parameter	OECF Loan Project	Study by JICA (1979/1980)	Grant aid project phase IV to VI	This Project
1.	Design Population	Mainly based upon the survey at the respective sites with reference to 1975 census by sampling by CPO Growth rate; Rural : 3% Urban : 6%	Based on the survey at the respective sites and 1981 census by CYDA Growth rate; Large Community : 6% Medium Community : 3% Small Community : 2.5%	Estimated with reference to 1982 and 1986 census by CPO Growth rate; Mountaneous area : 1.7% Plain area : 2.9%	Estimated with reference to 1982 and 1986 census by CPO, 1982/83 population census by UN, Design Criteria for rural water Supply Facilities by RWSD Growth Rate; Mountaneous area: 2.55%
2.	Target Year	15-20 years hence	15 years hence	20 years hence	15 years hence
3.	Per capita consumption	Rural:45 l/d/c Urban:70 l/d/c (indluding supply for livestock)	Rural:40 l/d/c Semi-urban:70 l/d/c (Supply for livestock added separately)	Same as Criteria of JICA study (Supply for livestock not included)	30-40 l/d/c (Survey results of natural environment, supply condition and village scale of sites)
4.	Design supply rate	Daily average supply=(Per capita consumption)×(Projected population in design target year) Daily maximum=(Daily average)×1.5	Daily average: Same as OECF loan project Hourly maximum = (Daily average)/10 hrs × 1.5	Daily average: Same as OECF loan poject Daily maximun: same as OECF loan project	Daily average: Same as OECF loan Project Daily maximum: Same as the study by JICA
5.	Service hour	not specifically determined	10 hrs	24 hrs	24 hrs
6.	Water source and intake pump	Deep well (Submersible motor pump:SP) Shallow well (Borehole pump:BP)	Deep well (Submersible motor pump)	Same as OECF loan project: Basically, SP: for pumping head higher than 200m BP: for pumping head less than 200m	Same as Grant Aid phase IV to VI
7.	Distribution tank	Type: Steel panel tank Storage volume: 12 hrs of daily average	Type: Same as OECF loan project Vol: (Hourlymax × 3hrs)+ (Emergency storage)	Type: Same as OECF loan project Vol:(Daily max) or (Storage hour rate by population of daily max)	Type: Same as OECF loan project Vol: Analysis of average water demand patern curve as design storage capacity + Emergency storage capacity
8.	Pipeline	Type: Galvanized steel pipes for water service (SGP) Diameter: Calculated by Hazen-Williams Formula	Type: SGP and carbon steel pipes for pressure service (STPG) Diameter: Same as OECF loan project	Type: SGP and STPG Diameter: Same as OECF loan project	Type: SGP and STPG Diameter: Same as OECF loan project 1-1/2"--6"
9.	Supply system	Initially point source type system, later upgraded to improved water system, service tank to a higher location in the village. Planned to serve by public fountain.	Basically point source type system with public fountain as service facilities. During implementation a part of projects were upgraded to improved systems.	Basically improved water system. In urban area distribution network is planned.	Basically improved water system, but distribution lins limited to the village near the tank. Planned to serve with public fountain & hosepipe feeder.

5.3 PLANNING OF FACILITIES

5.3.1 Water Source Facilities

(1) Deep Well Sources

The water sources in the respective sites of eleven have been studied, based upon the results of the field survey, the hydrogeological study and the analyses of existing drilling data. The details are referred to the descriptions on the features of the respective sites in Chapter 3 as well as to various hydrogeological data in Appendix. Table 5.4 summarizes the results of these studies, including the categories of deep wells, their depths, aquifer characteristics, planned yields and daily possible productions.

Although seven (7) sites out of 11 own existing deep wells which may be used for the Project, those where the existing wells can meet the planned demands are only two (2) - Site Nos. 9 and 12, and the number of the sites with existing well(s) where a new well (s) is planned to be additionally installed are four (4) - Site Nos. 4, 7, 11 and 14. In five (5) sites - Nos. 1, 2, 3, 5 and 6, the demand will be covered solely by new deep wells to be drilled in the Project. For Al Usfyn (No. 6), three deep wells are planned to be installed to cover a large demand.

In the planning covering the entire 11 sites, the number of required wells totals 19, out of which new ones are 12. For five (5) sites to be executed in the Project, 6 new wells are planned to be drilled.

(2) Yields

The daily productions of the respective wells listed in Table 5.5 have been estimated, based upon the hydrogeological study including field testing during the survey and the existing pumping records. On the other hand, the planned yields are based upon the daily requirement of planned average supply rates, which is intended to be pumped basically during a 10-hour operation period commonly employed in this country. The operation hours vary, however, with the demands, including the longest operation of 17

hours in Al Usfyn (No. 6).

Table 5.5 List of Deep Well Sources in 11 Sites

Category	Site No.	Site Name	Water Source/ Well Depth	Aquifer	Design Yield m^3/day	Daily Production m^3/day
Sites for the Basic Design Study	14	Al Mallaheeth	1)Existing 75m 2)New 130m	Precamblian Schist	80 107	210 500
	1	Iyal Qasim	1)New 200m	Upper Jurassic Limestone	76	270
	6	Al Usfyn	1)-3)New 150m	Alluvium/ Yemen Volcanics	415×3	576×3
	11	Aflah Al Yaman	1)Existing 148m 2)New 150m	Precamblian Granite Gneiss	134 129	450 450
	9	Al Ghudu	1)Existing 200m	Jurassic Limestone	78	720
Sites for Reference	3	Khamis Bani Hajaj	1)New 220m	Upper Jurassic Limestone	237 300	720 720
	5	Al Husha	1)-2)New 200m	Tertiary Yemen Volcanics	175×2	290×2
	12	Bait Al Sultan	1)Existing 102m	Cretaceous Sandstone	158	510
	4	Bani Afif	1)Existing 156m 2)Existing 270m 3)New 150m	Tertiary Yemen Volcanics	108 106 106	1,090 351 400
	7	Al Jabub	1)Existing 225m 2)New 200m	Tertiary Yemen Volcanics	50 50	220 220
	2	Mahalat Najr	1)New 100m	Quaternary Volcanic Rocks	117	720
Total			Existing Well 6 Nos. New Well 11 Nos.			

A daily production from a deep well varies with the hydrogeological conditions and aquifer characteristics, and those in this Project are seen to range from 200 to 1,090 m^3/day, with planned yields from 83 to 454 m^3/day. In case an average consumption of rural water supplies is assumed to be 30 liters/capita/day, one deep well is calculated to supply water to 2,700 to 15,000 inhabitants. A great difference in served

populations reflects complex hydrogeological conditions of this country.

(3) Structure of Deep Wells

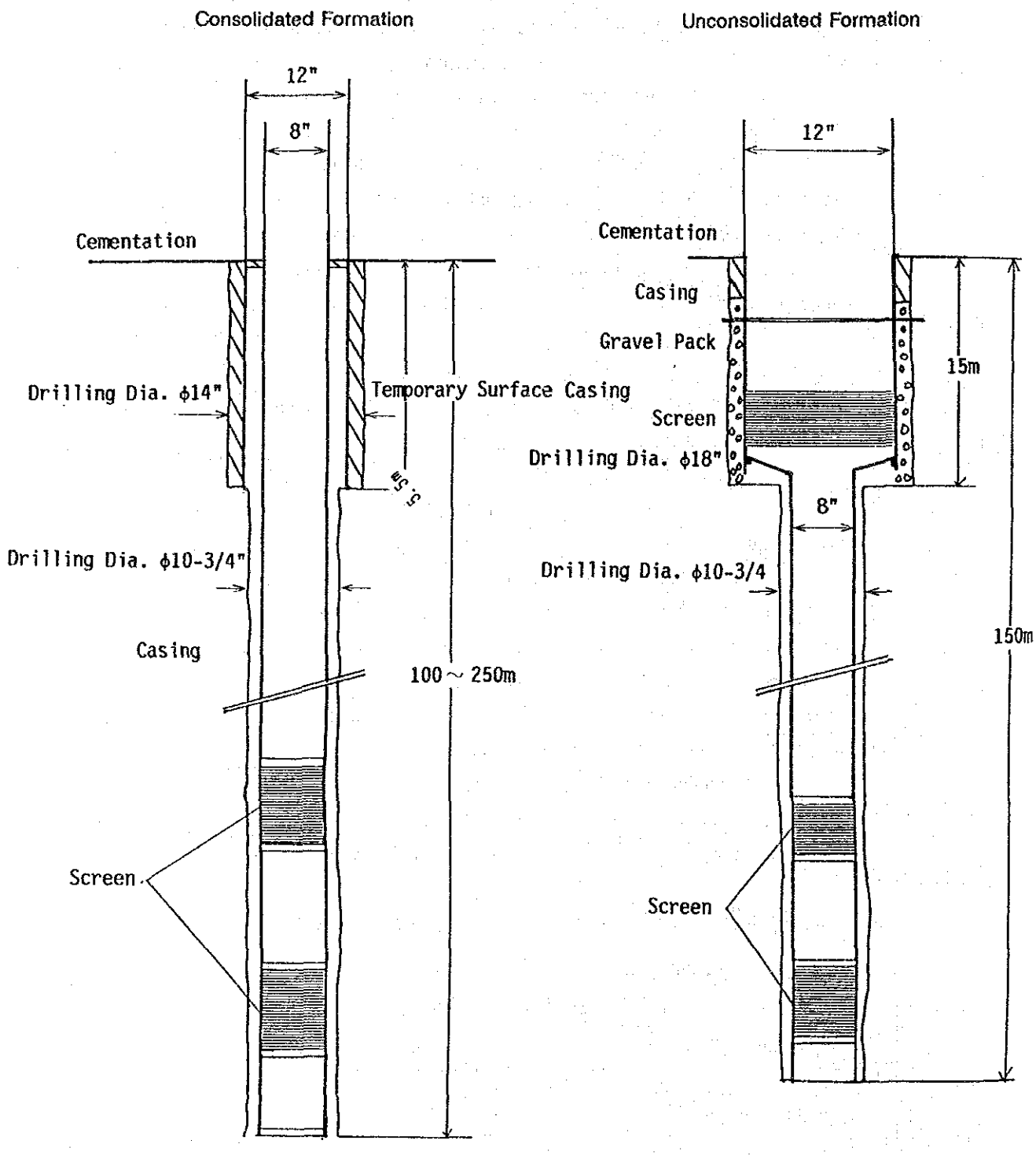
The factors determining the structure of new wells including their locations, drilling depths, sizes of wells, aquifer depths, etc. were studied through the hydrogeological studies including the application of geophysical survey and the analyses of existing drilling data and information for the respective sites. The sizes of boreholes and well casings have been decided after the estimate of their productions through the study has concluded the selection of suitable pumps. The drilling depths and screen lengths have mainly been based upon the results of geophysical survey, along with the analyses of existing drilling records. (Refer to Appendix III-a)

The size of well casing is designed to be 8" for housing pumps in sizes determined through the requirements of pumping rates and heads in water supply planning. The depths of the wells are designed to range from 100 m to 250 m, to tap fissure water in aquifers through lineaments penetrating various types of rocks such as the Precambrian granite gneiss and schist, the Jurassic limestone, the Cretaceous sandstone and the Tertiary and Quaternary volcanic rocks, based upon the results of the hydrogeological study. However, in Al Usfyn (No. 6), a design to tap the alluvial aquifer in the wadi zone is proposed, with its part of the well having a diameter of 12" to 15 m in depth, followed by a common size of 8", which penetrate underlying volcanic rocks. The table below summarizes these well structures and the diagrams of typical structures are shown in Fig. 5.1.

Table 5.6 Summary of Structures of Deep Wells

Sites	Well Casing Size	Well Depth	Average Well Screen Length
5 Sites other than Al Usfyn	ϕ 8"	100 m - 250 m	30 m
Al Usfyn(No.6)	ϕ12" ϕ 8"	0 m - 15 m 15 m - 150 m	5 m 25 m

Fig.5.1 Typical Structures of Project Wells



5.3.2 Pumping Equipment

(1) Selection of Pumping Equipment

Deep well pumps to be employed for the Project shall be either vertical shaft pumps driven by diesel engines or submersible motor pumps driven by diesel engine generators. The characteristics of both types are compared in the following table.

Table 5.7 Types of Deep Well Pumps

	submersible motor pump	vertical shaft pump
Structure	One assembly of a pump and a motor, both installed in the well, driven by a power source on the ground surface through electric cable.	A pump installed in the well and a drive unit on the ground surface, connected with a string of shaft for power transmission
Power source	Electricity (generator)	Mechanical power transmission with engines (electricity can also be used)
Capacity & other features	High-velocity driving. High-pressure types can be manufactured.	High velocity not possible due to long-shaft structure
	Overloading may be caused through intrusion of sand or other foreign material resulting in burning of motor.	Relatively strong against foreign materials due to its mechanical structure.

Of the two types, diesel engine driven vertical shaft pumps are overwhelmingly popular due to constraints in the availability of electrical power in this country, and their operation and maintenance are being undertaken without much difficulty in most of the country. Therefore, the employment of this type is basically desirable unless a specifically higher lifting pressure

becomes necessary because of the requirements of facilities. In this Project, it is to be employed for the deep well facilities where the required lifting is less than 200 m.

Under this Project, most of the sites need transmission facilities to send water up to reservoirs on the mountainsides with a booster pump installed in the deep well station. Since the booster pump normally requires a generator for its power source, it is considered to be relevant from the viewpoint of operation and maintenance to install one common unit of power source for driving both a deep well pump and a booster pump in the station. In this case, even when the lifting capacity required for the deep well pump is less than 200 m, a submersible motor pump is required to replace a vertical shaft pump. (For further details, refer to Appendix IV-c.)

The necessity of submersible motor pumps where either the lifting capacities are more than 200 m or they are stationed together with a booster pump requires arrangements for providing spare parts to protect against possible accidents of motor burning. For the past grant projects from Phase IV to Phase VI, standby submersible motors were supplied and such arrangements are deemed necessary for this Project as well.

(2) Control of Pumping Equipment

In view of ongoing operation of facilities for rural supplies by the LCCDs, overly complex automatic controlling of pumps is not pertinent, since it is most likely to result in confusion whenever something goes wrong with controls due to lack of expertise in electrical equipment. Accordingly it is proposed to be provided only with essentially required controls as follows:

1) Low Water Level Control for Deep Wells

The drastic fall of water levels in deep wells due to overpumping is likely to cause troubles with deep wells as well as with pumps such as burning of a submersible motor. The following protective measures are proposed to be taken in connection with the operation of both types of pumps:

a. Vertical shaft pumps: A line of tube for measuring the water is planned to be installed together with the pump inside the well. Through technology transfer the operator is directed to carry out daily measurement of the static water level as well as levels during pumping from time to time to oversee the condition of drawdown so that be can control the pumping rate. A potable unit of water level measuring device is planned to be installed at each pumping station for that purpose under this Project.

b. Submersible motor pumps: With this type of pump using electricity, a low water level cut-off switch can be installed on the control panel for safeguarding a pump against excessive drawdown. However, automatic restarting when the water level has recovered is not recommendable. The measurements of water levels by operators are instructed to be their duty, as is the case with a vertical shaft pump.

2) High Water Level Alarm for the Reservoir

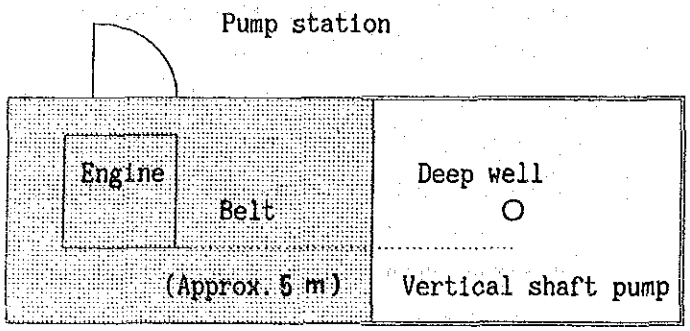
Reservoirs in rural water supplies usually have no controls, and after they get filled up to a high water level, water is left to drain out through an overflow until the pump is stopped. The control of pump operation, therefore, depends entirely upon the operator's daily experience, although they take care lest water should excessively drain out.

As a measure to improve such a conventional style of operation, this Project plans to provide an alarm to let operators know when the reservoirs are full. This device uses a detector/transmitter to the alarm, of an abrupt change of dynamic pressure in transmission lines when the reservoir is filled up.

(3) Deep Well Pump Stations

The pump station for housing a deep well/deep well pump needs a special measure different from that for a booster pump. In case any trouble happens to a well or a pump, a crane truck or sometimes a drilling machine is called for the operation at the

base of the well. Therefore, to seclude the well entirely in a pump house is not advisable. In many local pump houses, the well is left in the open outside the shed which houses only an engine for driving a pump, as shown below.



The existing water sources in Al Ghudu (Site No. 9), a site to be implemented under this project, has the pump house of such structure built of coarse material, and are required to be replaced by a new one of the Project design. On the other hund, the existing deep well in Al Mallaheeth (Site No. 14) is housed in the pump station of reinforced concrete block construction, with a hatch built on the roof to allow an operation for repairing. This pump station is attached with a reservoir of 30 m^3 in capacity, built of reinforced concrete. Since the entire construction of this station looks quite rigid, it is judged to be employed in this Project with minor work for renovation.

On the other hand, a design for a new pump station is planned to provide a detachable structure for the part of a well, of prefabricated construction of keystone steel plate fastened with bolts to the walls and floor of the pump house so that it can be removed when an operation is necessary at the base of the well. The pump house is made up of reinforced concrete roof and columns and concrete block walls with their outside surface finished with gun spraying of mortar. (For further details, refer to the basic design drawings in Appendix V.)

5.3.3 Booster Pumps

(1) Types of Booster Pumps

In contrast to vertical pumps for deep wells, booster pumps for this Project are horizontal pumps directly coupled to drive units. In most of the sites, the difference in height between the deep well source in the wadi lowland and the distribution tank on the mountain is so large that a booster pump is required to have a pressure head over 200 m. To meet this requirement, high-velocity and high-head pumps are designed in the respective supply systems.

This type of pump is driven with a 2-pole electric motor. Ordinary types with their heads in a range of 100 m or less use 4-pole motors at a revolution of 1,500 to 1,800 per minute. The revolution of a 2-pole motor rises to double that of a 4-pole motor. To sustain a balanced operation of the pump at such a high rate of revolution, it is necessary to drive it with a suitable electric motor under stable supply of electric power. For this purpose, it is advisable to employ a diesel engine driven generator for the operation of high-velocity pumps.

While it's possible to use industrial engines even for driving this type of pumps, this Project recommends to employ the most conventional style of operation of a high-velocity booster pump combined with a 2-pole electric motor powered by a diesel generator to ensure a stable and safe operating condition.

(2) Controls for Booster Pumps

Controlling of booster pump operation is based upon a similar principle to the one for the deep well pump, as follows:

1) Reservoir Low Water Level Controls

A booster pump shall be installed with a control panel including a system to automatically stop its running when the water level of the reservoir has dropped to its low. However, the automatic recovery of operation is not considered to be necessary.

2) Reservoir High Water Level Alarm

With a booster pump, an alarm device on the high water level of the destination tank shall be provided.

(3) Booster Pump Station

The main structure and finish of the booster pump station is the same as those of the deep well station except a well shed attached to the latter. In part of the sites, the booster pump is designed to be installed in the deep well station housing a generator for driving it and a deep well pump simultaneously.

5.3.4 Pipelines

(1) Classification of Pipelines

In this planning, pipelines are grouped into two large categories of transmission and distribution lines; the former includes every pipeline connecting the water sources and the distribution tanks; and the latter covers those extending from the distribution tanks including some service lines. The basic policy for pipelines in this Project is tabulated as follows:

Table 5.8 Groups of Pipeline

Group	Type	Pressure Head	Pipe Connection
Transmission Lines	Galvanized steel pipe for ordinary service	Less than 15 kg/cm²	Threaded
	Galvanized steel pipe for high pressure service	Over 15 kg/cm²	Flanged
Distribution Lines	Galvanized steel pipe for ordinary service	Less than 15 kg/cm²	Threaded

Since most of pipelines are laid exposed on the rugged rocky slopes of mountainsides, all pipe to be used shall be made of steel to ensure strength and flexibility. Pipe shall also be galvanized to prevent weathering and rusting.

Ordinary pipelines are basically connected with threads. However, connections with flanges or unions shall be installed at every 10 pieces of pipes (5.5 m/pc) to allow easy disconnection whenever maintenance work is later required. On the other hand, high-pressure pipelines shall be flange-connected. In normal cases such as pressure piping for various plants, this type of pipe is welded, but in view of its length and location of installation under this Project, on-the-site welding is judged to be extremely difficult, and flange connections are the only alternative. For high-pressure transmission lines in this Project, types of flanges must carefully be selected to suit the expected heads of 20 kg/cm² and 30 kg/cm² respectively.

(2) Pipe Sizes

Transmission and distribution lines in this Project require pipe sizes ranging from 1" to 6". For the calculation of sizes, the following formula has been employed, based upon the unit quantity of flow through the pipe:

Pipe of 2" or less in size	-	Experimental formula employed by Tokyo Metropolitan Water Works
Pipe of 2-1/2" to 6"	-	Hazen-Williams formula

The calculation also must take the velocity of flow at a given quantity into account. A higher velocity can make a pipe size smaller, but results in a larger scale of a pump and a drive due to the increase of pressure head. Experience has determined an *economic velocity* which can balance the relation of a pipeline to equipment in terms of the cost including both their construction and operation and maintenance. According to this standard, the economic velocity for the pipe sizes up to 6" used in the Project is recommended to be 0.7 to 1.0 m/second. This Project has further taken the following factors into consideration:

1) Transmission Lines

A smaller velocity is effective for protecting pipelines against water hammering. In this viewpoint, the lower range of economic velocity has been reduced to 0.5 m/second to overcome the complicated changes in mountainous slopes through which transmission lines run up.

2) Distribution Lines

For distribution and service lines, service pressure must be added to other considerations. Although the planning of the Project covers part of these lines in the respective sites, the sizes of lines to be provided under the planning are required to be adequate enough to deliver water to all the villages composing the sites with a given pressure maintained at ends of distribution lines which are assumed to be connected in due course by the efforts of the Yemeni side. The planning basically assumes a service pressure of no less than 5 m (0.5 kg/cm^2) at ends of such future lines, with reference to the RWSD's design criteria.

(3) Other Plumbing Materials

Various plumbing devices including valves are necessary for pumps and pipelines as follows. For high-pressure lines, types of valves, fittings, flanges, etc., must all comply with the required ranges of pressure heads.

1) Air Vent Valves

Air valves are necessary at the highest points of prominently elevated sections along the course of pipeline.

2) Drain Valves

Drain valves are a combination of gate valves to drain water at depressed sections along the pipeline courses where such arrangements are considered necessary, e.g. where the pipeline crosses a wadi, etc.

3) Gate and Check Valves for Pumps

Pumps shall be attached with valves withstanding the maximum pressures they are expected to encounter. Gate valves of outside screw type are preferred. Check valves shall be of a slow-closing type to protect against water hammer.

(4) Measures to Protect Pipelines against Damages

1) Expansion and Contraction of Pipelines

Pipelines in the country's mountainous regions are mostly exposed on the rocky ground surface. Directly affected by the typical highlands climate intensely differing in temperatures during the day and the night, in some cases reaching 20° C, the exposed lines follow a cycle of expansion and contraction. In an extreme case, this movement results in breakages in pipe connections. A rough estimate of such expansion/contraction range is about 1 cm with every 100 m of pipeline.

To absorb such expansion, several types of special fittings are effective, but most of them have difficulties in the installation on long pipelines over the rugged terrains. In particular, the fittings for high-pressure service are limited and costly, and their use in quantities is not considered practical. Local pipelines have no such fittings, but manage to avoid possible damage through an arrangement of pipes during installation: they don't run straight, having many bends, artificial or natural due to the weight of a pipeline, which function to absorb expansion; lots of elbow-to-elbow connections along steep slopes are another arrangement for evading contortion. Pipelines in the previous Japanese projects successfully employed such arrangements as well. However, for high-pressure transmission lines, a special type of fittings featuring a ball joint was used to preclude risks of possible accidents. In this Project too, this type of fittings is planned to be used for part of lines with dynamic heads exceeding 30 kg/cm^2.

2) Water Hammering

The transmission lines in this Project involve a high risk of causing water hammering due to their long distances over intensively varying rugged terrains of the sites. It frequently results in damages to pumps and/or pipelines. To safeguard against such accidents, the following measures are judged to exert practical effects:

a. Check valves for pumps shall be of slow-closing type.
b. Velocities of pipeline flows shall be kept at a minimum level.
c. Couplings of pumps shall be of flywheel type with a large inertia moment.

These measures have already been taken in the preceding projects with apparently satisfactory results. Although the respective measures involve a cost increase, they are judged to be indispensable for the safe and stable operation of facilities.

5.3.5 Service Facilities

The following service facilities are planned to be attached to the distribution lines under the Project:

(1) Public Fountains

A standard type of public fountain with 6 taps is installed at one or more locations in the respective sites, but the number of installations is advised to be limited to a minimum, since the fountains will cease their function once distribution lines have been extended in the future. The taps shall be of high-pressure type similar to those employed in the preceding project, made of a ball valve.

(2) Hosepipe Feeders for Tankers

Feeders are a simple type of hose stand to fill water tankers which may come from villages relatively distant from the service facilities. Basically they are planned to be installed beside

public fountains.

5.3.6 Water Tanks

(1) Functions of Water Tanks

Based upon the functions, the water tanks are divided into the following groups:

1) Booster Tanks

This type of tank temporarily stores the water to be transmitted to another tank at a higher location. It is exclusively used for transmission of the water by a booster pump, since there are no communities around it for receiving service. In this Project, most booster tanks are located near the deep well, with a booster pump installed in the deep well station.

2) Tanks for Boosting and Distribution

Located on the way of a transmission line, this tank functions as a temporary reservoir for a booster pump as well as a distribution tank to supply water to nearby villages.

3) Distribution Tanks

This involves tanks for distribution to villages. They are all planned to be built on elevated locations enabling to supply water by gravity to desired points.

(2) Structure of Tanks

The standard structure of local construction of tanks are of reinforced concrete. However, in view of local conditions such as inferior material of aggregate in this country (coarse one is crushed stone, while fine one is silty) and installation locations at tops of mountains or hills to which access usually raises questions, the previous Japanese projects including the loan project employed prefabricated steel panel tanks to ensure the quality as well as workability of the construction. Those

installed under the loan project have already passed ten years, and remain in service without raising any questions. Since the tank surface is processed with special rust- and weather-proof coating, they can tolerate under the coastal tropical weather of the Tihama plain. Taking their performance under the previous projects into account, this Project proposes to employ the same type of tanks.

Panel tanks are installed on the reinforced concrete foundations. A unit is assembled on the site, with each member of 1 m square panel fastened with a special gasket and stainless bolts and nuts. To ensure strength for safeguarding against leakage, its height is recommended to be 3 m at maximum, and its volume is determined by selecting a size of width and depth at a unit length of 1 m. Material for supporting and bracing inside the tank is of rust proof stainless steel.

(3) Tank Volume

1) Booster Tanks

Since this type of tank is used for temporary water storage, the volume of a booster tank is based upon a retention period of a booster pump discharge rate. A basic retention period of 30 minutes is adopted through experience in the previous projects, and the minimum tank volume is set at 20 m^3 regardless of cases of smaller pump discharges. For pumps of larger discharges, suitable sizes of tanks are selected among available ones according to the calculation of retention volumes. As a result, the planned booster tanks consist of 24 m^3 in nominal size (effective volume, 20 m^3), 36 m^3 (33 m^3) and 48 m^3 (44 m^3).

2) Distribution Tanks

The volumes of distribution tanks assume the supply to all the villages composing the sites through distribution lines extended in the future. Each tank is planned to store not only a basically required volume of supply determined through the analysis of the relation between the pumping rate from the water source and an assumed water consumption, but also a

volume for emergency supply in case of abrupt shutoff of equipment.

The water consumption pattern varies with the sites, but a typical one based upon the results of the field survey is shown in a diagram attached to Appendix IV-d. A basic supply volume is determined through the graphical analysis of the incremental consumption and pumping rate curves.

For an emergency supply, a rate of 5 liters per day is assumed as a basic minimum requirement of a grownup, while the assumed period for repairing equipment ranges from 5 to 7 days, reflecting various site conditions. It is noted, however, the actual total volume for emergency supply in the respective sites is fixed at 70% of the calculated volume since a rate for a child may be set at a lower rate. The details of this calculation for the respective tanks are listed in Appendix IV-d. As a result, the planned volumes of distribution tanks ranges from 48 m^3 to 180 m^3.

The volumes of tanks for a combined use are calculated, following the aforementioned procedures for both type of tanks.

5.4 DETAILS OF PLANING FOR THE RESPECTIVE SITES

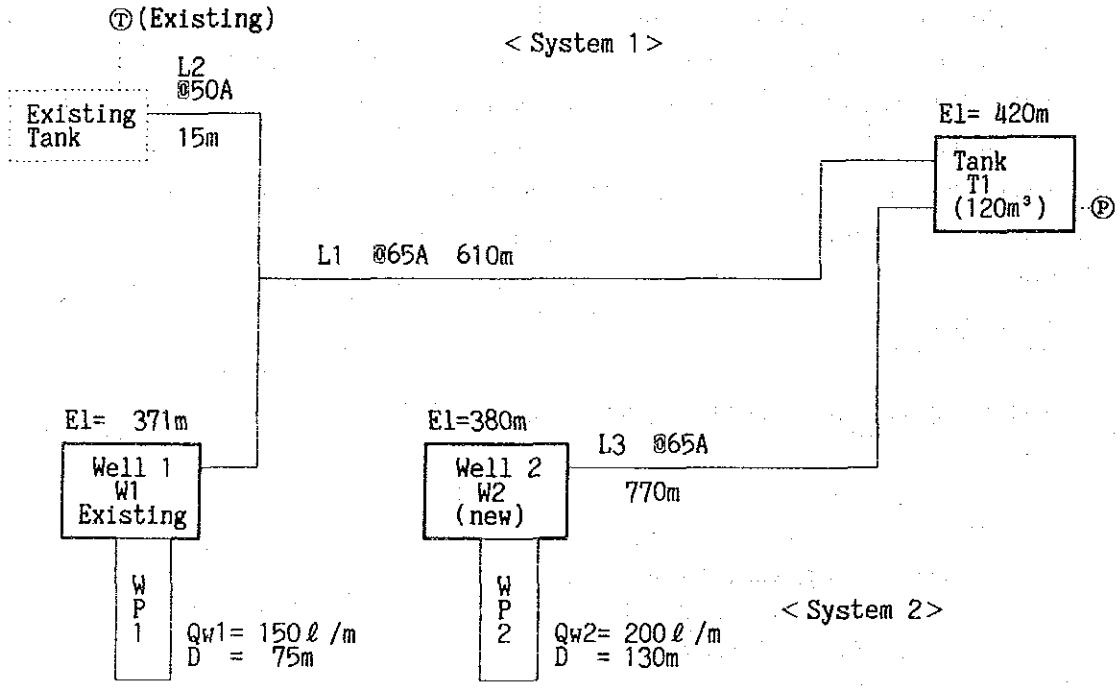
The details of facilities and equipment planned for the respective sites are described hereafter with the flow diagrams of facilities and the listings of equipment. The planned water supply systems are composed of various types and sizes of facilities and equipment, based upon the factors affecting the planning such as the water sources, topographic features, environments of dwelling areas in the planned areas. The respective systems, however, are planned to basically include the water source(s) in the wadi lowlands, pumping facilities up to the dwelling areas on the mountainsides and the distributing and service facilities to supply the planned rates of water to the inhabitants there. The reservoirs for distribution are to be installed in elevated locations to allow the gravity distribution of water supply to all the villages composing the sites, with the distribution lines extended to the centers of the villages nearest to the reservoirs in the respective sites, at the end of which the public fountains and the tanker feeder pipes are to be installed. Each of the distribution lines is designed to have fittings and valves for the future connection of pipes for the extension of distribution. Among the five (5) sites where the construction of facilities are to be executed under the planning, the three (3) sites are planned to be provided with more than one water source, with one of them designed to have the independent systems based upon the numbers of the water sources. In the listings of equipment, such independent systems are separately described.

The abbreviations used in the diagrams and the listings are listed as follows:

El	-	Elevation of location of a facility
W	-	Deep well water source
WP	-	Deep well pumping unit
QW	-	Yield from a well (liters/min.)
P	-	Horizontal booster pump
*	-	Equipment/facilities for a combined use
@	-	Galvanized steel pipe for ordinary pressure service
@	-	Galvanized steel pipe for high pressure service with both ends flanged
L	-	Length of pipeline
Ⓟ	-	Public fountain
Ⓣ	-	Hosepipe feeder for supply to a water tank on a vehicle
⋈	-	Valve

5.4.1 Al Mallaheeth

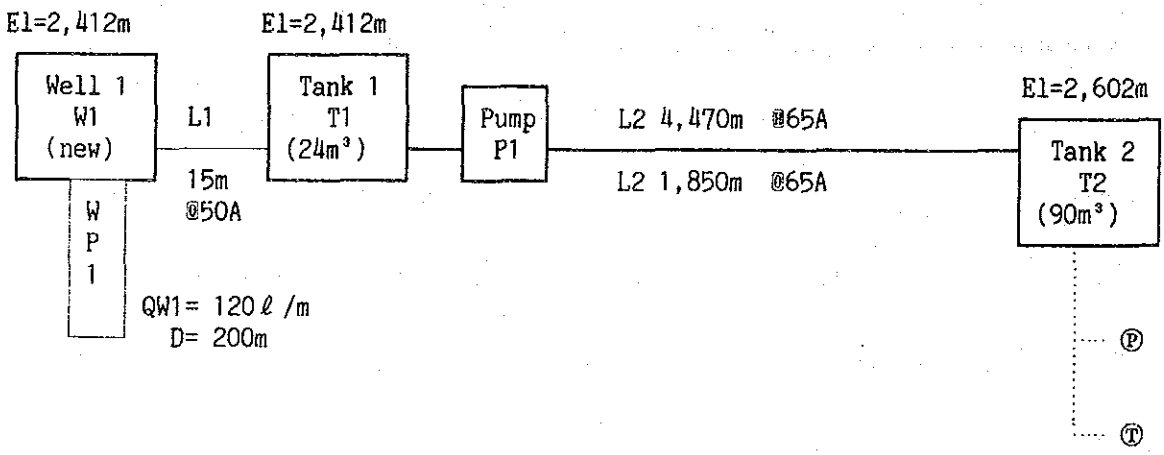
Serial No.	1	Site name	Al Mallaheeth		Gvernorate	Sa'dah
					District	Al Dhaher
Site Number	14	Population	Present total (1991)	3,180	Planned Service pop.(2006)	4,600
Water Source Location	371 m MSL		Final Distribution Tank Location		420 m MSL	
	380 m MSL					
Number of Villages	9	Planned Area for Water Service		14km^2	Population density	329 pers./km^2



Category			Facilities	Mark		Specifications	Q'ty
System 1	Well 1	Water Source	Deep Well	W1	Existing	Depth 75m	1 No.
		Intake Facilities	Deep Well Pump	WP1	New	Diesel driven vertical shaft pump 150 l/m × 146 m × 11.9ps	1 No.
			Drive Unit		New	Diesel engine 24.5ps	1 No.
			Deep Well Pump Station		Existing	Reinforced concrete construction with conc. block wall	1 No.
		Transmission Facilities	Pumping Main	L1	New	Ordinary pipe ø 2-1/2"	610m
				L2	New	Ordinary pipe ø 2"	15m
System 2	Well 2	Water Source	Deep Well	W2	New	8" × 130m	1 No.
		Intake Facilities	Deep Well Pump	WP2	New	Diesel driven vertical shaft pump 200 l/m × 195 m × 24.5ps	1 No.
			Drive Unit		New	Diesel engine 24.5ps	1 No.
			Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
		Transmission Facilities	Pumping Main	L3	New	Ordinary pipe ø 2-1/2"	770m
Distribution Facilities			Distribution Tank	T1	New	120m^3 ground type	1 No.
			Distribution Line		New	Ordinary pipe ø 2"-3"	20m
					New	Ordinary pipe ø 4"	2,123m
Service Facilities			Public Fountain	Ⓟ	New		1 No.

5.4.2 Iyal Qasim

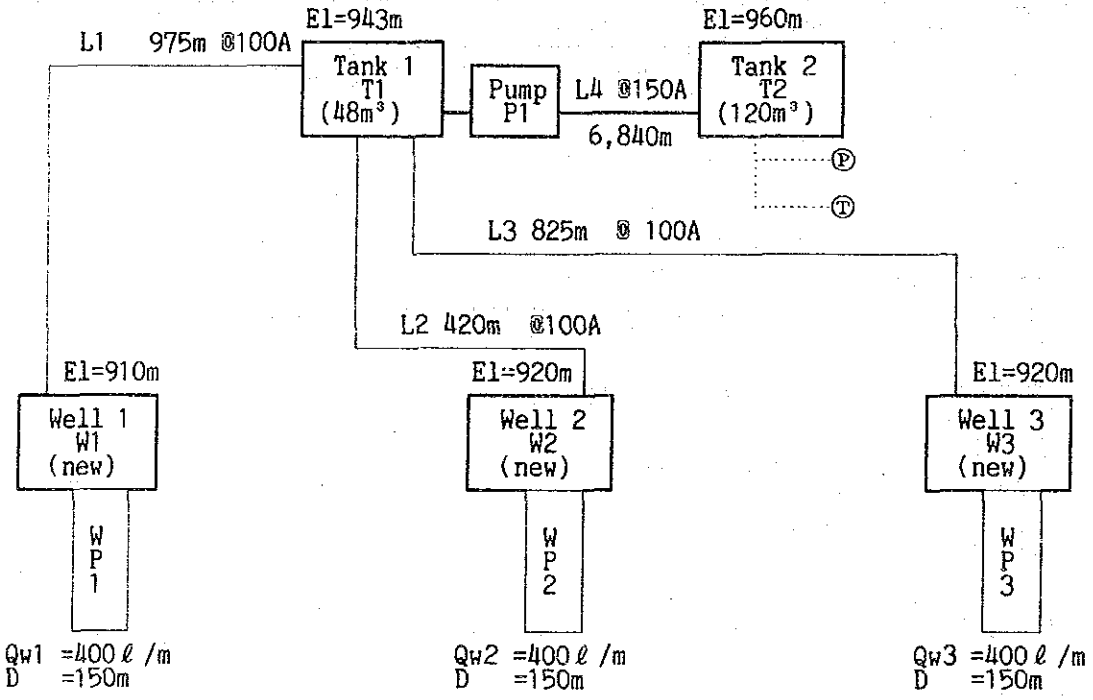
Serial No.	2	Site name	Iyal Qasim		Gvernorate	Sana'a
					District	Dhi-bin
Site Number	1	Population	Present total (1991)	1,500	Planned Service pop.(2006)	2,200
Water Source Location	2,412 m MSL		Final Distribution Tank Location		2,612 m MSL	
Number of Villages	9	Planned Area for Water Service		7.5 km^2	Population density	293 pers./km^2



Category	Facilities	Mark		Specifications	Q'ty
Water Source	Deep Well	W1	New	8" × 200m	1 No.
Intake Facilities	Deep Well Pump	WP1	New	Submersible motor pump 120 l/m × 184 m × 7.5kw	1 No.
	Drive Unit		New	Diesel generator 70KVA, 400V	1 No.
	Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
Transmission Facilities	Booster Pump	P1	New	Horizontal type volute pump 120 l/m × 298m × 18.5kw	1 No.
	Drive Unit		*	Diesel generator 70KVA, 400V	Combine
	Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
	Booster Tank	T1	New	24m^3 ground type	1 No.
	Pumping Main	L1	New	Ordinary pipe ø 2"	15m
		L2	New	High pressure pipe ø 2-1/2"	4,470m
				Ordinary pipe ø 2-1/2"	1,850m
Distribution Facilities	Distribution Tank	T2	New	90m^3 gound type	1 No.
	Distribution Line		New	Ordinary pipe ø 1-1/2"~3"	35m
			New	Ordinary pipe ø 4"	1,200m
Service Facilities	Public Fountain	Ⓟ	New		1 No.
	Hosepipe Feeder	Ⓣ	New		1 No.

5.4.3 Al Usfyn

Serial No.	3	Site name	Al Usfyn		Gvernorate	Taizz
					District	Al Qabaitah
Site Number	6	Population	Present total (1991)	28,500	Planned Service pop.(2006)	41,600
Water Source Location	910 m MSL 920 m MSL		Final Distribution Tank Location		960 m MSL	
Number of Villages	32	Planned Area for Water Service		160 km^2	Population density	260 pers./km^2

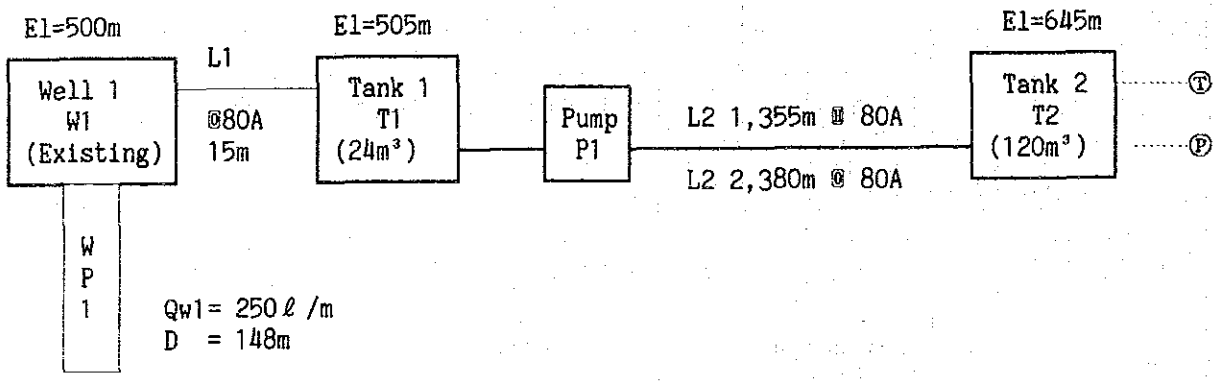


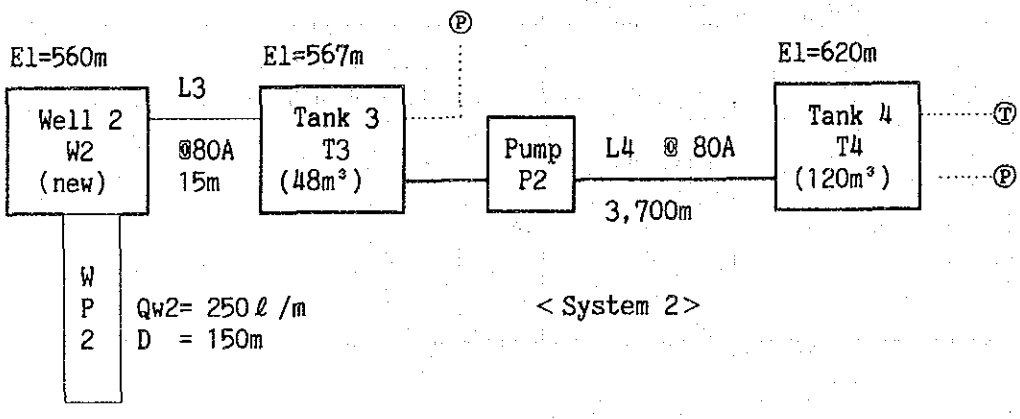
Category		Facilities	Mark		Specification	Q'ty
Well 1	Water Source	Deep Well	W1	New	12" × 0--15 m / 8"× 15--150 m	1 No.
	Inteke Facilities	Deep Well Pump	WP1	New	Diesel driven vertical shaft pump 400 l/m × 177 m × 28.1ps	1 No.
		Drive Unit		New	Diesel engine 39ps	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Pumping Main	L1	New	Ordinary pipe ø 4"	975m
Well 2	Water Source	Deep Well	W2	New	12" × 0--15 m / 8" × 15--150 m	1 No.
	Intake Facilities	Deep Well Pump	WP2	New	Diesel driven vertical shaft pump 400 l/m × 170 m × 27.0ps	1 No.
		Drive Unit		New	Diesel engine 39ps	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Pumping Main	L2	New	Ordinary pipe ø 4"	420m
Well 3	Water Source	Deep Well	W3	New	12" × 0-15 m / 8" × 15-150 m	1 No.
	Intake Facilities	Deep Well Pump	WP3	New	Diesel driven vertical shaft pump 400 l/m × 177 m × 28.1ps	1 No.
		Drive Unit		New	Diesel engine 39ps	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Pumping Main	L3	New	Ordinary pipe ø 4"	825m
Transmission Facilities		Booster Pump	P1	New	Horizontal type volute pump 1,200 l/m × 135 m × 45kw	1 No.
		Drive Unit		New	Diesel generator 130KVA, 400V	1 No.
		Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
		Booster Tank	T1	New	48m^3 ground type	1 No.
		Pumping Main	L4	New	Ordinary pipe ø 6"	6,840m
Distribution Facilities		Distribution Tank	T2	New	120m^3 gound type	1 No.
		Distribution Line		New	Ordinary pipe ø 1-1/2"--6"	30m
Service Facilities		Public Fountain	Ⓟ	New		1 No.
		Hosepipe Feeder	Ⓣ	New		1 No.

5.4.4 Aflah Al Yaman

Serial No.	4	Site name	Aflah Al Yaman		Gvernorate	Hajjah
					District	Aflah Al Yaman
Site Number	11	Population	Present total (1991)	4,500	Planned Service pop.(2006)	6,600
Water Source Location	500 m MSL		Final Distribution Tank Location		645 m MSL	
	560 m MSL				620 m MSL	
Number of Villages	22	Planned Area for Water Service		7.5 km^2	Population density	880 pers./km^2

< System 1 >



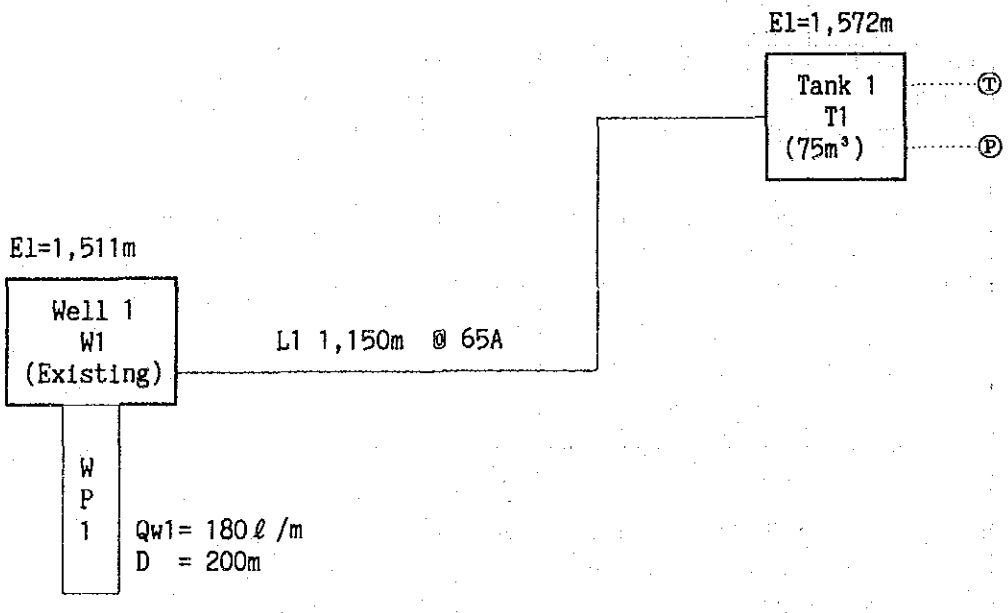


< System 2 >

Category		Facilities	Mark		Specification	Q'ty
System 1	Water Source	Deep Well	W1	Existing	Depth 148 m	1 No.
	Inteke Facilities	Deep Well Pump	WP1	New	Submersible motor pump 250 l/m × 138 m × 11kw	1 No.
		Drive Unit		New	Diesel generator 70KVA, 400V	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Booster Pump	P1	New	Horizontal type volute pump 250 l/m × 205m × 18.5kw	1 No.
		Drive Unit		*	Diesel generator 70KVA, 400V	Combine
		Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
		Booster Tank	T1	New	24m^3 ground type	1 No.
		Pumping Main	L1	New	Ordinary pipe ø 3"	15m
			L2	New	High pressure pipe ø 3"	1,355m
					Ordinary pipe ø 3"	2,380m
	Distribution Facilities	Distribution Tank	T2	New	120m^3 ground type	1 No.
		Distribution Line		New	Ordinary pipe ø 1-1/2"--2-1/2"	25m
				New	Ordinary pipe ø 4"	670m
	Service Facilities	Public Fountain	Ⓟ	New		1 No.
		Hosepipe Feeder	Ⓣ	New		1 No.
System 2	Water Source	Deep Well	W2	New	8" × 150 m	1 No.
	Intake Facilities	Deep Well Pump	WP2	New	Submersible motor pump 250 l/m × 140m × 11.0kw	1 No.
		Drive Unit		New	Diesel generator 55KVA, 400V	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Booster Pump	P2	New	Horizontal type volute pump 250 l/m × 144 m × 15kw	1 No.
		Drive Unit		*	Diesel generator 55KVA, 400V	Combine
		Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
		Booster Tank	T3	New	48m^3 ground type	1 No.
		Pumping Main	L3	New	Ordinary pipe ø 3"	15m
			L4	New	Ordinary pipe ø 3"	3,700m
	Distribution Facilities	Distribution Tank	T4	New	120m^3 ground type	1 No.
		Distribution Line		New	Ordinary pipe ø 1-1/2"--3"	35m
				New	Ordinary pipe ø 4"	672m
	Service Facilities	Public Fountain	Ⓟ	New		3 Nos.
		Hosepipe Feeder	Ⓣ	New		2 Nos.

5.4.5 Al Ghudu

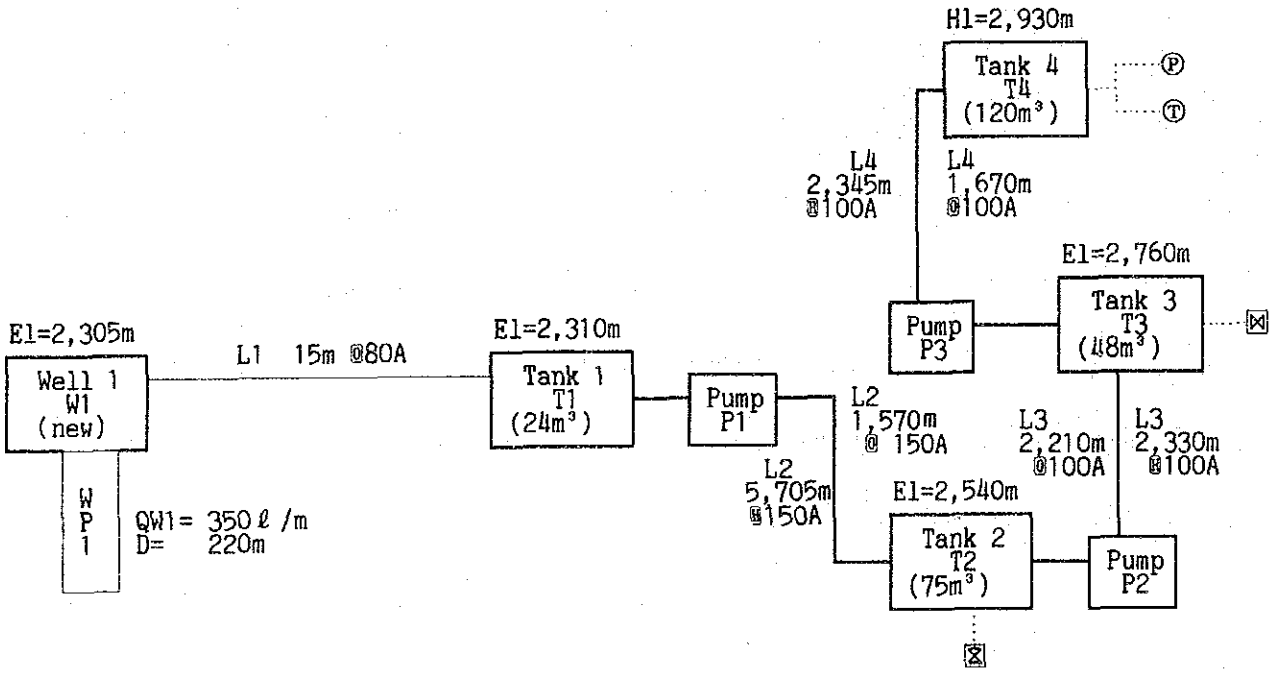
Serial No.	5	Site name	Al Ghudu		Gvernorate	Marib
					District	Sirwah
Site Number	9	Population	Present total (1991)	1,770	Planned Service pop.(2006)	2,600
Water Source Location	1,511 m MSL		Final Distribution Tank Location		1,572 m MSL	
Number of Villages	14	Planned Area for Water Service		15 km^2	Population density	173 pers./km^2



Category	Facilities	Mark		Specification	Q'ty
Water Source	Deep Well	W1	Existing	Depth 200 m	1 No.
Intake Facilities	Deep Well Pump	WP1	New	Submersible motor pump 180 l/m × 278 m × 18.5kw	1 No.
	Drive Unit		New	Diesel generator 55KVA, 400V	1 No.
	Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
Transmission Facilities	Pumping Main	L1	New	Ordinary pipe ø 2-1/2"	1,150m
Distribution Facilities	Distribution Tank	T1	New	75m^3 ground type	1 No.
	Distribution Line		New	Ordinary pipe ø 1-1/2"--2-1/2"	25m
			New	Ordinary pipe ø 4"	3,000m
Service Facilities	Public Fountain	Ⓟ	New		1 No.
	Hosepipe Feeder	Ⓣ	New		1 No.

5.4.6 Khamis Bani Hajaj

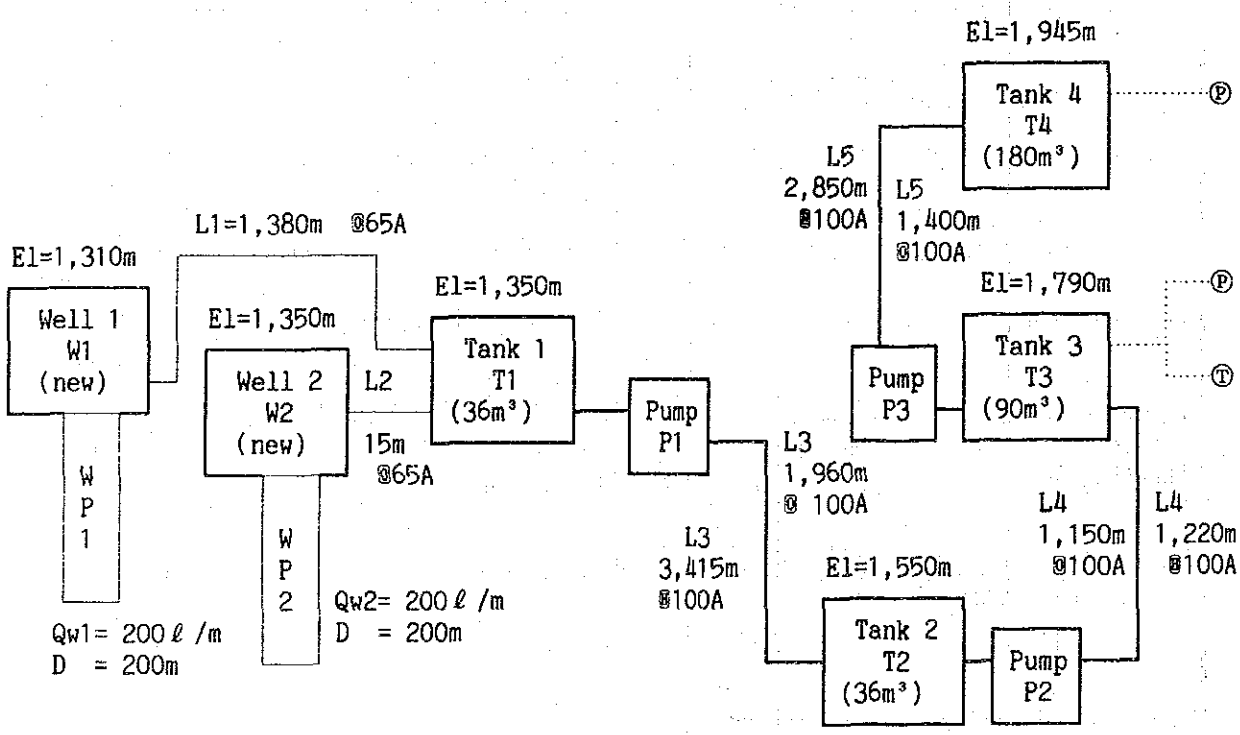
Serial No.	6	Site name	Khamis Bani Hajaj		Gvernorate	Sana'a
					District	Thila
Site Number	3	Population	Present total (1991)	5,400	Planned Service pop.(2006)	7,900
Water Source Location	2,305 m MSL		Final Distribution Tank Location		2,930 m MSL	
Number of Villages	7	Planned Area for Water Service		8 km^2	Population density	988 pers./km^2



Category	Facilities	Mark		Specification	Q'ty
Water Source	Deep Well	W1	New	8" × 220 m	1 No.
Intake Facilities	Deep Well Pump	WP1	New	Submersible motor pump 350 l/m × 206 m × 22kw	1 No.
	Drive Unit		New	Diesel generator 150KVA, 400V	1 No.
	Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
Transmission Facilities	Booster Pump	P1	New	Horizontal type volute pump 350 l/m × 296 m × 37kw	1 No.
	Drive Unit		*	Diesel generator 150KVA, 400V	Combine
	Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
	Booster Pump	P2	New	Horizontal type volute pump 350 l/m × 278 m × 37kw	1 No.
	Drive Unit		New	Diesel generator 100KVA, 400V	1 No.
	Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Booster Pump	P3	New	Horizontal type volute pump 330 l/m × 234 m × 30kw	1 No.
	Drive Unit		New	Diesel generator 100KVA, 400V	1 No.
	Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Booster Tank	T1	New	$24m^3$ ground type	1 No.
	Pumping Main	L1	New	Ordinary pipe ø 3"	15m
		L2	New	High pressure pipe ø 6"	5,705m
				Ordinary pipe ø 6"	1,570m
		L3	New	High pressure pipe ø 4"	2,330m
				Ordinary pipe ø 4"	2,210m
		L4	New	High pressure pipe ø 4"	2,345m
				Ordinary pipe ø 4"	1,670m
Distribution Facilities	Distribution Tank	T3	New	$48m^3$ ground type	1 No.
		T2	New	$75m^3$ ground type	1 No.
		T4	New	$120m^3$ ground type	1 No.
	Distribution Line		New	Ordinary pipe ø 1-1/2"--2"	10m
			New	Ordinary pipe ø 2-1/2"	183m
			New	Ordinary pipe ø 3"	450m
			New	Ordinary pipe ø 4"	735m
Service Facilities	Public Fountain	Ⓟ	New		1 No.
	Hosepipe Feeder	Ⓣ	New		1 No.

5.4.7 Al Husha

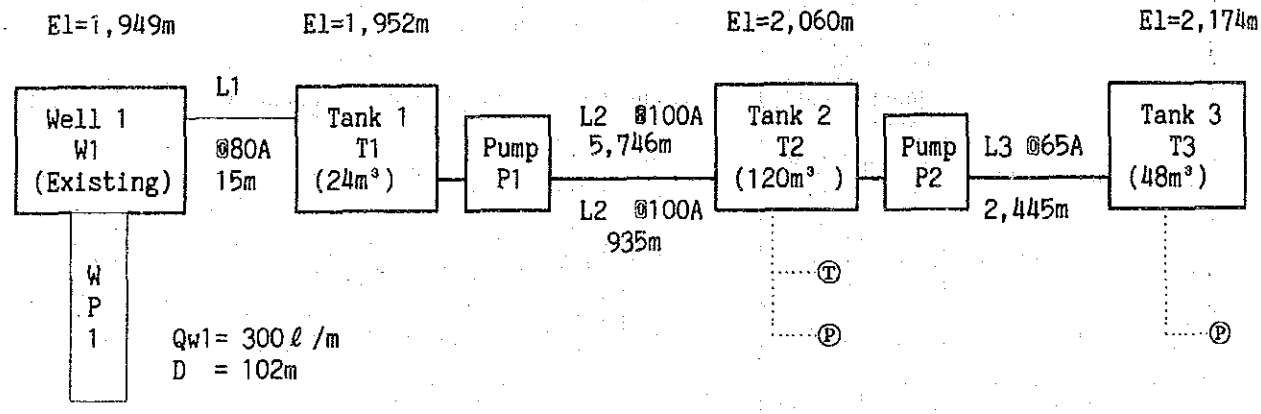
Serial No.	7	Site name	Al Husha		Gvernorate	Taizz
					District	Al Husha
Site Number	5	Population	Present total (1991)	5,000	Planned Service pop.(2006)	7,300
Water Source Location	1,310 m MSL 1,350 m MSL		Final Distribution Tank Location		1,945 m MSL	
Number of Villages	3 Area	Planned Area for Water Service		30 km^2	Population density	243 pers./km^2



Category		Facilities	Mark		Specification	Q'ty
Well 1	Water Source	Deep Well	W1	New	8" × 200 m	1 No.
	Intake Facilities	Deep Well Pump	WP1	New	Submersible motor pump 200 l/m × 267 m × 18.5kw	1 No.
		Drive Unit		New	Diesel generator 55KVA, 400V	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Pumping Main	L1	New	Ordinary pipe ø 2-1/2"	1,380m
Well 2	Water Source	Deep Well	W2	New	8" × 200 m	1 No.
	Intake Facilities	Deep Well Pumpe	WP2	New	Submersible motor pump 200 l/m × 184 m × 15kw	1 No.
		Drive Unit		New	Diesel generator 130KVA, 400V	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Pumping Main	L2	New	Ordinary pipe ø 2-1/2"	15m
Transmission Facilities		Booster Pump	P1	New	Horizontal type volute pump 400 l/m × 304 m × 45kw	1 No.
		Drive Unit		*	Diesel generator 130KVA, 400V	Combine
		Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
		Booster Pump	P2	New	Horizontal type volute pump 400 l/m × 305 m × 45kw	1 No.
		Drive Unit		New	Diesel generator 100KVA, 400V	1 No.
		Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
		Booster Pump	P3	New	Horizontal type volute pump 400 l/m × 239 m × 37kw	1 No.
		Drive Unit		New	Diesel generator 100KVA, 400V	1 No.
		Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
		Booster Tank	T1,2	New	$36m^3$ ground type	2 Nos.
		Pumping Main	L3	New	High pressure pipe ø 4"	3,415m
					Ordinary pipe ø 4"	1,960m
			L4	New	High pressure pipe ø 4"	1,220m
					Ordinary pipe ø 4"	1,150m
			L5	New	High pressure pipe ø 4"	2,850m
					Ordinary pipe ø 4"	1,400m
Distribution Facilities		Distribution Tank	T3	New	$90m^3$ ground type	1 No.
			T4	New	$180m^3$ ground type	1 No.
		Distribution Line		New	Ordinary pipe ø 1-1/2"--2-1/2"	30m
				New	Ordinary pipe ø 3"--4"	110m
				New	Ordinary pipe ø 6"	1,005m
Service Facilities		Public Fountain	Ⓟ	New		2 Nos.
		Hosepipe Feeder	Ⓣ	New		1 No.

5.4.8 Bait Al Sultan

Serial No.	8	Site name	Bait Al Sultan		Gvernorate	Ar Rajam
					District	Al Mahweet
Site Number	12	Population	Present total (1991)	3,600	Planned Service pop.(2006)	5,300
Water Source Location	1,949 m MSL		Final Distribution Tank Location		2,174 m MSL	
Number of Villages	11	Planned Area for Water Service		14 km^2	Population density	379 pers./km^2

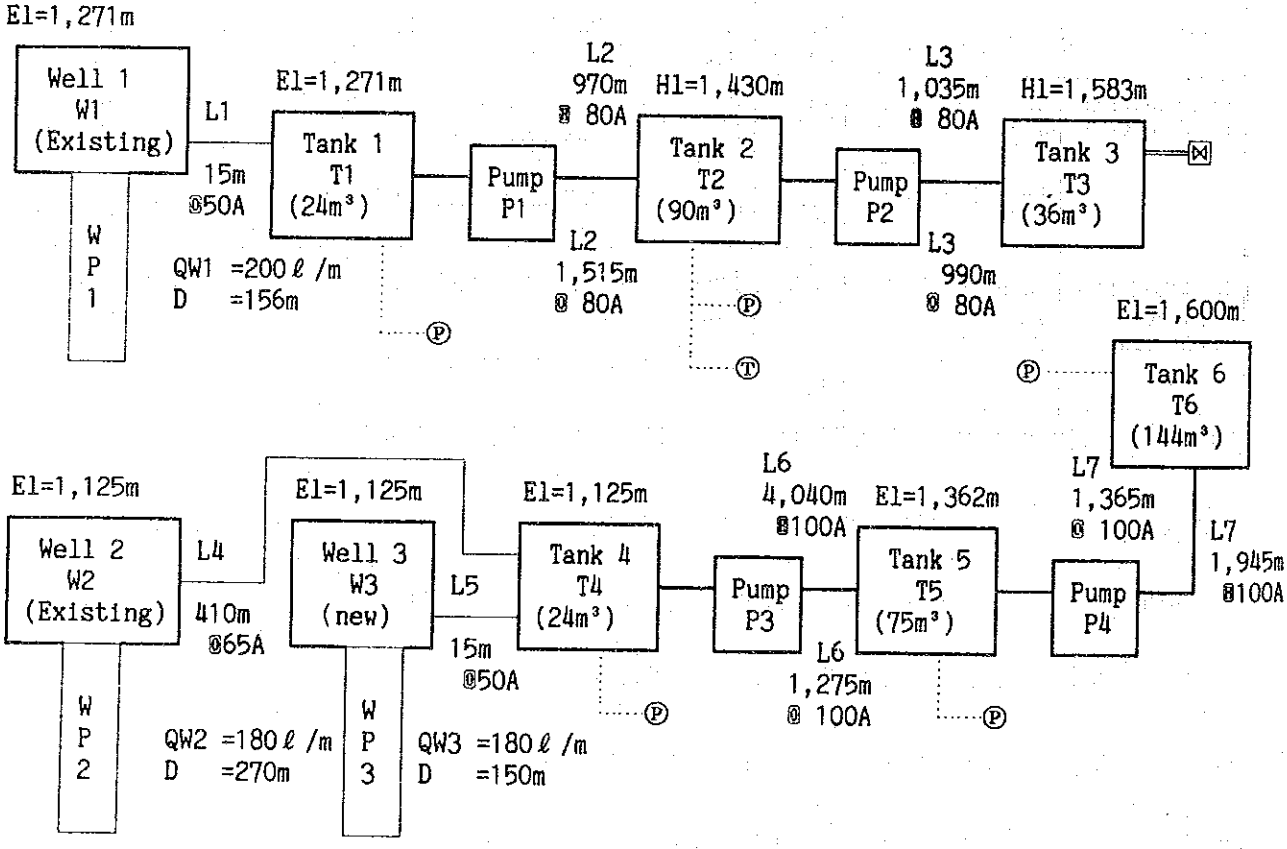


Category	Facilities	Mark		Specification	Q'ty
Water Source	Deep Well	W1	Existing	Depth 102 m	1 No.
Intake Facilities	Deep Well Pump	WP1	New	Submersible motor pump 300 l/m × 109 m × 11kw	1 No.
	Drive Unit		New	Diesel generator 70KVA, 400V	1 No.
	Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
Transmission Facilities	Booster Pump	P1	New	Horizontal type volute pump 300 l/m × 184 m × 18.5kw	1 No.
	Drive Unit		*	Diesel generator 70KVA, 400V	Combine
	Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
	Booster Tank	T1	New	24m^3 ground type	1 No.
	Booster Pump	P2	New	Horizontal type volute pump 100 l/m × 152 m × 11kw	1 No.
	Drive Unit		New	Diesel generator 27KVA, 400V	1 No.
	Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Pumping Main	L1	New	Ordinary pipe ø 3"	15m
		L2	New	High pressure pipe ø 4"	5,746m
				Ordinary pipe ø 4"	935m
		L3	New	Ordinary pipe ø 2-1/2"	2,445m
Distribution Facilities	Distribution Tank	T3	New	48m^3 ground type	1 No.
		T2	New	120m^3 ground type	1 No.
	Distribution Line		New	Ordinary pipe ø 1-1/2"--2-1/2"	35m
			New	Ordinary pipe ø 3"	354m
			New	Ordinary pipe ø 4"	5m
Service Facilities	Public Fountain	Ⓟ	New		2 Nos.
	Hosepipe Feeder	Ⓣ	New		1 No.

5.4.9 Bani Afif

Serial No.	9	Site name	Bani Afif		Gvernorate	Taizz
					District	Turbat Al Mawasit
Site Number	4	Population	Present total (1991)	7,300	Planned Service pop.(2006)	10,700
Water Source Location	1,271 m MSL		Final Distribution Tank Location		1,583 m MSL	
	1,125 m MSL				1,600 m MSL	
Number of Villages	9	Planned Area for Water Service		14 km^2	Population density	764 pers./km^2

< System 1 >



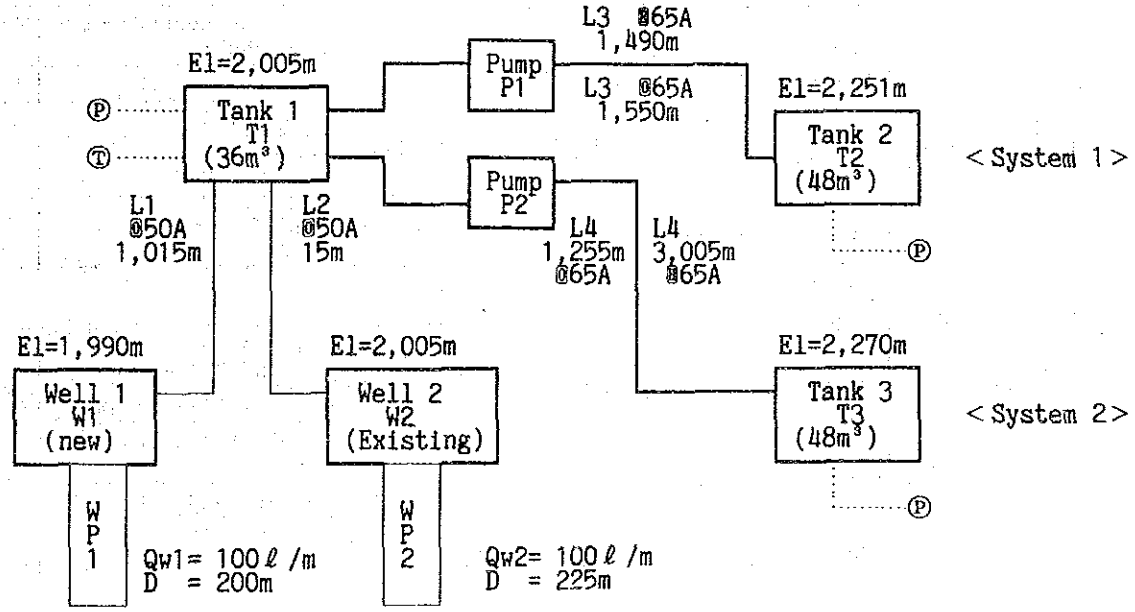
< System 2 >

Category			Facilities	Mark		Specifications	Q'ty
System 1	Well 1	Water Source	Deep Well	W1	Existing	Depth 156 m	1 No.
		Intake Facilities	Deep Well Pump	WP1	New	Submersible moter pump 200 l/m × 145 m × 11kw	1 No.
			Drive Unit		New	Diesel generater 55KVA, 400V	1 No.
			Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities		Booster Pump	P1	New	Horizontal type volute pump 200 l/m × 218 m × 15kw	1 No.
			Drive Unit		*	Diesel generater 55KVA, 400V	Combine
			Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
			Booster Pump	P2	New	Horizontal type volute pump 200 l/m × 205 m × 15kw	1 No.
			Drive Unit		New	Diesel generater 55KVA, 400V	1 No.
			Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
			Booster Tank	T1	New	24m^3 ground type	1 No.
			Pumping Main	L1	New	Ordinary pipe ø 2"	15m
				L2	New	High pressure pipe ø 3"	970m
						Ordinary pipe ø 3"	1,515m
				L3	New	High pressure pipe ø 3"	1,035m
						Ordinary pipe ø 3"	990m
	Distribution Facilities		Distribution Tank	T2	New	90m^3 ground type	1 No.
				T3	New	36m^3 ground type	1 No.
			Distribution Line		New	Ordinary pipe ø 1-1/2"--2-1/2"	30m
					New	Ordinary pipe ø 3"	930m
					New	Ordinary pipe ø 4"	309m
	Service Facilities		Public Fountain	Ⓟ	New		2 Nos.
			Hosepipe Feeder	Ⓣ	New		1 No.
System 2	Well 2	Water Source	Deep Well	W2	Existing	Depth 270 m	1 No.
		Intake Facilities	Deep Well Pump	WP2	New	Submersible motor pump 180 l/m × 246 m × 15kw	1 No.
			Drive Unit		New	Diesel generator 55KVA	1 No.
			Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.

Category			Facilities	Mark		Specifications	Q'ty
System 2	Well 2	Transmission Facilities	Pumping Main	L4	New	Ordinary pipe ø 2-1/2"	410m
	Well 3	Water Source	Deep Well	W3	New	8" × 150 m	1 No.
		Intake Facilities	Deep Well Pump	WP3	New	Submersible moter pump 180l/m × 149 m × 11kw	1 No.
			Drive Unit		New	Diesel generator 130KVA, 400V	1 No.
			Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
		Transmission Facilities	Pumping Main	L5	New	Ordinary pipe ø 2"	15m
	Transmission Facilities		Booster Pump	P3	New	Horizontal type volute pump 360 l/m × 339 m × 37kw	1 No.
			Drive Unit		*	Diesel generator 130KVA, 400V	Combine
			Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
			Booster Pump	P4	New	Horizontal type volute pump 300 l/m × 289 m × 30kw	1 No.
			Drive Unit		New	Diesel generator 100KVA, 400V	1 No.
			Booster Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
			Booster Tank	T4	New	24m^3 ground type	1 No.
			Pumping Main	L6	New	High pressure pipe ø 4"	4,040m
						Ordinary pipe ø 4"	1,275m
				L7	New	High pressure pipe ø 4"	1,945m
						Ordinary pipe ø 4"	1,365m
	Distribution Facilities		Distribution Tank	T5	New	75m^3 ground type	1 No.
				T6	New	144m^3 ground type	1 No.
			Distribution Line		New	Ordinary pipe ø 2"	30m
					New	Ordinary pipe ø 4"	1,320m
	Service Facilities		Public Fountain	Ⓟ	New		3 Nos.

5.4.10 Al Jabub

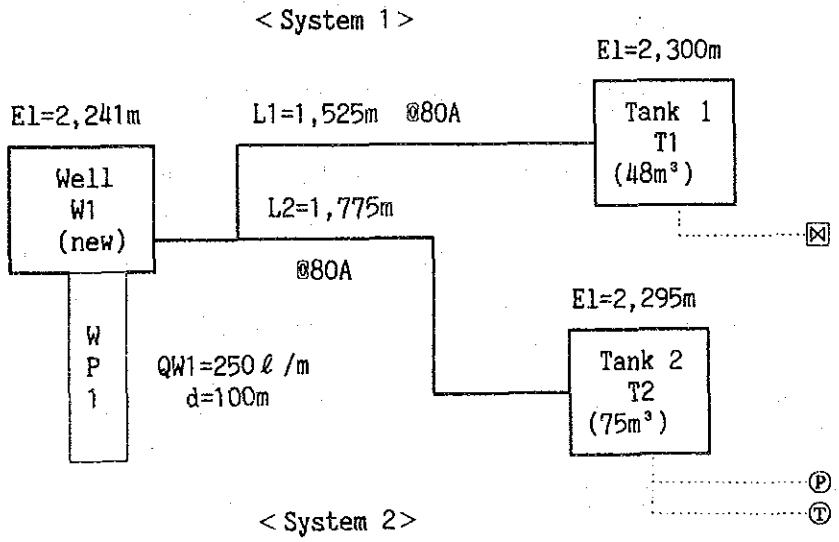
Serial No.	10	Site name	Al Jabub		Gvernorate	Ibb
					District	Ar Radmah
Site Number	7	Population	Present total (1991)	2,000	Planned Service pop.(2006)	2,900
Water Source Location	1,990 m MSL		Final Distribution Tank Location		2,251 m MSL	
	2,005 m MSL				2,270 m MSL	
Number of Villages	6	Planned Area for Water Service		10 km^2	Population density	290 pers./km^2



Category		Facilities	Mark		Specification	Q'ty
Well 1	Water Source	Deep Well	W1	New	8" × 200 m	1 No.
	Intake Facilities	Deep Well Pump	WP1	New	Submersible motor pump 100 l/m × 220 m × 15kw	1 No.
		Drive Unit		New	Diesel generator 37KVA, 400V	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Pumping Main	L1	New	Ordinary pipe ø 2"	1,015m
Well 2	Water Source	Deep Well	W2	Existing	Depth 225 m	1 No.
	Intake Facilities	Deep Well Pump	WP2	New	Submersible motor pump 100 l/m × 211 m × 15kw	1 No.
		Drive Unit		New	Diesel generator 100KVA, 400V	1 No.
		Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
	Transmission Facilities	Pumping Main	L2	New	Ordinary pipe ø 2"	15m
Transmission Facilities		Booster Tank	T1	New	36m^3 ground type	1 No.
Service Facilities		Public Fountain	Ⓟ	New		1 No.
		Hosepipe Feeder	Ⓣ	New		1 No.
System 1	Transmission Facilities	Booster Pump	P1	New	Horizontal type volute pump 100 l/m × 245 m × 11kw	1 No.
		Drive Unit		*	Diesel generator 100KVA, 400V	Combine
		Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
		Pumping Main	L3	New	High Pressure pipe ø 2-1/2"	1,490m
				New	Ordinary pipe ø 2-1/2"	1,550m
	Distribution Facilities	Distribution Tank	T2	New	48m^3 ground type	1 No.
		Distribution Line		New	Ordinary pipe ø 2"	10m
				New	Ordinary pipe ø 3	480m
	Service Facilities	Public Fountain	Ⓟ	New		1 No.
System 2	Transmission Facilities	Booster Pump	P2	New	Horizontal type volute pump 100 l/m × 336 m x 18.5kw	1 No.
		Drive Unit		*	Diesel generator 100KVA, 400V	Combine
		Booster Pump Station		*	Reinforced concrete construction with conc. block wall	Combine
			L4	New	High pressure pipe ø 2-1/2"	3,005m
					Ordinary pipe ø 2-1/2"	1,255m
	Distribution Facilities	Distribution Tank	T3	New	48m^3 ground type	1 No.
		Distribution Line		New	Ordinary pipe ø 1-1/2--2-1/2"	30m
				New	Ordinary pipe ø 4"	1,780m
	Service Facilities	Public Fountain	Ⓟ	New		1 No.

5.4.11 Mahalat Najr

Serial No.	11	Site name	Mahalat Najr		Gvernorate	Sana'a
					District	Amran
Site Number	2	Population	Present total (1991)	2,000	Planned Service pop.(2006)	2,900
Water Source Location	2,241 m MSL		Final Distribution Tank Location		2,300 m MSL	
					2,295 m MSL	
Number of Villages	1	Planned Area for Water Service		3 km^2	Population density	967 pers./km^2



Category	Facilities	Mark		Specifications	Q'ty
Water Source	Deep well	W1	New	8" × 100 m	1 No.
Intake Facilities	Deep Well Pump	WP1	New	Diesel driven vertical shaft pump 250 l/m × 200 m × 22.2ps	1 No.
	Drive Unit		New	Diesel engine 31ps	1 No.
	Deep Well Pump Station		New	Reinforced concrete construction with conc. block wall	1 No.
Transmission Facilities	Pumping Main	L1	New	Ordinary pipe ø 3"	1,525m
		L2	New	Ordinary pipe ø 3"	1,775m
Distribution Facilities	Distribution Tank	T1	New	48m^3 ground type	1 No.
		T2	New	75m^3 ground type	1 No.
	Distribution Line		New	Ordinary pipe ø 1-1/2"--2"	10m
			New	Ordinary pipe ø 2-1/2"	200m
			New	Ordinary pipe ø 3"	1,100m
Service Facilities	Public Fountation	Ⓟ	New		1 No.
	Hosepipe Feeder	Ⓣ	New		1 No.

5.4.12 Supply of Equipment and Materials

The schemes for the construction of facilities with equipment/materials for the respective sites of five (5) contained in the preceding clauses are executed by the Japanese side. In addition, the supply of equipment and materials to the Yemen side is planned under the Project for facilitating more effective use of completed facilities as well as inhabitants' needs for upgrading the systems in the respective sites.

(1) Piping materials for the Extension of Distribution Lines

In the four (4) sites other than Al Usfyn, where the construction work is to be executed by the Japanese side, trunk mains for distribution are installed by the Japanese side to the central parts of the sites, with fittings for connecting extension lines positioned in pertinent locations on their way as well as at their ends. The extension of trunk mains to villages in the respective sites from these connections would make it by far easier for inhabitants to install branches and house connections of smaller sizes with their own expenses. Since trunk mains require pipelines of larger diameters than those of house connections, resulting in larger costs for installation, to provide materials for such extension, even for significant and effective sections of distribution only in the respective sites, under the Project to the Yemeni side would be helpful and useful for upgrading the systems with their own funds. Such materials are to be supplied with not only pipes but also fittings, sealing materials, valves, etc., necessary for completing installation. The proposed supply of pipes for the respective sites are listed as follows:

Table 5.9 Supply of Piping Materials

Names of Sites	Pipe Specifications	Quantity
Al Mallaheeth	Galvanized steel pipe 65 - 80 mm	4,950 m
Iyal Qasim	Ditto: 40 - 65 mm	2,010 m
Aflah Al Yaman	Ditto: 50 - 80 mm	6,050 m
Al Ghudu	Ditto: 65 - 80 mm	2,365 m

The installation work of supplied piping materials is proposed to be undertaken by the RWSD and/or LCCDs which are responsible for

the Project for and on behalf of the Yemen government upon completion of the execution of the Project by the Japanese side.

(2) Supply of Water Tankers for Al Usfyn

The Al Usfyn site currently has no suitable water sources satisfying both quantity and quality, with all its mountainous inhabitants entirely depending upon costly water for sale. As the first step to realize the water supply system for this extensive area, the development of water sources has been focused under this Project. Due to its vastness, the pipelines are not extended to the mountainous areas where major parts of villages are located. To assist the LCCD responsible for the area in serving clean and stable water to be developed, therefore, the supply of water tankers for this site are proposed under the Project as follows:

1) Type of water tankers:
   Four-wheel drive water tankers with a capacity of 4 m^3
2) No. of units to be supplied:
   One (1) unit upon completion of facilities for the site and another one (1) unit upon final completion of the Project at Phase III (two units in total).

There are two main feeder roads leading to the mountainous villages of the site, the eastern and western routes. A minimum daily service by water tankers, therefore, needs to be undertaken by two (2) water tankers as proposed, taking the respective routes. Since this activity of water service by the LCCD responsible for the area becomes its first experience, one unit of tanker is initially supplied, and later in one year when such service is supposed to grow a routine business requiring an additional unit, another one is to be delivered.

The new water service station in this Project is planned to be built at a location along the highway where most mountain residents will be able to reach with ease. A portion of them, therefore, are supposed to come there by their own cars to directly fetch water for a less charge. Further, the LCCD could manage to earn and deposit the surplus from water income in preparation for the future planning of expansion of facilities, by means of setting a proper level of water price with the consent of recipients of its service.

5.5 IMPLEMENTATION PLAN

5.5.1 Structure for Implementation

This Project is aimed at constructing the water supply facilities in five (5) sites located in the five (5) governorates of the Republic of Yemen under Japan's grant aid system, taking specific conditions of the respective sites into account. In establishing the implementation plan for the Project, the formulation of the most relevant setup and period for construction are of vital importance. Although the local market for the construction of water supply facilities remains yet to reach an appreciable level, the involvement of local enterprises and labor force is highly encouraged to support smooth progress of works under harsh natural and social environments.

During the implementation of construction work, the RWSD of the MEW takes a key role as the executing agency of the Project headed by its general director. Under his direction, its Bilateral division engages in direct handling of the Project implementation through activities of full-time counterparts of two or three selected from this office as well as cooperative engineering staff assigned in specialty divisions for supporting the progress of the Project.

Under such supervising and supporting setup of the RWSD, a Japanese consulting firm is employed mainly for making the detailed design of the Project, assisting the RWSD in the execution of the tender and supervising the construction work.

The construction work is carried out by a Japanese company which has been awarded a contract through the tender. It is held responsible for constructing the water supply facilities in strict compliance with the requirements of the specifications and drawings under the administration of the RWSD and the supervision by the consultant. Its headquarter office is installed in the capital of Sana'a where the RWSD's main office is situated, with its staff headed by a project manager engaging in controlling the quality and progress of work under the contract. On the other hand, the site managers are assigned to head the construction teams in the respective sites where the work progresses. They are responsible for smooth progress of work in the respective sites in coordination with the project manager at the head office.

The construction of water supply facilities under the Project involves a variety of works such as drilling, civil work, plumbing work and mechanical work. In view of a technical level in this country, it is considered to be critically important that the contractor should establish an organization of its engineering staff in various fields of specialties to control the quality and progress of the work so that it could accomplish the work satisfactorily within the designated period under Japan's grant aid system.

Meanwhile the local cooperation and coordination with inhabitants are arranged by the LCCDs responsible for the respective districts involving the sites. Installed in the individual districts in the country, they are in charge of various local development projects. According to the direction of the RWSD, these organizations directly carry out the preparation of access, repair roads and secure land necessary for the work, developing a network of cooperation for the implementation of the project within the sites.

This structure is shown in a diagram as illustrated in Fig. 5.2.

5.5.2 Construction Supervising Plan

In this Project, the detailed design and the supervision of the construction work are carried out by a consulting firm organized under laws of Japan, on the basis of Japan's grant aid system. Its responsibilities are described as follows:

(1) Pre-construction Stage

1) Detailed design
2) Preparation of tender documents
3) Administration of tender process for and on behalf of the executing agency
4) Evaluation of tender results
5) Assistance in concluding the contract for the construction work

(2) Construction Stage

1) Supervision of construction work
2) Inspection and technology transfer
3) Preparation of completion reports

Fig.5.2 Implementation System