3.7 ADVERSE IMPACT ON GROUNDWATER RESOURCES

3.7.1 PRESENT CONDITION OF ADVERSE IMPACT

An adverse impact on groundwater means an impact resulting in a reduction of the quantity, that is, less yield of existing wells and ending up with the exhaustion of aquifer, and deterioration in groundwater quality, which bring about being unsuitable for domestic, industrial or agricultural use.

(1) Groundwater Level

1) Recent Monitoring Result

A reduction of the quantity shows a fall of groundwater level. Recently NWRA constructed the monitoring network for water levels in the Sana'a basin. There are 33 monitoring wells measured manually every month generally. The number of monitoring wells is planned to increase. In addition, six wells have been installed automatic water level recorder in 2007. *Table 3.19* and *Figure 3.29* shows the locations of these/ monitoring wells.

Table 3.19 Monitoring Wells in the Sana'a Basin

	Code No.	Site Name	District	UTM North	UTM East	Elev.m.	Aquifer	Well Typ
1	P8	W.F.Wes	Ban-Alhar	1704571	412810	2218	Sandstone	
2	O5	W.F.Wes	Ban-Alhar	1707273	411188	2238	Sandstone	
3	P17	W.F.Wes	Ban-Alhar	1708945	409750	2248	Sandstone	
4	P15	W.F.Wes	Ban-Alhar	1709656	409305	2234	Sandstone	
5	P21	W.F.Wes	Ban-Alhar	1710064	410067	2209	Sandstone	
6	F783A	Al Hawri	Hamdan	1715555	411390	2232	Volcanic	
7	A2069	Maribcamp	Ban-Alhar	1714346	4018244	2206	Volcanic	Borehole
8	F 2356	B-alhally	Ban-Alhar	1715014	416162	2192	Volcanic	Dug+Drill
9	F 2357	B-alhally	Ban-Alhar	1715109	416242	2145	Alluvium	
10	F 1446	B-alhally	Ban-Alhar	1718865	416298	2182	Alluvium	Borehole
11	F2131	Bossan	Arhab	1728956	417429	2217	Limestone	
12	F2143	Makarib	Arhab	1730178	421335	2136	Limestone	
13	F 1445	B-Mosaed	Ban-Alhar	1716838	417904	2188	Alluvium	Borehole
14	F1947A	Almasham	Ban-Alhar	1727571	421495	2129	Limestone	Borehole
15	F 2003	W-dogish	Arhab	1729224	425801	2052	Limestone	Dug+Drill
16	C1849	Al-req val.	Ban-Alhar	1711873	424320	2237	Volcanic	
17	C1564	Al-grass	Ban-Alhar	1716018	428437	2239	Sandstone	Dugwell
18	D25	Dharhan	Bani-Hus	1699850	426648	2400	Alluvium	Dugwell
19	C1 146	Alqariah	Bani-Hus	1700113	425179	2367	Alluvium	Dugwell
20	U358A	Aswad	Sanhan	168711	418990	2341	Volcanic	Dugwell
21	U1146A	Rihm	Sanhan	1678618	419008	2400	Volcanic	Borehole
22	B-665A	Maqwalah	Sanhan	1675449	429994	2500	Volcanic	Dugwell
23	B-683	Bit saani	Sanhan	1677294	426909	2502	Volcanic	Dugwell
24	E-2366	Safiat Tamash	Sanhan	1690120	422210	2349	Alluvium	
25	E-2377	Shahik	Sanhan	1701896	439685	2582	Alluvium	Dugwell
26	E-1749	Bani Bahlul	Sanhan	1698001	430469	2460	Volcanic	Dugwell
27	U-427A	Al Nahdeen	Sana'a	1692469	414845	2302	Volcanic	Borehole
28	U-502A	Haddah/azal	Al amanh	1692422	413170	2326	Volcanic	Borehole
29	A878	Almasjed	Bani mater	1692294	401298	2576	Alluvium	
30	A-1038	Raas Alhissin	Bani Matar	1695434	402468	2548	Alluvium	
31	A874A	Aser Almwred	Sana'a	1696814	408818	2411	Alluvium	
32	A-848-A-	Alkhasmah	Bani Matar	1695167	403380	2566	Alluvium	

33	A-691-A	Shamlan	Hamdan	1703827	407993	2342	Volcanic	
Monitoring Wells with Automatic Water Level Recorder								
	Motre well	Wadi Sawan		1704788	432456	-	Volcanic	Borehole
	HS50	Wadi Asir		1711250	427232	-	Sandstone	Borehole
	AS-6	Wadi Al Amanh		1696061	411221	-	Volcanic	Borehole
	ST-7	Wadi Al Amanh		1704200	413910	-	Sandstone	Borehole
	A2069	Wadi Al Amanh		1714346	401824	-	Volcanic	Borehole
	Lualuah	Wadi Hamdan		1701177	400882	-	Volcanic	Borehole

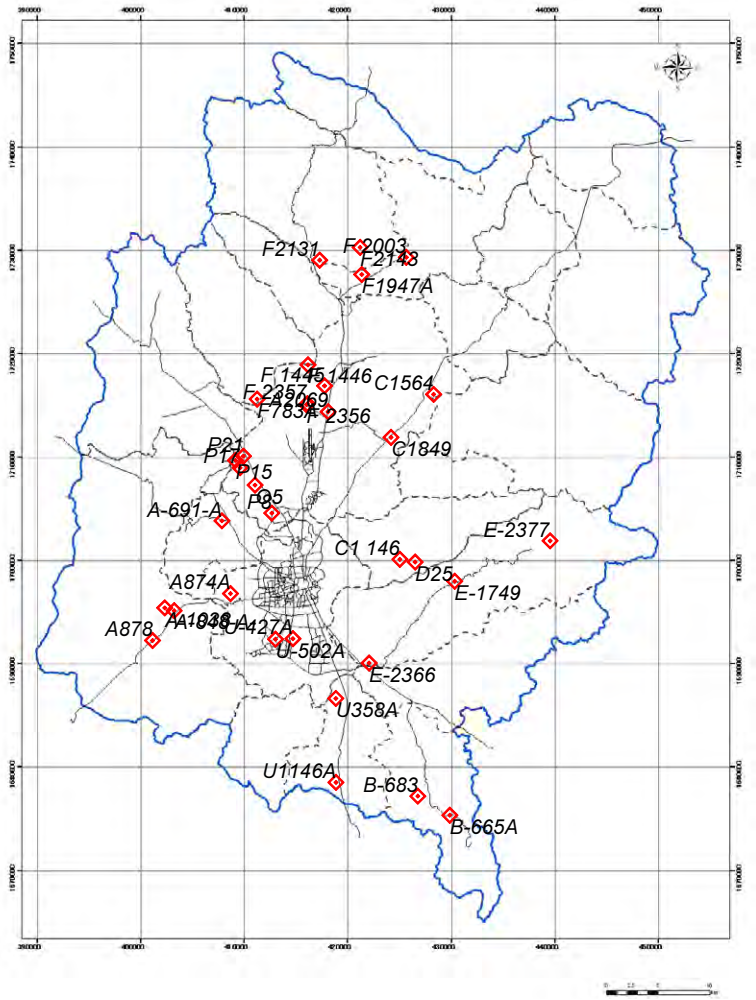


Figure 3.29 Locations of Water Level Monitoring Wells

The result of monitoring is tabulated in *Appendix 2*. *Figure 3.30* shows the fluctuation of water level from August 2003 to January 2007. The figure illustrates the change of water levels clearly especially from September 2005 to June 2006, because the periodical well-regulated monitoring had been continued during the term whereas the other periods with only scattering measurement. It indicates the importance of continual and regulated monitoring. From 2003 to 2007, however, it is not clear whether the water levels have a tendency of decline or not. Only a few wells, i.e. P8, P15 and P21, located in the sandstone well field, which is Western Well Field for the Sana'a water supply system, look to show a tendency of water level decline, though P18 was measured only four times during the period.

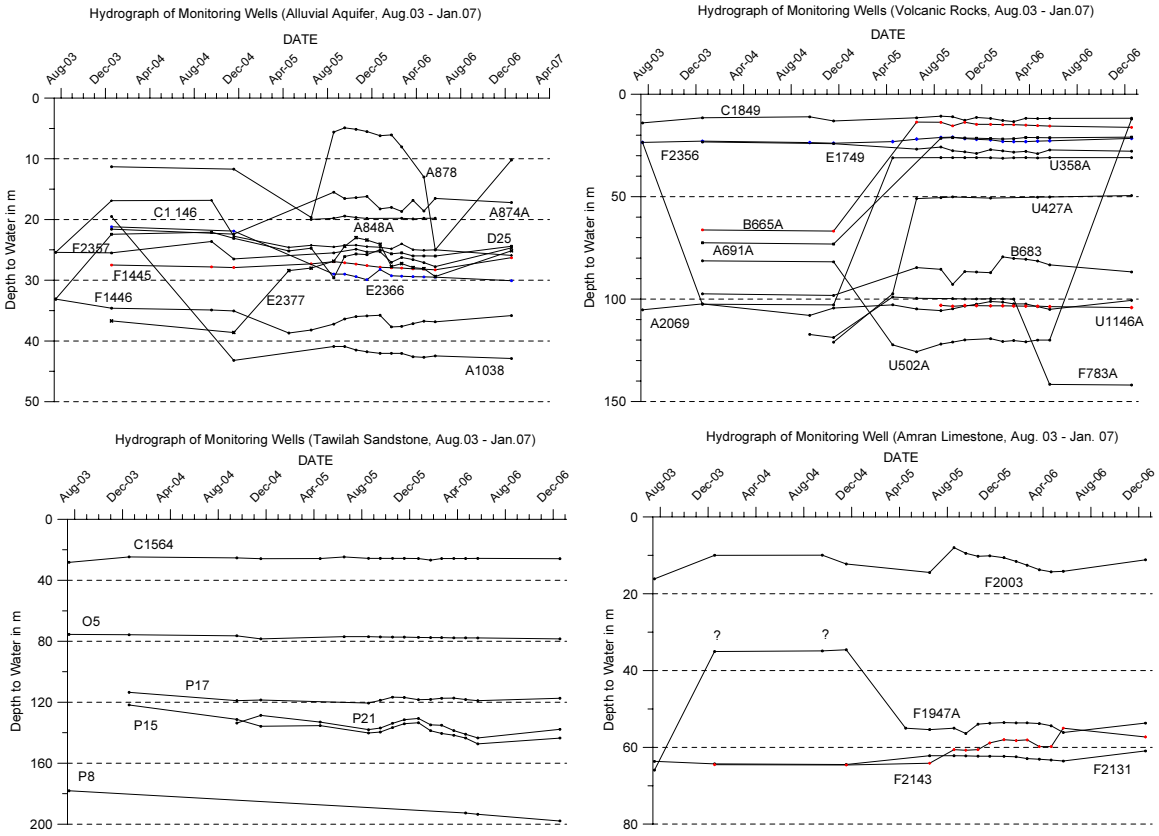


Figure 3.30 Hydrograph of Monitoring Well

2) Long-term Tendency of Water Level Change

<Water level of the western well field>

Howard Humphreys & Sons (1980)[17] shows the static water levels of the wells constructed in the Western Well Field measured in October - November 1979. *Table 3.20* show the comparison of water level between 1979 and 2007.

Table 3.20 Water Level Change between 1979 and 2007 in Western Well Field

Well	Elevation (mamsl)	Depth to Water (m)	Water Level (m-amsl)	Depth to Water (m)	Water Level (m-amsl)	Difference (m)	Annual Falling Water Level (m/year)
		Oct-Nov. 79		Jan. 07			
P8	2231.87	47.32	2184.55	197.87	2034.00	-150.55	-5.54
P15	2224.54	55.29	2169.25	143.49	2081.05	-88.20	-3.25
P17	2216.35	45.95	2170.40	117.40	2098.95	-71.45	-2.63
P21	2215.87	53.54	2162.33	137.79	2078.08	-84.25	-3.10
O5	2211.13	33.07	2178.06	78.42	2132.71	-45.35	-1.67

Although the recent monitoring shows not so clearly a decline of water level in the Sana'a basin as described in the previous section, *Table 3.20* indicate at least the water level of Western Well Field has dropped for these several decades. P8 that showed the largest falling of water level, -150 m for 28 years, is located in the almost center of the Well Field, so the result may reflect the well has been affected by pumping of surrounding production wells. P15, P17 and P21 are located at the northwest end of the Well Field, and there are few production wells around O5.

The expected thickness of the Tawilah Sandstone in the area of Western Well Field is only 400 m, which underlies the Alluvial deposits with the thickness of about 10 m. The range from 140 to 200m of the depth to water showing in the above table means that the thickness of the aquifer has decreased up to 60 to 70% of the original saturated thickness. It is recommended that the drawdown in an aquifer should not exceed around 50 to 60 % of the saturated thickness[18], not to cause any adverse impact such as the deterioration of quality. If the decline of the water level will continue with the annual rate of 3.1-5.5 m as shown in the above table, the water table will reach the critical level in 6 to 10 years.

<Another observable fact about water level>

Figure 3.31 shows the distribution of the depth of boreholes drilled from 1970s to 2002. The shaded area indicates where the drilled depth of more than 300m dominates. The area has clearly expanded with the times. It is considered that there are some reasons. One is the technical one that a depth of borehole became deeper with improved drilling technology, and boreholes have been drilled in highland areas where a borehole was not drilled before. Most of the areas with 400m or more drilled depth shown in the figure seem to be such highland areas. Another main reason is most likely that the depth of 300m or less became not enough to get sufficient water due to a decline of the groundwater level. It may be true especially the surrounding area of Sana'a city.

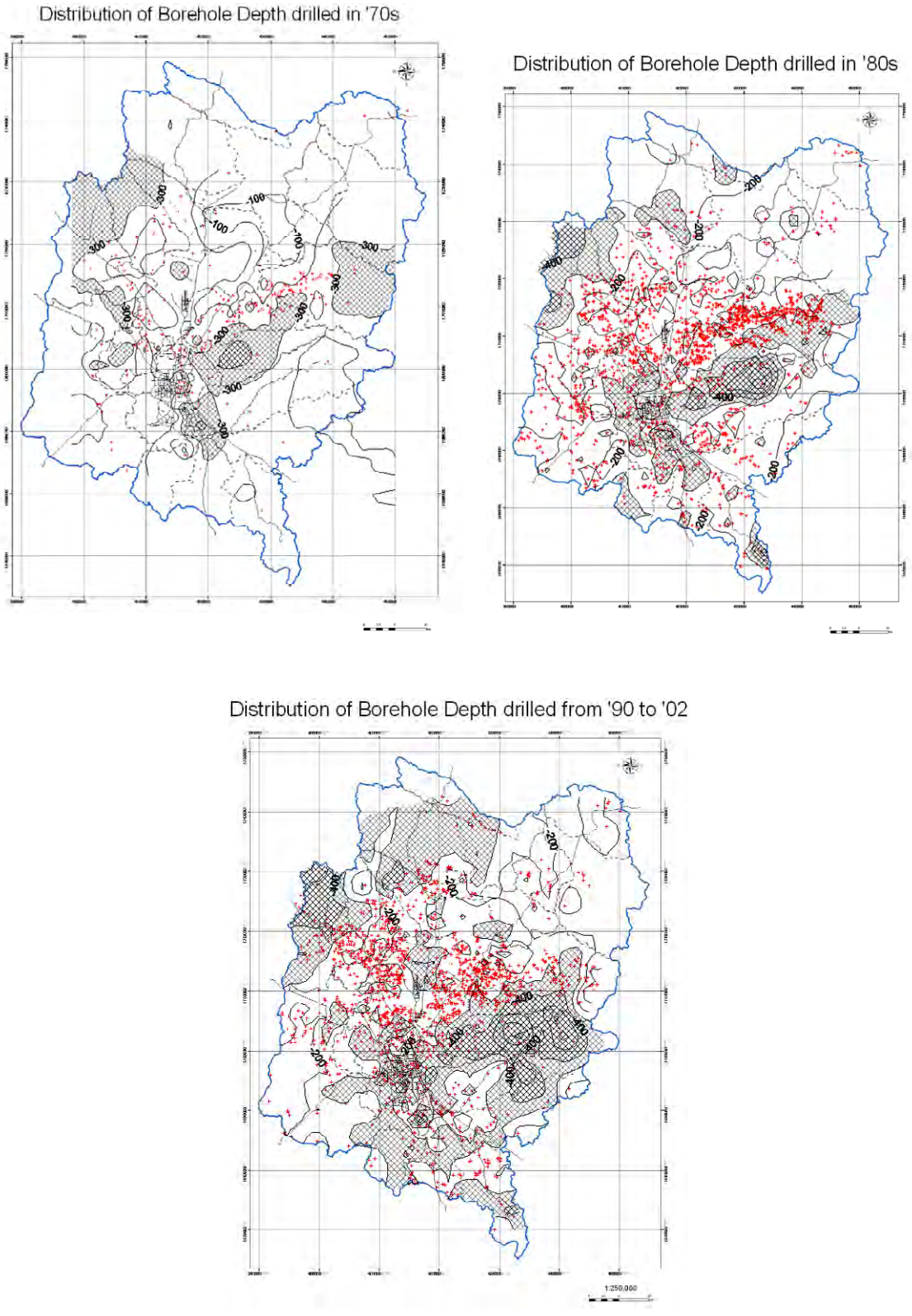


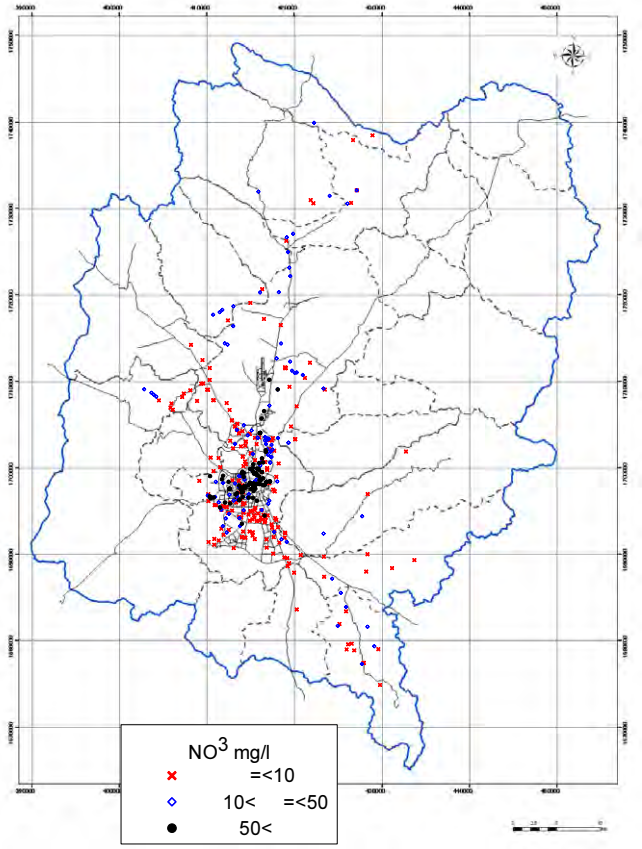
Figure 3.31 Depth of Boreholes drilled from 1970 to 2002

(2) Groundwater Quality

SAWAS Technical Report No.13 (1996) mentioned the possibility of groundwater

contamination in the Sana'a Basin. Most possible contamination source is sewage disposal on land at present. *Figure 3.32* shows the distribution of nitrate concentration based on the data measured in 1996 by SAWAS. The highest desirable limit (HDL) of nitrate is 10 mg/l and the maximum permissible limit (MPL) is 50 mg/l in the national standard for drinking water.

The figure indicates clearly that the area of Sana'a city had been polluted by high nitrate, which was considered to derive from a lot of cesspit constructed in the city. The figure also shows there is an area with high nitrate on the north of the Sana'a city, between the north edge of the city and the airport. It was the place where a sewage pond was located once, or Ar-Rawdah.



Data Source; SAWAS (1996)

Figure 3.32 Nitrate Distribution in the Sana'a Basin (1996)

The nitrate data provided by SAWAS were partial in the Sana'a basin as shown in the figure. Well inventory survey (2002) measured the EC values of 7,638 wells in the Basin. EC can be regarded as an indicator of water quality, which is related to the total dissolved solid (TDS) in the water. The data collected by GARWSP indicate the relationship between EC and TDS is roughly shown by the following equation; *TDS (mg/l) = (0.65～0.7) x EC (microS/cm)*

The HDL of TDS is 650 mg/l and the MPL of TDS is 1,500 mg/l in the national standard for drinking water. The values are converted to the EC of 1,000 (HDL) and 2,300 microS/cm (MPL) approximately. *Figure 3.33* shows the distribution of EC in the Sana'a basin based on the data of Well Inventory Survey (2002).

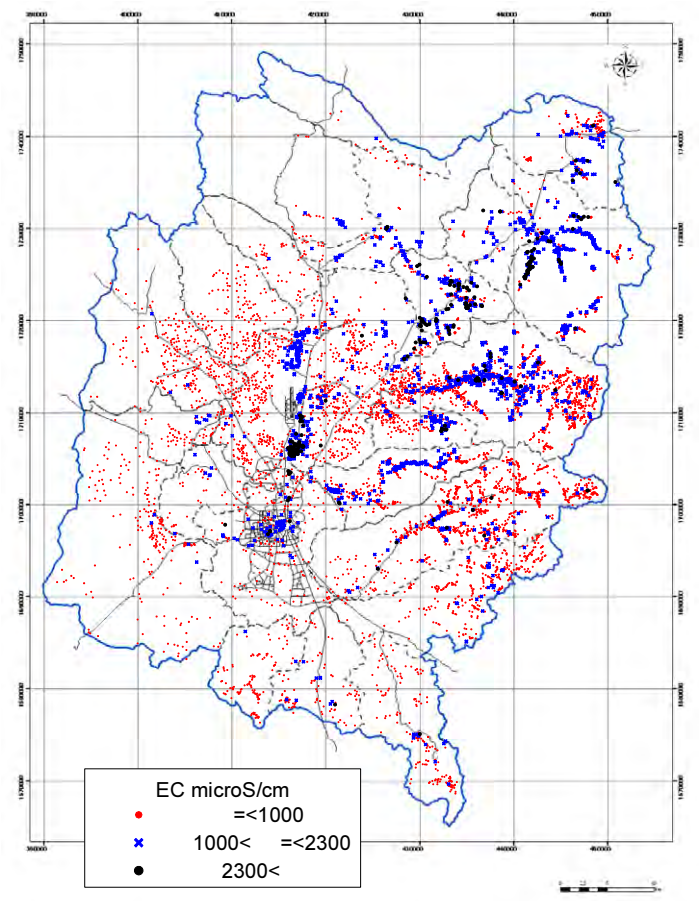


Figure 3.33 Distribution of EC in the Sana'a Basin (2001)

The figure indicates that, addition to the city area, the area along the flow of the Wadi Bani Huwat and other main wadi streambeds in the northeastern part of the Sana'a Basin, namely the upper Wadi Sa'wan, the upper Wadi Furs, Wadi Al Sirr, Wadi Thoma and Wadi A'sirm are probably polluted.

The upstream of Wadi Bani Huwat is the area where the wastewater treatment plant was constructed and started work in 2000, and Ar-Rawdah is located, where a sewage pond was placed once as mentioned before. It suggests that groundwater in this area are most likely contaminated by sewage. Similarly, other wadi streambeds are also highly possible to be polluted by domestic sewage from the surrounding villages, and/or by their agricultural activities, which may use organic fertilizer and leave the storage or disposal of livestock or fowl wastes on land.

3.7.2 Possible Adverse Impact

As described in the previous section, the falling water level in the Western Well Field and the high concentration of nitrate in groundwater has been clearly observed. In addition, the drilling depth of boreholes suggests that the water level around the Sana'a city is falling down and the high EC value indicates the contamination of groundwater in the Basin.

In terms of quantity, or water level, the observable fact about the falling water level is only the record of monitoring wells located in the Western Well Field. As described already, however,

the water balance in the Sana'a Basin shows a large deficit for recharge, that is, the storage is decreasing in the basin, especially several sub-basins mentioned in 4.6. Therefore, the falling water level occurs most probably not only in the Western Well Field but also in other areas. The number and the location of monitoring wells are not adequate to grasp the actual condition of groundwater at present. The further monitoring wells are necessary to be installed in other well fields for water supply system and some sub-basins where the large discharge volume as against the recharge is estimated.

In terms of quality, an overall water quality analysis survey has not been conducted in the Sana'a basin since 1996 (by SAWAS), except the well inventory survey in 2001-02, which assessed only EC, pH and temperature. Possible sources of groundwater contamination are not only sewage. There are many other sources having an adverse impact on groundwater quality such as agricultural activities, land disposal of solid wastes (refuse), petroleum leakage and spills, seepage from industrial waste and so on.

Fertilizers and pesticides used for agriculture and the storage and disposal of livestock waste on land effect widely the groundwater quality. YGGMP (2004) has pointed out the possibilities of pollution caused by insufficient waste disposal in the petrol stations, car service shops and the medical units like hospital, laboratory and clinic. The actual condition of groundwater contamination caused by these individual factors has not been clarified yet. YGGMP (2004) reported that the water quality collected the Al-Mashham Dam had been deteriorated since 2003. Though there are neither reports nor record in the other areas, it may be possible the quality of groundwater have become worse from 2001 onward. Therefore, comprehensive survey of groundwater quality in the Sana'a basin is required without delay.

3.8 NON-CONVENTIONAL WATER SOURCES

Water resources have been conventionally exploited by dug wells, boreholes and small-scale dams or pools for irrigation and domestic water use in the Sana'a basin. In addition to these conventional facilities, several ideas have been proposed by the previous studies to supply water for the area, which are called a non-conventional water source. The non-conventional water sources can be categorized to four groups. The categorized alternative water sources are listed as follow.

1. A large-scale storage dam in and out of Sana'a Basin
   - Wadi Kharid Dam
   - Wadi Surudud Dam
   - Diversion of water from Marib Dam
2. Desalination of Red Sea Water
3. Groundwater Development outside of Sana'a Basin
   - Development of Ramlat Sabatayn Area
   - Development of Wadi al Masilah, Hadramawt
4. Other alternatives
   - Deeper Pre-Jurassic Sandstone
   - Subsurface Dam for Promoting Recharge

SAWAS (1996)[19] evaluated these options except the sub-surface dam that was assessed by

Hydrosult (2002)[20]. The results of the previous reports are summarized in the following sections. *Figure 3.34* shows the locations of the above non-conventional alternative water sources.

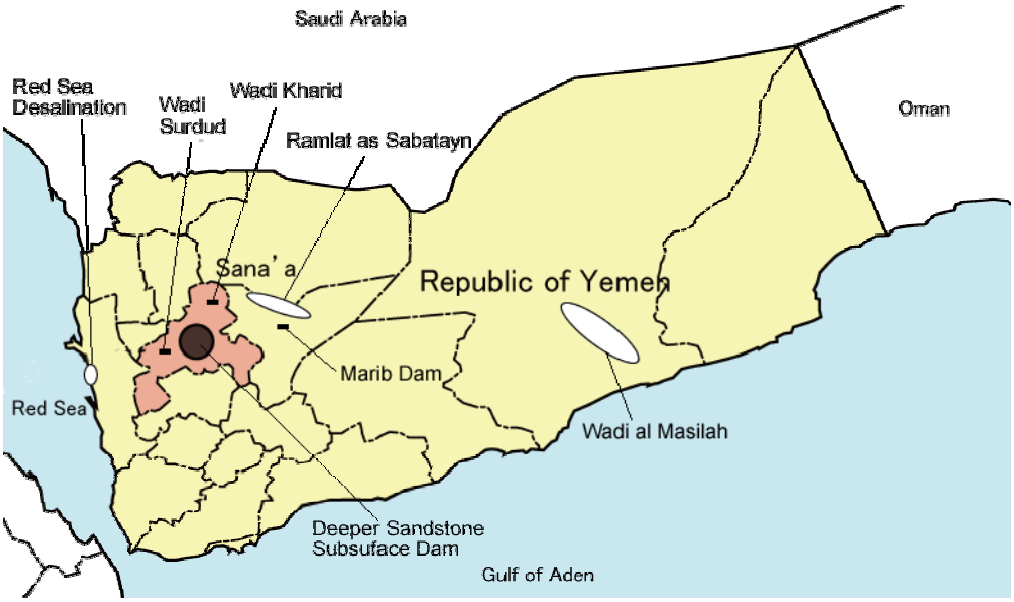


Figure 3.34 Locations of Alternative Water Sources

3.8.1 STORAGE DAMS IN AND OUT OF SANA'A BASIN

(1) Wadi Kharid Dam

Mosgiprovodkhoz (1986) proposed the plan for the Sana'a water supply system originally, and SAWAS Technical Report No.9 (1996) carried out the feasibility study. The result indicated that the average annual catchment yield might be about 11 MCM, or about 350 l/s, and the following works were required.

- A 70 m high rock fill dam, 45 MCM storage reservoir (35 MCM usable)
- Water intake in the upper pool
- Water treatment facilities (20,000 m^3/day)
- 58 km transmission main with a booster pumping station
- Centralized power supply from a sub-station in Sana'a
- Complementary works such as roads, communication systems, workshops, office etc.

The construction cost was estimated at US$87.2 million in total, and the annual cost was estimated at US$10.7 million based on the price level of April 1996. The unit cost was calculated at US$1.32 per m^3.

The environmental assessment has not been carried out, although the environmental impact on the downstream area is predicted.

(2) Upper Wadi Surdud Dam

A pilot study on water resources management of the Wadi Surdud area was implemented in 1991 (WRAY-22, 1991). The study[21] of SAWAS project assumed that a maximum of 500 l/s could be abstracted from the Upper Wadi Surdud. The level of the intake was at approximately 880 m.a.s.l. The proposed intake was a weir with a cylindrical crest and a submerged bucket

type dissipator, provided with a scouring sluice, intake sluice and a sand trap.

The construction cost was estimated at US$230.6 million, and the annual costs were estimated at US$32.6 million based on the price level of April 1996. The unit cost was calculated at US$2.03 per m^3.

The environmental assessment has not been carried out, although the environmental impact on the down stream area and the groundwater in Tihama plain is predicted.

(3) Diversion Water from Marib Reservoir

SAWAS[22] mentioned that the existing Marib dam was not able to satisfy the requirements for irrigation in the downstream area on the dam even at that time. In addition, it noted that conclusive decisions concerning the abstraction of water from the Marib reservoir were not expected to be taken in the near future due to the limited availability and high demand for water of the farmers in the Marib area.

Anyway, it is technically possible to abstract large amount of water from the existing reservoir at Marib, and a maximum amount of 1,000 l/s was assumed available from the Marib dam for the Sana'a water supply system by SAWAS.

The preliminary plan was designed for the transport of 500 l/s of raw water from the Marib dam to Sana'a. The total estimated construction cost was US$284 million and the annual costs were estimated at US$37.6 million based on the price level of April 1996. The unit cost was calculated at US$2.33 per m^3.

3.8.2 Desalination of Red Sea Water

SAWAS Technical Report No.7 noted that the cost of this option might prove to be prohibitive and the transmission system and pumping stations would be very vulnerable to damage and possible sabotage although there are no limits to the amounts of water technically.

The construction cost of the provisional design for the first stage (500 l/s) was estimated at US$900 million, including US$71.6 million for the intake work and desalination. The total annual cost was estimated at US$124.3 million. The unit cost was calculated at US$7.63 per m^3.

3.8.3 Groundwater Development outside of Sana'a Basin

Two groundwater development projects have been proposed. One is the development of Ramlat as Sabatayn and another one is the development of Wadi Masilah in Hadramawt.

(1) Ramlat as Sabatayn

There are two large wadis running in the area, namely Wadi Jawf and Wadi Adhana.

The Quaternary alluvial and eolian deposits of Wadi Jawf constitute an aquifer with the thickness of 50 to 70 m in the western part and 10 to 20 m in the Al Hazm area[23]. The Quaternary aquifer is underlain by moderately productive limestone of the Amran Group in the western zone. East of Al Hazm are the western edge of the Mukalla Sandstone with high porosity. The Quaternary deposits are probably connected hydraulically with these productive formations.

The Quaternary aquifer also occurs in Wadi Adhana with the thickness of 50 to 70 m[24]. In the

western fringe, it is underlain by the Amran Limestone. About 5 km of Old Marib and further east, it forms one aquifer complex with underlying Mukalla Sandstone. Transmissivity is expected high.

The further detailed study of the development in the area has not been conducted yet, but a feasibility study is planned by NWRA recently.

(2) Wadi Masilah in Hadramawt

A Canadian oil company discovered an aquifer of Mukalla Sandstone in Wadi Masilah during the oil exploration in the area in1990s. The World Bank had proposed it as the water source for the Sana'a water supply system. It, however, was realized that there were many problems such as too long distance, almost 700 km from Sana'a in a straight line, and socio-economic and security issues, although the aquifer was expected to have a potential.

3.8.4 OTHER ALTERNATIVES

(1) Development of Deeper Pre-Jurassic Sandstone

Pre-Jurassic Kohlan Sandstone have been exploited for Sa'dah water supply. The formation was supposed to underlie Amran Limestone in the Sana'a basin. SAWAS project drilled two exploration boreholes with the depth of 1600m in Arhab (Well DS1) and Al Hatarith (Well DS2) located to the northeast of Sana'a. The results were reported in SAWAS Technical Report No.8 (1996)[25].

The first test well (DS1) confirmed the pre-Jurassic sandstone at 1384m below surface. The thickness of the aquifer was only 40 m, which was 10% of the expected thickness. The water had high iron content and smelled H_2S during sampling. The temperature of water was 48 C at the surface.

The second test well (DS2) did not encounter the sandstone formation and it was considered a dry well.

Although, it was considered difficult to use as the source of water supply system due to the water quality and the lower productivity, a design was proposed for the Sana'a water supply system as follows. The well field consisting of four wells with a total capacity of 100 l/s, each spacing of 5,000 m and the depth of 1,400 to 1,500 m, was planned.

The construction cost was estimated at US$60.3 million and the annual costs were estimated at US$4.6 million based on the price level of April 1996. The unit cost was calculated at US$2.43 per m^3.

(2) Subsurface Dam for Promoting Recharge

Subsurface dam may be called a kind of artificial recharge dam. Hydrosult (2002) evaluated the nine sites propose to construct subsurface dams. The nine sites were selected because of the suitable locations for subsurface storage of water in order to reduce the abstraction for irrigation from the deeper aquifer.

The evaluation concluded that the three sites of the nine were the most suitable for the construction of pilot dams, namely Al Asha in Wadi Sawan, and Seil and Al Man in Wadi Dahr.

Assumed reservoir volumes of Al Asha, Seil and Al Man were 0.16, 0.95 and 1.22 MCM respectively. The costs were estimated from US$82 thousand (Al Asha) to US$373 thousand (Al Man).

3.8.5 CONSIDERATION OF THE ALTERNATIVE WATER SOURCES

Information about each alternative is summarized in *Table 3.21*. In these previous studies, capital cost, operation and maintenance cost and water tariff ware estimated on the basis of market price in early 90s. However, quantitative analysis from the view points of social and environmental aspects has not been conducted. It was pointed out that there were some restrictions to be considered prior to the implementation of these alternatives, such as an adverse impact on environment in the up and down streams of dam site, insecurity for the long distance installed pipes and consideration for the people who are living around ground water abstraction area.

Thus, even if the Government of Yemen allocates the budget for one of these alternatives, it is required to study the adverse impact which might be caused by the implementation. Based on the study, the countermeasures to be taken should be considered in both national and basin levels in order to mitigate the expected adverse impact in advance.

Table 3.21 Alternative Water Source

Source	Potential / Production Capacity		Cost**		
	l/s	Mm^3 /year	million US$	annual cost US$	Unit cost US$/m3
Wadi Kharid Dam	250	7.9	87.2	10.68	1.32
Wadi Surdud Dam	500	15.8	230.6	32.62	2.03
Diversion of water from Marib Dam	500	15.8	284.4	37.58	2.33
Desalination of Red Sea Water	500	15.8	902.9	124.28	7.63
Development of Ramlat as Sabatayn	not designed		not estimated		
Development of Wadi Masilah	not designed		not estimated		
Deeper Pre-Jurassic Sandstone	100	3.2	60.3	7.68	2.41
Susurface Dam for Recharge		(1.2)*	0.373		

Source; SAWAS Technical report No.14 and others

*): the maximum designed storage capacity, **): estimated in 1996 except Subsurface Dam (estimated in 2002)

3.9 PROBLEMS AND RECOMMENDATION CONCERNING WATER RESOURCES

3.9.1 PROBLEMS TO BE SOLVED

The present state of water resources was described in this chapter and several problems to be solved were revealed. The problems are:

- As the observed fact, the falling down of water level in the Western Well Field is occurring. Although the water level decreasing has not been confirmed clearly and officially in other areas, it can be considered to have occurred in some areas.
- The long-term tendency of water level change in the Western Well Field indicates that the water table will reach the critical level in 6 to 10 years, if the decline of water level will

continue with the same rate as before.

- The contamination of groundwater is suspected in the Basin, especially in the wadi beds of the northeastern sub-basins in the Sana'a Basin. The comprehensive water quality survey, however, has not been achieved since 1996.
- The water balance estimation in sub-basins indicates that the discharge volume of groundwater is more than 10 times of the estimated recharge volume in some areas. Wadi al Mawrid, Wadi Bani Huwat and Wadi al Furs may be in a very critical condition of groundwater resources.
- Even though the above critical condition is indicated in the areas, the actual volume of groundwater abstraction from wells has not been measured. Additionally, the recharge mechanism is still unclear.
- There are wells with the over fluoride concentration in the Basin.
- The serious issue in relation to the all above problems is that the monitoring system in the Basin is still not sufficiently run at present, though it has shown the progress recently, namely:
  - Some meteorological and rainfall stations have not been operated satisfactorily.
  - No runoff stations, (which is planned by NWRA-SB with the support of SBWMP)
  - Only six wells are installed automatic water level recorders, but others are not planned to be installed it.
  - In general, the wells used for monitoring were not constructed for the purpose originally.
  - Not monitored periodically groundwater quality
  - No plans to install a flow meter on production wells except NWSA wells.

3.9.2 RECOMMENDATION

Monitoring of the hydrological condition is one of the most important factors to do an appropriate management of water resources in the area.

- The monitoring information shall be fully used in the decision-making process for long-term operational strategy of water resources.
- The monitoring information is also essential for the assessment of the effect and satisfactoriness of the implemented activities.
- The monitoring information shall be used to provide a modification or adjustment of the operational plan for water resources utilization and development management.
- The monitoring information shall be open to the public to make them aware of the groundwater condition and to achieve the effective activities to save the resources in cooperation with them.

The following items are recommended.

- Expansion of water level monitoring network including the construction of new boreholes to monitor a specified aquifer
- Implementation of the periodical water quality monitoring and the comprehensive water quality survey in the area

- Investigation of the actual pumping rate of wells used for agriculture and others
- In addition, the continuous monitoring of the pumping rate with the installation of flow meter is necessary.
- The above expansion and implementation are urgently needed especially in the sub-basins of Wadi al Mawrid, Wadi Bani Huwat and Wadi al Furs.
- A periodical report of the monitoring results shall be provided and published by NWRA.
- Construction of the database system consisting of all the monitoring results and its update
- Construction of the aquifer model based on the monitoring results and its update for a future prediction about the water level and quality
- Water supply system shall be provided in rural areas, especially the areas where over fluoride concentration is observed.

Definitely, the recommendation can not be carried out in a short period. The priority level of the items should be decided based on the various factors including not only hydrogeological one but also socio-economical ones. Moreover, of course, the financial resources and the training of the personnel concerned shall be necessary to support the implementation of these items.

References;

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CHAPTER 4

PRESENT CONDITION OF SOCIO-ECONOMY

CHAPTER 4 PRESENT SOCIO-ECONOMIC CONDITIONS

4.1 GENERAL SOCIO-ECONOMIC CONDITIONS

4.1.1 DEMOGRAPHY

The latest population and housing census in Yemen in 2004 shows a total of 19.6 million population in the whole country. The annual average growth rate at the national level is 3.0% for the period from 1994 to 2004. The population growth rate for the Capital Secretariat (Sana'a City) is 5.55% while rural part of Sana'a governorate is 2.07% for the same period. *Table 4.1* shows the population distribution and other indicators by governorates based on the results of the 2004 census.

Table 4.1 Distribution of Population by Governorates

Governorate		No. of Houses	No. of Households	Population	Population Indicator				
				Total	Gender Ratio	Average No. of HH/ House	Average No. of Persons/ HH	Average Annual Growth Rate (1994-2004)	Ratio of Population Distribution
1	Ibb	313,684	305,252	2,131,861	96.0%	0.97	6.98	2.47	10.8%
2	Abyan	58,984	58,833	433,819	104.1%	1.00	7.37	2.36	2.2%
3	Capital Secretariat	267,125	254,866	1,747,834	122.3%	0.95	6.86	5.55	8.9%
4	Al-Baydha'a	69,818	67,572	577,369	102.6%	0.97	8.54	2.39	2.9%
5	Taiz	392,904	367,732	2,393,425	92.5%	0.94	6.51	2.47	12.2%
6	Al-Jof	56,466	59,028	443,797	119.0%	1.05	7.52	2.44	2.3%
7	Hajjah	186,900	194,972	1,479,568	108.8%	1.04	7.59	3.04	7.5%
8	Al-Hodeidah	367,749	349,309	2,157,552	105.8%	0.95	6.18	3.25	11.0%
9	Hadramout	142,145	124,809	1,028,556	106.4%	0.88	8.24	3.08	5.2%
10	Dhamar	198,977	187,765	1,330,108	98.7%	0.94	7.08	3.04	6.8%
11	Shabwah	53,082	53,065	470,440	107.0%	1.00	8.87	2.54	2.4%
12	Sa'adah	81,568	85,477	695,033	107.3%	1.05	8.13	3.67	3.5%
13	Sana'a	115,700	117,381	918,727	103.7%	1.01	7.83	2.07	4.7%
14	Aden	97,408	90,667	589,419	113.7%	0.93	6.50	3.77	3.0%
15	Lahij	114,714	105,013	722,694	99.8%	0.92	6.88	2.63	3.7%
16	Maareb	28,013	28,028	238,522	114.6%	1.00	8.51	2.72	1.2%
17	Al-Mahwit	65,604	69,184	495,045	100.9%	1.05	7.16	2.87	2.5%
18	Al-Muhrah	12,862	13,933	88,594	118.8%	1.08	6.36	4.51	0.5%
19	Amran	99,158	106,732	877,786	105.9%	1.08	8.22	1.82	4.5%
20	Al-Dhali	61,094	59,894	470,564	105.1%	0.98	7.86	3.55	2.4%
21	Rima	50,482	56,321	394,448	95.9%	1.12	7.00	3.02	2.0%
	Total	**2,834,437**	**2,755,833**	**19,685,161**	**104.0%**	**0.97**	**7.14**	**3.00**	**100.0%**

(Source: Central Statistical Organization, The General Population, Housing, Establishment Census 2004, General Frame of the Population: Final Results, 2006)

4.1.2 ADMINISTRATIVE SETTINGS AND SOCIAL STRUCTURE

Sana'a Basin is centrally located in Sana'a Governorate and covers districts of Bani Husheish, Khawlan, Bani Matar, Arhab, Hamdan, Nehm, Sanhan -Bani Bahluol among 16 districts in the governorate as well as the Capital Secretariat (Sana'a City) including former Bani Harith District. Due to proximity to Sana'a City, part of Sanhan-Bani Bahloul and Hamdan are categorized in the Capital Secretariat according to the 2004 population census.

Local administration is governed by the district councils which are represented by the councilors selected from respective constituencies through election. Apart from Sana'a City and adjoining area which is rapidly urbanized with influx of population, the rural area in Sana'a Governorate still maintain traditional social structure based on the tribal relationship in addition to aforementioned local administrative structure. Under the district (moderiah), there are usually several sub-districts (ozlah) which contain groups of villages (qaryha) and their attachments (mahallah).

At the village and/or sub-district level, head (sheikh) represents the area traditionally. Under the leadership of the sheikhs, aqel or adel are appointed in each village or hamlet to collect tax and notarization of contracts made by the community members.

4.2 WATER USAGE CONDITION SURVEY

This section presents results and findings of the Water Usage Condition Survey conducted in the period of June to July 2007.

4.2.1 OBJECTIVES OF THE SURVEY

Aiming at comprehending current conditions of water use for different purposes and perception of water users on the water resources management in Sana'a Basin, the Water Usage Condition Survey was carried out by Interaction in Development, a consulting firm based in Sana'a, under a sub-contract with the JICA Study Team as a part of the aforementioned study in the first stage. Specific objectives of the survey are as follows;

- to obtain information of the actual conditions of water use in the entire Sana'a Basin including for irrigation, domestic, industrial and tourism use.
- to understand water users' perception and practice of water resources management as well as their awareness of related laws and regulations.

The survey covered the whole Sana'a Basin which consists of 22 sub-basins in order to obtain basic data related to water use which represents the situation in the basin.

Results of the survey are to be utilized as the basic information on condition of water consumption for various purposes in the stage of water balance analysis and projection of future water demand. Also, findings on practice and perception of the community members on water resources management and conservation are supposed to be incorporated into formulation of the water resources management action plan for Sana'a Basin.

4.2.2 APPROACHES AND METHODOLOGIES

(1) Utilization of Output of Preceding Researches

Under the Sana'a Basin Water Management Project funded by World Bank, quantitative and qualitative surveys have been conducted in the basin to analyze socio-economic characteristics of the area and to collect baseline related to water use and awareness of water resources

management by the communities. For planning of the field survey in this study, outputs from these preceding researches were reviewed to consider the survey scope, target area, methodologies and procedures of the data analysis. Documents reviewed for this purpose are;

- Water and Environment Center, Sana'a University (2001) Basin Characterization and Selection of Pilot Study Areas: Volume IV Socio-Economics, Final Report, WEC, Sana'a
- Consulting Engineering Services (I) PVT. LTD. et al. (2006) Baseline Survey for Future Impact Evaluation, Consulting Engineering Services (I) PVT. LTD. et al., Sana'a

The first report constitutes outputs of the project preparation studies for SBWMP. Aiming at developing a clear picture of the water resources, agriculture, social, institutional, environmental and economic situation in the entire Sana'a Basin, 174 farmers (136 well owners and 38 non-owners) and village representatives were interviewed in a total of 40 villages spreading in eight districts[1] with regard to main issues including water resources, water use, socio-economic conditions and management and policy making. In addition, stakeholders meetings were organized by sub-basin to assess the situation and identify specific problems related to the area with a direct involvement of all concerned stakeholders (WEC 2001).

The second report was compiled to describe baseline of the key performance indicators of the on-going SBWMP Component 1 Demand Management and Irrigation Improvement so that the groundwater abstraction and subsequent recharge for future year will be monitored and the project impact will be measured according to the project stage (CES, 2006). The baseline survey consisted of 1) focus group discussion at village level, 2) structured interview to 294 farming households, 3) structured interview to the well-water users and well investigation at 206 water points in a total of 25 villages located in 11 sub-basins[2] selected among 22. Information and data collected in the survey are particularly related to land use and cropping patterns, gross earnings from the agricultural activities, characteristics and water use of existing water sources in the villages, irrigation method, and willingness and preparedness of community members on participatory water resources and irrigation management.

(2) Focused Areas of the Survey

Considering that both preceding field surveys mentioned in the previous section had limitation in number of collected samples and survey area covered due to several reasons, the Water Usage Condition Survey in this study was designed to obtain information and data which statistically represent the entire basin with targeting all 22 sub-basins. Referring to the survey items covered in the baseline survey under the SBWMP, salient issues and detail items to be surveyed were extracted so as to comprehend the present situation in the sub-basins including the ones that were not targeted in the baseline survey.

The focused issues of the survey were determined according to two clusters, namely rural and urban areas, with considering the different water use patterns in these geographical zones. The biggest amount accounting for 90% of total water consumption in Sana'a Basin is used for irrigation in farming which is the main economic activity in the rural communities in the basin. Farmers mostly relied on groundwater extracted from either boreholes, dug wells or dug bore for the water source for irrigation. The survey in the rural area, therefore, focused on interviews to well owners who constructed wells and use water for irrigation and community leaders where those wells are located in order to collect information on situation of land and water use, agricultural activities, and their awareness and perception on water resources management.

Meanwhile, in the urban area, industrial and tourism sectors as well as those who are in business

of water vending were targeted to assess water use in Sana'a City. This is supplementary to the updated information on municipal water supply in Sana'a City which is to be collected though Sana'a Water and Sewerage Local Corporation (SWSLC). The survey results for the urban cluster is compiled as a part of the well inventory in Appendix 11.

(3) Methodologies and Tools Employed

The survey employed the structured interview for each target group in accordance with the questionnaires prepared by the Study Team. *Table 4.2* shows the scope of the survey. The questionnaires adopted in the survey are attached in Appendix 6 to 10.

Table 4.2 Scope of the Water Usage Condition Survey

Cluster	Survey Category	Key Informants	Sample Size	Tools
Rural Area	1) Structured interview at village level	Community leaders such as Sheikh, Aqil, Amin, and representatives of WUG/WUA in the villages or sub-villages where the designated water points are located	400 samples	Questionnare for Village Authorities
	2) Structured interview at water point level	Well owners	400 samples	Questionnaire for Water Users
Urban Area (Sana'a City)	3) Structured interview to the industrial establishments	Management of factories or manufacturing campanies which has its own well inside the premise of the factory	8 samples	Questionnaire for Industrial Water Usage in Sana'a City
	4) Structured interview to hotels	Management of hotels	7 samples	Questionnaire for Tourism Water Usage in Sana'a City
	5) Structured interview to well owners in water vending by tankers	Well owners or responsible person for operation of the well	5 samples	Questionnare for Water Usage Conditions for Tankers

Three teams with five members (four enumerators and one team leader) each were formed and received a five-day training. Also, contents of the questionnaires were finalized based on one day pre-testing prior to commencement of the actual survey. Each team was responsible for an almost equal number of water points that are geographically located within close proximity to each other. Data collection in the filed took place during the period of 9th June – 9th July 2007.

(4) Sampling Method

1) Distribution of Samples

According to the terms of reference of the study, a total of 400 wells are targeted in the structured interview to the water users and village authorities in rural area. Additionally, another 20 private wells and those users were included in the target of the survey in Sana'a City with regard to water use in industry and tourism.

For allocation of samples to 22 sub-basins and selection of the target wells, the well inventory developed by WEC in 2002 was utilized. Approximately 7,900 water points[3] are recorded as functioning as of 2002 according to the inventory. Based on the distribution of these functioning water points by sub-basin, sample size of the water points was determined by sub-basins as shown in *Table 4.3.* The distribution of samples by the district boundaries is indicated in *Table 4.4.*

Table 4.3 Distribution of Samples by Sub-Basins

	Sub-Basin	District Located in the Sub-Basin	No. of water points in Use (2002)	No. of Samples (Wells Surveyed)	
				Rural Area	Urban Area (Sana'a City)
1	Wadi Al Mashamini	Arhab	15	3	-
2	Wadi Al Madini	Arhab	52	3	-
3	Wadi Al Kharid	Arhab Nehem	106	5	-
4	Wadi Al Ma'adi	Nehm	187	10	-
5	Wadi A'sir	Nehm	462	25	-
6	Wadi Khulaqah	Nehm	83	5	-
7	Wadi Qasabah	Arhab	43	3	-
8	Wadi Al Huqqah	Arhab Hamdan	190	10	-
9	Wadi Bani Huwat	Capital Secretariat Bani Husheish	1,299	64	-
10	Wadi Thumah	Arhab Nehm Capital Secretariat	236	10	-
11	Wadi As Sirr	Bani Husheish Nehm Khawlan	1,387	65	-
12	Wadi Al Furs	Bani Husheish	278	10	-
13	Wadi Al Iqbal	Hamdan	265	10	-
14	Wadi Zahr & Al Ghayl	Hamdan Bani Matar	343	20	-
15	Wadi Hamdan	Hamdan	85	5	-
16	Wadi Al Mawrid	Capital Secretariat	480	20	20
17	Wadi Sa'wan	Bani Husheish	650	40	-
18	Wadi Shahik	Sanhan & Bani Bahloul Khawlan Bani Husheish Capital Secretariat	1,000	49	-
19	Wadi Ghayman	Sanhan & Bani Bahloul Khawlan	383	20	-
20	Wadi Al Mulaikhy	Bani Matar Sanhan & Bani Bahloul	132	10	-
21	Wadi Hizyaz	Bani Matar Sanhan & Bani Bahloul	75	3	-
22	Wadi Akhwar	Sanhan & Bani Bahloul	184	10	-
	Total		7,935	400	20

Table 4.4 Distribution of Samples by Districts

District	No. of Samples (Wells Surveyed)	
	Rural Area	Urban Area (Sana'a City)
Arhab	19	-
Bani Husheish	123	-
Bani Matar	13	-
Khawlan	15	-
Sanhan & Bani Bahlool	78	-
Nehm	46	-
Hamdan	34	-
Capital Secretariat (Sana'a City)	72	20
Total	400	20

Concentration on the wells as the target of the survey is justified by the situation that boreholes, dug wells and dug bores constitute 98% of the total water points identified in the well inventory survey by WEC and 97% of the water points in use. A total of 420 wells sampled correspond to 5.4% of the total number of the functioning wells listed in the inventory.

2) Selection of Samples

Sampling was basically done at the water point level. Wells with relatively high yield among the ones in each sub-basin were selected as the samples of the survey. For the survey in rural area, one well each was picked up from one village in order to ensure even distribution of samples in location-wise in each sub-basin, hence 400 wells located in 400 villages. Samples for the urban cluster were selected from factories, hotels and water vendors which consume large amount of water for business.

(5) Constraints

Of the 400 designated wells for the rural cluster, the enumerators surveyed 352 samples while other 48 (12%) wells were replaced for various reasons, which include the followings;

- the absence of the well owner or the sheikh for a prolonged period of time
- the well owner and/or the sheikh refused to have interview
- the designated well is located in the same village where another well has already been surveyed
- the well is owned by the high-ranking officials in the government or army officers who can hardly be approached

4.2.3 WATER USAGE CONDITION AND AWARENESS SURVEY AT THE VILLAGE LEVEL

This section presents results and findings of the structured interview to the village authority which represents the respective communities where the sample wells are located.

(1) Characteristics of the Respondents

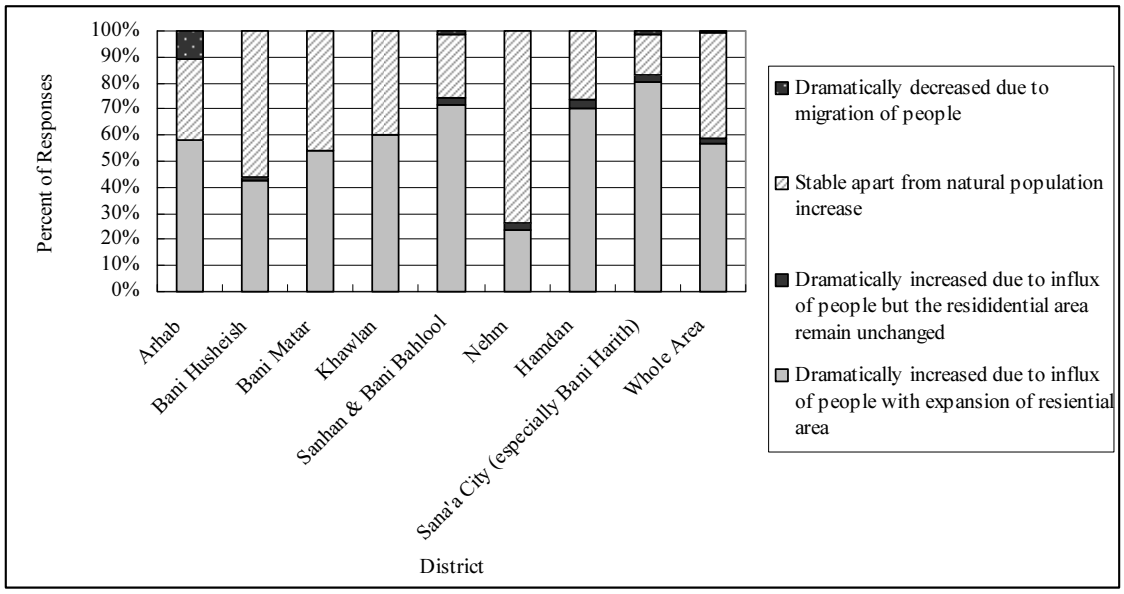
The water usage survey at the village level was targeted to the community leaders in the villages or sub-villages where the sample wells are located. Distribution of respondents by their position in the village are Sheikh (32.3%), Aqil (42.5%), Amin (18.8%), Imam (2.3%),

representative of WUA or WUG (4.3%). Age group of respondents is mostly in 30s and 40s with mean age at 45 years, 20 years at the youngest and 85 years at the oldest.

(2) General Socio-Economic Conditions of the Target Villages

In the context of social structure in rural part of Yemen, one village generally consists of several hamlets which are gradually formed according to creation of new settlements due to increase of population. 400 villages surveyed can be classified into two categories. One is the sub-villages/ hamlets (*mahall)* which are the most cases in these targeted communities while the other is the villages (*quarya*). A total of 471 communities were identified in the 400 villages. 92% of these targeted villages are actually at the sub-village level represented by either Aqil or Adel who are mainly responsible for collecting tax and notarization of contracts for the community members. One community consists of approximately 70 households with 560 populations on average, hence 8 persons per household. The smallest number of households in the surveyed villages is less than five while the largest one is 2,500.

Village population in Sanhan & Bani Bahlool, Hamdan and Bani Harith which was incorporated into Capital Secretariat (Sana'a City) are perceived as dramatically increased in the past 15 years due to influx of people from outside who settled in these districts to seek work in the downtown. *Figure 4.1* shows the perceived demographic trends in the target villages in the past 15 years.



(400 valid answers)

Figure 4.1 Perceived Demographic Trend in the Villages in the Past 15 years

Main economic activities involved by the community members are agriculture, government services, day labor and animal husbandry.

Due to proximity to Sana'a City, conditions of accessibility and communication network are generally better than the ones in rural area in other governorates. 74% of the targeted villages can be accessed through asphalt road. The telephone line is available in 83% of the samples and mobile network covers 93% of the same. Power supply is connected to 87% of the villages, most of which are from the public network.

With regard to social services, schools are existing in around 70% of the villages. 60% of these schools are at the primary level while others are at the secondary or both primary and secondary level. Average number of pupils at the primary school is 400. In case that there is no school in the village, children have to cover 3km on average to attend the school nearest from their villages.

Meanwhile, medical and health care services through health facilities are only available in 15% of them. 70% of these facilities are health units which provide first aid for the community members by the assistant health workers. At this level, neither doctors nor nurses are stationed. Health centers and hospitals are available in 27% and 10% of the villages, respectively, which answered that they have health facilities within the village area. Distance to the nearest health facility is 10km on average for the communities which have no access to the health services in their villages.

In the light of facilitation of IEC (Information, Education and Communication) related to the water resources management and conservation, the village authorities interviewed gave suggestions that mosque preaching is most preferable communication channel for adult men followed by house visits, television and radio. In case of adult women, television and radio were raised as the most preferable channels followed by the house visit. The respondents expect that the school can provide such function for children. Written materials such as poster and newspaper are not regarded as effective communication channels compared to other means mentioned above.

(3) Land Use and Agricultural Activities

1) Land Use Pattern

Figure 4.2 and *Figure 4.3* shows distribution of lands in the surveyed villages by type of ownership and usage, respectively. Approximately 70% of lands belong to private owners while remaining are either communal for the villagers, endowment land (*waquf*), or government-owned. The survey results further show that the agricultural land spreads out 78% of the total village land.

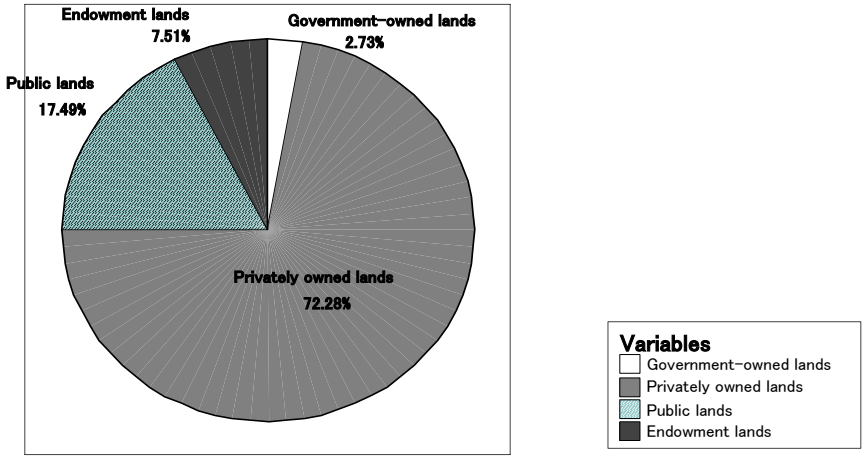


Figure 4.2 Distribution of Lands in the Surveyed Villages by Ownership

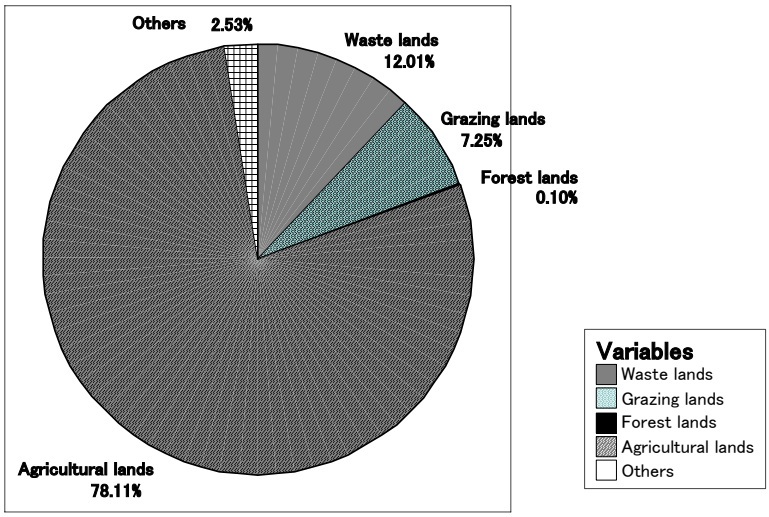


Figure 4.3 Distribution of Lands in the Surveyed Villages by Usages

42% of the respondents have perception that there is no change in area of the land in the past 15 years in their villages. Expansion of the agricultural land was reported in 31.5% of the surveyed villages while decrease in 26.5% of the samples.

Main reason of the land expansion is to increase farm production for improvement of livelihood. On the other hand, reasons of decrease in the area of agricultural land are 1) increase in construction of buildings to cater for the population and 2) difficulty to keep the farming area due to insufficient water and high cost of diesel.

2) Cropping Pattern

Major crops cultivated in the surveyed area are qat, grapes and cereals as indicated in *Figure 4.4*. Especially, qat is grown in 87% of the targeted villages. *Figure 4.5* shows distribution of area by crops and availability of irrigation system. Qat and grapes are generally planted in the irrigated area though these are also rain-fed in rainy season in some cases. Meanwhile, rainwater is used for cereals in most cases.

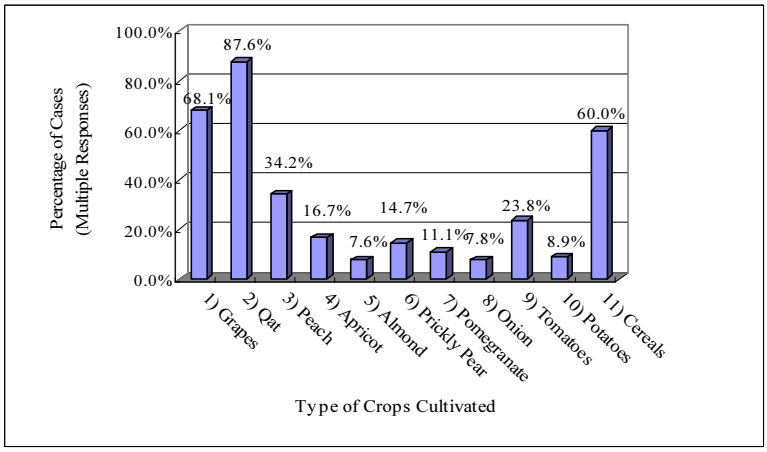
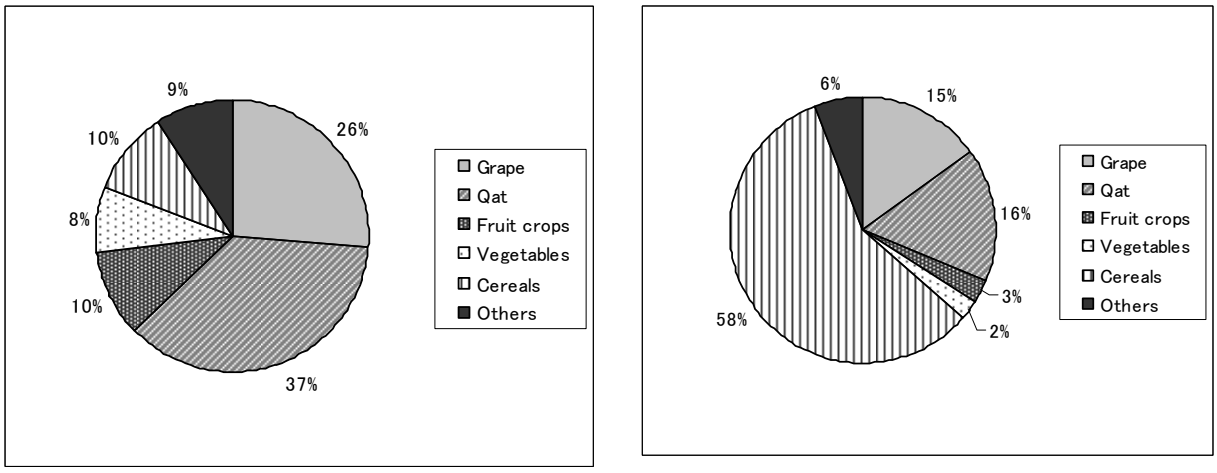


Figure 4.4 Type of Crops Cultivated in the Surveyed Villages



Irrigated Land **Unirrigated Land**

Figure 4.5 Comparison of Cropping Patterns between Irrigated and Unirrigated Lands

(4) General Water Supply Conditions in the Village

1) Water Use for Domestic Purpose and Animal Watering

The community members in the surveyed villages mainly rely on deep wells for daily water consumption for the domestic purposes. Approximately three deep wells are located in one village with around 70 use households.

These wells are privately owned and primary usage is for irrigation by the owners. In many cases, houses of the owners' families are connected with the piped network from the wells to supply water for domestic use. As a custom in the villages, the well owners allow other community members to draw water for the domestic use at their wells while the pump is being operated. Normally, user fee is not charged by the owners if it is for the domestic use. 25% of the villages use shallow wells and 10 % buy water from water vendors. Public water scheme is not available in most surveyed villages.

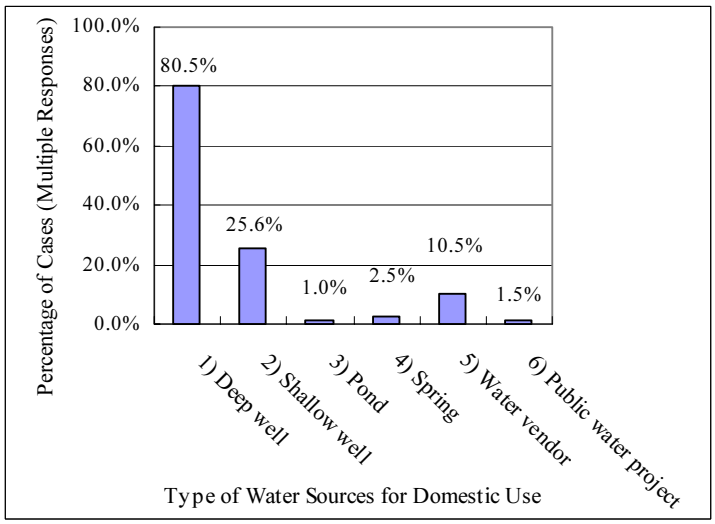


Figure 4.6 Type of Water Sources Available for Domestic Use

Daily water demand for the domestic use is around 38 liter/person/day. 64% of the respondents perceived that they can obtain enough quantity of water for domestic use from these water sources. Less than 20% of the respondents express their dissatisfaction on water quantity. No difference was observed in perception of the respondents on water quality for deep wells and shallow wells, which generally shows satisfaction in quality.

In addition to the domestic use, about 100-190 liters/day is required for the animal watering at the households which keep livestock. Most of the domestic animals raised in the surveyed area is goat, sheep and donkey. Mean number of livestock kept by a household is 20 while median is five.

2) Measures Taken by the Communities to Cope with Water Scarcity

60% of the villages experienced drinking water scarcity three to four times during the last 10 years and 70% were faced with the problem of dry up of wells in the same period. Number of wells which have been dried up is 20 on average (6 wells at median) including shallow wells. Usually, they had to abandoned shallow wells/ hand dug wells which are vulnerable to drought and relied on the deep wells.

The communities coped with the water scarcity by drilling new deep wells, re-deepening existing ones and buying water from water vendors.

Though most of the communities have experiences in difficulty to secure water for the domestic use in the past, water harvesting facilities are not being used widely in the surveyed area. *Table 4.5* shows distribution of water harvesting facilities identified in the area and those conditions.

Table 4.5 Distribution of Water Harvesting Facilities

Type of Water Harvesting Facilities	No. of Facilities in the Village (Working/ Not working)	Percentage of Non-Functioning Facility	Perceived Reasons why the Facilities are not Working
Collection tanks	164 (135/ 29)	18%	• The project was not well managed. • The well has dried up or does not have enough water to fill the tank. • The project is still under progress.
Recharge dam	36 (28/ 8)	22%	• The dam was burried by soil or collapsed. • There was leakage at the dam. • High water pressure on the dam.
Subsurface dam	0	-	-
Farm pond	100 (59/ 41)	41%	• Scarcity of rainfall • It was burried by clay. • Had electrical fault
Recharge well	1 (0/ 1)	100%	• The flood water does not enter into the well since the construction of the well

(5) Water Use for Irrigation

Main water sources for irrigation are deep wells and shallow wells as shown in *Figure 4.7.* Some respondents also indicated that water is sometimes bought from water vendors even for the irrigation purpose especially in dry season.

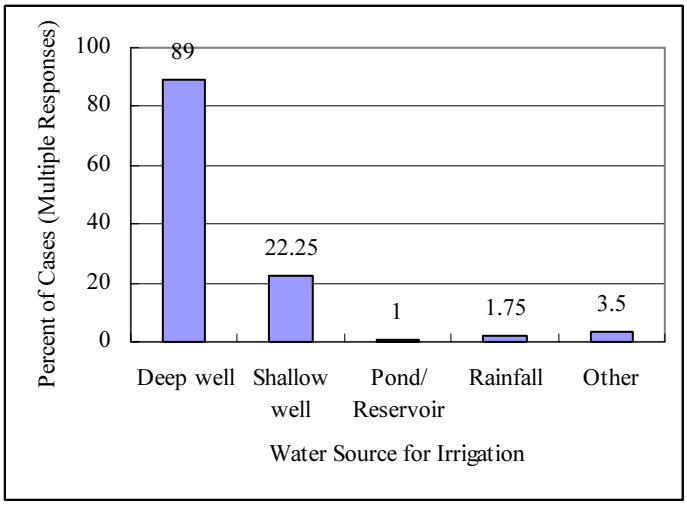


Figure 4.7 Type of Water Sources for Irrigation

For the irrigation network, the piped network is mostly used in the area as indicated in *Figure 4.8*. Apart from drain ditch and canals, a few cases to use the basin flooding and furrow method were also observed.

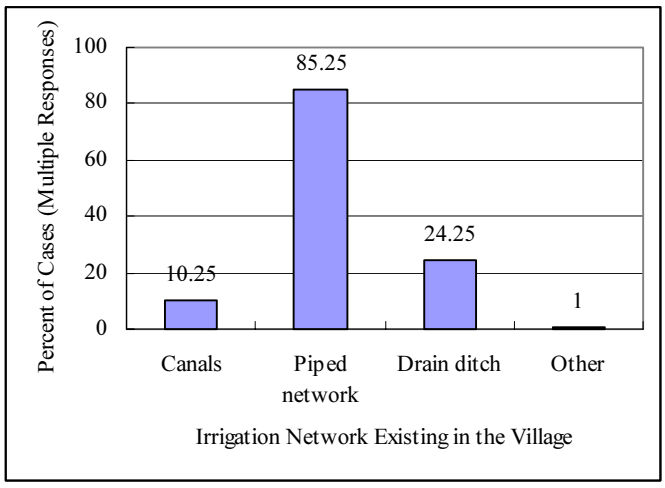
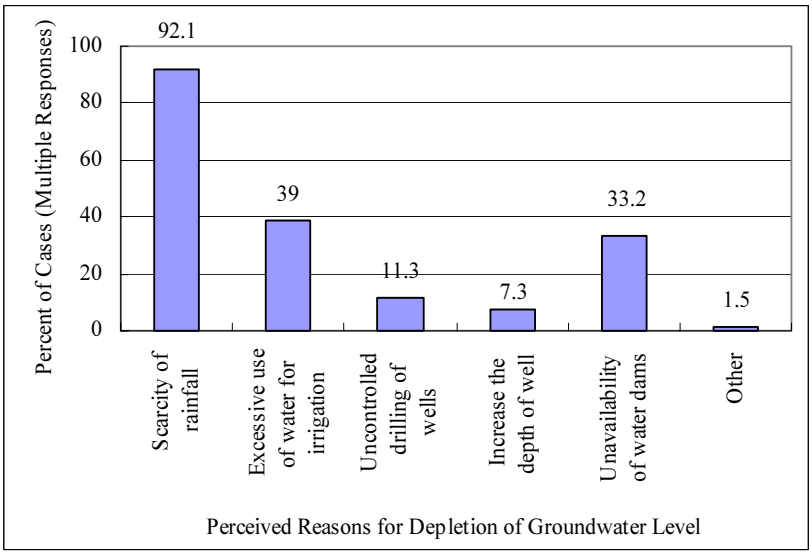


Figure 4.8 Type of Irrigation Network in Use

(6) Perceived Changes in Availability of Groundwater

Around 82% (328 cases) of the surveyed villages experienced the depletion of groundwater level according to the observation by the village authorities. Strong perception on the scarcity of rainfall is linked with the reduction of available groundwater resources as 92% of the respondents indicated as shown in *Figure 4.9*. Depletion of groundwater is also attributed to the excessive use of water for irrigation (39%), few response is given with connecting it to the random excavation and re-deepening of wells without control. Rather, lack of water harvesting facilities such as dams is pointed out as one of the causes of the problem.

While majority (89%) of the villages which have experiences in the groundwater depletion are concerned about the problem, the remaining responded that community members are not aware of it.



(328 valid cases which answered that the village experienced groundwater depletion)

Figure 4.9 Perceived Reasons for Depletion of Groundwater Level

Various measures were suggested by the respondents to address the depletion of groundwater level. Majority of them are expecting introduction of the modern irrigation technologies as well as construction of water dams and ponds with support of the government. Few respondents perceive that awareness raising and prohibition of uncontrolled excavation of wells or expansion of irrigated area would be possible solutions of the problem. Meanwhile, some of the respondents still pointed out that re-drilling of the existing wells or construction of new wells would reduce pressure of water demand in the communities.

(7) Activities of Water Users Group/ Water Users Association

The participatory irrigation management with forming community-based organization is not yet practiced in most of the surveyed villages. 28% of the villages currently have a form of group or association consisting of the water users for irrigation. According to *Figure 4.10*, around 80% of these existing organizations are Water Users Groups (WUG) formed at well level and the remaining is Water Users Associations (WUA) which is responsible for management of water sources for irrigation in the entire village. 16% of the WUG are supervised by WUA while others are existing only at the well level without linkage to WUA. Number of WUG available in one village is approximately three (median) to ten (mean) which corresponds to number of existing deep wells per surveyed village. While WUG/ WUA are supposed to be registered as the community-based organization under the Law of Local Authority, 67% of WUG/ WUA in the surveyed villages are not yet registered as the formal organizations.

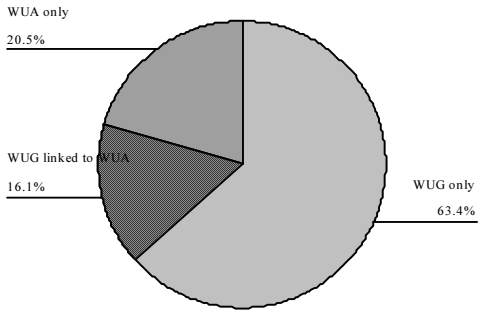
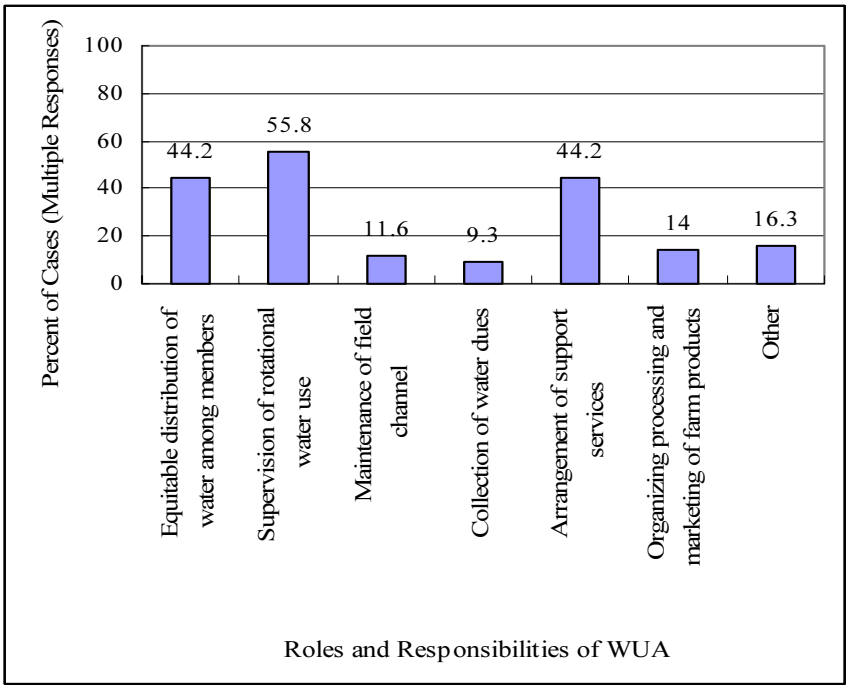


Figure 4.10 Type of Existing Community-Based Organizations for Irrigation Management

WUA in the surveyed villages are formed by the households who would like to join the association and the management board consisting of executive members is responsible for daily management of the organization. The operator of the well is also one of the members in the association. Decision making as WUA is normally done by the management board with consultation and approval of all members. One of the most important roles of WUA is to govern the equal distribution of water for irrigation to the members. Each WUA has its own regulation on water distribution according to either 1) the turn of each subscriber based on days or hours or 2) number of shares for each member which is defined by the amount of subscription, water unit paid, and/or capacity of the water pump.

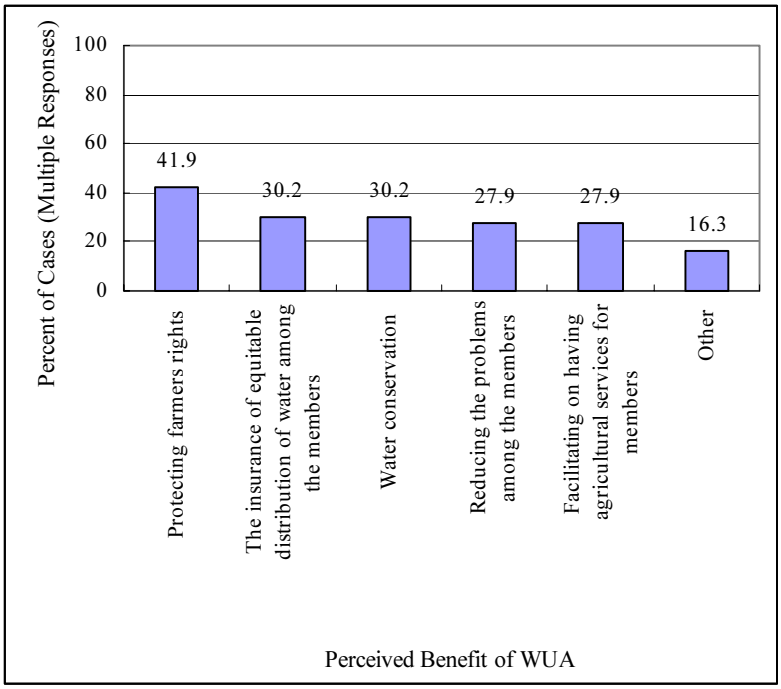
75% of the WUA existing in the surveyed villages collects membership fee of 1,000 Rial (median) and 60% also charge monthly subscription of 100 Rial (median) to the members.

Figure 4.11 and *Figure4.12* shows responsibilities assigned to WUA and perceived benefit on organizing WUA, respectively. Some of the respondents mentioned that WUA has not brought particular benefit through operation of the association according to their mandate. While WUA is existing in the surveyed area, it is observed that some of the associations are inactive. Also, significance of their activities is not recognized well among the village authorities.



("Others" includes "raising awareness among farmers on saving water and promote the modern irrigation technologies.)

Figure 4.11 Responsibilities of WUA

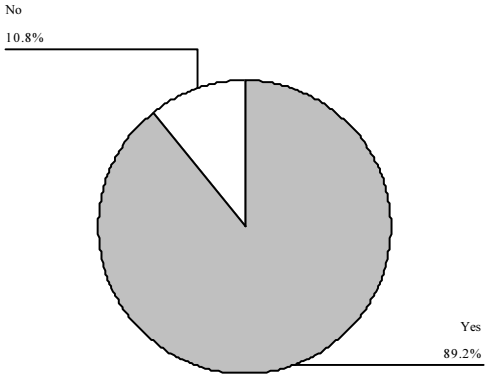


("Others" includes raising awareness among consumers about saving water, following up the concerned project authorities to install the modern irrigation networks.)

Figure 4.12 Perceived Benefit of WUA

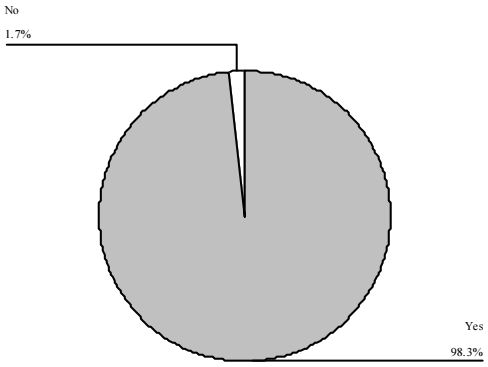
(8) Perception on Participatory Irrigation Management through WUA/WUG

Majority (89%) of the respondents are for the collective sharing of water among the community members as one of the measures for management of limited water resources. However, participatory irrigation management with forming WUA/WUG is not yet familiar with around 20% of the communities. In the communities which have knowledge on WUA/WUG, it is observed that the willingness of the community members is high with regard to formation of the organization, acceptance of regulations made by the organization and contribution for the membership fee as shown in *Figure 4.13*.



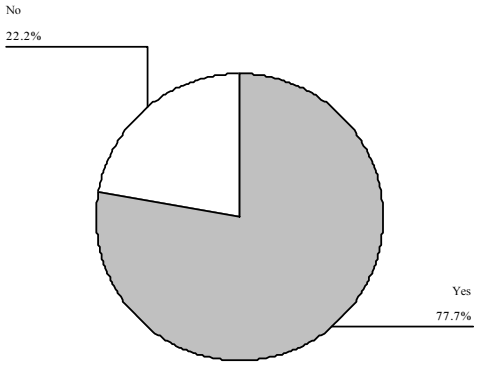
(400 valid cases)

Are you in favor of collective sharing of water among the villagers?



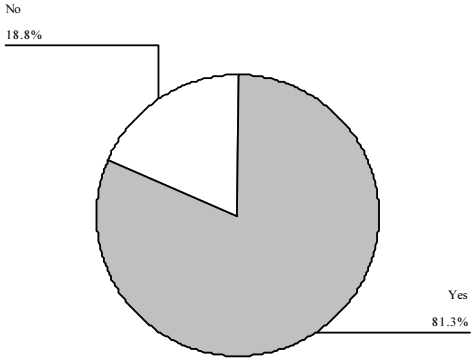
(357 valid cases. 43 cases excluded as not applicable)

Are you willing to give your services and/ or contribution if needed to form WUA/WUG in your village?



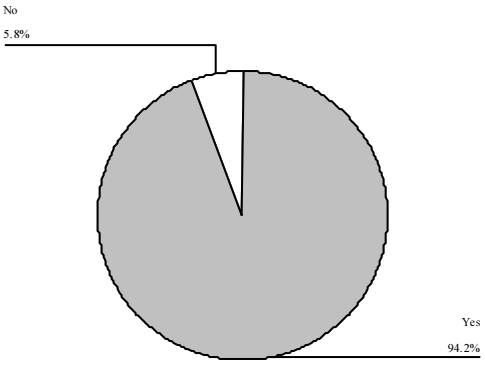
(400 valid cases)

Are the villagers familiar with participatory irrigation management with WUA/WUG?



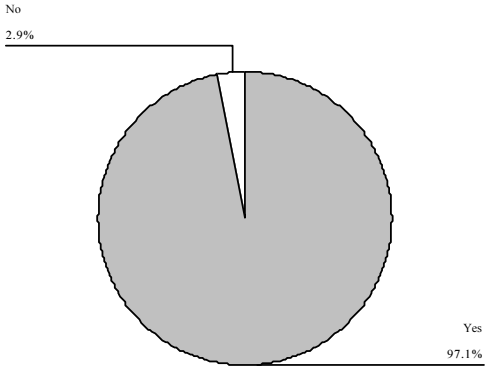
(400 valid cases)

Do you think that the adoption of participatory irrigation management could improve water conservation?



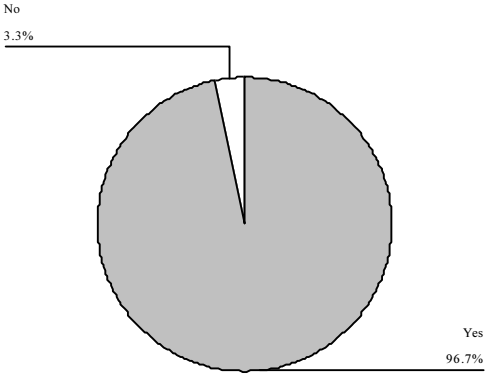
(325 valid cases. 75 cases excluded as not applicable)

Are the villagers prepared/ willing to form a WUA/WUG among themselves?



(306 valid cases. 94 cases excluded as not applicable)

If WUA/WUG is formed, are the villagers willing to accept the decision and regulations made by the organization?



(306 valid cases. 94 cases excluded as not applicable)

If WUA/WUG is formed, are the villagers ready to pay membership fee of the organization?

Figure 4.13 Perception on Participatory Irrigation Management through WUA/WUG

(9) Perception on Water Resources Management and Conservation

In the survey, acceptance of the communities on introduction of several measures for water resources management and conservation was asked through perception of the village authorities as shown in *Figure 4.14.* These issues are 1) register of wells, 2) installation of water meters at the wells, 3) monitoring of water consumption at the wells, 4) prohibition of drilling of new wells, and 5) prohibition of expansion of irrigated land.

1) Register and Monitoring of Wells

With regard to the register of wells, 60% of the respondents agree without any conditions. On the other hand, 20% put some conditions to accept the measure and the remaining expressed opposition to the idea. Both groups have the biggest concerns that the wells in the villages would be confiscated by the government as 64% of the respondents agreeing with conditions and 56% of the respondents opposing this point as one of the reasons on their opinions. Other major reason for against the register of wells is fear of being limited

the water abstraction rate at the wells and charged penalty on the excess of the water use.

Meanwhile, those who agree installation of water meters at the wells without any conditions are less than 40%. 20% put conditions such as the well should not be confiscated, the government should not prohibit the community members to drill new wells, the government should assist the communities technically and financially to construct water dams and apply improved irrigation technologies. Also, a certain percentage of the respondents mentioned that the water meters could be installed but those should not be monitored by the government authority. 41% of the respondents are against the idea with fearing the water abstraction rate to be determined and the water meters to be monitored by the government.

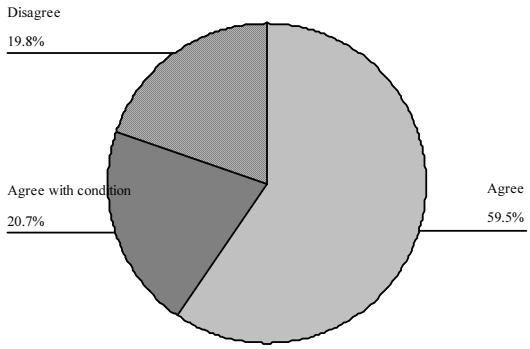
65% of those who agree with or without conditions on installation of water meters express their approval on monitoring of the water consumption at the wells regularly.

2) Prohibition of Drilling New Wells and Expansion of Irrigated Land

On the water abstraction rate of the wells in the village, 45% of the respondents perceive there will be no change in future due to insufficient water source and inability to increase operational capacity of the pump. 35% expect that the rate will decrease mainly because of depletion of water level followed by high cost of fuel. On the other hand, the remaining 20% consider that the abstraction will increase due to reasons such as expansion of agricultural land and increase in number of partners of wells.

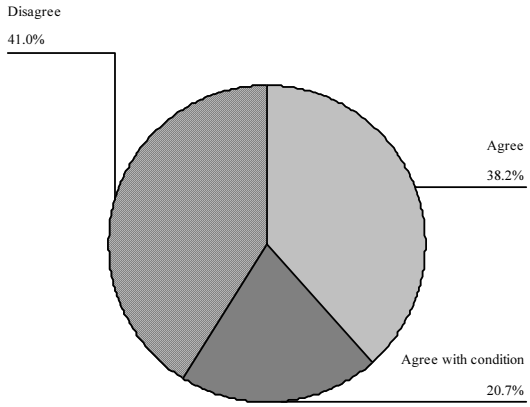
Regarding the prohibition of drilling of new wells in future, nearly half of the respondents are with the idea since they are afraid of further depletion of groundwater or dry up of the existing wells. Another half of the respondents oppose the measure with considering situations such as insufficient water supply at present and communities' expectation to expand agricultural land. Also, there is perception that each one has rights on his properties in the land and drilling of wells is accepted as long as it is conducted within his land or area agreed among the community members to avoid interference between the wells.

Prohibition of future expansion of irrigated land is not accepted by most of the communities surveyed (82%). Main reason to oppose the idea is expectation of the communities to improve their livelihood through increase of agricultural production. Those who are with the prohibition of expansion of the irrigated land have concern about depletion of groundwater. Other background of supporting the idea is that these communities are relatively limited to the area of land which can be expanded for agriculture. In the baseline survey conducted under the SBWMP, the same question was asked in the village level survey with an additional statement of condition that the government would compensate for prohibition of the land expansion with supplying fertilizers, improved irrigation instruments and others. 80% of the respondents agreed with the measure in this case. It means that those who oppose expansion of the irrigated land also have possibility to stop it if they are convinced that the improved irrigation technologies with water saving method can bring same or higher level of agricultural production with the exiting method which they are presently in use.



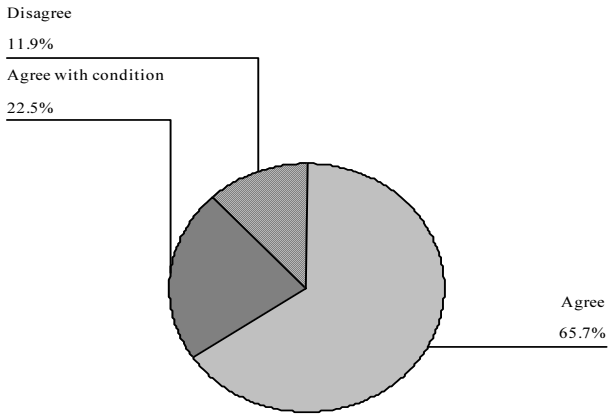
(400 valid cases)

1) Do you think that the villagers agree to register wells?



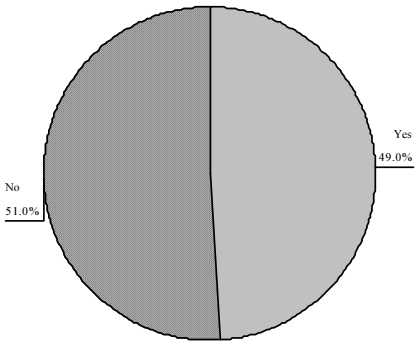
(400 valid cases)

2) Do you think that the villagers agree to install water meters at their wells?



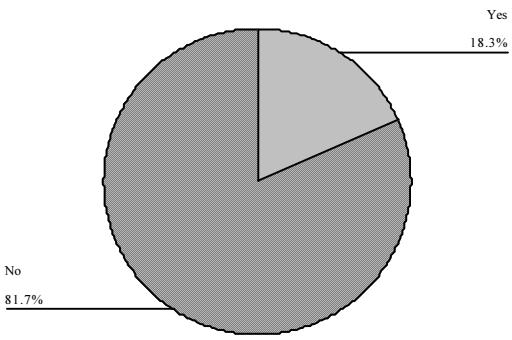
(236 valid cases. 164 cases excluded as not applicable.)

3) Do you think the villagers agree to monitor the pump regularly by the concerned Project Authority?



(400 valid cases)

4) Do you think the villagers agree to prohibit drilling of new wells?



(400 valid cases)

5) Do you think the villager agree to prohibit expansion of irrigated land in your village?

Figure 4.14 Perception on Water Resources Management and Conservation

3) Introduction of Water Saving Technology

Number of communities which have information on the water saving technology is still limited. Only 35% (140) of the respondents answered that the community members area aware of or were informed about water saving technology for irrigation. In these villages, the improved piped irrigation system is mostly preferred as shown in *Figure 4.15*. Approximately half of these villages currently apply any of the technology. High cost to purchase the equipment is the biggest reason for other villages not using the water saving system in their farms despite the availability of information. Other factors hindering application of the improved irrigation technology is that the method is not understood by the community members well or communities have doubt on effectiveness of the technology to apply for some particular crops.

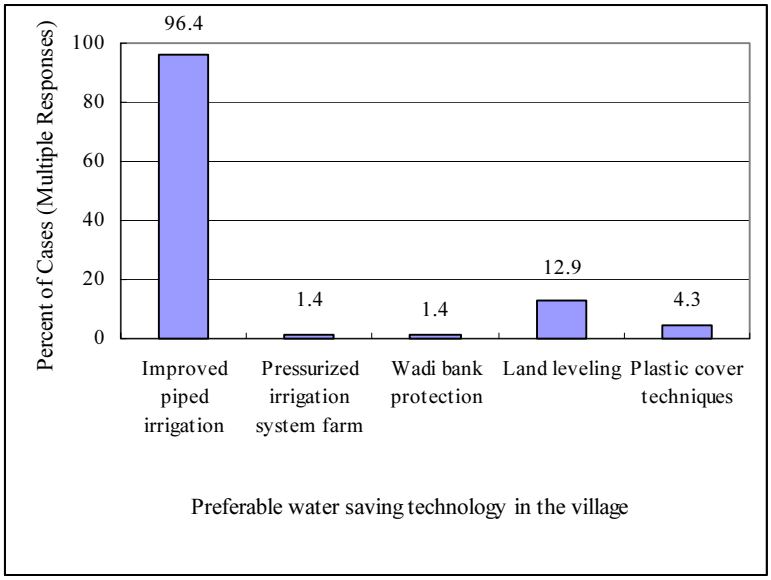


Figure 4.15 Water Saving Technology for Irrigation Preferred by the Surveyed Villages

(10) Awareness of Water Rights and Water Law

Awareness of the community members in the surveyed villages is low in terms of water rights and the Water Law 2002. 12% of the respondents answered that the community members are aware of water rights. With regard to the Water Law 2002, only 3% of the respondents indicated awareness of their communities. Common perception on the water rights for them is that water should be distributed equally to the farmers according to his share. Around 60% of those who are aware of the Water Law also have knowledge that the law contains penalties on offence of the law though contents of the law are not yet fully understood by them.

While most of the communities are not familiar with the Water Law, 57% of the surveyed villages have their own customs to conserve water. Among others these customs are;

- Each one can irrigate his land from his own well only.
- Water is shared equally among the partners as agreed.
- Drilling of wells should be done with valid distance (normally 200 – 500m depending of the villages) from each other. If the yield of the existing well is affected by construction of new wells, the owner of the existing well can become partner of the new well.
- Rainwater in wadi should be distributed equally among the villagers with agreed share.

4.2.4 SITUATION OF FARMING

This section describes results and findings of the structured interview to the water users particularly on situation of farming.

(1) Characteristics of the Respondents

In the interview to the water users in rural area, a total of 400 well owners were targeted. Among 400 respondents, 80% of them are full-time farmers while the remaining is involved in other jobs such as employees of government or companies, army officers, and school teachers. They mainly use the wells for irrigation and domestic purposes. Age of the respondents is 38 years on average, 20 years as minimum and 90 as maximum. With regard to literacy of the respondents, 78% of them can read and write. Illiteracy rate of the age group of 40 years and above is higher than 20s and 30s. Mean age of the literate group is 35 while the one for the illiterate group is 49.

(2) Holding of Farms and Cropping Pattern

Distribution of the respondents is indicated in the figure below according to the total area of the farm. The average size of the farm held by a respondent is 805 libna, which is equivalent to approximately 3.6 hectares[4]. The median value is 300 libna (1.3 hectares) and the mode is 200 libna (0.9 hectares). The respondents can be further divided into three groups according to percentiles of the distribution of the farm size as shown in table below.

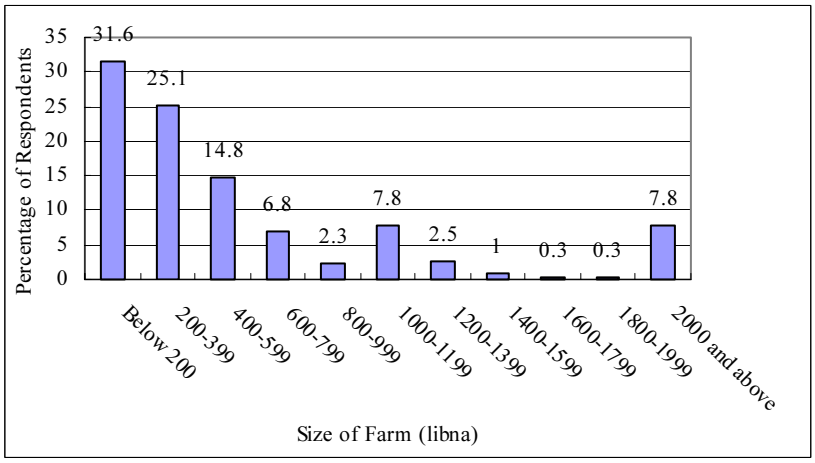


Figure 4.16 Distribution of Respondents by Total Area of Farm

Table 4.6 Distribution of Respondents by Farm Size

	Frequency	Percent	Valid Percent	Cumulative Percent
Small farm (below 200 libna)	166	41.5	41.5	41.5
Medium farm (200-499 libna)	92	23	23	64.5
Big farm (more than 500 libna)	142	35.5	35.5	100
Total	400	100	100	

Nearly 90% of the total area of farm is solely owned by the respondents while others are either rented (2%) or shared with others (9%). A total of 1,315 hectares (equivalent to 292,234 libna) is cultivated among 1,462 hectares (325,082 libna) of farm held by the respondents, which means that around 90% of the farm is cultivated.

Majority (87%) of the respondents explains that there is no change in size of their farms. Those who have experienced in reduction of farm size (6.5%) attribute it to scarcity of rainfall and water in the wells, high cost of diesel and agricultural implements, and expansion of residential areas or roads. Meanwhile, an increase of farm size is due to expansion of farm land to realize an increase of production of mainly qat and grape for improved livelihood according to the respondents (6.5%). As shown in the table below, an extent of reduction of the farm size is relatively larger than the proportion of increased farm size. It is observed that most of the farmers have been keeping the area of the existing farm land as it is difficult for them to expand it in the situation of water shortage and high cost of farming input such as diesel fuel, spare parts and lubricants of the agricultural machines.

Table 4.7 Trend of Change in the Farm Size

		What is the size of the decreased area of the farm? (libna)	What is the size of the increased area of the farm? (libna)
N	Valid	26	26
	Missing	374	374
Mean		616.58	201.35
Median		125.00	50.00
Mode		30(a)	20
Minimum		20	10
Maximum		7500	1120

a Multiple modes exist. The smallest value is shown

Major crops cultivated in the farms held by the respondents are qat (76%), grapes (58%), and cereals (42%) as shown in *Table 4.8*. Dependency on qat and grape is commonly observed among the farmers with small, medium and large sizes of the farms. *(Figure 4.17)* In terms of the cropping pattern, qat accounts for 38%, followed by grape (25%), and cereals (17%) in the total area of the cultivated land held by the whole respondents. Proportion of the cropping patterns does not show much difference according to the farm size.

Around 60% of the respondents cultivate more than one type of crops. While small-size and medium-size farmers select to cultivate qat and grapes which bring them high income compared to other crops, the large-size farmers grow other types of the cash crops such as vegetables and fruits in addition to qat and grape.

Table 4.8 Cropping Patterns in the Farms Held by the Respondents

	Grape	Qat	Fruit crops**	Vegetables**	Cereals	Others	Total Area
Whole samples (N=400)							
No. of cases*	231	304	178	86	170	56	
% of cases	57.8%	76.0%	44.5%	21.5%	42.5%	14.0%	
Total Area	73,646	113,182	30,678	18,460	50,384	5,468	291,818
% of area	25.2%	38.8%	10.5%	6.3%	17.3%	1.9%	100%

Small farm with below 200 libna (N=166)								
	No. of cases*	81	118	62	16	46	19	
	% of cases	48.8%	71.1%	37.3%	9.6%	27.7%	11.4%	
	Total Area	5,195	6,960	1,932	580	3,007	460	18,134
	% of area	28.6%	38.4%	10.7%	3.2%	16.6%	2.5%	100%
Medium farm with 200-499 libna (N=92)								
	No. of cases*	55	73	36	19	41	13	
	% of cases	59.8%	79.3%	39.1%	20.7%	44.6%	14.1%	
	Total Area	8,498	10,847	1,561	1,135	5,817	468	28,326
	% of area	30.0%	38.3%	5.5%	4.0%	20.5%	1.7%	100%
Large farm with more than 500 libna (N=142)								
	No. of cases*	95	113	80	51	83	24	
	% of cases	66.9%	79.6%	56.3%	35.9%	58.5%	16.9%	
	Total Area	59,953	95,375	27,185	16,745	41,560	4,540	245,358
	% of area	24.4%	38.9%	11.1%	6.8%	16.9%	1.9%	100%

*No. of cases cultivating each particular crops
** Peach, apricot, almond, prickly pear, and pomegranate are considered in the category of fruit crops. The category of vegetable contains onion, tomatoes, and potatoes. Other crops are included in "Others".

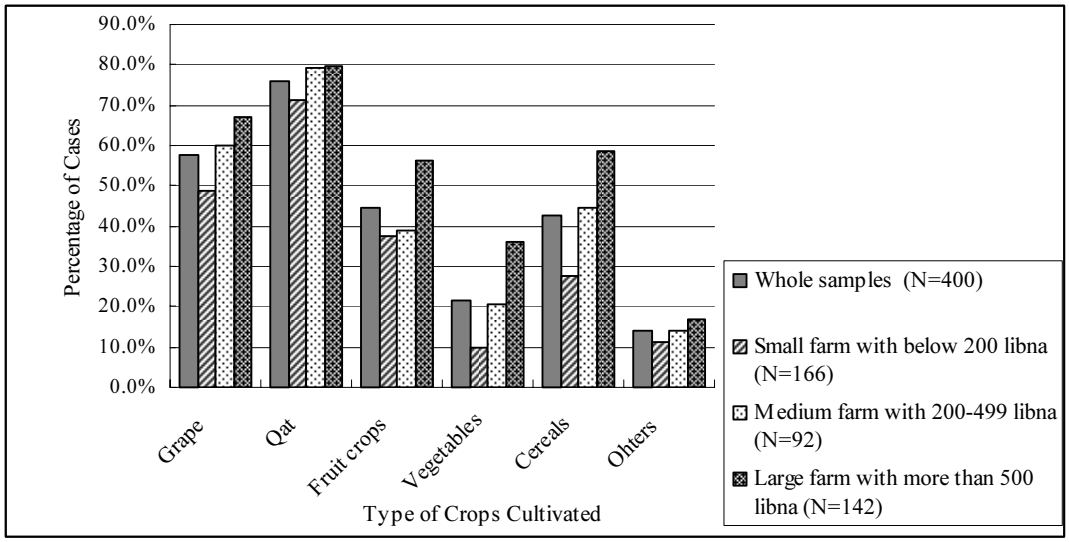


Figure 4.17 Type of Crops Cultivated in the Farms

(3) Irrigation System

Majority (89%) of the respondents depends on deep wells for irrigation as shown in *Table 4.9*. Approximately 1,400 deep wells in total are used as the water source for irrigation by the respondents. 73% of these wells were operational at the time of the field survey. Meanwhile, around 55% of 78 dug bores and 80% of 1,130 dug wells identified were not operational.

Table 4.9 Type of Water Sources for Irrigation

Water Source for Irrigation	Count	% of Responses	% of Cases
Deep well	357	75.6	89.9
Dug bore	33	7.0	8.3
Dug well	77	16.3	19.4
Pond/ reservoir	2	0.4	0.5
Others	3	0.6	0.8
Total	472	100	118.9

("Others" include water vendors and utilization of sewage from cesspit.)

For the water conveyance technology, 95% of the respondents currently use pipes/conduit to convey irrigation water from the water sources to the farms. Use of the earthen channel and lined channel is not common as those cases show only 8% and 0.3%, respectively.

With regard to the on-farm irrigation technology, the basin flooding method is widely used by the respondents (74%). The basin method is generally used for irrigation of qat, grape and other fruit trees in the orchard. (CES, 2006) Adoption of the improved irrigation system such as bubblers, drip and sprinkler is hardly observed among the samples.

Table 4.10 Type of On-Farm Irrigation Technology Adopted by the Respondents

Water Source for Irrigation	Count	% of Responses	% of Cases
Furrow method	73	17.2	18.4
Basin flooding	297	70.0	74.8
Uncontrolled flooding	52	12.3	13.1
Bubbler	0	0	0
Drip	2	0.5	0.5
Sprinkler	0	0	0
Total	424	100	106.8

("Others" include water vendors and utilization of sewage from cesspit.)

4.2.5 WATER USE AT WATER POINT LEVEL AND AWARENESS OF WELL OWNERS

(1) Basic Well Parameters in Rural Area

A total of 400 wells owned by the respondents under the rural cluster were targeted to identify physical characteristic of the wells located in the rural area in Sana'a Basin. Distribution of type of the wells is 347 deep wells (86.8%), 51 dug wells (12.8%), and 2 dug bore wells (0.5%). As the major types of the water sources, basic parameters of the deep wells and dug wells are summarized in the table below. The basic information on the wells was collected through the interview to the well owners. Since the respondents sometimes did not have concrete information on these parameters, it was observed in the data analysis that some of the cases show extreme values. 5% trimmed means were therefore computed as well so as to exclude influence of the extreme values on mean values.[5] Reliable information on the dynamic water level could no be obtained through the interview to the well owners.

Table 4.11 Well Parameters

	Deep Wells (N=347)			Dug Wells (N=51)		
	Mean	5% Trimmed Mean	Median	Mean	5% Trimmed Mean	Median
Diameter (m)	27.5	25.7	25.4	228.1	229.5	200.0
Depth (m)	331.4	319.3	300.0	28.5	24.7	25.0
Static Water Level (m)	146.5	130.7	100.0	11.1	9.8	5.0
Average Discharge (l/sec)*	14.2	8.3	5.0	3.3	2.8	2.0

* (Valid N for deep well : 244, Valid N for dug well: 25)

Around 70% of the deep wells were constructed in the period of 1980s-1990s. As shown in *Table 4.12* and *Figure 4.19* below, the well depth is getting deeper and proportion of wells with more than 600m depth has increased after year 2000. Distance from the sampled wells to the nearest operational wells is 300m for the deep wells and 150m for the dug wells at the median value.

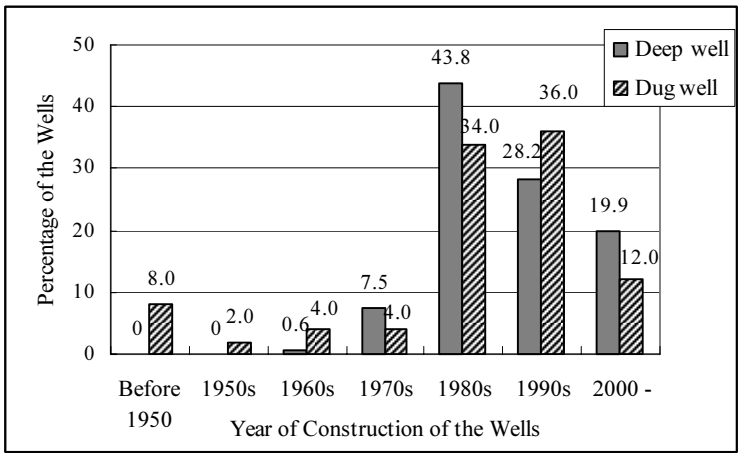


Figure 4.18 Distribution of Wells by Construction Year

Table 4.12 Distribution of Deep Wells by Well Depth and Construction Year

		Year of construction of deep wells					Total
		1960s	1970s	1980s	1990s	2000 -	
Depth of deep wells	Less than 100m	.0%	7.7%	5.3%	2.0%	1.4%	3.7%
	100 - 199m	50.0%	23.1%	13.2%	13.3%	7.2%	13.0%
	200 - 299m	.0%	34.6%	27.0%	21.4%	20.3%	24.5%
	300 - 399m	50.0%	19.2%	31.6%	35.7%	29.0%	31.4%
	400 - 499m	.0%	15.4%	15.8%	14.3%	10.1%	14.1%
	500 - 599m	.0%	.0%	3.9%	3.1%	2.9%	3.2%
	600 - 699m	.0%	.0%	2.6%	2.0%	7.2%	3.2%
	More than 700m	.0%	.0%	.7%	8.2%	21.7%	6.9%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total (N)		2	26	152	98	69	347

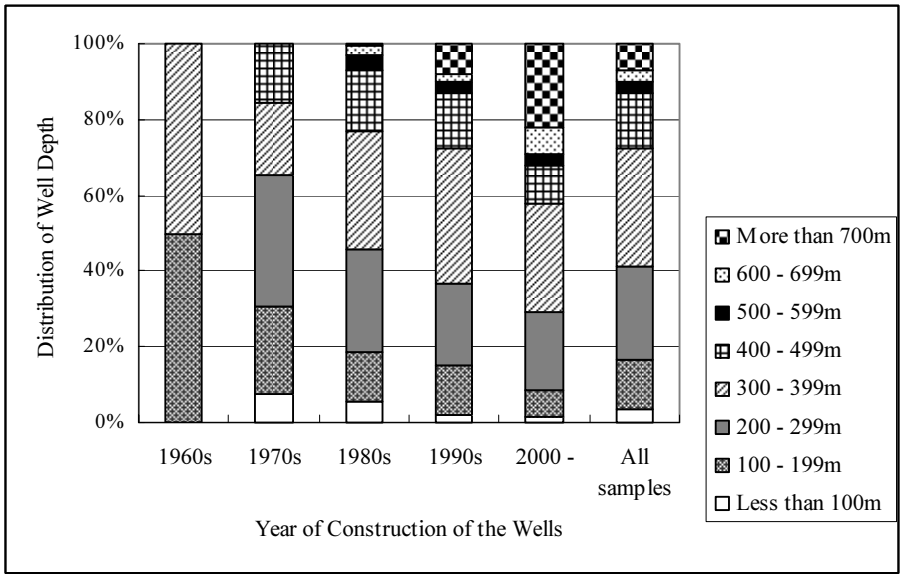


Figure 4.19 Depth of Sampled Deep Wells by Year of Construction

(2) Ownership of the Wells

80% of 400 sample wells are under the shared ownership. Proportion of the shared ownership of the deep wells is higher (83%) than the one for the dug wells (60%). Distribution of water from the well to each owner's farm is normally administered according to the proportion of shares in the capital and operation costs of the well by each partner. Other method for sharing system is to set frequency to allow each partner to use the well, such as three hours per day or two days per week.

(3) Water Use for Irrigation

The sampled wells are all equipped with motorized to pump water. Type of pumps and engines being used by the respondents is indicated in Appendix 11 Well Inventory. Diesel fuel is used for the pumps at 85% of the sampled deep wells while 14% are pumped with using electrical pump. Major sources of energy for pumps for the dug wells are diesel (74%) and petrol (21%). About 10 farms in a total area of 6.75 hectares are irrigated with a well.

Situation of water use for the irrigation was observed through interview to the respondents on duration of the operational hour of the pump in rainy and dry seasons, respectively, as shown in table below. As some respondents did not have complete information on operation of the pump, such cases were excluded from the data analysis. In case of the deep wells, a pump is operated for 6 hours/day and 3 days/week in rainy season (Feb.-Sep.) and 12 hours/day and 7 days/week in dry season (Oct.-Jan.) in the typical case. From 5 liter/sec. of the discharge rate of the wells and duration of pump operation, the water abstraction rate is estimated approximately 34,500 m^3 per well. Meanwhile, annual abstraction from the dug wells is around 4,000 m^3 per well due to its limited capacity.

Table 4.13 Water Abstraction Rate of the Sample Wells

		Total No. of Wells	Valid N	Pumping hour (hour/day)		No. of days to operate pump (days/week)		Water abstraction rate per well by seasons (m^3)		Water abstraction rate per well per year (m^3)
				rainy season	dry season	rainy season	dry season	rainy season	dry season	
Deep wells categorized by the well depth	< 100m	13	7	5	6	2	4	5,760	6,912	12,672
	100-199m	45	35	8	10	4	3	18,432	8,640	27,072
	200-299m	85	68	5.6	12	3	7	9,625	24,192	33,817
	300-399m	109	79	6	12	3	7	10,368	24,192	34,560
	400-499m	49	37	5	12	3	7	8,640	24,192	32,832
	500-599m	11	7	10	16	3	7	17,280	32,256	49,536
	600-699m	11	4	3	14	1.5	7	2,592	28,224	30,816
	>=700m	24	12	12	16	7	7	48,384	32,256	80,640
All Deep Wells		347	249	6	12	3	7	10,368	24,192	34,560
All Dug Wells		51	35	4	1	4	2	3,686	230	3,917

(Pumping hours and duration of pump operation per week are both at the median values.)

The cropping patterns with these wells are shown in the figure below. Qat and grape are cultivated in the area of 500 libna (2.2 hectares) with a well on average while the size of the area where cereals are grown is 350 libna (1.5 hectares). Average cultivated area of vegetables is 300 libna (1.3 hectares) and the one for fruit is 250 (1.1hectares).

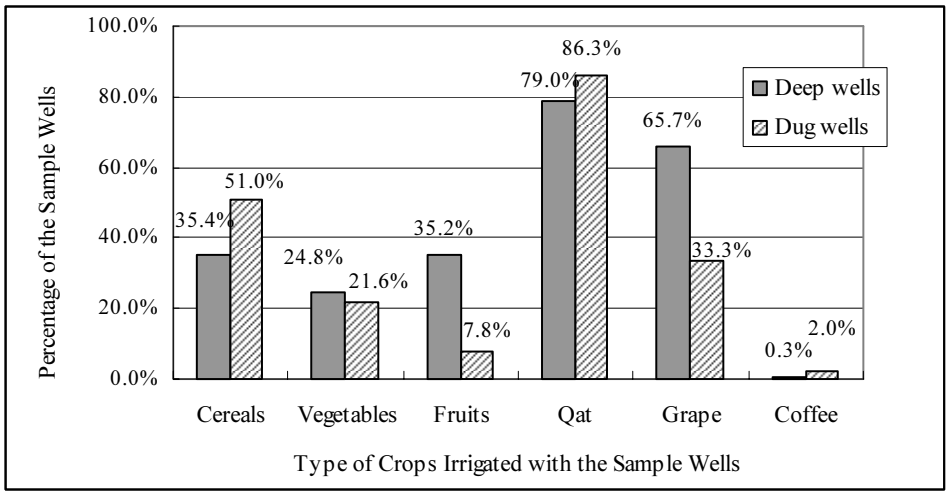


Figure 4.20 Cropping Patterns for the Sample Wells

(4) Water Use for Other Purposes

82% of the surveyed wells are used for domestic use and/or animal watering other than for irrigation. Approximately 20 households access to one well for domestic use and water consumption is approximately 16liter/day/person. Water from these wells is not sold to others in most cases (93%). In case that water is sold to others, water vendors are mainly consumers for them. They earn RY5,000-6,000 a day from the sales of water to other consumers. The unit price varies from 250 – 500 m3 for the sale to the water vendors and RY 500-3,000 per hour to sell to farmers or households.

(5) Well Owners' Perception on Changes in Availability of Groundwater and Adoption of Water Saving Technology

52% of the respondents perceive that the well capacity has decreased while 45% of the respondents do not observe any change in availability of groundwater. Only 3% of them expressed the wells they own increased the yield. Scarcity of rainfall is regarded as the main reason of decrease in the well capacity or dry-up of the wells by the respondents. Rate of water depletion is estimated around 3 – 11 meter by the respondents. Under this situation, 35% of the respondents re-drilled the wells up to 70-100 meter. Approximately 75% of these wells were deepened after year 2000.

Among those who perceive depletion of water level of the wells they own, half of them express dissatisfaction of water quantity of the wells and 25% of the same group have plan to drill new wells in the future.

Around 90% of respondents use pipe/ conduit as the water saving technology for water conveyance. However, progress of application of improved on-farm technology is slow mainly due to high cost of equipment. Also, insufficient information on the technology for the farmers also attributes delay in adoption of the same in the basin. For instance, some of the respondents raised in the interview that they would like to continue to use the basin flooding method as the water saving on-farm technology. In other case, it was mentioned by the respondents that these improved technologies recommended by the government are not necessarily suitable for some types of the crops they cultivate, hence no incentive to adopt the technology for them. It is required for NRWA to establish rapport with the farmers and WUG/WUA to ensure learning process with mutual communication for improvement of understanding and actions by the communities towards adoption of the improved irrigation method.

(6) Participation in Water Users Group/ Water Users Association

While 50% of the respondents explained that there is Water Users Group (WUG) for the wells they use, only 9.8% (N=39) of the respondents indicated that Water Users Association (WUA) is existing at the village level to manage the wells within the village. In the villages which has formed WUA, 69% (N=27) of the respondents are currently members of the organization. Considering that the village heads in 20% of the surveyed villages explained that they have WUA, some of the well owners might not be aware of existence of the organization as the responsible body for the water resources management in the village.

80% of the respondents currently participating in WUA pay membership fee while 60% also pay monthly subscription. They understand roles and responsibilities of WUA as the responsible actor to facilitate water conservation in the village through awareness raising of the residents and introduction of modern irrigation technologies to the farmers through obtaining support from the government.

In case that the village does not have WUA at present, 90% of the respondents expressed their acceptance that WUA will be the responsible organization for the irrigation management at the village level including the water conservation. 96% of the same have willingness to follow the decisions made by the WUA and 85% agree to pay for the membership fee and monthly subscription if the association is formed. Amount of the Willingness-To-Pay is RY5,000 for the membership fee and RY1,000 for the monthly subscription at the median and mode values.

While the equitable water distribution among the members is mostly desired by the respondents

through participation in WUA, contribution to activities for awareness raising and maintenance of the existing water storage facilities or irrigation system is not so welcomed by them as the roles of the members.

As mentioned in the findings from the interview to the village leaders, the concept of WUG/WUA and its function are not understood well by the community members in the area where NWRA's intervention has not put in place. In addition, even in case that WUG/WUA is formed in the community, its main role is limited to the equitable water distribution to the members and coordination of the project supported by the government for introduction of the improved irrigation technologies. Considering that the WUG/WUA is supposed to be the main body for the participatory water resources management at the community level, it is required that further sensitization and awareness raising are required to facilitate proper understanding of the community members towards the roles and responsibilities of these organizations and members.

(7) Well Owners' Perception on Water Resources Management and Conservation through Regulation

The survey results revealed that awareness of the well owners on the regulations related to water is very low as less than 10% of the respondents answered that thy are aware of water rights and Water Law. Nearly 50% of the respondents agree to register their wells without condition. Meanwhile the same proportion of the respondents is against installation of water meters at the wells, fearing that the water abstraction rate would be set by the government through monitoring the meters.

50% of the respondents are further against prohibition of drilling of new wells in future and 83% are against prohibition of expansion of the irrigated land as most of them have perception that the current water source is insufficient to increase agricultural production for improvement of the livelihood.

Extent of seriousness of the community members towards the water resources management and conservation varies in areas or sub-basins. While some of the sub-basins are currently not facing water depletion and the residents do not see the need for any support from the government, community members in other areas in serious water depletion problem show understanding on the interventions by the government at certain level. To the contrary, the communities in the areas with relatively enough water at present are concerned and have perception that the government may use their water to supply residents in Sana'a City especially in case that the sub-basin is in the close proximity to Sana'a.

Considering that NRWA has already shared experiences with some pilot communities in application of the improved irrigation technologies in the basin, it is recommendable to introduce these experiences by the farmers in the pilot area to others in non-intervention area. Strengthening the extension services under the Ministry of Agriculture is also required to facilitate linkage of farmers through this kind of formal and informal networks among the farmers.

References;

[1] The field survey by WEC was conducted in all the districts located in Sana'a Basin except for Capital Secretariat which is Sana'a City. These districts targeted in the survey are Bani Husheish, Bani Al Harith, Khawlan, Bani Matar, Arhab, Hamdan, Nehm, and Sanhan -Bani Bahluol.

[2] These sub-basins surveyed are Wadi Al Ma'adi, Wadi Al Khuluqah, Wadi Al Kharid, Wadi Bani Huwat, Wadi Al Sir, Wadi Al Furs, Wadi Sa'wan, Wadi Zahr & Al Ghayl, Wadi Al Huqqah, Wadi Hamdan and Wadi Ghayman.

[3] In this figure, springs, dams and pools are also included in addition to boreholes, dug wells and dug bore.

[4] Traditional agricultural surface measure in Yemen. 100 libna is equivalent to approximately 0.45 hectares.

[5] 5% of the cases in the lower and upper bounds, respectively, were excluded to compute mean values.