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

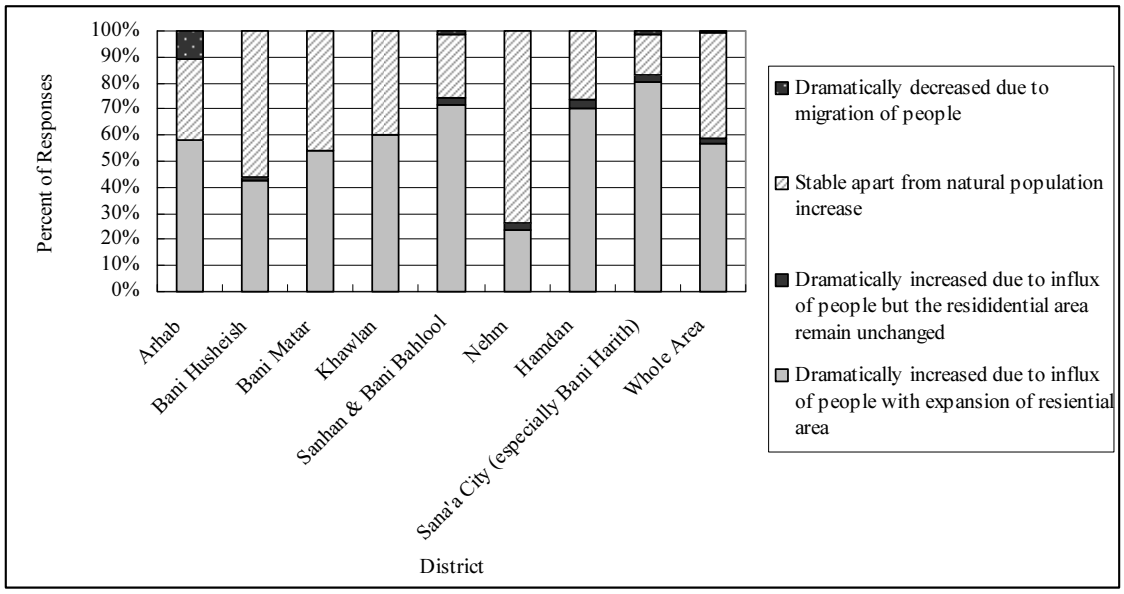
The water usage survey at the village level was targeted to the community leaders in the villages or sub-villages where the sample wells are located. Distribution of respondents by their position in the village are Sheikh (32.3%), Aqil (42.5%), Amin (18.8%), Imam (2.3%),

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.

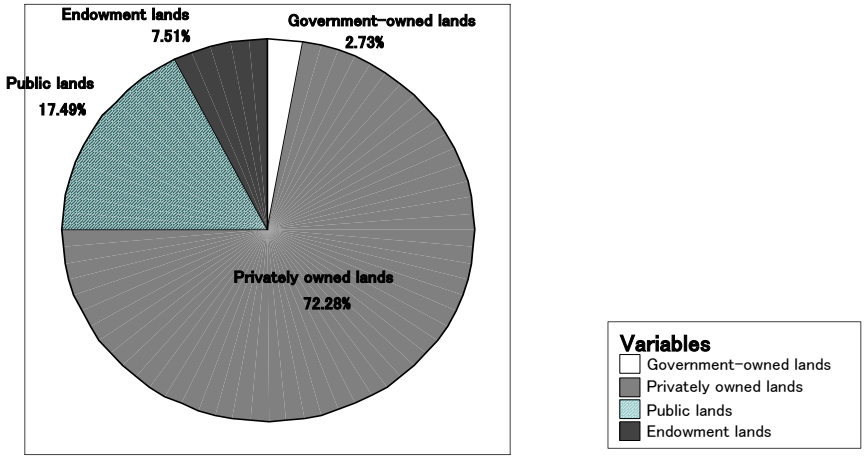


Figure 4.2 Distribution of Lands in the Surveyed Villages by Ownership

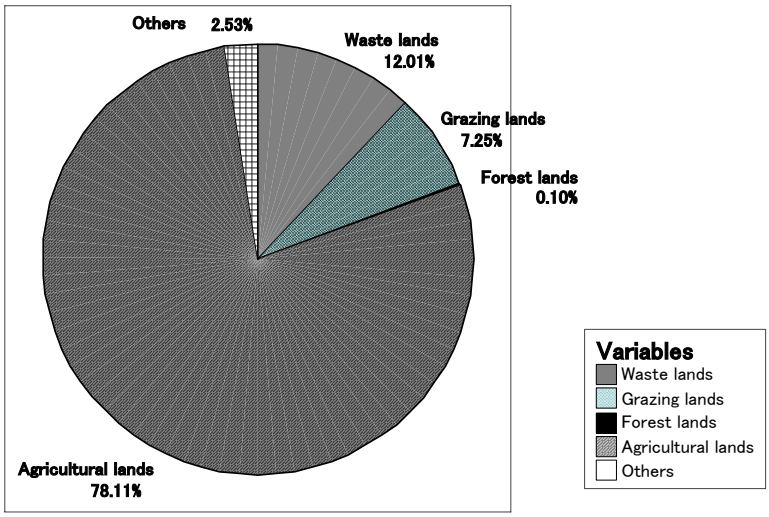


Figure 4.3 Distribution of Lands in the Surveyed Villages by Usages

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.

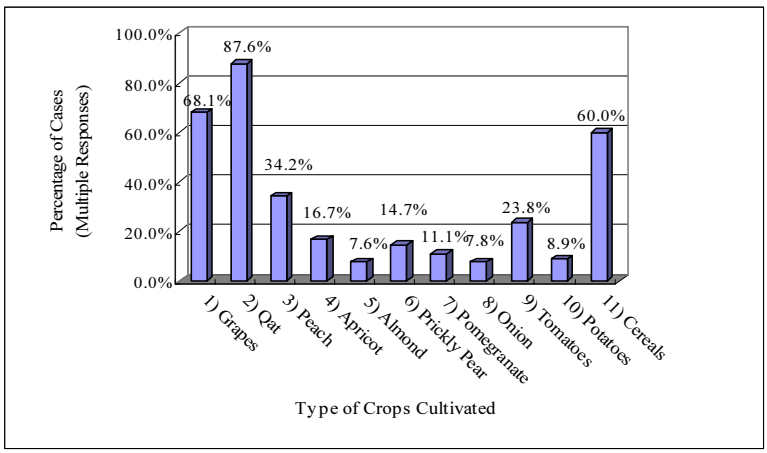
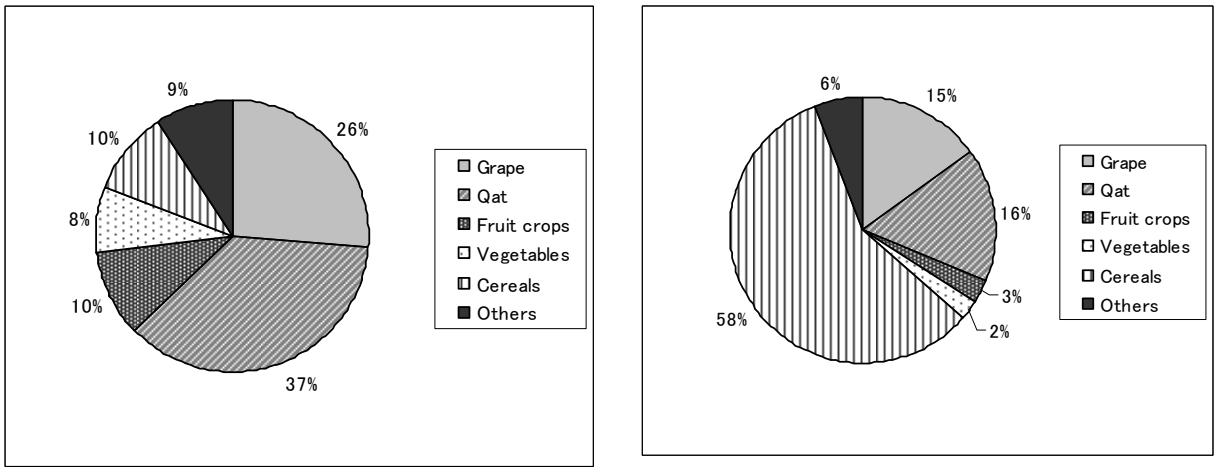


Figure 4.4 Type of Crops Cultivated in the Surveyed Villages



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.

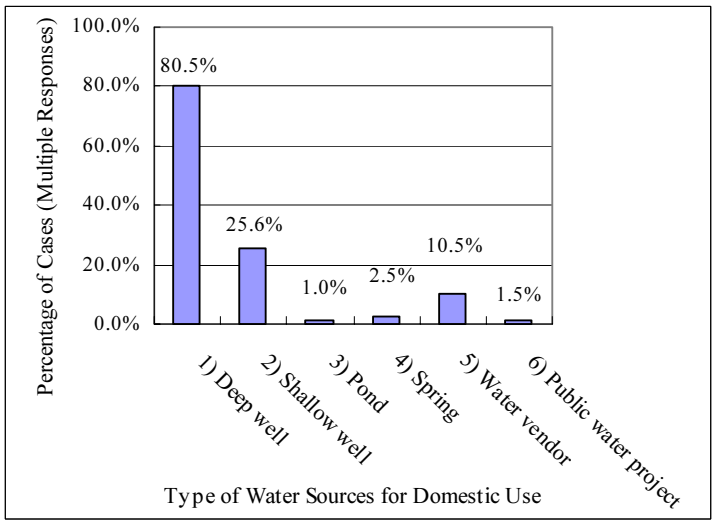


Figure 4.6 Type of Water Sources Available for Domestic Use

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.

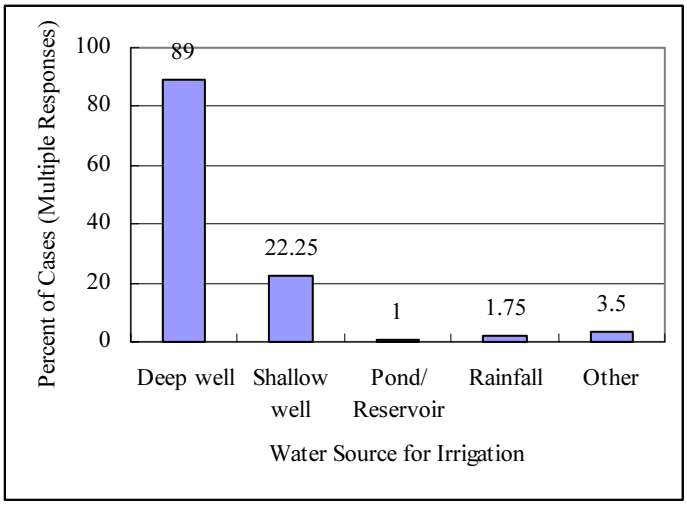


Figure 4.7 Type of Water Sources for Irrigation

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.

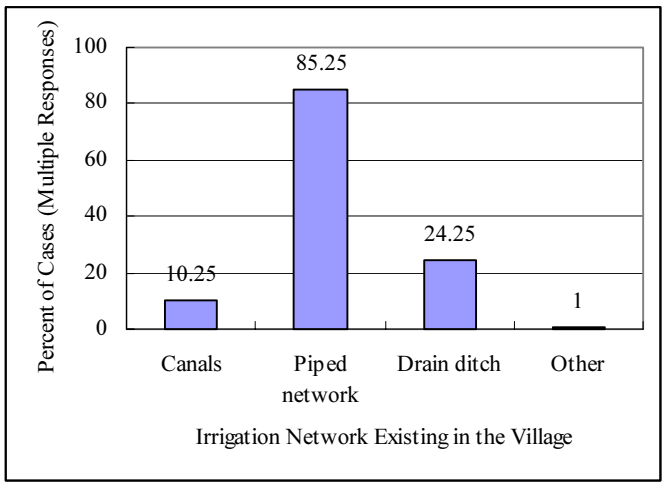
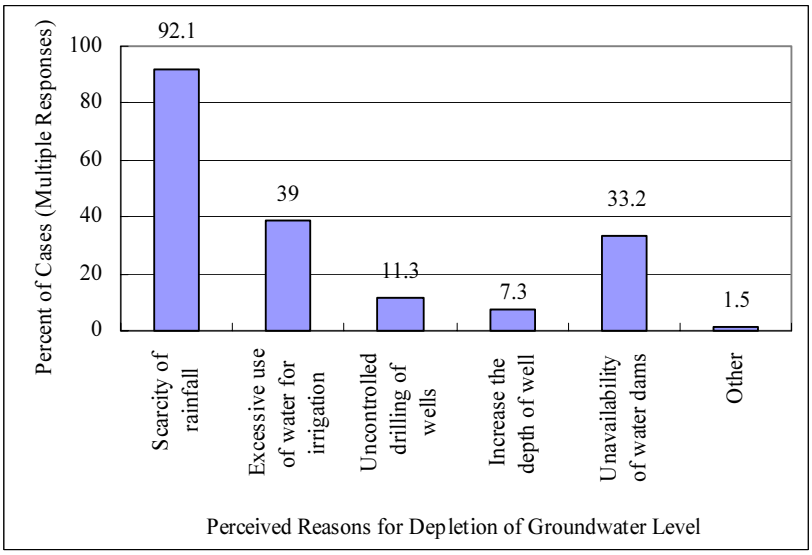


Figure 4.8 Type of Irrigation Network in Use

(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.

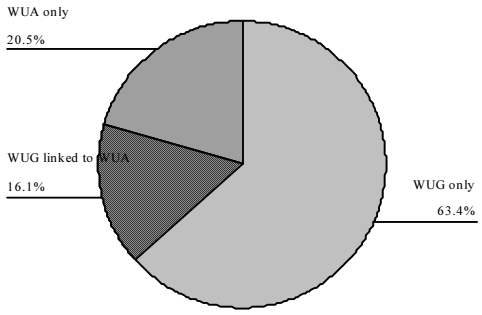
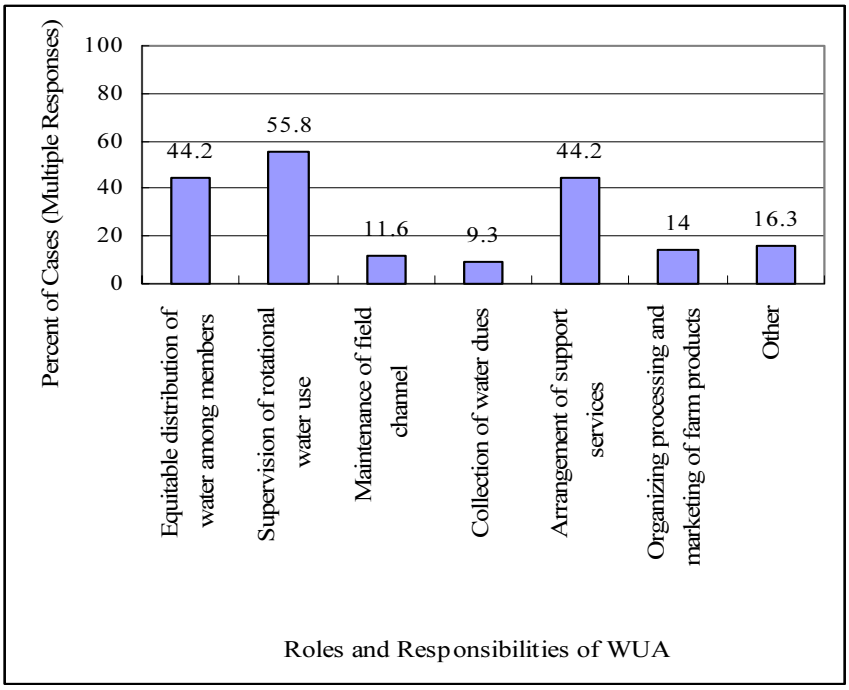


Figure 4.10 Type of Existing Community-Based Organizations for Irrigation Management

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.

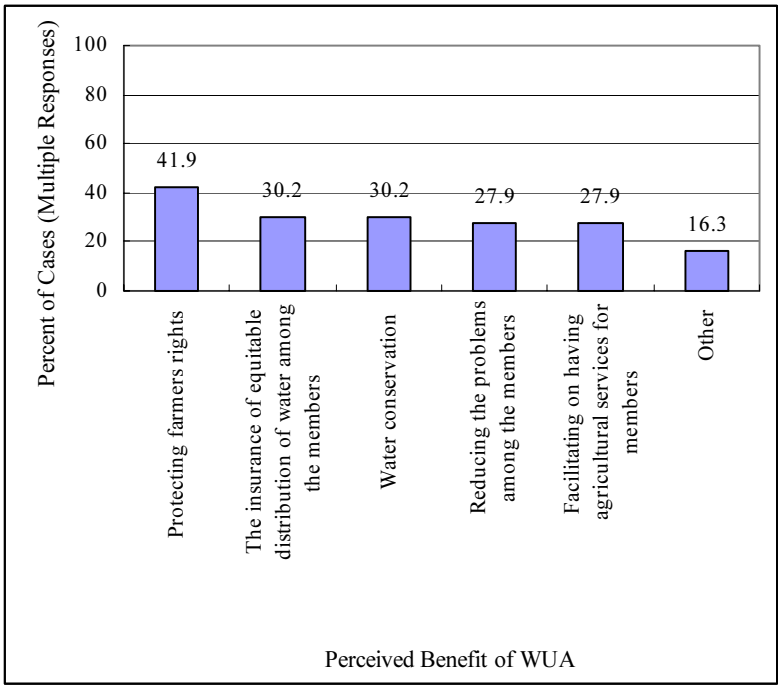
75% of the WUA existing in the surveyed villages collects membership fee of 1,000 Rial (median) and 60% also charge monthly subscription of 100 Rial (median) to the members.

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

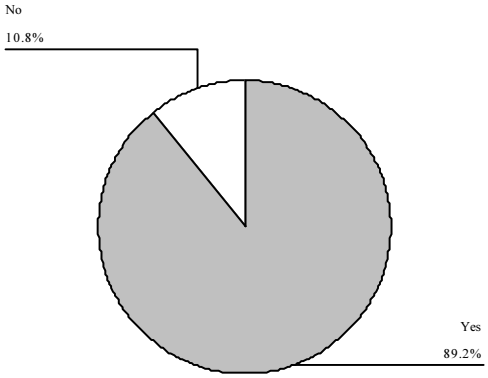


("Others" includes raising awareness among consumers about saving water, following up the concerned project authorities to install the modern irrigation networks.)

Figure 4.12 Perceived Benefit of WUA

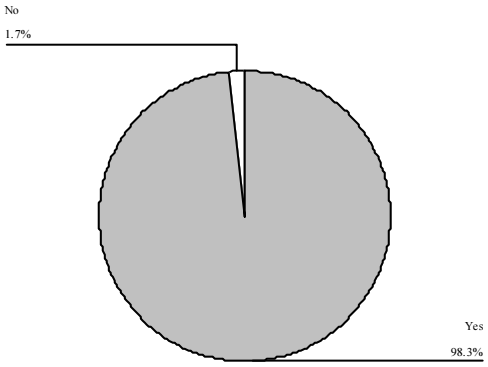
(8) Perception on Participatory Irrigation Management through WUA/WUG

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*.



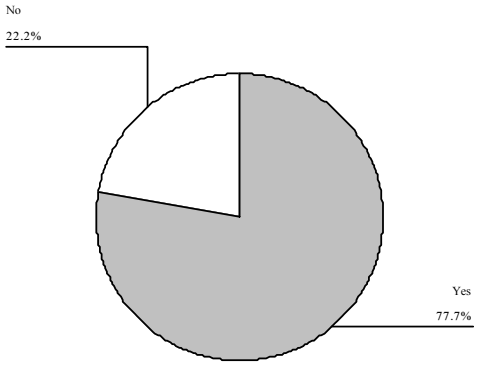
(400 valid cases)

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



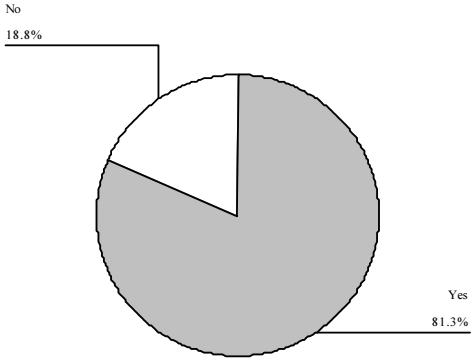
(357 valid cases. 43 cases excluded as not applicable)

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



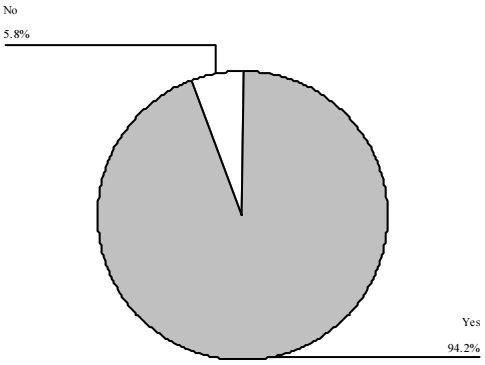
(400 valid cases)

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



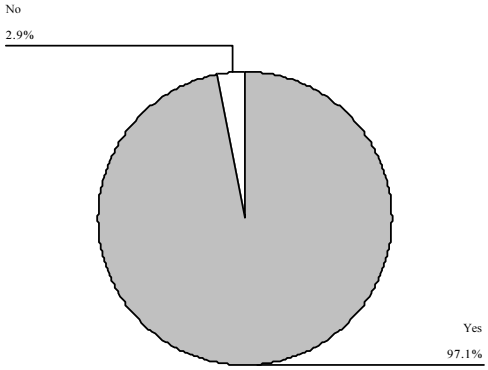
(400 valid cases)

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



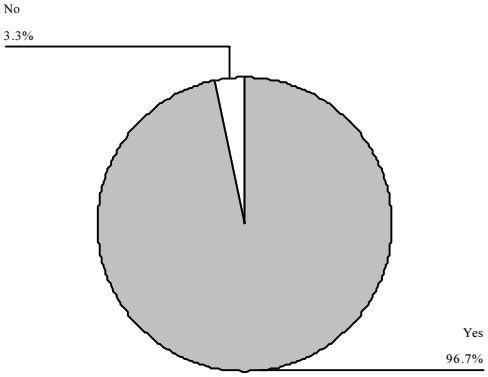
(325 valid cases. 75 cases excluded as not applicable)

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.

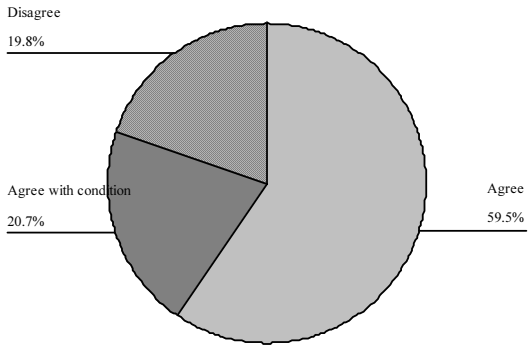
65% of those who agree with or without conditions on installation of water meters express their approval on monitoring of the water consumption at the wells regularly.

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.

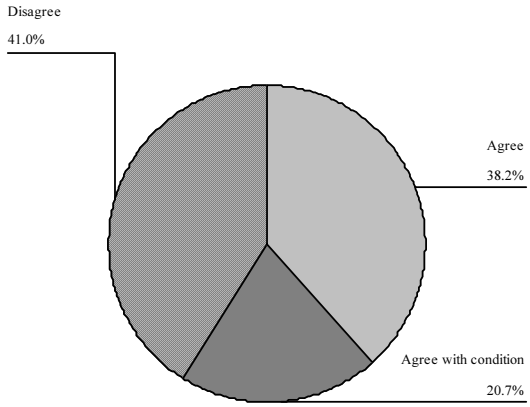
Regarding the prohibition of drilling of new wells in future, nearly half of the respondents are with the idea since they are afraid of further depletion of groundwater or dry up of the existing wells. Another half of the respondents oppose the measure with considering situations such as insufficient 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.



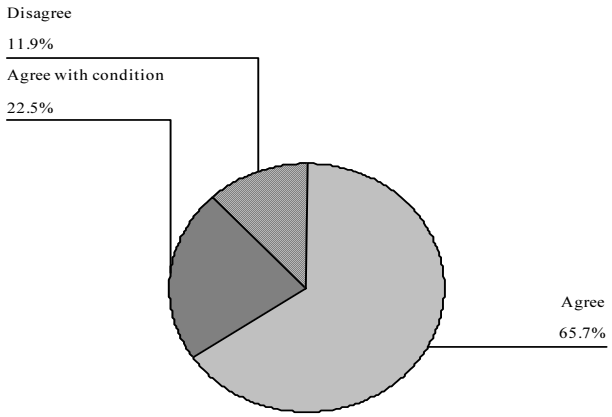
(400 valid cases)

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



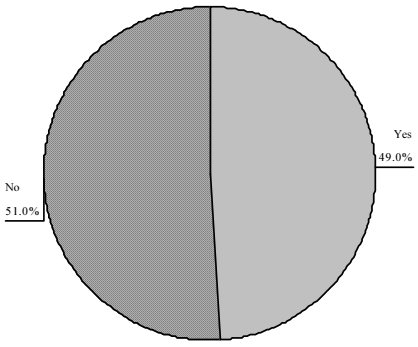
(400 valid cases)

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



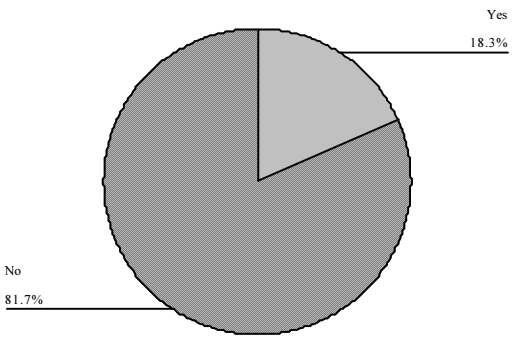
(236 valid cases. 164 cases excluded as not applicable.)

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.

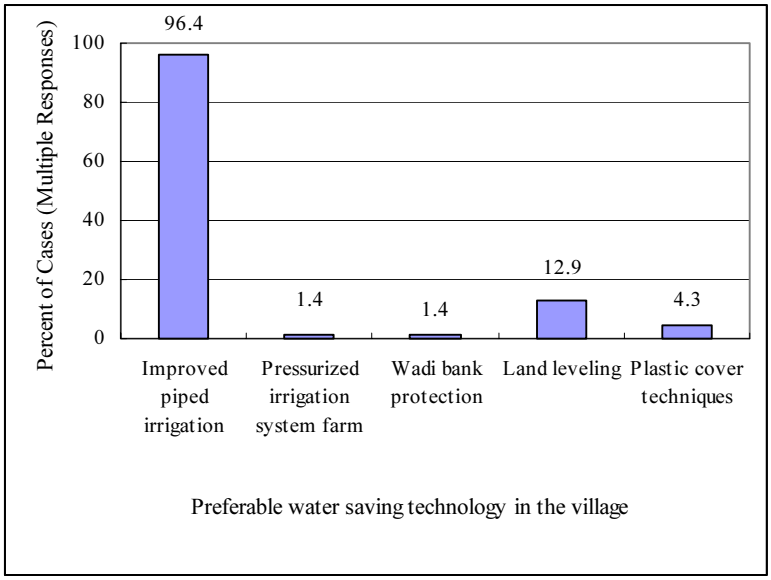


Figure 4.15 Water Saving Technology for Irrigation Preferred by the Surveyed Villages

(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.

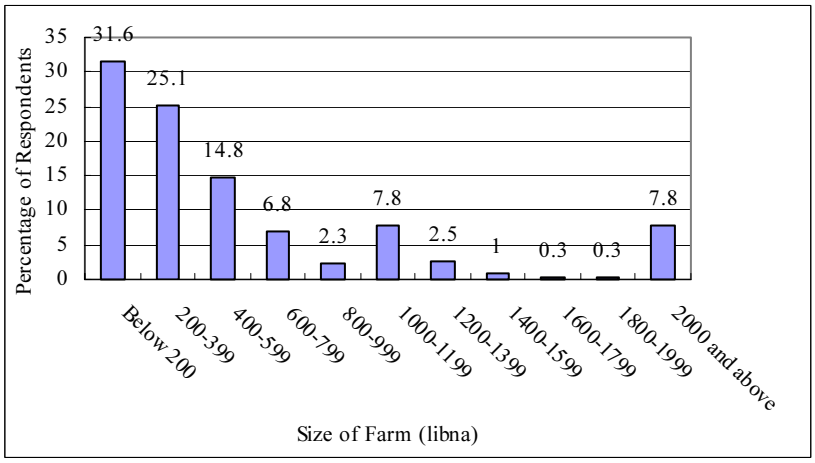


Figure 4.16 Distribution of Respondents by Total Area of Farm

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".

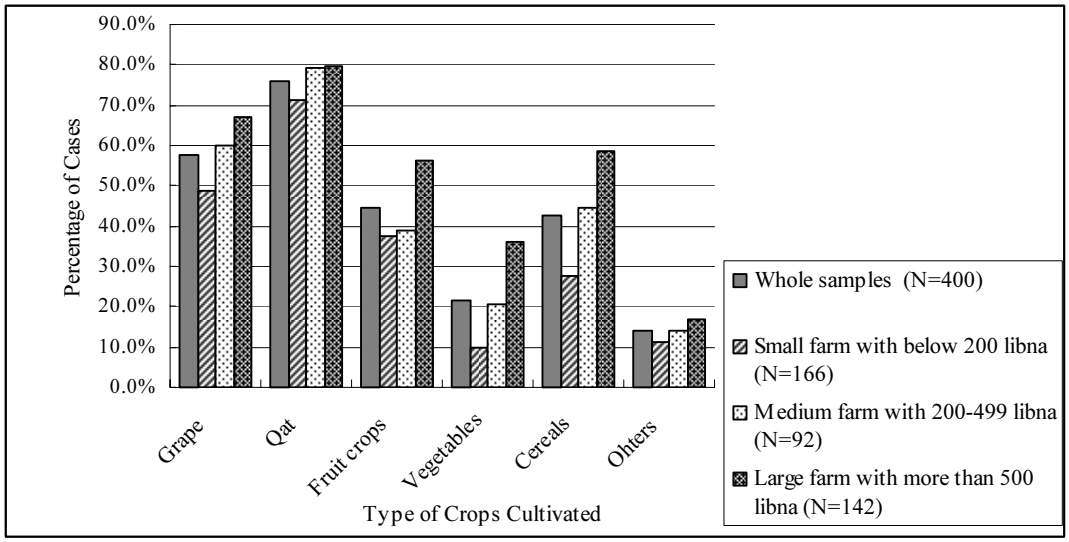


Figure 4.17 Type of Crops Cultivated in the Farms

(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.

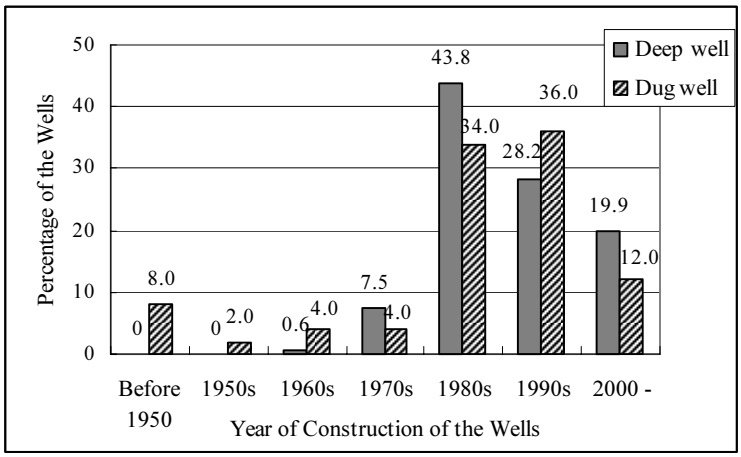


Figure 4.18 Distribution of Wells by Construction Year

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

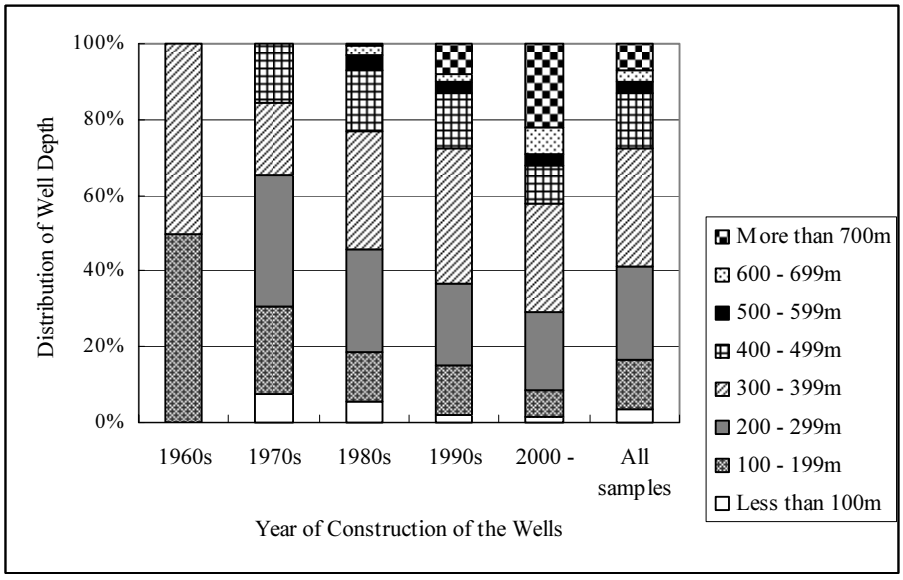


Figure 4.19 Depth of Sampled Deep Wells by Year of Construction

(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).

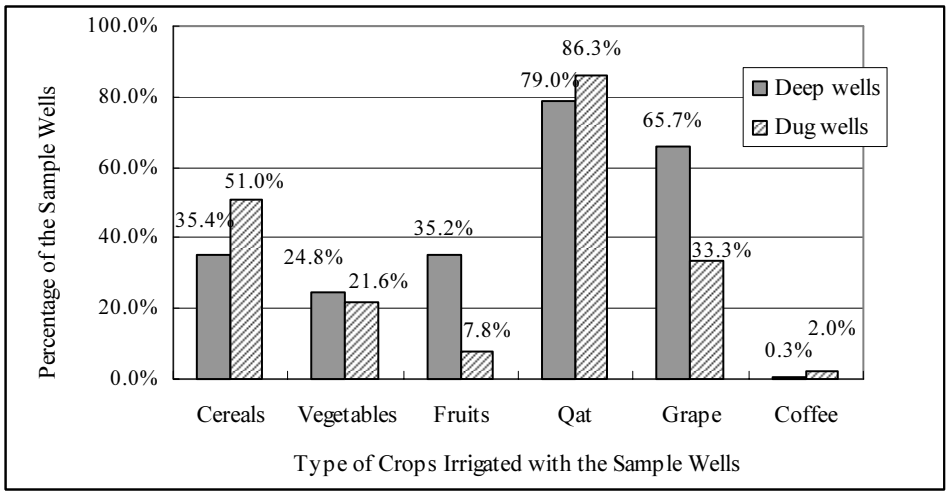


Figure 4.20 Cropping Patterns for the Sample Wells

(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.

CHAPTER 5

PRESENT CONDITION OF WATER USE

CHAPTER 5 PRESENT CONDITION OF WATER USE

5.1 GENERAL

According to CSO (2006) [1], groundwater, as a main source of water for domestic use accounts for 87% in Sana'a City and in the governorate of Sana'a, accounts for 68%. Water sources as springs, pools, cisterns, and roof top harvesting, 0.9% and 26% respectively for Sana'a City and Sana'a. Groundwater as a source for irrigation for agricultural holders is 57% for Sana'a City and 40% for the governorate of Sana'a. Rainwater is the other water source most used for irrigation and is accounted for 38% and 50% respectively for Sana'a City and Sana'a. Other water sources for irrigation as floods, springs, dams and water by cars account for 5% and 10% respectively for Sana'a City and governorate of Sana'a.

5.2 SOURCES OF WATER IN SANA'A BASIN (WELL INVENTORY SURVEY 2002)

Many studies have been carried out to count the number of wells in the Sana'a Basin. The latest well inventory survey (2002)[2] was carried out by Sana'a University Water and Environment Centre (WEC) for the National Water Resources Authority (NWRA) in conjunction with the Sana'a Water Supply and Sanitation Project (SWSSP) and 13,425 water points were inventoried in whole Sana'a Basin. Main results of the survey are summarized in *Table 5.1* and *Table 5.2*. Details of the well inventory are shown in *Appendix 3.*

Table 5.1 Status of Water Points Inventoried and the Main Purpose of Use for Operational Wells

Type of water points		Borehole	Dug Well	Dug / Bore	Spring	Dam / Pool	Total
Well Status	Operating	3,535	4,024	216	144	16	7,935
	Intermittent	8	656	2	0	2	668
	Temporary not in use	399	355	15	0	3	772
	Abandoned	1,217	1,132	82	0	0	2,431
	Dry	161	1,422	32	1	3	1,619
	Total	5,320	7,589	347	145	24	13,425
Water use pattern of operational wells	Irrigation	3,131	3,463	192	52	13	6,851
	Supply	153	9	5	1	0	168
	Domestic	152	482	14	48	0	696
	Tankers	78	10	2	0	0	90
	Industry	12	1	0	0	0	13
	Animal	3	50	2	43	3	101
	Other	6	9	1	0	0	16
	Total	3,535	4,024	216	144	16	7,935

Unit: number

Table 5.2 Yearly Abstraction by Purpose of Use and Irrigated Area by Source of Water

Type of water points		Borehole	Dug Well	Dug / Bore	Spring	Dam / Pool	Total
Abstraction ($000m^3$/year) by water use pattern	Irrigation	174,806.6	37,154.6	5,443.6	0.0	0.0	217,404.8
	Supply	18,163.0	102.6	211.9	0.0	0.0	18,477.5
	Domestic	6,856.4	3,799.8	269.2	0.0	0.0	10,925.3
	Tankers	6,055.1	458.6	84.2	0.0	0.0	6,597.9
	Industry	352.6	15.4	0.0	0.0	0.0	368.1
	Animal	108.6	518.0	29.6	0.0	0.0	656.2
	Other	283.2	93.0	1.1	0.0	0.0	377.4
	Total	206,625.6	42,141.9	6,039.7	0.0	0.0	254,807.2
Irrigated Area (ha) by Source of Water	Irrigation	21,524.6	3,721.8	843.2	64.3	82.0	26,235.9
	Supply	124.7	0.0	1.7	0.0	0.0	126.4
	Domestic	47.2	33.1	8.6	0.9	0.0	89.7
	Tankers	107.0	1.5	7.2	0.0	0.0	115.6
	Industry	0.1	0.0	0.0	0.0	0.0	0.2
	Animal	4.5	0.3	0.9	1.0	0.0	6.8
	Other	2.1	0.0	0.0	0.0	0.0	2.1
	Total	21,810.2	3,756.8	861.6	66.1	82.0	26,576.7

Unit: number

According to the results of the well survey (2002), 59% (7,935) of the sources inventoried were operational and 30% (4,050) were abandoned and/or dried-up wells. 86% of operational wells (6,851) were for irrigation purpose and boreholes and dug wells were the main sources of water. 85% (217 MCM) of the total water abstracted was used for irrigation purpose and the total area irrigated was accounted for 26,575 hectares.

5.3 DOMESTIC WATER USE

According to the well inventory survey (2002), 954 water points were inventoried for domestic water use and the total abstraction was 36 MCM as shown in *Table 5.3*. Here, water for domestic use is accounted for water abstraction of water points for domestic purpose, supply purpose and tankers. As for domestic water use, 40% (383) of the water points were accounted for boreholes, 53% (501) for dug wells, 2% (21) for dug/bores and 5% (49) for springs. As a source of water, 85% of the total water abstracted was from boreholes and 13% was from dug wells.

Abstraction of water accounts to 36 MCM from water points for domestic, supply and tankers use purpose. Note that water for urban supply network, domestic, commercial and institutional water use is included and it is a total quantity of water abstracted for domestic and non-domestic purpose.

Figure 5.1 shows the distribution of water points for domestic, supply and tankers purpose surveyed in the Basin.

Table 5.3 Abstraction of Domestic Water for each Sub-Basin

Sub-Basin		Domestic		Supply		Tankers		Total	
		Water Point	Abstraction (m^3/year)	Water Point	Abstraction (m^3/year)	Water Point	Abstraction (m^3/year)	Water Point	Abstraction (m^3/year)
1	Wadi Al Mashamini	0	0	3	256,871	0	0	3	256,871
2	Wadi Al Madini	0	0	3	150,032	1	84,942	3	234,974
3	Wadi Al Kharid	5	56,663	1	31,450	2	169,179	6	257,292
4	Wadi Al Ma'adi	19	189,359	0	0	0	0	19	189,359
5	Wadi A'sir	28	175,392	0	0	0	0	28	175,392
6	Wadi Khulaqah	4	43,632	0	0	0	0	4	43,632
7	Wadi Qasabah	2	78,663	2	55,037	0	0	4	133,700
8	Wadi Al Huqqah	2	3,931	3	73,382	0	0	5	77,314
9	Wadi Bani Huwat	98	1,011,651	24	2,382,425	10	700,736	122	4,094,811
10	Wadi Thumah	23	241,024	0	0	1	57,658	23	298,681
11	Wadi As Sirr	109	1,054,772	1	562	0	0	110	1,055,334
12	Wadi Al Furs	31	135,124	1	117,936	0	0	32	253,060
13	Wadi Al Iqbal	3	62,899	6	276,759	0	0	9	339,659
14	Wadi Zahr & Al Ghayl	29	404,508	43	1,521,875	1	60,024	72	1,986,408
15	Wadi Hamdan	10	197,957	14	397,173	7	490,444	24	1,085,574
16	Wadi Al Mawrid	129	5,226,574	59	12,134,324	57	4,263,801	188	21,624,699
17	Wadi Sa'wan	103	592,742	3	382,979	0	0	106	975,721
18	Wadi Shahik	82	814,311	2	21,816	7	502,587	84	1,338,714
19	Wadi Ghayman	20	199,831	8	123,590	0	0	28	323,421
20	Wadi Al Mulaikhy	16	44,939	10	291,188	0	0	26	336,127
21	Wadi Hizyaz	5	79,934	3	260,077	4	268,553	8	608,564
22	Wadi Akhwar	14	311,443	0	0	0	0	14	311,443
Total		732	10,925,349	186	18,477,476	90	6,597,923	918	36,000,748

* Domestic water use = total abstraction of water points for domestic purpose, supply purpose and tankers purpose.

According to information, results of survey carried by NWRA-SB recently, shows that there are 213 wells with purpose of supply water to tankers inside the Secretariat. However, detailed data and information

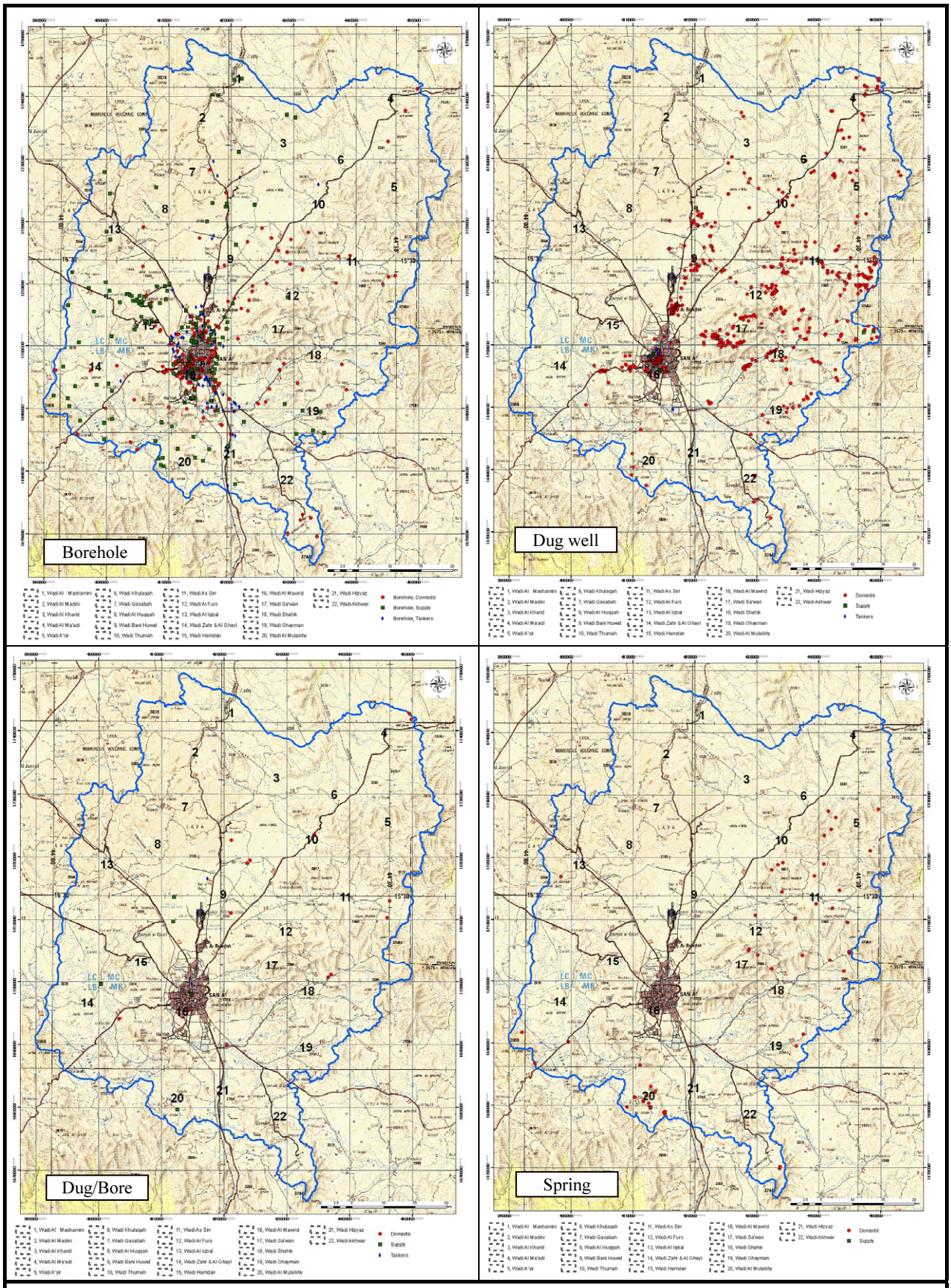


FIGURE 5.1 DISTRIBUTION MAP OF WATER POINTS FOR DOMESTIC USE BY TYPE

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5.3.1 URBAN WATER SUPPLY

(1) Public Water Supply

The first water supply system in Sana'a was installed in 1964 and consisted of public stand pipes fed from six hand-dug wells and a 600 m^3 ground level steel tank. In 1969 it was expanded and upgraded and in 1970 the National Cooperative has installed a small diameter piping system around five wells installed in 1969.

In 1974, the National Water and Sanitation Authority (NWSA) was created and took over a responsibility for the system, developing it into a centralized piped system, which commenced water supply to Sana'a in 1978. In 2000, Sana'a Water Supply and Sanitation Local Corporation (SWSLC) were created as an independent organization and now is the responsible body for urban water supply and sanitation for Sana'a City.

1) Water Supply System

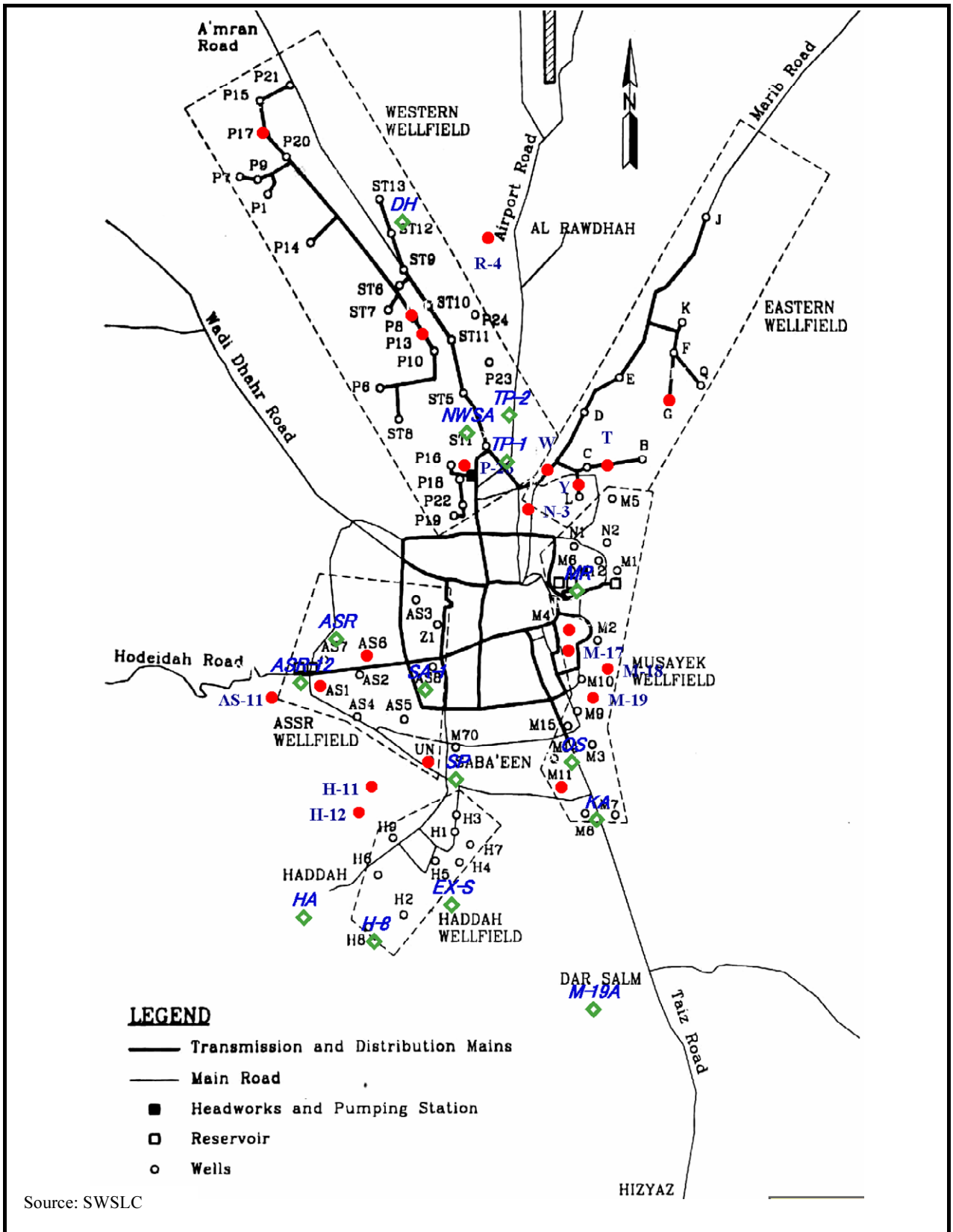
The main source of the public water supply for Sana'a City is groundwater abstracted from three main well fields called Eastern Well Field, Western Well Filed and Sana'a Well Field. Sana'a Well Field is divided into three sub-fields. Musayek Well Field, Asser Well Field and Haddah Well Field. Eastern Well Field, is located about 6km north-east Sana'a City, along Marib Road, Western Well Field, is located about 6 km north-west of the city along Amram Road, Musayek Well Field, is located in the east side of the city and Asser Well Field is located in the west side of the city and Haddah Well Field, in the southern area of the city.

SWSLC posses about 130 wells where 80 wells are productive and the remaining wells are not working. Wells not working are due to decrease on water production (decrease of water level), and others due to technical problems or had failure to reach the groundwater during drilling works. *Figure 5.2* shows the location of the wells and *Table 5.4* is a list of wells and their status. Details of wells is shown in *Annex 5.2*

Actually, project to drill 20 wells with depths from 700 to 1,000 m, for water supply are ongoing according to information. Details are unknown however pumping test for some of them are ongoing and others have stopped the drilling works due to technical problems. Some of wells are projected to cover the surrounding population and it will be not connected to the main network

- 10 wells funded by the World Bank and executed by SWSLC
- 3 wells funded by the World Bank and executed by NWRA-SB
- 5 to 7 wells funded and executed by SWSLC

Is expected an abstraction of about 20 to 30 l/s from each well at long term condition. From the point of view of Water Resources Management, progress of these works should be accompanied and collection of detailed information hereafter is necessary.



Source: SWSLC

FIGURE 5.2 LOCATION MAP OF WELL FIELDS

Table 5.4 Water Supply Wells Status by the year of 2005

No	Well Field	Well No	Well Satus	No	Well Field	Well No	Well Satus
1	Western well field	ST1		69	Asser well field	AS4	
2	Western well field	ST5		70	Asser well field	AS4R	
3	Western well field	ST6		71	Asser well field	AS5	
4	Western well field	ST7	decrease in production	72	Asser well field	AS6	failure
5	Western well field	ST8	dry	73	Asser well field	AS7	dry
6	Western well field	ST9		74	Asser well field	AS8	
7	Western well field	ST10		75	Asser well field	SA-1	
8	Western well field	ST11	decrease in production	76	Asser well field	AS9	
9	Western well field	ST12	decrease in production	77	Asser well field	AS10	
10	Western well field	ST13	decrease in production	78	Asser well field	AS11	
11	Western well field	P1	stopped	79	Asser well field	AS12	
12	Western well field	P6		80	Asser well field	ASR1	
13	Western well field	P7	dry	81	Asser well field	ASR-2	
14	Western well field	P8R	dry	82	Asser well field	UN	
15	Western well field	P9	dry	83	Asser well field	Z1	
16	Western well field	P10	decrease in production	84	Asser well field	MZ-1	
17	Western well field	P13	deeping through digging	85	Asser well field	M70	
18	Western well field	P14	dry	86	Asser well field	M71	*****
19	Western well field	P15	decrease in production	87	Asser well field	SP	
20	Western well field	P16		88	Asser well field	H3R	
21	Western well field	P17	dry	89	Asser well field	AS4R	
22	Western well field	P18		90	Musayek well field	M1	
23	Western well field	P19	decrease in production	91	Musayek well field	M2	
24	Western well field	P20		92	Musayek well field	M3	
25	Western well field	P21	decrease in production	93	Musayek well field	M4	
26	Western well field	P22		94	Musayek well field	M5	
27	Western well field	P23		95	Musayek well field	M6	dry
28	Western well field	P24		96	Musayek well field	Mr6	
29	Western well field	P25		97	Musayek well field	M7	
30	Western well field	P26		98	Musayek well field	M8	dry
31	Western well field	NWSA		99	Musayek well field	M9	
32	Western well field	D.H		100	Musayek well field	M9R	
33	Eastern well field	TP1		101	Musayek well field	M10R	
34	Eastern well field	TP2		102	Musayek well field	M11	decrease in level
35	Eastern well field	B		103	Musayek well field	M11R	still digging
36	Eastern well field	C		104	Musayek well field	M12	dry
37	Eastern well field	D		105	Musayek well field	M14	
38	Eastern well field	E		106	Musayek well field	M15	
39	Eastern well field	F		107	Musayek well field	M16	
40	Eastern well field	G		108	Musayek well field	M17	
41	Eastern well field	J		109	Musayek well field	M18	
42	Eastern well field	K		110	Musayek well field	M19	
43	Eastern well field	L		111	Musayek well field	M20	dry
44	Eastern well field	Q		112	Musayek well field	M21	dry
45	Eastern well field	SS		113	Musayek well field	M22	dry
46	Eastern well field	W		114	Musayek well field	M23	dry
47	Eastern well field	Y		115	Musayek well field	M24	
48	Eastern well field	T		116	Musayek well field	MR	
49	Eastern well field	MZ-2		117	Musayek well field	KA	
50	Eastern well field	KI		118	Musayek well field	M19-A	
51	Haddah well field	EX-S		119	Musayek well field	M24	
52	Haddah well field	H1	dry	120	Musayek well field	OS	
53	Haddah well field	H2	dry	121	Musayek well field	HZ	
54	Haddah well field	H3		122	Musayek well field	N1	
55	Haddah well field	H4		123	Musayek well field	N2R	
56	Haddah well field	H5	dry	124	Musayek well field	N3	
57	Haddah well field	H6	dry	125	Musayek well field	MZ-2	
58	Haddah well field	H7		126	Musayek well field	R1	
59	Haddah well field	H8		127	Musayek well field	R2	
60	Haddah well field	H9	dry	128	Musayek well field	R3	
61	Haddah well field	H10	failure	129	Musayek well field	R4	
62	Haddah well field	H11	failure	130	Musayek well field	R3R	
63	Haddah well field	H12	failure	131	Musayek well field	---	dry
64	Haddah well field	H13		132	Musayek well field	---	dry
65	Haddah well field	HA		133	Musayek well field	---	dry
66	Asser well field	AS1	failure	134	Musayek well field	---	dry
67	Asser well field	AS2		135	Musayek well field	---	?
68	Asser well field	AS3		136	Musayek well field	---	?

Source: SWSLC

Water production for Sana'a City for the past nine years is shown in *Table 5.5*.

Table5.5 Production and Consumption of Water (1988-2006)

Year	No. of wells	Water Produced	Water Consumed
1998	56	19,146,980	13,231,847
1999	62	17,289,380	12,201,750
2000	63	17,304,271	11,343,467
2001	64	16,779,443	10,336,823
2002	65	18,468,664	11,771,810
2003	68	20,320,782	12,868,174
2004	78	21,843,914	13,222,526
2005	77	24,347,334	13,785,339
2006	78	24,083,969	14,744,341

Source: Sana'a Water and Sanitation Local Corporation Unit: cubic meters

During the period of 1998 and 2006, number of wells operating for water production has increased 39%, and production of water has increased 26%.

Table 5.6 shows the performance indicator of the water supply system for 2005 and 2006. Domestic water use account for about 89% of the total water consumed in 2006, and per capita consumption of water was 51.6 l/c/d. Population targeted to be covered in 2006 was 1.7 million; however, only 49% of the targeted population was covered.

Table 5.6 Performance Indicator for the Water Supply System (2005-2006)

Item	Unit	Year	
		2005	2006
Total water produced (abstracted)	m^3	24,347,334	24,083,969
Total water consumed (billed)	m^3	13,785,339	14,744,341
Domestic consumption	m^3	12,472,844	13,106,926
Institutional consumption	m^3	1,312,495	1,047,531
Commercial consumption	m^3		589,884
No of water supply connections	no	78,018	80,741
Domestic connections	no	74,771	77,349
Institutional connections	no	3,247	1,146
Commercial connections	no		2,246
Connections with meters with Zero-Reading	no	11,635	11,901
No of beneficiaries	inhabitants	672,141	696,141
Per capita water consumption	l/c/d	50.8	51.6

Source: Closing Report for the Performance Indicator System (PIIS) for 2006 (SWSLC)
Basic data report 2006 (SWSLC)

2) Non-Revenue Water

Non-Revenue Water (NRW) is the difference between system input volume and billed authorized consumption and it consists of 1) unbilled authorized consumption, 2) apparent

losses and real losses[3].

Table 5.7 Definition of Non-Revenue Water

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Meterd Consumption (including water exported)	Revenue Water
			Billed Non-metered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Non-metered Consumptiom	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Metering Inaccuracies	
		Real Losses	Leakege on Transmission and/or Distribution Mains	
			Leakege and Overflow at Utility's Storage Tanks	
			Leakage on Service Connections up to Customers' Meters	

Source: International Water Association

Average NRW of public network for the period of 1998 to 2006 was 36.4%. Nevertheless for the latest three years (2004 to 2006), NRW accounts for an average of 40.6%, and in 2005, it shows the highest ratio, accounting for 43%. For 2006, it was accounted for 39%. NRW for the period of 1998 to 2006 is shown in *Table 5.8*.

Table 5.8 NRW for the Years of 1998 to 2006

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
NRW	30.9	29.4	34.4	38.4	36.3	36.7	39.5	43.4	38.8

Unit: percent

In 2006, about 11,900 water connections have meters with zero-reading and quantity of water lost due to leakages or illegal connections are unknown since studies and surveys was not carried out up to now.

3) Water Quality

Results of water quality analyses for the water supply system were collected from the laboratory of SWSLC. Handwritten analyses record notes from 1993 to 2006 were collected due to technical problems on laboratory's computer and also backup data (soft copy or hard copy) was not taken by the laboratory.

Parameters analyzed by SWSLC are shown in *Table 5.9* and the standard adopted is the World Health Organization (WHO) standard for drinking water. *Table5.10* shows wells which have poor water quality according to analyses results and detailed analyses results is attached in *Appendix 5.*

Table 5.9 Parameters for Water Quality Analyses

Parameter	Unit	WHO Guide line
Electrical Conductivity (EC)	μS/cm	
pH		6.5 - 8.5
Total Dissolved Solids (TDS)	mg/l	1,000
P. Alkalinity		
Total Alkalinity as $CaCO_3$	mg/l	
Carbonate (CO_3)	mg/l	
Bicarbonate (HCO_3)	mg/l	
Total Hardness as $CaCO_3$	mg/l	500
Calcium (Ca)	mg/l	200
Magnesium (Mg)	mg/l	
Chloride (Cl)	mg/l	250
Sulfate (SO_4)	mg/l	400
Nitrate (NO_3)	mg/l	50
Sodium (Na)	mg/l	200
Potassium (K)	mg/l	
Iron (Fe)	mg/l	0.3
Fluoride (F)	mg/l	1.5
Phosphorus as PO_4	mg/l	
Ammonium (NH_4)	mg/l	

Source: SWSLC Water Quality Analyses Report Sheet

Table 5.10 Analyses Results for Water with Poor Quality (1/3)

Western Well Field

Well No	Date	Poor Quality Items
ST5	09/Feb/1994	
	08/Oct/1994	Fe=0.32 mg/l
	14/Jan/2001	
	03/Feb/2001	Fe=0.49 mg/l
	13/Jan/2002	Fe=0.57 mg/l
	20/May/2002	
	13/Jan/2005	Fe=0.57 mg/l
	16/Aug/2005	
ST6	09/Feb/1994	Fe=1.38 mg/l
	14/Jan/2001	
	13/Jan/2002	
	20/May/2002	Fe=0.55 mg/l
	14/Jan/2006	
ST9	26/Apr/1994	
	04/Feb/2001	Fe=0.51
	14/Feb/2002	
	20/May/2002	
ST10	24/Nov/1993	
	09/Feb/1994	Fe=0.92 mg/l
	04/Feb/2001	Fe=0.36 mg/l
	06/May/2001	
	13/Jan/2002	Fe=0.30 mg/l
	20/May/2002	
ST11	08/Oct/1994	Fe=0.36 mg/l
ST12	***29/Oct/1994***	TDS=1,014mg/l, NO3=136.40 mg/l
	02/Nov/1994	NO3=141.00 mg/l
	05/Nov/1994	NO3=150.00 mg/l
	06/Nov/1994	NO3=146.00 mg/l
	20/Jan/1994	
	27/Sep/1994	
	14/Jan/2001	TDS=1,189 mg/l, SO4=925.o mg/l, Fe=0.40 mg/l
	13/Jan/2002	
	07/Jan/2006	TDS=1,189 mg/l, SO4=925.o mg/l, Fe=0.40 mg/l

Well No	Date	Poor Quality Items
ST13	24/Nov/1993	
	20/Mar/1994	Fe=0.41 mg/l
	13/Apr/1994	Fe=0.91 mg/l
	27/Sep/1994	TDS=1,063 mg/l, Na=200.0 mg/l Fe=0.35 mg/l
	05/Jun/2000	SO4=950.0 mg/l, Na=251.0 mg/l
	14/Jan/2001	TDS=1,217 mg/l, SO4=1200.0 mg/l, Na=238.0 mg/l
	13/Jan/2002	TDS=1,385 mg/l, SO4=900.0 mg/l, Na=280 mg/l, Fe=0.67 mg/l
	20/May/2002	pH=6.41
	13/Jan/2006	TDS=1,385 mg/l, SO4=900.0 mg/l, Na=280 mg/l, Fe=0.67 mg/l
TP1	11/Oct/2000	Fe=0.83 mg/l
	01/Nov/2000	Fe=0.34 mg/l
	01/Jan/2002	
	19/Mar/2002	
TP2	01/Jan/2002	
	01/Nov/2006	
P1	13/Apr/1994	Fe=0.41 mg/l
	04/Feb/2001	Fe=0.53 mg/l
P6	20/Mar/1994	
	04/Feb/2001	Fe=0.56 mg/l
	06/May/2001	
	14/Jan/2002	
	20/May/2002	
P8R	02/Dec/2001	Fe=0.31 mg/l
	27/Nov/2006	Fe=0.31 mg/l
P10	18/Jun/1994	
	04/Feb/2001	Fe=0.33 mg/l
P13	09/Feb/1994	
	27/Sep/1994	
	05/Jun/2000	
	04/Feb/2001	Fe=0.62 mg/l
	14/Jan/2002	
	20/May/2002	
	18/Dec/2003	Fe=2.43 mg/l

Well No	Date	Poor Quality Items
P15	06/Feb/1994	Ca=244.0 mg/l, Fe=0.54 mg/l
	26/Apr/1999	Ca=232.0 mg/l, SO4=613.0 mg/l
	14/Jan/2001	Ca=245.0 mg/l, SO4=838.0 mg/l, Fe=0.78 mg/l
	14/Jan/2006	Ca=245.0 mg/l, SO4=838.0 mg/l
P16	21/Jun/1994	
	27/Sep/1994	
	14/Mar/1999	
	03/Feb/2001	
	29/Mar/2003	pH=6.44
P19	14/Mar/1999	
	14/Jan/2001	
	06/May/2001	
	13/Jan/2002	Fe=0.50 mg/l
	14/Jan/2006	
P20	18/Jun/1994	TDS=1,105 mg/l, Ca=244.0 mg/l, SO4=688.0 mg/l
	27/Jan/2001	
	06/May/2001	SO4=775.0 mg/l
	23/Jan/2006	
P21	05/Jun/2000	
	17/Jan/2001	Fe=0.50 mg/l
	13/Jan/2002	
	20/May/2002	
	14/Jan/2006	Fe=0.50 mg/l
P22	24/Nov/1993	
	18/Jun/1994	
	03/Sep/1994	
	14/Mar/1999	Fe=0.32 mg/l
	14/Jan/2001	
	14/Jan/2006	
P23R	11/Jul/2006	
	14/Sep/2006	Fe=0.30 mg/l
P25	28/Oct/2001	Fe=2.80 mg/l
	27/Oct/2005	Fe=2.80 mg/l
	21/Jul/2006	Fe=0.41 mg/l

Well No	Date	Poor Quality Items
P26	09/Nov/2001	Fe=0.32 mg/l
	19/Nov/2005	Fe=0.32 mg/l
R4	04/Dec/2001	Fe=0.35 mg/l
	07/Apr/2005	Fe=0.50 mg/l
	05/Sep/2005	
	27/Nov/2005	Fe=0.35 mg/l
	25/Feb/2006	Fe=0.72 mg/l
	03/Mar/2006	Fe=0.72 mg/l
N3	06/Feb/2002	Fe=0.37 mg/l

Table 5.10 Analyses Results for Water with Poor Quality (2/3)

Eastern Well Field

Well No	Date	Poor Quality Items
B	28/Nov/1993	
	14/Mar/1993	Fe=0.34 mg/l
	10/Feb/2001	Fe=0.92 mg/l
	19/Mar/2002	
	03/Jun/2004	
C	28/Nov/1993	
	06/Feb/1994	
	27/Sep/1994	
	14/Mar/1999	
	10/Feb/2002	
	01/Jan/2002	
	18/Mar/2002	
	06/Jun/2004	pH=8.87
	01/Oct/2005	
E	27/Sep/1994	
	13/Mar/1994	
	07/Jan/2001	
	19/Mar/2002	Fe=0.56 mg/l
	07/Jan/2006	
F	13/Mar/1999	Fe=0.58 mg/l
	07/Jan/2001	
	18/Mar/2002	
	07/Jan/2006	
J	27/Sep/1994	
	05/Jun/2000	Fe=0.40 mg/l
	07/Jan/2001	
	07/Jan/2006	
K	28/Nov/1993	
	27/Sep/1994	
	11/Feb/2001	Fe=1.87 mg/l
	19/Mar/2002	
MZ2	14/May/2005	Fe=0.86 mg/l
	28/Jan/2006	Fe=3.70 mg/l
	12/Mar/2006	Fe=1.42 mg/l

Well No	Date	Poor Quality Items
Q	28/Nov/1993	
	27/Sep/1994	
	13/Mar/1999	
	11/Feb/2001	Fe=1.12 mg/l
	18/Mar/2002	Fe=2.65 mg/l

Musayek Well Field

Well No	Date	Poor Quality Items
M2	26/Apr/1994	Fe=0.38 mg/l
	01/Apr/1996	Fe=0.63 mg/l
	21/Mar/1999	
	07/May/2000	Fe=0.46 mg/l
	12/Mar/2006	Fe=2.50 mg/l
M3	24/Jan/2002	
	10/Feb/2002	Fe=1.25 mg/l
	20/Dec/2005	Fe=0.41 mg/l
	31/Aug/2006	
M4	15/Aug/1994	Cl=276.5 mg/l, NO3=97.00 mg/l
	12/Dec/1994	TDS=1,135 mg/l, Cl=264.0, NO3=111.00
	26/Mar/1995	NO3=98.00 mg/l
	15/Mar/1999	TDS=1,051 mg/l, Ca=200 mg/l Cl=290 mg/l, NO3=99.00 mg/l
	30/Jan/2002	
M5	07/Nov/1994	Fe=0.64 mg/l
	14/Mar/1999	
	06/May/2001	
	05/Jan/2002	Fe=0.47 mg/l
	04/Jul/2004	
	13/Feb/2005	
	14/Sep/2006	
M6	***29/Oct/1994***	TDS=1,014 mg/l, NO3=136.40mg/l,
	02/Nov/1994	NO3=141.00 mg/l
	05/Nov/1994	NO3=150.00 mg/l
	06/Nov/1994	NO3=146.00mg/l
	08/Nov/1994	NO3=140.00 mg/l
	26/Mar/1995	NO3=136.00 mg/l
	15/Mar/1999	TDS=1,020 mg/l, Ca=200.0 mg/l, Cl=252.0 mg/l, NO3= 150.00 mg/l
	30/Sep/2000	NO3=66.40 mg/l
	28/Nov/2000	NO3=58.00 mg/l, Fe=0.30 mg/l
	02/Jan/2001	
	07/Jan/2001	NO3=50.00 mg/l
	07/Jan/2006	NO3=50.00 mg/l
	09/Aug/2006	Fe=0.73 mg/l

Well No	Date	Poor Quality Items
MR6	***29/Oct/1994***	TDS=1,014 mg/l, NO3=136.40mg/l,
	02/Nov/1994	NO3=141.00 mg/l
	05/Nov/1994	NO3=150.00 mg/l
	06/Nov/1994	NO3=146.00mg/l
	11/Jul/2001	Fe=0.78 mg/l
M7	09/Aug/1997	NO3= 63.00 mg/l
	16/Mar/1999	
	07/May/2000	
	24/Jan/2002	
	28/May/2002	Fe=0.49 mg/l
	24/Jan/2006	
M10	04/Dec/1995	Fe=0.32 mg/l
M10R	14/Aug/2001	pH=8.64
M11	22/Apr/1996	Fe=0.31 mg/l
	08/Oct/1996	
M12	22/Dec/1997	Fe=1.27 mg/l
	15/Mar/1999	Fe=1.40 mg/l
	22/Jan/2000	Fe=1.20 mg/l
	30/Sep/2000	Fe=1.02 mg/l
M14	20/Sep/1997	Fe=1.50 mg/l
	20/Dec/2005	
M15	24/Jan/1999	
	15/May/1999	NO3=76.00 mg/l
	20/Dec/2005	NO3=58.52 mg/l
M17	03/Feb/2002	Fe=0.64 mg/l
	12/Aug/2006	
M19	06/Jul/2002	Fe=0.34 mg/l
	06/Jul/2005	Fe=0.34 mg/l
	12/Mar/2006	Fe=1.19 mg/l
M22	24/Jan/2002	pH=9.26
OS	28/Oct/2001	Fe=1.53 mg/l
	08/Jun/2002	Fe=0.68 mg/l
	20/Dec/2005	Fe=0.32 mg/l
HZ	01/Feb/2006	Fe=0.36 mg/l

Table 5.10 Analyses Results for Water with Poor Quality (3/3)

Asser Well Field

Well No	Date	Poor Quality Items
AS1	05/Jul/1995	pH=9.32
	27/Sep/2000	pH=9.19
	29/May/2002	pH=8.60, Fe=0.31 mg/l
	12/Oct/2002	Fe=0.45 mg/l
AS2	02/Oct/1995	Fe=1.05 mg/l
	30/Sep/2000	
	27/Nov/2001	F=1.80 mg/l
	22/Jul/2002	Fe=2.47 mg/l
	27/Nov/2005	F=1.80 mg/l
AS3	18/Mar/1999	
	30/Sep/2000	NO3=53.30 mg/l
	03/Feb/2001	NO3=56.00 mg/l
	24/Jan/2002	
AS4	30/Sep/2000	pH=9.01
	27/Nov/2001	
	24/Jan/2002	
	27/Nov/2005	
	20/Dec/2005	
AS5	21/Mar/1999	pH=9.40
	30/Sep/2000	pH=9.31
	27/Nov/2001	pH=9.70
	24/Jan/2002	pH=9.17
	27/Oct/2006	pH=9.70
AS6	09/Nov/1996	Fe=1.40 mg/l
	11/Jan/2000	F=2.09 mg/l
	20/May/2000	pH=9.40
	30/Sep/2000	pH=8.65
AS7	15/Jan/1995	pH=8.56, Fe=2.72 mg/l
AS8	30/Sep/2000	pH=9.15
	25/Mar/2001	
	06/May/2001	
	27/Nov/2001	pH=9.45
	24/Jan/2002	pH=9.38
	27/Nov/2006	pH=9.45

Well No	Date	Poor Quality Items
AS9	27/Nov/2001	F=1.77 mg/l
	24/Jan/2002	F=2.13 mg/l
	12/Aug/2002	
	27/Nov/2006	F=1.50 mg/l
AS10	14/Mar/2001	Fe=0.31 mg/l
	16/Apr/2001	Fe=0.31 mg/l
AS11	02/Jun/2002	pH=8.50
	12/Aug/2002	pH=9.26
AS12	05/Sep/2006	pH=8.59
ASR2	10/Aug/2002	Fe=0.98 mg/l
	11/Aug/2002	Fe=0.34 mg/l
	05/Sep/2006	pH=8.59
UN	28/Oct/1995	pH=9.47, F=1.81 mg/l
	18/Jul/2005	
Z1	15/Mar/1999	Fe=1.00 mg/l
	14/Jun/1999	
	15/Jun/1999	
	27/Sep/2000	
	27/Nov/2001	Fe=0.34 mg/l
	24/Jan/2002	
	27/Nov/2006	Fe=0.34 mg/l

Haddah Well Field

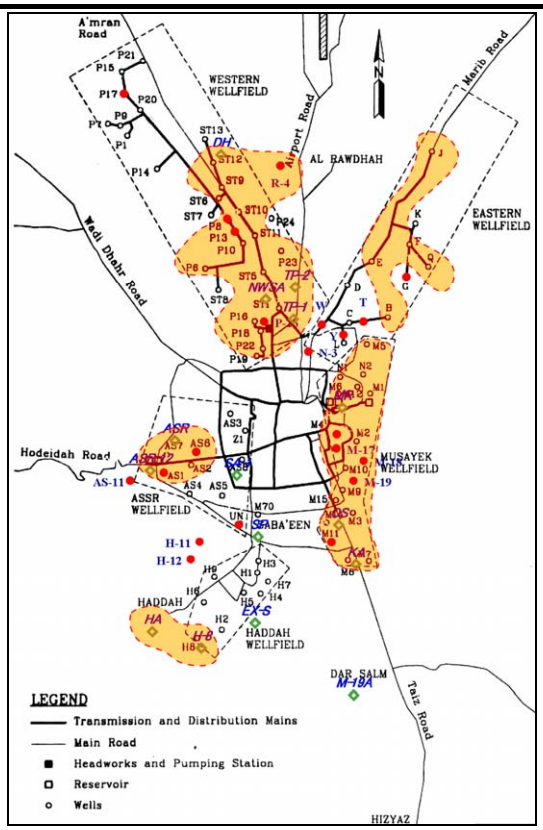
Well No	Date	Poor Quality Items
H2	06/Dec/1993	
	18/Jun/1994	pH=8.73
	24/Jan/1995	pH=8.80
	16/Apr/1996	pH=8.81
	20/Mar/1999	pH=8.68
H3	06/Dec/1993	pH=8.51
	18/Jun/1994	pH=8.70
	24/Jan/1995	pH=8.58
	16/Apr/1996	
	21/Mar/1999	
	13/Jun/1999	
	24/Jan/2001	pH=8.64
	03/Sep/2005	
H4	06/Dec/1993	pH=9.35
	18/Jun/1994	pH=9.30
	24/Jan/1995	pH=9.37
	04/Jul/1995	
	16/Apr/1996	pH=8.90
	20/Mar/1999	pH=9.27
	27/Jan/2001	pH=8.85
	27/Nov/2001	pH=9.80
	24/Jan/2002	pH=9.48, F=1.74 mg/l
	26/Aug/2002	
	03/Sep/2005	
	27/Nov/2005	pH=9.80
H5	06/Dec/1993	pH=9.05
	18/Jun/1994	pH 8.87
	24/Jan/1995	pH=8.91
	16/Apr/1996	pH=8.50
	21/Mar/1999	pH=8.75
H7	16/Apr/1996	pH=8.90
	27/Jan/2001	
	06/Feb/2001	NO3=77.00 mg/l
	27/Nov/2001	
	24/Jan/2002	

Well No	Date	Poor Quality Items
H8	21/Mar/1999	pH=9.90
	27/Sep/2000	Fe=1.65 mg/l
	27/Jan/2001	Fe=0.76 mg/l
	14/Apr/2001	Fe=1.15 mg/l
	27/Nov/2001	
	24/Jan/2002	Fe=0.70 mg/l
	19/Nov/2002	Fe=0.35 mg/l
	19/Nov/2006	Fe=0.94 mg/l
HA	***10/Nov/2002***	Fe=0.35 mg/l
	11/Nov/2002	
SP	07/Oct/2002	pH=9.45

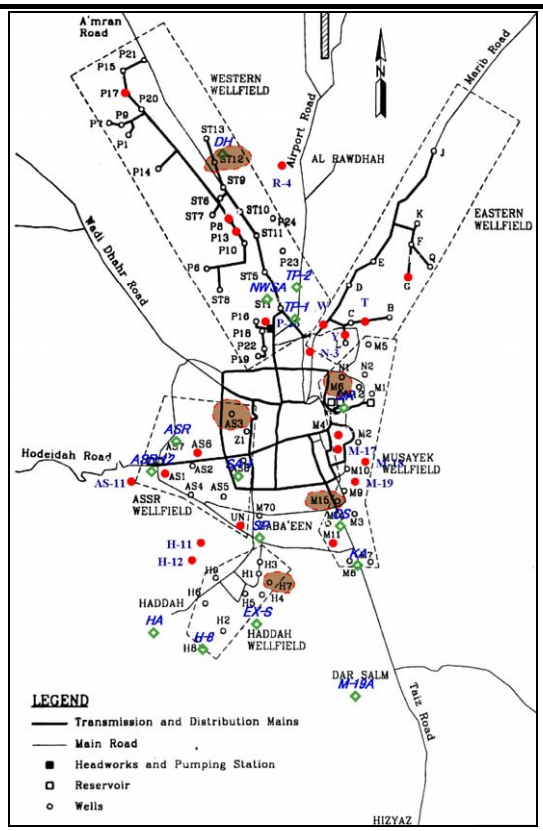
Results of water quality analyses are summarized as follows:

- Analyses results of some of the samples contain the same value for all results of analyses carried in different year for the same well. Most of these results which contain the same value were between samples of 2001 and 2005 or 2006 and is shown shaded in the above table.
- Analyses were not carried periodically. Some of them have 7 years interval between the analyses.
- Western Well Field: 30 boreholes (duplicated results were excluded), 111 samples of water were analyzed and 37 samples (36%), 22 wells (73%) show a higher concentration of Fe than the standard and the highest concentration which was 2.80 mg/l was detected in well P25. Higher concentration of TDS and SO3 was detected at wells ST12, ST13, P20. SO4 and Ca were also detected at well P15. Na was detected at well ST13.
- Eastern Well Field: 15wells, 62 samples were analyzed between 1993 and 2006. 12 (19%) samples show higher concentration of Fe than the standard. Higher concentration was detected at well MZ2 and Q.
- Musayek Well Field: 26 wells, 82 samples were analyzed and results with concentration higher than the standard for Fe was detected at 26 samples (32%), 10 wells. Higher concentration of TDS was detected at wells M4 and M6, and NO3 was detected at wells M4, M6, M7 and M15. Ca was detected at wells M4 and M6
- Asser Well Field: 20 wells, 55 samples were analyzed and 18 (33%) samples of 8 wells have pH higher than standard. 11 samples of 6wells show concentration of Fe higher than the standard. F was detected at wells AS2, AS6, AS9 and UN and NO3 was detected at well AS3.
- Haddah Well Field: 8 wells, 47 samples were analyzed and Fe with higher concentration was detected in 6 samples of well H8. pH higher than standard was detected in 25 samples of 6 wells. NO3 was detected at well H7 and F at well H4.

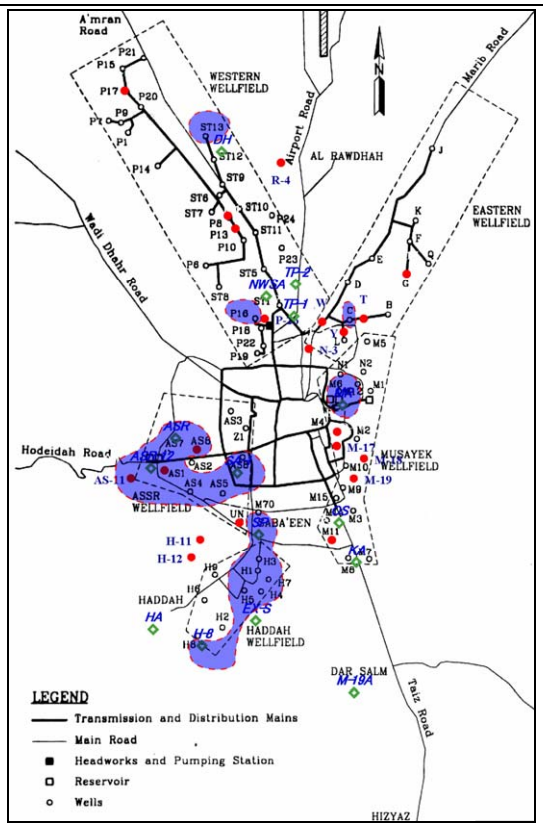
Figure 5.3 and *Figure 5.4* shows analyses results of wells with poor water quality by parameter analyzed. Actually, water abstracted from some wells are treated only by chlorination before discharged to distribution tanks and others are discharged directly to the main distribution pipe without treatment



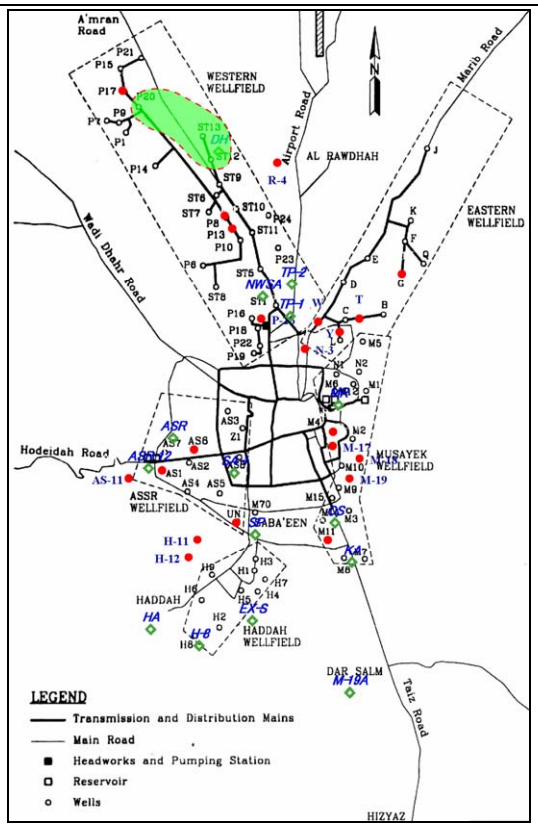
Parameter: Fe



Parameter: NO3



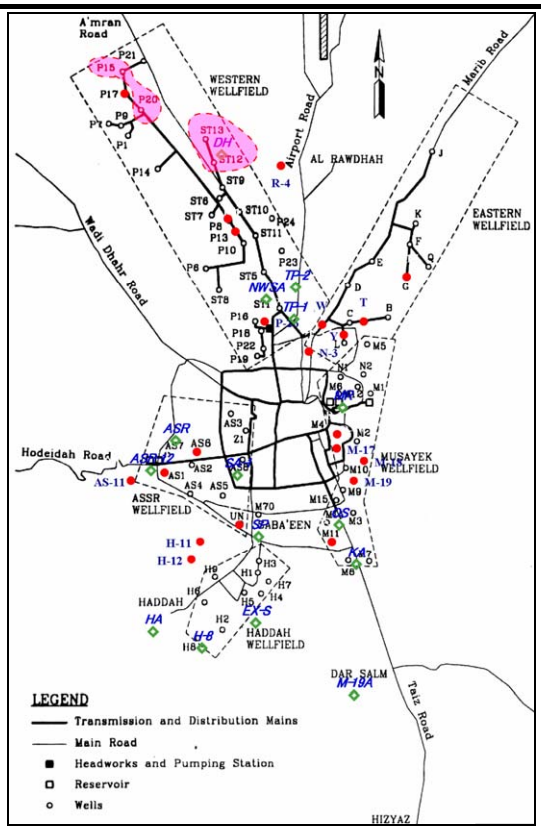
Parameter: pH



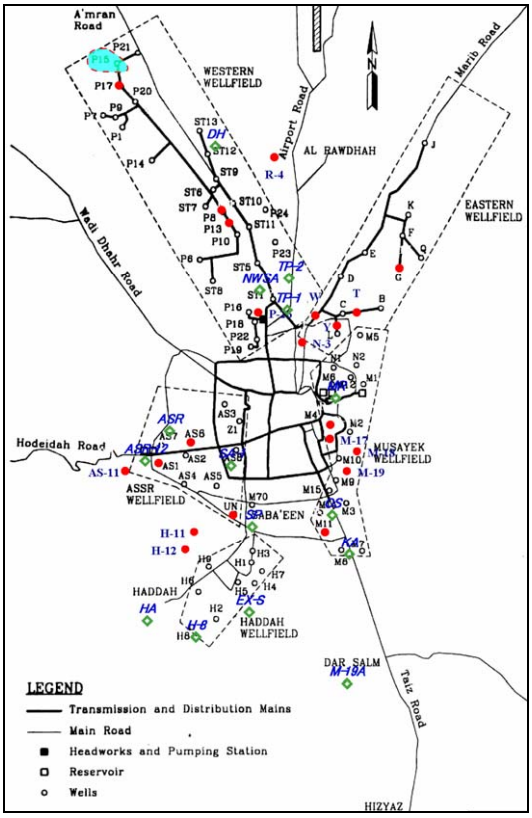
Parameter: TDS

FIGURE 5.3 WATER QUALITY ANALYSIS RESULTS (FE, NO3, PH, TDS)

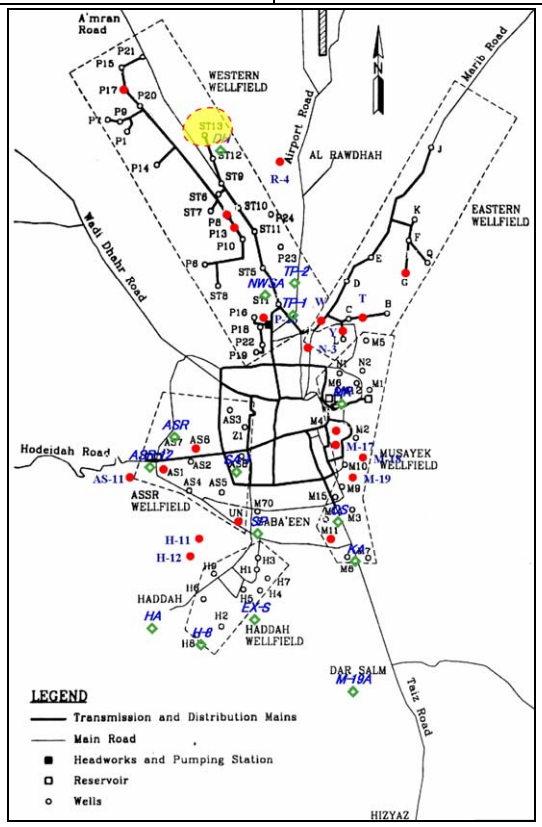
THE STUDY FOR WATER RESOURCES MANAGEMENT ACTION PLAN FOR SANA'A BASIN | **JICA**



Parameter: SO4



Parameter: Ca



Parameter: Na

FIGURE 5.4 WATER QUALITY ANALYSIS RESULTS (SO4, CA, NA)

4) Five Years Plan (2004-2008)

The targets of the Five Years Plan (2004-2008) concerning water supply is shown in *Table 5.11* and for comparison, the present condition (2003-2006), is also entered in the table. Population for 2004 is based on 2004 Census, and population for 2005 to 2008 is the population estimated in this study, under the moderate growth rate. Methodologies of population forecast are explained in the following paragraph of this Chapter.

In 2006, water connections has an achievement rate of 96%, nevertheless the achievement rate for unit water supply reaches only 54% of targeted rate of 95 l/c/d and water production has achieved 82% of the targeted quantity.

Table 5.11 Targets of the Five Years Plan (2004-2008) and the Present Situation

		Unit	2003	2004	2005	2006	2007	2008
Population	Five Years Plan	inhab.	1,572,114	1,627,138	1,688,088	1,743,031	1,804,036	1,867,179
	Present			1,747,834*	1,841,562**	1,937,783**	2,036,368**	2,137,168**
	Difference	%		7.4	9.2	11.6	12.9	14.5
Water Conecctions	Five Years Plan	no	72,900	76,545	80,372	84,391	88,611	93,042
	Present			75,771	78,018	80,741		
	Achievement	%		99	97	96		
Unit Water Supply Rate	Five Years Plan	l/c/d	80	85	90	95	100	105
	Present				50.8	51.6		
	Achievement	%			56.4	54.3		
Water Production	Five Years Plan	m^3/year	21,345,120	23,813,150	26,474,610	29,342,952	32,416,260	35,758,200
	Present		20,320,782	21,843,914	24,347,334	24,083,969		
	Achievement	%	95.2	91.7	92.0	82.1		
NRW	Five Years Plan	%	35	33	31	29	27	25
	Present		36.7	39.5	43.4	38.8		
	Difference		-1.7	-6.5	-12.4	-9.8		

Source: *2004 Census ** Estimated based on 2004 Census

5) Tariff System

Water supply and sewerage tariffs for domestic connections are based on block tariff system and for commercial, industrial and institutional connections are settled as a constant fee. Sewerage tariff is settled as 80% of the water tariff and also charge of 30% is added as services charge. *Table 5.12* shows the actual water and sewerage tariffs. In the Five-Years Plan, is mentioned an implementation of a new tariff starting from 2006, however the implementation has not started up to now. The new tariff is settled with an increase of 19% in average.

Table 5.12 Water and Sewerage Tariff

Water and Sewarege Tariff for 2006				
Purpose	Consumption	Water Tariff	Sewerage Tariff	Total tariff
Domestic + Mosque	0 – 5	35	28	63
	6 – 10	45	36	81
	11 – 20	80	64	144
	21 – 30	132	106	238
	31 –	160	128	288
Commercial, Industrial and Institutional.	Constant fee	160	128	288

Source: Five-Years Plan (2004-2008) (SWSLC)

Unit: Consumption: cubic meters, Tariff: Yemeni Rials per cubic meter

6) Incomes and Expenditures

According to the Closing Report of Performance Indicators issued by SWSLC for 2006, incomes and expenditures of SWSLC is shown in *Table 5.13*.

Table 5.13 Incomes and Expenditures of SWSLC for 2005-2006

Code	Item	2005	2006
ACC23	Total operational costs	1,622,573,328	2,013,335,981
ACC20	Total capital cost	5,500.000,000	2,000,000,000
ACC26	Total energy cost	837,723,771	892,038,308
ACC43	Energy cost for water production	616,188,677	865,391,404
ACC44	Energy cost for sewage treatment	207,512,438	270,029,307
ACC25	Total personnel cost	492,703,490	741,486,205
ACC5	Training expenses	932,125	6,059,333
ACC21	Total billed revenues (operational and capital)	2,401,075,282	3,201,259,804
ACC19	Total collected revenues (operational and capital)	1,956,765,513	2,689,990,452
ACC24	Total billed operational revenues	1,872,792,916	2,299,685,211
ACC22	Total collected operational revenues	165,062,137	2,214,541,254
ACC27	Disbursed investments	5,541,225,768	2,110,029,292
ACC28	Approved budget from Investment Program	10,900,000,000	2,000,000,000
BIL29	Total amount receivable	948,700,318	1,118,201,505

Source: Closing Report of Performance Indicator (PIIS) 2006 (SWSLC) Unit: Yemeni Rials

(2) Private Water Supply

Estimated population for Sana'a City for 2006, based on 2004 Census, was 1.9 million inhabitants and the population covered by the public network was 696,141 inhabitants, according to SWSLC. About 1.2 million inhabitants were not connected to the public water supply system.

Sources of water, for population not connected to the public network are private water sources, namely private piped network, water tankers (as sole/main source or as supplementary sources) and treated water in containers. Consumption of domestic water from private water supply was estimated for the year of 1997, by Dar-Al Handasah (2000) [4], at 7.45 MCM and a number of population served was estimated about 292,225, what give an average per capita consumption of water about 70 l/c/d. This high average consumption rate of water is due to weighted average water consumption rate from private network. As explained by Dar Al-Handasah,

customers with connections to the private piped networks do not have metered supplies, paying a monthly flat charge and most of these private connections serve large and affluent households, normally with gardens and cars, whose water consumption would be expected to be relatively high. Estimated average per capita water consumption for private network was 110 l/c/d.

Water consumption from private water supply for 2006 was estimated as shown in *Table 5.14*, adopting an average per capita of water consumption of 70 l/c/d.

Table 5.14 Domestic Water Consumption from Private Water Supply

Source	Year	Total Estimated Population (inhabitants)	Population served (inhabitants)	Average per capita water consumption (l/c/d)	Water consumption MCM/year
(1)	1997	1,123,942	292,225	70	7.45
	2005	1,640,091	539,401	70	13.78
(2)	2005	1,841,562	1,169,421	70	29.89
	2006	1,937,783	1,241,642	70	31.70

Source: (1) Dar Al-Handasah (2000): Population Based on 1975, 1986, 1994 Census, before modification of district boundaries. Population for 1994 was 954,448

(2) Study Team. Population based on 2004 Census, after modifications of district boundaries. Population for 1994 was 1,003,627

(3) Conclusion

As mentioned above, domestic water for the population is provided by public water supply and private water supply. In 2006, 696,141 inhabitants were supplied by public water supply network. It means 36% of all population of Sana'a City is beneficiated by public water supply and the remaining 64% of the population depends on private water supply which tariff is higher than public water. Domestic water consumption for the year of 2005 and 2006 is shown in *Table 5.15*.

Table 5.15 Domestic Water Consumption by 2005 and 2006

Supply System	Population served*** (inhabitants)		Average per capita water consumption (l/c/d)		Water Consumption (MCM/year)	
	2005	2006	2005	2006	2005	2006
Public water supply*	672,141	696,141	50.6	51.6	12.5	13.1
Private water supply	1,169,421	1,241,642	70**	70**	29.9	31.7
Total	1,841,562	1,937,783			42.4	44.8

Source:* Basic Data 2006, SWSLC, **unit water consumption: estimated based on Dar Al-Handasah (2000), *** Estimated based on 2004 Census

(4) Other Water Uses

Water abstracted to irrigate trees lining the streets and green parks from wells are listed below and the water is conveyed by tankers or the irrigation is practiced direct from the pump. Average monthly abstraction is about 0.05 MCM or 0.6 MCM/year.

Table 5.16 Monthly Abstractions from Wells Parks and Street Trees Watering Purpose

Well	Location	Digging year	Abstraction
Al-Saa'la well	Al-Saa'la	2004	7,000
26 September well	26 September Garden	2004	8,000
Radio Staton wel	Radio Station Garden	-	3,220
Sa'wan Garden	Sa'wan Garden	2004	9,000
Berlin Garden well	Berlin Garden	2004	2,500
Al-SabaeenGarden well	Al-Sabaeen Garden	2005	16,000
Al-Thawra Garden well	Al-Thawra Garden	-	3,500
The Zoo well	The Zoo	-	2,000
Total			51,220

Break down	
Conveyence Method	Quantity
by Tankers	21,670
direct from the well	29,550

Source: Sana'a Municipality, Parks and Gardens Department Unit: cubic meters per month

5.3.2 RURAL WATER SUPPLY

No suitable data or study was available regarding domestic water use condition for rural water supply. Planning and execution of rural water supply projects, such as well drilling and construction of supply facilities are carried by General Authority for Rural Water Supply Projects (GARWSP), the responsible body for rural water supply projects. However, maintenance and operation is applied by local authorities and/or Water User Group (WUG)s or Water User Association (WUA)s and information about present quantity of water consumed in each village is unknown. A lack of information on location of villages, where water supply projects were carried out by GARWSP was also faced.

WEC (2001)[5] has estimated the population within Sana'a Basin by districts and water-use zones namely Urban (Sana'a City), Urban-Rural (Bani Al Harith, Bani Husheish, Sanhan) and Rural zones (Hamdan, Bani Matar, Bani Bahlou, Arhab, Khawlan and Nehm). After that, estimation of water consumption by water-use zone has carried out. However, detailed explanation of methodology was not specified in the report. Calculating back the average per capita of water consumption adopted in this report, it is supposed that 70 l/c/d for Urban zone, 35 l/c/d for Urban-Rural zones and 21 l/c/d for rural zones was adopted as an average per capita consumption of water in this study carried by WEC (2001). GARWSP adopted an average per capita of water consumption between 25 to 40 l/c/d for rural water supply projects. However, in this study, the average per capita of water consumption adopted was 20 l/c/d; amount adopted by NWRA for water resources management.

In this study, population of rural areas within Sana'a Basin was not estimated by water-use zones due to modifications on district boundaries occurred during the period of 1994 and 2004 such as merging and division of districts. The population growth rate shown in 2004 Census results is not suitable for population projections. However, growth rate of 2.5% adopted by GARWSP was adopted in this study and estimations of population for rural areas by Sub-Basins were carried. *Table 5.17* shows the estimated water consumption for rural areas, for 2006, based on results of 2004 Census.

Table 5.17 Estimated Domestic Water Consumption for Rural Areas

Sub-Basin		2004		2005		2006	
		Population	Water Consumption	Population	Water Consumption	Population	Water Consumption
1	Wadi Al Mashamini	5,346	39,025	5,480	40,001	5,617	41,001
2	Wadi Al Madini	13,674	99,820	14,016	102,316	14,366	104,874
3	Wadi Al Kharid	9,067	66,192	9,294	67,847	9,526	69,543
4	Wadi Al Ma'adi	2,360	17,225	2,419	17,656	2,479	18,098
5	Wadi A'sir	4,449	32,476	4,560	33,288	4,674	34,120
6	Wadi Khulaqah	1,645	12,012	1,687	12,312	1,729	12,620
7	Wadi Qasabah	4,511	32,933	4,624	33,757	4,740	34,600
8	Wadi Al Huqqah	11,545	84,282	11,834	86,389	12,130	88,549
9	Wadi Bani Huwat	14,647	106,924	15,013	109,597	15,389	112,337
10	Wadi Thumah	2,008	14,660	2,058	15,026	2,110	15,402
11	Wadi As Sirr	34,529	252,060	35,392	258,361	36,277	264,820
12	Wadi Al Furs	9,937	72,540	10,185	74,354	10,440	76,212
13	Wadi Al Iqbal	25,552	186,528	26,191	191,192	26,845	195,971
14	Wadi Zahr & Al Ghayl	39,299	286,879	40,281	294,051	41,288	301,402
15	Wadi Hamdan	7,355	53,692	7,539	55,034	7,727	56,410
16	Wadi Al Mawrid	10,566	77,129	10,830	79,057	11,101	81,034
17	Wadi Sa'wan	18,841	137,541	19,312	140,979	19,795	144,504
18	Wadi Shahik	27,327	199,487	28,010	204,474	28,710	209,586
19	Wadi Ghayman	17,874	130,484	18,321	133,746	18,779	137,089
20	Wadi Al Mulaikhy	7,277	53,126	7,459	54,454	7,646	55,815
21	Wadi Hizyaz	10,498	76,637	10,761	78,553	11,030	80,517
22	Wadi Akhwar	16,424	119,895	16,835	122,893	17,255	125,965
	Total	294,733	2,151,547	302,101	2,205,336	309,653	2,260,469

Unit: Population: inhabitants, Consumption: cubic meters per year

Source: Population of 2004: calculated based on 2004 Census results and for 2006 was estimated adopting population growth rate of 2.5%, which is adopted by GARWSP

Water Consumption: calculated adopting average per capita water consumption of 20 l/c/d, which is adopted by NWRA for water resources management

Note that the results of the above table should be considered as a rough estimation of quantity of water abstracted to cover the rural population independent of the source of water. Detailed information such as total number of population benefited by the public water supply system and/or private water supply, location of each water supply projects carried and so was not available. However, according to the NWSSIP, the percentage of rural population with access to safe water accounts only to 25% for entire Yemen. Applying this rate for Sana'a Basin in the year of 2005, it results in 75,526 inhabitants with access to safe water, what means 0.6 MCM of water abstracted to serve the population through the public water supply system.

5.4 AGRICULTURAL WATER USE

5.4.1 SOURCES OF WATER FOR IRRIGATION

According to the well inventory (2002), 6,851 operational water points were inventoried for irrigation use purpose. 46% (3,131) water points were accounted for boreholes, 3% (192) and 50% (3,463) of the water points were accounted for dug/bores and dug wells respectively. Only 1% (65) of the water points inventoried was as springs and dam/pools. It is possible to note in the *Figure 5.5*, boreholes are concentrated in the middle area of the Basin, in the sub-basins as Wadi Bani Huwat, Wadi As Sirr, Wadi Al Furs and Wadi Al Iqbal. Dug wells are concentrated at the east side of the Basin.

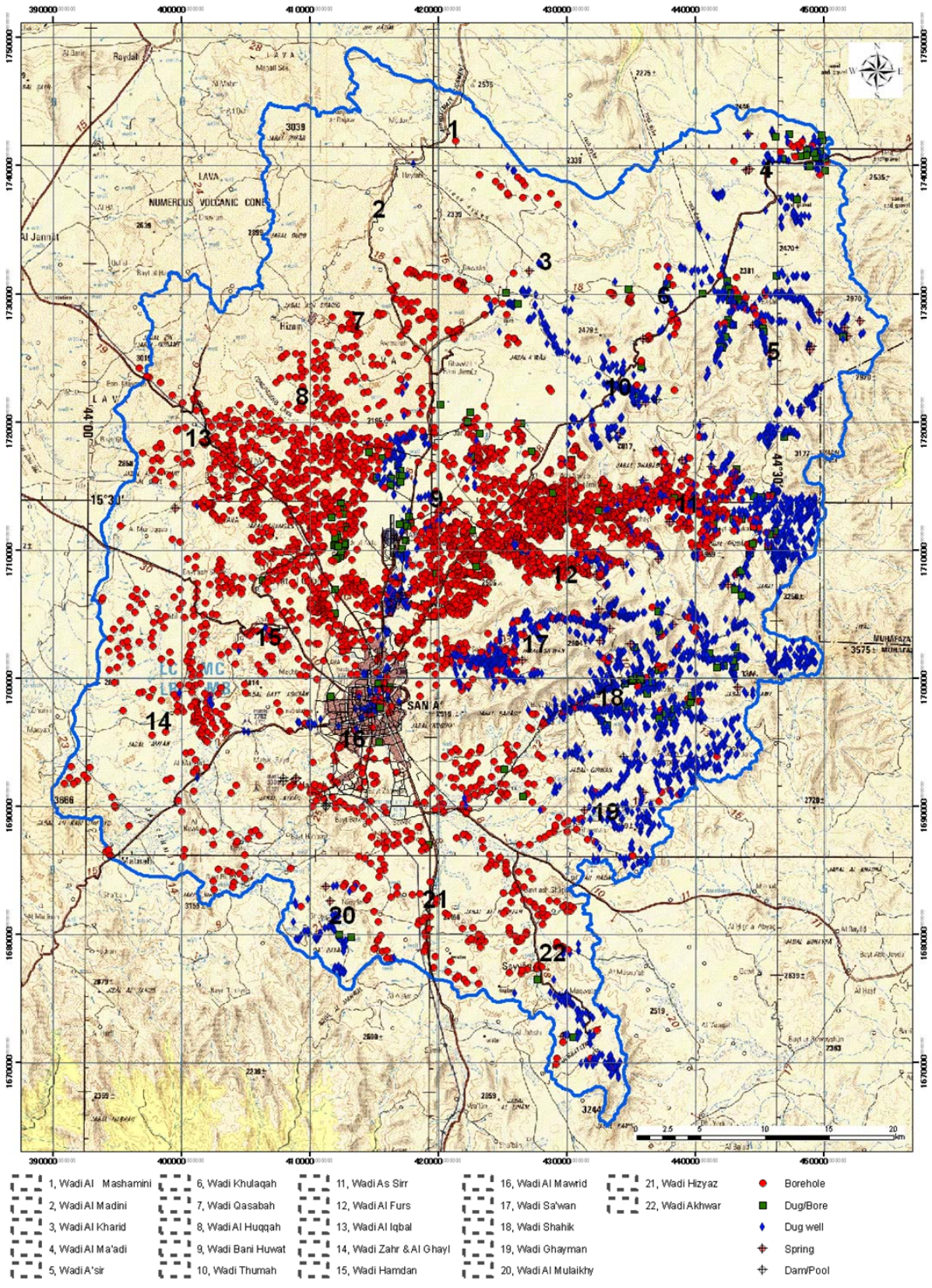


FIGURE 5.5 DISTRIBUTION MAP OF WATER POINTS FOR IRRIGATION USE BY TYPE OF WELL

5.4.2 IRRIGATION WATER USE

WEC-ITC (2001) [6] and GAF (2007)[7] have carried out satellite imagery data analyses to estimate the cropping pattern and water used for irrigation in Sana'a Basin calculating the actual evapotranspiration (ETa) of each crop classified in the study. The well inventory (2002) has estimated the water abstraction trough interviews to the well owners and well yield measurements in the field. In the study carried out by WEC-ITC (2001), Wadi Al Mashamini was not included and some sub-basins were considered as one sub-catchment. Irrigated area and quantity of water consumed by agriculture for each sub-basin is shown in *Table 5.18*.

Table 5.18 Irrigated area and water abstraction of each sub-basin

Source		WEC-ITC (2001)		Well Inventory 2002		Modified GAF (2007)	
Year		2000*		2002		2004/2005**	
Sub-Basin		Irrigated area	Abstraction	Irrigated area	Abstraction	Irrigated area	Abstraction
1	Wadi Al Mashamini	-	-	78	0.5	69	0.59
2	Wadi Al Madini	663	1.5	412	2.6	352	3.02
3	Wadi Al Kharid	659	4.2	408	3.6	238	2.02
6	Wadi Khulaqah			285	2.4	181	0.86
4	Wadi Al Ma'adi	187	0.8	455	2.2	100	5.10
5	Wadi A'sir	1,108	11.7	516	6.9	593	1.55
7	Wadi Qasabah	3,181	15.0	226	2.1	186	1.60
8	Wadi Al Huqqah			1,935	14.8	1,176	9.66
13	Wadi Al Iqbal			2,871	15.9	1,538	32.45
9	Wadi Bani Huwat	5,561	22.7	6,888	55.9	4,826	0.84
10	Wadi Thumah	393	2.0	286	2.1	126	16.49
11	Wadi As Sirr	3,461	33.4	3,874	39.7	2,603	5.74
12	Wadi Al Furs	1,198	11.9	1,302	13.2	856	13.12
14	Wadi Zahr & Al Ghayl	2,387	27.6	1,524	11.1	1,297	10.86
15	Wadi Hamdan	774	7.1	312	1.8	789	6.78
16	Wadi Al Mawrid	1,081	5.5	811	8.5	739	5.84
17	Wadi Sa'wan	870	2.7	1,442	7.5	1,055	6.71
18	Wadi Shahik	650	1.3	1,454	10.5	1,032	6.87
19	Wadi Ghayman	893	2.6	590	3.8	533	3.66
21	Wadi Hizyaz			279	2.7	206	2.32
22	Wadi Akhwar			419	7.3	191	1.76
20	Wadi Al Mulaikhy	314	1.4	211	2.4	269	1.63
Total		23,380	151.4	26,577	217.5	18,953	139.47

Unit: area in hectare, abstraction in million cubic meters

* Estimated adopting irrigation efficiency of 40%, ** Estimated adopting irrigation efficiency of 60%

Some considerations should be taken for results shown in the above table.

- Approaches and methodologies to estimate the ground water abstraction differs between the studies. As mentioned before, satellite imagery analyses was carried by WEC-ITC (2001) and GAF (2007) to estimate the groundwater abstracted for irrigation by calculating the ETa for each crop classified in their study. Estimation carried by the well inventory (2002) was based on field measurements of the well yield and interviews to the well owners about working conditions of their wells and pumps as daily pumping hours and weekly working days. Total duration of abstraction was calculated multiplying the daily pumping hours by the number of working days per week by dry season and wet season.

- Output or result of satellite analyses studies was the ETa, and based in this result multiplying by assumed irrigation efficiency, reaches the supposed quantity of groundwater abstracted.
- GAF (2007) has estimated an amount of 132.8 MCM of water used by agriculture (irrigation). In the process of recalculation of ETa of each crop based on results of GAF (2007), the total amount of water recalculated was 139.7 MCM. The difference between results was derived from number of decimal points expressed in the report, since recalculations use the numbers expressed in report and not raw data. Recalculated water abstraction was adopted in this paragraph because it was adopted for calculations of future water demand by crop and by sub-basin mentioned in the following paragraph.
- WEC-ITC (2001) has adopted irrigation efficiency of 40% as an example to compare with the result of the ground water modeling study (Foppen, 1996). GAF (2007) has adopted irrigation efficiency of 60% according to "State of Water in the Arabic Region, 2004" where for the Arabian Peninsula the publication listed an irrigation efficiency factor of 0.6. In other hand, irrigation efficiency of 35% is expressed on National Water Sector Strategy and Investment Program (NWSSIP).

Table 5.19 show the estimated groundwater abstracted for irrigation based on total ETa calculated by GAF (2007) by irrigation efficiency.

Table 5.19 Water Abstracted by Irrigation Efficiency Based on recalculated ETa of GAF (2007)

Sub-Basin		Total ETa	IE= 35%	IE= 40%	IE= 45%	IE= 50%	IE= 60%
1	Wadi Al Mashamini	0.36	1.02	0.89	0.79	0.71	0.59
2	Wadi Al Madini	1.81	5.18	4.53	4.03	3.62	3.02
3	Wadi Al Kharid	1.21	3.47	3.03	2.70	2.43	2.02
4	Wadi Al Ma'adi	0.52	1.48	1.29	1.15	1.03	0.86
5	Wadi A'sir	3.06	8.74	7.65	6.80	6.12	5.10
6	Wadi Khulaqah	0.93	2.66	2.33	2.07	1.86	1.55
7	Wadi Qasabah	0.96	2.74	2.40	2.13	1.92	1.60
8	Wadi Al Huqqah	5.79	16.55	14.48	12.87	11.59	9.66
9	Wadi Bani Huwat	19.47	55.62	48.67	43.26	38.94	32.45
10	Wadi Thumah	0.50	1.44	1.26	1.12	1.01	0.84
11	Wadi As Sirr	9.90	28.27	24.74	21.99	19.79	16.49
12	Wadi Al Furs	3.44	9.84	8.61	7.65	6.89	5.74
13	Wadi Al Iqbal	7.87	22.49	19.67	17.49	15.74	13.12
14	Wadi Zahr & Al Ghayl	6.52	18.63	16.30	14.49	13.04	10.86
15	Wadi Hamdan	4.07	11.62	10.16	9.03	8.13	6.78
16	Wadi Al Mawrid	3.51	10.02	8.76	7.79	7.01	5.84
17	Wadi Sa'wan	4.02	11.49	10.05	8.94	8.04	6.70
18	Wadi Shahik	4.12	11.78	10.30	9.16	8.24	6.87
19	Wadi Ghayman	2.20	6.28	5.50	4.89	4.40	3.66
20	Wadi Al Mulaikhy	1.39	3.97	3.47	3.09	2.78	2.32
21	Wadi Hizyaz	1.06	3.02	2.64	2.35	2.11	1.76
22	Wadi Akhwar	0.98	2.80	2.45	2.18	1.96	1.63
Total		83.68	239.09	209.20	185.96	167.36	139.47

Unit: million cubic meters

Conditions as methodologies, period, cropping pattern was different for the above three studies mentioned before. However, according to the table above, ETa at an irrigation efficiency of 40% shows a similar amount of water abstracted as calculated by the well inventory (2002)

which was about 217 MCM. Water abstracted estimated by WEC-ITC (2001) which was 151 MCM assumes an irrigation efficiency of 50 to 60%, in the above table.

Irrigation Efficiency assumes different value in different studies and different amount of water consumption is estimated. Many discussions was carried about this factor, however which one is the real irrigation efficiency for Sana'a Basin? From a Water Resources Management standpoint is necessary hereafter making it clear.

Cropping pattern for irrigated crops as qat, grape, irrigated mixed crop, and fruit orchards and for rain fed crops/natural vegetation was determined by GAF (2007) and the cropping acreage by sub-basin is shown in *Table 5.20*.

Table 5.20 Crop acreage in Sana'a Basin for 2004/2005

Sub-Basin		Irrigated area	Qat	Grapes	Irrigated Mixed Crops	Fruit Orchards	Rainfed crops /nat. veg	Total cultivated area
1	Wadi Al Mashamini	69.0	69.0	-	-	-	582.2	651.2
2	Wadi Al Madini	351.6	350.0	-	1.6	-	1,106.0	1,457.6
3	Wadi Al Kharid	237.5	228.0	3.6	5.9	-	449.6	687.1
4	Wadi Al Ma'adi	100.2	100.2	-	0.0	-	211.3	311.5
5	Wadi A'sir	593.2	593.2	-	-	-	186.3	779.5
6	Wadi Khulaqah	180.5	180.5	-	-	-	217.7	398.2
7	Wadi Qasabah	186.1	185.4	-	0.7	-	257.0	443.1
8	Wadi Al Huqqah	1,176.1	965.0	84.3	126.8	-	820.5	1,996.6
9	Wadi Bani Huwat	4,825.6	1,753.0	2,131.7	931.8	9.1	2,713.6	7,539.2
10	Wadi Thumah	125.5	61.8	63.7	-	-	163.2	288.7
11	Wadi As Sirr	2,603.2	1,039.1	1,559.0	5.1	-	437.0	3,040.2
12	Wadi Al Furs	855.9	427.1	428.8	-	-	66.9	922.8
13	Wadi Al Iqbal	1,538.1	1,384.0	32.5	58.7	62.9	1,366.6	2,904.7
14	Wadi Zahr & Al Ghayl	1,297.3	1,010.3	-	277.5	9.5	5,412.8	6,710.1
15	Wadi Hamdan	788.8	783.4	-	5.0	0.4	182.7	971.5
16	Wadi Al Mawrid	739.1	526.5	105.0	106.9	0.7	835.1	1,574.2
17	Wadi Sa'wan	1,054.9	415.1	630.2	0.7	8.9	171.7	1,226.6
18	Wadi Shahik	1,032.4	500.8	531.6	-	-	731.0	1,763.4
19	Wadi Ghayman	533.2	288.8	243.4	1.0	-	846.4	1,379.6
20	Wadi Al Mulaikhy	269.0	227.1	-	21.3	20.6	730.8	999.8
21	Wadi Hizyaz	205.6	197.0	-	7.6	1.0	526.5	732.1
22	Wadi Akhwar	190.8	186.4	0.7	3.7	-	483.8	674.6
Total		18,953.6	11,471.7	5,814.5	1,554.3	113.1	18,498.7	37,452.3

* Shaded bounds shows the crops which were irrigated by ground water Unit: hectare

According to the results of satellite imagery analyses, the consumption of water by agriculture has increased 11 % (18 MCM) by the year of 2000 to the year of 2004/2005 And the total irrigated area has decreased about 19 % (4,400 ha). Results of the well inventory survey (2002) shows higher results than other results due to differences on methods of estimation of water abstraction and irrigated area as explained before in the paragraph 5.2.

5.5 INDUSTRIAL WATER USE

Only 13 wells was recorded by the well inventory survey (2002) in whole Basin, where 12 water points were boreholes and one water point was recorded for dug well. Lower number of water points surveyed was due to accessibility problem. It is supposed that some industries

were located inside industrial complexes and interviewers were not allowed to enter inside the complex. Other problem is refusing of respondents to answer questions concerning quantity of water used.

Water supply for industries from public network is very few according to information from SWSLC. Water for most of the industries is supplied by their own well and it is supposed that the water abstraction is unregulated and unrecorded. Consequently, information regarding industrial water consumption is very scarce.

Due to lack of information mentioned above, TS-HWC (1992)[8] and WEC (2001)[9] has estimated the water requirement for industrial sector by using "Gross Water Requirement Method" which depends on (a) average water requirement per unit of physical output in varies industrial sub sector and (b) the physical outputs of the different industrial products. Dar Al-Handasah (2000)[10] has estimated industrial water consumption for 1997 about 0.46 MCM, based on results of survey carried in the same year, however, projection for future demand of industrial sector itself has not properly considered since it was included to non-domestic water supplied by private water sources.

In this study, present water demand for industrial sector was estimated based on study carried by WEC (2001) which was used an alternative approach involving the use of 'gross value of production (GVP)' and the gross water requirement mentioned above. Due to unavailability of recent data regarding GVP of industries within Sana'a Basin, estimation of water required up to 2005 was calculated as follow:

- Base year for projection is 1995; GVP for this year was taken from Sana'a Basin industrial survey 1995, as mentioned in WEC (2001).
- Growth rate for each industrial sub-sector is shown in *Table 5.21*. For 1996 to 2005, growth rate observed between 1990 and 1995 was extended up to 2005. For 2001-2005, the growth rate assumed was an observed in the same period as mentioned in "The Socio-Economic Development Plan for Poverty Reduction (2006-2010), Ministry of Planning & International Cooperation".
- Average water requirement per unit of gross value is :
  Manufacturing: 0.2269 (Mil.litters/Mil.YR)
  Mining and quarrying: 0.003230946 (Mil.litters/ Mil. YR)
- Value is based on prices of 1995

Table 5.21 Assumed Growth Rate to Estimate the Present Water Demand (2005)

Growth rate / Period	Mining and Quarrying	Manufacturing
1996-2000	9.8	2.83
2001-2005	6.1	4.7

Unit: percent

Table 5.22 Estimated Water Consumption for Industrial Sector in 2005

Industrial sub-sector	Manufacturing		Mining and quarrying		Total Water Requirement
Year	Gross Value Output	Water Requirement	Gross Value Output	Water Requirement	
1995	14,484.291	3.29	485.192	0.00157	3.29

1996	14,894.196	3.38	532.741	0.00172	3.38
1997	15,315.702	3.48	584.949	0.00189	3.48
1998	15,749.137	3.57	642.274	0.00208	3.58
1999	16,194.837	3.67	705.217	0.00228	3.68
2000	16,653.151	3.78	774.329	0.00250	3.78
2001	17,435.849	3.96	821.563	0.00265	3.96
2002	18,255.334	4.14	871.678	0.00282	4.14
2003	19,113.335	4.34	924.850	0.00299	4.34
2004	20,011.661	4.54	981.266	0.00317	4.54
2005	20,952.210	4.75	1,041.124	0.00336	4.76

Unit: Gross value: Million Yemeni Rials,
Water requirement: million cubic meters

5.6 TOURISTIC WATER USE

Studies have not been done up to now No studies have been carried out to estimate the water requirements for tourism sector. According to the census data shown in *Table 5.23*, in the period of 2001 to 2005, tourist arrivals was increased about 340% or an annual average of 35.8%.

Table 5.23 Number of Tourist Arrival

Item	Unit	2000	2001	2002	2003	2004	2005
Tourist Arrivals	persons	72,836	75,146	98,020	154,667	273,732	336,070
*Arrivals increasing rate	%		3.1	29.7	56.6	76.0	22.6
Total Tourist Nights	nights	473,434	224,165	588,120	928,002	1,642,392	2,016,694
Ave.no.of per tourist nights	nights	6.5	3	6	6	6	6

Source: Statistical Year Book 2004, 2005 (CSO), *Calculated

Quantity of hotels and their capacity by class in Sana'a City and governorate of Sana'a is shown in *Table 5.24*.

Table 5.24 Quantity of Hotels and Their Capacity by Class

Class of the Hotel and Capacity		2003		2004		2005	
		Sana'a City	Sana'a	Sana'a City	Sana'a	Sana'a City	Sana'a
Traditional	Beds	212	-	3,180	133	3,520	133
	Rooms	96	-	96	192	115	192
	Hotels	27	-	27	9	35	9
One Star	Beds	3,180	-	3,175	220	4,200	220
	Rooms	1,497	-	1,398	60	1,590	60
	Hotels	47	-	37	5	121	5
Two Stars	Beds	2,175	220	2,375	-	2,570	-
	Rooms	798	60	897	-	951	-
	Hotels	24	5	27	-	45	-
Three Stars	Beds	903	-	1,050	-	1,250	-
	Rooms	481	-	581	-	655	-
	Hotels	10	-	13	-	25	-

Four Stars	Beds	326	-	420	-	650	-
	Rooms	253	-	300	-	420	-
	Hotels	4	-	7	-	19	-
Five Stars	Beds	723	-	723	-	921	-
	Rooms	327	-	327	-	527	-
	Hotels	2	-	2	-	3	-
Total	Beds	7,519	220	10,923	353	13,111	353
	Rooms	3,452	60	3,599	252	4,258	252
	Hotels	114	5	113	14	248	14

Source: Statistical Year Book 2005 Unit: number

Due to unavailability of studies, reports and suitable information such as bed occupancy rate, average per capita water consumption, detailed data of number of tourists visiting Sana'a and so. Water consumption for 2005 has been estimated at many presupposed conditions as shown below and estimated water consumption of touristic sector is shown in *Table 5.25*.

- Occupancy rate of beds assumed as 40%
- Five and four stars hotels provide in general more water consuming accommodations than hotels of lower standard. Average per capita of water consumption assumed for five and four stars hotels is 350 l/c/d and for three to one star hotels, average of 180 l/c/d was assumed[11]. Consumption of water by traditional hotels is expected to be lower than other hotels and unit consumption was assumed at 120 l/c/d.
- All hotels of Sana'a City and Sana'a were included in estimation presupposing that most of hotels of Sana'a are located around the City.
- According to water usage condition survey carried in this study, five stars hotels were not connected to public water supply network and it is supposed that four stars hotels also were not connected to the public network. Number of hotels connected in to the public network is unknown

Table 5.25 Estimated Water Consumption for Touristic Sector in 2005

Classification	Total Hotels (no)	Total Number of Beds (no)	Beds Occupied (no)	Unit Water Consumption (l/c/d)	Total Water Consumption (MCM)
Traditional	44	3,653	1,461	120	0.06
One Star	126	4,420	1,768	180	0.12
Two Stars	45	2,570	1,028	180	0.07
Three Stars	25	1,250	500	180	0.03
Four Stars	19	650	260	350	0.03
Five Stars	3	921	368	350	0.05
Total	262	13,464	5,386		0.36

5.7 WASTE WATER USE

5.7.1 PUBLIC SEWERAGE NETWORK

According to data from SWSLC, the total effluent produced between the years of 2004 and 2006 have increased about 362% and the number of sewerage connections have increased about 48%. Percentage of population covered by the sewerage network was 31.7% and 33% of the targeted population of 1.7 million for the year 2005 and 2006 respectively. *Table 5.26* shows

the performance indicators of the sanitation system.

Table 5.26 Performance indicator for the Sanitation System (2005-2006)

Item	Unit	Year	
		2005	2006
Population	inhabitants	1,841,562	1,937,783
No of beneficiaries	inhabitants	538,794	560,259
Effluent produced*	m^3	10,952,371	16,033,000
No of sewerage connections	no	62,564	65,147
Domestic connections	no	59,866	62,251
Institutional and Commercial connections	no	2,698	2,896

Source: Report for the Performance Indicator System (PIIS) for 2006 (SWSLC),
Basic data report 2006 (SWSLC), Population based on 2004 Census
*Effluent produced: the gross quantity of wastewater which reaches the wastewater treatment plant

These performance numbers were slightly lower than the numbers settled as a target in the Five Years Plan of SWSLC, as shown in *Table 5.27*.

Table 5.27 Targets of the Five Year Plan (2004-2008)

		2003	2004	2005	2006	2007	2008
Sewerage conecctions	Five Year Plan	36,000	46,000	60,000	72,000	80,000	85,000
	Actual		43,900	62,564	65,147		
Percentage achieved			95%	104%	90%		

Unit: number

5.7.2 WASTEWATER QUALITY

(1) Wastewater Treatment Plant (WWTP)

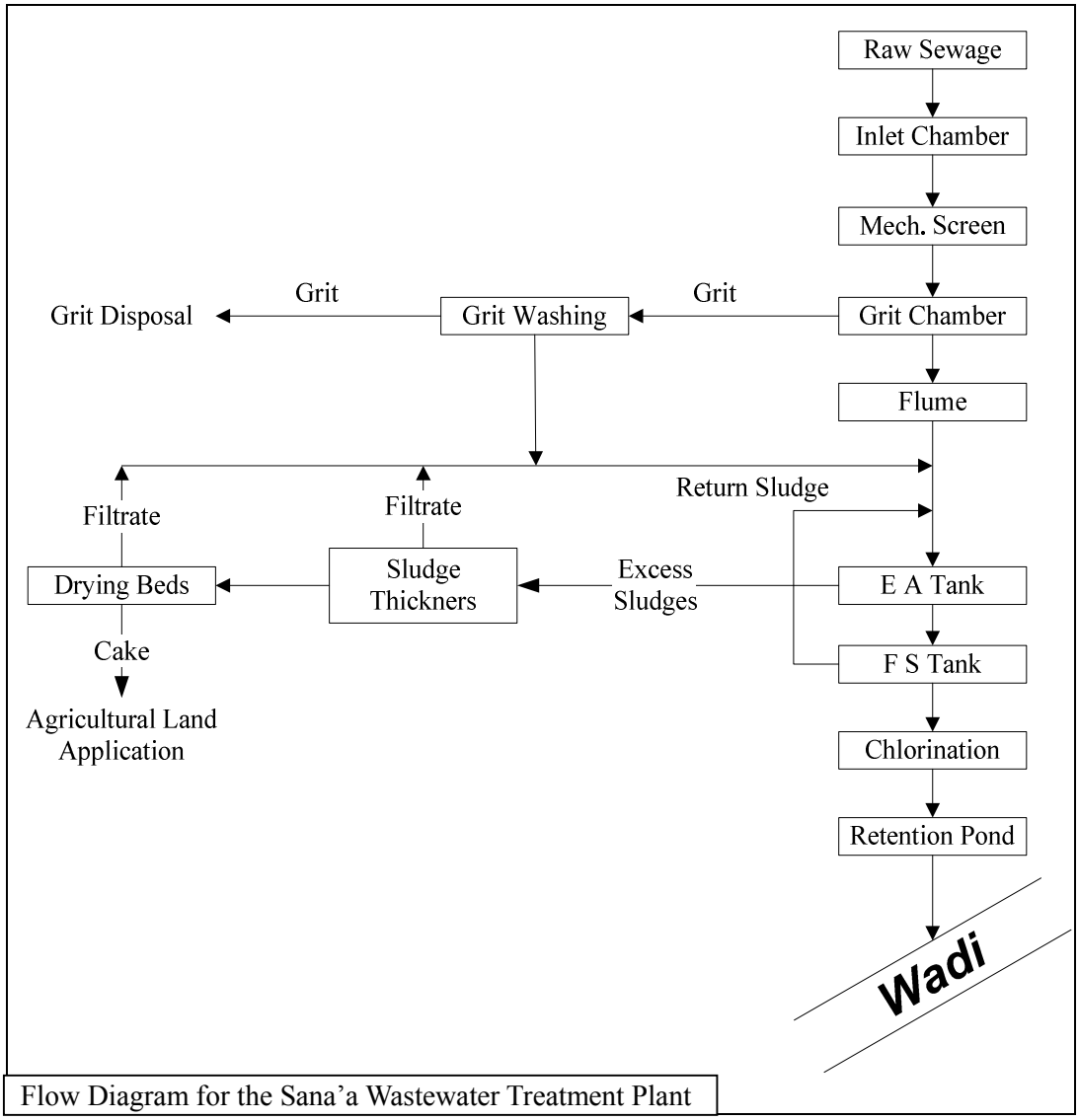
WWTP has been built in the middle of Capital city, in a sensitive area adjacent to the International Airport and was completed in mid 2000. It is presently operated by SWSLC and the effluent is treated by chlorination before it is discharged into a wadi via a lagoon and there are no facilities available for the reuse of the effluent[12] Outline of the Sana'a Wastewater Treatment Plant is shown in *Figure 5.6*.

According to Pacer (2006)[13], WWTP was, originally designed to receive an estimated volume of 50,000 m^3/day of wastewater with an average BOD5-load of 25,000 kg/day. But soon as started the operation in the middle of 2002, a conceptual design problem became apparent and by the end of September of 2002, the flow reached to an average of 23,350 m^3/day (47% of the designed capacity) while the BOD5 load averaged 30,500 kg/day. In 2006, WWTP has received a total amount of 16 MCM of wastewater. It means a daily average of 44,000 m^3 of wastewater which accounts for 80% of the designed capacity of 50,000 m^3. Actually WWTP is operating in an overloaded treatment condition and the wastewater inadequately treated is discharged in the wadi. Causes of overloaded BOD5-load are supposed caused by industrial wastewater which is discharged to the sewerage network without any treatment.

Design Capacity

Parameter	Unit	Raw Sewage	Effluent
Average flow	m^3/day	50,000	
BOD_5	mg/l	500	30
BOD_5 - load	kg/day	25,000	
SS	mg/l	700	30
SS - load	kg/day	37,500	
NH_4	mg/l	100	---
NH_4 - load	kg/day	5,000	
Temperature	°C	23	

Source: Consulaqua (2001)



Flow Diagram for the Sana'a Wastewater Treatment Plant

Source: PACER (2006)

FIGURE 5.6 DESIGN CAPACITY AND FLOW DIAGRAM FOR THE SANA'A WWTP

(2) Wastewater Quality

Wastewater quality analyses carried periodically by WWTP and the summarized yearly analyses results for 2005 and 2006 are shown in *Table 5.28.*

Table 5.28 Summarized Results of Wastewater Quality Analyses for 2005 and 2006

		INFLUENT								FINAL EFFLUENT							
		TEMP (°C)	PH	T.SS (mg/l)	BOD5 (mg/l)	COD (mg/l)	NH4 (mg/l)	PO4 (mg/l)	TDS (mg/l)	PH	T.SS (mg/l)	BOD5 (mg/l)	COD (mg/l)	NH4 (mg/l)	PO4 (mg/l)	NO3 (mg/l)	TDS (mg/l)
	Standard	23	--	700	500	--	100	--	--	--	30	30	--	--	--	--	--
2005	Min	19.8	6.3	256	865	810	88.0	24.3	600	6.9	13	22	62	25.5	1.3	0.2	536
	Max	28.3	8.2	3,344	1,420	3,680	250.4	163.7	1,367	8.3	3,512	278	420	123.0	58.8	128.0	1,365
	Ave	24.6	7.3	940	1,072	2,091	164.9	67.7	1,033	7.6	98	86	174	62.9	22.2	11.1	1,011
	Samples	37	231	292	75	76	75	56	70	229	290	76	73	75	62	72	72
2006	Min	**	6.7	204	748	816	76.4	71.9	1,245	7.8	24	21	64	61.2	8.4	1.2	1,150
	Max	**	7.8	2,324	1,576	2,925	215.2	126.8	1,245	8.0	5,212	724	785	157.6	93.3	18.0	1,150
	Ave	**	7.5	789	1,153	1,830	144.1	98.1	1,245	7.9	259	111	190	104.2	38.6	11.1	1,150
	Samples	**	4	252	38	42	42	35	1	2	230	80	41	44	42	44	1

Source: Sana'a Wastewater Treatment Plant *

*Shaded cells shows results higher than standard

Figures below shows the average monthly results of the analysis. *Figure 5.7* shows results of parameters which should be satisfied as influent and effluent. In addition, *Figure 5.8* shows the results of other parameters analyzed.

Results of analyses show an overloaded concentration of SS, BOD5 and NH4 for influent wastewater. For SS, maximum concentration detected was about five times higher than the standard and by the ends of 2006, concentration has decreased till acceptable values, however, these values are nearly to the standard. Maximum concentration of BOD5 was detected in March 2006 and the concentration was 3 times higher than the standard and in average it is 2 times higher for the period of 2005 and 2006. Maximum concentration of NH4 was observed in June 2005 and it was 2 times higher than standard. In average, it was about 1.5 times higher for the period of 2005 and 2006.

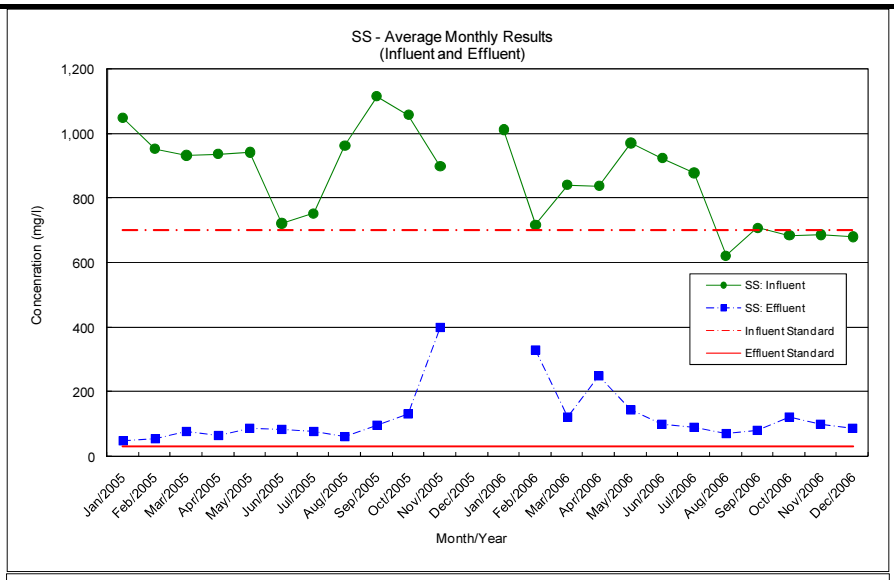
Higher concentration of SS, BOD5 and NH4 observed on influent wastewater, after treated, a significant reduction of concentration is observed. However the concentration still higher than standards for effluent and the treated water is discharged directly to wadi. This water flows through a wadi by gravity in an open channel and the population living around the channel is using this water to irrigate their lands.

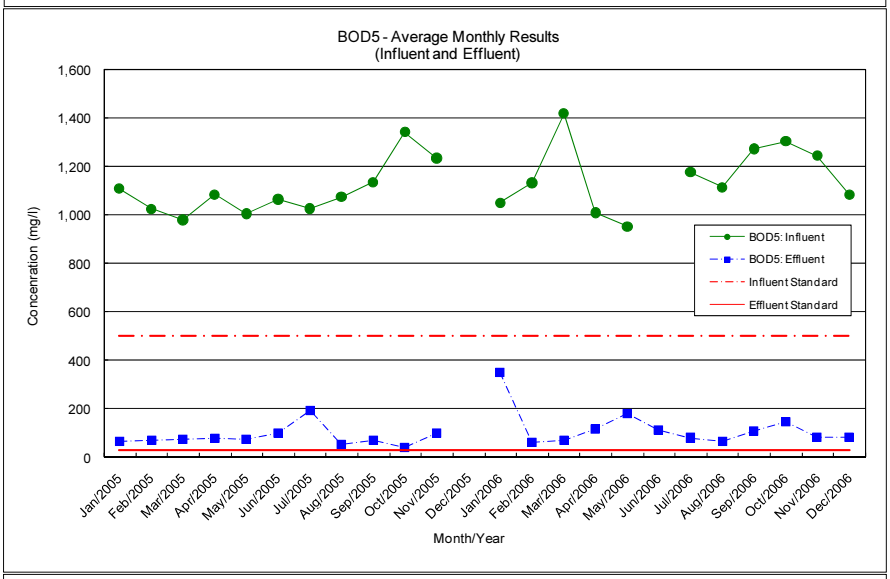
Actually, upgrading project for WWTP is ongoing. According to information, objective of project is increase the treatment capacity to manage the actual overloaded BOD5 and also installation of facilities to treat the water to acceptable quality for use in agriculture and watering the trees in the City. Tendering for this project has finished in middle of June/2007 and the construction is expected to start on later July/2007 for a period of 2 years.

Two other projects are planed:

1) A small treatment plant with daily treatment capacity about 500 m^3 to be constructed where was located the old treatment plant, in southern part of Rawdah area. The objective of this plant is to treat the sewage collected by tankers from overloaded cesspits of the City and save treated water in tanks for reuse in watering trees and gardens. Water treated which exceeds the tank capacity is programmed to be discharged to the existing main sewerage network.

2) New treatment plant with daily treatment capacity about 105,000 m^3 to be constructed at 30km north from the actual treatment plant.





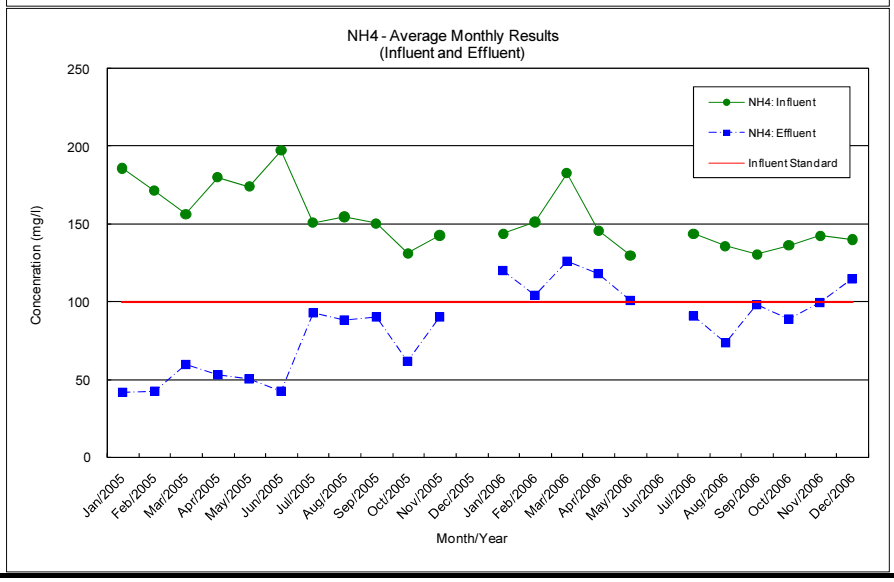


FIGURE 5.7 MONTHLY AVERAGE RESULTS OF INFLUENT AND EFFLUENT FOR SS, BOD5 AND NH4

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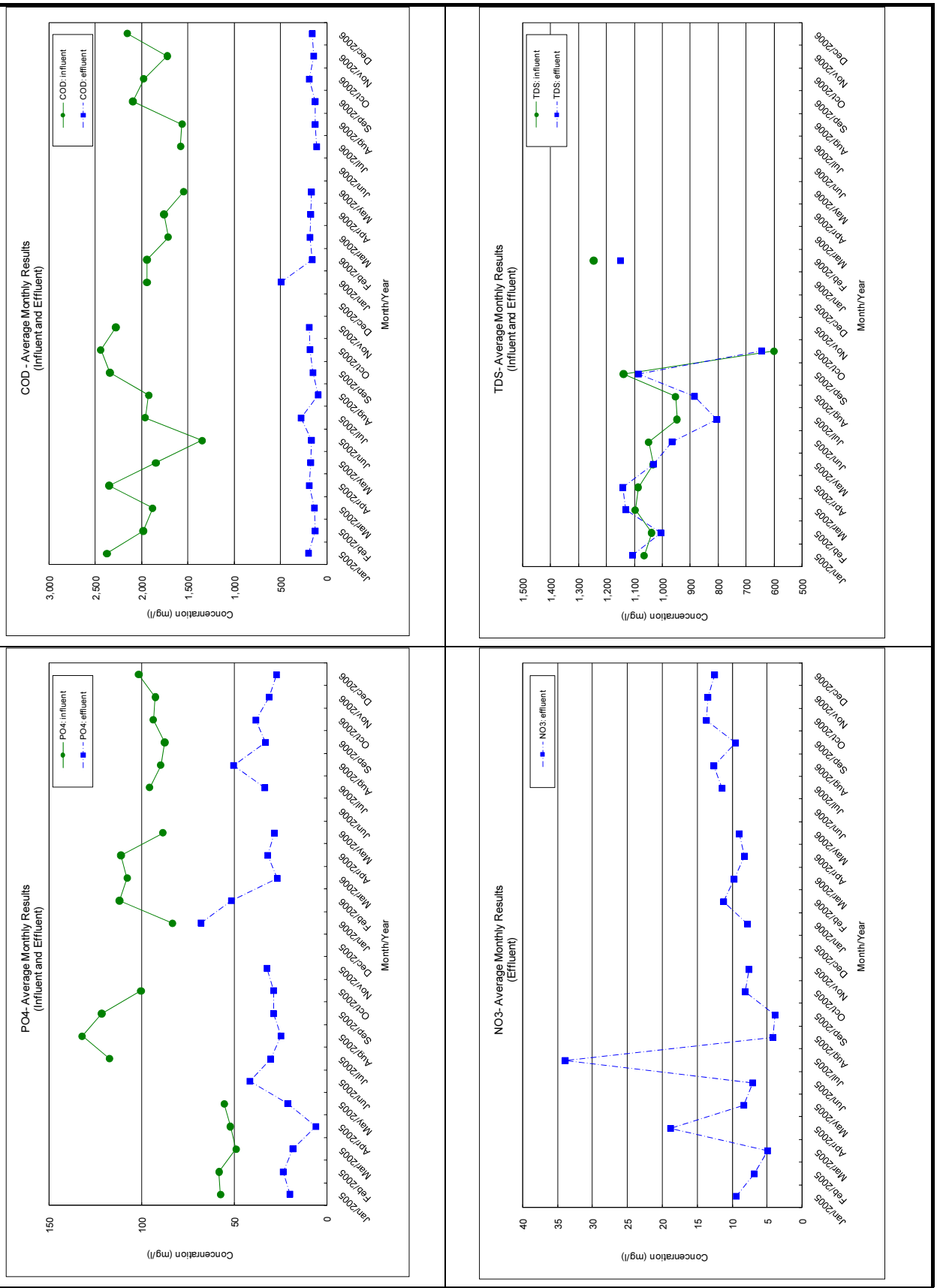

FIGURE 5.8 MONTHLY AVERAGE RESULTS OF INFLUENT AND EFFLUENT FOR PO4, COD, TDS, NO3

5.8 FUTURE WATER DEMAND

Based on the present condition of water use mentioned before, a projection of water demand for domestic, agricultural, industrial and tourism sectors were estimated in this paragraph.

5.8.1 POPULATION FORECAST FOR SANA'A BASIN

WEC (2001)[14] has estimated the population for the entire Sana'a Basin, by water-zone and district. Districts partially or totally within the Basin when this study was carried were, 1) Sana'a City, 2) Bani Al Harith, 3) Bani Husheish, 4) Sanhan, 5) Hamdan, 6) Bani Bahloul, 7) Arhab, 8) Khawlan and 9) Nehm. This estimation was based on 1994 Census, and the population within the Basin was accounted for 1.2 million inhabitants for the year of 1994. Methods and criteria for this estimation are not clearly mentioned in the report. Concerning the City of Sana'a, Dar Al-Handasah (2000) [15] has considered three population growth scenarios, reflecting the high, moderate and limited growth to estimate the population projection.

However, a modification in some administrative boundaries within the governorate of Sana'a, during the period of 1994 and 2004, has made. In the year of 1994, the Republic of Yemen was composed by 17 governorates plus the capital City of Sana'a and, in the year of 2004, the Republic was composed by 20 governorates plus the capital City of Sana'a. Concerning the governorate of Sana'a, it was composed by 37 districts in 1994 and by the year of 2004, it was composed by 16 districts where the capital city of Sana'a is included. Modifications made within the governorate of Sana'a in this period were, the merger of districts between Sana'a City and Bani Al Harith and the merger of districts between Sanhan and Bani-Bahloul. Other modification made in the same period was the division of the district of Khawlan. This district was divided in to a district of Khawlan and Al Taial and also Jahana has added as district. Boundaries of districts for the Governorate of Sana'a, adopted in this study were based on administrative boundary map provided by the governorate of Sana'a. *Figure 5.9* shows the boundaries of districts adopted in this study.

Districts included in Sana'a Basin are: 1) Sana'a City, 2) Bani Husheish 3) Sanhan and Bani Bahloul, 4) Hamdan, 5) Arhab, 6) Nehm, 7) Al Taial, 8) Bani Matar and 9) Jahana.

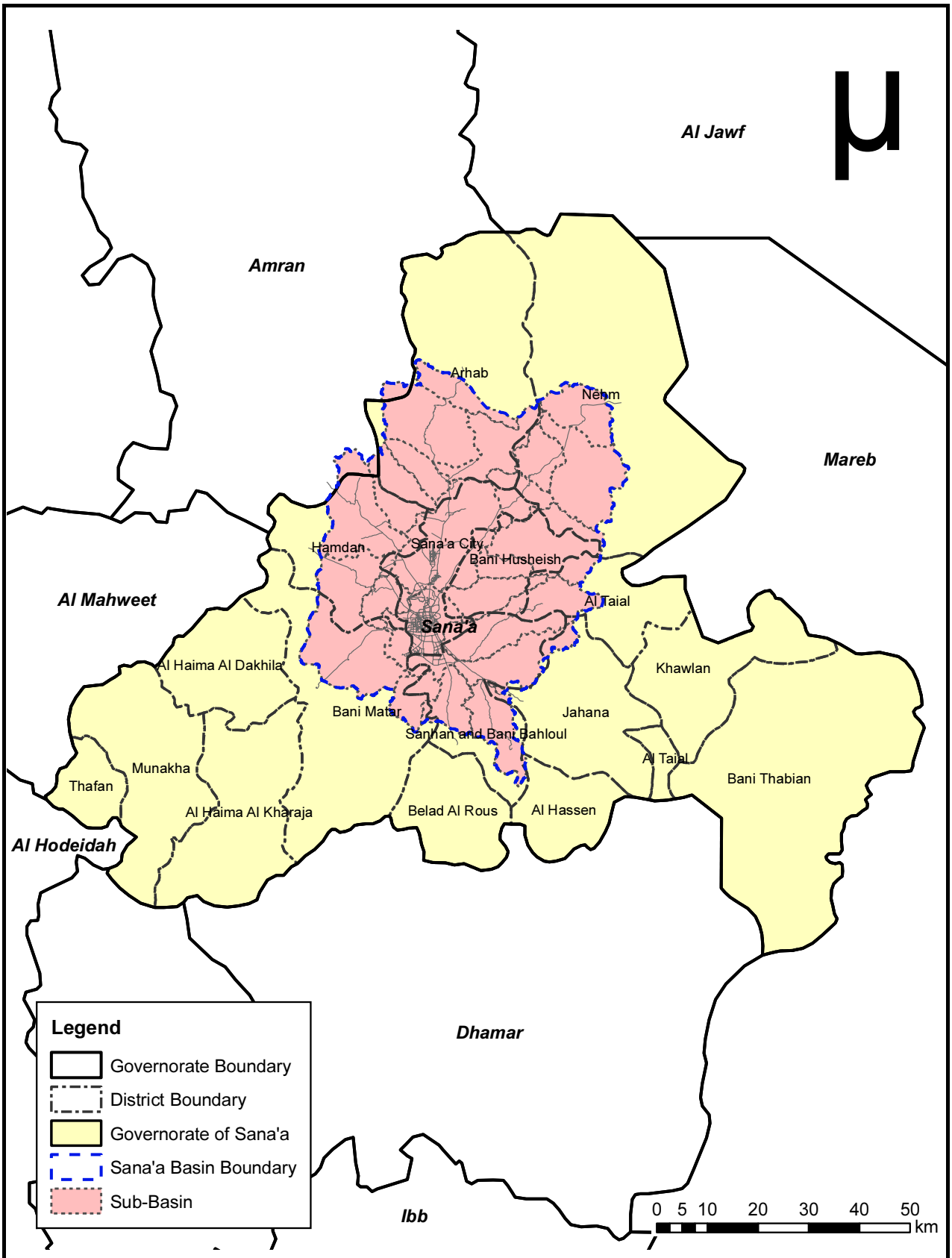

FIGURE 5.9 LOCATION OF SANA'A BASIN WITHIN THE GOVERNORATE OF SANA'A

(1) Population Forecast for Sana'a City

As mentioned above, population forecast for Sana'a City has been done by Dar Al-Handasah (2000), adopting three growth scenarios reflecting high, moderate and limited growth. The assumed rate under the high growth scenario was 6.1% in 1997 (base year of study carried by Dar Al-Handasah) and decease to 4.2% in 2020. Assumed rates under the medium and limited growth scenarios were 5.6% and 5.1% respectively in 1997 and decrease to 3.3% and 2.4% respectively in 2020.

Since that the study carried by Dar Al-Handasah (2000) is the master plan for urban water supply and sanitation projects for Sana'a City, followed by SWSLC, and no suitable updated data or report was available during the study period, in this study, population forecast was estimated based on growth rates mentioned above. Population growth rate for Sana'a City during the period between 1994 and 2004 was 5.5% and this rate is decreasing up to 4.2%, 3.3% and 2.4% respectively for high, medium and limited growth in the year of 2020.

Population forecast for Sana'a City is shown in *Table 5.29* and *Figure 5.10*. According to the results of population forecast, the population of Sana'a City under the moderate growth rate which was adopted for project planning purpose, for the year of 2006, the base year of this study, is 1.9 million inhabitants and for 2020, 3.4 million inhabitants is estimated.

Table 5.29 Population Forecast for Sana'a City by Scenario

Year	High Growth Rate		Moderate Growth Rate		Limited Growth Rate	
1994	1,003,627		1,003,627		1,003,627	
2004	1,747,834	5.50	1,747,834	5.50	1,747,834	5.50
2005	1,842,545	5.42	1,841,562	5.36	1,840,578	5.31
2006	1,940,891	5.34	1,937,783	5.23	1,934,678	5.11
2007	2,042,909	5.26	2,036,368	5.09	2,029,840	4.92
2008	2,148,629	5.18	2,137,168	4.95	2,125,750	4.73
2009	2,258,075	5.09	2,240,019	4.81	2,222,073	4.53
2010	2,371,261	5.01	2,344,740	4.68	2,318,455	4.34
2011	2,488,194	4.93	2,451,133	4.54	2,414,526	4.14
2012	2,608,871	4.85	2,558,983	4.40	2,509,900	3.95
2013	2,733,282	4.77	2,668,059	4.26	2,604,178	3.76
2014	2,861,404	4.69	2,778,117	4.13	2,696,952	3.56
2015	2,993,208	4.61	2,888,894	3.99	2,787,806	3.37
2016	3,128,650	4.53	3,000,117	3.85	2,876,319	3.18
2017	3,267,680	4.44	3,111,496	3.71	2,962,069	2.98
2018	3,410,232	4.36	3,222,732	3.58	3,044,636	2.79
2019	3,556,233	4.28	3,333,513	3.44	3,123,607	2.59
2020	3,705,595	4.20	3,443,519	3.30	3,198,573	2.40

Source: Statistical Year Book 2005 (population of 1994 and 2004)

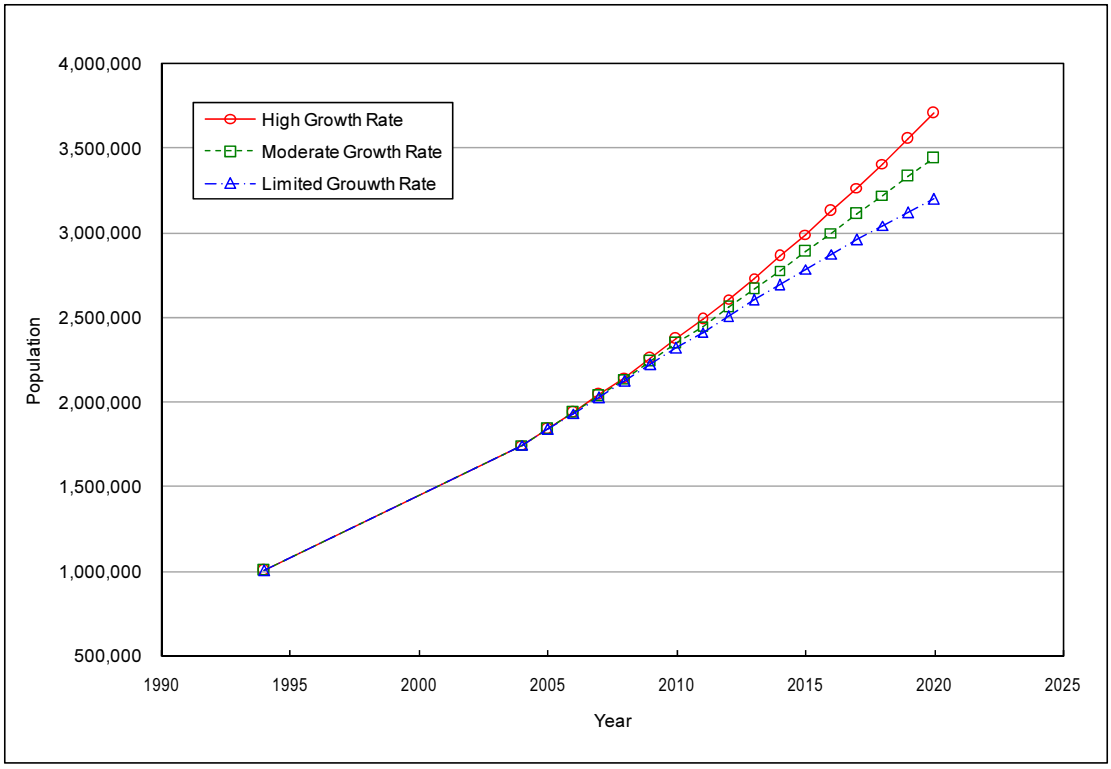

Figure 5.10 Chart of Population Forecast for Sana'a City

(2) Population Forecast for Rural Areas within the Basin

The population within the Basin for the year of 2004 was calculated according to the percentage of the area of each district included in the Basin and the population of each district based on results of 2004 Census as shown in *Table 5.30*. For this calculation, it was assumed that the population is uniformly distributed within the district.

In this study, population forecast for districts of Bani Husheish, Sanhan and Bani Bahloul, Hamdan, Arhab, Nehm, Al Taial, Bani Matar and Jahana was calculated based on the growth rate of 2.5%. This rate was adopted in this study, once this rate is the one adopted by GARWSP, the responsible authority for rural water supply projects and the growth rate determined by 2004 Census was not suitable due to the modifications in the district boundaries mentioned before. Results of projections are shown in *Table 5.31*.

(3) Population Forecast by Sub-Basin

The population within each of 22 sub-basins for the year of 2004 was calculated according to the percentage of the area of each district included in the sub-basin and population calculated above. Results of estimation are shown in *Table 5.32*.

Growth rate adopted for rural areas is 2.5% and for the urban area, moderated growth rate was adopted. Results of estimation are shown in *Table 5.33*.

Table 5.30 Estimated Population within the Basin by District (2004)

District	District		Area of the district within the Basin		
	Area (km^2)	Population (inhabitants)	Area (km^2)	%	Population (inhabitants)
Sana'a City	404.2	1,747,834	404.2	100.0	1,747,834
Bani Husheish	340.7	73,957	340.7	100.0	73,957
Sanhan and Bani Bahloul	600.0	80,399	483.8	80.6	64,832
Hamdan	589.9	84,882	442.1	74.9	63,612
Arhab	1,288.4	90,038	556.5	43.2	38,891
Nehm	1,961.0	41,502	474.7	24.2	10,046
Al Taial	395.8	36,253	128.6	32.5	11,779
Bani Matar	1,117.5	100,012	319.6	28.6	28,605
Jahana	617.8	50,747	36.6	5.9	3,009
Area within Amran Gov.*	49.9	---	49.9	100.0	---
Total	6,911.1	2,305,624	3,236.7	---	2,042,565

* Based on natural boundary for the catchment area of the Basin. This area is considered uninhabited

Table 5.31 Projection of Population by Districts Within the Sana'a Basin

District / Year	Bani Husheish	Sanhan and Bani Bahloul	Hamdan	Arhab	Nehm	Al Taial	Bani Matar	Jahana	Total
1994	54,375	60,999	47,415	27,061	8,397	***	34,370	***	232,617
2004	73,957	64,832	63,612	38,891	10,046	11,779	28,605	3,009	294,733
2005	75,806	66,453	65,203	39,864	10,298	12,074	29,320	3,084	302,101
2006	77,701	68,114	66,833	40,860	10,555	12,375	30,053	3,161	309,653
2007	79,644	69,817	68,504	41,882	10,819	12,685	30,805	3,240	317,395
2008	81,635	71,562	70,216	42,929	11,089	13,002	31,575	3,321	325,330
2009	83,676	73,351	71,972	44,002	11,367	13,327	32,364	3,404	333,463
2010	85,767	75,185	73,771	45,102	11,651	13,660	33,173	3,490	341,799
2011	87,912	77,065	75,615	46,230	11,942	14,002	34,003	3,577	350,344
2012	90,109	78,991	77,506	47,385	12,241	14,352	34,853	3,666	359,103
2013	92,362	80,966	79,443	48,570	12,547	14,710	35,724	3,758	368,081
2014	94,671	82,990	81,429	49,784	12,860	15,078	36,617	3,852	377,283
2015	97,038	85,065	83,465	51,029	13,182	15,455	37,532	3,948	386,715
2016	99,464	87,192	85,552	52,305	13,511	15,842	38,471	4,047	396,382
2017	101,951	89,372	87,691	53,612	13,849	16,238	39,432	4,148	406,292
2018	104,499	91,606	89,883	54,953	14,195	16,644	40,418	4,252	416,449
2019	107,112	93,896	92,130	56,326	14,550	17,060	41,429	4,358	426,861
2020	109,790	96,243	94,433	57,735	14,914	17,486	42,464	4,467	437,532

* Growth rate: 2.5%, rate adopted by GARWSP Unit: inhabitants

Table 5.32 Estimated Population by Sub-Basin (2004)

Sub-Basin			District			Area of District within the Sub-Basin			
Name		Area	Name	Population	Total Area	Area within	%	Population by District	Population by Sub-Basin
1	Wadi Al Mashamini	76.5	Arhab	90,038	1,288.4	76.5	5.9	5,346	5,346
2	Wadi Al Madini	211.5	Arhab	90,038	1,288.4	195.7	15.2	13,674	13,674
			Amran Gov.	---		15.9	---	---	
3	Wadi Al Kharid	136.7	Sana'a City	1,747,834	404.2	0.3	0.1	1,284	10,352
			Arhab	90,038	1,288.4	126.9	9.8	8,866	
			Nehm	41,502	1,961.0	9.5	0.5	201	
4	Wadi Al Ma'adi	111.5	Nehm	41,502	1,961.0	111.5	5.7	2,360	2,360
5	Wadi A'sir	210.2	Nehm	41,502	1,961.0	210.2	10.7	4,449	4,449
6	Wadi Khulaqah	75.9	Arhab	90,038	1,288.4	0.8	0.1	56	1,645
			Nehm	41,502	1,961.0	75.1	3.8	1,590	
7	Wadi Qasabah	64.6	Arhab	90,038	1,288.4	64.6	5.0	4,511	4,511
8	Wadi Al Huqqah	120.7	Sana'a City	1,747,834	404.2	1.1	0.3	4,953	16,499
			Hamdan	84,882	589.9	49.8	8.4	7,161	
			Arhab	90,038	1,288.4	62.7	4.9	4,385	
			Amran Gov.	---		7.1	---	---	
9	Wadi Bani Huwat	322.4	Bani Husheish	73,957	340.7	48.3	14.2	10,478	1,048,429
			Sana'a City	1,747,834	404.2	239.1	59.1	1,033,782	
			Hamdan	84,882	589.9	23.2	3.9	3,343	
			Arhab	90,038	1,288.4	11.8	0.9	826	
10	Wadi Thumah	77.6	Bani Husheish	73,957	340.7	1.0	0.3	212	141,095
			Sana'a City	1,747,834	404.2	32.2	8.0	139,087	
			Arhab	90,038	1,288.4	17.6	1.4	1,228	
			Nehm	41,502	1,961.0	26.8	1.4	568	
11	Wadi As Sirr	219.1	Al Taial	36,253	395.8	34.4	8.7	3,151	45,844
			Bani Husheish	73,957	340.7	140.5	41.2	30,499	
			Sana'a City	1,747,834	404.2	2.6	0.6	11,316	
			Nehm	41,502	1,961.0	41.5	2.1	879	
12	Wadi Al Furs	45.8	Al Taial	36,253	395.8	0.1	0.0	10	9,937
			Bani Husheish	73,957	340.7	45.7	13.4	9,927	
13	Wadi Al Iqbal	204.5	Hamdan	84,882	589.9	177.6	30.1	25,552	25,552
			Amran Gov.	---		26.9	---	---	
14	Wadi Zahr & Al Ghayl	364.8	Bani Matar	100,012	1,117.5	223.1	20.0	19,970	71,069
			Sana'a City	1,747,834	404.2	7.3	1.8	31,771	
			Hamdan	84,882	589.9	134.3	22.8	19,329	
15	Wadi Hamdan	63.6	Bani Matar	100,012	1,117.5	5.4	0.5	483	52,656
			Sana'a City	1,747,834	404.2	10.5	2.6	45,301	
			Hamdan	84,882	589.9	47.8	8.1	6,872	
16	Wadi Al Mawrid	179.6	Sanhan and Bani Bahloul	80,399	600.0	29.1	4.9	3,902	418,456
			Bani Matar	100,012	1,117.5	37.8	3.4	3,388	
			Bani Husheish	73,957	340.7	8.8	2.6	1,919	
			Sana'a City	1,747,834	404.2	94.3	23.3	407,891	
			Hamdan	84,882	589.9	9.4	1.6	1,356	
17	Wadi Sa'wan	95.4	Sanhan and Bani Bahloul	80,399	600.0	3.5	0.6	463	29,968
			Al Taial	36,253	395.8	8.1	2.1	743	
			Bani Husheish	73,957	340.7	81.2	23.8	17,635	
			Sana'a City	1,747,834	404.2	2.6	0.6	11,127	
18	Wadi Shahik	236.9	Jahana	50,747	617.8	2.4	0.4	200	88,650
			Sanhan and Bani Bahloul	80,399	600.0	119.2	19.9	15,967	
			Al Taial	36,253	395.8	86.0	21.7	7,875	
			Bani Husheish	73,957	340.7	15.1	4.4	3,286	
			Sana'a City	1,747,834	404.2	14.2	3.5	61,323	
19	Wadi Ghayman	143.8	Jahana	50,747	617.8	26.8	4.3	2,203	17,874
			Sanhan and Bani Bahloul	80,399	600.0	117.0	19.5	15,671	
20	Wadi Al Mulaikhy	69.8	Sanhan and Bani Bahloul	80,399	600.0	23.1	3.9	3,096	7,277
			Bani Matar	100,012	1,117.5	46.7	4.2	4,181	
21	Wadi Hizyaz	80.5	Sanhan and Bani Bahloul	80,399	600.0	74.0	12.3	9,915	10,498
			Bani Matar	100,012	1,117.5	6.5	0.6	584	
22	Wadi Akhwar	125.4	Jahana	50,747	617.8	7.4	1.2	606	16,424
			Sanhan And Bani Bahloul	80,399	600.0	118.1	19.7	15,818	

Unit: Population: inhabitants; Area: square kilometer

Table 5.33 Population Forecast by Sub-Basin

Sub-Basin \ Year		2005	2006	2010	2015	2020
1	Wadi Al Mashamini	5,480	5,617	6,200	7,014	7,936
2	Wadi Al Madini	14,016	14,366	15,858	17,941	20,299
3	Wadi Al Kharid	10,647	10,950	12,238	14,020	15,991
4	Wadi Al Ma'adi	2,419	2,479	2,736	3,096	3,503
5	Wadi A'sir	4,560	4,674	5,159	5,837	6,604
6	Wadi Khulaqah	1,687	1,729	1,908	2,159	2,443
7	Wadi Qasabah	4,624	4,740	5,232	5,919	6,697
8	Wadi Al Huqqah	17,053	17,622	20,035	23,337	26,900
9	Wadi Bani Huwat	1,104,206	1,161,546	1,403,916	1,728,142	2,058,854
10	Wadi Thumah	148,600	156,316	188,929	232,556	277,057
11	Wadi As Sirr	47,314	48,822	55,224	64,010	73,556
12	Wadi Al Furs	10,185	10,440	11,524	13,038	14,752
13	Wadi Al Iqbal	26,191	26,845	29,632	33,526	37,932
14	Wadi Zahr & Al Ghayl	73,755	76,512	88,198	104,083	120,944
15	Wadi Hamdan	55,268	57,953	69,306	84,537	100,186
16	Wadi Al Mawrid	440,583	463,330	559,482	688,139	819,450
17	Wadi Sa'wan	31,035	32,131	36,778	43,115	49,896
18	Wadi Shahik	92,620	96,700	113,963	137,228	161,407
19	Wadi Ghayman	18,321	18,779	20,729	23,453	26,535
20	Wadi Al Mulaikhy	7,459	7,646	8,440	9,549	10,803
21	Wadi Hizyaz	10,761	11,030	12,175	13,775	15,585
22	Wadi Akhwar	16,835	17,255	19,047	21,550	24,382
	Total	2,143,619	2,247,483	2,686,707	3,276,023	3,881,712

Unit: inhabitants

5.8.2 DOMESTIC WATER DEMAND

(1) Urban Water Supply

Urban water supply is in charge of SWSLC and projections for water demand for this sector is mentioned in the Development Programme, a report prepared by Dar Al-Handasah for the Sana'a Water Supply and Sanitation Project (SWSSP) which was issued in 2000.

The Development Programme has estimated the water consumption for the city by four alternative Strategies (options) and conditions showed below:

- Option 1- Minimum Option: 35 l/c/d for domestic consumption for entire city population.
- Option 2- Full Service Option: at a defined desirable minimum standard, 80 l/c/d for domestic consumption for entire city population
- Option 3- Compromise Option: variable supply of 35 and 80 l/c/d depending on urban location with a target of 75% of population provided with 80 l//c/d.
- Option 4- Sector Transfer Option: variant of the Compromise Option in which the Source Development Programme for the Minimum Option is supplemented from the Agricultural Sector.
- Non-domestic consumption is set at 30% of total consumption for all Options
- Physical losses of the system are assumed at 20%, through the implementation of leakage reduction measures.

- Population adopted was for Moderate Growth Rate Scenario

Demand projection in this Study was calculated based on above Options determined by the Development Programme, since it was followed by SWSLC.

Note that demand projection calculated below includes water consumption for all sources of water such as public water supply and private water supply. Unit water consumption for domestic water consumed from public water supply for 2005 and 2006 is based on actual condition of respective year and consumption from private water supply was calculated based on data of the Development Programme assuming the same rate up to now. Results of demand projection for urban water supply are shown in *Table 5.34*and *Figure 5.11*.

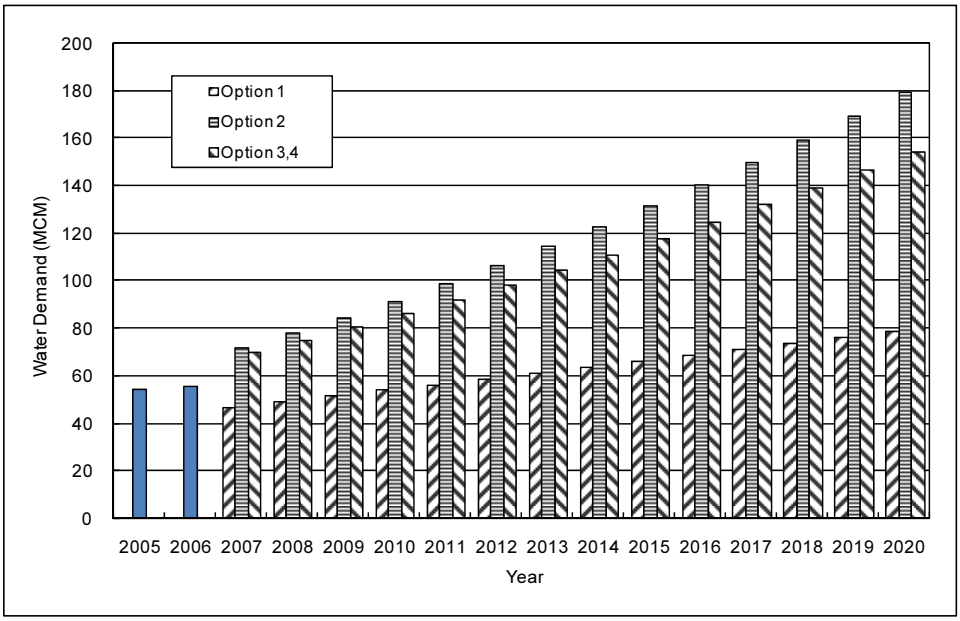

Figure 5.11 Urban Water Demand Projection Chart

Table 5.34 Water Demand for Urban Areas

	Unit	2005	2006	2010	2015	2020
Population	(no)	1,841,562	1,937,783	2,344,740	2,888,894	3,443,519
Public water supply		672,141	696,141	1,104,115	1,763,511	2,582,639
Private water supply		1,169,421	1,241,642	1,240,625	1,125,383	860,880
Unit Consumption						
Domestic						
Option 1	(l/c/d)	Pub. Supply	Pub. Supply	35.0	35.0	35.0
Option 2		50.8	51.6	59.7	69.9	80.0
Option 3, 4						
Public water supply		Priv. Supply	Priv. Supply	59.7	69.9	80.0
Private water supply		70.0	70.0	35.0	35.0	35.0
Non-domestic						
Option 1	(% of total)	---	---	30%	30%	30%
Option 2				30%	30%	30%
Option 3, 4				30%	30%	30%
Consumption						
Domestic						
Option 1	(MCM)	Pub. Supply	Pub. Supply	30.0	36.9	44.0
Option 2		12.5	13.1	51.1	73.7	100.6
Option 3, 4						
Public water supply		Priv. Supply	Priv. Supply	24.1	45.0	75.4
Private water supply		29.9	31.7	15.8	14.4	11.0
Non-domestic						
Option 1	(MCM)	1.3	1.6	12.8	15.8	18.9
Option 2				21.9	31.6	43.1
Option 3, 4				17.1	25.4	37.0
Total Consumption						
Option 1	(MCM)	43.7	46.4	42.8	52.7	62.8
Option 2				73.0	105.2	143.6
Option 3, 4				57.0	84.8	123.4
Total Supply Requirement Including Physical Losses @ 20% of Production						
Option 1	(MCM)	54.3	55.8	53.5	65.9	78.6
Option 2				91.3	131.5	179.6
Option 3, 4				71.3	106.0	154.3

*Population estimated based on results of 2004 Census, under the moderate growth rate scenario

*Population covered by the public water supply for 2005 and 2006 based on SWSLC annual report (2006)

*Unit consumption of 2005 and 2006: based on SWSLC's annual report (2006) for public water supply and for the private water supply was estimated based on the Development Programme (2000)

*Water consumption for non-domestic use was based on SWSLC's annual report (2006)

*Total Supply Requirement for 2005 and 2006 shows the total of water produced between the public water supply (based on SWSLC's annual report(2006)) and assuming water consumption = water production, for the private water supply

However, considering targets settled by the Five Years Plan (2004-2008) of SWSLC and focusing on domestic water consumption supplied by the public network, demand of water is estimated as shown in *Table 5.35* and *Figure 5.12* and conditions assumed for estimation is as follow:

- Number of water connections increasing according to the Five Years Plan at 5% per year
- Number of inhabitants connected to each water connection is assumed at 9, adopted by SWSLC
- Unit water consumption for "Based in 2006" will continue the same as of 2006 up to 2020, Five Years Plan has settled an unit water consumption for 2008 at 105 l/c/d and here it is assumed as constant up to 2020.
- Demand of domestic water from the public water supply includes physical losses at 20% of production.

Table 5.35 Domestic Water Demand from the Public Water Supply

		Unit	2005	2006	2010	2015	2020
Population		(no)	1,841,562	1,937,783	2,344,740	2,888,894	3,443,519
Domestic water connection			74,771	77,349	94,018	119,994	153,146
Population connected	Five Years Plan		672,141	696,141	846,164	1,079,943	1,378,312
	Option 3,4		672,141	696,141	1,104,115	1,763,511	2,582,639
Unit water consumption	Based in 2006	(l/c/d)	50.8	51.6	51.6	51.6	51.6
	Five Years Plan		50.8	51.6	105.0	105.0	105.0
	Option 1		50.8	51.6	35.0	35.0	35.0
	Option 2		50.8	51.6	59.7	69.9	80.0
	Option 3, 4		50.8	51.6	59.7	69.9	80.0
Domestic water consumption	Based in 2006	(MCM)	12.5	13.1	15.9	20.3	26.0
	Five Years Plan		12.5	13.1	32.4	41.4	52.8
	Option 1		34.1	36.5	30.0	36.9	44.0
	Option 2		34.1	36.5	51.1	73.7	100.6
	Option 3, 4		12.5	13.1	24.1	45.0	75.4
Total water demand *	Based in 2006	(MCM)	24.4	24.1	19.9	25.4	32.4
	Five Years Plan		24.4	24.1	40.5	51.7	66.0
	Option 1		42.7	45.6	37.4	46.1	55.0
	Option 2		42.7	45.6	63.9	92.1	125.7
	Option 3, 4		15.6	16.4	30.1	56.2	94.3

* Total water demand including Physical Losses @ 20% of production

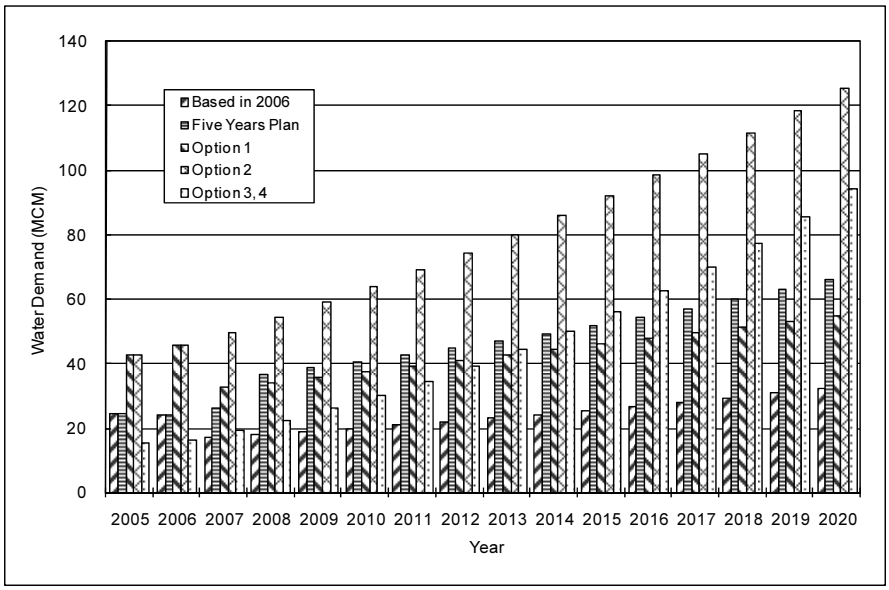

Figure 5.12 Domestic Water Demand Projection Chart

(2) Rural Water Supply

Demand of domestic water supply for rural area was estimated by sub-basin as shown in *Table 5.36*. GARWSP is the governmental body in charge for planning and implementation of rural water supply and village authorities where water supply projects were implemented are in charge of operation and maintenance. Difficulties to collect information concerning water consumption for rural areas were faced during the study period due to a lack of information as explained before. Water demand for this sector was calculated based on population growth rate of 2.5%, rate adopted by GARWSP for rural water supply projects and unit water consumption of 20 l/c/d, amount adopted by NWRA for water resource management.

Table 5.36 Water Demand Projection for Rural Areas by Sub-Basin

Sub-Basin		2005		2006		2010		2015		2020	
		Population	Water Demand	Population	Water Demand	Population	Water Demand	Population	Water Demand	Population	Water Demand
1	Wadi Al Mashamini	5,480	0.04	5,617	0.04	6,200	0.05	7,014	0.05	7,936	0.06
2	Wadi Al Madini	14,016	0.10	14,366	0.10	15,858	0.12	17,941	0.13	20,299	0.15
3	Wadi Al Kharid	9,294	0.07	9,526	0.07	10,515	0.08	11,897	0.09	13,461	0.10
4	Wadi Al Ma'adi	2,419	0.02	2,479	0.02	2,736	0.02	3,096	0.02	3,503	0.03
5	Wadi A'sir	4,560	0.03	4,674	0.03	5,159	0.04	5,837	0.04	6,604	0.05
6	Wadi Khulaqah	1,687	0.01	1,729	0.01	1,908	0.01	2,159	0.02	2,443	0.02
7	Wadi Qasabah	4,624	0.03	4,740	0.03	5,232	0.04	5,919	0.04	6,697	0.05
8	Wadi Al Huqqah	11,834	0.09	12,130	0.09	13,389	0.10	15,149	0.11	17,139	0.13
9	Wadi Bani Huwat	15,013	0.11	15,389	0.11	16,986	0.12	19,218	0.14	21,744	0.16
10	Wadi Thumah	2,058	0.02	2,110	0.02	2,329	0.02	2,635	0.02	2,981	0.02
11	Wadi As Sirr	35,392	0.26	36,277	0.26	40,043	0.29	45,305	0.33	51,258	0.37
12	Wadi Al Furs	10,185	0.07	10,440	0.08	11,524	0.08	13,038	0.10	14,752	0.11
13	Wadi Al Iqbal	26,191	0.19	26,845	0.20	29,632	0.22	33,526	0.24	37,932	0.28
14	Wadi Zahr & Al Ghayl	40,281	0.29	41,288	0.30	45,574	0.33	51,563	0.38	58,339	0.43
15	Wadi Hamdan	7,539	0.06	7,727	0.06	8,530	0.06	9,650	0.07	10,919	0.08
16	Wadi Al Mawrid	10,830	0.08	11,101	0.08	12,253	0.09	13,863	0.10	15,685	0.11
17	Wadi Sa'wan	19,312	0.14	19,795	0.14	21,850	0.16	24,721	0.18	27,970	0.20
18	Wadi Shahik	28,010	0.20	28,710	0.21	31,691	0.23	35,855	0.26	40,567	0.30
19	Wadi Ghayman	18,321	0.13	18,779	0.14	20,729	0.15	23,453	0.17	26,535	0.19
20	Wadi Al Mulaikhy	7,459	0.05	7,646	0.06	8,440	0.06	9,549	0.07	10,803	0.08
21	Wadi Hizyaz	10,761	0.08	11,030	0.08	12,175	0.09	13,775	0.10	15,585	0.11
22	Wadi Akhwar	16,835	0.12	17,255	0.13	19,047	0.14	21,550	0.16	24,382	0.18
	Total	302,101	2.21	309,653	2.26	341,799	2.50	386,715	2.82	437,532	3.19

Unit: Population: inhabitants, Water Demand: MCM

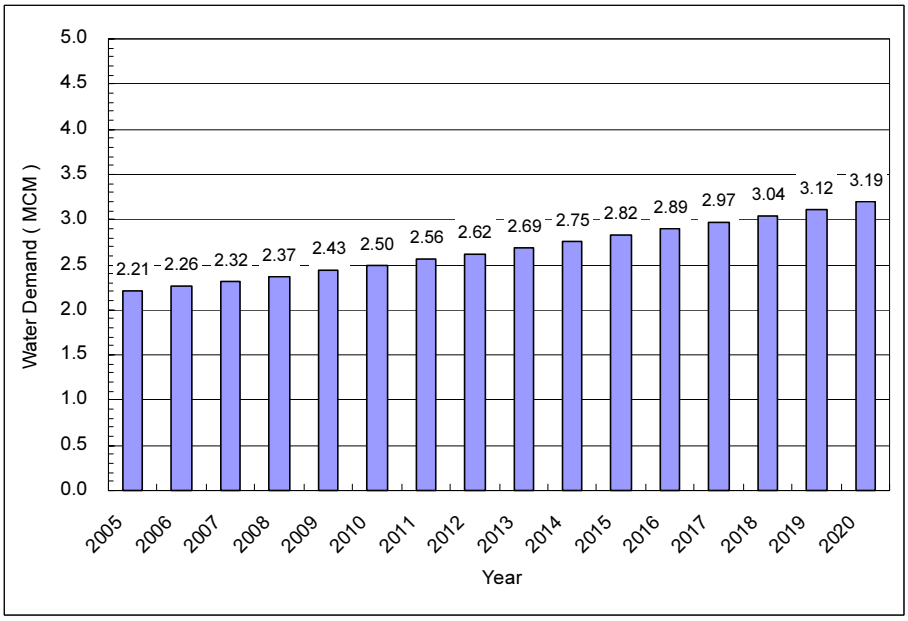

Figure 5.13 Rural Domestic Water Demand Projection Chart

5.8.3 AGRICULTURAL WATER DEMAND

(1) Growth of Irrigation Area

To forecast the agricultural water demand, annual growth of irrigated area by cropping pattern was estimated assuming the following conditions:

- Four types of crops were classified as an irrigated crop by GAF (2007)[16] through study on satellite imagery analysis, namely qat, grape, irrigated mixed crops and fruit orchards.
- Irrigated area of each crop was also based on study of GAF (2007).
- Annual growth rate of irrigated area was based on data of the Agricultural Statistics Year Book 2005 and an average growth rate of each crop between 2004 and 2005 for Sana'a City and Sana'a was assumed since historical growth rate is not suitable due to modification of the district boundaries as described before. Growth rate assumed was 1.04% for qat, 0.79% for grape, 0.12% for mixed crops and 1.41% for fruit orchards.
- It is assumed that sub-basins where crop cultivation was not observed by the GAF (2007) study will continue not cultivated in the future.

According to estimation result, irrigated area for qat will increase 3,000 ha (23%), area for grape will increase 70 ha (1.2%), and area for mixed crops will increase 28 ha (1.8%) and for fruit orchards will increase 27 ha (23%) as shown in *Table 5.37*. *Table 5.38* shows the total irrigated area for each sub-basin. Irrigated area of Sana'a Basin will increase 2,800 ha (14%) up to 2020, according to the result

Table 5.37 Projection of Irrigated Area by Cropping Pattern by Sub-Basin

Qat: Irrigated area (ha), annual growth rate= 1.04%						
	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	69.0	70.0	74.0	79.3	85.0
2	Wadi Al Madini	350.0	354.9	375.2	402.2	431.2
3	Wadi Al Kharid	228.0	231.2	244.4	262.0	280.9
4	Wadi Al Ma'adi	100.2	101.6	107.4	115.1	123.4
5	Wadi A'sir	593.2	601.5	635.9	681.7	730.8
6	Wadi Khulaqah	180.5	183.0	193.5	207.4	222.4
7	Wadi Qasabah	185.4	188.0	198.7	213.1	228.4
8	Wadi Al Huqqah	965.0	978.5	1,034.5	1,108.9	1,188.8
9	Wadi Bani Huwat	1,753.0	1,777.5	1,879.2	2,014.5	2,159.5
10	Wadi Thumah	61.8	62.7	66.2	71.0	76.1
11	Wadi As Sirr	1,039.1	1,053.6	1,113.9	1,194.1	1,280.0
12	Wadi Al Furs	427.1	433.1	457.8	490.8	526.1
13	Wadi Al Iqbal	1,384.0	1,403.4	1,483.6	1,590.4	1,704.9
14	Wadi Zahr & Al Ghayl	1,010.3	1,024.4	1,083.0	1,161.0	1,244.6
15	Wadi Hamdan	783.4	794.4	839.8	900.2	965.1
16	Wadi Al Mawrid	526.5	533.9	564.4	605.0	648.6
17	Wadi Sa'wan	415.1	420.9	445.0	477.0	511.4
18	Wadi Shahik	500.8	507.8	536.9	575.5	616.9
19	Wadi Ghayman	288.8	292.8	309.6	331.9	355.8
20	Wadi Al Mulaikhy	227.1	230.3	243.4	261.0	279.8
21	Wadi Hizyaz	197.0	199.8	211.2	226.4	242.7
22	Wadi Akhwar	186.4	189.0	199.8	214.2	229.6
	Total	11,471.7	11,632.3	12,297.5	13,182.8	14,131.8

Grape: Irrigated area (ha), annual growth rate= 0.79%						
	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	3.6	3.6	3.6	3.6	3.6
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	84.3	84.4	84.6	85.0	85.3
9	Wadi Bani Huwat	2,131.7	2,133.4	2,140.1	2,148.6	2,157.1
10	Wadi Thumah	63.7	63.8	64.0	64.2	64.5
11	Wadi As Sirr	1,559.0	1,560.2	1,565.2	1,571.4	1,577.6
12	Wadi Al Furs	428.8	429.1	430.5	432.2	433.9
13	Wadi Al Iqbal	32.5	32.5	32.6	32.8	32.9
14	Wadi Zahr & Al Ghayl	-	-	-	-	-
15	Wadi Hamdan	-	-	-	-	-
16	Wadi Al Mawrid	105.0	105.1	105.4	105.8	106.3
17	Wadi Sa'wan	630.2	630.7	632.7	635.2	637.7
18	Wadi Shahik	531.6	532.0	533.7	535.8	537.9
19	Wadi Ghayman	243.4	243.6	244.4	245.3	246.3
20	Wadi Al Mulaikhy	-	-	-	-	-
21	Wadi Hizyaz	-	-	-	-	-
22	Wadi Akhwar	0.70	0.70	0.70	0.71	0.71
	Total	5,814.5	5,819.1	5,837.5	5,860.6	5,883.8

Mixed Crops: Irrigated area (ha), annual growth rate 0.12%						
	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	1.6	1.6	1.6	1.6	1.6
3	Wadi Al Kharid	5.9	5.9	5.9	6.0	6.0
4	Wadi Al Ma'adi	0.0	0.0	0.0	0.0	0.0
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	0.7	0.7	0.7	0.7	0.7
8	Wadi Al Huqqah	126.8	127.0	127.6	128.3	129.1
9	Wadi Bani Huwat	931.8	932.9	937.4	943.0	948.7
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	5.1	5.1	5.1	5.2	5.2
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	58.7	58.8	59.1	59.4	59.8
14	Wadi Zahr & Al Ghayl	277.5	277.8	279.2	280.8	282.5
15	Wadi Hamdan	5.0	5.0	5.0	5.1	5.1
16	Wadi Al Mawrid	106.9	107.0	107.5	108.2	108.8
17	Wadi Sa'wan	0.7	0.7	0.7	0.7	0.7
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	1.0	1.0	1.0	1.0	1.0
20	Wadi Al Mulaikhy	21.3	21.3	21.4	21.6	21.7
21	Wadi Hizyaz	7.6	7.6	7.6	7.7	7.7
22	Wadi Akhwar	3.7	3.7	3.7	3.7	3.8
	Total	1,554.3	1,556.2	1,563.6	1,573.1	1,582.5

Fruit Orchards: Irrigated area (ha), annual growth rate= 1.41%						
	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	-	-	-	-	-
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	-	-	-	-	-
9	Wadi Bani Huwat	9.1	9.2	9.8	10.5	11.2
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	-	-	-	-	-
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	62.9	63.8	67.5	72.4	77.6
14	Wadi Zahr & Al Ghayl	9.5	9.6	10.2	10.9	11.7
15	Wadi Hamdan	0.4	0.4	0.4	0.5	0.5
16	Wadi Al Mawrid	0.7	0.7	0.8	0.8	0.9
17	Wadi Sa'wan	8.9	9.0	9.5	10.2	11.0
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	-	-	-	-	-
20	Wadi Al Mulaikhy	20.6	20.9	22.1	23.7	25.4
21	Wadi Hizyaz	1.0	1.0	1.1	1.2	1.2
22	Wadi Akhwar	-	-	-	-	-
	Total	113.1	114.7	121.3	130.1	139.5

Unit: hectares

Table 5.38 Total Irrigated Area by Sub-Basin

Sub-Basin		2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	69	70	74	79	85
2	Wadi Al Madini	352	357	377	404	433
3	Wadi Al Kharid	238	241	254	272	291
4	Wadi Al Ma'adi	100	102	107	115	123
5	Wadi A'sir	593	602	636	682	731
6	Wadi Khulaqah	181	183	193	207	222
7	Wadi Qasabah	186	189	199	214	229
8	Wadi Al Huqqah	1,176	1,190	1,247	1,322	1,403
9	Wadi Bani Huwat	4,826	4,853	4,966	5,117	5,277
10	Wadi Thumah	126	126	130	135	141
11	Wadi As Sirr	2,603	2,619	2,684	2,771	2,863
12	Wadi Al Furs	856	862	888	923	960
13	Wadi Al Iqbal	1,538	1,558	1,643	1,755	1,875
14	Wadi Zahr & Al Ghayl	1,297	1,312	1,372	1,453	1,539
15	Wadi Hamdan	789	800	845	906	971
16	Wadi Al Mawrid	739	747	778	820	865
17	Wadi Sa'wan	1,055	1,061	1,088	1,123	1,161
18	Wadi Shahik	1,032	1,040	1,071	1,111	1,155
19	Wadi Ghayman	533	537	555	578	603
20	Wadi Al Mulaikhy	269	272	287	306	327
21	Wadi Hizyaz	206	208	220	235	252
22	Wadi Akhwar	191	193	204	219	234
Total		18,954	19,122	19,820	20,747	21,738

Unit: hectares

(2) Irrigation Water Demand

Irrigation water demand was estimated by GAF (2007) calculating the ETa based on FAO approach and results from satellite data analyses. ETa reflects the gross amount of water consumed by the vegetation (crop), i.e. the minimum amount of water necessary to the plant. However, it must be considered that more water is used by farmers to irrigate his land than the plants itself. This difference is expressed in the Irrigation Efficiency. TS-HWC (1992)[17] recommends irrigation efficiency of 35% for low efficiency, 55% for medium efficiency and 75% for high efficiency to obtain a reasonable range of irrigation water requirement and GAF (2007) has adopted an irrigation efficiency of 60%.

Projection for water demand was estimated based on results of GAF (2007) which has calculated the total ETa of each crop. In this study, ETa per unit of irrigated area of each crop was calculated to calculate the water demand in relation to the increase of irrigated land projected above. Calculated ETa per unit of area is shown in *Table 5.39* and the demand projection by type of crop is shown in *Table 5.40* and *Table 5.41*. *Table 5.42* shows the total water demand by sub sub basin.

Table 5.39 Calculated ETa per Unit of Area by Type of Crop

Crop Type	Unit	Qat	Grape	Irr. Mixed Crop	Fruit Orchards
Total ETa	MCM	59.17	16.83	7.01	0.67
Irrigated Area	ha	11,471.7	5,814.5	1,554.3	113.1
ETa per unit of Area	MCM/ha	0.00516	0.00289	0.00451	0.00592

Table 5.40 Irrigation Water Demand of each Crop by Irrigation Efficiency (Qat and Grape)

Qat: Water Demand (MCM) at IE = 60%

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.59	0.60	0.64	0.68	0.73
2	Wadi Al Madini	3.01	3.05	3.23	3.46	3.71
3	Wadi Al Kharid	1.96	1.99	2.10	2.25	2.41
4	Wadi Al Ma'adi	0.86	0.87	0.92	0.99	1.06
5	Wadi A'sir	5.10	5.17	5.47	5.86	6.28
6	Wadi Khulaqah	1.55	1.57	1.66	1.78	1.91
7	Wadi Qasabah	1.59	1.62	1.71	1.83	1.96
8	Wadi Al Huqqah	8.30	8.41	8.89	9.53	10.22
9	Wadi Bani Huwat	15.07	15.28	16.15	17.32	18.56
10	Wadi Thumah	0.53	0.54	0.57	0.61	0.65
11	Wadi As Sirr	8.93	9.06	9.58	10.27	11.00
12	Wadi Al Furs	3.67	3.72	3.94	4.22	4.52
13	Wadi Al Iqbal	11.90	12.06	12.75	13.67	14.66
14	Wadi Zahr & Al Ghayl	8.69	8.81	9.31	9.98	10.70
15	Wadi Hamdan	6.73	6.83	7.22	7.74	8.30
16	Wadi Al Mawrid	4.53	4.59	4.85	5.20	5.58
17	Wadi Sa'wan	3.57	3.62	3.83	4.10	4.40
18	Wadi Shahik	4.31	4.37	4.62	4.95	5.30
19	Wadi Ghayman	2.48	2.52	2.66	2.85	3.06
20	Wadi Al Mulaikhy	1.95	1.98	2.09	2.24	2.40
21	Wadi Hizyaz	1.69	1.72	1.82	1.95	2.09
22	Wadi Akhwar	1.60	1.62	1.72	1.84	1.97
	Total	98.62	100.00	105.72	113.33	121.48

Qat: Water Demand (MCM) at IE = 70% (2004/2005: IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.59	0.52	0.55	0.58	0.63
2	Wadi Al Madini	3.01	2.62	2.76	2.96	3.18
3	Wadi Al Kharid	1.96	1.70	1.80	1.93	2.07
4	Wadi Al Ma'adi	0.86	0.75	0.79	0.85	0.91
5	Wadi A'sir	5.10	4.43	4.69	5.02	5.38
6	Wadi Khulaqah	1.55	1.35	1.43	1.53	1.64
7	Wadi Qasabah	1.59	1.39	1.46	1.57	1.68
8	Wadi Al Huqqah	8.30	7.21	7.62	8.17	8.76
9	Wadi Bani Huwat	15.07	13.10	13.85	14.84	15.91
10	Wadi Thumah	0.53	0.46	0.49	0.52	0.56
11	Wadi As Sirr	8.93	7.76	8.21	8.80	9.43
12	Wadi Al Furs	3.67	3.19	3.37	3.62	3.88
13	Wadi Al Iqbal	11.90	10.34	10.93	11.72	12.56
14	Wadi Zahr & Al Ghayl	8.69	7.55	7.98	8.55	9.17
15	Wadi Hamdan	6.73	5.85	6.19	6.63	7.11
16	Wadi Al Mawrid	4.53	3.93	4.16	4.46	4.78
17	Wadi Sa'wan	3.57	3.10	3.28	3.51	3.77
18	Wadi Shahik	4.31	3.74	3.96	4.24	4.55
19	Wadi Ghayman	2.48	2.16	2.28	2.45	2.62
20	Wadi Al Mulaikhy	1.95	1.70	1.79	1.92	2.06
21	Wadi Hizyaz	1.69	1.47	1.56	1.67	1.79
22	Wadi Akhwar	1.60	1.39	1.47	1.58	1.69
	Total	98.62	85.71	90.61	97.14	104.13

Qat: Water Demand (MCM) at IE = 80% (2004/2005 IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.59	0.45	0.48	0.51	0.55
2	Wadi Al Madini	3.01	2.29	2.42	2.59	2.78
3	Wadi Al Kharid	1.96	1.49	1.58	1.69	1.81
4	Wadi Al Ma'adi	0.86	0.66	0.69	0.74	0.80
5	Wadi A'sir	5.10	3.88	4.10	4.40	4.71
6	Wadi Khulaqah	1.55	1.18	1.25	1.34	1.43
7	Wadi Qasabah	1.59	1.21	1.28	1.37	1.47
8	Wadi Al Huqqah	8.30	6.31	6.67	7.15	7.66
9	Wadi Bani Huwat	15.07	11.46	12.12	12.99	13.92
10	Wadi Thumah	0.53	0.40	0.43	0.46	0.49
11	Wadi As Sirr	8.93	6.79	7.18	7.70	8.25
12	Wadi Al Furs	3.67	2.79	2.95	3.16	3.39
13	Wadi Al Iqbal	11.90	9.05	9.57	10.25	10.99
14	Wadi Zahr & Al Ghayl	8.69	6.60	6.98	7.49	8.02
15	Wadi Hamdan	6.73	5.12	5.41	5.80	6.22
16	Wadi Al Mawrid	4.53	3.44	3.64	3.90	4.18
17	Wadi Sa'wan	3.57	2.71	2.87	3.08	3.30
18	Wadi Shahik	4.31	3.27	3.46	3.71	3.98
19	Wadi Ghayman	2.48	1.89	2.00	2.14	2.29
20	Wadi Al Mulaikhy	1.95	1.48	1.57	1.68	1.80
21	Wadi Hizyaz	1.69	1.29	1.36	1.46	1.56
22	Wadi Akhwar	1.60	1.22	1.29	1.38	1.48
	Total	98.62	75.00	79.29	84.99	91.11

Grape: Water Demand (MCM) at IE = 60%

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	0.02	0.02	0.02	0.02	0.02
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	0.41	0.41	0.41	0.41	0.41
9	Wadi Bani Huwat	10.28	10.29	10.32	10.37	10.41
10	Wadi Thumah	0.31	0.31	0.31	0.31	0.31
11	Wadi As Sirr	7.52	7.53	7.55	7.58	7.61
12	Wadi Al Furs	2.07	2.07	2.08	2.08	2.09
13	Wadi Al Iqbal	0.16	0.16	0.16	0.16	0.16
14	Wadi Zahr & Al Ghayl	-	-	-	-	-
15	Wadi Hamdan	-	-	-	-	-
16	Wadi Al Mawrid	0.51	0.51	0.51	0.51	0.51
17	Wadi Sa'wan	3.04	3.04	3.05	3.06	3.08
18	Wadi Shahik	2.56	2.57	2.57	2.58	2.60
19	Wadi Ghayman	1.17	1.18	1.18	1.18	1.19
20	Wadi Al Mulaikhy	-	-	-	-	-
21	Wadi Hizyaz	-	-	-	-	-
22	Wadi Akhwar	0.003	0.003	0.003	0.003	0.003
	Total	28.05	28.07	28.16	28.27	28.38

Grape: Water Demand (MCM) at IE = 70% (2004/2005: IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	0.02	0.01	0.01	0.02	0.02
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	0.41	0.35	0.35	0.35	0.35
9	Wadi Bani Huwat	10.28	8.82	8.85	8.88	8.92
10	Wadi Thumah	0.31	0.26	0.26	0.27	0.27
11	Wadi As Sirr	7.52	6.45	6.47	6.50	6.52
12	Wadi Al Furs	2.07	1.77	1.78	1.79	1.79
13	Wadi Al Iqbal	0.16	0.13	0.13	0.14	0.14
14	Wadi Zahr & Al Ghayl	-	-	-	-	-
15	Wadi Hamdan	-	-	-	-	-
16	Wadi Al Mawrid	0.51	0.43	0.44	0.44	0.44
17	Wadi Sa'wan	3.04	2.61	2.62	2.63	2.64
18	Wadi Shahik	2.56	2.20	2.21	2.22	2.22
19	Wadi Ghayman	1.17	1.01	1.01	1.01	1.02
20	Wadi Al Mulaikhy	-	-	-	-	-
21	Wadi Hizyaz	-	-	-	-	-
22	Wadi Akhwar	0.003	0.003	0.003	0.003	0.003
	Total	28.05	24.06	24.14	24.23	24.33

Grape: Water Demand (MCM) at IE = 80% (2004/2005: IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	0.02	0.01	0.01	0.02	0.02
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	0.41	0.35	0.35	0.35	0.35
9	Wadi Bani Huwat	10.28	8.82	8.85	8.88	8.92
10	Wadi Thumah	0.31	0.26	0.26	0.27	0.27
11	Wadi As Sirr	7.52	6.45	6.47	6.50	6.52
12	Wadi Al Furs	2.07	1.77	1.78	1.79	1.79
13	Wadi Al Iqbal	0.16	0.13	0.13	0.14	0.14
14	Wadi Zahr & Al Ghayl	-	-	-	-	-
15	Wadi Hamdan	-	-	-	-	-
16	Wadi Al Mawrid	0.51	0.43	0.44	0.44	0.44
17	Wadi Sa'wan	3.04	2.61	2.62	2.63	2.64
18	Wadi Shahik	2.56	2.20	2.21	2.22	2.22
19	Wadi Ghayman	1.17	1.01	1.01	1.01	1.02
20	Wadi Al Mulaikhy	-	-	-	-	-
21	Wadi Hizyaz	-	-	-	-	-
22	Wadi Akhwar	0.003	0.006	0.006	0.006	0.006
	Total	28.05	24.06	24.14	24.24	24.33

Table 5.41 Irrigation Water Demand of each Crop by Irrigation Efficiency (Mixed Crops and Fruit Orchards)

Mixed Crop: Water Demand (MCM) at IE = 60%

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	0.012	0.017	0.017	0.017	0.017
3	Wadi Al Kharid	0.044	0.063	0.063	0.063	0.064
4	Wadi Al Ma'adi	0.000	0.000	0.000	0.000	0.000
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	0.005	0.007	0.007	0.008	0.008
8	Wadi Al Huqqah	0.953	1.348	1.355	1.363	1.371
9	Wadi Bani Huwat	7.004	9.908	9.955	10.015	10.075
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	0.038	0.054	0.054	0.055	0.055
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.441	0.624	0.627	0.631	0.635
14	Wadi Zahr & Al Ghayl	2.086	2.951	2.965	2.983	3.001
15	Wadi Hamdan	0.038	0.053	0.053	0.054	0.054
16	Wadi Al Mawrid	0.804	1.137	1.142	1.149	1.156
17	Wadi Sa'wan	0.005	0.007	0.007	0.008	0.008
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	0.008	0.011	0.011	0.011	0.011
20	Wadi Al Mulaikhy	0.160	0.226	0.228	0.229	0.230
21	Wadi Hizyaz	0.057	0.081	0.081	0.082	0.082
22	Wadi Akhwar	0.028	0.039	0.040	0.040	0.040
	Total	11.683	16.526	16.606	16.706	16.806

Mixed Crop: Water Demand (MCM) at IE = 70% (2004/2005: IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi A 1 Mashamini	-	-	-	-	-
2	Wadi Al Madini	0.012	0.010	0.010	0.010	0.010
3	Wadi Al Kharid	0.044	0.038	0.038	0.038	0.039
4	Wadi Al Ma'adi	0.000	0.000	0.000	0.000	0.000
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	0.005	0.005	0.005	0.005	0.005
8	Wadi Al Huqqah	0.953	0.818	0.822	0.827	0.832
9	Wadi Bani Huwat	7.004	6.011	6.040	6.076	6.113
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	0.038	0.033	0.033	0.033	0.033
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.441	0.379	0.380	0.383	0.385
14	Wadi Zahr & Al Ghayl	2.086	1.790	1.799	1.809	1.820
15	Wadi Hamdan	0.038	0.032	0.032	0.033	0.033
16	Wadi Al Mawrid	0.804	0.690	0.693	0.697	0.701
17	Wadi Sa'wan	0.005	0.005	0.005	0.005	0.005
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	0.008	0.006	0.006	0.007	0.007
20	Wadi Al Mulaikhy	0.160	0.137	0.138	0.139	0.140
21	Wadi Hizyaz	0.057	0.049	0.049	0.050	0.050
22	Wadi Akhwar	0.028	0.024	0.024	0.024	0.024
	Total	11.683	10.026	10.075	10.135	10.196

Mixed Crop: Water Demand (MCM) at IE = 80% (2004/2005: IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi A 1 Mashamini	-	-	-	-	-
2	Wadi Al Madini	0.012	0.009	0.009	0.009	0.009
3	Wadi Al Kharid	0.044	0.033	0.033	0.034	0.034
4	Wadi Al Ma'adi	0.000	0.000	0.000	0.000	0.000
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	0.005	0.004	0.004	0.004	0.004
8	Wadi Al Huqqah	0.953	0.716	0.719	0.723	0.728
9	Wadi Bani Huwat	7.004	5.259	5.285	5.316	5.348
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	0.038	0.029	0.029	0.029	0.029
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.441	0.331	0.333	0.335	0.337
14	Wadi Zahr & Al Ghayl	2.086	1.566	1.574	1.583	1.593
15	Wadi Hamdan	0.038	0.028	0.028	0.029	0.029
16	Wadi Al Mawrid	0.804	0.603	0.606	0.610	0.614
17	Wadi Sa'wan	0.005	0.004	0.004	0.004	0.004
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	0.008	0.006	0.006	0.006	0.006
20	Wadi Al Mulaikhy	0.160	0.120	0.121	0.122	0.122
21	Wadi Hizyaz	0.057	0.043	0.043	0.043	0.044
22	Wadi Akhwar	0.028	0.021	0.021	0.021	0.021
	Total	11.683	8.773	8.815	8.868	8.922

Fruit Orchards: Water Demand (MCM) at IE = 60%

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	-	-	-	-	-
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	-	-	-	-	-
9	Wadi Bani Huwat	0.090	0.091	0.096	0.103	0.111
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	-	-	-	-	-
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.621	0.630	0.666	0.714	0.766
14	Wadi Zahr & Al Ghayl	0.094	0.095	0.101	0.108	0.116
15	Wadi Hamdan	0.004	0.004	0.004	0.005	0.005
16	Wadi Al Mawrid	0.007	0.007	0.007	0.008	0.009
17	Wadi Sa'wan	0.088	0.089	0.094	0.101	0.108
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	-	-	-	-	-
20	Wadi Al Mulaikhy	0.203	0.206	0.218	0.234	0.251
21	Wadi Hizyaz	0.010	0.010	0.011	0.011	0.012
22	Wadi Akhwar	-	-	-	-	-
	Total	1.117	1.132	1.198	1.284	1.378

Fruit Orchards: Water Demand (MCM) at IE = 70% (2004/2005: IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi A 1 Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	-	-	-	-	-
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	-	-	-	-	-
9	Wadi Bani Huwat	0.090	0.078	0.083	0.089	0.095
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	-	-	-	-	-
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.621	0.540	0.571	0.612	0.657
14	Wadi Zahr & Al Ghayl	0.094	0.082	0.086	0.092	0.099
15	Wadi Hamdan	0.004	0.003	0.004	0.004	0.004
16	Wadi Al Mawrid	0.007	0.006	0.006	0.007	0.007
17	Wadi Sa'wan	0.088	0.076	0.081	0.087	0.093
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	-	-	-	-	-
20	Wadi Al Mulaikhy	0.203	0.177	0.187	0.201	0.215
21	Wadi Hizyaz	0.010	0.009	0.009	0.010	0.010
22	Wadi Akhwar	-	-	-	-	-
	Total	1.117	0.971	1.027	1.101	1.181

Fruit Orchards: Water Demand (MCM) at IE = 80% (2004/2005: IE=60%)

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi A 1 Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	-	-	-	-	-
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	-	-	-	-	-
9	Wadi Bani Huwat	0.090	0.068	0.072	0.078	0.083
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	-	-	-	-	-
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.621	0.472	0.500	0.536	0.575
14	Wadi Zahr & Al Ghayl	0.094	0.071	0.075	0.081	0.087
15	Wadi Hamdan	0.004	0.003	0.003	0.003	0.004
16	Wadi Al Mawrid	0.007	0.005	0.006	0.006	0.006
17	Wadi Sa'wan	0.088	0.067	0.071	0.076	0.081
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	-	-	-	-	-
20	Wadi Al Mulaikhy	0.203	0.155	0.164	0.175	0.188
21	Wadi Hizyaz	0.010	0.008	0.008	0.009	0.009
22	Wadi Akhwar	-	-	-	-	-
	Total	1.117	0.849	0.898	0.963	1.033

Table 5.42 Irrigation Water Demand by Irrigation Efficiency

Water Demand (MCM) at IE = 60%						
	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.59	0.60	0.64	0.68	0.73
2	Wadi Al Madini	3.02	3.07	3.24	3.47	3.72
3	Wadi Al Kharid	2.02	2.07	2.18	2.33	2.50
4	Wadi Al Ma'adi	0.86	0.87	0.92	0.99	1.06
5	Wadi A'sir	5.10	5.17	5.47	5.86	6.28
6	Wadi Khulaqah	1.55	1.57	1.66	1.78	1.91
7	Wadi Qasabah	1.60	1.62	1.72	1.84	1.97
8	Wadi Al Huqqah	9.66	10.17	10.66	11.31	12.00
9	Wadi Bani Huwat	32.45	35.57	36.53	37.80	39.16
10	Wadi Thumah	0.84	0.85	0.88	0.92	0.97
11	Wadi As Sirr	16.49	16.64	17.18	17.90	18.67
12	Wadi Al Furs	5.74	5.79	6.01	6.30	6.62
13	Wadi Al Iqbal	13.12	13.47	14.20	15.18	16.22
14	Wadi Zahr & Al Ghayl	10.86	11.85	12.38	13.07	13.82
15	Wadi Hamdan	6.78	6.89	7.28	7.80	8.36
16	Wadi Al Mawrid	5.84	6.24	6.51	6.87	7.25
17	Wadi Sa'wan	6.70	6.76	6.98	7.27	7.59
18	Wadi Shahik	6.87	6.93	7.19	7.53	7.90
19	Wadi Ghayman	3.66	3.70	3.85	4.05	4.26
20	Wadi Al Mulaikhy	2.32	2.41	2.54	2.71	2.89
21	Wadi Hizyaz	1.76	1.81	1.91	2.04	2.18
22	Wadi Akhwar	1.63	1.67	1.76	1.88	2.02
	Total	139.47	145.73	151.68	159.59	168.05

Water Demand (MCM) at IE = 70% (2004/2005: IE=60%)						
	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.59	0.52	0.55	0.58	0.63
2	Wadi Al Madini	3.02	2.63	2.77	2.97	3.19
3	Wadi Al Kharid	2.02	1.76	1.85	1.98	2.12
4	Wadi Al Ma'adi	0.86	0.75	0.79	0.85	0.91
5	Wadi A'sir	5.10	4.43	4.69	5.02	5.38
6	Wadi Khulaqah	1.55	1.35	1.43	1.53	1.64
7	Wadi Qasabah	1.60	1.39	1.47	1.57	1.69
8	Wadi Al Huqqah	9.66	8.38	8.79	9.35	9.94
9	Wadi Bani Huwat	32.45	28.01	28.82	29.89	31.04
10	Wadi Thumah	0.84	0.73	0.75	0.79	0.83
11	Wadi As Sirr	16.49	14.25	14.71	15.33	15.99
12	Wadi Al Furs	5.74	4.97	5.15	5.40	5.67
13	Wadi Al Iqbal	13.12	11.39	12.02	12.85	13.74
14	Wadi Zahr & Al Ghayl	10.86	9.42	9.87	10.46	11.09
15	Wadi Hamdan	6.78	5.89	6.22	6.67	7.15
16	Wadi Al Mawrid	5.84	5.06	5.29	5.60	5.93
17	Wadi Sa'wan	6.70	5.79	5.98	6.23	6.50
18	Wadi Shahik	6.87	5.94	6.16	6.46	6.77
19	Wadi Ghayman	3.66	3.17	3.30	3.47	3.65
20	Wadi Al Mulaikhy	2.32	2.01	2.12	2.26	2.42
21	Wadi Hizyaz	1.76	1.53	1.61	1.73	1.85
22	Wadi Akhwar	1.63	1.42	1.50	1.61	1.72
	Total	139.47	120.77	125.85	132.61	139.84

Water Demand (MCM) at IE = 80% (2004/2004: IE=60%)						
	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.59	0.45	0.48	0.51	0.55
2	Wadi Al Madini	3.02	2.30	2.43	2.60	2.79
3	Wadi Al Kharid	2.02	1.54	1.62	1.74	1.86
4	Wadi Al Ma'adi	0.86	0.66	0.69	0.74	0.80
5	Wadi A'sir	5.10	3.88	4.10	4.40	4.71
6	Wadi Khulaqah	1.55	1.18	1.25	1.34	1.43
7	Wadi Qasabah	1.60	1.22	1.29	1.38	1.48
8	Wadi Al Huqqah	9.66	7.37	7.74	8.22	8.74
9	Wadi Bani Huwat	32.45	25.61	26.32	27.27	28.27
10	Wadi Thumah	0.84	0.67	0.69	0.72	0.76
11	Wadi As Sirr	16.49	13.27	13.68	14.23	14.81
12	Wadi Al Furs	5.74	4.57	4.73	4.95	5.19
13	Wadi Al Iqbal	13.12	9.99	10.53	11.26	12.04
14	Wadi Zahr & Al Ghayl	10.86	8.24	8.63	9.15	9.70
15	Wadi Hamdan	6.78	5.15	5.45	5.84	6.25
16	Wadi Al Mawrid	5.84	4.49	4.69	4.95	5.24
17	Wadi Sa'wan	6.70	5.39	5.56	5.78	6.02
18	Wadi Shahik	6.87	5.47	5.67	5.93	6.20
19	Wadi Ghayman	3.66	2.90	3.01	3.16	3.32
20	Wadi Al Mulaikhy	2.32	1.76	1.85	1.98	2.11
21	Wadi Hizyaz	1.76	1.34	1.41	1.51	1.62
22	Wadi Akhwar	1.63	1.25	1.32	1.41	1.51
	Total	139.47	108.69	113.14	119.06	125.40

Unit: million cubic meters

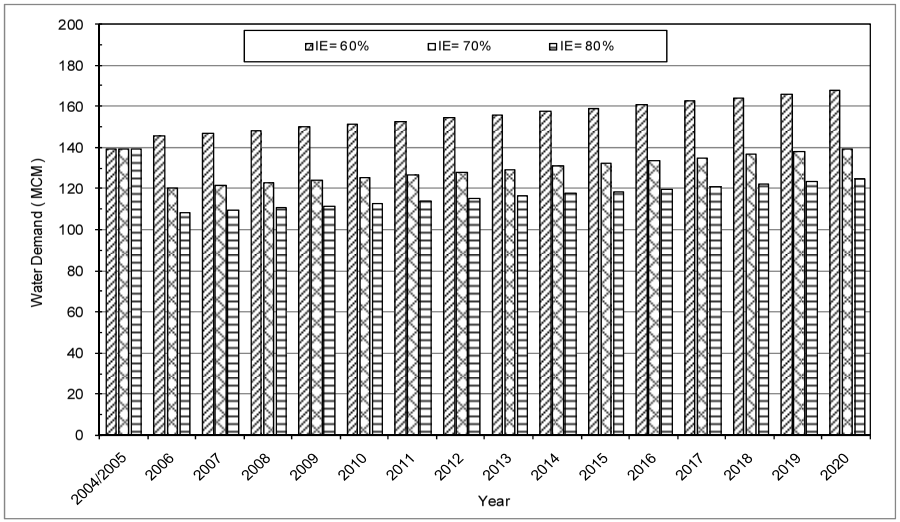

Figure 5.14 Irrigation Water Demand by Irrigation Efficiency

OBSERVATIONS

- GAF (2007) has calculated the total ETa by 113 MCM from irrigated crops.
- Forecast for agricultural demand (groundwater abstraction for irrigation) adopted the abstraction of 139.47 MCM for the base year of 2004/2005 according to modified GAF (2007) under irrigation efficiency of 60% as explained before, since information of irrigated area and abstraction are the latest ones.
- Source of Irrigation Efficiency followed by GAF (2007): "For the Arabian Peninsula a recent publication listed an irrigation efficiency factor of 0.6 (State of Water in the Arabic Region, 2004)". Different opinions concerning this IE exist. NWSSIP mentions IE factor about 0.35.
- As mentioned before, different report use different irrigation factor and different water consumption is presented. Case as of Sana'a Basin where difficulties to understand the water usage condition of all sector, it is supposed that Satellite Imagery Analyses is at least most applicable method to estimate the agricultural water consumption. Methods and technology for satellite analysis as well the accuracy is increasing year by year however without determination of irrigation efficiency for Sana'a Basin whenever an accurate estimation of irrigation water consumption will be reached. Needs of clarify the irrigation efficiency hereafter is recommended.

Assuming Irrigation Efficiency as 40% or 45% for the ETa calculated for 2004/2005, water consumed in 2004/2005 is estimated at 209 MCM and 186 MCM respectively for IE= 40% and IE= 45% compared with 139 MCM under IE= 60%. Demand of water per crop assuming IE= 40% and 45% for 2004/2005 is shown in *Table 5.43*, and the total water demand by sub basin is shown in *Table 5.44*. Total water demand projection chart for irrigation is shown in *Figure 5.15*.

Table 5.43 Water Demand by Crop (IE=40% and 45%)

Qat: Water Demand (MCM) at IE = 40% for 2004/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.89	0.90	0.95	1.02	1.10
2	Wadi Al Madini	4.51	4.58	4.84	5.19	5.56
3	Wadi Al Kharid	2.94	2.98	3.15	3.38	3.62
4	Wadi Al Ma'adi	1.29	1.31	1.39	1.48	1.59
5	Wadi A'sir	7.65	7.76	8.20	8.79	9.42
6	Wadi Khulaqah	2.33	2.36	2.50	2.67	2.87
7	Wadi Qasabah	2.39	2.42	2.56	2.75	2.95
8	Wadi Al Huqqah	12.44	12.62	13.34	14.30	15.33
9	Wadi Bani Huwat	22.60	22.92	24.23	25.98	27.85
10	Wadi Thumah	0.80	0.81	0.85	0.92	0.98
11	Wadi As Sirr	13.40	13.59	14.36	15.40	16.51
12	Wadi Al Furs	5.51	5.58	5.90	6.33	6.78
13	Wadi Al Iqbal	17.85	18.10	19.13	20.51	21.98
14	Wadi Zahr & Al Ghayl	13.03	13.21	13.97	14.97	16.05
15	Wadi Hamdan	10.10	10.24	10.83	11.61	12.44
16	Wadi Al Mawrid	6.79	6.88	7.28	7.80	8.36
17	Wadi Sa'wan	5.35	5.43	5.74	6.15	6.59
18	Wadi Shahik	6.46	6.55	6.92	7.42	7.96
19	Wadi Ghayman	3.72	3.78	3.99	4.28	4.59
20	Wadi Al Mulaikhy	2.93	2.97	3.14	3.37	3.61
21	Wadi Hizyaz	2.54	2.58	2.72	2.92	3.13
22	Wadi Akhwar	2.40	2.44	2.58	2.76	2.96
	Total	147.93	150.00	158.57	169.99	182.23

Qat: Water Demand (MCM) at IE = 45% for 2004/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.79	0.80	0.85	0.91	0.97
2	Wadi Al Madini	4.01	4.07	4.30	4.61	4.94
3	Wadi Al Kharid	2.61	2.65	2.80	3.00	3.22
4	Wadi Al Ma'adi	1.15	1.16	1.23	1.32	1.41
5	Wadi A'sir	6.80	6.89	7.29	7.81	8.38
6	Wadi Khulaqah	2.07	2.10	2.22	2.38	2.55
7	Wadi Qasabah	2.13	2.15	2.28	2.44	2.62
8	Wadi Al Huqqah	11.06	11.22	11.86	12.71	13.63
9	Wadi Bani Huwat	20.09	20.37	21.54	23.09	24.75
10	Wadi Thumah	0.71	0.72	0.76	0.81	0.87
11	Wadi As Sirr	11.91	12.08	12.77	13.69	14.67
12	Wadi Al Furs	4.90	4.96	5.25	5.63	6.03
13	Wadi Al Iqbal	15.86	16.09	17.01	18.23	19.54
14	Wadi Zahr & Al Ghayl	11.58	11.74	12.41	13.31	14.27
15	Wadi Hamdan	8.98	9.11	9.63	10.32	11.06
16	Wadi Al Mawrid	6.03	6.12	6.47	6.93	7.43
17	Wadi Sa'wan	4.76	4.82	5.10	5.47	5.86
18	Wadi Shahik	5.74	5.82	6.15	6.60	7.07
19	Wadi Ghayman	3.31	3.36	3.55	3.80	4.08
20	Wadi Al Mulaikhy	2.60	2.64	2.79	2.99	3.21
21	Wadi Hizyaz	2.26	2.29	2.42	2.59	2.78
22	Wadi Akhwar	2.14	2.17	2.29	2.46	2.63
	Total	131.49	133.33	140.95	151.10	161.98

Grape: Water Demand (MCM) at IE = 40% for 2004/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	0.03	0.03	0.03	0.03	0.03
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	0.61	0.61	0.61	0.61	0.62
9	Wadi Bani Huwat	15.43	15.44	15.49	15.55	15.61
10	Wadi Thumah	0.46	0.46	0.46	0.46	0.47
11	Wadi As Sirr	11.28	11.29	11.33	11.37	11.42
12	Wadi Al Furs	3.10	3.11	3.12	3.13	3.14
13	Wadi Al Iqbal	0.24	0.24	0.24	0.24	0.24
14	Wadi Zahr & Al Ghayl	-	-	-	-	-
15	Wadi Hamdan	-	-	-	-	-
16	Wadi Al Mawrid	0.76	0.76	0.76	0.77	0.77
17	Wadi Sa'wan	4.56	4.56	4.58	4.60	4.61
18	Wadi Shahik	3.85	3.85	3.86	3.88	3.89
19	Wadi Ghayman	1.76	1.76	1.77	1.78	1.78
20	Wadi Al Mulaikhy	-	-	-	-	-
21	Wadi Hizyaz	-	-	-	-	-
22	Wadi Akhwar	0.005	0.005	0.005	0.005	0.005
	Total	42.08	42.11	42.24	42.41	42.58

Grape: Water Demand (MCM) at IE = 45% for 204/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	0.02	0.02	0.02	0.02	0.02
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	0.54	0.54	0.54	0.55	0.55
9	Wadi Bani Huwat	13.71	13.72	13.77	13.82	13.87
10	Wadi Thumah	0.41	0.41	0.41	0.41	0.41
11	Wadi As Sirr	10.03	10.04	10.07	10.11	10.15
12	Wadi Al Furs	2.76	2.76	2.77	2.78	2.79
13	Wadi Al Iqbal	0.21	0.21	0.21	0.21	0.21
14	Wadi Zahr & Al Ghayl	-	-	-	-	-
15	Wadi Hamdan	-	-	-	-	-
16	Wadi Al Mawrid	0.68	0.68	0.68	0.68	0.68
17	Wadi Sa'wan	4.05	4.06	4.07	4.09	4.10
18	Wadi Shahik	3.42	3.42	3.43	3.45	3.46
19	Wadi Ghayman	1.57	1.57	1.57	1.58	1.58
20	Wadi Al Mulaikhy	-	-	-	-	-
21	Wadi Hizyaz	-	-	-	-	-
22	Wadi Akhwar	0.005	0.005	0.005	0.005	0.005
	Total	37.40	37.43	37.55	37.70	37.85

Mixed Crop: Water Demand (MCM) at IE = 40% for 2004/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	0.018	0.018	0.018	0.018	0.018
3	Wadi Al Kharid	0.067	0.067	0.067	0.067	0.068
4	Wadi Al Ma'adi	0.000	0.000	0.000	0.000	0.000
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	0.008	0.008	0.008	0.008	0.008
8	Wadi Al Huqqah	1.430	1.431	1.438	1.447	1.456
9	Wadi Bani Huwat	10.506	10.519	10.569	10.633	10.697
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	0.058	0.058	0.058	0.058	0.059
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.662	0.663	0.666	0.670	0.674
14	Wadi Zahr & Al Ghayl	3.129	3.133	3.148	3.167	3.186
15	Wadi Hamdan	0.056	0.056	0.057	0.057	0.057
16	Wadi Al Mawrid	1.205	1.207	1.213	1.220	1.227
17	Wadi Sa'wan	0.008	0.008	0.008	0.008	0.008
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	0.011	0.011	0.011	0.011	0.011
20	Wadi Al Mulaikhy	0.240	0.240	0.242	0.243	0.245
21	Wadi Hizyaz	0.086	0.086	0.086	0.087	0.087
22	Wadi Akhwar	0.042	0.042	0.042	0.042	0.042
	Total	17.53	17.55	17.63	17.74	17.84

Mixed Crop: Water Demand (MCM) at IE = 45% for 2004/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	0.016	0.016	0.016	0.016	0.016
3	Wadi Al Kharid	0.059	0.059	0.059	0.060	0.060
4	Wadi Al Ma'adi	0.000	0.000	0.000	0.000	0.000
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	0.007	0.007	0.007	0.007	0.007
8	Wadi Al Huqqah	1.271	1.272	1.278	1.286	1.294
9	Wadi Bani Huwat	9.339	9.350	9.395	9.452	9.508
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	0.051	0.051	0.051	0.052	0.052
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.588	0.589	0.592	0.595	0.599
14	Wadi Zahr & Al Ghayl	2.781	2.785	2.798	2.815	2.832
15	Wadi Hamdan	0.050	0.050	0.050	0.051	0.051
16	Wadi Al Mawrid	1.071	1.073	1.078	1.084	1.091
17	Wadi Sa'wan	0.007	0.007	0.007	0.007	0.007
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	0.010	0.010	0.010	0.010	0.010
20	Wadi Al Mulaikhy	0.213	0.214	0.215	0.216	0.217
21	Wadi Hizyaz	0.076	0.076	0.077	0.077	0.078
22	Wadi Akhwar	0.037	0.037	0.037	0.038	0.038
	Total	15.58	15.60	15.67	15.77	15.86

Fruit Orchards: Water Demand (MCM) at IE = 40% for 2004/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	-	-	-	-	-
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	-	-	-	-	-
9	Wadi Bani Huwat	0.135	0.137	0.145	0.155	0.166
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	-	-	-	-	-
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.932	0.945	0.999	1.072	1.149
14	Wadi Zahr & Al Ghayl	0.141	0.143	0.151	0.162	0.174
15	Wadi Hamdan	0.006	0.006	0.006	0.007	0.007
16	Wadi Al Mawrid	0.010	0.011	0.011	0.012	0.013
17	Wadi Sa'wan	0.132	0.134	0.141	0.152	0.163
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	-	-	-	-	-
20	Wadi Al Mulaikhy	0.305	0.309	0.327	0.351	0.376
21	Wadi Hizyaz	0.015	0.015	0.016	0.017	0.018
22	Wadi Akhwar	-	-	-	-	-
	Total	1.68	1.70	1.80	1.93	2.07

Fruit Orchards: Water Demand (MCM) at IE = 45% for 2004/2005

	Sub-Basin	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	-	-	-	-	-
2	Wadi Al Madini	-	-	-	-	-
3	Wadi Al Kharid	-	-	-	-	-
4	Wadi Al Ma'adi	-	-	-	-	-
5	Wadi A'sir	-	-	-	-	-
6	Wadi Khulaqah	-	-	-	-	-
7	Wadi Qasabah	-	-	-	-	-
8	Wadi Al Huqqah	-	-	-	-	-
9	Wadi Bani Huwat	0.120	0.121	0.128	0.138	0.148
10	Wadi Thumah	-	-	-	-	-
11	Wadi As Sirr	-	-	-	-	-
12	Wadi Al Furs	-	-	-	-	-
13	Wadi Al Iqbal	0.828	0.840	0.888	0.952	1.022
14	Wadi Zahr & Al Ghayl	0.125	0.127	0.134	0.144	0.154
15	Wadi Hamdan	0.005	0.005	0.006	0.006	0.006
16	Wadi Al Mawrid	0.009	0.009	0.010	0.011	0.011
17	Wadi Sa'wan	0.117	0.119	0.126	0.135	0.145
18	Wadi Shahik	-	-	-	-	-
19	Wadi Ghayman	-	-	-	-	-
20	Wadi Al Mulaikhy	0.271	0.275	0.291	0.312	0.335
21	Wadi Hizyaz	0.013	0.013	0.014	0.015	0.016
22	Wadi Akhwar	-	-	-	-	-
	Total	1.49	1.51	1.60	1.71	1.84

Table 5.44 Irrigation Water Demand (IE=40% and 45%)

		Total Water Demand (MCM) at IE = 40% for 2004/2005					Total Water Demand (MCM) at IE = 45% for 2004/2005				
Sub-Basin		2004/2005	2006	2010	2015	2020	2004/2005	2006	2010	2015	2020
1	Wadi Al Mashamini	0.89	0.90	0.95	1.02	1.10	0.79	0.80	0.85	0.91	0.97
2	Wadi Al Madini	4.53	4.59	4.86	5.20	5.58	4.03	4.08	4.32	4.63	4.96
3	Wadi Al Kharid	3.03	3.07	3.24	3.47	3.72	2.70	2.73	2.88	3.09	3.30
4	Wadi Al Ma'adi	1.29	1.31	1.39	1.48	1.59	1.15	1.16	1.23	1.32	1.41
5	Wadi A'sir	7.65	7.76	8.20	8.79	9.42	6.80	6.89	7.29	7.81	8.38
6	Wadi Khulaqah	2.33	2.36	2.50	2.67	2.87	2.07	2.10	2.22	2.38	2.55
7	Wadi Qasabah	2.40	2.43	2.57	2.76	2.95	2.13	2.16	2.29	2.45	2.62
8	Wadi Al Huqqah	14.48	14.66	15.39	16.36	17.40	12.87	13.03	13.68	14.54	15.47
9	Wadi Bani Huwat	48.67	49.01	50.43	52.31	54.32	43.26	43.57	44.83	46.50	48.28
10	Wadi Thumah	1.26	1.27	1.32	1.38	1.45	1.12	1.13	1.17	1.23	1.29
11	Wadi As Sirr	24.74	24.93	25.75	26.83	27.98	21.99	22.16	22.89	23.85	24.87
12	Wadi Al Furs	8.61	8.69	9.02	9.46	9.92	7.65	7.72	8.02	8.41	8.82
13	Wadi Al Iqbal	19.67	19.94	21.03	22.49	24.05	17.49	17.72	18.70	19.99	21.37
14	Wadi Zahr & Al Ghayl	16.30	16.49	17.26	18.30	19.41	14.49	14.65	15.35	16.27	17.25
15	Wadi Hamdan	10.16	10.31	10.89	11.67	12.51	9.03	9.16	9.68	10.38	11.12
16	Wadi Al Mawrid	8.76	8.86	9.26	9.80	10.37	7.79	7.88	8.23	8.71	9.22
17	Wadi Sa'wan	10.05	10.13	10.47	10.91	11.38	8.94	9.01	9.30	9.70	10.11
18	Wadi Shahik	10.30	10.40	10.78	11.30	11.85	9.16	9.24	9.59	10.04	10.53
19	Wadi Ghayman	5.50	5.55	5.77	6.07	6.38	4.89	4.93	5.13	5.39	5.67
20	Wadi Al Mulaikhy	3.47	3.52	3.71	3.96	4.23	3.09	3.13	3.30	3.52	3.76
21	Wadi Hizyaz	2.64	2.68	2.83	3.02	3.23	2.35	2.38	2.51	2.69	2.88
22	Wadi Akhwar	2.45	2.48	2.62	2.81	3.01	2.18	2.21	2.33	2.50	2.67
Total		209.20	211.35	220.24	232.06	244.71	185.96	187.87	195.77	206.28	217.52

Unit: million cubic meters

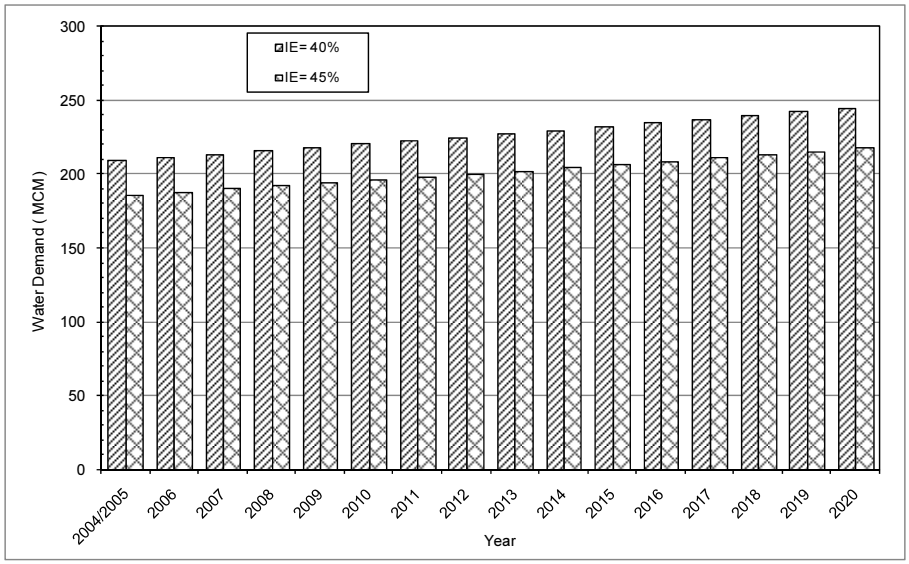

Figure 5.15 Irrigation Water Demand Projection Chart (IE=40% and 45%)

5.8.4 INDUSTRIAL WATER DEMAND

Studies and information of water consumption by industries is very scarce because most of industries are not connected to the public network and water for their consumption is supplied by own well, where abstraction of water is supposed to be unregulated and unrecorded.

TS-HWC (1992)[18] has used the industrial survey of 1986 to project the GVP of various industrial outputs in relation to the gross domestic product (GDP). Correspondingly, the average water requirement parameter was redefined from per unit of physical output to per unit of GVP.

WEC (2001)[19] has estimated the water demand using "Gross Water Requirement Method" to

calculate the water demand for the year of 1995. This method depends on identifying 1) the physical outputs of the different industrial products, and 2) the average water requirement per unit of physical output in various industrials sub sector.

The physical output data for various products in each industrial sub sector was taken from the physical output survey of 1995 for Sana'a Basin and water requirement of physical output were taken from TS-HWC (1992)[20]. Demand projection has adopted an alternative approach involving the use of GVP by industrial sub sector which was taken from The Sana'a Basin Industrial Survey for 1995. Average water requirement per unit of GVP was calculated converting growth rate for manufacturing and mining and quarrying which was considered the dominant industrial sector in Sana'a Basin.

Due to unsuitability of data, in this study, water demand projection was estimated based on estimations carried by WEC (2001). Assumed conditions were explained below:

- Growth rate adopted :
  1) Historical Growth Rate (HGR): growth rate observed during 2001-2005 according to The Socio-Economic Development Plan for Poverty Reduction 2006-2010 (DPPR) will continue in the future.
     - Mining and quarrying: 6.1%
     - Manufacturing: 4.7%
  2) Programmed Growth Rate (PGR): growth rate assumed according to the rates defined in the DPPR.
     - Mining and quarrying: 7.6%
     - Manufacturing: 8.4%
- GVP was based on values of 1995and projected up to 2005 as mentioned in a previous paragraph.

Results for projection on industrial water demand are shown in *Table 5.45*. Water demand projection chart is shown in *Figure 5.15*.

Table 5.45 Industrial Water Demand by Scenarios

Year	Historical Growth Rate			Programmed Growth Rate			Average
	Manufacturing	Mining and Quarrying	Total	Manufacturing	Mining and Quarrying	Total	
2005	4.75	0.00336	4.76	4.75	0.00336	4.76	4.76
2006	4.98	0.00357	4.98	5.15	0.00362	5.16	5.07
2007	5.21	0.00379	5.22	5.59	0.00389	5.59	5.40
2008	5.46	0.00402	5.46	6.06	0.00419	6.06	5.76
2009	5.71	0.00426	5.72	6.56	0.00451	6.57	6.14
2010	5.98	0.00452	5.99	7.12	0.00485	7.12	6.55
2011	6.26	0.00480	6.27	7.71	0.00522	7.72	6.99
2012	6.56	0.00509	6.56	8.36	0.00562	8.37	7.46
2013	6.86	0.00540	6.87	9.06	0.00604	9.07	7.97
2014	7.19	0.00573	7.19	9.82	0.00650	9.83	8.51
2015	7.53	0.00608	7.53	10.65	0.00700	10.66	9.09
2016	7.88	0.00645	7.89	11.54	0.00753	11.55	9.72
2017	8.25	0.00685	8.26	12.51	0.00810	12.52	10.39
2018	8.64	0.00726	8.64	13.57	0.00872	13.57	11.11
2019	9.04	0.00771	9.05	14.71	0.00938	14.71	11.88
2020	9.47	0.00818	9.48	15.94	0.01009	15.95	12.71

Unit: million cubic meters

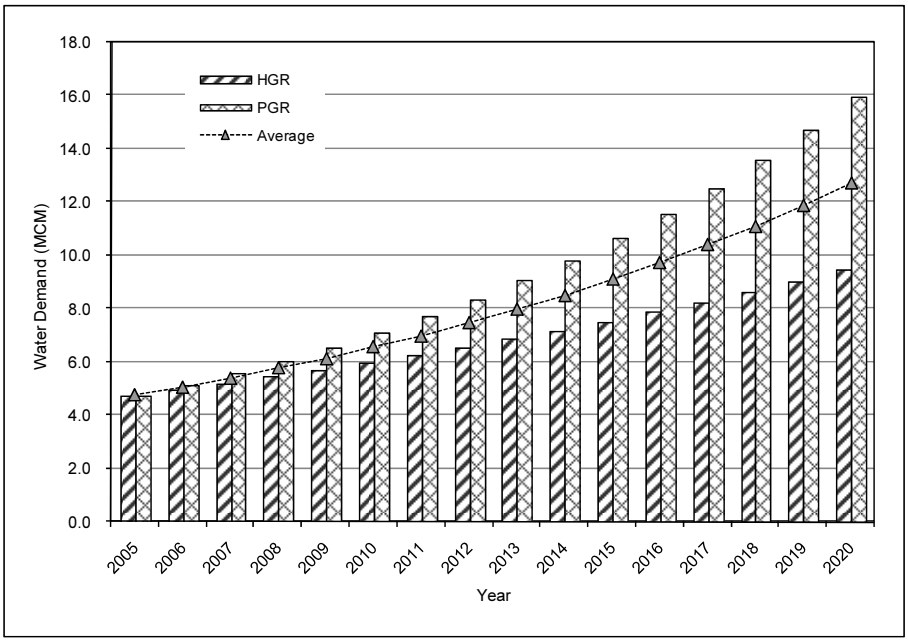

Figure 5.16 Industrial Water Demand Projection Chart

Projection for industrial water demand carried here, in this study should be handled carefully and it is recommended to treat it only as a roughly figure of industrial water demand. Needs to carry an industrial survey for Sana'a Basin hereafter, with the same approach used by TH-HWC (1992) and/or WEC (2001) to actualize the present condition and increase the accuracy of the result is recommended. This method used to estimate the water demand for industries at least is the one which matches with the actual condition of Sana'a Basin. Industries are not connected to the public water supply network, abstractions are unregulated and unrecorded and difficulties to have information of water consumption trough questionnaires surveys and so.

5.8.5 TOURISTIC WATER DEMAND

Suitable studies and/or information were not available for detailed demand projection of water for the touristic sector, which is increasing in number of tourists arrivals as shown in a previous paragraph. Difficulties to estimate water demand is seem where classified big hotels for example have pools and they are water supplied by their own wells, which water abstraction is not regulated or controlled. Quantity of water consumed by hotels connected to the public network is unknown even to ones supplied by private sources.

According to Statistical Year Book 2005, number of tourists' arrivals was increased from 72,836 arrivals in 2000 to 336,070 arrivals in 2005 and increasing peak was observed in 2004 in an average of 76% by the past year. Increasing for the period of 2000 to 2005 was in average 35.8% annually and for 2004 and 2005, increasing rate was about 23%.

Water demand projection for touristic sector in this study was calculated assuming the following conditions:

- It is supposed the increasing rate observed between 2004 and 2005 will not continue at the same rate in the future. It is supposed to decrease few percents yearly however; studies or official projections were not available. For the period of 2006-2010, DPPR has settled as an indicator for the tourism sector an average annual growth of 12% for tourists' arrivals and in this study, the same rate was assumed that it would continue until 2020.

- Due to a lack of information, water demand for touristic sector was estimated in this study, considering only on yearly increase of number of beds, and bed occupancy rate at 40%. Increasing rate of beds was settled at 22% according to the DPPR.
- Unit water consumption was settled according to hotel classification as 350 l/c/d for five and four stars hotels, 180 l/c/d for three to one star hotels. Quantities which were adopted from studies carried in Jordan for classified hotels depending on possession of pool. Water consumption in traditional hotels is supposed to be lower than other hotels and was settled at 120 l/c/d.
- It was assumed that all hotels of governorate of Sana'a are located within Sana'a Basin, around the City.

Table 5.46 shows the total number of hotel by classification and their capacity in Sana'a City and Sana'a.

Table 5.46 Number of Hotels and Capacity

Classification and hotel capacity		2003	2004	2005
Traditional	Beds	212	3,313	3,653
	Rooms	96	288	307
	Hotels	27	36	44
One Star	Beds	3,180	3,395	4,420
	Rooms	1,497	1,458	1,650
	Hotels	47	42	126
Two Stars	Beds	2,395	2,375	2,570
	Rooms	858	897	951
	Hotels	29	27	45
Three Stars	Beds	903	1,050	1,250
	Rooms	481	581	655
	Hotels	10	13	25
Four Stars	Beds	326	420	650
	Rooms	253	300	420
	Hotels	4	7	19
Five Stars	Beds	723	723	921
	Rooms	327	327	527
	Hotels	2	2	3
Total	Beds	7,739	11,276	13,464
	Rooms	3,512	3,851	4,510
	Hotels	119	127	262

Source: Statistical Year Book 2004, 2005 (CSO) Unit: number

Projection for touristic water demand is shown in *Table 5.47* and Projection chart is shown in *Figure 5.16*

Table 5.47 Touristic Water Demand Projection

Item		Unit	2005	2010	2015	2020
Tourists arrivals			336,070	592,270	1,043,782	1,839,501
Total number of beds	Traditional Hotel	no	3,653	9,873	26,684	72,119
	1 Star Hotel		4,420	11,946	32,286	87,261
	2 Stars Hotel		2,570	6,946	18,773	50,738
	3 Stars Hotel		1,250	3,378	9,131	24,678
	4 Stars Hotel		650	1,757	4,748	12,832
	5 Stars Hotel		921	2,489	6,728	18,183
	Total		13,464	36,389	98,350	265,810
Beds occuied per day	Traditional Hotel	no/day	1,461	3,949	10,674	28,847
	1 Star Hotel		1,768	4,778	12,915	34,904
	2 Stars Hotel		1,028	2,778	7,509	20,295
	3 Stars Hotel		500	1,351	3,652	9,871
	4 Stars Hotel		260	703	1,899	5,133
	5 Stars Hotel		368	996	2,691	7,273
	Total		5,386	14,556	39,340	106,324
Unit water consumption	Traditional Hotel	l/c/d	120	120	120	120
	1 Star Hotel		180	180	180	180
	2 Stars Hotel		180	180	180	180
	3 Stars Hotel		180	180	180	180
	4 Stars Hotel		350	350	350	350
	5 Stars Hotel		350	350	350	350
Water demand	Traditional Hotel	MCM/year	0.06	0.17	0.47	1.26
	1 Star Hotel		0.12	0.31	0.85	2.29
	2 Stars Hotel		0.07	0.18	0.49	1.33
	3 Stars Hotel		0.03	0.09	0.24	0.65
	4 Stars Hotel		0.03	0.09	0.24	0.66
	5 Stars Hotel		0.05	0.13	0.34	0.93
	Total		0.36	0.98	2.64	7.12

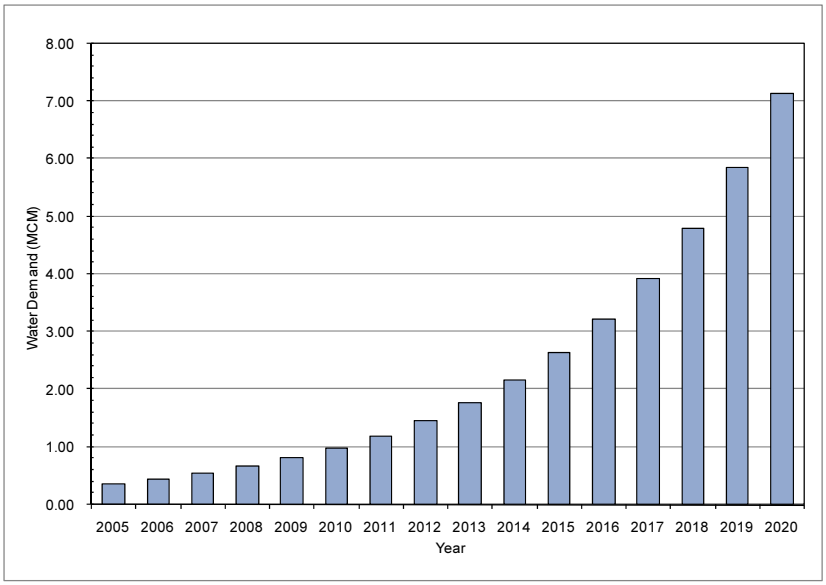

Figure 5.17 Touristic Water Demand Projection Chart

5.9 PROBLEMS AND RECOMMENDATIONS CONCERNING WATER USE

5.9.1 PROBLEMS TO BE SOLVED

Analysis and results of the present condition of water use in the Sana'a Basin was described in this Chapter. By the standpoint of water resources management, several problems became clear as mentioned below;

(1) Domestic Water Use

1) Urban Water Supply

- (Public Water Supply) Rate of Non-Revenue Water (NRW) for the year of 2006 was 39%. Detailed breakdown of NRW is unknown since studies and monitoring concerning quantity of water lost by leakege or illegal conections were not carried. Consumers' connection meters with zero-reading accounts for 12,000.

- (Public Water Supply) Number of water connections to the public network by sector is unknown. Type of water connection is divided as "Domestic" (domestic + mosque) and "Commercial" (commercial, industry, institution), according to the tariff system and detailed number of connnections and even the quantity of water consumed by each sector belonging to the "Commercial" type of water connection are unknown.
- (Public Water Supply) Periodical monitoring of water level, water quality of production wells is not carried adequately.
- (Public Water Supply) Inexistence of a detailed database with basic information of wells wich belongs to SWSLC.

- (Private Water Supply) Private suppliers supply the population not connected to the public network by tankers or private network, however, conditions such as location, scale, quantity and quality of water abstracted or consumed is unknown.

2) Rural Water Supply

- Detailed information regarding rural water supply is unknown for both private and public water supply. Supply system, basic data of the water source such as coordinates, production, consumption, number of beneficiaries, etc.

(2) Agricultural Water Use

- Furrow and small basin methods are the main irrigation methods adopted by farmers to irrigate the cultivated lands, which implies in a considerable quantity of water loss through infiltration and evaporation and run-off losses. Consequently, groundwater was over exploited.

- Leakages from conveying pipes are other factor for low efficiency irrigation water use, causing over exploitation of ground water.

- Groundwater abstraction is uncontrolled and unrecorded.

(3) Industrial Water Use

- Private wells provides water for industrial use and most of industries were not connected to the public network. Water abstraction is unregulated and unrecorded and therefore, detailed information concerning water consumption by industrial sector is unknown. Even the SWSLC does not know the number of industries connected to the public network

and the quantity of water consumed by the sector.

(3) Touristic Water Use

- Detailed information concerning water consumed by this sector is unknown due to an unavailability of previous studies. Private wells provides water for hotels and most of the hotels were not connected to the public network. Even the SWSLC does not know the number of industries connected to the public network and the quantity of water consumed by the sector.

(4) Wastewater Use

1) Wastewater Treatment Plant

- The Treatment Plant is actually working in an overloaded condition, the improperly treated water discharged directly to the wadi, and farmers are using this water to irrigate their lands. This water is also polluting the groundwater in the downstream.

- In 2006, daily quantity of sewage that has reached the Treatment Plant was in average 44,000 m^3/day. Considering the designed treatment capacity of 55,000 m^3/day and the high growth of the population of the city, the sewage production will overcome the treatment capacity in no time.

2) Industrial Wastewater

- Industries are not connected to the public water supply network, however most of then are connected to the public sewerage network. Industries discharges the wastewater produced directly to the network without any treatment due to inexistence of treatment facilities in the industries.

5.9.2 RECOMMENDATIONS

Understanding of actual water usage condition is one of the most important factors for an appropriate management of water resources in Sana'a Basin. By the viewpoint of actual water usage condition, items described bellow is recommended;

(1) Domestic Water Use

1) Urban Water Supply

- Reduction of NRW: quantity of water lost by leakage or illegal connections is very small, comparing with the amount used or wasted by agriculture. However, considering the situation of water resources, which is depleting year-by-year, reduction of NRW, is one of the important activities to save water.

  - Understand the quantity of water lost by leakages and illegal connections to the public network through studies and monitoring activities and elimination of illegal connections.

  - Periodical replacement or calibration of house connection meters and for meters settled on production wells.

  - Rehabilitation of the water distribution network. This activity is ongoing and it is expected some reduction of water lost by leakage however, periodical monitoring is recommended hereafter.

- Understand the detailed quantity of water consumed and water connection of each sector classified as "Commercial" connection.

- Continuous and periodical water level, water quality monitoring.

- Elaboration of a detailed database of all wells belonging to SWSLC and database of all monitored data such as water level, water quality and so.

- Registration and monitoring of all private water suppliers and water distribution network to understand the quantity of water produced and consumed by the sector.

2) Rural Water Supply

- Registration and monitoring of all domestic porpose wells to understand the quantity of water abstracted, consumed for an appropriate water resources management.

- Elaboration of a detailed database of all rural water supply projects with data such as supply system, well information, production, consumption, number of beneficiaries and so.

- Area-wide inventory survey concerning water sources for rural water supply

(2) Agricultural Water Use

- Implementation of high efficiency irrigation methods such as drip, sprinklers and bubblers. Leakage control of irrigation water conveying pipes and substitution of water conveyance method from open channel to pipes to reduce water loss caused by infiltration and evaporation. These activities are ongoing in some pilot farms; however, some difficulties due to a lack of detailed explanation and awareness are delaying the implementation schedule.

- Registration and monitoring of irrigation wells to understand the quantity of water abstracted to an appropriate water resources management.

(3) Industrial Water Use

- Registration and monitoring of industrial wells to understand the quantity of water abstracted, consumed by the sector to an appropriate water resources management.

- Elaboration of a database for all industrial wells.

(4) Touristic Water Use

- Understand the quantity of water consumed by the sector from the public network and private suppliers.

(5) Wastewater Use

- Reuse of treated wastewater for irrigation and for watering trees and green parks in the city. This activity is ongoing on Sana'a Wastewater Treatment Plant.

- Recycle and reuse of industrial wastewater through implementation of treatment facilities in the industries.

Put the industries under an obligation to build treatment facilities for a primary treatment and treat the wastewater before discharge to the public sewerage network.

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CHAPTER 6

CURRENT INSTITUTIONAL AND ADMINISTRATIVE FRAMEWORK

CHAPTER 6 CURRENT INSTITUTIONAL AND ADMINISTRATIVE FRAMEWORK

6.1 GENERAL (LEGAL AND REGULATORY FRAMEWORK)

Historically, institutional structure in the water sector has been fragmented, with many institutions implementing various mandates of water resource management specific to address their own missions and interests without efforts to coordinate and integrate them. With this institutional complexity coupled with their limited capacity, quasi-autonomous Project Management Units (PMUs), or Project Implementation Units (PIUs) were traditionally set up to implement projects, which often undermined the authority of line ministries and agencies.

This fragmented institutional structure in the country has hampered efficient and effective water resource management and strong needs to coordinate and integrate the sector has identified. It is also realized that, for integrated water resource management (IWRM), sector efforts to coordinate not only various ministries and institutions at national level, but also ones at basin and local level, is indispensable, as well as efforts to coordinate external assistant agencies (donor communities, private sector, and NGOs) and local communities. Thus, institutional development towards creating a strong water sector in Yemen becomes the first step to make efficient coordination and water resource management possible (NWRA 2006).

In this regard, National Water Resource Authority (NWRA) was established and intended as sole regulatory body, in accordance with the Republican Decree No. 154 of 1995. However, it had to be waited until issuance of the Water Law No. 33 of 2002 for creation of enabling legislative and juridical bases for institutional development in coordinated and integrated manners.

The Water Law No. 33 has been drafted since early 90s and approved by the parliament in 2002, after a long period of drafting, discussion, and consensus building in a complexity of existing institutional arrangement and interests of stakeholders in resource management and water right. Nonetheless, the Water Law is a key step to an effective resource management, and conceived as first and enabling legislation for IWRM in the country. Indeed, further legal and regulatory development has been drastically accelerated since ratification of the Water Law of 2002, with issuing a number of other official regulations such as Republican/Cabinet Decree, Prime Minister Resolutions, and Ministry of Water and Environment's (MWE) Decree to support and enforce the Water Law of 2002. At present, water resource management in the country and particularly in Sana'a Basin is implemented, regulated, and monitored with the following legal provisions (see *Table 6-1*).

Table 6.1 Major Legal Provision concerning Water Resource Management

	Date of Issue	Number of Law/Decree/Order	Law/Decree/Order
1	1995	Republican Decree No. (154)	on establishing National Water Resource Authority
2	Aug 2002	Water Law No. (33)	Water Law No. (33)
3	2002	Prime Minister Resolution No. (968)	regarding the Institutional Structure of NWRA
4	Sep 2002	Cabinet/Prime Minister Decree No. (263)	regarding Establishment of Sana'a Basin Commission (SBC)
5	Nov 2002	Cabinet Decree No. (343)	regarding Restructuring and Procedures in the Water Protection Zones
6	Nov 2002	Cabinet Decree No. (344)	declaring the Sana'a Basin a Water Protection Zones
7	Nov 2002	Cabinet Decree No. (345)	declaring the Sa'adah Basin a Water Protection Zones

	Date of Issue	Number of Law/Decree/Order	Law/Decree/Order
8	Nov 2002	Cabinet Decree No. (346)	declaring the Upper Wadi Rasyan in the Taiz Region a Water Protection Zones
9	Nov 2002	Cabinet Order No. (101)	to Prepare the Project of the Necessary Adjustment to the Water Law and Prepare Executive Regulations for the Water Law
10	Jul 2003	Prime Minister Decree No. (58)	regarding the establishment of the Sana'a Branch Office of NWRA
11	2003	Cabinet Decree No. (168)	regarding the Composition of Sana'a Basin Office
12	Apr 2004	Minister of Water and Environment's Decree No. (544)	regarding establishment of the Sa'adah Branch Office of NWRA
13	2004	Minister of Water and Environment's Decree No. (50)	regarding the establishment of the Hadhramawt Branch Office of NWRA
14	2004	Cabinet Decree No. (54)	regarding Amendment to the Cabinet Decree No. (168) of 2003 in relation to the Composition of Sana'a Basin Commission (SBC)
15	Oct 2004	Prime Minister Decree No. (277)	regarding the Regulation of the Activities and Transportation of Water Drilling Rigs within the Boundary of the Republic
16	Feb 2005	Republican Decree No. (22)	regarding some Changes in the Republican Decree No. (154) of 1995 Concerning the Establishment of NWRA
17	Apri 2005	Ministerial Resolution No. (50)	regarding Regulation of the Works of Sana'a Basin Commission (SBC)
18	Jun 2005	Minister of Water and Environment's Decree No. (68)	regarding the establishment of Hodaydah Branch Office of NWRA
19	Jan 2007	Republican Decree No. (41) of 2006	regarding the Adjustment of the Water Law No. (33) of 2002
20	Under Preparation		Executive Regulation to the Water Law No. (33) of 2002

Source: NWRA (2006)

In the following sections in this Chapter, some of major legal provisions to define legislative and institutional framework for water resource management in the county and Sana'a Basin are discussed with their uncertainties and constrains in regulation and monitoring, in particular, the issues concerning water right. Other important legislations governing the country's legal system and referring to water resource management and water right, such as Constitution, Civil Code, Islamic Law (*Sharia'h*), and customary law (*'urf*), are also reviewed to understand complexity of the concerned issues in traditional and tribal structure especially in north highland area of the country including Sana'a Basin. Another important legal provisions in the country's water resource management to be reviewed in this Chapter are "Local Authority Law (2000)" and its "Executive Procedures and Regulation (2000)", prepared prior to the Water Law of 2002. The Water Law of 2002, which was issued two years after the Local Authority Law of 2000, refers in many articles to Local Authority Law and Local Councils for water resource management. Local Authority Law defines functional responsibilities of Local Council and local organs of line ministries (including NWRA Branch Offices) in water management, and it plays an important roles and basis for integrated water management in decentralized principles enhanced in the country.

6.2 WATER LAW NO. (33) OF 2002 AND ITS ADJUSTMENT AND EXECUTIVE REGULATION

Water Law No. (33) of 2002 is very first and significant step in the direction of improved water management, providing "legislative, institutional, and administrative environment" enabling state's efforts towards integrated water resource management. The Law is currently supported by its adjustment ("Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No. (33) of 2002"). The Law shall be also enhanced by Executive Regulation, as bylaw to the Law providing regulatory and monitoring framework and procedure for its application and enforcement. The Executive Regulation is already drafted and sent to the Cabinet, yet not discussed and approved by the parliament. This section reviews those legislation conceived as administrative and institutional bases for the country's water resource management, considering its effects and shortcomings.

6.2.1 WATER LAW NO. (33) OF 2002

There has been a "legal vacuum regarding water rights and resource management" (Bahamish 2006). It comes at no surprise that parliament approval on the Water Law of 2002 was realized after more than 10 years discussion and negotiation in the circumstances that various institutions and authorities were carried over water management with their specific mandates. Moreover, complexity of interests of stakeholders in water rights, due to its economic and social value, and consideration on traditional and tribal rules on water management might have delayed the process, which are still remained as some of challenging issues for improvement of legal and institutional framework in integrated water resource management in the country based on the Water Law of 2002. However, there is no doubt that the Water Law is first enabling legislation and institutional back-up for the country's water resource management, particularly to some degree that it;

- Provides institutional and organizational framework at central and local levels for water management, as well as coordination mechanism which empowers decentralized institutions with stakeholder participation, with issuance of its Adjustment Law by Republican Decree No. (41) of 2007, defining functional responsibilities of MWE, Ministry of Agriculture of Irrigation (MAI), NWRA and its Branch Offices, Basin Committee, and community-based organization such as Water User Group (WUG), Water User Association (WUA) and Water User Federation (WUF);
- Introduces fair and equitable water management principles, defining priorities in water development and use;
- Redefines water resource as "the public property" which needs to be "administrated (registered and licensed)" by the State, hence, only use rights may accrue to individuals and entities based on the provision of the Law;
- Allows recognition of traditional water right unless use pattern is changed;
- Introduces principle of registration and licensing for wells, as well as for well drilling contractors and their equipment, which is further enforced by issuance of Prime Minister's Decree (277) regarding "the Regulation of the Activities and Transportation of Water Drilling Rigs within the Boundary of the Republic";
- Introduce participation and partnership model of water resources management with user communities through a system of self-regulation, instead of strengthening intervention, regulation and monitoring by the State;
- refers to declamation of "protected zone" by issuing another decree, to prohibit the erection of any structure for any industrial and agricultural development activities which could

increase the burden on the water reserves therein, which create administrative and organizational environment declaring "Sana'a Basin" as Protected Zone with Cabinet Decree No. (343) and (344) of 2002, and establishing and defining the functional responsibilities of Sana'a Branch Office of NWRA in accordance with Minister's Decree No. (58) of 2003 as well as of Sana'a Basin Commission (SBC) in accordance with Ministerial Resolution No. (50) of 2005;

- Provides clear rules that stakeholders can shared and internalize, such as the 500 meter spacing rule when constructing wells near existing ones; and
- Defines the essential (supporting) roles of public institutions in promoting stakeholder institutions, providing education, information, incentives, and legal resource in case of dispute.

The Water Law of 2002 is deliberately composed by nine main chapters, which could cope with major issues relating to water resource management. The following table (*Table 6.2*) shows the composition of the Water Law with description on the major issues dealt with in each chapter and sections.

Table 6.2 Contents of Water Law No. (33) of 2002

Chapter	Section	Brief Description on Major Provisions
First Chapter (Article 1-2) Nomenclature and Definition		
Second Chapter (Article 3-6) Objectives and General Principles		■ Article 3 sets out the goal of the Law as; developing and rationing of water resources, protecting water resource from depletion and pollution, improving the allocation of water and the operation and maintenance of water installation, and promoting the participation of beneficiaries in the management, development and conservation of the water resources from which they benefit. ■ Article 3 and 5 defines water as "public property" subject to a registration and licensing regime in accordance with the Law. ■ Article 6 provides that all potential beneficiaries of any water resources shall enjoy the right to benefit from them, if it does not harm the interests of the other beneficiaries and they carry out all the duties relating to the conservation and safeguarding of the water resource. ■ Article 6 also provides that the government intervenes to regulate the users' rights and responsibilities with the provisions in the Law and bylaws to execute its provisions.
Third Chapter Organization, Management and Planning of the Water Resources	**First Section (Article 7-12)** Organization and Management of Water Resources	■ Article 8 clarifies that the Republic shall be divided into Water Basins and Zones for water resource management. ■ Article 10 describes that "Water Users Association" may be formed for the purpose of involving the users in regulating water resources and in operation and maintenance of water installation, of which detail rules should be established in the Executive Regulations issued pursuant to the Law. ■ Article 11 determines that NWRA, in conjunction with the relevant authorities, is responsible for establishing Water Basin and Water Zone Committees to be operated under supervision of NWRA, of which responsibilities and composition are determined by executive regulation issued to the Law and Local Authority Law No. (4) of 2000.
	Second Section (Article 13-19) Water Resource Planning	■ Article 15 requires all government agencies and private and public legal entities to submit their project to NWRA for review and approval. ■ Article 16 describes that NWRA shall develop a water plan for each Water Basin and Zone, that becomes a part of National Water Plan, in consistent with the water policy. ■ Article 17 clarifies that NWRA shall formulates the foundation for water (management) planning in the Republic, based on; the assessment of the Water Basins and Water Zones, the general indicators of the water situation in the country, the trends in long-term demand for all types of water use and water budget. ■ Article 18 stipulates that the National Water Plan shall be issued by

Chapter	Section	Brief Description on Major Provisions
		Council of Ministers on the basis of presentation of NWRA, and in its execution, consideration of efforts to promote decentralization and public/beneficiaries' participation in the resource management must be taken.
Fourth Chapter Water Uses	**First Section (Article 20-21)** Priorities of Water Use	■ Article 20 puts absolute priority on drinking and domestic uses. ■ Article 21 describes thereafter water shall be allocated to the following purposes; livestock watering, use in public utilities, irrigation use, industrial use, and minimum environmental needs.
	Second Section (Article 22-24) Water Use Control	■ Article 23 regulates that water used for the following purposes should conform to the standards of NWRA, except in cases of necessity: water used for domestic purpose; water used in the manufacture and processing of medical materials; water used for livestock, irrigation, tourism and in hospital; treated wastewater used for irrigation and other purposes; and desalinated water.
	Third Section (Article 25-26) Sector Uses of Water	■ Article 25 clarifies that Ministry of Agriculture and Irrigation and its associated authorities shall operate and maintain their facilities, organize, rationalize and guide water uses assigned for irrigation in accordance with relevant laws and policies. ■ Article 26 clarifies that Ministry of Water and Environment and its associated authorities shall organize, manage and rationalize water uses assigned for the water supply and sewerage sector in accordance with relevant laws and policies.
Fifth Chapter Right and Licenses of Water	**First Section (Article 27-34)** Water Rights	■ Article 27 confirms that the right issued to use water entitles the holder of the right to use water in a way that does not conflict with the public interest or with the prevailing customs and tradition. ■ Article 29 confirms proper recognition to the tradition rights to rainwater harvesting and natural runoff flow to be used in irrigation. ■ Article 33 regulates that all users of groundwater from wells that existed prior to this Law shall register such rights with NWRA within three years from the date of the public announcement by NWRA. ■ Article 34 stipulates that NWRA is responsible to maintain a registration of water usage right.
	Second Section (Article 35-45) Licenses	■ Article 35 and 36 regulates that no individual, group, or entity of the government may dig water wells or water installation designed to hold back water without appropriate permit issued by the NWRA. ■ Article 38 regulates that the permits to use water can only be assigned to another person with the permission of NWRA. ■ Article 38 also regulates that permits issued are cancelled in cases of that; the permit holder does not commence the proposed water use within one year of the date of issuance, permit holder violates the conditions in the permit, there is an unauthorized transfer of the permit. ■ Article 40 determines that NWRA can cancel or amend the right to benefit from water during the determined periods, in the event that water in the well or the water installation is polluted or harmful to public health, and treatment of the water is not possible. ■ Under Article 41, the government has the authority to construct projects for water development and harvesting, and NWRA, if necessary, can review and revise the amount of water licensed depending on the overall water availability and use. ■ Article 42 regulates that the following activities can not be undertaken without prior permission of the NWRA, such as; drilling water wells, exploring for groundwater, and distribution of the water drawn from water wells through private supply network or by bottling.
Sixth Chapter Preservation of Water and Protection from	**First Section (Article 46-47)** General Technical	■ Article 46 determines that, with exception of works undertaken prior to the Law enforcement, the following undertakings are subject to the technical approval of NWRA 's standards such as; drilling of water wells, design of irrigation and water facilities, treatment and water desalination plant,

Chapter	Section	Brief Description on Major Provisions
Pollution	Standards and Specifications	protected areas of wells, floods and natural springs, drilling rigs inputs, drilling materials and well casing, pumps, and means of transmission and distribution of water for drinking purposes.
	Second Section (Article 48-53) Preservation of Water Resources from Depletion and Rationalization of their Use	■ Article 48 clarifies that the government, acting through NWRA and Ministry of Agriculture and Irrigation undertake the following tasks, such as providing support and facilities to farmers, encouraging them to adopt modern irrigation methods for more efficient use of water, building dams, and dikes and reservoirs for opium use of rainwater, providing such services as soil conservation and vegetate cover to conserve water and support and encourage community participation in management and conservation of water resources. ■ Article 49 also determines that specific regions (Water Basins and Water Zones) are defined as "Protected Basin" and "Protected Zone", to prohibit the erection of any structure or the development of any activities that increase the burden on the water reserves. Determination of Protected Basin and Zone shall be based on a decree issued by Council of Member replying on the minister's proposal, which also specify geological boundary of the area, duration of ban, and procedures and arrangement for its execution in consistent with the Law, as well as cancellation of all the licenses of work not commenced when the ban is announced and modification of the water volume utilized or its halt if it harms to the water resources. ■ Article 50 determines that NWRA permit specified volumes of groundwater or surface water to be pumped from one Water Basin or one Water Zone to another, if the conveyance will not have adverse effect on the water in the basin or zone on the condition that; the water will only be used for drinking or domestic purposes, there is a shortage of water in the recipient water zone or basin, there is coordination and consultation with all the relevant stakeholders, local authorities, water basin committees, and actual beneficiaries of the Water Basin from which the water is conveyed. ■ Article 51 and 53 clarifies that the employee assigned by NWRA to undertake studies and to take water measurements have the right to enter any privately owned land, farms and any of the commercial, industrial, or water installation that are subject to the Law.
	Third Section (Article 54-60) Protection of Water from Pollution	■ Article 54 determines that NWRA has the powers to protect water resources against pollution, to maintain water quality, to prevent activities that may lead to pollution or the degradation of the quality of water, and to prepare the procedures for regulating potentially polluting activities. ■ Article 58 clarifies that NWRA can modify any permit or license if it determines that the circumstances under which the license was issued have changed and the continuation of the permitted activities will cause environmental damages.
Seventh Chapter (Article 61-62) Protection from Floods		■ Article 61 and 62 specifies that the Ministry of Agriculture and Irrigation is responsible for flood control activities and policies.
Eighth Chapter Enforcement Procedures and Penalties	**First Section (Article 63-66)** Enforcement Procedures	■ Article 64 stipulates that the staff of NWRA has the status of judicial enforcement officers with responsibilities for enforcing the Law and regulations.
	Second Section (Article 67-71) Criminal Punishments	■ Article 67-71 stipulates that the sanctions for violating the Law and regulations includes both jail terms and fines. ■ Article 73 states that the Executive Regulation, being prepared, shall specify the rules and procedures relating to permits, their validity period, and fees to be charged by NWRA.
Ninth Chapter (Article 72-82) General and Final Provisions		■ Article 80 stipulates that where there is no stipulation included in the Law, the Civil Code and the principles of Islamic Jurisprudence shall be applied.

Although the Water Law of 2002 is a significant cornerstone to determine administrative and

institutional framework for country's water resource management, critical "legislative" shortcomings in its basic provisions has been pointed out since its ratification, as it is followed (World Bank, 2003):

- The Law does not provide for water abstraction measuring (and monitoring);
- The Law does not provide levying of water charges (in particular, for irrigation use);
- The Law allows well-digging/drilling up to 60m without a license, plus, it allows a deepening of any well by 20m once (who is monitoring?) without a license, which makes effectively wells up to 80m depth license-free; and
- The Law grandfathers all past water rights, plus gives water rights to wells drilled after the effectiveness of the Law. At the same time, each well may be registered within three years from the date of announcement addressed by the Authority (i.e. NWRA) after the issue of the Law, thus encourage farmers to drill as many wells as possible without license from now (2002) to the middle of 2005, when all wells have to be registered (this problem is continued by recent, due to unclearness of date of official announcement by the Authority). This would increase farmers' water rights, which – based on current abstraction – already exceed renewable resources by 100 percent to 150 percent.

It is widely recognized that those shortcomings in the basic provision of the Water Law of 2002 were brought by a group of some parliament members, through political maneuvering and lobbing to amend many of original articles which were already approved by the committee of parliament itself during parliament meeting. Such "legislative" shortcomings were well identified and recognized by the Cabinet Members as a risk to effects of the Law. Thus, in November 2002, immediately after three months from ratification of the Water Law in August 2002, the Cabinet ordered preparation of amendment to the Water Law of 2002 by issuing "Cabinet Order No. (101) to Prepare the Project of the Necessary Adjustment to the Water Law and Prepare Executive Regulations for the Water Law". This event indicates its importance and desire for its quick adjustment at the level of Cabinet, restraining some parliament members who manipulated parliament session meeting and brought critical changes on the original articles of the Law approved by the committee of parliament.

In spite of desire of the Cabinet to achieve immediate adjustment to the Water Law No. (33) after its first approval, however, it took a long period again for discussion, negotiation, and consensus building. Indeed, the amendment of the Water Law of 2002 was approved by parliament in January 2007, followed by issuing "Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No. (33) of 2002", of which effects and flaws are discussed in the following section.

6.2.2 Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No. (33) of 2002

Five years had been spent for amendment of the Water Law No. (33) of 2002 after Cabinet Order No. (101) to adjust the Law, to cope with legislative shortcomings in its provision mentioned above, such as for; 1) water abstraction metering, 2) levying a water charge for irrigation use, 3) banning exemption of license for drilling new well up to 60m and deepening any well by 20m, and, 4) regulating new well drilling during grace period of three years till enforcement of well registration from its public announcement. Draft amendment law to the

Water Law of 2002 was prepared to rectify such shortcomings, and approved by the Cabinet while waited for ratification by the parliament for its enactment.

However, its amendment law approved by the parliament, which is enacted by "Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No. (33) of 2002", has no additional and amended provision for water abstraction metering, nor for levying a water charge for irrigation use, although other shortcomings, such as exemption of license for drilling and deepening a limited depth, and new well drilling during grace period for enforcement, are reasonably resolved by amending original provision of the Water Law of 2002. Both water abstraction metering and water charge levying for irrigation use are, indeed, the major key undertakings primarily and urgently to be introduced in the country's water management for establishment of regulatory and monitoring mechanism and realization of demand control in the world most severe water scarcity situation.

It is self-evident again that cooping provisions on water abstraction metering and introduction of water charge for irrigation are refused by some of parliament members, and such provisions were refused and deleted from the original which is approved by the Cabinet. It is often mentioned that major counterforce in the parliament (i.e. members of parliament oppose such provisions) is dominant among the group of parliament members elected in highlands areas of the country, in particular Sana'a Governorate. The dominant economic activities in the governorate is agriculture as observed same at national level, cultivation of cash crops such as "qat" and grape, which requires relatively large amount of water for its irrigation, is the most flourishing in the country due to its natural conditions suitable for them. It is also due to large economic profitability of those cash crops comparing to others, locating in vicinities of the capital city, large cities and towns where the market values and economic benefit of those cash crops are considerably high. It is understandable that parliament members, who are elected and stand as representative of the civil society in the area, take precedence over economic benefit of the area and interest of the communities in production of such cash crop (in particular, cultivation of "qat") requiring larger amount of water, opposing state's interventions in water management through regulation, monitoring, and demand control over presently enjoying regulation-free water sources.

It shall not be also overlooked that traditional and "tribal" socio-culture in Sana'a Governorate is one of the most affecting factors against state's intervention in water management. Socio-cultural behavior and traditional customs based on the "tribalism" has been deeply entrenched by the generation over the generation in the highlands Yemen, including Sana'a Governorate. The society and community in the areas are unified and identified each based on the sense of belongings to their "tribal land". Thus, the land issue has been major conflicting factor among tribes. Prevailing customary law (*'urf*) in the areas interprets that traditional rights over groundwater are appurtenant to the land where it locates and that the overlying land owner (particular tribe dwelling over the land) is entitled to extract and to hold in a receptacle, such as well. According to the strong sense of tribal identification rooted in the land, and customary interpretation over groundwater rights entitled to the land owner, those tribal communities has owned, used, managed, and controlled the groundwater in their land in a very exclusive manner, eliminating interventions over the traditional rights by outsiders, in particular, regulation and monitoring on their groundwater sources by the state and its administrative organs. Those tribal communities and their leaders in the highland areas had kept some distances to the state politics in the past, their involvement in the national political entities has actively enhanced since the unification of north and south Yemen. Thus, many of parliament members and local politicians currently elected in Sana'a Governorates are traditional leaders of

those tribes and/or tribal alliances. Under the current political environment that conciliation of conflicting interests of the tribes respecting their unique traditional custom and tribalism, traditional water right for instance, is most affecting rein of the state politics, paradigm shifts in recognition and tribalism-oriented political willingness of those parliament members towards better introduction of state's intervention in water resource management could be rather challenging.

Significance of the amendment law to the Water Law of 2002 could be rather posed on the integration of newly established/reorganized ministries and their subordinate authorities into its administrative and institutional framework. MWE was established/reorganized in May 2003, while the Water Law was issued in August 2002, so there was no mention of MWE in the Law. Amendments to the Water Law were necessary because MWE was established later and its expected functional responsibilities were temporarily given to NWRA till its establishment/reorganization. The amendments provide the functions of MWE while defining NWRA as its executive and implementing authority. Also, the amendments provide for NWRA to be transferred under MWE as one of its authorities as well as General Authority for Rural Water Supply Projects (GARWSP).

Along with a Republican Decree issued in August 2004, regulatory ordinance of MWE stipulated in the amendment to the Water Law is considerably significant because it is the first step to start restructuring and coordinating water sector and its various authorities, corporations and agencies within one central ministry, that is MWE, while MAI is responsible for the irrigation sector and the Water Law and its amendment obliges both Ministries to cooperate and coordinate their activities in both supply and demand water management in a integrated manner.

6.2.3 EXECUTIVE REGULATION TO THE WATER LAW (DRAFT)

Apart from "legislative" shortcomings in the basic provision of the Water Law and its amendment law mentioned above, there are also several significant "regulatory" flaws for its effective execution and enforcement, which are described as followed:

- The Law does not clearly specify itself as the sole legal means to vest water right to beneficiary users among other significant laws referring (implying) to it such as Islamic Law (Sharia'h), Civil Code, and Customary Laws ('urf). It is one of hindrances in a legal sense to convince further registration and licensing for water wells and their users (owners) in accordance with the Water Law;
- Due to the same reason above that the Law fails to define itself as the sole legal means to manage water resources and water rights rather than other significant laws in the country, it does not provide legal mechanism to resolve the disputes over resource management and water rights and enforce punishment to the violator according to the LAW. Indeed, most of dispute regarding water resource management and water rights are resolved based on the interpretation by Civil Code and customary law ('urf) that "groundwater, particularly in rural area, is perceived as something that is attached to the land and that the overlying land owner is entitles to exact and to hold in a receptacle, such as a well". It also makes invalid the regulatory provisions for penalty and punishment set forth in the Law for its public compliance;
- Recognizing water resources as pubic property needed to be administrated by the States, hence, defining water right vested to individuals and entities as only usufruct, the Law also stipulates the right of the State to intervene the right of utilization of water if public interest so demands. However, the meaning of "public interest" is not clear, so that the rights of the States to intervene registered water rights of individuals and entities are limited in a

reality; and,

- The Water Law itself does not spell out the system and rules for maintaining such a register and the executive procedures for registering of acquired rights of benefit from water and amending such registration in accordance with its provisions.

In order to resolve those regulative flaws in the Water Law No. (33) of 2002 and its amendment law with provision of the procedures and conditions in detail for its execution and enforcement, "the Executive Regulation" to the Law has been prepared. The Executive Regulation" should have been issued by February 2003, as the Water Law (2002) refers to the Executive Regulation to be issued within six months after its issuance. However, it has been duly delayed for reorganization of the water sector in the state and establishment of new ministries and its associated authorities. On May 2003, a new government was established and former Ministry of Water and Electricity with other concerned ministries and its authorities were restructured under new MWE. Those changes in administrative framework in the water sector necessitated amendments to the Water Law of 2002 accordingly. In particular, some of functional responsibilities assigned to NWRA in the provisions of the Water Law (2002) should be reallocated to Ministry of Water and Environment. Moreover, a number of Republican Decrees issued during the restructuring process to transfer NWRA and other sector development authorities (e.g. rural water supply authority) from former Ministry of Electricity to MAI and eventually to new MWE required urgent amendment to the Water Law.

Thus, the requirements to reflect the amendments to the Water Law in accordance with restructuring of ministries and their authorities primarily delayed the preparation of the Executive Regulation as stipulated in the Water Law, and it has been further delayed due to the process for its amendment itself had been also delayed till the official gazette in January 2007 of "the Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No. (33) of 2002" because of the reasons described in the previous sections in this Chapter.

Thus, the current draft version of Executive Regulation to the Water Law, which was already approved by the Cabinet, has been prepared on the basis of the new administrative framework of the existence of new Ministry of Water and Electricity and Environment with its associated authorities executing the sub-sector development such as in rural and urban water supply, environmental protection, and resource management. However, it is said that the current draft version of Executive Regulation was prepared in 2006 prior to the parliament approval and finalization of the amendment law to the Water Law, in which some of crucial provisions in the original version such as introduction of water abstraction metering and water charge levying for irrigation use are denied, expecting original version of the amendment law approved by the Cabinet would be passed in the parliament. Thus, some of reviews shall be required prior to the parliament approval. Moreover, it is further anticipated that political pressure and opposition fraction among parliament members against state's intervention in water management manipulates some of provisions stipulated in the draft of Executive Regulation during the discussion in the parliament for its approval.

Due to the political sensitivities pertain to the Executive Regulation for the Water Law which could not be dealt in the Study as well as general concerns that its exposure prior to the parliament discussion would further confuse the situation, the draft Regulation becomes very confidential in custody of the Cabinet and access to it is quite limited. However, some of important issues in the provision of the draft Regulation (original approved by the Cabinet in 2006) were available, of which major concerns are as followed (Bahamish 2006):

(1) Authorization of the Water Law as Sole Means to Define Water Right

As one of regulative weakness of the Water Law mentioned above, the Law fails to clearly specify itself as the sole legal means to vest water right to beneficiary users among other significant laws referring (implying) to it such as Islamic Law (Sharia'h), Civil Code, and Customary Laws ('urf).

The Water Law defines water resources as the public property, administrated by the State. Hence, only use right (usufruct) may accrue to individuals and entities based on either on the provisions of the Law itself or on permits and licensing. The Law also recognizes and assures existing and traditional water right, but they are also subject to permits and licensing by the state (i.e. NWRA).

However, the legal framework and public consensus prevailed over the water right in the country, in particular highland areas including Sana'a Basin, is mostly based on Customary Law (*'urf*), which stem on the Islamic Law (*Sharia'h*). The Customary Law is unwritten and commonly defined as "the continued repetition of certain actions or practices by a collectivity in the conviction that they are legally binding". Since the Customary Law must adhere to the Islamic Law, the customary rules in a given region are simply an instrument to implement certain Islamic Law principles. The Customary Law and the Islamic Law both regards water resource as property of nobody (*res nullius or "Mubah"*), but it is appurtenant to the land located and overlying land owner is entitled to extract and to hold in a receptacle (ownership right), such as a well. Thus, it authorizes "the ownership right" over the water sources, which contradict to the Water Law allowing only "the use right" administrated by the state authority.

Another dominating legislation over the water right shall be Civil Code, which is often referred essentially as a present-day "modern formulation of the Islamic Law principles". It is also commonly called "the law of laws", since it contains the necessary provisions to guide the preparation of special laws in the various field of governmental sectors. The Civil Code recognizes the water right accordingly in a very similar manner to the Customary Law and the Islamic Law, defining in its Article (1163) that "land ownership is inclusive of what is above and beneath (hence water source) it to whatever height or depth is useful to enjoy it (the land)…", and in Article (1366) that "water is not owned as a private property except when transported or contained in receptacles, or the like … the drilling of a well to receive water is considered an appropriation by containment (hence ownership right is authorized), provided that the water comes from *res nullius* and it passed in the natural waterway".

As it is observed in the prior sections, arguments and manipulation of the critical provisions originally stipulated in the Water Law and its amendment law regulating water rights and efforts to limiting it to "usufruct" only, well indicates that many of parliament members insist on the traditional and tribal approaches in the Customary Law, Islamic Law, and Civil Code regarding groundwater "ownership right" as servitude property of the landlords, thus preventing any state's intervention on the issues.

Such predominance over custom and even in existing legal bindings in the country has protected ground water "ownership right" from any interference by the state, insisting the right in connection to the landlords that is the fundamental bases of their socio-culture, or "tribalism".

Draft Executive Regulation to the Water Law of 2002 copes very deliberately with the issues, and defines the Water Law as sole legal instrument to determine the water right accrued to beneficiaries only for its use (usufruct only), by separating the water "use right (usufruct)" from

land ownership established upon the custom and *Sharia'h*. Recognizing also the significance of the Civil Code in the country's legislative system, the Draft Executive Regulation stipulates;

"All beneficiaries and water right shall be subject to the rules that regulate it in the Civil Code and each case shall be treated separately subject to its legal status of the right of land ownership and water 'use right (usufruct)' and subject to *Sharia'h* principle or custom upon which such water right established."

According to the definition and principle above, Article (6) of the Draft Executive Regulation provides that any beneficiary and user of any resource of ground and surface water resource whether through succession or transfer or acquisition must satisfy and fulfill the following conditions and measures:

- That such water right has accrued to him or acquired by him through legal means in accordance with the Water Law.
- He must not inflict any damage whether direct or indirect with the traditional and non-traditional water resources and the environmental system related to it which may affect negatively upon the quantity sustainability of such resources or deterioration of its quality or which might cause obstruction or disruption of the equity of water distribution or which may damage the private and public interests at present or within the foreseeable future.
- The water user shall not sell his water right of dispose of it in a way that contradict or violate the rules of the Water Law and this Executive Regulation and that he must take into consideration of others attached to their water right or any other interest or servitude right recognized by law or by custom.
- The water beneficiary must bear the same duties imposed upon other beneficiaries in relation to protection from spate and floods and irrigation system and development and rationalization of water resources and its conservation and protection form overexploitation and pollution.
- The water beneficiary shall not exploit the groundwater resources except with special licenses permitting such action in accordance with the rules of the Water Law and this Executive Regulation.
- The water beneficiary accepts the right of the state to regulate the water beneficiaries' rights and duties in using their water rights and the state right to control and monitor the methods of exploitation of such water resources and its structures located in the private and public properties. The state can impose measures that include reduction of the allowed water to be utilized when such measures is necessary to be taken for the purpose of conservation of the sustainability of the water resources and for the fairness and equity of water distribution or when it is necessary to allocate water for drinking and for household consumption on the expense of other purposes.
- The water beneficiary must register his existing water right in present and which he might acquire in future and recording as such in accordance with system which NWRA prepares for his purpose in accordance with law and this Executive Regulation.
- The water beneficiary shall bear the responsibility and liability for any damages that he might inflict with the water and environment or with other interests and water rights. He shall pay the fines and the fair compensation in accordance with the Law and other prevailing laws.

As it is observed above, the Draft Executive Regulation possibly allows the water "ownership" right belongs to the land and overlaying land owners, stipulating in its provision as "all beneficiaries and water right (possibly including the water ownership right) shall be subject to

the rules that regulate it in the Civil Code". Nonetheless, those provisions in the Regulation, if all approved, could be robust and backstopping legal instrument to authorize right of the State to control water "use right (usufruct)" exclusively in accordance with the Water Law and its Executive Regulation.

Those provision and principle of the Draft Executive Regulation is based on the logic that separates the water "use" right intentionally from the water "ownership" right, the latter of which is firmly established and protected in the Civil Code, Customary Law (*'urf*) and Islamic Law (*Sharia'h*) interpreting it as the servitude property of the land and overlying land owners. This separation enables the creation of new concept in water right, that is "usufruct" (water use right), which is not interpreted and defined clearly in any legislation of the State even in the Civil Code, *'urf*, and *Sharia'h*. Thus, the Executive Regulation to the Water Law creates the precedent (a first established and sole legal provision) in the State's legislation and legal system that defines water "usufruct" and State's authority to control it, (Customarily and conventionally, the water use rights are defined only to the user who obtain water from his non-owned land, not to the land owner to use the water source located on his owned land.). Based on "the logic of separation", the Executive Regulation enables legislative and administrative environment to control water "usufruct" for the State's water resource management.

However, it shall be emphasized that those provisions in the Regulation reviewed above are still draft, which is approved only by the Cabinet prior to the parliament approval. "The logic of separation" could be key issues in the State's management of water resource in future, and political willingness whether to accept the logic would determine the effects of the Executive Regulation to the Water Law.

(2) Measures for Registering and Licensing of the Water Right

The Water Law No. (33) of 2002 refers in many of its provisions to its Executive Regulation that shall further provide procedures, measures, rules and conditions for registration and licensing of the water right. Those provisions in the Water Law referring to the Executive Regulations are, for example; Article (34) stipulating that "NWRA and all of its branches shall maintain a register of acquires rights of benefit from water. The Executive Regulations shall spell out the system and rules for maintaining such a register and procedures for registering and amending such regulation accordingly.", and Article (31) describing "The Executive Regulations shall spell out the cases when the Government may withhold the acquired rights of benefiting from water, if public interest so dictates or if the rationing of water use is required, with fair compensation to be provided in accordance with the effective laws."

Thus, without issuance of the Executive Regulation to the Water Law till present, the Law itself has no measures to effect and enforce some of key regulation for water resource management, such as registering and licensing the water right (although in the Water Basins declared as "Protected Basin" has coped with the issues and established their system and rules for registration and licensing in accordance with different Decrees issued for their establishment).

Therefore, one of major objective to develop the Executive Regulation to the Law is to define and provide administrative system and procedure with determination of conditions for the registration and licensing of the water right, as the Water Law admitting its necessity within six month of the issuance of the Law itself. The Draft Executive Regulation provides, in its Article (26), the following regulations regarding administration of the water right:

- The holder of water right must establish his water right and obtain certificate from NWRA entitling him of his acquired water right after the issuance of the Water Law.

- The beneficiary name must be included in the list of beneficiaries of water projects.
- If the water right whether through succession or transfer is before the issuance of the Water Law, such water right must be established by the beneficiary through evidencing documents or witnesses.
- Such traditional and acquired water rights shall be subject to rationalization. NWRA may limit or reduce the amount to be used by the beneficiary from each water resource or water establishment.
- In case of necessity to re-allocate water to existing holders of water rights for reasons that relate to shortage of water or to allocate part of it for drinking or household purposes, then the beneficiary must comply to use the allocated quantity of water for him and he is not allowed to expand in new other usage of water.
- Water right must be specified on a well known water source with defined location area or with defined boundaries and clear and well known geological aspect. Such information must be recorded in the certificate of the beneficiary of water right or in accordance with the traditional water rights through succession or transfer.
- The beneficiary of water right shall not be compensated from another water resource in lieu of water quantity re-allocated if the remaining quantity is sufficient to satisfy his water right for his specific purpose before the re-allocation or when such remaining quantity is sufficient to satisfy his water right in compliance with new methods and means imposed for the purpose or ratification of water.
- The beneficiary of water right shall be fairly compensated if he is prevented from his water right completely and absolutely whatever the reasons which called for such action of re-allocation of water
- Water rights shall be considered null and void and without compensation if any resource of water resource upon which such water rights was established had become dry for natural cases.

Moreover, the Draft Executive Regulation also regulates the MAI)to provide any guarantee for any new irrigation rights, which is the most contributing factor to impoverishments of the water reserve in the county. In the following provisions in Article (24) of the Draft Executive Regulation, provision of irrigation right by the MAI is regulated, of which function is assigned to limit granting irrigation right in accordance with the conditions of water use set out in the license issued by the government authority (i.e. NWRA):

- To survey and collect data on the existing water irrigation rights and to encourage its beneficiaries to have vertical agricultural expansion in the irrigated areas and to provide the necessary facilities to farmers in this respect and for that particular approach of policy
- MAI shall not give any guarantees for any new irrigation rights that arise from horizontal expansion in irrigated areas and to limit granting new irrigation rights to reclamated land in area where there is an excess of water availability or in areas where it is allowed to drill water wells to acquire water rights in accordance with the special system of granting licenses for drilling wells and water rights as provided for in the Water Law and this Regulation.

Those provisions seems to provide administratively and institutionally enabling environment for effective enforcement of registrations and licensing of the water right, with provision to define the water use right and the State's right to control over it. However, repetitiously it shall be noted that those provisions and the current version of the Executive Regulation is still draft, and subject to the parliament approval.

6.3 ADMINISTRATIVE AND INSTITUTIONAL STATUS OF WATER IN THE STATE'S LEGISLATIVE FRAMEWORK

As it is observed in the previous sections, legal and customary interpretation of water right has complicated the administrative and institutional environment for the State's water resource management through developing and enforcing relevant laws and regulations. It could be worth reviewing administrative and institutional status of water management in different but closely related legal sources which constitutes the basis of legal system of the country, in order to comprehend the complexity on the issues and to appropriate coping measures into Action Plan to be prepared under the Study.

The legal system in the country is based on three sources which are very closely related to each other, which can be listed in order of precedence as (Al-Eryani, et al., 1996); 1) Islamic Law (or *Sharia'h*), 2) legislations: the Constitution, Laws and Regulations, and 3) Customary Law (or 'urf).

National Legal system of Yemen has been primarily and subordinately developed under *Sharia'h*, as the Constitution stipulating in its Article (3) that "*Sharia'h* is the main source of all of the State's legislating (including the Constitution itself)". Thus, in principle, any legislation of the State can not be developed with legal provisions contradicting to principles of *Sharia'h*. However, some contradicting provisions in the laws are often identified as observed later, in particular, in a definition of water ownership in the Constitution.

The Constitution is standing as a prime component of legislation of the country, succeeding and comforting principles employed in *Sharia'h*. Laws become a secondary component of national legislation, which can be categorized into two types, "public" laws and "private" laws. The former of public laws have been developed and applied for the relevant government and specific public sectors, such as national administration and finance, agriculture, education, and water, in order to legitimatize administrative and institutional framework for the sector development and regulation. Along with this line, the specific sector laws and regulations, such as the Water Law of 2002 and its Executive Regulation, have been prepared and enforced. On the other hand, the latter of private laws have been developed and applied for the State as a whole, in both of public and private where the civil society is involved, in order to establish the norms and rules of the civil society in its varieties of activities and dealings. Thus, the prime foundation of the private laws can be referred to the Civil Code No. (19) of 1992. As observed earlier, the Civil Code also stems from *Sharia'h*, often cited as "Civil Code is essentially a present-day 'modern' formulation of *Sharia'h* principles". Thus, It can be said that the Civil Code has been developed, through transformation of *Sharia'h* principles into a modern form of legislation, in order to well establish norms and rules of civil society firmly based on *Sharia'h* principles in its activities and dealings. The Civil Code is also generally called as "the law of laws" since it contains the necessary provisions to guide the preparation of specialized laws in the various fields of sectors. The Civil Code is consisted of 1399 articles, of which 30 articles deal specifically with water and land. Finally the Customary Law (or *'urf*) composes third component of the legislative system, defining it as "the continued repetition of certain actions or practices by a collectivity in the conviction that they are legally binding". Being adhere to *Sharia'h*, the Customary Law is indeed an instrument to enforce certain *Sharia'h* principles. The Customary Law is rarely documented (i.e unwritten) and local variation is observed according to its physical, socio-economic, and socio-cultural conditions.

Reviewing legislative system specific in water resource management and water right in the country, it is obviously based on five major legal sources, namely; 1) Islamic Law (*Sharia'h*), 2)

Constitution, 3) Water Law (including its Executive Regulation), 4) Civil Code, and 5) Customary Law (*'urf*).

It is observed above that, due to a simple, but a supreme principle that *Sharia'h* is the prime foundation of the country's legislative system. Thus, it may be reasonable to conclude that all of those five major legislations share the common feature that they all originate from, and each of them forms an integral part of others, and/or any single legal provision in a specific laws can not be developed in a manner with contradicting; vis-à-vis the *Sharia'h* principles for water management and water right. However, some of differences and inconsistency in definition of the water right and determination of water management, and even non-existence of definition on the new concept in the water management, are observed among legislations.

The basic regulations and determinations of the water rights (thus, water management) are embodied in each of the Islamic Law (*Sharia'h*), the Constitution, the Water Law (including its Draft Executive Regulation), the Civil Code, and the Customary Law (*'urf*). There are a considerable number of regulations and determination of the water right provided in each of those legal sources, as well as in various forms and different aspects of it. Indeed, the water rights described in those various legal sources can be grouped into the following categories (Al-Eryani, et al., 1996);

- Water Ownership Right: which cover the legal status of water in general and the conditions for water ownership;
- Water Diversion Rights and Usufructs: which cover the basis for initiation of the diversion right and usufruct, changes in the right (by selling or transferring), and the conditions for losing the right;
- Water Use (Sharing) Rights: (which determine the right of users to share the water sources which owned by others) in terms of priorities of use, quantity of use, place of use, and burden-sharing during time of water shortage; and
- Water Administration: which cover the water allocation system, the operation and maintenance, the organization of users, quantity and quality protection measures, conflict resolving procedures, and law enforcement procedures.

Each of those four categories of water right regulation is reviewed in terms of the Islamic Law (*Sharia'h*), the Constitution, the Water Law (including its Draft Executive Regulation), the Civil Code, and the Customary Law (*'urf*), while identifying variations and differences, if any, in interpretation according to the legal sources above and analyzing effects and possible reconciliation of those variation and differences. The following reviews and analysis of the water right owes a considerable part to the technical report prepared and drafted by Dr. Al-Eryani et al. (1996), while incorporating additional reviews and analysis on the Water Law of 2002 and its associated Adjustment and Executive Law which are not issued at the time drafted the said report.

6.3.1 WATER OWNERSHIP RIGHT

There are two related aspects that determine the water ownership rights, namely; the legal status of water and the conditions on which such ownership is vested.

(1) The Legal Status of Water Ownership

According to *Sharia'h,* water is non-salable publicly owned commodity to which everyone has a right, in principle. That is, it is *res nullius* or *Mubah* (i.e. of nobody). Hence free access to water is the right of all people and community as a whole. However, as it is observed earlier in

the previous sections, this non-salable and public-owned principle is applicable only if it is not appropriated by carrying or transporting it inside a receptacle, such as well. Indeed, Sharia'h allows and authorizes private ownership of the water source when it is appropriated by means of receptacle.

Civil Code, which stems in *Sharia'h* principles, also supports public-owned principle of water, stipulating in its Article (1366) as "water is originally *res nullius* for all (*Mubah*)." However, its non-salable feature of water is true again only if the water is not appropriated, and provided that the water is needed for drinking and domestic use. In both Sharia'h and the Civil Code, containing water inside containers including as wells and pipes is regarded as means to own the water for selling and trading in general. Thus, in this case, the free nature of water access does not apply to all users, and also water is not *Mubah* for irrigation use if the new users will harm the senior benefactor.

In contrast to the definition on the legal status of water in *Sharia'h* and Civil Code, the Constitution determines the one as "property of the States", which oversees its utilization and exploitation in such a way that public welfare is served, stipulating in its Article (8) that "All types of natural resources and sources of energy, whether above ground, underground, in territorial waters, on the continental shelf or the exclusive economic zone, are property of the State, which assures their exploitation for the public welfare." Clearly, therefore, there is a clear contradiction between the principles on the legal status of water between the Constitution and Civil Code supported in *Sharia'h*, with the former defining the water resource as State's property whose use should be organized so as to serve public interest, while the latter regarding the one as *Mubah* with exception of which if it is appropriated and contained by means of receptacles to authorize private ownership.

The Water Law of 2002 has developed further deliberated interpretation of the legal status of water as "public property, subject to be administrated by the State", taking considerations on both of principles employed in the Constitution and the Civil Codes supported by *Sharia'h*. Without clearly referring to the State's ownership of water resources defined in the Constitution, but provably relying largely on it in implicated manners for determination of its own definition of the legal ownership of water, the Water Law stipulates in its Article (6) that "The water is principle permissible for all and does not possess a ownership except by means of conveyance or acquisition or within their rule and it is the opium to be secured by what is similar to it.", and in Article (5) that "The stream of the valleys are considered the common property of all the beneficiaries, all the water installations and wells which are which are erected by the State are considered public property, and notwithstanding their ownership, they are subject to the system of registration and licensing in accordance with the provision of this Law.". This principle of "water as public property, subject to the State's administration" is further supported by the provision in Article (6) of the Water Law describing "Each beneficiary of any of water resources enjoys the right of utilization … The State intervenes to regulate the right and duties of utilizing the water in accordance with the provision of this Law and the bylaws and rules that execute its provisions."

(2) Conditions for Water Ownership

According to Sharia'h, four types of water sources are distinguished, as followed; 1) water enclosed in "man-made" receptacles (containers and buckets), 2) water in wells, cisterns and springs, 3) water in small rivers or stream which belongs to a specific community, and 4) water in great rivers. Thus, as it is observed, unless the water is appropriated by placing it inside a privately owned containers or receptacle which sets it separate from the source, then it can not

be owned. This rule is explicitly stated in Article (1336) of the Civil Code referring "water is not owned as a private property except when transported or contained in receptacles, or the like … the drilling of a well receive water is considered an appropriation by containment (and hence an ownership), provided that the water comes from *res nullius* and it passed in the (natural) waterway."

In the Constitution, private ownership of water is not authorized, defining water as State's property (Article 8). Thus, distinctive contradictions are again identified in the definition on the condition to vest private ownership of water between the Civil Law and the Constitution. Determining all the natural resources are the properties of State, it is assumed "constitutionally" that the on-going exploitation and utilization of water resources is a kind of concession subject to permissions and regulations by the State.

Consistent with Article (8) of the Constitution, the Water Law further determines that only use rights (usufruct), notwithstanding their ownership, may accrue to individuals and entities based either on the provisions of the Law itself or on permits. Thus, the Water Law draws a distinction of the water use right (usufruct) subject to the State's administration according to the type of water resource and uses between;

- Rights to use water in a aquifer or a reservoir, which shall be authorized by NWRA and shall remain appurtenant to the land in use of irrigation right or to the use to which the water was allocated;
- Traditional rights to the water use spate water for irrigation, which shall be exercised according to regional traditions and customs, but without any administrative interference, these rights are not subject to prior authorization; and
- Traditional rights to the water of natural springs and to the base flow existing prior to the entry into force the Water Law.

These rights are preserved insofar the purpose of use of water for irrigation does not change, but are subject to registration with NWRA. There are a number of provisions in the Water Law and its associated Adjustment and Executive Regulations to determine those regulations.

6.3.2 WATER DIVERSION AND USUFRUCT

At first, distinction shall be made between water use diversion and usufruct right. On the one hand, "diversion rights" can be referred as the traditional rights accrued to an individual, a family, and a tribe or collectivity taking over the centuries by centuries when they began to utilize the water to develop agricultural land without objections or conflict with others, no interruption in their use of water for appreciable period of time. Therefore, although not necessarily, these traditional diversion rights are often associated with or servitudes to the land owned by those right holders. These rights has been well established in the country over the centuries, in particular for run-off management of surface water (also applicable to water well management), with well establish recognition of each right and compliance of traditional rules and regulations among communities. One of outstanding customs in the diversion right could be the fundamental rule governing surface (spate) water irrigation that grants the upstream riparian a priority right to irrigate his land. Downstream riparian users may not be denied the right to surplus water after utilization of water at sufficient amounts in which upstream riparian satisfy. This upstream/downstream rule has been practiced in many areas of the country, with development of other consent and penalties.

On the other hand, "water usufruct" is the right to utilize water accrued through a permit system with a concession relating to its utilization and /or its development awarded by the government. In contrast to water diversion right which exists in customs and traditions, therefore, water usufruct is a relatively recent development or approach of water right. They may often exist in the countries in which the water is declared as State's property to be managed based on the State's permits and regulations. "Water usufruct" shall be also clearly distinguished from "water use (sharing) right", while the latter often defines social norms in that the owner of the water source share it with others or the right of individuals or entities to obtain water from that source or the communal sources, whether it is practiced customary or regulatory.

As mentioned earlier, the following four aspects determine the basis and condition of diversion right; 1) initiation of the diversion right (the right to divert water from the source), 2) change in the right (by selling and transfer), 3) protection of the right (protection zones), and 4) losing right. The following section discuss each of those factors embody the diversion right in different legal sources.

(1) Basis for Initiation / Acquisition of Diversion Right

Basis of initiation and acquisition of the diversion right and usufruct applied in *Sharia'h* is well observed in the Article (1367) of the Civil Code, stipulating "*res nullius* water is the right of whoever reaches it first, and is a quantity which suffice him, even if taken from with a property (of others). It is prohibited to enter a neighbor's property to take water except by permission of the owner or his consent or by custom, and it is not allowed to harm the owner as a result of taking the water from his property except (if taken) for human drinking or to clean-up for praying."

Therefore, this article determines that:

- And "non-appropriated" water may be claimed for appropriation, even if taken from within a priority of others (private or public);
- Claims are recognized by seniority (first in time, first in service);
- The quantity of claim is determined by sufficiency to the appropriator;
- It is prohibited to enter a neighbors land to take water without the owner's permission or consent, unless such entry is based on a custom, and;
- Any diversion of water from a source should not cause any harm to existing users/owners, unless the water is taken fro drinking or to clean-up for praying.

Since the above article does not distinguish between surface and groundwater, it appears any water source can be applicable, whether it is a cistern, from a spring, or from an aquifer. However, the diversion right and usufruct of groundwater can be initiated and acquired by purchasing land and drilling a well as it observed in Article (1366) of the Civil Code in the above section. Moreover, as it is the conviction of the most people, Article (1163) of the Civil Code vests the owner of a land full control over exploitation and development of all resources located above and beneath the land to any "useful height and depth", describing "land ownership is inclusive of what is above and beneath it to whatever height and depth is useful to enjoy it (the land). It is permitted, by agreement, to separate the ownership of land surface from the ownership of what is above and beneath it, provided that no contradiction occurs with the regulations outlined in the law."

In the Constitution, however, all the natural resources, including surface and ground water, are determined as the property of the State, which is responsible for ensuring their optimum

exploitation in the public interest (Article 8). Again, a significant contradiction with the Civil Code is observed, which authorizes the exclusive right granted to the land owner over development and exploitation of natural resources located on and under the land, including groundwater. Furthermore, Article (18) of the Constitution states that "the awarding of concessions related to the exploitation of natural resources and public facilities cannot be done except by law. The law defined the situations and ways to grant the State's property freely, and the underwriting of its transferable property, and the rules and procedures to regulate this…" Thus, the Constitution recognizes a necessity to develop particular laws to regulate the awarding of concession to exploit State's natural resources, viewing the on-going exploitation of the resources as a kind of "concession".

The Water Law of 2002 might have been developed, based on the concept of "concession and "regulation by the State" employed in the Constitution, recognizing and allowing those traditional diversion rights. Those traditional diversion rights and usufruct has accrued to an individual, a family and a collectivity in benefiting from use of rain water, spate water, spring water, and water from shallow well and hydraulic structure. The Water Law regards, in principle, these traditional diversion rights are subject to the liens and servitudes which are connected them, determining in its Article (29) that "Traditional usufructs and the rights associated therewith, prior to the issuance of this Law, in the water of springs, valleys, natural streams and wells shall remain reserved without prejudice to the registration principle provided that they shall remain assigned for the purposes specified thereto and in case of their transfer to another owner, such rights shall necessarily be transferred to the new owner and in case of the division of the land which is making use of water, the water shall be distributed as per the areas of the plots resulting from such division." In the Water Law, however, these traditional diversion rights for the use of rain and spate water are recognized only as long as the water is used for irrigation purpose and in connection with agricultural land, regulating in its Article (28) that "The traditional right of utilization from the harvest of rains and water of floods flowing naturally shall be taken into consideration, as regards their use for irrigation and connection with the agricultural land benefiting from it. There shall also be considered in their rights the characteristics of the regions having connection with the customs, traditions, the established system of irrigation and observed in each of regions of the Republic." In the Water Law of 2002, therefore, for all other existing but not traditional, water diversion right and usufruct are subject to registration with NWRA.

(2) Changes in the Diversion Right and Usufruct (Selling and Transfer of Right)

In *Sharia'h,* there are two view points regarding the appurtenance of water rights to land. One group of Islamic school considers that the water right (diversion right and usufruct) belongs to the land itself not to the land owner. Hence, the water right is inseparable from the land and is included with it whenever the land changes owners (by selling or inheritance). This inseparability applies even though a land owner may not explicitly mention the transfer of the water right with the land in the purchase document. The other group of schools requires explicit statement of the transfer of the water right with the land. Otherwise, the water right remains a property of the original land owner even through the land is sold.

As it is observed in the prior section, the Civil Code defines that land ownership includes the water right, which can be permitted, by agreement, to separate from land ownership, referring in its Article (1163) that "land ownership is inclusive of what is above and beneath it to whatever height or depth is useful to enjoy it. It is permitted, by agreement, to separate the ownership of land surface from the ownership of what is above or beneath it, provided that no contradiction occurs with the regulations outlined in the law."

However, the Civil Code also defines that the irrigation right is a type of servitude to the land ("Servitude Right"). Hence, it is inheritable from benefactor to successor(s) and its use may be written out in wills. Nonetheless, this right cannot be sold separate from land, neither can it be conceded or rented except if this is in accordance with a recognized custom, defined in its Article (1370) that "the right to irrigate is inheritable and its use may be donated in wills, but it cannot be sold except with the land, neither can it be donated or rented except according to an established/recognized custom."

Determining any natural resources as the property of the State, the Constitution defines the right to utilize and develop water resources (i.e. water diversion right and usufruct) as "concession" vested to individuals or entities, of which terms and conditions are regulated by specific laws such as the Water Law. Thus, transferring and selling of these rights of concession vested by the State may not also allowed and regulated by the specific laws concerned.

The Water Law of 2002 and its amended Law allows traditional water diversion rights except for irrigation use accrued prior to the execution of the Law, so that the rights allocated for the purposes set for them according to the custom and applicable laws without application of the Law (Article 29). It also refer that, in the event that they are transferred to the ownership of others, these rights shall then be compulsorily transferred to the new owner, and in the event that the land benefiting from the water is partitioned, the water shall be apportioned according to the areas of the parts resulting from the partition. Therefore, these traditional diversion rights are regarded as servitudes of the land.

In the Water Law of 2002, the traditional water diversion rights and usufructs for irrigation are preserved insofar the purposes and condition (amount) of use for irrigation does not change, but are subject to registration with the State. All other diversion rights and usufruct such as for any groundwater use, whether these rights are acquired prior to the issuance of the Water Law or in future, becomes subject to the licensing and regulation by the State. Terms and conditions for such concessions of water diversion rights and usufruct shall be specified by the relevant authority (i.e. NWRA) and each of licenses issues, as the Article (37) of the Water Law providing that "No beneficiary may exceed the quantities or the purposes of use or any other technical specifications determined by the Authority. He must also abide by the conditions specified in the license, and the bylaw shows the details necessary for execution accordingly." Since

Although the Water Law of 2002 is not declaring the water resources as the State's property, in consistent with the Article (8) and (18) of the Constitution, the Water Law affirms the water resources as public property, administrated by the State, so that only usufruct may accrue to individuals and entities based on either on the provision of the Law itself or on permits issued by the State. Thus, it is assumed that the Water Law does not allow the selling of such rights vested by the State and transferring of them without regulation and monitoring by the relevant authority. However, there is no clear provisions in the Water Law of 2002 and its amended Law that refer to regulation of selling and transferring of such right vested by the State, although the ones for traditional diversion rights except for irrigation right are clearly stated in Article (29). Therefore, the Executive Regulation of the Water Law, which is still under draft, shall take into consideration these provisions for prohibition of selling such water usufruct, period of the rights vested, and amendment or renewing the licenses in such cases of changes and apportioning of land ownership, as the Article (34) to the Water Law referring that "The Authority and all its branches shall keep a register for the rights of utilization acquired on the water, and the bylaw shall show the system and rules for keeping this register and the procedures for entry and their amendments."

(3) Conditions for Losing the Diversion Right and Usufruct

In *Sharia'h*, defining the water diversion right and usufruct is appurtenant to the land, it cannot be lost. However, the actual use of these rights may cease when:

- The land is washed away or is buried under a thick sediment cover which was deposited by heavy floods. Both cases are common for lands along wadi channels or the inter-mountain wadis;
- The intake structure are destroyed and washed away;
- The beneficiary himself abandons the use; and,
- The source of water (well or spring) is depleted.

Allowing traditional diversion rights, except for irrigation, accrued prior to the execution of the Water Law, the Law preserves their customs relating transferring and ceases of these rights according to the recognized Customary Law unless the purposes and amount of water use stays as set originally set by the custom. The same principles are applied to the traditional diversion rights for irrigation, but subject to the registration with a relevant authority of the State (i.e. NWRA).

The usufruct vested in the form of licenses in accordance with the Water Law for all other water resources, in particular, for water well, are cancelled by the force of the Law in the following cases stipulated in its Article (38):

- If the licensee did not commence the drilling works one year from the date of issue of license;
- If the licensee used this license for a purposes other than that for which it was granted:
- If he violate the conditions stated in the license;
- If he assigns this license to others whether in return for a change or not, without the approval of the Authority. The bylaw shows the cases where it is possible to accept such an assignment. The Authority has also the right of periodic review of such a license according to the rule set for this purpose. Based on justifiable reasons, the license may be renewed for one time for a further period of three months, and the period may be extended if these reasons continue to exist.

The license of the well be also ceased in cases that pollution or deterioration of water is observed, as Article (40) of the Water Law regulating that "…, the Authority may cease the right of utilization if it is evident that the water of the well or the water installation is polluted, thus harmful to public health and environment, and the impossibility of treating that in accordance with a laboratory report by the competent authority". The water usufruct vested in the form of license may be also suspended, in accordance with the provisions stipulated in the Chapter Six of the Water Law referring to "Enforcement Procedures", when the right holder provides false information to the Authority at the time of application, uses the water for purposes other than those authorized, violates the technical conditions attached to the water right, wastes or misuse the water and fails to comply with the directions issued by the Authorities, transfers the right to another person without authorization, and so forth.

Furthermore, these water rights may be revoked and curtailed by the State in the public interests, or whenever such action is necessary to conserve water use, as the Water Law stipulating the right of the State to intervene to regulate these water rights with issuance of its Executive Regulation in its Article (31), referring "The Executive Regulation of this Law determines the conditions which make it possible for the State to lay hands on the right of utilization of water if

the general interest so demands or the need to rationalize the uses of water, along with the fair compensation to the beneficiaries according to operative laws."

6.3.3 WATER USE (SHARING) RIGHTS

Water use (sharing) rights refer to the regulations which are imposed on the water diversion right and usufruct when used. Four such regulations may be distinguished, such as priority of use, quantities of use, place of use, and the burdens on the various users under conditions of shortage or scarcity.

(1) Priority of Use

According to *Sharia'h*, first priority of water use is given to drinking and domestic uses (human drinking then animal drinking followed by domestic use). Denial to share the water with people and animals are customarily against the social norm, often regarded as sin or "*haram*". Second priority is given to irrigation use. The various uses and sharing must be reasonable, within the accepted norms of the community, and must cause no harm to others or to the owner of the water right out of which water is drawn. Social norms in water use and sharing is well established, as one of Islamic schools defines that "a person who bail out water for his own drinking or for his cattle or to wash his clothes, either from wells or springs cannot be prevented from doing so. He has right to access the wells which are in privately owned farms, whether walled or fenced or not, be it in the urban or rural areas. It is a sin to prevent him provided that he does not cause any harm.

The same order of priorities and social norm in water use and sharing is also stated in the Civil Code, in its Article (1367) referring to "*res nullius* water is the right of whoever reaches first (first come, first served) and in quantity which suffices him, even if it is taken from within a property (of others). It is prohibited to enter a neighbor's property to take water except of the owner or his consent or custom, and it is not allowed to harm the owner as a result of taking the water from his property except (if taken) for human drinking or to wash-up prior to praying".

In the Water Law of 2002, first, indeed, absolute priority is given to drinking water and domestic use (Article 20), allowing allocation of water also for the following purposes, without prejudice to the Article (20), such as purposes for animal drinking, for public utilities, for irrigation, for industrial, and for minimum environmental requirement. The Water Law of 2002, otherwise, does not spell out social norm for the holders of water utilization right in sharing the water resources to others, to which degree and rules may vary depending on the purposes of use for each well and duly determined in registering and licensing by the Authority in accordance with the relevant provisions to be guided by the Executive Regulation of the Law.

(2) Quantity of Use

According to *Sharia'h*, water is the gift of God. Hence wasteful use of water is a sin or *haram*, while water rationing is a virtue. Consequently, water over-use is subject to community's intervention to abate it. The quantity of use, for spate irrigated land, is equivalent to a layer of water whose depth is about the height to an ankle. Also, Article (1371) of the civil law gave the persons whose land is located in the same watershed along the same channel as that of an upstream land owner, the right to the surplus water which exceeds the need of the senior user(s) upstream, referring "a riparian cannot be denied his right, which is the surplus water after the senior user gets sufficient water. Sufficiency is to be assessed on the basis of either that was sufficient at the time the land first reclaimed or (if this use rate is known) what is sufficient at th e time it is being irrigated." Thus, the quantity to divert should be assessed on the basis of the quantity used when the land was first reclaimed, otherwise it should be estimated according to

the needs when it began being irrigated.

As it is observed in the previous sections, the Water Law of 2002 recognizes these traditional diversion rights of surface water for irrigation use subject to the registration with the Authority, and preserves these right insofar the purposes of use and "quantity" of water for irrigation does not change. Otherwise, the Authority determines and spells out the amount and purposes in utilization of water sources in the license, which shall be complied with all beneficiaries, regulating in the Article (37) that "no beneficiary may exceed the quantities or the purposes of use or nay other technical specifications and determined by the Authority. He must also abide by the conditions specified in the license, and the bylaw shows the detail necessary for execution accordingly".

(3) Places of Use and Sharing

The significant issue in determination of places of use and sharing water is whether the water can be utilized and shared wherever the holder of the right desires. The issue is indeed related to the principle in the custom of "the appurtenance of water right to the land", and also depends on the type of water sources.

For surface water, the traditional water diversion right, according to Sharia'h, is considered a right servitude to the land. Thus, a person can not take "his water" to another land if his action will harm another water right. Article (1372) of the Civil Code stipulate supports this principle, stipulating that "… a person is not allowed to draw water to irrigate land which has no right…if such drawing harms those who have a water right (e.g. by drying up their channel)." Thus, in principle, surface water utilized for irrigation of the land where the source located, can not be transferred to other land.

However the appurtenance of water right to the land introduces us to what is known as "the Servitude Right". The Civil Code provisions deals with irrigation as the Servitude Right. In essence, a Servitude Right is a kind of obligation or liability on one property to serve or benefit another, like the right of a peace of land to get irrigation water from a given source, or to have its water supply run over a neighbor's land, or to discharge its drainage water into a given drain. Those obligation and liability in the Servitude Right often include sharing duties of water to other parties in different locations. Analysis on these Servitude Right is further significant when considering opportunity and feasibility to transfer surface water (and ground water) of surplus from one place to the others where the water resource is scarce and in demand for drinking use.

For ground water, however, there are no restrictions on the place of use provided by the Customary Law and *Sharia'h*. It is customary allowed in all over the country to pump ground water from one wadi to use it in another. Thus, there seems to be no customary restriction on the place of use of a ground water supply. Nonetheless, there were several cases for NWASA (National Water and Sanitation Authority) dealing with urban water supply, that local communities claim that they will be harmed by the large water transferred to the City, both parties ending up in a legal conflict.

In the provision of the Water Law in its Article (50), the Authority (i.e. NWRA) can issue license for pumping specific quantities of ground water or surface water form a certain basins or area and transferring it for other basin or areas, subject to elaborated study on the potential of the resources and needs, and agreement of the Minister and approval of the Council of Minister, on the following conditions:

- That the transfer process does not prejudice the need for drinking and domestic use, provided that no future detriment be suffered to the quantity and quantity of the water in the basin from which the water is transferred;
- That the purposes for transfer of the water is for drinking and domestic use in the receiving basin;
- That the water stock in the basin to which the water is transferred is inadequate to satisfy the needs due to scarcity of water or its being not suitable for human consumption, after stopping all other users;
- That consultation and coordination be made with the local authorities, basins committees and the actual beneficiaries in the basin from which water is transferred;
- That if damages are sustained by the beneficiaries as a result of transfer of water, such damages should be fairly compensated for once only, and;
- That under all circumstances, and in the event of multiplicity of sources from which water can be transferred and closeness in economic cost of transfer from them or some of them compared with cost of transfer from a single source, then the required quantity should be transferred should be shared between more than one source to bring about a balance in distribution of impact on the sources.

Although the above provision does not spell out the transferable water sources located in whether private or public land, in accordance with the Article (31) of the Water Law to determine the right of the State with issuance of its Executive Regulation to intervene the right of utilization of water for the general interest, such transfer from private can be also possible in legislative points of view.

(4) Burden-Sharing among Users

In *Sharia'h*, if the water is privately owned by a single person then he has the right to utilize it as he wishes, while if owned by a group or a large number of people then it must be equally divided among them in proportion to their share, of which allocation may be either of the basis of time shares for pumping or appropriate opening to the water channel by share holders. In both cases, however, there is no limitation of as to the quantity that may be extracted from the water source (well).

The Water Law and its Executive Regulation regulates the conditions including the amount of water to be utilized on each of water resource and water installment which is subject to the licensing by the State. Then, the Water Law affirms the "self-regulating management" by the user communities themselves as the most promising solution to come to grip with the current indiscriminate exploitation of the water resources, introducing the community-based organization such as WUG , WUA, and WUF. The Article (10) of the Water Law of 2002 calls for the establishment of associations, groups, or committee of water users (WUA) to manage hydraulic structure and carry out water distribution at local and community level, which is expected to actively involved in operation and management, as well as demand and supply control of the water in a participatory manner. The organizational framework for the water resource management determined by the Water Law, including those community-based organizations, is further discussed in the Chapter 7 of "Current Organizational Structure" in this report.

6.3.4 WATER ADMINISTRATION

Regulation dealing with the administration of water rights may be distinguished into six aspects, such as water allocation system, operation and maintenance regulations, organization of users,

quantity and quality protection, conflict resolving measures, and law enforcement.

(1) Water Allocations System

As mentioned above, the water owned by a group of people may be allocated either according to the time shares, or by making appropriate openings along-side the water channel. In either case, the time shares or the opening sizes are allocated to each of individuals of the group in proportion to the contribution made by him in construction, and operation and maintenance of the water source and installations. A record of entitlements of the members is often kept by the person designated to operate the well, however, in this informal mechanism for water management, there is no limitation on amount of water extracted from the source.

The Water Law of 2002, however, regulates water extraction by beneficiary stipulating in its Article (37) that "no beneficiary may exceed the amounts or purposes spelled out by the Authority (NWRA) in the permit and must comply with all the terms spelled out in the license." The amount and purposes in water extraction at each of water sources would be determined and allocated by the Authority based on due considerations and elaborated study on potential and demand in each water zone and areas. Then, it is expected that the demand and supply control and allocation of water at the local and community level is managed by community-based organizations such as WUA in a self-regulatory and equitable manner, in compliance to the license.

(2) Operation and Maintenance

The various rules of Sharia'h concerning the sharing of operation and maintenance costs of the water structures are outlined in several articles of the Civil Code, for example, in its Article (1172) referring "the partners in a canal or drain are obliged to do the necessary repairs which must be done to make it usable or to prevent its harm to others. The partners may be forced to do these repairs if one of them requests it or if it is requested by the harmed party. The sharing of the costs is proportional to their shares in use", as well as in the Article (1369) of "if the owners of an irrigation right do not agree with respect to carrying out the necessary repairs of their common channel, then they may be forced, upon request from any one of them, to do these repairs on a pro-rata basis.

The Water Law of 2002 also place emphasis on the significance of community participation and decentralization in operation and maintenance, as its Article (18) stipulating "…delegation of authority shall be considered in order to enhance decentralization and the participation of the beneficiaries in the organization and management of the water at the level of the water basins and zones…" The Article (10) regards the community-based organization such as WUG and WUA is the local pivot to enhance operation and maintenance of their installations, referring that "Societies or groups or committees or association of federations for water beneficiaries and users, may be formed for the purpose of which is to involve the community and beneficiaries of water in organizing the water resource management, or in operation and maintenance of their installations. The Executive Regulation of this Law shall set out its purposes and all the detailed rules and relating thereto." Those community-based organizations such as WUG and WUA are expected to develop their own regulations and rules (bylaws) to manage, operate and maintain their own water resource and the installation, obtaining legal status through registration.

(3) Organization of Users

The level of organization of users of various sources of water depended on the type of source. Traditionally, the most elaborate system of organization is that of surface water source in

general, being it a base flow, spring water, or a surface reservoir. For those surface water resources, as it observed prior, well organized decision and management has been provided in compliance to recognized customs based on the Customary Law ('urf) and *Sharia'h*. In contrast, the users of groundwater aquifers in Sana'a and elsewhere relatively lack organized decision making and coordinated management with other stakeholders including local authorities and governmental institutions. As observed above, informal mechanism for groundwater management at the level appears to be successful in allocating the amount of water extracted among users in proportion to his contribution in construction, however, apart from this there is no limitation as to the quantity that may be extracted for the well, which ends up in the current competition among communities for indiscriminate over-exploitation of the water resource at basin and country level.

In such circumstances, the Water Law promotes decentralization and community participation in the State's water resource management, introducing WUA. An officially registered WUA is a prerequisite for participation in the irrigation modernization program, introducing water conservation technologies in irrigation while promoting productivity. WUAs constitute official stakeholder representation to whom the central structure (NWRA branch office) is expected to delegate management, regulatory and enforcement responsibilities, and who would also be represented in the stakeholders committee for decision making and promotion of its enforcement in water management at basin level. Thus, the WUA is expected to function in two-folded objectives; 1) self-regulation and enforcement of ground water abstraction rights; and 2) implementation and management of ground water schemes. The organizational framework in community participation and decentralization is further discussed in Chapter 7 of the report.

(4) Quantity and Quality Protection Measures

It is evident that the most established *Sharia'a* and *'urf* of water right are those which deal the water quantity and quality protection. The first of these rules in the Civil Code (1181) declares the most famous custom that when wells are constructed; consideration should be given to the separation distance form a neighbor's property, although the distance is not spelled out. The second rule also recognizes the right of an owner of pre-existing water source (spring, well, drainage channel, etc.) to have this source and structure protected by declaring a protection zone (harim) around it (Article 1185 of the Civil Code). The third rule is recognized in Article (1252) of the Civil Code, in relation to the second rule, to define the protection area around wells which will harm the users of the water, referring "the protection zones around towns, houses, wells and trees are not permissible (to develop). They cannot be fenced or reclaimed except by permission of the owner or the holder of the right. The protection zone of a well encompasses all of its normal facilities plus enough access (area) for the drinker or irrigator and which, if changed, will harm the user of the water itself…with due consideration to recognized customs." The well recognized customs set the distance between "deep wells" (popularly described as artesian wells to distinguish them from large diameter hand-dug wells) at 500 meters. For shallow wells, there are customarily no restricting distance. Water quality protection is granted by Sharia'a principles which prohibit the pollution of water. However, contrary to quantity regulations, it is evident that the number of rules dealing with water quality is very limited.

The Water Law of 2002 regulates the quantity of water exploited, as observe in previous sections, in its registering and licensing system in accordance to a number of relevant provisions stipulated in the Law itself and the Executive Regulation to the Law. The Law also defines that NWRA has the power to protect water resources against pollution, to maintain water quality,

to prevent activities that may lead to pollution or the degradation of the quality of water, and to prepare the procedures for regulating potentially polluting activities (Article 54). Designating authority to NWRA in preservation of water resources from depletion, a number of rules and standards, as well as technical specification to be applied, are described in the Water Law and its Executive Regulation.

(5) Conflict Settlement Procedures

There are basically two systems for conflict settlement; a judiciary one and an arbitration one. The judicial system is based on the law of Judicial Power of 1990. It stipulates that "courts are the judicial entities responsible for rulings in every litigation or crime…" The court system in the country comprises three levels of courts; the Supreme Court, the Appeal Courts, and Primary Courts.

The arbitration system comprises two types; legal arbitration, and custom (tribal) arbitration. The former follows the judiciary system and can produce out-of –court settlement. The latter is commonly used in rural area to resolve water right dispute. Usually, there are also several levels of arbitration in this system, beginning at the village level and ending at the level of the tribe's "*Shaikh* of *Sheikhs*".

These systems for conflict settlements can be also applied in the enforcement of the Water Law. According to current practice, these dispute are first brought before the village *aqil*, and if he does not succeed in their settlement, these disputes are submitted either to the *sheikh* responsible for the area, or directly to the courts. Although traditional *aqils* and area *sheikhs* have authority to enforce water rights and to settle disputes among water users, this authority is often exercised to satisfy the interests of influential users, with the result that fights are common. The ordinary courts on the other hand, do not have the capacity to examine cases related to water rights. In addition, judicial proceedings before these courts are normally lengthy.

(6) Enforcement Procedures

The enforcement of court rulings is the responsibility of special courts which are set solely for this purpose. Reportedly, the practice in the country is to create special division with the primary courts, or specialized courts, to deal with given matters. For instance, the president has established a special court and special branches of the office of the prosecutor general to deal with matter relating to the state funds. However, such specialized court or divisions for the issues here are not created, which shall be due considered in enforcement of the Water Law.

Otherwise, the Article (63) of the Water Law authorizes that the staff of NWRA has the status of judicial enforcement officers, while it Article (64) defines that they are responsible for enforcing the Water Law and regulations for reporting violation. The sanction for violating this law and regulation includes both jail terms and fines (Article 67-71). However, effects and feasibility of those provisions regulating enforcement of the Law shall be further considered.

6.4 LAW NO. (4) OF 2000, CONCERNING THE LOCAL AUTHORITY

One of major approaches employed in the Water Law of 2002, its associated amendment Law and the Draft Executive Regulation is delegation of authority in planning and implementation of water resource management to the branch offices of the relevant execution authority (NWRA Branch Offices), local authorities, local stakeholder committee such as Basin Committees, as well as local user communities (beneficiaries), which may realize better water resource management in decentralized and participatory manners. The Republic of Yemen is one of the

countries which facilitating decentralization. The important legal provisions that determine administrative and institutional principles and direction in decentralization of the State are stipulated in "the Law No. (4) of 2000 concerning the Local Authority (the Local Authority Law of 2002)" and "the Republican Decree No. (269) of 2000 concerning the Executive Procedure and Regulation for Local Authority Law of 2000 (the Executive Procedure and Regulation for the Local Authority Law of 2000)". The Water Law of 2002, which was issued two years after the Local Authority Law of 2000, in fact, refers in many articles to Local Authority Law and Local Councils for decentralized water resource management. Local Authority Law defines functional roles and responsibilities of Local Councils and local organs of line ministries (including NWRA Branch Offices) as well as community-based organizations in water resource management, thus it shall play important roles and basis for integrated water management in decentralized principles enhanced in the Water Law and the Stale as a whole.

The Local Authority Law No. (4) was issued on February 2000, and immediately followed by issuance of its Executive Procedures and Regulation after six months of issuance of the Law on August 2000 by the Republican Decree No. (269) of 2000. This indicates its importance and desire for its quick implementation at the level of governorates and districts. This Law is the first step of decentralization of functions and responsibilities of ministries at Sana'a.

The following articles in the Local Authority Law are pertinent and related to water management in general and water rights as followed:

Article (145) of the Local Authority Law spells out coordination mechanism in general, describing that each minister, in the sphere of his ministry's activity in respect of the administrative units, shall undertake the following:

- Inform the governors of the contents of the state's general orientations and policy, as well as whatever of technical guidelines and directives leading to improvement of the level of performance of services at the local level and control over them that he sees fit;
- Coordinate with the governors on needs of the administrative units at the governorate level and need for technical and specialist cadres and act for their provisions;
- Adopt measures to raise the level of competent performance of the executive organs of the administrative units and that through the process of training and qualification of various forms and types.
- Organize the management of national campaigns and fund their implementation;
- Formulate and prepare the general technical specifications, design and plans; and,
- Issue the organizational regulations in the sphere of activity of his ministry.

General funding arrangement in general are clarified in Article (165) of the Local Authority Law, spelling out that "Special funds of economic and social development must coordinate projects and activities that are funded by them with the local council form the planning and implementation aspect." Article (168) of the Local Authority Law is further important, in consideration and introduction of community-based organization for water management such as WUA, stipulating "The local council man constitute special committee form among the beneficiary public to manage, conduct and maintain services and project of the administrative unit. The Executive Procedures and Regulation to the Law shall show the fundamentals governing that."

Functional responsibilities of local authorities at governorate and district levels are defined in the Article (14) of the Law, describing "The Local Authority Law clearly defines the functions

and responsibilities in regard to the supervision, execution and implementation as well as management of project within the geographical limits of the governorates and districts as followed;"

- The powers of the central organs, each within its sphere of competence, over the executive organs of the administrative units are determined in formulation of general policy, enactment of organizational regulations, control, qualification and training and implementation of projects which are difficult to implement by the local councils in the administrative units and that upon their request or projects that are of a general national nature;
- In accordance with the provisions of this law, its regulation and resolutions in implementation thereof, the executive organs of the governorate undertake the role of central authority organs, each within its sphere of competence, in implementing activity at the level of the governorate and technical supervision over organs corresponding to it in the districts, without prejudice to the contents of paragraph above of this article;
- The executive organs of the administrative unit are deemed to be local organs. They represent the technical, administrative and executive organ of the local council and under its supervision, management and control they undertake founding, equipping and management of all development and budget. The Regulation shows the levels of the development and services projects whose implementation is assigned to the governorates and the districts.

Functional responsibilities particularly for Governorate Local Council, in implementation of the development activities, are further defined in the Article (19) of the Local Authority Law, defining "the Governorate Local Council shall undertake the study of draft comprehensive plans at the level of governorate and supervise over their implementation. It shall also undertake direction of, supervision over and control of the work of the District Local Councils and executive organs of the governorate. In particular, it will exercise the following tasks and responsibilities;"

- Consider and approve fundamentals and rules organizing citizen's contributions ot the funding, founding and maintenance of essential services projects funded by them or with their participation;
- Supervise over and control implementation of water policy, protection of water basins against exploitation and pollution and that in accordance with the provision of laws and regulations in force and directives issued by the central authorities in this respect;
- Promote the funding of qualitative cooperative societies of various forms as well as association of a social, vocational and creative nature and furnish them with facilitates; and,
- Supervise over cooperative their plans and programs in a manner that endure their complementation with the development plans of the administrative unit.

Article (61) the Law defines the roles and responsibilities of District Local Council, determining that "The District Local Council shall undertake the suggestion of the draft social and economic development plans of the District supervise over their implementation in a manner that provides and develop essential services for the local society and its development. It shall also undertake direction, supervision over and control of the work of its executive organs. In particular, it will exercise following responsibilities:"

- Care for development of water resources through promoting the founding of dams and water weirs, protecting water from depletion and pollution and that in accordance with

scientific studies and water legislation in force;

- Promote the establishment of qualitative cooperative societies of various forms as well as association of social, vocational and creative nature and provide them with facilities;
- Supervise over cooperative activities as well as those of societies of a social nature and coordinate their plans and programs to ensure complementation with the integrated development plans of the District;
- Supervise over implementation of environmental policies and legislation, adopt the necessary measures ensuring preservation of the environment and natural resources preserves and protect them form pollution and destruction upon them; and,
- Propose fundamental regulating citizens' contributions to the founding and maintenance of essential services projects funded by them or with their participation and supervise over their execution after approval of the Governorate Local Council.

The Executive Procedure and Regulation of the Local Authority Law further defines administrative undertakings for implementation and enactment of the Law, of which significant provisions in general and particular issues relating water resource managements are as followed:

Article (12) of the Executive Procedure and Regulation specifies the all executive offices of the ministers in the governorate shall be under supervision, control, and management of the Local Councils in the governorate within the framework of the general policy of the State and the prevailing laws and regulations. Such executive offices in the governorate shall carry out the role of the central authority in the execution of their activities on the level of the governorate and shall take the responsibility of the technical supervision of executive offices in the districts of the governorate such as the supervision and control on the implementation of policies and the public plans in agriculture and irrigation and water resources and the protection of the water basins from pollution and overexploitation at governorate level.

Article (13) of the Executive Procedure and Regulation specifies the functions and responsibilities of Local Council in the districts and governorates as follows:

- To provide the urgent and future requirements of the people for water whether for drinking or other house consumption and to execute projects and provide service of sanitation;
- To take measures necessary to conserve water resources form pollution and over exploitation;
- To grant licenses to drill artisan wells in the district in accordance with national policies and strategies, after the approval of the concerned authority in the governorate (i.e. NWRA Branch Office); and,
- To carry out awareness campaign among farmers concerning the modern agricultural systems and improved irrigation methods.

The functions of the governorate in the field of implementation of development and service projects, which may include water resource management, are defined in the Article (16) of the Executive Procedure and Regulation. In the Article, establishment, management and maintenance of dams is mentioned as one of functional responsibilities of the governorate. Another function for the Local Councils of the governorate is referred as establishment, management and maintenance of any projects assigned or delegated by central ministers to the governorate. Such projects which are centrally financed may have national characteristics. Also, on the basis this article, the local council of the level of the governorate shall manage, operate and maintain any project which is executed by any central authority and transferred and assigned through delegation of powers to the governorate. This provision is in compliance

with Article (72) of the Water Law of 2002 which authorize MWE to delegate some of its power and functions to any entity whether council, committee or office provided that it does not contradict or contravene the Local Authority Law No. (4) of 2000.

Article (17) of the Executive Procedure and Regulation defines the functions of Local Council of the level of the district concerning execution of service and development project, as such to establish, manage and maintain water barriers and water irrigation projects, as well as local projects of water and sanitation of the district.

The Local Authority Law of 2000 and its Executive Procedure and Regulation is a first significance step to create bases of administrative and institutional environment enabling decentralization of the State's undertakings, and as observed, it includes a number of provisions relating to the water (resources) management to support and compliment the decentralization principles in the Water Law of 2002. With decentralization framework defined in the Local Authority Law and its Executive Procedure and Regulation, branches of Ministries and NWRA become "local organ" under the Governorate. According to the Law, Local Councils at Governorate and District have a functional role and responsibility in supervising the implementation of water policy (the Water Law of 2002) and protecting water resources from overexploitation and pollution. Along with the same stream, the newly formed Sana'a Branch Office of NWRA assume responsibility for overall basin-wide water resource investigation, regulation and monitoring, which includes introduction of self-regulating resource management mechanism with beneficiary group, and increased participation of local stakeholders, local authorities and user communities in the resource management through decentralization.

Although the Water Law of 2002 might be prepared on the decentralization principles stipulated in the Local Authority Law of 2000 and its Executive Procedure and Regulation, the relevant local executing Authority of the water resource management, such as Sana'a Branch Office of NWRA, seems not to fully utilize and interiorize the administrative and institutional framework created by the Local Authority Law. Those opportunities to promote resource management at local and community level provided by the Local Authority Law shall be fully recognized and utilized in the further development of administrative and institutional framework at local and community level.

6.5 CONCLUSION AND ISSUES TO BE CONSIDERED IN THE ACTION PLAN

First of all, this Chapter reviewed and analyzed three major legislative and regulative sources that create administrative and institutional framework of the State for IWRM , which include the Water Law No. (33) of 2002, Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No. (33) of 2002, and the Draft Executive Regulation. In the review and analysis of those Laws and Regulation, a number of "legislative" and "regulative" shortcomings are identified, the former of which decline the legal effect and validity of the Water Law itself, while the latter hinder the execution and enforcement of the law. Rectifications of these shortcomings, in particular, introduction of water abstraction metering and water charge levying for irrigation in use of groundwater, has been one of the most debating issues in the society as well as political sphere of the country over a decade. Strong political commitments and leadership to pursue IWRM have been observed, indeed, which realized the establishment of sole regulatory body (i.e. NWRA) to be fully responsible for the State's IWRM through consecutive reorganization and restructuring of the water sector commenced from a chaotic institutional arrangement after unification in 1990 where a number of national institutions and their associate public entities carried over the mandate of water resources management in addition to their own specific mandates. Indeed, the original version of the Water Law which

is drafted by the special committee of the parliament and duly approved by the Cabinet included these regulations of groundwater abstraction metering and groundwater charge levying. However, these provisions were manipulated and amended in the parliament discussion, followed by the parliament approval. Several efforts and undertakings have been made to rectify and improve some of crucial provision of the Water Law of 2002 for realization of improved IWRM, through issuance of its Amendment Law and Executive Regulation. Robust political commitment, in particular by the Cabinet members, has been always observed in the issues. However, time to time and opportunity by opportunity for its rectification, denials were given by some of parliament members on the crucial provisions. Thus, the strong political commitment of the pro-IWRM wing formed by the Cabinet members has been always wiped out by other political will of anti-IWRM wing formed by some of Parliament members. The Study on the current institutional and administrative framework attributes the persistent objection against ratification of these essential provision in the Water Law to three major factors, as such to; 1) political environment as mentioned, 2) socio-economic conditions of the country, in particular, Sana'a that rely largely on the production of water-consuming cash crops particularly "qat", and 3) socio-culture of "tribalism" in the highland areas of the country, where exclusive management for their tribal land and any structures on it is their entrenched tradition and custom.

The latter parts of the Chapter assessed the legal status of water and the form of water resource management in deference in accordance with the interpretation given in four major legislations dealing with water management, as such legal source as; 1) Islamic Law or *Sharia'h*, 2) Constitution, 3) Water Law of 2002, 4) the Civil Code, and 5) the Customary Law or *'urf*. In the assessment, legal status of water and the forms of water management is grouped into four categories such as; 1) water ownership right, 2) water diversion right and usufruct, 3) water use (sharing) right, and 4) water administration. The Study identified considerable variations in legal status of water and the form of water management according to different legal sources, as well as inconsistency in interpretation and practice, in particular, between ones defined "recently" based on the Constitution/ the Water Law of 2002, and the other defined "traditionally and customary" based on *Sharia'h*/ Civil Code/ *'urf*. These variation and inconsistency in legal status and form of water management defined in the customary evolved and refined laws, such as *Sharia'h*/ Civil Code/ *'urf*, governing the social norm in the country of the Islamic society could be concluded as one of major reasons for difficulty and complexity in execution and enforcement of the newly issued Water Law, of which principles are stem in the Constitution.

Finally in this Chapter, Law No. (4) of 2000 concerning the Local Authority (Local Authority Law of 2000) and its Executive Procedures and Regulation is reviewed, which defines the decentralized framework of local administration and institution in execution of development project including water resource management programs. A considerable number of provisions in the Local Authority Law of 2002 and its Executive Procedures and Regulation are identified and applied in general and specifically to determine administrative and institutional framework and arrangement for water resource management at local level. Indeed, the Local Authority Law is a first step to determine decentralized framework of administration and institution at local level in execution of development project including water management. On the other hand, one of the most important principles and approached underlying in the Water Law of 2002, which is developed two years after the Local Authority Law of 2000, is also "decentralization" and "participation" of local stakeholders and communities in planning, execution, and monitoring and regulation, as well as operation and maintenance for sustainable water resource management. Along with this principle and approach in the Water Law of 2002,

various local institutions has been established at deferent levels in accordance with relevant decrees, such as branch office of the relevant regulatory authority (Branch Offices of NWRA), Basin Commissions composed of various national and local stakeholders, and community-based organizations (WUG, WUA, and WUF). Thus, in the first place, consistency of such locally decentralized framework of institution and administration determined by the Local Authority Law of 2000 and the Water Law of 2002 is examined in the Study. Without finding any inconsistency and conflicts between these two Laws in the framework setting, however, significant opportunities are identified for further development of institutional and administrative framework in water resource management in a decentralized manner, apportioning and utilizing the framework created by the Local Authority Law of 2000.

Based on those observation and analysis made in this Chapter, the following issues shall be major prerequisites or issues to be concerned in formulation of the Action Plan for Sana'a Basin under the Study.

6.5.1 FINALIZATION OF THE EXECUTIVE REGULATION TO THE WATER LAW OF 2002, AND DEVELOPMENT OF DECREE FOR WATER PROTECTION ZONE OF SANA'A BASIN

Although the Water Law of 2002 is a first step of significance towards the State's IWRM, some of "legislative" shortcomings in its basic provisions are the risk to decline its legal effect and validity of the Law itself. These shortcomings include particularly lack of provisions to introduce demand control measures such as groundwater abstraction metering, and water charge levying. These provisions originally stipulated in the Draft Water Law were amended and deleted in the parliament approval on the Law, while second attempt to rectify and include these had also been denied again in the parliament approval of the amendment Law for the Water Law of 2007 (Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No (33) of 2002). At present, the Final Draft of Executive Regulation of the Water Law of 2002 is submitted to and approved by the Cabinet, which is also subject to the parliament approval. The Draft Executive Regulation, which may include these regulations to introduce groundwater abstraction metering and groundwater charge levying, however, becomes highly confidential due to its political and social sensitivity, of which availability is also limited. Moreover, parliament approval on the Regulation without amendment on these regulations seems to be pessimistic, due observation on the recent decision made by the parliament on the Adjustment of the Water Law of 2002, in 2007.

Another negative decision may have to lead to the efforts to develop the other bylaw for the "protected zone", in particular for Sana'a Basin. The challenges and obstacles that are confronting water sector in Sana'a Basin in particular represent the highest percentage of loss and spoilage of such water which is not less than 40%. The irrigation, utilizing groundwater, is regarded as the most contributing factor to the future water crisis in the Basin. The agriculture sector in the country consumes not less than 93% of the available water resources. In Sana'a Basin, in particular, due to difficulties to develop other water sources, higher dependence on groundwater for irrigation is remarkable. The production of water-consuming cash crop, especially qat, increases further water demand in Sana'a Basin, which indeed requires more than half of the extracted groundwater. Moreover, commonly prevailed methods of irrigation customary and traditionally practiced in Sana'a Basin with less efficiency in water use increase the burden on water aquifers, in which practice not less than 40% of extracted water is lost. Thus, in the area like Sana'a Basin where considerable groundwater demand for water-consuming crop, over-consumption, and excessive loss of extracted water is remarkably observed, such measures to control demand and encourage an introduction of modern irrigation methods with high water efficiency shall be considered desirable. Groundwater metering and

groundwater charge levying shall be the most indispensable prescription to address the issues of over-consumption for water-demanding cash crop and excessive water loss typical in Sana'a Basin.

Considering time factors to increase social acceptance, thus, the bylaws for the" protection zones" of Sana'a Basin should have the objective of gradually and over time limiting abstraction to the annual natural recharge as a priority. They should include; 1) a ban on well drilling for agricultural and irrigation use, 2) licensing of all wells, irrespective of depth, 3) mandatory water abstraction metering, and 4) a provision that may allow over time levying water charges for agricultural and irrigation use. The development of the bylaw for protected zone of Sana'a Basin could be a key prerequisite for the effectiveness of Action Plan of Sana'a Branch Office of NWRA.

6.5.2 ADVOCACY OF WATER RESOURCE MANAGEMENT FOR PUBLIC AND POLITICAL LEADERS

The measures taken in the Action Plan to address such water crisis may necessitates undertakings to increase public awareness and gradually establish public consensus for water resource management, which would duly changes political attitude and further increase political willingness towards it. Thus, current efforts for public awareness campaign shall be further concentrated. All citizens in particular the water users, stakeholders, and public at large shall be informed of the seriousness of the water crisis in a first places. The awareness campaign shall be also extended to the authorities, corporations, and companies involved in the water development sector whether they are at central or local, and governmental or private for compliance of the relevant laws and regulations.

Moreover, a package of public awareness campaign shall be developed and implemented suitable for the country's unique socio-culture of "tribalism". Inheritance of their tribal land of prosperity to the next generation over the generation shall be one of the most important concerns for them so as to water on and under the ground which is regarded as servitude to the land in their custom. The lost opportunity cost in the land productivity incurred to the next generations, when the barren land due to overexploitation of groundwater by them is inherited, shall be fully recognized. Also, education and information network for tribal authorities may be established. As far as possible, inter-tribal coordination system for the conciliation of their interests shall be identified and utilized to ease the current competitions of over-development and over-abstraction of groundwater.

Provision of reliable information on the water crisis to the political entities shall be also significant. Along with the awareness campaign for the public in general, the "right" political decisions based on reliable evidence on the water crisis in future shall increase public support with "vote".

Those approaches for awareness and consensus building targeting for public, tribal communities, and political entities shall be taken in the Action Plan.

6.5.3 DISTINCTIVE DEFINITION OF WATER USUFRUCT

As reviewed in this Chapter, there are traditionally and customarily dominating legislative sources governing water resources management, such as *Sharia'h*, *'urf*, and the Civil Code, that define that land ownership gives the owner the full right and control over natural resources above and beneath (thus, surface and ground water) its surface. It is in fact the most prevailed

conviction of the people in the country, particularly in rural areas. Indeed, the most of disputes regarding water resource management and water right are "legally" resolved in accordance with the legal provision of Civil Code defining in its Article (1163) that "land ownership is inclusive of what is above and beneath it to whatever height or depth is useful to enjoy it (land)." The deliberations and discussions for the Water Law of 2002 and its amendment Law in parliament also indicates that most of the parliament members insist on the conservative approach of the Civil Code regarding groundwater ownership and protection of the landlords from any interference by the State.

The Water Law of 2002 clearly defines that water is public property that is subject to the State's administration and registration. Hence, only water use right (usufruct) may accrue to individuals and entities based on the provision of the Water Law or on permit and licensing issued by the State. This legal status of water defined in the Water Law shall be convinced to the public; otherwise the Water Law loses its effect in execution and enforcement, overwhelmed by other predominating legislations. As reviewed in the Draft Executive Regulation of the Water Law, such legal provisions to determine the Water Law as sole legal mean to regulate the water use right (usufruct) instead of other predominating legislations based on the logic to separate deliberately water usufruct that is subject to the State's administration from water ownership right that may stay as the other predominating legislations defines.

In this sense, parliament approval could be prerequisite for the effectiveness of the Action Plan, on the Executive Regulation of the Water Law of 2002 and such legal provisions to determine the Water Law as sole legal mean to regulate the water use right (usufruct) instead of other predominating legislations.

6.5.4 RESPECT ON TRADITIONAL AND TRIBAL SYSTEM

One of significant principles in institutional and administrative framework employed in the Water Law of 2000 is to delegate authorities in management of water resources and enforcement of regulations to decentralized local institutions and communities, in which self-regulating mechanism for water resource management is enforced. Thus, improved participation of local institutions and communities in all the process of water resource management in decision making, execution and regulation and monitoring, becomes the most important determinant for the success of self-regulating mechanism for water management.

Local institutions, not as formal but rater significant in their socio-culture, should include "tribes" or "tribal system", which can not be ignored and, in fact, can be regarded as the most governing institution particularly in highland area of the country including areas of Sana'a Basin. Decentralized framework of local institution and administration introduced by the Water Law and other relevant laws and bylaws, however, seems to lack effective mechanism to enhance active participation of "tribes" and "tribal system" in decision making and execution for improved water resource management.

Thus, channels and network to connect tribes and tribal system shall be identified and developed as it is possible. "Tribal system" herein refers to interrelationship among tribes, and it can be defined as the forum for groups of tribes to conciliate their interests, dispute, and conflict. Development of such mechanism to facilitate and institutionalize their participation shall be considered in the preparation of Action Plan of Sana'a Branch Office of NWRA under the Study. In this line, involvement of tribal authorities in Basin Committee could be also considered. As it may be further discussed in the Chapter 7 of "Current Organizational Structure", Sana'a Basin Commission has been established in accordance to the Water Law and relevant Decrees, of

which function has two-folded characteristics that one served as decision making body for the Basin water management, while one functioned as regulatory body. An active participation of tribal authorities in such decision making and regulation, if supports granted, could be a backstopping institutional support for enhancement of self-regulating mechanism in water resource management.

It shall be also emphasized that, the stakeholders involved in decision making process for the water resource management either at central, local, and community level, shall take account of and apply where possible the traditionally and generally accepted principles and considerations. Thus, tribal rules and customs developed over generation require respect, and can be often a sound and practical basis for cooperation between water users and resolution of conflicts in water management.

6.5.5 IMPROVEMENT IN DECENTRALIZED FRAMEWORK OF LOCAL ADMINISTRATION AND INSTITUTION

This Chapter reviewed the decentralized framework of local institution and administration delineated both in the Water Law of 2002 and the Local Authority Law of 2000, with their related by-laws and decrees. It is also confirmed that the institutional and administrative framework introduced in Sana'a Basin in accordance with Water Law and related decree is consistent with the one determined in the Local Authority Law. The Local Authority Law indeed shares an extensive parts for the provisions in relation to water resource management determining functional roles of local councils at governorate and district level, local organs of line-ministries, community and community-based organizations, as well as means and procedure in its planning, execution, and regulation and monitoring. However, the current institutional structure developed in Sana'a in accordance to the Water Law of 2002 seems to make less use of local institutions, particularly Governorate Local Council and District in execution, enforcement, and regulation and monitoring of the Water Law and program relating improved water resource management.

Apart from the institutional and administrative capacity of the sector, one of the major constrains to promote IWRM in Sana'a Basin, in fact, all in the country according to the applicable law and regulations is vacuum of organizational capacity of relevant regulatory authority, NWRA and its Branch Offices, to prepare local (basin) management plan through comprehensive study, execute program relating resource management, regulate and monitor the undertakings on resource development, and enforce applied duties and penalties. Those required undertakings are all related to "decentralized" and "local" institutions, of which functional responsibilities is defined and allocated to local authorities (i.e. Local Councils at district and governorate level) in collaboration with local organ of line-ministry (i.e. Sana'a Branch Office of NWRA) clearly under the Local Authority Law of 2000 and its Executive Procedures and Regulations. Thus, there are significant opportunities to improve decentralized framework of local institution and administration in Sana'a Basin, through full utilization of local capacity in Local Councils and institutionalization of those local institution of opportunity in the Basin management.

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CHAPTER 7

CURRENT ORGANIZATIONAL STRUCTURE

CHAPTER 7 CURRENT ORGANIZATIONAL STRUCTURE

7.1 GENERAL

In a past decade since its north-south Unification in 1990 up to the century, a considerable number of organizations and institutions had been involved in the water sector in the country, but not in a coordinated manner, rather scattered and fragmented over the various sectors (e.g. agriculture, mining, public health and sanitation, sewage, land development, and rural and urban water supply), as well as over different ministries, their associated authorities and public corporation, and independent and autonomous national/regional development institutions at different level of administrative level and locality (such water-related institutions in different form has been inherited from each of the past regimes in the north and south). This fragmentations and scatters of the organizations and institutions had been obstacle for efficient water resource management in the country.

After a long process for the sector reform and restructuring, the Water Law No. (33) of 2002 and relevant decrees consolidates the authorities in water resource planning and management into National Water Resources Authority (NWRA) established under Ministry of Water and Environment (MWE). Through the sector reform and restructuring, all the sub-sector authorities as such of urban water supply and sewerage, rural water supply, environmental protection, are incorporated under MWE, which is served as significant institutional bases for enabling Integrated Water Resource Management (IWRM), but except for irrigation sector that is under Ministry of Agriculture and Irrigation (MAI).

The Water Law of 2002 provides that specific regions on the brink of (ground) water crisis are declared as "protected zones" in order to prohibit any development activities to increase the burden on the water reserves therein in accordance with provisions of the Law. The Law also stipulates that NWRA may delegate some of its powers to relevant local institutions so as to complete its duties. These two provisions in the Water Law of 2002, along with relevant state's decree, enhanced a declaration of Sana'a Basin as "protected area" in 2002, followed by the establishment of NWRA Sana'a Branch (NWRA-SB) in 2003 as local wing of NWRA. Furthermore, in accordance with the provisions in the Water Law of 2002, following mistrial decree established Sana'a Basin Commission (SBC) in 2003, which is operated under the supervision of NWRA-SB to be a forum for stakeholder and decision maker for the basin management together with NWRA-SB. In addition, as reviewed in the Chapter 6, Local Authority Law No. (4) of 2000 also defines tasks and duties of Local Councils at governorate and district level in water resource management in collaboration with relevant local institution of the central government (i.e. NWRA-SB). Therefore, NWRA-SB, SBC, and Local Councils are forming a current organizational structure at the local level, although tasks and duties of Local Council are not fully activated as observed in Chapter 6.

At community level, the Water Law of 2002 advocates formation of Water User Association (WUA) to involve user communities in regulating water resources and in operation and maintenance of water installation. Although the decree and detail of its participation is not clearly defined, establishment of WUA is already in practice in Sana'a Basin. Through the current practices in establishment of WUA and community-based resource management, functional roles and responsibilities expected for WUA in "self-regulatory" water management can be observed.

In this Chapter, those institutions and organizations involved in water resource management at national as well as local and community level are reviewed, and their organizational capacity of current and possibility, in particular of Sana'a Branch of NWRA, SBC, Local Councils, and

WUA that play an important roles in Sana'a Basin management, would be assessed in accordance with the functional roles and responsibilities designated to them.

7.2 NATIONAL ORGANIZATIONS

In this section, functional roles and responsibilities of national responsible and relevant organizations in water resource management of the country are reviewed, which includes MWE, NRWA, and Ministry of Agriculture and Irrigation (MAI).

7.2.1 MINISTRY OF WATER AND ENVIRONMENT (MWE)

MWE was newly established in 2003 as a result of the sector reform and restructuring to consolidate national authorities related to water supply development and water resource planning and management, as well as environmental protection into a single ministry. Two distinctive roles and responsibilities are defined for MWE; 1) policy and decision making for national water supply development and water resource management as well as environmental protection in an integrated manner, and 2) enforcement and monitoring of national sector policy. It shall be emphasized that consolidation of national authority in three sub-sectors into a single ministry (MWE), as such water supply development in rural and urban, national water resource management, and environmental protection creates, creates an enabling environment in policy making of IWRM at national level. It can be only realized through close collaboration and coordination among affiliated sub-sector development entities under MWE namely, National Water Resources Authority (NWRA) for national water resource management, National Water and Sanitation Authority (NWSA) for urban water supply sector, General Authority for Rural Water Supply Projects (GARWSP), and Environmental Protection Authority (EPA). The functional responsibilities and roles of MWE are clarified as followed:

- Prepare policies and executive plans related to the water and environmental sector in a manner that secures the best utilization of the sector's water share assigned for it in the water plan;
- Conduct theoretical and applied studies and researches and setting up facilities, laboratories and water supply networks which supply the population with water for domestic, industrial, tourism and other service purposes within the limits of the water assigned for the Ministry in the water plan;
- Rationalizing and enhancing the efficiency of the use of water allocated for domestic, industrial, tourism and other businesses through enlightenment and guidance programs and regulatory controls and introduction of measures and technologies which reduces water losses and its conservation;
- Securing the service of supplying the population with potable water good for drinking and domestic uses, putting into effect controls and measures that secure the application and observation of its standards, specifications and suitability for human consumption and adoption of the measures and actions which prevents any health hazard to the population as well as developing and improving such services in terms of quantity and quality;
- Supply of water for various industrial, tourism and other private and public services which falls within the range of the water distribution networks and subjecting them to the application of the water standards and specifications control measures in accordance with the various use purposes and in line with the provisions of this Law and its executive bylaws;
- Installing and up and operating of sewerage networks and sewerage treatment plants for domestic and other public use and supervision of sewerage treatment plants for tourism and industrial projects taking into consideration coordination with the ministry of agriculture

and irrigation, the local authority and other relevant agencies about the best methods to use treated waste water for irrigation and other purposes in accordance with the technical , health and environmental specifications and guidelines set forth by the Ministry in association with related agencies; and,

- Treatment and disposal of waste water as per standard and environmental specifications specified by the executive bylaw of this Law taking into consideration that the treated waste water shall not be disposed of or allowed to be used except after coordination with the Ministry and the relevant authorities and after consultation and coordination with its users and those who are affected by its use.

7.2.2 NATIONAL WATER RESOURCES AUTHORITY (NWRA)

NWRA was established in 1995 in accordance with "the Republican Decree No. (154) of 1995 on establishment of the National Water Resources Authority." However, it had been difficult for NWRA initially after its establishment to make the Authority's mandate accepted and executed in institutional and organizational setup of chaos at that time. Since then, NWRA has gradually gained legislative and administrative foundations over a decade, along with issuance of Water Law of 2002, establishment of MWE in 2002 under which NWRA is affiliated, and issuance of decrees to consolidate and enforce its authority, in particular "the Republican Decree No. (22) regarding some Changes in the Republican Decree No. (154) of 1995 concerning the Establishment of NWRA".

Current legislative and administrative setup enables NWRA as sole agency responsible for water resource planning and management in the country. It plays a regulating and mediating role between the often conflicting interests of users in irrigation/agriculture, drinking water supply, and industry and commerce. IWRM can only be feasible if NWRA fulfills its tasks in close coordination with the users at all levels and sectors. As the regulatory body, the final decision of water use is subject to NWRA. The following mandates and functional roles of NWRA are well clarified in the Water Law of 2002, its amendment Law and its relevant bylaws.

(1) Water Resource Planning and Implementation

- Prepare principles of the national water resource management plan, based on the water resource assessment of water basins and zones in the county;
- Develop a system for classification of the water basins and zones according to the water situations, in which uniformed standards of procedures are applied;
- Receive all plans of water project to be carries out by the government, private, or public for review and approval;
- Prepare water resource management plan for each water basin and zones, which is integrated to the national water resource management plan;
- Review the sectorial (other sector such as agricultural and irrigation sector) plan and basin water resource management plan, and prepare national water resource management plan in coordination with the relevant authorities (i.e. the sub-sector development authorities as such for urban water and sewerage, rural water supply, environmental protection, and agriculture and irrigation);
- Comprehend the followings into the principles of national water resource management plan; 1) evaluation of water resources in the basins and zones in quantity and quality, 2) estimation of existing and future water demand, and 3) projects and procedures for improved water management, including equitable allocation of water, water treatment, and mean of control and monitoring for efficient and rational use of water, plans for flood protection, so forth;
- Prepare corresponding laws, bylaws, and others affiliated to the Water Law;

- Implement the approved national water resource management plan.
- Delegate authorities of NWRA in resource management in order to enhance decentralization to local institutions and participation of user communities, in water management.

(2) Regulation and Monitoring

- Regulate the development and utilization of water resources and the disposal of waste water through the registration of water utilization right of users and issuance of licenses and permits in accordance with the provisions in the Water Law, its Executive Regulations and relevant bylaws.
- Regulate the well drilling through registration and licensing for contractors and drilling equipment in the Water Law, its Executive Regulations and relevant bylaws
- Monitor the development of utilization of water resources and the disposal of waste water in accordance with license issued and provisions set in the Water Law, its Executive Regulations and relevant bylaws;
- Inspect and control violation specified in the provision of the Water Law and its Executive Regulation, and enforce penalties on these violators in the regulations;
- Apply relevant technical standards and specifications in regulation; and
- Enhance water resource management plan at water basin and zone level;

(3) Water Demand

- Provide, with relevant authorities, the following measures to preserve water resources as such; 1) support and facilities necessary for the farmers, and encourage them to use the modern and efficient irrigation methods, 2) dams, dikes and reservoirs, and the installation necessary for rain water harvesting to recharge groundwater, and, 3) assistance and support necessary for soil and botanical control, and so forth;
- Determine quarantine regions where prohibited any installation and development which could increase the burden on the water reserves in the region therein.
- Transfer the specific volume of groundwater or surface water from one water basin or zone to the others for efficient and quotable allocation of the resources on the conditions set in the Water Law.

(4) Water Quality Management

- Establish a national program to protect water resources and to control water quality;
- Protect water resources against pollution and maintain water quality;
- Prepare, in coordination with relevant concerned entities, the procedures for regulating the disposal of industrial wastes, the use of agricultural fertilizers and pesticides and all hazardous substances;
- Carry out studies and research related to the protection of ground water aquifers;
- Monitor the quality of water at the level of water resources; and,
- Harmonize policy with Environmental Departments in MWE, EPA and other stakeholders.

7.2.3 MINISTRY OF AGRICULTURE AND IRRIGATION (MAI)

MAI and its affiliated institutions are one of the major national partners for IWRM in the fact that the country's most serious water shortage is attributed to larger groundwater abstraction for irrigation without application of improved technology for water savings in irrigation (irrigation efficiency). Thus, achieving the state's IWRM objectives will depends considerably on water saving in irrigation. As it is overviewed in the prior section, in the water sector reform and restructuring of the State early in this century, most of its sub-sector authorities (i.e. NWRA,

NWASA, GARWSP, and EPA) were incorporated in MWE, which creates new enabling environment administratively towards IWRM, but except irrigation sub-sector. Recognizing the significance of MAI in IWRM, the Water Law of 2002 and its amendment Law clarifies the roles of MAI in water resource management as followed:

- Prepare policies and executive irrigation plans to ensure the best benefit from the agriculture sector's share from water;
- Conduct theoretical and applied studies and researches, implementation of guidance programs, taking the actions intended to rationalize water uses to increase the productivity of water used for agricultural crops and encouragement of modern irrigation techniques in accordance with the economic feasibility thereof, adoption with the water shares specified for irrigation purposes for conservation of water and environment protection;
- Establish the water installations, operate and maintain them so as to benefit from the rains and floods within the framework of the indicators to the water plan to the Republic, the water budget for the water basins and zones, and the water plan;
- Draw up a plan for protection from floss and also set up and operate an agricultural-climatic observation network, record and analyze the information which they observe and document and exchange them with the Authority and with the beneficiaries, and take advantage of the output of the national network for water observation;
- If any authority in the areas where there are uses of irrigation water, is exposed to the risks of rainfall and floods during handling them in the field and there was apprehension of incidents of injuries to lives and properties, where the general interest dictates adoption of urgent measures with regard to them, the MAI has the right to take whatever it deems proper in terms of such measures including the destruction or breakage of any installation or remove any barriers or erect them within the narrowest limits which enable it to prevent or avoid such injuries. The Ministry shall pay a fair compensation to the beneficiaries upon any injury that inflicts them to such measures being taken, within six months form their adoption;
- In this respect, the executive bylaw determines the controls of coordination between the Ministry, the Authority, and the other relevant bodies;
- Draw and implement the plans and programs relating to the refinement of the courses of the valleys and public canals, monitor the flow of the rainfall and floods, and monitor the uses of the irrigation water and its installations, so as to ensure the safety of these installations, and preservation of the water form waste and pollution;
- Prepare demand indicators on irrigation water in the short, medium and long term, including the need of the project of the private sector for irrigation water, where they constitute – after being reviewed and evaluated – one of the inputs of the water plans as stipulated in accordance with Water Law.

Furthermore, the Water Law of 2002 and its amendment Law places emphasis on the duties and tasks of MAI in flood protection in collaboration with other relevant national and local authorities and all the users of the water, of which measures are including as followed:

- Protection of the soil, the botanical cover, and the vegetation and ideal exploitation of water and other land resources to secure natural environmental stability and mitigate the effect of erosion and other damaging human and natural detrimental factors;
- Maintenance of valleys watercourses and protecting them from erosion; erection of facilities necessary for the protection of soil, public and private property and population conglomerations including the eradication of "Saysaban" trees;
- Protection and maintenance of agricultural terraces to minimize the power of floods flow

and enhancing rainfall water harvesting methods;

- Prohibition of expansion of agricultural lands, civil and industrial installation or others on the expense of water and flood courses and public-channels, if these would in any way hamper flow of flood water into the channels constructed for this purpose; also refining from erection of barriers, buildings and other structure in areas that could be possibly flooded, or construction of any buildings between water courses and any structures erected for protection form floods. An exception to this condition is the structure erected for the protection of adjacent buildings and properties in cases of emergency; and,
- Demolition of barriers, licensed building and any other structures, if these would hamper flow of water or otherwise assist in increasing the damages of floods, after payment of fair compensation to their owners.

7.3 LOCAL ORGANIZATIONS

IWRM calls for basin-level water management, which further requires coordinated decision-makings and actions with various local stakeholders involved in the related sub-sectors. There are three major local authorities leading (or expected to lead) water resource management in Sana'a Basin, namely National Water Resources Authority Sana'a Branch (NWRA-SB), Sana'a Basin Commission (SBC), and Local Councils in governorates and districts. In this section, at first, local setting of Sana'a Basin as nationally declared "protected zone", where any undertaking to increase burden on water resource are restricted, are reviewed in order to comprehend "specific and localized" tasks and duties in basin water management of "protected zone" that the relevant local authorities shall execute, followed by overview of roles and responsibilities designated according to relevant laws, executive regulation (procedure), governmental decrees, and internal (organizational) bylaws.

7.3.1 LOCAL ADMINISTRATIVE SETTING IN SANA'A BASIN

(1) The State's Declaration of Sana'a Basin as "Protected Area"

The Article (49) of the Water Law of 2002 provides that specific water basins or zones on the brink of (ground) water crisis are declared to be "protected zones" in order to prohibit any development activities to increase the burden on the water reserves therein. Due to the significance of the Article (49) of the Water Law in consideration of tasks and duties evolved for water resource management specific to the basin of "protected zones" on the edge of water crisis, the whole text of the article is quoted as followed;

"*Subject to the approved urban and towns plans which do not contradict with the provision of this Law, and by a degree of the Council of Ministers, based on a proposal by the Authority (NWRA) and submission of the Minister, (it is permissible for) defining restricted areas ("protected zones"), in which drilling or deepening wells, construction of any facilities, expanding or development of industrial activities or expansion of the agricultural area or any other activities which will negatively affect the water resources are prohibited. The decree shall identify the geological boundaries or each area, the restriction period and its executive procedure for its implementation, after fair compensation, the decree shall entail cancellation of licenses of all works that had not been started at the time of the issuance of the decree for the restricted area. It may also include modification of quantities licensed for use or even cancellation of the licenses if this would provide detrimental to the water resources in the restricted area. However, restriction shall come to an end by the elimination of the reasons that led thereto.*"

Thus, the Article (49) determines the nature of "protected zones" in its definitions and restricted undertaking, as followed;

- NWRA determines the "protected zone", which is subject to the urban development plans, and by issuance of Cabinet Decree.
- In the "protected zone" determined and declared, well drilling and deepening, construction of any facilities, and expansion or development of any industrial agricultural activities or alike to increase burden on the water resource
- The decree for declaration of "protected zone" identifies the area boundaries for it and its "executive procedure" which determines further regulatory framework (administrative means and procedures for execution of regulations).
- In accordance with "executive procedure", regulation and monitoring for restrictive water resource management is executed and enforced (by the relevant national and local authority, that is, NWRA and/or NWRA-SB).
- The regulatory measures may include, after proper compensation, cancellation of licenses of all work not commenced at the issuance of the decree, and modification and cancellation of issued license prior to the decree.

In accordance with this Article of the Water Law, identification of the most critical areas for the national and regional water resource management, and the official declaration of them as "protected zone" were one of priorities of the State's urgency in order to mitigate foreseeable water crisis in the county and the regions. Along this national and regional urgency, Sana'a Basin was the earliest declared in 2002 as a "protected zone" in the country with issuance of the Cabinet Decree No. (344) of 2002 declaring the Sana'a Basin a Water Protection Zone. Subsequent issuance of the degree to declare Sana'a Basin as protected area in a short period of only three month after the issuance of the Water Law in August 2002, may well indicates its significance in national and regional water management and desire of the State.

(2) Local Administrative and Regulative Framework in Sana'a Basin of "Protected Zone"

The Cabinet Decree No. (344) of 2002 to declare Sana'a Basin as protected area is further supported by the other Cabinet Decree No. (343) of 2002 regarding Restructuring and Procedures in the Water Protection Zones, which provides "executive procedure" for the basin management in the protected zones.

As observed in the Article (49) of the Water Law above, the Cabinet Decree No. (343) of 2002 is served as "executive procedure" as observed in the Article (49) of the Water Law above, and has much of significance to determine regulative framework specifically evolved for the basin management in the "protected zones". Thus, the decree defines the local (i.e. basin level) administrative means and procedures for execution of regulation and monitoring specific and additional for the basin management in the "protected zone", indeed which eventually determines tasks and duties executed and shared by the relevant local authorities in Sana'a Basin, such as NWRA-SB, SBC, and Local Councils. Under the Cabinet Decree No. (343), the following administrative measures and procedures are applied to the protected zone including Sana'a Basin;

1) Well Drilling

Drilling of deep well is prohibited as well as deepening such wells except for the following purposes;

A. For drinking purposes provided that:-

- The number of water beneficiaries from the well to be in accordance with Basin Committee's decision.

- That there is no other alternative source of water to be provided in a secured continuous condition for users.
- The approval of Local Authority must be obtained and to confirm that such application by the beneficiaries shall use water for drinking purposes and household consumption only.
- Drilling of such well and its usage shall be subject to the following controls; 1) to obtain drilling license from NWRA, 2) to comply with drilling specifications such as location depth and dimension, etc., and, 3) obligation to obtain beneficiary water right to use the well and to comply with the water quantity to be extracted from the well as specified in the water beneficiary right.

B. For Agriculture:-

- Deepening existing wells for agricultural purposes shall be subject to the following measures and control; 1) that such deepening shall not damage or affect neighboring or adjacent well because of exceeding the level of deepening more than the adjacent well levels, and 2) that such deepening is essential due to the decrease of the well productivity
- Drilling alternative wells for agriculture is subject to the following control; 1) it must be due to the stoppage of the old well because of technical failure or defect and so it is not possible for such old well to function or operate, 2) such new well must not cause damage or negative effect to the existing well as far as its location depth and dimension is concerned, and 3) the old well must be dumped and to be used as monitoring well by NWRA.

2) Drilling and Deepening License

Drilling or deepening licenses must comply with the following aspects;

- That such drilling or deepening must not be for expansion of agriculture or for new agricultural areas using ground water.
- Such wells must be licensed or registered in a legal mean.
- Such crops must be trees or crops for food and to be defined by Ministry of Agriculture and Irrigation within the application for such license.
- Full compliance with the drilling or deepening specifications.
- To obtain beneficiary water rights before using such well and comply with the quantity of water to be pumped as specified in the water right.
- That water users to adopt improved irrigation methods to ensure water use efficiency.

3) Well Registration

NWRA shall call well owners to register their existing wells within one year as maximum from the announcement. NWRA shall prepare the application forms and wells registration and complete the dated of wells registered, e.g. the owners, purposes of use, location, boundaries specifications of the existing wells and the quantity of water to be pumped as safe and secured, and so forth.

4) Facility Construction and Project Implementation

Any construction of facilities and development project shall not be permitted with increase the burden upon the water storage either through extraction or pollution. Projects within the protected zone must comply with the following;

- To obtain the approval and license from NWRA to establish the project.

- To submit a study showing the required quantity of water for the project and its source and to submit a study showing how to dispose of waste and its mechanism and its effects on the ground water.
- The existing projects and establishments within the protected zone which use water or dispose its waste within the protection zone must apply for registration within six months as maximum from the date of NWRA accouchement.

5) Groundwater Pollution

The following controls and measures must be taken;

- NWRA must define the sources of pollution of the groundwater (e.g. factories, waste water station, oil stations, etc) and to register as such.
- NWRA in coordination with other competent authorities to prepare program to monitor quality control in wells for drinking and factories outlets and waste station, etc.

6) Basin Commission

Functions of the Basin Commission for the protected zone to be as follows;

- To approve applications for drilling and deepening of wells and for any purpose before NWRA grants the license.
- Approval for establishment of projects that increase the burden upon the groundwater storage.
- Control of groundwater usage and to interfere through taking measures to prevent continuation of depletion and pollution on the basis of studies and indications submitted to it from the concerned entities.
- To determine the groundwater allocations and its usages.

7) Coordination

All concerned parties must notify the local authorities of any licenses granted to any one within the protected zone for the following works; 1) wells, and 2) water installations.

8) Implementation

All parties concerned are responsible to implement these measures, control and procedures within its function. The local authorities must take measures to prevent drilling or deepening of wells if there are no licenses granted to it issued by NWRA and security entities must cooperate with the Local Authorities to implement as such.

7.3.2 NWRA SANA'A BRANCH (NWRA-SB)

As observed above, the Water Law of 2002 provides that specific regions on the brink of (ground) water crisis are declared as "protected zones" in order to prohibit any development activities to increase the burden on the water reserves therein in accordance with provisions of the Law. In this policy line, the State declared Sana'a Basin as "protected zone" as earliest in the country and provided with "executive procedures" that determines regulatory means and procedures in basin water management specific to the "protected zones" to be implemented by relevant local authorities. Thus, the State's declaration of Sana'a Basin as "protected zone" and defined "executive procedures" required local authorities branched from the national relevant authority of NWRA.

NWRA, responsible for country-wide water resource monitoring and management as overviewed above, has currently seven basin branches: Sana'a, Aden, Taiz, Hadramout, Sa'da, Hudaidah, and Dhamar. NWRA-SB is one established earliest along with along with Taiz and Sa'da Branches in 2003, along with issuance of the Prime Minister Decree No. (58) of 2003

regarding the establishment of Sana'a Branch Office of NWRA.

The legislative and administrative basis of NWRA-SB is, however, basically provided only in the Article (72) of the Water Law of 2002, which stipulate as followed:

"The Authority (i.e. NWRA) may delegate some of its powers provided that its assignments stated in this Law are vested in any committee or office or unit emanating therein or is not affiliated thereto in accordance with Law and the Law of Local Authority, and in a manner that realizes accomplishment or these assignments if the Authority is not able to execute itself these powers and assignments."

It can be observed that the Water Law does not define the functional roles and responsibilities of NWRA-SB, neither does the Prime Minister Decree No. (58) of 2003 regarding its establishment. In fact, the Law allows delegation of the authority vested in NWRA either to entities branched from NWRA or ones not associated with it.

However, there is no doubt that NWRA-SB is to be the entity that, in its capacity as the water sector regulatory agency covering Sana'a Basin, ensures the sustainable continuation and further generation of benefits from executing water management, conservation, and intervention. This will require execution of tasks and duties not only to operate and maintain the water right monitoring and regulation system for the basin, but also to carry out the overall mandate for basin water resource planning, management, execution, and monitoring.

Thus, NWRA-SB may assume responsibility for overall basin-wide water resources investigation, regulation, and monitoring according to the tasks and duties defined for NWRA (headquarter) at the basin level, which include, delegation to user group and monitoring of the regulatory system, overview and execution of water resource research and monitoring programs in coordination with other responsible agencies and stakeholder group. It may also include supporting the establishment and operation of the SBC (representing all water sector stakeholders) in an equitable and sustainable development and use of the basin's water resources.

Currently, NWRA-SB has prepared its draft internal (organizational) bylaws to determine its functional roles and responsibilities, which is now subject to the approval by NWRA headquarters. Reviewing the draft internal bylaws of NWRA-SB, the relevant provisions in the Water Law of 2002, as well as "executive regulations" in the "protected zone" defined in the Cabinet Decree No. (343) of 2002 regarding Establishment and Procedures in Water Protection Zones reviewed above, tasks and duties of NWRA-SB can be possibly defined as followed:

(1) Water Resource Planning and Implementation

- Receive all plans of water project to be carries out in the basin by the government, private, or public for review and approval through SBC;
- Prepare water resource management plan for the basin and its zones, which is integrated to the national water resource management plan;
- Review the sectorial (other sector such as agricultural and irrigation sector) plan in the basin, and prepare basin resource management plan in coordination with the relevant authorities (i.e. the sub-sector development authorities as such for urban water and sewerage, rural water supply, environmental protection, and agriculture and irrigation);
- Comprehend the followings into the basin water resource management plan; 1) evaluation of water resources in the basins and zones in quantity and quality, 2) estimation of existing and future water demand, and 3) projects and procedures for improved water management, including equitable allocation of water, water treatment, and mean of control and monitoring for efficient and rational use of water, plans for flood protection, so forth;

- Prepare (the principle of) "improved" regulatory framework (executive regulations) for the water resource management of the basin of "protected zone" defined in the Water Law of 2002 and relevant governmental decrees.
- Implement the approved national water resource management plan at basin level.
- Delegate authorities of NWRA in resource management in order to enhance decentralization to local institutions and participation of user communities, in water management.

(2) Regulation and Monitoring

- Regulate the development and utilization of water resources and the disposal of waste water through the registration of water utilization right of users and issuance of licenses and permits in accordance with the provisions in the Water Law, its Executive Regulations and relevant bylaws.
- Regulate the well drilling through registration and licensing for contractors and drilling equipment in the Water Law, its Executive Regulations and relevant bylaws
- Monitor the development of utilization of water resources and the disposal of waste water in accordance with license issued and provisions set in the Water Law, its Executive Regulations and relevant bylaws;
- Inspect and control violation specified in the provision of the Water Law and its Executive Regulation, and enforce penalties on these violators in the regulations;
- Apply relevant technical standards and specifications in regulation; and
- Enhance water resource management plan at water basin and zone level;

(3) Water Demand

- Provide, with relevant local authorities, the following measures to preserve water resources as such; 1) support and facilities necessary for the farmers, and encourage them to use the modern and efficient irrigation methods, 2) dams, dikes and reservoirs, and the installation necessary for rain water harvesting to recharge groundwater, and, 3) assistance and support necessary for soil and botanical control, and so forth;
- Determine quarantine regions where prohibited any installation and development which could increase the burden on the water reserves in the region therein.
- Transfer the specific volume of groundwater or surface water from one water basin or zone to the others for efficient and quotable allocation of the resources on the conditions set in the Water Law.

(4) Water Quality Management

- Establish a basin program to protect water resources and to control water quality;
- Protect water resources against pollution and maintain water quality;
- Prepare, in coordination with relevant local concerned entities, the procedures for regulating the disposal of industrial wastes, the use of agricultural fertilizers and pesticides and all hazardous substances;
- Carry out studies and research related to the protection of ground water aquifers; and,
- Monitor the quality of water at the level of water resources.

It is observed that the most of tasks and duties of NWRA-SB assumed above is identical in ones for NWRA at national level, which could be true if the maximum delegation of the Authority's power at national to its local wing is realized. In fact, however, further facilitation to finalize and approve the draft internal bylaw of NWRA-SB is expected to confirm its functional responsibilities and roles in the basin water management of the "protection zone".

7.3.3 SANA'A BASIN COMMISSION (SBC)

As reviewed in the section 8.3.1, the "executive procedures" for the "protected zone" defined in the Cabinet Decree No. (343) of 2002 regarding Restructuring and Procedures in Water Protected Zones required the establishment of Basin Commission in the respective basins and NWRA's Branches, including Sana'a Basin and NWRA-SB, determining its functional roles in regulation and monitoring as followed;

- To approve applications for drilling and deepening of wells and for any purpose before NWRA grants the license.
- Approval for establishment of projects that increase the burden upon the groundwater storage.
- Control of groundwater usage and to interfere through taking measures to prevent continuation of depletion and pollution on the basis of studies and indications submitted to it from the concerned entities.
- To determine the groundwater allocations and its usages.

IWRM requires the basin-level water management by relevant local authorities. Then, the basin-level water management in IWRM and decentralized administrative level, indeed demands a broad sector-wide stakeholders and user communities' representation in decision making process and execution of decision made for the basin water management. In fact, SBC can be an initial step in the State's IWRM towards basin-level management, providing a common but sole platform for these stakeholders in decision making and collective execution and monitoring of the decisions made for the basin-level water resource management.

In accordance with the Cabinet Decree No. (54) regarding Amendment to the Cabinet Decree No. (168) in relation to the Composition of SBC, current composition and membership of SBC has been decided. SBC is chaired by Minister of MWE along with Minister of State and Mayor of the Capital as deputy chairperson. Membership consists of a broad representation, including governor of Sana'a governorate, chairperson of NWRA, chairperson of Agricultural Cooperative Union (ACU), chairperson of EPA, chairperson of Geological Survey Authority, deputy of MAI, deputy of Ministry of Finance, deputy of Ministry of Pubic Works and Highway (MPWH), deputy of Ministry of Interior, deputy of Ministry of Information, chairperson of the Local Councils within Sana'a Basin, as well as representative of Water User Association (representing user communities), and three individuals nominated by the Prime Minister.

The Ministerial Resolution No. (50) of 2005 regarding Regulation of the Works of SBC defines current roles and responsibilities of SBC in general, as followed;

- To submit the coordinating support to NWRA pertaining the institutional and legal aspects and planning of water resources and to encourage those working in this field to contact NWRA and to submit their plans and programs to that to emendable NWRA to prepare the water plan for Sana'a Basin.
- To review the water budget prepared by NWRA for the basin and to give their point in relation to the allocation and usages of water which shall include groundwater, surface and waste treated water.
- To coordinate with the concerned entities in relation to extraction and exploitation of water in the basin and to maintain and supervise the usages and action in relation to water beneficiary right and cases and issues of those beneficiaries of the water.
- To submit suitable recommendations in relation to strategic projects concerning water which are planned for establishment within the basin, e.g. dams, barriers, waste water treatment station, and water desalination.

- To give point of view in relation to development projects in other sectors which might affect water resources in the basin directly or indirectly and to submit their recommendations.
- To approve the basis, measures, control and procedures for issuance of drilling licenses in the basin for drinking, agriculture and other purposes and to review applications for licenses and to give their appropriate recommendation in relation to such applications.
- To review reports of the supervision and monitoring to be submitted periodically by NWRA concerning the water situation in the basin and the performance of water resources projects and their implementation in the basin.
- To carry out mechanism of coordination among existing projects in the basin so that to avoid intrusion and duplication among projects involved with water resources working within the basin.

Although these responsibilities and role of SBC quoted above is in general, the Cabinet Decree No. (54) regarding Amendment to the Cabinet Decree No. (168) in relation to the Composition of SBC specifies the practical mandate to be executed by SBC, as followed;

- To supervise establishment of WUA (i.e. user community organization; refer to the next section) in the basin.
- To assess and evaluate the present situation of land usages in the basin and in particular those establishment that pollute the environment and which deplete water and to propose suitable measures and controls.
- To approve the annual water plans for the basin and to determine allocations in accordance with the usages of sectors and to supervise its implementation
- To approve projects which are involved in water resources and implementation of such projects (e.g. drilling wells and establishments within the basin).
- To review the strategy of the Sana'a Basin water management and to supervise its implementation.

Among these mandates of SBC, the Study team observing its regular meetings, the significance seems to be given to; 1) review and approve project and other water sector development plans, investments and interventions, and, 2) to coordinate, implement, and supervise these development plans.

Considering its composition and membership with broad representation of the sub-sector stakeholders and users' community and its executive mandates defined in the Water Law and relevant decrees as well as its responsibilities and roles, SBC is expected to (Bahamish et al., 2006):

- be a forum for partnership and participation in the management of basin resources involving all water sector stakeholders;
- debate and explore ways and means to achieve more efficient water use, optimal exploitation of surface and groundwater, and rationalization of agricultural, domestic (rural and urban) industrial and commercial water use in the basin;
- make water management decisions for the basin that balance the interests of all users including those represented by the users' communities.
- help with resolution of conflicts between water users and competitors;
- anticipate conflicts that could arise from some water users refusing to participate in approved developments and to comply with agreed conditions, in an attempt to improve their own situation at the expense of the communities, and take precautionary measures to

avoid such conflicts;

- act as a medium for the awareness campaign to educate and solicit support from water users and the general public relating to water management improvement activities;
- be a vehicle for investments and adoption of modern technologies for improved water management in the basin.

Thus, it can be concluded that SBC is expected to function as platform for the sub-sector stakeholders and users' communities to make shared and agreed decisions and supervise its execution in the basin water resources management.

7.3.4 LOCAL COUNCILS

Restructuring of local governance and authorities in governorates and districts of the State has been facilitated since enactment of "the Law No. (4) of 2000 concerning the Local Authority" (the Local Authority Law of 2000) and "the Republican Decree No. (269) of 2000 concerning the Executive Procedure and Regulation for Local Authority Law of 2000" (the Executive Procedure and Regulation for Local Authority Law of 2000). Prior to enactment of the Local Authority Law and its Executive Procedure and Regulation in 2000, local governments in governorates and districts that oversee entire local administration and regional development had not existed in the State. Thus, local administration and regional development had been carried out independently by the sector by sector, through a number of local organs of the central ministries or directly by the central ministries and authorities, without integrated local administrative framework and supervision of local government.

For example, in the rural water sector at local level, local administration and development of the sector was executed by 2 ministries: the Ministry of Electricity and Water (MEW) and the MAI in the latter half of 1990's. General Authority for Rural Electricity and Water (GAREW), the predecessor to current GARWSP responsible for rural water supply development, was the "central" implementing agency of MEW, while Integrated Rural Development Authority (IRDA) was the "local" implementing agency of MAI handling local projects. Each IRDA office had responsibility for one or more governorates, and was relatively autonomous both administratively and financially to execute projects for development of infrastructures including rural water supply as well as agriculture, irrigation, schools and health centers. Both agencies of GAREW and IRDA are involved in the rural water administration and development at local level without proper sector coordination at local level. Meanwhile, NWRA was established in 1995 intending it as sole regulatory body in the State for water resource management. However, as it is reviewed in Chapter 6, NWRA had no means to execute its authorities for water resource management not only at local level but also at national level, without legislative and administrative backup provided, till enactment of the Water Law of 2002.

These scatters of local authorities and administrations were observed not only in the water sector, but also in other sectors at local level. Thus, integration of local authorities and administrations in various sectors, or at least creation of coordination mechanism in local government in governorates and districts has been intended and facilitated by the Local Authority Law of 2000 and its Executive Procedures and Regulation.

As it is reviewed in Chapter 6 (refer to 6.4 "Law No (4) of 2000 concerning the Local Authority Law), functional responsibilities of Local Council at governorates and districts are defined as supervising the implementation of water policies and protecting water resources from overuse and pollution (Article (19) of the Local Authority Law of 2000).

The Local Authority Law of 2000 further defines the supervisory roles and responsibilities of District Local Council in water resource management through promotion of dams and water

weirs, protection of water quality, as its Article (61) describes as followed;

- Care for development of water resources through promoting the founding of dams and water weirs, protecting water from depletion and pollution and that in accordance with scientific studies and water legislation in force;
- Supervise over implementation of environmental policies and legislation, adopt the necessary measures ensuring preservation of the environment and natural resources preserves and protect them form pollution and destruction upon them; and,

Moreover, the Law elaborates the tasks and duties of District Local Council in promotion of community-based organizations (cooperative society), which is also applied to the creation of user community organizations relevant in water resource management program, such as WUA. For its matter, the Article (61) of the Law also descries that District Local Council is responsible for the followings;

- Promote the establishment of qualitative cooperative societies of various forms as well as association of social, vocational and creative nature and provide them with facilities;
- Supervise over cooperative activities as well as those of societies of a social nature and coordinate their plans and programs to ensure complementation with the integrated development plans of the District;
- Propose fundamental regulating citizens' contributions to the founding and maintenance of essential services projects funded by them or with their participation and supervise over their execution after approval of the Governorate Local Council.

The Executive Procedure and Regulation to the Local Authority Law specifies the all executive offices of the ministers in the governorate shall be under supervision, control, and management of the Local Councils in the governorate within the framework of the general policy of the State and the prevailing laws and regulations. Such executive offices in the governorate shall carry out the role of the central authority in the execution of their activities on the level of the governorate and shall take the responsibility of the technical supervision of executive offices in the districts of the governorate such as the supervision and control on the implementation of policies and the public plans in agriculture and irrigation and water resources and the protection of the water basins from pollution and overexploitation at governorate level.

Article (13) of the Executive Procedure and Regulation specifies the functions and responsibilities of Local Council in the districts and governorates as follows:

- To provide the urgent and future requirements of the people for water whether for drinking or other house consumption and to execute projects and provide service of sanitation;
- To take measures necessary to conserve water resources form pollution and over exploitation;
- To grant licenses to drill artisan wells in the district in accordance with national policies and strategies, after the approval of the concerned authority in the governorate (i.e. NWRA Branch Office); and,
- To carry out awareness campaign among farmers concerning the modern agricultural systems and improved irrigation methods.

Reviewing these functional roles and responsibilities of Local Council at governorates and districts defined in the Local Authority Law of 2000, there a number of provisions to create administrative and organizational environment to support enforcement of the Water Law of 2002 at local level, in particular for the basin-level water resource management. For example, the regulations implementing the Local Authority Law vest the power to grant licenses for the construction of wells to District Local Council, as well as supervision on its compliance by local

user communities. Thus, an application for a license will have to be filed, and it compliance shall be monitored by the District Local Council. In addition, the tasks and duties determined in the Local Authority Law for the District Local Council in promotion of cooperative society (community-based organization) for the project/service management shall be emphasized, in consideration of establishment and involvement of user community organizations, such as WUA, for the basin-level water resource management.

However, as it is assessed in Chapter 6.4 "Law No (4) of 2000 concerning the Local Authority", these functional roles and responsibilities vested to Local Councils have not been activated, and organizational structures to enable these roles and responsibilities in the Councils have also not considered, particularly in establishment of local organizations in accordance with the Water Law for the basin-level water resource management. These opportunities to utilize Local Councils as outlined in the Local Authority Law in the basin management shall be taken into consideration in the current organizational setup at governorate and district level.

7.4 COMMUNITY ORGANIZATION

Customarily, well established communal and inter-communal system (i.e. social norms, values, rules, and penalties) exists in the county for surface water management, based on their customary law or *'urf* elaborated in their socio-cultural context of "tribalism". This customary management of surface water is, in many cases, referred as socially acceptable and environmentally recommendable. In contrast, however, such communal and inter-communal system is lacking conventionally for groundwater resource management, except if the well is owned in a sharing manner with others. Thus, prior to the enactment of the Water Law of 2002, individual well owners are given with "sovereign authority" in its use and groundwater abstraction (refer to Chapter6.3).

In Sana'a Basin and elsewhere in the highland area of the country, there is strong sense of community, based on their "tribalism", at the village level. It is observed commonly in the area that the well for irrigation/agricultural use is jointly owned and used in a sharing manner by a group of individuals. The well of shared ownership is utilized and managed, based on the informal but rather commonly recognized consensus among joint owners. Benefit in utilization of the well (i.e. diversion of abstracted water to their farm land) is equitably allocated among them in proportion to their contribution to the well construction and/or operation and maintenance, while duties to burden operation and maintenance cost is also shared among them in proportion to the degree of benefit received. According to this well recognized rule of water sharing, the amount of water extracted from the well for each member of the group is fairly determined and monitored by the group and/or pump operators for the well through regulating pumping time shared and controlling irrigation channels. This informal but rather traditional rule of water sharing is effective to prevent conflicts among users in its shared usage and regulate/limit quantity of water shared available to each of users "within the capacity of well". However, there is no imposing mechanism in this rule to regulate/limit the total amount of water extracted from a well, abstracting groundwater as much as possible and necessary for the irrigation within the capacity of the well and pumping unit. Moreover, this conventional rule of water sharing is applicable only to a single well, but not to a number of neighboring wells in the community and/or in other communities of the area. Thus, this traditional rule of water sharing and conventional group of users (shared owners) fails to manage and control quantity of water abstraction from wells sharing the same aquifer in the area located, indeed which further promotes competition in well drillings and overexploitation of groundwater in the area.

Thus incompetence of traditional rule of groundwater sharing and in particular conventional user group in its nature to cope with unrestricted discharge of groundwater in the basin calls for

renovated user community organizations and enhanced user participation in the basin-level water resource management. Particularly in the highland areas of the country including Sana'a Basin, where the strong autonomy of user communities (hence, non-acceptance of any interference/control by government) exists based on the traditional tribal structure or "tribalism", the basin-level water resource management can be only successful on a participatory basis.

One of uniqueness in the national strategy and approach for the State's IWRM, and for the basin-level water resource management in particular, could be referred in introduction of "self-regulating" mechanism in water resource management, in which user communities restricts themselves from overexploitation of the resources and control community's demand through adoption of improved water efficient technologies in particular improved irrigation technologies. In promotion of the State's IWRM and basin-level water resource management, it has become the most underlying concept among stakeholders that the self-regulating management by user communities, within the participatory framework of administration in decision making and its execution, may be the most promising solution to come gaps with the current indiscriminate exploitation of the basin's water resource.

Under this recognition, establishment of user community organization, such as Water User Group (WUG) and WUA, has been promoted in the basin management of Sana'a, as well as their representation in SBC for participatory decision making and its execution in the basin management. In this section, functional roles and responsibilities of these user community organizations and their representation and participation mechanism in the basin-level water resource management is reviewed.

7.4.1 WATER USER GROUP (WUG)

The Water Law of 2002 calls for the establishment of user community organization to be involved in the water resource management at community level, as well as in operation and maintenance of the water installations. Article (10) of Water Law stipulate as followed;

"Societies or groups or committees or associations or federations for water beneficiaries and users, may be formed for the purposes of which is to involve the community and beneficiaries of water in organizing the water resources or operating and maintaining their installations. The Executive Regulations executing the provisions of this Law shall set out its purposes and all the detailed rules and relating thereto."

The article above also stipulates that the purposes of these user community organizations, which may include roles and responsibilities, shall be spelled out in the Executive Regulations of the Law. It is also reviewed in 6.2.3."Executive Regulation to the Water Law (Draft)" that, due to delay in issuance of the Executive Regulation of the Law, the functional roles and responsibilities of these user community organizations are not clearly defined in any legislative document. However, current practices for improved basin-level water resource management and particularly in the implementation of project component of "Demand Management and Irrigation Improvement" supported under World Bank's "Sana'a Basin Water Management Program" further elaborates the functional roles and responsibilities expected for such user community organizations, namely Water Use Group (WUG) and Water User Association (WUA).

The project component of "Demand Management and Irrigation Improvement" is intended to save and conserve groundwater usage in agriculture by introducing improved technologies of irrigation efficiency to the farmers in Sana'a Basin. This project component is demonstrated by farmer group (initially around a well) interested in participating in the component by adopting the improved irrigation technologies, of which cost is largely subsidized.

WUGs are the lowest level institutions to be supported by the project component for involvement of water users in water resource management in the Sana'a Basin. WUGs around wells are already existing community groups. These "conventional" WUGs are informal farmer group that are usually organized around wells for irrigation comprising of 5 to 10 co-owners, functioning on informal but customary bases as traditional entities to operate and maintain the wells, structures and associated irrigation system (pumps, pipes and distribution networks) and for distributing water equitably to their members. As it is observed above, however, these "conventional" WUGs failed in the most cased to regulate and control total groundwater discharge of a single well and a number of wells in the area.

Improvement and formal recognition of these conventional WUGs is promoted and supported by the project component in selected villages. Some selected and amenable WUGs are then to; 1) be the primary recipient of project investment under the project's demand management and irrigation improvement component, 2) be the primary contributors to the community's share of the corresponding investment costs, and 3) serve as pilot and demonstration units for project activities. According to Bahamish (2006), WUG members are expected to;

- participate in project discussion and negotiation meetings at village level;
- assist and cooperate with the project in its initial technical, organizational, socio-economic and financial assessment;
- be involvement in the establishment of a village-based WUA and the appointment of WUG representatives to it;
- attend and participate in the demonstrations of improved irrigation system and techniques at pilot schemes and farms;
- in the case of the selected WUGs, enter into formal agreements with the WUA and through the WUA with the project, covering; 1) the types of investments to be made in their system, 2) the amounts and modes of payment of their financial contributions, and 3) the corresponding responsibilities and conditions to be assumed and complied with including, among others, the "no irrigation expansion and no-use of water saved as a result of use of modern irrigation techniques" condition; and accordingly, become recipients of project support investments;
- receive training and advice from the project aimed at capacity building for systems operation and maintenance, water management and conservation, and use of modern irrigation systems and techniques;
- the fully responsible for the management and operation and maintenance of their irrigation system; and,
- ensure that the irrigation areas under their wells and systems are not expanded.

A number of WUGs that satisfies these expected roles and responsibilities within a recognizable boundary, such as village or tribal area, are organized into WUA, which is explained in the following section.

7.4.2 WATER USER ASSOCIATION (WUA)

A WUA is formulated by consolidating a number of WUGs in a recognizable boundary, and with social mobilization provided by NWRA-SB, it is legally recognized and registered in accordance with Law No (39) of 1998 regarding Cooperative Associations and Societies. An officially recognized village or well-field WUA is a prerequisite for participation in the irrigation improvement program. WUAs constitute official stakeholder representation to SBC , as observed earlier, to participate in decision making and its enforcement process in the basin-level water resource management. WUAs are also delegated with power to as some

degree as desirable to manage, regulate, and enforce measures for the resource management in their areas covered. Thus, WUAs would be primarily responsible for; 1) self-regulation and enforcement of groundwater abstraction right; and 2) implementation and management of groundwater conservation schemes.

The expected roles and responsibilities of WUAs, particularly in demand management, are given as followed (Bahamish et al., 2006);

- provide a forum for coordination and exchange of information between WUGs, and for formulation of irrigation management decisions and measures in the best interest of the community as a whole;
- assist the project with coordination and execution of initial organizational, technical and socio-economic/financial assessments;
- coordinate the water management efforts of individual WUGs, and help identify, design and implement with both WUGs and the project any needed prior to parallel well or irrigation system rationalizations or reconfigurations;
- negotiate and research agreement on general conditions of project interventions in the community and specific types and locations of these; and,
- assume a major responsibility in ensuring that irrigation expansion is contained in accordance with project conditions, and in monitoring of this.

7.5 CURRENT CAPACITY OF LOCAL AND COMMUNITY ORGANIZATIONS IN THE BASIN-LEVEL WATER RESOURCE MANAGEMENT, AND ISSUES TO BE CONSIDERED IN THE ACTION PLAN

In this Chapter so far, tasks and duties of several organizations involved in IWRM in the country at national, local, and community levels has been reviewed. As it is observed here and in Chapter 6, IWRM in the country could be successful only if basin-level management is properly and effectively carried out by the relevant local authorities and user communities. Indeed, administrative and institutional framework as well as organizational structure set forth for IWRM in the Water Law and governmental decrees put great emphasis on delegation of power in water management to the lowest appropriate levels. In decentralized organizational framework determined for the State's IWRM and the basin-level water resource management in Sana'a Basin, the following organizations take leading roles and responsibilities, , NWRA-SB and Local Council as local authorities, SBC as stakeholders' platform for decision making in the basin management, as well as WUA as user community organization. In this section, the key capacity of these organizations to execute tasks and duties defined the sector policy and strategies are analyzed, and issues to be considered in organizational development plan under the Action Plan to be prepared under the Study are described.

7.5.1 NWRA SANA'A BRANCH (NWRA-SB)

(1) Organizational Structure

NWRA-SB has two major departments – Department of Studies and Information, and; Department of Licensing and Public Awareness. However, as it is observed above, organizational bylaws that determines tasks and duties of NWRA-SB has not finalized yet. Without finalization of organizational bylaws, further development of job-descriptions for each department/section and organizational charts defining interrelationship among departments/sections can not be possible at present. In the absence of defined organizational bylaws/job-description and chart, factors the most important for organizational operation and management, such as mutual understandings, decision making process, system for giving and monitoring orders, and interdepartmental coordination/cooperation, are being hampered. Thus,

there are strong needs to finalize their organizational bylaws and job-description based on tasks and duties allocated for them.

(2) Human Resources

Staff capacity of NWRA-SB was assessed as low by a number of past studies, which suggest that technical capacity is still a major issue. IWRM calls for basin-level water management, which requires coordinated actions from various sub-sectors. NWRA-SB was set up for this coordination, but is only a few years old since its establishment in 2002. In fact, most of current staff of NWRA-SB, as well as of headquarters, was transferred from various ministries and authorities involved in another sector development, so that most of current staff had not been equipped with their expertise in the water resource management.

Among 20 government staff in NWRA-SB, there are no Master or Ph.D degree holders. During 2006, training courses has been conducted for NWRA Headquarters and its seven Branch Offices including Sana'a. Total of 69 staff received training in basic skills such as English language and computer programs, 49 in technical fields, 18 in administrative and financial fields, and 4 in the MSc. program abroad. Training was also provided to the members of water basin committees locally and abroad. However, training opportunities are limited to its Branch Offices, including NWRA-SB. Under the training course provided in 2006, a few staff from NWRA-SB has received training in water supply, water quality, remote sensing and report writing. To enhance the authority's technical capacity to carry out its mandates, the following areas were identified as priority; groundwater modeling, legal framework, regulation and enforcement, user participation in the basin management. These areas are critical to equip NWRA-SB to be a relevant and responsible local authority for Sana'a Basin water resource management.

Moreover, lack of sufficiently qualified staff is serious problem in NWRA-SB. It is reported that 50% of NWRA-SB staff, or 20 staff out of 40 staff in total, is still under contract basis for the particular assignments under donor-funded project/program. Thus, relatively qualified staff of current tends to be contracted and employed by donor funded project/program, while it is often said and may be true that other qualified staff in NWRA-SB is looking for employment in the private sector. There seems to be necessity to review staff remembrance/salary and to introduce an improved incentive mechanism through pay rises and promotion based on performance-based staff evaluation system.

(3) Financial Management

IWRM requires coordination with other sub-sector not only in strategies and activities but also in investment plan. There are several sub-sector national authorities in water sector, such as for urban water supply and sewerage, rural water supply, irrigation/agricultural development, and environmental protection. In such circumstances, MWE formulated the National Water Sector Strategies and Investment Program (NWSSIP 2005-2009) in 2005, through series of consultative meetings and consensus buildings with stakeholders. NWSSIP is indeed regarded as sole and prime national investment program for improvement of the water sector as a whole, which enables IWRM in a coordinated and strategic manner with all related sub-sectors.

NWRA is the main executive authority to undertake the planned water resource management activities set forth in NWSSIP, so that budget is requested to the government in accordance with financial requirement determined in the investment program in NWSSIP. However, the requested funds planned for 2006 investment budget in NWSSIP, is much more than the actually approved budget, while real expenditures of NWRA in 2006 were about 60% of the planned investment budget for water resource management set in NWSSIP for 2006. However, approved funds were only about 67% of the requested investment budget. Real expenditure of

NWRA in 2006 was around 89% of approved investment budget. This simply implies both the government and NWRA could not meet the requirement in investment and planned activities determined in NWSSIP.

(4) Regulation and Monitoring

Regulation and monitoring is one of the most significant tasks and duties to be provided by NWRA-SB for its basin-level water resource management. NWRA-SB has made a beginning in well registration. Up-to-date, NWRA has inventoried about 65,000 wells in Sana'a, Taiz, Sa'da, Hadramout, Rada'a, Amran, Ibb, Abyan and the Southern Tihama, while in 2006 about additional 14,600 wells were inventoried in Southern Tihama (11,500), Ibb (1,000) and Abyan (2,099). This figure represents about 22% of the total wells and about 16% of the total estimated wells (93,000) in the country.

NWRA-SB has prepared well registration formats, which were approved by the NWRA Chairman. In implementation, NWRA-SB approved 43 out of 132 license requests for the use of groundwater by various users. Cases of violation of rules such as unlicensed drilling by drilling contractors were referred to the prosecutor. These field activities are a good start. However, the progress is very slow with only 43 well registered and licensed among a considerable number of wells in the Sana'a Basin. Furthermore, scaling-up of registration and licensing seems to be rather challenging, when reviewing capacity of NWRA-SB in execution and enforcement of the regulation on the ground without having adequate staff (only 20 government staff in total is available for NWSA-SB as a whole) and budget for the field monitoring. Thus, there is a significant need to develop mechanism on field monitoring network, in collaboration with other local authorities. Local Councils as other local authorities that are also responsible for supervision and enforcement of rules and regulations in the basin-level water resource management shall be fully utilized to establish such local monitoring network, as it is suggested Chapter 6 and this Chapter.

7.5.2 LOCAL COUNCILS

Local Councils are also relatively new organization with its establishment has been facilitated since issuance of Local Authority Law in 2000. Local Councils exists at governorate and district levels, of which tasks and duties in basin-level water resource management are supervision and enforcement of rules and regulations as it is observed in detail in the previous sections. Local Councils both at governorate and district levels composes of distinctive two entities; one is directive body of which director at governorate is appointed by prime minister while one at district is appointed by governorate director, and the other one is executive organ that execute local administration and development that composes of local administrative staff. Although the executive organs for water resource management in Local Councils located in Sana'a Basin are not developed yet, and NWRA-SB seems to neglect the possibilities to cooperate with these local executive organs particularly for establishment of local monitoring network, it shall be further utilized and incorporated in the local organizational framework for the basin-level water resource management.

7.5.3 SANA'A BASIN COMMISSION (SBC)

Since SBC had established, it meets fairly regularly at about 6 times in a year, and based on the advice with donor and expatriate experts, it appears that substantive decision are made and are considered from a multi-sectorial basis. This is very positive.

However, the capacity for institutional arrangement to improve water management is insufficient and fragmented. Public institutions often lack authority over tribal structures and the strong autonomy of local water users. Experiences show that enforcement can only be

successful on a participatory basis, through a system of self-regulation. The project would couple regulation with a participatory water resource management approach and a public information and awareness program.

Thus, means create and maintain channels to involve traditional leaders and tribal institution in decision making, enforcement of self-regulating water management mechanism, e.g. involvement of them in SBC.

Furthermore, in order to strengthen regulatory and monitoring system, relevant supporting organizations such as the Ministry of Interior, Ministry of Local Administration, and Ministry of Justice to enforce water regulations, seems to be involved in SBC for its purpose.

7.5.4 WATER USER ASSOCIATION (WUA)

Irrigation accounts for 90% of groundwater withdrawals in the country. Groundwater depletion, especially in the Sana'a Basin, has reached a stage where migration of the whole valley's population is no more a remote debate. Thus, on-farm water savings to reduce non-beneficial water losses and thus to reduce pumping form a central pieces of the national water strategy set forth in the Water Law and decree that defines Sana'a Basin as one of the "protected area". To be successful, it needs collective effort and working closely with farmers through WUA and WUG.

Currently, under the project component of "Demand Management and Irrigation Improvement" implemented by Sana'a Basin Water Management Project, traditional open channel flood irrigation is being replaced by modern irrigation technologies such as pipes with drip and bubbler. As a pre-condition to participate and benefit from the project investment in which a considerable portion of cost for introduction of improved technology is subsidized by NWRA-SB, farmer covering 6-12 ha with a few families, are required to form a WUA. The number of WUGs in each WUA varies, depending on location and vicinity of the wells, but is at times arbitrary. WUA collects farmer contribution to capital investment, organize farmer awareness activities, and acts as liaison between the Project and individual farmer or WUGs. The establishment of WUA forms an important part of this project component. Together with WUA formulation, demonstration farm (often 1-2 ha) has been selected for each WUA and received investment in modern irrigation infrastructure.

Establishment of demonstration farms is of vital significance. The significance of the demonstration farms stems from the fact that they are the major source and means for convincing the farmers to adopt improved irrigation systems. Farmers have to be confident with the soundness and profitability of the technology in a visible manner. The more practical an explanation is (actual demonstration), the more farmers will adopt the new improved technology.

The benefit from these on-farm investment have so far been obvious, as water saving reached over 50%, and it could be higher per the huge reduction in pumping time; reduction of diesel consumption due to reduced needs for pumping, better products and production.

However, this activities are highly delayed, and has had a negative impact on farmers" acceptance of the new irrigation technologies (MWE, SBWMP, 2006). Accompanied with this, farmer's awareness raising appears also inadequate. Some are hesitated in contribution to capital investment or in joining WUA (in some area, only 10 out of 40 WUGs joined WUA).

At present (July, 2007), 48 WUAs has been established with 530 WUGs formed and 4440 farmers involved. It can be said that this is good progress since the project component started in 2004. However, poor progress is observed in installing and converting improved irrigation system with only 211 ha installed, or less than 5% of the project target. The relatively higher

number of WUAs and WUGs formed against smaller area converted with improved irrigation technologies calls for good quality implementation in social mobilization, cohesion and training of WUAs and WUGs.

The key issue over longer term, herein, is the improved awareness of WUAs and WUGs. It is they that are going to handle the bulk of the regulation of water usage by the group and by each farmer through adoption of improved technologies with irrigation efficiency. If this is done, and farmers simply use the water saved for higher application levels or expand irrigated area, the entire point of this component – water saving – is lost. Thus, the quality of WUAs/WUGs is a key need, and is more fundamentally important than the project's achievement in terms of the number of WUGs and number of hectares. In essence, it is more important to develop successful program than to achieve targets that are not replicable or of demonstration value because they have not succeeded. In the assessment for the WUAs and WUGs that have already been formed, their quality, in terms of social mobilization and training is not yet sufficient.

Accompanied with this, there is limited training for WUAs/WUGs in agronomic practices that will result in water waving. Beneficiaries should be acquainted with appropriate cropping patters in order to adopt to growing less water consuming crops. Training programs for the staff should emphasize efficient water use through proper knowledge of crop water requirements, irrigation scheduling and water saving, leading ultimately to increased productivity. Thus, farmers' extension services should focus on the aspects of operation and maintenance of improved irrigation equipment and agronomic practices. Also, they should be convinces not to expand to more crop area as a result of water saving through the modern irrigation systems. Additionally, the tripartite agreement between farmers, the community organization and the NWRA-SB should be endorsed, and especially, the role of WUAs should be fully activated as referred above.

CHAPTER 8

ENVIRONMENTAL AND SOCIAL CONSIDERATION

CHAPTER 8 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

8.1 REGULATIONS AND LAWS CONCERNING ENVIRONMENTAL CONSIDERATION

8.1.1 ENVIRONMENTAL POLICY AND LAWS IN YEMEN

The environmental legal framework of Yemen started in 1991 when the Environment Protection Council (EPC) was established. Four years later, the backbone of the environmental policy in this country, that is, the Environmental Protection Law (Law No. 26 of 1995) was enacted. This law is consisted of five parts, of which the main parts are: the "Protection of water, soil and use of pesticides (Part two)", the "Environmentally damaging activities (Part three)" and "Marine pollution (Part four)". Regarding water, it stipulates in Articles 6 and 7 that the concerned body shall protect the surface and ground water, and that the necessary bodies shall prepare policies and plans concerning water resources program. Incidentally, this law is now under modification, which, is expected to be finished by the end of this year.

In the same year as the enactment of the Environmental Protection Law, (1995), the EPC adopted "National Environmental Action Plan (NEAP)". This was a plan set up to determine priority issues and priority actions in the main environmental fields, water resources, natural habitats, and waste management. The plan has set four key issues to be prioritized and the first one is concerning water depletion and pollution. (The other issues are land degradation, habitat degradation and waste management). Regarding water, the plan mentions that a) over-extraction of groundwater, b) lack of water allocation and conservation systems, c) water pollution and d) inadequate water services are the specific concerns. For these concerns, they have set 3 targets, namely: - a) To conserve Water Sources, b) To protect Water Sources from Pollution, and c) To provide clean drinking water to 75% of the population by the year 2000. This year, the Government of Yemen is making a new Plan, and of July, 2007, this new plan is already drafted for approval.

In 2001, the government took two important steps in the field of environment: a) The first is creating the Environmental Protection Agency (EPA) which have mandate of developing and implementing the environmental policies and legislation. b) The second is amendment of the constitution, article 35: "The protection of the environment is the responsibility of the state and society, and it is a national and religious obligation for every citizen". Regarding a), the EPA is now under the mandate of the Ministry of Water and Environment (since 2005, before it was under Ministry of Tourism and Environment), derived from the former EPC. Comparing with the former EPC which had just a coordinating role the new EPA has a clear mandate to implement the environmental legislation and to execute projects.

In October 2002, the EPA issued the "Environmental and Sustainable Development Investment Program 2003-2008 (ESIP)", which constitutes the framework for Government's environmental policy of the next years. The ESIP presents an outline strategy and priority interventions aimed at controlling and gradually reversing the trend of depletion and degradation of the natural resources and supporting the human development for the people of Yemen. The ESIP is already under implementation and it focuses on 6 main areas, which are: a) Habitat and biodiversity conservation, b) Sustainable land management, c) Sustainable water management, d) Sustainable energy management and e) Institutional development. As far as water is concerned, the programs which the ESIP has stated are shown in *Table 8.1*.

Table 8.1 The programs concerning Sustainable Water Management in the ESIP

Action	Concerning Bodies	Budget required
Support the enhancement of the water law and information system	EPA, NWRA, MOWE	0.1 million US $
Support the optimization of water use and securing additional water resources	EPA, NWRA, MOWE	0.2 million US $
Pollution control for fresh water resources, water supply and water harvesting systems	EPA, NWRA	1.0 million US $
Create public opinion against pollution and overexploitation of water resources	EPA, NWRA	0.2 million US $

Source: Environment and Sustainable Development Investment Program 2003-2008, EPA, 2002

As have stated above and also throughout this report, water problem is the most crucial problem of which the country of Yemen is presently confronting. Careless development in this sector shall call more problems. Therefore, in 2006, the National Water and Sanitation Authority (NWSA) issued "Sectoral Environmental Assessment Report (SEAR)", to assess the overall problems concerning the water sector development. This report sets guidelines to the future projects concerning water and sanitation, on what kind of impacts is anticipated in these projects, and shows what kind of alternatives are there to mitigate these impacts.

8.1.2 ENVIRONMENTAL IMPACT ASSESSMENT IN YEMEN

In articles 35 - 43 of the Environmental Protection Law (Law No.26 of 1995), it stipulates the role of the Environmental Impact Assessment (EIA) procedure in Yemen. In the following year, policy paper setting the procedure of the EIA was issued. The process of the EIA depends on the type and the scale of the project. The process of EIA in Yemen is shown in *fig. 8.1*

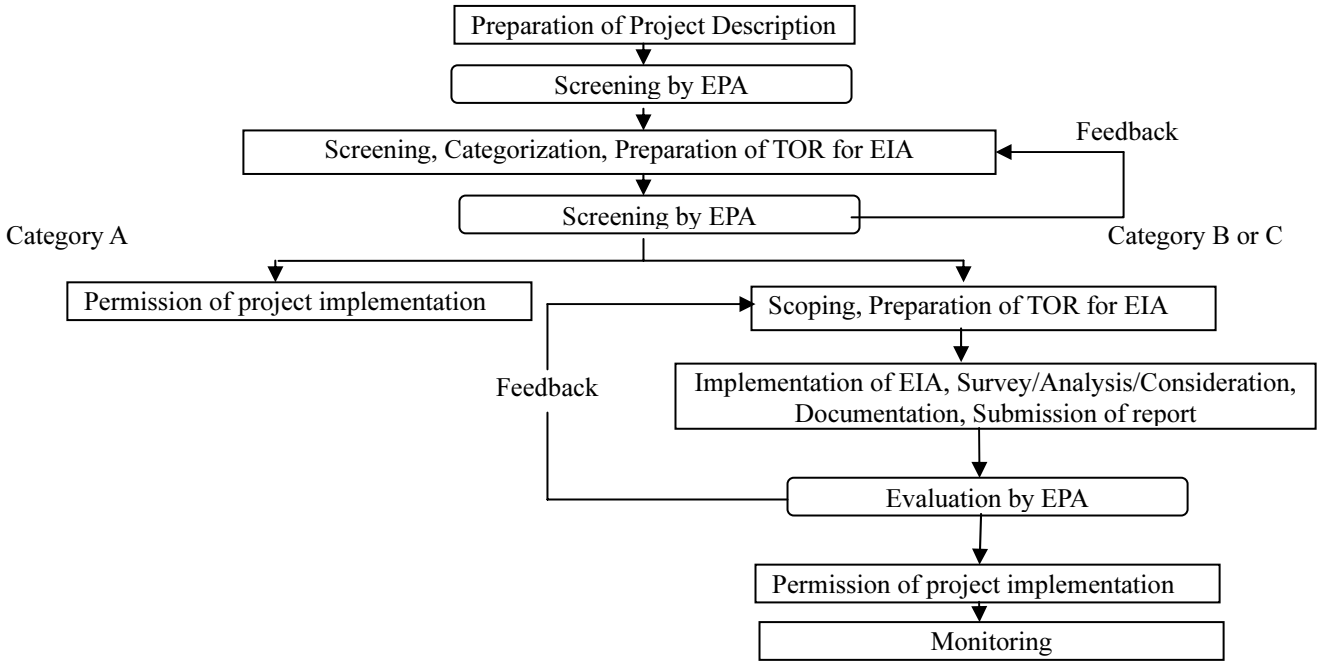

Figure 8.1 The EIA procedure in Yemen

8.2 INTRODUCTION OF STRATEGIC ENVIRONMENTAL ASSESSMENT

8.2.1 WHAT IS STRATEGIC ENVIRONMENTAL ASSESSMENT?

A Strategic Environmental Assessment (SEA) involves the evaluation or assessment of plans, programs or policies. SEA is a process to ensure that significant environmental effects arising from policies, plans and programs are identified, assessed, mitigated, communicated to decision-makers, monitored and that opportunities for public involvement are provided. The difference between the usual EIA ("project oriented EIA") and the SEA is that the project-oriented EIA (hereafter referred to as just EIA) focuses on one particular project, SEA assesses in a broader, long-termed scale. Thus, SEA is often done on a regional or sectoral basis. With the implementation of the idea of SEA, the policy makers can foresee the impacts from the policy, plan or programs concerned so that the environmental and social impact from the plan can be minimized as possible.

8.2.2 ANTICIPATED ENVIRONMENTAL IMPACTS FROM THE PLAN

From the plans already stated in the main report, impacts which can be anticipated are stated below. Also, impacts which can be anticipated if there is no action of the plan is taken, is shown as *No plan*.

(1) Inter-sectoral allocation of water resources

Table 8.2 Anticipated Impacts (1)

Action plan	Anticipated impact	Remarks
Inter-sectoral allocation of water resources	Tribal conflict	- The users of the current water supply will claim his rights to use it if the explanation is not properly conducted.
	Lowering of groundwater level	- If the reallocated water is used too much, this may cause depletion of groundwater level.
No plan	Depletion of groundwater	- If the water is used at this pace (especially for agriculture), the depletion of groundwater shall continue, and in years to come, there shall be no more water.
	Unfairness of water allocation widens	- The unfairness between the domestic water and agricultural water shall widen further.

(2) Use of water harvesting methods

Table 8.3 Anticipated Impacts (2)

Action plan	Anticipated impact	Remarks
Rainwater Harvesting	NEGLIGIBLE	(No significant impact is expected from this action plan)
Floodwater Harvesting	NEGLIGIBLE	(No significant impact is expected from this action plan)
Terraces	NEGLIGIBLE	(No significant impact is expected from this action plan)

No Plan	Soil erosion	If the terrace fields are left abandoned, the soil erosion shall eventually be serious.
	Depletion of groundwater	If the groundwater is used at this pace, then the depletion of groundwater shall continue, and, in years to come, there shall be no more water.

(3) Use of treated waste water

Table 8.4 Anticipated Impacts (3)

Action plan	Anticipated impact	Remarks
Use of treated waste water	Too much cost taken for irrigation	The treated water must be pumped up to be used for irrigation, which means there shall be cost for energy.
No Plan	Depletion of groundwater	If the groundwater is used at this pace, then the depletion of groundwater shall continue, and, in years to come, there shall be no more water.

(4) Improvement of water use efficiency of irrigation use

Table 8.5 Anticipated Impacts (4)

Action plan	Anticipated impact	Remarks
Introduction of improved irrigation system	Too much cost taken for irrigation	The initial cost of the improved irrigation system is too expensive for some farmers.
Introduction of less water consuming crops	Unfairness of income between farmers	If the new introduced crop cannot make enough cash compared to the former crops, there will be unfairness of income between the farmers
Control of expansion of irrigated area	Tribal conflict	If the land for expansion in some areas are limited, this might be potential for conflict between farmers
	Urban concentration	If the young people cannot get new land, these people might have to go to the urban area for new job
No Plan	Depletion of groundwater	If the usage of agricultural water continues to be used in the same manner, the groundwater depletion shall continue, and in the years to come, there will be no more water in the basin.
	Unfairness of usage of water between urban and rural	If the rural (especially for agriculture) usage of continues at this pace, the unfairness between rural and urban shall be greater.
	Degradation of crop biodiversity	If the farmers continue to grow only few types of crops (especially qat), the crop biodiversity will lower.

(5) Reduce of illegal drilling

Table 8.6 Anticipated Impacts (5)

Action plan	Anticipated impact	Remarks
Reduce of illegal drilling	Tribal conflict	If the drillers are not informed properly, conflict between the local people and the officers might breakout.
No Plan	Depletion of groundwater	If the illegal drilling is continued in this pace, the level of groundwater shall deplete, and eventually there shall be no more water left.

(6) Improvement of the water use efficiency of urban area

Table 8.7 Anticipated Impacts (6)

Action plan	Anticipated impact	Remarks
Reduce of leakage	NEGLIGIBLE	(No significant impact is expected from this action plan)
Reduce of illegal connection	Tribal conflict	If the illegal connectors are not informed properly, conflict between the connectors and the officers might breakout.
Establishment of monitoring system for private supplier	NEGLIGIBLE	(No significant impact is expected from this action plan)
No plan	Depletion of groundwater	If the urban water supply system is not maintained properly, the water consumption rate shall rise,
	The cost of water price shall rise	If the illegal connection and leaks from the system continues, "unaccounted for water" shall rise meaning that the cost for supply will increase. Finally, the cost will reflect on the water price.

(7) Improvement of sewage system in urban area

Table 8.8 Anticipated Impacts (7)

Action plan	Anticipated impact	Remarks
Improvement of capacity of WWTP	NEGLIGIBLE	(No significant impact is expected from this action plan)
Establishment of sewage collection system	NEGLIGIBLE	(No significant impact is expected from this action plan)
No plan	Water contamination	If the untreated water goes out to the wadis, the water shall be contaminated.
	Soil contamination	If the untreated water is seeped into the ground, then the soil shall be contaminated.

(8) Control of utilization of fertilizers and pesticides

Table 8.9 Anticipated Impacts (8)

Action plan	Anticipated impact	Remarks
Control of over utilization of fertilizer and pesticides	NEGLIGIBLE	(No significant impact is expected from this action plan)

No plan	Soil contamination	The chemicals shall contaminate the soil.
	Water contamination	The seeped water to the wadis from the contaminated soil shall contaminate the water

(9) Consideration of recharge and sub-surface dam

Table 8.10 Anticipated Impacts (9)

Action plan	Anticipated impact	Remarks
Consideration of recharge and sub-surface dam	Depletion of groundwater downstream	If there are no consideration of groundwater movement in construction of the dam, the groundwater stream may be cut off.
No plan	Depletion of groundwater	If the groundwater is exploited randomly at this pace, the groundwater in the region shall eventually be depleted.

(10)Consideration of transferring water from outside Sana'a Basin

Table 8.11 Anticipated Impacts (10)

Action plan	Anticipated impact	Remarks
Consideration of transferring water from outside of Sana'a Basin	Dams: Degradation of vegetation	The vegetation in the submerged area of the dam shall be damaged also. It must be taken care not to damage important species.
	Involuntary transmigration	The residents of the submerged area of the dam must be involuntarily moved.
	Groundwater: tribal conflicts	The residents of the water source area have the chance to demand their rights of using the new well.
	Depletion of groundwater in other area	The exploitation of new groundwater in other basins shall lead to depletion of groundwater in other areas.
	Desalination: Water price shall rise too much	Desalination is a costly alternative, meaning that the water price might rise too high for the people to pay.
No plan	Depletion of groundwater	If there is nothing done about the current situation, the groundwater level will continue to deplete.

(11) Better comprehension of water resources, consumption and demand

Table 8.12 Anticipated Impacts (11)

Action plan	Anticipated impact	Remarks
Better comprehension of water resources, consumption and demand	NO IMPACT	(No impact is predicted from this plan)
No Plan	Uncontrolled consumption of water resources	If there is no understanding of the critical situation within the users, then the consumption of water will be further uncontrolled.

8.2.3 PROPOSED MITIGATION MEASURES

The mitigation measures to countermeasure with the anticipated impacts are shown below.

(1) Tribal Conflicts

Although there has been many modern modifications have been brought out, the social system in Yemen, and in particular in the Sana'a Basin, has been dependant on their tribal traditions, including social hierarchy. The local tribe leaders in some cases do not hesitate to stop by force the implementation of a larger Government project if they feel that it does not seem to benefit them directly. The competition for scarce resources involves completion between tribes to obtain basic services from the Government. This often results in tensions and occasionally armed clashes about the location of infrastructure improvements, such as water supply facilities. To avoid these kinds of potential conflicts, the below countermeasures (mitigations) are recommended:-

- Involvement or participation of the concerned tribes (local residents) in the planning process to make them understand and accept the decided plan.

- Involvement or participation of the local residents in the construction stage

- Continuous effort to make the local people understand about the purpose of the plan

- Consideration of compensation measures such as supplying water to the villages which the water pipeline passes

(2) Depletion of groundwater

As have stated before in the previous chapters, the groundwater level in the Sana'a basin is gradually depleting. Therefore, intensive care is necessary upon planning any groundwater development, including reallocation of water supply to domestic uses. If the planning of the redistribution of the sources is not carefully done, the new plan may cause additional depletion of ground water in the Basin. As for sub-surface dams, care must be taken not to completely stop the groundwater flow. To avoid the depletion of water by implementation of the plan, the countermeasures (mitigation) are shown below:-

- Careful planning on the reallocation of groundwater, not to disturb the current groundwater level.

- Consideration of groundwater potential before any groundwater development

(3) High cost on irrigation

The new irrigation system is considered to be one of the solutions to the high consumption rate in the agricultural sector. However, because of the high initial cost compared to the traditional method, the farmers hesitate to introduce the system. To avoid the hesitation on introduction of the new system,

- Continuous explanation to the farmers on the necessity of the introduction of new irrigation system

(4) Degradation of vegetation

Construction of dam outside of the Basin shall create some area of vegetation degradation. To avoid or to minimize the effect, the countermeasures are shown below:-

- Conduction of environmental survey on the natural environment prior to the planning, and avoiding areas of vulnerable environment.

(5) Involuntary transmigration

Construction of dam outside of the Basin on the existing settlement shall arise involuntary settlement. To avoid or to minimize the effect, the countermeasures are shown below:-

- Location of the should be set to minimize the effect as possible.