CHAPTER 5

PRESENT CONDITION OF WATER USE

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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

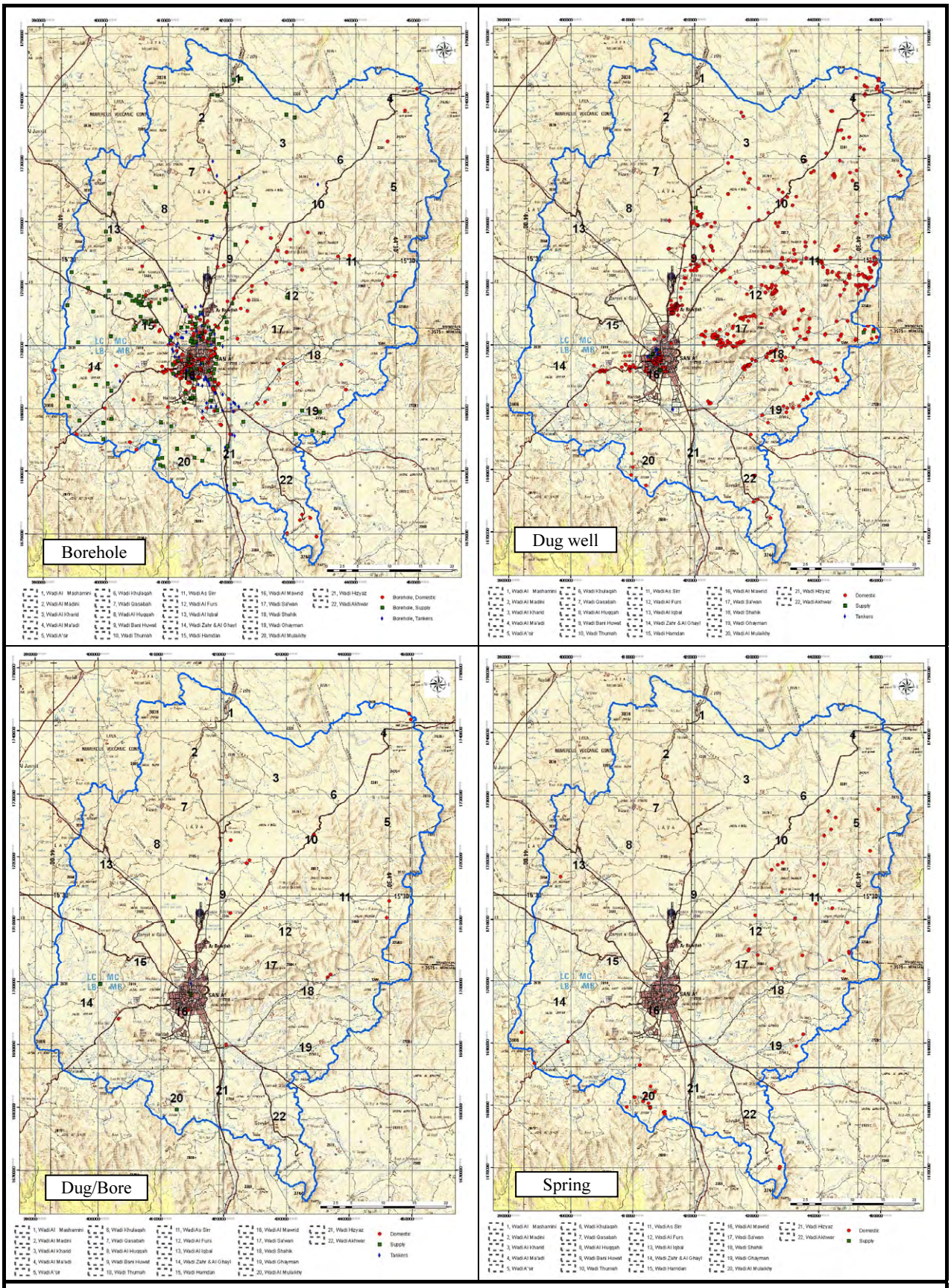


FIGURE 5.1 DISTRIBUTION MAP OF WATER POINTS FOR DOMESTIC USE BY TYPE

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

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

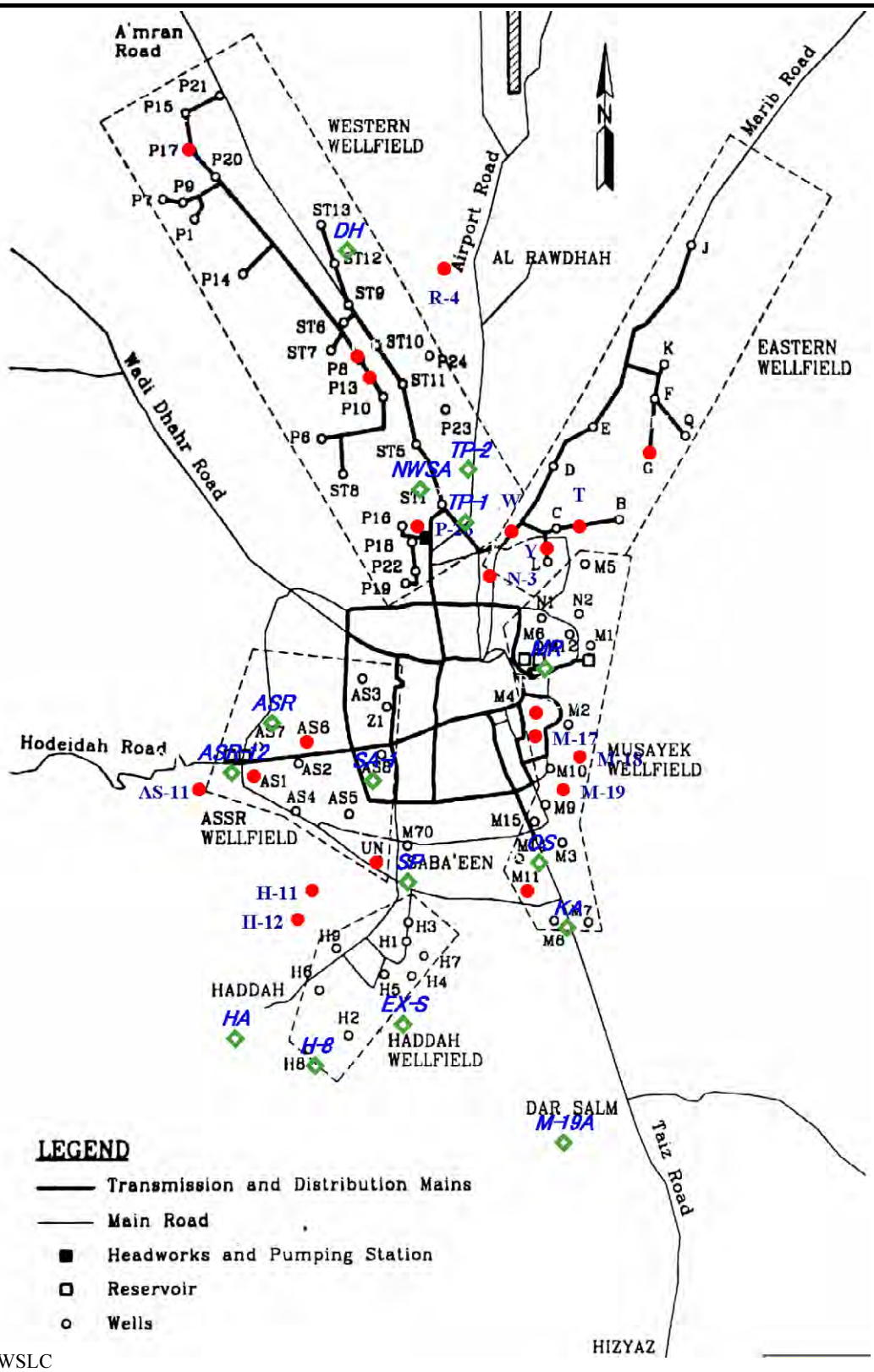
The main source of the public water supply for Sana'a City is groundwater abstracted from three main well fields called Eastern Well Field, Western Well Filed and Sana'a Well Field. Sana'a Well Field is divided into three sub-fields. Musayek Well Field, Asser Well Field and Haddah Well Field. Eastern 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

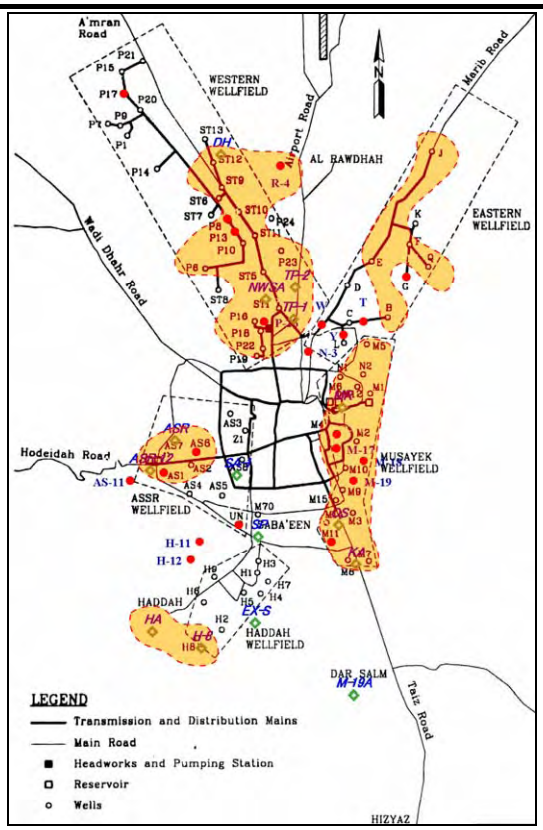
Well No	Date	Poor Quality Items
H2	06/Dec/1993	
	18/Jun/1994	pH=8.73
	24/Jan/1995	pH=8.80
	16/Apr/1996	pH=8.81
	20/Mar/1999	pH=8.68
H3	06/Dec/1993	pH=8.51
	18/Jun/1994	pH=8.70
	24/Jan/1995	pH=8.58
	16/Apr/1996	
	21/Mar/1999	
	13/Jun/1999	
	24/Jan/2001	pH=8.64
	03/Sep/2005	
H4	06/Dec/1993	pH=9.35
	18/Jun/1994	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

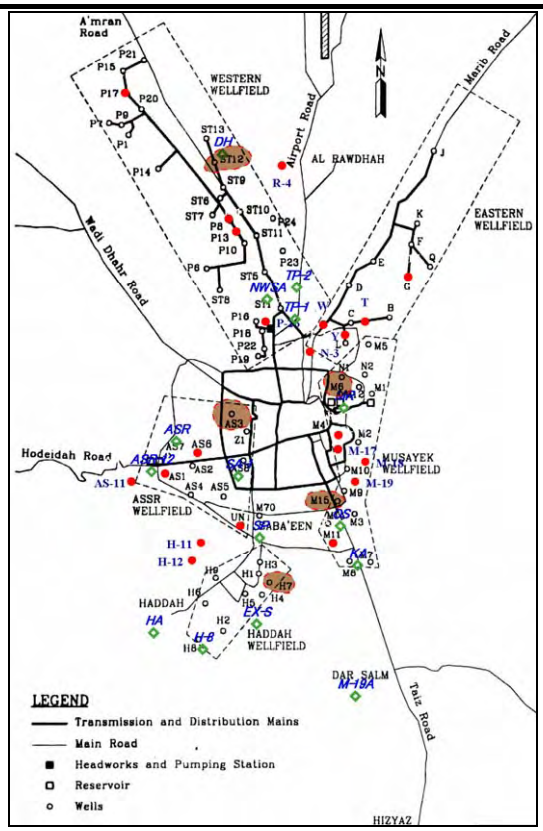
Results of water quality analyses are summarized as follows:

- 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.

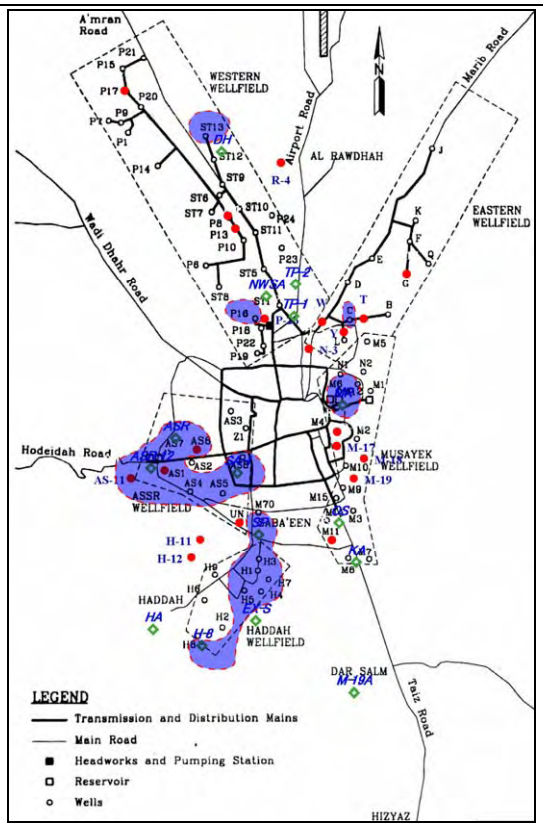
Figure 5.3 and *Figure 5.4* shows analyses results of wells with poor water quality by parameter analyzed. Actually, water abstracted from some wells are treated only by chlorination before discharged to distribution tanks and others are discharged directly to the main distribution pipe without treatment



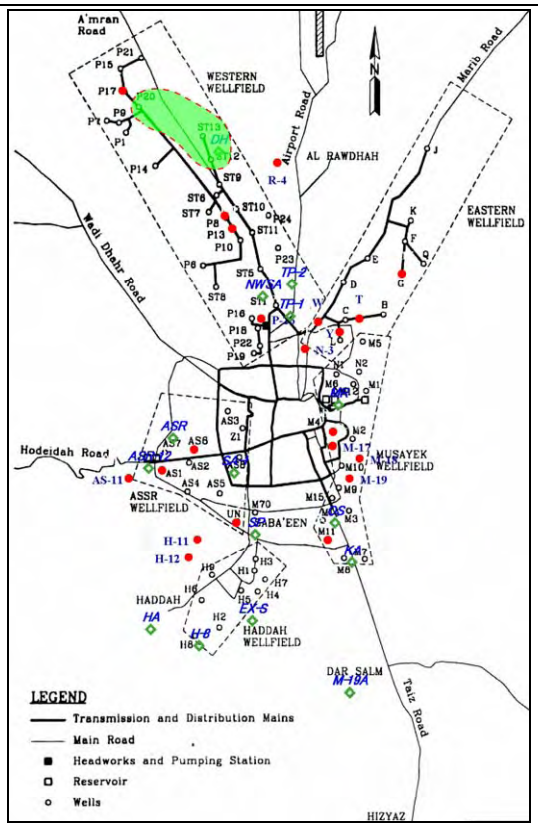
Parameter: Fe



Parameter: NO3



Parameter: pH



Parameter: TDS

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

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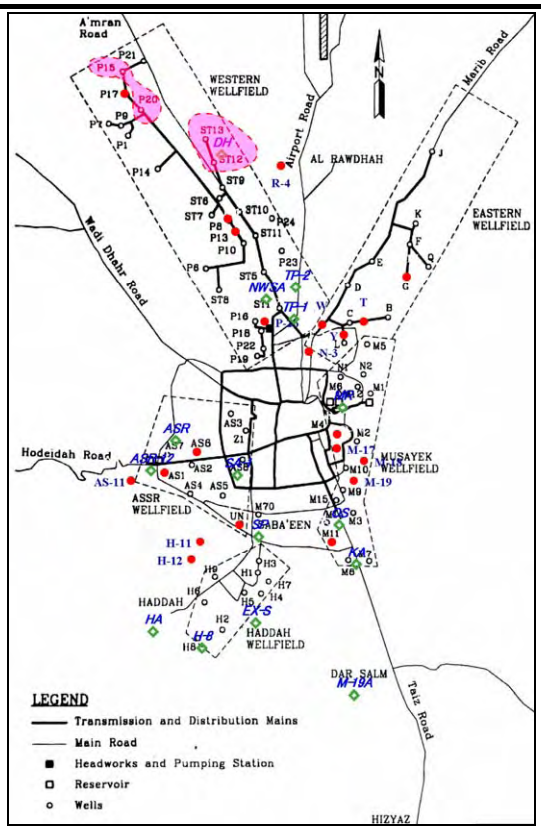
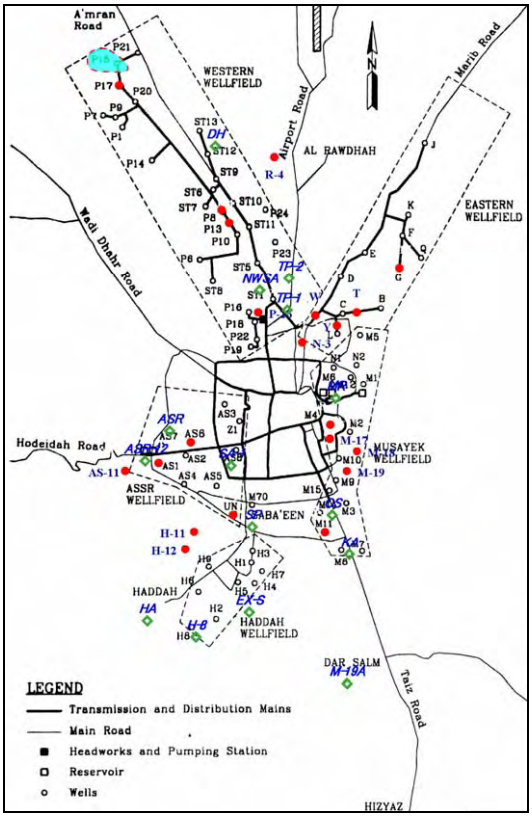
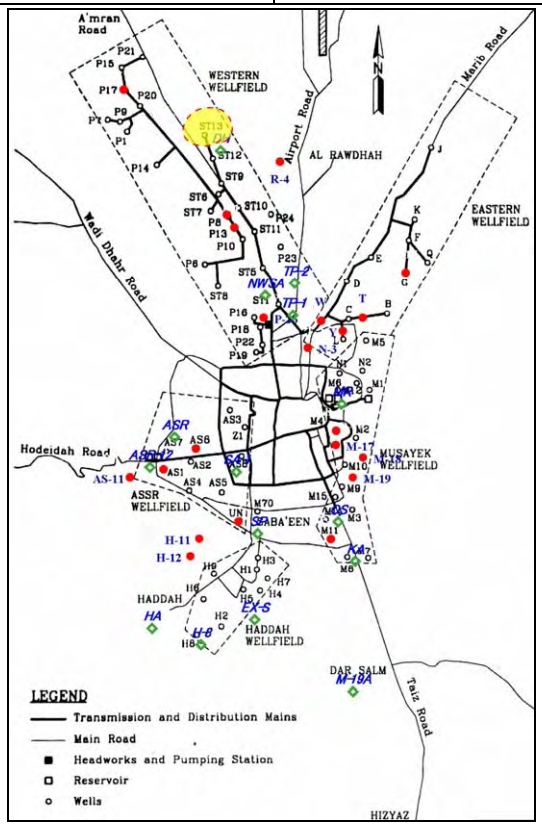


Parameter: SO4



Parameter: Ca



Parameter: Na

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

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

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.

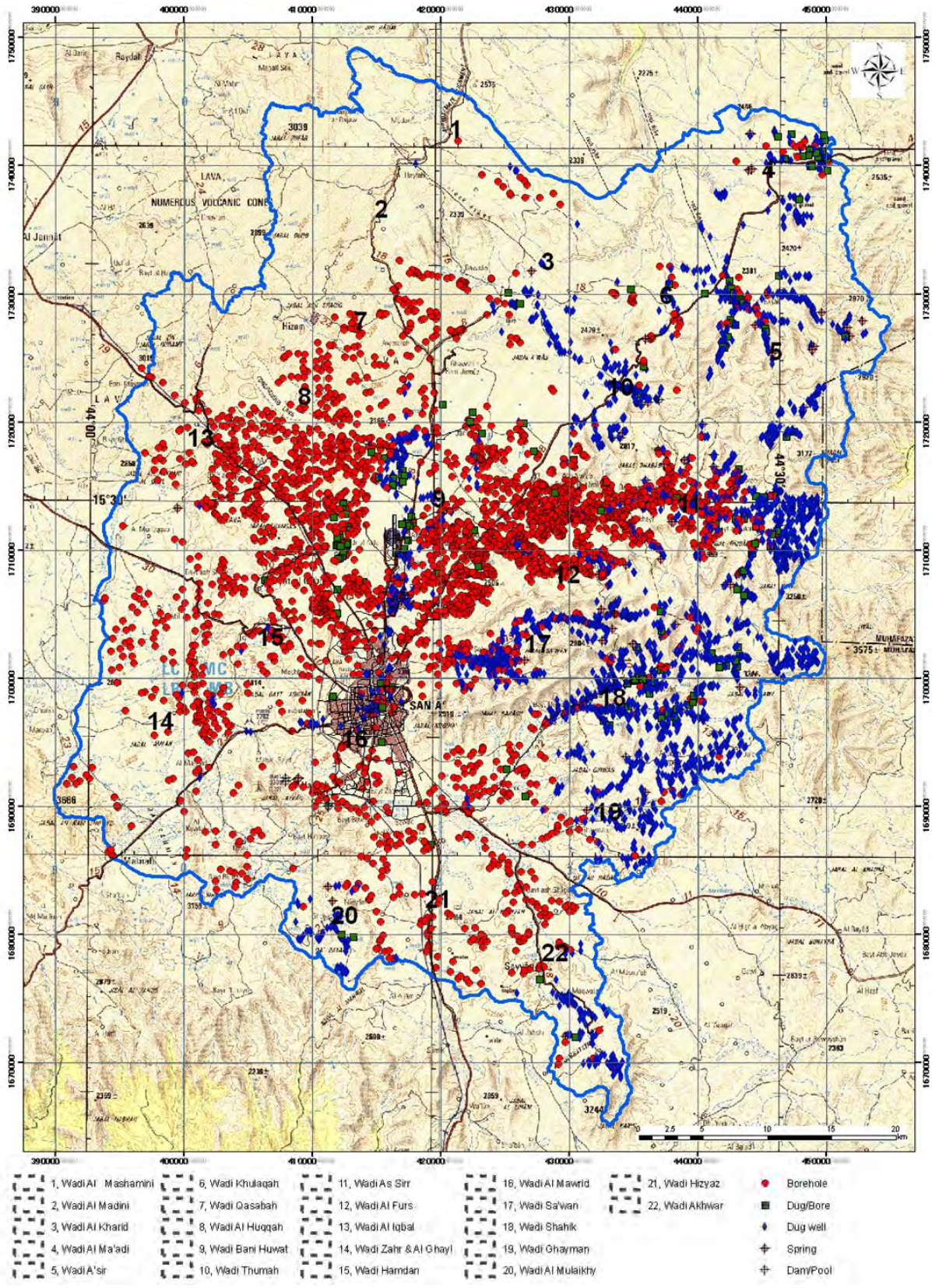


FIGURE 5.5 DISTRIBUTION MAP OF WATER POINTS FOR IRRIGATION USE BY TYPE OF WELL

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)

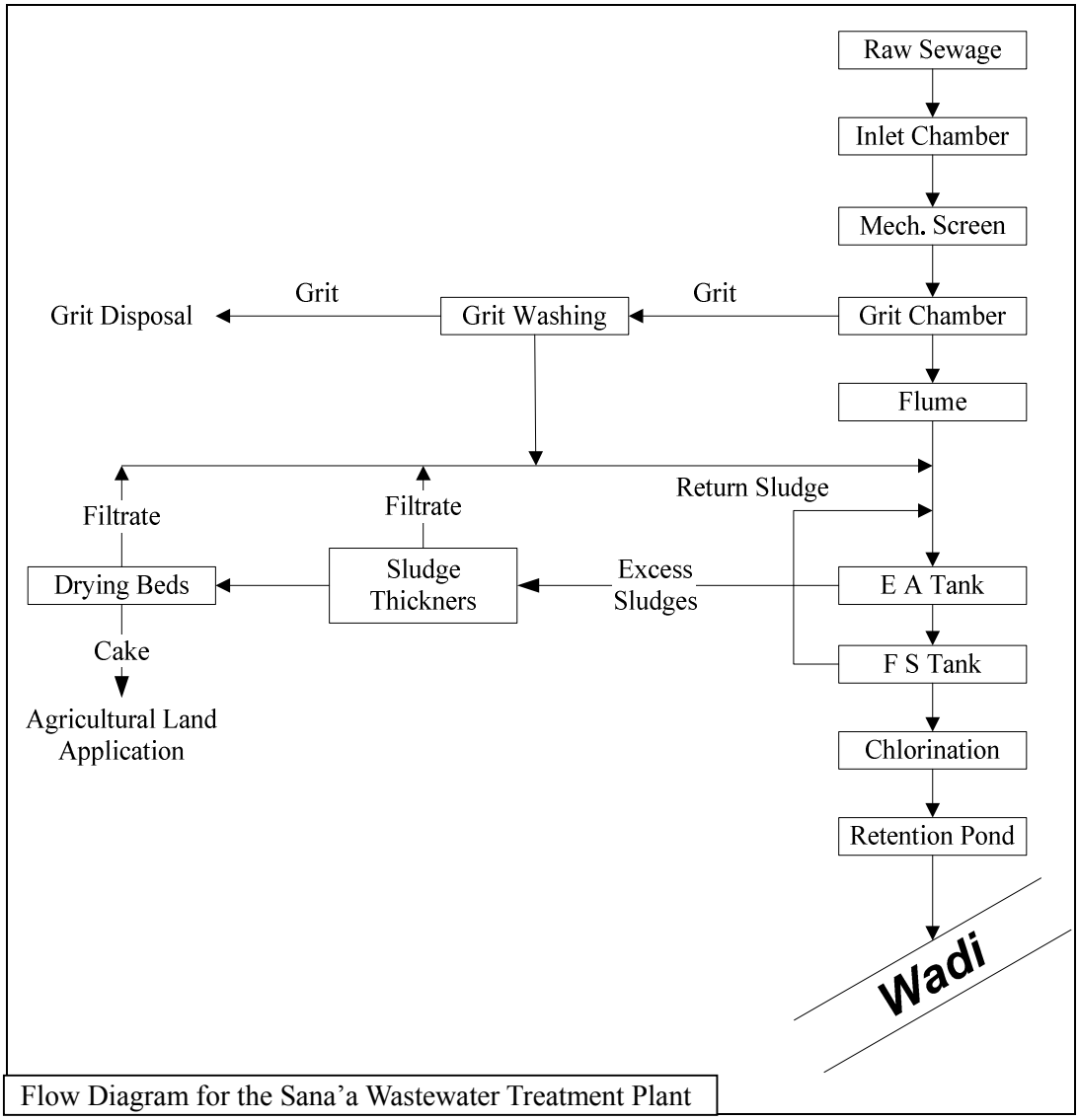
WWTP has been built in the middle of Capital city, in a sensitive area adjacent to the International Airport and was completed in mid 2000. It is presently operated by SWSLC and the effluent is treated by chlorination before it is discharged into a wadi via a lagoon and there are no facilities available 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.

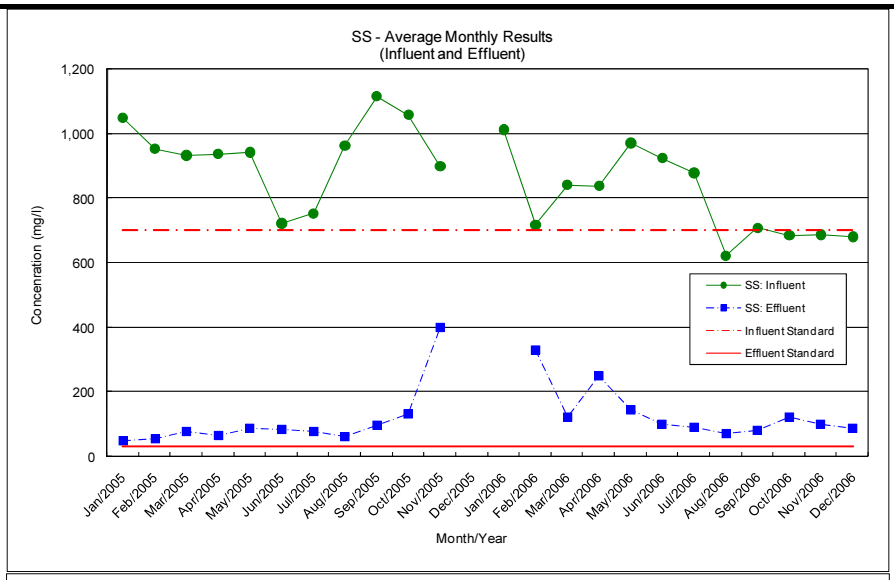
Higher concentration of SS, BOD5 and NH4 observed on influent wastewater, after treated, a significant reduction of concentration is observed. However the concentration still higher than standards for effluent and the treated water is discharged directly to wadi. This water flows through a wadi by gravity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

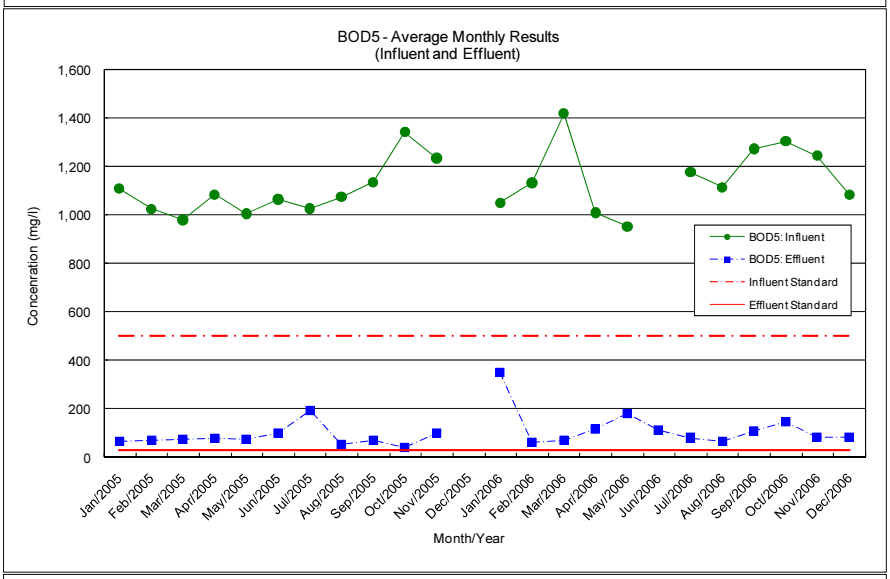
Actually, upgrading project for WWTP is ongoing. According to information, objective of project is increase the treatment capacity to manage the actual overloaded BOD5 and also installation of facilities to treat the water to acceptable quality for use in agriculture and watering the trees in the City. 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.





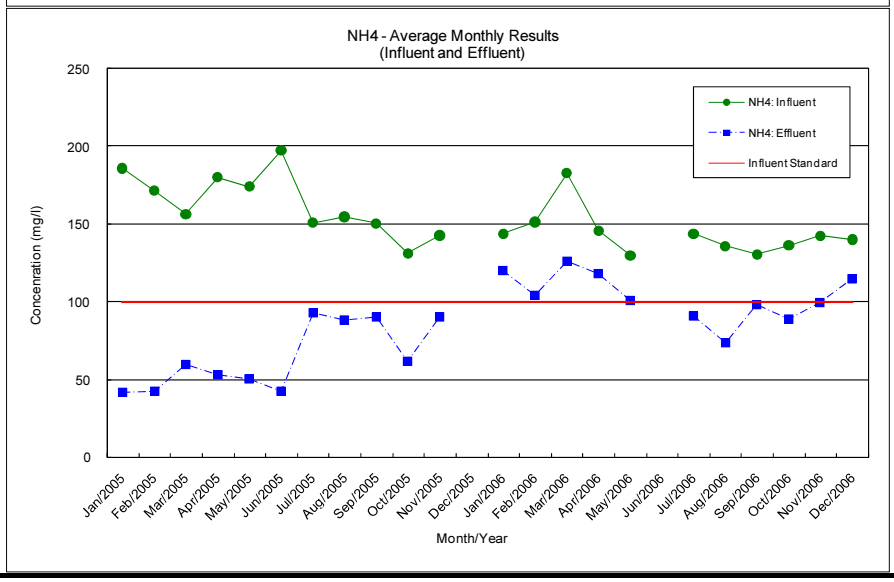


FIGURE 5.7 MONTHLY AVERAGE RESULTS OF INFLUENT AND EFFLUENT FOR SS, BOD5 AND NH4

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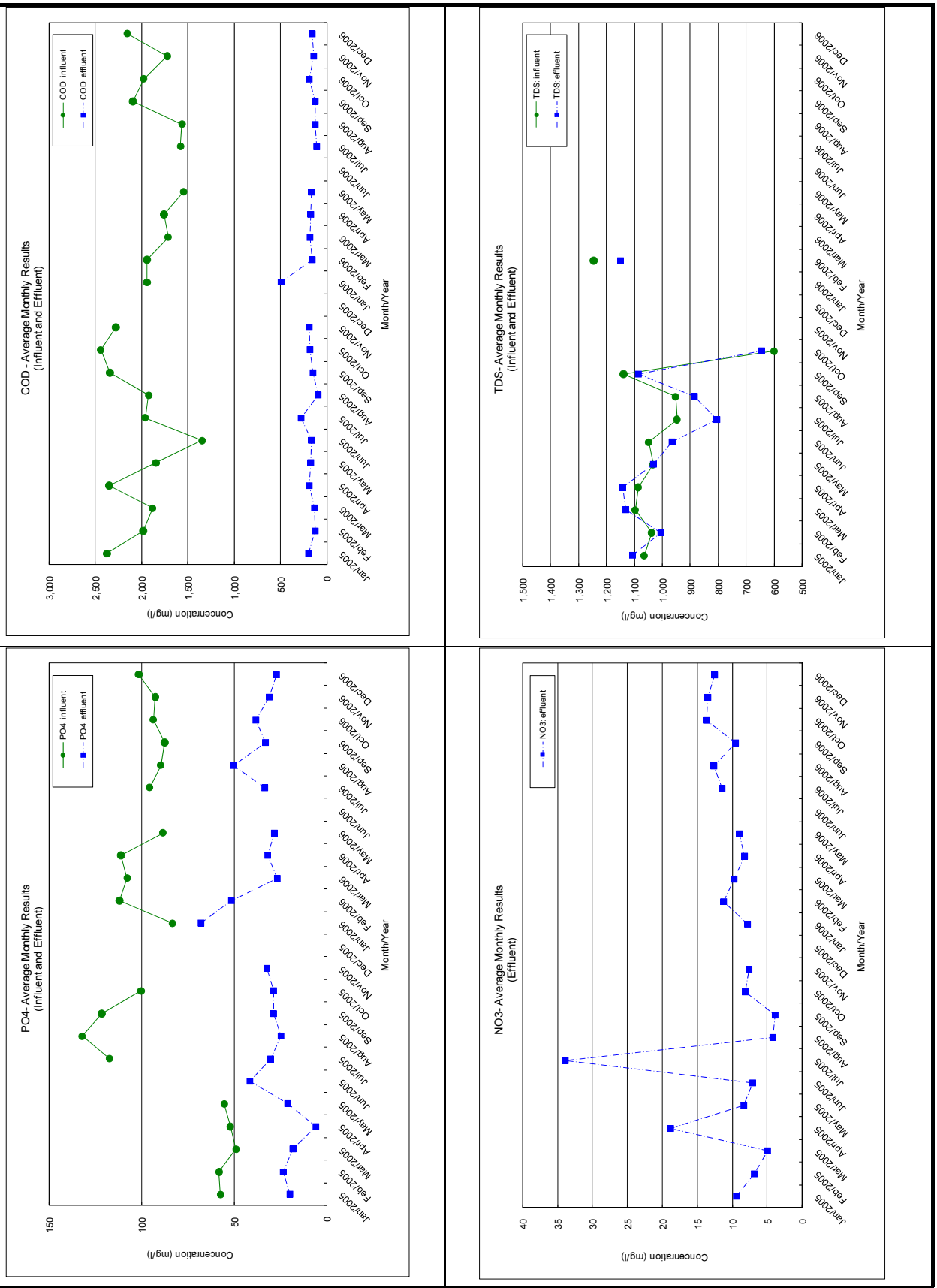

FIGURE 5.8 MONTHLY AVERAGE RESULTS OF INFLUENT AND EFFLUENT FOR PO4, COD, TDS, NO3

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.

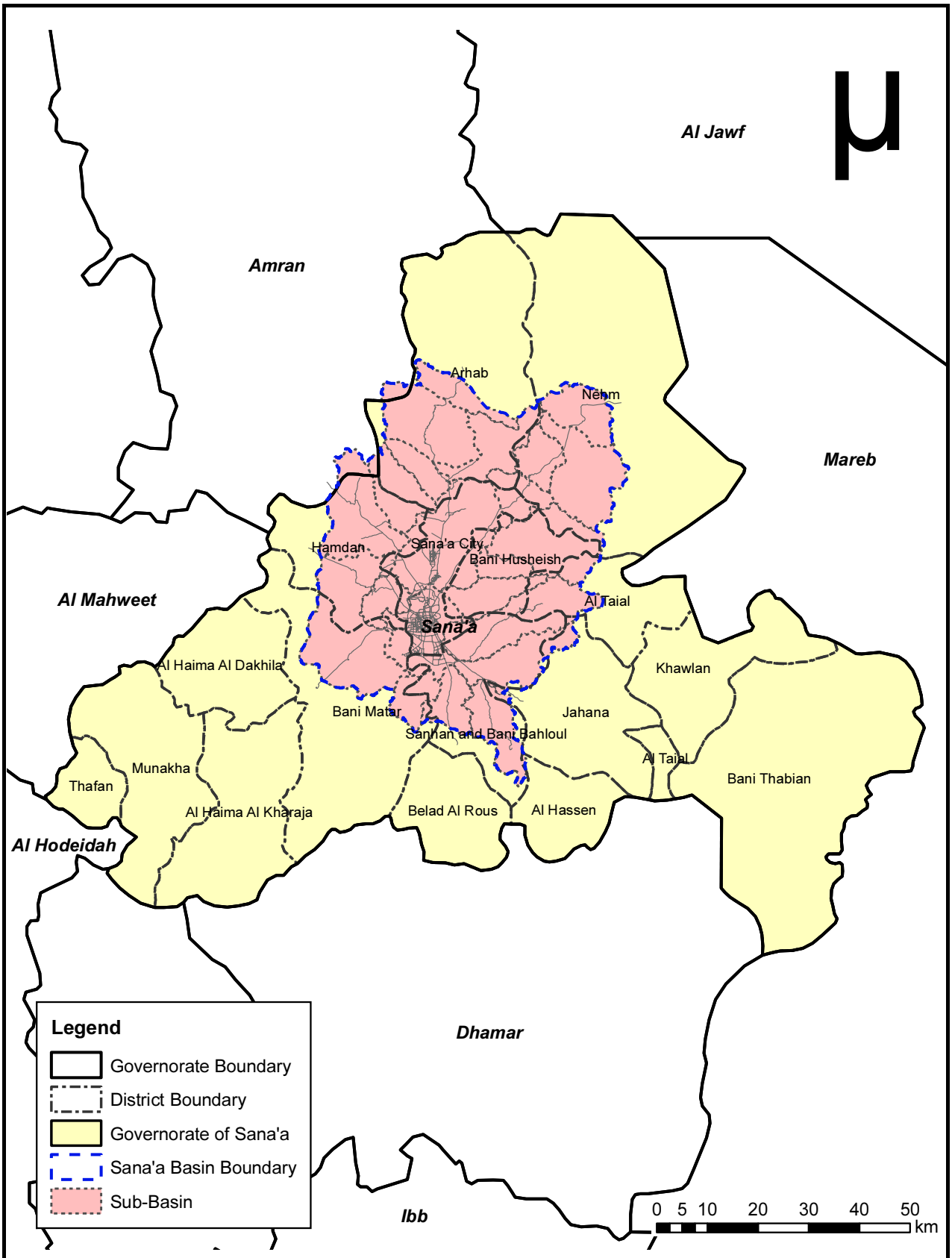

FIGURE 5.9 LOCATION OF SANA'A BASIN WITHIN THE GOVERNORATE OF SANA'A

(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)

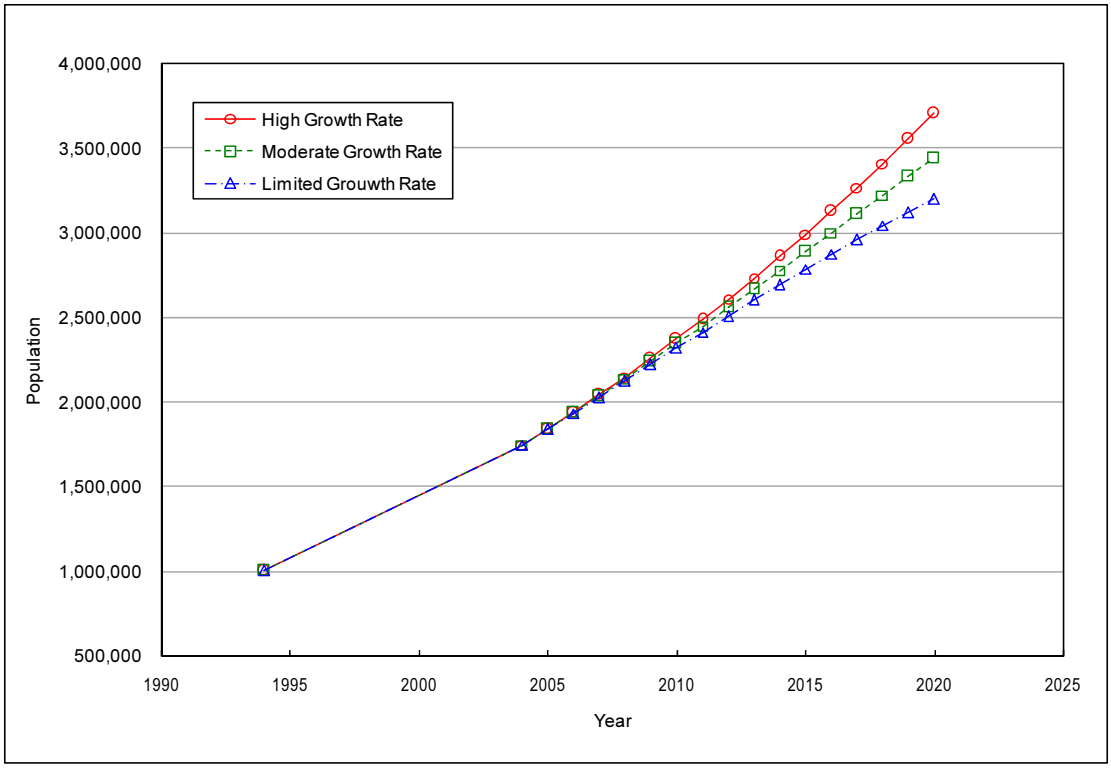

Figure 5.10 Chart of Population Forecast for Sana'a City

(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*.

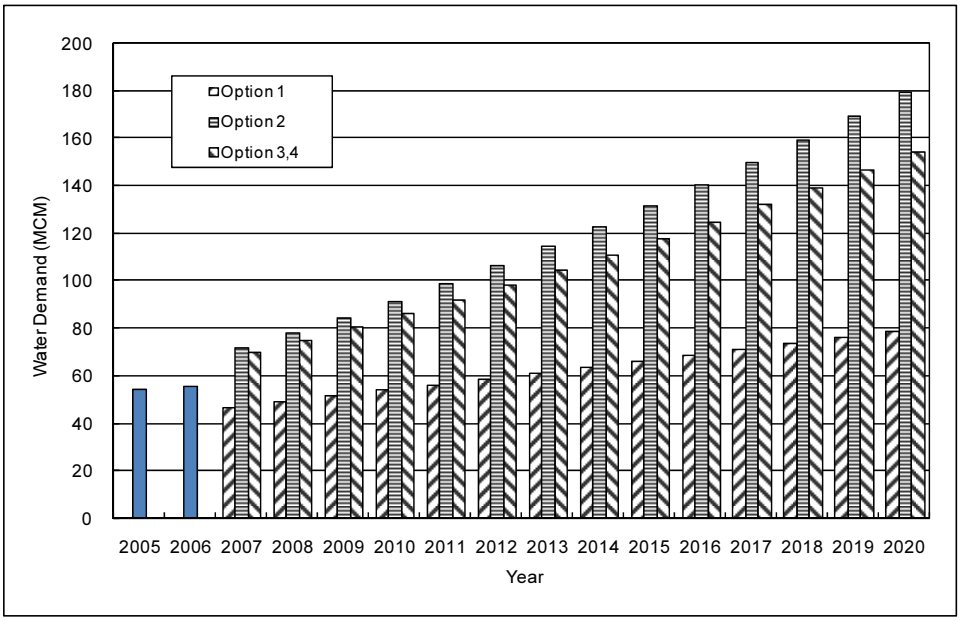

Figure 5.11 Urban Water Demand Projection Chart

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

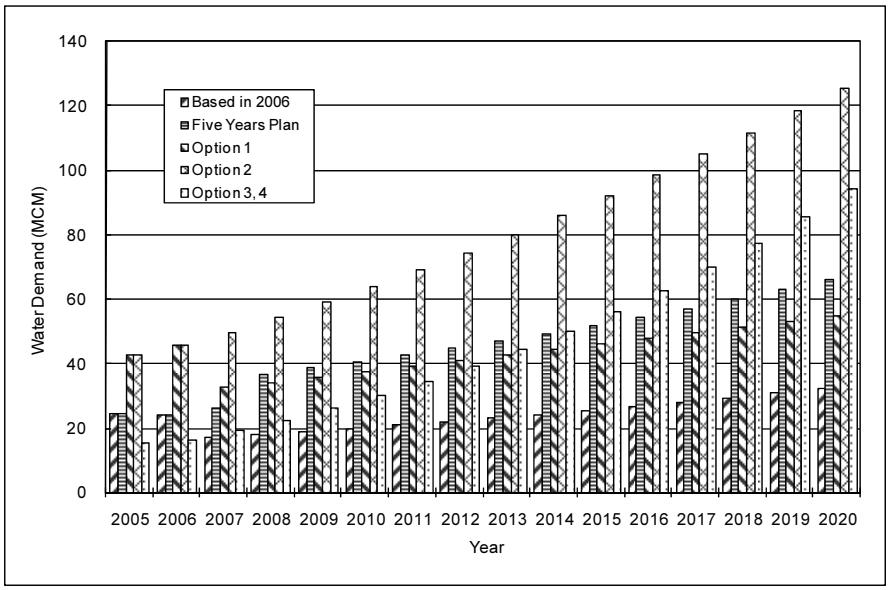

Figure 5.12 Domestic Water Demand Projection Chart

(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

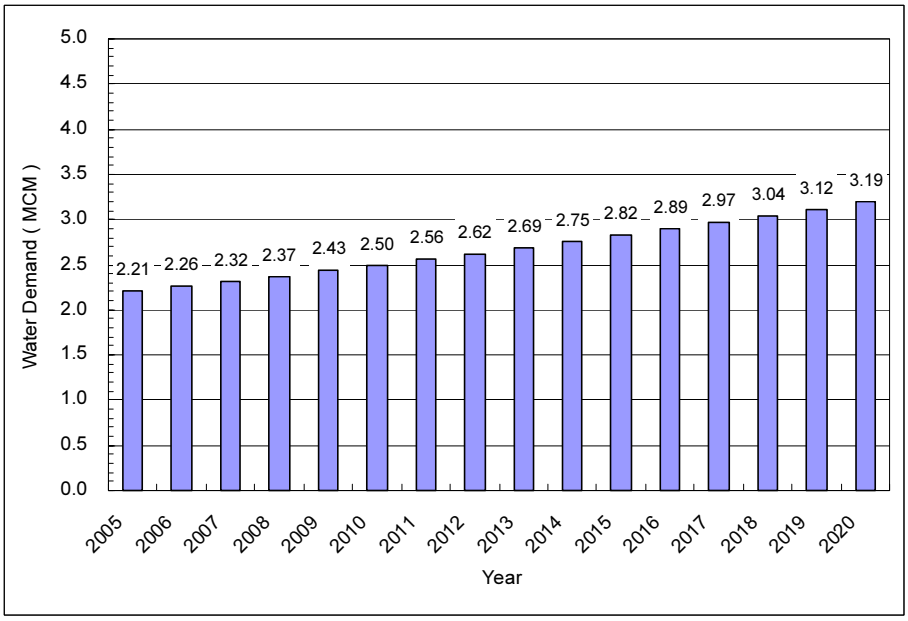

Figure 5.13 Rural Domestic Water Demand Projection Chart

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

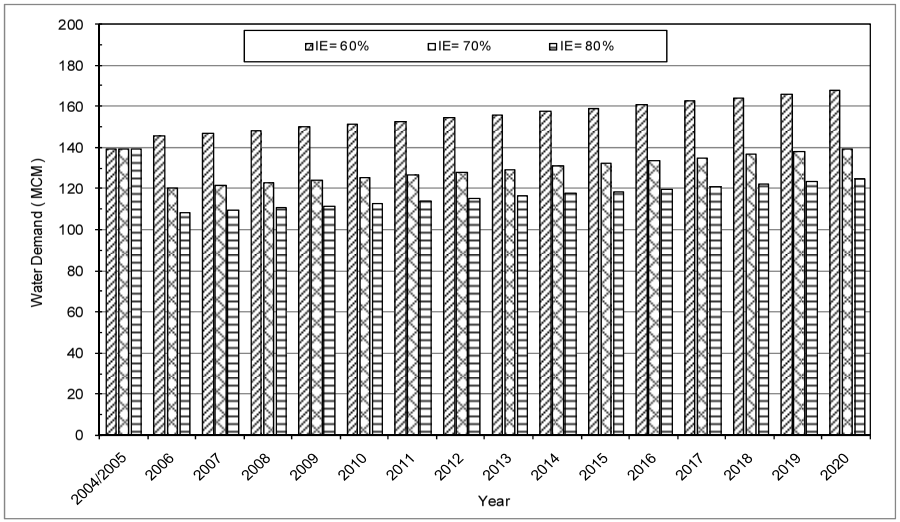

Figure 5.14 Irrigation Water Demand by Irrigation Efficiency

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

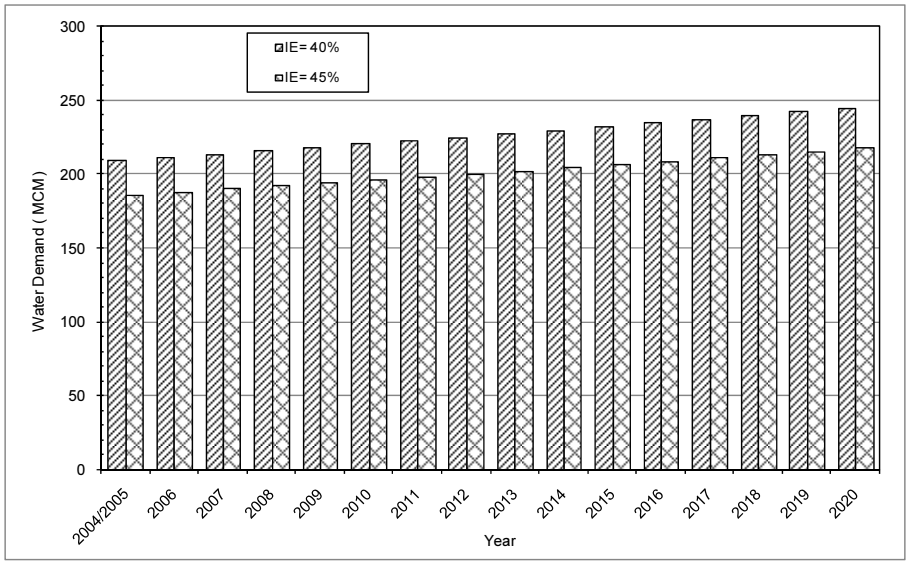

Figure 5.15 Irrigation Water Demand Projection Chart (IE=40% and 45%)

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

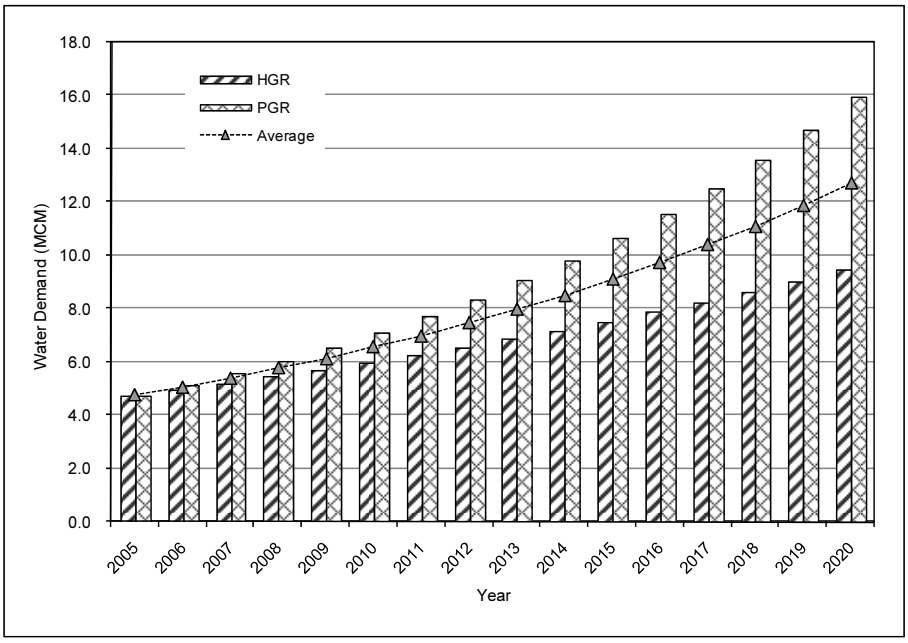

Figure 5.16 Industrial Water Demand Projection Chart

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

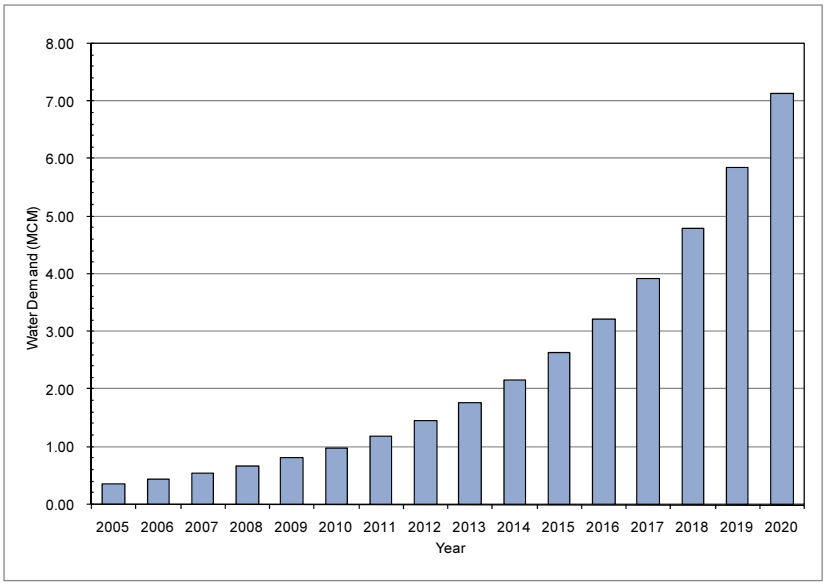

Figure 5.17 Touristic Water Demand Projection Chart

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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