No.

NATIONAL WATER RESOURCES AUTHORITY (NWRA)
MINISTRY OF WATER AND ENVIRONMENT (MWE)
THE REPUBLIC OF YEMEN

THE STUDY FOR THE WATER RESOURCES MANAGEMENT AND RURAL WATER SUPPLY IMPROVEMENT IN THE REPUBLIC OF YEMEN WATER RESOURCES MANAGEMENT ACTION PLAN FOR SANA'A BASIN

Final Report

SUPPORTING REPORT

November 2007

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

EARTH SYSTEM SCIENCE CO., LTD.
in association with
JAPAN TECHNO CO., LTD.

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<u>**TABLE OF CONTENTS (SUPPORTING REPORT)**</u>

CHAPTER 4 PRESENT CONDITION OF SOCIO-ECONOMY

CHAPTER 5 PRESENT CONDITION OF WATER USE

CHAPTER 6 CURRENT INSTITUTIONAL AND ADMINISTRATIVE FRAMEWORK

CHAPTER 7 CURRENT ORGANIZATIONAL STRUCTURE

CHAPTER 8 ENVIRONMENTAL AND SOCIAL CONCIDERATIONS

APPENDICES

<u>**LIST OF TABLES (SUPPORTING REPORT)**</u>

CHAPTER 2 WATER RESOURCES MANAGEMENT PLAN FOR FOR OTHER CRITICAL BASINS

CHAPTER 3 PRESENT STATE OF WATER RESOURCES

CHAPTER 4 PRESENT CONDITION OF SOCIO-ECONOMY

CHAPTER 5 PRESENT CONDITION OF WATER USE

CHAPTER 6 CURRENT INSTITUTIONAL AND ADMINISTRATIVE FRAMEWORK

CHAPTER 8 ENVIRONMENTAL AND SOCIAL CONCIDERATIONS

LIST OF FIGURES (MAIN REPORT)

CHAPTER 3 PRESENT STATE OF WATER RESOURCES

CHAPTER 4 PRESENT CONDITION OF SOCIO-ECONOMY

CHAPTER 5 PRESENT CONDITION OF WATER USE

CHAPTER 8 ENVIRONMENTAL AND SOCIAL CONCIDERATIONS

ABBREVIATIONS

ACU	Agricultural Cooperative Union
CSO	Central Statistical Organization
DPPR	The Third Socio-Economic Development Plan for Poverty Reduction
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EPC	Environment Protection Council
ESIP	Environmental and Sustainable Development Investment Program 2003-2008
ETa	Actual Evapotranspiration
GAREW	General Authority for Rural Electricity and Water
GARWSP	General Authority for Rural Water Supply Projects
GDI	General Directorate of Irrigation
GDP	Gross Domestic Product
GVP	Gross Value Product
HDL	Highest Desirable Limit
HGR	Historical Growth Rate
HWC	High Water Council
IRDA	Integrated Rural Development Authority
IWRM	Integrated Water Resource Management
MAF	Ministry of Agriculture and Fisheries
MAI	Ministry of Agriculture and Irrigation
MCM	Million Cubic Meters
MEW	Ministry of Electricity and Water
MPL	Maximum Permissible Limit
MPWH	Ministry of Public Works and Highway
MWE	Ministry of Water and Environment
NEAP	National Environmental Action Plan
NRW	Non-Revenue Water
NWP	National Water Policy
NWRA	National Water Resources Authority
NWRA-SB	National Water Resources Authority -Sana'a Branch
NWS	National Water Strategy
NWSA	National Water and Sanitation Authority
NWSSIP	National Water Sector Strategy and Investment Program
PGR	Programmed Growth Rate
PIUs	Project Implementation Units
PMUs	Project Management Units
PRS	Poverty Reduction Strategy
SAWAS	Sources for Sana’a Water Supply
SBC	Sana’a Basin Commission
SBWMP	Sana’a Basin Water Management Project
SBWRM-PPT	Sana'a Basin Water Resources Management Study
SEA	Strategic Environmental Assessment
SEAR	Sectoral Environmental Assessment Report
SFYP	The Second Five-Year Plan
SWSLC	Sana’a Water Supply and Sanitation Local Corporation
SWSSP	Sana'a Water Supply and Sanitation Project
TDS	Total Dissolved Solid
TWSLC	Ta'iz Water Supply Local Corporation
WEC	Sana’a University Water and Environment Centre

WHO	World Health Organization
WUA	Water User Association
WUF	Water User Federation
WUG	Water User Group
WWTP	Sana'a Wastewater Treatment Plant
YGGMP	Yemeni-German Geological Mapping Project
YSV	Yemen's Strategic Vision 2025

CHAPTER 1

NATIONAL POLYCY AND SRATEGY FOR WATER

CHAPTER 1 NATIONAL POLICY AND STRATEGY FOR WATER

1.1 NATIONAL WATER STRATEGY

Responding to the serious dimensions of the water crisis, Yemeni government has adopted National Water Strategy (NWS). The objectives of NWS are as follows;

- Protection of water resources from depletion and pollution.
- Optimal utilization of water resources to achieve the highest value for water.
- Provision of water to meet the demands of society for all purposes.

To fulfill the above objectives, NWS follows the following principles; 1) all surface and groundwater resources within the boundaries of the Republic of Yemen are considered natural resources owned as public property, 2) the State shall design the framework of legislation and regulations pertaining to water resources. 3) each citizen has the right of access to water to meet the basic demand of his household, 4) the water sector shall occupy the first rank among economic and social development sectors. Water security is ranked second to national security, 5) existing water rights shall be respected, and 6) NWS defines itself as a basis for other related strategies and policies, National Water Policy (NWP), National Water Sector Strategy and Investment Program (NWSSIP) and Water Law have been established accordance with the ethos of NWS.

1.2 NATIONAL WATER POLICY

To achieve the objectives of National Water Strategy, National Water Policy (NWP) was established. NWP provides that water policies, such as water resources policy, watershed management policy, irrigation policy, domestic water supply policy, and wastewater reuse policy should be formulated and implemented by water sector agencies. NWP prescribes the roles for water sector agencies, such as National Water Resources Authority (NWRA) and Ministry of Agriculture and Irrigation (MAI). This Policy is basis of Water Law.

1.3 WATER LAW

The Water Law is first enabling legislation and institutional back-up for the country's water resource management. After more than 10 years discussion and negotiation among various institutions and authorities, parliament approved the Water Law in 2002. In addition, for further legal and regulatory development a number of other official regulations such as Republican/Cabinet Decree, Prime Minister Resolutions, and Ministry of Water and Environment (MWE)'s Decree have been issued to support and enforce the Water Law of 2002. For example, the Prime Minister Resolution No.227, which issued on 2004 nominates NWRA as the only authority responsible for water well licensing and set down that other institutions should receive a written authorization from NWRA for any licensing and registration activities, or terminate issue of licenses (Article 11a). It is upholding and supporting statements of Article (73) of the Water Law.

However, the Water Law fails to define itself as the sole legal means to manage water resources and water rights rather than other significant laws, such as Islamic Law, Civil Code, and Customary Law in the country, it does not provide legal mechanism to resolve the disputes over resource management and water rights and enforce punishment to the violator according to the LAW.

Therefore, in 2007, the parliament approved the amendment of the Water Law No. (33) of 2002 to attempt to adjust the shortcoming above, however the Water Law still does not have enough effectiveness to regulate water consumptions.

1.4 National Water Sector Strategy and Investment Program

In accordance with National Water Strategy and National Water Policy, National Water Sector Strategy and Investment Program (NWSSIP) is initiated to prepare a consolidated strategy, action plan and investment program for the whole water sector as a multi-stakeholder process.

If the situation of water scarcity continues as it is without regulation of ground water extraction and use, without reduction of the current unsustainable level of water resources use, and without putting an end to the ongoing resource capture, then this will eventually harm everyone, including farmers, who will be the first victims of water exhaustion. In addition, water regulation is needed to safeguard or the economic and social growth of the cities.

Thus, NWSSIP proposes a set of institutional, financial and other measures, which aim at addressing discrepancies in the five sub-sectors (water resources, urban WSS, rural WSS, irrigation and environmental aspects of water) in order to protect the interests of all stakeholders in the resources.

NWSSIP sets four objectives for sector management.

- To ensure coordination among all partners working in urban and rural water supply and sanitation sub-sectors to ascertain that policies in each two sub-sectors are unified and that investments are equitably allocated among governorates according to unified rules and that no projects are duplicated
- To ascertain integration of water policies and national policies of sustainable growth and poverty reduction
- To ensure that sector financing effectively supports sector goals
- To monitor and evaluate performance

To achieve these objectives, NWSSIP proposes three policies.

- Giving immediate priority to defining and implementing the strategy, investment program and action plan
- To organize the institutional and administrative setup of sector institutions and to ensure that they are properly functioning and managed
- To ensure that cross-cutting issues are being dealt with in an integrated manner (funding, community contribution, tariffs, training, etc)

Regarding to water resources management, NWSSIP set following five objectives.

- To ensure greater degree of sustainability

- Giving priority to domestic needs of rural and urban populations
- Improved water allocation, while mindful of equity, social norms, meeting the domestic needs and maximizing economic benefits
- Creating a realistic and holistic water vision among the general population
- Contributing to poverty alleviation by promoting efficient water use and equity in water allocation.

1.5 DEVELOPMENT PLAN FOR POVERTY REDUCTION

The third Socio-Economic Development Plan for Poverty Reduction (DPPR, 2006-2010) is the second in a series of national plans designed to fulfill Yemen's Strategic Vision 2025 (YSV), which aims to raise the country's international ranking from a 'least developed country' to one of 'medium human development'. The Second Five-Year Plan (SFYP) served as the launch pad for realizing this national vision. It also provided a general framework for the national Poverty Reduction Strategy (PRS) for 2003-2005, as poverty reduction became the central theme for cooperation and partnership with the international community. The SFYP and the PRS included a group of goals and objectives to achieve economic growth, alleviate poverty, and create more job opportunities through diversification and strategic investments in promising sectors while ensuring political and social stability. What follows is a summary of results achieved under SFYP.

Yemen's severely scarce water resources are in increasing domestic, agricultural and industrial demand and suffers from poor management and use practices. Depletion of water resources has become a major constraint to growth and development and a serious threat to the stability and sustainability of Yemeni society. The DPPR's vision is to achieve integrated management of resources, improve the legislative environment, and safeguard access to water as a right. In the present circumstances, agriculture accounts for 91% of total water consumption, while domestic consumers account for 7%, with another 2% used for industry. The DPPR's vision aims to increase the domestic and industrial shares of total water use to 15% and 4% respectively and, to reduce the depletion ratio to 25%, while increasing water resources by 5% a year. The DPPR's vision is to provide safe water and appropriate sanitation services for all regions, and thus to improve the health and environmental human development needs of the country. Yemeni government aims to increase coverage of safe water supplies to about 71% of the urban and 47% of the rural populations. Similarly, sanitation services will be extended to 52% of the urban and 37% of rural residents by the year 2010. Furthermore, water loss in the networks will be cut down to 15%, and waste water treatment will be raised from 50,000m^3 in 2005 to 100,000m^3 by 2010.

CHAPTER 2

WATER RESOURCES MANAGEMENT PLAN
FOR OTHER CRITICAL BASINS

CHAPTER 2 WATER RESOURCES MANAGEMENT PLAN FOR OTHER CRITICAL BASINS

2.1 GENERAL

The Republic of Yemen is divided into 14 Water Basins and Zones. Actually, water resources management plan for two of them, namely Ta'iz Region and Sa'dah Basin have the management plan formulated and implemented. Formulation of management plan ongoing is for Sana'a Basin (this study), for Hadhramawt Basin and for Tuban-Abyan Basin. Management plan for Amran Basin, Rada-Dhamar Basin and Tihama Basin is planned to be formulated.

Five of the basins mentioned above were designated to be "Water Protection Zone" by the Cabinet Decree No. (344) in the year of 2002 and they are considered as critical basin on the point of view of water resources. These basins are Ta'iz Region, Sa'dah Basin, Hadhramawt Basin, Tuban-Abyan and Sana'a Basin.

Water resources management plan for others basins are listed in *Table 2.1* below.

Table 2.1 Water Resources Management Plan for Other Basin

Name of the Basin /Region	Title (year formulated)	Status
Ta'iz	Water Resources Management Action Plan for the Ta'iz Region (2000)	Implementation started in 2004
Sa'dah	Water Resources Management Plan for Sa'dah Basin (2005)	Implementation started in 2007
Sana'a	Water Resources Action Plan for Sana'a Basin (2007)	Formulated in this study
Hadhramawt	Title undecided (expected to be formulated in 2007)	Formulation is ongoing
Tuban - Abyan	Title undecided (expected to be formulated in 2007)	Formulation is ongoing
Amran	Title undecided (expected to be formulated in 2009)	Design study for the formulation is ongoing
Rada-Dhamar	Title undecided	Planned to be formulated
Tihama	Title undecided	Planned to be formulated

Water resources management plan for Ta'iz Region and Sa'dah Basin are described below.

2.2 WATER RESOURCES MANAGEMENT ACTION PLAN FOR THE TAI'Z REGION

2.2.1 BACKGROUND

Ta'iz Region, with catchments area of 650 km^2, is located in the upper part of the Wadi Raysan, which is one of the major wadis draining the highland and midland regions of the Red Sea Basin. Ta'iz City, distant 268 km south of Sana'a Capital City, is located inside the catchments area.

According to the results of 2004 census, the population of Ta'iz Region was around 650,000 inhabitants and the population of Ta'iz City was accounted at 317,000 inhabitants with a high growth rate of 7.9%. Nearly half of the population of the Region lives in the rural area and they are heavily dependent on agriculture relied on spate irrigation and rainwater harvesting methods. Ta'iz Governorate is one of the hubs of industrial activity in Yemen and a large number of industrial plants are located in and around Ta'iz City.

In the year of 1996, the total quantity of water consumed in Ta'iz Region was estimated at 43 MCM where groundwater consumption accounts for 95% (41 MCM). Groundwater consumption for agriculture use showed the highest ratio of consumption which was accounted for 27 MCM (67%). The higher quantity of water consumed by the sector was caused by the increasing in the number of wells accompanied by expansion of cultivated area. Other factor to be considered is the low irrigation efficiency of irrigation methods adopted by the farmers, causing over exploitation of groundwater. Urban water supply consumed around 7 MCM and industries around 4 MCM.

Water resources of Ta'iz Region are heavily dependent on rainfall and the mean annual precipitation is around 568 mm. The groundwater recharge was estimated at around 15 MCM, what means that the groundwater consumption is near to three times higher than the recharge and decreasing of groundwater level and depletion of water in some wells were observed.

In the following sectors, a brief explanation of the Water Resources Management Action Plan for the Ta'iz Region is described.

2.2.2 CONTENTS OF THE ACTION PLAN

The "Water Resources Management Action Plan for the Ta'iz Region" prepared between the years of 1996 and 2000 was issued in 2000 and approved by parliament in 2004.

(1) Water Resources Management Strategy

The water resources management strategy for the Ta'iz Region consists of five main components with sixteen subcomponents as shown in *Table 2.2*.

Table 2.2 Components of the Strategy

Components	Aproaches
General management enabling activities	Infromation system
	Awareness raising programs
	Communication and co-ordinations
Establishing regulatory framework for allocation of water	Regulatory framework for groundwater conservation
	Regulatory framework for rural-urban water transfers
Enhancing public water supply infrastructure and services	Program for improving Ta'iz urban water supply program
	Rural water supply program
Combating damage from water by means of wastewater control and flood control	Expansion of urban sewerage system
	Urban domestic wastewater treatment
	Industrial wastewater treatment
	Re-use of the treated wastewater
	Flood control and protection works
Sector targeted demand management	Recycle or re-use of treated wastewater
	Other urban demand management measures
	Improving the efficiency of agriculture water use
	Creating non-agricultural employment opportuities

Main important prerequisites for a successful implementation of the water resources management strategy are:

- *Consensus, ownership and commitment*
- *Maintaining a balanced and integrated view*
- *Flexibility*
- *Planning and providing operational inputs*

(2) Packages of Actions to be Implemented

Actions to be implemented by the Action Plan and their activities are listed below.

1) Development and Operation of Information System

Activities

- Monitoring networks of rainfall, runoff, groundwater level and water quality
- Monitoring systems for periodic assessment of diversion/abstraction of water, water use, waste and wastewater production, wastewater treatment, benefits from water, etc.
- Databases containing the collected monitoring and related administrative data
- Chemical laboratory for analysis of water samples
- Periodic updates of the diagnosis on water-related problems

2) Raising General Awareness on Water Problems and Solutions

Activities

All kinds of awareness raising activities have to be programmed: designing and disseminating posters and brochures; workshops; informative meetings in the field; messages at schools and mosques; radio and TV-messages; etc

3) Communication and Co-ordination

Activities

Monitoring on what is being done regarding the action plan; disseminating this information among relevant stakeholders; organizing meetings to discuss operational aspects of the action plan.

4) Establishing Regulatory Frameworks for Conserving Groundwater for Sustainable Use

Activities

- Defining zone(s) where the regulatory framework should be developed (conservation zones)
- Developing a communication structure between NWRA and the water stakeholders of the zone
- Establishing a local groundwater user association or any other organization with sufficient local support (or mandate) to organize local groundwater conservation
- Discussing principles on which groundwater rights should be based
- Defining and registering groundwater rights and the period of time of their validity
- Setting a target for maximum annual groundwater abstraction in the zone, and any other targets
- Discussing and agreeing on self-imposed restriction on groundwater abstraction (quantities abstracted, well spacing, pumping regime, etc) and on other activities (e.g. land use) needed to reach the targets

- Monitoring compliance
- Punishing violators

5) Establishing Regulatory Framework for Rural-Urban Transfer of Water

Activities

- Defining zone(s) where the regulatory framework should be developed (with priority)
- Developing a communication structure between NWRA and the water stakeholders of the zone
- Establishing a local water user association or any other organization with sufficient local support (or mandate) to negotiate water transfers from the zone to Ta'iz city
- Discussing principles on which groundwater rights should be based
- Defining and registering groundwater rights and the period of time of their validity
- Discussing and agreeing on conditions for transferring water to NWSA (quantities, price, term of payment, individual or community transfers, etc)
- Negotiation of deals between rural zones and NWSA
- Defining rules of arbitration in case of no compliance of any partner

6) Improving Ta'iz Urban Water Supply

Activities

- Rehabilitation of the urban public water distribution network in Ta'iz
- Institutional reform of NWSA's Ta'iz branch in order to increase efficiency and to enable complete cost recovery
- Eliminating illegal connections and revising the tariff structure as important demand management measures
- Exploratory studies to identify possible additional sources of water
- Initiating the development of rural-urban water transfer frameworks
- Exploratory drilling, in particular in zones where permeable Tawilah Sandstone are found at reasonable depths
- Feasibility studies for additional source development for urban water
- Negotiating deals between NWSA and local communities on rural-urban water transfers
- Design and implementation of works for capturing additional sources of water for urban water supply
- Feasibility studies (covering engineering, and financial aspects) for treating brackish water for augmenting urban water supply

7) Rural Domestic Water Supply

Activities

- Area-wide inventory and evaluation of rural water supply conditions
- Preparing annual plans for new schemes
- Preparatory field work at sites selected for new schemes
- Implementation of new schemes (usually by drilling completion, with pump and civil works)

8) Upgrading Urban Sewerage

Activities

In broad lines the work will consist of planning and design, procurement / tendering and other logistic activities, technical construction of the sewerage system, and administrative measures.

As the activity is a component of the Ta'iz Water Supply and Sanitation Project

9) Urban Domestic Wastewater Treatment

Activities

- Determining of type and concentration of pollutants in the untreated wastewater
- Setting water quality targets or standards for treated wastewater
- Identifying the optimal technical treatment system
- Designing and costing of a treatment system
- Defining a cost recovery system for urban water treatment
- Building the treatment plant(s) and related works
- Putting the treatment plant(s) in operation

10) Industrial Wastewater Treatment

Activities

- Determining of type and concentration of pollutants in the untreated wastewater
- Setting water quality targets or standards for treated wastewater
- Setting recycling targets for various types of industries
- Identifying the optimal technical treatment system
- Designing and costing of a treatment system
- Defining a cost recovery system for industrial water treatment
- Building the treatment plant(s) and related works
- Putting the treatment plant(s) in operation

11) Flood Hazard Reduction

Activities

- Forestation programs in the upper catchments of wadis where flood damage hazards are considerable
- Rehabilitation and proper maintenance of terraces in the upper catchments of wadis where flood damage hazards are considerable
- Providing for temporary storage of peak flow volumes at locations where they can do little harm
- Construction of defense walls or other defense structures in wadi beds
- Incorporating flooding risks as a criterion for land-use planning

12) Wastewater Recycling or Re-Use

Activities

- Identifying suitable combinations of wastewater producers and treated water users (e.g. several industries may recycle their own treated wastewater; treated urban domestic wastewater may be suitable for irrigation of certain crops).
- Organizing and evaluating pilot projects for wastewater recycling and wastewater re-use
- In case of favorable results: promoting wastewater recycling and wastewater re-use on a large scale and providing incentives to encourage this

13) Other Urban Demand Management Measures

Activities

- A strongly progressive water tariff
- Elimination of all illegal connections and of all privileged families that are currently

exempted from paying the water bills
- Public education on proper water economizing practices at the scale of single households

14) Improving the Efficiency of Agricultural Water Use

Activities

- Lining of canals and ditches
- Land leveling
- Replacing flooding irrigation by furrow, sprinkler or drip irrigation methods
- Changing to crops with relatively low unit water use
- Encouraging a shift away from irrigated cereals; increasing the yields of rainfed cereals
- Changing to crops with relatively high economic returns per unit of water used

15) Creating Non-Agricultural Employment Opportunities

Activities

- Improving and diversifying education at the rural level
- Identifying promising options for diversification of economic activities in the area (industries, manufacturing, services, etc)
- Government supported

The implementation activities of action plan related to NWRA-Ta'iz Branch started in May, 2006. Unfortunately, it has stopped since September, 2006 as result of ceasing the financial support. The implemented activities during the above mentioned period are as follows:

- Wells inventory and economic survey.
- Establishing of meteorological network.
- Monitoring of groundwater levels and meteorological network.
- Preparing the social mobilization team to establish associations of water users in some areas.
- Four workshops were done about public awareness for schools and mosques to explain the water problem dimensions.

2.3 WATER RESOURCES MANAGEMENT PLAN FOR SA'DAH BASIN

2.3.1 BACKGROUND

Sa'dah Basin lies at the north part of Yemen and it is represented by Sa'dah catchment area; extends approximately more than 900 km² which includes Sa'dah plain (213 km²). Sa'dah City is located in the middle of Sa'dah plain at about 255 km north of Sana'a Capital City.

In 1970, there were 800 wells in Sa'dah plain and most of the water extracted from the wells was used for irrigation. However, the number of wells increased by a rate of 10 to 15 wells/year until 1976 due to an introduction of drilling technologies, such as rigs and pumps. The number of wells came up to 2,000 in 1983 and 4,700 in 2002. The average depth of wells is 250m in Sa'dah plain and 400m outside of Sa'dah plain.

The average annual rainfall on the plain is about 128 mm/year. The total quantity of extracted groundwater is about 112 MCM/year, while the recharge is about 6 MCM/year. 84 MCM (75%) of the extracted groundwater volume is used for irrigated agriculture and urban and rural domestic groundwater use is estimated at 2 MCM (1.5%). About 26 MCM (23.5%) relate to unspecified and other uses.

Over exploitation of groundwater for irrigation, unregulated construction of new wells and the high rate increase of urban population (growth rate of 3.8%) are the factors to increase the groundwater consumption and it is clear, as mentioned above, that the groundwater extraction is around 20 times higher than the groundwater recharge. Consequently, the depletion of groundwater is observed through the decreasing of water level which is 3 to 6 m/year.

2.3.2 Water Resources Management Action Plan

(1) Plan Objectives and Planning Methodology

Approaches to be followed:

- Preparation of a hydrometric networks report summarizing current and future monitoring requirements
- Assessment of available water sources and preparation of water resources inventory
- Calculation of water demand forecasts
- Development and implementation of water resources and balancing tools
- Formulation of development scenarios
- Formulation of detailed resources and management strategies
- Formulation of mid-term investment plan for the water sector

These approaches proposed are based on the specific conditions set by principles of Integrated Water Resources Management (IWRM) and experience of the consultants.

(2) Plan Implementation

Plan implementation has three starting points:

1. Measures directly undertaken by NWRA
2. Measures undertaken by other stakeholders of the water sector
3. Planning and execution of investment projects

(3) Interventions at National Level

- Collection and Review of the Existing Data
- Assessment of Available Water Resources
- Calculation of Demand Forecast
- Investment Planning in the Water Sector
- Demand Management
- Formulation of Water Resources and Demand Management Strategies
- Formulation of Development Scenarios
- Formulation of Mid-Term Investment Plan for the Water Sector
- National Well Inventory

(4) Interventions at Sa'dah Basin Level

- Support to NWRA Sa'dah Branch Office
- Cooperation with World Bank Groundwater and Soil Conservation Project (WB GSCP)
- Developing Public Awareness Strategies
- Use of Non-Conventional Water Resources
- Community Partnership and Self-Regulation
- Training Program
- Institutional Set-Up and Expertise Required for WRMP Implementation

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[1] Groundwater formation in Sa'dah basin, Danikh and Van Der Gun, 1985.
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[3] Water Supply and Sanitation Sa'dah, Report on Mission II, July, 2005.
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CHAPTER 3

PRESENT STATE OF WATER RESOURCES

CHAPTER 3 PRESENT STATE OF WATER RESOURCES

3.1 GENERAL

This chapter describes the natural condition, namely geological, hydrological and hydrogeological setting, and water resources occurrence in the Sana'a Basin based on the previous study reports.

The main comprehensive water resources studies have been conducted to secure the resources for water supply to Sana'a city since 1970s, as tabulated below.

Table 3.1 Previous Studies in the Sana'a Basin

Study	Term	Organization	Consultant	Summary
Water Supply for Sana'a and Hodeida. Sana'a Basin Groundwater Studies	1970-1973	NWSA	Italconsult	The first study for Sana'a water supply system. The study area was a part of Sana'a basin, around Sana'a city. 15wells were drilled in the northwest of the City, where Tawilah Sandstone is distributed.(Western Well Field).
Water Supply for Sana'a Phase 2	1980, 1983	NWSA	Howard Humphreys & Sons	Addition to the above 15 wells, 15 wells were drilled in the Western Well Field and other 15 wells were drilled in the Eastern Well Field in order to meet the increasing water demand of Sana'a City.
Sana'a Basin Water Resources Scheme	1986	MAF	Mosgiprovodkhoz	The first study of the whole Sana'a basin. MAF conducted to meet the increasing agricultural use of groundwater in 80s. Wadi Kharid Dam was proposed for the future water supply.
Assistance to the High Water Council in the Preparation of a Water Master Plan	1988-1992	HWC	Individual Experts	The water resources study on the whole of Yemen. Geological and Hydrogeological characteristics were described in the northern part and the southern part of Yemen.
Sources for Sana'a Water Supply (SAWAS)	1987-1996	NWSA	TNO Institute of Applied Geoscience	The study on the condition and future plan of water supply. The rehabilitation of water supply system and non-conventional water sources including desalination of Red Sea Water were proposed and evaluated. Test wells were drilled to investigate the deeper sandstone and resulted negative. Water resources condition in Sana'a basin was summarized on the whole.
Sana'a Basin Water Resources Management Study (SBWRM-PPT)	2001-2003	NWRA	Sana'a University, WEC	The water points (well, spring, dam, etc) inventory survey and analysis in Sana'a Basin.
Sana'a Basin Water Management Project (SBWMP)	2003-	NWRA	Hydrosult, Others	Ongoing project for water resources management, including groundwater studies, irrigation improvement, capacity building and public awareness campaign.

3.2 TOPOGRAPHY AND GEOLOGY

3.2.1 TOPOGRAPHY

Yemen can be divided into 5 main topographical regions, which are the coastal plains, the western highlands, the central midland, the eastern plateau and the desert of Rub Al Khali and Ramlat Sabatayn. The Sana'a Basin is located in the eastern end of the western highland with the highest peak of the Jabal An Nabi Shu'ayb with the altitude of 3,666 m. The total area of the Basin is about 3,240 km^2, which is the figure calculated by the Satellite Imagery Analysis (GAF, 2007)[1] recently.

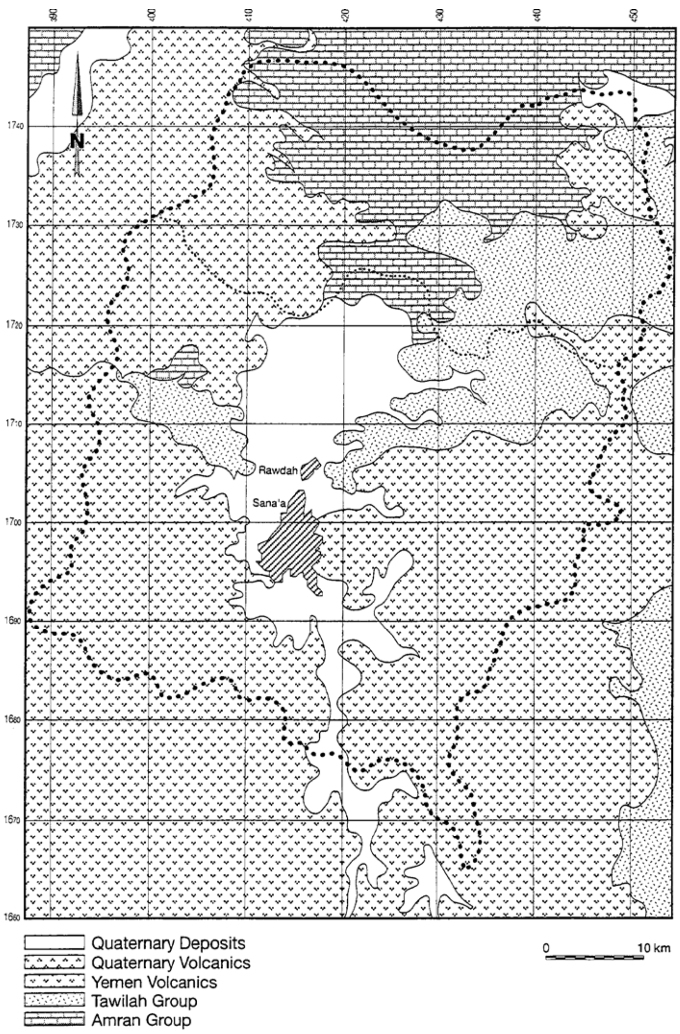
The Basin mainly consists of the central plain area with the altitude of 2,100-2,400 m surrounded by the western and eastern mountainous area.

3.2.2 GEOLOGY

Basement complex of Yemen consists of granite, gneiss, schist and other formations of the Precambrian, and is overlain by various younger rocks, or marine and continental sediments and volcanic rocks. In the Sana'a Basin, the distributed geologic units are categorized into five, namely Amran Group, Tawilah Group, Tertiary Volcanics, Quaternary Volcanic and Quaternary Deposits. The lithological summary of these five groups is described in the table below.

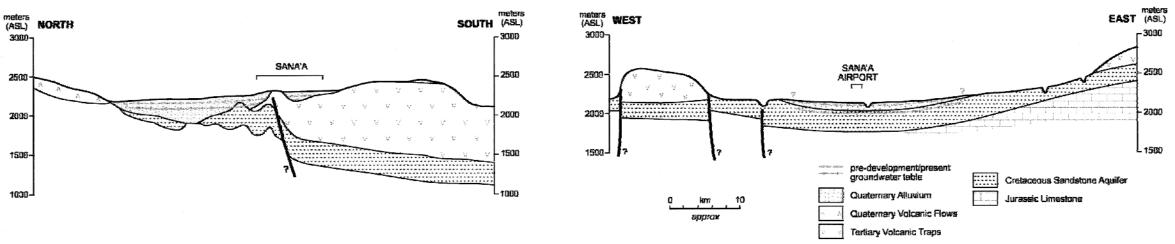
Table 3.2 Geology in the Sana'a Basin

Formation	Thickness	Lithology	Hydrogeological Description
Quaternary deposits	- 350m	Active alluvium, sand and gravel Gravel sheets, gravel plains and alluvial fans generally in areas of low relief with a stony surface Loess and ancient dunes: areas of wind-blown soils and sands (generally fertile land)	Unconfined aquifers are common, but semi-confined aquifers occur in places. Originally highly productive, but recently falling water tables are found throughout the alluvial aquifer. Water level fluctuations show a rapid response to rainfall.
Quaternary volcanics	- 400m	Trachytic flows and domes Basaltic lavas and scoria	Petrographically similar to Tertiary volcanics, but relatively unweathered and less permeable. Local and limited groundwater potential.
Tertiary volcanics (Yemen Volcanics)	2000m<	Gabbro Ignimbrite and ash-flow deposit Rhyolite and dacite Trachyte Basalt	Fracturing is widespread. Groundwater occurs in bedded ashes and tuffs, fractured lava flows, boundary zones between flows and major fault zones. Rhyolitic aquifers seem to provide higher yield. Overlie Tawilah group
Cretaceous Sandstone (Tawilah Group)	150 – 400m	Sandstones with minor calcareous horizons.	White, yellow or reddish fine to coarse grained sandstone. Generally productive aquifer, but highly anisotropic.
Jurassic Limestone (Amran Group)	100 – 400m	Bituminous limestone, dolomitic marl and sand	Fracture zones and bedding plane discontinuities, poorly productive aquifer



Source; SAWAS Technical Report No.9 (1995)

Figure 3.1 Geology in the Sana'a Basin



Source; Stephen Foster (2003), Yemen: Rationalizing groundwater resource Utilization in the Sana'a Basin, World Bank

Figure 3.2 Schematic Geological Cross Section in the Sana'a Basin

3.3 METEOROLOGY AND HYDROLOGY

3.3.1 GENERAL CLIMATE

Yemen is located within the tropical and subtropical climate zones. Although Yemen has no major seasonal difference, we can broadly divide it into summer from April to October with high temperatures and a milder winter season from October to April. There are 2 rainy periods, one from March to May, and the other from July to September. In the highlands and mountain regions, where the Sana'a Basin is located, the weather is moderate in summer, but in winter, it is cold during the night and early morning and moderate during the day.

3.3.2 MONITORING NETWORK

Monitoring of the hydrological and hydrogeological condition is one of the most important factors to do an appropriate management of water resources in the area. The monitoring information shall be essential for long-term operational strategy of water resources.

At present, the hydrological monitoring network in the Sana'a Basin consists of two meteorological stations, nine rainfall gauge stations, 33 water level monitoring wells, and no stations for wadi runoff. The locations of the meteor/rainfall stations are shown in *Figure 3.3* and listed in *Table 3.3*.

Monitoring Network in Sana'a Basin

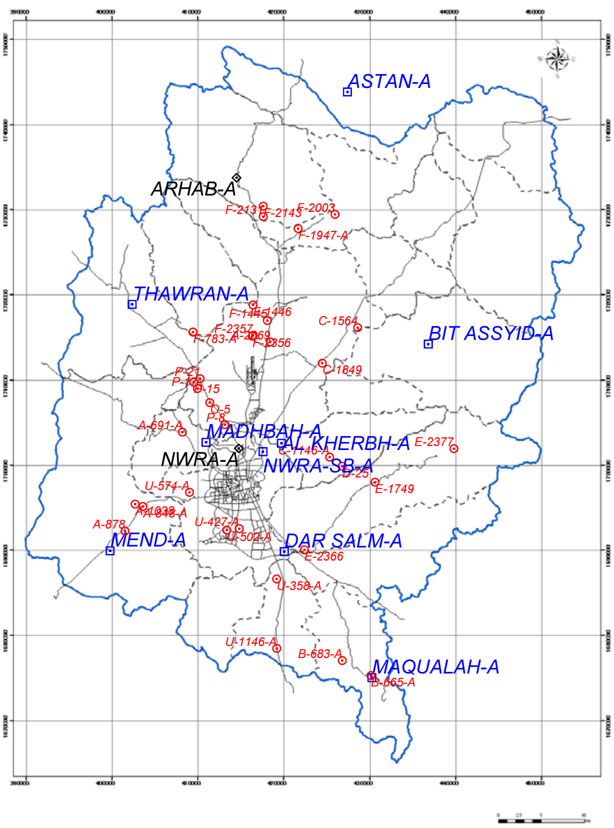


Figure 3.3 Meteor/Rainfall Monitoring Station in the Sana'a Basin

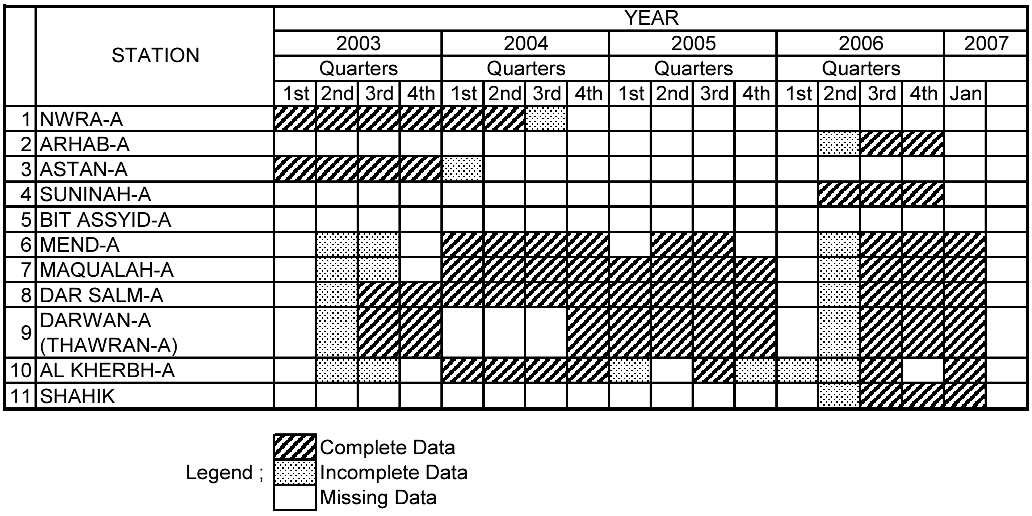
Table 3.3 Meteor/Rainfall Monitoring Station in the Sana'a Basin

No	StationName	StationType	UTM_N	UTM_E	Status	Installed
1	NWRA-A	Meteorological	1701935	414581	repairing	20-Apr-89
2	ARHAB-A	Meteorological	1733500	414310	operating	20-Dec-05
3	ASTAN-A	Rainfall	1743500	427250	operating?	09-Jul-91
4	SUNINAH-A	Rainfall	1695550	405422	operating	02-Apr-06
5	BIT ASSYID-A	Rainfall	1714095	436689	operating?	31-Aug-03
6	MEND-A	Rainfall	1690005	399550	operating	14-May-03
7	MAQUALAH-A	Rainfall	1675200	430100	operating	12-May-03

8	DAR SALM-A	Rainfall	1689906	419887	Operating	12-May-03
9	DARWAN-A (THAWRAN-A)	Rainfall	1718733	402126	Operating	14-May-03
10	AL KHERBH-A	Rainfall	1702540	419550	Operating	15-May-03
11	SHAHIK	Rainfall	1701830	439650	Operating	20-Jul-06

The two meteorological stations have been equipped with automatic recorders for relative humidity, temperature, wind speed, wind direction, rainfall, solar radiation and barometric pressure. Rainfall stations have been also equipped automatic data loggers. The water levels of 33 monitoring wells, however, have been measured manually with electrical tapes every month. Presently, surface water runoff has not been measured. SBWMP Technical Note (Norman and Mulat 2007)[2] has recommended installing three flow gauges in their experimental watersheds, Wadi Sirr and Wadi Barian. Additionally, seven sites of existing dams have been listed for installing staff gauges and water level recorders in order to determine the amount of water coming and stored in these reservoirs.

Table 3.4 Collected Rainfall Data



Some of rainfall data are missing as shown in *Table 3.4.* Unfortunately, in addition, the reliability of the collected data is partly doubtful[3]. Technical Report (NWRA-SB, 2006)[3] noted the following causes of the lack of the data, that is, a deficiency of financial resources to have field visits on time, lack of awareness of local people who abused and damaged the gauges, and some technical problems.

3.3.3 TEMPERATURE

Figure 3.4 and *Table 3.5* show the average monthly temperature recorded at the station of NWRA-A. The obtained records used to draw the figure are very limited. The figure, however, seems to show a general tendency in the Sana'a Basin.

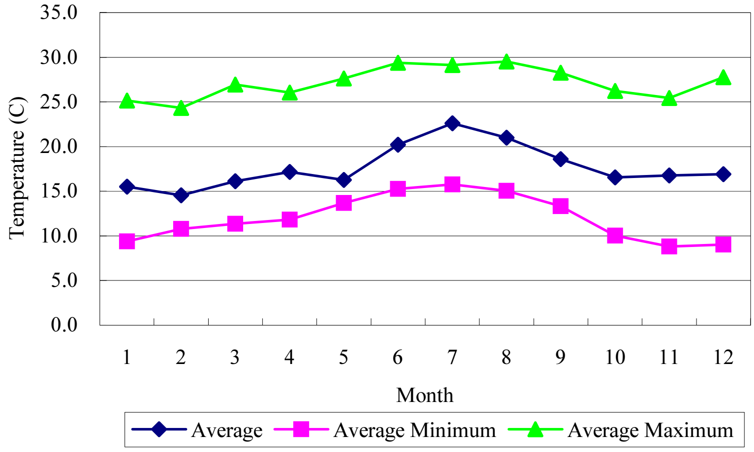


Figure 3.4 Monthly Temperature (NWRA-A, 1989-1997)

The hottest season is from June to August, and the coldest season is around January and February. The average monthly temperature ranges between about 15 and 25 C.

The station, NWRA-A, is located in the north edge of the urban area of Sana'a with the altitude of about 2,250 m. In the northwestern area, where the altitude is lower than Sana'a, the temperature may vary widely.

Table 3.5 Monthly Temperature (NWRA-A)

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average	Maximum	Minimum
1989	Average						22.1	23.5						22.8	23.5	22.1
	Minimum						14.9	15.9						15.4	15.9	14.9
	Maximum						28.5	28.6						28.6	28.6	28.5
1990	Average	15.5	16.8	18.6	18.9				23.2	21.4	19.4			19.1	23.2	15.5
	Minimum	8.6	11.7	11.5	12.2				16.7	13.9	11.3			12.3	16.7	8.6
	Maximum	23.8	23.8	27.1	26.2				29.9	28.3	25.8			26.4	29.9	23.8
1992	Average														0.0	0.0
	Minimum										6.6	6.6	6.0		6.6	6.0
	Maximum														0.0	0.0
1993	Average	15.3	15.6		17.2	20.5	23.1	22.8	22.5					19.6	23.1	15.3
	Minimum	8.0	10.4		11.9	14.2	15.8	16.5	15.6					13.2	16.5	8.0
	Maximum	23.5	22.7		24.7	27.4	29.9	30.2	30.1					26.9	30.2	22.7
1996	Average							21.7	22.5	21.8	18.0	15.1		19.8	22.5	15.1
	Minimum							16.2	15.7	14.3	9.6	6.9		12.6	16.2	6.9
	Maximum							29.0	30.1	28.3	25.8	23.6		27.4	30.1	23.6
1997	Average	15.7	11.2	13.6	15.4	12.1	15.4	22.4	15.7	12.5	12.3	18.5	16.9	15.1	22.4	11.2
	Minimum	11.6	10.3	11.2	11.4	13.2	15.1	14.4	12.2	11.7	12.6	12.8	12.0	12.4	15.1	10.3
	Maximum	28.1	26.5	26.8	27.3	27.9	29.7	28.7	28.0	28.2	27.1	27.3	27.8	27.8	29.7	26.5
Average	Average	15.5	14.6	16.1	17.1	16.3	20.2	22.6	21.0	18.6	16.6	16.8	16.9	17.7	22.6	14.6
	Minimum	9.4	10.8	11.4	11.8	13.7	15.3	15.8	15.0	13.3	10.0	8.8	9.0	12.0	15.8	8.8
	Maximum	25.1	24.3	27.0	26.0	27.6	29.4	29.1	29.5	28.3	26.2	25.4	27.8	27.1	29.5	24.3

3.3.4 PRECIPITATION

Figure 3.5 and *Table 3.6* show the monthly rainfall recorded at NWRA-A from 1989 to 2004. According to the table, the annual rainfall ranges from around 110 mm to 300 mm or more. The maximum annual rainfall was recorded at 341 mm in 1998. The figure indicates that rainy or wet seasons are generally from March to May and July to September, although there were some exceptional years. It is rather difficult to say about a long-term tendency.

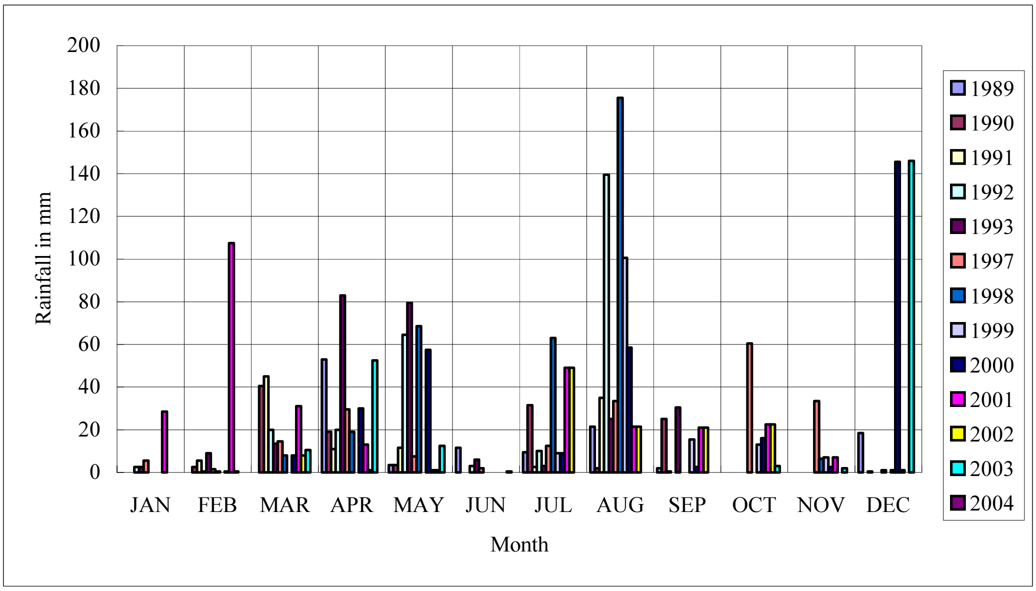
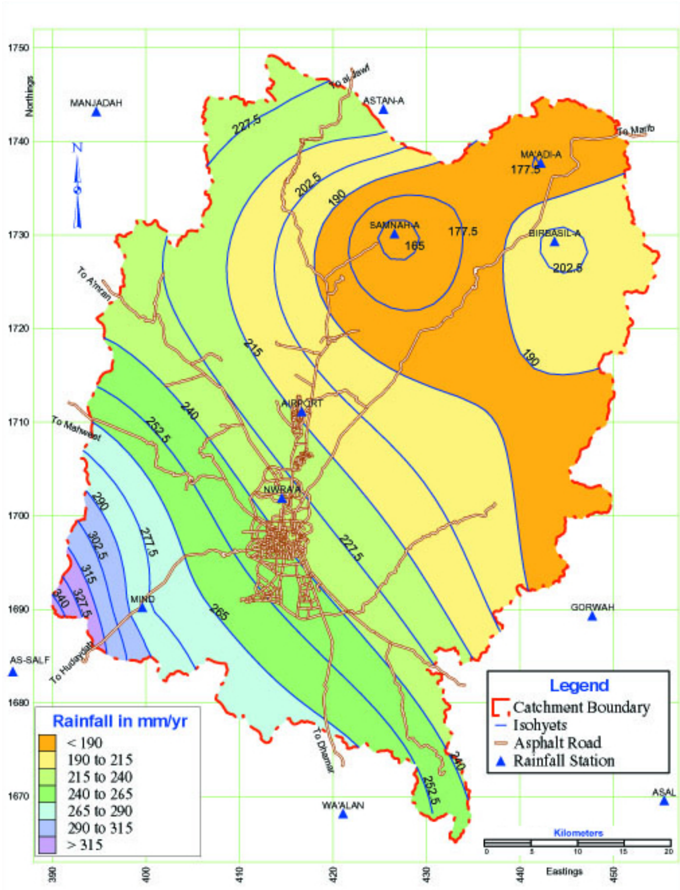


Figure 3.5 Monthly Rainfall (NWRA-A) 1989-2004

Table 3.6 Monthly Rainfall (NWRA-A)

	MONTH												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
1989				53	3.5	11.5	9.5	21.5	2	0	0	18.5	119.5
1990	0	2.5	40.5	19	3.5	0	31.5	2	25	0	0	0	124
1991	0	5.5	45	11	11.5	0	2.5	35	0.5	0	0	0.5	111.5
1992	2.5	0.5	20	20	64.5	3	10	139.5					260
1993	2.5	9	13.5	83	79.5	6	3	25	30.5				252
1997	5.5	1.5	14.5	29.5	7.5	2	12.5	33.5	0	60.5	33.5	1	201.5
1998	0	0.5	8	19	68.5	0	63	175.5	0	0	6.5		341
1999							9	100.5	15.5	13	7	1	146
2000		0.5	8	30	57.5		9	58.5	2.5	16	2.5	145.5	330
2001	28.5	107.5	31	13	1	0	49	21.5	21	22.5	7	1	303
2002	0	0.5	8	1	1	0	49	21.5	21	22.5	0	0	124.5
2003	0	0	10.5	52.5	12.5	0.5	0	0	0	3	2	146	227
2004	0	13.5	9	23	37	1	6.5	8.5					98.5
Average	3.9	12.9	18.9	29.5	29.0	2.2	19.6	49.4	10.7	13.8	5.9	34.8	230.5
Maximum	28.5	107.5	45.0	83.0	79.5	11.5	63.0	175.5	30.5	60.5	33.5	146.0	
Minimum	0.0	0.0	8.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Figure 3.6 shows the distribution of rainfall in the Sana'a basin provided by NWRA.



Source; NWRA Sana'a Branch (2006): Monitoring Activities in Sana'a Basin. Technical Report (2003-2005)

Figure 3.6 Isohyet Map of the Sana'a Basin

The northeastern area in the Basin has less than about 200 mm/year rainfall and the central plain area has from 200 to 250 mm. In the southwestern mountainous area, the annual rainfall reaches more than 300 mm.

It may be possible that the figure indicates the eastern mountainous area may actually have more rainfall. The further continuous observation is necessary to obtain more details precisely. And also it may be desirable to install another rain gauge station in this area[2].

3.3.5 Evapotranspiration

1:250,000 Hydrogeological map (Robertson 1990)[4] describes that potential evaporation estimated by the Penman method averages about 2,000mm annually. SAWAS (1995)[5] calculated that the potential evapotranspiration was an annual total of 2,475 mm based on a meteorological statistics. And it reported that calculated monthly potential evapotranspiration showed a seasonal variation, with a maximum in June (average 9.4 mm /day) and a minimum in February (4.8 mm/day). In any case, the figures are substantially higher than annual rainfall.

GAF (2007) estimated actual evapotranspiration based on the satellite imagery analysis in SBWMP. According to the report, the total of 113.1 MCM water were transpired in the Sana'a Basin during the period from 1 July 2004 to 30 June 2005. The figure was obtained on the basis of the irrigated area and the crop pattern analyzed in the study.

3.3.6 Surface Water

(1) General Feature

The Sana'a Basin is the upper part of the catchment of the Wadi Kharid streaming to the northeast of the Basin, which is one of the two main sub-catchments of the Wadi Jawf. The Wadi Jawf is also one of the primary watersheds streaming into the Ar Rub Al Khali, or the desert of Empty Quarter, in the east of Yemen.

There is no perennial flow in the Basin except a part of Wadi Kharid that has a base flow fed by springs whose discharge was reported to be about 0.2 m^3/sec (Mosgiprovodkhoz, 1986)[6]. And another exception is the flow discharged from a treatment plant for Sana'a. The outflow of the treatment plant was 22,700 m^3/day, or 260 l/sec, on the average of 2002.

The Sana'a Basin can be divided into 22 sub-basins as shown in *Figure 3.7* and *Table 3.7*. The figure shows also the flow direction of these sub-river systems. The mountainous area to the west, south and east of the Sana'a plain drained into the plain, that is, the catchments of the Wadi Al Mawrid and the Wadi Bani Huwat, and the flow direction goes northward. The surface flow, however, in the wadis flowing out of the mountainous area normally disappear in the Quaternary sediments of the plain.

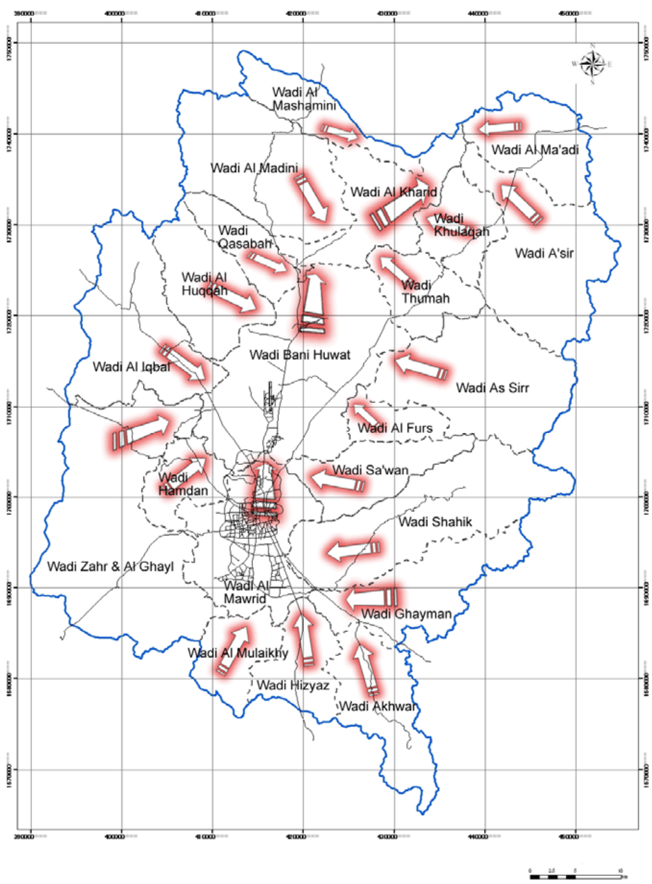


Figure 3.7 Sub-Basins in the Sana'a Basin

Table 3.7 Sub-Basins in the Sana'a Basin

	Sub-Basin	Catchment (km^2)
1	Wadi Al Mashamini	77.8
2	Wadi Al Madini	213.3
3	Wadi Al Kharid	138.2
4	Wadi Al Ma'adi	111.3
5	Wadi A'sir	208.8
6	Wadi Khulaqah	75.7
7	Wadi Qasabah	64.5
8	Wadi Al Huqqah	120.3
9	Wadi Bani Huwat	327.0
10	Wadi Thumah	77.0
11	Wadi As Sirr	218.6
12	Wadi Al Furs	45.8
13	Wadi Al Iqbal	202.9
14	Wadi Zahr & Al Ghayl	360.8
15	Wadi Hamdan	63.5
16	Wadi Al Mawrid	179.2
17	Wadi Sa'wan	95.9
18	Wadi Shahik	238.7
19	Wadi Ghayman	143.3
20	Wadi Al Mulaikhy	69.7
21	Wadi Hizyaz	81.9
22	Wadi Akhwar	125.6
	Total	3,239.8

(2) Runoff

At present, wadi runoff is not monitored at all as described already.

Two types of method have been used to estimate the runoff volume of wadis in the previous studies. One is the method using a runoff coefficient, or the ratio of runoff depth to precipitation depth, obtained by hydrological observation of main wadis in Yemen. Report WRAY-35 (1995)[7] suggested the average runoff coefficient of 0.055 for wadis in Yemen based on the observed flow volumes from primary watersheds. SAWAS Technical Report No.9 (1995) also calculated a runoff coefficient of 0.049, if only direct runoff was taken into account, and 0.061, if it was referred to total runoff. The volume of runoff in the Sana'a basin is estimated at about 40.9MCM/year with the supposition of the 230 mm of annual rainfall, the 3,240km^2 of the area of the Sana'a Basin and 0.055 of the runoff coefficient.

Another method to calculate runoff volume is the estimation using the SCS method that is the empirical model prepared by the U.S. Soil Conservation Service. TS-HWC Vol. III (1992)[8] constructed a rainfall-runoff model using the SCS method and obtained the figures shown in *Table 3.8*, which indicated the mean total and base flow per day was 74,000 and 67,000 m^3 respectively in the Sana'a Basin. It means the total outflow of the Sana'a Basin is 27 MCM/year.

Table 3.8 Mean Flow of Sana'a Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Annual Total
Total flow	26	29	75	208	110	63	68	129	69	45	41	24	74	26,980
Flood flow	0	0	0	50	4	0	0	29	0	0	0	0	7	2,525
Base flow	26	29	75	158	106	63	68	100	69	45	41	24	67	24,455

Source: TS-HWC Vol. 3 Surface Water Resources, 1992 Unit: thousand m^3/day

The reports of the feasibility study of 13 dam rehabilitations or constructions submitted by Hydrosult Inc.(2002)[9] also adopted the SCS method to estimate runoff volume in the wadi where a proposed dam site was located. The obtained runoff coefficient ranges from 0.049 to 0.17.

SBWMP (Noaman and Mulat, (2007)) carried out rainfall-runoff analysis for 22 sub-basins in the Sana'a Basin using SCS-CN method. The obtained runoff coefficient ranges from 0.22 to 0.122. The results have been used for the water balance analysis for each sub-basin, which is explained in the section of 3.6.

In addition to the above, General Directorate of Irrigation (GDI) provided a report of Engineering Data Sheet, or dam database. The data sheet is the summarized report of a survey of 44 existing dams in 2001. It describes the hydrological condition around each dam site including estimated runoff coefficient, which ranges from 0.03 to 0.4, although it is not clear how to be estimated the figures. The estimated mean annual flow of 44 dam sites totaled about 22.3 MCM.

(3) Usage of Surface Water

In the Sana'a basin, two surveys of the existing surface water points have been conducted since 2000, that is, the existing dam survey by GDI in 2001 described in the previous section, and the water point inventory survey by SBWRM in 2002. In the former survey, the information of 44 dams was summarized as the data sheets of dams and the latter survey listed 24 dams/pools and 125 springs in the Sana'a basin. These 24 dams/pools include obviously some small-scale cisterns. In addition to the above, a map of the Location of Dams in Sana'a Basin was recently issued by the project of Geo-Environmental Map of Sana'a, YGGMP (2004)[10], the explanatory note of which has not been provided yet. 56 dams including under or stopped construction ones are plotted on the map.

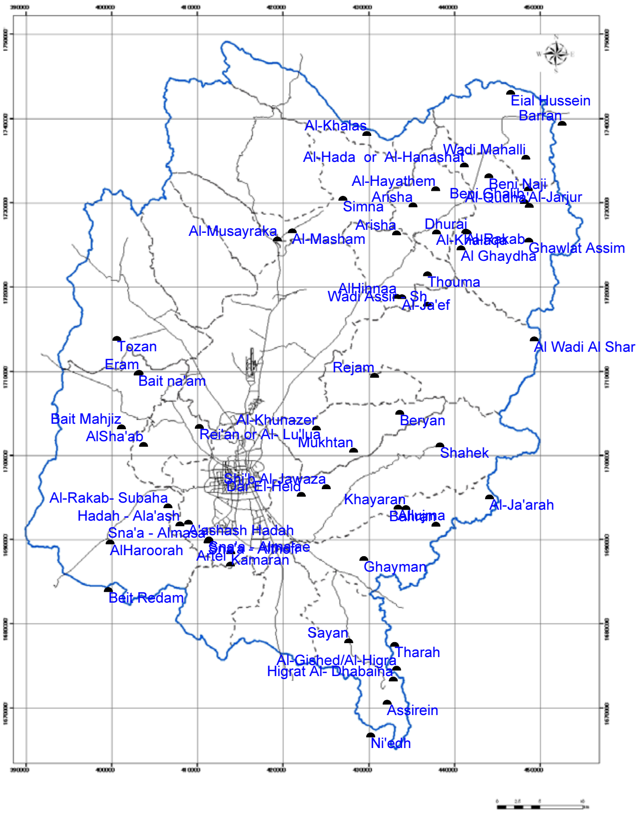


Figure 3.8 **Locations of Dams in the Sana'a Basin**

Table 3.9 Dams in the Sana'a Basin

No.	Name of Dam	GDI Dam No	Basin	UTM N	UTM E	Recharge	Irrigation	Drinking	Condtion	SBWMP rehabilitation	Catchment (km^2)	Annual Rainfall (mm)	Runoff Coefficient	Yiels (l/s)	Annual Flow 10^{3}m^3	source
1	Al-Khalas	8	1	1737900	429850	●	●		bad		64.87	42.3	0.15		412	Data sheet by GDI and Inventroy survey by SBWMP
2	Al-Masham	11	3	1726450	421125	●	●		good	○	2276.44	172	0.067		70.5	
3	Al-Musayraka	12	3	1725500	419375	●			good		2270.32	172	0.067		9500	
4	Simna	40	3	1730275	427050	●	●		bad		2407.93	172	0.067		1433.5	
5	Barran	20	4	1739100	452700	●			not operated		2.7	150	0.3		122	
6	Eial Hussein	27	4	1742750	446675	●			bad	○	1.36	187.7	0.15		38	
7	Wadi Mahalli	44	4	1735100	448450	●			bad	○	13.68	150	0.2		410	
8	Al Ghaydha	1	5	1724450	440875	●			good		1.875	191.4	0.2		72	
9	Al-Hada or Al-Hanashat	3	5	1734200	441250	●			not operated		187.67	210	0.087		3006.7	
10	Al-Jarjur	6	5	1731400	448750	●			good		8.575	191.4	0.15		246	
11	Al-Qudha'	13	5	1729450	448850	●	●		good		1.1	191.4	0.15		32	
12	Al-Rakab	14	5	1726425	441425	●			bad		1.925	191.4	0.2		74	
13	Beni Ghalib	22	5	1729900	448300	●			bad		0.225	191.4	0.15		6.46	
14	Beni Naji	23	5	1732925	444125	●			bad	○	6.63	210	0.087		121	
15	Dhurai	26	5	1726325	441600	●			good		2.1	191.4	0.2		80	
16	Ghawlat Assim	29	5	1725370	448800	●			good		2.5875	191.4	0.2		99	
17	Al-Hayathem	4	6	1731400	437900	●			……	○	32.195	191.4	0.15		924	
18	Al-Khalaqa	7	6	1726325	438000	●			not operated		5.525	200	0.35		387	
19	Arisha	17	6	1729500	435250	●			bad	○	6.45	140.9	0.2		182	
20	Al-Ja'ef	5	10	1718700	433950	●	●		good	○	2.7	175	0.14		66.15	
21	Arisha	16	10	1726200	433325	●			bad		0.6	140.9	0.2		17	
22	Thouma	42	10	1721400	436950	●	●		bad	○	7.1	191.4	0.35		476	
23	Rejam	35	12	1709450	430750		●				106.6	0.1	0.1			
24	Tozan	43	13	1713800	400600	●			bad	○	23.4	200	0.15		702	
25	Al-Rakab- Subaha	15	14	1694100	406575			●	good		0.9	119.7	0.1		11	
26	Beit Redam	21	14	1684250	399600	●	●	●	good		neglected	170	0.4		0.24	
27	Eram	28	14	1709800	403200	●			……		4	200	0.15		120	
28	Rei'an or Al- Lu'lua	36	15	1703450	410250	●			good		261	170	0.03		1300	
29	Artel	18	16	1687250	413880	●	●		good		0.675	234.3	0.15		24	
30	Kamaran	32	16	1688700	413925	●			……		4.1	234.3	0.15		144	
31	Al-Khunazer	9	17	1703250	423950	●			50% achieved		0.5	106.6	0.2		11	
32	Beryan	24	17	1705100	433700	●	●		bad		10.325	106.6	0.15		165	
33	Mukhtan	33	17	1700650	428300	●			good		5.1	194.8	0.2		199	
34	Allujma	10	18	1693950	433500	●			bad	○	1.275	198.8	0.35		87	
35	Dar El-Heid	25	18	1695450	422175	●			good		1.65	194.8	0.35		112	
36	Shahek	38	18	1701275	438400	●	●		good		47.125	170	0.035		280	
37	Shi'b Al-Jawaza	39	18	1696350	425100	●	●		good		1.45	194.8	0.35		99	
38	Ghayman	30	19	1687900	429500	●	●		……		102	194.8	0.035		669	
39	Al-Gished/Al-Higra	2	22	1675000	433325		●	●	good		0.7	122.6	0.2		17	
40	Assirein	19	22	1671000	432225	●			not operated		10.825	122.6	0.15		199	
41	Higrat Al- Dhabaina	31	22	1673725	432940	●			good		0.2	122.6	0.2		5	
42	Ni'edh	34	22	1667150	430300	●			85 % completed		3.69	122.6	0.2		90	
43	Sayan	37	22	1678225	427725	●			15 % achieved		6.8	250	0.2		340	
44	Tharah	41	22	1677800	433100	●	●		bad		5.3	122.6	0.1		65	
45	AlHinnaa		10	1718733	433362		●		Operational					4.7	148	Inventory survey by SBWMP
46	Al Wadi Al Shar		11	1713735	449437				Operational					4.7	148	
47	Wadi Assir - Sh		11	1717808	436943		●		Operational					4.7	148	
48	AlHaroorah		14	1689847	399809				Operational					4.7	148	
49	Bait Mahjiz		14	1703395	401131				Intermittent					4.7	148	
50	Bait na'am		14	1709720	403084		●		Intermittent					3	95	
51	AlSha'ab		15	1701325	403723		●		Temp. Not Use							
52	Sna'a - Althofr		16	1690000	411272		●		Operational					4.38	138	
53	Sna'a - Almasa'		16	1689969	411301		●		Operational					4.38	138	
54	Sna'a - Alma'ae		16	1690205	411370		●		Operational					1.5	47	
55	Hadah - Ala'ash		16	1691975	407972		●		Operational					0.6	19	
56	A'ashash Hadah		16	1692173	408966		●		Operational					4.7	148	
57	Bahran		19	1691939	437928				Dry							
58	Al-Ja'arah		19	1695150	444202				Operational					4.7	148	
59	Khayaran		19	1693893	434424		●		Operational					4.7	148	
														Total:	24,037	

Table 3.9 is the compiled result of the GDI inventory and the SBWMP inventory survey and *Figure 3.8* shows the location of dams. Most of the dams listed by GDI, No.1 to 44 in the table, are constructed to recharge groundwater. According to the remarks of the data sheet by

GDI, discharge from the wells around the dams increases generally whenever the dams fill. 15 dams of them are also used for irrigation and only three dams are used for domestic water. Dams numbered from 45 to 59 are used for irrigation mainly. Most of them may be small-scale reservoirs constructed by rural people. Total volume of the annual flow or yield of dam sites is calculated to be 24 MCM.

Another surface water source is a spring. The result of SBWMP inventory survey showed 145 springs in the Sana'a basin. The locations of the spring are shown in *Figure 3.9*.

51 of 145 springs, 35%, are used for irrigation, 43 springs, 30%, for animal or livestock, and 49 springs, 34%, for domestic water use for rural areas. The yield of spring ranges from 0.01 to 9.26 l/sec and totals 545 l/sec. This amount is equivalent to 17.2 MCM annually. The volume, however, is not likely an actual annual yielding amount, because the yield of spring is fluctuating seasonally. One third to half of the amount, about 6 to 9 MCM may be an acceptable figure.

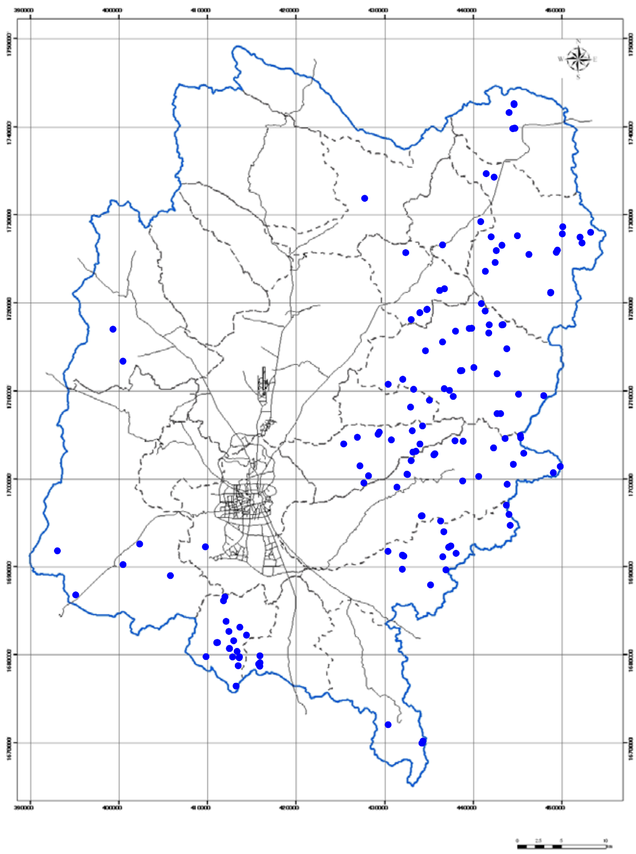


Figure 3.9 Springs in the Sana'a Basin

3.4 HYDROGEOLOGY

3.4.1 AQUIFERS

Geology in the Sana'a Basin is summarized in the section of 3.2.2. General hydrogeological description is also explained in 3.2.2 (*Table.3.2*). As shown in the table, the previous studies have revealed that aquifer developed in the Sana'a Basin can be classified to the four types, namely Alluvial Aquifer, Volcanic Rocks, Tawilah Sandston and Amran Limestone. Based on the result of the well inventory survey (2002), the characteristics of the aquifers are described in the section. The occurrence of predominant aquifer may be indicated by the distribution of boreholes. Yield of boreholes and the depth of boreholes suggest generally the aquifer potential and the depth or thickness of the aquifer respectively.

(1) Alluvial Aquifer

The well inventory survey (2002) recorded 1,110 operational water points developing the alluvial aquifer. 89 of them were boreholes, 988 were dug wells, 27 were Dug/Bore type and 6 springs. Dug wells, naturally, drilled in the alluvial plain and wadi beds in the Sana'a Basin. Boreholes are distributed mainly in the Sana'a plain as shown in *Figure 3.10*.

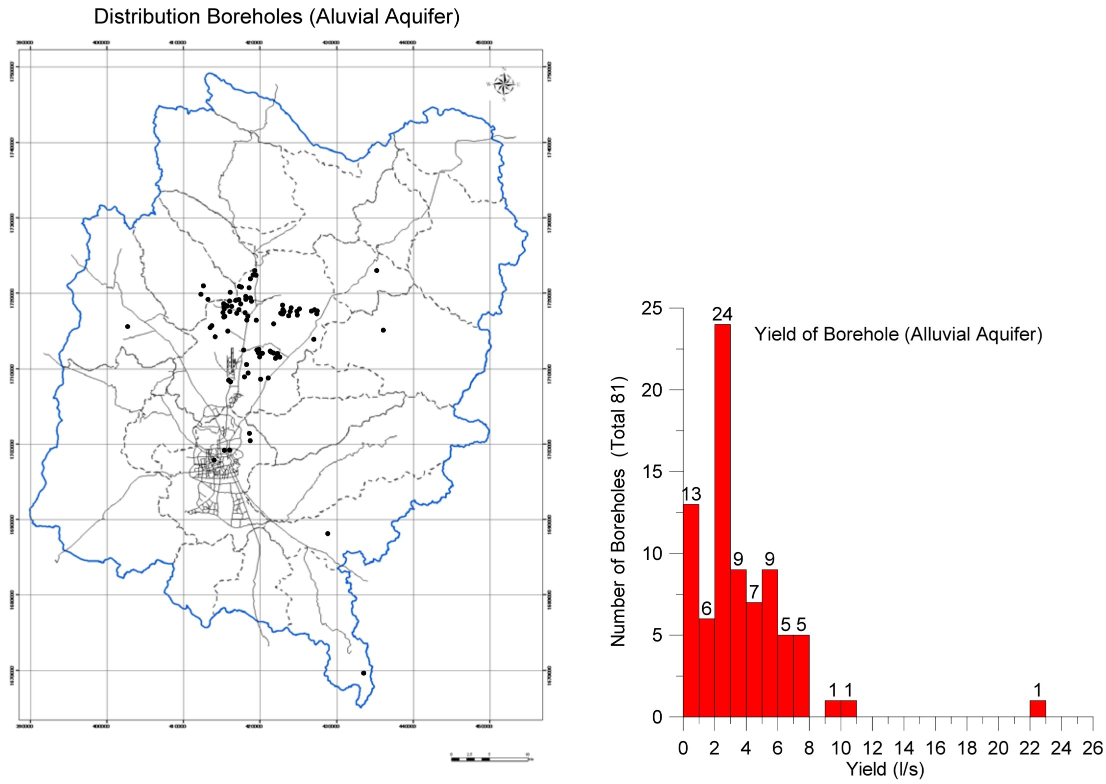


Figure 3.10 Distribution and Yield of Boreholes (Alluvial Aquifer)

Though the yield of boreholes ranges from 0.3 to 23 l/s as shown above, the yield of less than 3 l/s accounts for more than 50% of the whole boreholes.

Figure 3.11 shows the distribution of depth. The depth of boreholes ranges from 64 to 400 m and the depth of dug wells ranges from 3 to 80 m.

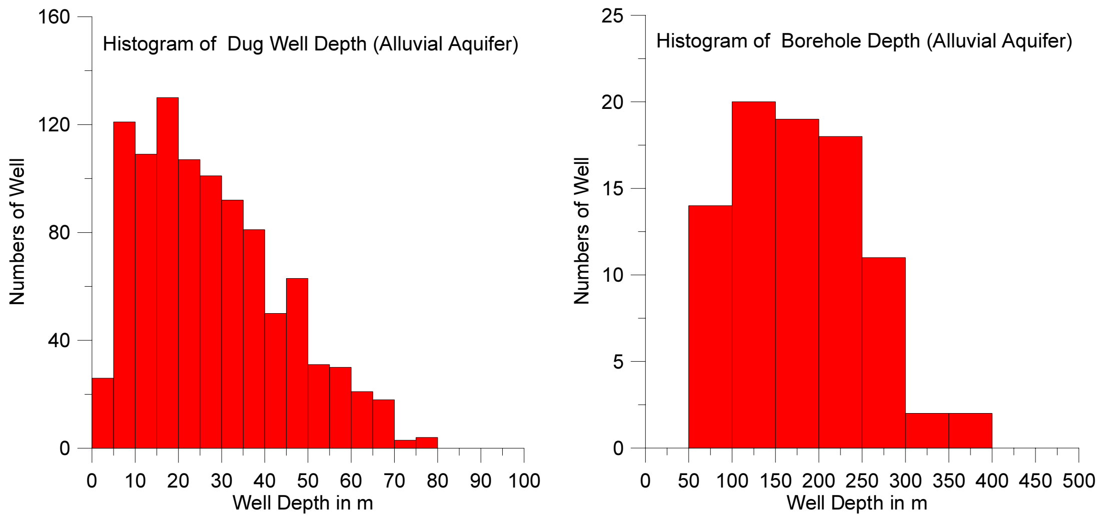


Figure 3.11 Distribution of Well Depth (Alluvial Aquifer)

Groundwater in the alluvial Deposits has been exploited mainly for irrigation use. 778 wells (70.1%) were used for irrigation, and 185 (16.6%) wells for domestic use.

(2) Volcanic Rocks

The well inventory survey (2002) shows that 4,214 operational water points exploited the aquifer in the Basin. 2,812 of them are dug wells, 1,294 are boreholes and others are Dug/Bore (88), Springs (18) and Dam/Pool (2).

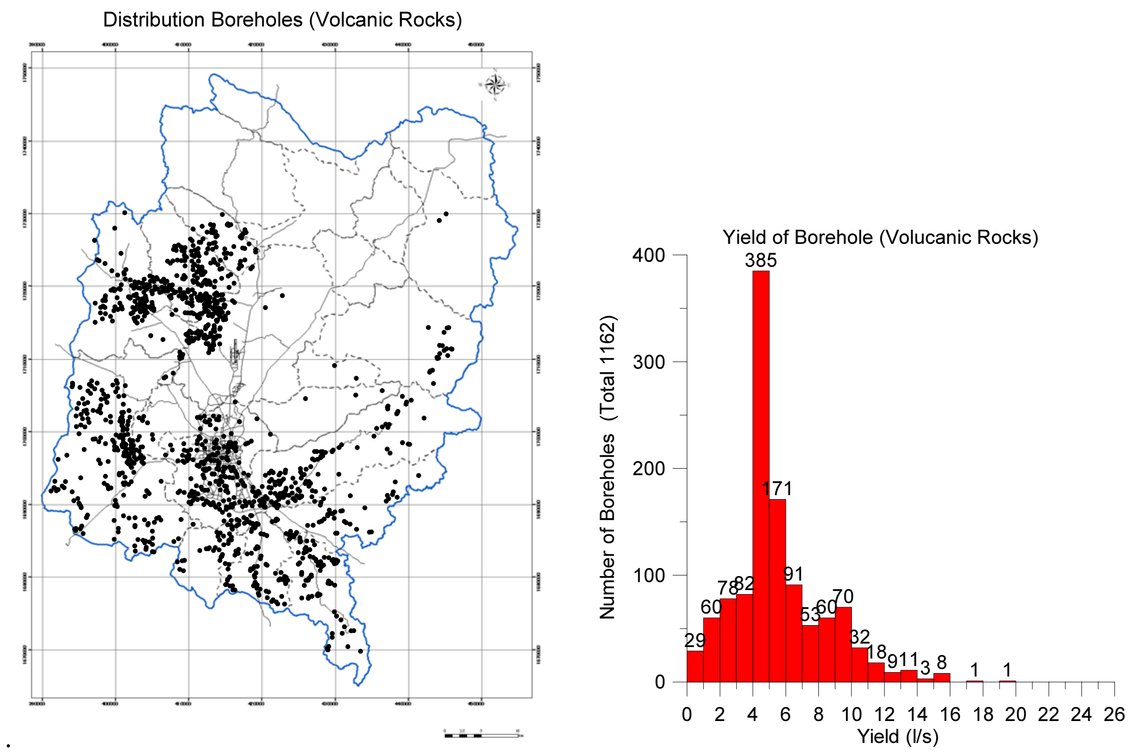


Figure 3.12 Distribution and Yield of Boreholes (Volcanic Rocks)

Figure 3.12 shows the distribution and yield of boreholes. About 48% of boreholes yield between 4 and 6 l/s. Dug wells generally penetrate to volcanic rocks up to 10 to 25 m, as shown in *Figure 3.13*. More than half of boreholes were drilled up to the depth of 150 to 300

m. 3,568 wells (85.1%) and 335 (7.9%) are used for irrigation and domestic respectively.

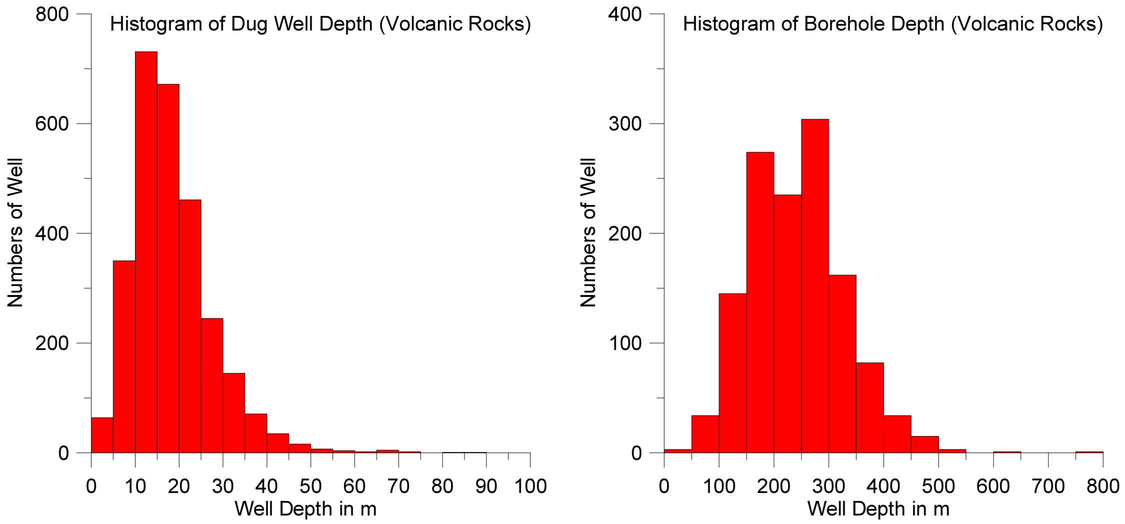


Figure 3.13 Distribution of Well Depth (Volcanic Rocks)

(3) Tawilah Sandstone

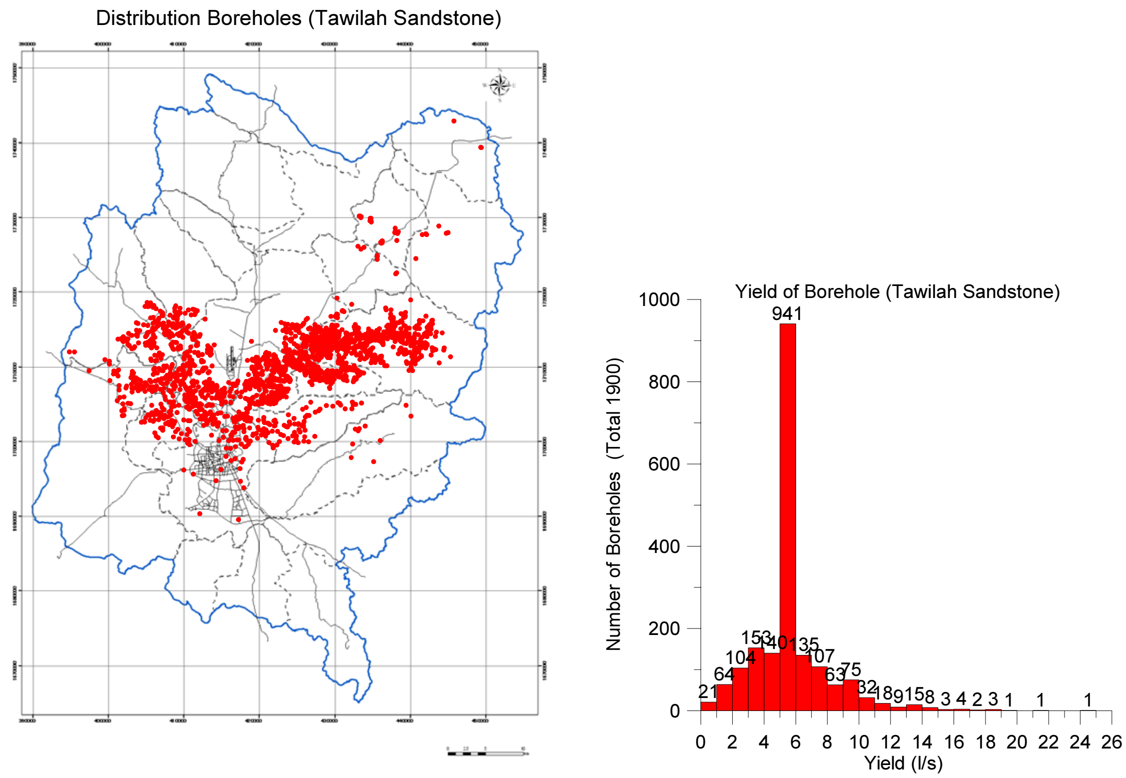


Figure 3.14 Distribution and Yield of Boreholes (Tawilah Sandstone)

According to the inventory survey (2002), 2,778 wells targeted the aquifer. 2,080 of 2,778 wells are boreholes and 630 wells are dug wells, and others are Dug/Bore (67), Springs (1) and Dam/Pool (1).

Figure 3.14 indicates the yield of 5-6 l/s is prominent, it means the Tawilah Sandstone aquifer is the most productive in the Basin generally. 60% of dug wells were drilled up to the depth of 20 m or less and 70% of boreholes were drilled up to the depth of 150 to 300 m as shown in *Figure 3.15* 2,540 (91.4%) of boreholes are used for irrigation and 85 (3.1%) for domestic use. Recently the sandstone aquifer underlying volcanic rocks has been exploited by drilling up to the depth of 1,000 m or less in the south of Sana'a City by Sana'a Water and Sanitation Local Corporation (SWSLC) and Sana'a Basin Water Management Project (SBWMP).

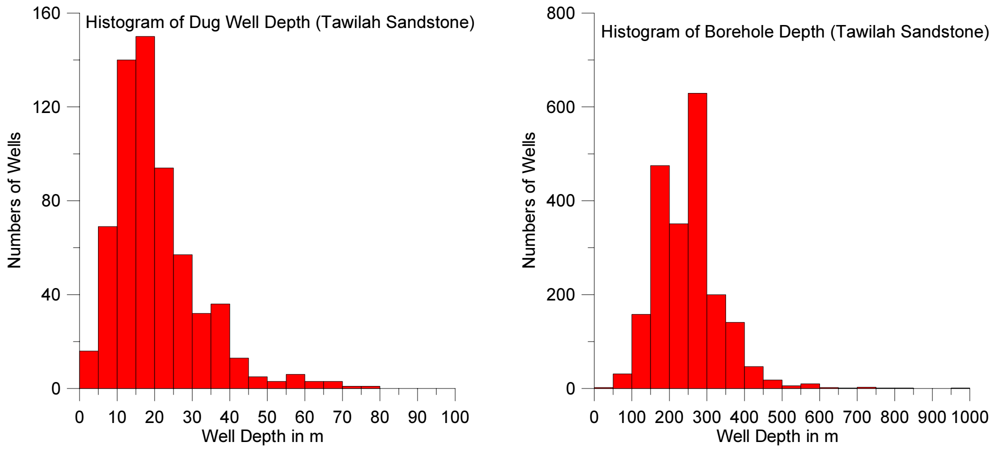


Figure 3.15 Distribution of Well Depth (Tawilah Sandstone)

(4) Amran Limestone

The inventory survey (2002) shows there were 791 operational water points exploiting the limestone aquifer. 460 of them were dug wells, 283 were boreholes and others were Dug/Bore (47) and one spring.

Figure 3.16 shows the distribution and yield of boreholes. The prominent yield is 3 to 4 l/s, 42% of boreholes. 62.8% of dug wells were drilled up to the depth of 10 to 25m and 70% of boreholes were drilled up to the depth of 150 to 350 m as shown in *Figure 3.17* 688 wells (85.8%) were used for irrigation and only 19 (5.7%) were used for domestic.

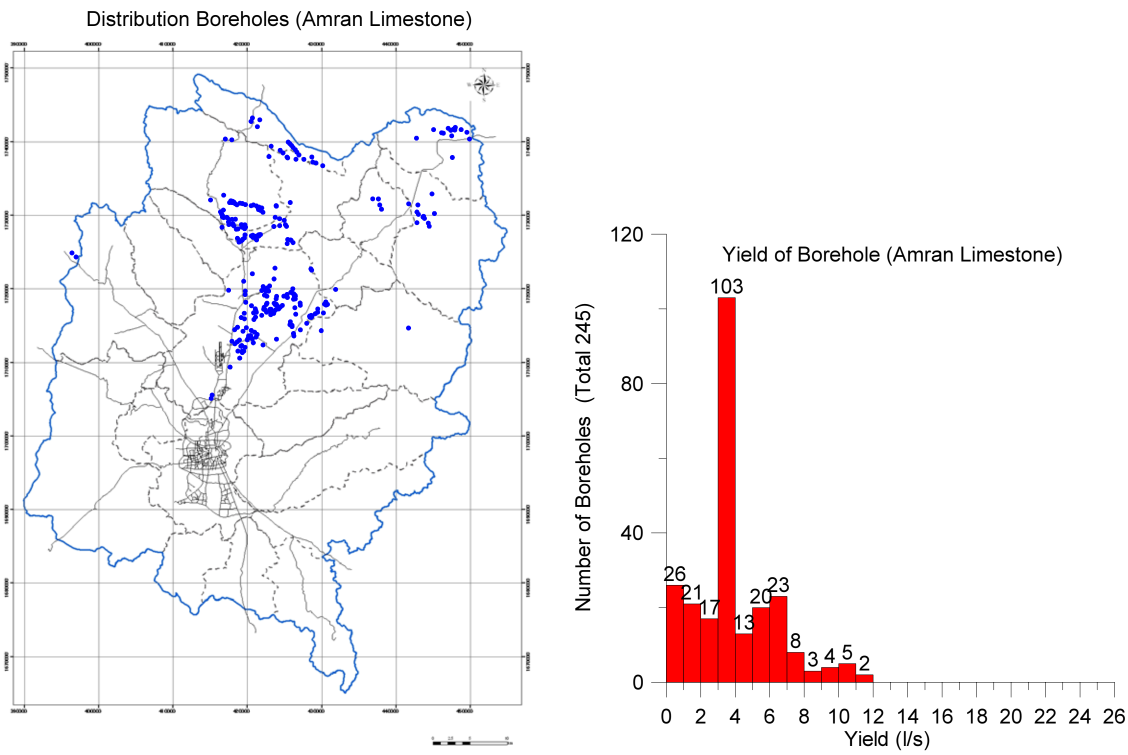


Figure 3.16 Distribution and Yield of Boreholes (Amran Limestone)

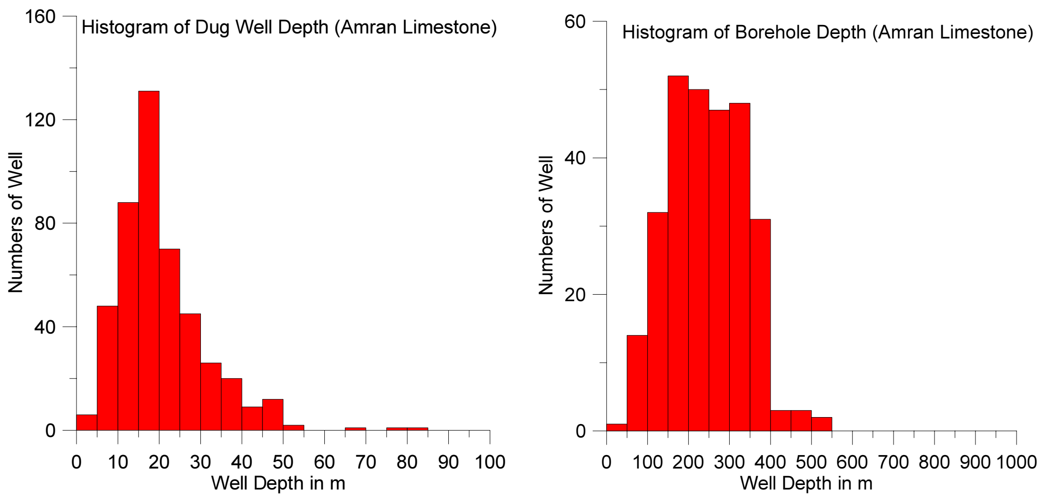


Figure 3.17 Distribution of Well Depth (Amran Limestone)

3.4.2 GROUNDWATER LEVEL

The well inventory survey (2002) recorded also water levels of the total 7,002 boreholes and dug wells, that is, 1,279 wells of Alluvial aquifer, 3,590 wells of Volcanic Rocks, 1,329 wells of Tawilah Sandstone and 645 wells of Amran Limestone. This section describes general condition of each aquifer based on the well inventory survey (2002).

(1) Alluvial Aquifer

Figure 3.18 shows the groundwater level of Alluvial aquifer. The map of the depth to water (left) indicates the water level of the central plain is generally 20 m or more, which means some shallow dug wells drilled in the past may not reach the water table now. The contour map of water level (right) shows that the water table slops first to the Sana'a Plain from the mountainous area to the west, south and east of the plain, and then slopes gently from south to north and northeast along the central low area.

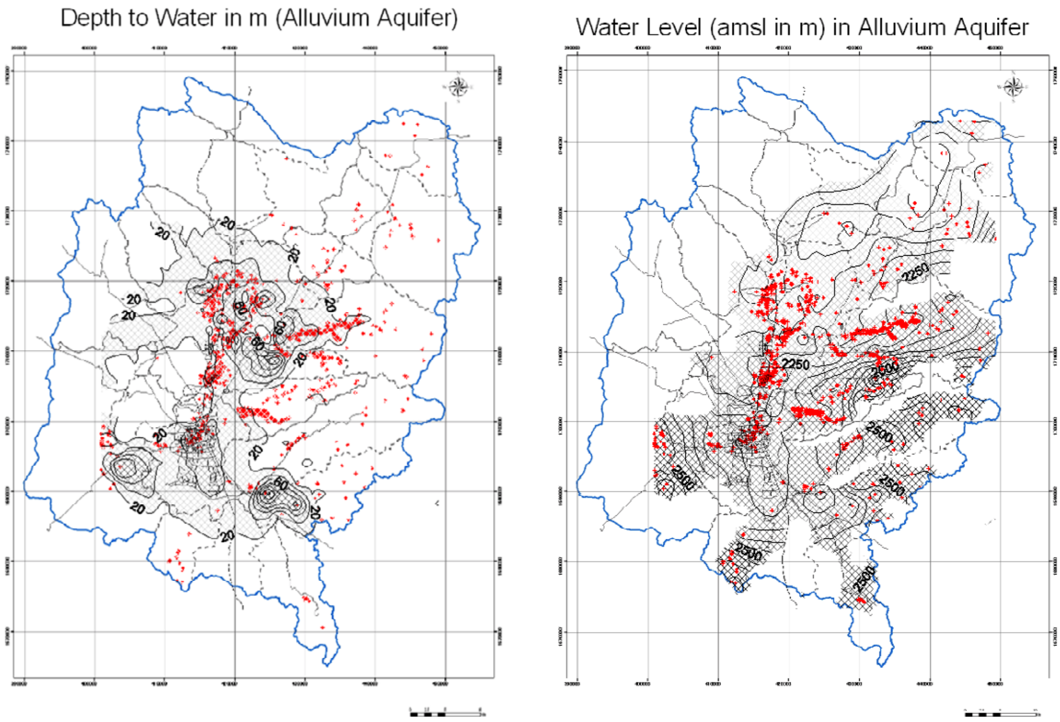


Figure 3.18 Water Level (Alluvial Aquifer)

(2) Volcanic Rocks

Figure 3.19 show the groundwater level of Volcanic Rocks. The map of the depth to water shows that the water level in the western mountain area is more than 100 m deep and the water level is less than 50 m in the eastern mountainous area. The elevation of water table inclines generally toward the north from the southern area in the Basin.

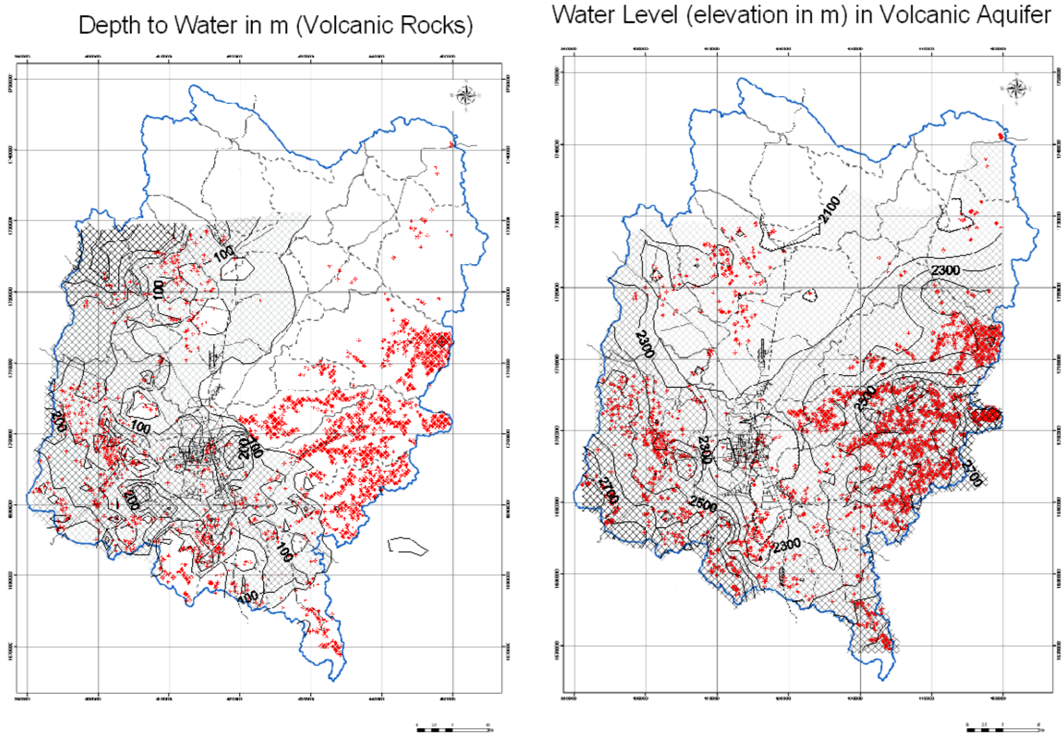


Figure 3.19 Water Level (Volcanic Rocks)

(3) Tawilah Sandstone

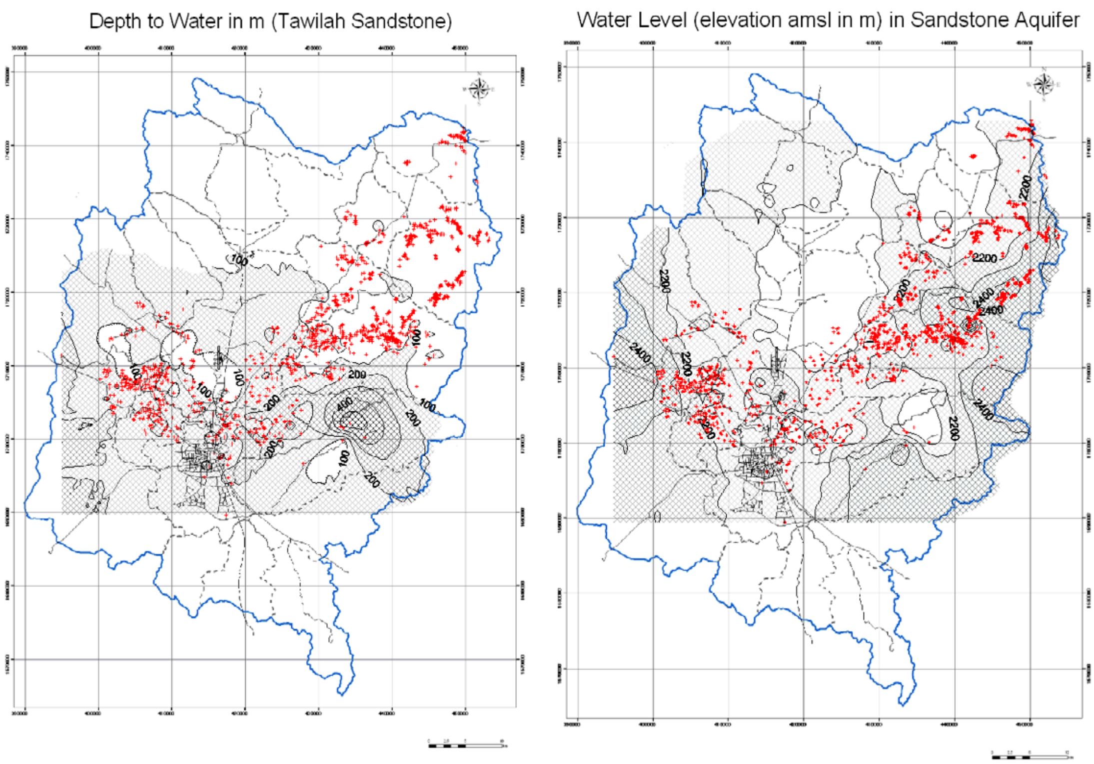


Figure 3.20 Water Level (Tawilah Sandstone)

Figure 3.20 show the groundwater level of Tawilah Sandstone. The map of the depth to water indicates that the water level in the central to southern area is generally more than 100 m deep and the water level in the northeastern part is less than 100 m. The contour map of water level shows that the water table slops from both sides of the mountainous area to the lower plain and then slopes toward the north.

(4) Amran Limestone

Figure 3.21 shows the groundwater level of Amran Limestone. The map of the depth to water shows that the water level in the northeastern area is generally less than 50 m deep and the water level in the north central part is more than 50 m. The contour map of water level indicates that the water table seems to slope from the northeast toward the south central, which is the opposite direction of other aquifers.

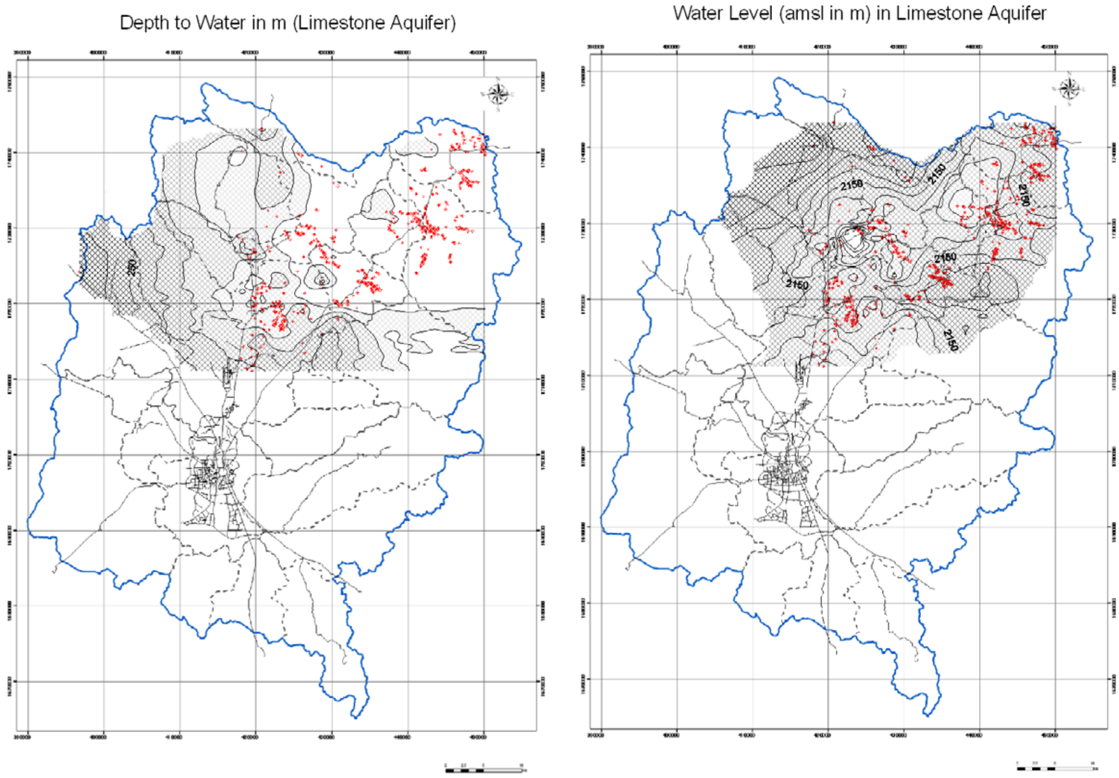


Figure 3.21 Water Level (Amran Limestone)

3.4.3 Aquifer Properties

The some previous studies carried out the pumping tests. SAWAS Technical Report No.5 (1996)[11] summarized the results of the previous pumping tests, which is shown in *Appendix.1*. The recent drilling results also have been added to the table.

(1) Transmissivity

The value of transmissivity indicates groundwater supply potential of the aquifer. SAWAS (1996) collected 12 values of Alluvial aquifer, 16 values of Volcanic Rocks, 62 values of Tawilah Sandstoen and 5 values of Amran Limestone. Additionally 15 values of Tawilah Sandstone drilled recently were added. Though the values of transmissivity ranges very widely from 0.25 to 2,000 as shown in *Appendix1*, *Table 3.10* indicates Tawilah Sandstone is the most productive aquifer. Transmissivity of Volcanic Rocks look to be scattering widely, it may suggest that the productivity of aquifer is probably affected by the scale of fissures or fractures in the rocks. Only five results of Amran Limestone seem to be not enough to indicate its characteristics.

Table 3.10 Transmissivity of Aquifers

(1) Alluvial aquifer

Transmissivity	Number of Wells		Groundwater supply Potential
10	3	(25.0%)	Low
10=< <100	8	(66.7%)	Intermediate
100=<	1	(8.3%)	High
	12	(100.0%)	

(2) Volcanic Rocks

Transmissivity	Number of Wells		Groundwater supply Potential
<10	8	(50.0%)	Low
10=< <100	5	(31.3%)	Intermediate
100=<	3	(18.8%)	High
	16	(100.0%)	

(3) Tawilah Sandstone

Transmissivity	Number of Wells		Groundwater supply Potential
<10	1	(1.3%)	Low
10=< <100	27	(35.1%)	Intermediate
100=<	49	(63.6%)	High
Total	77	(100.0%)	

(4) Amran Limestone

Transmissivity	Number of Wells		Groundwater supply Potential
<10	2	(40.0%)	Low
10=< <100	2	(40.0%)	Intermediate
100=<	1	(20.0%)	High
Total	5	(100.0%)	

(2) Hydraulic Conductivity (Permeability)

Hydraulic Conductivity is the rate of flow through a unit cross section under a unit hydraulic gradient, which is the coefficient of permeability of a layer. The values of hydraulic conductivity indicate that permeability is mostly moderate in aquifers in the Sana'a basin.

Table 3.11 Hydraulic Conductivity of aquifers

(1) Alluvial aquifer

Hydraulic Conductivity (m/day)	Number of Wells		Permeability
<0.1	1	(9.1%)	Low
0.1=< <1	5	(45.5%)	Moderate
1=< <10	4	(36.4%)	
10=<	1	(9.1%)	High
	11	(100.0%)	

(2) Volcanic Rocks

Hydraulic Conductivity (m/day)	Number of Wells	Permeability

<0.1	3	(20.0%)	Low
0.1=< <1	6	(40.0%)	Moderate
1=< <10	4	(26.7%)	
10=<	2	(13.3%)	High
	15	(100.0%)	

(3) Tawilah Sandstone

Hydraulic Conductivity (m/day)	Number of Wells		Permeability
<0.1	4	(5.6%)	Low
0.1=< <1	34	(47.9%)	Moderate
1=< <10	30	(42.3%)	
10=<	3	(4.2%)	High
	71	(100.0%)	

(4) Amran Limestone

Hydraulic Conductivity (m/day)	Number of Wells		Permeability
<0.1	2	(40.0%)	Low
0.1=< <1	0	(0.0%)	Moderate
1=< <10	3	(60.0%)	
10=<	0	(0.0%)	High
	5	(100.0%)	

3.4.4 GROUNDWATER QUALITY

The well inventory survey (2002) collected the data of EC, pH and temperature of water from 7,786 wells. In addition, SAWAS (1996)[12] conducted water quality analysis for 327 wells and collected the chemical analysis results of the previous studies.

Based on the above results, the characteristics of groundwater quality in the aquifers are generally described in this section. The issues concerning contamination are described in the section of 3.7.

(1) EC, pH and Temperature

1) Electric Conductivity (EC)

Almost 90% of groundwater has the EC value of 1,500 or less microS/cm as shown in *Figure 3.22*, or the water quality is generally good. And the figure also indicates that deeper wells have most likely a better water quality. The EC values more than 2,500 microS/cm appear mostly in the shallow wells with the depth of less than about 50 m. This may suggest that the shallower aquifer is possibly polluted in some areas.

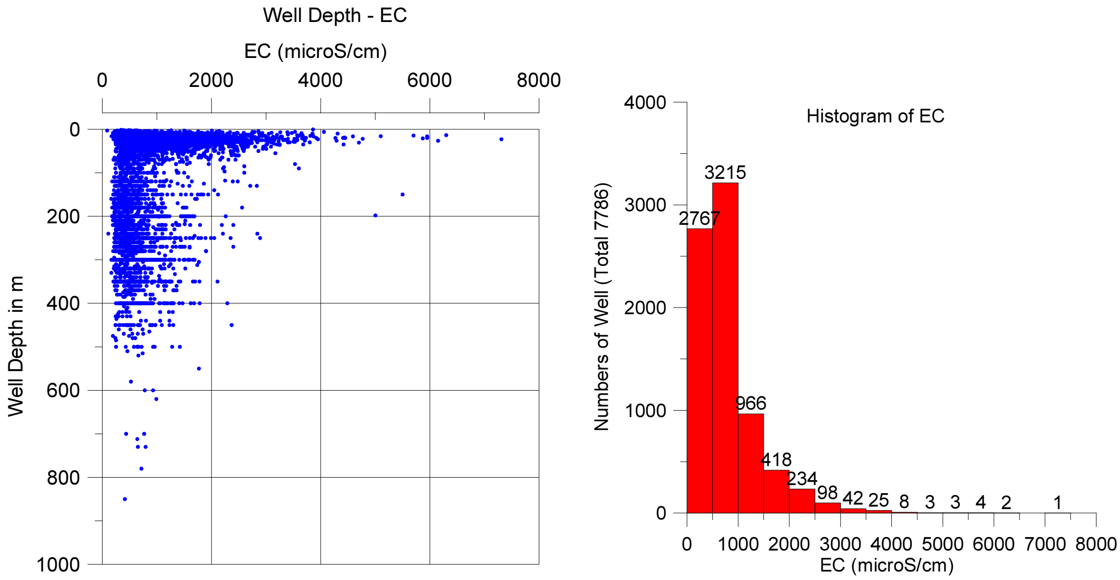


Figure 3.22 Relationship between Depth and EC, and Histogram of EC

Figure 3.23 shows the general tendency of the distribution of EC in the Sana'a Basin. The EC distribution of both dug wells and boreholes shows that there is a north-south long and narrow area around AR Rawdah and along the airport to the north of Sana'a city where the relatively higher EC values appear. AR Rawdah was the town where a sewage pond was once located and there is a wastewater treatment plant at the north end of the airport. Groundwater quality looks to be worse in the northeast area than the other area in the Sana'a basin. This issue is mentioned later again in the section of 3.7.

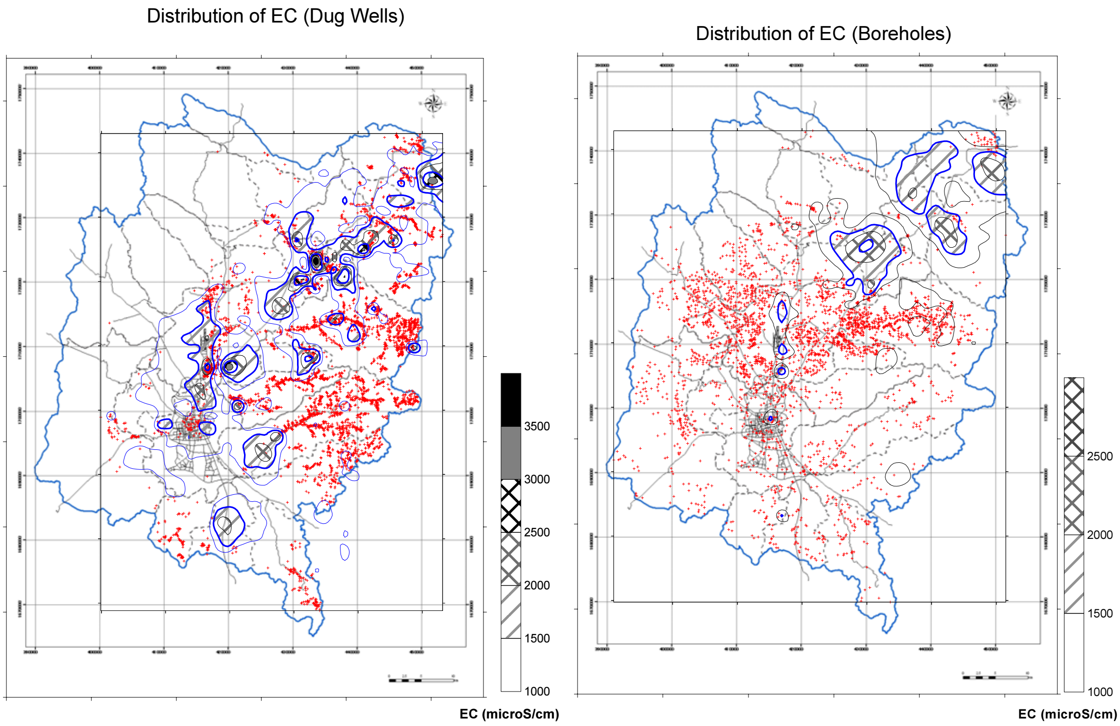


Figure 3.23 Distribution of EC

2) PH

The values of pH ranges mostly from 6 to 10, as shown in *Figure 3.24*. The histogram does not indicate any special tendency except that the mean value is 7.8 to 8, which is a little alkaline. In detail, water from volcanic rocks and limestone generally shows a little higher mean value of pH, about 7.9, than sandstone and alluvium, about 7.7. Depth and pH is also not related specifically.

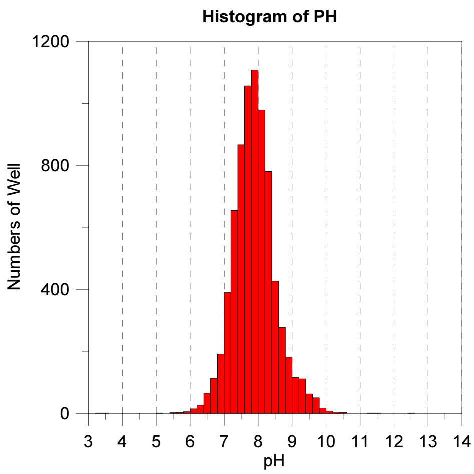


Figure 3.24 Histogram of pH

3) Temperature

The average temperature of groundwater is 22.6 C, though it ranges from 10.3 to 55.2 C. *Figure 3.25* shows the general tendency that a deeper aquifer has a higher temperature.

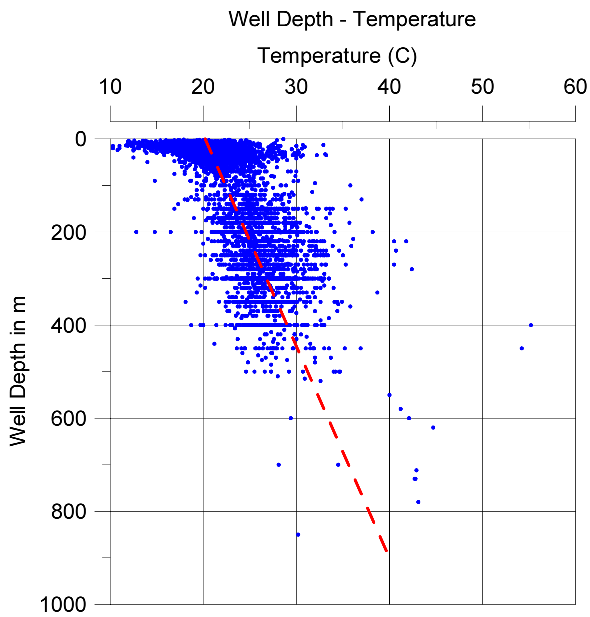


Figure 3.25 Well Depth and Temperature

(2) Result of Chemical Analysis

A detailed explanation about the result of groundwater chemical analysis has been described in SAWAS Technical Report No.13 (1996). The out line is briefly described with the Piper diagram in this section.

Figure 3.26 is the Piper diagrams showing the groundwater quality in the Sana'a Basin. In Alluvial aquifer, the cation composition is generally dominated by calcium and chloride dominates in the anion composition, that is, they are Ca Cl type of groundwater. Similarly, groundwater in the Sana'a basin is approximately classified to some types as below. The data of groundwater from Amran Limestone was not available.

Alluvial Aquifer;	Ca HCO3-Cl type, Ca Cl type, Ca Mixed-anion type
Volcanic Rocks;	Ca HCO3-Cl type, Ca Mixed-anion type
	Na HCO3-Cl type, Na Mixed-anion type
	Ca-Na HCO3-Cl type, Ca-Na HCO3-Cl type
Tawilah Sandstone;	Ca HCO3-Cl type, Ca Cl type, Ca Mixed-anion type
	Mixed-cation HCO3-Cl type, Mixed-cation Mixed-anion type

According to the figure, alluvial aquifer is characterized by relatively higher calcium and chloride, Volcanic Rocks aquifer is characterized by lower magnesium and relatively low sulfate, and Tawilah Sandstone aquifer is characterized by relatively higher calcium and mixed anion.

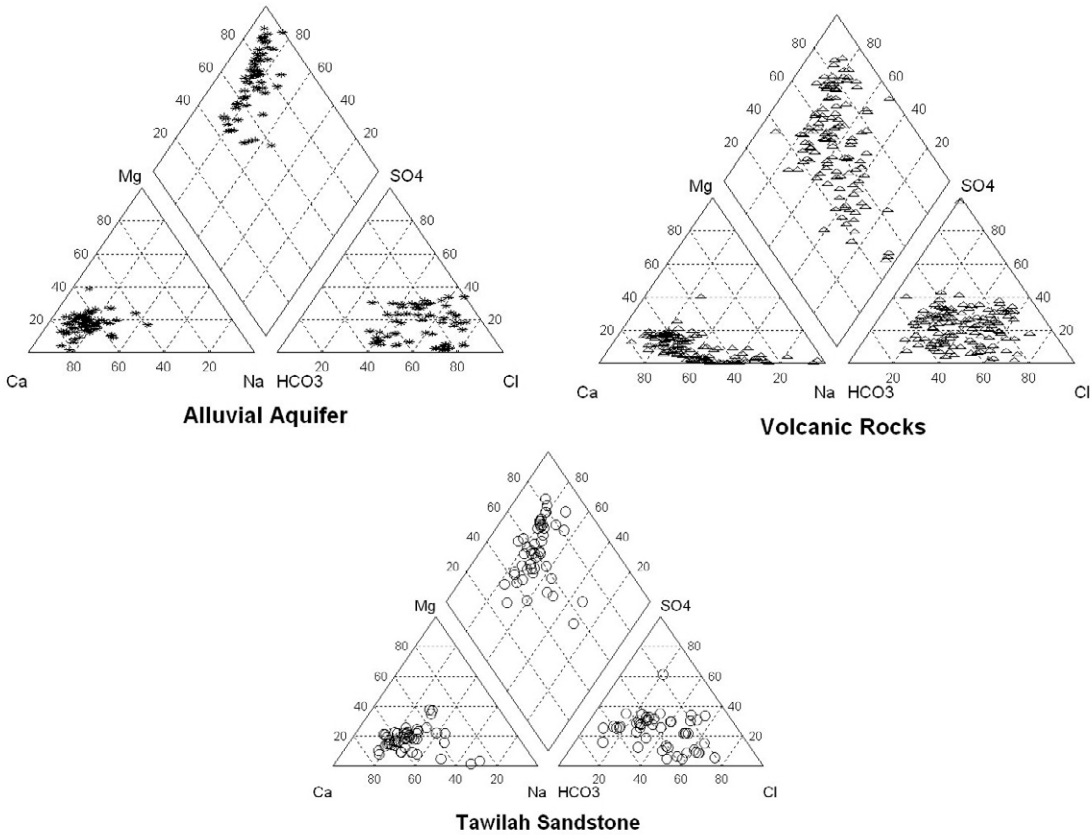


Figure 3.26 Piper Diagrams of Groundwater in the Sana'a Basin

(3) Fluoride

SAWAS Technical Report No.13 (1996) and GARWSP data collected by the Study team indicate some water samples have higher concentration of fluoride than the maximum permissible limit (MPL) of the national standard for drinking water. MPL is 1.5 mg/l and the highest desirable limit (HDL) is 0.5 mg/l. Fluoride in high concentration may cause "mottled enamel" in children's teeth.

Totally 202 samples with the concentration data of fluoride were collected and located. The concentrations of fluoride in 107 of 202 wells, 53%, were 0.5mg/l or less. 67 wells (33%) were in the fluoride concentration between 0.5 and 1.5mg/l. 28 other wells (14%) were in the fluoride concentration of more than 1.5 mg/l, including five wells more than 5 mg/l. *Figure 3.27* shows the distribution of the fluoride. Higher concentration of fluoride may be related to minerals in the volcanic rocks.

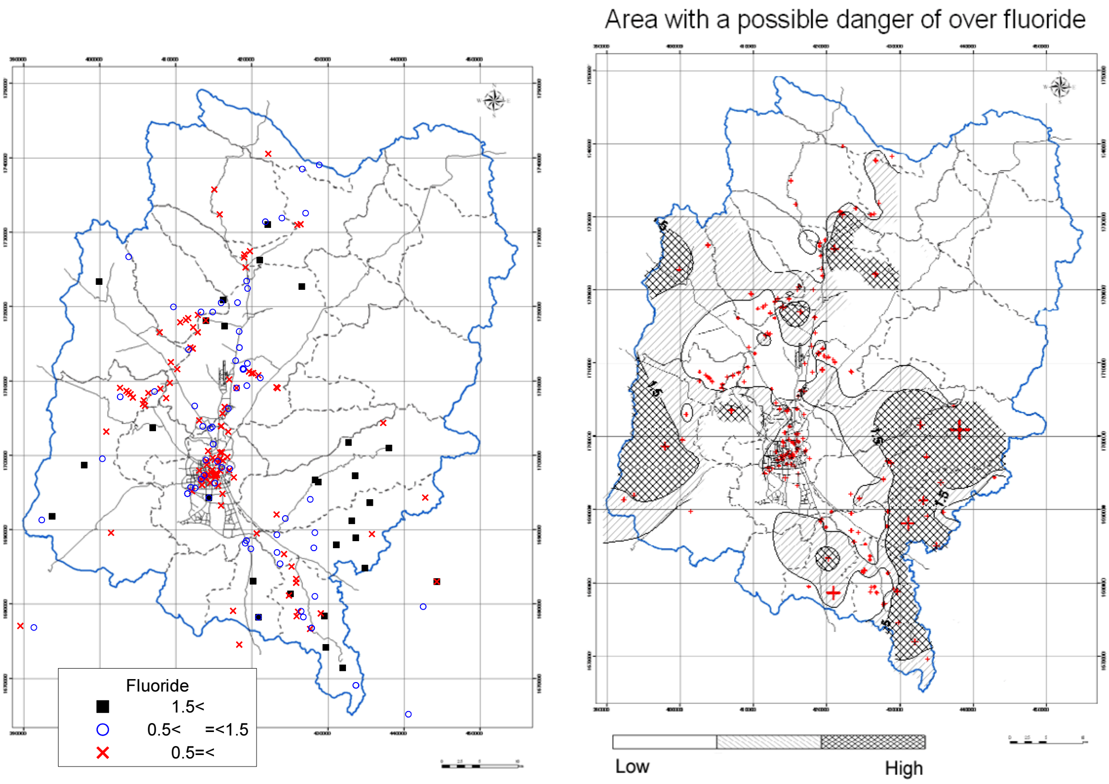


Figure 3.27 Distribution of Fluoride

3.5 WATER RESOURCES POTENTIAL IN SANA'A BASIN

3.5.1 GROUNDWATER RECHARGE

(1) Is it recharged?

WEC (2001)[13] cited some observable facts as evidence of the occurrence of recharge as follows,

- The very fast groundwater study in the Basin showed a water level rise in the Alluvial aquifer, Volcanic Rocks and Tawilah Sandstone for the period between 1965 and 1972. The rise was occurring when the over-pumping in the central part of the plain had already become a considerable subject.
- Reanalyzing the water level data collected during 1980's shows clear evidence of "water mound" following rainy seasons, which eventually disappears as the additional volume of water spreads across the aquifers.
- Rural habitants reported on a number of cases that water table had risen considerably due to the construction of small dams.

Several previous studies assumed that groundwater recharge occurred in the area of sandstone outcrop and wadi beds.

A recent survey of the isotope composition, which is mentioned in Foster (2003)[14], revealed evidence of contemporary (post-1965) natural recharge of the Quaternary Alluvial Aquifer. Although there is no definitive evidence in the current data of contemporary recharge having reached the Cretaceous Sandstone Aquifer, the report noted that the results do not yet exclude the possibility of modern recharge to the Cretaceous Sandstone Aquifer.

The Study team has considered that the natural recharge to the deeper aquifer is most probably occurring since:

- In the Sana'a Basin, the outcrop of the Sandstone is distributed widely from west to east in the central zone. And the volcanic rocks outcropped in the western and southern part of the Basin.
- Rainfall is considered able to infiltrate directly to these outcrops through the rich fissures and cracks of the rocks. There are a lot of springs flowing out from the rocks.
- The drilling works, especially the recent deep drilling up to 1,000 m, shows that there are many fractured zones in the rock underlying the wadi beds and the quaternary deposits.
- The monitoring well located in the Western Well Field, where the Tawilah Sandstone aquifer is exploited, shows the momentary increasing of the water level as shown in *Figure 3.28*. (A water level fluctuation may be caused by not only natural recharge and also various factors. Therefore it is important to monitor continuously water level, rainfall, pumping discharge and so on, in order to clarify the relationship of them.)

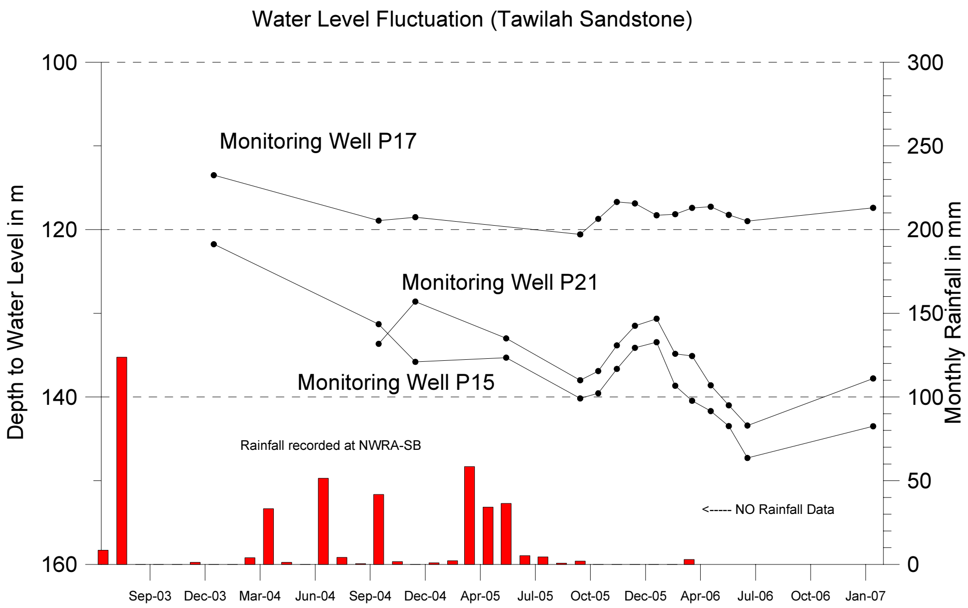


Figure 3.28 Fluctuation of Groundwater Level (Tawilah Sandstone)

(2) Estimation of Recharge

1) Previous Studies

Since 1970, several previous studies have estimated the amount of groundwater recharge in the Sana'a Basin. Adopted methods of the estimation can be grouped into two types, one is the method based on the Darcy Law, another one is the method using recharge coefficient.

The former one is the calculation of groundwater flow through the aquifer using the width and thickness of the aquifer, transmissivity and hydraulic gradient.

The latter one is the estimation using the rainfall in the area, the area or size of the surface, and recharge coefficient decided according to the surface conditions such as geology and land use.

The method using the Darcy Law is based on the transmissivity obtained from the results of few pumping tests and the assumed simplified shape of the aquifer though the geological structure is complicated in the Basin. Therefore, it is unclear whether the assumed values used for estimation reflect the actual characteristics of the aquifer. The recharge coefficients used for the estimation, also, are the empirical values, which are not obtained experimentally.

Consequently, the values of groundwater recharge have been calculated very roughly. In fact, the obtained valued range widely from 28 to 63 MCM annually as shown in *Table 3.12*.

Table 3.12 Estimation of Groundwater Recharge in the Sana'a Basin

Study	Term	Organization	Consultant	Method	Estimated Rechareg (Mm^3/y)
Water Supply for Sana'a and Hodeida. Sana'a Basin Groundwater Studies	1970-1973	NWSA	Italconsult	Darcy	59
Water Supply for Sana'a Phase 2	1980, 1983	NWSA	Howard Humphreys & Sons	Darcy	45-28
Sana'a Basin Water Resources Scheme	1986	MAF	Mosgiprovodkhoz	Recharge Coefficient	63
Assistance to the High Water Council in the Preparation of a Water Master Plan	1988-1992	HWC	Individual Experts	Recharge Coefficient	42
Sources for Sana'a Water Supply (SAWAS)	1987-1996	NWSA	TNO Institute of Applied Geoscience	Darcy	35
Sana'a Basin Water Resources Management Study (SBWRM-PPT)	2001	NWRA	Sana'a University, WEC	Recharge Coefficient	46

2) Recent Estimation of Groundwater Recharge in Sub-Basins

Norman and Mulat (2007) have recently estimated the amount of groundwater recharge in each sub-basin using the hydrological water balance equation of $\boldsymbol{R - (E + Q) = dS}$.

Where; R: rainfall (mm) = daily rainfall (1991 - 2003) data of the nearest observation station

E: evapotranspiration (mm) = estimated by ITC (1989)

Q: runoff (mm) = estimated by SCS Curve Number method

The daily change in soil moisture storage, *dS*, is calculated by the above equation and accumulated to estimate the average annual change of storage. Then, the following assumptions are adopted.

- The 90% of the soil moisture storage (*dS*) is consumed by plants and transpired or directly evaporated from the soil. The other 10% recharges the aquifer.
- The 40% of the runoff generated in the catchments is either directly used for irrigation, evaporate from reservoirs, or flow downstream in case of big floods. The other 60% recharges the aquifer.

Finally, the amount of groundwater recharge in the Sana'a basin has been calculated at 50.7 MCM/year in total. *Table 3.13* shows the detailed estimation of each sub-basin.

Table 3.13 Estimated Groundwater Recharge in Sub-basins

No	Sub Basin	Estimated Recharge (MCM)
1	Wadi al Mashamini	0.86
2	Wadi al Madini	2.73
3	Wadi al Kharid	1.76
4	Wadi al Ma'adi	1.71
5	Wadi A'sir	4.27
6	Wadi Khulaqah	1.54
7	Wadi Qasabah	0.83
8	Wadi al Huqqah	1.36
9	Wadi Bani Hwat	5.58
10	Wadi Thumah	1.00
11	Wadi as Sirr	3.81
12	Wadi al Furs	0.79
13	Wadi al Iqbal	2.31
14	Wadi Zahr & al Ghayl	7.11
15	Wadi Hamdan	0.82
16	Wadi al Mawrid	1.54
17	Wadi Sa'Wan	1.41
18	Wadi Shahik	4.12
19	Wadi Ghayman	1.24
20	Wadi al Mulakhy	1.66
21	Wadi Hizyaz	1.92
22	Wadi Akhwar	2.32
Total		50.7

Source; Dr. A.Norman and Eng. W. Mulat (2007), Water Balance and Hydrological Monitoring

3) Conclusion

As described above, the groundwater recharge in the Sana’a basin has been estimated at about 50 MCM/year based on the various assumptions. Even the results are very rough estimation, the adopted assumptions are passably reasonable from hydrogeological points of view. The actual natural recharge is most likely settled into the estimated range, 28-63 MCM annually, in the rough.

3.5.2 GROUNDWATER STORAGE

Storage of groundwater, S_t, can be estimated with the equation of $S_t = AHS_y$., where, A is the area of aquifer, H is saturated thickness and S_y is specific yield, or effective porosity.

TS-HWC (1992)[15] estimated the storage of groundwater in the Sana’a basin using this equation. They supposed that the depth of 250 m was the maximum depth that the groundwater storage could be commanded, and about 50% of this commandable storage could be extracted, or usable. Besides the specific yield was assumed at 0.1 for Alluvial aquifer, 0.01 for Amran Limestone and 0.03 for Tawilah Sandstone. Consequently, the estimated volume of commandable storage was 6,047 MCM and the usable storage was 3,221 MCM in the Sana’a Basin. Please note, however, that the assumptions used to derive these estimations are fairly rough figures as they themselves mentioned it.

WEC (2001) has revised the above approach with the updated water levels, and estimated the storage volume of each groundwater province in the Sana’a basin. As a result, the commandable storage and the usable storage were calculated 10,424 MCM and 5,212 MCM respectively. They mentioned that the volume obtained by TS-HWC should be very conservative estimates because of the water levels applied to calculations were over-estimated. The assumptions such as specific yield remain in rough and ready estimates.

3.5.3 Surface Water

Although surface runoff has not been measured for the present, the runoff volume of surface water has been estimated as described in the section of 3.3.6. *Table 3.14* shows the summarized figures of the annual flow of each sub-basin. Annual Flow is the values totaled by yield of dams/pools and springs in the basin. In addition, Annual Runoff was calculated based on the runoff coefficient suggested by WRY-35 (1995) and rainfall applied in SBWMP, Norman and Mulat (2007). In the Wadi Al Kharid, the accumulated annual flow is several times as much as the annual runoff estimated with the runoff coefficient. It seems to reflect there are springs yielding 0.2 m^3/s near Samnah in the Al Kharid Basin.

At any rate, most of them, flow or runoff water, have been used for irrigation and/or other purposes, and some of them infiltrate to wadi bed finally.

Table 3.14 Annual Flow/Runoff of Sub-Basins

Zone	Sub-Basin	Annual Flow (10^3m^3)	Rainfall (mm)	Catchment (km^2)	Runoff coefficient	Annual Runoff (10^3m^3)
1	Wadi Al Mashamini	412	171	76.5	0.055	719
2	Wadi Al Madini	-	191	211.5	0.055	2,222
3	Wadi Al Kharid	11,078	191	136.7	0.055	1,436
4	Wadi Al Ma'adi	1,033	185	111.5	0.055	1,135
5	Wadi A'sir	5,071	229	210.2	0.055	2,647
6	Wadi Khulaqah	1,588	229	75.9	0.055	956
7	Wadi Qasabah	-	191	64.6	0.055	679
8	Wadi Al Huqqah	-	187	120.7	0.055	1,241
9	Wadi Bani Huwat	-	242	322.4	0.055	4,291
10	Wadi Thumah	1,226	191	77.6	0.055	815
11	Wadi As Sirr	2,223	202	219.1	0.055	2,434
12	Wadi Al Furs	196	242	45.8	0.055	610
13	Wadi Al Iqbal	850	187	204.4	0.055	2,102
14	Wadi Zahr & Al Ghayl	617	279	364.8	0.055	5,598
15	Wadi Hamdan	1,300	217	63.7	0.055	760
16	Wadi Al Mawrid	659	210	179.6	0.055	2,074
17	Wadi Sa'wan	1,193	223	95.4	0.055	1,170
18	Wadi Shahik	1,815	202	236.9	0.055	2,632
19	Wadi Ghayman	1,519	210	143.8	0.055	1,661
20	Wadi Al Mulaikhy	550	249	69.8	0.055	956
21	Wadi Hizyaz	296	249	80.5	0.055	1,102
22	Wadi Akhwar	938	173	125.4	0.055	1,193
	Total	32,563				38,435

3.5.4 Treated Wastewater

Sana'a Wastewater Treatment Plant (WWTP) is located in a sensitive area adjacent to the International Airport with design capacity to treat 50,000 m^3/day of sewage water which comes from the city of Sana'a

According to data from Sana'a Water and Sanitation Local Corporation, who operates the WWTP, the quantity of sewage water have reached the WWTP in 2005 and 2006 is shown in

Table 3.15.

Table 3.15 WWTP Influent for 2005 and 2006

Year	WWTP influent
2005	11.0
2006	16.0

Unit: million cubic meters

Actually the WWTP is operating overloaded as explained in section 5.7.2 and the wastewater improperly treated is discharged to the wadi via a lagoon. The treated water flows by gravity to the downstream through an open channel and farmers are using this water to irrigate their lands. A very small amount of treated water is also used to water trees lining streets and green areas in the city.

Upgrading of WWTP to treat all influent wastewater to an acceptable quality following international standards for reuse in agriculture and watering trees is ongoing. Plans for construction of two new treatment plants are under preparation. One is with daily treatment capacity about 500 m^3/day, with objective to treat sewage brought by tankers from cesspits of the city and other with treatment capacity of 105,000 m^3/day. Details are explained on section 5.7.2.

Consequently, at least, treated wastewater cannot be accounted as a source of water. In the near future, however finishing the upgrade of present WWTP and construction of new treatment plant, the treated water could be accounted as a source of water for irrigation and the expected quantity is a minimum of 18.3 to a maximum of 56.6 MCM/year

3.6 WATER BALANCES IN SUB-BASINS

The water balance in the Sana'a Basin was generally calculated by the previous studies. The results were very rough estimation in the whole Sana'a Basin. The two types of somewhat detailed water balance evaluation in sub-basins have been provided recently by the parts of SBWMP, one is the hydrological approach adopted in Norman and Mulat (2007), which is mentioned in the previous section of 3.5.1, and another one is based on the satellite imagery analysis, GAF (2007).

3.6.1 HYDROLOGICAL APPROACH OF WATER BALANCE ANALYSIS

The estimation of groundwater recharge by the hydrological approach is explained in the 3.5.1. The water balance was calculated by the recharge minus the abstraction from well. The groundwater abstraction was obtained from the result of well inventory survey (2002). *Table 3.16* shows the result. Norman and Mulat (2007) have not counted the return flow from irrigation and sewage. A certain portion of the water applied to an irrigated area is not used up as consumptive use, but infiltrates, eventually reaching the water table. It may amount of as much as 20 to 40%[16] of the volume of water used for irrigation. On assumption that the ratio is 30%, the revised values are calculated and are shown in the same *Table 3.16*.

Table 3.16 Water Balance in Sub-Basins by Hydrological Approach

	Sub-Basin	Recharge (Mm^3)	Abstraction (Mm^3)	Water Balance (Mm^3)	Return Flow (30%) (Mm^3)	Consumed Volume (Mm^3)	Revised Balance (Mm^3)	Comsumed Ratio /Recharge
1	Wadi Al Mashamini	0.90	0.85	0.05	0.26	0.60	0.30	0.66
2	Wadi Al Madini	2.73	2.92	-0.19	0.88	2.04	0.68	0.75
3	Wadi Al Kharid	1.76	3.36	-1.60	1.01	2.35	-0.59	1.33
4	Wadi Al Ma'adi	1.71	2.67	-0.96	0.80	1.87	-0.16	1.10
5	Wadi A'sir	4.27	6.93	-2.66	2.08	4.85	-0.58	1.14
6	Wadi Khulaqah	1.54	2.12	-0.58	0.64	1.48	0.06	0.96
7	Wadi Qasabah	0.83	2.12	-1.29	0.64	1.48	-0.65	1.78
8	Wadi Al Huqqah	1.36	17.36	-16.00	5.21	12.15	-10.79	8.91
9	Wadi Bani Huwat	5.58	60.87	-55.29	18.26	42.61	-37.03	7.64
10	Wadi Thumah	1.00	3.25	-2.25	0.98	2.28	-1.27	2.27
11	Wadi As Sirr	3.81	39.06	-35.25	11.72	27.34	-23.53	7.17
12	Wadi Al Furs	0.79	13.60	-12.81	4.08	9.52	-8.73	12.02
13	Wadi Al Iqbal	2.31	17.46	-15.15	5.24	12.22	-9.91	5.29
14	Wadi Zahr & Al Ghayl	7.11	16.51	-9.40	4.95	11.56	-4.44	1.62
15	Wadi Hamdan	0.82	7.47	-6.65	2.24	5.23	-4.41	6.36
16	Wadi Al Mawrid	1.54	35.40	-33.86	10.62	24.78	-23.24	16.04
17	Wadi Sa'wan	1.41	8.82	-7.41	2.65	6.17	-4.76	4.37
18	Wadi Shahik	4.12	10.41	-6.29	3.12	7.29	-3.16	1.77
19	Wadi Ghayman	1.24	4.23	-2.99	1.27	2.96	-1.72	2.39
20	Wadi Al Mulaikhy	1.66	2.96	-1.30	0.89	2.07	-0.41	1.25
21	Wadi Hizyaz	1.92	3.17	-1.25	0.95	2.22	-0.30	1.16
22	Wadi Akhwar	2.32	8.44	-6.12	2.53	5.91	-3.59	2.55
	Total	50.7	270.0	-219.2	81.0	189.0	-138.2	(4.02)

Source; Modified Norman and Mulat (2007)

The above table also shows the consumed volume ratio per recharge amount in the sub-basin. The results are classified to four classes. The first one is the group with the ratio of over 10. The second is the group with the ratio between 5 and 10, the third is the ratio of between one and five, and the fourth is the ratio of less than one. The worst two groups are as follows:

1st Group: The two sub-basins where groundwater consumed volume is suspected more than 10 times of the recharge amount.

Wadi al Mawrid: The city of Sana'a is located in this sub-basin. Most of the abstracted groundwater is used for domestic use.

Wadi al Furs: This is the smallest sub-basin, but there are many wells along the wadi beds in the area.

2nd Group: The five sub-basins where groundwater consumed volume is suspected 5-10 times of the recharge amount.

Wadi al Huqqa, Wadi Bani Huwat, Wadi as Sirr, Wadi Hamdan, Wadi al Iqbal

3.6.2 WATER BALANCE ESTIMATED BY SATELLITE IMAGERY ANALYSIS

Table 3.17 Water Balance Estimated by Satellite Imagery Analysis (2004/05)

	Sub-Basin	Rainfall (04/05)		Eta Irrigated Crop	Agriculture Water Use (irrigation)	Effective Rainfall (Mm^3)			Balance (Mm^3)		
		(mm)	(Mm^3)	(Mm^3)	(Mm^3)	Min.		Max.	Min.		Max.
1	Wadi al Mashamini	290	22.6	0.4	0.6	1.3	-	1.5	0.7	-	0.9
2	Wadi al Madini	292	62.3	1.8	3.0	3.5	-	3.9	0.5	-	0.9
3	Wadi al Kharid	193	26.7	1.2	2.0	1.5	-	1.5	-0.5	-	-0.5
4	Wadi al Ma'adi	202	22.5	0.5	0.9	1.3	-	1.3	0.4	-	0.4
5	Wadi A'sir	251	52.4	3.1	5.1	2.9	-	3.1	-2.2	-	-2.0
6	Wadi Khulaqah	180	13.6	0.9	1.6	0.7	-	0.7	-0.9	-	-0.9
7	Wadi Qasabah	251	16.2	1.0	1.6	0.9	-	1	-0.7	-	-0.6
8	Wadi al Huqqah	261	31.4	5.8	9.7	1.8	-	2.3	-7.9	-	-7.4
9	Wadi bani Huwat	206	67.4	19.5	32.4	4.0	-	5.4	-28.4	-	-27.0
10	Wadi Thumah	210	16.2	0.5	0.8	0.9	-	1.0	0.1	-	0.2
11	Wadi as Sirr	247	54.0	9.9	16.5	3.1	-	3.8	-13.4	-	-12.7
12	Wadi al Furs	185	8.5	3.4	5.7	0.5	-	0.5	-5.2	-	-5.2
13	Wadi al Iqbal	305	61.9	7.9	13.1	3.6	-	4.4	-9.5	-	-8.7
14	Wadi Zahr & al Ghayl	366	132.1	6.5	10.9	11.8	-	11.8	0.9	-	0.9
15	Wadi Hamdan	297	18.9	4.1	6.8	1.1	-	1.4	-5.7	-	-5.4
16	Wadi al Mawrid	268	48.0	3.5	5.8	2.7	-	3.1	-3.1	-	-2.7
17	Wadi Sa'wan	228	21.9	4.0	6.7	1.3	-	1.5	-5.4	-	-5.2
18	Wadi Shahik	293	69.9	4.1	6.9	4.0	-	4.4	-2.9	-	-2.5
19	Wadi Ghayman	290	41.6	2.2	3.7	2.4	-	2.7	-1.3	-	-1.0
20	Wadi al Mulaikhy	327	22.8	1.4	2.3	1.3	-	1.6	-1.0	-	-0.7
21	Wadi Hizyaz	268	21.9	1.1	1.8	1.2	-	1.4	-0.6	-	-0.4
22	Wadi Akhwar	276	34.7	1.0	1.6	1.9	-	2.1	0.3	-	0.5
	Total Sana'a Basin		867.2	83.7	139.5	53.9	-	60.5	-85.6	-	-79.0

Source: Modified GAF (2007)

Using the irrigated area and the actual evapotranspiration estimated by the satellite imagery analysis, the amount of water for agriculture use, which was supposed to be abstracted all by wells, were calculated with the assumption of the irrigation efficiency of 60%. (The water amount was recalculated as explained in the 5.4.2.) Effective rainfall, that is, the amount of rainfall that could be used by vegetation, was estimated as the sum of infiltration of overland flow in wadi and the infiltration of precipitation after heavy rainfall event. Overland flow was estimated by the runoff coefficient, 5.5%, supposed by WRAY-35 (1995). The infiltration after heavy rain was estimated by the method introduced by the U.S. Department of Agriculture's Soil Conservation Service. Then, the water balance was obtained by the effective rainfall minus the amount of water use for agriculture. *Table 3.17* shows the results.

As explained above, this water balance is obtained only using the water use for agriculture (irrigated). The other water usages should be included in this calculation naturally. Therefore, *Table 3.18* is prepared after revising with the results of Chapter 5.

As a rough standard to compare the results, the ratio of the volume of water use to rainfall in the area was calculated. The higher ratio means the higher water consumption comparing with the natural replenishment, which is probably corresponding to rainfall. There are five sub-basins where the ratio is between 20 and 40%, two sub-basins where the ratio is between 50 and 70%.

One sub-basin has the ratio around 175%.

Five sub-basins where the ratio is between 20 and 40% are Wadi Huqqah, Wadi As Sirr, Wadi Al Iqbal, Wadi Hamdan and Wadi Sa'wan. Two sub-basins where the ratio is between 50 and 70% are Wadi Bani Huwat and Wadi Al Furs and the sub-basin with ratio of 176% is Wadi Al Mawrid where Sana'a City is located. Two sub-basins, Wadi Al Furs and Wadi Al Mawrid, are listed in the 1st group of the higher ratio of consumption to recharge by the hydrological approach, too. Wadi Huqqah, Wadi Bani Huwat, Wadi As Sirr Wadi Al Iqbal and Wadi Hamdan are listed in the 2nd group described in the previous section.

These seven double listed sub-basins as 1) Wadi Huqqa, 2) Wadi Bani Huwat, 3) Wadi As Sirr, 4) Wadi As Furs, 5) Wadi Al Iqbal, 6) Wadi Hamdan and 7) Wadi Al Mawrid are considered to be in a very critical condition of groundwater resources.

Table 3.18 Modified Water Balance Estimation based on the Satellite Imagery Analysis (2004/05)

		Water Use					Effective Rainfall (Mm^3)			Balance (Mm^3)			Water Use/Rainfall
		Agriculture (Mm^3)	Urban Water Supply (Mm^3)	Rural Water Supply (Mm^3)	Industry /Tourism /Others (Mm^3)	Total (Mm^3)	Min.		Max.	Min.		Max.	
1	Wadi al Mashamini	0.6	-	0.04	-	0.6	1.3	-	1.5	0.7	-	0.9	2.8%
2	Wadi al Madini	3.0	-	0.10	-	3.1	3.5	-	3.9	0.4	-	0.8	5.0%
3	Wadi al Kharid	2.0	-	0.07	-	2.1	1.5	-	1.5	-0.6	-	-0.6	7.7%
4	Wadi al Ma'adi	0.9	-	0.02	-	0.9	1.3	-	1.3	0.4	-	0.4	4.1%
5	Wadi A'sir	5.1	-	0.03	-	5.1	2.9	-	3.1	-2.2	-	-2.0	9.8%
6	Wadi Khulaqah	1.6	-	0.01	-	1.6	0.7	-	0.7	-0.9	-	-0.9	11.9%
7	Wadi Qasabah	1.6	-	0.03	-	1.6	0.9	-	1	-0.7	-	-0.6	10.1%
8	Wadi al Huqqah	9.7	-	0.09	-	9.8	1.8	-	2.3	-8.0	-	-7.5	31.2%
9	Wadi bani Huwat	32.4	-	0.11	2.38	34.9	4.0	-	5.4	-30.9	-	-29.5	51.8%
10	Wadi Thumah	0.8	-	0.02	-	0.8	0.9	-	1	0.1	-	0.2	5.0%
11	Wadi as Sirr	16.5	-	0.26	-	16.8	3.1	-	3.8	-13.7	-	-13.0	31.0%
12	Wadi al Furs	5.7	-	0.07	-	5.8	0.5	-	0.5	-5.3	-	-5.3	67.9%
13	Wadi al Iqbal	13.1	-	0.19	-	13.3	3.6	-	4.4	-9.7	-	-8.9	21.5%
14	Wadi Zahr & al Ghayl	10.9	-	0.29	-	11.2	11.8	-	11.8	0.6	-	0.6	8.5%
15	Wadi Hamdan	6.8	-	0.06	-	6.9	1.1	-	1.4	-5.8	-	-5.5	36.3%
16	Wadi al Mawrid	5.8	75.6	0.08	2.74	84.2	2.7	-	3.1	-81.5	-	-81.1	175.5%
17	Wadi Sa'wan	6.7	-	0.14	-	6.8	1.3	-	1.5	-5.5	-	-5.3	31.2%
18	Wadi Shahik	6.9	-	0.20	-	7.1	4	-	4.4	-3.1	-	-2.7	10.2%
19	Wadi Ghayman	3.7	-	0.13	-	3.8	2.4	-	2.7	-1.4	-	-1.1	9.2%
20	Wadi al Mulaikhy	2.3	-	0.05	-	2.4	1.3	-	1.6	-1.1	-	-0.8	10.3%
21	Wadi Hizyaz	1.8	-	0.08	-	1.9	1.2	-	1.4	-0.7	-	-0.5	8.6%
22	Wadi Akhwar	1.6	-	0.12	-	1.7	1.9	-	2.1	0.2	-	0.4	5.0%
	Total Sana'a Basin	139.5	75.6	2.21	5.1	222.4	53.9	-	60.5	-168.5	-	-161.9	25.6%

3.7 ADVERSE IMPACT ON GROUNDWATER RESOURCES

3.7.1 PRESENT CONDITION OF ADVERSE IMPACT

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

(1) Groundwater Level

1) Recent Monitoring Result

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

Table 3.19 Monitoring Wells in the Sana'a Basin

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

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

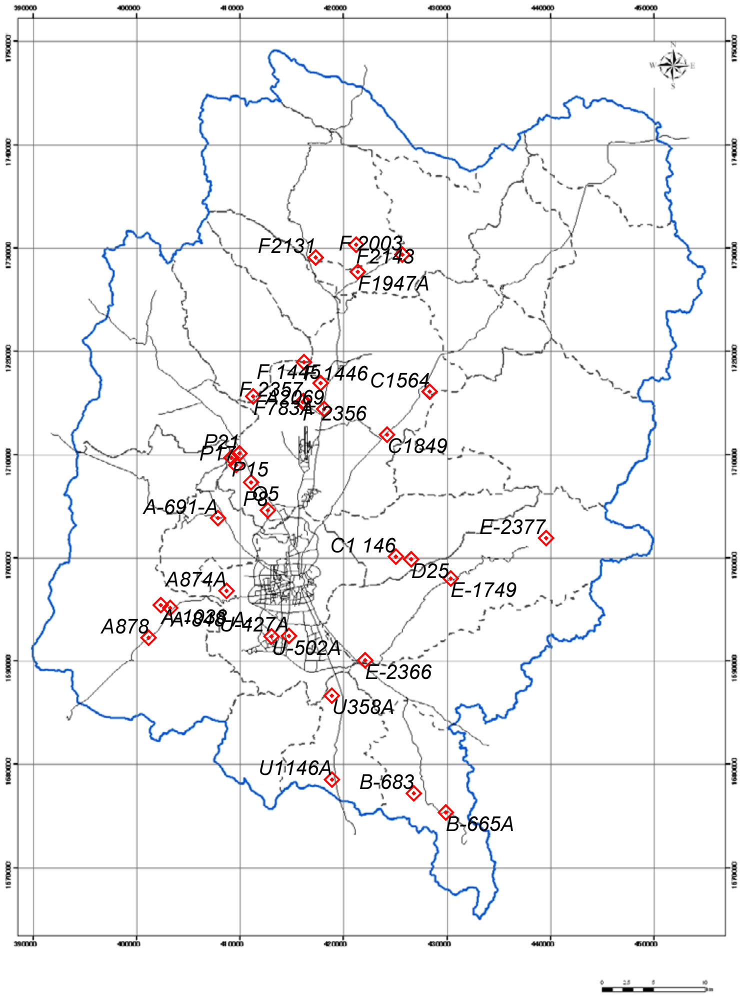


Figure 3.29 Locations of Water Level Monitoring Wells

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

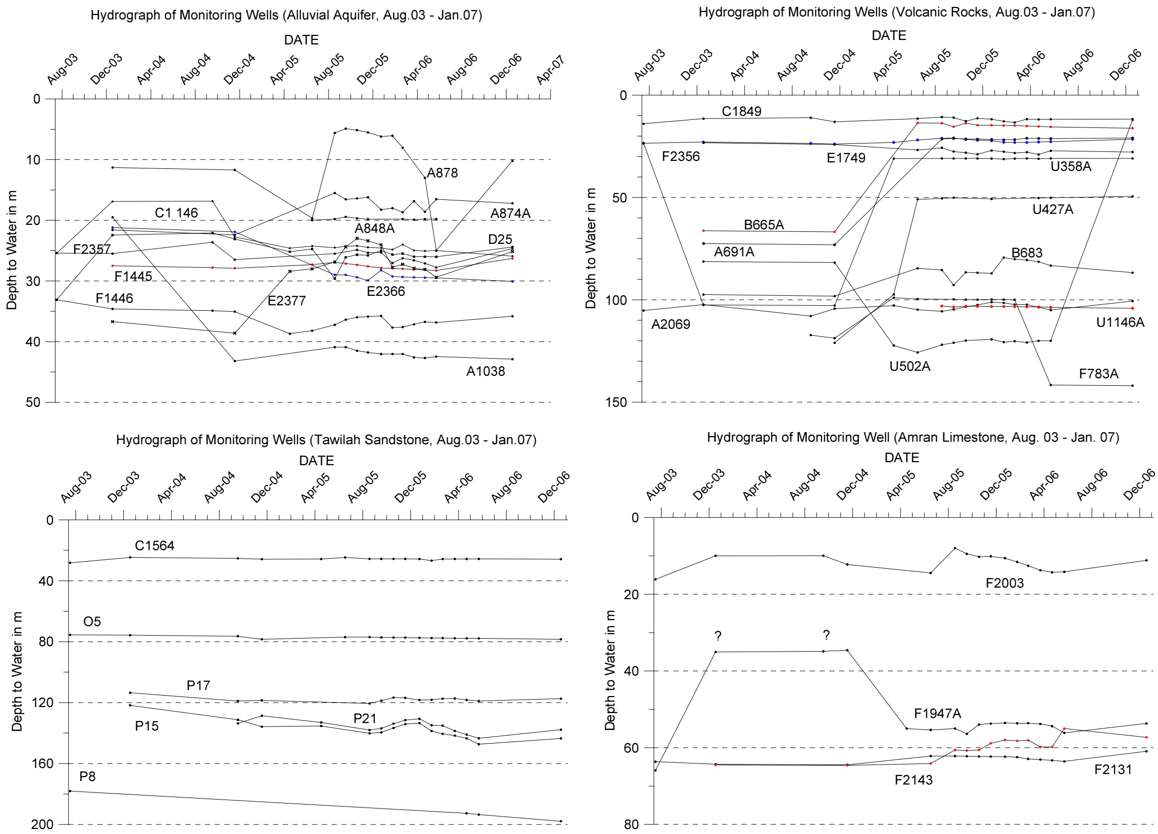


Figure 3.30 Hydrograph of Monitoring Well

2) Long-term Tendency of Water Level Change

<Water level of the western well field>

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

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

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

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

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

<Another observable fact about water level>

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

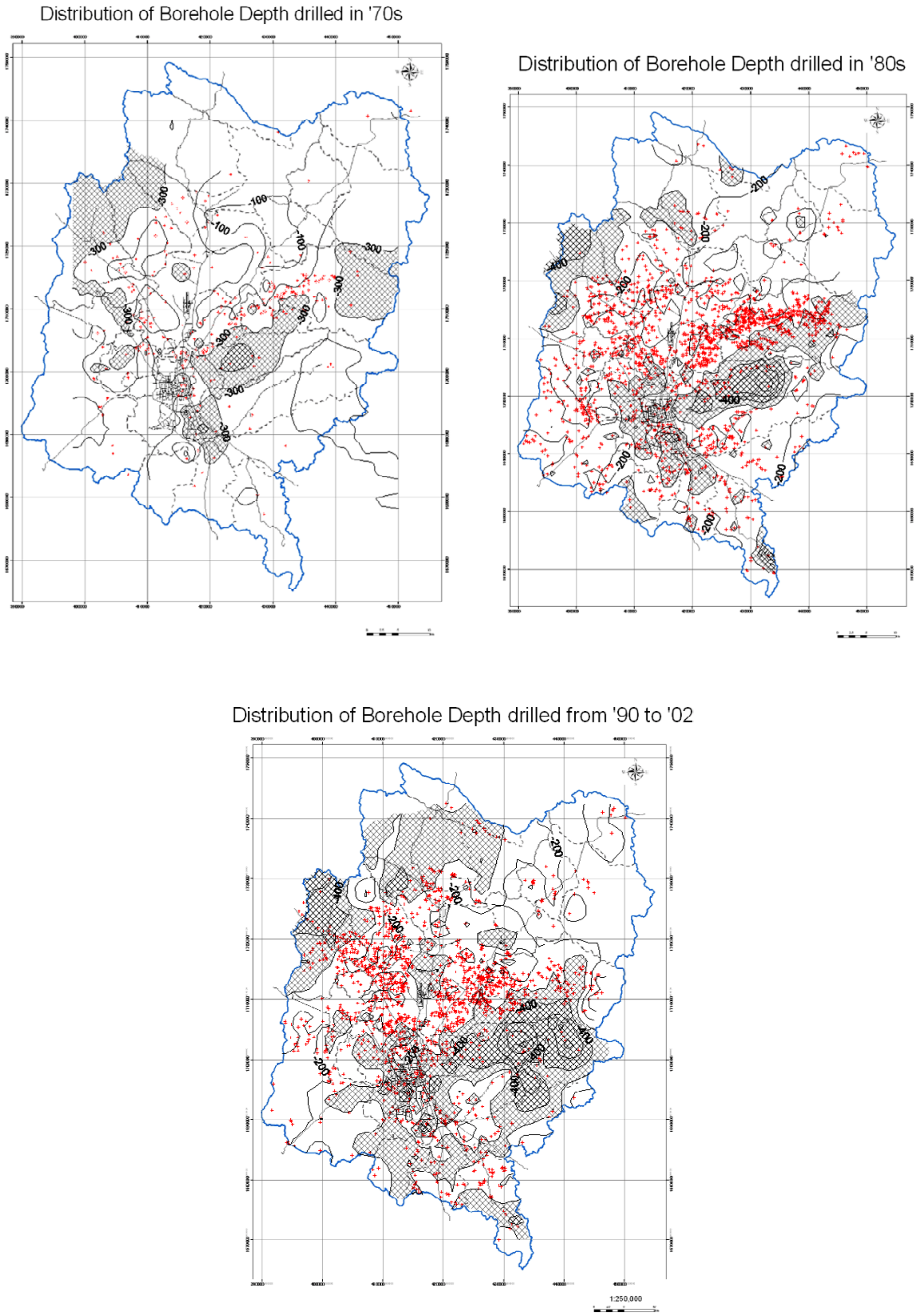
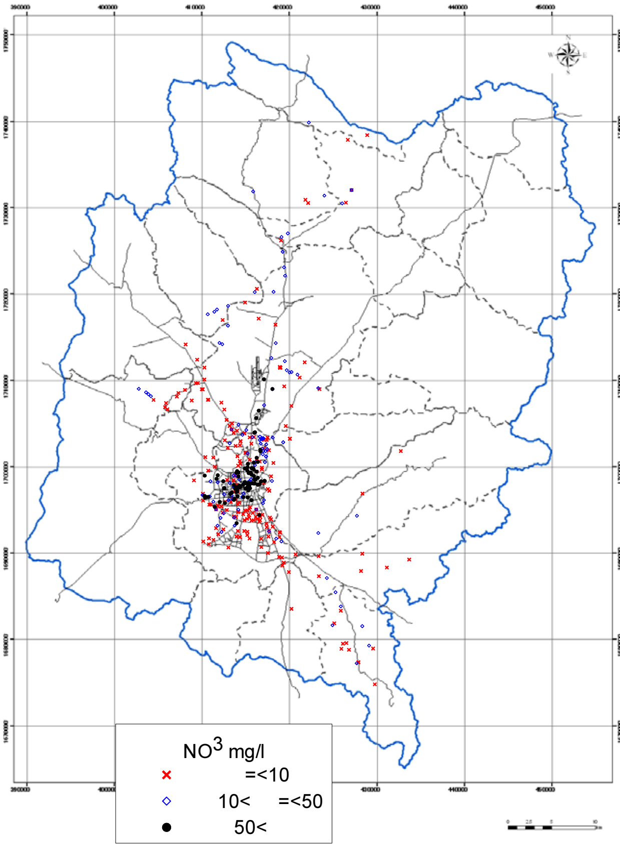


Figure 3.31 Depth of Boreholes drilled from 1970 to 2002

(2) Groundwater Quality

SAWAS Technical Report No.13 (1996) mentioned the possibility of groundwater contamination in the Sana'a Basin. Most possible contamination source is sewage disposal on land at present. *Figure 3.32* shows the distribution of nitrate concentration based on the data measured in 1996 by SAWAS. The highest desirable limit (HDL) of nitrate is 10 mg/l and the maximum permissible limit (MPL) is 50 mg/l in the national standard for drinking water.

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



Data Source; SAWAS (1996)

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

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

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

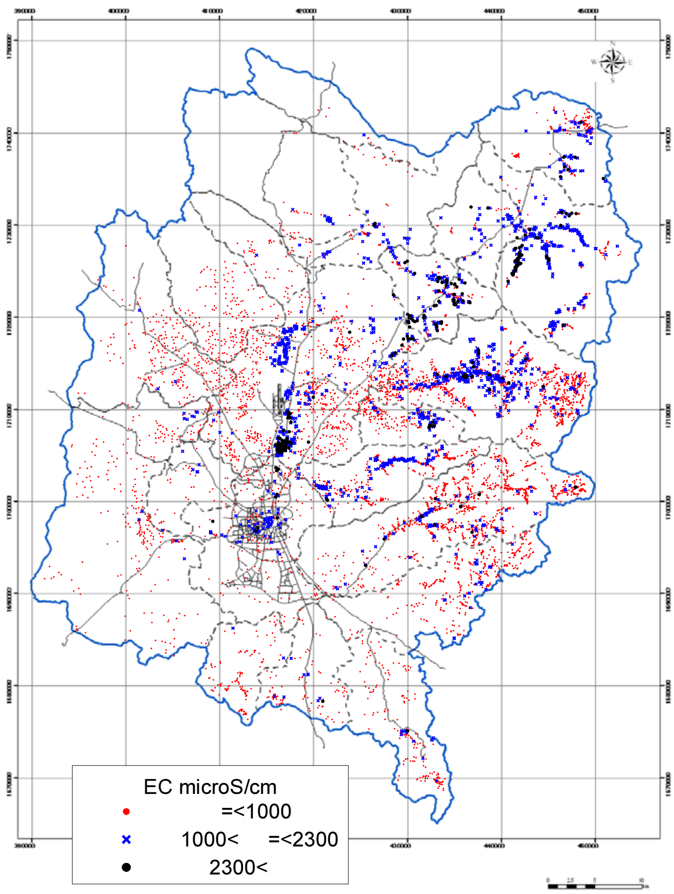


Figure 3.33 Distribution of EC in the Sana'a Basin (2001)

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

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

3.7.2 Possible Adverse Impact

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

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

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

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

3.8 Non-Conventional Water Sources

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

1. A large-scale storage dam in and out of Sana'a Basin

   Wadi Kharid Dam

   Wadi Surudud Dam

   Diversion of water from Marib Dam

2. Desalination of Red Sea Water
3. Groundwater Development outside of Sana'a Basin

   Development of Ramlat Sabatayn Area

   Development of Wadi al Masilah, Hadramawt

4. Other alternatives

   Deeper Pre-Jurassic Sandstone

   Subsurface Dam for Promoting Recharge

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

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

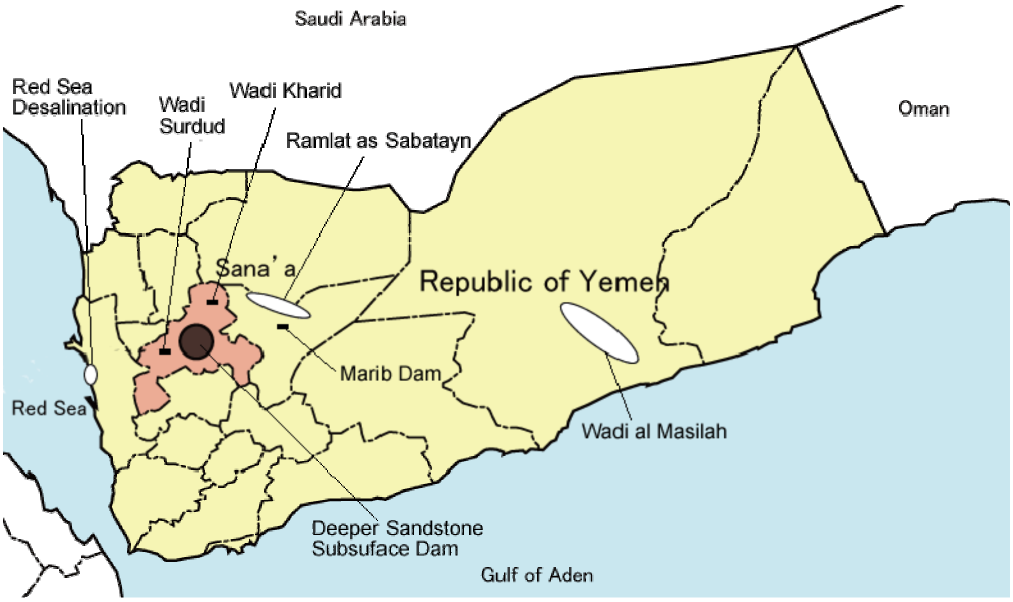


Figure 3.34 Locations of Alternative Water Sources

3.8.1 Storage Dams in and out of Sana'a Basin

(1) Wadi Kharid Dam

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

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

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

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

(2) Upper Wadi Surdud Dam

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

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

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

(3) Diversion Water from Marib Reservoir

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

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

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

3.8.2 Desalination of Red Sea Water

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

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

3.8.3 Groundwater Development outside of Sana'a Basin

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

(1) Ramlat as Sabatayn

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

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

The Quaternary aquifer also occurs in Wadi Adhana with the thickness of 50 to 70 m[24]. In the western fringe, it is underlain by the Amran Limestone. About 5 km of Old Marib and further east, it forms one aquifer complex with underlying Mukalla Sandstone. Transmissivity is expected high.

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

(2) Wadi Masilah in Hadramawt

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

3.8.4 OTHER ALTERNATIVES

(1) Development of Deeper Pre-Jurassic Sandstone

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

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

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

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

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

(2) Subsurface Dam for Promoting Recharge

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

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

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

3.8.5 CONSIDERATION OF THE ALTERNATIVE WATER SOURCES

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

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

Table 3.21 Alternative Water Source

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

Source; SAWAS Technical report No.14 and others

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

3.9 PROBLEMS AND RECOMMENDATION CONCERNING WATER RESOURCES

3.9.1 PROBLEMS TO BE SOLVED

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

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

continue with the same rate as before.

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

3.9.2 Recommendation

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

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

The following items are recommended.

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

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

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

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CHAPTER 4

PRESENT CONDITION OF SOCIO-ECONOMY

CHAPTER 4 PRESENT SOCIO-ECONOMIC CONDITIONS

4.1 GENERAL SOCIO-ECONOMIC CONDITIONS

4.1.1 DEMOGRAPHY

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

Table 4.1 Distribution of Population by Governorates

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

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

4.1.2 ADMINISTRATIVE SETTINGS AND SOCIAL STRUCTURE

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

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

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

4.2 WATER USAGE CONDITION SURVEY

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

4.2.1 OBJECTIVES OF THE SURVEY

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

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

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

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

4.2.2 APPROACHES AND METHODOLOGIES

(1) Utilization of Output of Preceding Researches

Under the Sana'a Basin Water Management Project funded by World Bank, quantitative and qualitative surveys have been conducted in the basin to analyze socio-economic characteristics of the area and to collect baseline related to water use and awareness of water resources management by the communities. For planning of the field survey in this study, outputs from these preceding researches were reviewed to consider the survey scope, target area, methodologies and procedures of the data analysis. Documents reviewed for this purpose are;

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

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

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

(2) Focused Areas of the Survey

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

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

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

(3) Methodologies and Tools Employed

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

Table 4.2 Scope of the Water Usage Condition Survey

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

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

(4) Sampling Method

1) Distribution of Samples

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

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

Table 4.3 Distribution of Samples by Sub-Basins

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

Table 4.4 Distribution of Samples by Districts

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

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

2) Selection of Samples

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

(5) Constraints

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

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

4.2.3 Water Usage Condition and Awareness Survey at the Village Level

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

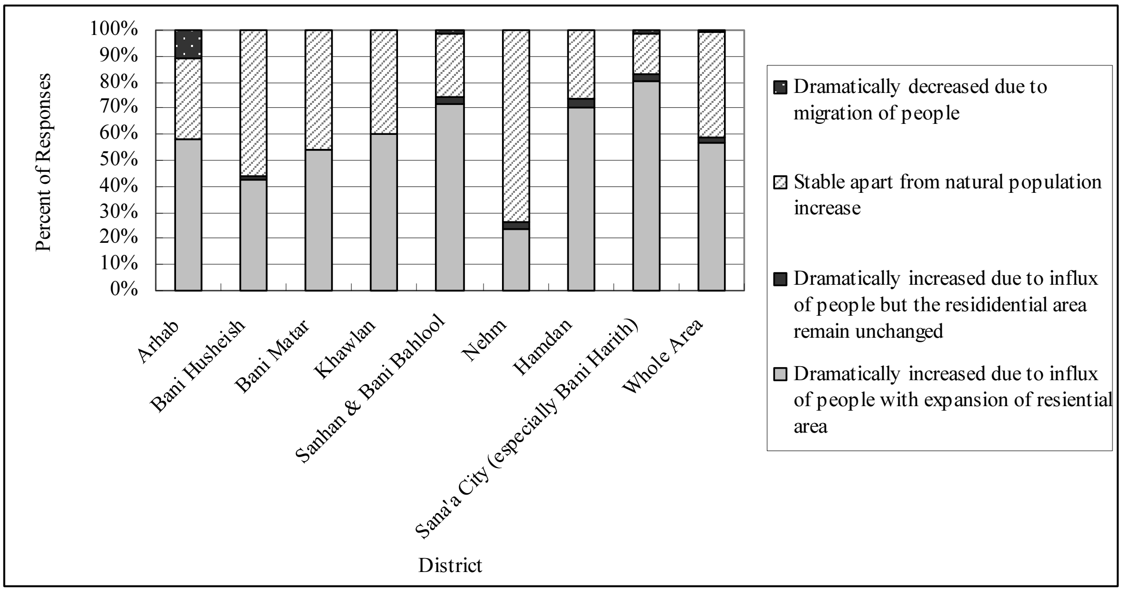
(1) Characteristics of the Respondents

The water usage survey at the village level was targeted to the community leaders in the villages or sub-villages where the sample wells are located. Distribution of respondents by their position in the village are Sheikh (32.3%), Aqil (42.5%), Amin (18.8%), Imam (2.3%), representative of WUA or WUG (4.3%). Age group of respondents is mostly in 30s and 40s with mean age at 45 years, 20 years at the youngest and 85 years at the oldest.

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

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

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



(400 valid answers)

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

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

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

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

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

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

(3) Land Use and Agricultural Activities

1) Land Use Pattern

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

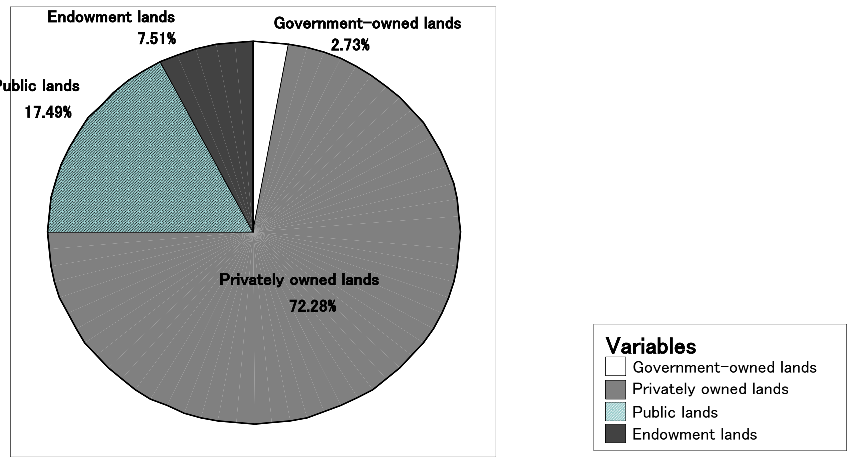


Figure 4.2 Distribution of Lands in the Surveyed Villages by Ownership

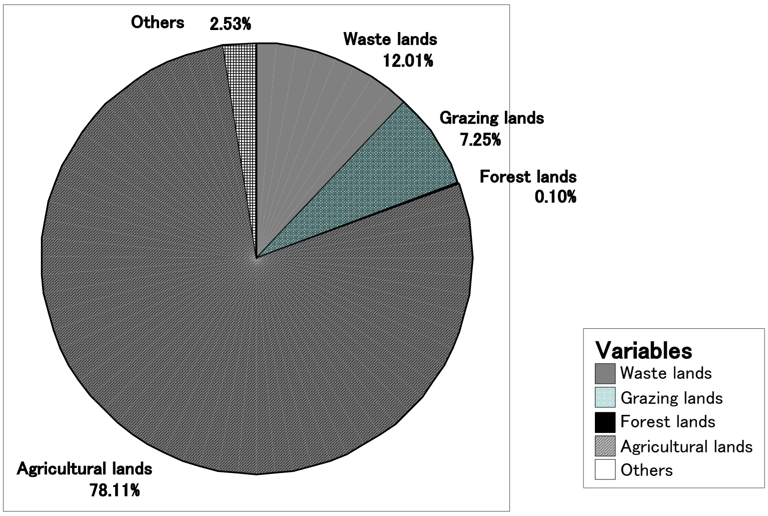


Figure 4.3 Distribution of Lands in the Surveyed Villages by Usages

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

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

2) Cropping Pattern

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

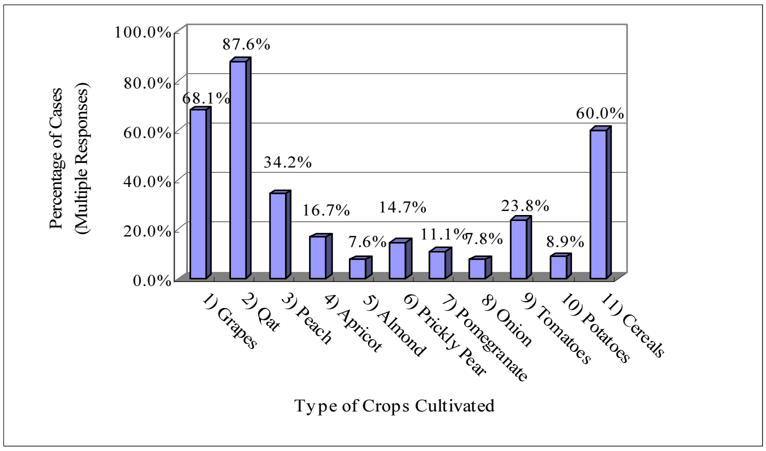
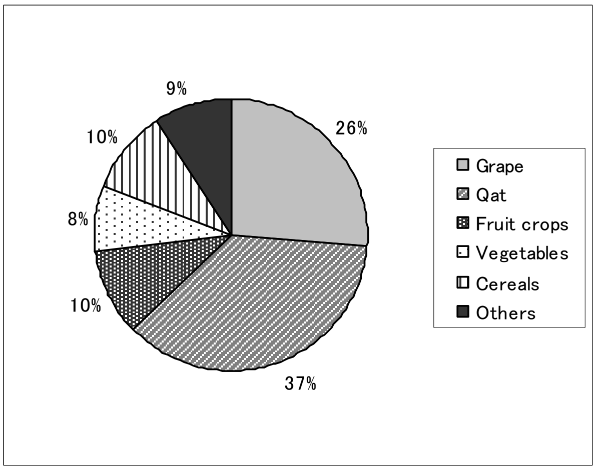
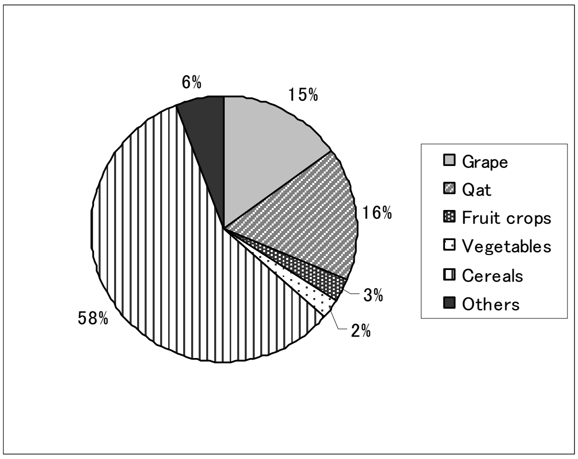


Figure 4.4 Type of Crops Cultivated in the Surveyed Villages



Irrigated Land



Unirrigated Land

Figure 4.5 Comparison of Cropping Patterns between Irrigated and Unirrigated Lands

(4) General Water Supply Conditions in the Village

1) Water Use for Domestic Purpose and Animal Watering

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

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

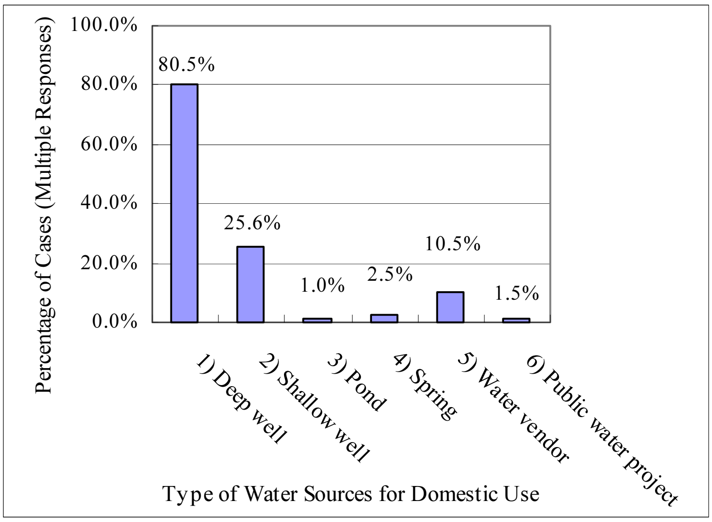


Figure 4.6 Type of Water Sources Available for Domestic Use

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

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

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

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

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

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

Table 4.5 Distribution of Water Harvesting Facilities

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

(5) Water Use for Irrigation

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

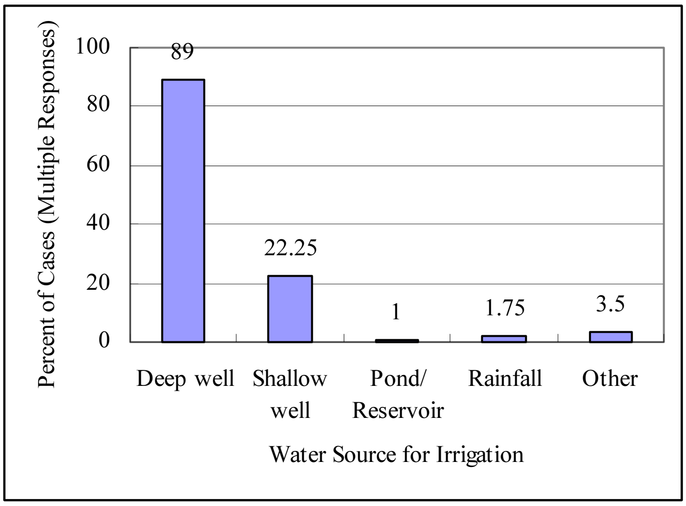


Figure 4.7 Type of Water Sources for Irrigation

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

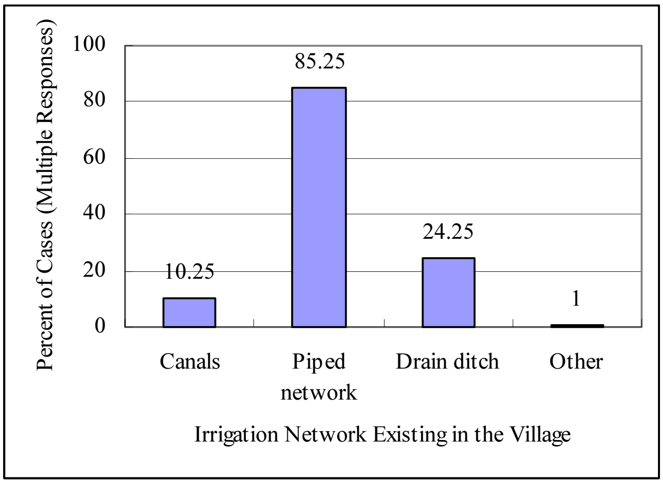
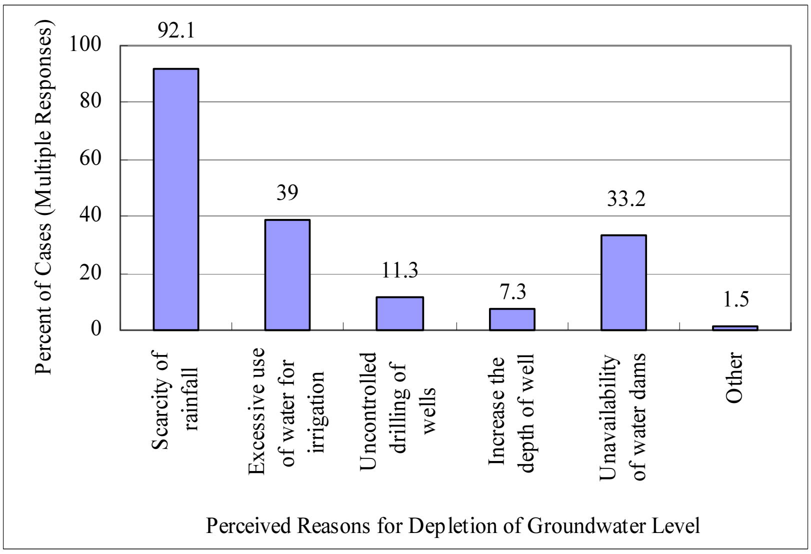


Figure 4.8 Type of Irrigation Network in Use

(6) Perceived Changes in Availability of Groundwater

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

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



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

Figure 4.9 Perceived Reasons for Depletion of Groundwater Level

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

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

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

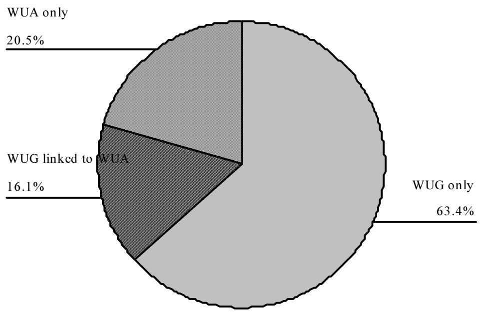
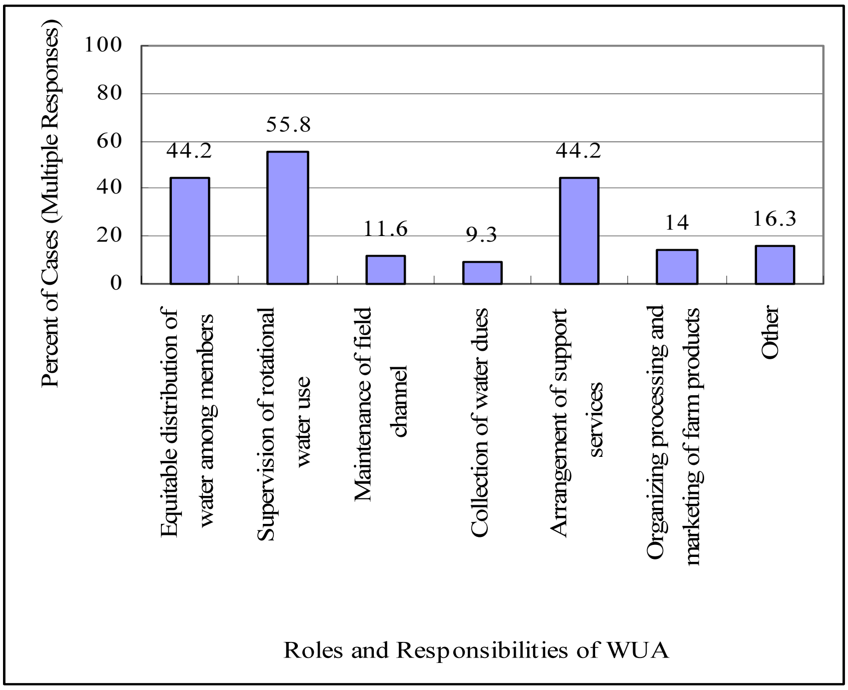


Figure 4.10 Type of Existing Community-Based Organizations for Irrigation Management

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

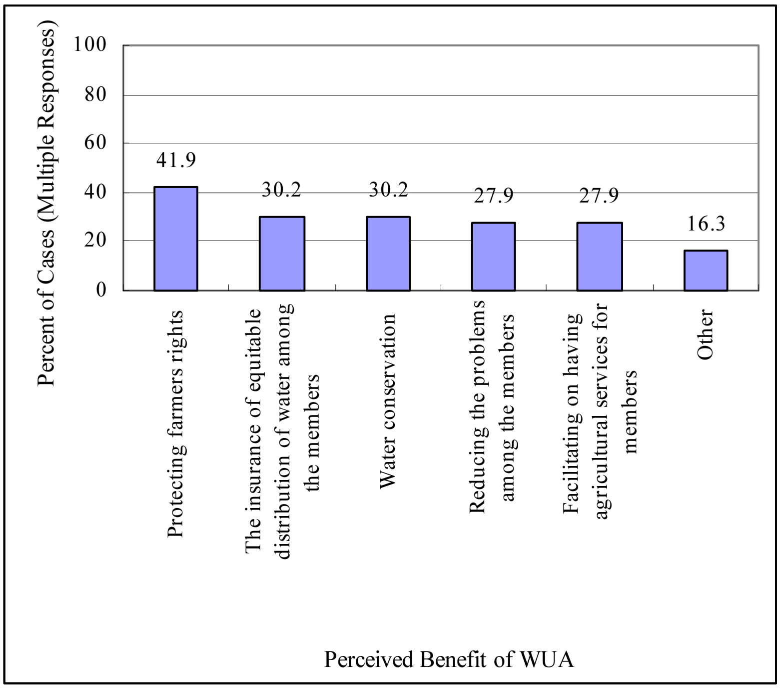
75% of the WUA existing in the surveyed villages collects membership fee of 1,000 Rial (median) and 60% also charge monthly subscription of 100 Rial (median) to the members.

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



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

Figure 4.11 Responsibilities of WUA

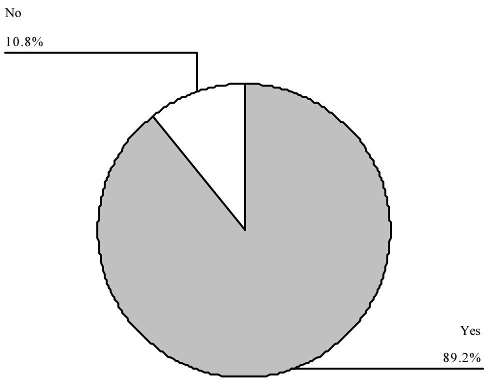


(“Others” includes raising awareness among consumers about saving water, following up the concerned project authorities to install the modern irrigation networks.)

Figure 4.12 Perceived Benefit of WUA

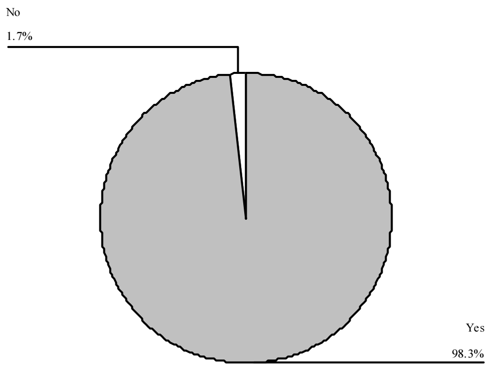
(8) Perception on Participatory Irrigation Management through WUA/WUG

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



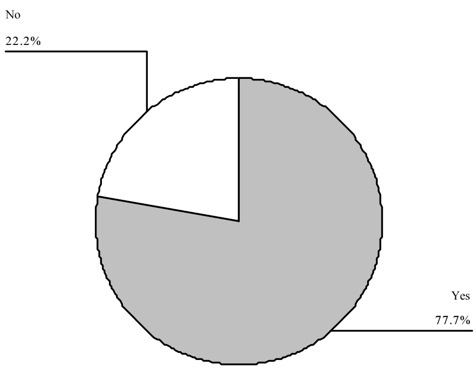
(400 valid cases)

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



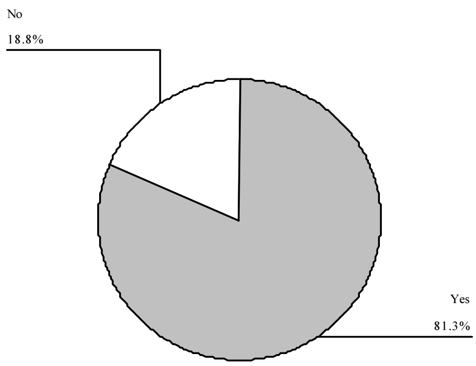
(357 valid cases. 43 cases excluded as not applicable)

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



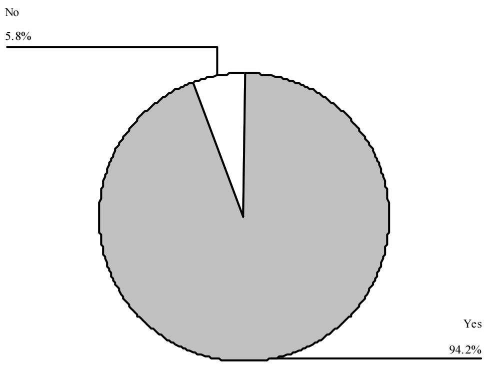
(400 valid cases)

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



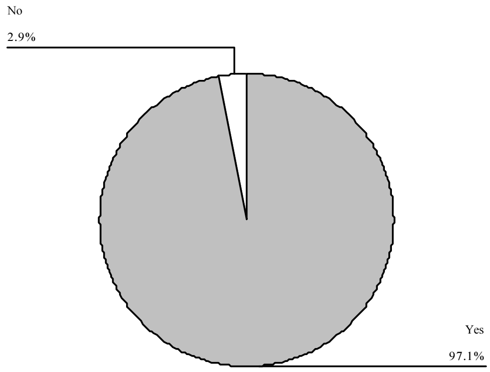
(400 valid cases)

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



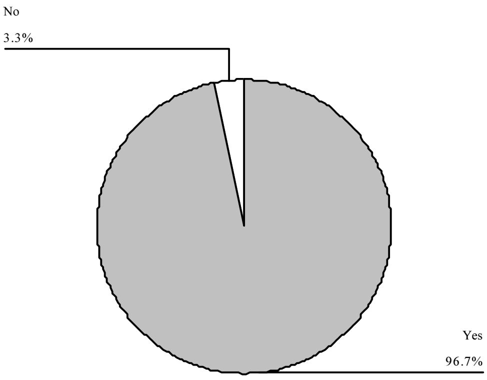
(325 valid cases. 75 cases excluded as not applicable)

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



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

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



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

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

Figure 4.13 Perception on Participatory Irrigation Management through WUA/WUG

(9) Perception on Water Resources Management and Conservation

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

1) Register and Monitoring of Wells

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

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

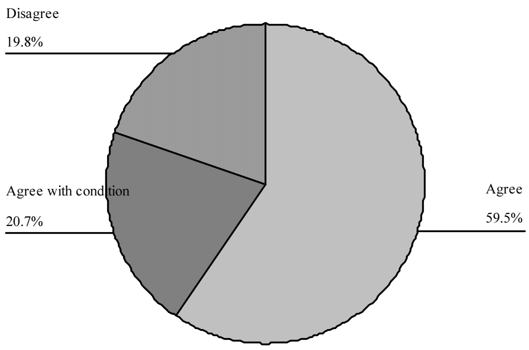
65% of those who agree with or without conditions on installation of water meters express their approval on monitoring of the water consumption at the wells regularly.

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

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

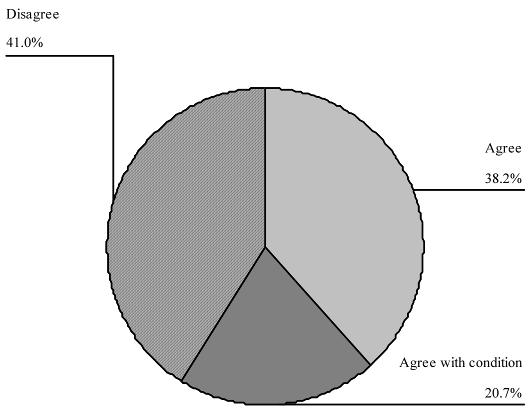
Regarding the prohibition of drilling of new wells in future, nearly half of the respondents are with the idea since they are afraid of further depletion of groundwater or dry up of the existing wells. Another half of the respondents oppose the measure with considering situations such as insufficient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

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



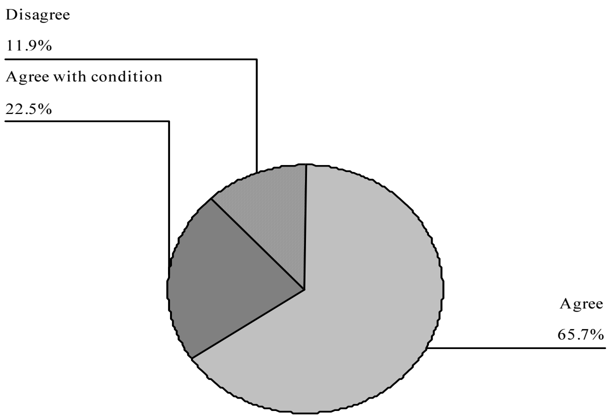
(400 valid cases)

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



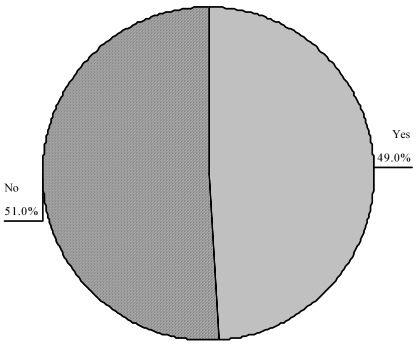
(400 valid cases)

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



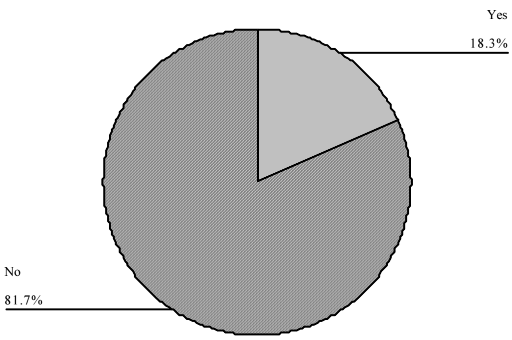
(236 valid cases. 164 cases excluded as not applicable.)

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



(400 valid cases)

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



(400 valid cases)

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

Figure 4.14 Perception on Water Resources Management and Conservation

3) Introduction of Water Saving Technology

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

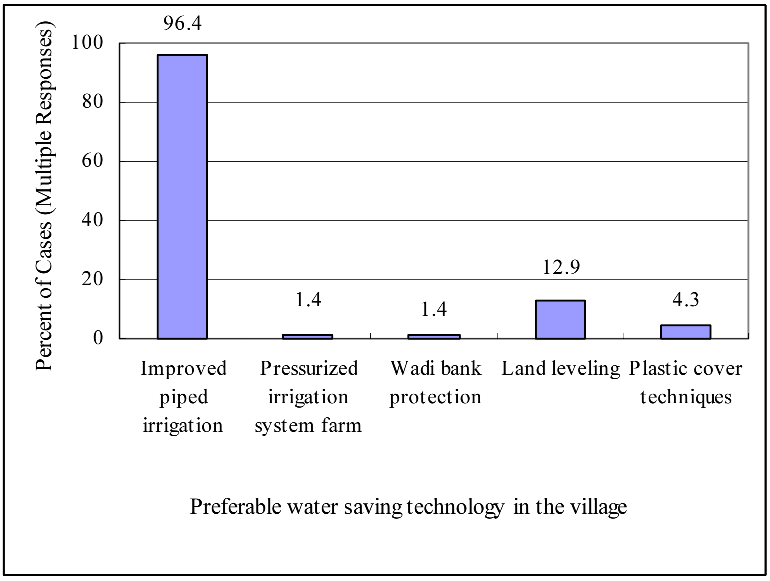


Figure 4.15 Water Saving Technology for Irrigation Preferred by the Surveyed Villages

(10) Awareness of Water Rights and Water Law

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

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

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

4.2.4 SITUATION OF FARMING

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

(1) Characteristics of the Respondents

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

(2) Holding of Farms and Cropping Pattern

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

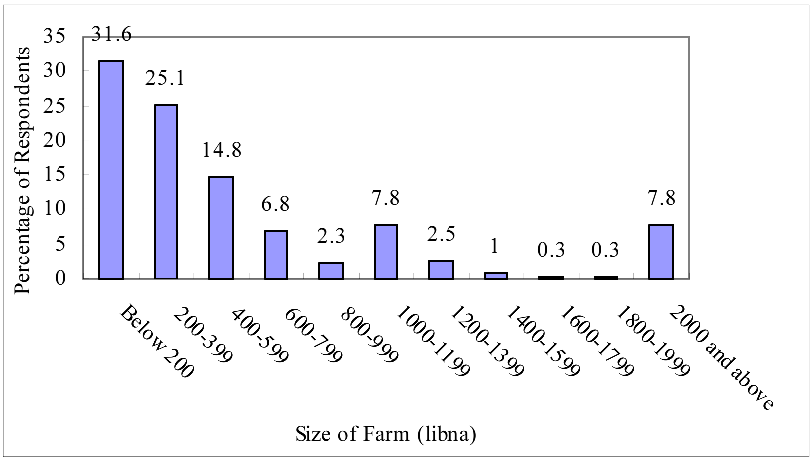


Figure 4.16 Distribution of Respondents by Total Area of Farm

Table 4.6 Distribution of Respondents by Farm Size

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

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

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

Table 4.7 Trend of Change in the Farm Size

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

a Multiple modes exist. The smallest value is shown

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

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

Table 4.8 Cropping Patterns in the Farms Held by the Respondents

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

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

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

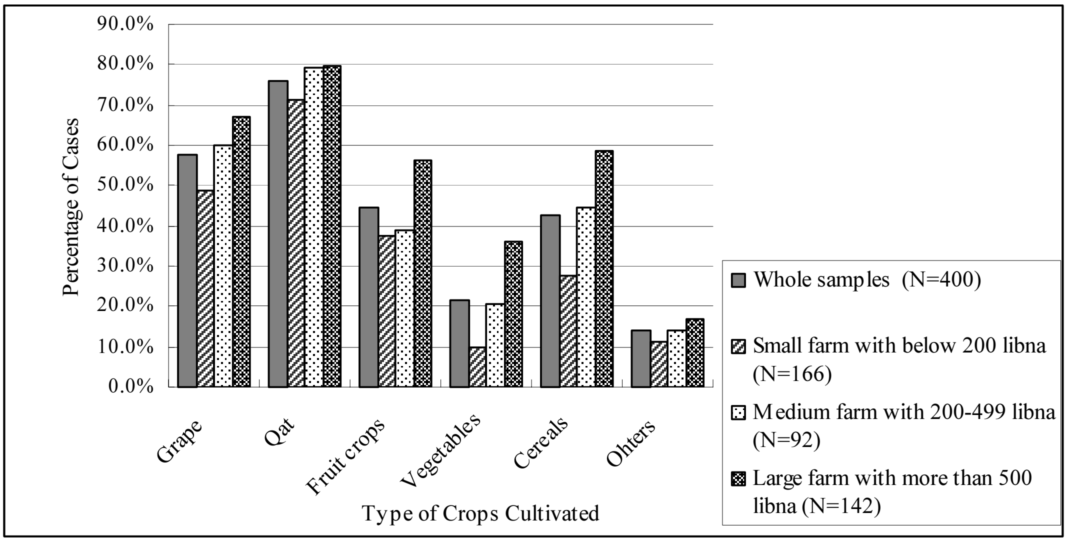


Figure 4.17 Type of Crops Cultivated in the Farms

(3) Irrigation System

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

Table 4.9 Type of Water Sources for Irrigation

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

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

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

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

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

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

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

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

(1) Basic Well Parameters in Rural Area

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

Table 4.11 Well Parameters

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

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

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

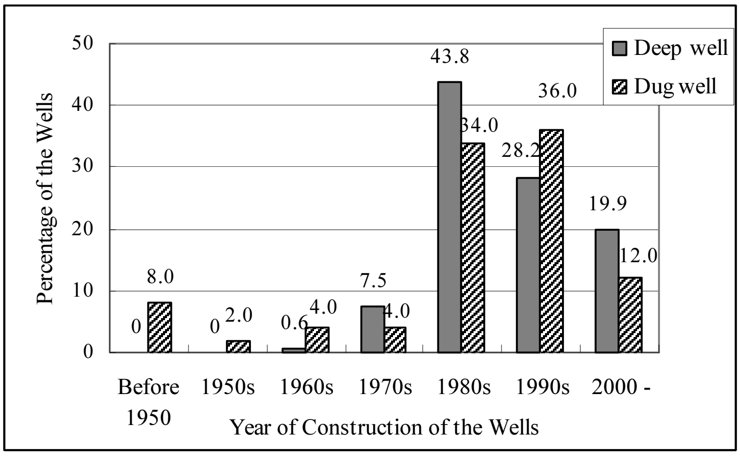


Figure 4.18 Distribution of Wells by Construction Year

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

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

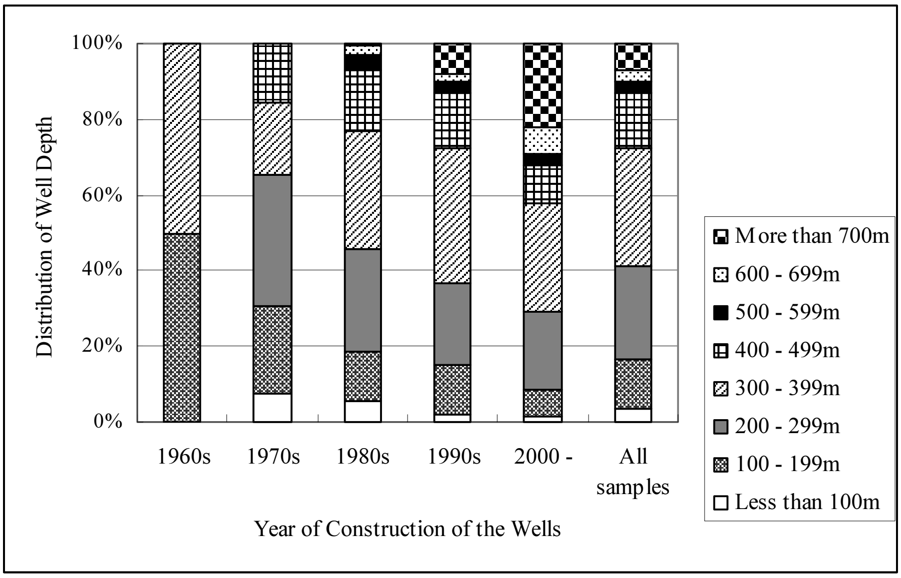


Figure 4.19 Depth of Sampled Deep Wells by Year of Construction

(2) Ownership of the Wells

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

(3) Water Use for Irrigation

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

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

Table 4.13 Water Abstraction Rate of the Sample Wells

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

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

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

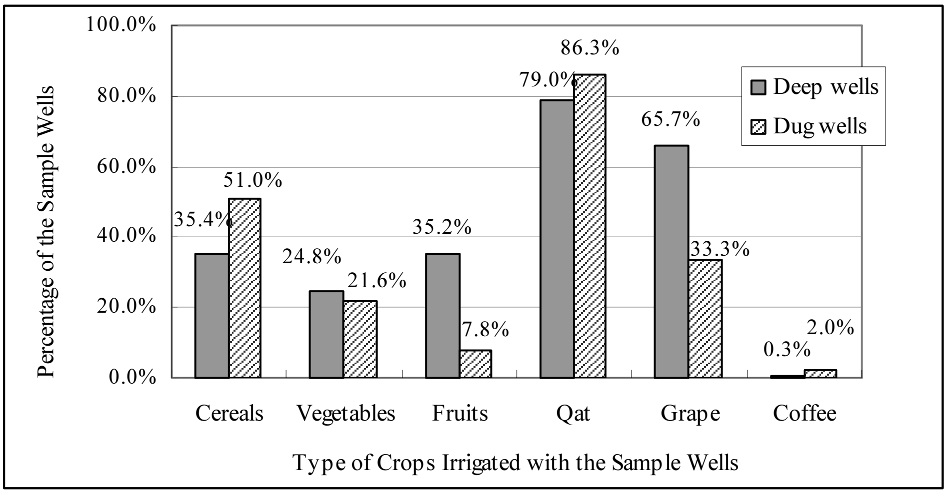


Figure 4.20 Cropping Patterns for the Sample Wells

(4) Water Use for Other Purposes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References;

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

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

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

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

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

CHAPTER 5

PRESENT CONDITION OF WATER USE

CHAPTER 5 PRESENT CONDITION OF WATER USE

5.1 GENERAL

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

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

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

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

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

Unit: number

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

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

Unit: number

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

5.3 DOMESTIC WATER USE

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

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

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

Table 5.3 Abstraction of Domestic Water for each Sub-Basin

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

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

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

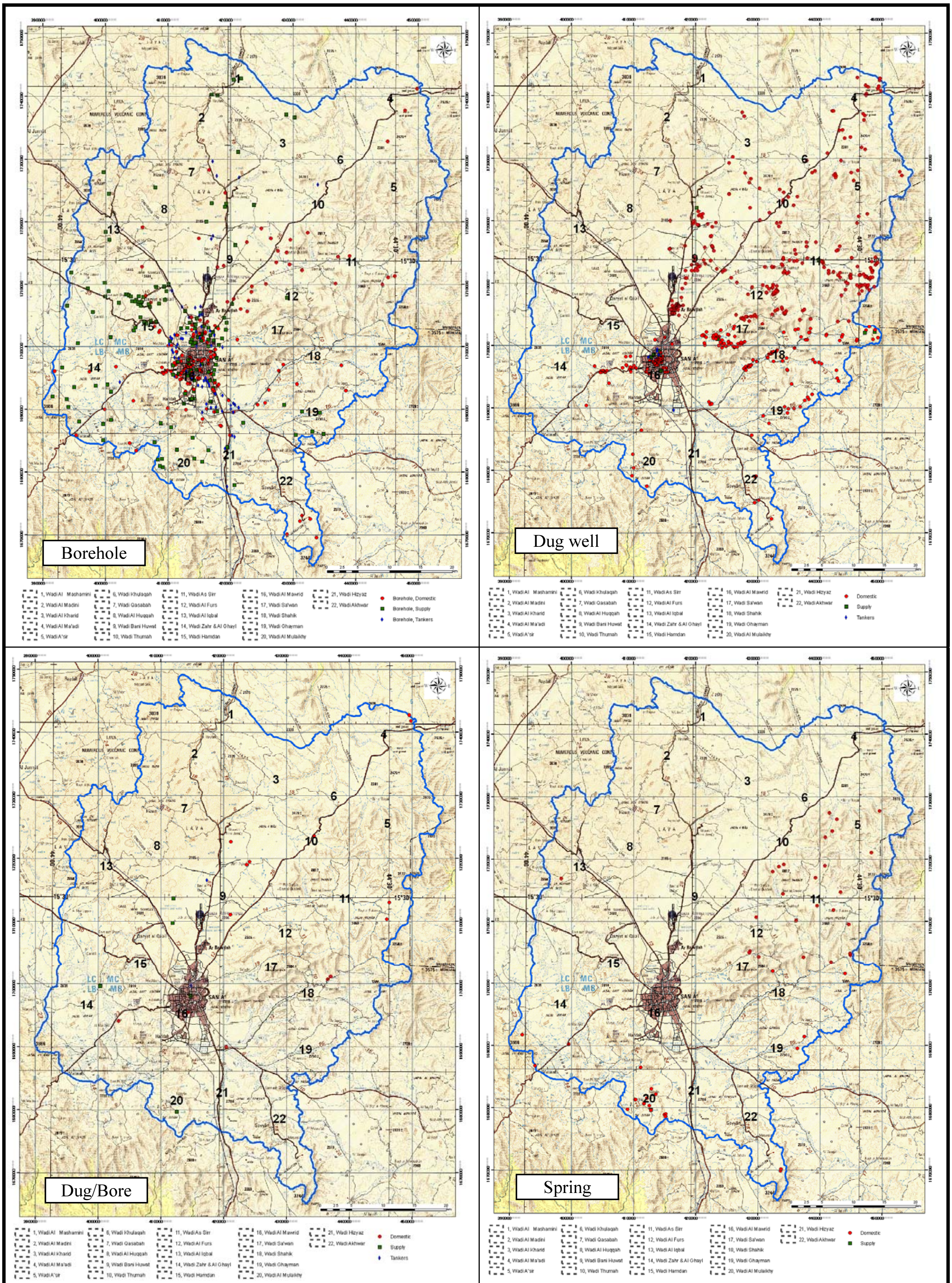


FIGURE 5.1 DISTRIBUTION MAP OF WATER POINTS FOR DOMESTIC USE BY TYPE

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

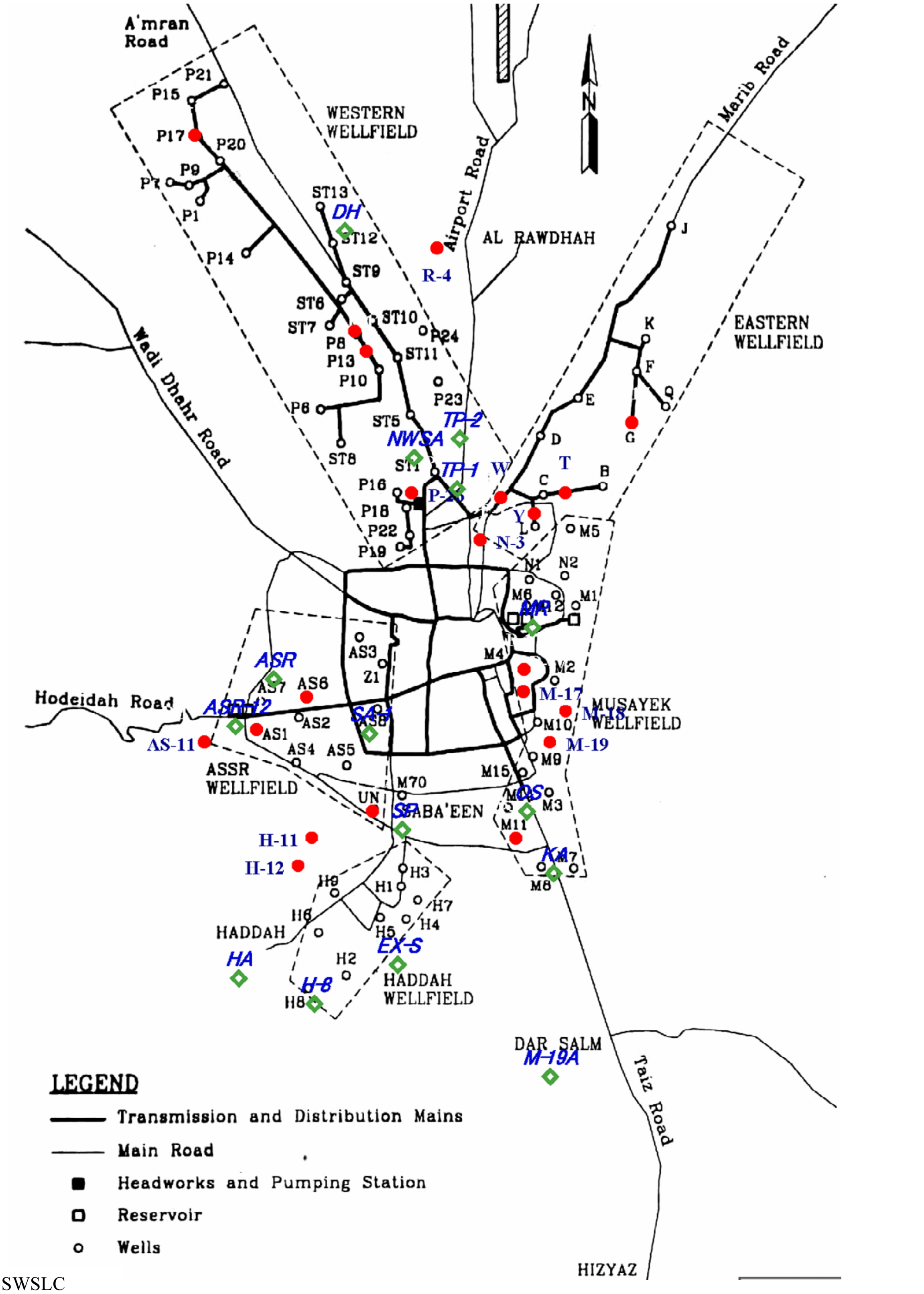
The main source of the public water supply for Sana'a City is groundwater abstracted from three main well fields called Eastern Well Field, Western Well Filed and Sana'a Well Field. Sana'a Well Field is divided into three sub-fields. Musayek Well Field, Asser Well Field and Haddah Well Field. Eastern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

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Meterd Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Non-metered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water</td></tr>
<tr><td>Unbilled Non-metered Consumptiom</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakege on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakege and Overflow at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Customers' Meters</td></tr>
</table>

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

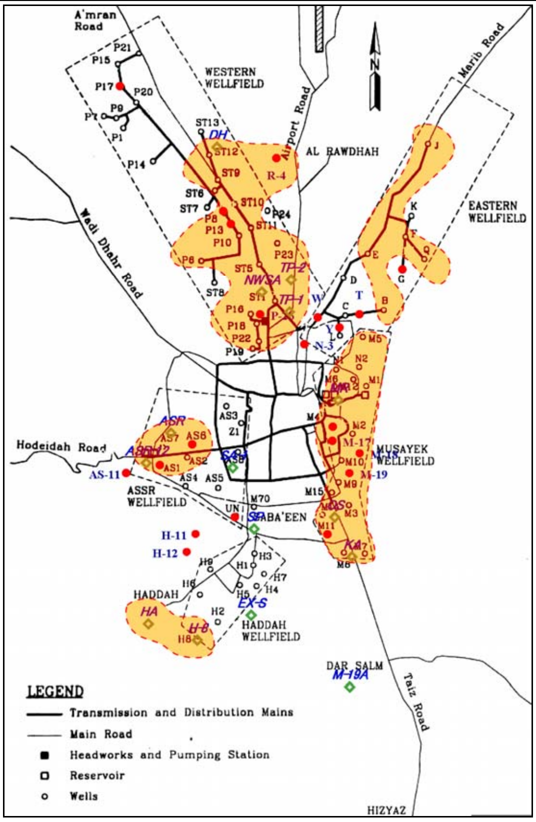
Well No	Date	Poor Quality Items
H2	06/Dec/1993	
	18/Jun/1994	pH=8.73
	24/Jan/1995	pH=8.80
	16/Apr/1996	pH=8.81
	20/Mar/1999	pH=8.68
H3	06/Dec/1993	pH=8.51
	18/Jun/1994	pH=8.70
	24/Jan/1995	pH=8.58
	16/Apr/1996	
	21/Mar/1999	
	13/Jun/1999	
	24/Jan/2001	pH=8.64
	03/Sep/2005	
H4	06/Dec/1993	pH=9.35
	18/Jun/1994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

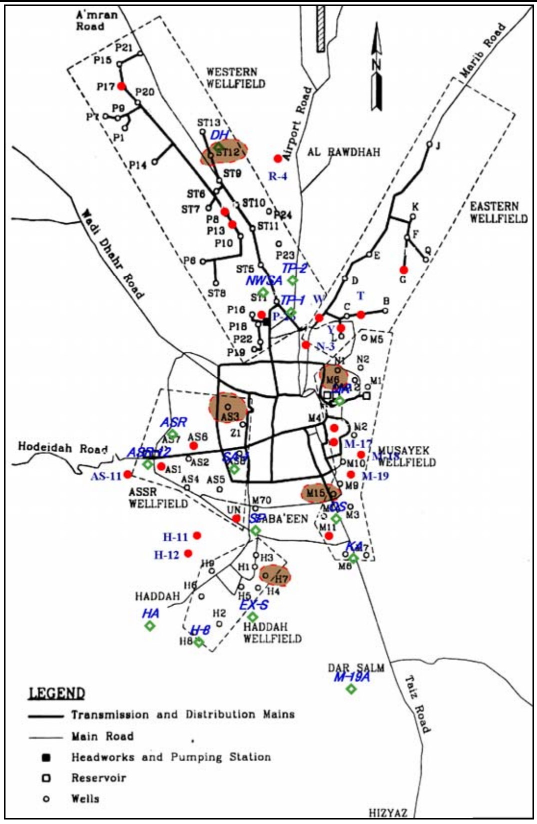
Results of water quality analyses are summarized as follows:

- 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.
- <u>Western Well Field</u>: 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.
- <u>Eastern Well Field</u>: 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.
- <u>Musayek Well Field</u>: 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
- <u>Asser Well Field</u>: 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.
- <u>Haddah Well Field</u>: 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



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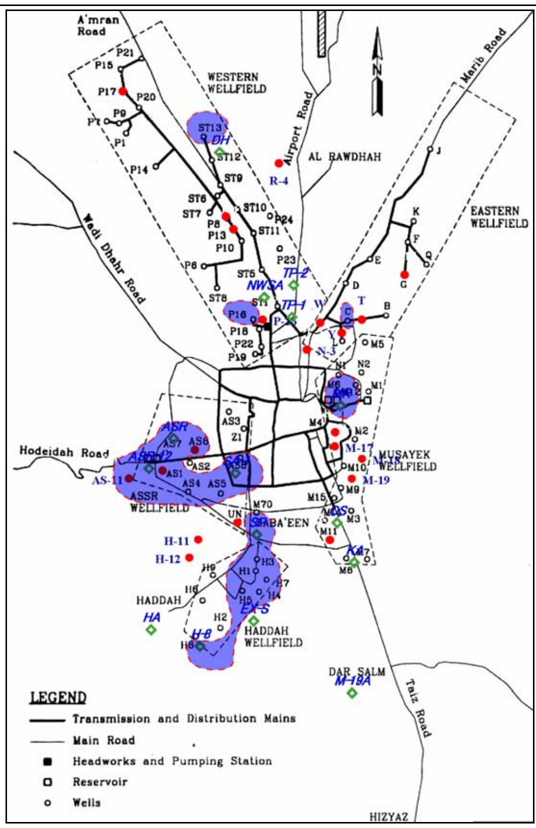
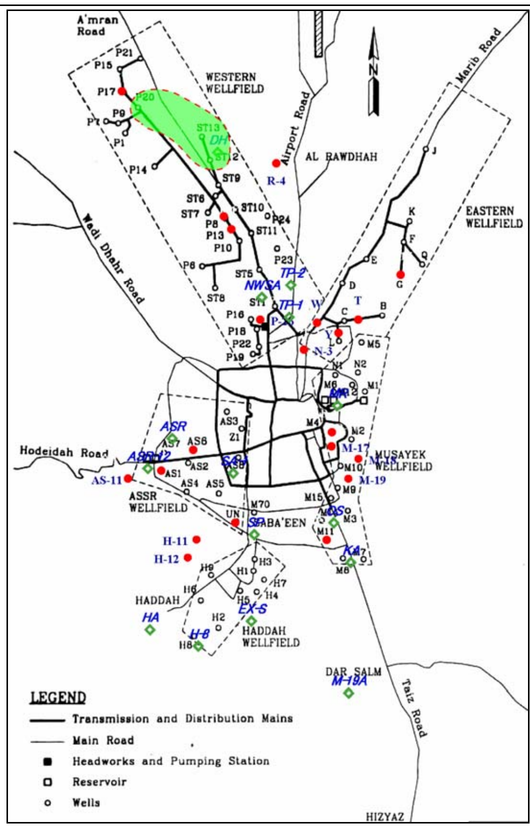


Parameter: pH



Parameter: TDS

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

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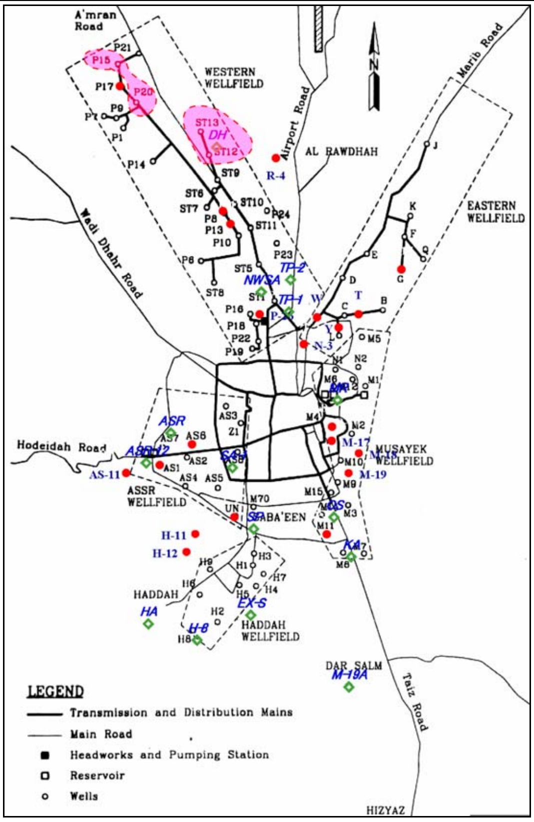
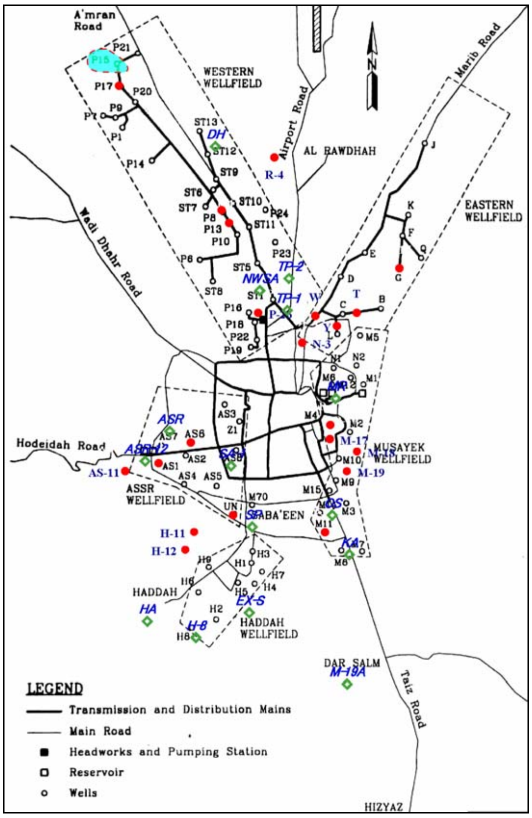
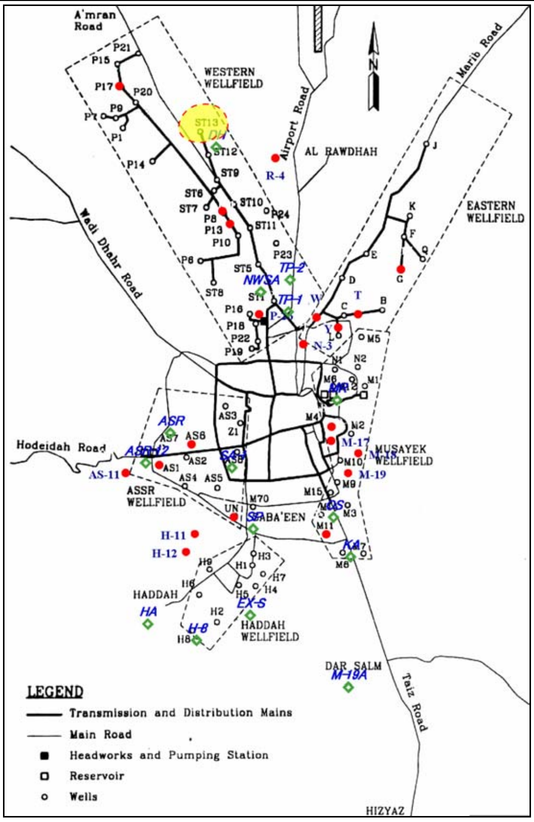


Parameter: SO4



Parameter: Ca



Parameter: Na

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

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.

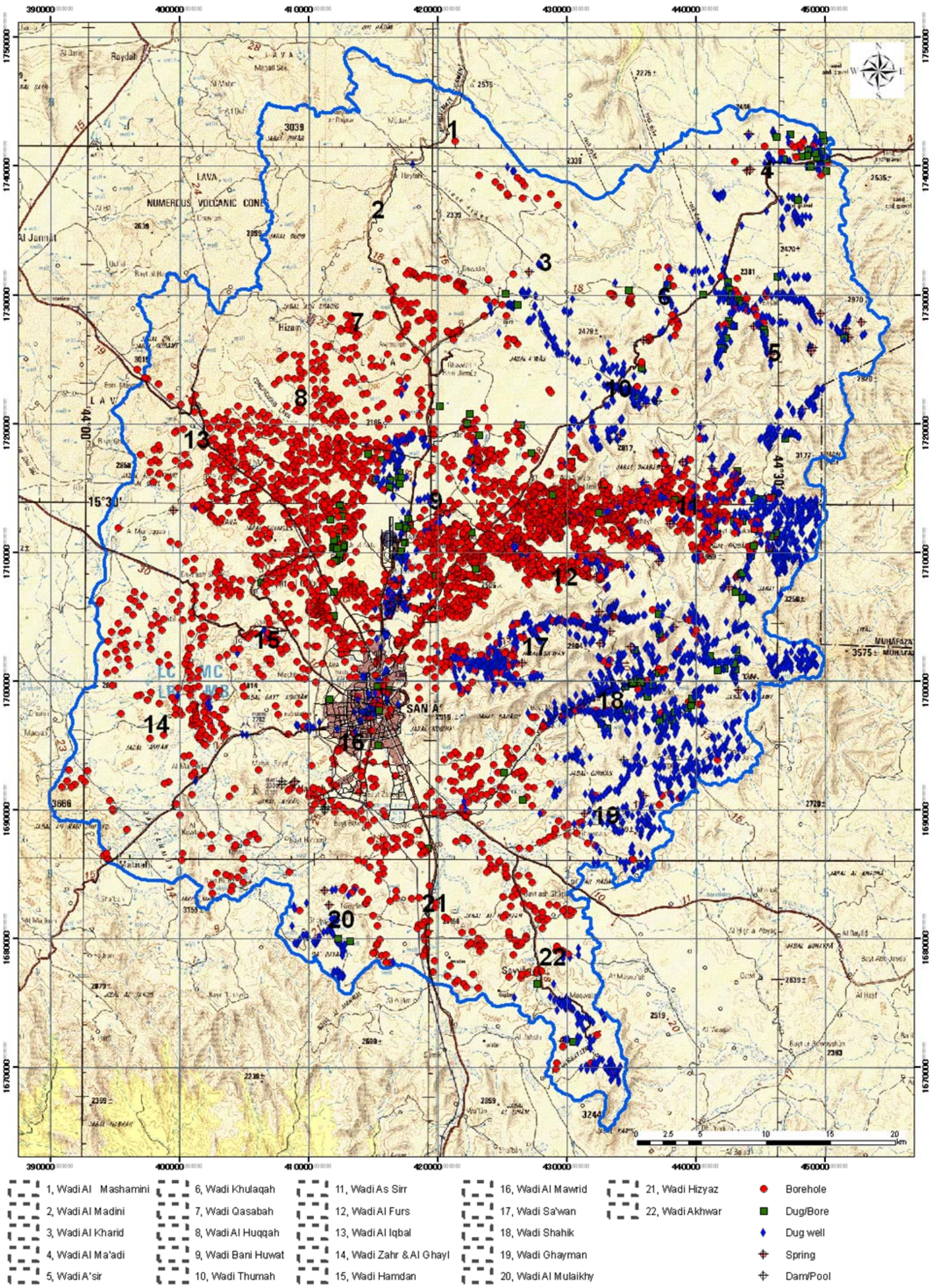


FIGURE 5.5 DISTRIBUTION MAP OF WATER POINTS FOR IRRIGATION USE BY TYPE OF WELL

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

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)

Period \ Growth rate	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)

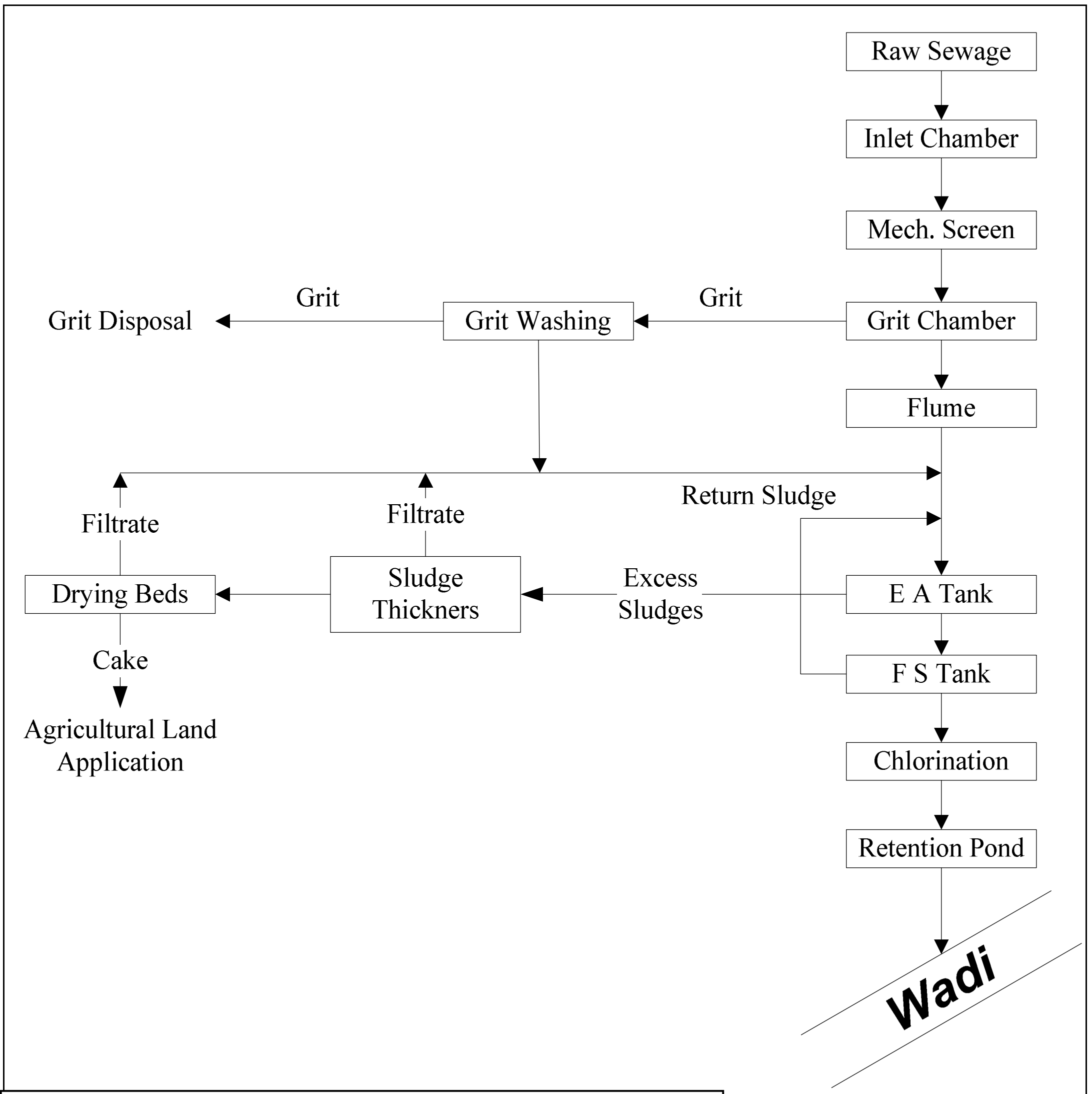
WWTP has been built in the middle of Capital city, in a sensitive area adjacent to the International Airport and was completed in mid 2000. It is presently operated by SWSLC and the effluent is treated by chlorination before it is discharged into a wadi via a lagoon and there are no facilities available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

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(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.

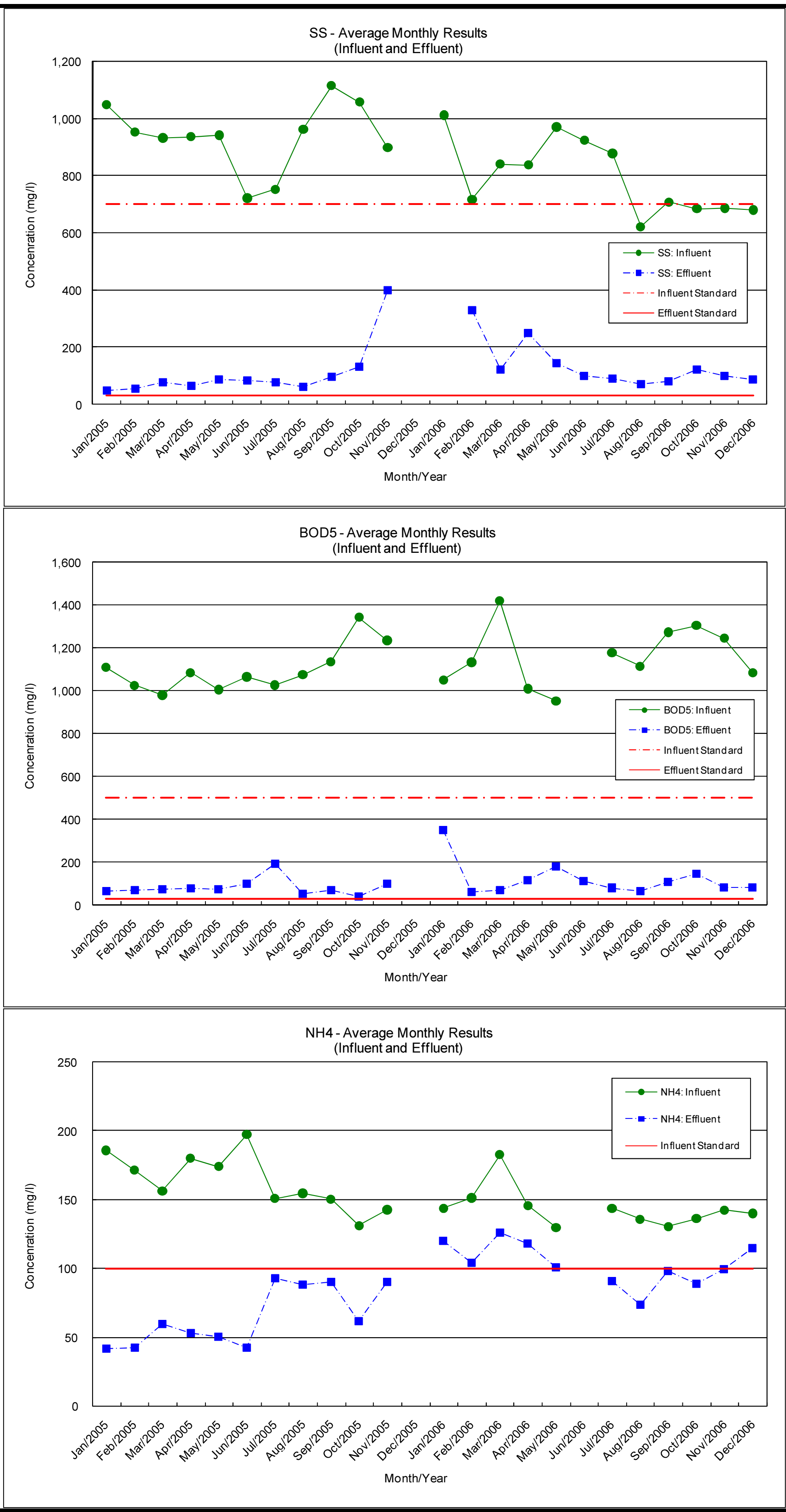

FIGURE 5.7 MONTHLY AVERAGE RESULTS OF INFLUENT AND EFFLUENT FOR SS, BOD5 AND NH4

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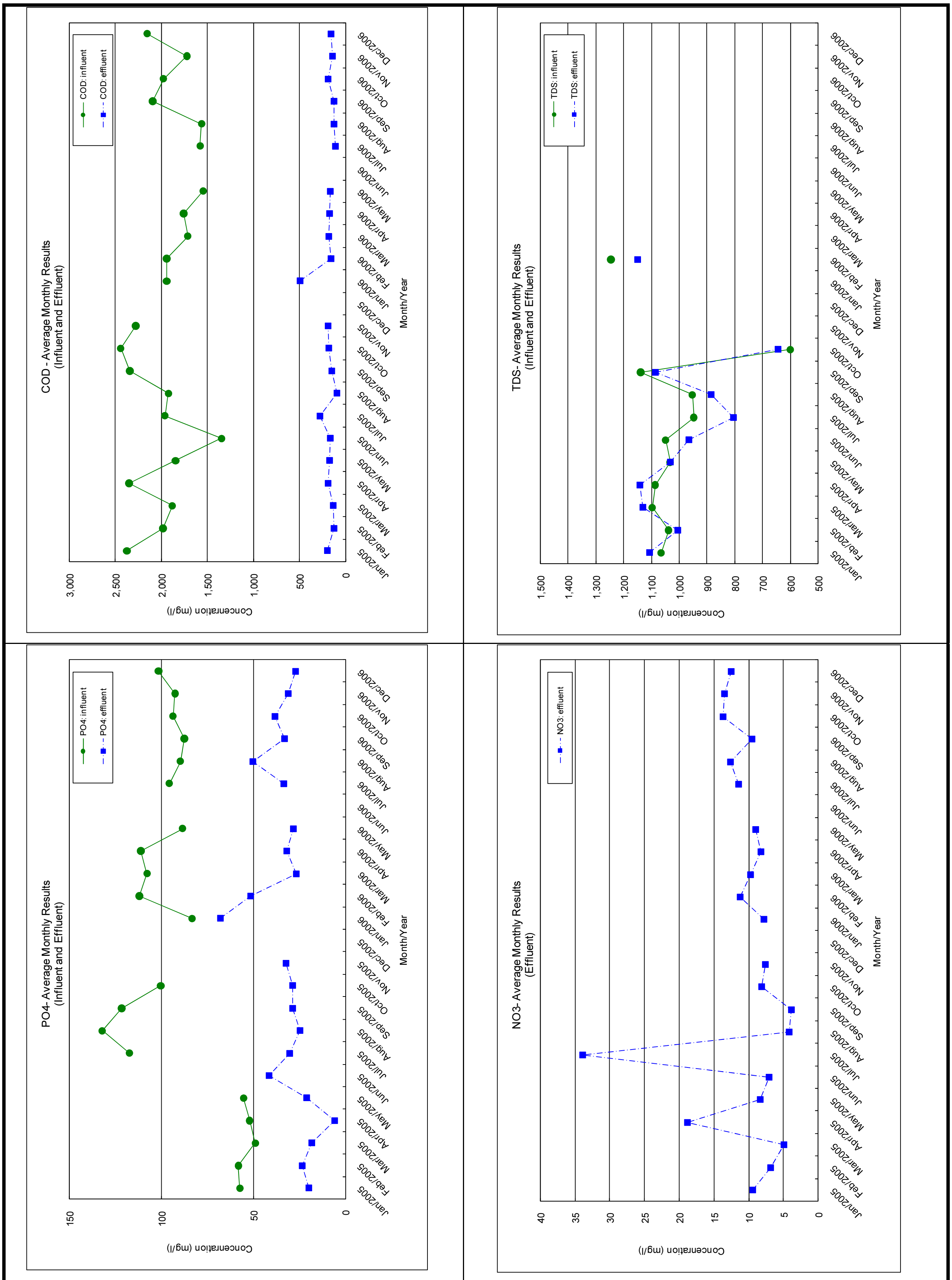

FIGURE 5.8 MONTHLY AVERAGE RESULTS OF INFLUENT AND EFFLUENT FOR PO4, COD, TDS, NO3

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.

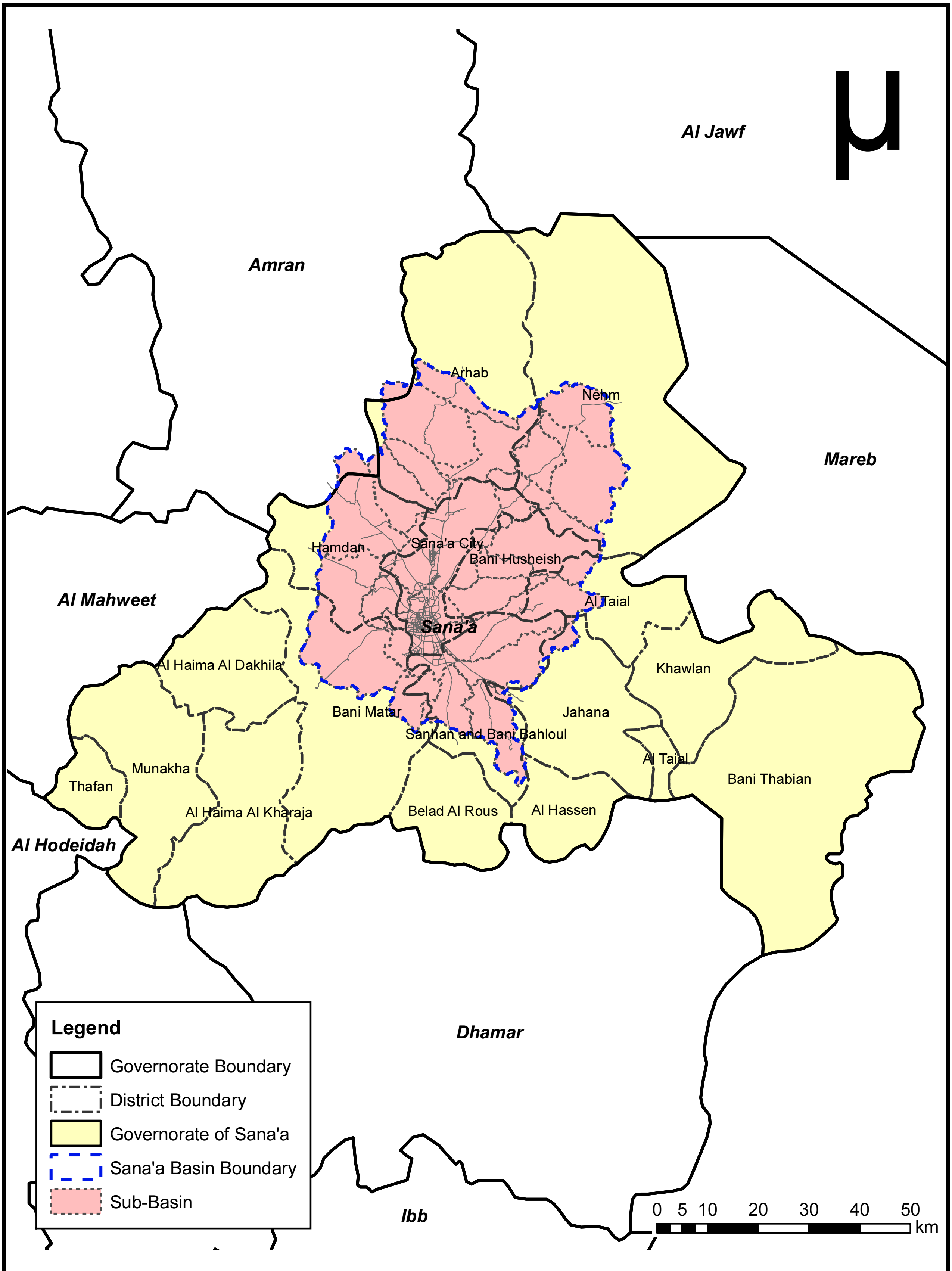

FIGURE 5.9 LOCATION OF SANA'A BASIN WITHIN THE GOVERNORATE OF SANA'A

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(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)

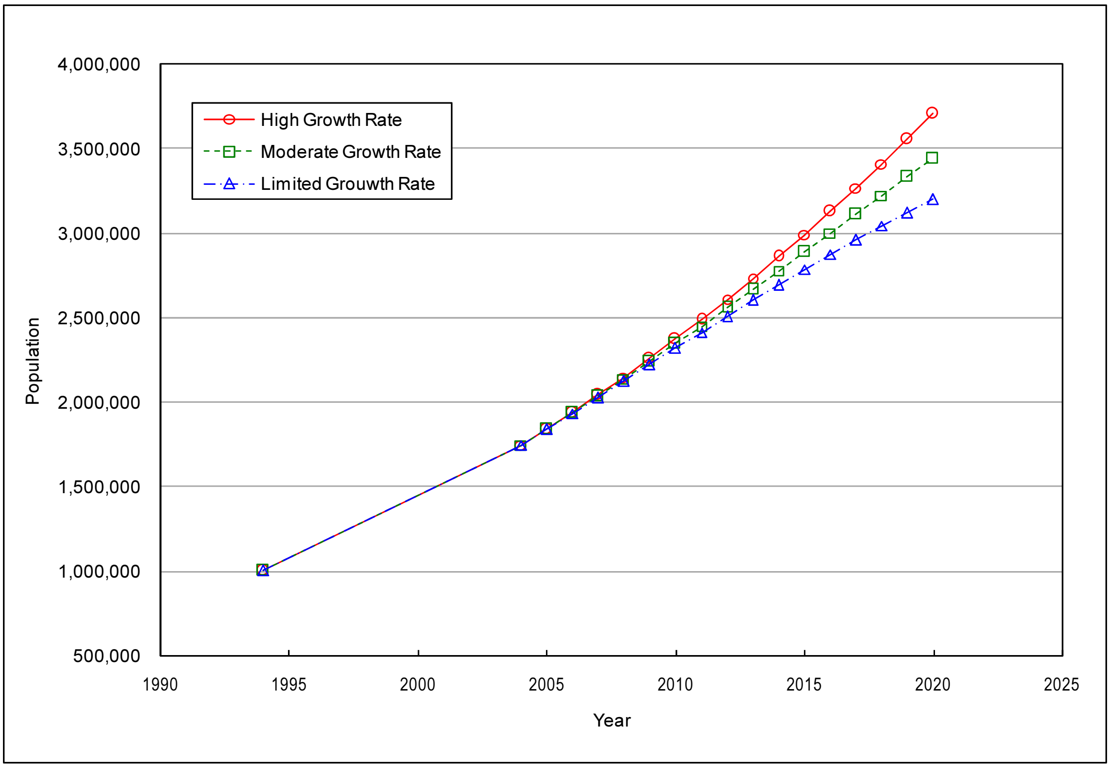

Figure 5.10 Chart of Population Forecast for Sana'a City

(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*.

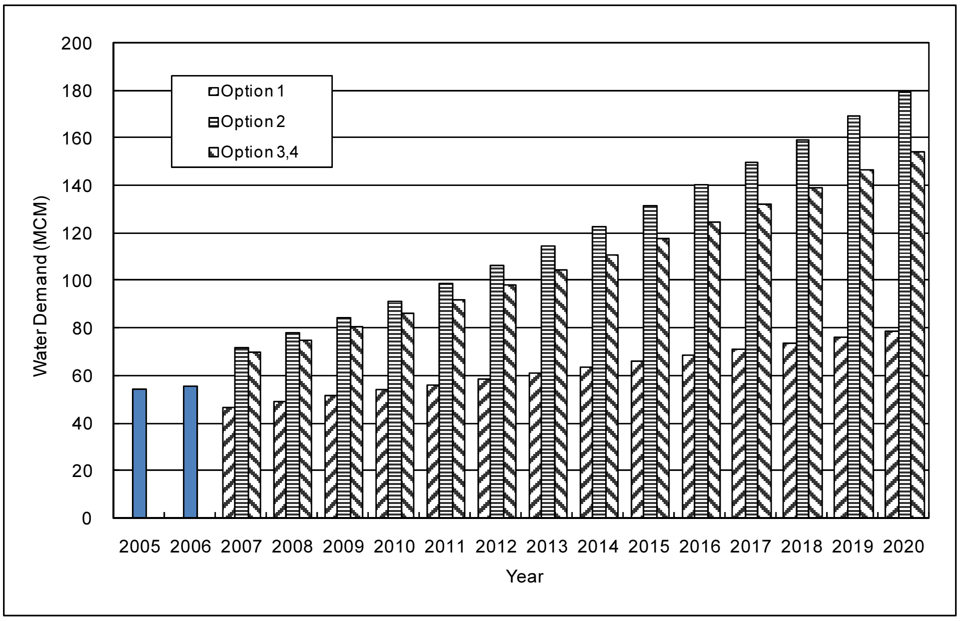

Figure 5.11 Urban Water Demand Projection Chart

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

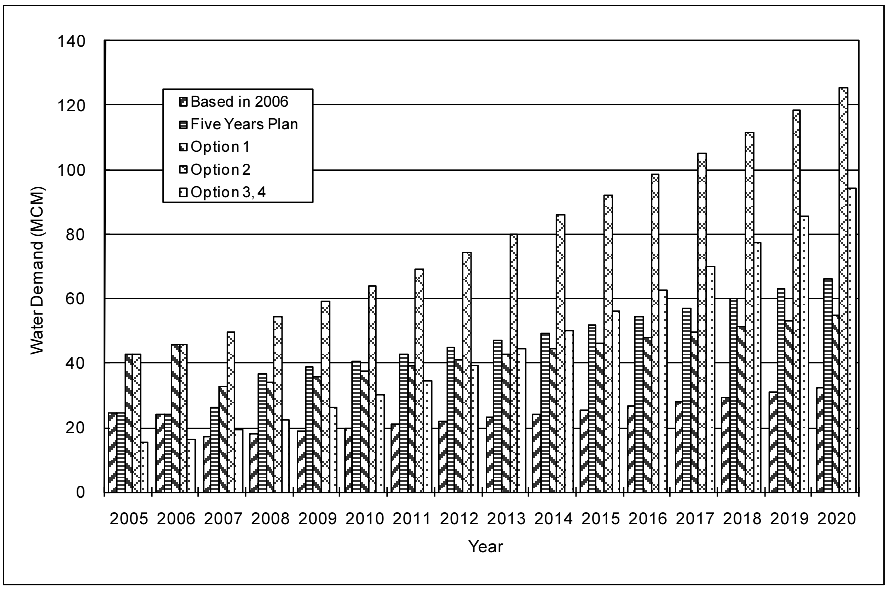

Figure 5.12 Domestic Water Demand Projection Chart

(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

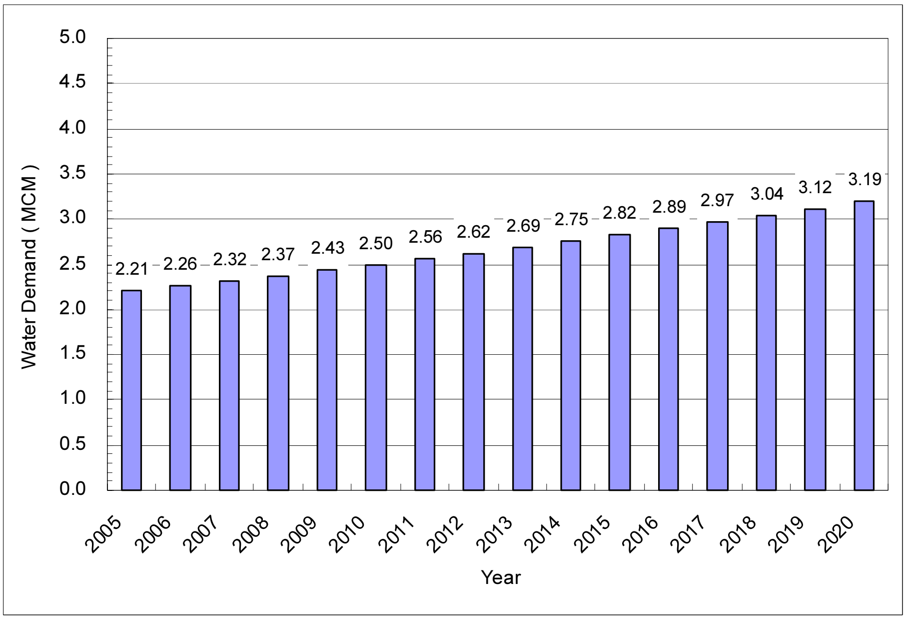

Figure 5.13 Rural Domestic Water Demand Projection Chart

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

Table 5.42 Irrigation Water Demand by Irrigation Efficiency

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

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

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

Unit: million cubic meters

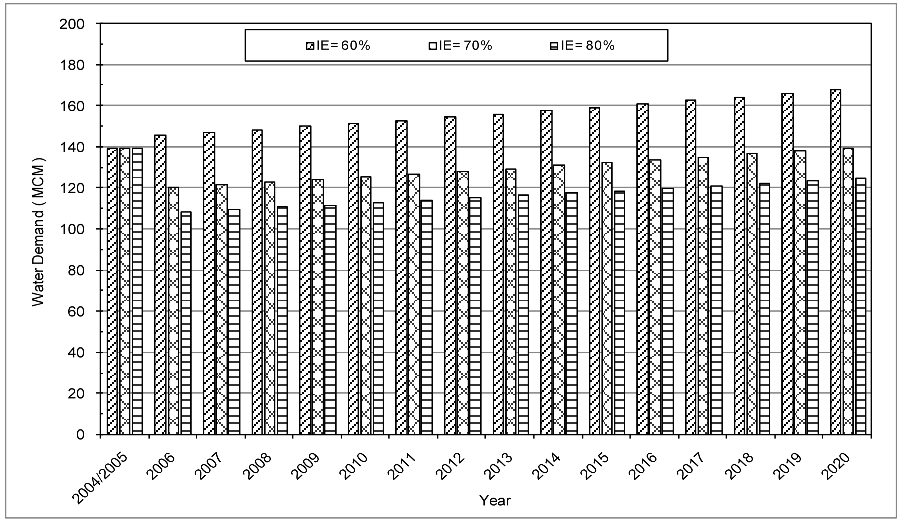

Figure 5.14 Irrigation Water Demand by Irrigation Efficiency

OBSERVATIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Unit: million cubic meters

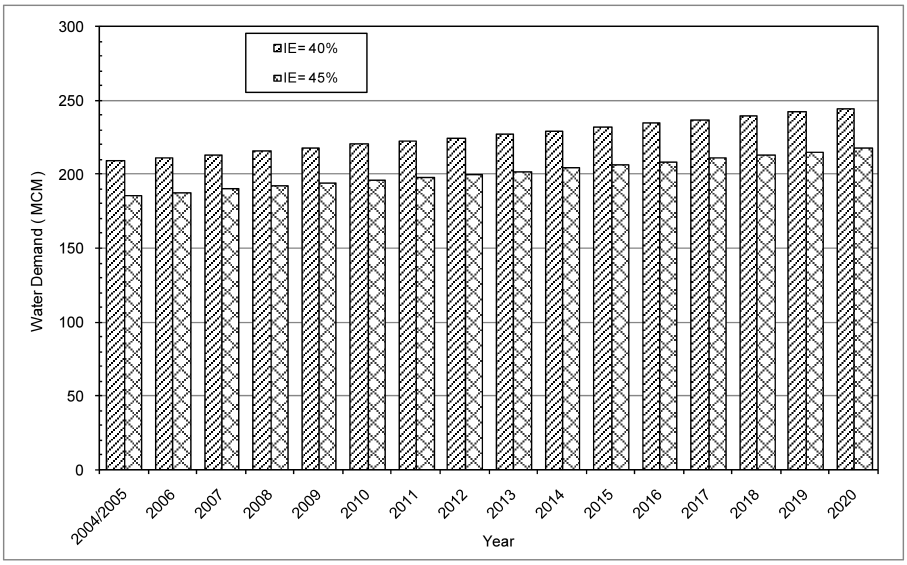

Figure 5.15 Irrigation Water Demand Projection Chart (IE=40% and 45%)

5.8.4 INDUSTRIAL WATER DEMAND

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

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

WEC (2001)[19] has estimated the water demand using “Gross Water Requirement Method” to calculate the water demand for the year of 1995. This method depends on identifying 1) the physical outputs of the different industrial products, and 2) the average water requirement per unit of physical output in various industrials sub sector.

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

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

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

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

Table 5.45 Industrial Water Demand by Scenarios

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

Unit: million cubic meters

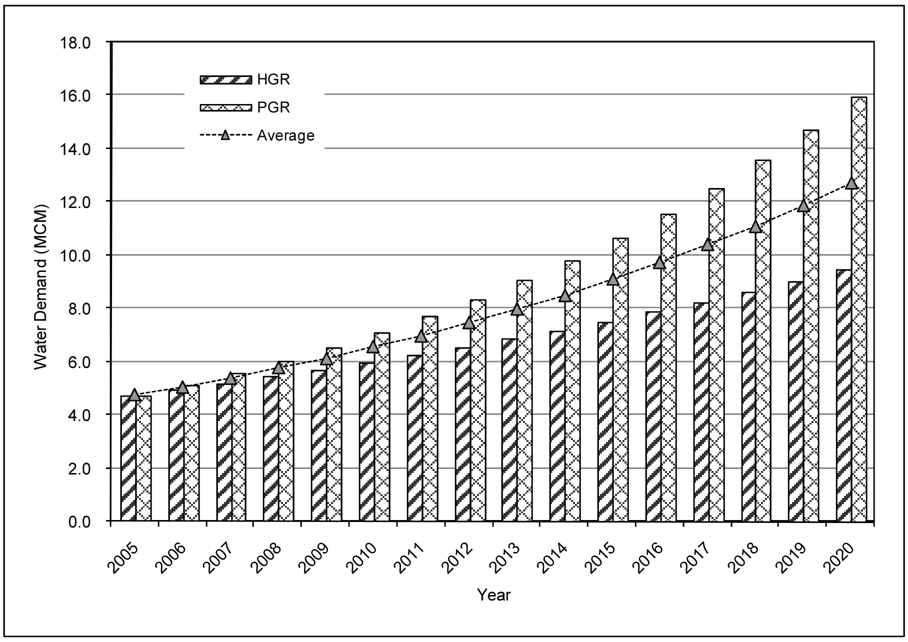

Figure 5.16 Industrial Water Demand Projection Chart

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

5.8.5 Touristic Water Demand

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

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

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

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

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

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

Table 5.46 Number of Hotels and Capacity

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

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

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

Table 5.47 Touristic Water Demand Projection

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

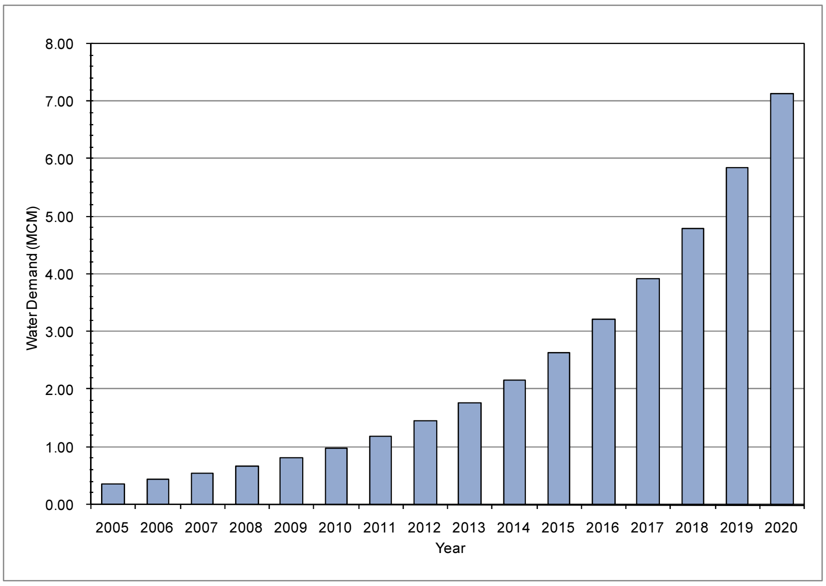

Figure 5.17 Touristic Water Demand Projection Chart

5.9 PROBLEMS AND RECOMMENDATIONS CONCERNING WATER USE

5.9.1 PROBLEMS TO BE SOLVED

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

(1) Domestic Water Use

1) Urban Water Supply

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

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

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

2) Rural Water Supply

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

(2) Agricultural Water Use

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

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

- Groundwater abstraction is uncontrolled and unrecorded.

(3) Industrial Water Use

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

(3) Touristic Water Use

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

(4) Wastewater Use

1) Wastewater Treatment Plant

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

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

2) Industrial Wastewater

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

5.9.2 RECOMMENDATIONS

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

(1) Domestic Water Use

1) Urban Water Supply

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

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

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

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

- Understand the detailed quantity of water consumed and water connection of each sector classified as "Commercial" connection.
- Continuous and periodical water level, water quality monitoring.
- Elaboration of a detailed database of all wells belonging to SWSLC and database of all monitored data such as water level, water quality and so.
- Registration and monitoring of all private water suppliers and water distribution network to understand the quantity of water produced and consumed by the sector.

2) Rural Water Supply

- Registration and monitoring of all domestic porpose wells to understand the quantity of water abstracted, consumed for an appropriate water resources management.
- Elaboration of a detailed database of all rural water supply projects with data such as supply system, well information, production, consumption, number of beneficiaries and so.
- Area-wide inventory survey concerning water sources for rural water supply

(2) Agricultural Water Use

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

(3) Industrial Water Use

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

(4) Touristic Water Use

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

(5) Wastewater Use

- Reuse of treated wastewater for irrigation and for watering trees and green parks in the city. This activity is ongoing on Sana'a Wastewater Treatment Plant.
- Recycle and reuse of industrial wastewater through implementation of treatment facilities in the industries.

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

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CHAPTER 6

CURRENT INSTITUTIONAL AND ADMINISTRATIVE FRAMEWORK

CHAPTER 6 CURRENT INSTITUTIONAL AND ADMINISTRATIVE FRAMEWORK

6.1 GENERAL (LEGAL AND REGULATORY FRAMEWORK)

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

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

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

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

Table 6.1 Major Legal Provision concerning Water Resource Management

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

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

Source: NWRA (2006)

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

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

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

6.2.1 WATER LAW NO. (33) OF 2002

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

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

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

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

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

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

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

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

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

Although the Water Law of 2002 is a significant cornerstone to determine administrative and institutional framework for country's water resource management, critical "legislative" shortcomings in its basic provisions has been pointed out since its ratification, as it is followed (World Bank, 2003):

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

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

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

6.2.2 REPUBLICAN DECREE NO. (41) OF 2007 REGARDING THE ADJUSTMENT OF THE WATER LAW NO. (33) OF 2002

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

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

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

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

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

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

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

6.2.3 Executive Regulation to the Water Law (Draft)

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

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

reality; and,

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

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

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

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

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

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

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

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

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

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

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

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

Draft Executive Regulation to the Water Law of 2002 copes very deliberately with the issues, and defines the Water Law as sole legal instrument to determine the water right accrued to beneficiaries only for its use (usufruct only), by separating the water "use right (usufruct)" from land ownership established upon the custom and *Sharia'h*. Recognizing also the significance of the Civil Code in the country's legislative system, the Draft Executive Regulation stipulates;

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

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

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

As it is observed above, the Draft Executive Regulation possibly allows the water "ownership" right belongs to the land and overlaying land owners, stipulating in its provision as "all beneficiaries and water right (possibly including the water ownership right) shall be subject to the rules that regulate it in the Civil Code". Nonetheless, those provisions in the Regulation, if all approved, could be robust and backstopping legal instrument to authorize right of the State to control water "use right (usufruct)" exclusively in accordance with the Water Law and its Executive Regulation.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6.3.1 WATER OWNERSHIP RIGHT

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

(1) The Legal Status of Water Ownership

According to *Sharia'h,* water is non-salable publicly owned commodity to which everyone has a right, in principle. That is, it is *res nullius* or *Mubah* (i.e. of nobody). Hence free access to water is the right of all people and community as a whole. However, as it is observed earlier in the previous sections, this non-salable and public-owned principle is applicable only if it is not appropriated by carrying or transporting it inside a receptacle, such as well. Indeed, Sharia'h allows and authorizes private ownership of the water source when it is appropriated by means of receptacle.

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

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

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

(2) Conditions for Water Ownership

According to Sharia'h, four types of water sources are distinguished, as followed; 1) water enclosed in "man-made" receptacles (containers and buckets), 2) water in wells, cisterns and springs, 3) water in small rivers or stream which belongs to a specific community, and 4) water in great rivers. Thus, as it is observed, unless the water is appropriated by placing it inside a privately owned containers or receptacle which sets it separate from the source, then it can not be owned. This rule is explicitly stated in Article (1336) of the Civil Code referring "water is not owned as a private property except when transported or contained in receptacles, or the like … the drilling of a well receive water is considered an appropriation by containment (and hence an ownership), provided that the water comes from *res nullius* and it passed in the (natural) waterway."

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

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

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

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

6.3.2 WATER DIVERSION AND USUFRUCT

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

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

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

(1) Basis for Initiation / Acquisition of Diversion Right

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

Therefore, this article determines that:

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

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

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

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

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

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

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

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

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

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

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

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

(3) Conditions for Losing the Diversion Right and Usufruct

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

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

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

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

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

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

Furthermore, these water rights may be revoked and curtailed by the State in the public interests, or whenever such action is necessary to conserve water use, as the Water Law stipulating the right of the State to intervene to regulate these water rights with issuance of its Executive Regulation in its Article (31), referring "The Executive Regulation of this Law determines the conditions which make it possible for the State to lay hands on the right of utilization of water if the general interest so demands or the need to rationalize the uses of water, along with the fair compensation to the beneficiaries according to operative laws."

6.3.3 WATER USE (SHARING) RIGHTS

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

(1) Priority of Use

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

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

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

(2) Quantity of Use

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

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

(3) Places of Use and Sharing

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

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

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

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

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

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

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

(4) Burden-Sharing among Users

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

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

6.3.4 WATER ADMINISTRATION

Regulation dealing with the administration of water rights may be distinguished into six aspects, such as water allocation system, operation and maintenance regulations, organization of users, quantity and quality protection, conflict resolving measures, and law enforcement.

(1) Water Allocations System

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

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

(2) Operation and Maintenance

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

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

(3) Organization of Users

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

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

(4) Quantity and Quality Protection Measures

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

The Water Law of 2002 regulates the quantity of water exploited, as observe in previous sections, in its registering and licensing system in accordance to a number of relevant provisions stipulated in the Law itself and the Executive Regulation to the Law. The Law also defines that NWRA has the power to protect water resources against pollution, to maintain water quality, to prevent activities that may lead to pollution or the degradation of the quality of water, and to prepare the procedures for regulating potentially polluting activities (Article 54). Designating authority to NWRA in preservation of water resources from depletion, a number of rules and standards, as well as technical specification to be applied, are described in the Water Law and its Executive Regulation.

(5) Conflict Settlement Procedures

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

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

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

(6) Enforcement Procedures

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

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

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

One of major approaches employed in the Water Law of 2002, its associated amendment Law and the Draft Executive Regulation is delegation of authority in planning and implementation of water resource management to the branch offices of the relevant execution authority (NWRA Branch Offices), local authorities, local stakeholder committee such as Basin Committees, as well as local user communities (beneficiaries), which may realize better water resource management in decentralized and participatory manners. The Republic of Yemen is one of the countries which facilitating decentralization. The important legal provisions that determine administrative and institutional principles and direction in decentralization of the State are stipulated in "the Law No. (4) of 2000 concerning the Local Authority (the Local Authority Law of 2002)" and "the Republican Decree No. (269) of 2000 concerning the Executive Procedure and Regulation for Local Authority Law of 2000 (the Executive Procedure and Regulation for the Local Authority Law of 2000)". The Water Law of 2002, which was issued two years after the Local Authority Law of 2000, in fact, refers in many articles to Local Authority Law and Local Councils for decentralized water resource management. Local Authority Law defines functional roles and responsibilities of Local Councils and local organs of line ministries (including NWRA Branch Offices) as well as community-based organizations in water resource management, thus it shall play important roles and basis for integrated water management in decentralized principles enhanced in the Water Law and the Stale as a whole.

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

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

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

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

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

Functional responsibilities of local authorities at governorate and district levels are defined in the Article (14) of the Law, describing "The Local Authority Law clearly defines the functions and responsibilities in regard to the supervision, execution and implementation as well as management of project within the geographical limits of the governorates and districts as followed;"

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

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

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

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

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

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

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

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

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

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

The functions of the governorate in the field of implementation of development and service projects, which may include water resource management, are defined in the Article (16) of the Executive Procedure and Regulation. In the Article, establishment, management and maintenance of dams is mentioned as one of functional responsibilities of the governorate. Another function for the Local Councils of the governorate is referred as establishment, management and maintenance of any projects assigned or delegated by central ministers to the governorate. Such projects which are centrally financed may have national characteristics. Also, on the basis this article, the local council of the level of the governorate shall manage, operate and maintain any project which is executed by any central authority and transferred and assigned through delegation of powers to the governorate. This provision is in compliance with Article (72) of the Water Law of 2002 which authorize MWE to delegate some of its power and functions to any entity whether council, committee or office provided that it does not contradict or contravene the Local Authority Law No. (4) of 2000.

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

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

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

6.5 CONCLUSION AND ISSUES TO BE CONSIDERED IN THE ACTION PLAN

First of all, this Chapter reviewed and analyzed three major legislative and regulative sources that create administrative and institutional framework of the State for IWRM , which include the Water Law No. (33) of 2002, Republican Decree No. (41) of 2007 regarding the Adjustment of the Water Law No. (33) of 2002, and the Draft Executive Regulation. In the review and analysis of those Laws and Regulation, a number of "legislative" and "regulative" shortcomings are identified, the former of which decline the legal effect and validity of the Water Law itself, while the latter hinder the execution and enforcement of the law. Rectifications of these shortcomings, in particular, introduction of water abstraction metering and water charge levying for irrigation in use of groundwater, has been one of the most debating issues in the society as well as political sphere of the country over a decade. Strong political commitments and leadership to pursue IWRM have been observed, indeed, which realized the establishment of sole regulatory body (i.e. NWRA) to be fully responsible for the State's IWRM through consecutive reorganization and restructuring of the water sector commenced from a chaotic institutional arrangement after unification in 1990 where a number of national institutions and their associate public entities carried over the mandate of water resources management in addition to their own specific mandates. Indeed, the original version of the Water Law which is drafted by the special committee of the parliament and duly approved by the Cabinet included these regulations of groundwater abstraction metering and groundwater charge levying. However, these provisions were manipulated and amended in the parliament discussion, followed by the parliament approval. Several efforts and undertakings have been made to rectify and improve some of crucial provision of the Water Law of 2002 for realization of improved IWRM, through issuance of its Amendment Law and Executive Regulation. Robust political commitment, in particular by the Cabinet members, has been always observed in the issues. However, time to time and opportunity by opportunity for its rectification, denials were given by some of parliament members on the crucial provisions. Thus, the strong political commitment of the pro-IWRM wing formed by the Cabinet members has been always wiped out by other political will of anti-IWRM wing formed by some of Parliament members. The Study on the current institutional and administrative framework attributes the persistent objection against ratification of these essential provision in the Water Law to three major factors, as such to; 1) political environment as mentioned, 2) socio-economic conditions of the country, in particular, Sana'a that rely largely on the production of water-consuming cash crops particularly "qat", and 3) socio-culture of "tribalism" in the highland areas of the country, where exclusive management for their tribal land and any structures on it is their entrenched tradition and custom.

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

Finally in this Chapter, Law No. (4) of 2000 concerning the Local Authority (Local Authority Law of 2000) and its Executive Procedures and Regulation is reviewed, which defines the decentralized framework of local administration and institution in execution of development project including water resource management programs. A considerable number of provisions in the Local Authority Law of 2002 and its Executive Procedures and Regulation are identified and applied in general and specifically to determine administrative and institutional framework and arrangement for water resource management at local level. Indeed, the Local Authority Law is a first step to determine decentralized framework of administration and institution at local level in execution of development project including water management. On the other hand, one of the most important principles and approached underlying in the Water Law of 2002, which is developed two years after the Local Authority Law of 2000, is also "decentralization" and "participation" of local stakeholders and communities in planning, execution, and monitoring and regulation, as well as operation and maintenance for sustainable water resource management. Along with this principle and approach in the Water Law of 2002, various local institutions has been established at deferent levels in accordance with relevant decrees, such as branch office of the relevant regulatory authority (Branch Offices of NWRA), Basin Commissions composed of various national and local stakeholders, and community-based organizations (WUG, WUA, and WUF). Thus, in the first place, consistency of such locally decentralized framework of institution and administration determined by the Local Authority Law of 2000 and the Water Law of 2002 is examined in the Study. Without finding any inconsistency and conflicts between these two Laws in the framework setting, however, significant opportunities are identified for further development of institutional and administrative framework in water resource management in a decentralized manner, apportioning and utilizing the framework created by the Local Authority Law of 2000.

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

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

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

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

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

6.5.2 Advocacy of Water Resource Management for Public and Political Leaders

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

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

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

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

6.5.3 Distinctive Definition of Water Usufruct

As reviewed in this Chapter, there are traditionally and customarily dominating legislative sources governing water resources management, such as *Sharia'h*, *'urf*, and the Civil Code, that define that land ownership gives the owner the full right and control over natural resources above and beneath (thus, surface and ground water) its surface. It is in fact the most prevailed conviction of the people in the country, particularly in rural areas. Indeed, the most of disputes regarding water resource management and water right are "legally" resolved in accordance with the legal provision of Civil Code defining in its Article (1163) that "land ownership is inclusive of what is above and beneath it to whatever height or depth is useful to enjoy it (land)." The deliberations and discussions for the Water Law of 2002 and its amendment Law in parliament also indicates that most of the parliament members insist on the conservative approach of the Civil Code regarding groundwater ownership and protection of the landlords from any interference by the State.

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

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

6.5.4 RESPECT ON TRADITIONAL AND TRIBAL SYSTEM

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

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

Thus, channels and network to connect tribes and tribal system shall be identified and developed as it is possible. "Tribal system" herein refers to interrelationship among tribes, and it can be defined as the forum for groups of tribes to conciliate their interests, dispute, and conflict. Development of such mechanism to facilitate and institutionalize their participation shall be considered in the preparation of Action Plan of Sana'a Branch Office of NWRA under the Study. In this line, involvement of tribal authorities in Basin Committee could be also considered. As it may be further discussed in the Chapter 7 of "Current Organizational Structure", Sana'a Basin Commission has been established in accordance to the Water Law and relevant Decrees, of which function has two-folded characteristics that one served as decision making body for the Basin water management, while one functioned as regulatory body. An active participation of tribal authorities in such decision making and regulation, if supports granted, could be a backstopping institutional support for enhancement of self-regulating mechanism in water resource management.

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

6.5.5 IMPROVEMENT IN DECENTRALIZED FRAMEWORK OF LOCAL ADMINISTRATION AND INSTITUTION

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

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

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CHAPTER 7

CURRENT ORGANIZATIONAL STRUCTURE

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7.1 GENERAL

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

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

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

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

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

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

7.2 National Organizations

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

7.2.1 Ministry of Water and Environment (MWE)

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

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

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

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

7.2.2 National Water Resources Authority (NWRA)

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

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

(1) Water Resource Planning and Implementation

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

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

(2) Regulation and Monitoring

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

(3) Water Demand

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

(4) Water Quality Management

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

7.2.3 MINISTRY OF AGRICULTURE AND IRRIGATION (MAI)

MAI and its affiliated institutions are one of the major national partners for IWRM in the fact that the country's most serious water shortage is attributed to larger groundwater abstraction for irrigation without application of improved technology for water savings in irrigation (irrigation efficiency). Thus, achieving the state's IWRM objectives will depends considerably on water saving in irrigation. As it is overviewed in the prior section, in the water sector reform and restructuring of the State early in this century, most of its sub-sector authorities (i.e. NWRA, NWASA, GARWSP, and EPA) were incorporated in MWE, which creates new enabling environment administratively towards IWRM, but except irrigation sub-sector. Recognizing the significance of MAI in IWRM, the Water Law of 2002 and its amendment Law clarifies the roles of MAI in water resource management as followed:

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

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

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

and enhancing rainfall water harvesting methods;

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

7.3 LOCAL ORGANIZATIONS

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

7.3.1 LOCAL ADMINISTRATIVE SETTING IN SANA'A BASIN

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

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

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

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

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

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

(2) Local Administrative and Regulative Framework in Sana’a Basin of “Protected Zone”

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

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

1) Well Drilling

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

A. For drinking purposes provided that:-

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

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

B. For Agriculture:-

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

2) Drilling and Deepening License

Drilling or deepening licenses must comply with the following aspects;

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

3) Well Registration

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

4) Facility Construction and Project Implementation

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

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

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

5) Groundwater Pollution

The following controls and measures must be taken;

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

6) Basin Commission

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

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

7) Coordination

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

8) Implementation

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

7.3.2 NWRA Sana'a Branch (NWRA-SB)

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

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

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

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

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

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

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

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

(1) Water Resource Planning and Implementation

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

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

(2) Regulation and Monitoring

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

(3) Water Demand

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

(4) Water Quality Management

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

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

7.3.3 Sana’a Basin Commission (SBC)

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

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

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

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

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

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

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

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

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

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

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

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

avoid such conflicts;

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

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

7.3.4 Local Councils

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

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

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

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

The Local Authority Law of 2000 further defines the supervisory roles and responsibilities of District Local Council in water resource management through promotion of dams and water weirs, protection of water quality, as its Article (61) describes as followed;

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

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

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

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

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

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

Reviewing these functional roles and responsibilities of Local Council at governorates and districts defined in the Local Authority Law of 2000, there a number of provisions to create administrative and organizational environment to support enforcement of the Water Law of 2002 at local level, in particular for the basin-level water resource management. For example, the regulations implementing the Local Authority Law vest the power to grant licenses for the construction of wells to District Local Council, as well as supervision on its compliance by local user communities. Thus, an application for a license will have to be filed, and it compliance shall be monitored by the District Local Council. In addition, the tasks and duties determined in the Local Authority Law for the District Local Council in promotion of cooperative society (community-based organization) for the project/service management shall be emphasized, in consideration of establishment and involvement of user community organizations, such as WUA, for the basin-level water resource management.

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

7.4 COMMUNITY ORGANIZATION

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

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

Thus incompetence of traditional rule of groundwater sharing and in particular conventional user group in its nature to cope with unrestricted discharge of groundwater in the basin calls for renovated user community organizations and enhanced user participation in the basin-level water resource management. Particularly in the highland areas of the country including Sana'a Basin, where the strong autonomy of user communities (hence, non-acceptance of any interference/control by government) exists based on the traditional tribal structure or "tribalism", the basin-level water resource management can be only successful on a participatory basis.

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

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

7.4.1 Water User Group (WUG)

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

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

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

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

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

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

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

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

7.4.2 Water User Association (WUA)

A WUA is formulated by consolidating a number of WUGs in a recognizable boundary, and with social mobilization provided by NWRA-SB, it is legally recognized and registered in accordance with Law No (39) of 1998 regarding Cooperative Associations and Societies. An officially recognized village or well-field WUA is a prerequisite for participation in the irrigation improvement program. WUAs constitute official stakeholder representation to SBC , as observed earlier, to participate in decision making and its enforcement process in the basin-level water resource management. WUAs are also delegated with power to as some degree as desirable to manage, regulate, and enforce measures for the resource management in their areas covered. Thus, WUAs would be primarily responsible for; 1) self-regulation and enforcement of groundwater abstraction right; and 2) implementation and management of groundwater conservation schemes.

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

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

7.5 Current Capacity of Local and Community Organizations in the Basin-Level Water Resource Management, and Issues to be considered in the Action Plan

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

7.5.1 NWRA Sana'a Branch (NWRA-SB)

(1) Organizational Structure

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

(2) Human Resources

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

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

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

(3) Financial Management

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

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

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

(4) Regulation and Monitoring

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

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

7.5.2 LOCAL COUNCILS

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

7.5.3 SANA'A BASIN COMMISSION (SBC)

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

However, the capacity for institutional arrangement to improve water management is insufficient and fragmented. Public institutions often lack authority over tribal structures and the strong autonomy of local water users. Experiences show that enforcement can only be successful on a participatory basis, through a system of self-regulation. The project would couple regulation with a participatory water resource management approach and a public information and awareness program.

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

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

7.5.4 WATER USER ASSOCIATION (WUA)

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

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

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

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

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

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

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

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

CHAPTER 8

ENVIRONMENTAL AND SOCIAL CONSIDERATION

CHAPTER 8 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

8.1 REGULATIONS AND LAWS CONCERNING ENVIRONMENTAL CONSIDERATION

8.1.1 ENVIRONMENTAL POLICY AND LAWS IN YEMEN

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

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

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

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

Table 8.1 The programs concerning Sustainable Water Management in the ESIP

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

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

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

8.1.2 Environmental Impact Assessment in Yemen

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

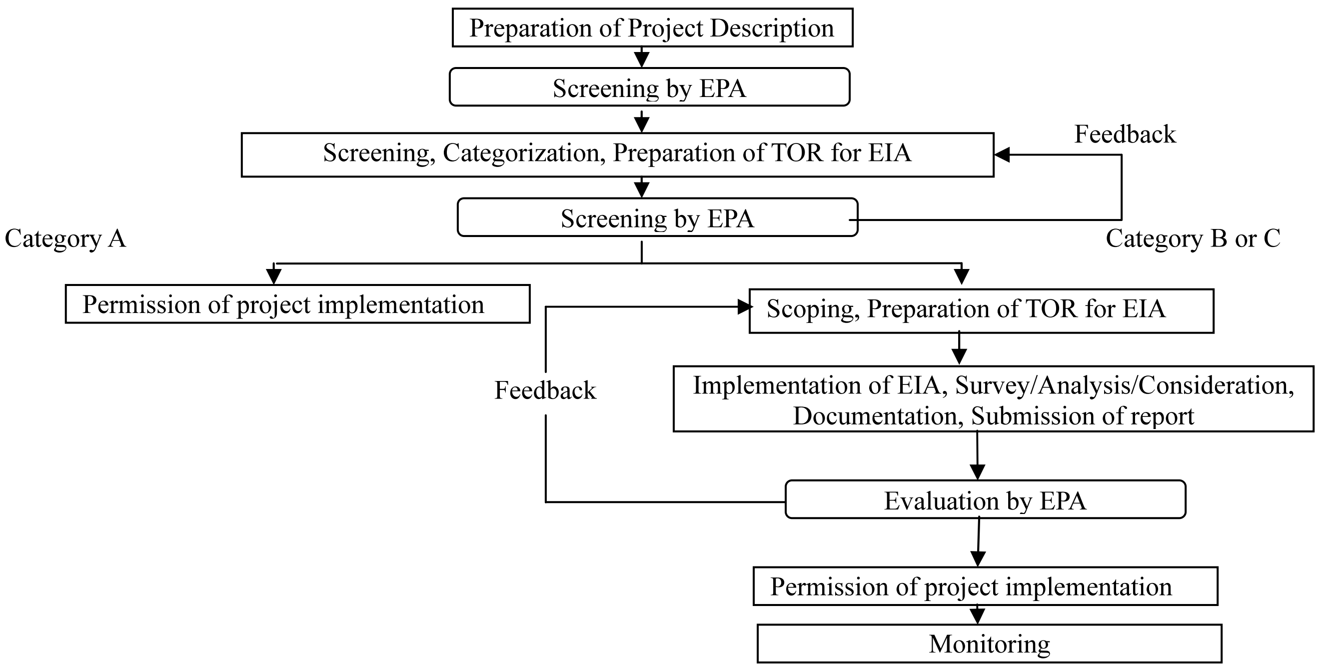


Figure 8.1 The EIA procedure in Yemen

8.2 INTRODUCTION OF STRATEGIC ENVIRONMENTAL ASSESSMENT

8.2.1 WHAT IS STRATEGIC ENVIRONMENTAL ASSESSMENT?

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

8.2.2 ANTICIPATED ENVIRONMENTAL IMPACTS FROM THE PLAN

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

(1) Inter-sectoral allocation of water resources

Table 8.2 Anticipated Impacts (1)

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

(2) Use of water harvesting methods

Table 8.3 Anticipated Impacts (2)

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

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

(3) Use of treated waste water

Table 8.4 Anticipated Impacts (3)

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

(4) Improvement of water use efficiency of irrigation use

Table 8.5 Anticipated Impacts (4)

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

(5) Reduce of illegal drilling

Table 8.6 Anticipated Impacts (5)

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

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

Table 8.7 Anticipated Impacts (6)

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

(7) Improvement of sewage system in urban area

Table 8.8 Anticipated Impacts (7)

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

(8) Control of utilization of fertilizers and pesticides

Table 8.9 Anticipated Impacts (8)

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

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

(9) Consideration of recharge and sub-surface dam

Table 8.10 Anticipated Impacts (9)

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

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

Table 8.11 Anticipated Impacts (10)

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

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

Table 8.12 Anticipated Impacts (11)

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

8.2.3 PROPOSED MITIGATION MEASURES

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

(1) Tribal Conflicts

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

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

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

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

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

(2) Depletion of groundwater

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

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

- Consideration of groundwater potential before any groundwater development

(3) High cost on irrigation

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

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

(4) Degradation of vegetation

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

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

(5) Involuntary transmigration

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

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

Appendix 1

Result of Pumping Test

Appendix 1 Results of Pumping Tests (1/2)

Well No.	UTM E	UTM N	AQUIFER	T(m2/day)	SATURATED THICKNESS(m)	ESTIMATED PERMEABILITY (m/day)
ST3	417700	1692750	Alluvial Aquifer	10		
SE5	417700	1692800	Alluvial Aquifer	105	115	0.91
1 - P	413680	1697830	Alluvial Aquifer	30	86.6	0.35
6 - P	413510	1698910	Alluvial Aquifer	33	28.2	1.17
WELL 41	411500	1681500	Alluvial Aquifer	16.8	5.05	3.33
WELL 126	421500	1684500	Alluvial Aquifer	3.6	45.4	0.08
WELL 646	403500	1698500	Alluvial Aquifer	35.8	3.7	9.68
WELL O467	416500	1688500	Alluvial Aquifer	10.9	3.5	3.11
WELL O734	420500	1717500	Alluvial Aquifer	0.25	1.4	0.18
WELL O867	415500	1715500	Alluvial Aquifer	82	5.2	15.77
WELL O874	416500	1714500	Alluvial Aquifer	2.4	9.6	0.25
HIZIAZ	419400	1683950	Alluvial/Volcanics	50	200	0.25
	Maximum			105		15.77
	Minimum			0.25		0.08
	Median			23.4		0.91
	Average			31.6		3.2
BOREHOLE	401500	1703500	Volcanic Rocks	4.5		
DAR SALM	418600	1688800	Volcanic Rocks	75	90	0.83
SE4	414850	1695300	Volcanic Rocks	113	311.1	0.36
2 - P	420600	1679490	Volcanic Rocks	0.41	189.1	0.002
3 - P	403700	1697970	Volcanic Rocks	4.7	30.0.16	
5 - P	413510	1698910	Volcanic Rocks	3.2	148.2	0.02
WELL 20(*)	415500	1678500	Volcanic Rocks	0.5	1	0.5
WELL 25	414500	1678500	Volcanic Rocks	14.6	9.2	1.59
WELL 47(*)	431500	1674500	Volcanic Rocks	29.5	3.1	9.52
WELL 160	432500	1699500	Volcanic Rocks	3	10.1	0.3
WELL 261	402500	1695500	Volcanic Rocks	2.4	7.1	0.34
WELL O125(*)	433500	1689500	Volcanic Rocks	21.8	1.3	16.77
WELL O128(*)	431500	1688500	Volcanic Rocks	30.2	2.5	12.08
BOREHOLE 48	415500	1681500	Volcanic Rocks	4	137.5	0.03
BOREHOLE 707(*)	403500	1694500	Volcanic Rocks	200.4	126	1.59
BOREHOLE 1126	413500	1691500	Volcanic Rocks	184.5	141.1	1.31
	Maximum			200.4		16.77
	Minimum			0.41		0.002
	Median			9.65		0.67
	Average			43.2		3.2
SABAEEN	414150	1694650	Tawilah Sandstone	26	200	0.13
BAYAT AD DAYL	387300	1708300	Tawilah Sandstone	400	300	1.33
SE1	414930	1701500	Tawilah Sandstone	551	353	1.56
SE2	414930	1701490	Tawilah Sandstone	526		
SE3	420860	1707950	Tawilah Sandstone	411	170	2.42
SE6	4088600	1704000	Tawilah Sandstone	5		
SE7	410550	1707625	Tawilah Sandstone	377	178.3	2.25
SE8	405550	1714200	Tawilah Sandstone	---		
SE9	411900	1699350	Tawilah Sandstone	274		
ST1	414860	1701495	Tawilah Sandstone	555	212	2.62
ST2	420800	1707950	Tawilah Sandstone	400	53	7.55
ST4	410620	1707625	Tawilah Sandstone	380	144.2	2.64
ST5	414300	1702850	Tawilah Sandstone	30	166	0.18
ST6	412700	175300	Tawilah Sandstone	2000	87	22.99
ST7	412400	1704800	Tawilah Sandstone	38	164	0.23
ST8	412700	1702200	Tawilah Sandstone	120	162	0.74
ST9	412775	1705650	Tawilah Sandstone	300	162	1.85
ST10A	413324	1704880	Tawilah Sandstone	430	160	2.69
ST11	413901	1704054	Tawilah Sandstone	120	148	0.81
ST12	412446	1706500	Tawilah Sandstone	110	170	0.65
ST13	412097	1707294	Tawilah Sandstone	120	164	0.73
EX2	419000	1704450	Tawilah Sandstone	50	151	0.33
EX3	421251	1706952	Tawilah Sandstone	20	145	0.14
EX4	421852	1708250	Tawilah Sandstone	100	155	0.65
P1	409566	1707426	Tawilah Sandstone	250	137	1.82
P6	412177	1702960	Tawilah Sandstone	34	160	0.21
P7(*)	408972	1707805	Tawilah Sandstone	140	143	0.98
P8	413047	1704606	Tawilah Sandstone	102	170	0.6
P9	409339	1707743	Tawilah Sandstone	170	121	1.4

Source: SWAS, NWSA

Appendix 1 Results of Pumping Tests (2/2)

Well No.	UTM E	UTM N	AQUIFER	T(m2/day)	SATURATED THICKNESS(m)	ESTIMATED PERMEABILITY (m/day)
P10	413503	1703816	Tawilah Sandstone	40	173	0.23
P13	413295	1704211	Tawilah Sandstone	200	171	1.17
P14	410593	1706303	Tawilah Sandstone	85	179	0.47
P15(*)	409405	1709557	Tawilah Sandstone	100	98	1.02
P16	413945	1701124	Tawilah Sandstone	500	161.5	3.1
P17	409559	1708837	Tawilah Sandstone	150	120	1.25
P18(*)	414209	1700572	Tawilah Sandstone	570	162	3.52
P19(*)	414028	1700030	Tawilah Sandstone	450	164	2.74
P20	409972	1708292	Tawilah Sandstone	60	153	0.39
P21	410159	1709961	Tawilah Sandstone	100	154	0.65
O2(*)	408894	1707637	Tawilah Sandstone	570	53	10.75
O3	411401	1707565	Tawilah Sandstone	50	168	0.3
O4	410628	1707093	Tawilah Sandstone	16	119	0.13
O5	411401	1707171	Tawilah Sandstone	10	169	0.06
O11	413524	1703238	Tawilah Sandstone	12	163	0.07
O12	412601	1704029	Tawilah Sandstone	12	170	0.07
B	418589	1701321	Tawilah Sandstone	430	222	1.94
C(*)	417228	1701086	Tawilah Sandstone	930	156	5.96
D(*)	417250	1702470	Tawilah Sandstone	2000	157	12.74
E(*)	418005	1703262	Tawilah Sandstone	600	158	3.8
F	419324	1703904	Tawilah Sandstone	80	155	0.52
G	419194	1702725	Tawilah Sandstone	310	176	1.76
H	421050	1706000	Tawilah Sandstone	10	123	0.08
I	419850	1705750	Tawilah Sandstone	30	157	0.19
J	420128	1706922	Tawilah Sandstone	70	178	0.39
K	419480	1704601	Tawilah Sandstone	45	200	0.23
L(*)	417093	1700443	Tawilah Sandstone	1016	203	5
M	420642	1705129	Tawilah Sandstone	65	119	0.55
N	416505	1702166	Tawilah Sandstone	20	146	0.14
Q	419956	1703132	Tawilah Sandstone	140	192	0.73
5 - P	413510	1698910	Tawilah Sandstone	100	211	0.47
9 - P	421660	1711940	Tawilah Sandstone	39.7	99	0.4
B 1	387300	1708300	Tawilah Sandstone	400	280	1.43
BOREHOLE O423A	427500	1710500	Tawilah Sandstone	131	149	0.88
M19 A (Alsbahi)	417176	1689477	Volcanics/Tawilah	535.37	219.34	2.44
H-8 (Haddah)	411300	1690690	Tawilah Sandstone	99.263		
HA(HADDAH AREA)	411005	1691410	Tawilah Sandstone	314.373	63.6	4.94
EX-S(Haddah)	414157	1691674	Tawilah Sandstone	80.5	117	0.69
KA(Kadisia)	417245	1693470	Tawilah Sandstone	177.1	148.71	1.19
SP -Sabeen park)	414245	1694334	Tawilah Sandstone	81.1	51.93	1.56
OS (Orphanage school)	416750	1694655	Tawilah Sandstone	234.185	109.5	2.14
SA-1(Zubairy Park)	413594	1696222	Tawilah Sandstone	200	62.77	3.19
ASR-12(Asser)	410938	1696367	Tawilah Sandstone	98.78	132.78	0.74
ASR-(Asser)	410938	1696367	Tawilah Sandstone	145.2	207.72	0.70
MR(Musaik)	417059	1698263	Tawilah Sandstone	200		
TP-1(Hasabah)	415350	1701200	Tawilah Sandstone	159	103.8	1.53
NWSA(Hasabah)	414480	1701500	Tawilah Sandstone	111.1	196.09	0.57
TP-2 (Hasabah)	415540	1702000	Tawilah Sandstone	111.1		
DH(Dahban)	413470	1706400	Tawilah Sandstone	28	121.03	0.23
	Maximum			2000		22.99
	Minimum			5		0.06
	Median			120		0.81
	Average			259.2		2.0
7 - P	441180	1733760	Amran Limestone	1.4	27	**0.05**
WELL 551/3(*)	444500	1728500	Amran Limestone	104.2	16.1	6.47
WELL 559/2	444500	1728500	Amran Limestone	11.3	9.4	1.2
WELL O971	433500	1723500	Amran Limestone	10.5	3	3.5
BOREHOLE O988	430500	1720500	Amran Limestone	0.5	146	0.003
	Maximum			104.2		6.47
	Minimum			0.5		0.003
	Median			10.5		1.2
	Average			25.58		2.24

Source: SWAS, NWSA

Appendix 2

Result of Water Level Monitoring

Appendix 2 Results of Water Level Monitoring (1/2)

	Code No.	Site Name	District	North	East	Elev.m.	Aquifer	Well Typ	Aug-03	Jan-04	Oct-04	Dec-04	May-05	Jul-05
1	**P8**	W.F.Wes	Ban-Alhar	1704571	412810	2218	Sandstone		178.1	Pump	Pump	Pump	Pump	Pump
2	**O5**	W.F.Wes	Ban-Alhar	1707273	411188	2238	Sandstone		75.52	75.73	76.4	78.41		77
3	**P17**	W.F.Wes	Ban-Alhar	1708945	409750	2248	Sandstone		Pump	113.5	118.93	118.52		
4	**P15**	W.F.Wes	Ban-Alhar	1709656	409305	2234	Sandstone		Pump	121.75	131.3	135.8	135.3	
5	**P21**	W.F.Wes	Ban-Alhar	1710064	410067	2209	Sandstone		Pump	Pump	133.65	128.6	133	
6	**F783A**	Al Hawri	Hamdan	1715555	411390	2232	Volcanic		Pump		117.2	118.7	98.98	99.57
7	**A2069**	Maribcamp	Ban-Alhar	1714346	418244	2206	Volcanic	Borehole	105.2	102.3	107.92	104.32	102.75	104.77
8	**F 2356**	B-alhally	Ban-Alhar	1715014	416162	2192	Volcanic	Dug+Drill	23.5	22.92	23.6	23.9	23.1	21.9
9	**F 2357**	B-alhally	Ban-Alhar	1715109	416242	2145	Alluvium		25.4	25.5	23.62	26.5		Pump
10	**F 1446**	B-alhally	Ban-Alhar	1718865	416298	2182	Alluvium	Borehole	33.1	34.6	34.9	35.05	38.7	38.2
11	**F2131**	Bossan	Arhab	1728956	417429	2217	Limestone		63.66	64.3	Pump	64.47		62.2
12	**F2143**	Makarib	Arhab	1730178	421335	2136	Limestone		Pump	64.5	Pump	64.6		64.13
13	**F 1445**	B-Mosaed	Ban-Alhar	1716838	417904	2188	Alluvium	Borehole	Pump	27.5	27.8	27.9		27.3
14	**F1947A**	Almasham	Ban-Alhar	1727571	421495	2129	Limestone	Borehole	65.92	35.05	34.9	34.6	55	55.37
15	**F 2003**	W-dogish	Arhab	1729224	425801	2052	Limestone	Dug+Drill	16.12	9.98	9.96	12.25		14.48
16	**C1849**	Al-req val.	Ban-Alhar	1711873	424320	2237	Volcanic		14	11.5	11.03	13.02		11.5
17	**C1564**	Al-grass	Ban-Alhar	1716018	428437	2239	Sandstone	Dugwell	28.2	24.65	25.3	25.8	25.75	24.68
18	**D25**	Dharhan	Bani-Hus	1699850	426648	2400	Alluvium	Dugwell	33.1	22.42	22.1	23.1	25.18	24.73
19	**C1 146**	Alqariah	Bani-Hus	1700113	425179	2367	Alluvium	Dugwell	25.4	16.9	16.85	22.75	24.6	24.25
20	**U358A**	Aswad	Sanhan	1686709	418990	2341	Volcanic	Dugwell	23.5	102.5		102.8	31	
21	**U1146A**	Rihm	Sanhan	1678618	419008	2400	Volcanic	Borehole						
22	**B-665A**	Maqwalah	Sanhan	1675449	429994	2500	Volcanic	Dugwell		66.2		66.8		13.6
23	**B-683**	Bit saani	Sanhan	1677294	426909	2502	Volcanic	Dugwell		97.4		98.2		84.6
24	**E-2366**	Safiat Tamash	Sanhan	1690120	422210	2349	Alluvium			21.2		21.9		
25	**E-2377**	Shahik	Sanhan	1701896	439685	2582	Alluvium	Dugwell		36.7		38.6	28.42	28
26	**E-1749**	Bani Bahlul	Sanhan	1698001	430469	2460	Volcanic	Dugwell		23.3		24.1		26.78
27	**U-427A**	Al Nahdeen	Sana'a	1692469	414845	2302	Volcanic	Borehole		Pump		121	97.37	50.88
28	**U-502A**	Haddah/azal	Al amanh	1692422	413170	2326	Volcanic	Borehole		81.3		81.8	122.28	125.7
29	**A878**	Almasjed	Bani mater	1692294	401298	2576	Alluvium			11.3		11.7		19.66
30	**A-1038**	Raas Alhissin	Bani Matar	1695434	402468	2548	Alluvium			19.5		43.2		
31	**A874A**	Aser Almwred	Sana'a	1696814	408818	2411	Alluvium			21.6		22.4		
32	**A-848-A-**	Alkhasmah	Bani Matar	1695167	403380	2566	Alluvium			121.5		122.4		19.98
33	**A-691-A**	Shamlan	Hamdan	1703827	407993	2342	Volcanic			72.5		73.1		
34	SBH1	bit handal	Bani al-har	1715809	414259	2191								

Appendix 2 Results of Water Level Monitoring (2/2)

	Code No.	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jan-07
1	**P8**	Pump	Pump	Pump	Pump	* P +205.30	*p 206.34	p 205.52 *	*p204.40	192.65	193.53	197.87
2	**O5**	77	77.16	77.24	77.28	77.43	77.58	77.62	77.76	77.76	77.85	78.42
3	**P17**	120.57	118.72	116.7	116.88	118.29	118.16	117.41	117.27	118.24	118.99	117.4
4	**P15**	140.17	139.56	136.64	134.12	133.45	138.65	140.45	141.68	143.47	147.28	143.49
5	**P21**	138	136.9	133.83	131.49	130.65	134.84	135.10	138.60	140.99	143.41	137.79
6	**F783A**		99.75	99.9	99.9	99.80	99.86	99.98	D	D	141.56	141.9
7	**A2069**	105.6	104.7	103.4	102.45	101.10	101.48	102.28	102.35	103.65	105.00	100.62
8	**F 2356**	21.1	20.94	21.61	22	22.27	23.06	23.09	23.13	22.90	22.73	21.55
9	**F 2357**	25.5	Pump	24.89	25.34	25.30	27.05	26.26	26.60	27.10	27.77	24.67
10	**F 1446**	37.23	36.38	35.98	35.87	35.77	37.68	37.60	37.15	36.74	36.84	35.82
11	**F2131**	62.2	62.23	62.3	62.32	62.34	62.46	62.94	63.10	63.31	63.58	60.95
12	**F2143**	60.58	60.74	60.6	58.87	58.00	58.24	58.07	59.81	59.79	55.00	57.29
13	**F 1445**	26.95	27.12	27.34	27.58	27.85	27.93	28.00	28.12	28.16	28.28	26.29
14	**F1947A**	55	56.4	53.98	53.72	53.55	53.65	53.62	53.82	54.40	56.13	53.7
15	**F 2003**	8	9.48	10.24	10.13	10.60	11.58	12.58	13.75	14.30	14.16	11.16
16	**C1849**	10.68	10.98	12.7	11.32	11.80	12.78	13.37	11.74	11.87	11.80	11.7
17	**C1564**	25.63	25.64	25.61	25.64	25.70	26.75	25.72	25.68	25.70	25.66	25.8
18	**D25**	29.6	26.1	25.67	25.78	25.00	25.65	25.49	26.00	26.00	26.02	24.4
19	**C1 146**	24.5	24.27	24.23	24.46	24.55	24.82	24.00	24.97	25.06	24.99	25.9
20	**U358A**	30.93	30.95	30.94	30.94	30.99	31.23	30.97	30.90	31.08	30.92	30.94
21	**U1146A**	103	103.5	103.1	103.2	103.23	103.26	103.35	103.40	103.45	103.62	104.13
22	**B-665A**	13.7	15.43	13.7	14.7	14.70	14.86	14.86	15.07	15.30	15.52	16.18
23	**B-683**	85.42	92.8	86.55	86.75	87.05	79.35	80.13	80.54	81.36	83.28	86.73
24	**E-2366**	28.98	29	29.4	29.9	28.22	29.26	29.33	29.40	29.45	29.49	30.08
25	**E-2377**	26.86	24.41	22.98	23.37	24.05	27.73	27.25	27.90	28.08	29.38	25.15
26	**E-1749**	25.74	27.56	28.1	28.9	27.05	27.63	28.27	27.90	29.00	27.20	27.8
27	**U-427A**	50.45	50.1	DRY	DRY	50.69	Dry	DRY	D	50.25	50.14	49.45
28	**U-502A**	121.9	120.94	119.9		119.30	120.67	120.18	120.80	120.00	120.00	12.1
29	**A878**	5.6	4.9	5.15	5.52	6.20	6.07	8.04	P+19.00	13.00	25.00	10.2
30	**A-1038**	40.9	40.91	41.5	41.78	42.04	42.04	42.05	42.60	42.69	42.46	42.89
31	**A874A**	15.5	16.54	16.39	16.2	18.25	18.00	18.67	16.85	18.60	16.52	17.2
32	**A-848-A-**	19.8	19.43	19.67	19.82		Dry	19.80	19.90	19.80	19.79	DRY
33	**A-691-A**	21.44	21.13	21.38	21.5	21.60	21.83	21.73	21.10	21.15	21.25	20.94
34	SBH1										45.78	…

Appendix 3

Detailed Result of Well Inventory (2002)

Appendix 3 Detailed Result of Well Inventory 2002 (1/3)

Zone	Sub Basin	Well Type	No. of Well by Status						No. of Operational Well by Water Use								Abstraction (m3/year) by Water Use								Irrigated Area (ha) by Source of Water							
			Operating	Intermittent	Temporaly not in use	Abandoned	Dry	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total
1	Wadi Al Mashamini	Borehole	12	0	4	7	0	23	9	3	0	0	0	0	0	12	472,985	256,871	0	0	0	0	0	729,855	76.8	0.2	0.0	0.0	0.0	0.0	0.0	77.0
		Dug Well	3	0	2	0	0	5	3	0	0	0	0	0	0	3	71,280	0	0	0	0	0	0	71,280	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3
		Dug / Bore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	15	0	6	7	0	28	12	3	0	0	0	0	0	15	544,265	256,871	0	0	0	0	0	801,135	78.1	0.2	0.0	0.0	0.0	0.0	0.0	78.3
2	Wadi Al Madini	Borehole	50	0	4	18	0	72	46	3	0	1	0	0	0	50	2,588,763	150,032	0	84,942	0	0	0	2,823,737	404.1	0.7	0.0	6.8	0.0	0.0	0.0	411.5
		Dug Well	1	0	2	1	0	4	1	0	0	0	0	0	0	1	5,087	0	0	0	0	0	0	5,087	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dug / Bore	1	0	0	0	0	1	1	0	0	0	0	0	0	1	25,639	0	0	0	0	0	0	25,639	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		Spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	52	0	6	19	0	77	48	3	0	1	0	0	0	52	2,619,489	150,032	0	84,942	0	0	0	2,854,463	404.3	0.7	0.0	6.8	0.0	0.0	0.0	411.7
3	Wadi Al Kharid	Borehole	42	1	7	22	0	72	38	1	1	2	0	0	0	42	2,283,516	31,450	20,008	169,179	0	0	0	2,504,153	300.8	0.0	2.3	14.4	0.0	0.0	0.0	317.5
		Dug Well	62	6	8	5	3	84	56	0	4	0	0	2	0	62	1,263,064	0	36,655	0	0	22,226	0	1,321,946	81.1	0.0	0.0	0.0	0.0	0.0	0.0	81.2
		Dug / Bore	1	0	1	0	0	2	1	0	0	0	0	0	0	1	28,318	0	0	0	0	0	0	28,318	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		Spring	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	106	7	16	27	3	159	96	1	5	2	0	2	0	106	3,574,898	31,450	56,663	169,179	0	22,226	0	3,854,416	391.1	0.0	2.3	14.4	0.0	0.0	0.0	407.8
4	Wadi Al Ma'adi	Borehole	14	0	4	23	1	42	12	0	2	0	0	0	0	14	265,361	0	22,392	0	0	0	0	287,753	138.6	0.0	1.4	0.0	0.0	0.0	0.0	140.0
		Dug Well	148	14	29	14	51	256	127	0	15	0	0	6	0	148	1,725,073	0	133,974	0	0	56,236	0	1,915,283	214.2	0.0	6.7	0.0	0.0	0.3	0.0	221.2
		Dug / Bore	19	1	1	6	1	28	16	0	2	0	0	1	0	19	225,164	0	32,993	0	0	25,639	0	283,796	61.4	0.0	4.5	0.0	0.0	0.0	0.0	66.0
		Spring	6	0	0	0	0	6	5	0	0	0	0	1	0	6	0	0	0	0	0	0	0	0	27.6	0.0	0.0	0.0	0.0	0.0	0.0	27.6
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	187	15	34	43	53	332	160	0	19	0	0	8	0	187	2,215,598	0	189,359	0	0	81,875	0	2,486,832	441.9	0.0	12.6	0.0	0.0	0.3	0.0	454.7
5	Wadi A'sir	Borehole	17	0	3	13	0	33	16	0	1	0	0	0	0	17	774,081	0	7,862	0	0	0	0	781,943	90.5	0.0	0.0	0.0	0.0	0.0	0.0	90.5
		Dug Well	402	42	16	62	17	539	377	0	19	0	0	5	1	402	5,461,856	0	167,530	0	0	54,540	6,577	5,690,502	355.8	0.0	0.1	0.0	0.0	0.0	0.0	355.9
		Dug / Bore	25	0	1	0	0	26	25	0	0	0	0	0	0	25	702,285	0	0	0	0	0	0	702,285	69.7	0.0	0.0	0.0	0.0	0.0	0.0	69.7
		Spring	18	0	0	0	0	18	9	0	6	0	0	3	0	18	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	462	42	20	75	17	616	427	0	26	0	0	8	1	462	6,938,221	0	175,392	0	0	54,540	6,577	7,174,730	516.0	0.0	0.1	0.0	0.0	0.0	0.0	516.1
6	Wadi Khulaqah	Borehole	26	0	4	16	5	51	26	0	0	0	0	0	0	26	1,528,271	0	0	0	0	0	0	1,528,271	239.0	0.0	0.0	0.0	0.0	0.0	0.0	239.0
		Dug Well	52	3	0	7	19	81	40	0	4	0	0	8	0	52	763,344	0	43,632	0	0	87,264	0	894,240	42.4	0.0	0.0	0.0	0.0	0.0	0.0	42.4
		Dug / Bore	3	0	0	0	0	3	3	0	0	0	0	0	0	3	54,907	0	0	0	0	0	0	54,907	3.4	0.0	0.0	0.0	0.0	0.0	0.0	3.4
		Spring	2	0	0	0	0	2	1	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	83	3	4	23	24	137	70	0	4	0	0	9	0	83	2,346,522	0	43,632	0	0	87,264	0	2,477,418	284.8	0.0	0.0	0.0	0.0	0.0	0.0	284.8
7	Wadi Qasabah	Borehole	40	1	4	16	8	69	38	1	1	0	0	0	0	40	2,073,698	55,037	78,663	0	0	0	0	2,207,399	225.1	0.0	0.0	0.0	0.0	0.0	0.0	225.1
		Dug Well	3	0	0	0	6	9	3	0	0	0	0	0	0	3	12,046	0	0	0	0	0	0	12,046	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.2
		Dug / Bore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	43	1	4	16	14	78	41	1	1	0	0	0	0	43	2,085,744	55,037	78,663	0	0	0	0	2,219,444	226.3	0.0	0.0	0.0	0.0	0.0	0.0	226.3
8	Wadi Al Huqqah	Borehole	189	0	20	46	22	277	187	2	0	0	0	0	0	189	14,767,549	73,382	0	0	0	0	0	14,840,931	1,935.1	0.0	0.0	0.0	0.0	0.0	0.0	1,935.1
		Dug Well	1	0	0	1	17	19	0	0	1	0	0	0	0	1	0	0	3,931	0	0	0	0	3,931	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dug / Bore	0	0	0	1	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	190	0	20	48	45	303	187	2	1	0	0	0	0	190	14,767,549	73,382	3,931	0	0	0	0	14,844,862	1,935.1	0.0	0.0	0.0	0.0	0.0	0.0	1,935.1
9	Wadi Bani Huwat	Borehole	945	1	114	235	11	1,306	897	16	19	9	2	2	0	945	49,416,203	2,293,580	490,227	666,413	20,862	51,476	0	52,938,760	5,904.4	0.9	1.8	33.3	0.0	0.0	0.0	5,940.6
		Dug Well	278	3	26	218	292	817	202	1	71	0	1	3	0	278	3,673,572	1,685	505,436	0	15,433	14,602	0	4,210,727	411.3	0.0	3.5	0.0	0.0	0.0	0.0	414.9
		Dug / Bore	76	0	7	40	10	133	68	2	4	1	0	1	0	76	2,848,515	87,160	15,988	34,322	0	3,931	0	2,989,916	524.4	0.1	0.5	7.2	0.0	0.0	0.0	532.1
		Spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	1,299	4	147	493	313	2,256	1,167	19	94	10	3	6	0	1,299	55,938,289	2,382,425	1,011,651	700,736	36,295	70,008	0	60,139,403	6,840.1	1.0	5.8	40.5	0.0	0.0	0.0	6,887.6
10	Wadi Thumah	Borehole	12	0	2	30	7	51	10	0	1	1	0	0	0	12	513,571	0	62,165	57,658	0	0	0	633,394	78.1	0.0	0.0	0.0	0.0	0.0	0.0	78.1
		Dug Well	211	8	40	35	37	331	195	0	16	0	0	0	0	211	1,559,818	0	153,220	0	0	0	0	1,713,037	193.2	0.0	1.0	0.0	0.0	0.0	0.0	194.2
		Dug / Bore	3	0	3	6	2	14	2	0	1	0	0	0	0	3	41,008	0	25,639	0	0	0	0	66,647	2.3	0.0	0.0	0.0	0.0	0.0	0.0	2.3
		Spring	7	0	0	0	0	7	3	0	3	0	0	1	0	7	0	0	0	0	0	0	0	0	11.7	0.0	0.1	0.0	0.0	0.0	0.0	11.8
		Dam / Pool	3	0	0	0	0	3	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	236	8	45	71	46	406	213	0	21	1	0	1	0	236	2,114,397	0	241,024	57,658	0	0	0	2,413,078	285.3	0.0	1.1	0.0	0.0	0.0	0.0	286.3

Appendix 3 Detailed Result of Well Inventory 2002 (2/3)

Zone	Sub Basin	Well Type	No. of Well by Status						No. of Operational Well by Water Use								Abstraction (m3/year) by Water Use								Irrigated Area (ha) by Source of Water							
			Operating	Intermittent	Temporaly not in use	Abandoned	Dry	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total
11	Wadi As Sirr	Borehole	587	0	32	134	0	753	577	0	9	0	0	1	0	587	33,549,859	0	222,486	0	0	57,142	0	33,829,487	2,976.3	0.0	0.0	0.0	0.0	4.5	0.0	2,980.8
		Dug Well	742	285	51	269	123	1,470	646	1	87	0	0	6	2	742	5,612,464	562	751,949	0	0	65,448	21,816	6,452,239	783.8	0.0	2.7	0.0	0.0	0.0	0.0	786.6
		Dug / Bore	30	0	0	6	1	37	28	0	2	0	0	0	0	30	528,968	0	80,336	0	0	0	0	609,304	99.6	0.0	0.0	0.0	0.0	0.0	0.0	99.6
		Spring	26	0	0	0	0	26	13	0	9	0	0	4	0	26	0	0	0	0	0	0	0	0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0
		Dam / Pool	2	0	0	0	0	2	1	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		Total	1,387	285	83	409	124	2,288	1,265	1	107	0	0	12	2	1,387	39,691,291	562	1,054,772	0	0	122,590	21,816	40,891,031	3,866.9	0.0	2.7	0.0	0.0	4.5	0.0	3,874.1
12	Wadi Al Furs	Borehole	189	0	12	53	2	256	187	1	1	0	0	0	0	189	12,464,041	117,936	2,246	0	0	0	0	12,584,224	1,195.9	0.0	0.0	0.0	0.0	0.0	0.0	1,195.9
		Dug Well	86	4	18	63	69	240	57	0	29	0	0	0	0	86	712,708	0	132,878	0	0	0	0	845,586	101.5	0.0	1.4	0.0	0.0	0.0	0.0	102.9
		Dug / Bore	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Spring	3	0	0	0	0	3	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	3.6
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	278	4	30	119	71	502	247	1	30	0	0	0	0	278	13,176,749	117,936	135,124	0	0	0	0	13,429,809	1,301.0	0.0	1.4	0.0	0.0	0.0	0.0	1,302.4
13	Wadi Al Iqbal	Borehole	262	0	31	53	3	349	255	5	2	0	0	0	0	262	15,852,949	276,759	62,899	0	0	0	0	16,192,607	2,850.9	19.4	0.0	0.0	0.0	0.0	0.0	2,870.3
		Dug Well	1	0	0	0	2	3	1	0	0	0	0	0	0	1	5,869	0	0	0	0	0	0	5,869	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
		Dug / Bore	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Spring	2	0	0	0	0	2	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	265	0	31	53	7	356	258	5	2	0	0	0	0	265	15,858,817	276,759	62,899	0	0	0	0	16,198,476	2,851.2	19.4	0.0	0.0	0.0	0.0	0.0	2,870.5
14	Wadi Zahr & Al Ghayl	Borehole	306	3	25	142	54	530	253	39	10	1	2	0	1	306	10,876,097	1,441,962	265,505	60,024	60,485	0	30,888	12,734,962	1,418.3	63.9	15.6	4.5	0.0	0.0	0.0	1,502.3
		Dug Well	28	0	0	31	117	176	10	0	14	0	0	4	0	28	153,953	0	111,858	0	0	43,632	0	309,443	14.1	0.0	1.4	0.0	0.0	0.0	0.0	15.5
		Dug / Bore	3	0	0	5	4	12	1	1	1	0	0	0	0	3	47,018	79,913	27,145	0	0	0	0	154,076	2.5	1.1	0.9	0.0	0.0	0.0	0.0	4.5
		Spring	5	0	0	0	0	5	1	0	3	0	0	1	0	5	0	0	0	0	0	0	0	0	0.9	0.0	0.5	0.0	0.0	0.0	0.0	1.4
		Dam / Pool	1	2	0	0	0	3	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	343	5	25	178	175	726	265	40	28	1	2	6	1	343	11,077,068	1,521,875	404,508	60,024	60,485	43,632	30,888	13,198,481	1,435.8	65.0	18.3	4.5	0.0	0.0	0.0	1,523.7
15	Wadi Hamdan	Borehole	81	1	20	21	6	129	55	10	8	7	1	0	0	81	1,732,525	397,173	197,957	490,444	21,370	0	0	2,839,468	263.6	26.8	9.9	5.9	0.0	0.0	0.0	306.1
		Dug Well	4	0	1	15	25	45	4	0	0	0	0	0	0	4	39,204	0	0	0	0	0	0	39,204	6.1	0.0	0.0	0.0	0.0	0.0	0.0	6.1
		Dug / Bore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	85	1	22	36	31	175	59	10	8	7	1	0	0	85	1,771,729	397,173	197,957	490,444	21,370	0	0	2,878,672	269.6	26.8	9.9	5.9	0.0	0.0	0.0	312.2
16	Wadi Al Mawrid	Borehole	336	0	65	101	27	529	148	52	80	46	6	0	4	336	7,400,492	12,024,460	4,816,535	3,755,350	247,915	0	103,680	28,348,431	651.5	0.7	16.2	25.5	0.1	0.0	2.1	696.1
		Dug Well	126	3	5	36	106	276	66	4	44	10	0	0	2	126	951,634	72,911	341,276	458,555	0	0	26,633	1,851,009	25.3	0.0	1.2	1.5	0.0	0.0	0.0	28.0
		Dug / Bore	10	0	0	2	2	14	5	1	2	1	0	0	1	10	183,137	36,953	68,763	49,896	0	0	1,134	339,883	6.7	0.0	0.5	0.0	0.0	0.0	0.0	7.1
		Spring	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	7	0	1	0	1	9	7	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	80.1	0.0	0.0	0.0	0.0	0.0	0.0	80.1
		Total	480	3	71	139	136	829	227	57	126	57	6	0	7	480	8,535,263	12,134,324	5,226,574	4,263,801	247,915	0	131,446	30,539,323	763.5	0.7	17.9	26.9	0.1	0.0	2.1	811.3
17	Wadi Sa'wan	Borehole	80	0	13	17	0	110	77	2	1	0	0	0	0	80	4,017,134	377,395	10,109	0	0	0	0	4,404,638	1,183.1	0.0	0.0	0.0	0.0	0.0	0.0	1,183.1
		Dug Well	556	53	41	152	160	962	459	1	92	0	0	4	0	556	3,463,285	5,584	582,633	0	0	43,632	0	4,095,133	254.5	0.0	3.9	0.0	0.0	0.0	0.0	258.4
		Dug / Bore	1	0	0	0	0	1	1	0	0	0	0	0	0	1	3,931	0	0	0	0	0	0	3,931	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		Spring	12	0	0	0	1	13	5	0	3	0	0	4	0	12	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	650	53	54	169	161	1,087	543	3	96	0	0	8	0	650	7,484,350	382,979	592,742	0	0	43,632	0	8,503,703	1,437.8	0.0	3.9	0.0	0.0	0.0	0.0	1,441.7
18	Wadi Shahik	Borehole	118	0	15	66	0	199	103	0	8	7	0	0	0	118	3,317,478	0	234,402	502,587	0	0	0	4,054,467	613.6	0.0	0.0	6.3	0.0	0.0	0.0	619.9
		Dug Well	823	152	85	123	189	1,372	758	2	59	0	0	2	2	823	6,678,658	21,816	561,567	0	0	21,816	21,816	7,305,673	770.1	0.0	1.1	0.0	0.0	0.0	0.0	771.2
		Dug / Bore	38	0	1	7	0	46	36	0	2	0	0	0	0	38	536,025	0	18,341	0	0	0	0	554,367	57.6	0.0	2.3	0.0	0.0	0.9	0.0	60.8
		Spring	21	0	0	0	0	21	3	0	6	0	0	12	0	21	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	1.8
		Total	1,000	152	101	196	190	1,639	900	2	75	7	0	14	2	1,000	10,532,161	21,816	814,311	502,587	0	21,816	21,816	11,914,507	1,443.0	0.0	3.4	6.3	0.0	0.9	0.0	1,453.7
19	Wadi Ghayman	Borehole	52	0	10	21	2	85	44	7	1	0	0	0	0	52	1,378,969	123,590	26,957	0	0	0	0	1,529,515	263.9	0.0	0.0	0.0	0.0	0.0	0.0	263.9
		Dug Well	314	66	27	45	65	517	293	0	16	0	0	4	1	314	2,427,664	0	172,874	0	0	43,157	10,908	2,654,603	312.1	0.0	9.2	0.0	0.0	0.0	0.0	321.4
		Dug / Bore	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4
		Spring	15	0	0	0	0	15	2	0	2	0	0	11	0	15	0	0	0	0	0	0	0	0	2.6	0.0	0.0	0.0	0.0	0.8	0.0	3.4
		Dam / Pool	2	0	1	0	1	4	1	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	383	66	39	66	68	622	340	7	19	0	0	16	1	383	3,806,633	123,590	199,831	0	0	43,157	10,908	4,184,119	580.0	0.0	9.2	0.0	0.0	0.8	0.0	590.0
20	Wadi Al Mulaikhy	Borehole	34	1	4	53	8	100	26	8	0	0	0	0	0	34	1,620,382	283,270	0	0	0	0	0	1,903,651	131.9	12.2	0.0	0.0	0.0	0.0	0.0	144.0
		Dug Well	77	2	3	9	44	135	68	0	5	0	0	4	0	77	669,326	0	44,939	0	0	43,632	0	757,897	55.1	0.0	0.8	0.0	0.0	0.0	0.0	55.9
		Dug / Bore	3	0	0	2	3	8	2	1	0	0	0	0	0	3	62,905	7,919	0	0	0	0	0	70,823	8.1	0.5	0.0	0.0	0.0	0.0	0.0	8.6
		Spring	18	0	0	0	0	18	2	1	11	0	0	4	0	18	0	0	0	0	0	0	0	0	1.8	0.0	0.3	0.0	0.0	0.2	0.0	2.4
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	132	3	7	64	55	261	98	10	16	0	0	8	0	132	2,352,612	291,188	44,939	0	0	43,632	0	2,732,371	196.9	12.6	1.1	0.0	0.0	0.2	0.0	210.8

Appendix 3 Detailed Result of Well Inventory 2002 (3/3)

Zone	Sub Basin	Well Type	No. of Well by Status						No. of Operational Well by Water Use								Abstraction (m3/year) by Water Use								Irrigated Area (ha) by Source of Water							
			Operating	Intermittent	Temporaly not in use	Abandoned	Dry	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total	Irrigation	Supply	Domestic	Tankers	Industry	Animal	Other	Total
21	Wadi Hizyaz	Borehole	68	0	4	95	2	169	58	3	2	4	1	0	0	68	2,642,561	260,077	79,934	268,553	2,016	0	0	3,253,141	262.4	0.0	0.0	10.4	0.0	0.0	0.0	272.7
		Dug Well	2	3	1	33	57	96	1	0	0	0	0	1	0	2	18,208	0	0	0	0	10,908	0	29,116	3.1	0.0	0.0	0.0	0.0	0.0	0.0	3.1
		Dug / Bore	1	0	0	4	0	5	1	0	0	0	0	0	0	1	44,388	0	0	0	0	0	0	44,388	3.2	0.0	0.0	0.0	0.0	0.0	0.0	3.2
		Spring	4	0	0	0	0	4	0	0	3	0	0	1	0	4	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	75	3	5	132	59	274	60	3	5	4	1	2	0	75	2,705,156	260,077	79,934	268,553	2,016	10,908	0	3,326,645	268.6	0.0	0.0	10.4	0.0	0.0	0.0	278.9
22	Wadi Akhwar	Borehole	75	0	2	35	3	115	69	0	5	0	0	0	1	75	5,270,136	0	256,018	0	0	0	148,680	5,674,834	320.9	0.0	0.0	0.0	0.0	0.0	0.0	320.9
		Dug Well	104	12	0	13	23	152	96	0	6	0	0	1	1	104	1,886,450	0	55,426	0	0	10,908	5,292	1,958,075	95.2	0.0	0.0	0.0	0.0	0.0	0.0	95.2
		Dug / Bore	2	1	0	0	1	4	2	0	0	0	0	0	0	2	111,410	0	0	0	0	0	0	111,410	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7
		Spring	3	0	0	0	0	3	1	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Dam / Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total	184	13	2	48	27	274	168	0	13	0	0	1	2	184	7,267,995	0	311,443	0	0	10,908	153,972	7,744,319	418.7	0.0	0.0	0.0	0.0	0.0	0.0	418.7

Appendix 4

Detailed Well Information for Urban Water Supply

Appendix 4 Detailed Well Information for Urban Water Supply (SWSLC) (1/5)

No	Well Field	Area	Well No	UTM N	UTM E	Altitude (masl)	Depth (m)	Dig Date	Operation date	Well situation	contract No.
1	Western well field	Omran line	ST1	1,701,599	414,786	2,251	417	1989	1990		
2	Western well field	Omran Road	ST5	1,702,935	414,328	2,260	400	1988	1989		
3	Western well field	Thahban	ST6	1,705,394	412,631	2,238	323	1990	1990		
4	Western well field	Thahban	ST7	1,704,798	412,360		374	91		decrease in production	
5	Western well field	Thahban	ST8	1,705,323	412,682		200	77		dry	
6	Western well field	Omran Road	ST9	1,705,856	412,679		335	90	93		
7	Western well field	Omran Road	ST10	1,705,170	413,247	2,249	368	92	93		
8	Western well field	Omran Road	ST11	1,703,122	414,328	2,239	400	88	89	decrease in production	
9	Western well field	Omran road- Jader	ST12	1,706,500	412,446	2,215	294	90	91	decrease in production	
10	Western well field	Omran road- Jader	ST13	1,707,294	412,097	2,211	312	90	91	decrease in production	
11	Western well field	Thahban	P1	1,707,426	409,566	2,223	292	90	91	stopped	
12	Western well field	Omran line	P6	1,703,069	413,077	2,282	410	88	91		
13	Western well field	Thakban	P7	1,707,834	409,995		190	78	2002	dry	
14	Western well field	Thahban	P8R	1,704,800	413,005	2,220	380	87		dry	(SWEP-A/2001-14)
15	Western well field	Thakban	P9	1,707,840	409,193		160	78		dry	
16	Western well field	Thahban	P10	1,703,816	413,503	2,243	355	90	91	decrease in production	
17	Western well field	Thahban	P13	1,704,211	413,296	2,236	385	2002	2002	deeping through digging	(SWEP-C/2001-16)
18	Western well field	Thahban village	P14	1,707,067	410,481		220	79		dry	
19	Western well field	Wadi Thahir Road	P15	1,709,557	409,405	2,225	212	87	88	decrease in production	
20	Western well field	Al-hasba	P16	1,701,227	413,863	2,218	340	2003	2003		(SWEP-C/2001-16)
21	Western well field	Thahban	P17	1,708,837	400,656	2,216	210	2002	2002	dry	(SWEP-C/2001-16)
22	Western well field	Al-hasba	P18	1,700,639	414,214	1,149	320	92	92		
23	Western well field	Al-Hasba-Sawad Hanash	P19	170,030	409,972	2,249	400	88	89	decrease in production	
24	Western well field	Thahban	P20	1,708,393	409,934		336	94	94		
25	Western well field	Omran Road	P21	1,709,961	410,159	2,216	213	88	89	decrease in production	
26	Western well field	Al-hasba	P22	1,700,729	414,321	2,207	410	88	90		
27	Western well field	Al-Jaraf	P23	1,703,727	414,407	????	393	89	94		
28	Western well field	Al-Jaraf	P24				300	88	99		
29	Western well field	Libyan City	P25	1,702,757	413,734	2,282	213	88	2002		
30	Western well field	Al-hasba	P26	1,700,607	414,109	2,198	428	2001	2001		(SWEP-B/2001-17)
31	Western well field	Omran line	NWSA	1,701,639	414,480	2,265	402	2001	2002		SWSSP-7

Appendix 4 Detailed Well Information for Urban Water Supply (SWSLC) (2/5)

No	Well Field	Area	Well No	UTM N	UTM E	Altitude (masl)	Depth (m)	Dig Date	Operation date	Well situation	contract No.
32	Western well field	Thahban	D.H	1,706,101	413,106	2,250	357	2001	2003		SWSSP-7
33	Eastern well field	Al-hasba	TP1	1,701,027	415,330	2,268	400	2001	2001		SWSSP-7
34	Eastern well field	Al-hasba	TP2	1,702,015	415,381	2,265	400	2001	2001		SWSSP-7
35	Eastern well field	Sawan	B	1,701,338	418,602	2,264	418	87	89		
36	Eastern well field	Al-Nasser St.	C	1,701,094	417,309	2,267	389	2003	2003		(SWEP-C/2001-16)
37	Eastern well field	Mareb Road	D	1,702,475	417,264	2,253	436	2003	2003		(SWEP-C/2001-16)
38	Eastern well field	Mareb Road	E	1,703,281	418,018	2,267	400	87	89		
39	Eastern well field	Saref Road	F	1,703,904	419,324	2,256	406	91	92		
40	Eastern well field	Al-Khaneq	G	1,702,725	419,194	2,260	383	2002	2002		(SWEP-C/2001-16)
41	Eastern well field	Mareb Road- Saref	J	1,706,903	420,207	2,245	251	82	84		
42	Eastern well field	next to Red Crescent	K	1,704,601	419,480	2,258	425	91	91		
43	Eastern well field	Hibra- Wadi Jameel	L	1,700,485	417,002		277	81	84		
44	Eastern well field	Saref Road	Q	1,703,132	419,956	2,270	410	1988	1991		
45	Eastern well field	Shoub Dam	SS	1,701,178	416,426	2,253	340	2001	2001		******
46	Eastern well field	Hibra	W	1,702,100	416,950	2,235	386	2001	2003		(SWEP-B/2001-17)
47	Eastern well field	Hibra	Y	1,700,542	417,048	2,245	389	2001	2004		(SWEP-B/2001-17)
48	Eastern well field	Sawan	T	1,701,005	417,885	2,248	400	2001	2004		(SWEP-B/2001-17)
49	Eastern well field	Sawan	MZ-2				*****	******	******		2004/16
50	Eastern well field	Mareb Road	KI				415	2005	new		2004/16
51	Haddah well field	Hadda- 14 October St.	EX-S	1,691,674	414,157	2,332	884	2001	2002		SWSSP-7
52	Haddah well field	Hadda- Housing Village	H1				260	84		dry	
53	Haddah well field	Hadda- Housing Village	H2				374	94		dry	
54	Haddah well field	Hadda	H3	1,690,912	414,092	2,315	450	2001	2001		******
55	Haddah well field	Hadda- 14 October St.	H4	1,691,719	414,127	2,343	312	92	2002		
56	Haddah well field	Hadda- Housing Village	H5	1,690,591	412,906	2,295	313	92		dry	
57	Haddah well field	Hadda	H6				306			dry	
58	Haddah well field	Hadda- Housing Village	H7	1,691,798	414,068	2,312	360	96	97		
59	Haddah well field	Hadda- 50 St. Sana	H8	1,690,907	412,506	2,367	890	2000	2000		SWSSP-7
60	Haddah well field	Hadda	H9				412	99		dry	
61	Haddah well field	Hadda	H10				300	98		failure	
62	Haddah well field	Hadda	H11	1,692,300	411,075	2,360	517			failure	(SWEP-A/2001-14)

Appendix 4 Detailed Well Information for Urban Water Supply (SWSLC) (3/5)

No	Well Field	Area	Well No	UTM N	UTM E	Altitude (masl)	Depth (m)	Dig Date	Operation date	Well situation	contract No.
63	Haddah well field	Hadda	H12	1,692,950	411,070	2,250	504			failure	(SWEP-B/2001-17)
64	Haddah well field	Hadda	H13								
65	Haddah well field	Hadda -AlAshash	HA	1,691,410	411,005	2,371	851	2002			SWSSP-7
66	Asser well field		AS1	1,695,865	411,840	2,285	465			failure	(SWEP-D/2001-15)
67	Asser well field	Al-taiseer neighbourhood	AS2	1,693,669	410,936	2,230	400	95	96		
68	Asser well field	Agricukture -AlKadir	AS3	1,697,112	413,154	2,298	320	95	96		
69	Asser well field		AS4	1,695,604	411,790	2,278	803				
70	Asser well field	Fach Atan	AS4R				272	96	97		2003/3
71	Asser well field	Political neighbourhood	AS5				332	96	97		
72	Asser well field	Green Dome	AS6	1,696,845	411,905	2,295	404	96	******	failure	(SWEP-D/2001-15)
73	Asser well field	Conference Hall	AS7				403		98	dry	
74	Asser well field	Al-qadissya	AS8				712	2001	2002		
75	Asser well field	Al-Zubairi Garden	SA-1	1,696,222	413,594	2,280	712	2001	2002		SWSSP-7
76	Asser well field	Asser	AS9	1,697,009	410,817	2,314	467	2000	2000		
77	Asser well field	Asser Village	AS10				475	2001			
78	Asser well field	Fach Atan	AS11	1,695,750	410,854	2,315	567	2001	2001		(SWEP-B/2001-17)
79	Asser well field	Fach Atan	AS12				******	******	******		
80	Asser well field	Conference Hall	ASR1	1,697,290	411,696	2,312	755	2002	2002		SWSSP-7
81	Asser well field	Asser Tanks	ASR-2	1,696,367	410,938	2,308	760	2002	2002		SWSSP-7
82	Asser well field	UN	UN	1,694,050	413,250	2,365	680	2002	2002		(SWEP-D/2001-15)
83	Asser well field	Al-Kae	Z1	1,697,198	413,281	2,298	366	99	99		
84	Asser well field	Khair and Salam neighbourhood	MZ-1				535	2004			
85	Asser well field	70 city	M70	1,694,676	414,160	2,296	850	91	93		
86	Asser well field	70 city	M71				900	2002	*****	*****	*****
87	Asser well field	70 city	SP			2,288	900	2002	2004		
88	Asser well field	حده	H3R				450				SWSSP-7
89	Asser well field	فج عطان	AS4R				803				2004/16
90	Musayek well field	Nikem	M1	1,698,282	417,745	2,312	405	90	92		
91	Musayek well field	Nikem	M2	1,697,180	417,990	2,312	446	89	91		
92	Musayek well field	Kawlan St.	M3	1,694,599	417,753	2,398	537	2001	2001		*******
93	Musayek well field	1st water area	M4	1,698,207	416,665	2,325	442	2001	2001		(SWEP-D/2001-15)

Appendix 4 Detailed Well Information for Urban Water Supply (SWSLC) (4/5)

No	Well Field	Area	Well No	UTM N	UTM E	Altitude (masl)	Depth (m)	Dig Date	Operation date	Well situation	contract No.
94	Musayek well field	Sawan- house campus	M5				360	94	94		
95	Musayek well field	Maseek Tanks	M6	1,698,090	416,825	2,318	262	94	2001	dry	
96	Musayek well field		Mr6	1,698,370	416,826	2,315	600				
97	Musayek well field	Thafar neighborhood	M7				297	94	97		
98	Musayek well field	Al-qadissya area	M8	1,693,461	417,255	2,294	204	94	2002	dry	
99	Musayek well field	majid neighbourhood	M9	1,695,625	417,193	2,312	95	295	96		
100	Musayek well field	majid neighbourhood	M9R				480	2005	******		2003/3
101	Musayek well field	Nikoum -camp	M10R				450	2001	2001		*******
102	Musayek well field	beer Abeed	M11	1,694,350	416,855	2,345	302	96	96	decrease in level	(SWEP-D/2001-15)
103	Musayek well field	beer Abeed	M11R				******	******	******	still digging	2004/16
104	Musayek well field	Nikem	M12				400	96	97	dry	
105	Musayek well field	Batel 70 Neighbourhood	M14	1,690,668	418,122	2,310	330	97	99		
106	Musayek well field	Al-Noor neighbourhood	M15	1,695,910	416,810	2,312	360	98	99		
107	Musayek well field	Sawan	M16				394	2001	2003		******
108	Musayek well field	Nikem	M17	1,698,250	416,505	2,345	420	2001	2002		(SWEP-A/2001-14)
109	Musayek well field	Nikem	M18	1,698,030	418,550	2,295	485	2002	2003		
110	Musayek well field	Nikem	M19	1,636,800	417,875	2,340	475	2002	2004		
111	Musayek well field	70 city	M20				258			dry	
112	Musayek well field	70 city	M21				200			dry	
113	Musayek well field	70 city	M22				270			dry	
114	Musayek well field	70 city	M23				200			dry	
115	Musayek well field		M24	417,679	2,262	820					
116	Musayek well field	Maseek Tanks	MR	1,698,308	416,825	2,337	600	2001	2001		SWSSP-7
117	Musayek well field	Al-qadissya area	KA	1,693,470	417,245	2,330	823	2002	2002		SWSSP-7
118	Musayek well field	70 city	M19-A	1,689,477	417,176	2,315	1000	2002	2003		SWSSP-7
119	Musayek well field	Bainoun St.	M24				854	2004	new		2003/3
120	Musayek well field	Taiz St.	OS	1,694,694	416,716	2,303	766	2001	2002		SWSSP-7
121	Musayek well field	Houzaiz - Alwahda area	HZ	1,685,107	419,176	2,343	470	2002	2004		تكليف
122	Musayek well field	Hiera	N1				360	95	96		
123	Musayek well field	Sheraton St.	N2R				482	2004	2004		2003/3
124	Musayek well field	Heira -Bank city	N3	1,699,120	416,455	2,222	350	2002	2003		(SWEP-A/2001-14)

Appendix 4 Detailed Well Information for Urban Water Supply (SWSLC) (5/5)

No	Well Field	Area	Well No	UTM N	UTM E	Altitude (masl)	Depth (m)	Dig Date	Operation date	Well situation	contract No.
125	Musayek well field	Al-Fawares Sawan Neighbourhood	MZ-2				480	2005			
126	Musayek well field	Rawda Shahran	R1	1,704,702	418,930	2,261	360	89	95		
127	Musayek well field	Rawda Al-mazafa	R2	1,707,764	420,478	2,237			93		
128	Musayek well field	Khashim Al-Bakra	R3	1,705,284	418,158	2,242			97		
129	Musayek well field	West Rawda	R4	1,706,200	415,355	2,223	335	2001	2004		(SWEP-A/2001-14)
130	Musayek well field	Khashim Al-Bakra	R3R				380	2003	new		2003/3
131	Musayek well field	Bani Harith								dry	
132	Musayek well field	Rawda								dry	
133	Musayek well field	Rawda								dry	
134	Musayek well field	Rawda								dry	
135	Musayek well field	Rawda									
136	Musayek well field	Bani harith									

Appendix 5

Summarized Wastewater Quality Analysis

Appendix 5 Summarized Monthly Waste Water Quality Analysis Results (2005-2006) (1/2)

		INFLUENT								FINAL EFFLUENT							
		TEMP (oC)	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)
Jan/2005	Min	19.8	7.19	400	994	1,680	136.2	46.3	845	7.32	14	49	99	25.5	16.3	3.5	988
	Max	25.3	7.63	1,324	1,220	2,831	213.0	97.0	1,254	7.94	82	82	284	56.3	35.6	11.3	1,302
	Ave	22.8	7.37	1,048	1,108	2,376	185.7	57.5	1,065	7.57	48	67	205	41.9	20.0	9.4	1,108
	Samples	10	31	31	10	11	10	10	10	31	31	10	10	10	8	10	10
Feb/2005	Min	21.8	7.2	480	967	1,535	102.0	39.5	780	7.4	32	50	82	34.2	14.4	3.2	907
	Max	27.3	7.6	1,246	1,162	2,561	201.0	90.0	1,216	7.8	104	88	186	59.0	35.0	10.7	1,075
	Ave	24.7	7.3	953	1,026	1,984	171.3	58.4	1,039	7.5	55	70	130	42.3	23.6	6.8	1,005
	Samples	9	28	28	9	9	9	9	9	28	28	9	9	9	5	9	9
Mar/2005	Min	**	7.2	484	875	1,340	88.0	24.3	894	7.3	13	48	99	38.6	1.3	1.4	948
	Max	26.8	7.6	1,152	1,092	2,351	194.5	83.0	1,367	7.8	236	96	184	93.0	28.4	10.6	1,317
	Ave	22.9	7.3	932	980	1,885	156.4	49.2	1,097	7.6	77	73	140	59.5	18.5	4.9	1,133
	Samples	11	31	31	10	10	10	10	10	31	31	10	10	10	10	9	10
Apr/2005	Min	23.9	7.2	546	989	1,985	149.0	38.6	922	7.3	27	45	165	38.4	4.3	13.5	975
	Max	28.3	7.5	1,292	1,187	2,733	197.5	62.0	1,217	7.9	113	104	215	78.8	7.4	28.6	1,365
	Ave	25.9	7.3	936	1,085	2,354	179.9	52.2	1,087	7.6	64	81	196	53.1	6.0	18.8	1,143
	Samples	8	30	30	9	9	9	9	9	30	30	9	9	7	9	8	9
May/2005	Min	**	7.1	396	871	1,456	143.0	46.5	866	7.2	28	58	98	39.0	17.6	5.8	940
	Max	**	7.5	1,234	1,217	2,511	193.6	60.0	1,246	7.8	708	85	220	59.0	26.2	11.5	1,210
	Ave	**	7.3	942	1,005	1,849	173.9	55.4	1,033	7.5	87	74	180	50.2	21.1	8.3	1,033
	Samples	**	26	26	8	8	8	7	8	26	26	8	8	8	3	8	8
Jun/2005	Min	**	6.9	296	944	810	167.0	**	1,044	7.4	36	68	62	30.0	41.5	4.8	950
	Max	**	7.7	994	1,184	1,893	227.0	**	1,056	8.3	320	165	275	54.5	41.5	9.4	982
	Ave	**	7.3	722	1,065	1,352	197.0	**	1,048	7.5	84	99	171	42.3	41.5	7.1	966
	Samples	**	17	24	3	2	2	**	3	17	24	4	3	2	1	2	2
Jul/2005	Min	**	7.0	256	865	880	108.0	83.5	632	7.4	26	94	155	66.0	10.5	4.6	536
	Max	**	8.2	1,792	1,236	3,680	220.0	163.7	1,252	8.3	172	278	420	114.0	49.9	128.0	1,044
	Ave	**	7.5	753	1,026	1,966	150.9	117.5	948	7.8	78	194	284	92.5	30.5	34.0	806
	Samples	**	17	27	8	9	9	4	9	17	26	8	6	9	8	8	10
Aug/2005	Min	**	7.0	342	944	1,585	105.5	119.6	678	7.4	32	22	90	36.5	6.9	0.2	656
	Max	**	7.8	1,624	1,248	2,865	250.4	151.6	1,194	8.1	100	134	115	123.0	33.1	15.5	1,093
	Ave	**	7.3	964	1,075	1,926	154.6	132.2	953	7.8	62	53	97	88.3	24.8	4.2	886
	Samples	**	18	26	6	6	6	4	8	18	26	6	6	6	6	6	10
Sep/2005	Min	**	6.7	564	908	1,880	114.5	113.3	1,129	7.6	48	56	115	59.0	23.4	0.7	1,070
	Max	**	7.6	1,832	1,372	3,430	198.0	130.0	1,147	7.9	146	88	180	103.5	38.8	9.5	1,113
	Ave	**	7.1	1,115	1,135	2,346	150.3	121.7	1,138	7.7	96	71	152	90.1	28.8	3.8	1,087
	Samples	**	20	22	5	5	5	2	3	19	22	5	5	5	5	5	3
Oct/2005	Min	**	6.3	296	1,236	2,220	110.5	100.5	600	6.9	25	36	155	50.0	10.2	4.0	646
	Max	**	7.4	3,344	1,420	2,790	164.0	100.5	600	7.8	636	46	225	82.0	58.8	11.0	646
	Ave	**	7.0	1,059	1,343	2,443	131.3	100.5	600	7.6	130	41	187	62.0	28.6	8.2	646
	Samples	**	8	28	3	3	3	1	1	7	28	3	3	3	3	3	1
Nov/2005	Min	**	7.4	416	1,128	1,724	125.6	**	**	7.6	40	31	116	40.4	22.4	6.5	**
	Max	**	7.8	1,312	1,308	2,952	159.6	**	**	8.0	3,512	277	332	113.2	48.1	9.3	**
	Ave	**	7.6	898	1,235	2,282	142.6	**	**	7.9	399	99	191	90.2	32.5	7.6	**
	Samples	**	5	19	4	4	4	**	**	5	19	4	4	4	4	4	**
Dec/2005	Min	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
	Max	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
	Ave	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
	Samples	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Jan/2006	Min	**	7.7	480	748	1,135	133.5	83.6	**	7.83	54	93	148	105.5	43.1	6.0	**
	Max	**	7.7	2,162	1,192	2,925	162.0	83.6	**	7.83	5,212	724	785	135.5	665.6	9.0	**
	Ave	**	7.7	1,012	1,050	1,946	143.9	83.6	**	7.83	1,559	350	497	120.2	217.9	7.8	**
	Samples	**	1	20	4	4	4	1	**	1	20	4	4	4	4	4	**
Feb/2006	Min	**	7.7	348	1,104	1,696	76.4	104.8	1,245	8.0	40	35	64	65.6	30.5	10.0	1,150
	Max	**	7.8	1,370	1,176	2,224	207.0	118.6	1,245	8.0	2,216	120	304	137.2	71.5	12.4	1,150
	Ave	**	7.7	717	1,133	1,944	151.2	112.1	1,245	8.0	328	63	163	103.9	51.5	11.2	1,150
	Samples	**	2	21	4	5	5	4	1	1	19	4	4	5	5	5	1
Mar/2006	Min	**	6.7	304	1,336	1,310	152.8	100.6	**	**	50	25	124	100.0	26.2	3.6	**
	Max	**	6.7	1,556	1,500	2,132	215.2	115.3	**	**	452	197	322	157.6	27.1	12.8	**
	Ave	**	6.7	841	1,418	1,717	182.5	108.0	**	**	123	71	183	125.9	26.6	9.7	**
	Samples	**	1	19	2	4	3	2	**	**	17	12	4	4	2	4	**
Apr/2006	Min	**	**	268	800	1,604	118.0	100.7	**	**	28	22	112	115.6	19.3	1.2	**
	Max	**	**	2,080	1,168	2,072	169.6	126.8	**	**	1,612	239	280	122.8	50.8	12.0	**
	Ave	**	**	838	1,009	1,763	145.9	111.4	**	**	248	117	177	118.1	31.9	8.2	**
	Samples	**	**	21	3	3	4	3	**	**	20	4	3	4	4	4	**
May/2006	Min	**	**	384	748	816	106.4	71.9	**	**	60	77	112	98.8	22.7	4.8	**
	Max	**	**	2,324	1,104	2,052	167.6	105.5	**	**	456	292	232	103.8	36.1	12.0	**
	Ave	**	**	970	953	1,552	130.0	88.7	**	**	144	182	171	101.0	28.2	8.9	**

Appendix 5 Summarized Monthly Waste Water Quality Analysis Results (2005-2006) (2/2)

		INFLUENT								FINAL EFFLUENT							
		TEMP (oC)	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)
	Samples	**	**	17	3	3	3	2	**	**	18	6	3	3	3	3	**
Jun/2006	Min	**	**	340	**	**	**	**	**	**	36	28	**	**	**	**	**
	Max	**	**	2,120	**	**	**	**	**	**	280	330	**	**	**	**	**
	Ave	**	**	924	**	**	**	**	**	**	98	112	**	**	**	**	**
	Samples	**	**	19	**	**	**	**	**	**	12	8	**	**	**	**	**
Jul/2006	Min	**	**	252	936	1,344	126.4	86.6	**	**	28	25	88	61.2	8.4	8.8	**
	Max	**	**	1,708	1,408	1,972	180.0	102.2	**	**	180	208	148	104.8	62.7	14.0	**
	Ave	**	**	878	1,177	1,583	143.7	95.8	**	**	90	82	116	90.9	33.7	11.5	**
	Samples	**	**	23	4	4	4	4	**	**	19	14	4	4	4	4	**
Aug/2006	Min	**	**	340	1,032	1,304	121.0	74.4	**	**	28	21	104	64.0	26.0	8.8	**
	Max	**	**	1,628	1,196	1,896	153.0	106.0	**	**	176	131	144	90.0	88.0	16.4	**
	Ave	**	**	622	1,114	1,568	136.0	89.8	**	**	72	65	129	73.3	50.2	12.7	**
	Samples	**	**	24	2	3	3	3	**	**	23	6	3	3	3	3	**
Sep/2006	Min	**	**	332	1,260	2,056	125.8	72.4	**	**	24	38	108	93.6	27.6	7.8	**
	Max	**	**	1,912	1,284	2,136	135.6	103.0	**	**	176	243	146	102.8	28.5	11.2	**
	Ave	**	**	707	1,272	2,096	130.7	87.7	**	**	81	109	127	98.2	33.1	9.5	**
	Samples	**	**	23	2	2	2	2	**	**	21	7	2	2	2	2	**
Oct/2006	Min	**	**	204	1,088	1,892	107.6	85.0	**	**	28	56	128	82.4	18.5	10.8	**
	Max	**	**	1,808	1,576	2,200	154.4	104.5	**	**	248	223	228	98.4	49.4	18.0	**
	Ave	**	**	684	1,305	1,979	136.3	93.8	**	**	123	145	192	89.0	38.3	13.7	**
	Samples	**	**	25	4	4	4	4	**	**	23	5	4	4	4	4	**
Nov/2006	Min	**	**	424	1,168	1,560	127.2	85.8	**	**	44	56	128	82.4	18.5	9.6	**
	Max	**	**	1,304	1,372	2,112	170.0	99.0	**	**	184	101	168	124.8	38.0	18.0	**
	Ave	**	**	687	1,245	1,726	142.4	92.8	**	**	99	83	146	99.5	31.2	13.5	**
	Samples	**	**	21	5	5	5	5	**	**	21	6	6	6	6	6	**
Dec/2006	Min	**	**	348	1,004	1,500	117.2	92.8	**	**	44	60	132	88.8	16.1	8.4	**
	Max	**	**	1,316	1,152	2,664	151.6	114.2	**	**	164	118	176	126.0	36.9	16.0	**
	Ave	**	**	680	1,085	2,158	140.2	101.6	**	**	86	85	159	114.6	27.1	12.5	**
	Samples	**	**	19	5	5	5	5	**	**	17	5	4	5	5	5	**

Appendix 6

Questionnaire for Village Authority
(Awareness Survey)

Appendix 6 Awareness Survey

Questionnaire for Village Authority
(Sheik, Aqil, Amin, WUG/WUA president)

A) INFORMATION ABOUT THE SITE & THE RESPONDENT

1) Questionnaire No.: ____________________
2) Wadi: ____
____
3) Village: ____
4) District: ____
5) Sub - Basin: ____
6) Name of Respondent: ____________________________________
7) Address: ____
____
8) Sex (Male, Female): ____________________________________
9) Age: ____
____
10) Position in the village: __________ (Sheikh, Aqil, Amin, Imam, , WUG / WUA president)
11) Name of Investigator: ______________________________

Signature: __________________________

12) Date of Survey: ___________________________________

Data of this questionnaire is confidential and should be used only for the intended purpose.

B) GENERAL INFORMATION

1) Details of current population

	Name of community	No. of household	No. of children		No. of adults	
			male	female	male	female
1						
2						
3						
4						
5						
6						
7						

2) Details of occupations of the villagers

No.	Occupation	No. of persons
1	Government Service	
2	Private Service	
3	Agriculture	
4	Animal Husbandry	
5	Business	
6	Landless Laborer / daily laborer	
7	Rural Artisans	
8	Others	
	Total	

3) Demographic trends for the past 15 years (one option)

- □ Dramatically increased due to influx of people with expansion of residential housing of the village.
- □ Dramatically increased due to influx of people but the residential housing of the village remained unchanged.
- □ Stable apart from natural population increase.
- □ Dramatically decreased due to migration of people.

4) Available amenities/services and accessibility

4.1. What is the distance from village to nearest agricultural market?

4.2. What is the time taken to the nearest agricultural market?

4.3. What is the type of access road (Earthen, Asphalt, Gravel).

4.4. What type of telephone available in the village? (landline, mobile, none)

4.5. Is there bank in the village?

4.6. Is there electricity network available in the village?

□ Yes (Local, Public, Other).

□ No

5) Schools

5.1. Is there any school in the village?

□ Yes

□ No (move to 5.3)

5.2. What type of schools is available in the village?

(After asking this question Move to Q 6)

No	Classification of Schools	No. of Schools	No. of Boys Student	No. of Girls Students
1	Basic Education			
2	Secondary Education			
3	Basic & Secondary Education			
4	**Total**			

5.3. What is the distance to the nearest school? ____________________________

6) Nearest Health Services

6.1. Is there any health facility available in the village?

□ Yes

□ No (move to 6.3)

6.2. What type of health facility available in the village? (After asking this question Move to Q 7)

No.	Type of Health Facility	Available medical Services	No. of Doctors	No. of primary health workers	No. of midwives	No. of Nurses
1	Health unit					
2	Health centre					
3	Hospital					

6.3. What is the Nearest Health Services to the village and how fare it is from the village?

____

7) Morbidity for the past three years (2004 - 2006). Data should be obtained from the health facility in the village (if such facility exists). Where there is not health facility, the respondent should be prompted to identify the most common health problems in order or priority.

Diseases	No. of cases in each category			Occurrence in month
	Male	Female	Children	
Malaria				
Cholera				
Diarrhea				
Bilharzias				
Diphtheria				

8) Mortality for past three years (2004 - 2006)

Year	Category	No. of Cases	Reason, if known
2004	Infant		
	Maternal		
2005	Infant		
	Maternal		
2006	Infant		
	Maternal		

9) What are the most suited communication channels to give information for the community?

	Mosque Preaching	Television	Radio	News paper	Poster / Hoardings	face-to-face	School	Others (specify)
For men								
For women								
For children								

C) LAND USE AND AGRICULTURAL ACTIVITIES

1) What is the total area of land? ___ Libna

2) Land extension trends in the past 15 years

☐ The reasons for the increase in the areas of lands ____________________

____

☐ The reasons of the decrease in the areas of lands ____________________

____

☐ There is no change

3) Details of land use

Distribution of land		Land use pattern	
Type of lands	Area of lands (libna)	Type of lands	Area of lands (libna)
Government owned lands		Waste lands	
Private owned lands		Grazing lands	
Public lands		Forest lands	
Endowment lands		Agricultural lands	
Total		Others	
		Total	

4) General cropping pattern of the village

No.	**Crop**	**Sowing time (month)**	**Irrigated area (libna)**	**Unirrigated area (libna)**	**Harvesting time (month)**
1	Grapes				
2	Qat				
3	Peach				
4	Gage				
5	Almond				
6	Prickly pear				
7	Pomegranate				
8	Onion				
9	Tomatoes				
10	Potatoes				
11	Cereal in general				
12					
13					
14					
15					
16					

D) WATER SUPPLY FOR DOMESTIC USE

1) Source and quality of drinking water to the community

Source	number of sources	No. of house holds	Quality of drinking water *	Seasonal availability
Deep well (artisans)				
Shallow well (dug well/hand dug)				
Dug bore				
Ponds				
Springs				
Others (specify)…....…..				

* Quality of drinking water: Good, fair, bad

2) Quantity of available water for domestic use

☐ enough ☐ fair ☐ inadequate ☐ very inadequate

3) Average of daily household requirement of water ____________ (liters/day)

_________ (Ave. no. of household members)

4) Average of water used by animals on each H/H level: ________ (liters/day)

__________________________ Average number of animals for each H/H

5) How many households having animals? _________________

6) Is there piped network system available in the village?

☐ Yes (move to 8)

☐ No

7) Who is the responsible person usually fetching water in household?

☐ adult males ☐ adult females ☐ children

8) Has the village experienced drinking water scarcity in the last 10 years?

☐ Yes ☐ No (move to 10)

9) How many times the village has experienced drinking water scarcity in the last 10 years?

____

10) Were the wells dried up in the village in the last 10 years?

☐ Yes ☐ No (move to 13)

11) How many wells were dried up in the village in the last 10 years?

____

12) How did the community deal and cope with water scarcity?

____

____

____

13) Details of water harvesting structures within the village

Type of structures	Total no. of structures	no. of structures working	no.. of structures not working	Date and reasons of not working
Collection tanks				
Recharge dams				
Subsurface dams				
Farm ponds				
Recharge wells				
Other (specify)……..				

E) IRRIGATION WATER REQUIREMENTS

1) Irrigation water sources (multiple options)

Type of Sources	No. of sources	Area of land irrigated (libna)	
		Rainy	Other seasons
Deep wells			
Shallow wells			
Ponds / reservoirs			
Rain – fed			
Others			

2) Network of irrigation water (multiple options)

Type of Irrigation Network	Length (m)	Area of land irrigated (libna)	
		Rainy	Other seasons
Canals			
Pipe networks			
Ditch drains			
Others			

3) Do the villagers experience the depletion of ground water level?

☐ Yes ☐ No (GOTO to F)

4) What are the reasons for the depletion of ground water level??

☐ Scarcity of rainfall ☐ Excessive use water for irrigation
☐ Uncontrolled drilling of wells ☐ Increase the depth of wells
☐ Unavailability of water dams ☐ Other (specify) ____________________

5) How do the people look at or feel about the depletion of ground water level?

☐ They are greatly concerned ☐ Are not aware of this problem (GOTO F)

6) What is the villagers' suggestion to address the depletion of ground water level?

____

____

____

F) WATER USER GROUP (WUG) / WATER USER ASSOCIATION (WUA) IN THE VILLAGE

1) Is the use of water for irrigation organized around an association or a group in the village?
   - ☐ Yes ☐ No (GOTO 8)
2) What type of organization available in the village?
   - ☐ Water groups (WUG) at the level of the well
   - ☐ Water groups (WUG) at the level of the well linked to the WUA at village level
   - ☐ WUA at the village level, but there is no WUG at the level of the well
3) How many of WUGs that are available in the village?

   ____
4) Is it a formal (registered) or informal (unregistered) organization?
   - ☐ Formal (registered) ☐ Informal (unregistered)
5) Description of the existing WUA

   5.1 What is the fee for membership and monthly subscription in the WUA?

   Membership fees is (_________ YER) and monthly subscription (_________YER)

   5.2 Name of the organization or the WUA: ________________________________

   5.3 Date of establishment: ____

   5.4 Executive members: ____

   5.5 Decision making process: ____

   5.6 Regulation in water distribution: ______________________________________
6) What are the roles and responsibilities of WUA?
   - ☐ Equitable distribution of water among users
   - ☐ Supervision of rotational water use
   - ☐ Maintenance of field channel
   - ☐ Collection of water dues
   - ☐ Arrangement of support services
   - ☐ Organizing processing and marketing of farm products
   - ☐ Other (specify)______________________________
7) Specify the Perceived Benefit by WUA?
   - ☐ Protecting the farmers rights
   - ☐ The insurance of equitable distribution of water among the members
   - ☐ Water Conservation
   - ☐ Reducing the problems among the members
   - ☐ Facilitating on having agricultural services for the members
   - ☐ Other (specify)______________________________

8) Is the community in favor of collective sharing of water among the villagers?

☐ Yes ☐ No (move to 9)

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

☐ Yes ☐ No

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

☐ Yes ☐ No

10) Do the villagers think that the adoption of participatory irrigation management could improve water conservation?

☐ Yes ☐ No (GOTO to G)

11) Are the villagers prepared / willing to form a WUG / WUA? Among themselves?

☐ Yes ☐ No (GOTO to G)

12) If WUG/ WUA are formed, are the villagers willing to accept the decisions and regulations made by WUG / WUA?

☐ Yes ☐ No

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

☐ Yes ☐ No

G) WATER RESOURCE MANAGEMENT AND WATER CONSERVATION

1) Will the villagers agree to register the well?

☐ Agree without conditions (GOTO to 2) ☐ Agree, but with conditions

☐ Disagree (GOTO to 1.2)

1.1. What are the conditions of agreements?

☐ The well should not be confiscated

☐ The pump should not be monitored

☐ They shouldn't prevent us from mobilizing the drilling machine

☐ Other (specify)_____________

1.2 What are the reasons for disagreement?

☐ Fear of defining limited water abstraction

☐ Fear of monitoring the pump

☐ Fear of being confiscated the well

☐ Fear of being prohibited re-deepening the well

☐ Other (specify)_____________

2) Will the villagers agree to install water meters on their pumps?

☐ Agree without conditions (move to 3) ☐ Agree, but with conditions

☐ Disagree (move to 2.2)

2.1. What are the conditions for agreeing to install the water meters?

- ☐ The well should not be confiscated
- ☐ The pump should not be monitored
- ☐ They shouldn't prevent us from mobilizing the drilling machine
- ☐ Other (specify)______________

2.2. What are the reasons for disagreement?

- ☐ Fear of defining limited water abstraction
- ☐ Fear of monitoring the pump
- ☐ Fear of being confiscated the well
- ☐ Fear of being prohibited re-deepening the well
- ☐ Fear of government penalties / sanctions
- ☐ Other (specify)_____________

(After answering 2.2 move to 4)

3) Will the villagers agree to monitor the pump regularly by the concerned Project Authority?

- ☐ Agree without conditions (move to 4)
- ☐ Agree, but with conditions
- ☐ Disagree (move to 3.2)

3.1. What are the conditions to allow monitoring of the pump?

- ☐ The well should not be confiscated
- ☐ They shouldn't prevent us from mobilizing the drilling machine
- ☐ Other (specify)_____________

3.2. What are the reasons of disagreement?

- ☐ Fear of identifying the water shares
- ☐ Fear of monitoring the pump
- ☐ Fear of being confiscated the well
- ☐ Fear of being prohibited re-deepening the well
- ☐ Fear of government penalties / sanctions
- ☐ Other (specify)_____________

4) Will the rate of water abstraction change in future years?

- ☐ Yes, there will be increase in the rate of water abstraction (GOTO 4.3)
- ☐ Yes, there will be decreasing in the rate of water abstraction (GOTO 4.2)
- ☐ No, the rate of water abstraction will remain as it is.

4.1 Why will there not be future abstraction of water?

- ☐ Inability to increase the operational pumping capacity
- ☐ The water source is not sufficient
- ☐ The village does not have areas to expand agricultural lands
- ☐ People can not afford the cost of expansion of agricultural lands
- ☐ Other (specify)_____________

(After answering 4.1 go to Q 5)

4.2 Why do you think the abstraction of water will decrease in future?

☐ Because of the depletion of water level ☐ Due to the high cost of fuel

☐ Due to the introduction of modern irrigation systems

☐ Recession of agricultural land ☐ Other (specify)________________

4.3 Why do you think the abstraction of water will increase in future?

☐ Due to the expansion in agricultural land ☐ Selling water to others

☐ Increase in number of partners for the well

☐ Other (specify)________________

5) Are the villagers agreeing to the prohibition of drilling new wells?

☐ Yes, we are with the idea of prohibiting the drilling of new well

☐ No, we are against this idea (move to 5.2)

5.1. Why are you with this idea?

☐ The fear from the depletion of water level or the dry up of the wells

☐ To abide with the Water Law / Government regulations

☐ The desire to solve the water problem ☐ Other (specify)________________

(After answering 5.1 go to Q 5)

5.2 Why you are against this idea?

☐ The current water source is insufficient

☐ people's desire to expand agricultural land

☐ The desire to have my own well

☐ Other (specify)________________

6) Will the villagers agree to the prohibition of expansion of irrigated land in their village?

☐ Yes, with the prohibition of expansion of irrigated land

☐ No, against the prohibition of expansion of irrigated land (move to 6.2)

6.1. Why are you with this idea?

☐ The fear from the depletion of water level

☐ The Water Law prohibits the expansion of agricultural land

☐ Other (specify)________________

(After answering 6.1 go to Q 7)

6.2 Why are you against the prohibition of expansion of irrigated land?

☐ The scarcity of rainfall

☐ It is the people's desire to expand agricultural land

☐ people want to utilize unused lands for agriculture

☐ people want o improve sources of income

☐ Other (specify)________________

7) Are the villagers aware or informed about water saving technology for irrigation?

☐ Yes ☐ No (GOTO H)

8) What are their preferences on water saving technology?

☐ improved piped irrigation ☐ pressurized irrigation system on farm

☐ wadi bank protection ☐ land leveling ☐ plastic cover techniques

☐ introduction of new variety of crops less water consuming

9) Why are the farmers not using any of these water saving technologies in their farms?

☐ The cost of purchase is too high

☐ Lack of skilled labors to install such technology

☐ Unsuccessful experience in the past

☐ Difficulties to maintain such system

☐ Each farmer sharing a well with a group wants to get full rotational share as agreed

☐ Other (specify)________________

H) AWARENESS ON WATER RIGHTS AND WATER LAW

1) Are the villagers aware of Water Rights?

☐ Yes ☐ No (GOTO 3)

2) What the common perception of villagers about the Water Rights?

____

____

3) Are the villagers aware of Water Law 2002?

☐ Yes ☐ No (GOTO 7)

4) What is the common perception of villagers about the Water Law is:

____

____

____.

5) Are the villagers aware that the Water Law contains penalties / sanctions for those who do not abide by the law?

☐ Yes ☐ No (GOTO 7)

6) If "Yes", do the villagers think these penalties / sanctions are acceptable? Please explain.

____

____

____

7) Do you have traditional customs to conserve the water rights?

☐ Yes ☐ No (END THE INTERVIEW)

8) What are the traditional customs?

Appendix 7

Questionnaire for Water Users
(Water Usage and Awareness Survey)

Appendix 7 **Water Usage and Awareness Survey**

Questionnaire for Water Users

A) Information about the Site & the Respondent

1) Questionnaire No.: ____________________
2) Site name: ______________________________-
3) Wadi: ____
   ____
4) Village: ____
5) District: ____
6) Sub - Basin: ____

7) Name of Respondent: ____
8) Address: ____
   ____
9) Sex (Male, Female): ____
10) Age: ____
   ____

11) Status of Respondent: ____________________ (sole farm owner, shared farm owner)
12) Educational Status: ____
13) Employment Status: ____

14) Name of Investigator: ____

Signature: ______________________

15) Date of survey:______________________

Data of this questionnaire is confidential and should be used only for the intended purpose.

B) Family Structure

Age group	**No. of household members**	
	Male	**Female**
From 0 to five years		
From 6 years to 14 years		
From 15 years to 24 years		
From 25 years to 60 years		
From 60 years and above		

C) Farm Structure

1) Size of farm: ____________ (libna)

Description of land	**Total area (libna)**	**Area cultivated (libna)**
Owned		
Rented		
Shared		

2) Recently changes in the farm size

Changes	**Area (libna)**
No change	
Decreased (libna)	
Increased (libna)	

2.3 Reasons for change in size:

____

____

____

3) Crop budget in Yemeni Rial for various crops

No	Crops	Cost per crop in Yemeni Rial									
		Cultivated Area (libna)	Seed		Fertilizer		Crop chemicals (pesticides)		Irrigation cost / water abstraction cost	Machinery cost (including fuel for machineries)	Labor charges
			quantity	cost	quantity	cost	quantity	cost			
1	Grapes										
2	Qat										
3	Peach										
4	Gage										
5	Almond										
6	Prickly pear										
7	Pomegranate										
8	Onion										
9	Tomatoes										
10	Potatoes										
11	Cereal in general										
12											
13											
14											

Specify quantities of seed, pesticides, etc applied per libna

D) Farm Production

No	Crops	Source of Irrigation	Water provided in field (hrs/libna/day)	Sowing Period	Harvesting Period	Aprox. Yield in tons	Market price		Gross Income
							Unit	Unit price	
1	Grapes								
2	Qat								
3	Peach								
4	Gage								
5	Almond								
6	Prickly pear								
7	Pomegranate								
8	Onion								
9	Tomatoes								
10	Potatoes								
11	Cereal in general								
12									
13									
14									
15									

Source of irrigation: Canal, Deep well, Shallow well, Dug well, Pond/Reservoir, Rain-fed, Others

E) Irrigation System

1) Source of irrigation and quantity of source owned

Source of irrigation	Quantity			Average depth (m)	Ave. consumption per day (l / day)
	Total	Operating	Non operating		
Deep well (artisan well)					
Shallow well (dug well/hand dug)					
Dug well					
Ponds / reservoirs					
Rain fed					
Others (specify____________)					

2) Source of irrigation and percentage of land (multiple options):

Source of irrigation	% of land under various sources	
	Summer	Rainy
Deep well (artisan well)		
Shallow well (dug well/hand dug)		
Dug well		
Ponds / reservoirs		
Rain fed		
Others		

3) Currently adopted water conveyance technology (multiple options):

☐ Earthen channel ☐ Lined channel

☐ Pipe / Conduit ☐ Others (___________________)

4) Currently adopted on-farm irrigation technology (multiple options):

Method of irrigation	Area (libna)	% of total farm
Furrow method		
Basin flooding		
Uncontrolled flooding		
Bubbler		
Drip		
Sprinkler		
Other		

F) Domestic Water Use

1) Source of drinking water, seasonal availability and quality (multiple options):

Source	No. of household	Seasonal availability	Water Quality (see options below)
Deep well (artisan well)			
Shallow well (dug well/hand dug)			
Dug well			
Ponds			
Rainwater harvesting			
Spring			
Other			

Water quality options: very good, good, fair, bad, very bad

2) Quantity of available water for domestic use

☐ Enough ☐ Fair ☐ Inadequate ☐ Very inadequate

3) Daily household requirement of water

________________ (Liters/day)

________________ (No. of household members)

4) Is the house connected to piped network system?

☐ Yes (move to 6) ☐ No

5) Who is usually responsible for fetching water from the source?

☐ men ☐ women
☐ children

6) Has the village experienced drinking water scarcity in the last 10 years?

☐ Yes ☐ No (move to 7)

6.1 How many times the village has experienced drinking water scarcity in the last 10 years?

____

6.2 How many wells were dried up in the village in the last 10 years?

____

6.3 How did the villagers cope with in water scarcity?

____

____

____

7) Details of water harvesting structures within village premises

Type of structures	Total no. of structures	No. of structures working	No. of structures not working	Date and reasons of not working
Collection tanks				
Farm ponds				
Recharge wells				
Other				

G) Well Inventory

1) Well Parameter

Well No.		
Coordinates	Latitude	
	Longitude	
	Elevation	
Type of well (deep well, shallow well, hand dug or dug well)		
Year of construction and or commissioning of the well		
Diameter of the well (cm)		
Depth of the well (m)		
Static water level (m)		
Dynamic water level (m)		
Average discharge of the well (l / s)		
Pump type		
Diameter of pump discharge pipe (cm)		
Engine type		
Source of energy (diesel/ petrol/ human/ animal/ electricity)		
Distance from nearest operational wells (m)		

2) Is the ownership of the well shared?

☐ Yes ☐ No. (move to 4)

3) What is the sharing system?

____

____

____

4) Irrigation water use purpose for the above well

No.	Details	
1	Total number of beneficiaries (no.)	
2	Total number of farms (no)	
3	Total area of above farms (libna)	
4	Average area irrigated by well in wet season (Feb to Sep) (libna)	
5	Average area irrigated by well in dry season (Oct to Jan) (libna)	
6	Average pumping hr/day in wet season (Feb. to Sep.) (hrs/day)	
7	Average pumping hr/day in dry season (Oct. to Jan.) (hrs/day)	
8	Average pumping days/week in wet season (days/week)	
9	Average pumping days/week in dry season (days/week)	

5) General Cropping pattern for the above well

Cropping Pattern		Cultivated area (libna)	Irrigation method
Cereals			
Vegetables			
Fruits			
Cash crops	Qat		
	Grape		
	Coffee		
	Total Area		

*Irrigation method: drip, sprinkler, canal, etc.…

6) Other water use purpose

6.1 Is the water being utilized other than irrigation purpose?

☐ Yes ☐ No. It is only for irrigation purpose. (GOTO 6.3)

6.2 What is the water being utilized other than irrigation purpose?

☐ Domestic (drinking) ☐ Animal

☐ Other (specify) ___________

6.3 Is there other water users using this well water?

☐ Yes ☐ No (move to 6.5)

6.4 Who are the other users?

Users	number of users	Quantity of water used (l/day)
Families		
Animals		
Tankers		
Others		

6.5 Is the water sold?

☐ Yes ☐ No (Move to 7)

6.6 What are the price and quantity of sold water?

Consumers	Unit	Price per unit	total number of units sold	total amount of money collected day

Information for the enumerator: 1 m^3 = 5 barrels ; 1 barrel = 200 liters; 1 m^3 = 1,000 liter

7) Other information

7.1 Has any depletion occurred to water level after commissioning of the well?

☐ Yes ☐ No (move to 7.3)

7.2 What is the rate of water depletion per year?

The rate of depletion per year is _______________ (in meter or no. of pipes)

7.3 Was the well re-drilled?

☐ Yes ☐ No. It was not re-drilled (move to 7.5)

7.4 What is the depth of well re-drilled? And when?

It was re-drilled ____________________meters in the year of : _______________

7.5 What is the quality of water according to the users?

☐ Very good ☐ Good ☐ Fair ☐ Bad ☐ Very bad

7.6 If "Bad" or "Very bad", When the deterioration was started?

the deterioration was started from the year:_________________

7.7 Is the quantity of well water enough to irrigate cultivated area?

☐ Yes ☐ No

7.8 Do you have future plans to increase cultivated area? When?

☐ Yes, within __________(years) ☐ No

7.9 Do you have plans to drill a new well?

☐ Yes ☐ No

H) Farmers Willingness

❖ **Perception on groundwater situation**

1) Are there any changes in currently using well capacity?

☐ Yes, there is increase in the well capacity

☐ Yes, there is decrease in the well capacity

☐ No, there is no change (GOTO 2)

1.1 What are the perceived reasons for the change in well capacity?

____

____

____

2) Were any wells abandoned in the past due to dry-up:

☐ Yes ☐ No (GOTO 3)

2.1 What are the perceived reasons for dry-up of wells?

____

____

____

❖ **Water Saving Technology**

3) What is the improved technology for water conveyance preferred by you?

(Multiple Options) (for the enumerator read the options)

☐ Earthen channel ☐ Pipe / Conduit

☐ Others (specify_________)

3.1. Do you use any of this improved technology?

☐ Yes (GOTO 4) ☐ No

3.2 What are the reasons for not introducing improved technology for water conveyance?

☐ The cost of procurement is too high ☐ The pipes get corroded

☐ The cost of maintenance is too high

☐ We got used to what we have ☐ Others (_________________)

4) What is the preferred improved on-farm irrigation technology?

☐ Bubbler ☐ Drip ☐ Sprinklers ☐ Others (specify______)

4.1. Do you use any of this improved technology?

☐ Yes (GOTO I) ☐ No

4.2 What are the reasons not to introduce improved on-farm irrigation technology?

☐ The cost of procurement is too high ☐ Lack of skill labors for installation

☐ Unsuccessful experience in the past ☐ Difficulties of maintenance

☐ I am sharing the well with a group and I want to get my full rotational share as agreed

☐ Others (____________________)

I) PARTICIPATION IN WUG /WUA

1) Is there a water users group (WUG) to manage this well?

☐ Yes ☐ No

2) Is there any water users association (WUA) to manage irrigation water at village level?

☐ Yes ☐ No (move to 7)

3) Are you a member in the WUA at village level?

☐ Yes ☐ No (move to 6)

4) How much money do you pay for membership fee and monthly subscription in the WUA?

The membership fee is: (__________YER) and monthly subscription: (_________YER).

5) What are the roles and responsibilities of the WUA?

____

____

____

(If there is a WUA at village level the enumerator should GOTO part J)

6) What are the reasons for not joining the WUA at the village level?

____

____

____

7) If there is no WUA at village level, have you heard about Water irrigation committee in one of the nearest villages?

☐ Yes ☐ No (GOTO 9)

8) What do you know about WUAs?

____

____

____

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

☐ Yes ☐ No **(GOTO J**)

10) Do you agree that the management of the irrigation at the village level to be done by WUA?

☐ Yes ☐ No

11) Are you ready to pay membership fee and monthly subscription for the WUA?

☐ Yes ☐ No (**GOTO J)**

11.1 What is the amount of money you are willing to pay as a membership fee and the monthly subscription?

The membership fee is: (_________YER) and monthly subscription: (_________YER).

12) What are the preferred modes of participation in WUA?

☐ Equitable distribution of water among the members
☐ Supervision of rotational water ☐ Maintenance of field channel
☐ Collection of water dues ☐ Arrangement of support services
☐ Organizing processing and marketing of farm products
☐ Any other (_______________________)

13) What are the perceived/expected benefits by WUA?

☐ Protecting the farmers rights
☐ Ensure equitable distribution of water among the members
☐ Conservation of water level
☐ Solve problems among members
☐ Facilitating farmers access to agricultural services
☐ Other (specify)_____________________________________

14) Is the respondent willing to follow the decisions and regulations made by WUA?

☐ Yes ☐ No

J) Awareness of Water Right and Water Law 2002

1) Are you aware of Water Rights?

☐ Yes ☐ No (GOTO 2)

1.1 What is your perception about the Water Rights?

____

____

2) Are you aware of Water Law 2002?

☐ Yes ☐ No (move to k)

2.1 What is your perception about the Water Law is:

____

____

3) From the following provisions of the Water Law, will you agree to abide by Water Law (in the future)? (Please give reasons for each circumstance)

3.1 Licensing of rigs / Registering drilling rigs ☐ Agree ☐ Disagree

____

____

____

3.2 Prohibiting the drilling of new wells ☐ Agree ☐ Disagree

____

____

____

3.3 Maintaining the current abstraction rate (bylaw) ☐ Agree ☐ Disagree

____

____

____

3.4 Imposing the non expansion of irrigated area ☐ Agree ☐ Disagree

____

____

____

4) The respondent knows that Water Law contains penalties / sanctions for those who do not abide by the law?

☐ Yes ☐ No (move to k)

4.1 If "Yes", do you think these penalties / sanctions are acceptable? Please explain.

____

____

5) Is the respondent satisfied with current rate of water abstraction?

☐ Yes ☐ No

☐ Not aware of the abstraction rate referred to in the law

K) WATER CONSERVATION

1) Will you agree to register the well?

☐ Agree without conditions (GOTO to 2) ☐ Agree, but with conditions

☐ Disagree (GOTO to 1.2)

1.1. What are the conditions of agreements?

☐ The well should not be confiscated

☐ The pump should not be monitored

☐ They shouldn't prevent us from mobilizing the drilling machine

☐ Other (specify)_____________

1.2. What are the reasons for disagreement?

☐ Fear of identifying the water shares

☐ Fear of monitoring the pump

☐ Fear of being confiscated the well

☐ Fear of being prohibited re-deepening the well

☐ Other (specify)_____________

2) Will you agree to install water meters on their pumps?

☐ Agree without conditions (move to 3) ☐ Agree, but with conditions

☐ Disagree (move to 2.2)

2.1. What are the conditions for agreeing to install the water meters?

☐ The well should not be confiscated

☐ The pump should not be monitored

☐ They shouldn't prevent us from re-drilling

☐ Other (specify)______________

2.2. What are the reasons for disagreement?

☐ Fear of defining limited water abstraction

☐ Fear of monitoring the pump

☐ Fear of being confiscated the well

☐ Fear of being prohibited re-deepening the well

☐ Fear of government penalties / sanctions

☐ Other (specify)_____________

(After answering 2.2 move to 4)

3) Will you agree to monitor the pump regularly by the concerned Project Authority?

☐ Agree without conditions (move to 4) ☐ Agree, but with conditions

☐ Disagree (move to 3.2)

3.1. What are the conditions to allow monitoring of the pump?

- ☐ The well should not be confiscated
- ☐ They shouldn't prevent us from mobilizing the drilling machine
- ☐ Other (specify)_____________

3.2. What are the reasons of disagreement?

- ☐ Fear of identifying the water shares
- ☐ Fear of monitoring the pump
- ☐ Fear of being confiscated the well
- ☐ Fear of being prohibited re-deepening the well
- ☐ Fear of government penalties / sanctions
- ☐ Other (specify)_____________

4) Will the rate of water abstraction change in future years?

- ☐ Yes, there will be an increases in the rate of water abstraction (GOTO 4.3)
- ☐ Yes, there will be decreasing in the rate of water abstraction (GOTO 4.2)
- ☐ No, the rate of water abstraction will remain as it is.

4.1 Why will there be no change in future abstraction of water?

- ☐ Inability to increase the operational pumping capacity
- ☐ The water source is not sufficient
- ☐ We do not have areas to expand agricultural lands
- ☐ I can not afford the cost of expansion of agricultural lands
- ☐ Other (specify) _____________

(After answering 4.1 go to Q 6)

4.2 Why do you think the abstraction of water will decrease in future?

- ☐ Because of the depletion of water level
- ☐ due to the high cost of fuel
- ☐ Due to the introduction of modern irrigation systems
- ☐ Recession of agricultural land
- ☐ Other (specify)_________________

4.3 Why do you think the abstraction of water will increase in future?

- ☐ Due to the expansion in agricultural land
- ☐ Selling water to others
- ☐ Increase in number of partners for the well
- ☐ Other (specify)________________

5) Will you agree to the prohibition of drilling new wells?

- ☐ Yes, with the idea of prohibiting the drilling of new well
- ☐ No, against this idea (move to 5.2)

5.1. Why are you with this idea?

☐ The fear from the depletion of water level or the dry up of the wells

☐ To abide with the Water Law / Government regulations

☐ The desire to solve the water problem

☐ Other (specify)________________

(After answering 5.1 go to Q 5)

5.2 Why you are against this idea?

☐ The current water source is insufficient

☐ I intend to expand agricultural land

☐ I intend to have my own well

☐ Other (specify)________________

6) Will you agree to the prohibition of expansion of irrigated land in the village?

☐ Yes, with the prohibition of expansion of irrigated land

☐ No, against the prohibition of expansion of irrigated land (move to 6.2)

6.1. Why are you with this idea?

☐ The fear from the depletion of water level

☐ The Water Law prohibits the expansion of agricultural land

☐ Other (specify)________________

(After answering 6.1 go to Q 7)

6.2 Why are you against the prohibition of expansion of irrigated land?

☐ The scarcity of rainfall

☐ I intend to expand agricultural land

☐ I intend to utilize unused lands for agriculture

☐ I want o improve sources of income

☐ Other (specify)____________________________________

Appendix 8

Questionnaire for Industrial Water Usage Condition
(Water Usage Survey)

Appendix 8 Water Usage Survey دراسة إستخدامات المياه

Questionnaire for Industrial Water Usage Condition in Sana'a city

إستبيان خاص بإستخدام المياه في الصناعة

يتم تعبئة هذا الإستبيان في المصانع أو الشركات المصنعة التي يوجد لديها بئر خاص بها. المدلي بالبيانات مدير الشركة أو المسئول المعني

The questionnaire should be used in factories or manufacturing companies that has its own well inside the factory. The respondent should be the company manager, the production manager or the person in charge

Wadiإسم الوادي: ______________________________

Villageالقرية/neighborhood حارة:Street/ شارع ______________________________

District: المديرية ______________________________

____

Sub - Basin: الحوض المائي الفرعي ______________________________

Date of Survey: تاريخ الدراسة ________

Name of the Company / Factory: إسم الشركة / المصنع ______________________________

Address: العنوان______________________________

Contact telephone number: ______________________________

Contact facsimile number: ______________________________

Date of Establishment: تاريخ التأسيس ______________________________

Respondent: Name:إسم المدلي بالبيانات ______________________________

Sex of Respondent (Male, Female): الجنس(ذكر ، أنثى)

Age: العمر____________________

Position of the respondent:المنصب _________________

Name of Investigator: اسم الباحث ______________________________

Signature of the investigator: توقيع الباحث___________________________

Data of this questionnaire is confidential and should be used only for the intended purpose.

جميع البيانات سرية ويجب استخدامها في الأغراض المحددة لها

1. Current state of water use استخدامات المياه حالياً

(if there is more than one production facility within the factory/ company), then please use a separate sheet for each production facility) (يرجى جمع البيانات لكل وحدة إنتاج في صفحة خاصة عند وجود اكثر من خط انتاج)

a) Outline of the facility معلومات عن وحدة الانتاج

Main Product المنتج الرئيسي	Annual production حجم الإنتاج سنوياً	Unit الوحدة
1)		
2)		
3)		
4)		
5)		

b) Monthly variation in production التغيير الشهري في حجم الانتاج

Is there any monthly variation for each main?

هل في أي تغيير شهري في حجم الإنتاج أم الإنتاج ثابت طوال العام

☐ Yes there is a monthly variation for the whole production

☐ Yes there is a monthly variation for each main product

☐ No. It is constant in the year لا- الانتاج ثابت على مدار السنة

If yes, then can you tell me the variation for each month?

Month الشهر	Monthly production الانتاج الشهري	Month الشهر	Monthly production الانتاج الشهري
Jan.		Jul.	
Feb.		Aug.	
Mar.		Sep.	
Apr.		Oct.	
May		Nov.	
Jun.		Dec.	

c) Source of water and consumption الاستهلاك و مصدر المياه

1)Water consumption by the year 2005: الاستهلاك م3/سنة__________ m^3/year

2)Water consumption by the year 2006: الاستهلاك م3/سنة __________ m^3/year

3)**Actual** sources of raw water(multiple):مصدر المياه

☐ Own well بئر خاص

Characteristics of the Well(s) to be administered if there is a well:خصائص البئر يتم تعبئته في حالة وجود بئر

Well No.		البئر رقم 1	البئر رقم 2	البئر رقم 3	البئر رقم 4	البئر رقم 5
Coordinate	Latitude					
	Longitude					
	Elevation					
Type of well (dug well, borehole, dug bore)						
Year of construction						
Diameter of the well (cm)						
Depth of the well (m)						
Static water level (m)						
Dynamic water level (m)						
Average discharge (l / s)						
Pump type						
Pump setting depth (m)						
Number of working hours per day						
Working days per week						

☐ Network:شبكة مياه ________ m^3/day, _______ days/week

☐ Other اخرىm^3/day, (specify)_______________ days/week

Is there any variation in the monthly water consumption in the production facility?
هل يوجد تغير في الاستهلاك الشهري

☐ Yes and they are نعم وهي كما يلي

Month الشهر	Monthly discharge التصريف الشهري (m^3/month)	Month الشهر	Monthly discharge التصريف الشهري (m^3/month)
Jan.		Jul.	
Feb.		Aug.	
Mar.		Sep.	
Apr.		Oct.	
May		Nov.	
Jun.		Dec.	

☐ No. It is constant in the year.لا- إستهلاك المياه ثابت على مدار السنة

d) Purpose of water use الغرض من استخدام المياه

(Brief explanation, for example, cooling water, process water, etc) شرح مختصر

____

____

e) Required water quality (e.g. drinking water, does not matter)

Does the Water have to follow specific quality standard (for example drinking water standard, there has to be quality standard of some sort ……or it is not important for the water to follow any specific standard)? Please explain:

____

____

f) Do you have water treatment facility? هل يوجد لديكم وحدة لتنقية للمياه

☐ Yes and they are نعم وهي

Process: طريقة المعالجة/التنقية____________________________________

Quantity of water treated :

____________day/week عدد أيام المعالجة في الأسبوع__________m3/dayكمية المياه التي يتم معالجتها في اليوم

☐ No

2. Future expansion of the facility

التوسعة المستقبلية لالمنشأة في المستقبل

a) Do you have expansion plan of the production facilities? هل يوجد خطط توسعية في المنشأة

☐ Yes and those plans are:نعم وهي

Current capacity: الطاقة الحالية________________________ (2007)

By 2010: الطاقة بحلول ______________________________

By 2015: الطاقة بحلول ______________________________

By 2020: الطاقة بحلول ______________________________

☐ No

b) Do you expect any increase in the water consumption?

هل يوجد خطط لزيادة استهلاك المياه في المستقبل

☐ Yes, and those plans are:نعم وهي

By 2010: الاستهلاك بحلول _________________________ m^3

By 2015: الاستهلاك بحلول _________________________ m^3

By 2020: الاستهلاك بحلول _________________________ m^3

And their sources are (multiple:مصادر المياه هي

☐ Own wellبئر خاص

☐ Network شبكة مياه

☐ Other sources اخرى ____________________

☐ No, and:

Current consumption:الاستهلاك الحالي _________________ m^3/year (2006)

☐ Future consumption expected to be on the same levelيتوقع ان لايتغير الاستهلاك

☐ Future consumption expected to be decreased يتوقع أن ينخفض الاستهلاك

to ____________________ m^3 or ___________________ %

by means من خلال ________________________________

3. Disposal of wastewater طريقة التخلص من المياه العادمة

a) Is there any wastewater discharged from the facility to outside?

هل توجد مياه عادمة يتم تصريفها الى خارج المنشاة

- ☐ Yes. (Please go to "b") نعم (يرجى الانتقال الى
- ☐ No. (End of the Inquiry)لا

b) How much in volume is the wastewater discharged?

ماهي كمية المياه العادمة التي يتم تصريفها

volume in 2005: ______________________________ m^3/year (2005) الكمية عام

volume in 2006: ______________________________ m^3/year (2006) الكمية عام

Is there any monthly variation in the discharge of wastewater?

- ☐ Yes, and the monthly variation of discharge is as follow:

Month الشهر	Monthly discharge of 2006 الاستهلاك الشهري (m^3/month)	Month الشهر	Monthly discharge of 2006 الاستهلاك الشهري (m^3/month)
Jan.		Jul.	
Feb.		Aug.	
Mar.		Sep.	
Apr.		Oct.	
May		Nov.	
Jun.		Dec.	

- ☐ No. (End of the Inquiry) لا

c) Where is the wastewater discharged to إلى أين يتم تصريف المياه العادمة **(to the enumerator please observe method of discharge) (multiple choices)**

- ☐ Wadi وادي
- ☐ Public sewerage systemشبكة الصرف الصحي العامة
- ☐ Reuse in irrigation اعادة الاستخدام في الري
- ☐ Others

d) Is the water treated by the treatment facilities of the factory (pretreatment or primary treatment) before discharging into wadi or public sewerage system?

هل يتم معالجة المياه العادمة في وحدة معالجة داخل المنشأة قبل التصريف؟

☐ Yes, and the treatment process is:نعم وطريقة المعالجة المستخدمة هي

- ☐ Screeningالغربلة/التصفية
- ☐ Sedimentation (settling) الترسيب
- ☐ Degreasing فصل الدهون
- ☐ Biological treatment معالجة بيولوجية
- ☐ Chemical treatment معالجة كيميائية
- ☐ Neutralization معادلة التأين
- ☐ Others أخرى ________________________

☐ No (End of the Inquiry)

e) What are the final qualities of wastewater at discharge point? (to the enumerator please prompt the respondent for any test that has been conducted to verify answer and observe the results)

ماهي نوعية المياه العادمة عند مخرج التصريف

☐ Quality according to Standard (please specify the standard): ______________________________
____

☐ Quality according to Regulation, Law: (please specify the standard):________________
____ ____________

☐ There is no standards and/or regulations and laws but the wastewater is treated as follow.(Please explain for which substance you are treating and why)?

____

____

____

Appendix 9

Questionnaire for Touristic Water Usage Condition (Water Usage Survey)

Appendix 9 Water Usage Survey

Questionnaire for Touristic Water Usage Condition

Wadi: ______________________________

Village: ______________________________

District: ______________________________

Sub - Basin: ______________________________

Date of Survey: ______________

Name of the Hotel and category: ______________________________

Address: ______________________________

Date of Establishment: ______________________________

Respondent Name: ______________________________

Sex (Male, Female): ______________ Age: ______________

Position: ______________ Telephone No. ______________

Signature: ______________

Name of Investigator: ______________________________

Signature: ______________

Data of this questionnaire is confidential and should be used only for the intended purpose.

1. Current quantity of rooms: ________________

2. Current quantity of beds: _________________

3. Average monthly nights spent by tourists per year

	Nights spent by tourists (persons/month)					
	2001	2002	2003	2004	2005	2006
Jan.						
Feb.						
Mar.						
Apr.						
May						
Jun.						
Jul.						
Aug.						
Sep.						
Oct.						
Nov.						
Dec.						
Total						

4. Source of water consumption

Total water consumption in the year 2005: _______________ m^3/year

Total water consumption in the year 2006: _______________ m^3/year

Sources of raw water: ☐ Own well

Well quantity: __________

Specifications:

Well No.						
Coordinate	Latitude					
	Longitude					
	Elevation					
Type of well (dug well, borehole, dug bore)						
Year of construction						
Diameter of the well (cm)						
Depth of the well (m)						
Static water level (m)						
Dynamic water level (m)						
Average discharge (l / s)						
Pump type						
Pump setting depth (m)						
Working time and working days per week						

☐ Network: _____________ m^3/day, __________ days/week

☐ Other ________________ m^3/day, __________ days/week

Is there any monthly variation on water consumption (2006)?

☐ Yes and they are

Month	Monthly consumption (m^3/month)	Month	Monthly consumption (m^3/month)
Jan.		Jul.	
Feb.		Aug.	
Mar.		Sep.	
Apr.		Oct.	
May		Nov.	
Jun.		Dec.	

☐ No. It is constant in the year.

Is there any depletion of water level after commissioning of the well?

☐ Yes, it started in the year of __________ , and

the rate per year of depletion is ________________ (in meter or no. of pipes)

☐ No

Was the well redrilled?

☐ Yes and it was redrilled __________meters in ________(years).

☐ No. It was not redrilled.

What is the quality of water according to the users

☐ Very good ☐ Good ☐ Fair ☐ Bad ☐ Very bad

If "Bad" or "Very Bad", when did it start? The year of __________

5. Do you have water treatment facility?

☐ Yes and they are

Process: ____

Capacity: ____

☐ No

6. Disposal of wastewater

a) Where is the wastewater discharged to?

☐ Public sewerage system and the volume is

__________________ m^3/year for the year 2005

__________________ m^3/year for the year 2006

☐ Other: ____________________________________

__________________ m^3/year for the year 2005

__________________ m^3/year for the year 2006

7. Future expansion plan

a) Do you have expansion plan for quantity of beds and rooms?

☐ Yes and those plans are:

year	beds	rooms
current year 2007		
2010		
2015		
2020		

☐ No

Appendix 10

Questionnaire for Water Usage Condition for Tankers (Water Usage Survey)

Appendix 10 Water Usage Survey

Questionnaire for Water Usage Condition for Tankers

Wadi: ____________________

Street:

Neighborhood: ____________________

District: ____________________

Sub - Basin: ____________________

Date of Survey: ________/ ______/2007

Name of the Company / Organization/Owner: ____________________

Address: ____________________

Date of Establishment: ____________________

Respondent:: Name ____________________

Sex (Male, Female): ____________ Age: ____________

Position: ____________ Telephone No. ____________

Signature: ____________

Name of Investigator: ____________________

Signature: ____________

Data of this questionnaire is confidential and should be used only for the intended purpose

1. Well Inventory

a) Well Parameter

Well No.		
Coordinate	Latitude	
	Longitude	
	Elevation	
Type of well (dug well, borehole, dug bore)		
Year of construction and or commissioning of the well		
Diameter of the well (cm)		
Depth of the well (m)		
Static water level (m)		
Dynamic water level (m)		
Average discharge of the well (l / s)		
Pump type		
Diameter of pump discharge pipe (cm)		
Engine type		
Source of energy (diesel/ petrol/ human/ animal/ electricity)		
Distance from nearest operational wells (m)		

b) Water Production

Average pumping hr/day in wet season (Feb. to Sep.) (hrs/day)	
Average pumping hr/day in dry season (Oct. to Jan.) (hrs/day)	
Average pumping days/week in wet season (days/week)	
Average pumping days/week in dry season (days/week)	
Average pumping days/season in wet season (days/season)	
Average pumping days/season in dry season (days/season)	
Average water pumped in a year (m^3) (to be done by investigator)	

2. Water Usage

a) Is the well owner, also owner of Tankers?

☐ Yes.

Number of Tankers	Capacity of Water (m3)

And the price and quantity for each consumer is:

Consumers*	Water Use**	Unit	Price per unit	Quantity sold per day in m3

*Consumers: private person, company, school, hospital, restaurant, building contractors, etc

**Water use: irrigation, water treatment station, Kawther, domestic, domestic, drinking, others etc.

☐ No.

b) Is the water sold to other tankers?

☐ Yes. And the capacity and quantity of tankers supplied per day are:

Tanker Capacity (m3)	number of tankers supplied per day	Price YR/ Tanker

Outline of the consumers for the other tankers

Consumers*	Unit	Price per unit	Quantity sold per day	Water Use**

*Consumers: private person, company, school, hospital, etc

**Water use: irrigation, private water supply, domestic etc. - if the respondent knows

☐ No.

3. Other information

Is there any depletion of water level after commissioning of the well?

☐ Yes, it started in the year of ______,

and the rate per year of depletion is ___________ (in meter or no. of pipes)

☐ No

Was the well redrilled?

☐ Yes and it was redrilled __________ meters in _________ (years).

☐ No. It was not redrilled.

What is the quality of water according to the users (to be verified by the water tanker or the driver):

☐ Very good ☐ Good ☐ Fair ☐ Bad ☐ Very bad

If "Bad" or "Very Bad", when did it start to be bad? The year of ___

5. Awareness of Water Right and Water Law 2002

a) Is the respondent aware of Water Rights?

☐ Yes, and the common perception about the Water Rights is:

____

____

____ .

☐ No

b) Is the respondent aware of Water Law 2002?

☐ Yes, and the common perception about the Water Law is:

____

____

____

☐ No

c) From the following provisions of the Water Law, will you agree to abide by Water Law (in the future)? (Please give reasons for each circumstance)

- Licensing of rigs / Registering drilling rigs ☐ Agree ☐ Disagree

____

____

____

- Prohibiting the drilling of new wells ☐ Agree ☐ Disagree

____

____

- Maintaining the current abstraction rate (bylaw) ☐ Agree ☐ Disagree

- Imposing the non expansion of irrigated area ☐ Agree ☐ Disagree

d) The respondent knows that Water Law contains penalties / sanctions for those who do not abide by the law?

☐ Yes ☐ No

If "Yes", do you think these penalties / sanctions are acceptable? Please explain.

e) Is the respondent satisfied with current rate of water abstraction?

☐ Yes ☐ No

4. Water Conservation

a) Will the well owner agree to register the well?

☐ Yes ☐ No

What are the conditions of the owner to agree or reasons not to agree well registration?

____

____

____

b) Will the owner agree to install water meters in his well?

☐ Yes ☐ No

What are the conditions of the owner to agree or reasons not to agree installation of water meters in his well?

____

____

____

c) Will the owner agree to monitor the pump regularly by the concerned Project Authority?

☐ Yes ☐ No

What are the conditions of the owner to agree or reasons not to agree monitoring of pump by concerned Project Authority?

____

____

____

d) Will the owner maintain the current rate of abstraction or reduce the amount of water abstraction in the future years? What are the reasons for both cases?

☐ Yes ☐ No

Reason: ____

____

____

____

e) Will the owner agree to the prohibition of new well drilling? What are the reasons?

☐ Yes ☐ No

What are the conditions of the owner to agree or reasons not to agree the prohibition of new well drilling?

____

____

____

Appendix 11

Well Inventory

Appendix 11Well Inventory [Results of the Water Usage Survey in the Industrial Sector in Sana'a City]

					1. Current State of Water Use																					
Well ID No.	Wadi	District	Sub-Basin	Date of Establishment of the Company/ Factory	a) Outline of Factory									b) Monthly Variation in Production												
					Main Producut (1)	Annual Production (1)	Unit (1)	Main Producut (2)	Annual Production (2)	Unit (2)	Main Producut (3)	Annual Production (3)	Unit (3)	Monthly variation for main product	Monthly Production											
															Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.
16-I-01	Wadi Al Mawrid	Sana'a	Wadi Al Mawrid		Light food			Bumpers			Garments			Yes, for the whole production												
16-I-02	Wadi Al Mawrid	Sana'a	Wadi Al Mawrid	1976	School books	12,000	Tone per year							No	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
16-I-03-A	Wadi Artel	Bani Matar	Wadi Artel	2005	Bricks	300,000	Brick	Stone	100,000	Stone				Yes, for the whole production	30000	10000	0	0	0	15000 - 36000	15000 - 36000	15000 - 36000	10000 - 36000	15000 - 36000	10000 - 36000	10000 - 36000
16-I-04	Wadi Al Mawrid	Sana'a	Wadi Al Mawrid	1975	Powder Soap	5	Tone/ Hour	Beautify Soap	220	Tone/Year				No												
16-I-05	Wadi Artel	Bani Matar	Wadi Artel	2004	Bricks	120,000	Brick							Yes, for the whole production	8000	8000	8000	8000	8000	8000	10000	10000	10000	8000	8000	8000
16-I-06	Wadi Al Mawrid	Sana'a	Wadi Al Mawrid		Differnet Texture and medical cotton	400,000	KG							No												
16-I-08	Wadi Dhahar	Sana'a	Wadi Al Mawrid	1979	Bottled Water	120,000	M3 per year							No												
16-I-07-A	Wadi Al Mawrid	Sana'a	Wadi Al Mawrid	1982	Ready mix concrete	27,500	M3 per year							Yes, for the whole production	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know

Appendix 11Well Inventory [Results of the Water Usage Survey in the Industrial Sector in Sana'a City]

c) Source of Water and Consumption

Well ID No.	1) Water Consumption (2005)	2) Water Consumption (2006)	3) Source of Raw Water	Characteristics of Well (No.1)												
	m3/year	m3/year	Own Water	Latitude	Longitude	Elevation	Type of Well	Year of Construction	Diameter (cm)	Depth (m)	S.W.L (m)	D.W.L (m)	Average Discharge (l/s)	Pump Type	Working Hours/Day	Working Days/Week
16-I-01	15,000	15,000	Yes	04 13 759	17 02 192	2278	Borehole	1978		800					3.5	6
16-I-02	8,640	8,640	Yes	04 43 71	17 01 963		Borehole	2005		260			25		3	6
16-I-03-A	900	1,300	Yes	04 14 355	16 89 354	2329	Deep well	2005	25.4	350	30	10	4	Caprari	10	6
16-I-04	3,960	4,500	Yes	04 12 470	16 92 074	2327	Borehole	1975	120	300	260		3.3	Electrical	1.5	6
16-I-05	1,000	1,200	Yes	04 14 362	16 89 241	2318	Deep well	2004	20.32	370	30	5	4	Caprari	12	6
16-I-06	195,000	195,000	Yes	04 15 685	17 00 013	2275	Borehole		25.4	300	126	12-Sep		Franklin	24	6
16-I-08	100,000	120,000	Yes	04 09 075	17 03 006	2325	Borehole	1991	20.32	300	205	216	9	Sp27.31	8	6
16-I-07-A	6,875	6,000	Yes	04 11 200	16 95 585	1318	Borehole	1982	25.4	500	Don't know	Don't know	Don't know	Ghatas	8	6

Well ID No.	Characteristics of Well (						
	Latitude	Longitude	Elevation	Type of Well	Year of Construction	Diameter (cm)	Depth (m)
16-I-01							
16-I-02							
16-I-03-A							
16-I-04							
16-I-05							
16-I-06							
16-I-08	04 09 070	17 03 000	2325	borehole	1995	20.32	300
16-I-07-A	04 11 201	16 95 586	1318	borehole	1982	25.4	350

Appendix 11Well Inventory [Results of the Water Usage Survey in the Industrial Sector in Sana'a City]

Well ID No.	(No.2)						Monthly variation for main product	Monthly Discharge (m3/month)												d) Purpose of Water Use	e) Required Water Quality
	S.W.L (m)	D.W.L (m)	Average Discharge (l/s)	Pump Type	Working Hours/Day	Working Days/Week		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.		
16-I-01																				Cleaning potatoes and the water is consumed by the people of the living complex	Drinking Water
16-I-02							Yes	720	720	720	720	720	720	720	720	720	720	720	720	For irrigating trees, for labors use and washing hand for labors of book press	For cleaning the water from oil to protect the machines from salt
16-I-03-A							Yes	90	90	90	90	90	100	100	100	100	100	90	90	For mixing and spraying it with cement and making wet stones	The water is light for stone
16-I-04							No													To dissolve some of the chemical materials, to generate steam, to cool machines and equipment, and for domestic use	Filtered water for the boiler and the remaining is water for drinking
16-I-05							No													For mixing and spraying it with cement and for labors use	There is no specified standard but the water is too clean and pure
16-I-06							No													For printing, dye, cooling and ventilation	Filtered water for cooling, Drinking water and hot water
16-I-08	205	216	10.15	Sp27.31	8	6	Yes	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Drinking pure water	PH conductivity TDS and mineral as per W.H.O standard and maintain biological control as guide linr of W.H.O
16-I-07-A	Don't know	Don't know	Don't know	Ghatas	8	6	No													Mix the water with the concrete	Doesn't matter

Appendix 11Well Inventory [Results of the Water Usage Survey in the Industrial Sector in Sana'a City]

Well ID No.	2. Future Expansion of the Facility f) Existence of Water Treatment Facility	Process	Quantity of Water Treated		a) Expansion Plan of the Production Facilities	Current Capacity (2007)	By 2010	By 2015	By 2020	b) Expectation of Increase in Water Consumption Increase is expected	Expected Consumption (By 2010)	Expected Consumption (By 2015)	Expected Consumption (By 2020)	Water Sources to be Used for Expansion		Increase is **not** expected	Current Consumption (2006)	Change in Future Consumption	Expected consumption decrease		Means to Decrease Consumption
			day/week	m3/day							m3	m3	m3	Type of Source	(specify "other")		m3/year		m3	%	
16-I-01	No				No					No											
16-I-02	Yes	Adding aqua water to protect the press machines	4.25	2	Yes	8,640	9,504	10,800	11,664	No				Our own well does not cover the need due to water scarcity so we have to search for an additional source							
16-I-03-A	Yes	Sedimentation	1	1	No					No								To be same lavel			
16-I-04	Yes	Ion exchanging softner	6	5.5	No					Yes	6,750	10,125									
16-I-05	No				No					No							1,200	To be same lavel			
16-I-06	Yes	Drip and filtering	168	6	Yes	400	4,800			No							25,200	To be decreased	Don't know	Unknown	Plans of transfering the printing and dying to Hodiedah which leads to decrease the water consumption inspite of increase of production
16-I-08	Yes	Filteration	1350	225	No																
16-I-07-A	Yes	Filteration and sedimentation	Don't know	Don't know	No	3,500				No							3,500	To be decreased	400	60	

Appendix 11Well Inventory [Results of the Water Usage Survey in the Industrial Sector in Sana'a City]

Well ID No.	3. Wastewater Disposal a) Any wastewater discharged from the facility to outside?	WasterWater Discharged		Monthly Variation in Discharge of Wastewater	Monthly Discharge of 2006 (m3/month)												c) Discharge Place of Wastewater	d) Treatmet of Wastewater before Discharged to Outside			e) Final Quality of Wastewater at Discharge Point		
		Year 2005	Year 2006		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul	Aug.	Sep.	Oct.	Nov.	Dec.			Treatment Process	Treatment Process (Others)	According to the Standard	According to Regulation, Law	No standard/regulation, but treated
		m3	m3																	(specify)	(Specify)	(Specify)	(specify)
16-I-01	Yes			No													Public sewerage system	No					
16-I-02	Yes	7,344	7,344	Yes	612												Public sewerage system	No					No need, because it does not have any checmicals
16-I-03-A	Yes	40	60	No																			
16-I-04	Yes	300	300	No													Others	No					Water description contains soluted soap
16-I-05	No																						
16-I-06	Yes	105	1,050	No													Public sewerage system	No					
16-I-08																							
16-I-07-A	Yes	Don't know	Don't know	Yes	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Others	Yes	Sedimentation				

Appendix 12

Result of PCM Workshop

Results of the PCM workshop of this project

1. Purpose of the workshop

The purpose of this workshop was to find out the main problems confronted in the Basin. This workshop was conducted in a participatory approach, so that each of the stakeholders relating to the water resources management in the Basin can think, express and understand the problems confronted.

2. Date, place, etc.

Date: 10 - 11 July 2007

Time: Both days, 9:00 AM to 14:00 PM

Place: Eagle Hotel, Sana'a

3. Participants

First day: 61 persons, Second day: 59 persons

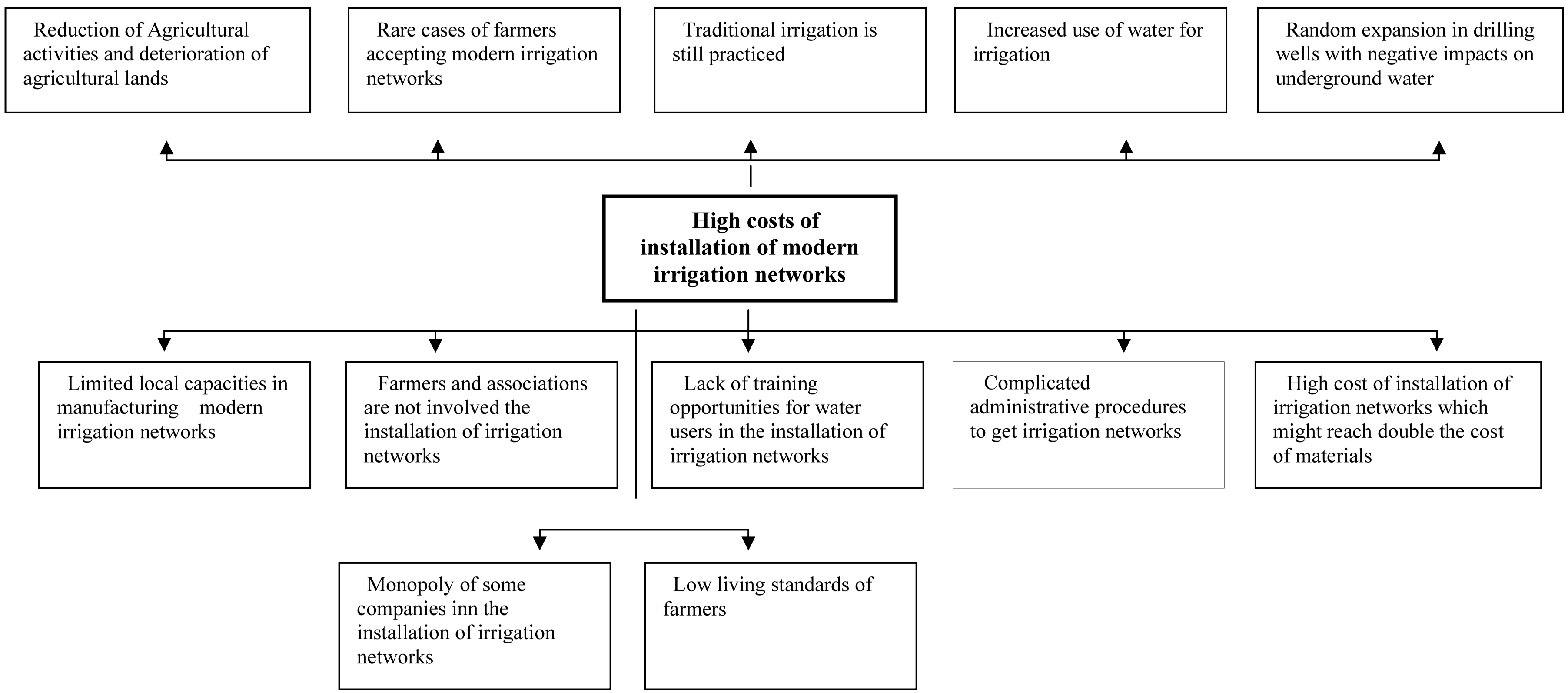
4. Method

1) Explanation of the method, explanation of the project
2) Brain storming on the major problems faced by the participants in Sana'a Basin
3) The problems were sorted out into themes
4) The participants were grouped according to each theme
5) Each group discussed about their own themes to reach the consensus for a core problem (group session)
6) Problem analysis: direct causes and direct effects from the core problem was discussed. (group session)
7) Solutions were discussed (group session)
8) Stakeholders were discussed (group session)

5. Summary of Results.

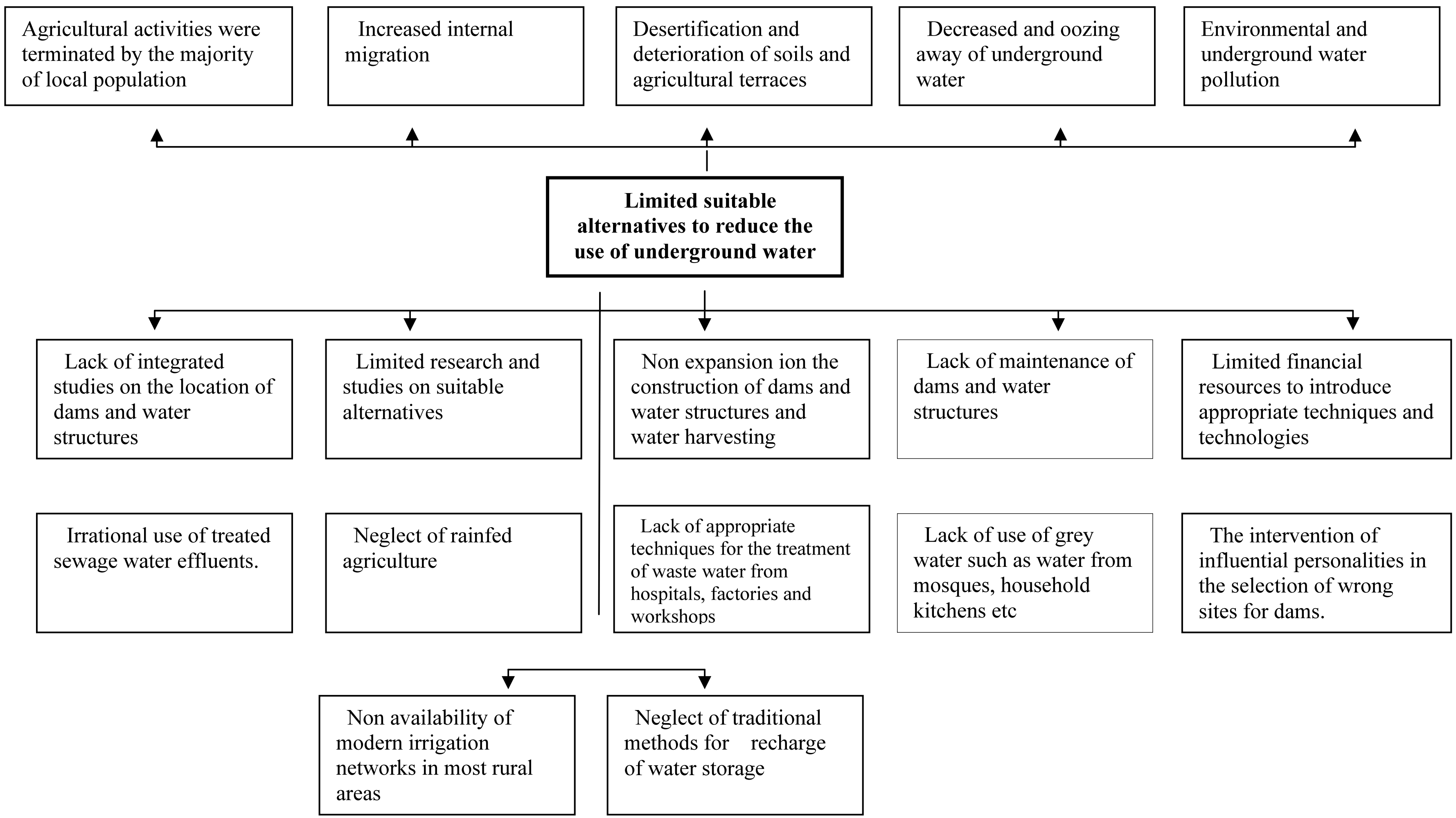
(next page)

Problem analysis and preparation of suggested solutions



Solutions

Conduct training programs and increase capacity of farmers in the installation and maintenance of irrigation networks	Support and promote local manufacturing of irrigation networks	Simplify procedures to get irrigation networks	Stop monopoly of companies in the erection of irrigation networks



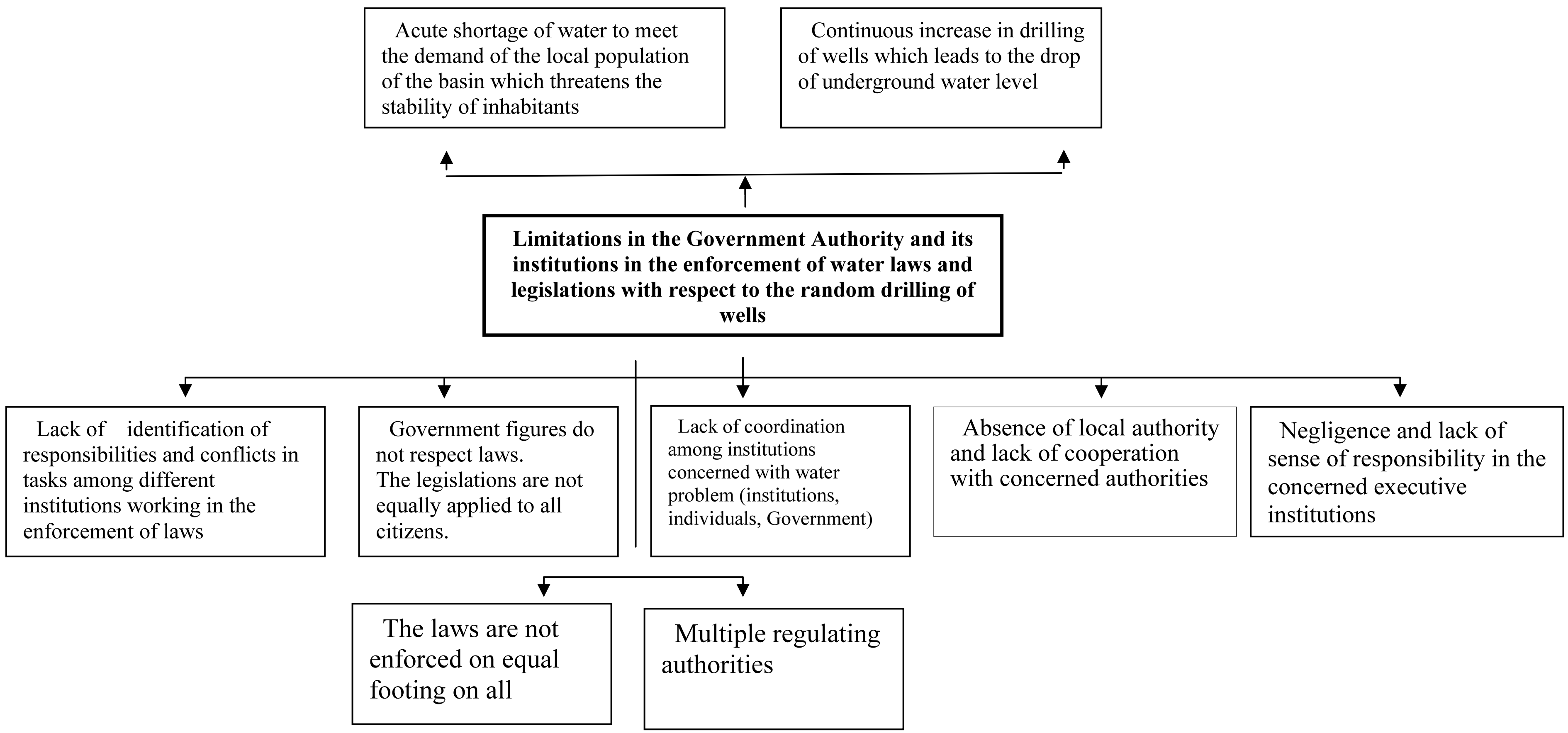
Agricultural activities were terminated by the majority of local population
Increased internal migration
Desertification and deterioration of soils and agricultural terraces
Decreased and oozing away of underground water
Environmental and underground water pollution
Limited suitable alternatives to reduce the use of underground water
Lack of integrated studies on the location of dams and water structures
Limited research and studies on suitable alternatives
Non expansion ion the construction of dams and water structures and water harvesting
Lack of maintenance of dams and water structures
Limited financial resources to introduce appropriate techniques and technologies
Irrational use of treated sewage water effluents.
Neglect of rainfed agriculture
Lack of appropriate techniques for the treatment of waste water from hospitals, factories and workshops
Lack of use of grey water such as water from mosques, household kitchens etc
The intervention of influential personalities in the selection of wrong sites for dams.
Non availability of modern irrigation networks in most rural areas
Neglect of traditional methods for recharge of water storage

Solutions

- Create a data base for compilation all cases related to the status of water in the basin
- Analyze and evaluate studies related to the status of water in the basin
- Conduct environmental impact assessment for the water structures
- Create job opportunities and sources of income to rural inhabitants to minimize migration to urban centers

- Introduce appropriate technologies to utilize grey water and treated sewage water
- Expand in an organized manner in the construction of dams and water structures.
- Support farmers in the construction of water structures and irrigation networks

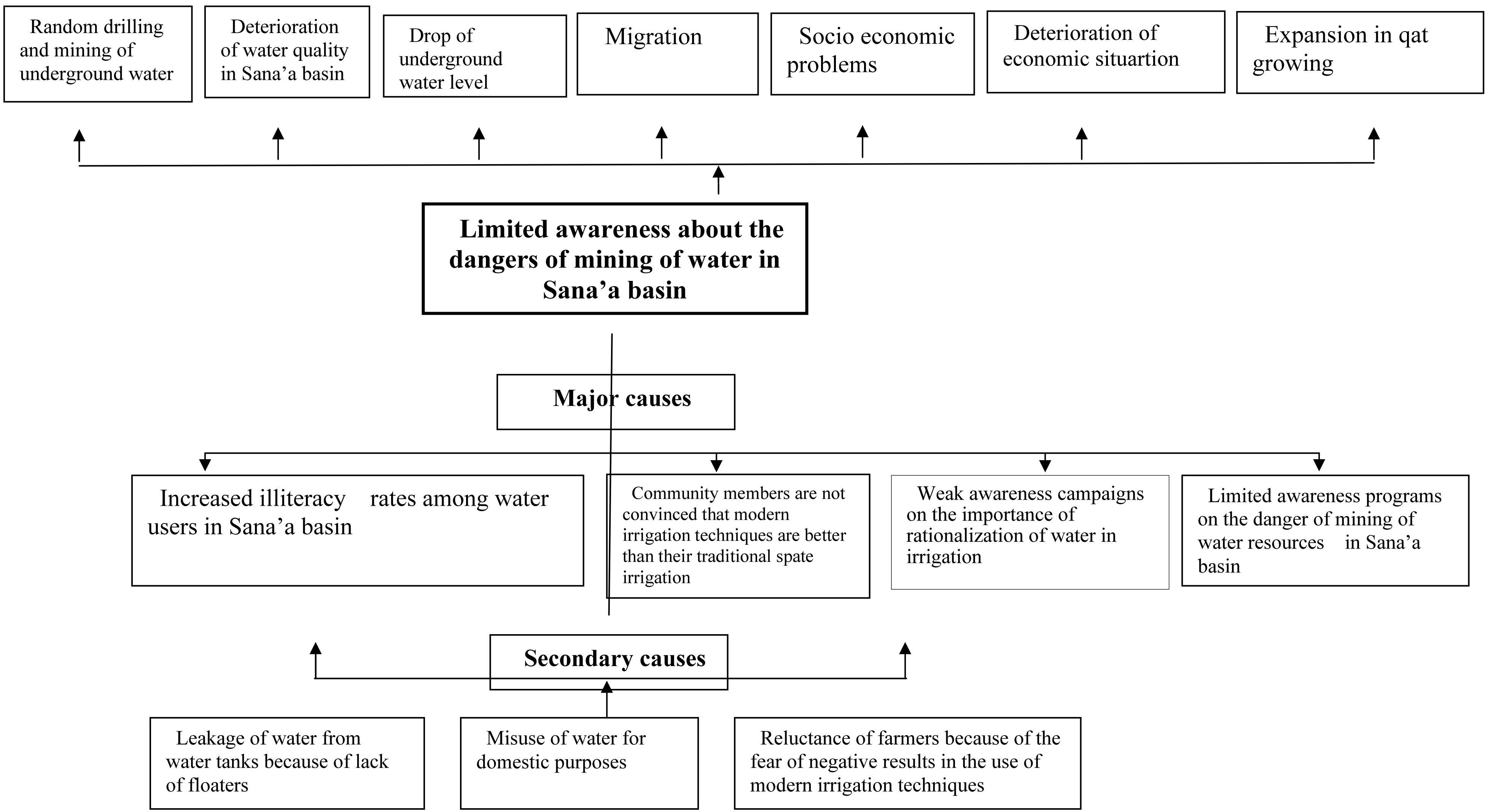
Analysis of problems and suggestions for solutions : Group number (2)

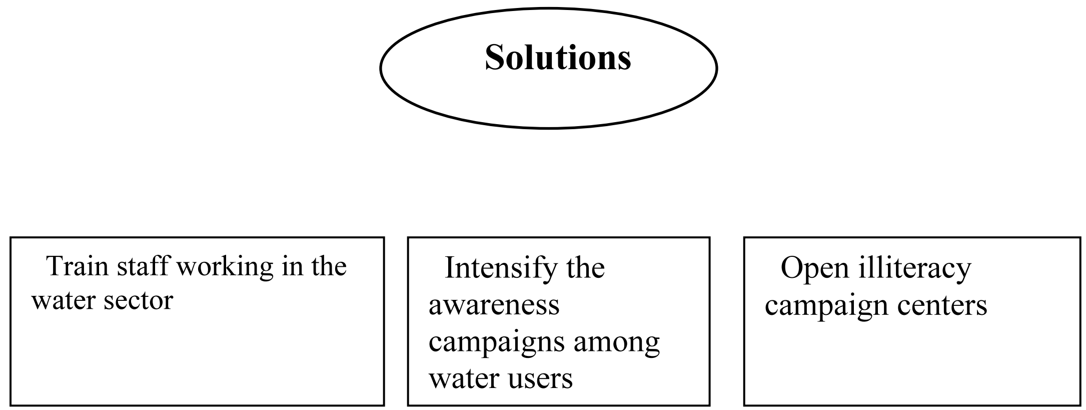


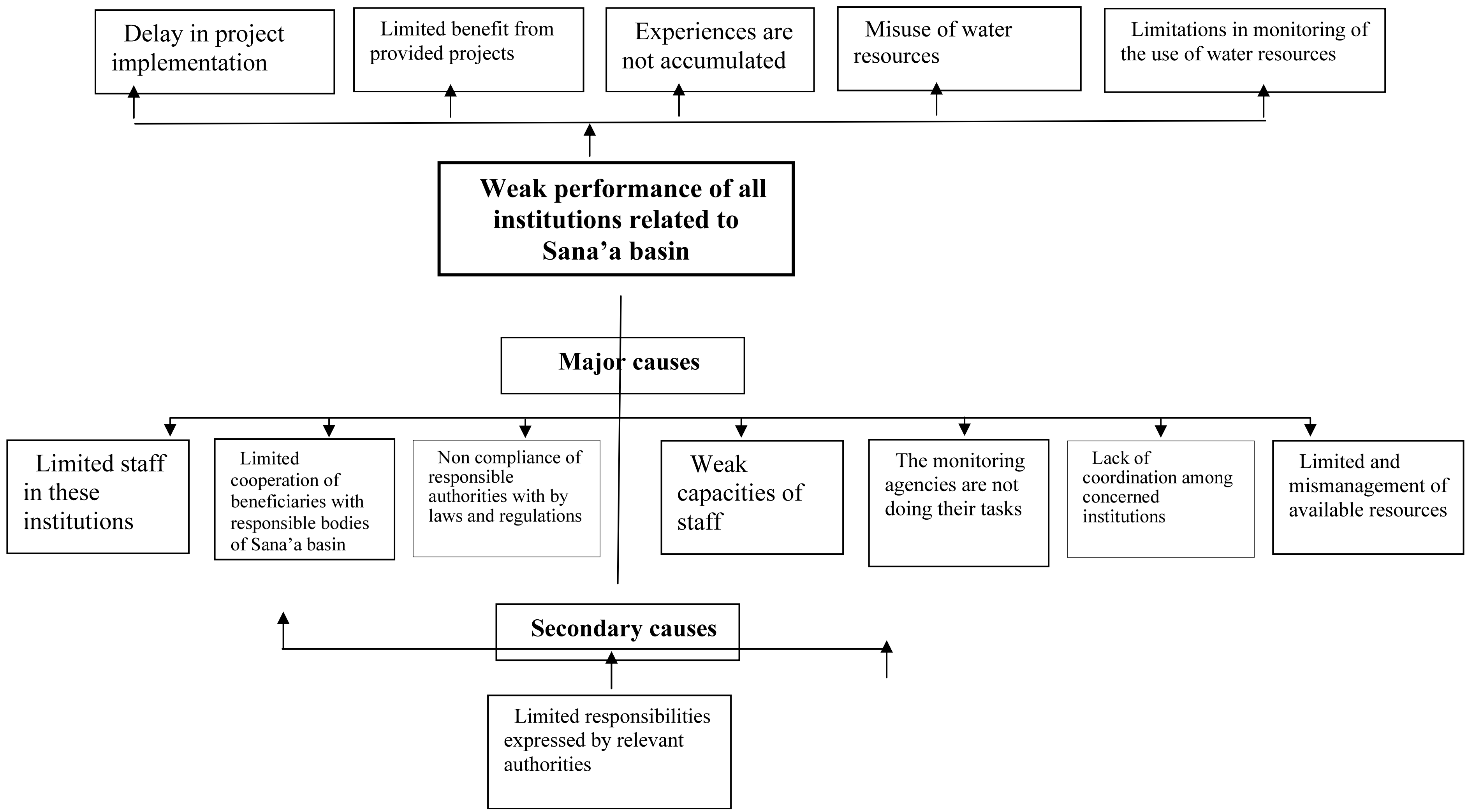
Solutions

- Give total authority to local councils for regulating and infracting actions related to random drilling of wells
- Prohibit the import of drilling rigs to the country
- Enforce government laws and regulations without hesitation and stop any interference by individuals which might affect the the laws and regulations with respect to random drilling of wells
- Ensure that the owners of drilling rigs do not drill wells without proper certificates issued by concerned authorities.
- Involve local communities in monitoring and enforcement of laws because they are equally responsible and they are the first to suffer

Analysis of problems and potential solutions : Group number (3)



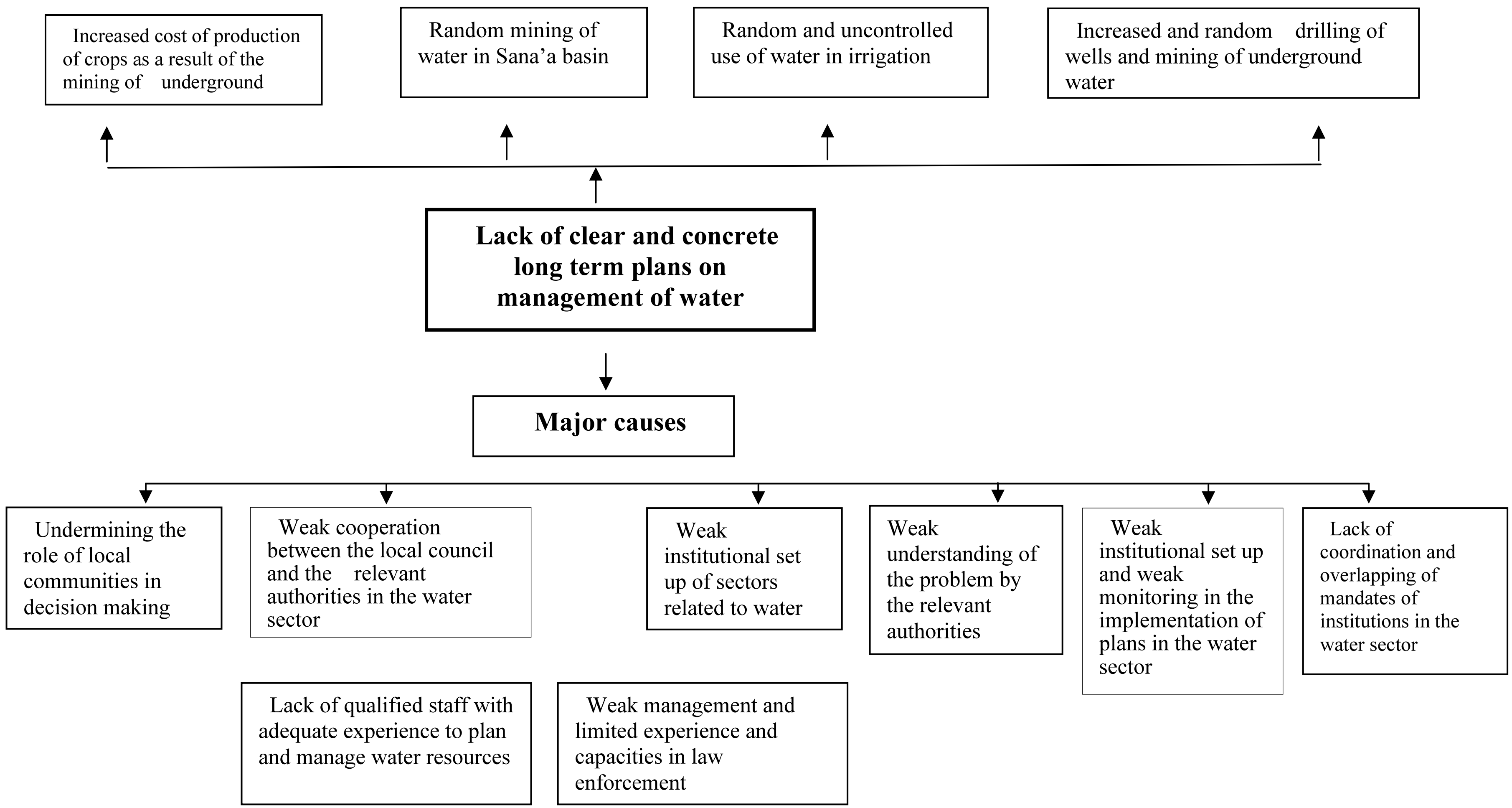

Solutions
Train staff working in the water sector
Intensify the awareness campaigns among water users
Open illiteracy campaign centers


Delay in project implementation
Limited benefit from provided projects
Experiences are not accumulated
Misuse of water resources
Limitations in monitoring of the use of water resources
Weak performance of all institutions related to Sana'a basin
Major causes
Limited staff in these institutions
Limited cooperation of beneficiaries with responsible bodies of Sana'a basin
Non compliance of responsible authorities with by laws and regulations
Weak capacities of staff
The monitoring agencies are not doing their tasks
Lack of coordination among concerned institutions
Limited and mismanagement of available resources
Secondary causes
Limited responsibilities expressed by relevant authorities

Solutions

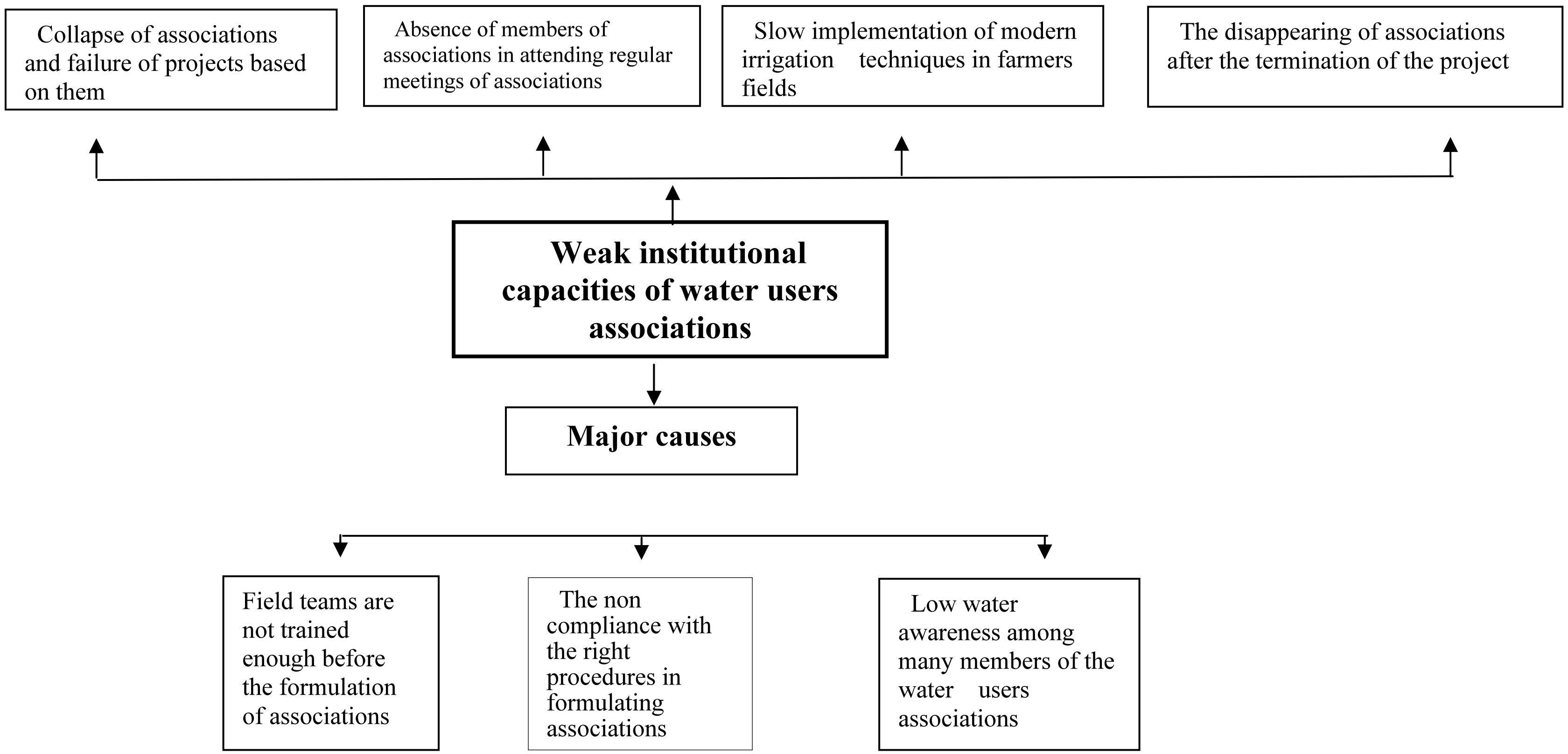
Train staff working in the water sector	Make use of available loans and grants	Provide required resources

Problem analysis and potential solutions : Group number (4)



Solutions

- Train staff working relevant agencies related to the water sector as well as the local community leaders in the management of water resources
- Conduct regular meetings of the water users associations
- Cooperate and coordinate among relevant authorities sand the local communities in preparation of plans and programs


Collapse of associations and failure of projects based on them
Absence of members of associations in attending regular meetings of associations
Slow implementation of modern irrigation techniques in farmers fields
The disappearing of associations after the termination of the project
Weak institutional capacities of water users associations
Major causes
Field teams are not trained enough before the formulation of associations
The non compliance with the right procedures in formulating associations
Low water awareness among many members of the water users associations

Solutions

Train staff engaged in the formulation of associations	Select qualified staff in the management positions of the associations	Train members of water users associations	Formulate a general union of association to ensure sustainability	Formulate associations and select management positions on the basis of social prestige and influence

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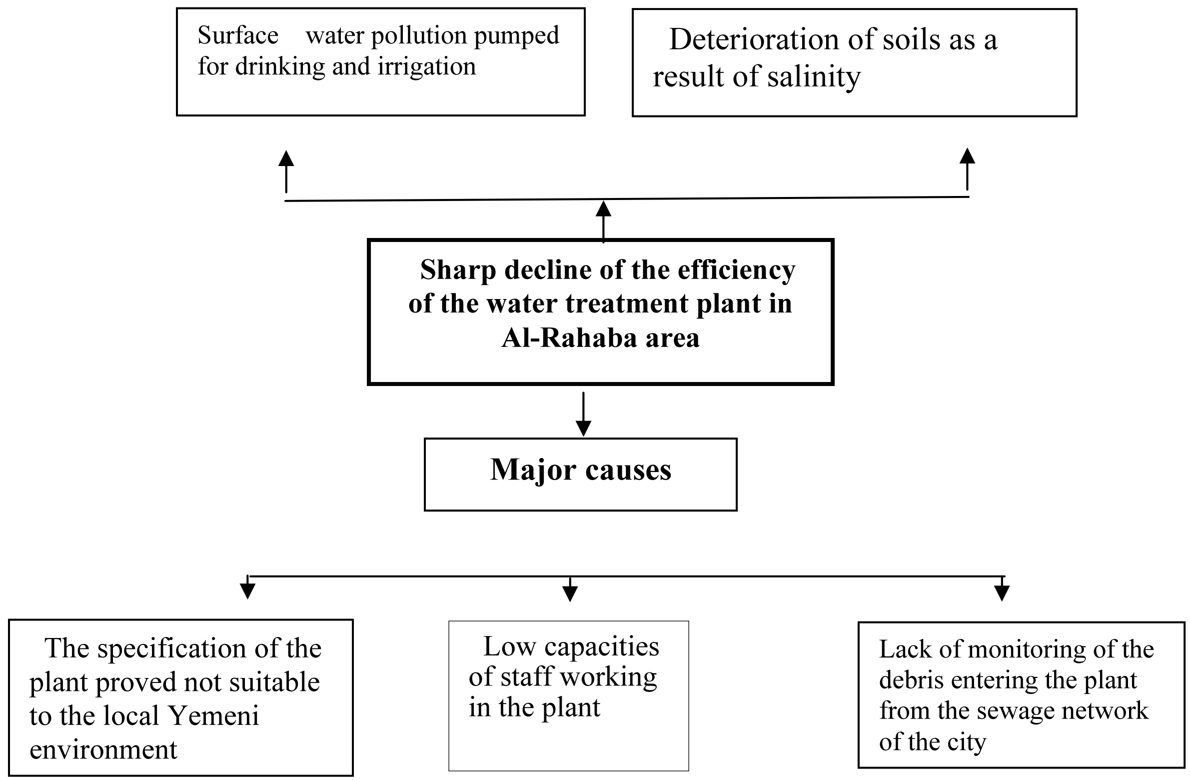
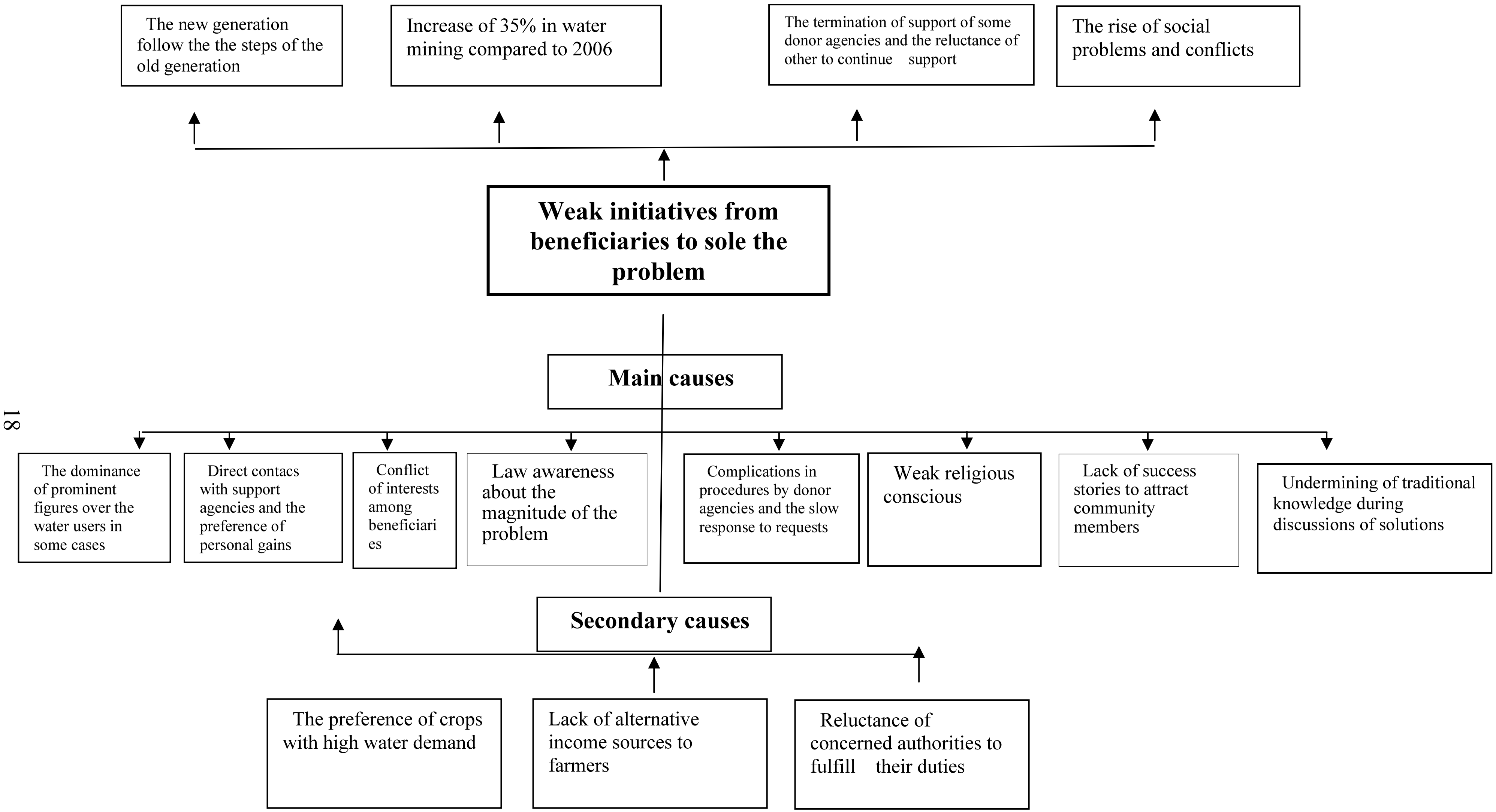
ت Analysis of problems and potential solutions : Group number (5)



Solutions

Increase capacity of the treatment plant to deal with hard and liquid debris

Control floods and prevent them from mixing with the sewage water


The new generation follow the the steps of the old generation
Increase of 35% in water mining compared to 2006
The termination of support of some donor agencies and the reluctance of other to continue support
The rise of social problems and conflicts
Weak initiatives from beneficiaries to sole the problem
Main causes
The dominance of prominent figures over the water users in some cases
Direct contacs with support agencies and the preference of personal gains
Conflict of interests among beneficiari es
Law awareness about the magnitude of the problem
Complications in procedures by donor agencies and the slow response to requests
Weak religious conscious
Lack of success stories to attract community members
Undermining of traditional knowledge during discussions of solutions
Secondary causes
The preference of crops with high water demand
Lack of alternative income sources to farmers
Reluctance of concerned authorities to fulfill their duties

Solutions

Intensify campaigns to raise awareness on the importance of personal initiatives

Simplify procedures in the donor agencies

Build capacities of local councils members

Appendix 13

Report of the Study on Water Resources Management in Jordan

Appendix 13

Republic of Yemen
Ministry of Water and Environment
NWRA
Sana'a Branch

A Report of the visit to Jordan during the period between the 10th-14th /6/2007 Concerning Water Resources Management Action Plan

Prepared by

Ibrahim Rajeh Al-Zubairy **Mohammad Abdul Salam Salim** **Eng. / Saleh Abdullah Al-Dubby**
NWRA- Sana'a
General Manager of Sana'a Basin

June -2007

Table of Content

In the Name of God Most gracious, Most Merciful

A Report of the visit to Jordan during the period between the 10^{th}-14^{th} /6/2007 Concerning Water Resources Management Action Plan

1. General background:

Sana'a basin, which the capital of Yemen falls in, is considered as one of the most critical underground water basin in the country. And it is threatened of drying. Also, it is one of the basins that were announced as protection water area according to the Cabinet decree no. (344) for 2002.

And until the current time, the basin lacks an implementation plan in order to manage its water resources which will be appropriate with its complications and different water circumstances socially and economically and go with the future plans and changes and to secure achieving a complete water resources management contributions on the society level, governmental and non- governmental, so as to decrease water crisis and reach a complete water development.

Through this, the Government of Yemen with the cooperation of the Government of Japan represented by JICA has signed a mutual cooperation agreement that includes preparing a drafting implementation plan for water resources management for the basin. The Japanese team from JICA is preparing it with the help of the Yemeni counterparts who are working in NWRA Headquarter and Sana'a Branch.

The visit of the Japanese and Yemeni team to Jordan falls under the program frame to prepare the plan and to benefit from the Jordanian experience in preparing and implementing the water resources management action plan in Jordan.

2. Arrangements and visits program:

1- **Arrangements :**

Preparing for this visit was made through the preparation of a group of inquiries and questionnaires, and then it was isolated according to the concerned administrations, as well as, preparing a timetable which shows the visits program in order to be sent in advance to the Ministry of Water and Irrigation, in Jordan. (Attached with a copy of the questionnaire and also a copy of visits programs)

2- **The program**

The program included a visit to many specialized authorities that belong to the Ministry of Water and Irrigation (Water Authority of Jordan and Jordan Valley Authority) and also to the JICA office in Jordan. Through the meetings with the Authorities a review of the full roles which are implemented by the concerned authorities in water resources management has been discussed. There was an exchange of discussions in order to understand the water policies, and the strategies in Jordan, so as to adopt a method according to the situation of Sana'a basin through a plan frame that must be prepared for the basin. The following is a summery of the visit according to the program:

3. First Day Visits (Monday 11 / 6/2007);

1- JICA office- Jordan

Host Names**:** Mr. Sato Takeaki Resident Representative
Ms**.** Fujiie Natsuko Assistant. Residential Representative

Meetings Topic:

- Explain the objectives of the visit to Jordan including the following elements:
- The Visits Goal
- The importance of benefiting from the Jordanian experience in water resources management.
- Training sessions in water resources management.

2- Training and Development Unit

Host names: Eng./ Basem Al-Zawaideh Director of Training and Development Unit –Water Authority of Jordan

Meetings Topic:

- Discuss the policy of training the water sectors crew in Jordan
- How to improve and develop the training procedures and mechanism
- To define the training priority's in training according to the work needs and necessity requirements to implement policies and strategies.
- Policy of suggested plans for University graduates and an employment system for the new staff.

The benefits from the lessons;

- A complete system of training exists and preparations in all fields concerning water are built on the necessary priorities.
- The application process should not be neglected and the interest in field work and transfer the theoretic scientific knowledge to operational knowledge and the ability the trainee will gain through this training policy.
- Follow a training policy for the new university graduates under the supervision of experienced engineers for a year. And through this direct contact office and field experience will be gained (100 new engineers will be trained annually).
- Follow the policy of connecting the employment degree with the training. With the least of training of 40 hours annually.
- Follow the policy of not limiting the specialization because the training may include a variety of specializations staring from operating and maintenance to planning and management.
- Follow the policy of before and after evaluation for the trainees and its effect on their performance level.

3- Underground Basins Management Directorate
Host: Dr. Khairi Al-Hadidi Director of Groundwater Basins Directorate – Water Authority of Jordan

Discussions;

- A background on the Ministry of water and irrigation in Jordan, and, the duties of the Basin directorate in implementing the requirements of the water resources management.
- Training the water basin programs and water information system (level, quantity, quality).
- Field survey, list the existing wells, collected information that concerned wells and modernize this information.
- The Government support in implementing water rules and legislations.
- The procedure that is being followed in order to control the digging of wells, seize illegal digging and the movement of rigs in the country.
- Digging licenses system, register wells and limit the quantity of water allowed to extract annually.
- Distribute the number of wells concerning its different uses.
- How convince the well owners of putting meters and impose water tariff system.
- Restructure the water sector and raise the irrigation ability concerning farm level.
- Rain water harvesting and artificial recharge.

Benefited lessons;

- The priority needed to build a complete water resources management and it include the following:

- List all the existing water resources, collect data and information concerning it and continue in modernize and monitoring the information as the first step to prepare a resources management plan.
- Qualified and provide the specialized staff in order to do field works.
- Provide equipments, machines and transportations and any necessary necessities, also, establish offices on regions level.
- Political support to apply water legislation and enhance field monitoring role and control the digging and rigs.
- Society awareness about the necessity of organizing and decreasing water uses and trying gradually to convince them to accept the new situation.

- considering water as a national property1 owned by the country is a good thing to help in controlling on digging wells and the extracted quantity of water.
- increase water awareness campaigns accompanied with setting meters on water wells in Jordan from 1994 till 2003.
- Existing private wells belong to the Ministry of Water and Irrigation to monitor the groundwater.
- obligate the requires of digging licenses for agricultural purposes to put meters and modern irrigation net.
- stop licenses issuing for digging wells that used for agricultural purposes and impose hard procedures to issue digging licenses for other purposes.
- mend the wells that are dug without license.
- improve irrigation capability, water harvest activities and artificial recharge for the ground basins.

4- Water Loss Directorate and the first indications of performance
Host: Eng./ Waleed Suker   Directorate Manager   - Water Authority of Jordan

Meeting subjects;

- The water situation in Jordan.
- Each person share of water in Jordan annually.
- The water cost according to the quality of water and the average crops
- Water providing system for the participants.
- The disadvantages of distributed pumping in the water net.
- The water loss in the net, the reasons and the precautionary procedures.
- The problems of illegal usage and connections.
- The precautionary procedures in order to stop the illegal usage.
- The role of the concerned authority in reducing the water loss.
- The procedures followed in order to reduce water loss.
- Information Waiba project.

Benefits from the meeting;

- the procedures and policies that followed in water loss management :

• Usage of minimum –night flow.

* The area is divided into a number of small and each area is isolated from the other.
* This area must be buried with water.
* A survey must be made in order to find the leakage.

• Setting water meters at the nets entrances in order to compare the quantity of water pumped with that in the bills.
• A complete and periodic survey must be made in order to discover the illegal usages.
• the procedures taken in order to implement the policies of water loss management :
• Establish numerous units and offices for water loss management in different areas in the governorates.
• These units are provided with experienced and qualified technicians.

These units are provided with developed vehicles in order to locate the loss and place of leakage.

• These developed equipments are:
• Ultrasonic flow meter.
• Noise data recorder equipment.
• Pressure and flow measurement equipment.
• Periodic training policy is made for the employees in loss water management with JICA help.
• Periodic awareness campaigns are made
• Distribute posters for the purpose of public awareness

• Policy of controlling violations:

- Punishments are implemented firmly according to the law.
- Reward to the employees to detect violation pipelines.
- The water supply network must be monitored and also the pipelines that transfer between the cities must also be monitored because these pipelines support Amman with water.
- The use of GIS program find out where the leakage and the loss.
- WAIBA project to provide water: Put special equipment on water faucets so as to reduce water consumption from it.

4. Second Day Visit (Tuesday 12/6/2007)

1- Water Systems Operation Directorate

Host: Dr. Mustafa Al-Assaf Director of Directorate of Water Authority of Jordan

Meetings subjects:
- Emergency plan to use private wells for domestic and municipality purposes.
- Improve the water type and observe pollution in nets and wells.
- How to face the demand on water because of increase in population.
- How to transfer water from rural areas to the cities with the agreement of the people and the treat the water rights.
- How to pump water through the nets and the type of nets used.

Lessons Benefited:
- Private Wells, when it is necessary, connect to water supply network system with the agreement of the wells owner by paying a specific amount.
- With the cooperation of the Ministry of Health, there should be a daily observation cycle for the quality of water coming out from the wells or when it flows to the net until reaching the final net and then analysed in laboratories.
- Interests in precaution procedures depending on the evaluation results of the quality of water.
- There are specific standards concerning drinking water nets and the importance of being distances away from sewage water nets.
- Find appropriate plans in order to cover the demand on water in areas where will be increase in population.
- Buy well with a circular area of 600 meters when the necessity comes to transfer water from areas that belong to locals.
- When digging wells with high salty water, there is no need to use developed irrigation system.

2- Water Resources and Planning Directorate

Host: Dr. Issa Al-Nasoor Directorate of Water Resources and Planning Directorate - Water Authority of Jordan

Meeting Topic:
- Planning for Water resources Management

Lessons Benefited:
Factors concerning the success of planning for the water resources management.
- The political support in preparing plans, programs, implementing laws, and water legislations.
- Find infrastructure and a good information basis.
- Prepare Water Observation programs for the basins.
- Prepare a map of areas where it is possible for the layers that easily become polluted and establish zone to protect water resources.
- Prepare a water strategy for the present and future.
- Prepare and implement awareness programs that are appropriate to the community and the participation of the water resources management and other authorities in these programs.
- Change the crops to less water consuming crops.
- Take strong actions against drillers and reduce the digging of wells.

3- Water Projects Directorate
Host; Dr. Othman Al-Kurdy Directorate Manager Water Authority of Jordan

Meeting Topic:

- There is no successful management for water resources in Yemen.

Lessons Benefited:
- There are crises because of unsuccessful management for water resources in Jordan.
- First, it is necessary to conserve the water uses in agricultural sector which is the most sector that consumes water and then the other.
- There should be water scenario and future predictions in order to take the necessary water resources management policies in Yemen.
- Improve the living circumstances for the employees of the water sectors, provide the necessary equipments and transportation which are basic condition for the success of the Water Resources management.

4- National Water Plan:

Host: Eng./ Susan Taha National Water Plan Manager – Ministry of Water and Irrigation

Meeting topics:

- General background concerning the National Digital Plan
-.General database system.
- General awareness and water users associations.
- Future water scenarios considering the increase in population.
- Re allocation of water for the purpose of reducing the gap and demand.
- Conditioning the existence of rainwater harvest system form the roofs of the houses (new buildings).

Benefits from the meeting;

- The digital plan is a mathematical patterns which are established in a GIS program (geographical information system) and it is formed from the following:
  - Description of the quantity and the quality of surface and underground water resources as well as the alternative resources.
  - Description of the current and future water necessity by different sectors.
  - Description for the needed technical and operational procedures in order to reduce water deficiency in deferent areas of the country for the coming years, as well as , take in consideration the social, economical and environmental aspects.
- Knowing the water scenarios and the future meditations are important to put fit plans and policies to avoid water crisis or reduce it.
- The importance of school awareness and place the water awareness subjects as a part of the curriculums
- The necessity of connecting between the public awareness and reduce the average population growth through a developmental plans for the country with a concentration on the population growth on each persons annual share form water.
- The interesting in establishing rain water harvest institutions to benefit from the lost rainwater.
- Count the annual water budget, taking in consideration all available abilities to provide agricultural sector needs.
- Encourage the investments in neighboring areas where there are no buildings or people.

5. Third Day Visits (Wednesday. 13/6/2007)

1- surface water control unit – Deer Ula

Hosts Dr. Shafek manager of water department – Jordan Valley Authority

Meeting topics

- Rationalization surface water use and rain water harvest**.**
- Use treated water for irrigation and pure water for drinking.
- Improvement of the irrigation efficiency using drop irrigation system.
- The problem of marketing crops.
- Use computer control system in distributing surface water called SCADA system

<u>Benefited lessons;</u>
Consumption tactics concerning water uses:
-The use of sewage and treated wastewater in irrigation and provide the pure water for drinking.
- Interested in rainwater agricultural and encourage harvesting rainwater.
- Raise the irrigation qualification from the water resources to the farm and follow the drop irrigation system and reduce the evaporation.
-Support and encourage the farmers in following modern irrigation techniques.
- Notice the pumping stations distribution from king Abdullah channel to the capital Amman (supported by JICA).

2-The national center for agricultural researches and technology transformation- AlBaka'a- Jordan Wadi
<u>Hosts;</u> Dr/Mohammad AlDabas National Center Manager

<u>Meeting topics:</u>

-Training programs and manners in researches center.
- Discussion about the needed level for implementation of a successful training session for the representatives of water users associations.

<u>3- JICA Office- Jordan:</u>

<u>Hosts</u>	Sato Takeaki	Resident Representative
	Mr. Fujii Natsuko	Assistant Resident Representative
	Mr. Uskiki Hisao	JICA Advisor

<u>Meeting topics:</u>
- The benefit from the Jordanian's experience in order to compose an implementation plan for water resources management for Sana'a basin.
- The important of having a tax system for water consumption as a successful step to reduce the use of water.
- Awareness campaigns importance, and change the culture of the community concerning the consumption of water use and the monitoring system.
- Fasten the procedures of issuing wells digging license.
- Future programs in Sana'a basin.
- Raise the interest for the specialized staff for both quantity and quality in water resources management.
- How far the implementation of the monitoring system on extracts water in different sectors (in Sana'a basin for example) as in Jordan.
- Water property, the difficulty of registration wells, limits the quantity of extract water and the importance of monitoring the wells digging.
- Training sessions for the water sector staff (concentration on training and qualify the technical staff in the water sector so as to implement the water strategies and polices with high efficiency.

6. Notices on the visits:

We were pleasure to have chosen Jordan because its nature and water situation is similar to ours. There are few differences concerning experiences, scientific and practical, in water resources management. But there are some notes that should be mentioned so to not happen in the future when having such studies, there notes are:

- The visit was short; there were no field visits which enhance the theoretical information.
- The lack coordination for the visit and this led to difficulty of implementing the program because some administrations were busy.
- There was no break between the meetings which would ease the internal discussions of the team in order to put a plan to get benefit form the next meeting.

7. Summary:

1- the necessity that plan have a clear policy for training the water sector staff through :

- Put a complete training and qualifying system in all different fields concerning water according to the priorities and taking into consideration the variety of knowledge for all work fields that are related to water.
- The importance of training the new employees by the experienced employees.
- Put the regulations for the employment degrees which include personal development through training programs and scientific researches.
- Never neglect the evaluation of the training to get the concerned authorities benefit from the trainees according to their creative abilities.
- Provide the financial support for the training.

2- Improve the living situations for the water sector employees and provide the necessary equipments and transportation and all the necessary materials needed. And establish offices at water areas level.

3- Limit the existing water resources, collect data and information concerning it. Also prepare programs to monitor water basins using limited monitor wells and infrastructure, also locate infrastructure and a good information basis.

4- The importance of the political support to raise the following activities concerning the control of the underground water because it is a public property.

- The enforcement of water laws and implements the water legislations and raises the standards of field monitoring, and controls the illegal digging and the driller's violations.
- Stop the issuance of licenses for well digging for irrigation purposes and impose strict regulations in issuing licenses for other uses.
- Fill up (bury) the wells that are building illegally without a license and seize the unlicensed drillers and impose strict procedure concerning this matter.

- Impose on wells digging licenses for the purpose of agriculture to install meters on their wells and install developed irrigation net and limit the flow

area and the total amount pumped out with the coordination with the Ministry of Agriculture and Irrigation.
- Observe over the wells digging and trail digging.
- The management should be decentralization and the participation should be with local communities through the establishment and training of the waters users associations. Also the concerned authorities should participate in these trainings and workshops must also be made, conferences and there should be encouragement.
- Interest in raising the water awareness to the new generations through special school programs and put these programs as a main lesson in schools.
- Put an organizational frame in order to benefit from drinking wells in cities.

5- When putting the plan what must be taken into consideration are as follows:
- Follow up water and sewage water projects according to the increase population.
- Prepare protection zone to prevent the water resources from pollution.
- Study the possibility of changing the agriculture system and plant crops that are high in economically and low in water usage.
- It is necessary to conserve water uses in agricultural sector which it is the most sectors of water consumption and then the other.
- Understand the water scenario and the future predictions in order to take the necessary water policies so as not to face any crises.
- Establish collection facilities for rain water and artificial feeding for the underground basins. And also encourage agriculture through rain water irrigation.
- Raise and improve the irrigation abilities from the water source to the farms through the support of farmers to use developed irrigation systems like drop irrigation and reduce vaporization.
- Use treated sewage and waste water for agriculture and provide pure underground water for domestic and drinking.
- Encourage water investment in areas that has enough water resources..

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