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

MAIN REPORT

November 2007

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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

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Exchange Rate Employed

in the Study

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PREFACE

In response to a request from the Government of the Republic of Yemen, the Government of Japan decided to conduct a study on the Water Resources Management and Rural Water Supply Improvement in the Republic of Yemen, Water Resources Management Action Plan for Sana'a Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Hiroyoshi YAMADA of Earth System Science Co., Ltd. (ESS) and composed of ESS and Japan Techno Co., Ltd., between February 2007 and October 2007.

The team held discussions with the officials concerned of the Government of the Republic of Yemen, and conducted field surveys in the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of a friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Yemen for their close cooperation extended to the study.

November 2007

Ariyuki Matsumoto
Deputy President
Japan International Cooperation Agency

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

November 2007

Mr. Ariyuki Matsumoto
Deputy President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit you the final report entitled "The Study for Water Resources Management and Rural Water Supply Improvement in the Republic of Yemen, Water Resources Management Action Plan for Sana'a Basin". This report has been prepared by the Study Team in accordance with the contracts signed on 30 January 2007 and 27 Apr 2007 between Japan International Cooperation Agency and the Joint Study Team of Earth System Science Co., Ltd. and Japan Techno Co., Ltd.

In the study, we examined the existing conditions related to water resources, socio-economy and institution and organization in Sana'a Basin, set the scenario to be followed for mitigation of the critical situation of water resources from the view point of utmost possibility of the implementation and presented the water resources management action plan for Sana'a Basin to be taken for achievement of the scenario.

The report consists of the Summary, Main Report and Supporting Report. The Summary summarizes the results of all studies. The Main Report contains the existing conditions, the future scenario to be followed, the water resources management action plan for Sana'a Basin, and conclusions and recommendations. The Supporting Report includes technical details of the Study.

All members of the Study Team wish to express grateful acknowledgement to Japan International Cooperation Agency (JICA), JICA Advisory Committee, Ministry of Foreign Affairs, Embassy of Japan in the Republic of Yemen, other donors, NGOs and also to Yemeni officials and individuals for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the solution of the unprecedented critical condition of water resources in Sana'a Basin, and that friendly relations of both countries will be promoted further by this occasion.

Yours Faithfully,

Hiroyoshi Yamada
Team Leader

EXECUTIVE SUMMARY

1. BACKGROUND OF THE STUDY

In Sana'a Basin, where the capital of Yemen is situated, development of deeper aquifer has been greatly increased to meet the dual demands of domestic water supply and irrigation. As a result, the water shortage has become worse, and is now being accelerated by continued imbalance between annual recharge and the growing water demand.

Sana'a Basin was designated to be "Water Protection Zone" by the Cabinet Decree No. (344) in 2002, and was designated as the one of the five critical basins. Then, the National Water Resources Authority Sana'a Branch (NWRA-SB) was established in 2003 to implement activities related to water resources management for Sana'a Basin. Additionally, the Sana'a Basin Commission (SBC) was organized with the technical secretariat NWRA-SB to execute management of water resources in Sana'a Basin. Comprehensive water resources studies inside Sana'a Basin have been conducted since 1970s; however, NWRA-SB has faced difficulties in implementing water resources management effectively. In this context, the Government of Yemen requested the Government of Japan to execute the technical cooperation plan, to formulate water resources management action plan for Sana'a Basin, based on the existing data and information.

2. FUTURE SCENARIOS BASED ON SOCIO-ECONOMY AND WATER DEMAND IN SANA'A BASIN

(1) Future Water Balance

The projected future water demand is gradually increased from 269.3 MCM in 2005, to 349.6 MCM in 2020. As the same time, renewable groundwater resources were estimated to be only 50.7 MCM/year. The balance, between renewable resources and demand is estimated to be minus 298.9 MCM in 2020, if the recharge amount is not changed. The implication of these numbers is that non-renewable water resources will continue to decrease. Additionally, the estimated amount of usable groundwater in the existing data is 5,212 MCM. Therefore, if the water consumption is continued in accordance with the projected future water demand, usable groundwater would not be able to meet the demand in the year of 2021, as shown in *Figure 1*.

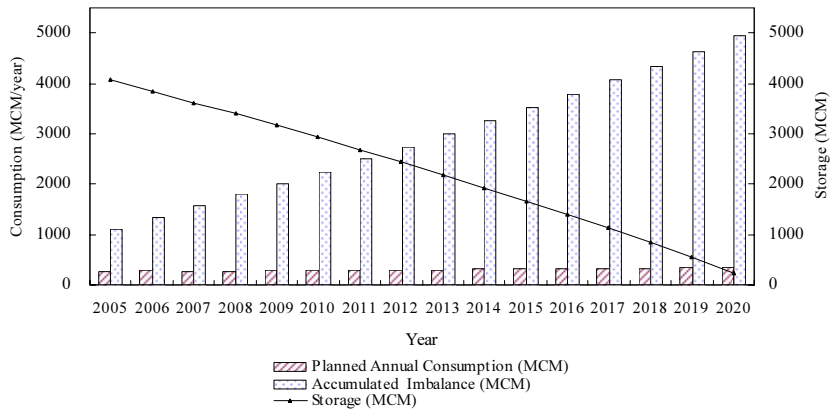

Figure 1 Decreasing of Storage with Planned Future Demand

(2) Future Scenarios

In order to keep sustainability of water resources in the Basin, all irrigation activities should be stopped and water to be supplied for urban areas should be nearly two thirds. However it is unrealistic way considering that economic activities rely on the agriculture sector. Therefore, all stakeholders are strongly required to reduce water consumption by 2020 at the very latest so as to obtain the opportunity to approach the next steps, in accordance with the scenario showing the direction towards reducing water consumption. In this study, from the view point of this, the scenarios for water demand were considered. Considered scenarios with a target figure in the year of 2020 are summarized in *Table 1* and shown in *Figure 2*. These four scenarios are prepared in combination with scenarios of five sectors. Condition of setting for each scenario is as follows.

- Scenario 1: The values for less contribution to reduction of water consumption in each sector such as higher growth rate and lower irrigation efficiency, which are set in the existing plan and set by the Study team, are applied.

- Scenario 2: The values for the most possible reduction of water consumption set by the Study team for urban area water supply and irrigation use that account for large portion of total water consumption are applied.

- Scenario 3: The values for the most possible reduction of water consumption set by the Study team are applied to not only urban area water supply and irrigation use but also industrial and touristic use.

- Scenario 4: The values for the most possible reduction of water consumption set by the Study team are applied to urban area water supply, industrial use and touristic use. For irrigation use, reduction of water consumption to 50 MCM is applied taking into consideration the reuse of treated wastewater in the year 2020.

Table 1 Summarized Scenario of Water Demand

	Urban Area Water Supply (Domestic and Institutional)	Domestic Use in Rural Area	Industrial Use	Touristic Use	Irrigation Use	Total*8) Consumption
Scenario 1	Population: 3,198,573 LPGR*1) Physical Loss: 14.6 MCM (20%)*2) Unit water consumption : 35 l/c/d*3)	Population: 437,532*5) Unit water consumption: 20 l/c/d*5)	Historical growth rate, DPPR*6)	Based on DPPR	No expansion of irrigated area since 2005 IE: 60%*7) Actual requirement: 83.68 MCM/year	***232.3***
MCM/year	**73**	**3.2**	**9.5**	**7.1**	**139.5**	
Scenario 2	Population: 3,198,573 LPGR Physical Loss: 10.3 MCM (15%)*4) Unit water consumption: 35 l/c/d	Population: 437,532 Unit water consumption: 20 l/c/d	Historical growth rate, DPPR	Based on DPPR	No expansion of irrigated area since 2005 IE: 70% Actual requirement: 83.68 MCM/year	***208***
MCM/year	**68.7**	**3.2**	**9.5**	**7.1**	**119.5**	
Scenario 3	Population: 3,198,573 LPGR Physical Loss: 10.3 MCM (15%) Unit water consumption: 35 l/c/d	Population: 437,532 Unit water consumption: 20 l/c/d	No growth in Industry inside the Basin since 2005	No growth in Tourism inside the Basin since 2005	No expansion of irrigated area since 2005 IE: 70% Actual requirement: 83.68 MCM/year	***196.6***
MCM/year	**68.7**	**3.2**	**4.8**	**0.4**	**119.5**	
Scenario 4	Population: 3,198,573 LPGR Physical Loss: 10.3 MCM (15%) Unit water consumption: 35 l/c/d	Population: 437,532 Unit water consumption: 20 l/c/d	No growth in Industry inside the Basin since 2005	No growth in Tourism inside the Basin since 2005	Reduce 11,111 ha of irrigated area out of 18,954 ha Install improved irrigation system for 7,843 ha	***127.1***
MCM/year	**68.7**	**3.2**	**4.8**	**0.4**	**50**	

*1) LPGR: Limited Population Growth Rate set in Sana'a Water Supply and Sanitation Project (SWSSP)
*2) Physical Loss, 20% is set in SWSSP
*3) Option 1 set in SWSSP, Minimum option, water is supplied of entire city population

*4) Physical Loss, 15% is set by the Study team
*5) Population growth rate in rural area: 2.5%adopted by GARWSP and unit water consumption, 20 l/c/d: adopted by NWRA.
*6) Calculated value based on the Socio-economic development plan for poverty reduction (DPPR, 2006-2010)
*7) Irrigation efficiency
*8) Total consumption includes loss of water supply and overuse in irrigation

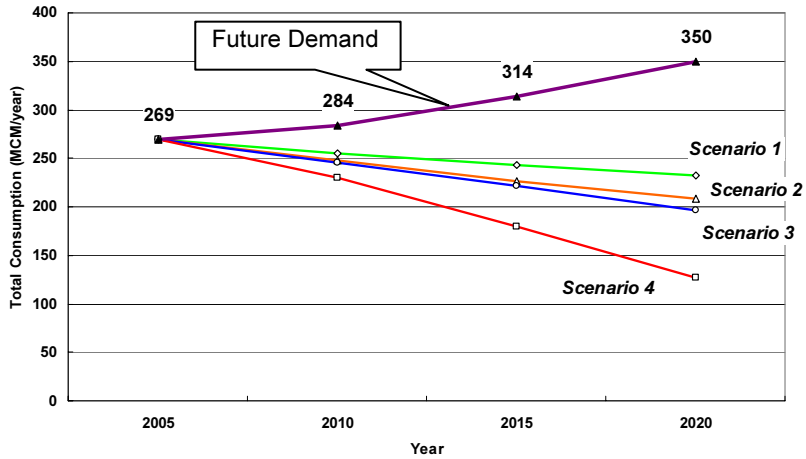

Figure 2 Scenarios for Water Demand (2005 – 2020)

(3) Future Scenario towards Maximum Sustainability

Four scenarios aiming at reducing consumption of water resources set are evaluated taking into consideration the difficult condition of water resources, in order to select most reasonable scenario. Result of evaluation of each scenario is as follows.

- Scenario 1: Though the irrigation efficiency is set at 60%, there is a possibility of further improvement of the efficiency by installing pipes for water conveyance. In addition, physical loss in urban water supply is set at 20%. However, the percentage of physical loss is able to be reduced by introducing the technology of water leakage detector for invisible leakage from the ground. Therefore, it can be concluded that there is a possibility of further reduction of water consumption in this scenario.

- Scenario 2: Reduction of water consumption in irrigation use and urban area water supply sectors which account for large portion of total water consumption, is the largest as much as possible. While no measure to reduce water consumption in industrial and touristic use is taken. Therefore, it can be concluded that there is a possibility of further reduction of water consumption in this scenario.

- Scenario 3: Reduction of water consumption in irrigation use and urban area water supply sectors which account for large portion of total water consumption, is the largest as much as possible. In addition, control of the growth of water demand in industrial and touristic sectors is set in this scenario. Therefore it is concerned that economic activities would be affected if further measures are taken to reduce water consumption.

- Scenario 4: In addition to the settings in the scenario 3, water consumption for irrigation use is set to be reduced to 50 MCM that corresponds to available treated wastewater in the year 2020. In this setting, farmers are required to reduce their irrigated area to one third of present area and agricultural products would be decreased. As a result, decrease of farmers' income and adverse impact on agricultural activities would be concerned. Therefore, implementation of the scenario is assumed to be very difficult.

As mentioned above, there is a possibility of further reduction of water consumption in the scenarios 1 and 2. Adverse impact on the agricultural activities is concerned in the scenario 4, though the amount of reduction is the maximum among above 4 scenarios. Therefore, the scenario 3 which has possibility of implementation of measures and the most possible reduction amount of water consumption, is selected as the scenario towards sustainability of water resources in Sana'a Basin.

By implementing the Scenario 3, water resources of 153 MCM in 2020 can be saved, in turn, the grace to be critical situation of water resources will be expanded until the year of 2036 that is around 30 years later from 2007.

Improvement of the irrigation efficiency, improvement of the physical loss in the water supply in urban area, reuse of the treated wastewater for irrigation are the actions to be taken with top priority by the year of 2020 in conformity with the scenario 3. Since the contribution towards reducing water consumption is very high and implementation of each component is practicable.

However, it should be mentioned that though the Scenario 3 is completely implemented, the precious groundwater resources will be definitely in very critical situation in the year 2037.

3. WATER RESOURCES MANAGEMENT ACTION PLAN

(1) Contents of Action Plan

In order to mitigate the critical situation facing water resources and to secure sustainable water sources for future generations, potential action plans, and related details, are listed in *Table 2*; these plans take into consideration the present condition of water resources and future socio-economic scenarios. Each "Water resources management action plan" is composed of "Immediate Action Plan" and "Action to be taken for Long-Term Progress" the former are the actions to be taken right away in order to achieve the Scenario 3, which is to reduce 153 MCM of water consumption by 2030, greatly contributing to mitigate severe condition of water resources. The latter are concrete steps to enhance the long-term effectiveness achieved by the "Action Plan". Both will help mitigate severe water resources conditions, however, it should be noted that the amount of water that can be reduced is not clarified. Therefore, understanding of present condition is the first step of any of these actions.

Table 2 Actions to be Taken

No.	Contents of Water Resources Management Action Plan for Sana'a Basin
Immediate Action plan	
1	**Reduction of water consumption for irrigation purpose** (1) Increasing the farmer's perception of effectiveness of improved Irrigation System (2) Facilitation of farmers' understanding not to expand their farmland (3) Installing improved irrigation system (4) Introducing watering control system with installation of water flow meter (5) Improvement capability of GDI/NWRA-SB staff in charge of irrigation activities

	(6) Reconsideration of subsidizes for irrigation activity
2	**Reduction of physical loss of urban water supply** (1) Promotion of understanding of water users in Sana'a city to accept the reduction of unit water consumption (2) Improvement of the capability of leakage detection (3) Monitoring the production amount and progress of improvement of losses
3	**Assuring reuse of treated waste water** (1) Assuring the improvement of existing WWTP and new construction of WWTP (2) Planning the distribution of treated water (3) Promotion of farmers' understanding of the treated wastewater use by the demonstration (4) Monitoring of water quality
4	**Control of consumption of industrial use** (1) Preparation of inventory of existing water sources used in factories (2) Promotion of understanding of owners of factroies not to expand their activities inside Sana'a Basin (3) Reducing overuse of water in factories and reuse of water inside factories (4) Preparation of master plan for industrial sector taken into consideration water resources condition
5	**Control of consumption of touristic use** (1) Preparation of inventory of water sources used for touristic use (2) Facilitation of hotel owners to understand not to expand their water consumption (3) Preparation of sector development plan wich considers the current condition of water resources.
6	**Institutional development** (1) Finalization of the "Executive Regulation to the Water Law of 2002", and development of the "Decree for Water Protection Zone of Sana'a Basin" (2) Increasing awareness of public and political leaders for water resource management (3) Respect to both traditional and tribal system (4) Improvement of decentralized framework of local administration and organization
7	**Organizational development** (1) Enhancement of functions of NWRA SB as follows: (a)Develop organizational structure, (b) Develop human resources, (c) Improve financial management, (d) Improve regulation and monitoring mechanisms (2) Promotion of incorporation of Local Council in the local organizational framework of basin-level water resources management (3) Promotion of involvement of traditional leaders and tribal institution in the implementation of water resources management, under the initiative of the Sana'a Basin Commission (SBC) (4) Improvement of awareness of Water User Association (WUA) for reducing water consumption
Actions to be taken for Long-Term Progress	
1	**Protection of groundwater resources from contamination** (1) Control of contamination caused by discharge from factories - Preparation of inventory of possible sources of groundwater contamination - Increasing of awareness of owners of factories, petrol stations, and small shops - Enforcement of Article (54) of the Water Law and preparing its Executive Bylaw - Preparation of collection system for the disposal of industrial wastewater (2) Control of over utilization of chemical fertilizer and pesticides
2	**Effective use of surface water** (1) Increasing the effective use of water harvesting - Preparation of inventory of existing water harvesting methods - Promotion of farmers' understanding to use water harvesting systems properly (2) Consideration of "recharge" and "sub-surface" dams - Monitoring and evaluation of on-going activities related to recharge improvement - Consideration of integrated approach towards appropriate management of recharge systems
3	**Optimization of water supply covered by private suppliers in Sana'a city** (1) Comprehension of the present situation of the private water supply and establish a database (2) Increasing the awareness of water saving practices among private suppliers (3) Introduction of meter-use for monitoring purposes
4	**Inter-Regional and Sectoral Reallocation of Water Resources** (1) Reallocation of water from irrigation-use to urban/ domestic-use (2) Persuading the tribes to agree to both (a) transfering water from their own land to other places, and (b) allowing water transfers across their property

(2) Implementation Schedule for Action Plan

Proposed implementation schedule for Action Plan is shown in *Table 3*. This schedule is prepared in consideration of the ongoing projects such as SBWMP and the rehabilitation of the WWTP, and should be re-scheduled based on the progress of each activity and in accordance with actual conditions on the ground, under the initiative of NWRA-SB, together with relevant organizations.

Table 3 Proposed Schedule for Action Plan

Action to be Taken			Responsible Organization*1	Status*2	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Reduce of Water Consumption for Irrigation Purpose	(1)	MAI	SBWMP														
				Action plan														
		(2)	MAI	Action plan														
		(3)	MAI	SBWMP														
				Action plan														
		(4)	MAI	Action plan														
		(5)	MAI	SBWMP														
				Action plan														
		(6)	MAI	Action plan														
2	Reduce of Physical Loss of Urban Water Supply	(1)	SWSLC	Action plan														
		(2)	SWSLC	SWSLC														
				Action plan														
		(3)	NWRA-SB	Action plan														
3	Assuring Reuse of Treated Wastewater	(1)	SWSLC	SWSLC														
				Action plan														
		(2)	SWSLC	SWSLC														
				Action plan														
		(3)	MAI	Action plan														
		(4)	NWRA-SB	Action plan														
4	Constant Consumption of Industrial Use	(1)	NWRA-SB	Action plan														
		(2)	NWRA-SB	Action plan														
		(3)	NWRA-SB	Action plan														
		(4)	MoI	Action plan														
5	Constant Consumption of Touristic Use	(1)	NWRA-SB	Action plan														
		(2)	NWRA-SB	Action plan														
		(3)	MoT	Action plan														
6	Institutional Development	(1)	NWRA-HQ	NWRA HQ														
				Action plan														
		(2)	NWRA-HQ	Action plan														
		(3)	SBC	Action plan														
		(4)	SBC	Action plan														
7	Organizational Development	(1)	NWRA-SB	Action plan														
		(2)	SBC	Action plan														
		(3)	SBC	Action plan														
		(4)	NWRA-SB	SBWMP														
				Action plan														

*1): MAI: Ministy of Agriculture and Irrigation
SWSLC: Sana'a Water and Sanitation Local Corporation
NWRA-HQ: National Water Resources Authority Headquarters
NWRA-SB: National Water Resources Authority Sana'a Branch
MoI: Ministry of Industry
MoT: Ministry of Tourism

*2) : "SBWMP" means that Sana'a Basin Water Management Pjoject has already addressed .
"SWSLC" means that Sana'a Water Supply and Sanitation Local Corporation has already addressed.
"Action Plan" means that the schedule proposed in this

Note: Numbers appearing in parentheses in Table 3 (above) correspond to the same numbers found in "Part I: Immediate Action Plan" (Table 2).

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ABBREVIATIONS

DPPR	(The third Socio-Economic) Development Plan for Poverty Reduction
EPA	Environmental Protection Agency
ETa	Actual Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
GARWSP	General Authority for Rural Water Supply Projects
GDI	General Directorate of Irrigation
GVP	Gross Value of Production
HWC	High Water Council
IPAC	Information and Public Awareness Campaign
IWRM	Integrated Water Resources Management
IWRM-SB	Integrated Water Resources Management for Sana'a Basin
JICA	Japan International Cooperation Agency
MAF	Ministry of Agriculture and Fisheries
MAI	Ministry of Agriculture and Irrigation
MCM	Million Cubic Meters
MDGs	Millennium Development Goals
MWE	Ministry of Water and Environment
NO3	Nitrate
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
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
SWSLC	Sana'a Water Supply and Sanitation Local Corporation
SWSSP	Sana'a Water Supply and Sanitation Projects
WEC	Sana'a University Water and Environment Centre
WHO	World Health Organization
WUA	Water User Association
WUG	Water User Group
WWTP	Wastewater Treatment Plant

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The Republic of Yemen is one of severe water scarcity seldom seen in other countries, which is caused by increasing domestic, agricultural and industrial demand. The per capita share of water resources, that is, 150 m^3 per annum is very low compared with the global average of 2,500 m^3, or even that of regional average of 1,000 m^3 (Ministry of Planning & International Cooperation, 2006)[1]. Total annual renewable water resources are estimated at 2.5 billion m^3 (1.5 billion m^3 of groundwater, and 1.0 billion m^3 of surface water). Total annual consumption, however, stands at 3.4 billion m^3. This means that 0.9 billion m^3 of groundwater is being depleted every year, with a concurrent lowering the water tables in most aquifers, ranging between 2 to 6 meters a year. Consequently, precious groundwater resources are expected to run dry within 15 to 50 years.

In order to mitigate this nationwide serious water problem, the Government of Yemen constituted the "Law No.(33) for the year 2002 Concerning Water" which was amended by Law No.(41) in 2006, in addition, Yemen established Ministry of Water and Environment in 2003. The National Water Resources Authority (NWRA) under Ministry of Water and Environment (MWE) has been developing the institutional capacity for sustainable usage of water resources. Next, the Government of Yemen formulated the National Water Sector Strategy and Investment Program (NWSSIP), which was supported by donors. These donors, including Japan have expressed their strong intention to support the implementation of the NWSSIP.

In 2002, Sana'a Basin was designated as a "Water Protection Zone" by Cabinet Decree No. (344), and designated as the one of five critical basins. In Sana'a Basin, where the capital of Yemen is situated, annual rainfall is quite limited; therefore, work towards the development of a deeper aquifer has been rapidly increased, to meet the domestic water supply and irrigation demands. This process has been accompanied by the introduction of modern well drilling technology, coupled with a large cash inflow that followed the oil boom. As a result, the water shortage has become worse, a situation now being accelerated by a continuing imbalance between annual recharge and the growing demand for water .

Based on the Water Law, NWRA was delegated to formulate a water resources management plan, to execute the integrated water resources management and to establish the basin commission. In 2003, NWRA Sana'a Branch (NWRA-SB), was given responsibilities legally based on a delegation of power vested to by NWRA, in accordance with article (72) of the Water Law, was established in 2003 and shall implement activities related to water resources management for Sana'a Basin. The Sana'a Basin Commission (SBC), which is now under the chairmanship of the Minister of Water and Environment, was organized in the year of 2003 with the technical secretariat NWRA-SB to execute management of water resources in Sana'a Basin.

Comprehensive water resources studies have been conducted since the 1970s, and a water resources management project was launched in the year of 2003, however, NWRA-SB has faced difficulties in implementing water resources management effectively.

In this context, the Government of Yemen requested the Government of Japan to execute a technical-based cooperation agreement in order to formulate water resources management action plan for Sana'a Basin, based on the existing data and information.

1.2 OBJECTIVES OF THE STUDY

The objectives of the Study are:

(1) Formulate a water resources management action plan for Sana'a Basin based on existing data and information:

(2) Ttransfer technology and knowledge regarding water resources management to the counterpart personnel, through their direct participation into the Study.

1.3 STUDY AREA

The Study covers Sana'a Basin and its surrounding areas as shown in *Figure 1.1*. All or some parts of seven districts belonging to Sana'a Province and Sana'a City are included in Sana'a Basin. Sana'a Basin is divided into 22 sub-basins.

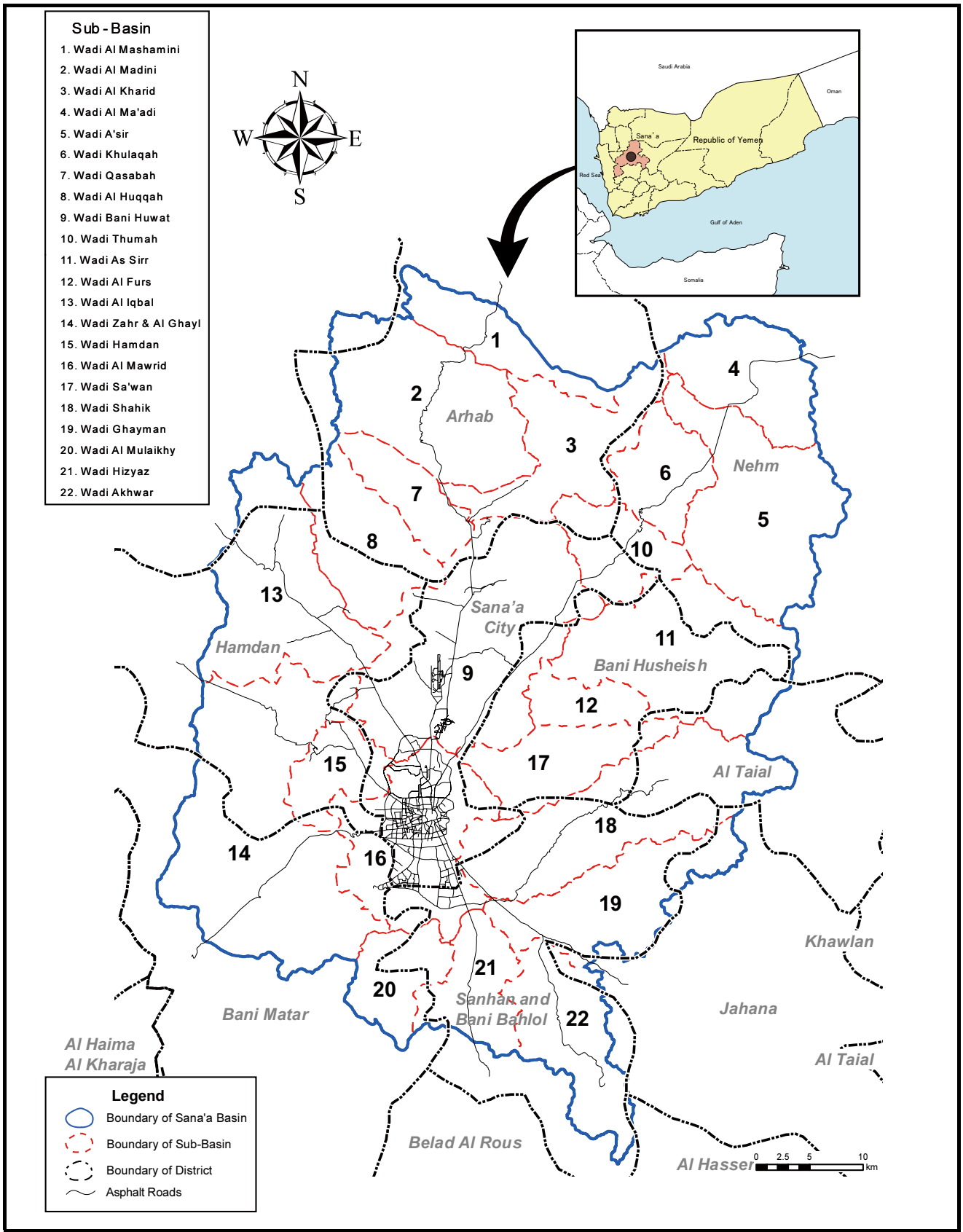


Figure 1.1 Study Area

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

1.4 IMPLEMENTATION OF THE STUDY

The National Water Resources Authority (NWRA) Headquarters and NWRA Sana'a Branch of the Ministry of Water and Environment (MWE), were assigned as the counterpart organizations by the Government of Yemen, while the Japan International Cooperation Agency (JICA) was assigned as the official agency responsible for the implementation of the technical cooperation program by the Government of Japan.

The Study was conducted by the Japanese study team, comprised of members from Earth System Science Co., Ltd and Japan Techno Co., Ltd, officially retained by JICA for the purpose of conducting this Study; counterpart staff was provided by NWRA.

The members involved in the Study are shown in *Table 1.1*

A comprehensive schedule of the Study is shown in the Flow Chart (see, *Figure 1.2*).

1.5 COMPOSITION OF THE REPORT

This report consists of three (3) volumes: Summary Report, Main Report and Supporting Report. The Main Report presents the summarized results of all the studies, and the Water Resources Management Action Plan for Sana'a Basin. In Chapter 2, the present situation of water resources, water use and relevant institutions and organizations are described. Issues to be considered in the action plan are described in Chapter 3. In Chapter 4, future scenarios based on socio-economy and water demand are presented. In Chapter 5, a water resources management action plan for Sana'a Basin is presented. Chapter 6 deals with the conclusions and recommendations.

Detailed study results are described in the Supporting Report. The contents of the Supporting Report are as follows:

Chapter 1: National Policy and Strategy for Water

Chapter 2: Water Resources Management Plan 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 7: Current Organizational Structure

Chapter 8: Environmental and Social Considerations

1.6 MEMBERS INVOLVED IN THE STUDY

Members involved in the Study are listed in *Table 1.1*.

Table 1.1 List of Members involved in the Study

1) Steering Committee for the Project

The Steering Committee for the Project is composed of the following seven (7) members:

Name	Assignment
Eng. Salem H. Bashuaib	: Chairman
Eng. Abdulla Dhaban	: Sana'a Governorate
Eng. Yahya Al-Eryani	: Ministry of Water and Environment
Eng. Mutaher Zaid	: Ministry of Agriculture and Irrigation
Eng. Salem A. Baquhaizel	: Environmental Protection Authority
Eng. Ibrahim Al-Mehdi	: Sana'a Water Supply and Sanitation Local Corporation
Eng. Saleh Al-Dubby	: NWRA Sana'a Branch Manager

2) The Counterpart Team

The team is composed of following six (6) members:

Name	Assignment
Eng. Mohamaed Abdul Salam	: Leader of Counterpart Team / Water Resources Management
Eng. Khalid Al-Bar	: Former Leader of Counterpart Team / Water Resources Management
Eng. Ahmed Nagi Al-Razeki	: Hydrogeology / Hydrology / Water Quality
Ms. Wafa Al-Akwa	: Hydrogeology / Hydrology / Water Quality
Eng. Ibrahim Al-Zubairi	: Water Use Planning
Eng. Ibrahim Mohammed Ismaeel	: Institutional Development / Socio-economic Analysis, Social Survey / Institutional Analysis, Environmental and Social Considerations / PCM Facilitation

3) The JICA Study Team

The Team is composed of the following seven (7) experts:

Name	Assignment
Mr. Hiroyoshi YAMADA	: Team Leader / Water Resources Management
Mr. Yusuke OSHIKA	: Hydrogeology / Hydrology / Water Quality
Mr. Masao UEMATSU	: Water Usage Planning
Mr. Naoki MORI	: Institutional Development / Socio-Economic Analysis
Ms. Mikiko AZUMA	: Social Survey / Institutional Analysis
Mr. Keiji NIIJIMA	: Environmental and Social Considerations / PCM Facilitation
Mr. Arata SASAKI	: Study Administration

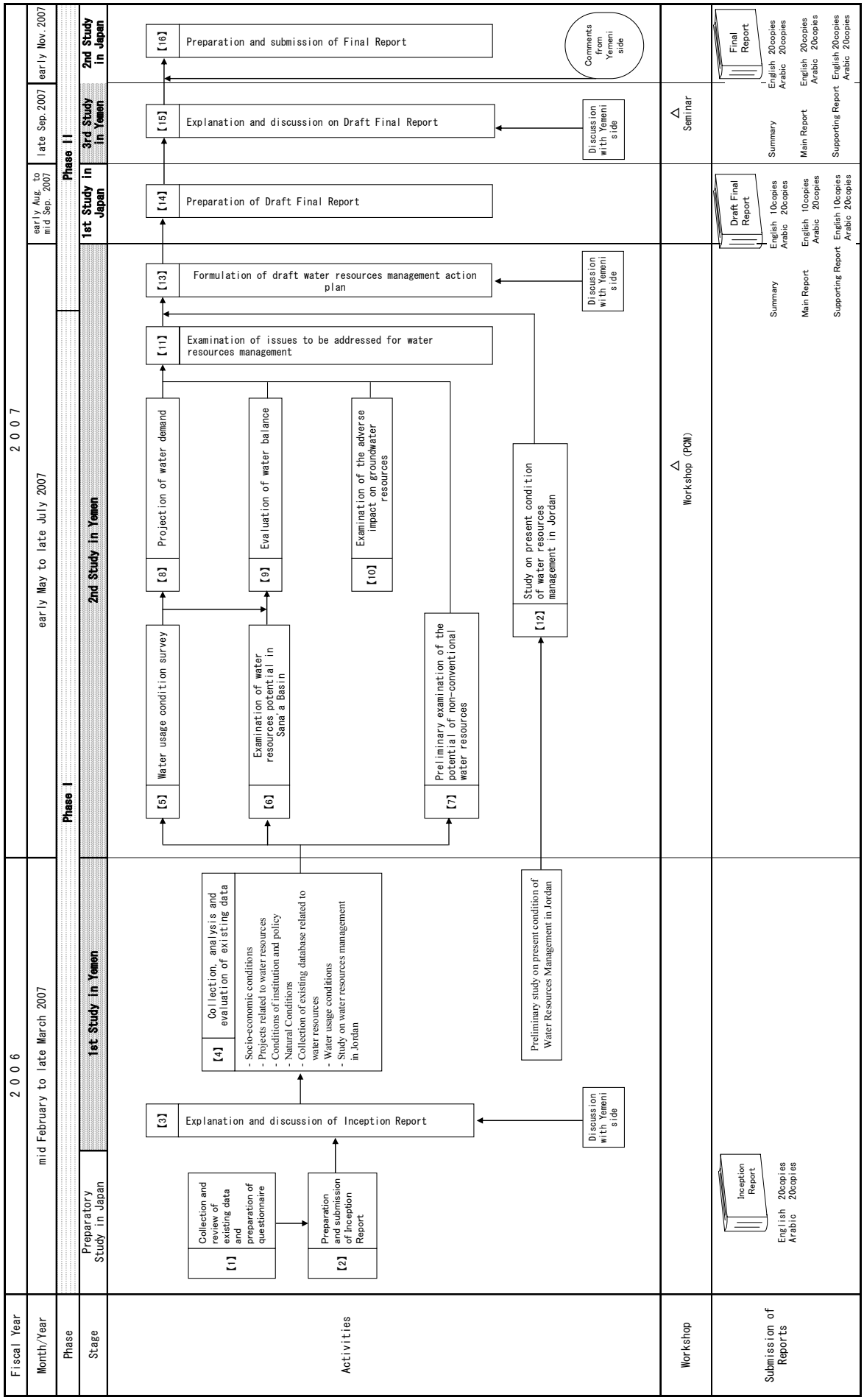


Figure 1.2 Flow Chart of the Study

REFERENCES

Ministry of Planning & International Cooperation (2006) "The Socio-Economic Development Plan for Poverty Reduction (2006-2010)"

CHAPTER 2

PRESENT SITUATION OF WATER RESOURCES AND WATER USE IN SANA'A BASIN

CHAPTER 2 PRESENT SITUATION OF WATER RESOURCES AND WATER USE IN SANA'A BASIN

2.1 GENERAL

In this chapter, the present situations of water resources in Sana'a Basin, well known as facing a critical situation, are described in order to understand the availability of water resources. This is followed by the a description of the present condition of water use. Then, the current situation of the institutional framework and organizational structure related to water resources management are described.

2.2 WATER RESOURCES

2.2.1 SURFACE WATER

(1) Meteorology

1) Temperature

The average monthly temperature recorded at the station of NWRA-A is graphed in *Figure 2.1* and summarized in *Table 2.1*. Though obtained records are very limited, a general tendency in the Sana'a Basin was observed. 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 degree C.

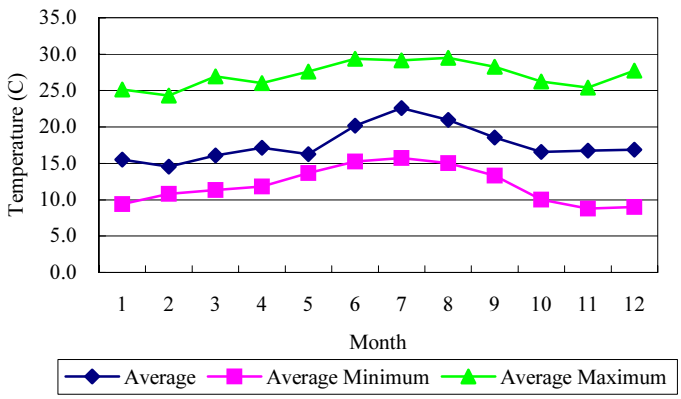


Figure 2.1 Monthly Temperature (NWRA-A, 1989-1997)

Table 2.1 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

2) Precipitation

The annual rainfall recorded at NWRA-A from 1989 to 2004, ranges from around 110 mm to 300 mm or more as shown in *Table 2.2*. 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.

Table 2.2 Monthly Rainfall (NWRA-A)

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	

The annual precipitation from 1989 to 2004 is graphed in *Figure 2.2*. Some gaps in the measurements are included, it is also rather difficult to mention about a long-term tendency.

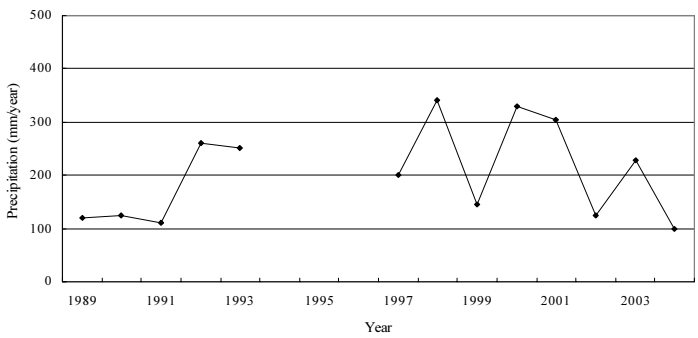
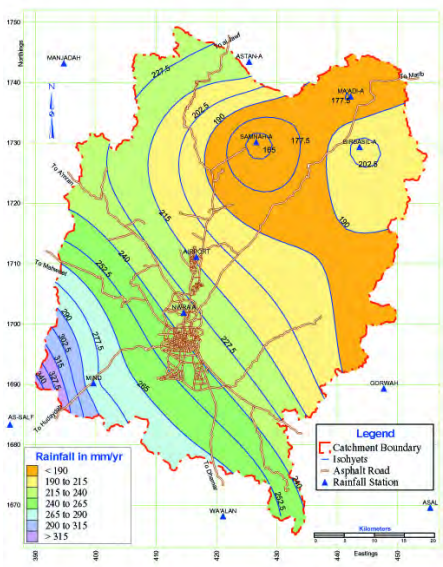


Figure 2.2 Annual Precipitation (NWRA-A)

Figure 2.3 shows the distribution of rainfall in the Sana'a basin provided by NWRA. 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.



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

Figure 2.3 Isohyet Map of the Sana'a Basin

3) Evapotranspiration

Looking at a "1:250,000 Hydrogeological map" (Robertson 1990), one sees that potential evaporation estimated by the Penman method, averages about 2,000mm annually. According to SAWAS (1995), the potential evapotranspiration demonstrated an annual total of 2,475 mm, based on a meteorological statistics with a maximum in June (average 9.4 mm /day), and a minimum in February (4.8 mm/day). These figures are substantially higher than annual rainfall.

GAF (2007) estimated actual evapotranspiration based on the satellite imagery analysis in SBWMP. According to the report, a total of 113.1 MCM water were transpired in the Sana'a Basin during the period from 1 July 2004 to 30 June 2005.

(2) Runoff

Though wadi runoff is not monitored, two types of methods have been used to estimate the runoff volume of wadis in the previous studies. One method involves using a runoff coefficient, or the ratio of runoff depth to precipitation depth, obtained via the hydrological observation of main wadis in Yemen. The average runoff coefficient of 0.055 for wadis in Yemen was suggested by WRAY-35 (1995), based on the observed flow volumes from primary watersheds. The volume of runoff in the Sana'a basin is estimated at about 40.9MCM/year with the supposition of 230 mm of annual rainfall, the allowing 3,240km^2 as the area of the Sana'a Basin and 0.055 as the runoff coefficient.

Another method to calculate runoff volume is the estimation using the SCS method, which is the empirical model prepared by the U.S. Soil Conservation Service. TS-HWC Vol. III (1992) constructed a rainfall-runoff model using the SCS method and obtained the figures shown in *Table 2.3*, which indicated the mean total and base flow per day was 74,000 m^3 and 67,000 m^3 respectively in the Sana'a Basin. It reads to the total outflow of the Sana'a Basin as being 27 MCM/year.

Table 2.3 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

In addition, General Directorate of Irrigation (GDI) provided a report of the Engineering Data Sheet, the summarized report of a survey of 44 existing dams in 2001. It describes the hydrological conditions around each dam site, including an estimated runoff coefficient, which range from 0.03 to 0.4, although it is not clear the method of estimation. The estimated mean annual flow of 44 dam sites totaled about 22.3 MCM.

(3) Usage of Surface Water

Surface water is used for recharge, irrigation, and domestic purposes, through 44 surface dams, 24 dams/pools and 145 springs inside Sana'a Basin. Locations of dams and springs are shown in *Figure 2.4* and *Figure 2.5*, respectively.

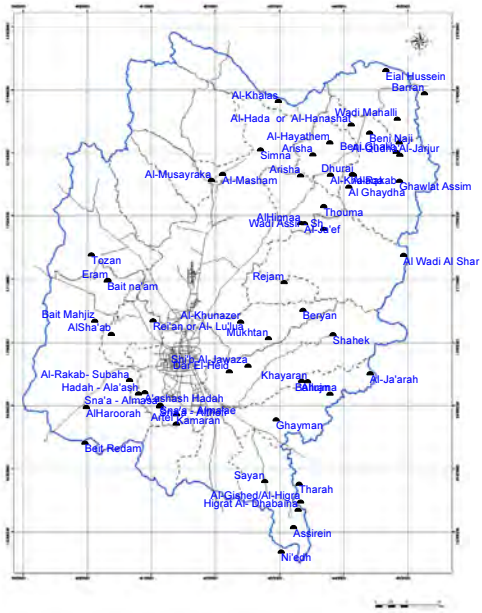


Figure 2.4 Locations of Dams

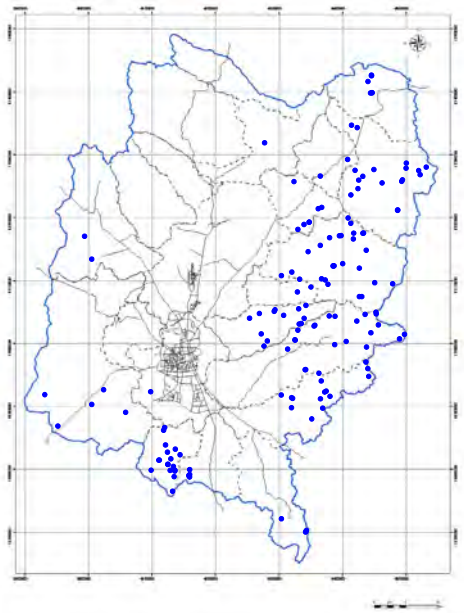


Figure 2.5 Locations of Springs

Most of these dams are constructed to recharge groundwater. 15 dams are also used for irrigation, and only three dams are used for domestic purposes. 15 dams, which may be small-scale reservoirs constructed by rural people, are mainly used for irrigation purposes. The total volume of the annual flow or yield of dam sites is calculated to be 24 MCM.

Concerning springs, 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 total yield of spring is estimated to be 17.2 MCM annually. The volume, however, is not likely an actual annual yielding amount, because the yield of spring is fluctuates seasonally. One third to half of the amount, about 6 to 9 MCM, may be an acceptable figure.

(3) Potential of Surface Water

As mentioned in the previous section, the annual runoff was estimated to be between 27 MCM and 40.9 MCM, depending on the method applied. Usage amount of surface water were estimated to be 24 MCM/year through dams, and 6 to 9 MCM/year from springs. This indicates that more than 75% of surface water resources have been already utilized.

Therefore, it can be concluded that there is no enough potential to further develop the surface water inside Sana'a Basin.

2.2.2 GROUNDWATER

(1) Recharge

Since 1970s, several studies have estimated the amount of groundwater recharge in the Sana'a Basin. Applied methods for the estimation are categorized into two types; one is a method based on the Darcy Law; another is the method using the recharge coefficient. *Table 2.4* describes the recharge amount estimated in the previous studies.

Table 2.4 Estimation of Groundwater Recharge in the Sana'a Basin

Study	Term	Organization	Consultant	Method	Estimated Recharge (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 and 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
Water Balance and Hydrological Monitoring (SBWMP)	2007	NWRA	Dr. A.Norman and Eng. W. Mulat	Recharge Coefficient	50.7

The estimated amount, using the Darcy Law, is based on the transmissivity and assumption of the presence of simplified aquifer. On the other hand, the recharge coefficients applied for estimation are the empirical values, which are not obtained experimentally. Though there are some assumptions for the estimations, the values calculated, which widely range from 28 to 63 MCM annually, are reasonable from a hydrogeological point of view. In this study, the latest figure, that is 50.7 MCM/year, was adopted as an annual recharge amount inside Sana'a Basin. Because the value was calculated on the basis of the recharge amount as estimated each sub-basin as shown in *Table 2.5*, they can be utilized for sub-basin-wise consideration for water resources management.

Table 2.5 Estimated Groundwater Recharge in Sub-Basins

No	Sub Basin	Estimated Recharge (Mm^3)
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"

The recharge amount applied in the study, that is 50.7 MCM/year, was estimated using the precipitation data from 1991 to 2003. Although the phenomenon of decreasing precipitation has been pointed out, it is rather difficult deduce the long-term tendency of precipitation, as shown in *Table 2.2* and *Figure 2.2*. Therefore, it is assumed in this study that this recharge amount will continue unchanged.

In addition to the recharge by infiltration of precipitation, return flow of irrigation and infiltration of treated wastewater used to be regarded as recharge amount in some studies. Though there is a possibility to be recharged, this amount is not considered as source of recharge in this study. Because improvements in irrigation efficiency make the recharge amount small and treated wastewater will be used for irrigation purpose in future and considering being in the safe side.

(2) Groundwater Storage

With regard to the groundwater storage (S_t), two values were estimated with the equation of $S_t = AHS_y$, where, A is the area of the aquifer, H is the saturated thickness and S_y is specific yield, or effective porosity as described in Chapter 3 of the Supporting Report. The estimated value in TS-HWC (1992) is that the storage is 6,047 MCM and the usable storage is 3,221 MCM in the Sana'a Basin. Then, WEC (2001) then revised their approach, and estimated the storage volume of each groundwater province in the Basin. As a result, the storage and the usable storage are estimated at 10,424 MCM and 5,212 MCM, respectively. However, as mentioned in these previous studies, the assumptions used for estimations are fairly rough figures. Therefore, further study is required.

In this chapter, the latest estimated usable storage, that is, 5,212 MCM, was adopted, since this volume was revised during a previous study in the year 1992, by using updated water levels data, though the assumptions used for this estimation still remain in rough and ready estimates.

2.2.3 TREATED WASTEWATER

Sana'a Wastewater Treatment Plant (WWTP) is located adjacent to the International Airport with design capacity to treat 50,000 m^3/day of sewage water which coming from the Sana'a City. According to the data from Sana'a Water and Sanitation Local Corporation (SWSLC), who operate the WWTP, the volume of sewage water that reaches the WWTP is 16 MCM (44,000 m^3/day) in 2006. However, the WWTP is operating in an overloaded condition in terms of BOD5-load, as explained in Chapter 5 in the Supporting Report, and the wastewater improperly treated is discharged to the wadi via a lagoon. This improperly treated wastewater flows by gravity to the downstream through an open channel and farmers are using this water to irrigate their lands and finally it is collected at Al Mashan Dam, which is located 12 km downstream from the WWTP. 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 has a daily treatment capacity about 500 m^3/day, with the objective of treating sewage brought by tankers from cesspits of the city, and another has a planned treatment capacity of 105,000 m^3/day.

Consequently, in actual conditions, the treated wastewater cannot be considered a usable water source. In the near future, however finishing the upgrade of the present WWTP and construction of new treatment plant, the treated wastewater could be accounted as a water

source for irrigation and the expected quantity is a minimum of 18.3 to a maximum of 56.6 MCM/year

2.2.4 ALTERNATIVE WATER SOURCE OUTSIDE SANA'A BASIN

Since the serious depletion of water resources in Sana'a Basin is well known, studies on the alternative water sources for Sana'a city from outside of Sana'a Basin have been conducted, including utilizing desalination as one of the potential solutions. These alternatives are categorized into four groups, and were studied by SAWAS (1996). *Figure 2.6* shows the locations of these alternatives. *Table 2.6* shows the results of the previous studies.

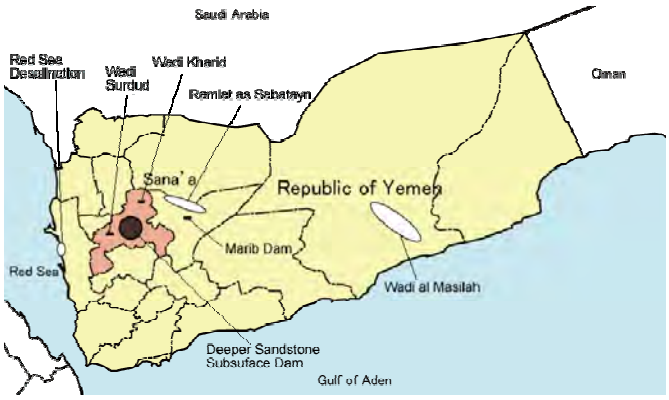


Figure 2.6 Locations of Alternative Water Sources

Table 2.6 List of Alternative Water Sources

Source		Production Capacity *1	Construction Cost	Recurrent Cost	Unit Cost for Water		Cost/ Public *3	Legal Feasibility Appreciation			Restriction
		litter/sec	Million US?$	Million US$	US$/m^3 *1	YR/m^3 *2		Source of Water	Transport System	Protected Zone	
1	Wadi Kharid Dam	250	87.2	10.68	1.32	145	5.6	positive	complex	positive	- It will reduce availability of water along this wadi. Use of water from this dam is known to be disputed between two tribes
2	Wadi Surdud Dam	500	230.6	32.62	2.03	223	8.7	complex	complex	positive	-This affects groundwater recharge in Tihama area
3	Diversion from Mareb Dam	500	284.4	37.58	2.33	256	10	complex	complex	negative	-Forceful objection from the farmers in the Mareb area can be expected. -It was not able to satisfy the requirement for irrigation in the down stream area
4	Deeper Pre-Jurassic Sandstone	100	60.3	7.68	2.41	265	10.4	normal	complex	positive	-A growing fear among the population that their sources will dry up
5	Desalination (Red Sea)	500	902.9	124.28	7.63	839	32.9	positive	complex	n.a.	- Water has to be lifted nearly 2700m with approximately 150km transmission
6	Ramlat as Sabatayn Area	Feasibility Study is planned by NWRA						-	-	-	
7	Wadi Al Masilah, Hadramawt	not designed yet						-	-	-	- Almost 700km transmission in a straight line

Note: *1) SAWAS Technical Report No.14, costs are based on the price level in April 1996.
*2) Exchange rate, 110YR/US$ in the year 1996 is applied.
*3) Public means the tariff of public water supply, 25.5 YR/m^3 in 1998

The total of expected production capacity that is around 58 MCM/year is possible to cover present water consumption in Sana'a city, calculated as 54.2 MCM in 2005. However, in order

to cover the demand in 2020 that is 78.6 MCM, both alternative sources and groundwater resources inside Sana'a Basin should be utilized.

Construction cost, recurrent cost and unit cost for water were calculated on the basis of the price level in April 1996, with the exchange rate at 110 YR/US$. According to the information from SWSLC, a water tariff composed of the water supply cost and sanitation cost for the consumed volume from 0 to 10 m^3 , was 25.5 YR/m^3 in 1998. Water tariffs of alternative water sources are from 5.6 to 10.4 times of that of public water supply, which source from surface water and groundwater. As for a desalination system transferring water from the Red Sea to Sana'a city, the difference in tariffs is more than 32 times of the public water supply. The qualitative appreciation of obtaining the required rights, that is, the water rights, the transport rights and establishing protection zones was also carried out for each source. Obtaining the transport rights were regarded as "complex" for all alternatives by SAWAS (1996). In addition, some restrictions are noted for each alternative which are the expectation of reduction of groundwater recharge downstream, and forceful objections from the farmers, etc.

As for a water supply project for which maintenance and operation costs are principally borne by the beneficiaries, financial evaluation is generally based on the affordability to pay and the willingness to pay from the perspective of possibility to cover the cost by water tariff. Assuming that the water tariff in 1996 was established considering these factors, an overload to the beneficiaries was too large to pay for water supplied by alternative sources. The cost of the materials was inflated more than three times, depending on the sorts comparing that in 1996, and the exchange rate of local currency to US$ has been dropped. In addition, the tariff of electricity for commercial consumption was increased from 7 YR/kW in 1996, to 17 YR/kW in 2007. Considering these economic changes, it should be mentioned that the cost of construction and water tariffs should clearly reach higher levels. On the other hand water tariffs including sanitation, was set at 63 YR/m^3 and 81 YR/m^3 in 2007, for consumption between 0 to 5m^3 and from 5 to 10 m^3, respectively. The tariff has become more than twice or three times depending on consumption comparing that in 1998.

Considering these financial changes, the implementation of water supply alternatives should be considered financially unrealistic from both an operational and maintenance point of view, even if adverse impacts on society and the environment are mitigated.

In addition to the studies carried out by SAWAS (1996), NWRA has planned to carry out studies on the feasibility of two other groundwater excavations outside of Sana'a Basin, namely the Ramlat as Sabatayn Area, and Wadi Al Masilah, Hadramawt, (see *Figure 2.6* and *Table2.6*).

As for the Ramlat as Sabatayn, it is expected that there is enough potential to transfer water from the Quaternary deposit, limestone of Amran Group and Mukalla sandstone. This alternative requires transferring water more than 120km, and lifting it up more than 1,500 m. Since the conditions of water transmission are more difficult than that of the alternative groundwater source, namely, "deeper pre-Jurassic sandstone" (*Table 2.6*), the water tariff is estimated at more than 2.41 US$/$m^3$ as of 1996.

Another alternative source for is Wadi Al Masilah, Hadramawt, which was discovered by a Canadian oil company during their oil exploration in 1990s. This source is expected to have enough potential to supply water to Sana'a city. However, this alternative requires transferring water more than 700 km, and lifting it around 2,000 m. Therefore, the water tariff is estimated to be even more than that of the "deeper pre-Jurassic sandstone" alternative.

Therefore, it is preliminarily mentioned that the feasibility of these two alternatives are very low.

Consequently, these alternative water sources were concluded to be unfeasible, considering that the cost for maintenance should be borne by beneficiaries, even if the adverse impacts on society aspect and the environment are mitigated. In order to resolve this issue, financial support from the Government may be required.

2.3 PRESENT WATER USE

2.3.1 DOMESTIC WATER USE

(1) Urban Water Supply

1) Public Water Supply

The main source of the public water supply for Sana'a City, which is operated by SWSLC, is groundwater abstracted from three main well fields: the Eastern well field, Western well field and Sana'a well field. SWSLC possesses around 130 wells; around 80 of these wells function, and the remaining are not functional due to a decrease in production (i.e. decreasing the water level), technical problems, and drilling failure.

Production of water for the Sana'a City water supply for the past nine years is shown in *Table 2.7*.

Table 2.7 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

Between 1998 and 2006, water production increased by 26%, and the number of wells in operation increased by 39%. The production amount in 2005 was reported as 24.4 MCM, of which 12.5 MCM was the "billed amount" of domestic consumption, supplying 672,141 inhabitants with unit consumption of 50.8 l/c/d.

2) Private Water Supply

The estimated population of Sana'a city for 2005, based on 2004 census data, is 1.84 million inhabitants, with the population covered by the public network at 672,141 inhabitants. Around 1.17 million inhabitants were not connected to the public water supply system. These inhabitants obtained water from private water sources, namely private piped networks, water tankers, and treated water in containers. Data from 1997, related to consumption of domestic water from the private water supply, was estimated by

adopting an average per capita consumption of 70 l/c/d (as described in Chapter 5 in the Supporting Report).

Water consumption from private water supply is estimated as shown in *Table 2.8*, adopting an average per capita of water consumption of 70 l/c/d.

Table 2.8 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

(2) Rural Water Supply

The planning and execution of rural water supply projects was carried out by the General Authority for Rural Water Supply Projects (GARWSP), the responsible body for the rural water supply. However, no suitable data or study was available regarding water use conditions for the rural water supply.

WEC (2001) carried out the estimation of water consumption by water-use zone with the per capita consumption of water of 21 l/c/d for rural area, after the estimation of the population inside Sana'a Basin by districts and water-use zones. However, GARWSP adopted an average per capita of water consumption of 40 l/c/d and 2.5% of population growth rate for the rural area.

However, in this study, the unit water consumption adopted was 20 l/c/d, an amount adopted by NWRA for water resources management, and the population growth rate used by GARWSP (2.5%) was adopted, Water demand was estimated based on the population of each sub-basin. *Table 2.9* shows the estimated domestic water consumption for rural area.

Table 2.9 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	191,19	26,845	195,971

Sub-Basin		2004		2005		2006	
		Population	Water Consumption	Population	Water Consumption	Population	Water Consumption
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 in 2004: calculated based on 2004 Census results; the 2006 value was estimated adopting a population growth rate of 2.5%, which was subsequently adopted by GARWSP
Water Consumption: calculated adopting average per capita water consumption of 20 l/c/d, the value which was adopted by NWRA for water resources management

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

2.3.2 AGRICULTURAL WATER USE

Annual water consumption for irrigation purpose, which was estimated by WEC-ITC (2001) by calculating the actual evapotranspiration (ETa) through an analysis of cropping patterns based on satellite imagery analysis, was calculated at 151.4 MCM, adopting 40% as the irrigation water efficiency. The well inventory (2002) was estimated at 217.5 MCM for the annual water abstraction, through interviews with owners of wells and on-site measurement. Approaches and methodologies for the estimation of these studies are different. Later, GAF (2007)made an estimation at 139.47 MCM, applying the 60% as irrigation water use efficiency, for annual water consumption of irrigation purpose using the same methodology as WEC-ITC (2001) by sub-basin.

As for irrigation water use efficiency, the adopted value differs from study to study. In this study, the irrigation water efficiency of 40% was adopted after considering following conditions:

According to MWE (2006), the main irrigation methods used inside Sana'a Basin are furrow and small basin methods, and farmers use surface irrigation by applying a sheet of water to the fields up to knee height; therefore the field application efficiency is very low, and might reach 45%. While the conveyance used for irrigation are iron and plastic pipes with considerable amount of water leakage, and earth channels crossing tracks with long distance causing

infiltration, evaporation and run off losses. Consequently, the scheme efficiency is very low for surface irrigation, probably between 30 to 40% (Ministry of Water and Environment, 2006).

According to FAO, the field application efficiency for surface irrigation such as border, furrow and basin is 60%, and it may be lower if the level of farmers discipline is not satisfied. Therefore, the irrigation efficiency of 60% adopted by GAF (2007) is relatively high to apply to the irrigation activities in Sana'a Basin

Irrigated area and quantity of water consumed by agriculture for each sub-basin is shown in *Table 2.10*.

Table 2.10 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	**0.89**
2	Wadi Al Madini	663	1.5	412	2.6	352	**4.53**
3	Wadi Al Kharid	659	4.2	408	3.6	238	**3.03**
6	Wadi Khulaqah			285	2.4	181	**2.33**
4	Wadi Al Ma'adi	187	0.8	455	2.2	100	**1.29**
5	Wadi A'sir	1,108	11.7	516	6.9	593	**7.65**
7	Wadi Qasabah	3,181	15.0	226	2.1	186	**2.40**
8	Wadi Al Huqqah			1,935	14.8	1,176	**14.48**
13	Wadi Al Iqbal			2,871	15.9	1,538	**34.87**
9	Wadi Bani Huwat	5,561	22.7	6,888	55.9	4,826	**33.71**
10	Wadi Thumah	393	2.0	286	2.1	126	**12.08**
11	Wadi As Sirr	3,461	33.4	3,874	39.7	2,603	**16.56**
12	Wadi Al Furs	1,198	11.9	1,302	13.2	856	**5.74**
14	Wadi Zahr & Al Ghayl	2,387	27.6	1,524	11.1	1,297	**16.30**
15	Wadi Hamdan	774	7.1	312	1.8	789	**10.16**
16	Wadi Al Mawrid	1,081	5.5	811	8.5	739	**8.76**
17	Wadi Sa'wan	870	2.7	1,442	7.5	1,055	**10.05**
18	Wadi Shahik	650	1.3	1,454	10.5	1,032	**10.30**
19	Wadi Ghayman	893	2.6	590	3.8	533	**5.50**
21	Wadi Hizyaz			279	2.7	206	**2.64**
22	Wadi Akhwar			419	7.3	191	**2.45**
20	Wadi Al Mulaikhy	314	1.4	211	2.4	269	**3.48**
Total		23,380	151.4	26,577	217.5	18,953	**209.20**

Unit: area in hectare, abstraction in million cubic meters

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

2.3.3 INDUSTRIAL WATER USE

Water supply for industries from the public network is very low, according to information supplied by SWSLC. Water for most industries is supplied via their own wells, and it is supposed that the water abstraction is unregulated and unrecorded. Consequently, information regarding industrial water consumption is very scarce. Due to this lack of information, TS-HWC (1992) and WEC (2001) estimated the water requirement for the industrial sector using the "Gross Water Requirement Method," which depends on (a) average water requirement per unit of physical output in various industrial sub sectors and (b) the physical outputs of the different industrial products.

In this study, present water demand for the industrial sector, which is shown in *Table 2.11*, was estimated based on the results of the study carried out by WEC (2001), which used an alternative approach involving the use of "gross value of production (GVP)," and the "gross water requirement method." Due to the unavailability of recent data regarding GVP of industries within Sana'a Basin, an estimation of water requirements up to 2005, was estimated based on results from 1995. Conditions related to this calculation are mentioned in section *5.5* "Industrial Water Use," in the Supporting Report.

Table 2.11 Estimated Water Consumption for the 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

2.3.4 TOURISTIC WATER USE

No studies have been carried out to estimate the water requirements for the tourism sector. Due to this unavailability of data, water consumption for 2005 was estimated under many presupposed conditions, as shown below; the estimated water consumption for the tourism sector is shown in *Table 2.12*.

- Occupancy rate of beds assumed as 40%
- In general, five and four stars hotels provide more water consuming accommodations than lower standard hotels. The average per capita water consumption was assumed for five and four stars hotels at 350 l/c/d, and for three to one star hotels an average of 180 l/c/d was assumed[1]. Consumption of water by traditional hotels was assumed to be lower than other hotels, with unit consumption was estimated at 120 l/c/d.
- All hotels of Sana'a City and Sana'a were included in the estimation, presupposing that most of hotels of Sana'a are located around the City.
- According to a water usage condition survey carried out in this study, five stars hotels were not connected to the public water supply network, and it was assumed that four stars hotels were also not connected to the public network. In addition, the number of hotels connected to the public network is unknown

Table 2.12 Estimated Water Consumption for Tourism 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

2.4 WATER BALANCE

2.4.1 WATER BALANCE IN ENTIRE SANA'A BASIN

More than a decade has passed since the imbalance between groundwater recharge and water abstraction was clarified. The water balance in Sana'a Basin was calculated in this study based on the existing data and the present water use as described in section 2.2 and 2.3 in this chapter. The abstraction amount is almost six times the recharge amount as shown in *Table 2.13*.

Table 2.13 Water Balance in Sana'a Basin (2005)

Urban water use*		Rural water supply	Irrigation	Industry	Tourism	**Total**	Recharge	**Balance**
Public	Private							
24.3	29.9	0.6	209.2	4.76	0.36	**269.1**	50.7	**-218.4**

*: It is composed of both domestic and non-domestic
Unit: million cubic meter

Such an imbalance means that non-renewable water resources are consumed every year. If this annual amount increases, non-renewable water resources will continue to be depleted

2.4.2 WATER BALANCE IN EACH SUB-BASIN

The water balance in the Sana'a Basin was calculated using the previous studies. Two types of detailed water balance evaluations in sub-basins have been provided recently by departaments within SBWMP:one is the hydrological approach, adopted by Norman and Mulat (2007), and another one is based on the satellite imagery analysis, GAF (2007).

Water balance studied by Norman and Mulat (2007) is calculated by the recharge minus the abstraction from wells. The balance studied by GAF (2007) used 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 assuming the irrigation efficiency of 60%. Since this water balance is obtained only using the water use for agriculture, consumption for other purposes was added. *Table 2.14* describes the calculated water balance in the two previous studies

Table 2.14 Water Balance in Sub-Basins by Hydrological Approach

Sub-Basin		After Norman and Mulat (2007)						After GAF (2007)			
		Recharge	Abstraction	Return Flow (30%)	Consumed Volume	Revised Balance	Consumed Ratio /Recharge	Rainfall	Agriculture Water Use	Total Water Use	Water Use/Rainfall
		(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)		(Mm^3)	(Mm^3)	(Mm^3)	
1	Wadi Al Mashamini	0.9	0.85	0.26	0.6	0.3	0.66	22.6	0.6	0.7	3.1%
2	Wadi Al Madini	2.73	2.92	0.88	2.04	0.68	0.75	62.3	3	3.2	5.1%
3	Wadi Al Kharid	1.76	3.36	1.01	2.35	-0.59	1.33	26.7	2	2.2	8.2%
4	Wadi Al Ma'adi	1.71	2.67	0.8	1.87	-0.16	1.10	22.5	0.9	0.9	4.0%
5	Wadi A'sir	4.27	6.93	2.08	4.85	-0.58	1.14	52.4	5.1	5.2	9.9%
6	Wadi Khulaqah	1.54	2.12	0.64	1.48	0.06	0.96	13.6	1.6	1.6	11.8%
7	Wadi Qasabah	0.83	2.12	0.64	1.48	-0.65	1.78	16.2	1.6	1.7	10.5%
8	Wadi Al Huqqah	1.36	17.36	5.21	12.15	-10.79	8.91	31.4	9.7	9.9	31.5%
9	Wadi Bani Huwat	5.58	60.87	18.26	42.61	-37.03	7.64	67.4	32.4	51.8	76.9%
10	Wadi Thumah	1	3.25	0.98	2.28	-1.27	2.27	16.2	0.8	3.1	19.1%
11	Wadi As Sirr	3.81	39.06	11.72	27.34	-23.53	7.17	54	16.5	17.2	31.9%
12	Wadi Al Furs	0.79	13.6	4.08	9.52	-8.73	12.02	8.5	5.7	5.9	69.4%
13	Wadi Al Iqbal	2.31	17.46	5.24	12.22	-9.91	5.29	61.9	13.1	13.5	21.8%
14	Wadi Zahr & Al Ghayl	7.11	16.51	4.95	11.56	-4.44	1.62	132.1	10.9	12	9.1%
15	Wadi Hamdan	0.82	7.47	2.24	5.23	-4.41	6.36	18.9	6.8	7.6	40.2%
16	Wadi Al Mawrid	1.54	35.4	10.62	24.78	-23.24	16.04	48	5.8	90.9	189.4%
17	Wadi Sa'wan	1.41	8.82	2.65	6.17	-4.76	4.37	21.9	6.7	7.2	32.9%
18	Wadi Shahik	4.12	10.41	3.12	7.29	-3.16	1.77	69.9	6.9	8.3	11.9%
19	Wadi Ghayman	1.24	4.23	1.27	2.96	-1.72	2.39	41.6	3.7	3.9	9.4%
20	Wadi Al Mulaikhy	1.66	2.96	0.89	2.07	-0.41	1.25	22.8	2.3	2.4	10.5%
21	Wadi Hizyaz	1.92	3.17	0.95	2.22	-0.3	1.16	21.9	1.8	1.9	8.7%
22	Wadi Akhwar	2.32	8.44	2.53	5.91	-3.59	2.55	34.7	1.6	1.9	5.5%
Total		50.7	270	81	189	-138.2	-4.02	867.2	139.5	253.1	29.2%

Source: Modified Norman and Mulat (2007); Modified GAF (2007)

As shown in *Table 2.14*, the difference between recharge and abstraction differs from sub-basin to sub-basin. This tendency implies that these high imbalanced sub-basins would be quickly affected by severe water scarcity, unless appropriate measures are taken.

REFERENCES

[1] Digital National Water Master Plan (2004) Ministry of Water and Irrigation, The Hashemite Kingdom of Jordan

CHAPTER 3

ISSUES TO BE CONSIDERED IN THE ACTION PLAN

CHAPTER 3 ISSUES TO BE CONSIDERED IN THE ACTION PLAN

3.1 GENERAL

In order to clarify the essential issues for a smooth and effective implementation of water resources management for Sana'a Basin, and to formulate a practicable action plan, the present situation of aspects related to water resources management are considered based on the existing data and information, and summarized in each category, as mentioned in this Chapter.

3.2 ISSUES TO BE CONSIDERED IN THE ACTION PLAN

3.2.1 HUGE AMOUNT OF WATER CONSUMPTION FOR IRRIGATION PURPOSES

Inside Sana'a Basin, annual water consumption for irrigation purpose is approximately 78% (209 MCMC) of total water consumption (269 MCM). According to the Ministry of Water and Environment (2006), as the water conveyance methods used for irrigation are iron or plastic pipes; thus, a considerable amount of water is lost via leakage. In addition, as an irrigation method, the furrow method is mainly applied for vegetables, and the small basin method is mainly applied for qat, grape and other fruit trees. Looking at scheme efficiency, one can see it is very low for these surface irrigation systems, possibly between 30 and 40% (according to NWSSIP, irrigation efficiency is estimated at around 35% in Yemen). Assuming that the present irrigation efficiency is improved to 70% from 40%, approximately 90 MCM, which could cover the present water consumption for domestic use, could be saved.

Improvements in efficiency in water consumption could be achieved by (1) introducing improved irrigation systems, and (2) changing pipes, together with control systems, allowing for more appropriate watering for crops. The introduction of such improved irrigation systems, has been already addressed by Sana'a Basin Water Management Project (SBWMP), at some demonstration farms. According to NWRA, some of these operations do not run at full capacity, a result of a lack of experience related to these new irrigation systems. Therefore, an understanding of the present activities related to the dissemination of improved irrigation systems, and possible countermeasures, is necessary.

Qat is well-known as one of the intensive water consumer cash crops. Since the 1970s, the area of qat cultivation expanded at a fast rate, due to the introduction of drilling techniques and pumps, which increased the quantity of water applicable for irrigation, and also due to a high economic return provided by the crop. Irrigation methods usually applied for qat plantations is the small basin method; here, farmers irrigate their land with more water than the necessary. This is because they believe that the more water they give to the plant, the more the plant will produce. As a result, water consumed by qat plantations has become nearly half of all water consumption using for irrigation purposes. From the point of view of water resources management, it is necessary to understand qat as a plant which consumes excessive amounts of water. One must also be careful when dealing with qat, due to its social and economical influence; however, further expansion of qat plantations should not be supported, considering the water scarcity Sana'a Basin is facing. In addition, since some of qat farmers have utilized dangerous pesticides, it is necessary to encourage farmers to use safe and suitable pesticides.

Other approaches should be considered simultaneously, such as controlling the expansion of irrigated land, and the introduction of less water-consuming crops. In addition, the control of

illegal drilling, which has already conducted by National Water Resources Authority Sana'a Branch (NWRA-SB), must be continued.

In addition, the quantity of water abstracted or consumed for irrigation purpose was estimated using different approaches in different studies, such as through inventory survey and through satellite imagery analysis. These methods depend on unreliable coefficients and information, such as yearly pump schedule by season; as a result irrigation efficiency, and the real quantity of water abstracted or consumed, is still unknown.

For these approaches, the following consideration should be taken.

- capacity development of the staff on financial, administrative and management aspects
- registration of all wells inside Sana'a Basin, and installation of meters, with the objective of understanding the real quantity of water abstracted
- reduction of water loss by leakage
- increasing public awareness of water saving irrigation systems
- providing incentives, such as increasing crop yield, saving money for pumping through pilot projects, and showing the period of cost recovery against investment (related to the introduction of improved irrigation systems)
- control and/or prohibition of the expansion of irrigated land
- securing stable incomes by helping create a market for newly introduced less water consuming crops.

3.2.2 PHYSICAL LOSS IN URBAN WATER SUPPLY

In 2006, the domestic water for 36% of the population of Sana'a City was supplied through a public network system maintained by SWSLC. Since the National Water and Sanitation Authority (NWSA), established in 1974, was charged with taking responsibility for the public water supply system, a network system has been developed through two phases from 1976 to 1982. Afterwards, only emergency improvements were carried out in order to meet growing demand caused by rapid population growth. In 2000 SWSLC was created as a financially independent organization and took the responsibility for urban water supply and sanitation of Sana'a City. In 2002, in order to meet demand, NWSA provided the Sana'a Water Supply and Sanitation Project, including its implementation. According to SWSLC's report, Non-Revenue Water (NRW) was 38.8% in 2006 (total production is 24.1 MCM). However, the amount of water lost by leakage and illegal connections is not clear, and a great effort, which includes technology and funding to clarify and reduce NRW, is required. The amount of water to be saved with the reduction of NRW is not so large when compared to irrigation; however, an improvement in NRW to save water is required, since the depletion of groundwater in the Basin is steadily progressing. Considering this necessity, SWSLC already started to change pipes in the public network, with support from the World Bank; a considerable decrease on NRW is expected. In addition, water connection meters, with zero-reading, is another factor that contributes to the increase of NRW, and by the year of 2006, 11,900 connections were accounted as meters with zero-reading,(an estimated amount of water of 2 MCM). A relevant tariff system also prevents overuse of produced water.

Uncovered populations by SWSLC, which is 64% of the total population in Sana'a City, have obtained water from private tankers and small scale networks, with higher tariffs and unsecured quality. However, presently this consumption by private suppliers has not been periodically monitored (it was reported that 16.1 MCM and 25.5 MCM were supplied by public and private resources in the year of 1997, respectively (SWSLC (2000)). Although the portion of overuse

is likely to be less than that of public network system due to higher tariffs, water loss from the tankers, and leakage from networks, might represent a major cause of inefficient water use.. Therefore, the establishment of a monitoring system with private suppliers' agreement is required.

For these approaches, the following should be taken into consideration:

- rather high investment cost and period are required to reduce water loss from the network
- leakage detector and its knowledge of its operation are necessary
- monitoring the distribution network to detect illegal connections
- enforcement of regulations concerning periodical replacement or calibration of meters
- increasing awareness of private suppliers regarding water resources management
- registration and monitoring of private wells by installing meter, with the aim of understanding both the quantity of water abstracted and consumed by private suppliers

3.2.3 AVAILABILITY OF TREATED WASTEWATER

An existing Wastewater Treatment Plant (WWTP) has operated since 2000, with a designed daily maximum capacity of 55,000 m^3, which covers only 29% of the urban populations' needs. The treated waste water has been drained directly to an open channel in a wadi, and it is not officially used for any other purposes. Indeed, farmers who have farmland along the wadi have utilized the effluent for irrigation purposes, and some portion has also recharged groundwater. The quantity of effluent discharged from the WWTP is almost equal to the influent quantity (approximately 44,000 m^3/day), and assuming this daily discharge of treated water, approximately 16 MCM of treated waste water could be regarded as an "available water resource," depending on the quality. Actually, the WWTP is working without the proper facilities to treat wastewater to an acceptable quality for reuse in irrigation. Additionally, the WWTP is unfortunately being operated beyond its designed capacity (explained in Chapter 5 of the Supporting Report), and effluent is discharged into the wadi in an improperly treated state. This improperly treated wastewater is not only unaccountable as a water resource in a water scarce region, but also is a source of adverse impact for both environmental and human health. If treated wastewater with acceptable quality for agriculture was used for irrigation purposes, accumulated groundwater assigned for use in agriculture could be transferred for domestic use.

Improving the existing WWTP, and construction of a new WWTP, has already begun at the initiative of Sana'a Water Supply and Sanitation Local Corporation (SWSLC). Industrial wastewater, it actually discharged directly to the public sewerage network without any treatment. The exact quantity of wastewater produced by industry is unknown; however the installations of treatment facilities, and reuse of treated wastewater by industry, are other approaches that should be considered to decrease the quantity of groundwater abstraction.

For this approach, the followings should be taken into consideration:

- reduce both water loss by evaporation and random abstraction of the treated wastewater
- farmers' acceptance for using treated wastewater for irrigation purpose, and a water tariff, should be taken into consideration
- enforcement of regulations concerning construction of treatment facilities by industry, and incentives to reuse the recycled water, should be taken in consideration

3.2.4 DIFFERENCE OF WATER IMBALANCE AMONG SUB-BASINS

Most of the population in Sana'a Basin relies on agriculture, the most predominant economic activity in the area. A trend within irrigated land indicates that farmers have changed

production from ordinary crops to cash crops such as qat, which provides high economic return to the farmers. However, qat is considered a heavy water consumer, consuming more than 71% of the total water consumed by irrigation in Sana'a Basin; in addition, agricultural water demand is expected to increase, despite the depletion of potential groundwater. Considering the high yearly population growth rate at 5.5% observed in Sana'a City, it is clear that the demand for domestic water will increase more than production, and that the agricultural water demand is expected to increase, despite the depletion of potential groundwater.

Giving priority within the domestic water supply for urban and rural populations is one of the main objectives of National Water Strategy. From the view points of the priority given to domestic water and basic human needs, transferring water from irrigation purposes, to the domestic purposes, seems to be a favorable option.

Allocation of water resources is established considering two policies:, 1) Priority of allocation of water is given to the domestic purposes, and 2) Clean and safe water shall be utilized for domestic purposes as much as possible. Based on these policies, three options for allocation of water are presented: 1) Water for irrigation and watering of roadside trees is transferred to domestic use in urban areas; 2) Water for irrigation is transferred to domestic use in rural areas; 3) Water for irrigation in rural areas is transferred to domestic use in urban area. Simultaneously, the potential of water resources in the regional level (e.g. sub basin level) shall be taken into consideration. In order to take this approach, other approaches such as improvements in irrigation water-use efficiency, and reuse of treated wastewater for irrigation purposes, shall be conducted simultaneously.

As for effective implementation of water resources management for Sana'a Basin, comprehension of the actual situation of water resources such as water level fluctuation, distribution of water quality, volume of recharge to groundwater, run-off, distribution of aquifers with hydrogeological characteristics, evapotranspiration, etc. is a fundamental activity. Considering this necessity, NWRA-SB has started these activities as a part of the SBWMP, funded by World Bank since 2004, and has accumulated useful data and information, as well as experience.

The following considerations shall be taken to encourage smooth implementation.

- demand in the domestic sector and irrigation-use in the rural area shall be satisfied
- increasing of public awareness shall be carried out
- incentives or regulation will be necessary
- NWRA-SB, as the regulatory body for water resources management, shall give instructions and advice to both relevant individuals and organization with regards to water development; NWRA-SB is required to take into consideration plans and the situation of water development activities of all other organizations, e.g. water consumption, demand, and water quality
- all organizations concerned with water development are required to submit information to NWRA-SB

3.2.5 INSTITUTIONAL DEVELOPMENT

(1) Finalization of the Executive Regulation to the Water Law of 2002, and Development of Decrees 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 the political considerations in its basic provisions risk weakening its legal effect and validity of the Law itself. These considerations include in particular a 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 a 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 was submitted to and approved by the Cabinet, which is also subject to parliamentary approval. The Draft Executive Regulation, which may include these regulations to introduce groundwater abstraction metering and groundwater charge levying, however, became highly confidential due to its political and social sensitivity; its availability is also limited. Moreover, parliamentary approval on the Regulation without amendment on these regulations seems to be pessimistic, due observations of the recent decision made by the parliament regarding the Adjustment of the Water Law of 2002, in 2007.

Another negative decision may affect 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%. 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 crops, especially qat, increases further water demand in Sana'a Basin, which indeed requires more than half of the extracted groundwater. Moreover, prevalent methods of irrigation traditionally practiced in Sana'a Basin with less efficiency in water use increase the burden on water aquifers,; here, not less than 40% of extracted water is lost. Thus, in the area like Sana'a Basin, where considerable groundwater demand for water-consuming crops, 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 should be considered desirable. Groundwater metering and groundwater charge levying should be the most indispensable prescription to address the issues of over-consumption by water-demanding cash crops and excessive water loss typical in Sana'a Basin.

Considering time factors to increase social acceptance , the bylaws for the "protection zones" of Sana'a Basin should make the objective of gradually limiting abstraction to the annual natural recharge 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 a protected zone in the Sana'a Basin could be a key prerequisite for the effectiveness of the Action Plan of NWRA-SB.

(2) Increasing awareness of Public and Political Leaders for Water Resource Management

The measures taken in the Action Plan to address such water crisis may necessitate undertakings to increase public awareness and gradually establish public consensus for water resource management, which would duly change political attitude and further increase political willingness towards it. Thus, current efforts towards public awareness campaigns shall be further concentrated. Firstly all citizens, in particular the water users, stakeholders, and public at large shall be informed of the seriousness of the water crisis. The awareness campaign shall be also extended to the authorities, corporations, and companies involved in the water

development sector, whether they are central or local, and governmental or private, for compliance with the relevant laws and regulations.

Moreover, a packaged public awareness campaign shall be developed and implemented, suitable for Yemen's unique socio-culture of "tribalism." Inheritance of their tribal land, prosperity from generation to generation, is one of their biggest concerns; thus water on and under the ground is regarded as servitude to the land in their customs. Lost opportunities regarding land productivity will be incurred by the next generation. The impact of barren land, resulting from overexploitation of groundwater, inherited by them, shall be fully recognized. Also, the establishment of an education and information network for tribal authorities may be considered. As far as possible, an inter-tribal coordination system for the conciliation of their interests shall be identified and utilized to ease current competitions related to over-development and over-abstraction of groundwater.

The Provision of reliable information related to water crisis to political entities is also significant. Along with an awareness campaign for the public, in the future the "right" political decisions based on reliable evidence related to the water crisis, and validated by a "vote," shall increase public support

These approaches for awareness and consensus building targeting the general public, tribal communities, and political entities, shall be integrated into the Action Plan.

(3) Distinctive Definition of Water Usufruct

There are tradition-based and custom-based legislative sources governing water resources management, such as "*Sharia'h*," "*'urf*," and the Civil Code, which define that land ownership gives the owner the full right and control over natural resources both above and below (thus, surface and ground water) its surface. The deliberations and discussions for the Water Law of 2002, and its amendment Law in parliament, also indicated that most of the parliament members insisted 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 subject to the State's administration and registration. Hence, only water use rights (*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 urged to the public; otherwise the Water Law loses its effect in execution and enforcement, overwhelmed by other predominating legislations. Parliament approval could be a 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 the sole legal means to regulate the water use right (*usufruct*) instead of other predominating legislations.

(4) Respect Towards Traditional and Tribal System

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

Local institutions should include "tribes" or "tribal systems," which cannot be ignored and, in fact, should be regarded as the most governing institution, particularly in the highland area of the country, including areas of Sana'a Basin. A decentralized framework of local institutions and administrations introduced by the Water Law, and other relevant laws and bylaws, however, seems to lack an effective mechanism to encourage the active participation of "tribes" and "tribal systems" in decision making and execution of improved water resource management.

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

It shall be also emphasized that, the stakeholders involved in the decision making process for water resource management, either at the 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 generations require respect, and can often serve as a sound and practical basis for cooperation between water users, helping to resolve conflicts in water management.

(5) Improvement in Decentralized Framework of Local Administration and Institutions

The decentralized framework of local institutions and administrations delineated both in the Water Law of 2002 and the Local Authority Law of 2000, with their related by-laws and decrees, was reviewed in Chapter 6 of the Supporting Report. It was 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 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 a 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 the decentralized framework of local institutions and administrations in Sana'a Basin, through the full utilization of local capacity in Local Councils and institutionalization of those local institutions of opportunity in the Basin management.

3.2.6 ORGANIZATIONAL DEVELOPMENT

As observed in Chapters 6 and 7 of the Supporting Report, 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 the organizational structure set forth for IWRM in the Water Law and governmental decrees, puts great emphasis on a delegation of power in water management to the lowest appropriate levels. In the 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 a 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.

(1) NWRA Sana'a Branch (NWRA-SB)

1) Organizational Structure

NWRA-SB has two major departments: (1) The Department of Studies and Information, and, (2) The Department of Licensing and Public Awareness. However, as observed above, organizational bylaws that determine tasks and duties of NWRA-SB have not been finalized yet. Without finalization of organizational bylaws, further development of job-descriptions for each department/section, and organizational charts defining the interrelationship among departments/sections, cannot be possible at the present. In the absence of defined organizational bylaws/job-description and charts, factors most important for organizational operation and management, such as mutual understandings, decision making processes, systems for giving and monitoring orders, and interdepartmental coordination/cooperation, are being hampered. Thus, there are strong needs to finalize their organizational bylaws and job-descriptions 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 those of the of headquarters, were 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 PhD degree holders. During 2006, training courses had been conducted for NWRA Headquarters and its seven Branch Offices including Sana'a. 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 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 priorities:; 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 a 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 raises and promotion based on performance-based staff evaluation system.

3) Financial Management

IWRM requires coordination with other sub-sectors, not only in strategies and activities, but also in investment planning. There are several sub-sector national authorities in the 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 the 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 wells 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 mechanisms of an on0field 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.

(2) Local Councils

Local Councils are also relatively new organizations, and their 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 the 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, are composed of two distinctive entities: one is directive body of which director at governorate is appointed by prime minister, while one at district is appointed by governorate director; the other one is an executive organ that carries out local administration and development that is composed 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.

(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-sector basis. This is very positive.

However, the capacity for institutional arrangement to improve water management is insufficient. Public institutions can not cope with tribal structures and local water users due to their 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 to create and maintain channels to involve traditional leaders and tribal institutions in decision making, enforcement of self-regulating water management mechanism (e.g. involvement of them in SBC), are an important step.

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.

(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 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 areas." To be successful, it needs a collective effort, and working closely with farmers through Water User Association (WUA) and Water User Group (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 drips and bubblers. 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, farmers 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 contributions for capital investment, organizes farmer awareness activities, and acts as a liaison between the Project and individual farmers or WUGs. The establishment of WUA forms an important part of this project component. Together with WUA formulation, demonstration farms (often 1-2 ha) have been selected for each WUA, and received investment in modern irrigation infrastructure.

Establishment of demonstration farms is of vital significance. This significance 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 (i.e. via actual demonstration), the more farmers will adopt the new, improved technology.

The benefit from these on-farm investments has so far been obvious, as water saving reached over 50%, and it could be higher given the huge reduction in pumping time; reduction of diesel consumption due to reduced needs for pumping, better products and production, are all important components

However World Bank reported these activities are highly delayed, and have had a negative impact on farmers' acceptance of the new irrigation technologies (Baseline Survey for Future Impact Evaluation, Sana'a Basin Water Management Project, MWE, (2006)). Accompanied with this, the raising of farmers' awareness also appears inadequate. Some hesitate to contribute to capital investment or join WUA (in some areas, only 10 out of 40 WUGs joined WUA).

At present (July, 2007), 48 WUAs have been established with 530 WUGs formed and 4,440 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 systems, with only 211 ha installed, or less than 5% of the project target. The relatively higher number of WUAs and WUGs formed, compared to the smaller area converted with improved irrigation technologies, reinforces the need for good quality implementation in social mobilization, and cohesion and training of WUAs and WUGs.

The key issue over the long term, is the improved awareness of WUAs and WUGs. It is these organizations that are going to handle the bulk of the regulation of water usage, by both groups and individual farmers, through adoption of improved technologies with irrigation efficiency. If this is done, and farmers simply use the water saved for higher application levels or to expand irrigated areas, 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 a successful program, than to achieve targets that are not replicable or of demonstration value because they have not succeeded. In the assessment of 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 saving. Beneficiaries should be acquainted with appropriate cropping patterns, in order to adapt to growing less water-consuming crops. Training programs for 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 convinced not to expand their crop area because of water savings through these modern irrigation systems. Additionally, the tripartite agreement between farmers, the community organizations, and the NWRA-SB, should be endorsed, especially the role of WUAs should be fully activated as referred above.

3.2.7 CONTAMINATION OF LIMITED GROUNDWATER RESOURCES

(1) Contamination in Urban Area

In urban areas, 29% of population, which is equal to 560,259 inhabitants, was covered by a public sewage network in t2006, according to SWSLC's report. Discharge from a wastewater treatment plant, has been drained directly to an open channel in the wadi since the year of 2000, and farmers have used the drained water for irrigation purposes. And as mentioned above, WWTP is working in beyond treatment capacity,, and the quality of treated water is not satisfactory, even for irrigation purposes. Therefore, in 2007, NWRA-SB has started to raise awareness of among farmers, not to use of the drained water, in order to avoid health risk. In addition, the drained water not utilized for irrigation purposes, has infiltrated into the ground and might contaminate groundwater. Indeed, the quality of groundwater downstream of the treatment plant has become worse, as reported in a case related to the Al-Masham Dam, located around 12 km downstream of the WWTP, where the treated wastewater is collected. Actually, improvement of existing WWTP by construction of new plant downstream of wadi was planned by SWSLC.

Population not covered by the public sewage network depend on the cesspits, and problems reported included that with heavy rain, rain water flows into the cesspits, with these cesspits finally overflowing contaminated water to the outside. In the other hand, pollution of groundwater by infiltration is also reported. Depletion of groundwater quality by infiltration of sewage became visible, as a high concentration of nitrate (NO3) at a concentration two to three times higher than the World Health Organization (WHO) permissible limit for drinking water, which is 50 mg/l, was found in the older central part of Sana'a City. Several hundred private wells affected by the contamination by sewage were reported, and what should be remembered is that the public well fields are located closer to the city. Since the SWSLC and Sana'a

Municipality have been aware of necessity of treatment of sewage, they allocated budget from the Arab Fund and national budget, to deal with this situation.

Another factor pointed out, is the pollution caused by insufficient waste disposal in the petrol stations, car service shops, and medical units like hospitals, laboratories and clinics, and even industry - since these establishments are not equipped with any wastewater treatment facilities, and discharge of wastewater is presumably uncontrolled, unregulated and unmonitored. Groundwater contamination caused by these individual factors has not been clarified, therefore, a comprehensive groundwater quality survey, and implementation of regulations concerning the construction of treatment facilities at these establishments, is required without delay.

Once water resources are polluted, it is not easy to remediate them to their original state; , this results in a decrease in available safe water resources. In addition, if the polluted water is consumed for drinking, irrigation and other purposes, it will cause health problems for human beings and animals, deterioration of farmland (e.g. lowering the yields of agricultural crops), and adverse impact on the environment.

(2) Contamination in Rural Area

In order to grow crops as much as possible, unfortunately, the farmers have overused not only water resources, but also chemical fertilizer and pesticides; as a result, contamination of groundwater is observed along wadis where agriculture activity is conducted. The Government of Yemen has prohibited the use of some pesticides and fertilizers that can cause not only adverse impact on nature, but also to human live. However, since agriculture is considered the main economic activity in the Basin, and farmers are intent to protect their assets and incomes, farmers are using fertilizer and pesticides in an uncontrolled and unregulated manner, unaware of risk caused by these chemicals. Fertilizers and pesticides might be one of the sources of groundwater pollution; however storage and disposal of livestock waste on land is yet another pollution source that widely effects the groundwater quality

Approaches to increase the awareness among farmers, concerning the risks caused by over-use of pesticides and fertilizers, as well as the utilization of illegal chemicals, is needed. They should be aware that that they are not only exposing water resources to danger, but also endangering consumers and most important, the lives of them and their families.

Considering this situation, the Integrated Pest Management Plan for Grapes and Qat has already been launched by SBWMP, in cooperation with the General Department for Plant Protection.

(3) Concentration of Fluoride

It was reported that the effects by high concentration of fluoride, such as dental fluorosis and skeletal fluorosis, were also observed inside Sana'a Basin. In total, 202 samples were analyzed in the previous studies. The concentration of fluoride in 28 of 202 wells (14%) exceeds the maximum permissible limit, that is, 1.5 mg/l; these were observed in the southeastern, western and north part of the Basin. 67 wells (33%) have a concentration of fluoride between 0.5 and 1.5 mg/l. The causes of contamination is unknown (i.e. if it originates from a natural source, or from an infiltration of contaminated water, etc.); the only information available, is that most of samples analyzed are located in an area of distribution of volcanic rocks. However, it is only a rough figure concerning contamination by fluoride, and since the people who live in the high fluoride concentration area have a limited choice of water source for drinking purposes, measures should be taken by the governmental body.

For these approaches, the followings should be taken into consideration

- improvement of a sewage network system shall be considered, in order to meet the increasing population in the urban area, in conformity with city development plans
- enforcement of regulation for the construction of wastewater treatment facilities for industries, petrol stations, car service shops, medical units, etc.
- increasing the awareness of farmers via education of effective farming technique
- enforcement of the regulation of internationally prohibited pesticides and fertilizers, and heightening awareness among farmers regarding the health and environmental dangers related to utilization of such pesticides and fertilizers

3.2.8 NECESSITY OF CONSIDERATION OF EFFECTIVE USE OF SURFACE WATER

The precipitation inside Sana'a Basin, which varies from 200 mm/year in the northeastern area, to 350 mm/year in the southwestern area, is low; therefore, States and farmers have made an effort to utilize these precious water resources as much as possible, using water harvesting methods and surface structures. These methods and structures have also contributed to recharge the groundwater. However, the dependence on water harvesting systems has been decreased because of the expansion of farmland and the use of groundwater resources. As for surface structures, discussions related to optimizing the effectiveness of the structures, from the view point of integrated water resources management, have been carried out. Therefore, appropriate action for improvement of recharge groundwater should be considered.

(1) Water Harvesting and Maintenance of Terrace

Traditional water harvesting methods have been used in Yemen for a long time, in an effort to obtain water for domestic-use, animals, and irrigation purposes, while contributing contributed to recharge groundwater simultaneously. However, since agricultural activities have increased the consumption of groundwater, dependence on traditional water harvesting methods have been decreased. Unmaintained terraces in the mountainous region were sometimes abandoned. Considering the scarcity of water in the basin, such kinds of traditional methods should be utilized as much as possible.

(2) Consideration of Construction and Rehabilitation of Recharge and Subsurface Dam

In general, dams function of recharge to groundwater; indeed, a recovery of the water level of shallow wells was observed inside Sana'a basin. However, NWSSIP points out that in spite of the tremendous efforts in dam construction, dams that have been built have not stopped the continuously declining levels of groundwater or helped replenish the depleting aquifers in many basins. It was concluded concludes that dams' policy should be accompanied by measures and actions to control and rationalize water demand.

For these approaches, the followings should be taken into consideration:

- increasing the awareness of farmers on the necessity of water harvesting
- availability of mountainous area for terraces
- measures and actions to control and rationalize water demand
- analysis of costs and benefits
- possible adverse impact on social and environmental aspects and necessary mitigation should be made on the basis of results of a comprehensive study

REFERENCES

Ministry of Water and Environment (2006) "Baseline Survey for Future Impact Evaluation," Sana'a Basin Water Management Project, MWE, p.107

CHAPTER 4

FUTURE SCENARIOS BASED ON SOCIO-ECONOMY AND WATER DEMAND IN SANA'A BASIN

CHAPTER 4 FUTURE SCENARIOS BASED ON SOCIO-ECONOMY AND WATER DEMAND IN SANA'A BASIN

4.1 GENERAL

In this Chapter, first, future water demand is projected in accordance with information provided by organizations concerned, in order to make clear the quantity of water which will be deficit, and how long the limited water resources will be able to be consumed inside Sana'a Basin. Then, possible scenarios to mitigate the severe condition of water resources are considered. Based on these results, one scenario to be taken is chosen.

4.2 FUTURE WATER DEMAND

Water sector in Sana'a Basin is classified into five sectors as follows: 1) urban area water supply composed of domestic and institutional purposes; 2) domestic purpose in rural area, 3) industrial purpose, 4) touristic purpose and 5) irrigation purpose. Projection of future water demand of each sector was conducted in this study, based on the existing information provided by the organization concerned. The results are described in the following sections.

4.2.1 POPULATION FORECAST FOR SANA'A BASIN

(1) Population Forecast for Sana'a City

The population forecast for Sana'a City was done by the National Water and Sanitation Authority (NWSA) (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 decreased to 4.2% in 2020. Assumed rates under the moderate and limited growth scenarios were 5.6% and 5.1% respectively in 1997, and decreased to 3.3% and 2.4% respectively in 2020.

Since the study carried by NWSA (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 the growth rates mentioned above. The population growth rate for Sana'a City during the period between 1994 and 2004 was 5.5% and this rate was projected to decrease up to 4.2%, 3.3% and 2.4% respectively for high, medium and limited growth in the year of 2020.

The population forecast for Sana'a City is shown in *Table 4.1* and *Figure 4.1*. According to the results of population forecast, the population of Sana'a City, under the moderate growth rate which was adopted for project planning purposes, for the year of 2006, the base year of this study, is 1.9 million inhabitants, and for 2020, 3.4 million inhabitants was estimated.

Table 4.1 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

Year	High Growth Rate		Moderate Growth Rate		Limited Growth Rate	
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)

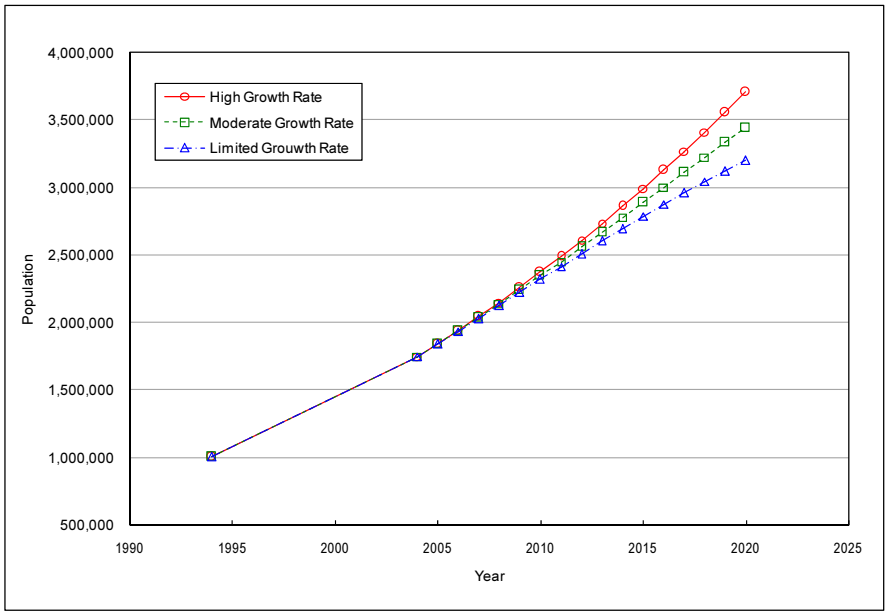


Figure 4.1 Chart of Population Forecast for Sana'a City

(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 4.2*. For this calculation, it was assumed that the population is uniformly distributed within the district.

In this study, population forecasts for districts of Bani Husheish, Sanhan and Bani Bahloul, Hamdan, Arhab, Nehm, Al Taial, Bani Matar and Jahana were calculated based on a growth rate of 2.5% that was adopted by GARWSP. Results of the projections are shown in *Table 4.3*.

(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 as calculated above. The growth rate adopted for rural areas is 2.5%, and for the urban areas, moderated growth rate was adopted. Results of estimations are shown in *Table 4.4*.

Table 4.2 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 a natural boundary for the catchment area of the Basin. This area is considered uninhabited

Table 4.3 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 4.4 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

4.2.2 DOMESTIC WATER DEMAND

(1) Urban Water Supply

SWSLC had prepared the Development Program namely Sana'a Water Supply and Sanitation Projects (SWSSP). Future water demand for urban areas was projected in this Development Program, with four alternative options and conditions, as mentioned in the section 5.8.2 in the Supporting Report, and includes water demand of both domestic and non-domestic water use supplied by both public and private suppliers. According to SWSLC, water supply for urban areas is forwarded in accordance with the Option 1, that is, 35 l/c/d for domestic consumption for the entire city population. Designed physical loss is planned at 20%. Future water demand for the urban water supply is shown in *Table 4.5*.

Table 4.5 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	80.0	80.0	80.0
Private water supply		70.0	70.0	35.0	35.0	35.0
Non-domestic						
Option 1	(% of total)	---	---	30%	30%	30%
Consumption						
Domestic						
Option 1	(MCM)			30.0	36.9	44.0
Public water supply		12.5	13.1	32.2	51.5	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
Total Consumption						
Option 1	(MCM)	43.7	46.4	42.8	52.7	62.8
Total Supply Requirement Including Physical Losses @ 20% of Production						
Option 1	(MCM)	54.3	55.8	53.5	65.9	78.6

*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; 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

(2) Rural Water Supply

GARWSP is of the governmental body in charge of planning and implementation of the rural water supply. However, there is a lack of available information related to the projection of the future water supply. Future water demand for this sector, therefore, is calculated based on a population growth rate of 2.5%, adopted by GARWSP for rural water supply projects, and the unit water consumption of 20 l/c/d, adopted by NWRA for water resources management by sub-basin, as shown in *Table 4.6*.

Table 4.6 Future Water Demand for Rural Area by Sub-Basin

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

Unit: Population: inhabitants,
Water demand: million cubic meters

4.2.3 AGRICULTURAL WATER DEMAND

Irrigation water demand was estimated by GAF (2007) calculating the actual evapotranspiration (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 for the plant. However, it must be considered that more water is used by farmers to irrigate their land than the plants themselves need. This difference is expressed in the irrigation efficiency. As it is mentioned in section 2.3.2 in Chapter 2, 40% is applied for the irrigation efficiency.

Projection of future 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. *Table 4.7* shows the total water demand by sub sub-basin.

Table 4.7 Irrigation Water Demand (IE=40%)

		Total 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	4.53	4.59	4.86	5.20	5.58
3	Wadi Al Kharid	3.03	3.07	3.24	3.47	3.72
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	2.40	2.43	2.57	2.76	2.95
8	Wadi Al Huqqah	14.48	14.66	15.39	16.36	17.40
9	Wadi Bani Huwat	48.67	49.01	50.43	52.31	54.32
10	Wadi Thumah	1.26	1.27	1.32	1.38	1.45
11	Wadi As Sirr	24.74	24.93	25.75	26.83	27.98
12	Wadi Al Furs	8.61	8.69	9.02	9.46	9.92
13	Wadi Al Iqbal	19.67	19.94	21.03	22.49	24.05
14	Wadi Zahr & Al Ghayl	16.30	16.49	17.26	18.30	19.41
15	Wadi Hamdan	10.16	10.31	10.89	11.67	12.51
16	Wadi Al Mawrid	8.76	8.86	9.26	9.80	10.37
17	Wadi Sa'wan	10.05	10.13	10.47	10.91	11.38
18	Wadi Shahik	10.30	10.40	10.78	11.30	11.85
19	Wadi Ghayman	5.50	5.55	5.77	6.07	6.38
20	Wadi Al Mulaikhy	3.47	3.52	3.71	3.96	4.23
21	Wadi Hizyaz	2.64	2.68	2.83	3.02	3.23
22	Wadi Akhwar	2.45	2.48	2.62	2.81	3.01
Total		209.20	211.35	220.24	232.06	244.71

Unit: million cubic meters

4.2.4 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 their own wells, where abstraction of water is supposed to be unregulated and unrecorded.

WEC (2001) estimated the water demand using the "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 industrial sub sectors. In this study, future water demand was estimated based on the estimations carried out by WEC (2001), with assumed conditions mentioned in section 5.8.5 in the Supporting Report. Results of projections on industrial water demand are shown in *Table 4.8*.

Table 4.8 Industrial Water Demand by Scenarios

Year	Historical Growth Rate			Programmed Growth Rate		
	Manufacturing	Mining and Quarrying	Total	Manufacturing	Mining and Quarrying	Total
2005	4.75	0.00336	4.76	4.75	0.00336	4.76
2010	5.98	0.00452	5.99	7.12	0.00485	7.12
2015	7.53	0.00608	7.53	10.65	0.00700	10.66
2020	9.47	0.00818	9.48	15.94	0.01009	15.95

Unit: million cubic meters

In this study, future water demand for industry, in accordance with Programmed Growth Rate is adopted, since it is estimated and planned in the Socio-Economic Development Plan for Poverty Reduction (2006-2010).

4.2.5 TOURISTIC WATER DEMAND

Suitable studies and/or information were not available for a detailed demand projection of water for the touristic sector, which is increasing with the greater number of tourist arrivals. Water demand projection for the touristic sector in this study, was calculated assuming the following conditions:

- It was supposed the increasing rate observed between 2004 and 2005 will not continue at the same rate in the future. It was supposed to decrease few percent points 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 the touristic sector estimated in this study has considered only the yearly increase in the number of beds, and a bed occupancy rate at 40%. An 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 out 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 the governorate of Sana'a are located within Sana'a Basin, around the City.

Projection of touristic water demand is shown in *Table 4.9*.

Table 4.9 Touristic Water Demand Projection

Item		2005	2010	2015	2020
Water demand	Traditional Hotel	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**	**2.63**	**7.12**

Unit: million cubic meters

4.3 FUTURE WATER BALANCE

The projected future water demand (described in the previous section), and the totaled amount of these water demands are summarized in *Table 4.10*. The totaled amount is gradually increased, from 269.3 MCM in 2005, to 349.6 MCM in 2020. On the other hand, renewable groundwater resources were estimated to be only 50.7 MCM/year in the previous study as described in Chapter 2. The balance between renewable resources and demand is minus 218.5 MCM in 2005 and minus 298.9 MCM in 2020, if the recharge amount is not changed. It means that non-renewable water resources will continue to decrease.

Table 4.10 Future Water Balance

Purpose		Water Demand (MCM/year)				Remarks
		2005	2010	2015	2020	
Urban Area Water Supply (Domestic and Institutional)	a	-	42.8	52.7	62.8	Water demand in accordance with the Sana'a Water Supply and Sanitation Project (SWSSP) of SWSLC. Option 1, unit water consumption is 35 l/c/d
	b	54.3 (20.1 %)	53.5 (18.8 %)	65.9 (21.0 %)	78.6 (22.5 %)	**Production amount** from 2010 to 2020 including physical loss with 20% of production, which is adopted by SWSLC. Demand in 2005 is the actual production.
Domestic Use in Rural Areas	c	0.6 (0.2 %)	2.5 (0.9 %)	2.8 (0.9 %)	3.2 (0.9 %)	Demand from 2010 is calculated by using 2.5% of population growth rate with 20 l/c/d, Value of 2005 is 25% of estimated demand
Industrial Use	d	4.8 (1.8 %)	7.1 (2.5 %)	10.7 (3.4 %)	16.0 (4.6 %)	Programmed Growth Rate according to DPPR (2006-2010)
Touristic Use	e	0.4 (0.2 %)	1.0 (0.4 %)	2.6 (0.8 %)	7.1 (2.0 %)	Growth rate of 10% for traditional to three stars, 3% for four and five stars. Unit water consumption is 350l/c/d for five and four stars, 180l/c/d for three to one stars, 120l/c/d for traditional
Irrigation Use	f	83.7	88.1	92.8	97.9	Actual Evapotranspiration (ETa), GAF (2007) Growth rate depends on cultivated area of each type of crop
	g	209.2 (77.7 %)	220.2 (77.4 %)	232.1 (73.9 %)	244.7 (70.0 %)	**Calculated Consumption** with present irrigation efficiency (40%). This efficiency is continued until 2020
Total Consumption	h	**269.3**	**284.3**	**314.1**	**349.6**	Total Consumption (h) =(b) + (c) + (d) + (e) + (g)
Recharge	i	50.7	50.7	50.7	50.7	Based on A.Norman and W.Mulat (2007), Water Balance and Hydrological Monitoring
Balance	j	**-218.6**	**-233.6**	**-263.4**	**-298.9**	Balance(j) = Recharge(i) - Total Consumption(h)

Note : Values in parentheses are the proportion of water consumption of each purpose to total consumption

As described in Chapter 2, the groundwater storage has been roughly estimated in the previous studies. The estimated amount of usable groundwater by WEC (2001) is 5,212 MCM, which is adapted to this study. Therefore, if the water consumption continues in accordance with the projected future water demand as shown in *Table 4.10*, the usable groundwater would not be able to meet the demand in the year of 2021 as shown in *Figure 4.2*.

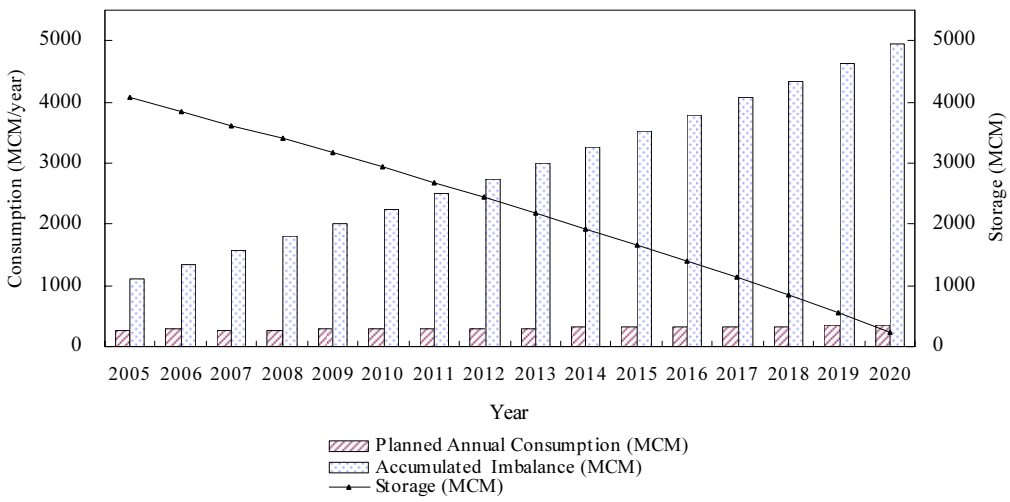


Figure 4.2 Decreasing of Storage with Planned Future Demand

Even if the present water consumption of 269.3 MCM/year remains as it is, the usable groundwater would expect to be in a very critical situation within 23 years from the year of 2001.

It means that by the year of 2020 at the very latest, groundwater abstraction has to be drastically reduced to the recharge amount, that is, from 269.3 MCM/year at present, to 50.7 MCM/year.

In order to achieve this goal, all farmers are required to completely stop irrigation activity which uses groundwater, and water consumption for domestic purposes must be almost two thirds. Implementation of water saving is obviously unrealistic. However, it is also obvious that all of the stakeholders are strongly required to reduce water consumption immediately, so as to extend the life of limited water resources.

4.4 FUTURE SCENARIOS

4.4.1 BASIC POLICY FOR FUTURE SCENARIO SETTING

As mentioned in the previous sections, the water resources in Sana'a Basin are in critical condition. In order to keep sustainability of water resources in the Basin, water consumption should be drastically reduced to 50.7 MCM/year by 2020 that is the equal amount of recharge amount. In order to achieve this, all farmers have to stop irrigation and the water to be supplied for urban areas should be nearly two thirds. This may be unrealistic, considering that economic activities rely on the agriculture sector. Therefore, all stakeholders are strongly required to reduce water consumption by 2020 for the purpose of extension of the grace period to be critical situation of water resources, and to prepare further countermeasures. Considering this situation, the water resources management for Sana'a Basin is required to show the direction towards reducing water consumption. For this purpose, the future water demand should be projected by applying low population growth rate and low economic growth rate of each sector, which are estimated in the existing information. In this study, from the view point of this, the scenarios for water demand are considered.

Considered scenarios with target figure in the year of 2020 are summarized in *Table 4.11* and shown in *Figure 4.3*. These four scenarios are prepared in combination with scenarios of five sectors. Scenarios of each sector are prepared considering existing economic growth plan and some of are set by the study team considering the possibility. Condition of setting for each scenario is as follows.

- Scenario 1: The values for less contribution to reduction of water consumption in each sector such as higher growth rate and lower irrigation efficiency, which are set in the existing plan and set by the Study team, are applied.

- Scenario 2: The values for the most possible reduction of water consumption set by the Study team for urban area water supply and irrigation use that account for large portion of total water consumption are applied.

- Scenario 3: The values for the most possible reduction of water consumption set by the Study team are applied to not only urban area water supply and irrigation use but also industrial and touristic use.

- Scenario 4: The values for the most possible reduction of water consumption set by the Study team are applied to urban area water supply, industrial use and touristic use. For irrigation use, reduction of water consumption to 50 MCM is applied taking into consideration the reuse of treated wastewater in the year 2020.

As shown in *Figure 4.3*, reduction of water consumption is attained in each scenario comparing

with the future water demand estimated in accordance with the values of existing economic growth plan and development plan.

Table 4.11 Summarized Scenario of Water Demand

	Urban Area Water Supply (Domestic and Institution)	Domestic Use in Rural Area	Industrial Use	Touristic Use	Irrigation Use	Total*8) Consumption
Scenario 1	Population: 3,198,573 LPGR*1) Physical Loss: 14.6 MCM (20%)*2) Unit water consumption : 35 l/c/d*3)	Population: 437,532*5) Unit water consumption: 20 l/c/d*5)	Historical growth rate, DPPR*6)	Based on DPPR	No expansion of irrigated area since 2005 IE: 60%*7) Actual requirement: 83.68 MCM/year	***232.3***
MCM/year	**73**	**3.2**	**9.5**	**7.1**	**139.5**	
Scenario 2	Population: 3,198,573 LPGR Physical Loss: 10.3 MCM (15%)*4) Unit water consumption: 35 l/c/d	Population: 437,532 Unit water consumption: 20 l/c/d	Historical growth rate, DPPR	Based on DPPR	No expansion of irrigated area since 2005 IE: 70% Actual requirement: 83.68 MCM/year	***208***
MCM/year	**68.7**	**3.2**	**9.5**	**7.1**	**119.5**	
Scenario 3	Population: 3,198,573 LPGR Physical Loss: 10.3 MCM (15%) Unit water consumption: 35 l/c/d	Population: 437,532 Unit water consumption: 20 l/c/d	No growth in Industry inside the Basin since 2005	No growth in Tourism inside the Basin since 2005	No expansion of irrigated area since 2005 IE: 70% Actual requirement: 83.68 MCM/year	***196.6***
MCM/year	**68.7**	**3.2**	**4.8**	**0.4**	**119.5**	
Scenario 4	Population: 3,198,573 LPGR Physical Loss: 10.3 MCM (15%) Unit water consumption: 35 l/c/d	Population: 437,532 Unit water consumption: 20 l/c/d	No growth in Industry inside the Basin since 2005	No growth in Tourism inside the Basin since 2005	Reduce 11,111 ha irrigated area out of 18,954 ha Install improved irrigation system to7,843 ha	***127.1***
MCM/year	**68.7**	**3.2**	**4.8**	**0.4**	**50**	

*1) LPGR: Limited Population Growth Rate set in Sana'a Water Supply and Sanitation Project (SWSSP) (Dar Al-Handasah, 2000)

*2) Physical Loss, 20% is set in SWSSP

*3) Option 1 set in SWSSP, Minimum option, water is supplied of entire city population

*4) Physical Loss, 15% is set by the Study team

*5) Population growth rate in rural area, 2.5% and unit water consumption, 20 l/c/d are provided by GARWSP.

*6) Calculated value based on the Socio-economic development plan for poverty reduction (DPPR, 2006-2010)

*7) Irrigation efficiency

*8) Total consumption includes loss of water supply and overuse in irrigation

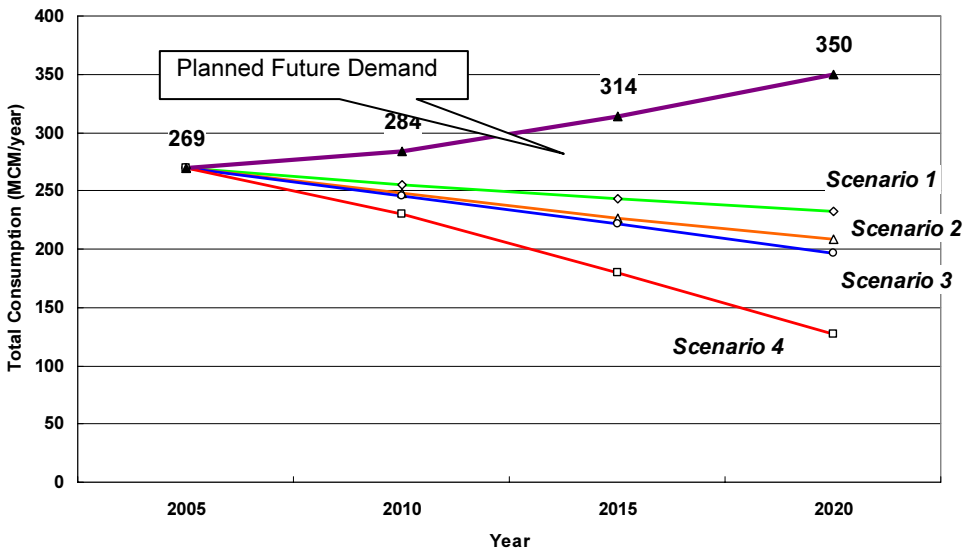


Figure 4.3 Scenarios for Water Demand (2005 – 2020)

4.4.2 URBAN AREA WATER SUPPLY

(1) Population

Since the future water demand described in section 4.2.2 is projected by using "moderate growth rate," "limited growth rate" is applied for the scenario so as to make the population growth rate low as shown in *Table 4.12*.

Table 4.12 Population Forecast with Limited Growth Rate

Year	2005	2010	2015	2020
Population	1,840,578	2,318,455	2,787,806	3,198,573
Growth Rate	5.31 %	4.34 %	3.37 %	2.40 %

*1) Growth rate is quoted from Dar Al-Handasah (2000).
*2) Population is projected based on the population in the Statistical Year Book 2005

(2) Scenario of Water Demand

Two types of scenarios of water demand which are shown in *Table 4.13*, are prepared for urban area water supply with the following conditions. . It is noted that the scenario number in *Table 4.13* corresponds to that in *Table 4.11*

- Population growth rate is decreased from "moderate" to "limited."
- Unit water consumption is 35 l/c/d in order to cover the entire population in Sana'a city, which is in conformity with the direction of SWSLC

"Scenario 1" is calculated by applying the physical loss of 20% in accordance with SWSSP with assuming to be continued until the year 2020. "Scenario 2, 3 and 4" is calculated by applying the physical loss of 20% until the year 2020, then assuming to be improved to 15% in

the year 2015.

By implementing these scenarios, 5.6 MCM/year in 2020 in scenario 1 and 9.9 MCM/year in 2020 in scenario 2, 3 and 4 are saved comparing projected future water demand that is 78.6 MCM/year as mentioned in section 4.2.2.

Table 4.13 Scenario for Urban Water Supply

Scenario 1

Year	2005	2010	2015	2020
Unit water consumption (l/c/d)	50.8	35	35	35
Consumption of Institution (30% of total)	-	15	15	15
Demand	-	50	50	50
Production amount including loss (l/c/d)	-	62.5	62.5	62.5
Leakage (%)	-	20	20	20
Population to be covered (LGR)	-	2,318,455	2,787,806	3,198,573
Production amount (MCM/year)	54.2	52.9	63.6	73.0

Scenario 2, 3 & 4

Year	2005	2010	2015	2020
Unit water consumption (l/c/d)	50.8	35	35	35
Consumption of Institution (30% of total)	-	15	15	15
Demand	-	50	50	50
Production amount including loss (l/c/d)	-	62.5	58.8	58.8
Leakage (%)	-	20	15	15
Population to be covered (LGR)	-	2,318,455	2,787,806	3,198,573
Production amount (MCM/year)	54.2	52.9	59.9	68.7

4.4.3 DOMESTIC USE IN RURAL AREA

Since the useful information about population growth rate in rural area is not available, and the priority of the allocation of water resources is given to domestic purpose, the growth rate of 2.5% that is adopted by GARWSP, is applied and is assumed to continue until the year 2020.

4.4.4 INDUSTRIAL USE

As for the water demand of industry, two kinds of scenarios are examined. The "Historical Growth Rate (HGR)" mentioned in the DPPR is applied for the scenarios 1 and 2. No further expansion of industrial activities inside Sana'a Basin is applied for scenarios 3 and 4. These scenarios are shown in *Table 4.14*. It is noted that the scenario number in *Table 4.14* corresponds to that in *Table 4.11*

Table 4.14 Scenario for Industrial Use

Scenarios 1 & 2

Year	2005	2010	2015	2020
Manufacturing (MCM)	4.75	5.98	7.53	9.47
Mining and Quarrying (MCM)	0.00336	0.00452	0.00608	0.00818
Demand (MCM)	4.8	6.0	7.5	9.5

Scenarios 3 & 4

Year	2005	2010	2015	2020
Manufacturing (MCM)	4.75	4.75	4.75	4.75
Mining and Quarrying (MCM)	0.00336	0.00336	0.00336	0.00336
Demand (MCM)	4.8	4.8	4.8	4.8

As for the scenarios of 1 and 2, the future water demand for industrial use estimated growth ratio based on the actual performance during 2001-2005, since the ratio is lower than the "Programmed Growth Rate (PGR)" of DPPR (2006-2010). Furthermore, as for the scenarios of 3 and 4, zero growth ratio for industrial use is applied. Along of the implementation of these scenarios, 6.5 MCM/year in 2020 in scenarios by 1 and 2, And 11.2 MCM/year in 2020 by scenarios 3 and 4 are saved respectively, comparing projected future water demand that is 16.0 MCM/year planned in DPPR as mentioned in section 4.2.4.

4.4.5 TOURISTIC USE

Since the available information about future water demand for the tourism sector is limited, two kinds of scenarios are considered. The growth rate of 12% for tourists' arrivals set in DPPR (2006-2010) is applied for scenarios 1 and 2. No further expansion of tourism is applied for scenarios 3 and 4. The scenarios are shown in *Table 4.15*. It is noted that the scenario number in *Table 4.15* corresponds to that in *Table 4.11*. By implementing only scenario 3 and 4, 6.7 MCM/year in 2020 is saved comparing projected future water demand that is 7.1 MCM/year as mentioned in section 4.2.5.

Table 4.15 Scenario for Touristic Use

Scenario 1 & 2

Year	2005	2010	2015	2020
Demand (MCM)	0.4	1.0	2.6	7.1

Scenario 3 & 4

Year	2005	2010	2015	2020
Demand (MCM)	0.4	0.4	0.4	0.4

4.4.6 IRRIGATION USE

Irrigation is the main activity for income generation for farmers. Water consumption for irrigation purposes accounts for 77% of total water consumption inside Sana'a Basin in the year 2005. Though saving water in this sector much contributes for reducing total water consumption, it is necessary to secure farmers' livelihood by minimizing the adverse impact on and economic structure in Sana'a Basin. Considering the importance and sensitivity of the

sector, three types of scenario are considered as shown in *Table 4.16*. It is noted that the scenario number in *Table 4.16* corresponds to that in *Table 4.11*

Table 4.16 Scenario for Irrigation Use

Scenario 1

Year	2005	2010	2015	2020
Substantial Demand (MCM)	83.7	83.7	83.7	83.7
Irrigation Efficiency (%)	40	-	-	60
Total Requrement (MCM)	209.2	193.1	166.3	139.5

Scenarios 2 & 3

Year	2005	2010	2015	2020
Substantial Demand (MCM)	83.7	83.7	83.7	83.7
Irrigation Efficiency (%)	40	-	-	70
Demand (MCM)	209.2	188.5	154.0	119.5

Scenario 4

Year	2005	2010	2015	2020
Areas to be reduced annualy (ha)	0	855	855	855
Total of reduced area (ha) out of 18,954 ha	0	2,564	6,838	11111
Possible saved amount (MCM)	**0**	**28**	**75**	**122**
Areas where improved irrigation system shall be installed (ha)	0	603	603	603
Total of installed area (ha) out of 7,843	0	1,810	4,826	7,843
Possible saved amount (MCM)	0	9	23	37
Total saved amount	**0**	**37**	**98**	**159**
Demand (MCM)	**209.2**	**172.2**	**111.2**	**50.2**

Scenario 1, and Scenarios 2 and 3, are shown in *Table 4.16* are set to reduce water consumption by improvement of irrigation efficiency from present efficiency 40% to 60% and 70%, respectively. It is required for all farmers not to expand their own irrigated land. In these scenarios, the present situation of economic structures related to irrigation activity will not be damaged. Production is expected to be increased.

Scenario 4 is set to reduce water consumption to 50 MCM/year considering that around 50 MCM/year of treated wastewater will become available in the year 2020. In this scenario, irrigation activity on two thirds of present irrigated land that is 11,111 ha should be stopped, and the improved irrigation system should be disseminated to a third of present irrigated land that is 7,843 ha. In this case, alternative income generation should be secured for the farmers who have to stop irrigation activity to fill the reduced income.

By implementing these scenarios, 105.2 MCM/year in 2020 in scenario 1, 125.2 MCM/year in 2020 in scenarios 2 and 3, and 194.5 MCM/year in 2020 in scenario 4 are saved comparing projected future water demand that is 244.7 MCM/year as mentioned in section 4.2.3.

Irrigation improvement activity composed of social mobilization and enhanced community

water management, physical intervention on irrigation schemes, and technical assistance and implementation support has been already started as a part of SBWMP from the year of 2004. Saving amount was estimated to be 7.12 MCM/year by conducting the rehabilitation of existing piped conveyance systems, the conversion of existing piped conveyance systems and localized irrigation system in this component, which seems to be not enough to be in line with above scenario. As it is mentioned in section 3.2.6 (4) in Chapter 3, poor progress is observed in installing and converting improved irrigation system with only 211 ha, or less than 5% of the project target. Therefore, enhanced and concentrated activities for implementation of these scenarios are necessary.

4.5 FUTURE SCENARIO TOWARDS MAXIMUM SUSTAINABILITY

4.5.1 EXPECTED PERIOD OF USABLE GROUNDWATER RESOURCES IN EACH SCENARIO

As mentioned in section 2.2.2 (1) and (2) in Chapter 2, recharge amount was estimated to be 50.7 MCM/year and usable storage inside Sana'a Basin was estimated to be 5,212 MCM in accordance with the previous study, WEC (2001). In addition to recharge amount, as it is mentioned in section 2.2.3 in Chapter 2, expansion of capacity of wastewater treatment plant has been launched and reuse of treated wastewater for irrigation purpose is planned to be achieved in the year 2020. Expected quantity of treated wastewater is 56.6 MCM/year in maximum. Therefore, around 50 MCM of treated wastewater can be regarded as new water resources, and should be made certain. Based on these estimated value, expected period of usable groundwater resources in Sana'a Basin in each scenario is estimated in the following 3 cases.

Case 1: Expected period without any recharge to groundwater

Case 2: Expected period with constant recharge to groundwater that was estimated in the previous investigation.

Case 3: Expected period with constant recharge and utilization of treated wastewater from the year 2020

Table 4.17, *Figure 4.4 and 4.5* show the results of the estimation.

Table 4.17 Expected Period of Usable Groundwater Resources in Each Scenario

Scenario 1 (MCM)

	2005	2010	2015	2020
Urban	54.3	52.9	63.6	73
Rural	0.6	2.5	2.8	3.2
Industry	4.8	6	7.5	9.5
Tourism	0.4	1	2.6	7.1
Irrigation	209.2	193.1	166.3	139.5
Total Consumption	269.3	255.5	242.8	232.3

Period of depletion (by the year of)		
without Recharge	with Recharge	Reuse of treated wastewater from 2020
2021	2027	2030

Scenario 2 (MCM)

	2005	2010	2015	2020
Urban	54.3	49.8	59.9	68.7
Rural	0.6	2.5	2.8	3.2
Industry	4.8	6	7.5	9.5
Tourism	0.4	1	2.6	7.1
Irrigation	209.2	188.5	154	119.5
Total Consumption	269.3	247.8	226.8	208

Period of depletion (by the year of)		
without Recharge	with Recharge	Reuse of treated wastewater from 2020
2022	2029	2034

Scenario 3 (MCM)

	2005	2010	2015	2020
Urban	54.3	49.8	59.9	68.7
Rural	0.6	2.5	2.8	3.2
Industry	4.8	4.8	4.8	4.8
Tourism	0.4	0.4	0.4	0.4
Irrigation	209.2	188.5	154	119.5
Total Consumption	269.3	246	221.9	196.6

Period of depletion (by the year of)		
without Recharge	with Recharge	Reuse of treated wastewater from 2020
2023	2030	2036

Scenario 4 (MCM)

	2005	2010	2015	2020
Urban	54.3	49.8	59.9	68.7
Rural	0.6	2.5	2.8	3.2
Industry	4.8	4.8	4.8	4.8
Tourism	0.4	0.4	0.4	0.4
Irrigation	209.2	172.5	111.2	50
Total Consumption	269.3	230	179.1	127.1

Period of depletion (by the year of)		
without Recharge	with Recharge	Reuse of treated wastewater from 2020
2028	2045	after 2045

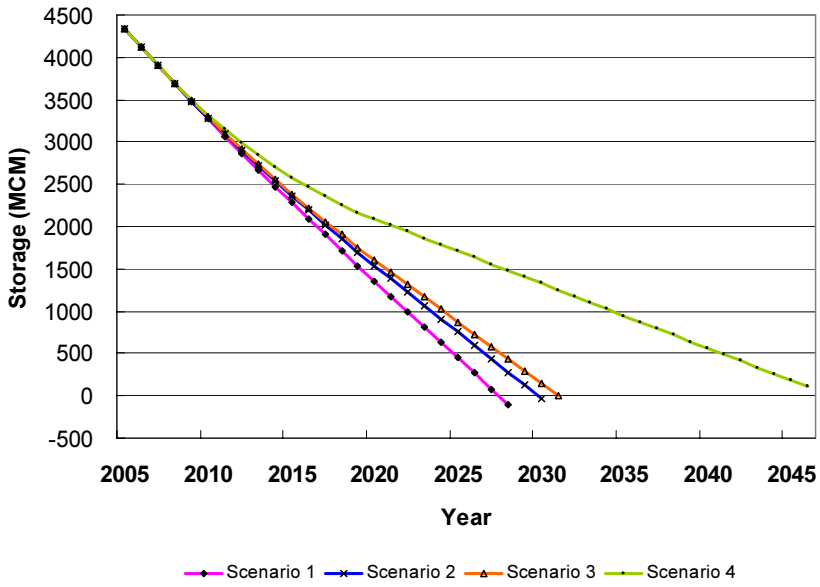


Figure 4.4 Expected Period of Usable Groundwater Resources with Recharge

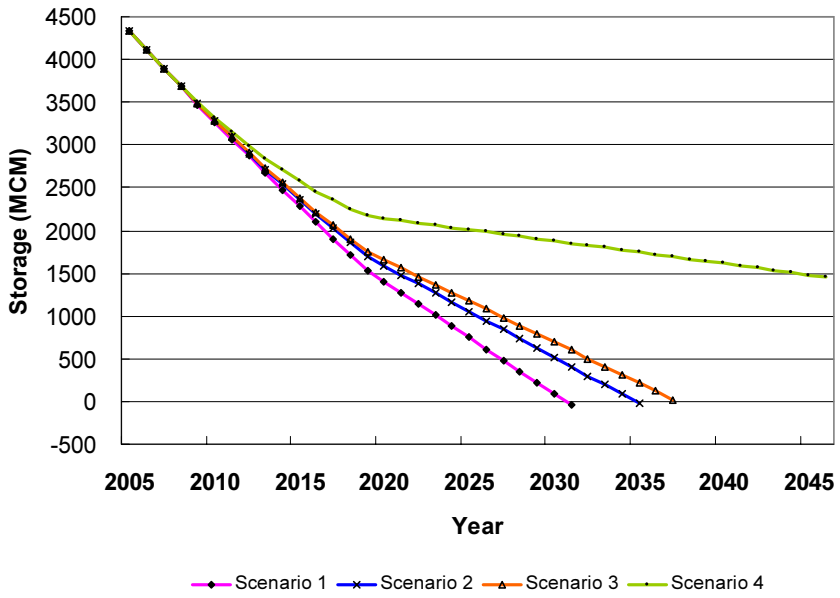


Figure 4.5 Expected Period of Usable Groundwater Resources with Reuse of Treated Wastewater from the year 2020 and Constant Recharge

It should be noted that even if the scenarios considered based on the socio-economic condition are implemented, groundwater resources will continue to be gradually decreased and over time will be in a very critical situation.

4.5.2 SELECTION OF FUTURE SCENARIO TOWARDS MAXIMUM SUSTAINABILITY

As described in section 4.3 in this Chapter, if the water consumption is continued in line with projected water demand, usable groundwater would be very critical situation in the year of 2020. It means that economic activity will be definitely damaged, and even the domestic water will not be able to supply to those who live inside Sana'a Basin in the year 2020. As for transferring water from outside Sana'a Basin as an alternative water source for Sana'a City, it is regrettably concluded to be not feasible considering that the cost for maintenance should basically be borne by beneficiaries as mentioned in section 2.2.4 in Chapter 2.

Therefore, the ultimate solution is to reduce water consumption to the recharge amount by the year 2020 at the very latest so as to keep minimum sustainability inside Sana'a Basin. For the achievement of the ultimate solution, all of irrigation activity should be stopped and domestic consumption should be reduced to around two thirds of demand in 2020. However, it is obvious that tremendous effort is required for all stakeholders and is unrealistic.

Four scenarios aiming at reducing consumption of water resources set in the section 4.4.1 are evaluated taking into consideration the difficult condition of water resources, in order to select most reasonable scenario. Result of evaluation of each scenario is as follows.

- Scenario 1: Though the irrigation efficiency is set at 60%, there is a possibility of further improvement of the efficiency by installing pipes for water conveyance. In addition, physical loss in urban water supply is set at 20%. However, the percentage of physical loss is able to be reduced by introducing the technology

of water leakage detector for invisible leakage from the ground. Therefore, it can be concluded that there is a possibility of further reduction of water consumption in this scenario.

- Scenario 2: Reduction of water consumption in irrigation use and urban area water supply sectors which account for large portion of total water consumption, is the largest as much as possible. While no measure to reduce water consumption in industrial and touristic use is taken. Therefore, it can be concluded that there is a possibility of further reduction of water consumption in this scenario.

- Scenario 3: Reduction of water consumption in irrigation use and urban area water supply sectors which account for large portion of total water consumption, is the largest as much as possible. In addition, control of the growth of water demand in industrial and touristic sectors is set in this scenario. Therefore it is concerned that economic activities would be affected if further measures are taken to reduce water consumption.

- Scenario 4: In addition to the settings in the scenario 3, water consumption for irrigation use is set to be reduced to 50 MCM that corresponds to available treated wastewater in the year 2020. In this setting, farmers are required to reduce their irrigated area to one third of present area and agricultural products would be decreased. As a result, decrease of farmers' income and adverse impact on agricultural activities would be concerned. Therefore, implementation of the scenario is assumed to be very difficult.

As mentioned above, there is a possibility of further reduction of water consumption in the scenarios 1 and 2. Adverse impact on the agricultural activities is concerned in the scenario 4, though the amount of reduction is the maximum among above 4 scenarios. Therefore, the scenario 3 which has possibility of implementation of measures and the most possible reduction amount of water consumption, is selected as the scenario towards sustainability of water resources in Sana'a Basin.

By implementing the Scenario 3 with saving water resources of 153 MCM in 2020, such very severe condition of water resources will be mitigated as much as possible, and the grace to be critical situation of water resources will be expanded until the year of 2036 that is around 30 years later from 2007.

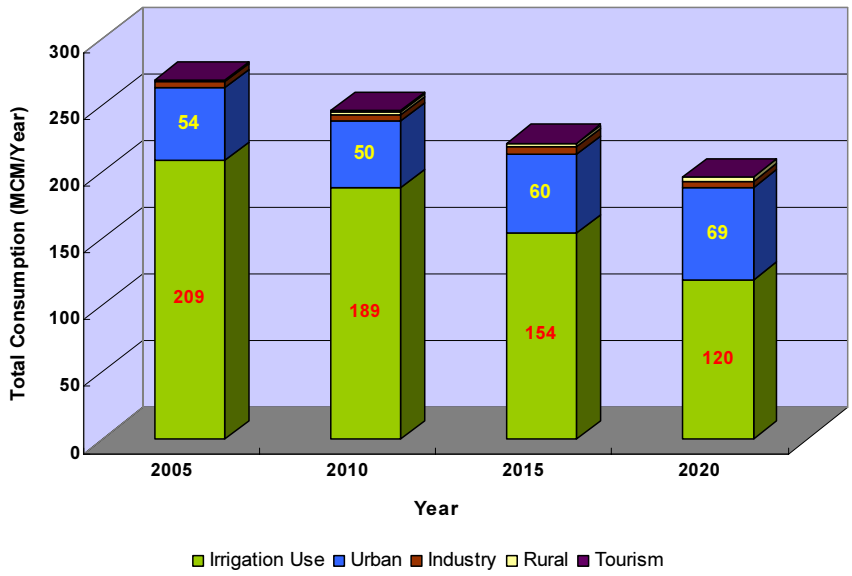


Figure 4.6 Reducing Schedule of Scenario 3

Followings are the actions to be taken with top priority by the year of 2020 in conformity with the scenario 3. Since the contribution towards reducing water consumption is very high and implementation of each component is practicable.

- Improvement of the irrigation efficiency from 40% to 70% by the year 2020 and no further expansion of irrigated land, which can save 125.2 MCM/year of groundwater resources comparing the projected water demand based on the tendency of the expansion of irrigated land studied in the previous study.

- Improvement of the physical loss in the water supply in urban areas from the 30% (inferred value) to 15% by the year 2015, which can save 9.9 MCM/year of groundwater resources

- Reuse of the treated wastewater for irrigation purposes and improvement of capacity of sewage system. Around 50 MCM of treated wastewater is expected to be reused in the year of 2020 in accordance with the plan of SWSLC.

Detailed activities for actions mentioned above are described in Chapter 5.

However, it should be mentioned again that though the Scenario 3 is completely implemented, the precious groundwater resources will be definitely in very critical situation in the year 2037 as shown in *Figure 4.7*.

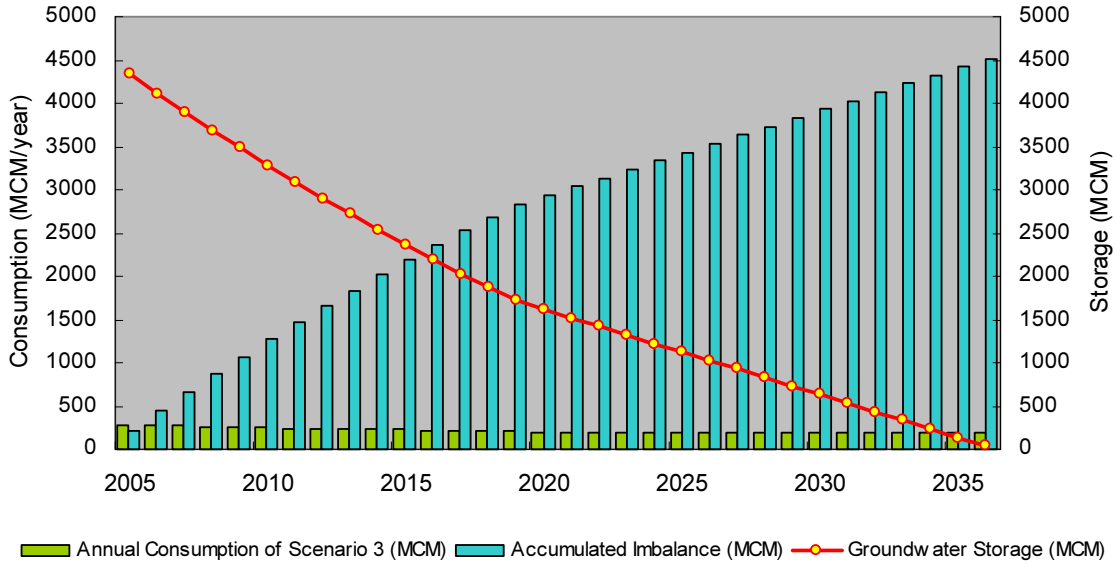


Figure 4.7 Expected Period of Usable Groundwater Resources for Scenario 3

REFERENCES

GAF (2007): Sana'a Basin Water Resources Management Study, Satellite Data Analysis of Cropping and Irrigation Water Use. Final Report, SBWRM-PPT, Sana'a

National Water and Sanitation Authority (NWSA) (2000): Sana'a Water Supply and Sanitation Project Development Program, Main report, NWSA, Sana'a, 224p

WEC (2001): Sana'a Basin Water Resources Management Study, Basin Characterization and Selection of Pilot Study Areas, Vol. II Water Resources Availability and Use, Final Report, SBWRM-PPT, Sana'a

CHAPTER 5

WATER RESOURCES MANAGEMENT ACTION PLAN FOR SANA'A BASIN

CHAPTER 5 WATER RESOURCES MANAGEMENT ACTION PLAN FOR SANA'A BASIN

5.1 DIRECTION OF ACTION PLAN

In order to mitigate the critical situation of water resources, and to secure the future of the next generation, action plans to be taken are formulated as listed in *Table 5.1*, considering the present condition of water resources and future scenarios of socio-economy as described in the previous chapters. Water resources management action plan is composed of "Immediate Action Plan" and "Actions to be taken for Long-Term Progress." The former is the action to be taken immediately in order to achieve Scenario 3 as mentioned in section 4.5 in Chapter 4, and contributes greatly to mitigate severe condition of water resources. The latter are the actions to enhance the effectiveness of the results of the "Action Plan." The actions contribute to mitigate severe water resource conditions; however, the amount of water that can be reduced is not clarified. Therefore, understanding of the present condition is the first step of these actions.

Table 5.1 Actions to be Taken

No.	Contents of Water Resources Management Action Plan for Sana'a Basin	Section No.
	IMMEDIATE ACTION PLAN	
1	Reduction of fwater consumption for irrigation purposes	5.2.1
2	Reduction of physical loss of urban water supply	5.2.2
3	Assuring reuse of treated waste water	5.2.3
4	Control of water consumption for industrial use	5.2.4
5	Control of water consumption for touristic use	5.2.5
6	Institutional development	5.2.6
7	Organizational development	5.2.7
	ACTIONS TO BE TAKEN FOR LONG-TERM PROGRESS	
1	Protection of groundwater resources from contamination	5.3.1
2	Effective use of surface water	5.3.2
3	Optimization of water supply covered by private supplier in Sana'a city	5.3.3
4	Inter-Regional and Sectoral Reallocation of Water Resources	5.3.4

By implementing the action plan until the year 2020, around 150 MCM/year of water resources can be saved comparing the water demand based on the present conditions in the year of 2020, and limited water resources can be utilized until the year 2036 which is around 30 years later from 2007. During this expanded period, all stakeholders are seriously required, for future generations to consider next actions towards sustainability of water resources.

Detailed contents of action plan are described in following sections.

5.2 ACTION PLAN

5.2.1 REDUCTION OF WATER CONSUMPTION FOR IRRIGATION PURPOSES

Purpose

To save the amount of 90 MCM of water consumption for irrigation purposes by the year of 2020 by improving irrigation efficiency from 40% to 70%.

To reduction the water consumption for irrigation purposes by means of improvement of irrigation efficiency from 40% to 70% should be implemented so as to save 90 MCM/year of limited water resources by the year of 2020 comparing present water consumption of irrigation that is 209 MCM. Therefore, consumption for irrigation purpose will be reduced to 119 MCM/year in 2020. The action should be carefully carried out not to support extension of their irrigated land, which might be easily happened by transferring saved water.

Activities

(1) Increasing the farmers' perception of effectiveness of improved irrigation system

Although substantial improvements, such as lower water consumption crops, increased crop yield, less fertilizer, and less fuel consumption, have been observed at pilot farms through the introduction of improved irrigation systems as one of the components of SBWMP, dissemination of these methods still remains insufficient. Improved irrigation systems have been installed in irrigated land with an area of 771 ha by SBWMP, which is less than 20% of the project target of 4,000 ha as of September 2007. Though the progress of installation has remained slow, it should be addressed by developing successful program accompanied with improvement of the capability of WUAs by conducting activities mentioned in section 4.2.5 4).

Thus, the promotion activities for raising awareness of farmers on the effectiveness of improved irrigation systems shall be enhanced in close cooperation with Local Council, WUA and WUG, showing the positive results of installation of the system effectively to other farmers, and the period of cost recovery to investment by using the results obtained by SBWMP.

(2) Promotion of farmers' understanding not to expand their own farmland

Control of expansion is also one of the activities to minimize water consumption. This activity, however, shall be simultaneously executed with raising awareness of farmers, incentives and enforcement of regulation.

(3) Installation of improved irrigation systems

The annual amount to be saved, accumulated saved amount and total consumption of irrigation use are graphed in *Figure 5.1*. *Table 5.2* shows the detailed schedule for annual reduction of water consumption by the improvement of irrigation efficiency for sub-basin until the year of 2020.

The amount of water that can be saved at irrigated land by improvement of irrigation efficiency is estimated as follows:

Water consumption for irrigation purposes is estimated to be 0.011 MCM/ha. This value is calculated by adopting 40% of irrigation efficiency to present water consumption of 0.0044 MCM/ha that is the weighted arithmetic mean of the actual evapotranspiration of each crop. Therefore, the consumed water in 1.0 ha will be estimated at 0.0063 MCM by improvement of irrigation efficiency from 40% to 70%. It means that the amount of 0.0047 MCM/ha can be saved comparing present water consumption for irrigation purposes that is 0.011 MCM/ha.

Improvement of irrigation efficiency should be carried out by sub-basin and addressed first the large water imbalanced sub-basins.

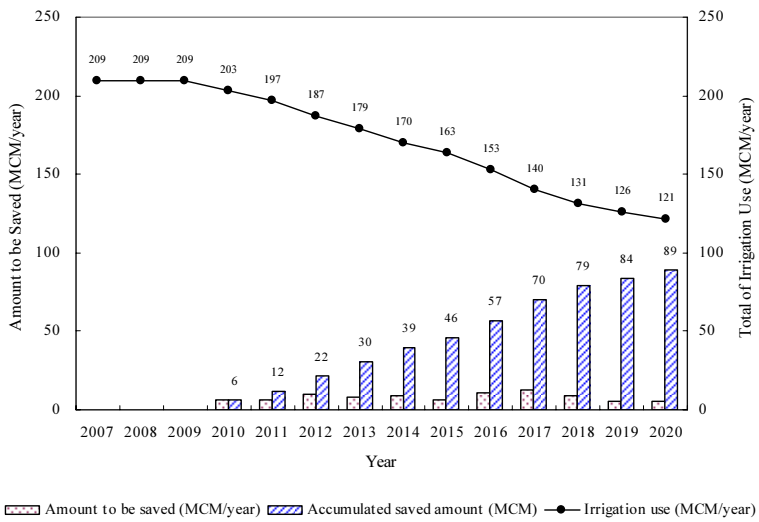


Figure 5.1 Scenario for Reducing Water Consumption for Irrigation Purpose

For the implementation, "Wadi Al Huqqah," "Wadi Bani Huwat," "Wadi As Sirr," "Wadi Al Furs," and "Wadi Al Mawrid" should be addressed first in the year of 2010. Then other sub-basins should be gradually addressed. Finally, 90 MCM of overuse water can be reduced by the year 2020.

Cost for installation of improved irrigation system is estimated to be between 3,600 and 4,800 US$/ha depending on the conveyance system and irrigation system to be applied (Ministry of Water and Environment). Then total cost for system is estimated to be between 68 million US$ and 91 million US$ in 11 years from 2009 to 2020 (from 6.2 to 8.3 million US$/year in average) for 18,955 ha. According to NWSSIP, from 5 to 6.5 million US$/years from 2005 to 2009 are scheduled to be allocated for Sana'a Basin Water Management Project for the part of irrigation and watershed management. Difference of cost and the cost from 2010 should be allocated.

(4) Introducing watering control system with installation of water flow meter

Watering control system with installation of water flow meter, which is one of the most important factors to reduction overuse of water and maximize productivity, should be introduced. This activity requires the technical support from experts so as to keep and

improve effectiveness of modern irrigation techniques.

(5) Improvement of capability of GDI/NWRA-SB or staff in charge of irrigation activities

As mentioned in section 3.2.6 in Chapter 3, it is also necessary to establish an effective training course, with an experienced trainer, to develop the capability of organizations related to the installation, operation and maintenance of improved irrigation systems in the early stage of the above schedule, that is, from the year 2008 to 2011.

(6) Stop subsidizing irrigation activities

Since the subsidizing system concerning irrigation activities is recognized as the one of the reasons behind over exploitation of groundwater resources, this system should be gradually stopped.

Table 5.2 Schedule for Reduction of Irrigation Water Consumption

	Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
	Amount to be reduced by year	0.0	0.0	0.0	6.00	6.00	9.82	8.52	9.00	6.53	10.99	12.90	9.06	5.17	5.10	
1	Wadi Al Mashamini	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.6	0.6	0.6
													0.32			0.3
		69											68			68
2	Wadi Al Madini	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	3.5	2.9	2.9	2.9	2.9
												1.0	0.7			1.7
		352										213	138			351
3	Wadi Al Kharid	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	1.9	1.9	1.9	1.9
												1.0	0.1			1.1
		238										213	26			238
4	Wadi Al Ma'adi	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	0.8	0.8	0.8	0.8	0.8
												0.5				0.5
		100										100				100
5	Wadi A'sir	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	6.6	5.6	4.9	4.9	4.9	4.9
											1.0	1.0	0.79			3
		593									213	213	168			594
6	Wadi Khulaqah	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	1.4	1.4	1.4	1.4	2.3
											0.85					0.9
		181									181					181
7	Wadi Qasabah	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	1.5	1.5
															0.87	0.9
		186													185	185
8	**Wadi Al Huqqah**	14.5	14.5	14.5	13.5	12.5	11.5	10.5	9.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0
					1.0	1.0	1.0	1.0	1.0	0.53						5.5
		1176			213	213	213	213	213	113						1177
9	**Wadi Bani Huwat**	48.7	48.7	48.7	46.7	44.7	42.7	40.7	38.7	36.7	33.7	30.2	26.0	26.0	26.0	26.0
					2.0	2.0	2.0	2.0	2.0	2.0	3.0	3.5	4.18			22.7
		4826			426	426	426	426	426	426	638	745	889			4826
10	Wadi Thumah	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	0.7	0.7
															0.59	0.6
		126													126	126
11	**Wadi As Sirr**	24.7	24.7	24.7	23.7	22.7	21.7	20.7	18.7	16.7	14.7	12.5	12.5	12.5	12.5	12.5
					1.0	1.0	1.0	1.0	2.0	2.0	2.04	2.20				12.2
		2603			213	213	213	213	426	426	434	468				2604
12	**Wadi Al Furs**	8.6	8.6	8.6	7.6	6.6	5.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
					1.0	1.0	1.0	1.0								4.0
		856			213	213	213	217								855
13	**Wadi Al Iqbal**	19.7	19.7	19.7	19.7	19.7	18.7	17.7	16.7	15.7	14.2	12.4	12.4	12.4	12.4	12.4
							1.0	1.0	1.0	1.0	1.5	1.73				7.2
		1538					213	213	213	213	319	368				1538
14	**Wadi Zahr & Al Ghayl**	16.3	16.3	16.3	16.3	16.3	15.3	14.3	13.3	12.3	10.2	10.2	10.2	10.2	10.2	10.2
							1.0	1.0	1.0	1.0	2.1					6.1
		1297					213	213	213	213	447					1298
15	Wadi Hamdan	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	9.2	7.7	6.5	6.5	6.5
												1.0	1.5	1.21		3.7
		789										213	319	257		789
16	**Wadi Al Mawrid**	8.8	8.8	8.8	7.8	6.8	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
					1.0	1.0	1.47									3.5
		739			213	213	313									738
17	Wadi Sa'wan	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	9.6	8.6	7.1	5.1	5.1	5.1
											0.5	1.0	1.5	1.96		5.0
		1055									106	213	319	417		1055
18	**Wadi Shahik**	10.3	10.3	10.3	10.3	10.3	9.0	7.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
							1.35	1.5	2.0							4.9
		1032					287	319	426							1032
19	Wadi Ghayman	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	4.5	3.0	3.0
														1.0	1.5	2.5
		533												213	319	532
20	Wadi Al Mulaikhy	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	2.5	2.2	2.2
														1.0	0.3	1.3
		269												213	57	270
21	Wadi Hizyaz	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	1.7	1.7
															1.0	1.0
		206													206	206
22	Wadi Akhwar	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.6	1.6
															0.9	0.9
		191													191	191

unit : million cubic meter

above : Annual water consumption in sub-baisn in accordance with plan
middle : Amount of water to be reduced in sub-basin
below : Areas in hectar where improved irrigation sytem should be installed
Note : Figures in below cell on the left side is the present irrigated area in hectare, Noman and Mulat (2007)

Alternatives to reduction water consumption for irrigation purposes

(1) Introducing the lower water consumption crops

In addition to installation of improved irrigation systems, introduction of lower water consumption crops also contributes to reduction consumption of water. However, trial for diversion of crops has been just started under the SBWMP and the result of the trial has not been reported yet. Therefore, it is necessary to understand detailed information including effectiveness first by conducting pilot scheme.

In case the introduction of lower water consumption crops is concluded to be effective, it is required for governmental body in early stage, to create the market for introduced crops so as to secure stable income generation of farmers.

(2) Reduction of irrigated land

A reduction of irrigated land also contributes to save water. For this activity, compensation system for farmers should be established in advance.

Responsibilities

Related organizations and their responsibilities are described in *Table 5.3*.

Table 5.3 Responsibility for Improvement of Water Use Efficiency for Irrigation Use

Organizations	Responsibility
MAI	Execution organization
WUA, WUG	Dissemination of improved irrigation system for others
Local Council	Support for increasing awarenes of farmers and dissemination
NWRA-SB	Increasing awareness of farmers

Under the initiative of NWRA-SB, this action shall be taken by MAI, Local Council and WUA. NWRA-SB will be a responsible for increasing awareness of farmers and monitoring water consumption for irrigation use.

5.2.2 REDUCTION OF PHYSICAL LOSS OF URBAN WATER SUPPLY

Purpose

To save the amount of 9.9 MCM of water consumption for urban water supply by the year of 2020 by reducing physical water loss from 30% (inferred figure) to 15%.

To reduction overuse of urban water supply network operated by SWSLC should be implemented to save water with the amount of 9.9 MCM comparing the projected future water demand that is 78.6 MCM in 2020 by reducing physical water loss from 30% to 15%.

Activities

(1) Promotion of understanding of water users in Sana'a city to accept a reduction of unit water consumption

According to SWSLC's water supply plan, unit water consumption of 35 l/c/d is designed aiming at supplying water to the entire population in Sana'a city. Since the actual per capita consumption in 2005 was 50.8 liter/day, if the designed unit consumption is applied, per capita consumption should be reduced around 30% of present consumption. Therefore, SWSLC is required to take the necessary actions to promote understanding of water users in Sana'a city to accept reduction of consumption in parallel with reducing physical loss.

(2) Improvement of the capability of leakage detection

In order to effectively reduction water leakage, improvements in the capability of leakage detection is the one of the key factors. Therefore, SWSLC is required to prepare a detailed schedule to reduction leakage to 15% in the year 2015 and to improve the capability including the investigation of leakage, the introduction of leakage detectors together with technology transfer by well-experienced experts and investment program for the investigation and renewable or repair of damaged distribution pipes, taking into consideration of the progress of on-going project of replacement of distribution pipes funded by World Bank. In addition, the schedule for the periodical replacement or calibration of house connection meters and meters installed on production wells should be also included in the schedule.

Assuming that leakage of 30% is reduced to 15% based on the actual production amount of 2004, saved amount of water is converted to between 1.35 and 1.74 million US$/year depending on the consumption amount in household and institutions.

(3) Monitoring of production amount and progress of reduction of losses

NWRA SB is required to periodically collect information about production amount of urban water supply and the progress of reduction of losses from transmission and distribution mains, storage tanks and connections which are carried out by SWSLC in order to manage water resources properly.

Responsibilities

Related organizations and their responsibilities are described in *Table 5.4*.

Table 5.4 Responsibility for Improvement of Water Use Efficiency for Urban Water Supply Covered by SWSLC

Organizations	Responsibility
SWSLC, Municipality	-Promotion of undersyanding of water users to accept reduced per capita consumption. - Preparing a detailed schedule for reducing losses
NWRA-SB	Monitoring of production amount and improvement of leakage

5.2.3 ASSURING REUSE OF TREATED WASTEWATER

Purpose

> ***To reuse of treated wastewater with the amount of 50 MCM for irrigation purposes by the year 2020 so as to save water consumption for irrigation purposes.***

As mentioned in section 3.6.3 in Chapter 3, SWSLC has already launched the expansion of capacity of the wastewater treatment plant (WWTP) with the capacity of 105,000 m^3/day and aimed at utilizing for the irrigation purposes. Total capacity will become 155,000 m^3/day by the year 2020. Assuming that around 90% of the effluent with sufficient quality is regarded as usable, the amount of available water resources is estimated at 50 MCM/year. Then water consumption for irrigation purpose can be saved 50 MCM/year from the year 2020. Therefore, it is necessary for SWSLC, NWRA-SB and WUA to assure the reuse of treated wastewater for irrigation purpose by the year of 2020 by conducting the activities mentioned below.

Activities

(1) Assuring improvements in the existing WWTP and new construction of WWTP

Procedures of rehabilitation of the existing WWTP, with a capacity of 50,000 m^3/day, and construction of a new WWTP with a capacity of 105,000 m^3/day, as well as a treatment facility for sewage on cesspit, should be properly managed by SWSLC.

(2) Planning for distribution of treated wastewater

Though it seems to be the most feasible way to distribute treated wastewater by gravity to the farm lands situated downstream, the organizations concerned especially MAI and SWSLC are required to consider the feasibility for distribution of the treated wastewater to other sites where the balance between recharge and abstraction inside sub-basin will be still remained in large minus as of the year 2020. Since there will not be enough demand of irrigation to consume the treated wastewater at the area of downstream, it is necessary to consider proper way to use the limited water resources as much as possible.

Proposed areas for distribution of treated wastewater are "Wadi Al Huqqah," "Wadi Bani Huwat," "Wadi Al Furs," and "Wadi Al Mawrid" as listed in *Table 5.5*. These proposed areas are selected considering the balance between abstraction amount and recharge amount, and geographical distribution. As shown in Table 5.5, the ratio of "abstraction/recharge, with reuse" has remained high in "Wadi Al Mawrid" compared to other sub-basins, though the irrigation demand is fully covered by reuse of treated wastewater. Because this sub-basin includes main part of the capital city of Sana'a and the main purpose of water abstraction is for domestic use.

Table 5.5 Proposed Sub-Basins for Distribution of Treated Wastewater

Sub-Basin		Consumption of Irrigation				Recharge	Abstraction / Recharge		Proposed Sub-Basin
		2007	2010	2015	2020		wihout Reuse	with Reuse	
1	Wadi Al Mashamini	0.9	0.9	0.9	0.6	0.90	0.64		
2	Wadi Al Madini	4.5	4.5	4.5	2.9	2.73	1.06		
3	Wadi Al Kharid	3.0	3.0	3.0	1.9	1.76	1.27		
4	Wadi Al Ma'adi	1.3	1.3	1.3	0.8	1.71	1.29		
5	Wadi A'sir	7.6	7.6	7.6	4.9	4.27	1.14		
6	Wadi Khulaqah	2.3	2.3	2.3	2.3	1.54	1.51		
7	Wadi Qasabah	2.4	2.4	2.4	1.5	0.83	1.84		
8	**Wadi Al Huqqah**	14.5	13.5	9.0	**9.0**	1.36	**8.70**	**2.12**	◎
9	**Wadi Bani Huwat**	48.7	46.7	36.7	**26.0**	5.58	**6.84**	**2.19**	◎
10	Wadi Thumah	1.3	1.3	1.3	0.7	1.00	2.66		
11	Wadi As Sirr	24.7	23.7	16.7	12.5	3.81	7.04		
12	**Wadi Al Furs**	8.6	7.6	4.6	**4.6**	0.79	**12.13**	**6.32**	◎
13	Wadi Al Iqbal	19.7	19.7	15.7	12.4	2.31	5.39		
14	Wadi Zahr & Al Ghayl	16.3	16.3	12.3	10.2	7.11	1.46		
15	Wadi Hamdan	10.2	10.2	10.2	6.5	0.82	7.87		
16	**Wadi Al Mawrid***	8.8	7.8	5.3	**5.3**	1.54	**20.73**	**17.30**	◎
17	Wadi Sa'wan	10.1	10.1	10.1	5.1	1.41	3.61		
18	Wadi Shahik	10.3	10.3	5.5	5.5	4.12	1.35		
19	Wadi Ghayman	5.5	5.5	5.5	3.0	1.24	2.42		
20	Wadi Al Mulaikhy	3.5	3.5	3.5	2.2	1.66	1.33		
21	Wadi Hizyaz	2.6	2.6	2.6	1.7	1.92	1.15		
22	Wadi Akhwar	2.5	2.5	2.5	1.6	2.32	3.25		

*: Main part of Capital city of Sana'a is located in this Sub-basin

(3) Promotion of farmers' understanding of the treated wastewater use by the demonstration

NWRA-SB has started to promote farmers' understanding not to use insufficiently treated wastewater in order to avoid negative influence on their livestock, themselves and the productivity of their crops in the year 2007 as a part of SBWMP. Therefore, the activity of promotion of farmers' understanding of use of adequately treated wastewater for irrigation purposes should be conducted as a part of SBWMP in combination with demonstration of farming with treated wastewater .

Since the improvement of existing WWTP is planned to be completed by 2015 prior to the construction of another large capacity WWTP, arrangement for the demonstration of farming with treated wastewater should be started in 2013 targeting farmers who posses their own farmland along the wadi in north of WWTP involving WUAs.

In addition, acceptance of farmers to be charged for consuming treated wastewater, which may not be readily, shall be also considered so as to save the limited water resources.

(4) Monitoring of water quality and quantity

Monitoring of quality and quantity of the effluent should be carried out by SWSLC and the results should be submitted to NWRA-SB in order to assure the reuse of treated wastewater properly. The result of monitoring should be open to the public especially for the farmers.

Responsibilities

Related organization and their responsibilities are described in *Table 5.6*.

Table 5.6 Responsibility for Assuring Reuse of Treated Wastewater

Organizations	Responsibility
SWSLC, Sana'a Municipality	Execution organization
MAI	Execution organization, Farmers' acceptance for use of treated wastewater and tariff
WUA	Farmers' acceptance
NWRA-SB	Monitoring of quality and quantity of effluent, Increasing awareness of farmers' acceptance

5.2.4 CONTROL OF WATER CONSUMPTION OF INDUSTRIAL USE

Purpose

To control water consumption for industrial use, in order to prevent the acceleration of the depletion of water resources.

In order to prevent the depletion of limited water resources, it is necessary to establish the control system of water consumption for industrial use.

Activities

(1) Preparation of inventory of existing water sources used in factories

NWRA SB in cooperation with Ministry of Industry is required at first to carry out an inventory survey to understand the actual condition of water usage in industrial use. Since most of water sources are reported to be private wells and located inside the factory, actual water consumption has been estimated by using indirect factors. Therefore, an inventory survey is the fundamental to control water consumption in proper way.

(2) Promotion of understanding of owners of factories not to expand their activities inside Sana'a Basin

No expansion of factories is one of the ways not to increase water consumption in the industrial sector. Therefore, NWRA-SB and Ministry of Industry should promote understanding of owners of factories not to expand their factories that bring into increase of water consumption.

(3) Reduction of overuse of water in factories and reuse of water inside factories

In order to save the limited water resources, factories are required to reduction water-overuse and encourage water-reuse as much as possible.

(4) Preparation of master plan for industrial sector taken into consideration water resources condition

The Ministry of Industry and authorities concerned are strongly required to address preparation of the sector development program considering the present condition of water resources in consultation with NWRA-SB, in order to mitigate such severe condition of water resources.

If the development of industrial sector inside Sana'a Basin is demanded, discussion with authorities related to agriculture sector should be carried out in order to arrange reallocation of water from irrigation to industry.

Responsibilities

Related organization and their responsibilities are described in *Table 5.7*.

Table 5.7 Responsibility for Control of Water Consumption of Industrial Use

Organizations	Responsibility
Ministry of Industry	Preparation of sector development plan considering water resoruces
NWRA-SB	Inventory survey, Promotion of understanding of factory owners not to expand their activities

5.2.5 CONTROL OF WATER CONSUMPTION OF TOURISTIC USE

Purpose

To control water consumption of Touristic use in order to prevent acceleration of depletion of water resources

In order to prevent the depletion of limited water resources, it is necessary to establish the control system of water consumption of touristic use.

Activities

(1) Preparation of inventory of water sources used for touristic purpose

NWRA-SB in cooperation with Ministry of Tourism is required at first to carry out an inventory survey to understand the actual condition of water usage for touristic purposes.

(2) Promote understanding of owners of hotels not to expand their activities that bring about an increase of water consumption

NWRA SB and Ministry of Tourism are required to promote understanding of owners of hotels not to expand their activities that make an increase of water consumption.

(3) Preparation of a sector development plan taking into consideration water resources condition

Ministry of Tourism and authorities concerned are strongly required to address preparation of the sector development plan considering the present condition of water resources in consultation with NWRA-SB, in order to mitigate such severe condition of water resources.

If further development of the tourism sector is demanded, discussion with authorities related to the agriculture sector should be carried out in order to arrange a reallocation of water from irrigation to tourism.

Responsibilities

Related organization and their responsibilities are described in *Table 5.8*.

Table 5.8 Responsibility for Control of Water Consumption of Touristic Use

Organizations	Responsibility
Ministry of Tourism	Preparation of sector development plan considering water resoruces
NWRA-SB	Inventory survey for the tourisum water use Facilitation of hotel owners to understand not to expand their water consumption

5.2.6 INSTITUTIONAL DEVELOPMENT

1) Finalization of the Executive Regulation to the Water Law of 2002, and Development of Decree for Water Protection Zone of Sana'a Basin

Purpose

To finalize Executive Regulation and develop Sana'a Basin's Bylaw in order to implement the Action Plan effectively.

For the purpose of effective implementation of the Action Plan by Sana'a Branch Office of NWRA, finalization of Executive Regulation and development of Sana'a Basin's Bylaw should be achieved by conducting the activities followed below, These bylaws shall be developed, taking consideration that groundwater metering and groundwater charge levying shall be one of the most indispensable prescriptions to address the issues of over-consumption water-demanding cash crop and excessive water loss typical in Sana'a Basin,

It might take a considerable time to increase social acceptance for introduction of ground water metering and levying. Therefore, the bylaws for the "protection zones" of Sana'a Basin should have the objective of gradually and over time limiting abstraction (over five to ten years) 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. .

Activities

The following package of actions shall be implemented for finalization of Executive Regulation and development of Sana'a Basin's Bylaw:

- Review the Water Law of 2002, its amendment Law of 2007, Draft Executive Regulation of the Water Law, and relevant decrees.
- Identify shortcomings in the relevant laws, decrees, and bylaws, particularly as related to Sana'a Basin's water resource management as a "protected area."
- Assess the negative impacts and social costs if these shortcomings are not amended.
- Prepare additional and necessary principles and strategies for Draft Executive

Regulation of the Water Law, such as mandatory groundwater abstraction metering and groundwater charge levying.

- Prepare Draft Bylaw and Regulation for Sana'a Basin as a "protected area."
- Initiate consultative meetings with stakeholders in preparation of Draft Bylaw and Regulation for Sana'a Basin, and build consensus.
- Determine strategy and a time frame to introduce groundwater abstraction metering and groundwater charge levying for irrigation purposes.
- Receive legal consultation for finalization of the Draft Bylaw and Regulation for Sana'a Basin.
- Submit the final draft of Bylaw and Regulation for Sana'a Basin to the Cabinet and Parliament for approval.

Responsibilities

The prime responsibility for the development of Bylaw and Regulation for Sana'a Basin rests with NWRA-SB with support from NWRA Headquarters. A working group shall be established under NWRA-SB or SBC. Where convenient and feasible, cooperation with other Basin Offices, which are defined as "protected areas," shall be undertaken to share the problems and experiences for development of the bylaw, particularly for the protected area.

2) Increasing Awareness of Public and Political Leaders on Water Resource Management

Purpose

To change political attitude and further increase political willingness towards water resources management, through increasing public awareness and establish consensus for water resources management gradually

In order to duly change political attitude and further increase political willingness towards water resources management, increasing public awareness and gradual establishment of consensus for water resources management shall be important. In other words, it is necessary to facilitate political commitment through increasing public awareness and consensus. Thus, current efforts for public awareness campaign shall be further enforced by informing the seriousness of the water crisis in a first places through conducting activities mentioned below.

Activities

The awareness campaign shall be further conducted to the government agencies, corporations, and companies associated with 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. Inheritance of less productive land to the next

generation due to overexploitation of groundwater, shall be seriously recognized. Furthermore, 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"

In addition, the following activities shall be undertaken for advocacy on IWRM for public and political leaders:

- Review the existing Information and Public Awareness Campaign (IPAC) and assess its impact in groundwater preservation/control particularly in the rural area where tribal autonomy is strongly observed.
- Study the system, value and autonomy of tribal communities in water resource management.
- Develop the most effective and suitable options of IPAC for tribal communities.
- Set program for all kinds of awareness raising activities for the public; designing and disseminating posters and brochures, workshop, informative meetings in the field, messages at schools and mosques, radio and TV messages, etc.
- Intensify and scale-up the IPAC program developed as above.
- Develop comprehensive sets of information to help progressive political decision making in water resource management for the parliament members and local politicians.
- Organize consultative meetings for parliament members and local politicians to provide the right information for right political decision making in the basin-level water resource management.

Responsibilities

Prime responsibility for development of Bylaw and Regulation for Sana'a Basin rests with NWRA-SB. However, involvement of parliament members and local politician shall be facilitated with support from NWRA Headquarters.

3) Respect of Traditional and Tribal System

Purposes

To include "tribes" or "tribal systems" in Local institutions, not as formal but rather significant in their socio-culture, in order to enforce regulations by decentralized local institutions and communities effectively.

The decentralized framework of local institutions and administrations introduced by the Water Law and other relevant laws and bylaws, however, seems to lack an effective mechanism to enhance active participation of "tribes" and "tribal systems" in decision making and execution for improved water resource management. Therefore, Local institutions, not as formal but rather significant in their socio-culture, should include

"tribes" or "tribal systems," which cannot be ignored and, in fact, can be regarded as the most governing institution, particularly in the highland area of the country, including areas of Sana'a Basin.

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

With the present severe water condition, grade of impact on water resources will be different among sub-basins, which will be a cause of water conflict among tribes. Therefore, the establishment of an effective mechanism to enhance active participation of "tribes" and "tribal systems" in decision making and execution for improved water resource management is necessary to prevent such conflicts related to water.

Activities

Channels and networks to connect tribes and tribal systems shall be identified and developed as it is possible. The term "tribal system" herein refers to the interrelationship among tribes, and it can be defined as a forum for groups of tribes to conciliate their interests, disputes, and conflicts. In this line, involvement of tribal authorities in Basin Commission could be also considered. Sana'a Basin Commission has been established in accordance with the Water Law and relevant Decrees, of which function has a two-fold characteristic: one served as a decision making body for the Basin water management, while another functioned as a regulatory body. The active participation of tribal authorities in such decision making and regulation, if support is granted, could be a supporting institutional support for enhancement of a self-regulating mechanism in water resource management.

It shall be also emphasized that, the stakeholders involved in the decision making process for water resource management either at the 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 generations require respect, and can often be a sound and practical basis for cooperation between water users and resolution of conflicts in water management.

The following activities shall be considered for incorporation of traditional and tribal systems in IWRM:

- Study norms, values, autonomy, and conflict resolution systems of the tribal communities in water resource management;
- Identify and develop channels and networks to involve tribal communities in decision making and enforcement of regulations in IWRM, as well as in settlement of the conflicts;
- Review the membership of SBC, and include traditional leaders influential on the traditional communities in water resource management.

Responsibility

Prime responsibility for the development of Bylaw and Regulation for Sana'a Basin rests with NWRA-SB with support from NWRA Headquarters.

4) Improvement in Decentralized Framework of Local Administration and Organization

Purpose

To improve the current institutional structure in order to involve local institutions particularly Governorate Local Council and District in improved water resources management

In order to involve local institutions particularly Governorate Local Council and District in execution, enforcement, regulation and monitoring of the Water Law and program related to management in improved water resources management, and to improve decentralized framework, the current institutional structure should be improved by implementing the activities mentioned below.

Activities

The following activities shall be undertaken for the improvement of decentralized framework of local administrations and organizations:

- Review the Water Law of 2002, Local Authority Law of 2000, and their relevant bylaws and regulations, to comprehend legislative framework for local administration and institutional settings in IWRM and basin-level water resource management;
- Consult with Local Councils and Ministry of Local Administration to improve local administrative and organizational framework in IWRM and the basin-level water resource management;
- Facilitate and support Local Councils to establish their executive organ for basin-level water resource management;

Establish a mechanism to cooperate with Local Councils in the basin-level water resource management, in particular, in monitoring and enforcement of the regulations and rules set forth in the Water Law and its Executive Regulation.

5.2.7 ORGANIZATIONAL DEVELOPMENT

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 the 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, namely, 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, key organizational capacity areas to be developed for each of these organizations are discussed, as well as actions to be undertaken for the improvement.

1) NWRA Sana'a Branch (NWRA-SB)

(1) Development of Organizational Structure

Purpose

> ***To finalize NWRA-SB's organizational bylaws and job-description, in order to ensure the organizational operation and management.***

In order to ensure the organizational operation and management, such as mutual understandings, decision making process, system for giving and monitoring orders, and interdepartmental coordination/cooperation in NWRA-SB, finalization of their organizational bylaws and job-description based on tasks and duties allocated for them should be achieved by executing the activities mentioned below.

Activities

The following activities shall be undertaken for improvement of NWRA-SB's organizational structure:

- Review the Water Law of 2002, and its related executive regulation and decree, to comprehend the tasks and duties assigned to NWRA-SB.
- Review and revise the draft organizational bylaws based on the assessment above.
- Prepare organizational structure and job-description for each department/section of NWRA-SB, putting emphasis on proper planning, monitoring, and decision making process.
- Facilitate approval on the prepared bylaws, organizational structure, and job-descriptions for each department/section.

Responsibility

Prime responsibility for development of organizational bylaws and structure rests with NWRA-SB with support from NWRA Headquarters.

(2) Human Resource Development

Purpose

> ***To enhance NWRA-SB's technical capacity, in order to be a relevant and responsible local authority for Sana'a Basin.***

In order for NWRA-SB to be a relevant and responsible local authority for Sana'a Basin water resources management, enhancement of the authority's technical capacity identified as priority such as groundwater modeling, legal framework, regulation and enforcement, user participation in the basin management should be carried out.

Activities

The following activities shall be undertaken for improvement of NWRA-SB's human resources:

- Identify the training needs according to the capacity gaps assessed with re-defined tasks and duties in above.
- Prepare strategic training program with budget setting.
- Identify competent training providers in the country and abroad for the identified capacity development area.
- Implement the training program and evaluate the impact.
- Review staff remembrance/salary and introduce an improved incentive mechanism through pay rises and promotion based on a performance-based staff evaluation system.

Responsibility

Prime responsibility for the development of Bylaw and Regulation for Sana'a Basin rests with NWRA-SB with support from NWRA Headquarters.

(3) Improved Financial Management

Purpose

To improve the capability of financial management in NWRA-SB, in order to undertake water resources management properly.

Improvement of the capability of financial management should be addressed by implementation of activities mentioned below so as to properly undertake the planned water resources management.

Activity

The following activities shall be undertaken for improvement of NWRA-SB's financial management:

- Study the development and investment needs in the basin management according to the re-defined duties and tasks above.
- Prepare middle and longer term (i.e. five-year and ten-year) development and investment plans according to the development and investment needs identified above.

Responsibility

Prime responsibility for the development of Bylaw and Regulation for Sana'a Basin rests with NWRA-SB with support from NWRA Headquarters.

(4) Improved Regulation and Monitoring Mechanism

Purpose

To develop a mechanism of field monitoring network, in order to accelerate the progress of well registration and licensing.

In order to accelerate the progress of well registration and licensing, development of a mechanism of field monitoring network, in collaboration with other local authorities, especially with Local Councils, should be addressed by conducting activities mentioned below.

Activity

The following activities shall be undertaken for improvement of NWRA-SB's monitoring and regulation.

- Facilitate to develop bylaws and regulation particularly for Sana'a Basin as "protected area;"
- Intensify the current registration and licensing program;
- Develop local administrative and organizational framework for enforcement and monitoring with Local Councils.

Responsibility

Prime responsibility for the development of Bylaw and Regulation for Sana'a Basin rests with NWRA-SB with support from NWRA Headquarters.

2) Local Councils

Purpose

To incorporate Local Councils in the local organizational framework of basin-level water resources management.

Local Councils, whose tasks and duties include supervision and enforcement of rules and regulations, shall be further utilized and incorporated in the local organizational framework for the basin-level water resources management by the activities mentioned below.

Activity and Responsibility

Activities and responsibilities necessitated to improve local administrative and organizational coordination with Local Councils can be referred in section 5.2.7 4) "Improvement in Decentralized Framework of Local Administration and Organization".

3) Sana'a Basin Commission (SBC)

Purpose

To involve traditional leaders and tribal institution in order to ensure the institutional arrangement, and relevant supporting organizations in order to strengthen regulatory and monitoring systems

In order to ensure the institutional arrangement to improve water resources management by means of a participatory water resources management approach, and a public information and awareness program, it is required for SBC to involve traditional leaders and tribal institution in decision making, enforcement of self-regulating water management

mechanism by implementing the activities mentioned below.

Furthermore, in order to strengthen regulatory and monitoring systems, 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.

Activity and Responsibility

Activities and responsibilities necessitated to improve SBC's coordination with tribal system can be referred in section 5.2.6 3) "Respect on Traditional and Tribal System".

4) Water User Association (WUA)

Purpose

To improve awareness of WUAs and WUGs in order to save water consumption for irrigation use.

The key issue over the long 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 to 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 a 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 saving. Beneficiaries should be acquainted with appropriate cropping patters in order to adapt to growing lower water consumption 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 convinced 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.

Activity

The following activities shall be undertaken for improvement of WUA in self-regulating water resource management:

- Review the current methodologies and approaches to establish WUA, and assess its effectiveness in self-regulating water resource management.

- Develop self-regulatory mandates for WUA in basin-level water resource management, and monitor its compliance.
- Introduce monitoring system among Local Councils, NWRA-SB, and WUA for compliance of the self-regulatory mandates.

Responsibility

Prime responsibility for the development of Bylaw and Regulation for Sana'a Basin rests with NWRA-SB with support from NWRA Headquarters.

5.3 CONSIDERATION OF ACTION PLAN

Since the seven actions mentioned in this chapter are set to achieve the Scenario 3 as mentioned in section 4.5.2 in Chapter 4, it is required to address all actions. The responsible organizations for each action are summarized and the relationship between action for institutional development and other actions are shown in *Table 5.9*. In addition, the situation to be considered in each action is summarized in *Table 5.9*.

In the column entitled "Situation of Activities," three kinds of situations are listed. In the column entitled "Effectiveness," the saving amount by each action is mentioned. Since the total amount of present water use for irrigation purposes is quite large, the contribution to saving is larger than others. In the column of "Sate", the status of the listed activities, whether it is already addressed by other projects or not, is mentioned. Since some activities have been already addressed by SBWMP, SWSCL and the Government of Yemen, it is necessary to be taken into consideration the implementation of actions. Then considering the progress of these activities by other projects and urgency, the activities to be accelerated are selected.

Table 5.9 Consideration and Responsible Organizations of Action Plan

		Actions to be Taken	Relation to Institutional Development				Responsible Organization								Siuation of Activities		
			Finalization of the executive regulation to the Water Law of 2002, and development of decree for water protection zone of Sana'a basin	Increase awareness of public and political leaders on water resources management	Respect on traditional and tribal system	Improvement in decentralized framework of local administration and organization	NWRA Sana'a branch office	Sanna' basin comission (SBC)	Ministry of Agriculture and Irrigation (MAI)	Local Council (Governorate and District)	Sana'a Water and Sanitation Local Corporation (SWSLC)	Ministry of Industry, Sana'a Branch	Ministry of Tourismy, Sana'a Branch	Water user association (WUA)	Effectiveness (Saving Amount, MCM in 2020)	Status (already addressed in other projects or not yet)	Activity to be accelerated
5.2.1	Reduction of Water Consumption for Irrigation Purpose	Increasing the farmers' perception of effectiveness of improved irrigation system	○	○			○		◎	○				○	125	SBWMP*1	○
		Facilitation of farmers to understand not to expand their farmland	○	○			○		◎	○				○			○
		Installation of improved irrigation system	○	○			○		◎					○		SBWMP	○
		Introducing watering control system with installation of water flow meter	○				○		◎								
		Improvement of capability of GDI/NWRA-SB or staff in charge of irrigation activities	○				◎		○							SBWMP	○
		Stop of subsidizing for irrigation activity	○					○	◎								
5.2.2	Reduction of Physical Loss of Urban Water Supply	Promotion of understanding of water users in Sana'a city to accept the reduction of unit water consumption	○	○			○				◎				10		○
		Improvement of the capability of leakage detection	○								◎					SWSLC*2	
		Monitoring of production amount and progress of improvement of losses	○				◎				○						
5.2.3	Assuring Reuse of Treated Wastewater	Assuring the improvement of existing WWTP and new construction of using treated wastewater	○					○			◎				50	SWSLC	
		Planning for distribution of treated wastewater	○		○		○	○	○		◎			○		SWSLC	
		Promotion of farmers' understanding of the treated wastewater use by the demonstration	○	○			○		◎	○				○			
		Monitoring of water quality	○			○	◎				○						
5.2.4	Control of Water Consumption of Industrial Use	Preparation of inventory of existing water source used in factories	○				◎								11		
		Promotion of understanding of owners of factories not to expand their activities inside Sana'a Basin	○	○			◎					○					
		Reduce of overuse of water in factories and reuse of water inside factories	○	○			◎					○					
		Preparation of master plan for industrial sector taken into consideration water resources condition	○				○	○				◎					
5.2.5	Control of Water Consumption of Touristic Use	Preparation of inventory of existing water source used for touristic purpose	○				◎								7		
		Facilitation of hotel owners to understand not to expand their water consumption	○	○			◎						○				
		Preparation of sector development plan taken into consideration water resources condition	○				○	○					◎				
5.2.6	Institutional Development	Finalization of the executive regulation to the Water Law of 2002, and development of decree for water protection zone of Sana'a basin					◎	○							-	Gov.*3	○
		Increase awareness of public and political leaders on water resources management	○				◎	○									
		Respect on traditional and tribal system	○				○	◎		○							
		Improvement in decentralized framework of local administration and organization	○				○	◎		○				○			○
5.2.7	Organizational Development	NWRA Sana'a branch office	○				◎	○							-	SBWMP	○
		Local council	○			○	○	◎									
		Sanna' basin comission (SBC)	○		○			●								SBWMP	
		Water user association (WUA)	○				◎		○	○						SBWMP	○

*1 : Sana'a Basin Water Resources Management Project, SBWMP, *2 : Sana'a Water and Sanitation Local Corporation, SWSLC, *3 : Government of Yemen

5.4 IMPLEMENTATION SCHEDULE FOR ACTION PLAN

Table 5.10 shows the proposed implementation schedule for the Action Plan. This schedule is prepared in consideration of the ongoing projects such as SBWMP and rehabilitation of WWTP, and is required to be re-scheduled considering the progress of each activity and in conformity with actual conditions under the initiative of NWRA-SB together with relevant organizations.

Table 5.10 Proposed Schedule for Action Plan (1/2)

Action to be Taken			Responsible Organization*1	Status*2	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
5.2.1	Reduce of Water Consumption for Irrigation Purpose	Increasing the farmers' perception of effectiveness of improved irrigation system	MAI	SBWMP														
				Action plan														
		Facilitation of farmers to understand not to expand their farmland	MAI	Action plan														
		Installation of improved irrigation system	MAI	SBWMP														
				Action plan														
		Introducing watering control system with installation of water flow meter	MAI	Action plan														
		Improvement of capability of NWRA-SB or staff in charge of irrigation activities	MAI	SBWMP														
				Action plan														
		Stop of subsidizing for irrigation activity	MAI	Action plan														
5.2.2	Reduce of Physical Loss of Urban Water Supply	Promotion of understanding of water users in Sana'a city to accept the reduction of unit water consumption	SWSLC	Action plan														
		Improvement of the capability of leakage detection	SWSLC	SWSLC														
				Action plan														
		Monitoring of production amount and progress of improvement of losses	NWRA-SB	Action plan														
5.2.3	Assuring Reuse of Treated Wastewater	Assuring the improvement of existing WWTP and new construction of using treated wastewater	SWSLC	SWSLC														
				Action plan														
		Planning for distribution of treated wastewater	SWSLC	SWSLC														
				Action plan														
		Promotion of farmers' understanding of the treated wastewater use by the demonstration	MAI	Action plan														
		Monitoring of water quality	NWRA-SB	Action plan														
5.2.4	Constant Consumption of Industrial Use	Preparation of inventory of existing water source used in factories	NWRA-SB	Action plan														
		Promotion of understanding of owners of factories not to expand their activities inside Sana'a Basin	NWRA-SB	Action plan														
		Reduce of overuse of water in factories and reuse of water inside factories	NWRA-SB	Action plan														
		Preparation of master plan for industrial sector taken into consideration water resources condition	MoI	Action plan														

Table 5.10 Proposed Schedule for Action Plan (2/2)

Action to be Taken				Status*	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
5.2.5	Constant Consumption of Touristic Use	Preparation of inventory of existing water source used for touristic purpose	NWRA-SB	Action plan														
		Facilitation of hotel owners to understand not to expand their water consumption	NWRA-SB	Action plan														
		Preparation of sector development plan taken into consideration water resources condition	MoT	Action plan														
5.2.6	Institutional Development	Finalization of the executive regulation to the Water Law of 2002, and development of decree for water protection zone of Sana'a basin	NWRA-HQ	NWRA HQ														
				Action plan														
		Increase awareness of public and political leaders on water resources management	NWRA-HQ	Action plan														
		Respect on traditional and tribal system	SBC	Action plan														
		Improvement in decentralized framework of local administration and organization	SBC	Action plan														
5.2.7	Organizational Development	NWRA Sana'a branch office	NWRA-SB	Action plan														
		Local councile	SBC	Action plan														
		Sanna' basin comission (SBC)	SBC	Action plan														
		Water user association (WUA)	NWRA−SB	SBWMP														
				Action plan														

*1): MAI: Ministy of Agriculture and Irrigation
SWSLC: Sana'a Water and Sanitation Local Corporation
NWRA-HQ: National Water Resources Authority Headquarters
NWRA-SB: National Water Resources Authority Sana'a Branch
MoI: Ministry of Industry
MoT: Ministry of Tourism

*2) : "SBWMP" means that Sana'a Basin Water Management Pjoject has already addressed .
"SWSLC" means that Sana'a Water Supply and Sanitation Local Corporation has already addressed.
"Action Plan" means that the schedule proposed in this JICA

5.5 ACTIONS TO BE TAKEN FOR FURTHER PROGRESS

5.5.1 PROTECTION OF GROUNDWATER RESOURCES FROM CONTAMINATION

(1) Control of Contamination caused by Effluent from Factories

Purpose

To control the disposal of industrial waste in order to avoid groundwater contamination/pollution

It was reported that the infiltration of untreated effluent from factories, and oil and lubricant from small shops, have resulted in the contamination of groundwater. Since the improvement of the sewage system will be completed more than 10 years from now, it is required for organizations concerned to take necessary action as soon as possible so as to protect limited groundwater from pollution.

Activity

(1) Preparation of inventory of possible sources of groundwater contamination

Since there is little available information about effluent from factories and small shops which deal with oil and lubricant, it is necessary first to understand the present status of possible sources of contamination.

(2) Increasing awareness of owners of factories, petrol stations, and small shops

NWRA-SB in collaboration with SBWMP and EPA, has to carry out increasing awareness of owners of factories and small shops to minimize the adverse impact caused by the infiltration of untreated effluent, oil and lubricant.

(3) Enforcement of Article (54) of Water Law and preparing its Executive Bylaw

Article (54) of Water Law stipulating protection of water from contamination/pollution should be enforced by Ministry of Water and Environment properly. In addition, its Executive Bylaw should be developed immediately.

(4) Preparation of collection system for disposal of industrial waste

Before the completion of expansion of WWTP in the year 2020, a collection system for the disposal of industrial waste should be considered and started in parallel with increasing awareness and enforcement of Water Law, in order to stop groundwater contamination as soon as possible.

Responsibility

Organizations related to these approaches and their responsibilities are described in *Table 5.11*. NWRA-SB is responsible for increasing awareness of owners of factories and small shops.

Table 5.11 Responsibility for Control of Contamination

Organization	Responsibility
MWE	Development of executive bylaw
NWRA-SB	Increasing awareness of owners of factories and small shops

(2) Control of Over-Utilization of Chemical Fertilizer and Pesticides

Purpose

To reduction the over-utilization of chemical fertilizers and pesticides, in order to prevent groundwater contamination

The purpose of the control of over-utilization of chemical fertilizers and pesticides is to protect groundwater from contamination. Since the beginning of cash crop cultivation c, farmers have applied much chemical fertilizer and pesticides to more benefit. Sometimes, they have used dangerous pesticides which cause cancer.

Activities

NWRA-SB has already addressed to issue in cooperation with General Department of Plant Protection as one of the component of SBWMP. Therefore, following activities shall be enhanced.

- Promotion of farmers' understanding to minimize these chemical fertilizer and pesticide use through enhanced awareness campaign, in cooperation with WUA.

Responsibilities

Organizations related to these approaches and their responsibilities are described in *Table 5.12*. NWRA-SB is responsible for increasing awareness of farmers and the monitoring of water quality.

Table 5.12 Responsibility for Control of Over-Utilization of Chemical Fertilizer and Pesticides

Organizations	Responsibility
General Department for Plant Protection	Increasing awarenes of farmers regarding overuse of chemical fertilizer and pesticides
WUA	Increasing awareness of farmers
NWRA-SB	Increasing awareness of farmers, Monitoring of water quality

5.5.2 EFFECTIVE USE OF SURFACE WATER

(1) Effective Use of Water Harvesting

Purpose

To utilize water harvesting structures as much as possible in order to mitigate the depletion of groundwater.

In order to mitigate the decrease of groundwater, surface water shall be utilized as much as possible by means of water harvesting methods which has been used for a long time in the country such as cisterns, ponds, terraces, rooftops in urban areas, and the diversion of floods, etc..

Activities

(1) Preparation of an inventory of existing water harvesting methods

Prior to promote the farmers' understanding to use water harvesting systems properly, it is necessary to prepare an inventory of existing water harvesting methods so as to understand the present status of these methods and to formulate the plan of activities followed.

(2) Promotion of farmers' understanding of proper use of water harvesting system

Based on the inventory prepared, a program for the increasing awareness of farmers on using water harvesting methods should be prepared, then this activity should be commenced and supported under the initiative of WUAs and Local Councils.

Responsibilities

Organizations related to these approaches and their responsibilities are described in *Table 5.13*. NWRA-SB will be responsible for the evaluation of recharge and monitoring.

Table 5.13 Responsibility for Effective Use of Water Harvesting

Organizations	Responsibility
MAI	Support for maintenance of these method
WUA, WUG	Maintenace and operation
Local Council	Support for maintenace
NWRA-SB	Increasing awareness of farmers regarding the necessity of water harvesting

(2) Consideration of Recharge and Sub-Surface Dams

Purpose

To consider the most effective way in order to optimize the recharge to groundwater through surface and/or subsurface dams

Purpose of this activity is to consider the right way to optimize the recharge to groundwater through surface and/or subsurface dams. Inside Sana'a Basin, so far, 38 dams, of which 13 dams are also used for irrigation and drinking purpose, have constructed, and another three dams are under construction for the purpose of recharge to groundwater. According to the information from SBWMP, the good result, that is, recovering the groundwater level at shallow wells were observed, but insufficient results were also observed in some cases. Thus, the necessity of a comprehensive study for optimizing the recharge function of these structures has been discussed among organizations concerned.

Activities

(1) Monitoring and evaluation of on-going activities related to recharge improvement

NWRA-SB in collaboration with MAI should monitor and evaluate the results of rehabilitation and construction of dams which will be conducted in SBWMP form the view point of effectiveness.

(2) Consideration of an integrated approach towards appropriate management of recharge system

Based on the results of evaluation of activities of SBWMP related to the enhancement of recharge, a comprehensive plan to improve the effectiveness of recharge to groundwater should be considered.

Responsibilities

Organizations related to these approaches and their responsibilities are described in *Table 5.14*. NWRA-SB will be responsible for the evaluation of the results of activities carried out in SBWMP.

Table 5.14 Responsibility for Consideration of Dams

Organizations	Responsibility
MAI	Execution agency
WUA	In charge of operation and maintenance
EPA	Evaluation of the results of social and environmental considerations
NWRA-SB	Evaluation of the results of dam rehabilitation and construction

5.5.3 OPTIMIZATION OF WATER SUPPLY COVERED BY PRIVATE SUPPLIER IN SANA'A CITY

Purpose

To optimize water supply condition covered by private supplier in order to save overuse amount of water

The portion of the population not covered by the public network, which is around 64% of population of Sana'a city, has obtained water from private suppliers by means of tankers and small networks with rather high tariffs and unsecured water quality. No monitoring system for this private water supply has been established, therefore, efficiency of the private water supply has not been clarified yet. As observed inside the city, water tankers has moved having leakage of water.

In fact, since the public water supply does not have enough capacity to supply water for the increasing demand caused by rapid population growth in Sana'a city, private suppliers have functioned to fulfill the demand. However, from the view point of reducing water loss and securing water quality, a monitoring system aimed at private suppliers shall be

established so as to manage water resources.

Activities

- Comprehension of the present situation of private water supply and establishment of a database;
- Increasing awareness of private suppliers on water saving;
- Consideration of introduction of meter for monitoring purposes;

For these activities, the following considerations should be taken:

- incentives and regulation for private suppliers;
- coordination with SWSLC;
- compensation for private supplier which might be caused by the expansion of public network

Responsibilities

Related organizations and their responsibilities are described in *Table 5.15*.

Table 5.15 Responsibility for Improvement of Water Use Efficiency for Urban Water Supply Covered by Private Suppliers

Organizations	Responsibility
SWSLC, Municipality	Coordination with private supplier
NWRA-SB	Increasing awareness of private supplier on saving water, Monitoring of quantity

NWRA-SB is responsible for the increasing awareness of private supplier on saving water, and monitoring of their water use situation.

5.5.4 INTER-REGIONAL AND SECTORIAL REALLOCATION OF WATER RESOURCES

Purpose

To reallocate water resources from sub-basin to sub-basin and irrigation use to domestic use in order to make the period to depletion of water in the sub-basin even as much as possible by reducing irrigated area

In order to make the period of depletion of the sub-basin even as much as possible, it is required to reallocate water resources among sub-basins and from irrigation purposes to urban domestic purposes. Around 20 MCM of groundwater has to be transferred to "Wadi Al Mawrid" where the capital city of Sana'a is located from other neighbor sub-basins in the year 2020 by reducing irrigated area.

Activities

(1) Reallocation of water from irrigation purpose to urban domestic purpose

Around 20 MCM of groundwater should be transferred to "Wadi Al Mawrid" for urban water supply from other neighboring sub-basins in the year 2020. Then the grace to be very critical situation of water resources of each sub-basin could be nearly even and source of urban water supply can be secured. In addition, water conflict among tribes which might be happened can be reduced. Sub-basins where water resources can be transferred are selected from the view points of the following:

- Consumption of irrigation is high
- Location of sub-basin is relatively close to capital city of Sana'a

(2) Promotion of understanding of the tribes to transfer water from their own land to other places, and to across the transmissions

The success of this activity is recognized as the most important and difficult one. The activity should be properly addressed in early stage, since without their understanding and cooperation, the transferring water cannot be successfully implemented. Therefore, considering the sensitivity of "tribes," this activity should be addressed in accordance with the activity mentioned in the section 5.2.6 3) "Respect towards Traditional and Tribal Systems" in this Chapter.

Responsibilities

Related organizations and their responsibilities are mentioned in *Table 5.16*.

Table 5.16 Responsibility for Improvement of Reallocation of Water for Urban Water Supply

Organizations		Responsibility
1	Sana'a Water Supply and Sanitation Local Corporation (SWSLC), Sana'a Municipality	Execution organization
2	Ministry of Agriculture and Irrigation (MAI)	Execution organization
3	WUA	Raising public awareness of people
4	General Authority for Rural Water Supply Projects (GARWSP)	Execution agency
5	Local Council	Coordination among villages in the distict
6	NWRA-SB	Analysis of available water resouces, Propose relevant reallocation plan, Raising public awareness on water transfer

Under the initiative of NWRA-SB, increasing awareness of farmers on improvement of water use efficiency, incentive or compensation to be given, coordination among Local Councils and WUAs and implementation of water reallocation shall be conducted.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Conclusions obtained through the Study are as follows.

(1) As a result of review of the existing reports and literature, it is concerned that the water resources potential in Sana'a Basin would not be able to meet the projected future water demand after the year 2020. Therefore, the reduction of water consumption is fundamental measures towards sustainability of water resources in Sana'a Basin.

(2) Four scenarios of future water demand are made on the basis of the existing plans and plans set in the Study so that the possibility of reduction of water resources consumption is examined. As a result, the scenario aiming at reducing water demand in the year 2020 from 349.6 MCM to 196.6 MCM is selected as the scenario having possibility of implementation of measures and utmost reduction of water consumption. The scenario makes possible to extend the grace to be very critical situation of water resources until the year 2036 that is around 30 years later from 2007.

(3) Water Resources Management Action Plan for Sana'a Basin focuses on reducing overuse of water resources, securing domestic water and development of institution and organization. Total amount of water to be reduced by 2020 is estimated to be 153 MCM/year in 2020 in the selected Scenario. The reduction is able to mainly be accomplished by the improvement of irrigation efficiency, reducing physical loss of urban water supply and reuse of treated wastewater.

(4) Difference of degree of water imbalance among sub-basins which would become one of the causes of conflict happened by deficit of water, will be mitigated by utilizing treated wastewater and reallocation of water resources consumed in irrigation purpose.

6.2 RECOMMENDATIONS

Recommendations for the implementation of Action Plan towards sustainability of water resources in Sana'a Basin are as follows.

(1) Immediate commencement of the actions

Considering the critical conditions of water resources inside Sana'a Basin, under the initiative of SBC and NWRA-SB, organizations concerned are strongly required to immediately launch actions formulated in the Action Plan.

(2) Effective implementation of the Action Plan

In order to smoothly and effectively implement the water resources management action plan, NWRA-SB is advised to take necessary actions for budget allocation, and required to periodically monitor the progress of implementation of actions and modify the plan, if necessary, in accordance with the result of monitoring with SBC.

(3) Finalization of Executive Regulation and bylaw

It is recommended that finalization of Executive Regulation and development of Sana'a Basin Bylaw be forwarded, since groundwater utilization metering and groundwater charge

levying shall be one of the most indispensable prescriptions to address the issues of over-consumption for water-demanding cash crop and excessive water loss.

(4) Incorporating Local Council into implementation of actions

Given the limited number of staff of NWRA-SB and responsibility of Local Council for basin level water resources management, there is a significant need of establishment of system to incorporate local council in the field monitoring network.

(5) Effective dissemination of improved irrigation method

The improvement of irrigation efficiency at all farmlands is one of the pillars of the Action Plan. However, it has been reported that the progress of dissemination of improved irrigation method was in behind, which was attributed to the lack of awareness of farmers on the system and insufficient experience of officials. Therefore, the officials of MAI and NWRA-SB, and member of WUAs are strongly recommended to enhance their skills on the method and to carry out more effective promotion activities.

(6) Reducing the water consumption for Qat plantation

Since Qat plantation has consumed more than half of the extracted groundwater for irrigation purpose, in case Qat plantation was continued, the limited groundwater resources would be continue to be decreased. Therefore, water consumption for Qat plantation should be greatly reduced to keep the sustainability of groundwater resources. For this purpose, it is recommended that courageous solutions, for example, allowing import of Qat from outside of Yemen as proposed by Bahamish (2006), be discussed and launched by the Government of Yemen immediately.

(7) Improvement of capacity of NWRA for monitoring and analysis

In order to appropriately manage water resources, monitoring and analysis based on the hydrogeological condition such as depth of aquifers and those distribution, and feedback of result of analysis on the contents of action plan are required. Therefore, NWRA is further advised to enhance their competence in hydrogeological analysis and feedback the result of analysis on the action plan.