

**The Potential of Strategic Environmental Assessment for
Integrated and Sustainable Water Resources Management in
the Republic of Yemen:**

**Scenario-Based Strategic Assessment of the Water Resources
Policies Adopted in ‘Yemen’s Strategic Vision 2025’**

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Declaration

I hereby declare that this thesis is the result of my original work carried out at Brandenburg University of Technology (BTU) Cottbus, Germany, within the framework of the doctoral program in Environmental and Resource Management. The thesis contains no material previously published or written by another person except where due acknowledgement is made in the text of the thesis. I also declare that this thesis has never been presented for a degree in this or any other university.

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Cottbus, 15th July 2013

ABSTRACT

Yemen is one of the most water-stressed countries in the world. The water deficit has been aggravated by the rapidly increasing demands for both surface and groundwater resources that are being unsustainably exploited. To address the country's severe water scarcity, the government has adopted long-term intervention policies as stated in 'Yemen's Strategic Vision 2025'. These policies are aimed at restoring the balance between water demand and availability, and at reducing the existing water deficit. Although 11 years have passed since this vision was adopted, the water deficit is still on the rise.

The present situation raises questions about the efficiency of the intervention policies adopted by 'Yemen's Strategic Vision 2025' and about the effectiveness of implementing these policies. Another fundamental question pertains to the availability of a strategic assessment tool in the water resources sector that can be used to assess strategically future and current policies, strategies and plans, in order to ensure their efficiency in supporting water resources and in producing the positive impacts for which these strategic initiatives were developed in the first place.

Strategic Environmental Assessment (SEA) is an assessment tool designed to function at a strategic level and help to bring aspects of environmental sustainability into the decision-making process. This research aims to demonstrate the potential of SEA in enhancing environmental sustainability in water policies for achieving sustainability of water resources in Yemen. In order to show the potential of SEA in the Yemeni water resources sector, this research has applied SEA methodologies and adopted a scenario-building approach for assessing the intervention policies adopted by 'Yemen's Strategic Vision 2025' to support augmentation of water resources.

Qualitative and quantitative approaches have been used in this research. Quantitative historical data on water availability, water demand and water savings by interventions have been collected from the databases of national institutions and international organizations concerned. Statistical analyses have been used to project future trends until 2025. Qualitative analyses of relevant studies and reports covering the environmental, administrative, socio-cultural and political-economic aspects of water resources management in Yemen have been implemented as well. In addition, 13 semi-structured key informant interviews have been

conducted with decision-makers, managers and leading experts in the water and irrigation sectors.

The research produced three future scenarios for the total water balance that may play out until 2025 in Yemen. These scenarios provide impact assessment and alternatives' comparison of the existing intervention policies. The resulting scenarios are as follows: the 'Business as Usual' scenario, which forms an assessment of currently applied interventions and provides an image for the future, if current interventions are maintained at the same pace; the 'Do-nothing' scenario representing the situation if no interventions are implemented; and the 'Sustainability' scenario, which represents the potential future of the total water balance if existing interventions are to be scaled up and out.

The findings confirm the significant potential of currently adopted intervention policies to support water resources. They also reveal that the current level of implementing the intervention policies has hindered the potential of these intervention policies in achieving the expected positive impact on the water balance by 2025. In order to achieve a significant decrease in the water deficit, the strategic quantitative targets that need to be implemented were identified. The methodology followed in implementing the research and achieving the findings demonstrates the potential of SEA in enhancing environmental sustainability in water policies for achieving integrated and sustainable water resources management in Yemen.

The recommendations of the research covered improving the existing water balance as well as improving the assessment and planning context in the water resources sector. In order to improve the water balance situation, the research recommends implementing quantitative targets for water savings and augmentations, such as those developed by this research. These targets have been identified based on the capacities of sectors implementing these interventions. The research also recommends further decentralization of planning and management of water resources and the establishment of Water User Associations (WUAs) as the main vehicles for ensuring sustainable planning and management of water resources, including the scale out of interventions, subject to assessment in this research. In order to improve assessment and planning of water resources, the research recommends the adoption of SEA, the updating of water resources data and conducting regular assessments of policies, plans and programmes as part of monitoring their impact and providing a chance for amending these policies and strategies, if required, to achieve sustainability of water resources.

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DEDICATION

I dedicate my work to my wife, daughter and son for their unconditional love and unwavering support without which the journey towards completing this research would have been much more difficult.

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List of Acronyms and Abbreviations

ACWUA	Arab Countries Water Utility Association
BAU	Business as Usual
CEDARE	Center for Environment and Development for the Arab Region and Europe
CSO	Central Statistical Organization
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency, of the Republic of Yemen
ESCWA	Economic and Social Commission For Western Asia the United Nations
FAO	Food and Agricultural Organization of the United Nation
GARWSP	General Authority for Rural Water Supply Projects, of the Republic of Yemen
GIZ	German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit)
GWP	Global Water Partnership
ha	hectare
IWRM	Integrated Water Resources Management
lpcd	liters per capita per day
M	meters
MAI	Ministry of Agriculture and Irrigation, of the Republic of Yemen
MCM	Million Cubic Metres
MOPIC	Ministry of Planning and International Cooperation, of the Republic of Yemen
MPWH	Ministry of Public Works and Highways, of the Republic of Yemen
MWE	Ministry of Water and Environment, of the Republic of Yemen
NIC	National Information Center, of the Republic of Yemen
NWRA	National Water Resources Authority, of the Republic of Yemen
NWSSIP	National Water Sector Strategy and Investment Plan
OECD	Organization For Economic Co-Operation And Development
PPP	Policies, Plans and Programmes

PRSP	Poverty Reduction Strategy Paper
SEA	Strategic Environmental Assessment
SFD	Social Fund for Development
Sq. Km	Square Kilometer
UN	United Nations
UNDP	United Nations Development Programme
WB	The World Bank
WUA	Water User Association

1. INTRODUCTION

Water resources in Yemen deplete rapidly and the total water balance is continuously in deficit (see National Water Resources Authority [NWRA], 2002 and World Bank [WB] 2010). If the situation does not improve, Yemen will consume its groundwater reserves in another two to three decades (WB, 2010). In 2002, the government recognized this alarming situation and adopted alternatives for supporting water resources in a national vision known as ‘Yemen’s Strategic Vision 2025’.

Eleven years later, and despite its reforming policies, the vision has failed to produce a favourable turnaround in the balance of water consumption. Ward (2001), who studied Yemen’s water situation, affirms that one of the main causes of the current water crisis is that the Yemeni government implemented policies that have promoted expansion rather than efficient use of water resources.

The present research adds to Ward by focusing on the efficiency and efficacy of Yemeni policies to achieve a favourable water situation. Thus, the research argues that holding everything else constant and equal *ceteris paribus*, well-assessed policy alternatives support sustainable water resources. To that end, the research applies SEA methodologies to assess current and future impacts on the national water balance resulting from the application of the alternatives mentioned in ‘Yemen’s Strategic Vision 2025’. The overall assessment proves and showcases the potential of applying SEA in the water sector at a strategic level.

1.1 Statement of the Problem and Research Questions

Yemen suffers from acute water shortage. The country’s location in the arid Arabian Peninsula and the absence of a perennial river contribute to the lack of water resources. This has led to overexploitation of the reliable, yet limited, groundwater resources. Hellegers et al. (2008) state that Yemen’s per capita water availability decreased as early as 2005 to 120m³/person/year to become one of the lowest in the world compared to 1,250 m³/person/year in the Middle East and North Africa (MENA) region and 7,500 m³/person/year worldwide.

In 2002, the Yemeni government adopted the national-level policy of ‘Yemen’s Strategic Vision 2025’ (see Annex 1). It includes, *inter alia*, policies on alternatives for supporting water resources and mitigating the impacts of rapidly increasing demand on water balance. These alternatives involve introducing modern irrigation systems, providing alternatives for qat agriculture and expansion of water harvesting. The policy has also adopted the treatment of wastewater but as a measure for protecting the environment rather than as a potential non-conventional resource for supporting water resources.

The government has been implementing the alternatives adopted in ‘Yemen’s Strategic Vision 2025’ since 2002 through sectoral programmes. However, their current and potential impacts on the water balance are yet to be assessed. At the same time, available studies report that water resources continue to deteriorate rapidly and that the water deficit is expected to increase (see NWRA 2002 and WB 2010).

In describing the intermediate impact resulting from the implementation of one of the alternatives proposed by ‘Yemen’s Strategic Vision 2025’—namely, using modern irrigation systems—the Ministry of Water and Environment (MWE) (2008: p.2) concludes that ‘there is as yet little evidence of a beneficial impact on the water balance’.

Although existing water policies that have not undergone strategic assessment may not be the reason behind the country’s inability to arrest the water balance deficit, there is no assessment of the policies or of their impacts to confirm as much. As a long-term policy, ‘Yemen’s Strategic Vision 2025’ should include alternatives that still have great potential in supporting water resources to regain their sustainability. By focusing only on ‘Yemen’s Strategic Vision 2025’ as the long-term guiding policy for lower level strategies, programmes and interventions in the water resources sector while other factors—such as economic or cultural factors—that may influence governmental responses to improve water resources are kept constant and held equal, the research raises the following questions:

- Do the alternatives adopted by ‘Yemen’s Strategic Vision 2025’ have the potential to contribute significantly to achieving water resources sustainability?
- What has been the impact of the alternatives currently adopted by ‘Yemen’s Strategic Vision 2025’ on the water balance?
- What are the potential futures of the water balance and the underlying condition producing them until 2025 if these alternatives are followed?
- Is sustainability still achievable by 2025 using these alternatives? What strategic targets should be adopted to achieve sustainability?

Fundamental questions are also raised regarding the availability of and the need for a strategic assessment and planning tool in the water sector that would enable the systematic evaluation of existing or proposed policies and strategies. The current water resources situation also calls into question the extent to which Integrated Water Resources Management (IWRM) can function effectively at a strategic level. The IWRM approach was adopted in Yemen in 1990 as part of reforms in the water sector. The approach has been accepted internationally as the way forward for sustainable development and management of water resources and for coping with conflicting

demands (UN-Water, 2008). In Yemen, policymakers have viewed IWRM as the right tool due to its balanced consideration of both supply and demand dynamics (Michel, 2012). Nevertheless, IWRM is not a tool that ‘functions’ at the strategic level for assessing water policies; it is rather a tool for program evaluation (Xie, 2006). Thus, it is clear that the water resources sector in Yemen lacks a strategic assessment tool that can be used to systematically assess existing and future policies, plans and programmes.

1.2 Research Hypothesis

The acute water shortage in Yemen leaves no alternative but for effective, efficient and well-planned interventions that are based on policies that have been subject to prior assessment. Policies are the main sources for subsequent lower level strategies and plans that are implemented as interventions for supporting water resources. Bearing this in mind, and given the continuous and rapid deterioration of water resources in Yemen and the current lack of a SEA, the present research recommends adopting a tool that functions at the strategic level. This tool which should be used for systematic planning and assessment is a critical success factor for ensuring that the water resources sector develops policies and strategies that are efficient in eliminating the existing water deficit while meeting the increasing demand for water. Therefore, the main hypothesis of this research is that ‘Using the Strategic Environmental Assessment (SEA) process and methodologies to assess currently applied water policies has the potential to support planning for integrated and sustainable water resources in Yemen’.

1.3 Aim and Objectives

In response to the aforementioned statement of the problem, the aim of the research is to demonstrate the potential of SEA in enhancing environmental sustainability considerations in water policies for achieving integrated and sustainable water resources management in Yemen.

The following objectives have been set to achieve the above-stated aim:

- To identify the environmental, institutional and socio-economic determinants of the future of water resources in the Republic of Yemen;
- To assess—quantitatively and qualitatively—the current and potential futures of water balance in Yemen resulting from the implementation of alternatives adopted by ‘Yemen’s Strategic Vision 2025’ until the year 2025
- To identify qualitative and quantitative strategic targets to support water resources in Yemen until 2025.

1.4 Overview of Research Methodology

This research has been carried out by applying a methodology that is analogous to the SEA process. The SEA process includes several phases such as baseline data collection, impact assessment and mitigation. The research also compares alternatives in an assessment context, which, according to Joao (2004), is a fundamental principle in implementing SEA.

Why SEA?

There are various tools for policy-level assessment. The present research, however, adopted SEA to implement this research as well as to demonstrate the potential of this tool in the water sector. SEA has been selected to implement this research for the following reasons:

- The research aims to assess the environmental impacts of a policy to support sustainability, which is the core function of SEA. ‘SEA has the capacity to support the development of policy and planning practices with a stronger environmental component and, above all, may perform a fundamental role in promoting sustainable principles and practices and the consideration of cumulative effects’ (Wood, 1995; Partidário, 1996a; Sadler, 1998; Fischer, 1999; Goodland and Mercier, 1999; Clark, 2000; Partidário, 2000 in Partidário 2003).

- Although the policy to be assessed in this research—namely, ‘Yemen's Strategic Vision 2025’—should only have positive impacts on water resources, SEA can contribute in further supporting these positive impacts. Joao (2005, p:10) asserts, ‘Importantly, SEA contributes to the improvement of the strategic action not only by mitigating negative impacts but also by enhancing positive impacts’.

- The policy to be assessed was adopted by the government in 2002, and policies afforded by this strategic vision are already being implemented by the water and agriculture sectors. SEA is a flexible approach to be applied ex-ante (very early in the decision-making processes), integrated (accompanying assessment allowing for periodic review of the environmental effects of decisions following implementation) and can also be used ex-post (as an evaluation tool of the whole process and its outcomes) (Ehrhardt, and Nilsson, 2006).

- The research aims to demonstrate the potential of SEA as a participatory tool for strategic assessment and planning that can support sustainability in the water resources sector. SEA has been selected as there is a legal, administrative and professional basis that facilitates its adoption. Both Environmental Impact Assessment (EIA) and SEA belong to the bigger family of Environmental Assessment. Nevertheless, SEA interfaces

the scope of application of project-level EIA, represents an extension of project-level EIA and borrows methods from EIA (Partidário, 2003). As applied to the Yemeni context, EIA is legally required by the Environmental Protection Law (EPL) of 1995 and is an established tool in Yemen. Although SEA is not legally required yet, it has been applied to several donor-funded programmes and plans in the water sector. This has introduced decision-makers and professionals in the water sector to the importance and utility of the tool. Therefore, SEA has better chances of being adopted in the water sector to complement the existing EIA and is supported by the existing legal, administrative and professional foundation of EIA in Yemen.

Approaches Adopted for Implementing the Research

Two approaches have been adopted for implementing the research. These are qualitative and quantitative approaches.

The Qualitative Approach

The qualitative approach has been used to:

a) Establish background on different themes covered by the research and the inter-relation between these themes, mainly in the following:

- Strategic Environmental Assessment (SEA)
- Integrated Water Resources Management (IWRM)
- Strategic planning in relation to water resources
- Scenario building approach and development methods

b) Study the environmental, socio-cultural and political-economic aspects that provide the context of water resources planning and management in Yemen. Studying these aspects leads to the identification of the most important factors that are expected to continue to influence water resources planning and management in Yemen until 2025. These factors have been identified based on the literature review and on the worldview of the key informants interviewed within the research.

c) It is important to mention that the research does not seek statistical generalization. This explains why targeted sampling has been adopted in selecting key informants, as will be detailed in Chapter 6. The qualitative investigation relies, however, on the construction of analytical generalizations (Yin, 1994: 35-36) in order to define the main qualitative factors that control the future of water resources in Yemen.

d) Establish future potential qualitative scenarios for water resources using factors that will influence the future of water resources as identified during the qualitative analysis.

The Quantitative Approach

This approach aims at achieving the following:

- a) Establishing the current water balance in Yemen. This has been achieved by collecting data on current sectoral water demand and water availability from conventional and non-conventional water resources.
- b) Developing quantitative future water balance scenarios until 2025. This has been implemented by carrying out statistical analysis of the collected data on water demand, water availability and water that is augmented or saved by technical interventions adopted by 'Yemen's Strategic Vision 2025'. These interventions are modern irrigation systems, dams, water harvesting, replacement of qat agriculture and reusing treated wastewater.

Research Methods and Data Collection

In implementing the research's qualitative and quantitative approaches, the following methods have been applied:

- **Literature Review:** This includes reviewing available and up-to-date literature including journals, scientific books, studies and records of governmental and international organizations.

Field Visit: A field visit to Sana'a, the capital of the Republic of Yemen, was made for the following purposes:

- **Conducting Interviews:** Semi-structured, face-to-face interviews have been conducted with experts, decision-makers and managers. The selected interviewees are the key informants as they are: a) in charge of strategic planning in the water resources and agriculture sector in Yemen, and b) experts with years of experience in the field of water resources and agriculture, particularly, in the themes covered by this research.
- **Data Collection:** Available historical and up-to-date quantitative and qualitative data are collected from the databases of authorities and institutions in the water resources sectors and other institutions supporting the sector. The collected data are on water availability, water consumption, water savings and augmentations by modern irrigation systems, dams, water harvesting, replacement of qat agriculture and reusing treated wastewater.

Research Problems

No improvement in water balance despite the adoption of alternatives to support water resources under ‘Yemen’s Strategic Vision 2025’ which was adopted in 2002.

Hypothesis

Applying Strategic Environmental Assessment (SEA)- to assess currently applied water policies – has the potential to support planning for integrated and sustainable water resources in Yemen.

Aim

To demonstrate the potential of Strategic Environmental Assessment (SEA) in enhancing environmental sustainability considerations in water policies for achieving integrated and sustainable water resources management in Yemen.

Objectives

- To identify the environmental, institutional and socio-economic determinants of the future of water resources in the Republic of Yemen.
- To assess, both quantitatively and qualitatively, the current and potential futures of water balance in Yemen resulting from alternatives adopted by ‘Yemen’s Strategic Vision 2025’ until the year 2025.
- To identify qualitative and quantitative strategic targets for supporting water resources in Yemen until 2025.

Methodology

Analysis of Main Water Resources Policies

e.g.

- Yemen’s Strategic Vision 2025
- National Water Sector Strategy and Investment Programme (NWSSIP) 2005-2009 and NWSSIP 2010-2015
- National Agriculture Strategy 2012-2016
- National Water Resources Policy of 1998
- Irrigation Water Policy of 2001
- The Water Law nr. 33 of 2002 and its amendments of 2006

Literature Review

- Environmental, institutional, legal and socio-economic aspects of water resources management in Yemen
- Water resources availability, consumption, savings and augmentation in Yemen
- Strategic Environmental Assessment
- Sustainable and Integrated Water Resources Management
- Scenario building and development

Semi-structured Interviews
with decision-makers and key experts in the water and irrigation sectors

Scenario Planning & Building

Statistical Analysis
of key variables and driving forces

Outputs

Future water balance scenarios in Yemen, i.e.
Do-nothing, Business As Usual and Sustainability scenarios

Strategic targets and recommendations for the sustainable and integrated management of water resources

Showcase demonstrating the potential and added value of applying SEA in the water sector in Yemen

Figure 1: Research schematic overview

1.5 Expected Contribution of the Research

Contribution to the Body of Knowledge

- The research establishes that SEA as a tool can complement IWRM in the water sector. The research shows that SEA can prove a participatory tool in the systematic, integrated and sustainable strategic planning of water resources.
- The research demonstrates the potential of SEA for application not prior to the adoption of a policy but during the implementation phase of a long-term policy—in this case, Yemen’s Strategic Vision 2025.

Contribution to the Context of Strategic Planning in the Water Resources Sector

- Identifies an essential, achievable quantitative target of annual water savings using technical interventions to reverse the current decreasing water balance in Yemen.
- Provides a comprehensive assessment of four major technical interventions that the government has been implementing to support water resources in Yemen—viz. modern irrigation systems, dams, wastewater reuse and replacing qat agriculture.
- Helps decision-makers to anticipate the future water balance until 2025 by observing certain indicators that show which of the developed scenarios might play out. This should help to adapt type or scale of interventions to achieve desired results.
- Showcases the potential of applying SEA in the water sector to complement IWRM’s lack of functionality at the policy level.

1.6 Research Scope

It is important to mention some factors that have been excluded from the scope of this research as well as the meanings of some key terms used in this research.

It warrants mention that in establishing future scenarios of water balance until 2025, climate change impacts on water availability due to potential change in precipitation have not been considered in this research. This is because there is no conclusive evidence regarding either increase or decrease of precipitation in Yemen, as the world maps on projected precipitation change differ depending upon the models used to construct them (Van der Gun, 2009). This means that the sustainability aimed for in this research is based on managing the quantity of annually renewable water resources.

Another point is the meaning of sustainability as adopted in this research. Using the term ‘sustainability’ in the context of the situation of Yemen—a country that is unable to meet the demand of its existing population—may seem inaccurate. This is true when considering the common meaning of this term as defined by Brundtland (United Nations (UN), 1987: p.16). According to this definition, sustainability entails using the resource ‘without compromising the ability of future generations to meet their own needs’. Notwithstanding this, the meaning of the term as used in this research follows that which is mentioned in the Yemeni Water Law nr. 33 of 2002, Article 2 (11). This article states that sustainability of water resources is the ‘extraction of water from underground basins in quantities equal or less than the renewable quantities thereof during the same year or during a period already fixed in advance in a manner which does not affect the quantity and quality of water in the long run’.

Sustainability may be achieved through several technical or non-technical alternatives. Nevertheless, this research focuses on only four alternatives—using modern irrigation systems, dams, wastewater reuse and replacing qat agriculture. These alternatives are adopted by ‘Yemen’s Strategic Vision 2025’.

Finally, the term ‘integrated’ in water resources management has several connotations, some of which are applicable to the context of this research. Biswas (2004) mentions that Integrated Water Resource Management may have different connotations and interpretations. These connotations include water supply and water demand, surface water and ground water, different types of water uses, and the policies of different sectors that have implications for water in terms of quantity.

1.7 Structure of the Dissertation

This dissertation is structured into eight chapters as follows:

The first chapter presents a background that introduces the reader to the context, essence and relevance of the research project. This chapter begins by presenting the fundamental challenge to which the research responds. The aim and objectives of the research are then presented. Thereafter, an overview of the methodology and data collection method is provided.

Chapter two provides an ‘environmental baseline’ on the condition of water resources in Yemen. The chapter offers an overview of the geographic and climatic factors that influence water resources. Information on available conventional and non-conventional water resources and on water consumption by different sectors with projected future demand are provided thereafter. The chapter concludes by mentioning the current status of applied technical interventions to augment and save water.

Chapter three describes the existing organizational structure and legal foundations for water resources planning and management. The chapter provides an overview of the role of governmental institutions and non-governmental organizations in planning and managing water resources. Then, the legal framework for water resources management is presented along with the legal foundations that support the use of alternatives for augmenting and saving water. The chapter then highlights the main policies and strategies of the water resources sector. Due to the importance of the irrigation sector as the biggest consumer of water in the country, an overview of irrigation sector strategies is provided in this chapter.

Socio-economic forces affecting water resources are analysed in chapter four. The scope of this chapter extends to capture the political-economic factors that underlie decision-making and how these factors influence governmental attitudes and policies concerning water resources. Cultural aspects that form the customary water law in Yemen are highlighted as well. The chapter concludes by presenting the potential socio-economic impacts of water resources depletion.

In chapter five, main existing environmental and water resources management approaches that are adopted in the water sector are described—namely, environmental assessment and IWRM. The chapter begins with an overview of water resources planning at the national and basin levels in the Yemeni context. The chapter then describes the strengths, weaknesses, shortcomings and challenges of IWRM application at the strategic level in Yemen. The process of SEA as well as the importance and advantages of applying SEA in the water sector are mentioned. Before concluding, the chapter points out the shortcomings and limitations of applying SEA, particularly, at the policy level.

The approaches adopted and the methodology applied in the research are explained in chapter six. The chapter begins by describing the qualitative and quantitative approaches adopted in carrying out this research. The rationale for selecting the scenario-building method is also presented along with scenario-building process. Collection methods of qualitative and quantitative data are then explained. The chapter also explains the statistical analysis applied to develop the quantitative scenarios, and ends by describing how data validity and reliability were ensured.

Chapter seven includes the scenarios developed from the qualitative and quantitative analyses based on the selected driving forces and variables. The chapter interprets these scenarios and discusses their significance.

Finally, in chapter eight, conclusions drawn from the research findings are presented. Policy implications on strategic planning and assessment in the water sector are

presented. In light of these findings, final recommendations and future outlooks for the application of the potential of SEA in the Yemeni water resources sector are provided.

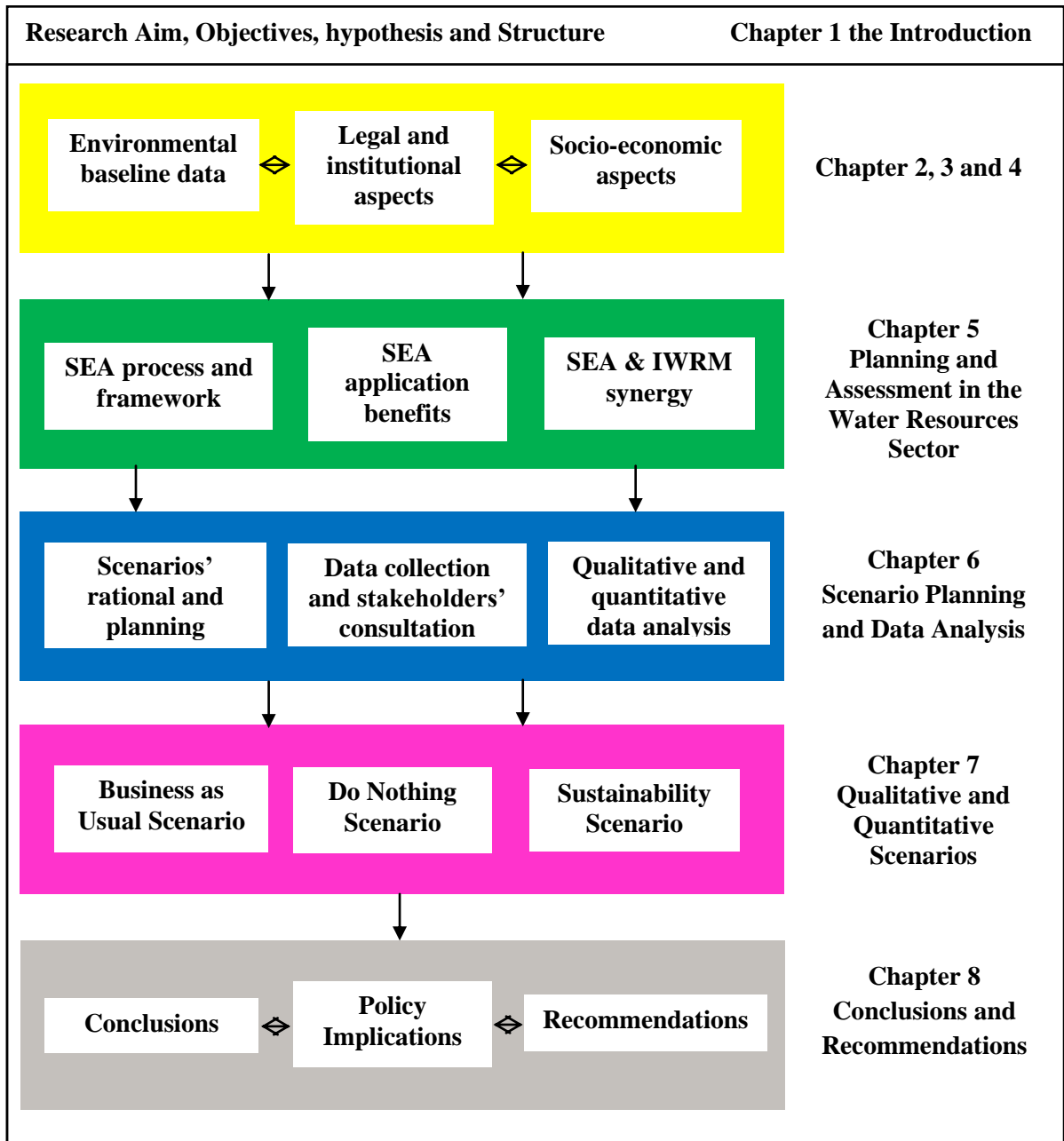


Figure 2: Structure of the dissertation

2. ENVIRONMENTAL ASPECTS OF WATER RESOURCES IN YEMEN: BASELINE DATA

This chapter provides baseline data on the existing environmental settings of water resources availability and consumption in Yemen. The chapter begins with a brief background to the geographic and climatic factors. This is followed by descriptions of the available surface and groundwater resources, including conventional and non-conventional water resources. Thereafter, the water demands of different sectors—namely, domestic, agricultural and industrial sectors—are presented. The main technical interventions that are used currently to augment and save water resources are highlighted at the end.

2.1 Introduction to Yemen

2.1.1 Geographic Location

The Republic of Yemen is located on the south-western corner of the Arabian Peninsula between latitudes 12° and 20° north of the Equator and between longitudes 41° and 54° east of Greenwich. Yemen has a total area estimated at 527,970 sq. km with about 2,500 km along the Red Sea, the Gulf of Aden and the Arabian Sea (Environmental Protection Authority [EPA], 2009).

Yemen is bordered by Saudi Arabia to the north, Oman to the east, the Arabian Sea and the Gulf of Aden to the south, and the Red Sea to the west as shown in Figure 3. The altitudinal range of Yemen extends from 0 m at sea level up to 3,760 m at Jebel Al-Nabi Shuaib, the highest point in the Arabian Peninsula (NIC, 2012a).

2.1.2 General Topography

Yemen has different geographical and climatological regions that can be divided into five main regions, as follows:

The Mountain Massif

The Mountain Massif, which is parallel to the Red Sea, separates the highland plains from the eastern deserts of the Arabian shield and from the Tihama plains in the west. It constitutes a high zone of highly irregular and dissected topography. The elevation ranges from a few hundred metres to 3,760 m above sea level. Accordingly, the climate varies from hot at lower elevations to cool at the highest altitudes.

The Mountain Massif is characterized by mountainous terraces and a temperate climate with monsoon rains. It stretches over parts of the governorates of Sana'a, Dhamar, Taiz, Ibb and Hajjah and areas of Dale'a and Mukairas. Rainfall ranges from 100-1,000 mm, except in the Ibb and Taiz areas, where the mean annual rainfall may range from 600-

1,000 mm. Within the Mountain Massifs, four sub-regions are identified: the highland plains, the southern slopes, the western slopes and the eastern slopes (MPWH, 2009).



Figure 3: Political map of Yemen
Source: The Nations Online Project, 2012

The Eastern Plateau

The Eastern Plateau covers the eastern half of the country including the Hadramout-Mahrah uplands and areas from Mareb, Aljouf and Shabwah. The climate is generally hot and dry in summer and cool in winter; the rainfall ranges from 60-100mm. Nevertheless, floods following rare rainfall may be devastating (Food and Agricultural Organization [FAO], 2007). Elevations range from 1,200 to 1,800 m at the main water divides to sea level in the southern plateau zone and 900 m in the north towards the Rub Al Khali desert (MPWH, 2009). The Eastern Plateau includes four sub-regions: the northern plateau zone, the southern plateau zone, the wadi Hadramout plateau and the al Ghaydah basin.

The Desert Regions

This includes parts of the northern areas of the country extending to Al-Rub-al-Khali (The Empty Quarter). The climate in these regions is generally dry. Rainfall ranges from

5-10 mm and temperatures range from 40°C to 45°C in summer and may drop to 20°C in winter. The desert regions include two main sub-regions, which are:

1- Ramalt as Sabatayn, a desert of a maximum of (E-W) 350 km (MPWH, 2009) that lies between the Yemen Mountain Massif and the Eastern Plateau. There is almost no rain and vegetation in this desert 'except along its margins where rivers bring water from adjacent mountain and upland zones' (FAO, 1997).

2- The Rub Al Khali (The Empty Quarter) extends between the northern part of the Mountain Massif and the northern part of the Eastern Plateau (MPWH, 2009). Because of the extremely dry conditions, the desert is inhospitable area that supports little economic activity.

The Coastal Plains

The plains are located in the west and south-west. However, some of the plains extend to the boundaries of Oman (MPWH, 2009). These flat slopes have a low elevation (less than 300 meters) above sea level. They have a hot climate and, generally, low to very low rainfall (< 50 mm/year). However, the plains are important agricultural lands (FAO, 1997). Four areas can be found in the Coastal Plains: the Tihama plain, the Tuban-Abyan plains, the Ahwar Maifa'ah plains and the Eastern Coastal plains.

The Islands

Yemen has more than 112 islands, most of which are situated in the Red Sea and the Arabian Sea. The largest and most populated island is Socotra in the Arabian Sea. Some other islands are scattered in the Red Sea, the largest of which are Kamaran, Great Hunish, Little Hunish, Zakar, Al-Zobair and Al-Tair (NIC, 2004) .

2.1.3 Climatic Factors

Yemen lies within the northern stretches of the tropical climatic zone and its border with the sub-tropical climatic zone. The great variations in temperature and climate over the different regions of the country are attributed to the extreme differences in elevation (MPWH, 2009).

Rainfall

Yemen receives an annual average of 50 to 60 billion cubic metres of rainfall (MWE, 2005). The rainfall varies from less than 50 mm in the coastal plains region and desert plateau region, to more than 1,200 mm in the western mountainous highland region. The highest and most consistent rainfall occurs in the southern highlands near the Ibb/Taiz area (MPWH, 2009). Rainfall occurs in two main seasons: the first season is during the spring season (March-May) and the second season is in the summer (July-September); however, there is more rainfall in the summer (EPA, 2004). Rainfall occurs mostly as a

single storm event per day; rain events are short, rarely extending beyond a few hours (MPWH, 2009). Precipitation ranges over agro-climatic zones are shown in Figure 4.

Considering the impact of climate change on precipitation, van der Gun (2009) states that world maps on projected precipitation differ depending on the models used to construct them. He concludes that there is no conclusive evidence of either an increase or a decrease in precipitation in Yemen.

Temperature

In general, Yemen has a semi-arid to arid climate with high temperatures throughout the year in low-altitude zones (FAO, 1997). Temperature, which depends on the elevation, has an annual mean that ranges from less than 12°C in the highlands (with occasional freezing) to 30°C in the coastal plains (EPA, 2004). Recorded temperatures may rise to 40°C during summer in the coastal plains region and to over 40°C in the desert plateau region. However, the winter temperature may fall below freezing in the highlands (MPWH, 2009).

Humidity

Humidity is high on the coastal plains and reaches more than 80%. However, it decreases toward the internal parts and reaches a minimum of around 15% in the desert areas (NIC, 2005).

Annex 2 shows the long term annual mean for main weather elements of selected cities.

Precipitation over the Agro-climatic zones in Yemen

الهطول المطري في النطاقات المناخية المختلفة للجمهورية اليمنية

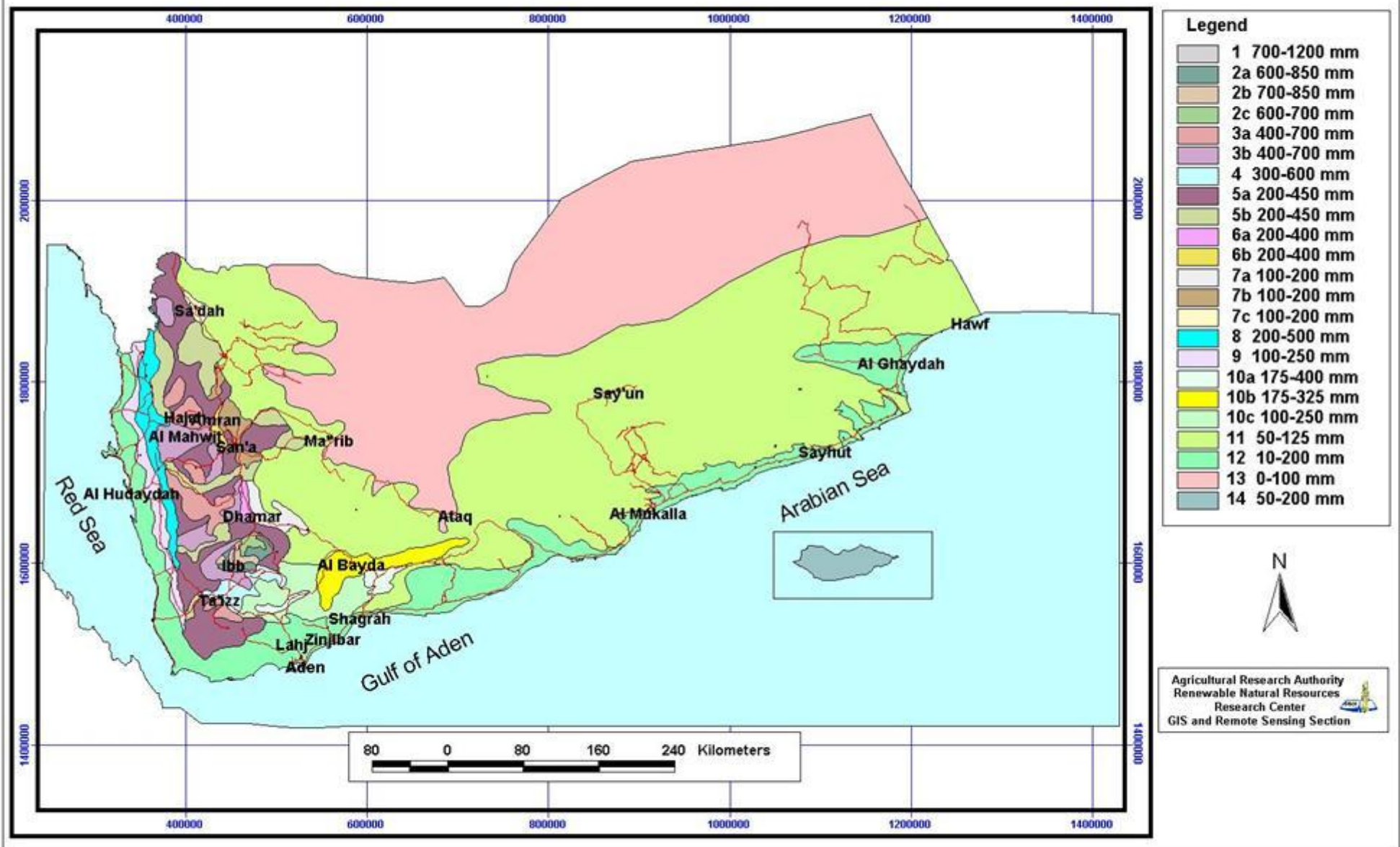


Figure 4: Precipitation over the agro-climatic zones in Yemen

Source: Yemen Water, 2013

2.2 Water Resources¹

Water has always been scarce in Yemen. The country has no permanent rivers and the average annual rainfall is 200 mm. This comes in irregular heavy torrents as mentioned by the National Water Resource Authority (NWRA, 2009).

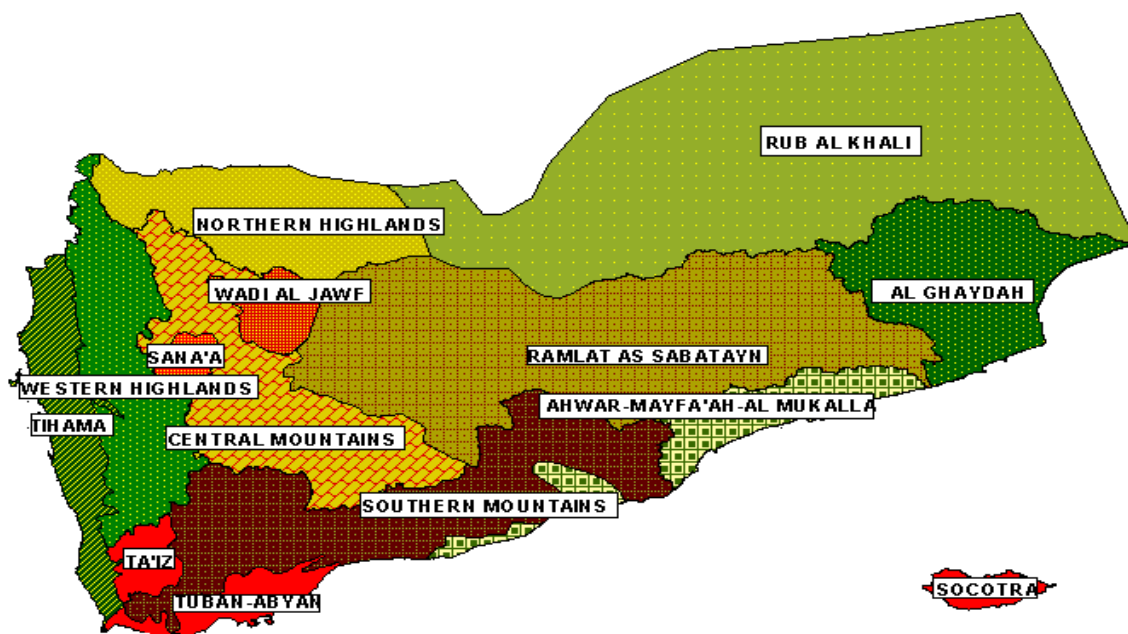


Figure 5: Water management regions in Yemen

Source: NWRA, 2008²

The Environment Protection Authority (EPA) (2006) mentions that rapid population growth has been causing per capita water availability to fall steadily from 1,098 cubic metres in 1955 to 460 cubic metres in 1990 to 137 cubic metres in 2003. It is projected to drop to 150 cubic metres by 2025 under the Business as Usual (BAU) scenarios of increased demand. Nevertheless, Hellegers et al. (2008) mention that per capita water availability had already decreased by 2005 to 120 m³/person/year to become one of the lowest in the world compared to 1,250 m³/person/year in the Middle East and North Africa (MENA) region and 7,500 m³/person/year worldwide. Water scarcity is more acute in the western part of the country (the area comprising the highlands, Tihana and the Arabian Sea region), which is home to 90% of the population; here, per capita availability is only 90 m³ (WB, 2006a). Atroosh (2007) and Noman (N.A) write that per capita water availability will decrease to 66 m³ by 2026 as shown in table 1.

¹ The water resources and consumption data mentioned in this section have been obtained from the National Water Resources Management and the Ministry of Water and Environment in year 2012. Nevertheless, these data may date back to year 2002, as the data has not been updated since. Therefore, data that are used in this section are the most updated available data.

² The map was obtained from the data base of the National Water Resources Authority.

Table 1: Per capita share of water

Year	m ³ /Year
1955	1098
1990	460
2003	137
2026	66

Source: Atroosh, 2007

2.2.1 Surface Water

Rainfall is the main source of surface water in the country. Although Yemen receives an annual average of 50 to 60 billion cubic metres of rainfall, the nature of rain bursts—most of which occur during the summer—cause most rainwater to be retained in the upper surface soil layers to be used directly by vegetation or to evaporate thereafter. Hence, it is practically impossible for runoff water to exceed 10% of rainfall water on average (3-6 billion cubic metres) (MWE, 2005).

Surface water constitutes 1.5 billion m³ of the 2.5 billion cubic metres of the annual renewable water (NWRA, 2002). According to Al-Asbahi (2007), surface water consists of seasonal spate water and springs, with differing quantity and quality depending on the area. FAO (1997) mentions that Yemen can be subdivided into four major drainage basins by regrouping the numerous smaller wadis (valleys):

- the Red Sea basin
- the Gulf of Aden basin
- the Arabian Sea basin
- the Rub Al Khali interior basin

The floods of the wadis in Yemen are generally characterized by abruptly rising peaks that rapidly recede. Between the irregular floods, the wadis are either dry or carry only minor base flows. Main continental watersheds, catchments' names and sizes, and average rainfall are mentioned in Annex 3.

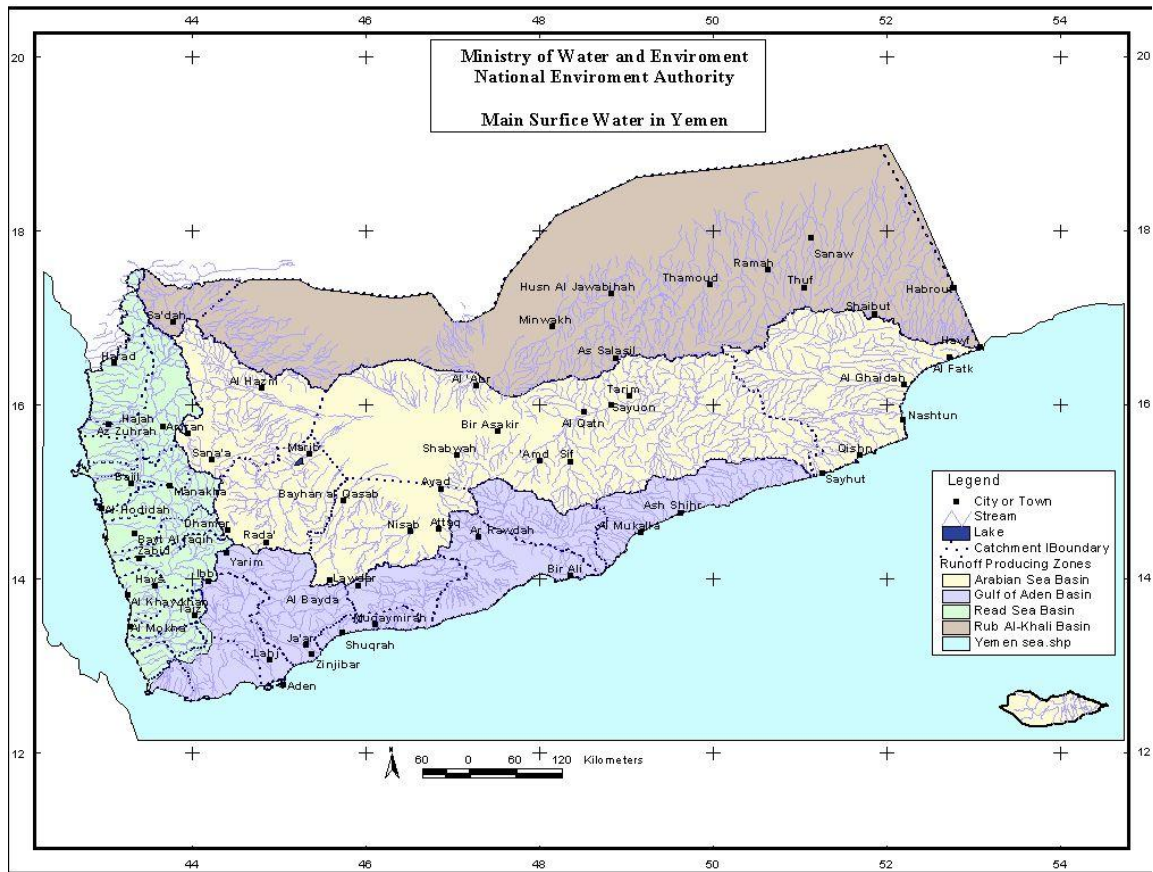


Figure 6: Surface water basins in Yemen
 Source: Environmental Protection Authority, 2012

Surface Water Harvesting

Historically, Yemen has been recognized for the magnificence of its ancient water engineering. The summit of hydraulic construction in ancient times is the Marib dam, the ruins of which evidence the broad engineering knowledge and construction abilities of the Yemenis of about the sixth century B.C (Hadden, 2012). According to Chanson (1999), the dam was built in the seventh century B.C. However, Marib dam is not the oldest irrigation structure in Yemen. Some ruins of irrigation structures dating from the middle of the third millennium B.C (some 4,000 years ago) were discovered around Marib city by a German archaeological team in 1982 and 1984 (Prinz, 1996).

At present, dams are considered the main solution for meeting increasing water demand and saving ground water. The increasing demand for water by different sectors is being met mainly by overconsumption of groundwater resources. In order to stop the overconsumption of ground water, the government has started interventions directed at maximizing the use of surface water resources, including the construction of dams. As the territory is formed mainly by wadis whose flows are characterized by temporal disparities, dams are seen nationally as a viable option to store water for use during droughts.

Dam water has multiple uses, such as for irrigation and domestic purposes. Nevertheless, dams may be constructed for recharging aquifers (Al-Asbahi, 2005) or for flood control (FAO, 1997).

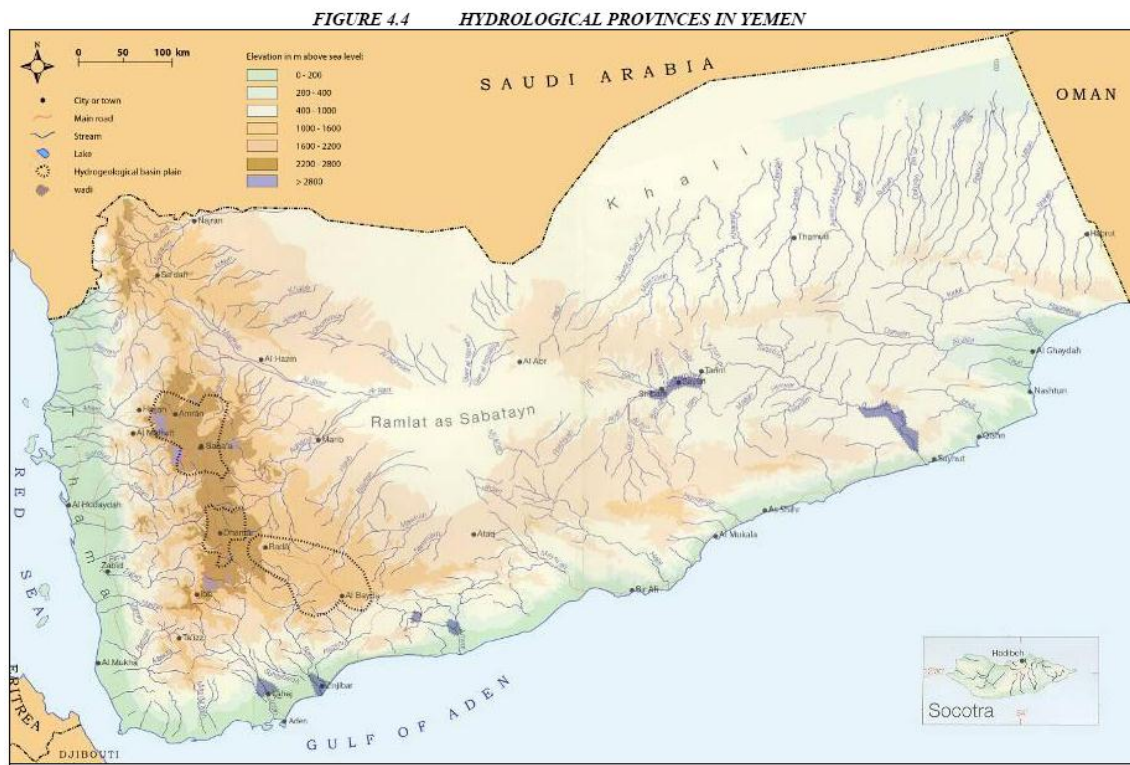


Figure 7: Hydrological provinces in Yemen
Source: MPWH, 2009

2.2.2 Groundwater Resources

Groundwater resources in Yemen are scarce and being exploited rapidly and unsustainably. Ground water constitutes about one billion m³ of the 2.5 billion cubic metres of the annual renewable water (NWRA, 2002). With no significant perennial sources of surface water, Yemen relies almost exclusively on the exploitation of ground water (WB, 2006b). While the total demand is estimated to be 3.4 billion cubic metres, the 900 million cubic metres deficit is covered from deep aquifers (MWE, 2008 & Al-Asbahi, 2005). On an average, the depletion rate in Yemen is about 138% of the replenishment rate; however, in some critical aquifers, it varies between 250% and 400% (MWE, 2008).

Ground water is mainly consumed by the agriculture sector and rapid groundwater depletion is attributed to the expansion of irrigated agriculture. NWRA (2009) mentions that the irrigated area has expanded from 37,000 hectares (ha) in 1970 to more than 500,000 ha in 2005. This expansion, which depends mostly on ground water has led to rapid decreases in water levels in most of the basins (between 0.5-7metres annually) and to the drying up of the majority of dug wells. MWE (2008) mentions the need to improve the spate water irrigation system in order to reduce the dependence on ground water for irrigating agricultural fields. With the increasing rate of rural groundwater abstraction, the World Bank (2006b) states that

the estimated number of agricultural wells is about 50,000; these cause groundwater levels to fall throughout Yemen, particularly in heavily populated areas.

Groundwater resources in Yemen are subdivided into 18 groundwater basins (Hübschen, 2011). Highly productive aquifers exist along the coast in alluvial-filled wadis, and in the fans and deltas created by the continuous process of flooding and sedimentation. Important aquifers exist in the Tihama plain, Tuban Abyan, Ahwar, and Mai'ah in the south, in Ramlat-as-Sagatayn in the west and south, and in the wadi Hadramout. In the highland plains, there are important sedimentary aquifers in Sadah, Amran, Sana'a, the Ma'bar-Dhamar plain and the Rada Basins. In the east are the Mukalla sandstones, which constitute the largest aquifer complex in Yemen with moderate productivity that continues into Saudi Arabia and Oman (FAO, 2009a). Main aquifer systems with estimates of recharge, abstraction rates and groundwater storage are listed in Table 2.

Table 2: Main aquifer systems and their recharge estimates

Aquifer	Recharge (in MCM/yr)	Withdrawals (in MCM/yr)	Storage (in MCM)
Tihama Quaternary	550	810	250,000
Southern Coastal Plains	375	225	70,000
Extended Mukalla Complex	500	575	10,000,000
Highland Plains	100	500	50,000

Source: van der Gun and Ahmed, 1995

According to NWRA (2009), over-extraction of ground water has been resulting in deteriorating quality of the ground water; seawater intrusion is taking place in most of the coastal aquifers. It explains that over-extraction of ground water is supported by different factors, which are summarized in the following:

Technological factors

- Introduction of new technologies empowers us to extract water faster than the rate of replenishment
- Drilling technology and pumps
- Inefficient use—particularly in the agricultural sector
- Random drilling of wells
- There are about 381 drilling companies, with about 656 drilling rigs

Social factors

- Population growth
- Absence of effective awareness
- Absence of correct implementation of groundwater use right
- Process of privatisation in the southern Yemen

Economic and financial factors

- Subsidy on diesel fuel and lending interest rates

- No pricing policy—water is free for agriculture
- Cropping patterns are guided by market signs
- Low water tariffs

Institutional and legal factors

- Difficulties in enforcement of water laws and by-laws
- Slow and difficult implementation of legislations and regulations

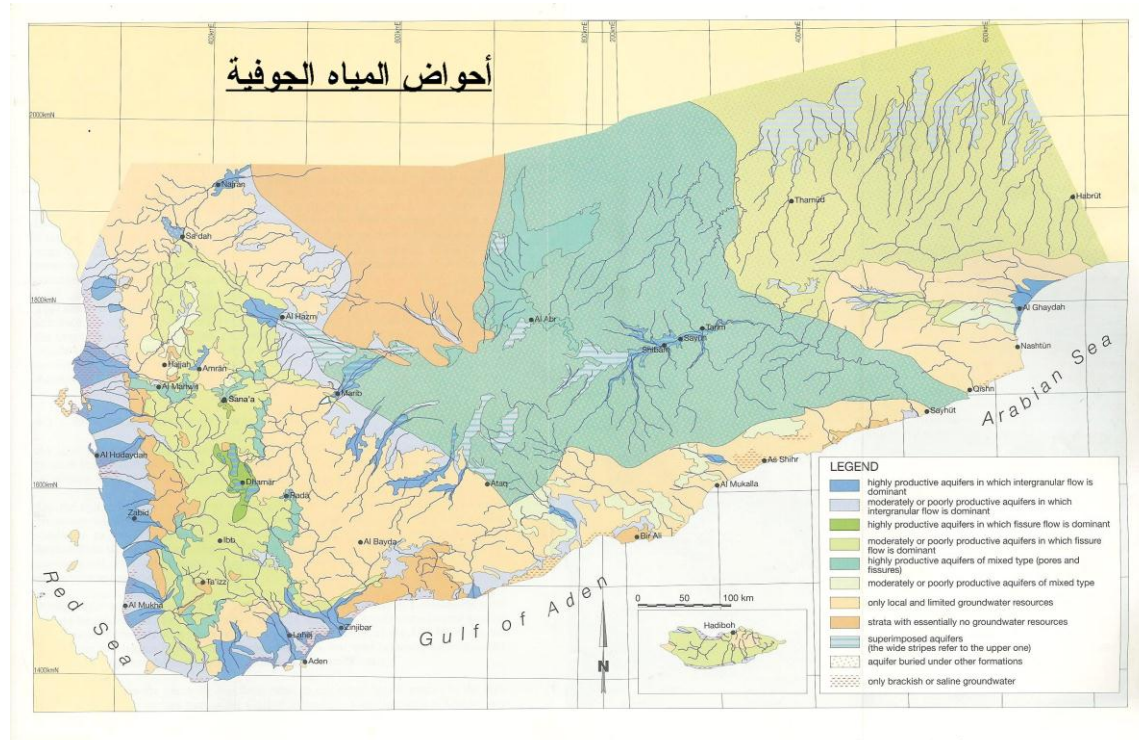


Figure 8: Schematic hydrological map of Yemen
Source: NWRA, 2009

2.2.3 Non-Conventional Water Resources

Wastewater

In addition to using conventional water resources, Yemen tries to make use of non-conventional resources such as wastewater. In 2007, as Hübschen (2011) mentions, 17 wastewater treatment plants were in operation in the country with a total annual capacity of about 110 million cubic metres. She explains that the plants were running at 75% of their total design capacity. These treatment plants are concentrated in the capitals of the governorates and in some secondary cities. Despite the fast growth of these cities, the capacity of the plants has not increased (FAO, 2009b). This is evidenced by the amount of generated wastewater compared to the treated wastewater. According to FAO (2013), the total generated wastewater in 2000 was 74 million cubic meters (MCM) while the treated water was 46 MCM and only 6 MCM was used in irrigation. Taking into consideration the abundant amount of untreated wastewater and the rapid increase of population, these factors make treated wastewater a potential resource for augmenting water resources in irrigation.

Desalination

Desalinated water in Yemen contributes a minor percentage to water resources. According to Hübschen (2011), desalination currently forms only 0.3% of water resources and comes from desalination plants in Aden and Hudeyda.

The minor contribution of desalination to water resources in the country can be explained by the fact that most of the Yemeni population lives at high elevations of more than a mile above sea level; this makes pumping desalinated drinking water prohibitively expensive (Alterman and Dziuban, 2010). Nevertheless, in cities with critical water basin conditions—e.g. Taiz city, which has access to the sea—desalination projects must be implemented as a potential water resource for domestic use (Saba, 2012a). Even for the capital city of Sana’a, which is located 2,200 m above sea level, the water basin is in a critical situation. TREC (2006) claims that saving Sana’a by constructing a water pipeline providing desalinated water is preferable to relocating its population. Nevertheless, expecting cost recovery of the unit price of desalinated water, especially if it were transferred to a mountainous area, is wishful thinking (Al-Asbahi, 2005. In: Hübschen, 2011).

2.3 Water Demand

Water demand in Yemen has been increasing drastically. The consumption sectors are the agriculture, domestic and industrial sectors. The following sections present the water consumption per sector. Table 3 shows water consumption by different sectors.

Table 3: Use of water by consuming sectors (in MCM/year)

Water Use	1990	2000	2005	2010
Agriculture/Irrigation	2,700	3,060	3,235	3,328
Domestic/Urban/Rural	201	272	265	552
Industrial and Mining	31	68	65	90
Total	2932	3400	3565	3970

Source: FAO, 20133

2.3.1 Agriculture

Yemen has 55 million ha of land, only 3% of which is arable (NIC, 2012b). The actual cultivated area is 2.5%, which is 1.4 million ha (Ministry of Agriculture and Irrigation [MAI], 2012a).

The agriculture sector, including the irrigation and livestock sub-sectors, is the biggest consumer of water in Yemen. It uses about 90% of water resources in the country (MAI,

³ Data on sectoral water demand has been collected from the National Water Resource Authority (NWRA), but these data cover only the period from 2000-2010. As NWRA data are identical to the data in the FAO database, FAO data are presented in table (2) as they cover a longer period.

2012a; FAO, 2008; MWE, 2005) as shown in Table 4. With an average irrigation efficiency estimated between 35% and 40% (MAI, 2011), water consumption in the irrigation sector is increasing continuously at an average rate of 30 MCM/year or 5% per year, which means that if expansion were to continue, the overdraft would reach 200% by 2025—although many aquifers would have been pumped dry before then (MWE, 2008).

Table 4: Agricultural water consumption from 1990 to 2010

Sub-sector	1990	1998	2000	2005	2010
Irrigation	2,675	2,896	2,958	3,119	3,224
Livestock	25	29	30	33	37
Total	2700	2925	2988	3152	3261

Source: Ministry of Agriculture and Irrigation (MAI), 2010b

Use of groundwater resources for irrigation has been increasing rapidly. While a large part of the cultivated area is still rain-fed, which explains the fluctuating number of total cultivated area from year to year, irrigated area has increased more than 10 times since 1970 (Table 5) as ground water is a more reliable resource compared to surface water resources. As a result, groundwater resources have been decreasing drastically as mentioned in Section 2.2.2. While groundwater resources are being used for irrigating different types of agriculture, a considerable share of groundwater goes to the irrigation of qat (*Catha edulis*) as will be explained in Section 2.4.3.

Table 5: Total cropped area and system of irrigation for selected years from 1970 to 2011

Systems of Irrigation	Unit	Situation in 1970	Situation in 2007	Situation in 2009	Situation in 2011
Total Cropped Area	Ha	1,290,000	1,484,852	1,306,376	1,411,929
Groundwater-Irrigated Areas	Ha	37,000	453,616	365,897	409,460
Spate-Irrigated Areas	Ha	120,000	147,602	235,219	240,028
Rain-fed Areas	Ha	1,056,000	752,823	614,185	663,607
Spring-Irrigated Areas	Ha	73,000	29,492	33,976	38,112

Source: Adapted from the Ministry of Agriculture and Irrigation (MAI), 2010b and 2012a.

2.3.2. Domestic Use

Driven mainly by the increasing population, the share of water consumed for domestic purposes has been increasing consistently. The percentage of water used for domestic purposes was relatively low compared with agriculture (8% compared to 90% respectively) in 2005 (MWE, 2008). Table 3 shows water demand by the domestic sector since 1990. This percentage is expected to increase further over the years. The 232 MCM consumed in this

sector in year 2000 is expected to increase to 16.3% (758 MCM) in 2025 as Table 6 shows (NWRA, 2002).

Urban Water

In urban areas where 28.7% of the population lives (CSO, 2010), the daily per capita water consumption differs from one area to another depending on the availability of water in the public water supply network and the local climate of the area, mainly temperature. For an example showing the influence of these two factors on water consumption in urban areas, consider the cities of Taiz and Aden. The Ministry of Water and Environment (2009) mentions that in Taiz—where the water basin is heavily depleted—the average consumption through the public water network in 2009 was 21 litres per capita per day (lpcd). However, in the coastal city of Aden, the average value for the same year was 99 lpcd. The daily per capita consumption in other urban areas varies between the extreme values mentioned above, making the average national per capita water consumption stand at 62 lpcd in 2009 (MWE, 2009). The average per capita share of water in urban areas is shown in Annex 4.

Furthermore, there is considerable water loss in urban areas. According to MWE (2008), the operational efficiency of the Local Water Supply and Sanitation Corporations (LWSSCs) is low and the proportion of non-revenue water (system loss, illegal connections, etc.) is quite high—around 35% to 40% in most of the utilities.

Rural Water

For rural areas, where 71.2% of the population lives (CSO, 2010), there is no available detailed data on per capita water consumption. While the National Water Resources Authority (NWRA, 2002) mentions that the average per capita water consumption is 20 litres per day, the General Authority for Rural Water Supply Projects (GARWSP) adopts an average per capita water consumption of 40 litres per day (JICA, 2007).

2.3.3 Industrial Use

Water demand in the industrial sector is considered the lowest compared to the domestic and agricultural sectors as Table 3 shows. According to MWE (2008), the industrial sector consumes 2% (68 MCM) of the total water consumption in Yemen compared to the agricultural and domestic sectors, which consume 90% and 8% respectively.

Nevertheless, the NWRA (2002) estimates that the share of water consumption by the industrial sector will increase to 6.5% of the total demand (300 MCM) by 2025, as shown in Table 6.

Estimated Future Water Demand

The NWRA (2002) provides estimations for future sectoral and total water demand until 2025 as shown in Table 6.

Table 6: Water demand and deficit in 2000 and 2025

Water Use	2000	2025
Agriculture/Irrigation	3100	3550
Domestic/Urban/Rural	232	758
Industrial and Mining	68	300
Total	3400	4628 ⁴
Deficit	900	2128

Sources: NWRA, 2002

2.4 Technical Interventions to Augment and Save Water Resources

The previous sections mention conventional and non-conventional water resources in Yemen. According to the NWRA (2002), future projections of the water balance until 2025 (Table 6) based on water resources and increasing water demand will result in increasing water deficit. In the following section, alternatives for augmenting and saving water resources are presented. The alternatives explained below includes those that are mentioned in ‘Yemen’s Strategic Vision 2025’. The following section highlights these alternatives and presents their current implementation status as well as their future potential.

2.4.1 Modern Irrigation Systems

As a response to the increasing demand for water by groundwater-irrigated agriculture, which was 409,460 ha in 2011 (MAI, 2012a), and considering the low efficiency in the agriculture sector of 35-40 % (MAI, 2011), the Yemeni government has been supporting the introduction of modern irrigation systems to increase irrigation efficiency and consequently reduce groundwater depletion by the agriculture sector.

Modern irrigation systems that are provided include conveyance systems using a closed piping network to convey and distribute the irrigation water up to the field without any losses to replace traditional open water conveyance channels. Modern irrigation systems that are supported also include localized irrigation systems—i.e. the drip, bubbler and sprinkler systems.

The use of modern irrigation systems improves irrigation efficiency remarkably. According to the MAI (2010b), a conveyance system increases irrigation efficiency to over 60%. The use of a localized on-farm irrigation system increases the overall efficiency to 80-90 %.

In order to achieve such an increase in irrigation efficiency in irrigated agriculture, the government has been supporting the introduction and installation of modern irrigation systems through several projects as shown in Table 7.

⁴ When calculating the sum of sectoral demands, a difference of 20 MCM is noticed between the resulting total and what is mentioned in the table. Nevertheless, the values are retained as they appear in the references.

Table 7: Area covered by modern irrigation systems by different projects

Project	Conveyance Systems in Hectare	On-farm Systems in Hectare	Implementation Period in Years
Groundwater and Soil Conservation Project (GSCP)	30489	1132	5
Land and Water Conservation Project (LWCP)	14754	59	8
Agriculture and Fisheries Production Promotion Fund (AFPPF)	10500		10
Sana'a Basin Water Management Project (SBWMP)	3048	1685	4
Total	58791	2876	

Sources: MAI, 2010b; WB, 2010a; MAI, 2005; MAI, 2004

MAI (2010b) mentions that, generally, 1,483 m³/ha and 4,285 m³/ha can be taken as the average potential maximum groundwater savings from pipe conveyance and localized on-farm systems, respectively. It also explains that the major savings in groundwater irrigation resulted from localized systems that can save as much as 34% of pumping requirements

Even though water savings are influenced by many factors, such as the temperature of the area where the irrigation systems are installed and crop needs, improved irrigation systems can cover the entire area where irrigated agriculture is practiced in Yemen.

Thus, there is great potential for achieving groundwater savings by increasing irrigation efficiency through modern irrigation systems. This is obvious considering that only 14% of the irrigated area is covered by conveyance systems and only 1% of irrigated area is covered by on-farm systems—namely, drip, bubbler and sprinkler—as MAI (2011) asserts and as shown in Table 7. Therefore, MAI (2011) recommends preparing a plan that covers the entire groundwater-irrigated area with improved irrigation systems within the next 10-15 years.

Although more water savings is achieved through localized on-farm systems, Table 7 shows that the total area equipped with conveyance systems is considerably larger than the area covered equipped with localized on-farm systems. MAI (2010b) explains that farmers are more attracted to invest in conveyance systems than in localized on-farm irrigation systems for many reasons. The most important of these reasons include the initial investment for the conveyance systems, which represents only about 15-20% of the investment costs in localized on-farm irrigation. Moreover, the subsidy given to small farms to acquire conveyance systems is higher than the subsidy for localized on-farm irrigation systems. Therefore, and in order to encourage more farmers to adopt localized on-farm systems and subsequently save more ground water, MAI (2011) recommends increasing the subsidy level on localized on-farm irrigation systems such that they are comparable or higher than the subsidy level granted to farmers for the installation of the piped conveyance system.

Increasing irrigation efficiency by modern irrigation systems has still not reached its complete potential as only a small part of the 409,460 ha of irrigated area is covered with modern irrigation systems as shown in Table 7. MAI (2010b) concludes, nevertheless, that modern irrigation for irrigated land is not a permanent solution to the water deficit problem confronting Yemen; even by covering the entire groundwater-irrigated area with improved irrigation systems, the country will not be able to meet the water demand of the growing population. However, it is necessary to investigate how this alternative, in combination with other alternatives, helps decrease the total water deficit.

2.4.2 Water Augmentation by Dams

As mentioned in Section 2.2.1, dams in Yemen have a long history of being a major solution to meeting peoples' demand for water for different uses. In its efforts to meet the increasing demand for water, the government has been supporting the establishment of dams.

Dams in Yemen vary in height and storage capacity, but almost all dams in Yemen are small dams⁵. Except for the reservoir behind the Ma'rib dam with a capacity of 400 MCM, which provides water irrigation for an area of 10,000 hectare, there are no large bodies of surface water in the country (Bamatraf in Al-Hemiary, 2000). Bamatraf (in Prinz 1996) indicates that the government has been developing small dams for storing runoff since the beginning of the 1980s. According to MAI (2010a), there are 1,351 water structures in Yemen, of which 523 are dams, 656 are tanks and 133 are canals. The total capacity of dams in Yemen is 138 MCM^{6 7}.

Nevertheless, there is still a great potential for water harvesting using dams. The MWE (2005) mentions that Yemen receives an annual average of 50 to 60 billion cubic metres of rainfall. It also mentions that the nature of rain bursts, most of which occur during the summer, cause most rainwater to be retained in the surface soil layers to be used directly by vegetation, or to evaporate thereafter; hence, it is practically impossible for runoff water to exceed 10% of rainfall water on average (3-6 billion cubic meters). Therefore, considering this average amount of runoff and the water currently harvested by dams—about 137 MCM—one can concluded that water harvesting by dams still has great potential in Yemen.

Considerations for Building Dams

Yemen is a country where water-harvesting structures are constructed in wadis, which form the geographical structure of the country. The construction of dams in a wadi system is

⁵ Dams are classified according to their capacities to the following scales (World Bank, 2008):

Large dam: reservoir capacity > or = 100 million cubic meters

Medium dam: 100 million cubic meters > reservoir capacity > or = 10 million cubic meters

Small dam: reservoir capacity < 10 million cubic meters

⁶ Based on the head of Supervision Division in the Irrigation Structure Directorate of the Ministry of Agriculture and Irrigation.

⁷ This amount of water does not include water retained by Marib dam.

always accompanied by some problems that may lead to deterioration of the structure or of the water quality in the structure. Some of these constraints are mentioned below.

Water Irregularity and Quantity Disparities

Benbiba (2002) states that water flow in the wadi system is characterized by important temporal disparities. He adds that these irregularities and disparities result in either periods of drought that last for several years or heavy flusher rainfalls that can cause sudden floods resulting in human and material damage. Sudden floods can be explained by the nature of flows in a wadi. Al-Eryani (1996) explains that flows in a wadi are flashy as water levels rise very quickly in response to rainstorms and then recede within a limited time.

Water Pollution and Quality Deterioration

Water-harvesting structures in Yemen are always constructed in wadis. However, the quality of the water that reaches these structures can deteriorate, thereby impacting human health and restricting the usage of water. According to Benbiba (2002 p.113), the main sources of pollution in wadi catchments, *inter alia*, include:

- domestic and industrial waste water, which are most often discharged without any pre-treatment,
- domestic and industrial solid waste discharged without any pre-treatment, and
- eutrophication of reservoirs.

Erosion and Siltation of Dam Reservoirs

Sediment transport is a major practical issue in considering the sustainability of surface water management, whether for floods or water resources (Wheater and Al-Weshah, 2002). In situations where erosion and sediment transport are not controlled effectively, the upshot is rapid loss of reservoir capacity behind impoundment structures (Ackers and Thompson, 1987; Reid et al., 1998b in Al-Hamid and Reid, 2002). In arid and semiarid countries, nature of soil and land-use density in a wadi affect the erosion process and limit development of water resources (Benbiba, 2002). Therefore, soil erosion and sediments should be considered in technical studies when designing dams. Arrangements for maintaining dam structures should be put in place as an integral part of dam operation to ensure sustainable function— i.e. maintaining the total capacity of the dam.

Evaporation

The predominantly arid to semiarid climate that Yemen has, which reflects itself in the form of high temperatures, makes evaporation from water bodies of dams one of the main concerns that should be considered when designing and selecting the location of dams. According to Noman (N.A), mean annual temperature ranges from less than 12°C in the highlands to 30°C in the costal plains. During summer, recorded temperatures may rise to 40°C in the coastal plains and to over 40 °C in the desert plateau region (MPWH, 2009).

2.4.3 Replacing Qat (*Catha edulis*) Agriculture

Qat, a mildly narcotic plant profusely cultivated in Yemen, impacts on water and land resources. Qat produces natural stimulants when its leaves are chewed. It plays a major economic role in the Yemeni economy as it accounts for around 6% of GDP, 10% of consumption and a-third of agricultural GDP (WB, 2007). Qat agriculture has replaced food crops, such as coffee, fruits, and vegetables that otherwise could have been consumed or exported. Cultivation of qat has increased by more than 20 times since 1970; 162,584 ha of agricultural land is now being used to cultivate qat, a crop that does not contribute towards achieving food security (MAI, 2009).

Table 8: Main cropped areas for selected years for the period 1970-2011

	Unit	Situation in 1970	Situation in 2007	Situation in 2009	Situation in 2011
Total Cropped Area	Ha	1,290,000	1,484,852	1,306,376	1,411,929
Qat Areas	Ha	8,000	141,000	154,000	162,584
Areas under Cereal Crops	Ha	1,082,000	890,633	677,725	784,844
Areas under Irrigated Fruits & Vegetables	Ha	39,000	169,884	181,878	174,784
Fodder Crops	Ha	40,000	147,007	163,002	155,248

Source: Adapted from Ministry of Agriculture and Irrigation (2010b & 2012a)

This increase in the qat-cultivating area has also spurred a rapid increase in the limited water resources allocated to qat. According to Muharram (2008), qat consumes 8500 m³/ha⁸ at an irrigation efficiency of 75%—average irrigation efficiency in Yemen is about 20-40% (Al-Eryani, 2011). The MWE (2008) mentions that qat agriculture consumes 33%⁹ of ground water. Table 9 shows qat agricultural area and water consumption in the main governorates producing qat.

In the context of searching for potential alternatives to qat agriculture, published studies mention potential crops that can replace qat. Grapes, almonds, peaches, mangoes and prickly pears are the leading potential qat alternatives depending on the agro-climatic area according to Muharram (2008). He explains that coffee and mango agriculture can be encouraged in warm valleys while grapes and peaches are potential competitors for qat in the highland plains.

⁸ According to Muharram (2010), qat water requirements increase up to 12,000 m³/ha in the Sana'a area. The MAI (2010) mentions that the water requirement for qat irrigation is 11.970 m³/ha.

⁹ The International Food Policy Research Institute (2011) mentions that qat production uses between 40-50% of agriculture water while cereal agriculture consumes only 10% of irrigation water despite Yemen's high cereal import dependency.

Table 9: Area covered by qat and the most cultivated crops at the governorate level

Governorate	Qat cultivated area (ha)	1 st most cultivated crop	Area (ha)	2 nd most cultivated crop	Area (ha)
Sana'a	41,131	Grape	10,421	Almond	5,413
Amran	21,711	Grape	657	Peach	250
Dhamar	15,163	Potato	6,826	Tomato	3,209
Hajjah	14,798	Mango	12,104	Coffee	2,763
Ibb	14,156	Potato	6,523	Coffee	1,083
Taiz	12,603	Onion	8,533	Mango	968
AL-Beida	9,381	Onion	713	Potato	419
Sadah	7,283	Grape	975	Pomegranate	1,813
AL-Mahwit	6,128	Coffee	3,416	Banana	466
AL-Daleh	5,156	Tomato	83	Kurrat	26
Abyan	2,989	Cotton	4,519	Sesame	4,091
Raimeh	2,729	Coffee	7,700	Banana	286
Mareb	783	Orange	4,576	Tomato	2,285
Hodiedah	388	Cotton	12,113	Mango	10,951
Shabwa	107	Sesame	1,733	Tomato	513

Source: Compiled from the Agricultural Statistical Year Book, MAI, 2012a

Regarding the economic returns of qat alternatives, FAO (2008) explains that grapes are more profitable than qat in the Amran governorate while coffee is more profitable in Al-Dhaleh and offers equal returns in Dhamar, Hajjah and Al-Mahweet. Their water needs are shown in table 10. In addition, Muharram (2008) explains that in areas where qat still offers higher returns than coffee and grapes, using modern irrigation systems that help to save water and increase agricultural productivity can increase the economic returns of coffee and grapes to a level that makes them strong competitors to qat.

Table 10: Crops and their water needs under modern irrigation systems

Crop	Water Need (m ³ /ha)	Governorate
Almond	4,608	Sana'a
Coffee	11,723–11,301	Mahweet- Sana'a
Grape	5,017	Sana'a
Peach	5,223-4,703	Amran-Sana'a
Tomato	5,280	Sana'a
Potato	4,343	Amran

Source: GSCP, 2010

In the southern plains, water needs differ due to differences in agro-climatic conditions. For example, while onion consumes an average 5,500 m³/ha (Al-Ghori, 2009) and potato consumes up to 6,788 m³/ha (Al-Hakimi, 2003), other crops like mango and banana may consume higher amounts of water. The water needs for some crops in the southern plain are shown in Table 11.

Table 11: Water needs of selected crops in the southern plain

Crop	Water Need (m ³ /ha)
Cotton	6500
Tomato	6000
Watermelon	6000
Banana	22000
Mango	13600

Source: Al-Maktari and Haidara, 2006

Despite the high economic returns of qat agriculture¹⁰, some initiatives for replacing qat with other crops have been implemented successfully. The considerable amount of water that qat agriculture consumes, as well as other socio-economic impacts of qat consumption and agriculture, enhance awareness about the need to replace qat agriculture.

The government, local communities and the private sector currently support several initiatives to replace qat with other crops. For example, the MAI supports initiatives implemented by local communities in Bani Maymon in the Amran governorate where qat was replaced by almonds (Saba, 2012b), in Haraz in the Sana'a governorate, where qat was replaced with coffee, mango and almond (WB, 2010a), and more recently, in the Dhamar governorate, where 1,900 plants of qat were replaced with coffee seedlings (Sep.26, 2013). Regarding initiatives supported by the private sector, WB (2010a) mentions that a businessman in Haraz has been supporting a coffee project that has replaced 30,000 qat plants

¹⁰ According to Muharram (2008), studies and surveys implemented on production systems in which qat and other crops are cultivated, indicate variability of economic returns. While some studies indicate that qat has more economic returns, most of these studies show that some crops compete with qat in terms of net revenue, production costs, efficiency of water units or in terms of labour use.

since. It mentions that the project provides farmers with financial assistance for replacing qat and buys produced coffee at a high price from farmers to sell it outside Yemen.

The Strategic Foresight Group (2010) mentions that a campaign called ‘Environment and Planting’ in the Ibb governorate replaced 3,800 acres (about 1537 hectare) of qat with 2,500 mango trees. It also mentions that a major initiative launched in the Haraz region in 2006 continues to assist an unprecedented number of farmers in replacing qat with coffee, which resulted in the removal of 250,000 qat plants in Eastern Haraz. The region is likely to be free of qat by 2020.

Qat impacts water resources, but it also has economic, social and environmental dimensions that complicate dealing with the qat ‘phenomenon’ within the water and agriculture sectors. Some social and political-economy aspects of qat cultivation are mentioned in Chapter 4.

2.4.4 Wastewater Treatment

The amount of generated wastewater is increasing constantly. Figures from the year 2000 show that 74 MCM of wastewater was generated (FAO, 2009b). In 2009, the collected wastewater was 136 MCM (FAO, 2013), a reflection of increasing domestic water use and the potential of this non-conventional resource in future.

Given that the current Yemeni population of about 23 million is growing rapidly and is expected to reach 35 million in 2025, the potential of reusing wastewater is promising, particularly in the main cities. This is especially true in big cities and towns where wastewater treatment plants already operate and their capacity can be extended to treat more domestic wastewater. The Food and Agriculture Organization (FAO) provides examples of the overloading of some existing wastewater treatment plants; the wastewater is treated insufficiently and results in poor quality water that is unsuitable for irrigation. According to FAO (2009), the wastewater treatment plant in the capital city of Sana’a was designed to treat 25,000 m³/day of wastewater, but now receives more than 50,000 m³/day. Similarly, in Ibb city, the wastewater treatment plant was designed to receive 5,000 m³/day, but now receives more than 10,000 m³/day. These examples show that wastewater can contribute considerable amounts of water for irrigation.

While the quality of treated wastewater is highly variable from one area to another (Al-Asbahi, 2005), a large fraction of wastewater effluents is disposed of in wadis (valleys) and subsequently used for irrigation of cropped lands without treatment (Choukr-Allah, 2010). If wastewater is to be used on a large-scale in irrigation, it should be treated properly according to existing national standards.

2.5 The Conclusion

Yemen is water scarce even as the increasing demand for water depletes its existing water resources. The increasing demand, which is mainly from the irrigation sector, has led to overexploitation of ground water as the only reliable resource in the country. While water resources continue to be depleted, considerable amounts of water are being wasted due to low irrigation efficiency or the insufficient development of surface water. The non-food narcotic crop of qat continues to consume a considerable share of ground water that could have been used to irrigate other crops.

There is some progress in implementing interventions for augmenting and saving water resources, but the progress varies from one alternative to another. While the governments have been supporting some alternatives for decades—e.g. surface water harvesting using dams—other alternatives have been introduced in later stages—e.g. the use of modern irrigation systems for agriculture and re-using treated wastewater in irrigation. The alternative of replacing qat with other crops, although it offers great potential for saving water resources, is still applied as pilots. Nevertheless, what all these alternatives have in common is that none of them have been utilized to its full potential yet. Although most studies on water resources balance confirm that the water deficit will continue, investigation into the combined contribution of the abovementioned four alternatives for reducing water deficit has not been made yet.

3. INSTITUTIONAL AND LEGAL ASPECTS OF WATER RESOURCES MANAGEMENT IN YEMEN

Institutional aspects including organizational and legal aspects play a determinant role in organizing, supporting and monitoring water resources. This chapter highlights the institutional and legal aspects of water resources in Yemen. The chapter begins by presenting the organizational structure of the water sector, before going on to provide a brief description of the institutions responsible for the planning, management and development of water resources, including non-governmental organizations. Thereafter, legal aspects related to water resources are explained, including laws and traditional norms. As agriculture is the biggest consumer of water resources in Yemen, legal and organizational aspects related to the agriculture sector and to water resources management are highlighted. The chapter ends with recommendations for improving the institutional aspects of water resources planning and management in Yemen.

3.1 Institutional Aspects

3.1.1 Administrative and Organizational Structure

Public Institutions

Throughout history, Yemenis have successfully managed their limited water resources within local communities. Ward (2000) mentions that until the 1960s, water management was recognizably similar to that described in the medieval almanacs wherein the management of springs, spate flows and watersheds was a local affair with evolved systems of rights and responsibilities.

In the 1970s, while aiming at developing the rural areas, the government supported the modernisation of the agricultural sector by supporting water resource development. This was a turning point in terms of water resource exploitation. The growth of irrigated agriculture has drastically increased the demand for water (IOB, 2008) in the absence of governmental control over depleting resources. Negenman T. (1997) states that it was only in 1981 that the government first attempted to introduce water resources management and control (through the establishment of the 'High Water Council) after water resources studies confirmed rapid depletion of groundwater resources. He adds that after assigning the responsibility of managing water resources to the Ministry of Agriculture and Water Resources in 1990, the National Water Resources Authority (NWRA) was established in 1995 with far-reaching authority and mandate for becoming operational, after reaching a consensus on the need to create an authority that is separated from the water users. ESCWA (2007) mentions that the consolidation of water resources management functions under one authority (NWRA) was the first activity in the reform of the water sector in 1995. ESCWA (2007) explains that the government started the reform in the water sector urged by challenges to manage groundwater abstraction that exceeded the safe yield, to fulfil the increasing water demands in all water-using sectors, and to improve low water use efficiency, groundwater quality and inadequate institutional capacities. Political awareness in the water sector as a whole, and in

water management in particular, was reflected by the establishment of the Ministry of Water and Environment in 2003, which gave the water sector representation at the Cabinet level (Al-Harithi, 2009). Most of the water agencies and institutions were transferred to the MWE. It is important to mention that the Ministry of Agriculture and Irrigation (MAI) remains responsible for irrigation, which uses about 90% of the available water (MAI 2012b, CES 2008, Al-Asbahi 2005).

The Ministry of Water and Environment (MWE)

The MWE was established in 2003 to end the previous institutional de-fragmentation (Al-Asbahi, 2005). Various governmental organisations in the water sector came under the purview of the MWE; however, irrigation and watershed management remained outside MWE's ambit (WB, 2005a, CES 2008, Al-Asbahi 2005). The MWE is generally responsible for sector investment planning and the coordination between all water sector agencies (Abuzaid, n.d). According to Ward et al. (2007) four public agencies report to the MWE with different mandates: the National Water Resources Authority (NWRA) for planning, monitoring and regulation of water resources; the National Water and Sanitation Authority (NWSA) for overseeing urban water supply and sanitation and providing service delivery in secondary towns; the General Authority for Rural Water Supply Projects (GARWSP) for overseeing rural water supply and sanitation, and implementing a large share of public investment in rural water; and the Environmental Protection Authority (EPA) for environmental supervision and proposing environmental regulation. Urban water in major towns is the responsibility of quasi-autonomous utilities, the Local Corporations (LCs).

The National Water Resources Authority (NWRA)

The National Water Resources Authority (NWRA) was established under presidential decree no 154/1996. The establishment of NWRA consolidated water resources management functions under one authority (ESCWA, 2007). NWRA is responsible for water resources planning and monitoring, legislation and public awareness (Al-Asbahi, 2005). CES (2008) mentions that the water law of 2002 and its amendments in 2006 as well as various government resolutions have strengthened NWRA's institutional role over time. Al-Harithi (2009) mentions that some roles and responsibilities of NWRA were transferred to MWE as the NWRA establishment had been approved before the establishment of MWE. These included responsibilities related to policies, strategies and plans for water resources management. Nevertheless, following the creation of the Ministry of Water and Environment (MWE), NWRA received powerful responsibilities in 2003. NWRA currently discharges the following functions as CES (2008) mentions:

- Framing and coordinating appropriate policy measures, with relevant water sector institutions and donors.
- Exploring and analysing technical options available for more efficient use and conservation of water resources throughout the country with emphasis on local community participation.
- Implementing water laws and facilitating water usage through license or registration and enforcement measures.

- Mobilising and building up public support and awareness for a sustainable water management regime.

Under NWRA, projects work on the basin level to promote aspects of sustainable management of water resources, including supporting the introduction of the modern irrigation system, increasing the recharge of shallow groundwater aquifers and the establishment of WUAs—e.g. the Sana'a Basin Water Management Project. With only five branches in the governorates besides its headquarters, Al-Asbahi (2005) believes that the NWRA is under capacity building stage.

The Ministry of Agriculture and Irrigation (MAI)

The MAI is a key player in the water sector. This is because irrigation water, which forms more than 90% of total water consumption, is controlled by MAI's Irrigation and Land Reclamation Sectors. The WB (2005a) explains that the General Directorate for Irrigation (GDI)—now restructured as the General Directorate for Irrigation Structures and the General Directorate for On-farm Irrigation—in the MAI is responsible for dams and providing support to groundwater irrigation while decentralised units manage major spate schemes and the Forestry Department is responsible for watershed management.

Ward et al. (2007) indicate that the Agricultural Research and Extension Authority (AREA), which is responsible for research and technology transfer in irrigated agriculture, reports to MAI. Ward et al. add that the MAI executes the program of the Agriculture and Fisheries Production Promotion Fund (AFPPF), which invests in sustainable pro-poor agriculture and fisheries. MWE (2008) indicates that AFPPF, in recent years, has begun to review its structure and activities; it has also begun to allocate a growing share of its financing to support irrigation improvement, which is expected to be at least 20% of its fund. MWE (2008) also mentions that MAI has decided to set up a National Irrigation Programme (NIP) as the best institutional and financial model that delivers efficiency and water-saving improvements at the farm level. Besides the AFPPF, a main project under the MAI that promotes sustainable water management including water savings and irrigation efficiency increase at the farm level is the Groundwater and Soil Conservation Project.

Other Ministries Involved in the Water Sector

According to CES (2008) and Ward et al. (2007), four ministries have key involvement in the water sector. These ministries are:

- Ministry of Planning and International Cooperation (MoPIC), which is responsible for investment planning and programming, sustainable development and poverty reduction.
- Ministry of Finance (MoF), which is responsible for budgeting and investment resource allocation, subsidies and trade policy, regulation of diesel price and the like.
- Ministry of Local Administration (MoLA), oversees decentralisation and local authorities, and supports implementation of the Water Law at the local level; and

- Ministry of Interior (MoI), which is responsible for law enforcement, including that of the Water Law.

Challenges of Existing Organisational Structure for Managing Water Resources

The institutional and organisational structure of the water sector has been developing over the last three decades—starting from the 1980s, when the Supreme Water Council was established, then the creation of the Water Resources Authority in 1995 and ending with the establishment of the MWE with a representation in the cabinet. These phases of organisational change in the water sector reflected increasing concern over the country’s water resources. They have resulted in further institutional improvement in water resources management on both the national and local levels.

Challenges are caused by the current organisational structure for managing water resources. The first challenge is dealing with the fragmentation of water controlling responsibilities between the MWE and the MAI. The MWE through the NWRA is responsible for the planning and monitoring of water resources in the whole country, while irrigation water, which accounts for 90% of the total water consumption in the country (MAI, 2012b), is controlled by the Ministry of Agriculture and Irrigation. According to the MWE (2008), the government has considered institutionalising the cooperation between MAI and MWE, and determining the most appropriate division of responsibilities between the two ministries since the creation of the Ministry of Water and Environment. The Inter Ministerial Steering Committee (IMSC) and the Program Management Committee (PMC) are expected to serve as the prime means of coordination between MAI and MWE. Nonetheless, this situation necessitates establishing an institutional structure that ends this fragmentation. Solutions may include gathering all responsibilities of controlling water in the whole country under one institution.

Another challenge is the lack of separation of institutions responsible for policy making, and water resource planning, allocation, management and monitoring from other institutions that are considered water ‘polluters’ as their functions include responsibilities for supporting water resource development and use. If this separation is not achieved, each concerned party may support projects or allocations of water resources according to functional interests, without concern for the source of supply or the soundness of investments and projects (Solanes and Gonzalez-Villarreal, 1999).

The Social Fund for Development (SFD)

The Social Fund for Development (SFD) is a major national public sector institution that was established by Law No. 10 of 1997 (SFD, 2007). It contributes towards achieving and aligning its programs with the goals of the national, social and economic development plans for poverty reduction (DPPRs). SFD is a multi-donor fund including contributions from the Yemeni government. Through the ‘Community and Local Development Program’, SFD contributes to improving the access of poor communities to basic services including water. SFD activities in the water sector include providing drinking water for domestic use. In the

agriculture sector, SFD interventions include implementing rainwater-harvesting projects, small dams and surface and groundwater irrigation systems (SFD, 2012).

Water User Organisations

The Dublin Principles of IWRM promotes the involvement of local communities in managing and making decisions about their water resources at the lowest appropriate level (GWP, 2012a; IWMI, 2009; UNDP, 2009). In Yemen, where the formal governance structures are weak, management approaches have to be cooperative rather than controlling (Ward et al., 2007). The need to involve local communities in the management of and decision-making regarding water resources through WUAs is needed even more for achieving sustainability of these resources.

WUA is constituted by consolidating Water User Groups (WUGs) in a well-defined territorial area and is registered under Law No. (39) of 1998 dealing with Cooperative Associations and Societies. In 2008, the number of WUAs reached 100 and included 967 WUGs (MWE, 2008). While CES (2007) states that an officially recognized village or well-field WUA is a prerequisite for participation in a irrigation improvement program, Bonzanigo and Borgia (2009) mention that WUAs are often established in anticipation of getting access to government or donor support. Nevertheless, Bruns and Taher (2009) confirm that traditional institutions for managing surface irrigation water continue to work relatively well and should not be disturbed by external intervention.

Ward et al. (2007) differentiate between four types of WU organisations as follows:

- *Water management WUAs* being piloted by NWRA and are being trained to carry out local level water management tasks including awareness, water monitoring and preparation for water conservation programmes.
- *Irrigation WUGs*, which are promoted for both surface and groundwater management and which are responsible for operation and maintenance at the tertiary canal level. WUGs are also formed where investments are around a common well.
- *Rural water supply WUAs*, which have long existed to manage community-based schemes, and which are now actively promoted under public or NGO projects.
- *Full service WUAs* are yet to be piloted in discrete water management areas. Irrigation farmers in these WUAs will be responsible for sustainable management of the water resource.

As WUAs are promoted particularly under donor-financed projects and mainly by the NWRA and the MAI (Ward et al., 2007), Steenbergen et al. (2011) state that, at present and in almost all cases, the engagement between the government and WUAs ends with project closure. This makes longer-term sustainability questionable according to Bruns and Taher (2009). They also indicate that the representation of WUO federations (including WUAs) in water management decisions at the sub-basin level and above are not yet well developed. Nevertheless, they conclude that WUAs should be developed from the bottom-up, with genuine representation in decision-making. This will improve water governance at the local

and sub-basin levels for sustainable local water management. Steenbergen et al. (2011) emphasize the need to encourage WUAs to play long-lasting roles.

Factors Support WUAs

WUAs are being promoted and seen as the basic unit for community-based sustainable management of water resources. Ward et al. (2007) mentions that WUAs are embryonic ‘water management agencies’ that set their own rules—e.g. WUAs that organize well drilling, well deepening and number of pumping hours. They mention that WUAs may face some risks, such as going too fast and overloading. On the other hand, other factors help WUAs to function successfully and sustainably. Arguing that sustainability depends on the ability to survive using local resources, Bruns and Taher (2009) believe that WUOs (including WUAs) need to diversify in forms that suit local needs and circumstances, and deliver services that members want and are willing to contribute to. They believe that WUAs should link ‘horizontally’ with local councils for resources and enforcement, and ‘vertically’ with higher-level organisations for funding, advice, enforcement and other support.

Ward et al. (2007) stress the importance of improving governance and the regulatory environment in order to help WUAs to work better and have higher chances of becoming ‘water managers’. They quote the Chairman of the Agriculture Committee of Parliament who observed, ‘WUAs alone cannot control water management. Enforcement and monitoring and supervision are required from NWRA and MWE. The police and attorney general’s office need to be involved... solid cooperation is required from Security... and support from the local councils.’

Private Sector

In the water sector, private sector involvement is mainly limited to supplying water. According to CES (2008), private water suppliers sell drinking water by tankers or in bottles. This is a vital supplement to the erratic and inadequate public supply, and private piped schemes exist in some places but usually on a small scale. CES adds that in both urban and rural areas, farmers and ex-farmers sell water for both agricultural and domestic use. Atroosh (2005) mentions that private companies play a major role in supplying the market with equipment for water extraction and use—e.g. pumps and irrigation systems.

3.1.2 Decentralisation

Decentralisation in Yemen is legally founded by the issuance of the Local Authority law nr. 4 of 2000 (MOLA, 2007). In the water sector, the legal framework of authorities and corporations affiliated to the MWE depend on law no.35 for 1991 concerning public authorities, corporation and companies (Al-Harithi, 2009).

As the NWRA is the authority responsible for water resource planning and monitoring, legislation and public awareness (Al-Asbahi, 2005), decentralisation of water resources

planning and management will be explained while highlighting NWRA's role and achievements in this regard.

In water resources management and after the issuance of the Water Law nr.33 of 2002, NWRA has supported the decentralisation of water resources management, which includes water resources management at the basin level through the establishment of NWRA branches at the governorate level, water basin committees and preparation of a water resources management plan (GIZ, 2012). In the ongoing decentralisation programme of NWRA, the following main steps have been taken:

- a) Several branches have been established. NWRA branches in Taiz, Sana'a and Aden are fully staffed and effective, However, the decentralisation remains incomplete in terms of empowerment (MWE, 2008).
- b) From 14 water basins into which Yemen has been divided by NWRA, only five committees have been established in Sana'a, Taiz, Sa'ada, Tuban and Abyan (MWE, 2008), whereas the aim is to establish 14 basin committees as the chairman of the NWRA mentioned (Ward et al 2007). While these committees are in charge to implement basin action plans, the MWE (2008) mentions that they are not fully empowered to implement the plans due to limited political will in enforcing laws and limitation in capacity and maturity of the organisations.
- c) Basin plans, according to the MWE (2008), have been prepared for three basins— i.e. Sana'a, Taiz and Sa'ada—and are in preparation for Amran, Hadramawt, Tehama and Tuban-Abyan.
- d) Governmental authorities and donor organisations have promoted and supported the establishment of WUAs. These are seen as a main step in decentralisation towards enhancing local water resources management as explained earlier in this chapter.

The NWRA's potential at the local level has been shown through the most successful initiative of delegation of responsibilities to branches as Ward et al (2007) confirm. Al-Harithi (2009) mentions the strengths of decentralisation by NWRA as follows:

- Enhance juridical role for drilling wells
- Divide Yemen into basins to promote the participation of local stakeholders
- Donor interests to decentralize WRM at basin levels
- Promote Water User Associations to handle water issues at their areas
- Capacity building for local authorities and basin management committees to apply water law

Nevertheless, Ward et al. (2007) mention some of the limitations to NWRA's initiative to delegate responsibilities to branches. Such limitations include the small operating budget for branches, centralized finances and too many decisions that are still handled centrally, all of which limit the potential of branches at the local level and impede NWRA's initiative through 'incomplete decentralisations'. Other weaknesses of the NWRA branches are summarized by Al-Harithi (2009) in the following:

- No juridical powers and capacities for applying water law provisions
- No clear coordination mechanisms with involved stakeholders (Local Authorities, governmental agencies, NGOs)

- Water scarcity and deterioration of water quality
- Weak coordination with MAI for WRM in the agriculture sector
- Weak capacities of branches hinders regional planning
- Limited technical and financial resources

Decentralisation by the NWRA has also contributed to creating a positive impact on water governance. Ward et al. (2007) explain that decentralized water management, the stakeholder partnership approach and secure water rights show ‘promising signs’ indicating improvement in water governance on any scale that this approach is implemented. Such signs, they add, include the beginning of regulation and a growing WUA movement, fledgling basin committees and plans, and increased awareness and cooperation among the population. Nevertheless, Ward et al. (2007) believe that the current pace of change at the local level is extremely slow, and more resources and a long-term commitment are essential.

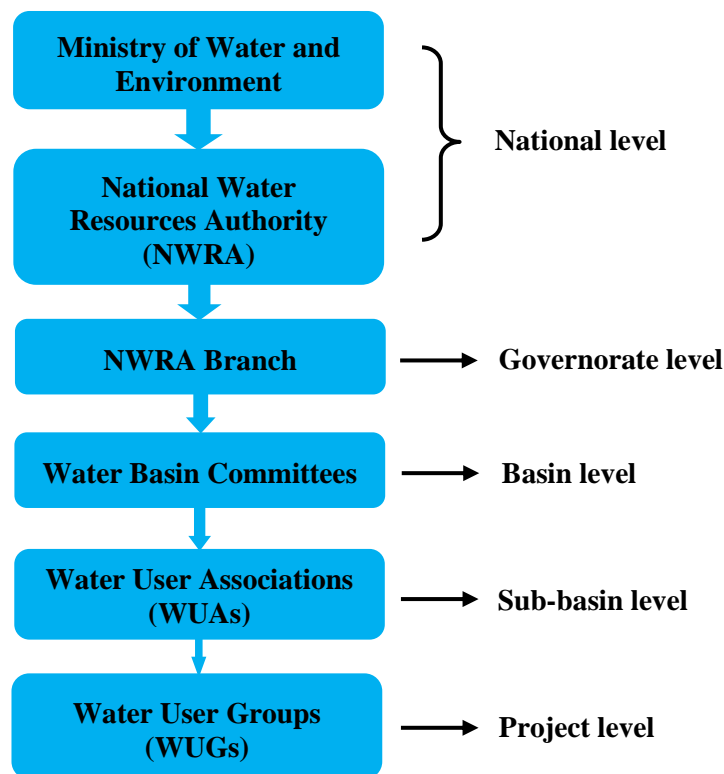


Figure 9: Decentralization levels of water resource planning and management in Yemen
Source: the Author

3.2 Legal Framework of Water Resources Management

The development and use of water resources management in Yemen is organized by several legislations. According to Al-Shaibani (2009), all these legislations and laws come from three closely-related sources. These are: a) Islamic Law (or Sharia’ah); b) legislations: the constitution, laws and regulations; and c) customary law (or ‘urf).

3.2.1 Islamic Law

Islamic law (shari'ah) is the source of all legislations, as the constitution provides in Article (3). Although a formal Water Law exists, in practice, Islamic and customary principles of water management are the most relevant (LANDAC, 2012). According to Faruqui et al. (In: Wickström, 2010) water ownership in Islam can be categorized into one of the following three categories:

- Private ownership: water exists in personal containers, treatment plants, distribution systems or reservoirs, and the owner in this case has the right to use, sell or trade it.
- Restricted ownership: water exists in restricted private property, i.e. on land that includes lakes, streams and springs. In this case, the owner has special rights and can trade water within these limits, but also has certain obligations towards others.
- Public property: water in rivers, lakes, glaciers, aquifers and seas, and from snow and rainfall, which is water in its natural state. In this case, it is public property and cannot be bought or sold. However, the water becomes private property if infrastructure and knowledge have been invested in withdrawing it.

Ward (2009) summarizes some of the principles of Islamic law (Shari'a) affecting water and accepted in Yemen are:

- Water is mubah or 'the property of no one'. However, those who develop it can appropriate the usufruct.
- Upstream riparians have priority: al 'ala fa al 'ala.
- Water may not be alienated from the land.
- Wells must be spaced a certain distance apart, outside a 'protection zone' or harim (Rule 58 in the Document of Seventy Rules).
- No one can deny a person drinking water—'the right of thirst'.

3.2.2 Yemeni National Legislations

- The Constitution of 1994 and its amendments of 2001
- Water Law nr.33 of 2002 and its amendments of 2006

A) The Constitution of the Republic of Yemen

The constitution provides that natural resources—including surface and underground water—are state owned or communal property as per Article (8), which states, 'All types of natural resources and sources of energy, whether above ground, underground, in territorial waters, on the continental shelf or the exclusive economic zone are owned by the State, which assure their exploitation for the common good of the people' (The Republic of Yemen, 2012).

B) The Water Law

The primary civil law governing water resources development, management and use is the Water Law nr. 33 of 2002 and its amendments in Water Law nr. 41 of 2006.

Richards (2002) thinks that the water law covers the issues expected in water resources management legislation. Morill and Simas (2009) believe that the law reflects modern water principles and attempts to address country-specific issues. They explain that the law provides a licensing regime to control drilling and classify drilling operators, and provisions to control the equipment used in drilling wells. Nevertheless, Morill and Simas (2009) mention that almost the entire focus of the law is on the specifics of water rights administration.

As the research aims at assessing and enhancing sustainability of water resources, the following highlights aspects in the water law that are directly related to the aims of this research.

Ownership & Water Rights

The water law confirms instructions of Islamic law in permitting the right of all to access water. Private ownership is possessed only 'by means of conveyance or acquisition or within their rule' as per article 4. The water law in article 28-29 maintains traditional acquired water rights associated with groundwater use from springs, streams and wells, and the rights of utilisation of harvest of rains and water flowing naturally in connection with agricultural lands benefiting from it. The law provides that these rights shall be maintained given that water use remains for its initial purpose.

In this context, it is mentionable that the water law prescribes well licensing through the NWRA, but the Yemen Civil Law grants the landowners the right to exploit whatever water may exist underground (Heun and Vulto 2008).

Water Allocation

The law gives absolute priority to drinking water in article 20. Article 21 provides other uses for which water shall be allocated. This includes water for animals, public utilities, irrigation, industry and environment.

Stakeholder and Public Participation in Water Resources Management

The water law in article 3 mentions among its targets the involvement of stakeholders and local communities in the development, management and maintenance of water facilities. In article 11, the law provides entitlement for the Ministry of Water and Environment to propose the establishment of basins' committees, leaving the determination of tasks and responsibilities of the basin committees to the by-law. Article 10 mentions that 'Societies or groups or committees or associations or federations for water beneficiaries and users, may be formed for the purpose of which is to involve the community and beneficiaries of water in organising the water resources or operating and maintain their installation'. The water law also leaves the rules and purpose of such functions to be set out by the by-law to be issued.

On public participation in Water Resources Management, the law provides in article 48 that the MWE shall 'encourage public efforts in participating in the management and conservation of water resources'.

Decentralisation

The water law in article 11 supports the decentralisation of water resources planning and management by encouraging the formation of basin committees and requiring close working with the Local Councils in implementing water management measures.

Sustainability

The water law and its amendments focus on water resources management. The law promotes the sustainable use of water, protects water resources from overexploitation and balances the water needs of various communities and sectors according to FAO (2008). Given that sustainable water management is achieved through the application of ‘good practice’ principles, it is relevant to provide the result of the assessment of the water law nr. 33 of 2002. In this assessment, Richards (2002) compared the law against key principles of international best practices in water resources management, which are:

- Water as an economic good;
- Statement of ownership of water;
- Catchment management approach;
- User or stakeholder participation;
- Equity in resource allocation;
- Sustainability of resource; and
- Polluter pays.

The law includes provisions on the catchment management approach, user or stakeholder participation and polluter pays. However, it remains neutral with respect to the sustainability of the resource as the law, according to Richards (2002). It includes provisions on sector allocations, but on other provisions aims at improving efficiency of water use, rather than on limiting abstractions. The assessment shows that the law does not satisfy the principles of ‘water as an economic good’ as the law provides for charges levied only specifically for registration of water rights and abstraction for ‘commercial’ use. Richards (2002) finds that the law does include ‘statement of ownership of water’ keeping water a ‘right accessible to all’. As the law provisions give preferences to traditional and common water rights, which may not be equitable, Richards (2002) claims that the law does not satisfy the principle of ‘equity in resource allocation’.

Water Law and Alternatives of Water Saving and Resource Augmenting

The research assesses policies for augmenting water resources and achieving more water savings through the implementation of certain interventions—namely, re-using treated wastewater, using modern irrigation techniques, water augmentation using dams and qat agriculture replacement. The following section highlights the provisions of the water law regarding the use of these alternatives and the responsibility of disseminating them.

Water Quality and Reusing Treated Wastewater

The law authorizes the MWE and its associate authorities to plan and manage the supply and sewerage sector and prepare plans to utilize the water sector in the best possible way. The law in article 26 states that ‘the Ministry of Water and Environment and its associate agencies and institutions, whether in the urban or rural areas, shall organize, manage and rationalize water uses assigned for the water supply and sewerage sector in the water plan and in the light of the water general strategies and polices in a manner consistent with the local administration law’.

The law in article 26 provides that the ‘Ministry of Water and Environment shall prepare policies and executive plans related to the water and sanitation sector in a manner that secures the best utilisation of the sector’s water share assigned for it in the water plan’. It provides that the treated wastewater can be used for irrigation, in coordination with the Ministry of Agriculture and Irrigation, or for any other purposes in compliance with technical, health and environmental specifications. In article 26, the law states that the Ministry of Water and Environment shall ‘take into consideration coordination with the Ministry of Agricultural and Irrigation, the local authority and other relevant agencies about the best methods to use treated wastewater for irrigation and other purposes in accordance with the technical, health and environmental specifications and guidelines’.

As provided in article 23 of the law, water quality should be in compliance with standards set by the NWRA for water use in drinking, domestic, agriculture and food and pharmaceutical industrial production. It also provides in the same articles that water quality should comply with standards when re-using treated wastewater for irrigation or other purposes.

Using Modern Irrigation Techniques

While the law in article 25 provides that the MAI is responsible for the operation and maintenance of irrigation facilities as well as for the organisation, rationalisation and guidance of water uses assigned for irrigation, the law states that the MAI shall ‘take actions intended to rationalize water uses to increase the productivity of water used for agricultural crops and to encourage modern irrigation techniques in accordance with the economic feasibility thereof, adaptation with the water shares specified for irrigation purposes of conservation of water and environment protection’. In article 48, the law provides that the state, the MWE and other relevant agencies shall assist in providing necessary support and facilities to farmers and encourage them to use modern irrigation techniques and technologies.

Structures for Water Augmentation

Provisions of the law maintain traditional rights of utilisation from the harvest of rains in connection with the agricultural land benefiting from it. In article 28, the law states that ‘traditional rights of utilisation from the harvest of rains and water of floods flowing naturally shall be taken into consideration, as regards their use for irrigation and connection with the agricultural land benefiting from it’.

While the law in article 25 provides that the Ministry of Agriculture and Irrigation is responsible for the operation and maintenance of irrigation facilities, the law states in article 48 that the MWE and other relevant agencies shall ‘erect water dams, dikes, cisterns and structures that are necessary for rain water harvesting in order to maximize the benefit from rainfall and floods in replenishing underground water’. It also provides in article 48 that ‘it is allowed for a natural or corporate person to contribute in the establishment of water facilities for the purpose of irrigation in a way that is not in contradiction with the Ministry of Agriculture and Irrigation’.

Implementation of the Law

Whilst the aim of the law is stated clearly, there is no clear institutional framework within which the provisions of the water law will be exercised. In a significant number of areas, detailed consideration of how the law will be implemented, and by whom is unclear and was left for the promulgation of by-law as Richards (2002) mentions. He also explains that that mechanisms for implementing the law—e.g. for stakeholder participation in WRM—the responsibilities of Water Basin Committees are left to the by-law. Richards (2002) adds that the lack of a water by-law makes assessing the implementability of the law and its effectiveness difficult. According to Heun and Vulto (2008), the long process of bylaw preparation indicates the complexity of the matter.

The law provides for several issues related to water resources planning, allocation, management and use. A main manifestation of the water law implementation in Yemen is to control the depleting ground water. As explained in Chapter 1, most of the ground water is consumed for agriculture; therefore, the water law provides for controlling water resources deterioration in general and groundwater depletion in particular. While the law provides for the establishment of a wells’ licensing system administrated by NWRA and provides for controlling well drillers, in practice, the effects have been negligible because sheikhs and other traditional community leaders who are the only actors with effective control over water use are closely implicated in agrarian patronage and political representation structures (WB, 2007a).

3.3 Sectoral Policies and Strategies

3.3.1 Water Resources Sector Policies and Strategies

The water resources sector features a number of policies and strategies, most notably:

- National Water Sector Strategy and Investment Program (NWSSIP) 2005-2009
- National Water Sector Strategy and Investment Program (NWSSIP) 2010-2014
- National Water Policy (2001)
- Water Resources Policy and Strategy (2000-1999)

All water-related policies and strategies in Yemen call for sustainable management of water resources and the utilisation of water in a proper rationalised manner (Al-Asbahi, 2005). The following sections highlight the main policies and strategies in the water resources sector.

The National Water Sector Strategy and Investment Program (NWSSIP) 2005-2009 & 2010-2014

After the establishment of the MWE in 2003, the ministry prepared a consolidated strategy, action plan and investment programme for the water sector as a whole, which is the National Water Sector Strategy and Investment Program 2005-2009 (MWE, 2005). NWSSIP sets strategic directions for governmental interventions and investments in the water sector; donors perceive NWSSIP as the guiding document for improved donor harmonisation and alignment with government priorities and policies (CEDARE, 2005). The following section highlights NWSSIP targets, achievements and its latest developments. More focus is given to water resources management and irrigation water.

The process of preparing, reviewing and monitoring NWSSIP forms a common ground for the stakeholders of the main water sector. MWE (2008) explains that the process provides a common framework for planning, financing, implementation and monitoring as well as a point of reference and a forum for stakeholders to maintain continuous dialogue through the Joint Annual Reviews (JARs). According to the WB (2005a), the approach and process employed to prepare NWSSIP included many positive innovations, notably a long-term, integrated approach and an inclusive process.

NWSSIP (2005-2009) was adopted and published by the government in 2004. The aim of the strategy was recovering control over groundwater resources and moving Yemen towards the Millennium Development Goal (MDG) targets for water supply and sanitation (MWE, 2008).

NWSSIP comprises five themes: water resources management, urban water supply and sanitation, rural water supply and sanitation, irrigation and watershed management and human and environmental aspects, which are divided into four main sub-sector strategies as shown below.

Besides elements that are related to urban and rural water service, key elements of NWSSIP that are related to water resources management include: strengthening the institutional basis for regulating water rights and using a decentralized partnership approach to water management at the basin and local levels; supporting water user associations as the basic building blocks of water management at the lowest level; and investing in irrigation modernisation and the use of economic instruments for demand management (MWE, 2008).

According to MWE (2008), the implementation of NWSSIP (2005-2009) is described as considerable, although uneven across the sub-sectors as shown below. With regard to water resources management, MWE (2008) explains that there has been progress in strengthening the institutional framework for integrated water resource management (IWRM) although decentralisation to the basin and local levels is yet to be completed. It also mentions that more basin plans and committees and measures to support local-level water management are progressively being put in place but need more authority and resources. The MWE (2008) mentions that the NWRA continues to face challenges in implementation capacity, which results in limited impacts on the ground. The MWE (2008) concludes that there is little

evidence of a beneficial impact on the water balance so far, although there is evidence of localized reduction in groundwater use where farmers have collaborated in modernising their irrigation systems.

In the irrigation and watershed management sub-sector, the MWE (2008) mentions that progress had been made in terms investing in creating water user associations and in water saving for both groundwater and spate irrigation; however, scaling up is proceeding slowly. The MWE (2008) gives an example from 2007, when the government's program for irrigation modernisation covered 6,800 ha of piped conveyance and about 700 ha equipped with modern irrigation (drip, bubbler, sprinkler)—out of a total groundwater-irrigated area of about 450,000 ha—due to limited budgets. Also in 2007, MAI constructed 36 new dams and rehabilitated 21 existing dams (MWE, 2008). Regarding coordinating efforts between the MWE and MAI, it mentions that cooperation has improved between the MAI with the MWE and the NWRA. However, the challenge remains at the local and basin levels and with regard to linking water saving in agriculture with efforts to create the institutional basis for local water management and brining irrigation user associations within the local water resources management framework.

In urban water supply and sanitation, there has been progress on the same track of reform started in 1997 (MWE, 2008). While the NWSSIP target is to provide services to more than four million inhabitants in urban areas and to more than five million inhabitants in rural areas by 2015 (MWE, 2005), water supply coverage has increased from 2.4 million urban residents (47% of the total urban population) in 2002 to 3.6 million (56% of the increased urban population) in 2007. Sanitation coverage has increased from 1.3 million urban residents (25% of the total) in 2002 to 2.0 million, which is 31% of the (increased) total in 2007 (MWE, 2008).

In the rural water supply and sanitation sub-sector there have been considerable gains in rural safe water coverage. This has increased from 25% in 2003 to 44% by the end of 2007, while sanitation coverage lagged with an increase from 20% to just 21% over the same period. Institutional reform is being implemented with improvements in agency performance, particularly in the GARWSP. Some progress has been made in decentralisation, the demand responsive approach and user responsibility. Progress has also been achieved in aligning institutional approaches and technologies with the joint programming of interventions by main public agencies working in rural water supply and sanitation—namely, the General Authority for Rural Water Supply Projects, the Public Works Project, the Social Fund for Development, and the Rural Water Supply and Sanitation Project. MWE (2008) mentions that water resources are a growing problem, as groundwater depletion increases costs and threatens the sustainability of schemes.

NWSSIP Update (2010-2014)

In order to adjust policy and programme measures in light of experience and to incorporate irrigation fully into an IWRM framework, the Yemeni government took the decision to

prepare an update of NWSSIP I. According to the MWE (MWE, 2008), the NWSSIP's updated overall goal for the water sector is 'To improve the Yemeni population's sustainable and economically efficient use of the nation's scarce water resources'. This overall goal will be achieved through five key objectives:

- Strengthen institutions for sustainable water resources management
- Improve community-based water resource management
- Increase access to water supply and sanitation services
- Increase returns to agricultural water use
- Recover control over groundwater abstraction in critical water basins

In water resources management, the central pillar of the NWSSIP Update will continue to be the creation of a suitable enabling environment for decentralisation at the basin and local levels, with empowerment of basin committees and local water users to act responsibly in their own interests. The main themes and changes in the NWSSIP update will include:

- Increased investment in building the capacity of NWRA headquarters
- Decentralisation of effective responsibilities, resources and capacity to the branches
- Extending basin planning to several new high-priority areas

In the irrigation and watershed management sub-sector, objectives set in the NWSSIP Update are slightly reordered and strengthened but broadly similar to those of NWSSIP I. The goal is 'a profitable, economically efficient, equitable and sustainable agriculture'. The targeted objectives are: 1) to strengthen institutions to play their role in promoting efficient water use; 2) to promote sustainable agriculture through water resources protection and allocation; 3) to increase farmer incomes through increased water use efficiency; and 4) to enhance resource sustainability and quality through watershed management

The NWSSIP update mentions that one of the changes it includes is a 'massive increase in investment in irrigation across the board, which would bring improved irrigation to more than half the current groundwater area by 2015, and upgrade the modern spate irrigated area'.

While NWSSIP (2005-2009) and NWSSIP (2010-2014) provided quantitative targets to be achieved in urban and rural water supply and sanitation, only NWSSIP (2010-2014) provided a quantitative target in terms of area for increasing irrigation efficiency to equip a further 250,000 ha with piped conveyance and 61,000 ha with drip or bubbler irrigation, and to rehabilitate a further 100,000 ha of spate irrigated land by 2015 (Table 12). In setting these targets, MWE (2012) explains that the achievement of these targets depends on the availability of financing and on implementation capacity. The MWE adds that for the achievement of these ambitious targets, the creation of the proposed National Irrigation Program and reorganisation of the MAI headquarters and field service functions together with considerable investment in capacity building should increase implementation capability.

In urban water supply and sanitation, the NWSSIP update target for 2015 is to bring safe water via public network to a further 1.75 million urban inhabitants to reach a total coverage of 60% of population serviced with safe water and 33% of centralized sanitation systems.

In rural water supply and sanitation, the NWSSIP update target for 2015 is to bring safe water to an additional 6.4 million rural people and to ensure that sanitation and hygiene are integrated into every scheme

The NWSSIP update mentions actions that will need to be jointly planned and implemented. These include, *inter alia*, developing alternative water sources, improving water use efficiency and reuse of mainly wastewater and drainage water.

Table 12: NWSSIP Targets that are related to research themes

NWSSIP Action Area	Targets
Decentralisation	- Eight NWRA branches fully decentralized by 2015. - Eight basin plans prepared and operational by 2015. - New basin committees in Abyan/Ahwar, Tuban, Hadramawt, Tehama, Dhamar
Irrigation Efficiency	- Equip a further 250,000 ha with piped conveyance and 61,000 ha with drip or bubbler irrigation, and rehabilitate a further 100,000 ha of spate-irrigated land (indicative target).
Re-using Wastewater	- Central sewage treatment plant capacity to reach a daily capacity of 325,000 m ³ by 2015.
Community-based Management	- Scaling up of WUAs based on assessment of current water user groups and the identification of their achievements and shortcomings
Harvesting Structures (Dams)	- Establishment of dams, mainly large dams, is proposed

Sources: Compiled from the NWSSIP, the Ministry of Water and Environment (MWE), 2008

NWSSIP and Dublin Principles

After testing NWSSIP against the Dublin Principles¹¹, WB (2005a) concluded that if NWSSIP is carried out as stated, many aspects of Yemen’s water sector will be “managed” in line with global best practices. Nevertheless, the WB identified areas of significant uncertainties which include ‘uncertainties about water resource allocation and sustainability, in particular, the outcome on key questions of reducing groundwater mining and facilitating inter-sectoral water transfer remain uncertain’. Such certainties depend on the ‘Government’s willingness to take tough policy decisions—on macroeconomic policy on incentives and on microeconomic policy on water allocation and markets’ (WB, 2005).

¹¹ Dublin Principles are the guiding principles that were recommended after the meeting of experts on water related problems that took place on 31 January 1992 at the International Conference on Water and the Environment (ICWE) in Dublin, Ireland, which was organized on 26-31 January 1992. The four guiding principles, which are known as Dublin Principles- are:

- 1) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- 2) Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
- 3) Women play a central part in the provision, management and safeguarding of water.
- 4) Water has an economic value in all its competing uses and should be recognized as an economic good (ICWE, 1992). These principles are globally considered the principles of good water management (WB, 2005).

National Water Policy

This policy was prepared by the National Authority for Water Resources in 2000. The policy provides a general statement on water resources allocation, development, management and balance.

In allocating water resources, the policy gives absolute priority to water use for domestic purposes over other uses. In the development of water resources, the policy provides for the use of conventional and non-conventional resources. In developing conventional water resources, the policy recommends controlling floods, storage structures and water harvesting. It states that perennial surface water is currently being used completely and that savings can only be achieved by improving its management and use. The policy provides for the preparation of studies for water harvesting, recharge of groundwater and supporting rain-fed agriculture to decrease the demand for complementary irrigation. In the development of non-conventional water resources, the policy provides for the desalination of seawater and salty groundwater and the reuse of treated wastewater in agriculture in accordance with applied quality standards.

Other aspects on water resources management that the policy covers, *inter alia*, include: reducing groundwater depletion; water cost and pollution, improving efficiency in irrigation and domestic water uses; stakeholder participation and formation of WUAs and water basin committees.

The policy stipulates the preparation of supply-demand predictions and water balance scenarios by NWRA for short-, mid- and long terms. It also stipulates that the most appropriate scenarios should be presented to the decisions makers and the stakeholders for discussions and approval if they are to be considered the index for development, management and water use allocations for the different purposes across the domestic, agriculture, and industry sectors.

National Water Strategy

The water strategy was prepared in 1998 to address the water crisis in Yemen arising from the scarcity of water resources, depletion of groundwater, low efficiency of use, and the low coverage of water and sanitation services (Atroosh, 2005). According to NWRA (1998), the objectives of the strategy are:

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

The strategy adopts directions provided in the National Water Policy. However, guiding mechanisms for implementing the strategy were provided in the form of tasks to be implemented by the government. These guiding mechanisms include raising irrigation efficiency, reducing excessive abstraction of groundwater, and maximizing the use of rain and surface water. The strategy provides for aspects related to water resources planning, management and use including those of legislation and institutional set-up, public awareness,

capacity building and performance, health and environment standards, private sector participation, investment and water pricing, and research and development.

Some of the provisions made by the strategy were adopted by NWSSIP I and then by its updates; provisions that are being implemented include decentralization of WRM and supporting the adoption of modern irrigation systems. Other provisions mentioned in the strategy were implemented at the time of its preparation in 1998. These include the creation of a ministry of water resources and environment, issuance of the water law, introducing a gradual increase of diesel price, preparing a long-term, prioritized investment programme for the water sector, employing an integrated water resources approach and conducting environmental assessment for major projects.

3.3.2 Agriculture Sector Policies and Strategies

Several strategies and policies have been developed for the agriculture sector in Yemen. The most notable strategies that are related to themes covered by this research are:

National Agriculture Sector Strategy (2012)

National Irrigation Policy (1999)

Agricultural Sector Reform Policies and Strategies—the Aden Agenda (2000)

NASS is the most recent and comprehensive strategy in the agriculture sector (MAI, 2012b). It includes water use and management in irrigation. Nevertheless, it is important to present other strategies and policies developed in the agriculture sector that are directly related to irrigation water management and use. This will provide a clear understanding for strategic perspectives from the point of view of the agriculture sector and facilitate identifying common strategies with the water sector; consequently, it will aid in drawing more realistic recommendations for the sustainable management of irrigation water.

National Agriculture Sector Strategy 2012–2016 (NASS)

The NASS was issued in February 2012 by the MAI. The strategy seeks to provide a comprehensive guide to the development of the agriculture sector and includes a plan of action for five years from 2012–2016 with needed development programmes and projects in different subsectors. It provides clear paths on how to achieve the sector’s objectives, unlike previous strategies that identified constraints to agriculture but remained mute on actual solutions (MAI, 2012b). MAI also indicates that several policies and strategies were considered when preparing NASS. These included the Irrigation Policy, the Climate Change Impact Assessment on Agriculture and Water Sectors, and the Agriculture Sector Strategy included in the Fourth Socio-Economic Development Plan for Poverty Reduction.

As the first challenge affecting the development of the agriculture sector in all parts of Yemen, NASS highlights the problem of water scarcity and low rainfall. It explains the rapid decline in the water table in highland basins and the unsustainable rate of utilizing groundwater in coastal areas, which leads to increasing salinity. The strategy indicates the

need to preserve water resources to prevent or ameliorate the impact of groundwater depletion in irrigated areas.

MAI (2012b) mentions that given the critical constraint of water resources, a key element of the national agriculture sector strategy is to expand production in non-irrigated agriculture. The strategy emphasizes that expansion of surface water resources through dam construction should be considered. It explains that such expansion relies on surface water or spate irrigation, both of which are dependent on rainfall levels that can vary from year to year. The NASS argues that rain-fed agriculture, which takes place in most parts of Yemen, should be strongly supported as ‘low levels of production are better than allowing desertification’.

A strategic element in NASS is to expand rain-fed agriculture. The implementation programme emphasizes this by strongly supporting the construction of small and medium dams. Increasing irrigation efficiency through modern irrigation systems is also supported. Nevertheless, with four times the proposed investment for the construction of dams, this intervention is supported by the irrigation sector more than irrigation efficiency.

The overall objective of the agriculture sector is to increase growth, sustainability and equity by raising agricultural output and to increase rural incomes, particularly for the poor. Several objectives are mentioned to achieve the overall objective including ‘preservation of the environment and natural resources, and activating the role of community participation to ensure sustainability’. The MAI (2012b) mentions four ‘strategic elements’ to achieve its objectives. These, *inter alia*, include:

- More efficient use of water in irrigated agriculture through adoption of modern irrigation techniques and increased efforts to expand rain-fed agriculture; and
- Watershed management, terrace rehabilitation and wadi banks protection.

Under the ‘Sector-wide Development Strategies in Agriculture’, MAI (2012b) places water resources as the first cross-cutting issue in the list of key areas that impact all subsectors in agriculture. MAI (2012b) lists actions to account for water scarcity. These include:

- Continued infrastructure development of irrigation schemes to promote the use of rainwater-harvesting techniques, increase development of surface water resources, replenish groundwater basins by reducing excessive pumping, prevent and mitigate floods and flood damage, and reduce, as much as possible, wastewater that reaches the sea
- Integrated water-saving approaches to on-farm management that include the introduction of modern irrigation techniques, promotion of better management practices, and programmes for integrating soil and water conservation, rainwater harvesting and storage.
- Promotion of water resources sustainability through improvement of watershed management,
- Promoting the use of treated wastewater including gray and brackish water to support environmental preservation activities
- Promoting community participation in water management and involvement of farmers, water user associations, cooperatives and the private sector.

Regarding the relation of this strategy to other available strategies, MAI (2012b) states that the NASS is intended to work with existing strategies in the areas of water, food security and climate change. Particular emphasis was given to the relation between NASS and the NWSSIP when MAI mentioned that ‘the success of the NASS is closely linked to the implementation of the National Water Sector Strategy Program and Investment Plan (NWSSIP), as agriculture is wholly dependent on the continued availability of water’.

In addition to studies and researches that are proposed to help to improve institutional and technical improvement towards better WRM, the following part highlights only targets that are directly related to the alternatives for enhancing water resources as proposed by the research.

National Irrigation Policy

The Irrigation Policy was adopted by the Cabinet of Ministers Decree No. 8 on March 1999. The Irrigation Policy, according to the MAI (2000), includes the following aims:

- Optimization of the use of the limited water resources allocated for irrigation.
- Economic and sound use of water to be practiced to reach the highest yield and income from the unit of water and land in irrigated agriculture.
- Gradual and practical increase of the very low overall irrigation efficiency (30–40%) should be achieved through the mid-term plans.
- Establishment of a strong institution to form the central body fully responsible for irrigation in the country.

The policy provides a statement on the reuse of treated sewage water that should be practiced in irrigated agriculture and according to accepted standards.

National Watershed Management Policy

A National Watershed Management Policy was prepared by the MAI and the NWRA; the Cabinet endorsed this policy in May 2000. The policy aims to achieve the following objectives:

- (1) Protection and development of natural resources as they represent the basic elements for economic and social development.
- (2) Implementation of Integrated Watershed Management. This concept consists of comprehensive planning, which takes into consideration the techno-socio-economic aspects that ensure natural resources protection and development aiming at improving the socio-economic conditions of the communities.
- (3) Enhancement of institutional and legislative measures through the establishment of adequate institutions that are able to implement the plans and programmes resulting from the developed policies and the development and elaboration of appropriate legislation that organizes the use and exploitation of the natural resources.

The policy includes statements on natural resources that discuss, *inter alia*, the need to use water-harvesting techniques, manage surface water for most beneficial use and to use treated wastewater for afforestation and agriculture production to reduce pressure on water resources.

The policy also includes statements on the socio-economic, institutional and legal aspects of watershed management.

Agricultural Sector Reform Policies and Strategies—the ‘Aden Agenda’

The National Agricultural Strategies and Policies or ‘Aden Agenda’ was prepared by the MAI in 2000 as a framework for reforming the agriculture and irrigation sectors (MAI, 2000). The Aden Agenda sets general objectives for the agricultural sector. These are: a) Food Security, b) Combating Poverty, c) Sustainable Growth.

Strategic targets for achieving these general objectives as related to irrigation water management include: giving farmers who use rain-fed systems access to financial facilities; improving groundwater use; activating the participation of farmers in irrigation management from both surface and groundwater; creating an integrated incentives system for the sustainable methods of land and water use; and finding alternative crops that compete with qat.

The Aden Agenda also provides sectoral policies for agricultural sectors including:

- Increasing irrigation efficiency and achieving maximum economic returns for irrigated agriculture and reducing the excessive waste of water used through the introduction of efficient and suitable irrigation techniques and systems, with a view towards the achievement of equilibrium between the available water supply and increasing water needs.
- Prepare and update the legal and institutional frameworks and take the required measures that will ensure community participation of the beneficiaries in bearing the responsibility for operations and maintenance of irrigation structures.
- Continue the development of wadis and the construction of water barriers and dikes. Construction of small dams to support the use of rainwater-harvesting techniques with the aim of increasing the development of surface water resources, and the replenishment of groundwater basins. These would help to reduce excessive extraction of groundwater, avert flooding and rushing runoff as well as alleviate the damage they cause, and reduce the amount of water lost to the sea.
- Take advantage of treated wastewater as a continuing resource in order to protect the environment and to use such water for unrestricted agricultural plants, and in economic and environmental activities whenever possible, and in such a manner that will protect the environment from pollution.

Qat in Water and Agriculture Sector Strategies

In response to the impact of qat agriculture on water resources and food security, water and agriculture sectoral policies and strategies have adopted measures that aim at reducing the impact of qat agriculture on water resources and on the agriculture sector. The MWE and through the National Water Sector Strategy and Investment Programme NWSSIP (2010–2014) plan activities that aim at dealing with qat as a problematic crop—e.g. by including qat in the dissemination of modern irrigation techniques to farmers provided they do not expand their cultivated areas (MWE, 2008). The MAI (2012b) mentions that limiting qat cultivation

and promoting alternatives for qat is one of the eight priorities that the ministry will work on to meet its commitments in implementing the National Food Security Strategy¹².

3.4 The Conclusion

Reflecting the increasing concern over water resources, the administrative structure of the water sector has been developing. Although far from complete, considerable steps have been taken to establish institutions towards achieving decentralized, participatory and community-based planning and management of water resources.

As is evident from this chapter, the existing institutional structure of the water resources sector still needs to be developed to be able to achieve sustainable water resources management. Such challenges include the need to complete the decentralisation of water resources planning and management and to delegate responsibilities to local level institutions. A cornerstone in achieving sustainable management of water resources is supporting the participatory and community-based management of water resources; in other words, by scaling up WUAs (WUAs).

Reviewing water strategies and policies shows that strategies are not bound to quantitative targets. Water policies—e.g. the National Water Policy of 2000, provided for implementing periodical assessment of water resources by preparing scenarios for water availability and consumption over the short, mid and long terms. Nevertheless, available strategies and plans that have been developed by the water and irrigation sectors for controlling water depletion and supporting water resources lack quantitative targets.

Guided by the technical alternatives provided in ‘Yemen’s Strategic Vision 2025, strategies in the water and irrigation sectors have been developed by agreeing on several common intervention policies. Such policies include increasing irrigation efficiency, water augmentation and harvesting, reuse of treated wastewater in irrigation and replacing qat agriculture with crops that consume less water. Such agreements pave the way for synergic positive effects on implementing these interventions by both sectors for supporting water resources and water balance in Yemen.

¹² According to the Ministry of Planning and International Cooperation (2010), the food security situation in Yemen is alarming. 32.1 percent (7.5 million) of the population is food insecure, which places Yemen among the bottom 10 countries in the world.

4. SOCIO-ECONOMIC ASPECTS OF WATER RESOURCES MANAGEMENT IN YEMEN

Presently available technical studies on water resources describe the current deteriorating conditions of water resources as well as the potentially catastrophic consequences of continued deterioration along with their potential impacts on people, the economy and the environment. Available strategic documents include recommendations on how to use economic and non-economic tools to stop the deterioration and depletion in critical water basins as well as preserve other basins that are still in a better situation.

Continuous rapid depletion of water resources is accompanied by a lag in the enforcement of required measures and proposed tools to control this deterioration and return to a sustainable water balance. This is because controlling water resources does not merely involve the enforcement of regulations by the water sector or by other partner sectors. It also involves the willingness of water users to adopt such regulations—which is, of course, linked to the potential impacts of such regulations and measures on these users—and the willingness and readiness of the initiator of these regulations to accept and deal with the potential impacts of enforcing regulations and measures to control water resources.

The government's willingness to enforce regulations and the water user's willingness to accept regulations are determined not only by the law but also by the more complex interaction of socio-economic, cultural and political factors. In this context, and having explained the environmental aspects of water resources management and planning in Chapter 2 as well as the legal and institutional aspects in Chapter 3, this chapter highlights the main socio-economic and cultural driving forces essential to shaping and planning the future of water resources. In explaining the role and impact of these driving forces, the chapter examines the role of politics in decision-making on issues that directly or indirectly affect water resources. The relation between main power groups in the context of economy and politics is highlighted in the section on political economy. This section explains also how such relations have been influencing water resources and the implementation of water-controlling measures.

4.1 Population Growth

Yemen has a total population of 22.5 million, of which 71.2% live in rural areas and 28.7% in urban areas (CSO, 2010). Its annual population growth rate of 3% is one of the highest globally (MoPIC and UNDP, 2010). The Central Statistical Organization (CSO, 2010) mentions several scenarios for population growth until 2025 as shown in Annex 5. These scenarios show that the total population of Yemen will fall between two values depending on the growth rates. While the lowest growth rates scenario projects that Yemeni population will touch 33.2 million in 2025, the scenario with the highest growth rates indicates a figure closer to 35.5 million.

Public demand for water and food represents the biggest pressure on natural resources. Population growth in Yemen is the main driving force that has been influencing the use of

natural resources in the country, including water resources. Since 1975, the population of Yemen has more than doubled (UNDESA, 2010). The NWRA (2002) mentions that in the years 1990, 2000 and 2010, total water needs increased from 2,799 million/m³ to 3,400 million/m³ to 3,970 million/m³ respectively, and that it is expected to reach 4,628 million/m³ by the year 2025. The total water deficit is expected to increase from 900 million/m³ in 2000 to 2,128 million/m³ as per NWRA (2002) estimates. Section 2.3 provides more details on total water needs and water use by the sector.

Furthermore, over 90% of the population is concentrated in the western part of the country, where water scarcity is acute and where major cities like the capital Sana'a and Taiz are located (Hellegers et al., 2008).¹³ Noman (NA) states that population density in the western Yemen reaches up to 300 inhabitants/km² (Ibb province) while the average population density is about 31 inhabitants/km. He explains that significant rainfall, although not high in many locations, is the main reason behind population concentration in western Yemen. In comparison, the three eastern provinces have a population density of less than five inhabitants/km. The low population density in the eastern region reflects the 'hostile environment' of the desert and eastern uplands.

4.2 Importance of Water for the Economy

Water is an essential element for the economy of Yemen. Agriculture and industry are the main sectors to use water. The agriculture sector is the biggest water user in Yemen; it consumes 90% of the water in the country. Although it contributed only 17.5% of the national Gross Domestic Product (GDP) in 2010, agriculture provides direct employment to 33.1% of the workforce and accounts for significant employment in related transport, processing and trading sectors, thereby raising the percent employed to 54% (MAI, 2012). Agriculture is the main source of livelihood for more than two-thirds of the population (FAO, 2011). Second sector of economy in water consumption is the industrial sector, which represents 2% consumption of the total water resources. According to UNDP (2011), this sector contributes 10.3% to the national GDP.

4.2.1 Poverty & Water Resources

With more than half of the population living in poverty (WB, 2012), Yemen faces major economic challenges that make the implementation of policy reforms to reduce water depletion difficult. The economic implications of such reforms may not be tolerable for the community, particularly the poor. Besides water resources depletion, Yemen also faces the

¹³ During one of the research interviews with a top MWE official, the interviewee suggested future strategies for the re-distribution of the population so that most of the population will no longer be concentrated in the western, mountainous, densely-populated areas with water scarcity problems but in the coastal areas instead. He explained that achieving this would offer solutions to the water resources scarcity by: a) facilitating access to sustainable alternative water resources—namely, desalinated water—while giving the government a chance to plan the new urban centers in a better way, including in terms of water supply services; b) relieving the water shortage crisis and resulting tensions in the western mountainous areas; c) diluting the negative impacts of prevailing tribal power in the mountainous areas as a result of re-distribution to the new urban centers, which should result in a positive impact on water resources governance (for more on the impact of tribal power on water resources management, see Section 4.3).

challenges of high population growth, high unemployment, diminishing crude oil reserves and food insecurity (BIC, 2007). The agricultural sector employs more than half of the labour force in Yemen but contributes only 15% of the national GDP (FAO, 2011). This discrepancy between the contribution of the agriculture sector to GDP and the percentage of those employed in this sector, as FAO (2008) explains, reflects seasonal employment, underemployment and the low productivity of workers and factors of production, thereby resulting in low incomes and poor standards of living for agriculture workers.

An example of the mixed results that reforms aimed at increasing water use efficiency is the bold 2005 reform that doubled diesel prices. The reform was introduced for several reasons, including for enforcing more efficient water use and thereby reducing water extraction. A study by the World Bank analysed and assessed the impact of the reform in water resources and irrigated agriculture as well as in rural water supply and sanitation. The study concluded that the reform had little impact on resource conservation and a negative impact on incomes and welfare, particularly for the poor (Ward et al., 2007). The study concluded that efficiency and welfare gains will be broadly attained only if changes in the incentive structure are accompanied by programmes that promote investment in efficient irrigation and low-cost rural water supply. The study concludes that the reform is best implemented as a package that includes mitigative measures to help the poor to avoid the negative impacts of the reform and enhance its positive impacts.

Considering the World Bank analysis and conclusions regarding the 2005 reform as well as Yemen's economic challenges and the current condition of the national economy, particularly after the 2011 revolution, one cannot predict whether the government will act to reduce water depletion if the overall economic situation of the country starts improving or exercise caution to avoid unnecessary negative impacts on the people if the economic situation does not improve. Alterman and Dziuban (2010) suggest that 'where national governments are weaker, as in Yemen, water remains tied to how people earn livelihoods in the absence of government efforts at development'.

4.3 Political Economy and Water Resources' Controllers

Water resources policies in Yemen are influenced by several key players and different considerations, as well as by 'political economy'. According to O'Meally (2009), political economy 'focuses on the interaction between political and economic processes, examining how power and resources are distributed and contested in different contexts'. He explains that political economy 'should look beneath surface appearances to uncover the underlying incentives, formal and informal institutions, and economic structures that drive, or constrain, change'. Political economies generally focus more on distributional issues and on short-term objectives (including national food security and rural welfare), rather than on economic efficiency and longer-term issues (Al-Eryani et al, 2006).

The political economy plays an important role in determining the uptake or rejection of water demand management measures (Zeiton, 2009). Ward et al. (2007) maintain that understanding the political-economic aspects when considering a reform could increase the

chances of the reform passing successfully; such an understanding has considerable explanatory power in determining what will work and what will not.

In the following sections, the importance of political economy is highlighted by focusing on the role and interaction of two key players that influence water resources—viz. the government and irrigation farmers. The interaction is highlighted by laying bare the politics underlying water policies in the irrigation sector, the biggest water consumer in Yemen.

4.3.1 Setting the Context

To understand the role of the political economy in water governance in Yemen, one must understand the role of key stakeholders influencing water resources. Before explaining the role and interaction of the key players and the resulting impact on water resources, a brief introduction to the political and economic history of Yemen is essential.

Stakeholders in the water resources sector include, as Ward et al. (2007) suggest, central and local governments, political leaders and parliamentarians, traditional leaders, NGOs, the private sector, the media, farmers and domestic water users. Ward et al. also consider donors as stakeholders because Yemen remains dependent on external support. Nevertheless, they consider the government and irrigating farmers to be the most important players. Therefore, the following sections will focus more on these two key players.

It is important to note the influential role of the tribal structure in Yemeni society. Ward (2000) believes that the republican system established in 1962 ensured the power of tribes by maintaining the old ‘contract’ that existed before the establishment of the republic—the ‘contract’ that gives the tribes autonomy in return for fealty and military support. He asserts that the reciprocity inherent in this contract has limited the government's freedom to manoeuvre. Hence, the governance remains weak and subordinated to the need to retain control.

Lichtenthäler and Turton (1999) claims that the devaluation of the Yemeni currency, the Rial, after the Gulf crisis in 1990 forced many out of trade and into agriculture—the only alternative remaining. They explain that after 1990, various crises—such as the Gulf crisis, the 1994 Civil War, the Hunaysh dispute and tensions along the Saudi-Yemeni border—have fostered a climate of uncertainty re-enforcing tribal notions of autonomy and food self-sufficiency. Cropping and water use patterns are largely determined by these perceptions and notions. Consequently, penetration by the central government into the area has become increasingly tenuous. 2012 and the subsequent political unrest in the country further weakened the power of the central government and its control over the national territories, thereby causing further economic deterioration. This situation brings back the climate of uncertainty—much like the one that occurred in the 1990s—to an enhancement of tribal power. This makes governmental interventions to arrest the depletion of water resources harder¹⁴.

¹⁴ In an interview conducted during the research, a top Yemeni official from the National Water Resources

4.3.2. The Role of the Government

Reviewing the role of the government in influencing water resources since the 1970s shows that direct and indirect economic subsidies of agricultural inputs comprise the most common and most used governmental policies.

Ward (2000) admits that governmental weakness—which is usually taken to mean that the government can accomplish little except through agreements with powerful constituencies—did not stop the government from achieving its objectives with respect to the development of irrigation; rather, the ‘weak’ government proved strong when it came to irrigation development.

The ‘Development and Expansion’ Phase

This phase is characterized by governmental policies that promoted rapid development, use and allocation of water (Ward et al., 2007). The beginning of this phase can be traced to the 1970s when modern water pump technology was introduced in Yemen. This was a turning point for water resources in the country. Tube-well technology facilitated the exploitation of water from deep aquifers as the annual balance between renewable supply and utilization was not ‘naturally’ constrained by annual rainfall. Its use has now become unsustainable in many areas (Hellegers et al., 2009).

The dissemination of modern technology for pumping water was supported and facilitated by the government within what was then called the ‘Rural Development Programme’. Ward (2000) explains that some of the macroeconomic policies implemented by the government—e.g. low-interest loans and cheap diesel pricing—helped the government to raise farmers’ incomes and consolidate alliances with many important interest groups including *shaykhs* (tribal leaders) and large landowners. The government ensured as much by directing a large share of the benefits and adjusting the credit mechanism provided by the agricultural credit bank towards the key groups supporting its power base. Another source for supporting irrigation development was the remittance sent by Yemeni expatriates. About one million Yemenis working in neighbouring countries at the beginning of the oil boom era in these countries ensured an influx of capital; individuals with abundant capital used this to finance the proliferation of wells throughout the country (Ward, 2000).

Another turning point in this phase came in 1983 when a fruit import ban was introduced to enhance food security. The ban, which was lifted in 2000, acted as an economic stimulus to agriculture, prompting many farmers to invest in the production of cash crops (Lichtenthäler

Authority responded to a question on the existing status of implementing measures to stop water depletion. He said that the NWRA face difficulties in implementing legal measures and indicated the prevailing tribal power that prevented the enforcement of measures to stop water depletion. As an example, he mentioned an incident in 2012, when they were informed about illegal private well drilling and had informed the Ministry of Interior to stop the drilling. He explained that the owner of the farm who was digging the well along with some armed tribesmen refused to stop.

and Turton, 1999). Such crops flourished in Yemen during the 1990s and included qat, a stimulant—but not food—that is chewed widely in Yemen.

Alterman and Dziuban (2010) link the use of some subsidies in agricultural inputs to security. They explain that the government allows qat growers to pump water easily through low diesel prices and ensures that they continue doing so through a lack of robust water regulation. By exercising a light hand in the process, the government keeps powerful tribes from causing security problems so that it can focus on other relevant threats. This phase of ‘development and expansion’ during which governmental policies promoted rapid development, use and allocation of water was used as source of power and patronage, making the government and politicians definitive ‘winners’ (Ward et al., 2007).

Ward (2000) concludes that the ‘reputedly weak government’ was able to promote rapid development in the agriculture sector, modernize it substantially and make the nation self-sufficient in high-value food products, such as fruits and vegetables.

The ‘Management’ Phase

Policies applied during the ‘development and expansion’ phase continued through the mid-1990s, when the government, driven by water shortages and the fiscal crisis, started the ‘management phase’ by changing its attitudes and adopting policies that were increasingly driven by considerations regarding water conservation, its efficient use and sustainable service, including by applying price rises and restraints on use to those who had captured the resource. In this phase, the government began to adopt demand management policies and implement pro-poor programmes—including a poverty objective that transfers resources from the wealthy to the poor—that reduced the scope for patronage of the old and powerful clientele. Hence, this phase proved much less attractive politically (Ward et al., 2007). The reform, which includes the devolution of power to user groups, means that the government loses a source of patronage while running the risk of provoking social unrest and strengthening the centrifugal tendencies ever-present in Yemeni politics (Ward, 2001). Alterman and Dziuban (2010) believe that for the government, water is a dependable and cheap way of eliminating one set of political threats when a host of others remain intractable. Thus, the Yemeni government may be unwilling to adopt policies or apply measures that strictly control the rapidly depleting water resources

4.3.3 The Controllers of Water Resources: Farmers

In Yemen, where two thirds of the population work in agriculture (FAO, 2011), governmental policies for enhancing farmers’ livelihoods have impacted water resources, particularly groundwater. Arguing that at least 93% of water is consumed in rural irrigated agriculture, Ward et al. (2007) conclude that irrigating farmers control Yemen’s water resources.

This was enhanced by policies that strongly support the agricultural sector, such as control of diesel pricing, credit pricing and allocation, regulation of fruit and vegetable imports. Such policies subsidized the cost of groundwater irrigation; they resulted in increasing incomes

that spread across a large segment of farmers and promoted rapid development of groundwater for an important segment of the farm population (Ward, 2000). Groundwater has been rapidly depleted and the total area irrigated by groundwater expanded from 37,000 ha in 1970s to 398,410 in 2003 (CSO, 2004). Policies that promoted the rapid use of water resources resulted not only in resource depletion but also in ‘resource capture’ by large landowners in some areas.

Considering the abovementioned, farmers can be classified into two categories according to a) their land ownership—i.e. large or small, and b) their ability to access government credits and subsidies, which is co-influenced by the farmer’s position and influence in his local community—e.g. if the farmer is a tribal leader. These categories are:

- The first category comprises farmers with big land ownerships who have the ability to invest in water resources developments like digging new wells or deepening old wells and can afford the cost of energy—i.e. diesel to lift water to their agricultural lands at any cost without facing financial problems. Therefore, they are the ones who ‘capture the resource’. Mollinga (2010) asserts that farmers who own large-scale farms make considerable profit through poor use of irrigation water. Such farmers are not vulnerable to income loss due to water resource deterioration. They are often influential tribal leaders who benefited the most from governmental support in the ‘development and expansion’ phase. At the time, the government subsidized agricultural inputs as well as initiated a ‘hands off’ policy and the absence of any administrative or traditional controls on drilling. This concentrated a valuable resource in the hands of the local powers (Ward et al 2000b). These farmers can help the government to extend its power base. Nevertheless, some reform policies and pro-poor programmes reduced the scope for patronage of these farmers who benefited from the earlier fast development of water use. They emerged potential losers following the changes (Ward et al, 2007).
- The second category includes farmers with small land holdings whose income does not allow them to afford the cost of developing water resources—e.g. deepening water wells. Resources deterioration is more likely to affect their income. Impacted by the depletion of water resources, such farmers may have to sell part of their land to get water wells in their lands deepened or to access alternative water resources. This category of farmers is more vulnerable to policy reform—e.g. increasing diesel prices; they may not be able to afford the cost of maintaining the same level of agricultural activities following reform, which may force them to reduce their activities and, therefore, their income.

Considering the aforementioned categories of farmers, future policy reform and strategies to enhance water resources need to balance the potential impacts on both types of farmers. Zeiton (2009) mentions that the key to successful reform is in identifying projects beneficial to the weaker side but that are also beneficial to the stronger side; hence, ‘win-win’, which he refers to as ‘create positive-sum outcomes’. Ward et al. (2007) stress the importance of introducing reform programmes in water resources and irrigated agriculture that are cooperative rather than controlling, particularly in the context of Yemen’s weak formal

governance structures. Future policies and strategies need to assess the potential negative impact on poor groups and apply mitigative measures where required. Ward et al. (2007) stress the importance of supporting farmers to reduce water use while maintaining their current income levels. They suggest introducing policy reform to enhance water resources conservation as a ‘package’ that includes mitigative measures targeting vulnerable groups like poor farmers.

4.4 Cultural Aspects and Water Resources Management

The perception of water resources and how they should be used in Yemen is influenced considerably by Islamic instructions. Islam considers water, like the other resources on earth, to be subjected to humans. At the same time, the protection and regulation of water and watercourses are central requests in the Quran (Foltz in Wickström, 2010). Negenman T. (1997) explains that according to Islamic cultural traditions, water is a natural, free and open-access resource; in other words, it is permissible, free and available for all. This explains, according to Jagannathan (2009), why many leaders in Middle Eastern countries are reluctant to charge for water services.

According to Ward (2009), some commonly accepted Islamic law (Shari’a) principles that pertain to water are:

- Water is mubah, or ‘the property of no one’. However, the usufruct can be appropriated by those who develop it.
- Upstream riparians have priority: al ‘ala fa al ‘ala.
- Water may not be alienated from the land.
- Wells must be spaced a certain distance apart, outside a ‘protection zone’, or harim (Rule 58 in the Document of Seventy Rules).
- No one can deny a person drinking water—‘the right of thirst’.

Misusing the interpretation of the first principle is the base for legitimizing the ‘tragedy of commons’ in Yemen. The first principle explains why water resources have been exploited intensively without any initiatives by local communities to control these resources.

Even though religious teachings have repeatedly emphasized the need to make judicious use of water, the protection and regulation of water and watercourses are central requests in the Quran (Foltz in Wickström, 2010). Lichtenthäler and Turton (1999) noticed significant change in the Islamic interpretation when an Islamic scholar who serves a tribal community in Sa’dah, a place that is particularly hard-hit by the falling groundwater table, quoted the following verse from the Quran:

Say: ‘See ye?-
If your stream be
Some morning lost
(In the underground earth),
Who then can supply you
With clear-flowing water?’
Surat (Al-Mulk) 67:30 Sovereignty

Lichtenthäler and Turton (1999) explain that the scholar understood this to mean that farming communities have a collective responsibility towards common groundwater resources; they must be used in a way that eliminates the possibility that the ‘stream be some morning lost’. This interpretation stresses man’s responsibility for managing his environment in a sustainable way. Lichtenthäler (In: Lichtenthäler and Turton, 1999) recommends placing greater emphasis on the Islamic principle of *maslaha ‘amma* (public interest) to regulate groundwater abstraction and well drilling. He explains that this explanation clearly recognizes that the interests and welfare of the wider community have priority over and above individual rights and benefits, even if these are lawful.

4.5 Potential Impacts of Water Resources Depletion

4.5.1 Poverty as a Result of Water Depletion and Resource Capture

Given the current critical situation of water resources in Yemen, one must consider potential future impacts of developing water policies and implementing strategies that are not effective enough to help to regain sustainability in water resources. In this context—and considering water’s vital role in the economy—it is clear that the rapid depletion of water resources will be reflected in lower levels of economic activities, particularly in agriculture. Loss of income due to lowered water-dependant activities in areas witnessing depleting water resources is a leading cause of poverty. As two-thirds of the population work in the agriculture sector, poverty resulting from water depletion is more likely to affect people in this sector. While the MAI (2012) indicates that the primary factor affecting agriculture is water scarcity and low rainfall, farmers are forced to lower their agricultural activities because they cannot afford sinking new wells and deepening existing ones to reach the falling water table.

Water depletion may manifest itself in different forms such as by ‘resource capture’. For example, Lichtenthäler and Turton (1999) explain how ‘resource capture’ began to develop and show itself in the Sa’da Water Basin. They mention that the process of resource capture¹⁵ began when the cost of deepening water wells increased. Many poor farmers were forced to sell parts of their land in order to afford the increased costs of well deepening, re-equipping and higher operating expenses. As resource capture exacerbates, WB (2006) asserts that inequality in water will become a major issue in Yemen, placing the community at large at risk of water scarcity. WB mentions that, in some areas, the rapid drawing of groundwater has dried springs and wells, forcing small farmers to abandon their fields, and driving them into poverty. Al-Eryani (2011) mentions that some rural economies are already collapsing because of water resources depletion, such as in the areas of Al-Haima in Taiz, Mawya, Bani Khawlan and Saadah.

¹⁵ Resource Capture is the process by which powerful social groups shift resource distribution in their favor over time (Homer-Dixon and Percival, 1996:6). This is particularly relevant under conditions of extreme water scarcity, where access to a critical natural resource like water provides considerable advantage to those who control the access and allocation of that resource (Lichtenthäler and Turton, 1999).

Stressing the importance of introducing water demand management measures that contribute towards poverty alleviation, Tyler (2007) states that institutional reforms should include, among other measures, the following: securing poor users' rights to access the resource, increased role of women and poor water users in decision-making, water pricing that is sensitive to basic needs of the poor, extension of service to unserved areas and user engagement in technology selection, and investment in order to generate early returns.

Various proposals have been made to mitigate the negative impacts of water depletion on local communities and to facilitate a transition to a non-water-dependent economy, mainly in areas with non-renewable water resources. Starting from the macroeconomic level, Allan (in Zeiton, 2009) thinks that diversification of the Yemeni economy is the best way to overcome physical water scarcity. Al-Eryani et al. (2006) provide two strategic scenarios to achieve social sustainability in areas that depend on non-renewable water resources. The first scenario, 'Planned Depletion', is applied to aquifer reserves with little pre-existing development. In this situation, a planned depletion of the resources through an "exist strategy" needs to be identified, developed and implemented by the time the aquifer is substantially depleted, and this would normally imply that society will have used the mined groundwater to advance economically, socially and technically so as to enable future generations to develop substitute water sources at tolerable capital and operational cost. But it could equally mean strengthening the capacity of existing water-users to cooperate in managing water resources more efficiently'. Al-Eryani et al. (2006) clarify that a key challenge in planning for the proposed strategy is determining the quantity of groundwater that can be pumped over the planning period to best serve the communities involved.

In case of unplanned situations and for achieving social sustainability, the second scenario, 'rationalization' comes into effect. Herein, aquifer reserves should be utilized in a way that maximizes groundwater productivity and minimizes quality deterioration, while allowing time to promote social transition to a less water-dependent economy. Al-Eryani et al. (2006) add that demand-management measures are needed to progressively reduce abstraction rates. They explain that under this scenario, lower productivity uses may have to be discouraged and potable water supply use will have to be given highest priority in the long run.

4.5.2 Migration

Migration is one of the main consequences of water resources depletion. In rural areas, 75% of the population depends on agriculture and a significant share of agriculture is for subsistence; about 76% of agricultural holdings have self-consumption as their primary purpose of production (UNDP 2006). While agriculture helps to stabilize the population by reducing internal migration and its related social and economic problems (MAI, 2012), low productivity and emerging water shortages result in stagnating rural incomes and increasing poverty. Alterman and Dziuban (2010) argue that since people feel that their governments have failed fundamentally, they doubt the durability of any proposed solutions to the problem. In addition to the lack of job opportunities outside the agriculture sector, people will migrate in search of a better income. The tendency for internal migration from rural

depressed areas to the main cities for economic reasons, according to MoPIC (2002), has been increasing gradually, reducing the percentage of rural population to the total population from about 88.6% in 1975 to 76.5% in 1994 and to 73.5% in 2001.

Due to migration from the agricultural hinterlands, the urban coastal areas are growing at a rate of about 3% per annum and are facing high risks of exceeding the carrying capacity of the coastal areas to support livelihoods (UNISDR, 2012). Major cities in Yemen have seen alarming growth rates since 1976. For example, the population of the capital Sana'a increased from 427,502 in 1986 to 972,011 in 1994 to 1747834 in 2004 at an annual growth rate of 5.55 % (NIC, 2004). IOB (2008) claims that Sana'a is expected to run out of water in a decade and become the first capital in the world to be out of water. Alterman and Dziuban (2010) explain that the population in Sana'a is exploding, not shrinking, and thereby creating the conditions for a major crisis: it is not clear where the water could come from when the wells run dry. A study by the World Bank (2010c) states that by 2025 and as a result of groundwater depletion, agricultural output will reduce by 40%. Alterman and Dziuban (2010) believe that a massive influx of migrants would create trouble for the other Yemeni cities absorbing them and that neighbouring Gulf countries might have neither the water resources nor the political will to accept them either.

4.5.3 Tensions and Conflicts over Depleting Water Resources

One of the main impacts of water resources depletion is the increasing tensions and conflicts over water resources. Kuster (2009) believes that Yemen has more potential for conflicts resulting from water resources depletion. He attributes this to four facts: a) Yemen is one of the most arid countries in the world to struggle with water scarcity, b) the extremely docile government as opposed to the aggressive tribes, which makes Yemen prone to conflict at the regional and local levels; c) the population depends for the most part on agriculture not only as an economic branch that generates labour but one that serves as a source for self supply of food in the absence of adequate financial sources to meet such supply by food imports (Wehner and Arvidsson, 2001 in Kuster, 2009).

The driving force for conflicts within countries, as Ohlsson (1997) concludes, is the attempt to increase supply, which results in competition between different sectors of society and different groups of population. Kuster (2009) summarizes three types of scarcity that may lead to conflicts. These are absolute physical scarcity from supply through rainfall, demand-induced scarcity as with population pressure, and structural scarcity arising out of distributional changes.

Water conflicts can exist over all water resources. However, the risk of conflicts differs among different types of water-allocation systems. This difference in conflict risks depends on the traditional norms organizing the allocation and use of water in these systems, where the natural characteristics of the resource may also contribute in facilitating its allocation and use. Three major types of water-allocation systems can be identified in Yemen—the groundwater, springs and spate (flood) systems.

The first type is the groundwater allocation system. Here, Islamic belief gives the landowner the ultimate right to utilize and abstract groundwater on their own property. This explains the amazing absence of tension and conflict over groundwater resources where land rights are firmly established (Lichtenthäler and Turton, 1999).

The second type is the spring water allocation system. Kuster (2009) mentions that springs are a prevalent source of irrigation in the highlands, most of which are located in the north-western part of the country. He attributes the relatively few disputes over water rights to springs to the exact appropriation cycles of irrigation water sourced from springs. Kuster explains that this exact appropriation is facilitated by the central feature of springs flowing as a perpetual stream of water and by the clear right to access to water as linked with land ownership.

The third type is the spate water allocation system, which is used mainly for irrigation. According to Mehari et al. (2007), in spate irrigation, flood water is emitted from wadis (ephemeral streams) and diverted to fields using earthen or concrete structures. Farmers who use, co-share and co-manage spate as floodwater face additional challenges because floodwater is unpredictable in occurrence, timing and volume. In addition, Kuster (2009) indicates that since there are no permanent rivers in any part of the Yemen, the spates that descend the major dry river courses or 'wadis' after the rains in spring and late summer are of great importance. Considering the importance and nature of spate water aspects, Viscus (in Kuster, 2009) concludes that the risk of conflict in spate flood systems is much higher.

After quantitatively analysing the relationship between water availability and conflicts, Kuster (2009) concludes that at least during the period from 1995 to 2002, 'negative freshwater availability anomalies do correlate with the occurrence of violent conflict at the local level in Yemen'. Glass (2010) reports that a study by Sana'a University researchers found that 70–80% of all rural conflicts in Yemen are related to water.

The impact of such conflicts is indicated by Al-Eryani (2011) who asserts that water depletion poses a serious threat to social peace and security. Glass (2010) claims that the negative implications of conflicts induced by water-scarcity on Yemen's economy as well as the food shortage and health impacts resulting from water shortage, all have the potential to destroy the nation.

The government will also face the unprecedented situation of resource scarcity and social unrest. This is explained in a report on Middle Eastern water crises that describes the potential consequences of water depletion in the countries of Yemen and Jordan. Alterman and Dziuban (2010) mention that water loss may go beyond citizens' previous experiences with resource scarcity, and major water loss would cast citizens into unfamiliar geographic and social contexts causing people to participate—angrily, perhaps violently—in protesting the threat to their welfare. They believe that such situations may pose unfamiliar challenges

to the governments in these countries and could go beyond states' previous experiences with demographic shifts and social unrest.

4.6 The Conclusion

This chapter highlighted the main socio-economic factors that influence the planning and management of water resources. While population growth is the force driving the continuous increase in water demand, poverty is a driver and a result for water depletion.

The tribal structure of the community and the paradigm whereby the government deals with this structure shows that the political economy will continue to be a key factor in shaping governmental water resources policies in Yemen. The most important aspect here is the relation between the government—the body responsible for the development of water policies and strategies—and water users—mainly powerful leaders of local communities.

5. ENVIRONMENTAL AND WATER PLANNING AND MANAGEMENT IN YEMEN

Water and environmental planning and management tools have been adopted and promoted in the water resources sector in Yemen. Although these tools differ in terms of the field in which they were developed as well as in their function, their aim is to support the sustainability of water resources.

This chapter aims at introducing planning and management tools applied currently in the water sector in Yemen—namely, IWRM and environmental assessment. While presenting their current status of application, the chapter compares this with the accepted principles of IWRM. The chapter presents some shortcomings and implementation challenges associated with applying these tools as well.

5.1 Integrated Water Resources Management (IWRM) in Yemen

IWRM is based on the four Dublin Principles¹⁶ presented at the World Summit in Rio de Janeiro in 1992. It is defined as ‘a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems’ (GWP, 2000). A more functional definition is used by the United States Agency for International Development (USAID in Xie 2006): ‘IWRM is a participatory planning and implementation process, based on sound science, which brings together stakeholders to determine how to meet society’s long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits’.

To apply IWRM, GWP (2012b) explains that three pillars should exist: an enabling environment, an institutional framework and management instruments. IWRM focuses on planning and management mainly at the basin level (Global Flow Network, 2012).

In the water resources sector, IWRM is formally incorporated into Yemen’s national water policies (Michel, 2012). The country’s move towards IWRM was part of a series of economic, financial and administrative reforms (GWP, 2000). Legal and institutional reforms in the water sector have been in place in Yemen for decades now, and have created the required environment for applying IWRM to manage the scarce water resources. Nevertheless, it is the 1995 reforms in the water sector that can be seen as the beginning

¹⁶ The Dublin Principles for IWRM are:

Principle 1 ‘Ecological’: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

Principle 2 ‘Institutional’: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

Principle 3 ‘Gender’: Women play a central part in the provision, management, and safeguarding of water.

Principle 4 ‘Instrument’: Water has an economic value in all its competing uses and should be recognized as an economic good (Cap-net, 2003).

towards adapting the IWRM approach. The following sections highlight the status and achievement of applying IWRM¹⁷ in Yemen.

Creating Enabling Environment

Reforms implemented after the establishment of the NWRA have had major achievements. These include: the issuance of the water law in 2002 and its amendments in 2006; the national water resources strategy of 1998; the water resources policy of 1998; and finally, the NWSSIP 2005–2009 and its update 2009–2014, which is the guiding document for improved donor harmonization and alignment with government priorities and policies (CEDARE, 2005). Other achievements that enhanced the IWRM-enabling environment include the issuance of the law of decentralization of 2000, which plays a role in the delegation of water planning and management responsibilities to local authorities. Environmental Law nr. 26 was issued in 1995; it stipulates in article 36 the application of environmental assessment for projects with potential negative impacts on the environment.

Enhancing Institutional Roles

In 1995, the NWRA was established to consolidate water resources management functions under one authority and introduce basin planning approaches (ESCWA, 2007). The reforms have continued with the establishment of the MWE in 2003, which includes four water and environment institutions. One of the main manifestations of these reforms is adapting decentralization and participatory approaches in water planning and management. Decentralization has taken place in water institutions, and branches at the local level established for water authorities included the NWRA, the GARWSP, the National Water and Sanitation Authority (NWSA) and the EPA. After the NWRA divided the country into 14 water basins, a number of water basin plans were prepared (CEDARE, 2005). At the same time, and under the basin planning approach, five basin committees have been established (MWE, 2008). The government has also been supporting the establishment of WUAs to enhance the community-based participatory management. On the other hand, adopting the stakeholder participation approach has begun in water resources planning. The most notable

¹⁷ An IWRM approach requires positive change in the 13 key change areas as follows:

The enabling environment

1. Policies: setting goals for water use, protection and conservation.
2. Legislative framework: the rules to follow to achieve policies and goals.
3. Financing and incentive structures: allocating financial resources to meet water needs.

Institutional roles

4. Creating an organizational framework: forms and functions.
5. Institutional capacity building: developing human resources.

Management instruments

6. Water resources assessment: understanding resources and needs.
7. Plans for IWRM: combining development options, use of resources and human interaction.
8. Demand management: using water more efficiently.
9. Social change instruments: encouraging a water-oriented civil society.
10. Conflict resolution: managing disputes, ensuring sharing of water.
11. Regulatory instruments: allocation and water use limits.
12. Economic instruments: using value and prices for efficiency and equity.
13. Information management and exchange: improving knowledge for better water management (GWP, 2004).

example is the preparation of the IWRM-based NWSSIP 2005–2009 (Michel, 2012) and its joint annual review. Such reforms have supported the creation of the enabling environment and a framework for IWRM. They place emphasis on participation and decentralization (Hübschen, 2011).

Applying Management Instruments

Until the mid-1990s, governmental policies in the water sector mainly focused on water supply management. The present water crisis is largely the result of more than 30 years of ad-hoc water policy that concentrated on water supply development projects for various users with little or no consideration of water resources demand management or sustainability of the water resources (Negenman T., 1997). Therefore, reforms have introduced demand management; this includes introducing cost-sharing investments with farmers in new irrigation techniques that conserve water and reducing government subsidies for the diesel fuel traditionally used to power groundwater pumps (Michel, 2012). Michel concludes that policy makers in Yemen view IWRM as the right tool due to its balanced consideration of both supply and demand dynamics.

Encouraging social change and the creation of a water-oriented civil society have been introduced under IWRM through various steps. These include: conducting public awareness and education campaigns, establishing and operating an information system (MWE, 2008) and offering a Master of Science degree in IWRM since 2004 in Sana'a University (WEC, 2005).

Water Resources Planning

The water scarcity in Yemen leaves no margin for irrational use or wastage of water; it makes careful and rational strategic planning imperative in the short and long terms. The NWRA is responsible for water resources planning. It follows a decentralization programme for delegating responsibilities, including planning, to the local level. This initiative has been successful as per Ward et al. (2007). Nevertheless, the weak capacities of branches still hinder regional planning (Al-Harithi, 2009).

To ensure effective water resources planning and informed decision-making, updated data on water availability, quality and use are required. Yemen has seen considerable progress in installing monitoring stations, well surveying and establishing National Water Information System (NWIS). However, the country still needs an improved water monitoring network and national water resources management information system. The latter is an objective for ongoing projects such as the IWRM National Programme (UNDP, 2012). One of the existing challenges is that most of the data collection and information systems are still scattered among water resources/supply and sanitation/irrigation projects in autonomous agencies (Al-Asbahi, 2005).

Water Resources Planning on the Basin Level

Water resources planning at the basin level includes the establishment of NWRA branches at the governorate level, establishment of water basin committees and the preparation of a water resources management plan (GIZ, 2012). One of the main achievements of the NWRA was the division of the country into water basins (CEDARE, 2005). Basin planning is consistent with the principles of IWRM and its application resulted in dividing the country into 14 water management zones with boundaries delineated based on hydro-geological criteria (NWRA, 2003). So far, the NWRA has established fully-staffed, effective branches in Taiz, Sana'a and Aden; however, only five committees have been established in Sana'a, Taiz, Sa'ada, Tuban and Abyan (MWE, 2008).

Conflict Resolution

In Yemen, community/tribe leaders and influential people are those in charge of conflict resolution (CEDARE, 2006). However, this may be changing as the local systems for solving water-related conflicts are under stress from customary institutions because the modern state systems lack sufficient legitimacy (WB, 2006). CEDARE (2006) explains that modern mechanisms that have been added to the matrix under the water law includes NWRA which has regulatory powers over water management; hence, a number of disputes are now being referred to NWRA branches for decisions on issues of legality—e.g. well drilling. Basin committees have also been established in some areas comprising representatives of central and local government and civil society. NWRA policy involves engaging the newly-elected local councils at the district level; these councils are responsible for all local matters pertaining to water resources regulatory activities. CEDARE (2006) states that it is too early to judge the effectiveness of basin committees in imposing order on water resources.

Yemen's efforts towards applying the IWRM approach, although not yet complete, have been recognized. According to Michel (2012), at the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, targets were set to develop national IWRM and water efficiency plans by 2005. At the fourth World Water Forum in Mexico in 2006, Yemen was recognized among the most successful MENA countries to formally incorporate IWRM into their national water policies.

5.2 IWRM: Approach Shortcomings and Implementation Barriers¹⁸

Undoubtedly, IWRM has become a powerful and all-embracing slogan in the area of water resources (Biswas, 2004). Nevertheless, it is not without its shortcomings. In the Yemeni context, and despite steps being taken on the national and local levels to develop a legal and institutional enabling environment for IWRM, some challenges still hamper the functionality of IWRM in Yemen. Shortcomings inherent in the IWRM and factors that hamper its functionality in the Yemeni context are mentioned below.

¹⁸ The limitations and implementation gaps of the IWRM approach are mentioned while focusing on those that deal with strategic level planning and decision-making as well as the implications of implementation.

IWRM Approach Shortcomings

Level of Application

While the final impact on water resources in quality and quantity is the result of several levels of strategic planning—namely, policies, plans and programmes, and then the management of these resources—IWRM is a tool that aims at assessment and programme evaluation (Xie, 2006).

No Specific Process and No ‘Built-in’ Mechanisms

The IWRM approach is founded on the Dublin principles; there are no set IWRM ‘rules’ (GWP, 2004). IWRM can only be built on experimentation and there are no blue prints regionally, nationally, or even sub-nationally (Cap-net, 2005). IWRM is rather a broad set of principles, tools and guidelines that must be tailored to the specific context of the country or region or a river basin (Xie, 2006). Biswas (2004) explains that operationally it has not been possible to identify a water management process that can be planned and implemented in such a way that it becomes inherently integrated.

Not Legally Binding

Being an approach that merely follows set of principles, IWRM cannot be as legally binding as other processes. Slootweg (2009) mentions that IWRM itself is not embedded in any legal procedures and, consequently, cannot be ‘enforced’.

Barrier to Implementing IWRM

In addition to the shortcomings inherent in IWRM, the application of IWRM in reality is encountered by barriers that hinder using IWRM to its full potential. According to Cap-net (2005), barriers to implementing IWRM, *inter alia*, include the incompleteness in water management policy and legal and regulatory frameworks—common in developing countries where water policies are often rudimentary—as well as the weak regulatory mechanisms for implementing and enforcing. The barriers also include the lack of understanding of IWRM principles and practices as well as of the inter-relationships between biophysical and socioeconomic aspects of a system.

Another barrier to IWRM in practice is the traditional boundaries between sectors. Slootweg (2009) indicates that even though IWRM looks beyond sector boundaries, IWRM implementation is limited by these boundaries and that sectors outside the water sector may be totally ignorant of the principles of IWRM. He also mentions another challenge in practice—the intention of creating a participatory, multi-stakeholder process that is usually not implemented fully; as a result, the potential benefits of the approach do not always materialize.

A World Bank study found that in the bank’s client nations that have weak environmental policies or laws or environmental agencies that lack influence and authority, environmental

considerations in IWRM are often given less priority and they play little role in decisions about water allocation, water quality management, source protection, or the protection of water-dependent ecosystems (WB, 2007b). The study also showed that implementation of IWRM principles at the regional and local levels is much slower in developing countries than in developed countries, and that wherever implementation has taken place, it has been piecemeal, with some principles being adopted but not others (WB, 2007b).

Challenges of the Implementation of IWRM in Yemen

Weak Institutional Capacity

Much progress has been made in establishing institutions for water resources management. NWRA has been working towards decentralizing its functions including planning, decision-making and management of water resources to the lowest level. There are also effort is in capacity building at the central, regional and local levels. However, CEDARE (2005) states that human resources development and institutional capacity building remain a major obstacle to the implementation of IWRM plans in Yemen.

Weak Governance

Hübschen (2011) concludes the existence of a governance deficit that hampers the enforcement of the existing legislation and the implementation of IWRM-principles in Yemen in general. She attributes this to the strong tribal influence in the most parts of the state. She mentions that loyalty to the tribe often has priority over the central government and that legal plurality prevails; hence, the government does not have monopoly on the use of force to intervene in local matters. She adds that the Yemeni government, and considering the context of Yemen's weak formal governance structure, agrees to the fact that management approaches have to be cooperative rather than controlling.

In this context, it is worth mentioning what Caton indicated about the critical analysis of the role of 'modern' global knowledge underpinning IWRM perspectives as promoted by international agencies in national water governance and policy processes. Caton (in Mollinga, 2010) questions how 'innovative' the global knowledge actually is, and whether it does not risk leaving the 'politics' of water governance and policy out of the equation involving the instrumental forms of participation.

Neglect of Water for the Environment

Under IWRM, water for environmental purposes is regarded as both a legitimate use of water equivalent to water for consumptive purposes such as irrigation, water supply/sanitation, and hydropower, and as fundamental to the provision of environmental services (WB, 2007b). While one of the key elements of IWRM is to provide enough water to sustain and protect ecosystems (GWP, 2004) this key principle is yet to receive attention in Yemeni water resources legislations. Hirji and Davis (2009) explain Yemen shows considerable concern over the lack of physical sustainability of groundwater at the current rates of use but no mention of any environmental impacts from the drop in water tables. They also explain that

surface catchment problems focus on the evident deterioration of watersheds with impacts on downstream communities from upstream abstractions and pollution. However, environmental issues do not figure in this description. They conclude that the absence of any mention of environmental flow issues in surface water or groundwater probably reflects the much higher priority being accorded to physical sustainability and equity issues.

Weak Involvement of Women

The third principle of IWRM states that ‘Women play a central part in the provision, management and safeguarding of water’ (GWP, 2004). Acceptance and implementation of this principle requires positive policies to address women’s specific needs and to equip and empower women to participate at all levels in water resources programmes, including decision-making and implementation, in ways defined by them (ICWE, 1992).

In Yemen, women and girls are responsible for securing water; therefore, they spend large parts of each day fetching water (Ward et al., 2007). With the adoption of IWRM principles, Yemen promotes the involvement of women in water management and decision-making. For example, Ward et al. (2007) mention that women are members in the water basin committee in Sa’ada and that the governorate’s community representatives include women. Nevertheless, the evaluation of women’s roles in the management and decision-making in Yemen is still modest compared to that of men. Ward et al. (2007) mention that the chairman of the GARWSP said that despite his personal conviction that women are better water managers than men, ‘women only participated in three new WUAs in 2006’ (out of about 200 that were established). The study explains that a combination of community reluctance and GARWSP’s lack of social mobilization capacity appears to be the cause. It concludes that proper involvement of women in community self-management still has a long way to go; with a few exceptions, gender appears more neglected than mainstreamed.

Weak Inter-sectoral Coordination and Stakeholder Participation

Stakeholder participation is a core principle in IWRM, but the lack of participatory mechanisms under IWRM and the fact that the IWRM approach cannot be enforced as mentioned above makes stakeholder participation an ad hoc event rather than an institutional-systematic and legally-enforced practice.

The government has been trying to institutionalize the coordination between the MWE and the main water-consuming sectors—e.g. the MAI through the creation of the Inter-Ministerial Steering Committee (IMSC) and the Program Management Committee (PMC) under the NWSSIP. Means for stakeholder participation have been established including the NWSSIP Joint Annual Review (JAR) and the Donor Core Group as well as the subsector working groups (MWE, 2008). Nevertheless, such mechanisms are yet to achieve the required level of coordination and involvement. ESCWA (2011) states that in ESCWA member countries, including Yemen, intra-governmental institutions dealing with water issues in an integrated manner—such as inter-ministerial committees—do not seem popular; and where they exist, they have limited success. It also adds that the involvement of non-governmental

stakeholders is still limited and has not yet been effectively incorporated into the water-related, decision-making process.

5.3 Strategic Environmental Assessment (SEA)

Historically, Strategic Environmental Assessment (SEA) evolved out of the field of Environmental Impact Assessment (EIA) (WB, 2005b). EIA is applied in the decision-making process at the project level and after high-order questions of whether, where and what type of development should take place have been decided (when policies, programmes, and plans were being formulated and approved) often with little or no environmental analysis (Dalal-Clayton and Sadler, 1999). Consequently, SEA was developed as a tool to move environmental considerations earlier in the process from project-level analysis to the levels of policies, legislation, strategies, programmes, and plans.

Many definitions of SEA have been proposed (Sadler, 2005). A definition for SEA by OECD (2012a) states that ‘SEA is an umbrella term for analytical and participatory approach to integrate environmental (and linked social and economic) considerations into policies, plans and programmes and assess their potential development effectiveness and sustainability’. A generic¹⁹ definition provided by Sadler and Verheem (1996) states that ‘SEA is a systematic process for evaluating the environmental²⁰ consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision-making on par with economic and social consideration’.

5.3.1 SEA in the Decision-making Cycle

The role and aims of SEA vary according to the planning and decision-making context in which it is applied (Tetlow and Hanusch 2012). Ehrhardt and Nilsson (2006) assert that SEA can be used flexibly according to the situation and the desired outcome as well as for the evaluation of all stages of the decision-making cycle. They explain that SEA can be integrated as a strategic decision support that can operate ex-ante (very early in decision-making processes), integrated (accompanying assessment allowing for periodic review of the environmental effects of decisions following implementation) and can also be used ex-post (as an evaluation tool of the whole process and its outcomes) as Figure 10 shows.

¹⁹ Sadler (2005) mentions that SEA definitions can be broken down into ‘generic’ definitions, which are definitions without reference to particular EIA-related elements (such as the definition by Sadler and Verheem of 1996 mentioned in the main text), and ‘procedural’ definitions, which are those with reference to particular EIA-related elements such as the definition of Therivel et al (1992). The latter states that SEA is ‘The formalized, systematic and comprehensive process of evaluating the environmental effects of a policy, plan or programme and its alternatives, including the preparation of a written report on the findings of that evaluation, and using the findings in publicly accountable decision-making’.

²⁰ It is important to mention that according to Sadler (2005), there has been a debate on the extent to which SEA should move towards an integrative approach that includes not only environmental considerations but also economic and social considerations. Partidario (1996) adds political consideration to the scope covered by SEA, mentioning that ‘SEA looks at a range of possible alternatives in a way that is systematic and ensures full integration of relevant issues in the total environment including biophysical, economic, social, and political considerations’.

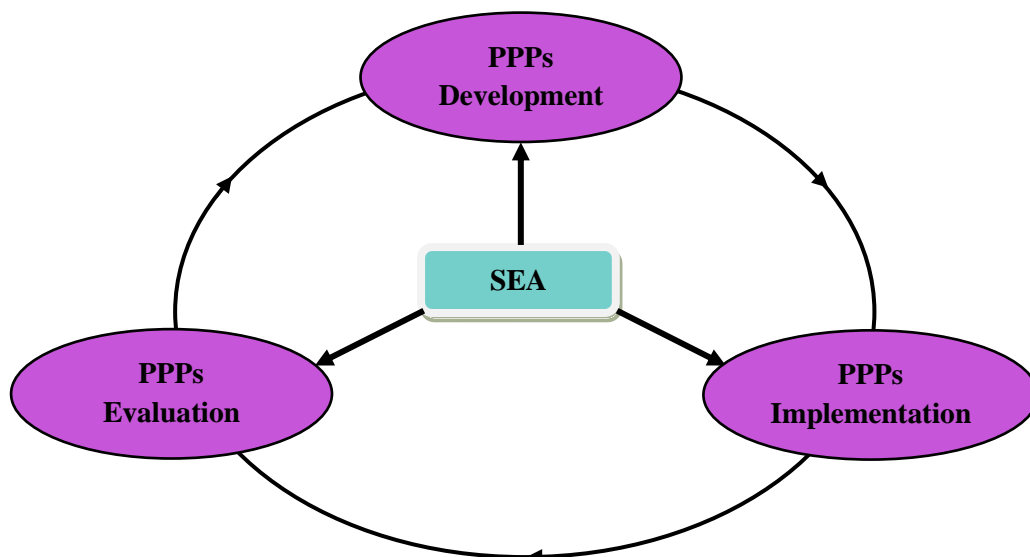


Figure 10: SEA Implementation in Different Phases of a Policy, Plan or Programme Cycle
Source: based on Ehrhardt and Nilsson, 2006

5.3.2 SEA Procedure, Methodology and Techniques

SEA is an umbrella term for diverse methods and techniques that are borrowed from different planning and assessment tools and used in varying procedures and methodologies. Partidário (2003) mentions that several references can be found in reviews of SEA methods including SEA procedural methodologies and techniques; however, each case adopts a specific SEA methodology, encompassing a sequence of several activities through stages in a rather systematic phasing, independent or integrated in the decision-making process. She concludes that there are no specific SEA methods or techniques; SEA borrows methods and techniques from diverse sources ranging from policymaking and evaluation, planning, project assessment.

Such diversity has raised questions by SEA experts about the ability to develop a unified SEA process with specific methods. Noble et al. (2012) point out that SEA is not challenged by a lack of methods, but that the major challenge to SEA practice is making the ‘right choices’ about methods and methodology. The broadness of the SEA procedures, methodologies and techniques led Tetlaw and Hanusch (2012) to conclude that there is no ‘one-size-fits all’ SEA. They said that it is time to stop trying to formulate a common standardized understanding of SEA, but rather, to give due recognition to the richness of different approaches²¹ and the value they add to different contexts.

²¹ The World Bank (2007) classifies SEA as a family of approaches that lie on a continuum. At one end is the impact-centered SEA and at the other end is the institution-centered. The former assesses the potential environmental impacts of the PLSP while the institution-centered SEA typically examines the capacities of institutions, the relevance and consistency of policies and legislation, mechanisms to involve vulnerable groups, and political economy factors that affect the implementation of plans and programs that trigger the SEAs. Partidário (2003) classifies SEA according to the methodological and procedural elements that the SEA exhibits to policy-based or (decision-centered) SEA and EIA-based SEA. In the policy-based version, SEA adopts a policy or a planning rationale, with principles of environmental assessment tailored in the formulation of policies and plans, through the identification of needs and options for development. These may then be assessed

Nevertheless, several guides exist on SEA process and good practice. The World Bank (2005b) mentions the typical steps in SEA processes as follows:

- Screening: This activity is conducted to answer the following threshold question: For any particular policy, plan, or programme, should an SEA be conducted? If the proposal has an environmental impact, one moves to the next step.
- Scoping: Given the determination that an SEA must be conducted, what are impacts that the SEA must assess?
- Identification, Prediction and Evaluation of Impacts: The process of forecasting and evaluating impacts in an SEA can employ some of the same tools and procedures used in project-level EIA. As in the case of EIA work, professional expert opinion often plays a major role.
- Mitigation: The term ‘mitigation’ is employed widely in both EIAs and SEAs. Mitigation measures are intended to avoid, reduce or offset the adverse effects of an action, such as the decision to approve a policy or implement a plan.
- Monitoring: Programmes to monitor the effects of a policy are often advocated because such monitoring can alert responsible authorities to the unintended outcomes that may be controlled using mitigation measures. Furthermore, by comparing predicted outcomes with those observed via monitoring, analysts may be able to improve their ability to predict impacts in future.

5.3.3 SEA Scope

The scope of SEA and which impacts should be covered by SEA have been debatable points among experts and practitioners in the field who aligned themselves into two schools of thought. The first school of thought promotes the integrative approach whereby SEA should provide a sustainability focus and consider economic and social as well as environmental considerations; this approach is widely promoted, notably by the International Association for Impact Assessment (Sadler, 2005). The second school holds that SEA should focus mainly on environmental issues as stated by Dalal-Clayton and Sadler (1999).

5.3.4 SEA Benefits and Constrains

In the context of adopting the SEA approach in this research to show its potential in the water sector, it is important to mention the benefits of and constraints of applying SEA.

Benefits

Many of the original arguments in favour of SEA focused on the need to counteract some of the limitations of project-level EIA (Tetlow and Hanusch, 2012). Nonetheless, the benefits of

in a systematic way, in the context of a vision for sustainable development. EIA-based SEA is literally an extension of the practice of project EIA, and sometimes applies to plans and programmes the existing EIA legal procedures and requirements, but certainly the experienced practice on the environmental information to be included, methodologies and other assessment tasks such as comparison of alternatives and mitigation measures and requirements for the presentation of environmental impact statements.

Fischer (2007) distinguishes between ‘administration-led SEA’, which is conducted by public planning authorities and private bodies, and ‘cabinet SEA’ that is applied in cabinet decision-making, such as drafting legislation.

adopting SEA can extend to cover aspects related to good governance and institutional efficiency, in addition to ensuring sustainable decision-making. Dalal-Clayton and Sadler (1999) mention some of these benefits, which include the following:

- promote integrated environment and development decision-making;
- facilitate the design of environmentally-sustainable policies and plans;
- provide for consideration of a larger range of alternatives than is normally possible in project EA;
- take account, where possible, of cumulative effects (particularly by focusing on the consequences of sectoral or regional level developments) and global change;
- enhance institutional efficiency (particularly where EIA-related skills, operational funds and institutional capacities are limited) by obviating the need for unnecessary project-level EIAs;
- strengthen and streamline project EA by:
 - the incorporation of environmental goals and principles into policies, plans and programmes that shape individual projects;
 - prior identification of impacts and information requirements;
 - clearance of strategic issues and information requirements; and
 - reducing time and effort taken to conduct reviews; and
- provide a mechanism for public engagement in discussions relevant to sustainability at a strategic level.

Other benefits of applying SEA, according to UNDP and REC (2003), include improving good governance and building public confidence in decision-making as well as saving time and money by avoiding costly mistakes.

Constraints

On the other hand, adoption of SEA still faces constraints. There is debate on the suitability of SEA in developing countries, where there is growing evidence that EIA is not working well (Mwalyosi and Hughes in Dalal-Clayton and Sadler, 1999). Some of these constraints, according to IIED (2009), are:

- limited interest of many government agencies in subjecting policy and planning proposals to assessment, reinforced by fear of losing control, power and influence by opening up such processes;
- limited appreciation of the potential utility of upstream assessment among senior staff (in both governments and donor agencies), and doubts about the robustness of results;
- a perception that SEA will add significant costs and increase workload;
- concern that SEA will increase the time frame for decision-making or delay development;
- an absence of a single, 'recipe' approach;
- unclear lines of accountability and responsibility for undertaking SEA; and
- a lack of practitioners with expertise in SEA approaches.

Why SEA over other Tools?

In assessing the environmental impacts of a long-term policy like ‘Yemen's Strategic Vision 2025’, a strategic assessment tool is needed. While there are various tools at the policy level, SEA is the most suitable tool for the purpose of this research for the following reasons:

- ‘Yemen's Strategic Vision 2025’ has already been adopted by the government since 2002, and the policies provided by this strategic vision are presently being implemented by the water and agriculture sectors. SEA is a flexible approach that can be applied ex-ante (very early in decision-making processes), integrated (accompanying assessment allowing for periodic review of the environmental effects of decisions following implementation) and ex-post (as an evaluation tool of the whole process and its outcomes), as mentioned in Section 5.3.1.
- Policies on water that are mentioned in ‘Yemen's Strategic Vision 2025’ (see Annex1) are embedded in the policies and strategies of the water and agriculture sectors. Therefore, the assessment of ‘Yemen's Strategic Vision 2025’ will require assessing currently-applied policies and strategies in the two sectors. SEA as a tool can be used not only to assess the impacts of policies but also to assess other strategic-level initiatives including programmes and plans. This comprehensiveness endows SEA with the ability to cover all strategic documents examined by this research.
- The research aims at assessing existing explicitly stated policies concerning water resources. As the focus of the assessment is on policy aspects that are explicitly mentioned, a tool like policy environmental assessments²², whereby implicit and non-declared policies of the government should also be assessed, is not adopted by this research.
- It is known that SEA is an extension of project-level EIA for a higher level of decision-making. SEA also borrows some methodologies from EIA. This makes the adoption of SEA in the water resources sector easier as the scientific and professional foundation in Yemen is partly established.
- SEA has been applied to several donor-funded programmes and plans in the water sector. This has introduced decision-makers and sector professionals to the importance and use of the tool.
- SEA has the capacity to support the development of policy and planning practices with a stronger environmental component. Above all, it may perform a fundamental role in promoting sustainable principles and practices as well as the consideration of cumulative effects (Wood, 1995; Partidário, 1996a; Sadler, 1998; Fischer, 1999; Goodland and Mercier, 1999; Clark, 2000; Partidário, 2000. From: SEA_Training_Manual [Petiderio])
- While the research looks at the ‘bigger picture’ of water resources sustainability, the scope of the research does not include checking the consistency of these policies with ‘highest-level

²² *Policy environmental assessments*: Based on the premise that policies are different from plans and programmes. It ‘should cover as many policy levels as possible and include implicit as well as explicit policies’ (Bailey and Dixon, 1999).

societal goals'. Therefore, a tool such as Policy Assessment²³ is not applicable in this research. Moreover, the research does not aim to assess the potential environmental, economic and social effects²⁴; hence, a tool such as integrated assessment²⁵ does not fit the purpose of the research.

The abovementioned reasons resulted in SEA emerging as the most suitable approach for use in this research and led to the exclusion of the other two policy assessment tools.

5.3.5 SEA of Policies²⁶

The research applies SEA to assess the impacts of a policy i.e. 'Yemen's Strategic Vision 2025'. Thus, it is important to highlight the main aspects related to policy assessment as well as provide a clear delineation between the meaning and characteristics of policy assessment and other types of strategic-level assessments—e.g. programmes and plans—covered by SEA. The focus is on the use of SEA as applied to the policy formulation and implementation process, which is a subset of applications on SEA.

Policy-level SEA assesses different types of initiatives. Sadler (2005) mentions that policies subject to SEA can, *inter alia*, include legislations, government strategies, papers, memoranda or statements of intent that outline new policies or proposed directions or options at the highest level. He adds that policy-level SEA is recognized as a distinct area that covers the highest echelons of decision-making.

SEA in general, and at the policy level in particular, is challenging because the initiative or proposal subject to assessment lacks specific spatial and temporal characteristics at this stage. Dalal-Clyton and Sadler (2005) confirm greater uncertainty in SEA than in (project level) EIA. They explain that the relationship of policy-level proposals to environmental effects is indirect or difficult to locate in time or space, mediated by intervening factors. Hence, they recognize the use of indicator-based methods that can show 'direction of movement' for an impact—e.g. increase in habitat loss, reduction in volume of hazardous waste—and

²³ *Policy assessment*: combines the functions of 'policy vetting' to check consistency with 'highest-level societal goals' and impact analysis to address any potential adverse consequences (Sadler, 2005).

²⁴ It is important to mention that SEAs need not be environment-led, as the World Bank (2007) concludes. After analysing 10 SEA case studies, the World Bank (2007) found that some effective SEAs in the case studies were primarily driven by factors other than the environment, although environmental sustainability played an important role.

²⁵ *Integrated assessment (IA) or sustainability appraisal (SA) (also sustainability impact assessment)*: Addresses environmental, economic and social effects, particularly valuable for weighing competing considerations of macro-policy initiatives (UNEP 2001). SA is an integrated assessment that is carried out within an explicit framework of sustainability objectives and criteria (Sadler, 2002) or a structurally integrated assessment and planning system (Abaza et al., 2004).

²⁶ Fischer (1999) provides characterisations for policies, programmes and plans. *Policies* formulate overall development needs and identify intermodal development options, integrating different sectors. Development scenarios are compared, taking account of external circumstances, such as population and economic growth. Preferred development scenarios are identified. *Plans* identify spatial alternatives that help to achieve previously identified needs. Alternatives are compared and advantages and disadvantages are weighted and balanced, in order to choose the preferred alternatives. *Programmes* list the previously identified projects. Criteria are developed that allow projects to be ranked and project priorities to be determined.

projection methods that are used to deal with uncertainty, such as trend extrapolation and scenario development.

SEA practice at the policy level is still limited to a relatively small group of countries and international organizations (Sadler, 2005). Nevertheless, the application of SEA to policies is expected to increase further. Tatlow and Honusch (2012) mention indications in the development cooperation context and the Western world, that SEA will continue to become more strategic than it is at present. Donor agencies that support developing countries—e.g. the World Bank—promote policy-level SEA as it works towards improving policy making from an environmental mainstreaming perspective as well as supports better planning and policy making from an overarching development point of view (WB, 2011).

There is no specific procedure or approach for conducting SEA at the policy level. Where SEA is applied to plans and programmes, a more structured approach to integrating environmental considerations can be used, adapting the characteristic steps of EIA. In policy-making, this will not be possible usually because of the complex, non-linear character of this process (OECD, 2006). Nonetheless, there exist guiding principles for SEA of policy²⁷.

At the policy level, Brown and Therivel (2000) explain that SEA provides the potential to do the following: incorporate new objectives and constraints in policy formulation; substitution of alternative objectives; policy instruments and implementation strategies; and the identification, clarification and resolution of conflicts, compromises and inter-linkages. They add that SEA at the policy level provides an opportunity to internalize externalities that are often inadequately considered in much sectoral policy formulation and decision-making; they assert that the intention of SEA is moving policy—and PPP, generally—towards sustainable outcomes.

²⁷ Sadler (2005) mentions guiding principles for SEA of policy and legislation in which the SEA process should be:

- *fit-for-purpose*: adapted to the context and characteristics of the policy or law-making process
- *sustainability-directed*: conducted through the lens of sustainability principles and rules to place the potential effects of a proposal within a long-term, precautionary frame of reference
- *objectives-led*: undertaken with reference to relevant environmental goals, targets and indicators
- *source-focussed*: concentrated on the policy, legislative and other government proposals that are environmentally significant or implicated in unsustainable development
- *decision-relevant*: addressed to the issues and information that matter in law or policy-making
- *outcomes and effects-oriented*: targeted, whenever possible, at promoting good policy outcomes for the environment as well as ensuring adverse effects do the least possible harm
- *integrative*: concerned with policy linkages across sector boundaries and with economic, social, health and other effects as appropriate and necessary (e.g. in the absence of equivalent processes)
- *transparent and open*: based on clear, easily understood requirements and procedures, including provision for an appropriate forms of public consultation
- *quality-assured*: established through arrangements and guidance that meet international standards and fit-for-purpose, and
- *cost-effective*: completed in accordance with terms of reference and within available time, budget and resources

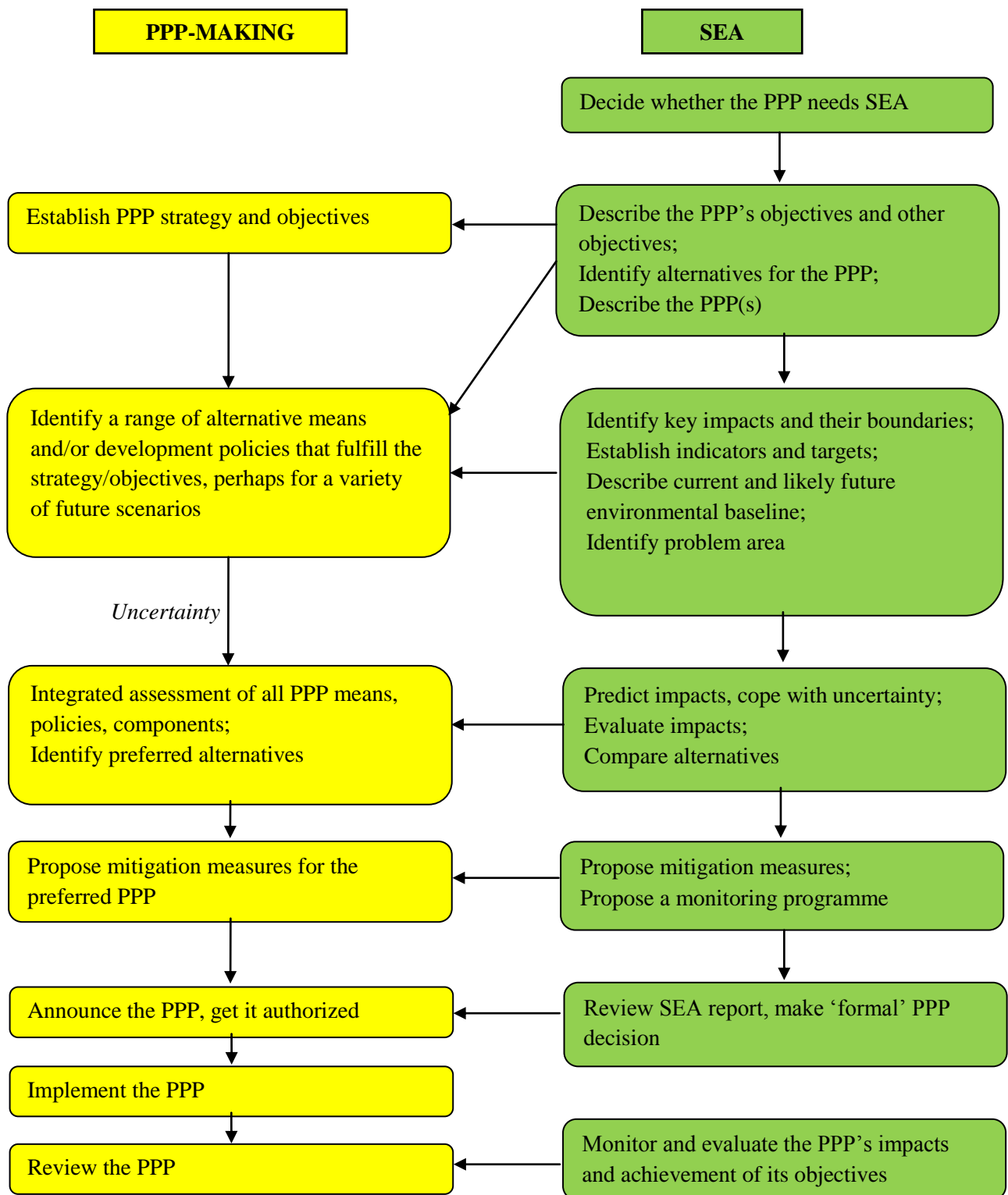


Figure 11: Steps of and links between PPP-making and SEA
 Source: Thérivel and Partidário, 1996

5.4 Environmental Assessment in Yemen

Environmental assessment was introduced in Yemen through Environmental Impact Assessment (EIA). EIA is now a widely accepted systematic planning tool used to integrate environmental concerns into decisions on initiatives at the project level. EIA application is a legal requirement as per the Environmental Protection Law of 1995.

At the strategic level, and to evaluate the environmental impacts of policies, plans and programmes, the application of SEA has been increasing as the tool for such assessment in many countries around the world. SEA is undertaken, both formally and informally, in an increasing number of countries and international organizations (Sadler, 2011). Tatlow and Honusch (2012) confirm that there is hardly any country that has not been in touch with the idea of SEA or SEA-like processes. Yemen is one of those countries where SEA studies have been conducted, though mostly for fulfilling the requirements of donor organizations²⁸.

Yemen's Legal Framework of Environmental Assessment

The Environmental Protection Law (EPL) No. (26) of 1995 is the legal foundation for undertaking the environmental assessment of development initiatives. The environmental assessment provided for in the EPL focuses on the application of EIA at project level. This focus on project-level environmental impacts has resulted in issuing the EPL Executive Regulations (By-law 148 of 2000) that serve the sole purpose of enforcing EIA at the project level, thereby limiting the scope of these legislations and the requirement of applying environmental assessment at the strategic level. Although there is no legal provision for applying SEA in Yemen, several programmes and plans in the water sector have been subject to SEA. These SEAs²⁹ have been conducted to fulfil the legal requirements of international funding agencies and donor countries.

5.5 The Need for SEA in Water Sector

The increasing and competing demand for available water by different sectors has made the planning of water resources more challenging. This is particularly true in countries like Yemen that already suffer from water scarcity. To ensure a sustainable policy development and informed decision-making, the following challenges should be dealt with in the water sector:

- The need to adopt inter-sectoral approach in planning for sustainable water resources. Such an approach allows for considering different aspects—i.e. environmental, social, economic and political aspects—that may influence/be influenced by water policies.

²⁸ The evolution of SEA in the development co-operation context not only provided for capacity building, but also enhanced the concept of SEA in other contexts. For example, it strengthened the role of SEA in promoting public participation and extended its scope to also cover policy-based approaches, including lending and sector level programming (Dalal-Clayton and Sadler, 2005) in (Tatlow and Honusch, 2012).

²⁹ Some Strategic Environmental Assessment (SEA) studies that have been implemented in the water sector in Yemen include the Sector-wide Environmental and Social Assessment (SwESA) that was conducted in 2008, and the Strategic Assessment Programme Poverty and Social Impact Analysis (PSIA) that was conducted in 2007.

- The need to assess immediate and cumulative impacts resulting from water policies in order to eliminate negative impacts on water resources and on water users in the short and long terms.
- Initiating the process of stakeholder involvement and the process of assessing potential effects from the highest level of decision-making—the policy level—to ensure that the policy is properly formulated before being adopted by lower level decision-makers, and before the policies are translated to programmes and projects.

Meeting these challenges call for adopting a systematic, inter-sectoral planning tool that provides a proper forum for different stakeholders to discuss and consider all aspects related to a proposed initiative at the strategic level, including policies, plans and programmes.

Advantage of Applying SEA in the Water Resources Sector

The World Bank (2007b) asserts that SEA should be seen as a process rather than a specific study; this process of interacting with different stakeholders, examining causative influences and longer-term consequences, and integrating environmental, social, and economic considerations is often as important as the output from the SEA study. NCEA (N.A) summarizes these advantages in the following:

- Integrated approaches: SEA can assess and process the trade-offs between environmental, economic and social issues. Water resources provide multiple goods and services. Therefore, interventions have a variety of interrelated consequences that cannot be seen in isolation.
- External effects: SEA can provide a structured and transparent mechanism for negotiation and decision-making in national and international river basins.
- Cumulative effects: SEA can help to provide a better understanding of cumulative impacts, preventing costly and unnecessary mistakes.
- Changing management perspectives: SEA can support the establishment of a clear policy analysis and decision framework to guide decentralized water management.

The World Bank (2005b) mentions that SEA, as an evolving tool, could improve its influence on policymaking by addressing more directly the institutional and governance dimensions, implying a continuous effort by a country to incorporate the following four elements:

1. Prioritization of environmental issues (in this context, water quantity) in terms of their effect on economic development and poverty reduction, using both quantitative and participatory techniques in order to select themes or sectors for which there is a definite recognition of the severity of environmental problems.
2. Mechanisms that bring together different viewpoints during the policy formulation and implementation process, particularly the viewpoint of the most vulnerable groups—i.e. those most affected by environmental degradation, who typically have less representation in policy making. Establishing institutional mechanisms that do not favour one stakeholder above another disproportionately—as in the case of regulatory capture—is also important.
3. Mechanisms that ensure social accountability in the context of environmental issues, such as passage of legislation to allow for greater transparency in decision-making and outcomes, advocacy through a free press, and strengthening of recourse measures linked to, for example,

environmental quality outcomes or licensing processes, such as complaints systems or the judiciary.

4. Mechanisms through which social learning can occur, so that key environmental priorities are given attention and continuously brought before the policy agenda so that incremental improvement can occur over time.

5.6 SEA and IWRM: Integration and Synergy

Even though they originate from different disciplines, SEAs and IWRM, according to the World Bank, share many objectives with regard to WRM. However, they differ in analytical approaches and terminology. Common characteristics include application at different spatial scales, multi-sectoral decision-making, stakeholder participation, use of quantitative data, monitoring and evaluation, and broadening perspectives beyond immediate sectoral issues (WB, 2007b). Nevertheless, differences between both approaches in addition to gaps in IWRM application make SEA a potential complementary tool that can be used to support IWRM.

As mentioned in Section 5.2, IWRM limitations, *inter alia*, include: the limited strategic level of IWRM application (Xie, 2006), that it is not embedded in legal binding procedures (Slootweg, 2009), lack of a clear and systematic process for IWRM application and lack of ‘built-in’ mechanisms for stakeholders’ involvement and public participation (see Cap-net, 2005 and GWP, 2004). Such limitations leave the process of developing water policies, plans and programmes subject to arbitrary arrangement rather than subject to a systematic, participatory, inter-sectoral and legally-binding procedure. Challenges to IWRM application in Yemen include neglect of water for the environment, limited inter-sectoral coordination and stakeholder participation, and weak governance. SEA can support IWRM in overcoming these challenges. The following explain SEA characteristics that qualify SEA to achieve this goal and overcome IWRM limitations and challenges:

- SEA is a systematic process that is applicable to the first and highest level of decision-making—i.e. at the policy level—and also to plan and programme levels for assessing potential impacts of the proposed initiatives at these levels before their adoption by lower level decision-makers and implementation at project level.

- Although there is no ‘one-size-fits all’ SEA, as Tetlaw and Hanusch (2012) assert, the fact that SEA is a systematic, defined process and has ‘good practice’ increases the chances of SEA becoming more ‘operational’ than IWRM, which is only formed by principles.

- SEA can be legally enforced. Slootweg (2009) mentions that the availability of regulations asking for an assessment of new policies, plans and programmes provides a formalized (legal) foothold for SEA to influence the planning process, thereby making SEA a legally-embedded tool. This compensates for the IWRM’s limitation of not being embedded in legal procedure.

- With regard to stakeholder and public participation, Gauthier et al. (2011) mention the common view that public participation must be a part of SEA (SEA) procedures. SEA has typical opportunities for public participation. OECD (2006) includes stakeholder involvement in three of the four stages of SEA good practices. After reviewing SEA experiences in development co-operation in nine developing countries, OECD (2012b) concludes that ‘in many countries where SEAs were carried out, the SEA process not only brought together ministries within governments, but also marginalized sections of society and civil society groups’. After analysing 10 SEA case studies, the World Bank (2007b) concludes that ‘some institutions, initially skeptical of stakeholder involvement, became advocates of increased stakeholder participation in their usual work as a result of their experiences during the SEA’.

-The monitoring plan in SEA provides a systematic mean for checking the overall impact on water resources ‘quantity in the case of this research’. This can be achieved by providing targets and milestones for future follow-ups on the condition of resources as a result of implementing the strategic initiative.

While some of the SEA characteristics mentioned above support IWRM application in general, the mentioned characteristics overcome some of the implementation challenges facing IWRM in Yemen, as mentioned in Section 5.2. Nevertheless, other advantages that can be gained from applying SEA to meet IWRM in the Yemeni context are explained in the following:

- While there is no mention of ‘water for environment’ in Yemeni policies and programmes, SEA is a tool that mainly promotes the integration of environmental concerns in policies, plans and programmes. Hence, adopting SEA in the water sector will help in considering and allocating ‘water for the environment’, which is completely neglected under the existing practice of IWRM.
- Policy-based SEA supports good governance, which is another reason for strongly supporting the application of SEA in developing countries by the World Bank and other donor agencies (Tatlow and Honusch, 2012). Long periods and continuous engagements will be necessary to strengthen institutional capacity for good environmental governance (WB, 2005b).
- Supports public participation and inter-sectoral participation.
- SEA can support establishing clear policy analysis and decision framework to guide decentralized water management that has been initiated already. WB (2007b) mentions that SEA contributes to decentralization of water resources institutions and the establishment or strengthening basin institutions for operational management.
- SEA offers through its monitoring plan an opportunity to investigate systematically and periodically the impact of the strategic interventions through monitoring specific factors—e.g. the water balance. Such monitoring will provide regular feedback to decision-makers on the status of implementing these interventions and on their impact, thereby allowing the taking of required measures to adapt these strategies, plans or programmes to achieve their aims.

5.7 The Conclusion

IWRM has been adopted in Yemen since 1995. However, the limitations of IWRM's approach, in addition to IWRM implementation challenges in Yemen, result in the inability of IWRM to achieve its potential, particularly at the strategic level.

In Yemen, the lack of a tool for assessing the environmental impacts of initiatives at the strategic level in the water sector necessitate extending the current practice of environmental assessment from the project level (EIA) to the strategic level (SEA).

SEA has great potential in the water resources sector in Yemen. SEA shares several principles with IWRM that can create a positive synergic effect in the water resources sector. SEA offers characteristics to help to overcome some IWRM limitations, particularly at the strategic level. The diverse methods and approaches that SEA offers play a key role in realizing the potential of SEA as the following chapter explains.

6. SCENARIO BUILDING, DATA COLLECTION AND ANALYSES

This chapter explains the methodology used to collect and analyse data. It also explains the methods adopted to plan and build research scenarios. The chapter begins by explaining the process of scenario planning and development. To provide an adequate picture, each step adopted for developing scenarios is first explained and then followed up by showing how the step is applied in the context of this research. The chapter then highlights methods used to collect the required qualitative and quantitative data. Finally, the methods applied in implementing the qualitative and quantitative analysis are presented.

This chapter also seeks to clarify the process of scenario building for potential users of these scenarios. Coates (2000) asserts that ‘the ideal scenarios are transparent in the sense that the user knows what the rules of the game were for its construction, understands the stepwise process by which it was produced and sees the result with the feeling that he or she could go through the process and come up with similar results’.

6.1 Introduction into Scenarios Planning and Building

6.1.1 Definition

The word scenario is borrowed from performance theatre (UNEP, 2007) and means ‘an outline for a screenplay’ (The American Heritage Dictionary, 2011). According to the scenario-building pioneer Shell (2008), a scenario is a story that describes a possible future. Early scenario developers Kahn and Wiener (in ICIS, 2000) define scenarios as ‘hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points’.

6.1.2 Purpose of Scenario Building

The aim of using the scenario approach is to systematically explore, create and test possible and desirable future conditions (Glenn, 2009). In this research, the scenario approach is used as a scientifically-based method to qualitatively and quantitatively achieve the following:

- Evaluate ongoing technological interventions adopted in ‘Yemen’s Strategic Vision 2025’ and explore their potential future impacts on water balance
- Identify future strategic targets to support water resources and bring the water balance back to the sustainability track

6.1.3 Why Scenarios Building over other Tools?

To serve the aim of this research of assessing ‘Yemen’s Strategic Vision 2025’ and showing the potential of using SEA in supporting strategic planning and decision-making, scenario building has been selected for implementing this research. Before mentioning reasons for this selection, it is important to mention a main common aspect between SEA and scenario building. Scenario building and SEA are both used at the strategic level to improve strategic planning and decision-making. According to Ratcliffe (1999), the prime aim of scenarios

building is to enable decision-makers to detect and explore alternative possible futures in order to clarify present actions and their consequences, thereby preventing them from making any strategic decisions without doing some strategic thinking. The aim of an SEA is to improve decision-making and the development of policies and plans by establishing an environmentally-friendly and sustainable integrated context when developing these policies and plans (Partidário, 1999 in Partidário, 2003).

The following explains why scenario building was selected for implementing this research and why it is a particularly helpful method when implementing SEA.

Scenarios for Policy Analysis

Scenarios are applied within this research to analyse existing policy alternatives of ‘Yemen’s Strategic Vision 2025’ and to foresee the potential outcomes of such alternatives. Ratcliffe (2000) explains that a scenario may be used to describe a future state, and thereby form the basis for policy analysis. Conversely, Ratcliffe (2000) mentions that the scenario may tell a complete story including possible or probable policy actions and outcomes.

Creating a Context for Planning

Planning a development or an initiative needs a context. This context is formed by understanding the current trends produced by a functioning system as well as how these trends will come together and unfold when creating the future. Developing a comprehensive image for these trends is a prerequisite for creating the proper context within which the planning process can take place. According to Ratcliffe (2000), trends do not automatically come together to create a picture of the future applicable to planning; therefore, the primary purpose of scenario planning is to create holistic and integrated images of how the future might evolve. These images, in turn, as Ratcliffe (2000) explains, become the context for planning.

Using Scenarios for Identifying Strategic Targets

In building future scenarios of a system, factors of success and failure that may impact that system are identified and analysed. Focusing on success factors in various scenarios is a common way for using scenarios as input for generating strategies (Lindgren and Bandhold, 2009). Therefore, the researcher uses scenarios not to develop a strategy, but rather, to identify targets that are extracted based on the analysis of success factors in each scenario.

Reading Signals and Being Prepared

Building scenarios is based mainly on understanding drivers and factors that affect the function of a system. Scenarios also help to understand how each of these influential drivers and factors may turn to create one scenario and impact the system that was subject to the scenario development. Therefore, the research adopted scenario planning to highlight the actual factors that may shape the future of water resources. Shell (2008) affirms that once the developed scenarios have been understood, the users of scenarios can begin to work with

signals by scanning the environment for indications on dynamics that they have used to create their scenarios. Shell explains that based on these signals, scenario users can underpin their decision or strategy as well as identify other or new dynamics that were not considered when developing the scenarios. This will ultimately enable faster and more effective response.

6.1.4 Scenarios as a Method for SEA

The development of scenarios is used increasingly in SEAs. As mentioned earlier, scenario building and SEA are powerful tools for improving strategic planning and supporting decision-making. As Figure 12 shows, scenario development in this research is used for assessing the impacts of ‘Yemen’s Strategic Vision 2025’ and also for comparing future alternatives of implementing interventions adopted in this policy. Features that help scenario building to better serve the aim of and are more suitable to be used in SEA are mentioned below.

Impact Prediction

Scenario planning, according to Therivel (2004), is a method for impact prediction that brings in factors that are outside the sector developing the plan. These factors determine the advantages or disadvantages of the plan and control its success but are outside the control of the strategic action.

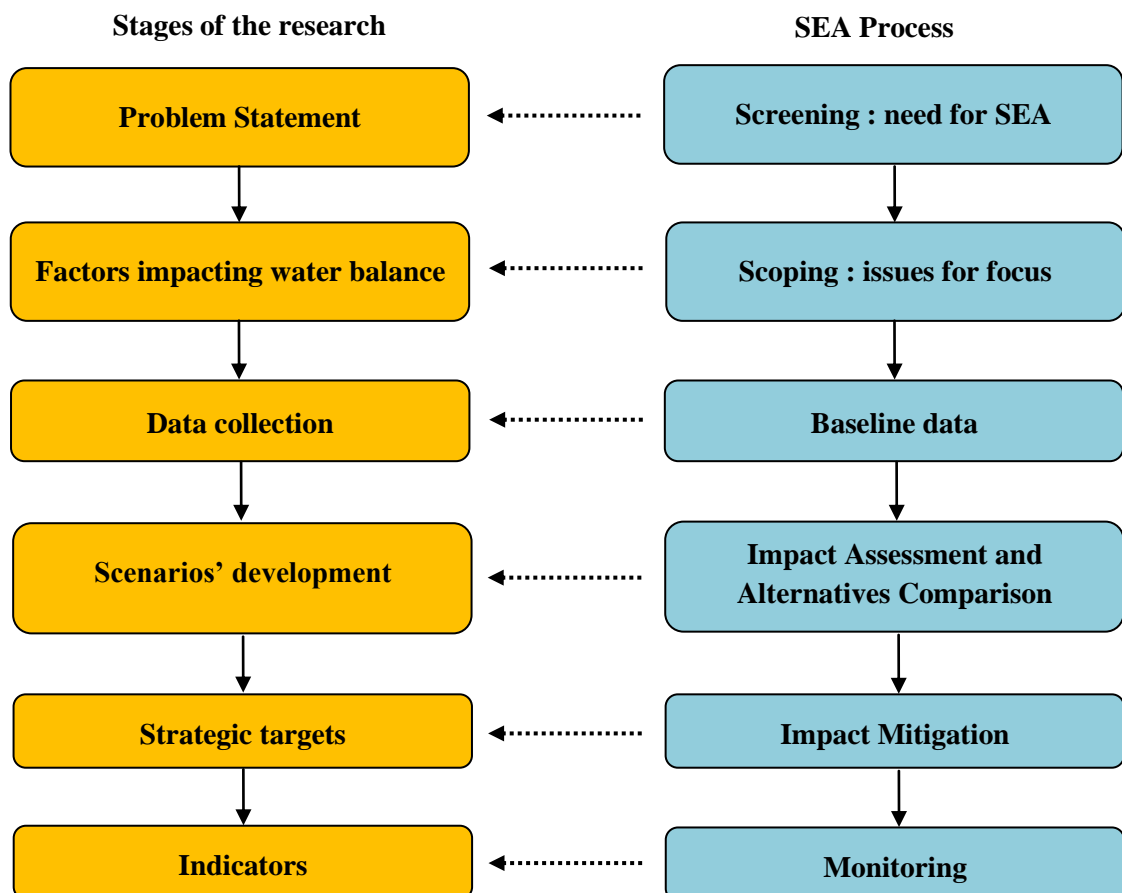


Figure 12: Scenario development as a main stage of the assessment in this Research

Source: the author

Assessment of Strategic Options

According to Partidário (2007), scenarios play a core role in strategic analysis and assessment as well as in the identification and assessment of strategic options and in the comparison of options that enable choice.

Considering Likely Consequences

In addition to its use in predicting the future, Dalal–Clayton and Sadler (in Kerstin Ehrhardt and Måns Nilsson, 2006) affirm that scenarios are especially helpful for SEA as they consider the likely environmental, social and economic consequences of current and possible future trends, and the consequences of taking particular actions or implementing particular policy options.

Dealing with and Adjusting, Entailing and Accommodating Uncertainties

Planning and managing water resources in a country like Yemen that lacks sufficient, updated and comprehensive data on water resources. Hence, uncertainty becomes unavoidable for planners, manager and researchers. Scenario planning, according to Schoemaker (1995) and Schnaars (1987), is especially beneficial in cases where the uncertainty is higher than the manager's ability to predict and adjust. Scenario planning helps decision-makers to think about worrying uncertain aspects of the future, discover aspects they should be concerned about and explore ways in which these aspects might unfold (Shell, 2008).

SEA deals with a policy and planning level that is characterized, as Partidário (2003) asserts, by uncertainty due to limitations in the availability of information, uncertainty regarding action implementation and the respective timings; decisions are uncertain and incremental. Dalal-Clyton and Sadler (2005) mention scenario development as projection methods used to deal with uncertainty.

Complexity Reduction

Through scenarios, complexities in the systems being studied—e.g. water resources—can be reduced to a manageable number of uncertainties (Lindgren and Bandhold, 2009).

6.1.5 Limitations of Scenario Building

Although scenarios were first used in the 1960s, they are not widely used today. Nobel et al. (2011) list scenario analysis among methods that are data-, time- and resource-intensive in comparison with other methods such as expert judgement. Lindgren and Bandhold (2009) mention disadvantages that do not help scenarios to be widely used. These include the following:

- Uncertainty in conclusions: as scenarios do not give one single answer about the future.

- Counterintuitive to managerial simplicity: meaning that scenarios use holistic or systemic approaches to planning instead of the traditional managerial methods, which says that each question has one right answer and every problem can be divided into parts that can then be solved separately.
- Soft methods and soft answers: scenarios tend to use qualitative methods and are based on reasoning and intuitive pattern recognition.
- Scenarios are time-consuming

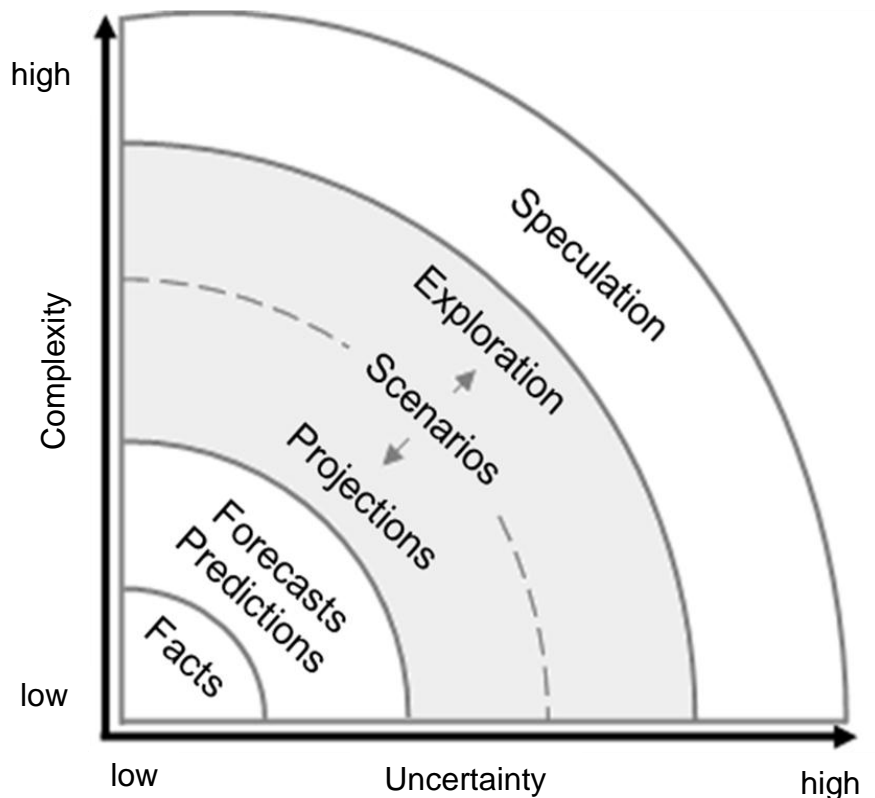


Figure 13: Scenarios and uncertainty in complex systems³⁰

Source: Zurek and Henrichs, 2007

6.2 Scenario Building Process

Available literature on scenario planning and building describes several methods for building future scenarios. These methods differ from simple to complex and from qualitative to quantitative (Glenn, 2009). Nevertheless, all processes include certain steps that form the basis of scenario building. These steps mainly include:

- understanding the system of the issue being studied,

³⁰ Note that scenarios differ from facts, forecasts, predictions and speculations (Zurek and Henrichs , 2007)

- identifying key factors that will shape the future; and
- forming scenarios by interconnecting key factors to produce storylines over a defined period of time.

There is no one process that is exclusively right in planning and building scenarios. Thus, to construct water balance scenarios, the research follows two main scenario-building methods developed by two leading futurologists. The first one, which is the main method adopted in implementing this research, was developed by Schwarz in the Global Business Network³¹. The second method was developed by Ute von Reibnitz. According to Ogilvy and Schwartz (1998) and Schwarz (1991), the steps of scenario planning and building include:

- Identifying the decision focus or focal question
- List of key factors
- Distinguishing pre-determined elements from uncertainties
- Identifying a few scenario logics
- Fleshing out the scenarios
- Defining implications
- Selecting the leading indicators

In this research, the logic for building a scenario is adopted from the method developed by Ute von Reibnitz³². This method includes the use of qualitative and quantitative data to produce scenarios that represent trend extrapolation of historical data and scenarios representing best-case and worst-case scenarios. It is mentionable here that the von Reibnitz technique emphasizes the construction of scenarios including two extreme, yet plausible, future scenarios (best and worst case scenarios). In explaining this logic, Schwab (2003) mentions that the philosophy and the proof in practice show that if an organization is capable of dealing successfully with these two extreme scenarios, then it is capable of dealing with all the variants between them.

By following the von Reibnitz method, this research has aimed at developing two extreme future scenarios—the Do Nothing and Sustainability scenarios—and a third reference scenario representing the extrapolation of current trend—the Business as Usual scenario.

Von Reibnitz's method of identifying the logics of scenarios has been adopted in this research for two main reasons. Firstly, it meets the need to adopt scenarios as a main method for policy assessment by allowing the user to develop a desired scenario to follow and an undesired scenario to avoid. Secondly, the scenarios' logic under the von Reibnitz method follows an easier path in forming the scenarios' logics; it results directly in a reduced number

³¹ According to Chermack (2001) the scenario planning and building method of the Global Business Network was developed in the 1960s out of Shell's application for scenario technology. The method was developed after refining the concepts of Kahn—the father of the scenario-building tool—by Pierre Wack and then by Peter Schwarz who took over and established his own company 'Global Business Network'.

³² Mietzner and Reger (2005) state that Ute von Reibnitz introduced the scenario-building method in the German-speaking countries. According to Schwab et al. (2003), this method includes the following steps: task analysis, influence analysis, projection, clustering alternatives, scenario interpretation, consequences analysis, wild card analysis and scenario transfer.

of scenarios and accordingly reduces the effort and time needed. Comparing this method to the one adopted by the Global Business Network approach shows that the latter method ends by developing four initial scenario logics, by using the 2x2 matrix. This is then manipulated to develop the final scenarios, and may be more or less than the initial four basic logics.

6.2.1 Identifying the Issue of Concern or ‘The Focal Question’

It is useful at the beginning of scenario development to identify the focal question of concern (Schwartz, 1998. In: Pastor 2009). The identification of the focal question:

- Offers a more focused approach for the identification of the issue of concern and, accordingly, the identification of the system needed to be studied for developing the future scenario
- Helps the developer of the scenario to stay focused during the process and get specific answers at the end.
- Helps the user of the scenario to identify from the beginning the exact issue of concern in this scenario and whether this issue is related directly to his function in the system.

For the scenarios developed in this research, the focal questions are those that have been raised at the beginning of the research:

- What are the potential futures of the water balance until 2025 on following these alternatives?
- Is sustainability still achievable by 2025 using these alternatives? At what rate should these alternatives be implemented to achieve sustainability?

6.2.2 List of Factors Delineating the System to be Analysed

In this step, the developer identifies factors that influence the system being studied or the universe of concern that the scenario developer is dealing with. Some futurologists like Godet (1994), and Lindgren and Bandhold (2009) refer to this step as defining the ‘system’ under study.

In this research, the focal questions concern the water resources system, which includes factors and driving forces that influence it. Table 13 shows influential factors and driving forces.

Table 13: Factors & driving forces influencing the water resources system

<p>Agricultural Factors</p> <ul style="list-style-type: none"> - Irrigation efficiency - Irrigation water consumption - Area of agricultural land - Area of qat agriculture - Cropping choices - Land fragmentation <p>Legal and Institutional</p> <ul style="list-style-type: none"> - Institutional structure of water and irrigation sectors - Decentralization - Participation of local communities' in water management - Technical capabilities of water institutions - Availability of technical criteria for selecting type and location of intervention water resources developments - Coordination with other sectors and stakeholders - Coordination between the government and donors supporting the water sector - Coordinating with the private sector for providing water saving systems - Availability of strategies with quantitatively-bounded targets - Prevalence of customary water law - Availability of updated monitoring data - Clear water rights system - Application of wells licensing system - Control of drilling-rags import and movement - Water metering of wells - Enforcement of the water law - Enforcement of environmental regulations related to water quality and resources development <p>Environmental Factors</p> <ul style="list-style-type: none"> - Precipitation - Temperature - Water quality - Climate change - Groundwater availability - Surface water availability 	<p>Political and Security Factors</p> <ul style="list-style-type: none"> - Political commitment and support - Security situation in the country <p>Economic Factors</p> <ul style="list-style-type: none"> - Water price - Diesel prices - Prices of agricultural crops - Availability of markets of agricultural outputs - Poverty rate - Price of modern efficient technologies - Taxes of irrigation equipments - Food price - Availability of jobs in non-agricultural activities - Per capita income - Cost recovery of water supply and irrigation systems <p>Social Factors</p> <ul style="list-style-type: none"> - Population growth - Tribal social structure - Farmers acceptability of modern efficient technologies - Geographic distribution of population - People's dietary patterns - Public awareness on water issues and shortage <p>Technological Factors</p> <ul style="list-style-type: none"> - Availability of modern irrigation technologies - Use of desalinated water - Efficiency of water supply and irrigation systems - Pace of implementation of interventions to enhance water resources <p>Other Factors</p> <ul style="list-style-type: none"> - Per capita water consumption - Industrial water consumption - Use of water-harvesting techniques - Wastewater reuse - Urbanization
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Source: the Author

6.2.3 Key Factors of Influence

Water resources are influenced by many factors that create a number of issues for consideration when developing scenarios; hence, the number of resulting scenarios can become unmanageable. Therefore, the best approach, according to Glenn (2009) is to focus from the outset and identify variables that are the most influential in building scenarios to respond to the addressed questions.

In selecting the key factors that influence the success or failure of the issue or focal question developed, factors and driving forces identified in the previous step are winnowed down in a process that results in a short list of variables. The variables listed below have been selected based on the input obtained from interviews conducted with the experts and decision-makers in the water resources sector and from reviewing related literature. The variables are then classified into two types of factors—namely, certain factors and uncertain factors. Wack (in Chermack et al., 2001) defines predetermined elements as ‘those events that have already occurred (or that almost certainly will occur) but whose consequences have not yet unfolded’. In contrast, critical uncertainties, according to Wack (in Chermack et al., 2001), are those events that can only be imagined. For the water resources scenarios developed in this research, Table 14 shows identified predetermined and uncertain variables.

Table 14: Key certain and uncertain variables selected for developing future scenarios

Certain	Uncertain
<p>Quantitative</p> <p>Annual renewable water</p> <p>Population growth</p> <p>Growth of water consumption in irrigation</p> <p>Growth of domestic water consumption</p> <p>Growth of industrial water consumption</p> <p>Qualitative</p> <p>Tribal social structure</p> <p>Prevalence of customary water law</p>	<p>Quantitative</p> <p>Amount of water saved by modern irrigation systems</p> <p>Amount of water harvested by dams</p> <p>Amount of reused wastewater</p> <p>Area of qat replaced by other crops</p> <p>Qualitative</p> <p>Government commitment and support to enhance water resources</p> <p>Farmers’ attitude (acceptability of alternatives and modern technologies, participatory and communal management)</p> <p>Institutional sittings, i.e. central organization and decentralization of water resources planning and management</p> <p>Establishment of WUAs for community-based management</p>

Source: the Author

When selecting the aforementioned key factors influencing water resources, a conceptualization of the system under study was necessary to

- Distinguish and connect qualitative factors that can be used for scenario narratives and quantitative factors that can be simulated
- Establish a connection between the abovementioned two types of factors for creating scenarios that are internally consistent, balanced, plausible and based on reliable data in order to be considered credible and trust-worthy by planners and decision-makers.

6.2.4 Selecting the Scenario Logic

In selecting the logic of building future scenarios, the research has adopted the method developed by Ute von Reibnitz. As explained in Section 6.2 of this chapter, the method recommends developing two extreme future scenarios (Figure 13) by putting all the negative variables in one extreme and all the positive variables in another. Following this logic, the resulting two main plausible scenarios in this research are the Do Nothing and Sustainability scenarios.

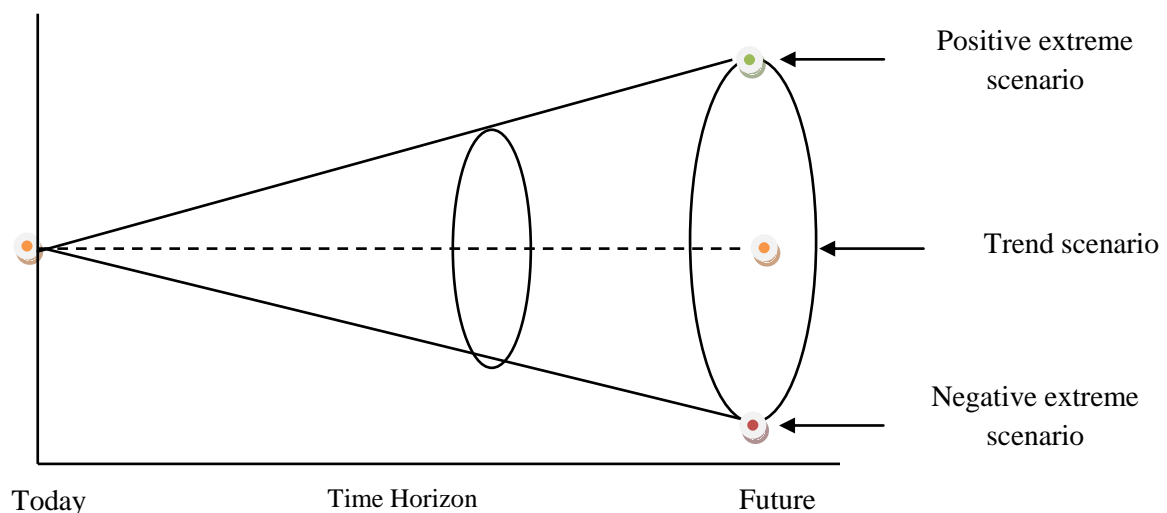


Figure 13: Scenario Funnel with the Three Basic Scenarios
Source: Modified from Albers and Broux (in Kaulfuß, 2011)

In this research, a scenario building logic developed by Schwartz is adopted in building a third scenario. Ogilvy and Schwartz (1998) suggest that two logics for forming the basic premises of a small number of scenarios can be selected following one of two approaches—the inductive and deductive approaches. The inductive approach relies on reaching a consensus between the participants in the scenario development process. The deductive approach uses the simple technique of a 2x2-scenario matrix based on the two most critical uncertainties.

In selecting the logic for developing the Business as Usual (BAU) scenario, the inductive approach was adopted³³. In this approach, Schwartz distinguishes between two variants. The first variant, which Schwartz calls ‘emblematic events’, starts with individual events or plot elements, and then spins larger stories around these seeds. The other variant is called the ‘official future’; this is a more systematic variant of the inductive approach and has been adopted in developing the BAU scenario in this research³⁴ (Ogilvy and Schwartz, 1998).

Schwartz mentions that the ‘official future’ variant is the future that the decision-makers believe will occur, either explicitly or implicitly. This future, they mention, is usually a plausible and relatively non-threatening scenario, featuring no surprising changes to the current environment. To identify the key components and drivers of such a future, Ogilvy and Schwartz (1998) recommend interviewing 10 to 15 top managers and decision-makers and using annual reports, forecasts, and the analysis done on individual business units as valuable information sources.

Following the process recommended by Schwartz, 13 interviews have been conducted with top managers and decision-makers in the water sector. These interviews, along with the qualitative and quantitative data extracted from governmental organizations and reports, form the ‘official scenario’ of this research. This scenario represents the future as described by experts and decision-makers, including extrapolation of existing trends; it is named the Business as Usual scenario.

6.2.5 Fleshing Out Scenarios

Ratcliff (2000) explains that fleshing out scenarios and developing scenario narratives can best be accomplished by returning to the lists of key decision factors and driving forces of the change identified earlier. Ogilvy and Schwarz (1998) state that each identified key factor and trend should be given some attention in at least one scenario. They explain that sometimes it is immediately obvious which scenarios should include which side of an uncertainty, but sometimes not.

To flesh out scenarios and develop scenario narratives in systematic thinking, the approach of the ‘patterns and systems thinking’ is adopted. According to Ogilvy and Schwarz (1998), this approach suggests that we should not focus on an individual event, but rather, explore the underlying patterns of events to understand the appropriate plot for a scenario. They explain that at the tip of this ‘iceberg’ lie events, but that delving deeper helps to examine the patterns

³³ The inductive approach was followed in forming scenarios’ logic in this research as the deductive approach requires reaching consensus on the top two uncertain factors to be used as drivers in all scenarios (Ogilvy and Schwartz, 1998). Reaching consensus on two uncertain factors was not applicable following the interview method applied in the research.

³⁴ The ‘Official Future’ variant in developing scenarios’ logics was selected as this variant reflects the future that the decision-maker thinks will unfold, so it is a good entering point for attracting the attention of decision-makers to this scenario as well as to other potential scenarios and their consequences. On the other hand, the second variant for developing scenarios’ logics, ‘Emblematic Events’, was not adopted in this research because this process of developing scenarios using this logic is unsystematic and relies more on the imagination (Ogilvy and Schwartz 1998).

suggested by these events; beneath these patterns lie important structural changes that can define meaningful scenario logics.

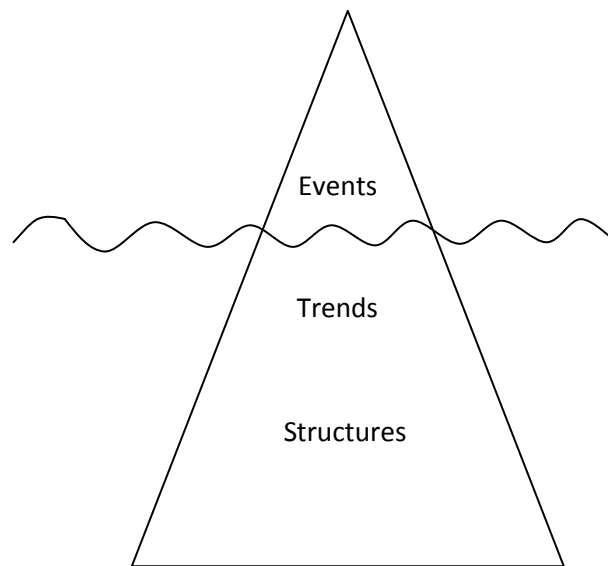


Figure 14: The iceberg metaphor: structural changes are driving systems at lower levels and are eventually observed as events and actions

Source: Lindgren & Bandhold (2009)

Thereafter, scenarios are constructed by relating trends while events identify each scenario through cause-and-effect linkages (Walsh, 2005). Walsh adds that scenarios should grow logically from the past through to the present and into the future, and be consistent with an organization's past, current and potential direction.

In fleshing out scenarios and developing the narratives of these scenarios, this research has adopted the abovementioned approach of trends and system thinking. Thus, the researcher has analysed existing settings of water resources, and studied some key events and underlying trends to identify potential future structural changes. The fleshing out of scenarios has involved establishing connections, inter-dependencies and mutual implications among key variables influencing the water resources. The events and trends have then been allowed to grow into the future through the pre-identified logics of the scenarios.

This phase results in the development of three scenarios—namely, the Business as Usual, Do Nothing and Sustainability scenarios as explained in Chapter 7.

6.2.6 Defining Implications

The final stage of scenario development, as Chermck (2001) asserts, is the examination of scenario implications. In this stage, critical issues pertaining to the impact of those scenarios are identified. In this context, Lindgren and Banhold (2009) mention that scenarios can be used as a basis for generating and selecting strategic issues.

This research focuses on the impact of policies adopted in ‘Yemen’s Strategic Vision 2025’ on the water balance. The research has developed three main scenarios that show the potential impact of the policy under study on the water balance. Based on the results of these scenarios, strategic targets that can help to support water resources have been identified. Implications and strategic targets resulting from the scenarios are explained in Chapter 8.

6.2.7 Leading Indicators

Following the development of the scenarios, indicators signifying the unfolding of actual events according to a developed scenario have been selected (Schoemaker 1995). Such identifiers help the planners to monitor how unfolding events may impact the organization.

Leading indicators for monitoring the three scenarios developed during this research are as follows:

- Area covered with modern irrigation systems and water savings achieved
- Agricultural water demand
- Amount of water harvested by dams
- Amount of reused treated wastewater
- Area under qat cultivation

6.3 Main Scenario Features³⁵

Different types of scenario planning and building methods can result in scenarios with various features. The following section presents the main features that a scenario can have and how these features apply or do not apply to the scenarios developed as part of this research.

Time Scale of Scenarios

When considering scenario building as a method, it is necessary to select carefully the time scale of the scenarios. Short time scale scenarios covering a period of two to five years are considered no more than a forecast of the current situation (Godet, 2006). Therefore, Duinker and Greig (2007) assert that scenarios building is highly applicable to mid- and long-range future studies that bear considerable levels of both predictability and uncertainty. Nevertheless, decision-makers may mistrust scenarios that cover very long time scales—e.g. more than 30 years—because these will be coupled with huge uncertainty that hinders the ability to identify answers that provide any guidance (Lindgren and Bandhold, 2009).

³⁵ There are various proposals available in literature for the typologies of scenario-building techniques based on their features. These typologies include ‘qualitative’ vs. ‘quantitative’, ‘explorative’ or ‘normative’ vs. ‘descriptive’, ‘inductive’ vs. ‘deductive’, ‘formal’ vs. ‘intuitive’ and ‘soft’ vs. ‘hard’.

Time Scale of Research Scenarios

The selected time scale of scenarios in this research is (2014–2025) for the water balance scenarios. For the prediction of water consumption, data of water consumption in 2009 is used as the base line year. Reasons for selecting this time scale are:

- To investigate the possibility of achieving success from the policies adopted by the Yemeni government in ‘Yemen’s Strategic Vision 2025’ which calls for implementing four alternatives to support water resources.
- The available records of historical data in Yemen do not allow statistical analysis that includes extrapolation for long periods into the future.
- The selected time scale (2014–2025) is considered appropriate as it allows changes on key factors influencing water balance while avoiding the pitfalls of building a short time scale or too long a time scale as mentioned earlier.

Qualitative vs. Quantitative Scenarios

Based on the techniques used for scenario building, two schools can be differentiated in this regard. The first one includes futurologists who promote using only qualitative techniques. One of these futurologists is the father of scenario building, Hermann Kahn, who emphasized the application of reasoned judgement and intuition as a qualitative approach to scenario planning (Kahn and Weiner, 1967 in Chermack 2001). Kahn rejected the notion of quantitative model building in favour of a more qualitative approach, arguing that the focus of quantitative models is only on the easily-quantifiable aspects of a problem, and that, therefore, they represent only a partial formulation of the forecasting problem (Schnaars, 1987).

The other school includes futurologists that support highly-quantitative approaches for scenario development. Schnaars (1987) mentions that one of the futurologists supporting this approach is Durand, who believes that the problem with scenario development using only the qualitative approach is that these scenarios rely heavily on intuitive and subjective analysis, the scenarios proposed are abstract and difficult to apply, and their advice is hard for the planner to adopt.

This research used both qualitative and quantitative approaches in developing the water balance scenario. Using quantitative factors allows building scenarios with quantitatively traceable trends that consider the evolution of influencing key factors and driving forces over time. Such factors include water availability, consumption and intervention supporting water resources. Using these quantitative factors will also ensure that the resulting scenario is independent of intuitive and subjective analysis. Thus, the acceptability of scenarios projected by experts and decision-makers in the water sector was increased through the verifiable value-based trends used in these scenarios.

At the same time, the present research has also followed the qualitative approach for developing scenarios. The scenarios developed under this research have incorporated non-quantifiable key factors that influence the planning and management of water resources and

ultimately impact water balance in Yemen—e.g. decentralization of water resources management and political commitment to support water resources. Using qualitative factors will ensure that the resulting scenarios do not form a quantitative forecast of historical trends. This helps to create more balanced scenarios that reflect in a better way the reality of water resources planning and management.

However, proceeding from the qualitative scenario narratives produced in the scenario definition phase to quantitative-projection scenarios is one of the most challenging tasks in the scenario construction phase (Idris, 2008). To simulate the water balance in alternative future scenarios, inputs into the qualitative simulation model should be numerical in nature. Since water resources are influenced by quantifiable and non-quantifiable factors, a scenario narrative of water resources is composed of a series of key variables and not all variables may represent a quantitative dataset. For that reason, and for a connection between the narrative and a simulation model to take place, either the narratives need to be modified to fit an existing model or a model needs to be modified to fit the scenario narratives (Idris, 2008).

Exploratory vs. Descriptive

Scenarios can be either exploratory or descriptive depending on their purpose of development. Exploratory scenarios, as Glenn (2009) mentions, describe events and trends as they could evolve based on alternative assumptions on how these events and trends could influence the future. Exploratory methods essentially use the present as a point of departure (Eurofound, 2003). Such future exploratory methods include time series forecasts, decision and statistical models, system dynamics or trend impact analysis. Such scenarios answer the following questions: What are the possible futures? Are they desirable or not? (Moniz, 2005).

Conversely, normative scenarios describe how a desirable future can emerge from the present (Glenn, 2009). Normative scenarios use methods such as participatory methods, decision analysis and morphological analysis to answer questions like, ‘What is the desirable future?’ (Moniz, 2005) and/or questions that take possible futures as their point of departure, such as ‘How can we get there?’ and ‘What must happen in order for it to become reality?’ (DIE, 2008). Normative scenarios can also be constructed to include a feared future. Then, one or more paths are portrayed as to how one could arrive at or avoid, that future(s). Hence, this process is the equivalent of ‘backcasting’ (Elliott et al., 2005).

Based on the aforementioned definitions, this research develops both exploratory and normative scenarios. The research uses exploratory methods, i.e. time series analysis, to ascertain the possible future of water balance following the BAU settings; hence, this scenario is considered explorative. On the other hand, the sustainability and Do Nothing scenarios are seen as normative scenarios. The sustainability scenario is developed to demonstrate how a desirable situation of sustainable water resources can be reached. The Do Nothing scenario portrays paths leading to situation that should be avoided.

External vs. Internal vs. Systems Scenarios

Depending on the different decision situations, three general types of scenarios can be created—namely, external, internal and systems scenarios. External scenarios describe external conditions and factors that are not influenced by the scenario owner. Internal scenarios focus on internal factors that can be influenced fully. Finally, systems scenarios which include both internal and external factors, and can be influenced only partially (Fink and Schalke, 2000).

The scenarios developed under this research include two types of factors—internal factors that are influenced by the water sector institutions and external factors that are either not influenced or influenced in parts by factors from outside the sector. Thus, these scenarios are considered systems scenarios.

Snapshot vs. Future History

Godet (1994) and Glenn (2009) mention that scenarios can be categorized into two categories based how they are used. They differentiate between ‘situational scenarios’ wherein the developer describes a snapshot in time or the conditions of important variables at a particular time in future. The second type, they explain, is the ‘future history’ scenario or ‘development scenario’, which describes evolution from present conditions and then moves to one of several futures.

Glenn (2009) affirms that the ‘future history’ approach is generally preferred because it lays out the causal chain of decisions and circumstances that lead from the present. He adds that scenarios are often used in policy analysis to illustrate the consequences of different initial assumptions, different evolutionary conditions, or both. The nature of evolutionary paths is often important since policies can deflect those paths. He concludes that the most useful scenarios are those that display the conditions of important variables over time.

Based on the abovementioned categorization, the scenarios developed under this research are ‘development scenarios’. The three scenarios develop start from present conditions and evolve into several potential futures.

6.3 Data Collection

Qualitative and quantitative data were required to implement the research. Collected data included national-level data on water availability, consumption, saving and augmentation in Yemen. Data about driving forces and factors that influence water resources planning covering the environmental, institutional, legal and socio-economic aspects were also collected.

To that end, this research has adapted multiple research methods for data collection. The rationale for selecting multiple research methods has been to avoid limitations that may arise when the research uses one method in collecting required data. This is particularly important for the present research as it includes the identification of qualitative factors that depend on people's understanding. Midgley (in McCarthy et al., 2010) explains some of these limitations and their causes as follows: a) the researcher is unlikely to address issues of relevance that may emerge as people's understanding evolve, and b) the researcher may see all issues and perspectives through the same lens.

This research, therefore, used the following methods to collect the required qualitative and quantitative data:

- Literature Review
- Semi-structured Interviews
- Statistical Data Collection

6.3.1 Literature Review

During this phase, the researcher reviewed available literature including journals, books, records, studies, and governmental and international reports covering the main themes of the research. These themes include:

- The environmental, institutional, legal and socio-economic aspects of water resources management in Yemen
- Water resources availability, consumption, savings and augmentation in Yemen
- Strategic Environmental Assessment
- Integrated Water Resources Assessment
- Scenario building and development

During this phase, the researcher identified themes to be discussed with the key informants. These themes were identified based on the need to validate data extracted from literature or gain more insight into some identified themes. Initial identification of prospective informants to be interviewed was also done during this phase.

Analysis of the Main Relevant Governmental Policy Documents

In the literature review phase, relevant government policies and strategies were analysed. As Chapter 3 shows, these policies and strategies include:

- The Water Law nr. 33 of 2002 and its amendments of 2006
- The National Water Sector Strategy and Investment Programme (NWSSIP) 2005–2009 and 2010–2014
- The National Water Policy (2001)
- The Water Resources Policy and Strategy (2000–1999)
- The Irrigation Water Policy (2001)
- The National Watershed Management Policy (2000)
- National Agriculture Sector Strategy (2012)
- The Agricultural Sector Reform Policy (2000)
- National Irrigation Policy (1999)
- National Watershed Management Policy (2000)
- Agricultural Sector Reform Policies and Strategies—the ‘Aden Agenda’ (2000)

6.3.2 Semi-Structured Interviews³⁶

Semi-structured, face-to-face interviews were conducted with key informants.

These interviews were conducted for the following purposes:

- To cover qualitative and quantitative data gaps identified during the secondary data collection phase.
- To validate data extracted during the literature review phase.
- To gain insight into selected themes related to water resources planning and management in Yemen.
- To identify potential future strategic targets to improve water resources.

Why semi-structured interviews?

This type of interview gives the researcher the chance to gather evidence and insights from informants and allows informants to provide not only answers, but also the reasons and explanations for those answers (Sprint, 2009).

Sampling and Sample Size

In identifying the sampling method under this research, the fact that this research seeks to establish valid analytical—but not statistical—generalizations, was decisive. The analytical generalization in this research means that the qualitative factors identified as influential in controlling the future of water resources, represent concerns of the decision-makers, managers and experts who were interviewed during this research. In order to achieve that and to establish the themes that represent the concerns of the broader group of experts and

³⁶ No statistical analysis or generalizations will be made based on the interviewees’ inputs.

decision-makers, the selection of ‘knowledgeable informants’ was a crucial element (Hammersley and Atkinson 1995, p. 136).

According to Campbell, the sampling size of the informants is not a crucial element in assuring the accuracy of information (cited in Johnson, 1990:35). Johnson points out that a small number of specially selected informants is often better than a larger, extensive random sampling of informants; in addition, he indicates that the accuracy of information provided by the informants ‘was related to the extent to which they interacted with others in the network; those who were more active were also the most accurate...’ (1990: 35).

Considering the above, 13 key informants were selected based on purposive sampling. Decision-makers, managers and experts from the water resources and irrigation sector were selected based on the assumption that they would provide accurate and reliable information concerning selected themes. These informants were selected based on the following:

- a) positions these key informants occupy in the leadership and top management that are concerned directly with planning and decision-making in the water and irrigation sectors in Yemen; and
- b) experience these informants have, as they are classified within the water and irrigation sectors as top experts with years of experience and accumulated knowledge in their fields. The experience of the researcher as a permanent employee with the MWE helped to identify these key informants.

Interviewees

Semi-structured interviews were conducted with 13 key informants. Selected interviewees are decision-makers and managers from the water and irrigation sectors. The water sector was selected as the sector concerned with initiating, developing, implementing and assessing water resources strategies, plans and programmes. Key informants from the irrigation sector were also interviewed as this sector is by far the biggest water consuming sector compared to other sectors—i.e. domestic and industrial (MWE, 2005).

Interviewees included water and irrigation experts working in governmental projects. Water and wastewater treatment experts from academic institutions were also interviewed. Annex 6 shows list of interviewees met in the course of implementing this research.

Themes and Questions of Interviews

Prior to the field visit and based on data requirement identification, the researcher prepared a list of open-ended questions that he wanted to address during the interview (see Annex 7). These questions were the results of a process that started during the literature review phase. When reviewing literature, specific data gaps and issues of concern requiring in-depth analysis were identified. Questions were then formulated to address these gaps and concerns. Open-ended questions were used as they allow the interviewee to respond as they deem

appropriate. In responding to these types of questions, interviewees are able to provide the answers that are relevant and important from their own points of view. Open-ended questions are composed in order to define a context for the informant's responses.

The main interview themes included³⁷:

- Factors contributing to the existing water resources situation
- Policies and measures that could have prevented the existing situation
- Challenges to the application of existing policies and measures
- Strategic challenges to water resources in Yemen
- Driving forces and factors that shape the future of water resources
- Potential alternatives that can improve the water resources situation in Yemen
- The potential of alternatives adopted by ‘Yemen’s Strategic Vision 2025’
- The potential adoption of SEA in the water resources sector in Yemen
- Quantitative up-to-date data—e.g. total capacity of dams in the country and runoff that still reaches the sea from wadis in Yemen.

Interviews Transcription

Data obtained from the interviews were transformed from tape recordings to written transcripts. During the transcription process, answers obtained from the key informants were translated from Arabic into English, and the obtained information was organized into the themes originally set by the researcher.

6.3.3 Statistical Data Collection³⁸

Visits to governmental authorities and international organizations working in and supporting the water sector in Yemen were conducted. List of visited authorities and institutions is provided in Annex 8. These visits were conducted to collect historical and up-to-date data on water resources and their uses—i.e. irrigation, industry and domestic use. Collected data formed the ‘raw material’ used in the statistical analysis for projecting future water needs and balance in Yemen until 2025.

The collected data included:

- Renewable water resources and water balance
- Domestic, industrial and irrigation water use
- Cultivated land and annual expansion of the area under cultivation
- Savings achieved thus far by using modern irrigation technologies and the total implementation of each technique per year
- Capacity of existing wastewater treatment plants and total wastewater treated
- Per capita water consumption in urban and rural areas
- Population growth and future population projections by the government

³⁷ The questions directed to informants during the semi-structured interviews are shown in Annex 6.

³⁸ The list of institutions and authorities that were visited is in Annex 7.

6.4 Data Analysis

6.4.1 Methods of Qualitative and Quantitative Analysis

Quantitative Analysis

In this analysis, quantitative data were analysed to calculate:

- a) future total population until 2025,
- b) current and future water needs of the consuming sectors—namely, the domestic, agricultural and industrial sectors,
- c) the potential of each technical alternative adopted by ‘Yemen’s Strategic Vision 2025’—i.e. of modern irrigation systems, water augmentation by dams, wastewater reuse and replacement of qat agriculture,
- d) current and future water balance until 2025 under different scenarios using correlation analysis, inferential and descriptive statistics.

Methods Applied for the Statistical Analysis

In implementing the statistical analysis in this research, several methods have been used, including, but not limited to:

- Time series analysis
- Regression analysis
- Correlation analysis

In analysing, organizing and interpreting quantitative data, spreadsheets were used³⁹. The main software used is the Statistical Package for the Social Sciences (SPSS). SPSS is a data management and analysis program produced by SPSS, Inc. Among its features are modules for statistical data analysis, including descriptive statistics such as plots, frequencies, charts, and lists, as well as sophisticated inferential and multivariate statistical procedures like analysis of variance, factor analysis, cluster analysis and categorical data analysis.

Qualitative Analysis

This included analysing collected qualitative data obtained from literature and interviews. The purpose of this analysis was to:

- Delineate and ensure in-depth understanding of the institutional, legal and socio-economic aspects of water resources planning and management in Yemen.
- Identify influential qualitative factors that play a key role in shaping the future of water resources planning and management.

³⁹ The SPSS was selected as it serves directly the tasks required for the quantitative analysis of data in this research. The software was selected after consulting the head of the chair of Environmental Informatics in the BTU-Cottbus. Several software options were considered for implementing this research but were excluded because they do not serve directly the required purpose of analysis in this research.

The analysis follows five main steps as described by Powel and Runner (2003):

1. Obtained data were thoroughly examined while considering the quality of these data and addressing limitations.
2. The analysis was focused based on subtopics and the time period.
3. Data was categorized by:
 - Identifying themes
 - Organizing them into coherent categories
4. Patterns and connections within and between categories were identified.
5. Data were interpreted by using themes and connections to explain the findings.

6.5 Analysing Data for Establishing Existing Water Balance and Building Future Water Balance Scenarios

The Yemeni government has been implementing interventions adopted in ‘Yemen’s Strategic Vision 2025’ through governmental institutions. To assess the existing and future impacts of these interventions on the water balance, a statistical analysis was conducted. The statistical analysis calculates the current and future water balance until 2025 by statistically analysing water availability, demand by consuming sectors as well as water augmentation and savings by governmental technical interventions.

To that end, three main tasks had to be implemented: firstly, calculating the total renewable water resources available; secondly, calculating total water demand by each water-consuming sector; and thirdly, calculating current and potential water savings or augmentation by each of the targeted interventions. The following sections show how the aforementioned tasks were implemented.

6.5.1 Renewable Water Resources

As mentioned in Chapter 2, the annual renewable water in Yemen is 2.5 billion cubic metres (NWRA, 2002). Of this, surface water constitutes 1.5 billion cubic metres and groundwater constitutes about one billion cubic metres (NWRA, 2002).

In projecting the future water balance, it is assumed that the renewable water resources will remain constant for the period from 2010 to 2025.

6.5.2 Analysing Data of Water Consuming Sectors and Projection of Future Demand

For the projection of total water demand, historical data on the annual needs of water by consuming sectors—i.e. domestic, agricultural and industrial sectors—were collected. The required data and projection methods are explained in the following.

Domestic Water Demand

To project future domestic water demand, it was necessary to project the future population in rural and urban areas for the 21 governorates that form Yemen administratively. Then, the total demand for water in urban and rural areas for each governorate was estimated based on per capita water consumption in these governorates. To obtain the results, the following data were collected:

- Historical data of the population at the governorate level in urban and rural areas since 1994⁴⁰.
- Average per capita water consumption in urban and rural areas as per 2009⁴¹ as mentioned in baseline data in Chapter 2.

⁴⁰ These data were obtained from Yemen’s Central Statistical Organization and the Ministry of Planning.

Projection of Population

To project population growth until 2025, historical population data on the governorate level was obtained for 21 governorates. These data were classified from the sources into urban and rural populations since 1986 and were based on three main national censuses implemented in 1986, 1994 and 2004. Quantitative time series analysis of historical data for each governorate was done using spreadsheets. Data of each governorate was projected using the following exponential formula:

$$P_n = P_o (1+R/100)^n$$

Where

r = annual rate of growth

P_n = population in the current year

P_o = population in the base year

n = number of intermediary years.

For each governorate from the 21 that administratively form Yemen, the following steps were required to reach the population projection:

- 1) Rural population of each governorate was extrapolated using the exponential growth formula.
- 2) Urban population of each governorate was extrapolated using the exponential growth formula.
- 3) The total population of each governorate in a given year was calculated as the sum of extrapolating rural and urban populations in that year.

Results of data extrapolation of population in each governorate are shown in Annex 9.

Projection of Domestic Water Needs

Total domestic water demand was calculated by multiplying the population on the governorate level in urban and rural areas by the per capita water needs per governorate in the urban and rural areas of the corresponding governorate⁴².

⁴¹ Data obtained from the MWE – DG of Planning and General Authority for Rural Water Supply Projects.

⁴² Due to the lack of historical data which can enable establishing a trend, it is assumed that per capita water consumption will stay the same of year 2009.

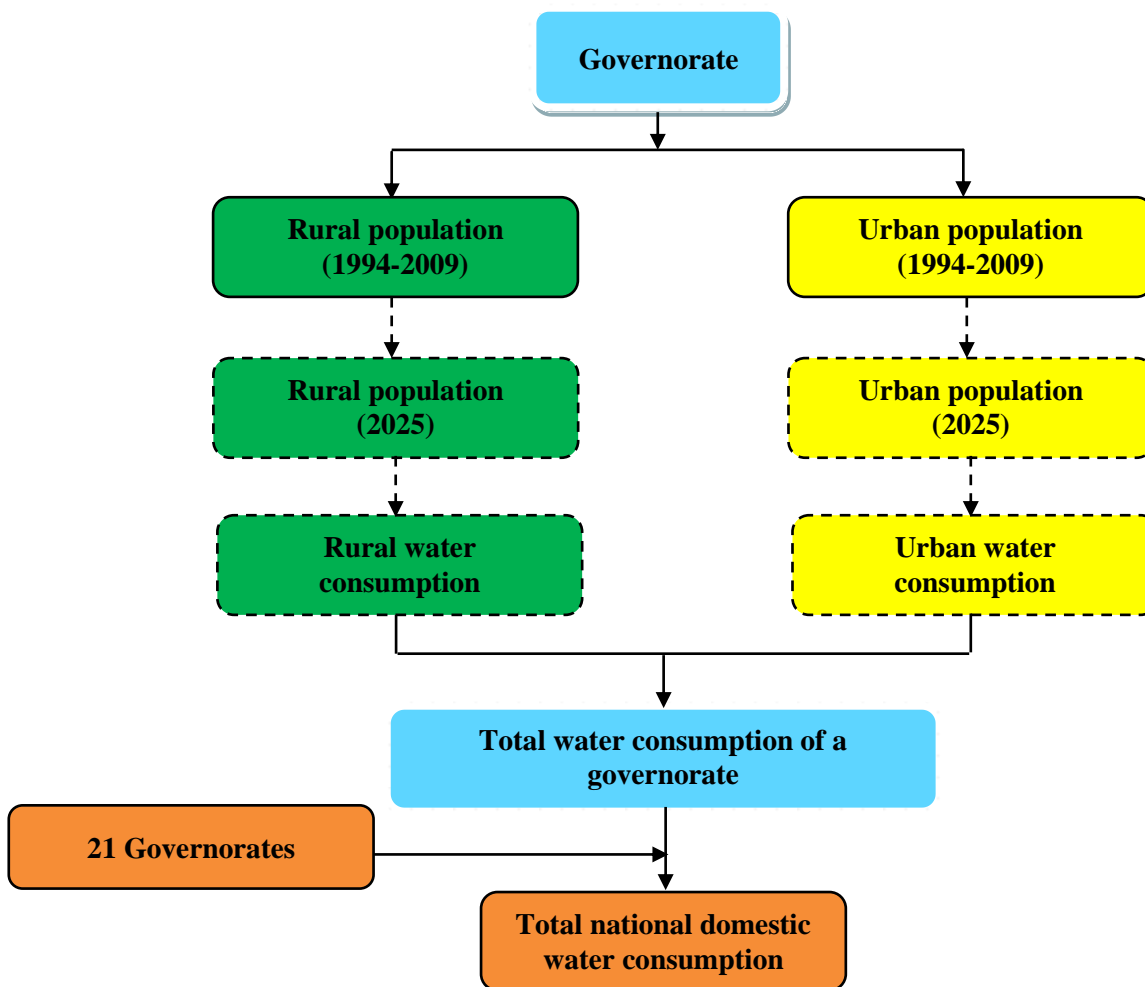


Figure 15: Schematic diagram showing the steps for calculating the national domestic water needs
Source: the Author

The following steps were applied to calculate the total domestic water demand:

- Per capita water use of urban and rural areas was multiplied by the corresponding projected population in urban or rural areas.
- This was calculated as the sum of two calculations: first, by multiplying per capita water use in urban areas by the projected urban population in each governorate; second, by multiplying per capita water use in each governorate in rural areas by the projected rural population of the same governorate⁴³.
- Total water consumption of each governorate is the sum of rural and urban water consumption.
- Total domestic water need at the national level is the sum total of the water consumption by the 21 governorates.

Chapter 7 shows the results of population projection and of estimating water needs in rural and urban areas for each governorate. For projection per governorate, see Annex 9.

⁴³ Based on data obtained from the Ministry of Water and Environment and the General Authority for Rural Water Supply and Sanitation, average per capita water use in urban and rural areas is 65 and 40 cubic meters respectively.

Industrial Water Demand

To project future industrial water needs, governmental historical data on industrial water use since 1990 were obtained.^{44 45} The following steps were applied in projecting the future industrial water demand:

- 1) Historical data on industrial water use as mentioned in the baseline data in Chapter 2 were interpolated to arrive at the missing values in the linear formula.
- 2) To project future water needs, data were extrapolated using data sheets. Linear trends showed best goodness-of-fit—i.e. $R^2= 0.942$ for obtained data. Therefore, the linear equations obtained were applied to extrapolate data from 2010–2025. The linear formula is shown below:

$$y = 4.787x + 24.88$$

Chapter 7 shows the projected industrial water demand for the period 2009–2025.

Agriculture Water Demand

For projecting future agricultural water demand, historical data on water needs were collected since 1990⁴⁶ of the two subsectors forming agricultural demand—namely, the irrigation and livestock sectors. Official data produced by the MAI were used to project future agricultural water needs for both sub-categories. The projection of future demand was implemented as follows:

Irrigation Demand Projection

- 3) Historical data on irrigation water use as mentioned in the baseline data in Chapter 2 were interpolated to arrive at the missing values in the linear formula
- 4) To project future water needs for each sub-category, data were extrapolated using data sheets. Linear trends showed best goodness-of-fit—i.e. $R^2=$ of 0.997 for obtained data. Therefore, the linear equations obtained were applied to extrapolate data from 2010–2025. The linear formula is shown below:

$$y = 28.49x + 2645$$

- 5) Total agricultural water need was obtained by summing up water needs for each year.

⁴⁴ Data obtained from the National Water Resources Authority.

⁴⁵ Data published by FAO on industrial water needs for the period 1990–2010 were compared with the available governmental data produced by the National Water Resources Authority, both data sets were similar. For this research and for the purpose of consistency, governmental data were used.

⁴⁶ Data obtained from the Ministry of Agriculture and Irrigation.

Livestock Water Demand Projection

- 1) Historical baseline data as mentioned in Chapter 2 were obtained and interpolated to arrive at the missing values in the linear formula.
- 2) To project future water needs for each sub-category, data were extrapolated using data sheets. Exponential trend lines showed best goodness-of-fit—i.e. $R^2 = 0.998$ for obtained data. Therefore, the exponential equations obtained were applied to extrapolate data from 2010–2025. The exponential formula shown below:

$$y = 24.45e^{0.019x}$$

- 3) Total agricultural water need was obtained by summing up the water needs for each year.

The projected irrigation and livestock water demand for the period 2009–2025 is shown in Chapter 7.

6.5.3 Analysing Data of Technical Alternatives for Enhancing Water Resources

One of the research objectives is to assess quantitatively the existing and future impact of the four alternatives adopted by ‘Yemen’s Strategic Vision 2025’. Qualitative data on the four alternatives that the government implements to support water resources were collected. These alternatives are installing modern irrigation systems, water augmentation by dams, wastewater reuse and replacement of qat agriculture with crops that consume less water.

To calculate the current achieved amount of water saving and augmentation by these alternatives, available historical data were collected as presented in the baseline data in Chapter 2. For each of the alternatives, the following data were collected.

Modern Irrigation Systems

Data on area covered by modern irrigation systems were collected. These include:

- Land covered with conveyance and/or on-farm irrigation systems
- Water savings achieved by each type of modern irrigation system

Dam Water Harvesting

The following data were collected to project the future potential of water harvesting using small dams:

- Data on the number of existing dams (which has been limited in this research to small dams)
- Total storage capacity of existing dams

Treated Wastewater

To project the potential future contribution of treated wastewater in supporting water resources and the potential impact on the water balance, available data on existing wastewater treatment plants and their treatment capacities were collected.

Qat Cultivation

To calculate the potential water savings achieved by replacing qat agriculture with crops that consumed less water, the data collected included:

- Historical and current land under qat cultivation
- Average water consumption of qat per hectare
- Average water consumption of alternative crops per hectare

In calculating the potential water savings, the following steps were implemented:

- 1) Historical data obtained were interpolated to ascertain the missing values in the linear formula.
- 2) To project future water needs for each sub-category, data were extrapolated using data sheets. Exponential trend lines showed best goodness-of-fit—i.e. $R^2 = 0.982$ for obtained data. Therefore, the exponential equations obtained were applied to extrapolate data from 2010–2025. The linear formula is provided below:

$$y = 3.268x + 7.839$$

Qat Water Consumption

To project future water consumption by qat, the obtained data on historical and current water consumption by qat were analysed as follows:

- 1) Historical data obtained were interpolated to ascertain the missing values using the linear formula.
- 2) To project future water needs for each sub-category, data were extrapolated using data sheets. The linear trend showed the best goodness-of-fit—i.e. $R^2 = 0.982$ for obtained data. Therefore, the linear equations obtained were applied to extrapolate data from 2010–2025. The linear formula is given below:

$$y = 27.78x + 66.63$$

Data Reliability and Validity

To ensure reliability of the data used in the quantitative analysis, and considering that there is no unified database that includes all the data required for implementing the quantitative analysis under this research, the following steps were applied to validate collected data:

- Available data on each of the aforementioned variables were collected from several national databases (if applicable). For example, data on water consumption by the agricultural sector are published by the MAI and by the NWRA that belongs to the MWE. In such cases, both sets of data were collected.
- The databases of international organizations were accessed for obtaining available data on variables required for the quantitative analysis. For example, the database of the Food and Agricultural Organization (FAO) and that of AQUASAT provided historical data on water consumption by consuming sectors. Such databases were accessed to obtain data.
- The collected data was evaluated, mostly by crosschecking and comparing the data published by different institutions.

It warrants mention that quantitative data of a very limited number of variables differs among governmental institutions. Data of some variables differ when comparing data collected from governmental institutions and international organizations. Therefore, the following measures were taken:

- In case of inconsistency between data obtained from governmental authorities and data published by international organizations, priority was given to data obtained from governmental authorities provided that the data sources and methods used to obtain these data were checked by the researcher.
- In case of inconsistency between data obtained from different governmental authorities, priority was given to data collected by the organization that bears the legal responsibility for producing the data.

While implementing this research, the researcher tried to eliminate his own subjective views and bias, and to maximize objectivity. To that end, and to elimination potential self-inclination, the researcher has constantly and critically questioned his own motives, methodology and arguments during the implementation of this research.

6.6 The Conclusion

The chapter explains the qualitative and quantitative approaches applied in carrying out this research. The chapter shows how the data were collected, giving an overview of the collection and analysis methods to provide a basis for producing the intended result—i.e. building scenarios for future water balance.

The chapter also shows that scenario-building method adopted in this research provides a suitable approach for the strategic assessment of policies. As a SEA method, the scenario-building approach accommodates qualitative factors and quantitative variables, thus allowing for the development of water scenarios that are qualitatively and quantitatively balanced as the next chapter will show.

7. RESULTS AND DISCUSSION

This chapter presents the results of the qualitative and quantitative analyses implemented under this research. Using qualitative and quantitative factors, three scenarios—namely, the Business as Usual, Do Nothing and Sustainability scenarios—have been developed to provide potential images for the future national water balance until 2025.

These scenarios provide the results of key stages of the SEA process. The developed scenarios present the quantitative contribution of water policies mentioned in ‘Yemen’s Strategic Vision 2025’ on the total national water balance for the period 2010–2025. These results are from the ‘impact prediction and assessment’ stage. The resulting scenarios provide ‘alternatives comparison’ between the potential three alternative futures that may develop until 2025 including the alternative of Do Nothing as recommended by SEA guidelines (Abaza et al., 2004). These results are also based on other SEA stages that were implemented during the research, such as ‘stakeholder consultation’ and ‘baseline data collection’.

The chapter begins by presenting the developed scenarios. The sections on each scenario begin by listing the underlying main assumptions of that scenario. The results obtained under each scenario are then presented and discussed starting with the qualitative factors and followed by the quantitative factors. Quantitative factors cover both, water demand by different consuming sectors as well as water savings and augmentation resulting from alternatives for enhancing water resources. Each scenario concludes by presenting the potential total water balance projected under the scenario. In presenting these developed scenarios, the qualitative and quantitative results are discussed.

Common Considerations for Future Developed Scenarios

For developing future water balance scenarios, the considerations and assumptions common to the resulting scenarios are as follows:

- As the main aim of developing quantitative scenarios is to examine the impact of implementing the alternatives mentioned in ‘Yemen’s Strategic Vision 2025’ on saving and augmenting water resources, it is assumed that water demand by different sectors as projected under the Business as Usual scenario will be valid under the Do Nothing and Sustainability scenarios as well.
- The potential impact of climate change on water availability is not considered in these scenarios. This means that the amount of water received as rainfall is assumed to remain constant as explained in Chapter 2.
- 2009 is the base year for calculating and projecting water savings by modern irrigation systems, water augmented by dams and reuse of wastewater.

Table 15: Main qualitative assumptions under the developed scenarios

Quantitative Factors	BAU	Do Nothing	Sustainability
Scenario Time scale	Starts in 2010 and continues until 2025	Follows BAU until 2014, and starts thereafter	Follows BAU until 2014, and starts thereafter
Modern Irrigation Systems			
Area equipped annually with on-farm irrigation systems (ha/year)	226	0	1,500
Area equipped annually with conveyance systems (ha/year)	6,098	0	6,098
Savings by modern irrigation systems (MCM/year)	10	0	15
Dams			
Augmentation by dams (MCM/year)	5.5	0	7
Wastewater Treatment & Reuse			
Reuse of treated urban wastewater annually (%)	13%	0	Increase by 4% annually
Reused treated wastewater (MCM/year)	3	0	9
Qat Replacement			
Area of qat replaced by another crop (ha/year)	0%	0%	Increase by 2% annually
Water saved by replacing qat (MCM)	0	0	17

Source: the Author

Table 16: Main qualitative assumptions under the developed scenarios

Qualitative factor	BAU	Do Nothing	Sustainability
Governmental commitment and support to the water resources sector	Modest	Non-existent	Complete
Decentralization of planning and management	Incomplete and slow-paced	Hindered	Fast-paced
Community-based management—e.g. the establishment and empowering of Water User Associations (WUAs)	Limited to areas covered by new project	Hindered	Encouraged and supported by the several government institutions
Control over water resources	Mainly by farmers	Completely by farmers	Based on the allocation of the government

Source: the Author

7.1 Reference Scenario: ‘Business-As-Usual’ (BAU) Scenario

General Assumption

As the name indicates, this scenario examines the consequences of maintaining the existing rate of water saving and augmenting by continuing the current rate of implementing technical interventions—i.e. installing modern irrigation systems, building dams, treating wastewater and replacing qat agriculture with crops that consume less water.

Specific Assumptions

The main assumptions of the Business as Usual scenario, as shown in Tables 15 and 16, are:

- Water savings from installing modern irrigation systems will continue as per the 2009 rate, achieving total water savings of 10 MCM as a result of installing modern on-farm and conveyance systems.
- Construction of dams for augmenting water resources is assumed to continue at an annual capacity rate of 5.5 MCM.
- Urban treated wastewater reuse will continue as per 2009 at an annual reuse rate of 3 MCM.
- Qat agriculture will continue with no replacement. Hence, no water savings will be achieved in this alternative.
- Water demand by consuming sectors is projected to increase according to the following annual rates:
 - o Agricultural: 0.87%
 - o Domestic: 2.85%
 - o Industry: 5.06%

7.1.1 Current and Future Water Demand

Current and Future Domestic Water Demand

To project domestic water consumption, rural and urban populations in the 21 governorates that form Yemen administratively was projected for the period 2010–2025. Annex 9 shows results of the projection for each governorate. Table 17 presents a summary for the population projection for the period 2010–2025.

Rural and urban water demand for each governorate and the total domestic water demand at the governorate and national levels are shown in Annex 9. Table 19 presents a summary of the projected domestic water demand at the national level.

Population Growth

Under this scenario, the trend of population growth is assumed to continue until 2025. Projections suggest that the rural population will increase from 16 million in 2009 to 21.7 million in 2025. The urban population will increase from 6.4 million to 13.3 million during the same period. The total population, consequently, will grow from 23.2 million to 35.1 million between 2010 and 2025 (Table 17).

The obtained results show a rapid increase in the rural population across nearly all governorates. However, the Sana'a governorate is projected to witness a decrease in its rural population that could be attributed to the internal migration from that governorate to the neighbouring capital city of Sana'a (see Annex 9).

Rapid population increase is also projected in urban areas, where the population is expected to rise from 6.4 million in 2009 to 13.3 million in 2025. The result is the summation of projected urban population in the 21 governorates.

The statistical model for obtaining these results was tested when extrapolating the respective populations of each of the 21 governorates using the 'goodness of fit' test. The goodness of fit 'R²' value, which can take values between zero and one, shows the accuracy of the statistical models used in obtaining these results. 'R²' shows better fit if a value is close to one as was observed in the exponential extrapolation of historical trends in rural and urban populations as shown in Annex 9.

The resulting projections of total population (Table 17) are comparable to projections of the Yemeni Central Statistical Organisation (CSO). The total population by 2025, which is projected in this research to reach 35.1 million falls between two of the six scenarios (Annex 5) produced by the CSO (2010) to project population until 2025. The first scenario, 'High Fertility & Median Mortality', projects a total population of 34.8 million by 2025 while the second scenario, 'High Fertility & Low Mortality', projects that the total population will reach 35.5 million by 2025 as shown in Table 18.

Table 17: Projected population for the period 2010–2025

Year	Rural Population (in millions)	Urban Population (in millions)	Total Population (in millions)
2010	16	7	23
2011	16	7	24
2012	17	8	24
2013	17	8	25
2014	17	8	26
2015	18	9	26
2016	18	9	27
2017	18	9	28
2018	19	10	29
2019	19	10	29
2020	19	11	30
2021	20	11	31
2022	20	12	32
2023	21	12	33
2024	21	13	34
2025	22	13	35

Source: Projections by the Author

Even though the population projection in this research is based on data obtained by previous population censuses—i.e. of 1994 and 2004—which presents the same data used for projecting the CSO scenarios, the difference between the results could be attributed to the different projection methods used. In this research, an exponential method is used to extrapolate historical data for the rural and urban populations of each of the 21 governorates that administratively form Yemen, while the CSO used a component method (CSO, 2010) that involves summation of population growth components such as births and deaths (Graves, 2012). The same reasoning may explain the projected population of Yemen by the UN (2007), which states that the Yemeni population will reach 36.5 million in 2025; a projection that is higher than other available projections.

Table 18: Comparison between population projections in the present research and by the CSO

Year	Projected Population in the Research (in millions)	Population Growth Rate %	Population Projection by CSO-Scenario Nr. 3 (in millions)	Population Growth Rate %	Population Projection by CSO Scenario Nr. 3 (in millions)	Population Growth Rate %
2010	23.1		23.1		23.2	
2015	26.2	2.68	26.8	2.89	27.0	2.98
2020	30.1	2.96	30.8	2.65	31.1	2.78
2025	35.0	3.23	34.8	2.31	35.5	2.47

Source: CSO, 2010 and the author's projections

Domestic Water Demand

The results of projecting future water demand in the domestic sector shows an increase in rural and urban water consumption. Rural water demand will increase from 160 MCM to 317 MCM between 2009 and 2025, while the urban water demand will increase from 128 to 265 MCM during the same period. This will result in a rise in the total water demand by the domestic sector from 389 MCM in 2009 (FAO, 2008) to 639 MCM in 2025.

As the research aims at projecting the potential future water balance, projection of water demand by each sector, including by the domestic sector is required. The results produced under this scenario show that the domestic water demand will increase rapidly. The obtained results for water consumption are based on the assumption that per capita domestic water demand will be 40 lpcd in the rural areas during the period 2009–2025, while in urban areas it will be 65 lpcd.

An important factor affecting these results is the per capita water consumption in rural and urban areas. The amount of per capita consumption in rural areas is adopted from the official number mentioned by the GARWSP to estimate the needs of rural areas when designing rural water supply projects (JICA, 2007). Furthermore, the NWRA (2002) projects that the per capita consumption in rural areas in 2025 will reach 50 lpcd for people living in households connected to water supply projects and 30 lpcd for people who have live in households that are not connected to water supply projects. This makes 40 lpcd an average per capita consumption for people in urban areas, whether connected or otherwise. The daily per capita water consumption is expected to stagnate at 40 litres during the projection period. This stagnation is assumed to continue during the projection period even if more areas will be covered by rural water supply projects. The reason for this stagnation is that the pace of population growth will outpace the coverage of rural areas with water supply projects; the current figure of coverage with water supply projects stands at 44% of the rural population (GARWSP, 2010).

In urban areas, 65 lpcd was adopted as the average per capita water use. According to NWRA (2002) projections, by 2025, the figures are expected to be 80 lpcd for urban households

connected to a water supply project and 50 lpcd for households not connected to such projects. The average of 65 lpcd is assumed to continue during the scenario period as the coverage of urban water supply projects is assumed to stand at 59% (MWE, 2009). This is because coverage is expected to fall behind the rapidly increasing urban population.

The projected total domestic demand in 2025 of 639 MCM (see Table 19) is less than the 758 MCM projected by the NWRA (2002). Nevertheless, these projections are lower than other estimations—such as that of ESCWA (2003), which states that the consumption of the domestic sector in Yemen in 2000 was 360 MCM and will reach 845 MCM in 2025.

The differing projections can be attributed to several factors such as the per capita consumption used in estimation, the projection method, and the factors that may influence the amount of water needed—e.g. water loss in urban networks.

In projecting future urban water demand, very low efficiency in urban networks is assumed to continue. About 40% of the water pumped in urban water networks is assumed to be wasted. While the MWE (2009) mentions that the water loss in urban networks was 36% in 2009, Hübschen (2011) states that unaccounted for water in the urban water supply amounts to 40–50%. Assuming that the water loss in urban water networks will continue to be 40%, the results under this research show that the water loss will amount 46 MCM by 2025. The results of projecting the water demand in the domestic sector shows an increase in the amount of water required by domestic sector, which was expected due to the increase in population. It also shows an increase in the share of this sector in terms of total water demand. From 2% in 2003, the share of domestic demand will increase to 14% by 2025 as per the results of the present research. Nevertheless, this is far less than the share of 18% that Hellegers et al. (2008) expect for this sector in 2025.

Since meeting the demand of the domestic sector is the first priority according to the Water Law nr. 33 of 2002, more allocation of water for the sector is required. This will have to be taken from other sectors given the assumption that renewable water resources will remain stagnant at 2,500 MCM annually.

Table 19: The Domestic water need and generated wastewater of the total population for the period 2010–2025

Year	Urban Population (Million)	Urban Water Demand (MCM)	Rural Population (Million)	Annual Rural water Demand (MCM)	Total Population (Million)	Total Annual Domestic Water Demand in MCM (Without water loss)	Urban Water Loss (MCM)	Total Annual Water Demand (MCM)	Total Wastewater Generated (MCM)
2010	7	139	16	236	23	375	35	419	281
2011	7	145	16	240	24	385	36	430	288
2012	8	151	17	244	24	395	37	441	296
2013	8	158	17	248	25	406	37	453	304
2014	8	164	17	253	26	417	38	465	313
2015	9	172	18	257	26	429	39	478	322
2016	9	179	18	262	27	441	39	491	331
2017	9	187	18	267	28	454	40	505	341
2018	10	195	19	273	29	468	41	519	351
2019	10	204	19	278	29	482	41	534	362
2020	11	213	19	284	30	497	42	550	373
2021	11	222	20	290	31	513	43	566	384
2022	12	232	20	297	32	529	44	583	397
2023	12	243	21	303	33	546	44	601	409
2024	13	254	21	310	34	564	45	620	423
2025	13	265	22	317	35	583	46	639	437

Source: Projections by the Author

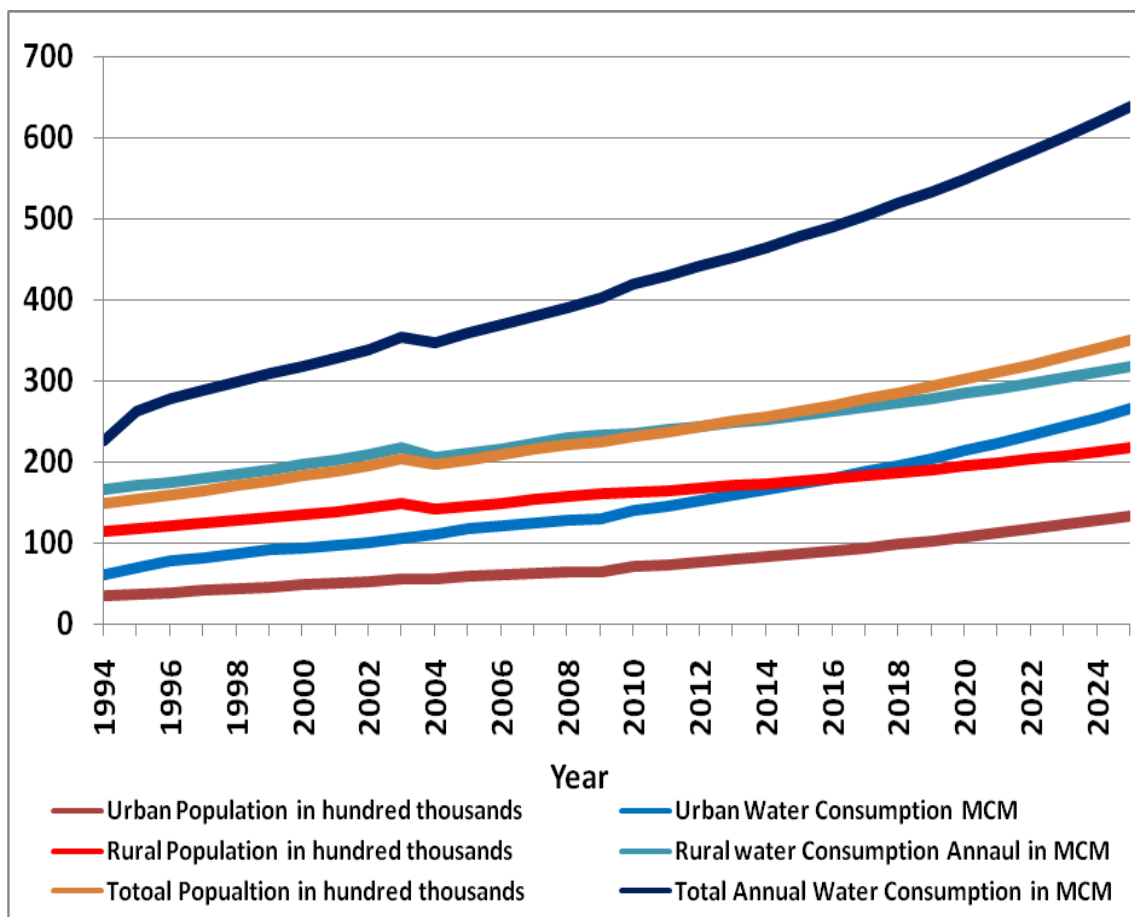


Figure 16: Population growth and water consumption
 Source: the Author

Industrial Use

Assuming that industrial demand continues as per current trends, results show that industrial demand will increase from 85 MCM in 2009 (FAO, 2008) to 188 MCM in 2025 (Table 20).

Thus, the industrial sector in Yemen will be the only sector to more than double its consumption of 2009 by 2025. This projection reflects the potential rapid projected growth of the industrial sector shown as an increase in water demand over the coming period. Based on the results, the share of the industrial sector will increase from 2% in 2005 (FAO, 2008) to more than 4% in 2025.

Compared to other available projections, the results obtained during this research project a relatively high demand for industrial water. ESCWA (2003) expects that industrial demand will be only 134 MCM by 2025, thereby forming only 2.8% of the total future water demand of 4624 MCM. Hellegers et al. (2008) expect that the share of the industrial sector will be 3% by 2025. But with a projected demand of 300 MCM, NWRA (2002) expects that the share of

the industrial sector will form 6% of the total demand; this represents the highest projected share for this sector.

Nevertheless, the industrial sector will continue to be the smallest consumer of water in Yemen compared to other sectors and its demand will remain small compared to irrigation demand as shown below.

Table 20: Future industrial water demand for the period 2010–2025.

Year	Industrial Water Consumption (in MCM)
2010	90
2011	88
2012	93
2013	98
2014	104
2015	110
2016	116
2017	122
2018	129
2019	136
2020	144
2021	152
2022	160
2023	169
2024	178
2025	188

Source: Projections by the Author

Agriculture Sector

In the BAU scenario, the agricultural sector is assumed to continue its current demand trend. The produced results show that most of the demand will come from the irrigation sub-sector, which consumed 3,203 MCM in 2009 (MAI, 2010) and is projected to demand 3,671 MCM in 2025. The results of projecting the livestock sub-sector show that the demand of this sector will increase from 37 MCM to 48 MCM during the period 2009–2025. Accordingly, the total share of the agricultural sector from water resources will reach 3,716 MCM (Table 21) compared to 3,239 MCM in 2009 (MAI, 2010), recording an annual increase of 0.87% during the same period.

The results under this scenario show that the agricultural sector will remain the biggest consumer in the country compared to other water consuming sectors—namely, the domestic and industrial sectors. With a water demand of 3,716 MCM in 2025, the agricultural sector outpaces the domestic and industrial sectors, which consume 639 and 188 respectively.

The results also show that, in the agriculture sector, livestock water consumption will form a smaller share of the water demand compared to irrigation. The livestock sub-sector is projected to increase its water demand from 37 MCM to 48 MCM between the period 2009–2025. Given that the projected agricultural demand will rise from 3,239 MCM to 3,716 MCM during the same period, the consumption of the livestock sub-sector will remain a small fraction of the projected total agricultural demand. Irrigation will sustain its share as the subsector with the highest water demand among all water-consuming sectors in Yemen.

While the obtained results are comparable to some published studies projecting agricultural demand, they project higher demand compared to other available projections. For instance, NWRA (2002) projects the agricultural water consumption to be 3,550 MCM in 2025. By the same token, ESCWA (2003) mentions that agricultural demand will amount 3,650 MCM in 2025.

Table 21: Projected water demand by the agricultural sector for the period 2009–2025.

Year	Irrigation Water Needs (in MCM)	Livestock Water Needs (in MCM)	Agricultural Water Need (in MCM)
2010	3224	37	3261
2011	3272	37	3309
2012	3300	38	3338
2013	3329	39	3367
2014	3357	39	3396
2015	3386	40	3425
2016	3414	41	3454
2017	3443	42	3483
2018	3471	42	3512
2019	3500	43	3541
2020	3528	44	3570
2021	3557	45	3600
2022	3585	46	3629
2023	3614	47	3658
2024	3642	48	3687
2025	3671	48	3716

Source: Projections by the Author

Different projections of agricultural demand could be attributed to several factors, including area of cultivated land and irrigation efficiency. This research assumes that the total cultivated land will increase from 1.4 million ha in 2009 (FAO, 2012) to 1.7 million ha in 2025 while the irrigation efficiency will remain within the estimated average between 35–40% (MAI, 2011). However, NWRA (2002) projects an increase of the total cultivated land from 1.3 million hectare in 2009 (MAI, 2010) to two million hectare in 2025. Despite this substantial increase in the cultivated area—about 300,000 ha more than the projection in this

research—the NWRA projects that the amount of required irrigation water will be 3,550 MCM, which is 237 MCM less than the demand projected in this research. The difference between the NWRA projections and the results obtained in this research could be explained by the higher irrigation efficiency of 60–70% assumed by NWRA.

The abovementioned projections of agricultural water demand, including the results produced in this research, are notably different from other projections such as that by the World Bank. In developing possible scenarios for the evolution of groundwater extraction over the next 40 years, WB (2010) concludes that following the current trend of groundwater exploitation, water reserves are projected to deplete by 2025–2030 and could reduce agricultural production by more than 40%.

7.1.2 Water Savings and Augmentation

Under this scenario, the government will retain its current level of commitment to deal with water resources. This means that the existing level of support for the water resources sector will continue, thereby maintaining the same rate of implementing interventions intended to save and augment water resources. These interventions include support for adopting modern irrigation systems, construction of dams and extending existing wastewater treatment plants where necessary. Institutionally, the lack of required support and resources will not increase the pace of decentralization of water resources planning and management. This will result in a slow pace in establishing Water User Associations (WUAs) at the community level. As a result, water resources will continue to be controlled and overexploited by farmers.

The result of this scenario projects retaining the current level of governmental support in the water resources sector. This continuation will reflect the level of political commitment to supporting the water resources sector, which corresponds with the lower position of water resources issues in the government's priority list. This is because the government's attention will be on issues other than water resources. These issues include poverty, unemployment and the ever-present concern of security.

The continuation of current governmental priorities of supporting policies aimed at reducing poverty and unemployment over other issues, such as water depletion in future, can be noticed easily. Comparing the current situation regarding these issues with targets set by the government in 2002 confirms the projected results under this scenario. The government aim in 2002, as mentioned in 'Yemen's Strategic Vision 2025', is 'halving food poverty by 2015, and its complete elimination, with the decline of relative poverty to 10% by 2025'. Nevertheless, reports state that the 17.6% who had lived below the food poverty line in 1998 fell according to the 2010 food poverty line (extreme poverty) to 12.46% before increasing to 16.15% during the period 2006–2010 (UNDP, 2013). Unemployment increased to 14.6% in 2009 (ILO in WB, 2013) compared to 11% in 2000 (MoPIC, 2003). Reporting on the 'reversal in development that Yemen has faced', UNDP (2011) concludes that Yemen is unlikely to achieve most of the Millennium Development Goals (MDGs) by 2015. These

reports confirm that poverty reduction and unemployment will continue as the main governmental priorities over the coming years as projected by this scenario.

Lack of political commitment and the resulting support for the water resources sector will maintain the same pace of decentralising water resources planning and management. This means that NWRA branches and basin committees that have been established will continue to work as per varying efficiencies based on the availability of resources. This result extends the findings of the MWE (2008) on the existing situation wherein decentralization remains incomplete in terms of empowerment and basins' committees are not fully empowered. This is due to the lack of political will as well as the capacity and maturity required for the effective functioning of the organizations.

The establishment of WUAs will continue mainly with support from governmental projects when implementing irrigation or water resources development schemes. This will bind the functionality of these associations to the support they receive from projects. The result conforms to the finding of Steenbergen et al. (2011), who concluded that the engagement between the government and WUAs ends with project closure.

Water resources will continue to be controlled by 'tribal' farmers and local communities. The tribal structure of society along with continuous concerns about security issues and loyalty of tribes to the central government will be the main driver for the government not issuing regulatory measures to control water resources. Alterman and Dziuban (2010) agree with this statement and assert that by exercising a light hand in the process, the government keeps powerful tribes from causing security problems while it focuses on other relevant threats. The result also extends what Ward (2000) calls the 'contract' between the republican system established in 1962 and the tribes. He explains that according to that contract, the tribes are given autonomy in return for their fealty and military support to the government.

Savings from Irrigation

This scenario assumes a continuation of the current support for the introduction and installation of modern irrigation technologies at the same rate as in 2009. This means that an average of 6,098 ha of agricultural land will be covered by modern conveyance systems and only an average of 226 hectare will be covered by on-farm irrigation systems annually (MAI, 2010). Accumulative water savings by modern irrigation is 100 MCM, which is the total water savings achieved annually by irrigation systems installed before 2010. Installing these systems will maintain the existing annual savings of 10 MCM, thereby resulting in total cumulative water savings of 160 MCM by 2025.

The results obtained under this scenario show that there is still potential for increasing irrigation efficiency using modern irrigation systems, and that such intervention forms an opportunity for achieving considerable water savings. Nevertheless, comparing the area of irrigated agriculture that is annually covered by modern systems—6,324 hectare—and the total area with potential to be covered—about 331,770 hectare (MAI, 2010)—it is observed that the contribution of irrigation efficiency in achieving water savings is still far below the

level that can be achieved. This is obvious when comparing the area of land that is covered by on-farm systems annually—about 226 hectare—and the area that is covered by conveyance systems annually—about 6,098 hectare.

Dams

In parallel to other interventions to augment water resources, this scenario assumes that the construction of dams will continue at the pace of 2009, thereby augmenting the depleting water resources by an average of 5.5 MCM annually. The accumulative water augmented by dams comprises 138 MCM as explained in Section 2.4.2. This represents the total water provided annually by dams constructed prior to 2010. By 2025, the cumulative amount of water provided by all dams in the country, including the current 138 MCM, will reach 226 MCM.

Reusing Treated Wastewater

By continuing the current policy of treating wastewater only in the main cities and towns, the increased consumption of water in the domestic sector will lead to an increase in wastewater generated in urban areas from 110 MCM in 2009 to 206 MCM in 2025. Even though more wastewater treatment plants will be established, it is assumed that the cultural view for this reusing wastewater as well as health concerns will continue to restrict the reuse of treated wastewater in some regions. Thus, only 13% of treated wastewater will be reused, thereby marking an increase from 14 MCM in 2010 (based on FAO, 2008) to 49 MCM in 2025.

Although non-conventional water resources are already being used, their potential is still not fully tapped. Wastewater reuse has strong potential considering the rapid increase of populations in urban areas.

Qat Replacement

In this scenario, the government will continue its current policy of refusing to adopt any official legislation against qat agriculture. This means that qat consumption will continue and farmers will keep growing qat. The efforts of non-governmental organisations will result in individual initiatives among farmers for replacing qat agriculture with other crops. Nevertheless, the scale of such initiatives will be too small to impact the water balance. Therefore, the potential of achieving savings using this alternative will continue to be neglected.

7.1.3 Water Balance

Under this scenario, the total demand for water will increase rapidly. The projection reveals that the total water demand will increase from 3,713 MCM in 2009 to 4,543 MCM by 2025 owing to increasing demand driven mainly by the irrigation sector. While the effort of the government will continue in augmenting and saving water resources, technical interventions will contribute about 18.5 MCM annually. However, this will not be sufficient to cover the increased demand for the period from 2009–2025.

This means that with annual renewable water of 2,500 MCM, the water balance will continue to be impacted negatively. This scenario results in an increase in the deficit from 1,018 MCM in 2010 to 1,508 MCM in 2025. This deficit will be met by a greater withdrawal of underground water.

As explained in the previous sections on sectoral demands, rapid increase in the water demand of these sectors will drive demand to a level that is higher than the water available.

Comparing the total water demand projected under this research to the total water demand by 2025 as mentioned by other reports shows comparable results. While this research projects that total demand will continue to increase from 3,713 MCM in 2009 to reach 4,543 MCM by 2025, according to ESCWA (2003) estimate, the total water demand will reach 4,624 MCM. NWRA (2002) projects that the water demand will increase from 3,400 MCM in 2000 to 4,628 MCM in 2025. While the difference between the total demands has been explained in the previous section on sectoral demand, all results agree that water demand will exceed 4,500 MCM by 2025.

Under the Business as Usual scenario, it is projected that the per capita share of water will decrease to 79 cubic metres in 2025. This amount is less than the per capita share reported by EPA (2006). The latter projects that the per capita share will drop to 150 cubic metres by 2025. Nevertheless, Hellegers et al. (2008) mention that, in 2005, the per capita water availability decreased to 120 m³/person/year to become one of the lowest in the world as compared to 1,250 m³/person/year in the Middle East and North Africa (MENA) region and 7,500 m³/person/year worldwide. Hellegers et al. show that the reality of the per capita share has already outpaced the projection reported by the EPA; this shows that the projected per capita share under this research is a more accurate reflection of the current and potential future situation. On the other hand, Atroosh (2007) and Noman (N.A) mentioned that per capita water availability will decrease to 66 m³ by 2026. Because the methods and assumptions used in projecting the data are not available, differences in projections under this scenario and other projections can be attributed to differing assumptions made about annual renewable water and/or the population growth, both of which are variables used to calculate the annual per capita share of water.

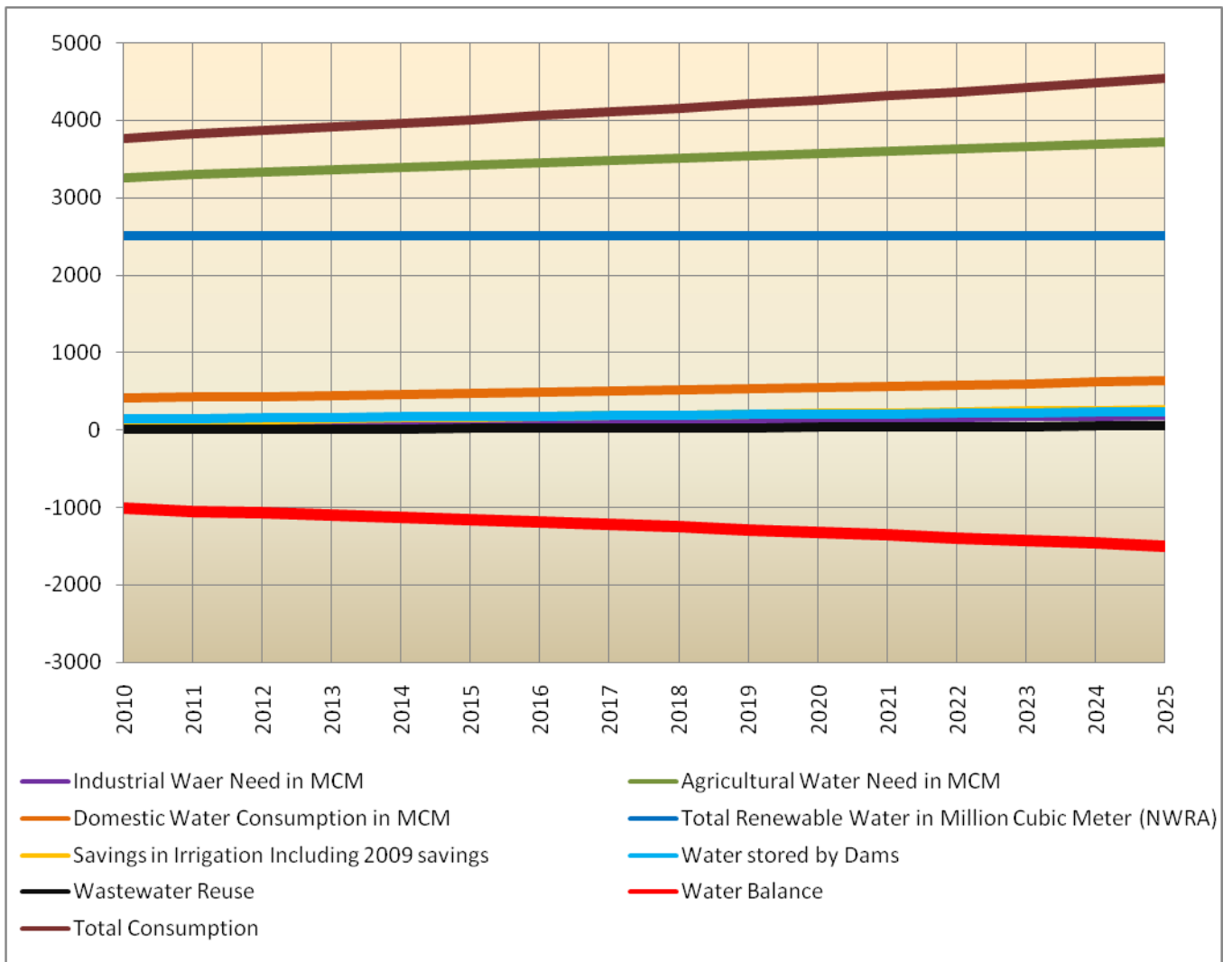


Figure 17: Projected water balance under the BAU scenario
 Source: the Author

Table 22: Projected water demand, savings, augmentation and balance under the BAU scenario

Year	Industrial Water Demand (in MCM)	Agricultural Water Demand (in MCM)	Domestic Water Demand (in MCM)	Total Demand (in MCM)	Total Renewable Water (in MCM) (NWRA)	Savings in Irrigation, Including 2009 savings (in MCM)	Water stored by Dams (in MCM)	Wastewater Reuse (in MCM)	Water Balance (in MCM)
2010	90	3261	419	3770	2500	110	144	14	-1003
2011	88	3309	430	3827	2500	120	149	16	-1043
2012	93	3338	441	3872	2500	130	155	17	-1071
2013	98	3367	453	3918	2500	140	160	18	-1100
2014	104	3396	465	3965	2500	150	166	20	-1130
2015	110	3425	478	4012	2500	160	171	22	-1160
2016	116	3454	491	4061	2500	170	177	24	-1191
2017	122	3483	505	4110	2500	180	182	26	-1223
2018	129	3512	519	4160	2500	190	188	28	-1255
2019	136	3541	534	4212	2500	200	193	30	-1289
2020	144	3570	550	4264	2500	210	199	33	-1323
2021	152	3600	566	4317	2500	220	204	35	-1358
2022	160	3629	583	4372	2500	230	210	38	-1394
2023	169	3658	601	4428	2500	240	215	42	-1431
2024	178	3687	620	4485	2500	250	221	45	-1469
2025	188	3716	639	4543	2500	260	226	49	-1508

Source: the Author

7.2 Do Nothing Scenario

1.1 General Assumptions

Under this scenario, it is assumed that the demand for water will continue as in the BAU scenario until 2025. The government will rapidly reduce its financial and political support to the water resources sector and this will be accompanied by a lack of awareness among farmers about the importance of saving water resources. Consequently, this will lead to increasing unwillingness among farmers to adopt alternatives for saving water resources. As a result, implementing new technical interventions for saving and augmenting water resources will cease from 2014, and water savings and augmentation will be limited to what was already available prior to that year.

1.2 Specific Assumptions

As shown in Tables 15 and 16, the main assumptions in the Do Nothing scenario are as follows:

- Starting from 2104, water savings by modern systems will be limited to 100 MCM saved annually by systems that already exist.
- As scenario BAU will continue until 2014, the water provided thereon by dams will be limited to 138 MCM annually as provided by the dams constructed before 2010.
- Wastewater reuse, starting from 2014, will be limited to the amount generated in 2010, which is 14 MCM annually.
- Water demand by consuming sectors will continue to increase as per the BAU scenario according to the following annual rates:
 - o Agricultural: 0.87%
 - o Domestic: 2.85%
 - o Industry: 5.06%

7.2.1 Water Demand

Given the rapid population growth, it is assumed that water demand will continue to rise in all sectors in the Do Nothing scenario as per the BAU scenario shown in Table 22.

7.2.2 Water Savings and Augmentation

Under this scenario, the support required for implementing technical interventions for saving and augmenting water resources will decrease from 2014. Major social and economic challenges, primarily the spread of poverty and unemployment among larger parts of the population, will shift governmental attention and support from the water resources sector to other sectors.

The absence of any new governmental projects and subsidized programmes for farmers and awareness campaigns to promote water-saving interventions will hinder the implementation of technical interventions. The lack of resources will add to difficulties facing further decentralization of water resources planning and management. It will also hinder existing institutions at the local level, rendering them non-functional. The absence of governmental projects will negatively impact the establishment of the new WUAs.

The prediction under this scenario is that socio-economic issues of poverty reduction and unemployment will redirect governmental support from the water resources sector to these other major issues. This prediction conforms to recent reports by the Ministry of Planning and International Cooperation (MoPIC, 2012), which mentioned that ‘the deterioration in the political and security scene since the beginning of 2011 caused an acute regression of the economic, financial and monetary indicators and unprecedented deterioration of the livelihood and humanitarian situations.... [T]he developments the Yemeni economy witnessed during the last year left myriad negative impacts on the living standards of the population. These impacts include the loss of jobs and incomes. This led to increased poverty levels, especially among those who are already poor to start with. In addition, the slippage of many families below the national poverty line was widely witnessed. Estimates indicate that poverty rates have reached nearly 54.4% of the population in 2011’.

Unemployment is another persistent challenge that haunts the government and will remain a top concern in future. This is obvious from the MoPIC (2012) report that states that ‘the unemployment problem is considered the most important challenge facing the development process. It contributes to undermining the political and security stability in the country particularly as it is highly concentrated among youth at 52.9% (age group 15–24 years). It also reaches a percentage of 44.4% in the age category (25–59 years). Unemployment is widespread even among educated people’.

Future lack of support for the water resources sector will result from the financial deficit expected to follow the depletion of oil reserves. MoPIC and UNDP (2010) state that oil revenues contribute about 70% of the central state budget, and accounted for over 90% of the gross commodity export in 2008. They affirm that reliance on oil exports makes economic activity vulnerable to decline in oil production. This decline had already begun in 2001 and will continue rapidly until the expected complete exhaustion of oil reserves by 2017 (MoPIC, 2012).

The lack of governmental funding for subsidizing and introducing technical interventions will significantly and negatively impact the implementation of interventions to save and augment water resources. This prediction is supported by the fact that the government, through its projects, bears most of the costs of these interventions. For example, when introducing modern irrigation systems, the government covers 50–90% of material cost and 0–90% of installation cost (MAI, 2011), as Table 23 shows. Another example is the construction of dams, wherein governmental programmes cover at least 50% of the cost (Vermillion and Al-

Shaibani, 2004) through programmes such as the Agriculture and Fisheries Production Promotion Fund (AFPPF), which is a the main fund in the MAI for providing credit, grants, and interest-free loans to farmers (MAI, 2012).

Table 23: Subsidies Provided to Farmers by Different Projects for Introducing Modern Irrigation Systems

Projects	Subsidy on Conveyance Pipe Irrigation System		Subsidy on Modernized System	
	Subsidy on Material	Subsidy on installation	Subsidy on Material	Subsidy on installation
LWCP	50–60 %	50%	50 %	50%
SBWMP	60%	90%	75%	90%
GSCP	50–70 %	No	50%	No
NIP	50–90 %	-	50–90%	-
AFPPF	50%	No	50%	No

Source: MAI, 2011

The implementation of tasks and responsibilities in water resources planning and management assigned to local level institutions will be hindered because of the lack of resources, mainly financial resources. Among the 14 water basins into which Yemen has been divided by the NWRA, only five committees have been established in Sana’a, Taiz, Sa’ada, Tuban and Abyan (MWE, 2008). Hindrance of decentralisation caused by the lack of financial resources is built on the finding of Ward et al. (2007). They list very small operating budgets for branches and centralized finances among the main limitations to NWRA’s initiative to delegate responsibilities to branches all of which limit the potential of branches at a local level and impede NWRA’s initiative through ‘incomplete decentralizations’. The hindering of decentralization and the delegation of planning and management of water resources to local authorities will form a main difficulty against the scaling out of technical alternatives to support water resources—e.g. dissemination of modern irrigation systems and the achievement of sustainable management of water resources.

Establishing no further projects and programmes for supporting the water resources sector will also negatively impact the establishment of Water User Associations. According to Steenbergen et al. (2011) WUAs are created under a large number of projects. Therefore, decreasing the number of projects working in the water resources sector will also reduce the number of WUAs to be established as predicted in this scenario.

Savings from irrigation

Under the Do Nothing scenario, it is assumed that the level of support for the introduction and installation of modern irrigation technologies that existed in 2009 will continue at the same rate until 2014. Thereafter, the amount of water savings by modern irrigation systems will stabilize at 100 MCM annually until 2025.

The results obtained under this scenario show that no further water savings by modern irrigation systems will be achieved starting from 2014 as no more agricultural land will be covered with modern irrigation systems until 2025, thereby resulting in no additional savings in the irrigation sector. Water savings will then remain stagnant at 100 MCM annually.

The scenario builds on the fact that in the absence of subsidized programmes, farmers will stop installing modern irrigation systems, particularly the costly on-farm systems. The MAI (2010) mentions that on-farm irrigation systems can save as much as 34% of pumping requirements resulting in greater savings through groundwater irrigation compared to conveyance systems (4.285 m³/ha and 1.483 m³/ha of water savings respectively). Even during the availability of programmes that subsidize the introduction of modern on-farm systems, farmers prefer to invest in conveyance systems. MAI (2010) attributes this to various factors. For instance, the initial investment cost for the conveyance systems represents only between 15–20% of the investment costs in localized on-farm irrigation and the subsidy level for small farms to be equipped with conveyance systems (70%) is higher than the subsidy level for small farms to be equipped with the on-farm irrigation systems (50%). Steenbergen et al. (2011) report on the resistance of farmers to invest in on-farm systems. They attribute this resistance partially to the scepticism, that they consider ‘partly well founded’, on the usefulness of drip systems in irrigating the widely spread out root system; in the reported case, these were the roots of old grape plants.

The predicted future situation can be illustrated further by the current modest rates of installing irrigation systems, particularly on-farm systems. This supports the assumption of this scenario. Table 7 shows that the total implementation of on-farm systems, by all projects that have provided modern irrigation in Yemen, is only 2,876 ha compared to 58,791 ha of conveyance systems until 2009.

The results achieved can also be explained in light of current practices in the agricultural sector that are based on the perception that water is an ‘open’, rather than a communal, resource. This view stems from customary law. These practices and perceptions are protected by the predominating tribal social structure of the society. Such practices and perceptions are exemplified by a top official and decision-maker in the NWRA interviewed within this research. He stated that security forces were unable to stop the drilling of a new well in a farm located in a suburb near the capital city of Sana’a due to the insistence of an armed tribal farmer to continue drilling the well on his farm. The farmer’s reaction stems from the fact that civil and customary laws give farmers the right to unlimited use of water beneath the land he legally owns. These laws contradict the constitution of the country, which states that

all natural resources—including surface and underground water—are state owned, as explained in Chapter 2.

The aforementioned facts indicate that in the absence of subsidized programmes, the control of farmers over water resources will continue; they will carry on using water as free resource. This situation will further demotivate farmers from adapting technical interventions for saving water, which will result in no further savings in the irrigation sector.

Under the Do Nothing scenario, the produced results on the impact of agricultural sector on the water balance depends on the level of installing modern irrigation systems and on the sector's water demand, which is kept constant. Other published scenarios depend mainly on the level of agricultural water consumption as the main factor. Such scenarios include the 'no action' scenario developed by Redecker (2007). In the 'no action' scenario until 2020, Redecker assumes that the irrigation water demand will continue at a rate of 9,500 m³/hectare/year and the irrigation area will continue to grow at a slower rate of 2% per year. This will increase irrigation demand to about 4,900 MCM in 2020. Nevertheless, the contribution of available technical interventions—e.g. modern irrigation systems is not mentioned in Redecker's scenario.

Dams

Based on the main assumption of this scenario, the construction of dams will continue as per BAU until the end of 2013. Thereafter, no further savings will be achieved starting from 2014. Consequently, the dams will maintain the same level of water augmentation as per 2009. Starting from 2014, an average of 138 MCM of water will be provided annually by dams constructed prior to 2009.

This scenario builds on questions regarding the efficiency of existing dams. The World Bank (2010) mentions that the government has been promoting small dams for more than a decade, as part of the answer to the growing constraint in water resources constraint. However, the programme has had limited impact on the water balance. TID (2010) mentions that an estimated 20–30% of rainfall is thought to be wasted through faulty collection and poorly maintained dams in Yemen.

While these dams are constructed to harness surface water that runs through the wadis (valleys) and ends in the sea, several experts and decision-makers from the water sector interviewed in the course of this research claim that surface water no longer runs into the sea. Such claims support the direction of this scenario. One of these experts in the MWE explained that surface water in wadis is consumed completely by farmers for irrigation and does not reach the sea; if at all it reaches the sea, it happens only once every 15–20 years. Thus, building more dams in wadis will not help the water balance.

Considering the above claims, the government will finally decide to significantly reduce its support to the dam construction programme. This will result in decreasing levels of water savings to negligible levels as projected by this research.

Reusing Treated Wastewater

Under this scenario, it is assumed that the reuse of treated wastewater will continue as per the BAU scenario until 2014 and only 13% of the treated wastewater will be reused. Therefore, and influenced mainly by concerns regarding effluent quality and financial constraints, no further wastewater will be used until 2025. The same level of reuse as per 2009 (14 MCM annually) will continue until 2025.

There is potential for reusing wastewater in Yemen as only 13% of wastewater is reused currently. Nevertheless, several considerations may impact the future of wastewater reuse in Yemen, thereby allowing the amount of reused wastewater to stagnate at 14 MCM until 2025.

Several concerns may influence the reuse of water in Yemen making both the government and farmers opt for other water resources. A main concern in this regard is the quality of the treated water. A study conducted in Yemen covering five cities concluded that current effluent quality is generally poor as none of the existing WWTPs produce effluents that comply with the effluent quality regulations (EPA, 2003). The study mentions that there are no formal reuse schemes for the effluent currently produced by the WWTPs covered by the study, 'although at least some of the effluents are used by farmers, directly or indirectly'. ACWUA (2010) mentions that farmers illegally abstract water either directly from the plants or downstream from the effluent discharge point. It adds that the WWTPs do not meet national quality requirements and that reuse patterns are completely uncontrolled. This explains why 'some farmers are put off by the poor quality of most effluents and some farmers have experienced poor crop performance' (EPA, 2003).

The decrease in reusing treated wastewater may also be attributed to financial concerns as improving the quality of the effluent is not cheap. The EPA (2003) mentions that additional treatment of the effluent to improve its quality will be costly. While the main scenario assumption is that the government will not be willing to invest in water resources, the EPA (2003) indicates that even farmers are not willing to cover the cost of the treatment as the crops allowed to be grown using wastewater are not high value cash crops and also because the cost that farmers already cover in conveying treated wastewater to their farms as effluent do not always coincide with easily accessible land for irrigation (EPA, 2003).

The abovementioned concerns will retain what the ACWUA (2010) calls the 'current lack of suitable treatment and distribution systems'. This will result in abandonment of the potential of this resource by limiting its use to existing levels as mentioned above.

Qat replacement

Under this scenario, the government, through its concern about the potential negative impact on farmers, will refuse to adopt any official legislation that restricts qat consumption or agriculture. This means that the situation will continue as per 2009 until 2025; hence, no water savings will be achieved by replacing qat agriculture with other crops that consume less water and this potential will remain untapped.

The result projected by this scenario is based on the assumption that the government will not enact legislation to restrict qat agriculture and will not provide the required support to implement programmes for replacing qat with other crops. This may be due to several governmental concerns that are greater priorities; these largely include the security and socio-economic aspects.

Alterman and Dziuban (2010) link some governmental policies to qat agriculture and security. They explain that by subsidizing diesel prices, the government allows qat growers to pump water cheaply; the lack of robust water regulation ensures that farmers continue doing so. Alterman and Dziuban assert that by exercising a light hand in the process, the government keeps powerful tribes from causing security problems while it focuses on other relevant threats.

Economic consideration plays a major role in limiting governmental choices in dealing with qat agriculture and replacement, particularly during periods where poverty prevails. With more than half of the population living in poverty (WB, 2012), the implementation of policy reforms aimed at reducing water depletion may have economic implications which will not be affordable for the local community, particularly the poor. Such economic challenges pressure the government and hinder attempts to adopt legislations restricting qat agriculture or reducing subsidies for agricultural inputs that may negatively impact the economic situation of farmers. Vilorio (2010) mentions that qat contributes 10% of GDP in Yemen and provides 12–14% of employment for the working population, of which 30–33% represent the agricultural labour force. She explains that the interests groups that benefit from qat production include producers, traders, dealers, regional and district governments (from tax receipts).

The abovementioned factors and concerns complicate dealing with the qat issue. These concerns support the assumption made under the Do Nothing scenario and thereby, the produced results.

7.2.3 Water Balance

The total demand for water will continue to increase driven mainly by the rapidly increasing population. While the total water demand will reach 4,543 MCM by 2025, the total contribution of different alternatives will be 250 MCM annually. This will be reflected in the water balance as the water deficit will rise from 1,018 MCM in 2010 to 1,791 MCM in 2025. More underground water will have to be withdrawn to cover the huge water deficit.

Under the Do Nothing scenario, the demand for water will increase as per BAU as explained in Section 7.1.1. The total water demand will increase from 3,770 MCM in 2010 to 4,543 MCM in 2025.

The results obtained under this scenario show the negative impact of the decreased level of water augmentation and savings on the water balance. Projections show that water savings provided by different technical interventions will be reduced to only 250 MCM annually. The

statistical analysis under this scenario shows that as a result of decreased water savings, the water deficit will rise substantially to an unprecedented level (Figure 18) of 1,791 MCM in 2025 compared to 1,018 MCM in 2010.

Comparing the obtained amount of water deficit under this scenario with the 'no action' scenario developed by Redecker (2007) shows a considerable difference. In his scenario, Redecker (2007) projects higher levels of water deficit that will reach more than 3,000 MCM by 2020. Comparing both scenarios shows a difference not only in results obtained but also in factors underlying both scenarios that are used, mainly to project water demand. As the biggest consumer of water resources in Yemen, irrigation water demand is a major factor influencing total demand and, accordingly, the obtained results of the future water balance in both scenarios. While this research projects that the agricultural water demand will reach 3,716 MCM by 2025, Redecker (2007) projects an increase in agricultural demand reaching about 4,900 MCM by 2020 compared to the 3,570 MCM projected for 2020 under this research. Such a considerable difference in demand may explain the resulting difference in the water deficit.

Further comparison of the main factors used for projecting the water balance in this research and in Redecker's study (2007) reveals that Redecker uses sectoral demand variations to produce future scenarios. However, in this research, variations in water augmentations and savings are used to develop future scenarios for water balance.

In the same way, comparing the water balance produced under this scenario by that projected by the NWRA (2002) shows that NWRA projects a water deficit of 2,128 MCM by 2025; this is more than the water deficit of 1,791 MCM projected under this scenario. The NWRA (2002) mentions that this deficit will result from water demand, which by 2025, will note increases in the domestic, industrial and agricultural demands to 758 MCM, 300 and 3,550 MCM, respectively. However, projected demands in this research for the domestic, industrial and agricultural sectors amount to 639 MCM, 188 MCM and 3,716 MCM, respectively. Comparing the factors used in developing future water balance scenarios in both studies shows that while the water availability of 2,500 MCM annually is assumed to continue until 2025 in both studies, the NWRA projects higher demand by water consuming sectors compared to projected sectoral demands produced in this research, except for in the irrigation sector. A lower irrigation water demand by 2025, as projected by the NWRA, compared to the results produced by this research may be attributed to the high irrigation efficiency of irrigated agriculture of about 70% that the NWRA assumes; this is not the case under the Do Nothing scenario. Nevertheless, in building this scenario, an annual amount of about 252 MCM of water, which results from the already existing technical interventions for augmenting and saving water resources, is projected to support the water resources. This quantity of water that supports water resources can explain the lower water deficit projected under the Do Nothing scenario developed in this research.

Under the Do Nothing scenario, the annual per capita share of water is projected to decrease rapidly to 71 cubic metres by 2025. Comparing this result to other projections shows that this result is higher. For example, Atroosh (2007) and Noman (N.A) mentioned that the projected

annual per capita share of water in 2026 is 66 cubic metres while GSCP (2010) mentions 54 cubic metres as an annual per capita share of water. Although the assumptions and method of projection for the published results are not provided, a major factor influencing the high projected result under this scenario is the assumption that higher water availability will result from water savings generated by already existing technical interventions.

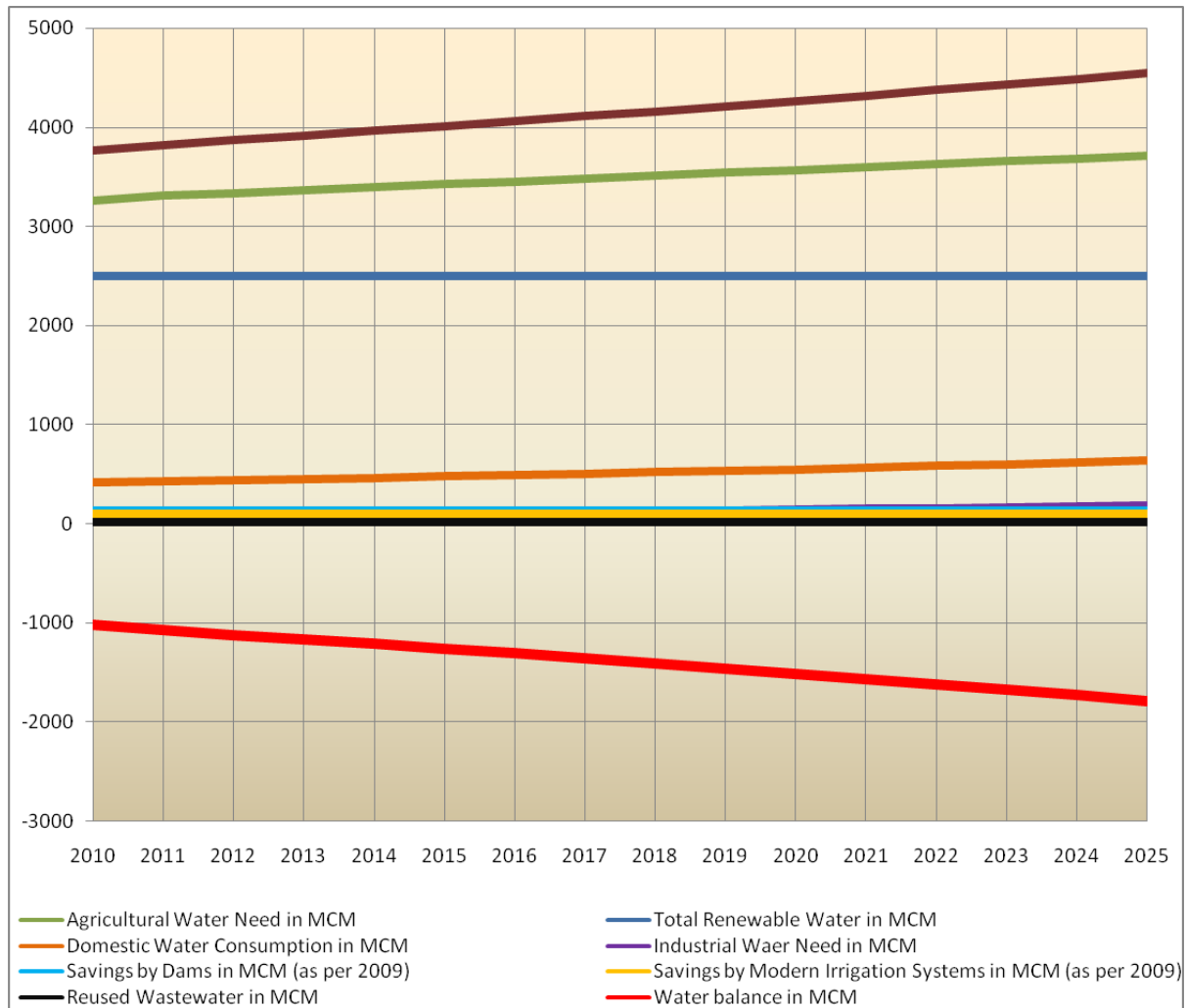


Figure 18: Projected water balance under the Do Nothing scenario

Source: the Author

Table 24: Projected water demand, savings, augmentation and balance under the Do Nothing scenario

Year	Total Population in hundred thousand	Total Renewable Water in MCM	Industrial Water Need in MCM	Agricultural Water Need in MCM	Domestic Water Consumption in MCM	Total Consumption in MCM	Savings by Modern Irrigation Systems in MCM (as per 2009)	Savings by Dams in MCM (as per 2009)	Reused Wastewater in MCM	Water balance in MCM
2010	232	2500	90	3261	419	3770	100	138	14	-1018
2011	238	2500	88	3309	430	3827	100	138	14	-1075
2012	243	2500	93	3338	441	3872	100	138	14	-1120
2013	250	2500	98	3367	453	3918	100	138	14	-1166
2014	256	2500	104	3396	465	3965	100	138	14	-1212
2015	263	2500	110	3425	478	4012	100	138	14	-1260
2016	270	2500	116	3454	491	4061	100	138	14	-1308
2017	278	2500	122	3483	505	4110	100	138	14	-1358
2018	285	2500	129	3512	519	4160	100	138	14	-1408
2019	293	2500	136	3541	534	4212	100	138	14	-1459
2020	302	2500	144	3570	550	4264	100	138	14	-1511
2021	311	2500	152	3600	566	4317	100	138	14	-1565
2022	320	2500	160	3629	583	4372	100	138	14	-1619
2023	330	2500	169	3658	601	4428	100	138	14	-1675
2024	340	2500	178	3687	620	4485	100	138	14	-1732
2025	351	2500	188	3716	639	4543	100	138	14	-1791

Source: the Author

7.3 Sustainability Scenario

General Assumptions

In this scenario, it is assumed that the demand for water will continue as in the BAU scenario until 2025. Implementation of different technical interventions for augmenting and saving water resources will continue as BAU until 2014. Thereafter, it is assumed that the implementation of technical interventions for enhancing water resources will increase at a constant rate.

Specific Assumptions

In this scenario, the following assumptions are made:

- The water storage of dams is assumed to increase starting from 2014 as a result of establishing more water harvesting systems, thereby achieving an annual increase of 6.9 MCM instead of 5.5 MCM achieved in 2009.
- Urban treated wastewater reuse will increase 4% annually starting from 2014, which is exactly the annual increase of generated wastewater in urban areas, and will increase from the 3 MCM achieved in 2009 to average 12 MCM annually.
- Water savings from installing modern irrigation systems will increase starting from 2014 from 10 MCM as per 2009 to 15 MCM annually as a result of increasing the area covered with on-farm modern systems by 1,600 ha annually.
- Replacing qat agriculture by other crops will result in water savings of 17 MCM annually.
- Water demand by consuming sectors will continue to increase as per the BAU scenario according to the following annual rate:
 - o Agricultural: 0.87%
 - o Domestic: 2.85%
 - o Industry: 5.06%

7.3.1 Water Demand

Under this scenario, water demand will continue as per BAU scenario until 2025 as shown in Table 22.

7.3.2 Water Savings and Augmentation

Motivated by the rapidly deteriorating conditions of water resources and to avoid the potential catastrophic impacts of water resources depletion, the government will prioritize water resources issues and will spare no effort to support water resources. The full political commitment to support water resources in regaining sustainability will

be reflected as full support for central- and local-level water resources planning and management institutions. Required technical, human and financial resources will be made available for local level authorities.

The governmental commitment and support will impact water resources planning and management positively. At the national level, and aiming at rectifying existing institutional structure in the water sector, a ministry for water resources and environment will be established. At the local level, the decentralization of water resources planning and management will be completed resulting in delegating the planning and management of water resources to local water resources authorities. The establishment of WUAs for community-based management of water resources along with awareness campaigns will be initiated all over the country to rectify local perception and practices based on the understanding that water is a common resource but not an ‘open’ resource. This will lead to more integrated and sustainable management of water resources and enforcement of the water law. An important result for such improvements will be scaling out the implementation of alternatives for saving and augmenting water resources.

To achieve the projected increase in the implementation of interventions to support water resources, it is predicted that full political will and commitment will be secured. This precondition for scaling up the implementation of technical alternatives was explicitly stated by most of the key informants interviewed within this research. An expert in modern irrigation systems mentioned that achievement of increased annual coverage by modern irrigation systems is achievable if there is a political commitment to do so by providing the required resources and support. Another top official in the MWE mentioned that political will is required for supporting water resources, particularly water demand management. On the other hand, a decision-maker from the MAI asserted that political considerations affect the taking of hard decisions regarding replacing qat cultivation. Other similar statements agree with the prediction under this scenario, that the political will and commitment to support water resources is a key success factor that should underlay any future planning for increasing the implementation of alternatives to support water resources.

The sustainability scenario projects that it will be possible to increase implementation rates to those suggested under the scenario if the required financial support is secured. This result can be seen from the percentage of the governmental contribution and subsidies provided for implementing alternatives for supporting water resources. While this support can reach 100% as in the case of wastewater treatment plants, this support is at least 50% in the case of dam construction (Vermillion and Al-Shaibani, 2004) or different percents to farmers for supporting the introduction of modern irrigation as shown in Table 23.

This prediction agrees completely with the capacity of national institutions to implement assumed levels of interventions. For example, two experts who in charge of introducing modern irrigation in two systems projects stated that if the required financial resources are

made available, 5,000 ha of irrigated land can be covered by modern irrigation systems annually.

The established water basin committees beside the decentralized water resources authorities will cooperate to plan and manage water sustainability with local communities through WUAs. A top official in the NWRA stressed the importance of local and stakeholder participation for integrated and sustainable management. In the same direction, a prominent decision-maker in the MWE, who was interviewed in the course of this research, asserted that farmers play the key role in the desired change and should be supported by the government to play this role. He explained that the ideal situation would be to develop community-based management by initiating communal discussion among farmers mediated by governmental representation to develop tailor-made local regulations on basin or stream levels.

The resulting regulations should replace existing regulations that were not developed according to traditional practices. These regulations should be based on the following:

- a) traditional values and practices that consider water a communal resource
- b) water availability
- c) type of use of the stream's or basin's water
- d) geological and geographical characteristics of the area
- e) quantity of water from the stream or basin; and
- f) type of crops grown.

Hence, for each stream or basin, water is distributed fairly according to an agreement between farmers.

The predicted increase in the adoption of interventions to support water resources will be facilitated through decentralized and participatory community-based planning and management. This improvement will include governmental support for the establishment of basin committees and the establishment of WUAs through water management, irrigation projects and the decentralized water resources authorities. This result agrees with the aim of the NWRA as expressed by its chairman, who confirmed that the institution aims at establishing 14 water committees covering the 14 water basins in Yemen (Ward et al., 2007). The predicted role of WUAs in supporting water savings is based on the existing role of the WUAs as Bruns and Taher (2009) reported. Bruns and Taher mention that in surface water and groundwater irrigation projects, the WUAs have initiated requests, mobilized resources and participated in planning and implementing projects for surface irrigation; in the case of groundwater irrigation, WUAs have helped to improve awareness that groundwater resources are limited and being depleted and have facilitated the provision of pipes and other subsidized equipment intended to reduce water consumption. The predicted role of WUAs extends the finding of Steenbergen et al. (2012) who conclude that if properly empowered, WUAs might play a role in local groundwater management.

Another manifestation of the predicted increase in political commitment to support integrated and sustainable water resources management involves rectifying the existing institutional structure of the water resources sector. This is expected to be implemented through the establishment of a Ministry of Water Resources and Environment Protection. This ministry

will have its mandates of allocating, supervising and regulating water resources development and use. The existing MWE controls only 10% of water resources in the country, which is the amount of water not consumed by the agriculture sector, whereas the Ministry of Agriculture controls the other 90%. Nevertheless, the current MWE is still considered a polluter because the ministry includes in its structure the Water Supply and Sanitation Corporations. So, there is a ‘conflict of interest’ in the mandates of the existing ministry. Under this scenario, the current institutional situation will be rectified as mentioned. The situation will be as follows: the independent ministry that allocates water among different uses and users will ‘own’ the surface- and groundwater in the country as stated by the constitution. Following the issuance of the water resources licences for irrigation, domestic or industrial use, the responsibility of managing the resources will be transferred to bodies and authorities when the water is transferred and allocated to the user—e.g. the responsibility is then passed on to the Ministry of Irrigation or public water supply corporations.

Savings from irrigation

As the biggest water-consuming sector, the government will decide to invest in modern irrigation technology, particularly on-farm technologies. This support will include subsidies for installing these systems and supporting maintenance services. The continuous decentralization of institutions on the basin and local levels will play a key role in facilitating the introduction of these systems through awareness campaigns and by facilitating farmers’ access to governmental subsidies that will result in the scaling out of these systems.

It is assumed that the installation of on-farm modern irrigation systems will rise from 226 hectare annually in 2009 to 1,500 hectare starting from 2014. The adoption of conveyance systems, however, will remain steady by achieving the ‘BAU’ coverage of 6,098 hectare annually. The rise in adopting irrigation technology will substantially increase the amount of water savings by modern irrigation systems from 10 MCM to 15 MCM annually. The cumulative water savings will jump, consequently, from 110 MCM in 2010 to 749 MCM in 2025.

The projected savings under this scenario results mainly from the scaling out of on-farm irrigation system by covering an area of 1,500 hectare annually. It is assumed that the government will support the scale out of such irrigation systems as the water savings from using on-farm systems is 4.285 m³/ha compared to only 1.483 m³/ha of water savings by irrigation water conveyance systems (MAI, 2010). The will result in annual water savings of 5 MCM.

It should be mentioned that projected water savings of 15 MCM annually are achievable under this scenario. The assumption of an annual coverage of 7,600 ha by modern irrigation systems research is less than the area that could be covered annually. This can be explained by considering the target set by the MWE. MWE (2008) sets a target that agricultural land of 61,000 ha must be equipped with modern irrigation systems during the period 2009–2015. This means that about 8,714 hectare will be covered with modern systems annually. In other

words, this scenario assumes that coverage of more than 7,600 ha is achievable annually. On comparing this number with the NWSSIP target of 61,000 ha by 2015, one can conclude that the research provides an achievable target.

While the research assumes that scaling out modern irrigation systems will help to support the sustainability of water resources in Yemen, modern irrigation systems alone cannot face the increasing demand for water and bring water resources to sustainable levels. According to MAI (2010), increasing irrigation efficiency through modern irrigation systems is not a permanent solution to the water deficit problem confronting Yemen. MAI explains that even if the entire groundwater irrigated area of 425,000 ha is covered by improved irrigation systems, the country shall never be able to meet the water demand of the growing population. This also means that other technical interventions play key roles in facing the current water crisis in Yemen and in supporting the sustainability of water resources.

While increasing irrigation efficiency through modern irrigation should result in water savings and a positive impact on water resources, there are concerns that a counterproductive impact may result from increasing irrigation efficiency on water resources. Al-Asbahi (2005) mentions that 'for their recharge, groundwater resources in Yemen depend mainly on spates running water and rainfall'. He asserts that 'there are also estimates that there will be an improvement for using the available water at a 35% to 60% higher efficiency rate in irrigated areas, which will result in a reduction of water consumption'. Disagreeing with that conclusion, Allen (2009) mentions that the ultimate impact of such measures may result in a negative impact on water resources. He quotes the findings of Ward and Pulido-Velazquez (2008): 'Water conservation in irrigation can increase water use'. Pulido-Velazquez (2008) explains that 'adoption of more efficient irrigation technologies reduces valuable return flows and limits aquifer recharge'. As a result, 'policies aimed at reducing water applications can actually increase water depletions' (ibid). Nevertheless, key informants interviewed in Yemen within this research confirmed that increasing irrigation efficiency through modern irrigation is the 'safest' way for using water in irrigation.

Another issue to consider when introducing modern irrigation systems to achieve the expected water savings from installing modern irrigation systems and to improve the overall situation of water resources is that expansion of agricultural areas should be stopped and crops that consume less water should be introduced. The MAI (2010) mentions that it is vital to raise awareness among farmers regarding the need for water savings in areas of cropping intensity (vertical expansion), or to stop them from expanding their agricultural land (horizontal expansion). Reduction in planted areas and compensation by introducing higher productivity and crops that demand less water is an important approach that can be promoted by extension agents among beneficiaries in order to sustain the maximum water savings being achieved.

Dams

The sustainability scenario assumes that within the governmental direction to augment water resources, the government will support greater construction of dams in the country. Therefore, the pace of constructing dams will increase and the water provided by dams will climb from 5.5 MCM in 2009 to 6.9 MCM annually starting from 2014. Including the cumulative, dams will contribute 248 MCM by 2025, as shown in Table 25.

These results support the potential of using surface water that is still unharnessed. According to MWE (2005), Yemen receives an annual average of 50 to 60 billion cubic metres of rainfall. Nevertheless, the nature of rain bursts, most of which occur during the summer, cause most rain water to be retained in the upper or surface soil layers to be used directly by vegetation, or to evaporate thereafter; hence, it is practically impossible for runoff water to exceed 10% of rainfall water on average (3–6 billion cubic metres). To maximize the harnessing of surface water, the MWE (2005) mentions that the construction of big dams is needed.

Considering the abovementioned fact and considering that existing dams in Yemen retain about 138 MCM as mentioned by the MAI (2012), water augmentation through dams still has great potential. The assumed savings and projected results under this scenario support this direction through achievable increase in the construction of dams.

In discussing the potential of dam construction in augmenting water resources in Yemen, it warrants mention that dams alone are not sufficient to solve the problem of water shortage in Yemen. The MWE (2005) states that focusing on increasing quantities of available water without implementing demand management and conservation measures is not a sustainable policy in the long run. It explains that existing dams have not arrested the continuously declining levels of groundwater or recovered the depleting aquifers in many basins. This shows that the policy of supply management alone cannot meet the growing demand in the medium and long term; it cannot constitute a sole and sufficient solution. Hence, a policy regarding dams should be accompanied by measures and actions to control and rationalize water demand.

Reusing Treated Wastewater

Driven by the need and the strategic policy to use each possible water resource, and considering the increased amount of generated wastewater, this scenario assumes that the government will further support the reuse of wastewater. This will be through establishing more wastewater treatment plants to raise the total amount of reused wastewater by 4% annually with a quality that complies with applied standards. Through this level of treatment, 168 MCM of treated wastewater will be reused by 2025 compared to 14 MCM in 2010, as shown in Table 25.

The projected increase in generated wastewater showed that there is potential for reusing wastewater in Yemen. Given that only 14 MCM of wastewater was used in 2010 and that the

collected wastewater in the major cities, where population is increasing rapidly, was 136 MCM in 2009 (FAO, 2013), the wastewater potential is far from being fully tapped.

This research projected that the amount of generated wastewater will reach 351 MCM by 2025 (Table 25) compared to 74 MCM in 2000 (FAO, 2008). Nevertheless, the results assume that the reuse of wastewater will occur only in the major cities. This is because treatment plants are concentrated in the capitals of the governorates and in some secondary cities (FAO, 2009b).

In urban areas, while the collected amount of wastewater was 136 MCM in 2009 (FAO, 2013), the results show an increase in this amount to reach 679 MCM in 2025. Nevertheless, the research assumes that the reused wastewater will increase annually by only 4%. For example, out of the 679 MCM of wastewater collected in 2025, the research projects that reused wastewater will amount to a mere 168 MCM.

This scenario projects that the annual increase of wastewater reuse is 4% of the wastewater generated in urban areas. This increase in the reuse was selected purposely as it equals the projected amount of wastewater to be generated annually in urban areas. This means that treatment plants should be constructed to accommodate that annual increase of 4%, which should also be reused in totality.

Compared to the total amount of generated wastewater, the limited amount of reused treated wastewater projected by the research reflects the limited number of wastewater treatment plants. According to Hübschen (2011), there are currently 17 wastewater treatment plants distributed across the main cities and towns of Yemen. The ACWUA (2010) states that almost all treatment plants are heavily overloaded resulting in limited effluent quality. Therefore, the construction of new treatment plants is inevitable to accommodate the increasing amount of wastewater that will be generated in urban areas. Construction of new plants or extension of existing plants is necessary to enable strict control of the quality of the treated wastewater to meet national standards.

Qat replacement

Under the Sustainability scenario, it is assumed that policies limiting the consumption of qat will be adopted. These policies will be accompanied by programmes of agricultural extension and support for farmers to replace qat with other crops that consume less water. Awareness campaigns similar to those used against drugs or smoking will also be initiated by the government to motivate continuous reduction of qat consumption. These policies will be effective starting from 2014. As a result, farmers will start shifting from qat agriculture to crops that consume less water with comparable economic returns.

The Sustainability scenario assumes that 3.6% of the 162,584 hectare planted with qat in 2011 (MAI, 2010) will be replaced annually. Qat will be replaced by fruits and vegetables. The crop replacing qat will be selected depending on local conditions and economic returns. As a result, water savings will rise annually to reach 206 MCM in 2025.

The results show that the potential of replacing qat agriculture with other crops that consume less water will result in considerable water savings. Results show that this alternative, which has not been tapped yet in Yemen, will gradually and increasingly achieve water savings starting from 2014.

Assuming that the government passes a legislation to phase out qat by 2035 (as a draft law to the parliament suggested in 2013), it means that other crops should replace half of the area used for qat agriculture by 2025.

The achieved results agree with the current agricultural production trends at the governorate level. For example, the scenario assumes that in the Sana'a governorate, qat will be replaced with grape, the most cultivated crop in this governorate. MAI (2011) reports that the production of grapes in the Sana'a governorate was 113,290 tonnes cultivated on 10,421 hectare in 2011. In the same way, it is assumed that qat agricultural areas in other governorates will be replaced gradually, mainly by crops that are mostly cultivated in these governorates. This will ensure that selected qat alternatives will be environmentally and economically acceptable by farmers as strong competitors for qat as these alternatives are already widely cultivated in these governorates as shown in Chapter 2, Table 9.

The results of qat replacement extend the success achieved by existing initiatives to replace qat by local initiatives. As mentioned in Chapter 1, local campaigns for replacing qat with other crops by support from the private sector have already proved their success. In the Ibb governorate, 3,800 acres (about 1537 ha) of qat were replaced by 2,500 mango trees. In 2006, a major initiative was launched in the Haraz region which still continues to assist an unprecedented number of farmers to replace qat with coffee. This initiative resulted in the removal of 250,000 qat plants in Eastern Haraz. The region is likely to be free from qat by 2020.

The success of these local initiatives and the positive response from farmers to these initiatives support the assumption made under this scenario. These initiatives can be scaled out with governmental support and following a strategy with quantitative targets as assumed under this scenario. This will ensure that the assumption of replacing an area of about 5,887 ha annually will result in achieving water savings as the results of this scenario projected.

Continuing the current decentralization programme will play a key role in achieving expected water savings through governmental programmes to support qat replacement at the local level. The governmental outreach to support farmers will be facilitated by decentralized local organizations such as branches of the NWRA, Irrigation Advisory Service and WUAs whose establishment and capacities will continue to be enhanced during the scenario period.

Other governmental measures assumed to reduce demand for qat are expected to play a main role in supporting the replacement of qat agriculture. However, the parliament failed in December 2012 to adopt a legislation to phase out qat agriculture in Yemen until 2035. Under

this scenario and driven by concerns over the negative environmental, social and health impacts of qat, it is assumed that the government will adopt several legislations that limit qat consumption and agriculture. Such legislations include allowing qat import from other countries. According to a former top decision-maker in the MWE, who was interviewed during the implementation of the research, due to the high economic returns from qat, allowing qat import could lead to decreasing qat prices in the Yemeni market and, consequently, result in farmers shifting to other agriculture with comparable or more economic returns. This legislation will be adopted within more comprehensive legislation that aims to phase out qat agriculture in Yemen.

It is also assumed that the government will initiate a massive awareness campaign about the negative impacts of qat consumption. Such campaigns, according to a national water expert interviewed during the research, should be similar to national campaigns against smoking or drugs in order for them to provide the expected results.

7.3.3 Water Balance

With rapidly increasing demand for water by consuming sectors, demand is projected to reach 4,543 MCM by 2025. Under the Sustainability scenario, it is assumed that the BAU scenario will continue until the end of 2013. Projections of water savings show that starting in 2014, technical interventions will contribute 49 MCM annually. As a result, the deficit will decrease from 1,100 MCM in 2013 to reach 614 MCM in 2025, as shown in Figure 19.

Results show that the water balance under the Sustainability scenario will be impacted positively. The results obtained under this scenario show considerable increase in the contribution by technical interventions in saving and augmenting water resources which will contribute 49 MCM water annually. For the first time, water savings from technical interventions will be sufficient to meet the annual increase in water demand starting from 2014. Thus, the water balance will be impacted positively under this scenario and will show a gradual decrease of the deficit. Projections show that the deficit will steadily decrease from 1,100 MCM in 2013 to reach 614 MCM in 2025.

A comparison of the obtained results to the results obtained by Redecker (2007) shows that such a decrease of water deficit is achievable. In the scenario, 'Dynamic Action Scenario 2', Redecker (2007) projects that the water deficit will decrease to about 725 MCM by 2020, which is less than the 933 MCM of the water deficit projected under this scenario.

Comparing Redecker's scenario to the Sustainability scenario reveals that the water balance under Redecker's scenario is mainly the result of a lower agricultural demand that he projects will decrease to about 2600 MCM in 2020. The agricultural demand expected under this research is projected to increase steadily to 3570 MCM by 2020. However, under the Sustainability scenario in this research, the projected increase in irrigation efficiency that results from using modern irrigation systems will save 383 MCM by 2020. This means that the agricultural demand will amount to 3,187 MCM, which is still higher than the demand

projected under Redecker's scenario. Nevertheless, as the agriculture sector consumes the largest share of water resources in Yemen, irrigation water demand is a main factor influencing total demand and projected results regarding the future water balance. Thus, the difference between agricultural demand projected under Redecker's scenario, which is 930 MCM less than that projected under this research is the main factor causing the decrease of water deficit and explains that lower amount of water deficit projected by Redecker's 'Dynamic Action Scenario 2', compared to the Sustainability scenario produced under this research.

In his 'Dynamic Action Scenario 2', Redecker (2007) projects additional renewable water resources to be tapped at a rate of 0.5% per year from water harvesting, desalination and effluent reuse. Knowing that the current annual renewable water resources in Yemen is estimated at 2,500 MCM, which is also the amount of water used in Redecker's scenario, he projects about 12.5 MCM of additional renewable water resources that will be tapped annually to support available water; this will help to bring down the water deficit to the abovementioned level of 725 MCM by 2020. Under the Sustainability scenario, however, the projected annual water savings by different interventions will average about 51 MCM annually at a rate of 1.6 %.

In summary, the 'Dynamic Action Scenario 2' developed by Redecker (2007) projects decreasing agricultural demand compared to 2006 levels, with modest additional water resources tapped (only 0.5 % annually). Whereas the Sustainability scenario developed in this research projects a slight annual increase in agricultural demand for water compared to 2009 levels, considerable amounts of water savings are projected to be achieved at a yearly average of 1.6 %.

Nevertheless, the 'Dynamic Action Scenario 2' developed by Redecker and the Sustainability scenario developed in this research, both support the idea that long-term sustainability for Yemen's water resources cannot be achieved by focusing only on increasing the quantities of available water, but also by considering demand management and conservation as the MWE (2005) suggests.

It should also be mentioned that the reversed trend of water deficit under the Sustainability scenario does not mean that water mining will stop completely. The projected remaining water deficit will be compensated from the groundwater aquifer. Moreover, the projected decrease in water deficit may not continue in the long run against the increasing demand for water that is driven mainly by drastic population growth. Thus, long-term scenarios for strategic planning of water resources use and augmentation should be prepared regularly to guide interventions in the water resources sector and to balance available water resources with demand.

Under the Sustainability scenario, it is projected that the annual per capita share of water will not decrease as projected in other scenarios. It will decrease from 108 in 2010 to 95 cubic metres (compared to 79 m³ under the Business as Usual scenario and 71³ under the Do Nothing scenario. Despite the projected decreased annual per capita share of water under this

scenario, it projects a greater annual per capita share of water compared to the other projections—e.g. the projected decrease to 54 cubic metres by 2025 as reported by GSCP (2010) or the projected annual per capita share of water of 66m³ as reported by Atroosh (2007). Although methods and assumptions used in projecting these values are not published, the higher value of projected annual per capita share of water may be attributed to the increased availability of water that will result from water savings by different technical alternatives to support water resources.

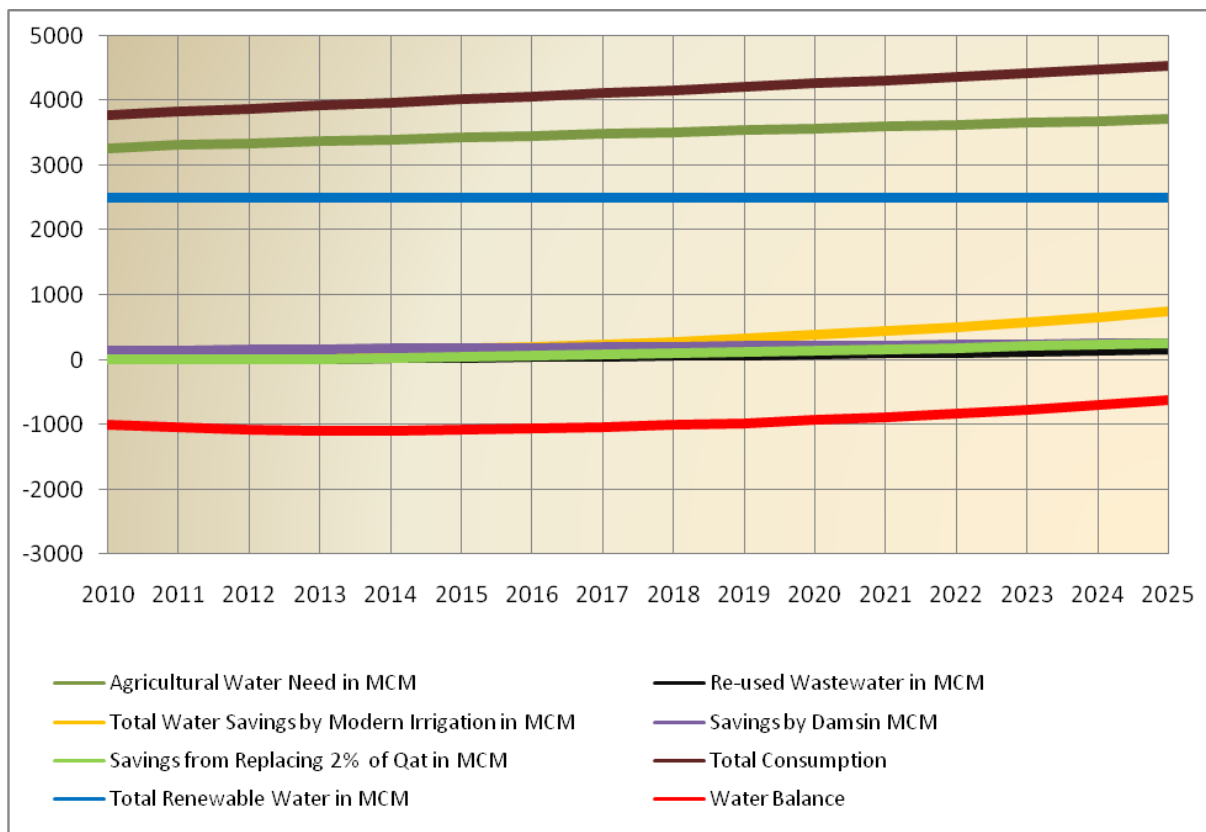


Figure 19: Projected water balance under the Sustainability scenario
Source: the Author

Table 25: Projected water demand, savings, augmentation and balance under the Sustainability scenario

Year	Industrial Water Need (in MCM)	Agricultural Water Need (in MCM)	Domestic Water Consumption (in MCM)	Reused Wastewater (in MCM)	Conveyance Systems Savings (in MCM) Including Savings of Year 2009	On-farm Systems Savings with 1500 ha increased implementation since 2014 (Including Savings of Year 2009)	Total Water Savings by Modern Irrigation (in MCM)	Savings by Dams (in MCM)	Savings from Replacing 3.6 % of Qat Area Annually (in MCM)	Total Consumption (in MCM)	Total Renewable Water (in MCM)	Water Balance (in MCM)
2010	90	3261	419	14	96	13	110	144	0	3770	2500	-1003
2011	88	3309	430	16	105	14	120	149	0	3827	2500	-1043
2012	93	3338	441	17	114	15	130	155	0	3872	2500	-1071
2013	98	3367	453	18	123	16	140	160	0	3918	2500	-1100
2014	104	3396	465	26	132	23	155	173	17	3965	2500	-1094
2015	110	3425	478	35	141	35	177	179	34	4012	2500	-1087
2016	116	3454	491	44	150	55	205	186	52	4061	2500	-1074
2017	122	3483	505	54	160	80	240	193	69	4110	2500	-1055
2018	129	3512	519	64	169	113	281	200	86	4160	2500	-1029
2019	136	3541	534	76	178	151	329	207	103	4212	2500	-997
2020	144	3570	550	88	187	196	383	214	120	4264	2500	-958
2021	152	3600	566	102	196	248	443	221	137	4317	2500	-914
2022	160	3629	583	117	205	305	510	228	155	4372	2500	-863
2023	169	3658	601	133	214	370	583	235	172	4428	2500	-805
2024	178	3687	620	150	223	440	663	242	189	4485	2500	-741
2025	188	3716	639	168	232	517	749	248	206	4543	2500	-671

Source: the Author

7.4 The Conclusion

The chapter provided the results of assessing the water policies mentioned in ‘Yemen’s Strategic Vision 2025’. The developed future scenarios reveal potential futures of the water balance. These scenarios formed, at the same time, the result of two key stages of the SEA process—namely, ‘impact prediction and assessment’ and ‘alternatives comparison’.

While the water deficit is projected to keep increasing under the Business as Usual and Do Nothing scenarios, a projected decrease of the water deficit may be obtained under the Sustainability scenario if the implementation of alternatives to support water resources is scaled out.

The discussion of the developed scenarios sheds light on several aspects pertaining to those scenarios. Comparing the scenarios developed under this research with other scenarios published showed similarities and differences. It also showed remarkable contributions. The most noticeable contribution is that the scenarios resulting under this research were developed by quantitatively projecting and combining the potential contribution of the four main alternatives implemented by the government to decrease the water deficit. In addition, these scenarios have shown qualitatively and quantitatively how to maximize the positive impacts of these alternatives on the water balance. This has paved the way for identifying quantitative and qualitative strategic targets that should be adopted to achieve significant reduction in the water deficit as presented in the following chapter.

8. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions drawn from the research findings. These conclusions are presented as answers to questions raised at the outset of this research. These conclusions help to reaffirm the contribution of this research towards solving the research problem and to the body of knowledge. Thereafter, identified strategic targets are presented. These targets are based on projections obtained under the Sustainability scenario that shows how to achieve significant reduction of the water deficit. The chapter then provides implications on policy and recommendations that support the achievement of the main goal aimed for in this research, which is the sustainability of water resources. Finally, constraints that were met during the implementation of this research are presented before concluding with proposals for further directions of future researches.

8.1 Conclusions

This research deals with two main issues. First, it offers a strategic assessment of water policy alternatives adopted by ‘Yemen’s Strategic Vision 2025’ of 2002 which are implemented through sectoral strategies and plans. Secondly, by applying key stages and methods of SEA, the research provides evidence of the potential of SEA in assessing policies already adopted in the water resources sector in Yemen.

Despite the adoption of ‘Yemen’s Strategic Vision 2025’ in 2002 and despite the availability of strategies and plans that serve the implementation of the alternatives mentioned in ‘Yemen’s Strategic Vision 2025’, the deterioration of these resources continues rapidly. The situation raised several crucial questions about the ability of and extent to which currently adopted alternatives support re-gaining sustainability of water resources by 2025 and the potential future of water resources balance that Yemen may face. The deterioration of water resources, which has been taking place despite the adoption of IWRM, raises a fundamental question about the need for a complementary tool at the strategic level that can be used to assess alternatives adopted by water resources policies and assist planning for sustainable water resources.

In answering the aforementioned questions, this research used SEA as a systematic process for assessing the environmental consequences of proposed or existing policies, plans or programmes, hence the main hypothesis was that ‘Using the Strategic Environmental Assessment (SEA) process and methodologies to assess currently applied water policies has the potential to support planning for integrated and sustainable water resources in Yemen’.

In order to demonstrate the potential of SEA in the water resources sector in Yemen, key SEA stages have been implemented in this research to answer questions raised at the outset. In a process that is analogous to SEA, the research has included the following steps: baseline data collection, stakeholder consultation, impacts assessment and prediction, assessment of alternatives and proposing mitigation measures.

Before drawing conclusions about the main hypothesis, the following section presents the research questions and conclusions on the research findings in answering these questions. These conclusions, at the same time, will pave the way for drawing conclusions about the potential of SEA in the water resources sector in Yemen.

Do the alternatives adopted by ‘Yemen’s Strategic Vision 2025’ have the potential to contribute significantly to achieving water resources sustainability?

The results of the statistical analysis under the Sustainability scenario showed that these alternatives adopted by ‘Yemen’s Strategic Vision 2025’ still have significant potential to support water resources, although this potential may vary. The results revealed that implementing alternatives in the irrigation sector holds the highest potential for achieving water savings. Following the implementation rates assumed under the Sustainability scenario has revealed that the highest potential for supporting water resources until 2025 comes respectively from a) increasing irrigation efficiency by installing modern irrigation systems, and b) augmenting water resources from dams.

Other alternatives adopted by ‘Yemen’s Strategic Vision 2025’—viz. replacing qat agriculture with crops that consume less water and reusing wastewater—are shown to have significant potential for considerably supporting water resources. Nevertheless, results of the Sustainability scenario show that the potential of these alternatives, which is not fully tapped yet, is less than the potential presented by the alternatives of using modern irrigation systems and dams.

Therefore, ‘Yemen’s Strategic Vision 2025’ identified and adopted alternatives that still present great potential for supporting sustainable water resources in Yemen, though with varying potential.

This question was answered in the ‘impact assessment’ stage of the SEA. This stage included the statistical analyses of data on the current status of ‘conventional and non-conventional’ water resources and the status of implementing each alternative with the resulting water savings or augmentation. Quantitative analyses of these data and projections of the potential of each alternative on the ‘impact prediction’ of water balance under the Sustainability scenario showed that these alternatives still have significant potential to support water resources.

What has been the impact of the currently adopted policies from ‘Yemen’s Strategic Vision 2025’ on the water balance?

As part of the SEA process, the answer to this question was provided in the ‘impact assessment’ stage, which included statistical analyses of data on the current status of ‘conventional and non-conventional’ water resources and the status of implementing each alternative with the resulting water savings or augmentation. Findings revealed that the current interventions have positive impact, but it is not enough to meet the water demand or even the annual increase in the demand. This situation has resulted in a continuous increase of water deficit.

What are the potential futures of water balance and the underlying condition producing them until 2025 following these alternatives?

The potential futures of water balance until 2025 and the condition underlying these futures were developed in the ‘alternatives comparison’ stage, which is a key stage in the SEA process. This comparison resulted in the development of three potential future scenarios—the Business as Usual, Do Nothing and Sustainability scenarios.

The Business as Usual scenario projected the potential future of current qualitative and quantitative factors including the implementation rate of technical alternatives continuing into the future until 2025. This scenario showed that if Yemen continues with its current implementation rate of technical alternatives, the imbalance between demand and availability will lead to a greater increase in the water deficit. The scenario also showed that these alternatives are not implemented up to the levels that achieve water savings and water augmentation, which, in turn, can influence water balance and reverse the current trend of water deficit.

The Do Nothing scenario presented a more gloomy future for the water balance compared to the other scenarios. This potential future is the result of including all negative qualitative and quantitative variables that will shape the future of water resources and balance. The scenario was developed to identify clearly what should be prevented in the period until 2025. It showed rapid decrease of political and financial support. Accordingly, the decrease in the implementation of alternatives to support water resources starting from 2014 will result in a stark increase in water deficit.

The Sustainability scenario reflected an ‘optimistic’ future compared to the other scenarios. It aims at ‘mitigating’ the existing adverse impacts on water resources. In policies that are developed to achieve a positive impact on natural resources, a main contribution of SEA is to maximize the potential impact on the resources. Thus, this scenario was developed by including positive qualitative and quantitative variables. The scenario was developed assuming increased support for the water resources sector and increased implementation of alternatives to support water resources starting from 2014. The assumed increased in the implementation rate under this scenario is based on the input obtained during the ‘stakeholders consultation’ stage. The input of stakeholders determined the possible maximum implementation rate of each alternative based on the existing capacities of the sectors implementing these alternatives. This scenario showed that despite the continuously decreasing water resources, there is still a chance to reverse the currently increasing trend of water deficit before 2025. The achievable significant reduction in the water deficit as assumed under this scenario is a major step towards regaining sustainability of water resources.

The findings of the qualitative analysis under the Sustainability scenario revealed that none of the alternatives adopted by ‘Yemen’s Strategic Vision 2025’ result in reversing the increasing trend of water deficit if implemented alone. The findings show that only parallel

implementation of all alternatives adopted by ‘Yemen’s Strategic Vision 2025’ can result in significant reduction and reverse the current increasing trend of water deficit.

Is sustainability still achievable until 2025 using these alternatives? What are the strategic targets that should be adopted to achieve sustainability?

The results of the ‘alternatives comparison’ stage that are based on the quantitative projection of demand and water availability under the three scenarios developed in the research, showed that re-gaining water resources sustainability by reaching a point of balancing water availability with annual demand will not be achievable by 2025. Nevertheless, the Sustainability scenario revealed that the current trend of increasing water deficit can be reversed and the deficit can be significantly decreased by 2025.

Based on the results of the qualitative and quantitative assessment of the current status and future potential of the alternatives adopted by ‘Yemen’s Strategic Vision 2025’ for supporting water resources, the following strategic targets were identified:

- To achieve an annual quantity of water savings and augmentation of 51 MCM on average throughout the period 2014–2025. This target can be achieved by scaling out the implementation of the following alternatives according to the following rates:
 - Installing 1,500 ha of on-farm modern irrigation systems and 6,098 ha of modern conveyance systems annually.
 - Constructing dams that augment 7 MCM annually.
 - Increasing the reuse of treated urban wastewater by 4% annually.
 - Replacing 3.6% of qat annually by crops that consume less water as clarified in Table 9, Chapter 2.
- To accelerate the decentralization of water resources planning and management by establishing and empowering NWRA branches in the remaining governorates and completing the establishment of water basin committees.
- To support greater involvement of the local communities in managing water resources through establishing and empowering WUAs.
- To secure greater political commitment as a pre-condition for obtaining the resources and support required to achieve the aforementioned strategic targets.

The hypothesis posed at the beginning of this research was that ‘Using the Strategic Environmental Assessment (SEA) process and methodologies to assess currently applied water policies has the potential to support planning for integrated and sustainable water resources in Yemen’. In investigating this hypothesis, the research adopted scenario planning as a main method for implementing key stages of the SEA process—namely, impact prediction and alternatives comparison. In addition, the research carried out key SEA stages

of baseline data collection and stakeholders' consultation. The methodologies and findings of this research confirmed the hypothesis that using SEA has provided:

- Systematic process with pre-defined stages for the assessment of existing policies, which, in this research, are the policies for supporting water resources adopted by the 'Yemen's Strategic Vision 2025';
- Methodologies that enabled successful assessment through key stages that were carried out such as stakeholders' participation, impact assessment of existing policies and comparison of alternatives for the future implementation of adopted policies;
- Resulted in identifying strategic qualitative and quantitative targets required for maximizing the positive impact of 'Yemen's Strategic Vision 2025' and mitigating the existing negative impacts on water balance resulting from the high demand for water and the low implementation of alternatives to save and augment water resources;
- Integrated planning for water resources by considering a) existing policies, plans and programmes in sectors involved in realizing the 'Yemen's Strategic Vision 2025', b) water demand and supply alternatives that might support water resources, and c) surface water and groundwater;
- Support strategic planning to achieve sustainability of water resources by a) evaluating the existing situation, and b) setting qualitative and quantitative targets that can reverse the increasing trend of water deficit as a main step towards achieving the sustainability of water resources.

It is also important to provide conclusions on the strengths, weaknesses, opportunities and threats for adapting and applying SEA in the water sector in Yemen. These conclusions have been drawn based on the investigation, findings and experiences gained during this research.

Strengths

- SEA functions at the strategic level (unlike the existing IWRM) and offers methodologies for assessing existing or new strategic initiatives.
- SEA systematically provides opportunities for the participation of stakeholders in the water resources sector which will support participatory and efficient planning for sustainability by these stakeholders, particularly the MWE and the MAI, each of which controls the development of part of the country's water resources.
- Methodologies used under SEA helps to identify and to deal with uncertainty inherited during strategic planning, as demonstrated in this research.

Weaknesses

- Updated data on the water resources situation and on the status of implementing each alternative countrywide is required to enable reliable assessment of alternatives and projection of future impacts.

- Resources—e.g. time, experts and cost—required for implementing the SEA.
- The ability of SEA to influence decision-making.

Opportunities

- SEA is strongly supported by donor institutions as a means for enhancing good governance and strengthening capacities for achieving sustainability.
- Highly critical situation of water resources in Yemen calls for adapting tools to support sustainable strategic planning.
- Increasing awareness among decision-makers about environmental threats and the importance of adopting environmental assessment and planning tools to face future challenges.

Threats

- Lack of explicit legal requirement for the application of SEA.
- Lack of political acceptance and the common belief that SEA is a tool used only for including ‘less important’ environmental aspects in water policies or plans.
- Limited number of SEA conducted in the water sector, and mostly for donor-funded programmes.

8.2 Policy Implication

The research findings show that the share of the domestic sector will increase rapidly throughout the period from 2014–2025 as an inevitable result of the rapid population increase projected until 2025. The demand of the domestic sector will reach 14% of the total water demand by 2025. As meeting the demand of this sector is the first priority according to Water Law nr. 33 of 2002, water resources should be identified and allocated for domestic use. In highly populated urban areas that already witness a shortage in water resources, complementary or alternative resources should be identified.

Projections under the Sustainability scenario until 2025 show that the potential for achieving water savings in the irrigation sector is far higher than in any other sector. These savings can be achieved by increasing irrigation efficiency or using crops that consume less water as alternatives for qat. Therefore, this sector should be prioritized when planning and allocating support for interventions to save water resources.

To ensure sustainability of alternatives that support water resources and to maximize the qualitative and quantitative outputs of these alternatives, it is also important to ascertain the following aspects:

Modern Irrigation Systems

- In supporting the installation of modern irrigation systems, no extension of agricultural lands covered by modern irrigation systems should be allowed.

- The introduction of modern irrigation systems should be accompanied by installation and maintenance services to ensure the sustainability of these systems.

Dams

- The construction of dams and site selection should be based only on studies that determine the feasibility, necessity and impacts of each dam. Technical studies, feasibility and EIA studies are crucial in this regard and for identifying potential negative impacts on the environment or on local communities that may result from these dams.
- Suitable alternatives should be considered in proposals for dam construction in low lands (areas of hot climate) as high evaporation of dam water may cause considerable water losses.
- Ensuring the sustainability of dams by providing complementary structures and regular maintenance. A dam should be constructed completely to ensure efficient function. For example, if a dam is built for irrigation purposes, it should be equipped with irrigation networks. Regular maintenance of dams is required to avoid problems that may limit dams' function and capacity—e.g. as a result of siltation.

Wastewater Treatment

- In addition to increasing the reuse of wastewater by constructing new plants or extending existing ones, the quality of wastewater should be improved as per national quality standards (Annex 10). These standards should be applied before allowing the reuse of treated wastewater to prevent potential negative, environmental or health impacts.

Qat

- Alternative crops for qat should be promoted in each governorate based on criteria that include, in addition to the water needs of the crop, the following: agro-climatic suitability, economic returns and strategic importance of the crop to achieve food security.
- The government should facilitate the shift from qat agriculture to crops that consume less water by implementing two parallel strategies. The first strategy should help to reduce demand for qat while the second strategy should support qat agriculture alternatives. In order to discourage qat demand, policies and measures similar to those used against smoking and drugs can be followed. This would include disincentives for qat agriculture, such as by raising taxes. To promote qat alternative agriculture, policies may endorse subsidizing the provision of seedlings of crops replacing qat and improve farmers' access to markets in which they can sell their agricultural produce.

8.3 Recommendations

- SEA should be adopted as a tool for systematic and participatory assessment of existing or new strategic initiatives in the water resources sector.
- Assigning quantitative targets of water savings and augmentations to existing and future water resources strategies and plans is recommended. This initiative will facilitate monitoring progress and evaluation of the outputs of strategies and plans.
- Considering Yemen's current severe water crisis and the looming uncertainty about water availability, it is recommended that the MWE at the national level and its branches at the basin level regularly conduct assessments of water resources policies, strategies and plans. Such assessments should cover outputs of technical interventions implemented by different agencies to support water resources. These assessments should also include scenarios for future water needs, availability and water deficit. Implementing such assessments on a regular basis will help to evaluate the overall situation of water resources, comprehensive assessment of policies, strategies, plans and interventions adopted by all ministries or agencies concerned. This will also provide a chance for amending these policies and strategies, if required, to achieve sustainability of water resources.
- Planning for and the monitoring and assessment of water resources require an updated database. Data on water resources and water availability, water use by consuming sectors and water savings and augmentation should be updated and reported to a unified databank to facilitate the use of such data and information by sector agencies, stakeholders and other interested parties.

8.4 Research Limitation

One issue faced during this research and which is also reported by other researchers and experts in the water resources sector is the lack of updated data in the water resources sector. Data, particularly on water availability, are not updated regularly. Reliable records and reports used by water sector experts for producing new studies and reports may date back to 1990s.

8.5 Future Research

Scaling out alternatives for supporting water resources requires the availability of sufficient understanding of the local context in which these alternatives are to be implemented. To facilitate the replacement of qat agriculture, investigations are required to identify the most appropriate alternatives for qat in each agro-climatic area. The identification of alternative crops should not only be based on water needs but also on other criteria such as economic returns and strategic importance of these crops to Yemen. These criteria will ensure that the identified alternative crops are well-received and adopted by farmers while also contributing to the country's food security.

8.6 Future Outlook

The research, through assessment of the water policies in ‘Yemen’s Strategic Vision 2025’ and its subsequent water resources policies and strategies, has laid bare several critical challenges and opportunities pertaining to the future of water resources. These foreseen challenges and opportunities provide a fresh perspective on sustainable strategic water resources planning. That strategic planning for water resources in Yemen is riddled with uncertainties and that the impact of the water resources policies and strategies can be felt only in the long run should not come in the way of consistent long-term water resources planning. In fact, regular strategic assessment and iterative planning processes at the national, local and basin levels are even more important in case of persistent uncertainty.

This research emphasizes that the potential for positive change in the strategic planning of water resources through the introduction of SEA is enormous; hence, SEA adoption should not be delayed. As demonstrated in this research, SEA as a tool is conducive to informed decision-making and planning for sustainability, mainly by assessing the environmental aspects of policies, strategies and plans. Like the process that resulted in the adoption of project-level EIA in Yemen, SEA is likely to be legally adopted owing to the lack of tools for environmental assessment at the strategic level. Nevertheless, the earlier that SEA is adopted in the water resources sector, the faster assessing and planning at the strategic level can become systematic, participatory and adaptive.

To see the bigger picture, strategic assessment and planning is only one critical success factor for achieving the sustainability of water resources among other factors that support avoiding the approaching catastrophe of water depletion. Policies and strategies will remain paralyzed if they are not turned into realities. To that end, complete political commitment and support is the cornerstone for facing the current challenge of dealing with rapidly depleting water resources and re-gaining sustainability of water resources. The current alarmingly rapid depletion of water resources necessitates raising the issue of water resources depletion to be a top national priority like unemployment and poverty reduction. Otherwise, the imminent threat of an unprecedented water shortage will trigger a national disaster, impinging on the sustainability of the national economy mainly by impeding agricultural activities, which thrive on water. While careful strategic planning and consistent action on the environmental, socio-economic and institutional fronts to eliminate water deficit look very challenging now, they could save unimaginable future resources that would be needed to act on the same fronts in order to mitigate the catastrophic consequences of a dry Yemen.

Annexes

Annex 1:
Yemen's Strategic Vision 2025

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Introduction

Within the context of preparing the Second Five-Year Plan for Economic and Social Development (2001–2005), and on the basis of assessing the current situation of the national economy and the course of development during the last decade, a serious and careful pause was inevitable. In such pause, it was deemed necessary to identify the challenges and difficulties facing the country, as well as the available and potential opportunities for the future. As a result, a conviction materialized that continuing the process of preparing typical plans would no longer succeed in breaking the noose and surpassing the challenges. Moreover, the need was evident for adopting new approaches based on the following three necessities:

- Long term policies to deal with challenges that require long time horizons, and which should be continuously subjected to revisions and correction through medium term plans.
- Comprehensive policies that mobilize all the wherewithal of the society and the economy to overcome the obstacles and difficulties.
- Combining typical and innovative policies while stressing on the characteristics of the society and the economy.

Adopting such approaches requires that Yemen possess a long-term strategic vision that reflects its ambitions and spells out the goals that the society aspires for, economically, socially, educationally, culturally and politically. The vision would also lay out the country's development course, in addition to enabling Yemen to participate effectively and equitably in the international economy, in accordance with suitable and concordant strategies and policies. Accordingly, and then, the strategic vision becomes the course for economic and social progress, which all the groups and associations of the society rally around, and the guideline for Government actions, notwithstanding the replacements and successions of the Governments and the differences in the duties and roles thereof.

The gravity of the major challenges, such as high population growth, poor human development indicators, depleting water resources, large expansion of Qat cultivation and the crop's social and economic impact, apart from the weakness of the public administration, should not thwart our commitments nor should it undermine our ambitions for achieving the desired development and for a decent livelihood. After having accomplished the unification of Yemen with democracy becoming firmly entrenched, there is still the struggle of building up a modern state, which is not less in importance to the accomplishment and maintenance of Yemeni unity. This requires a comprehensive vision that absorbs the broad ambitions and the challenges that were inherited from the past, with all their negative attributes, distortions and paradoxes, besides having to deal with all the variables, renditions and forms of the new and developing challenges.

1. Framework and Directions of Yemen's Strategic Vision 2025

Yemen's Strategic Vision 2025 stems from a multitude of considerations and justifications that reflect the economic, social, political and cultural situation and the challenges and obstacles that stand in the way of catapulting comprehensive development and enhancing the capacities and capabilities of the society. The Vision sets out the long-term ambitions and goals, which the society aspires for and keeps pace with developments and with the rapid economic, scientific and technological changes. It also covers all the sectors and groups that make up the society, the political organizations and the local communities as well as the economic, social, political and cultural aspects of life. The vision aims for the progress of the society as a whole and as individuals in all aspects and at all levels, in addition to ensuring consistency with the civilized and cultural heritage of the country.

Therefore, over the next twenty five years, Yemen's Vision aims –God willing– to improve the level of human development and to become among the countries with middle human development that reflects higher standards of living and decent lives for individuals and the society at large. Accomplishing this aim requires improving the demographic and health conditions, eliminating illiteracy, increasing school enrollment for basic education, especially among females, in addition to raising the per capita income. Raising income should be accompanied by the diversification of the sources of generating GDP, rather than continuing to rely almost completely on oil and gas production and exportation. This would require identifying the sources of growth and the promising sectors, and the creation of job opportunities and the achievement of a strong leap in exports.

Diversifying the economic base of Yemen, increasing production and exports and creating productive job opportunities necessitate turning the country towards the "new economy", stimulating the society to improve its productivity and its competitiveness in all fields and the development of a national system for creativity. Such a system transforms the individual from a job seeker to a generator of job opportunities and enables him to convert natural resources into commodities and services. Technology, in general and communications and information technology, in particular, will help to increase the ability to improve local products.

The achievement of economic progress can not be realized without being accompanied and dependent on the improvement of the social, scientific, cultural and political frameworks that collectively manifests the comprehensive development. Accordingly, the formulation of Yemen's Strategic Vision 2025 shall call for: ***the transformation of Yemen to the rank of countries with middle human development with a diversified economy and social, scientific, cultural and political progress.***

1.1 Directions of the Strategy to Reach the Ambitions and Aims of the Economic Vision

For Yemen to reach the rank of countries with middle human development requires that the per capita income be multiplied several times. This can be accomplished by means of stimulating economic growth to increase real GDP by an annual average of not less than 9% over the next quarter of the century, coupled with reducing the current high population growth. The need to achieve high economic growth becomes obvious also in order to confront unemployment by creating job opportunities for the growing labor force. The economy will need to start, in the first few years, to achieve at least an increase in per capita GDP by 2.5% per annum, considering the current population growth rate.

These ambitious growth rates will need simultaneous increase in domestic and foreign investments, as neither of them is indispensable in the forthcoming stage. The achievement of such growth will also still depend on improving productivity, the identification of the non-oil sectors that are capable of achieving high growth, focusing on comparative advantage, taking the correct development options and the proper management of resources.

1.1.1 Sources of Growth and Promising Sectors

1.1.1.1 Rejuvenation of the Coastal Regions

The limited natural resources, topped-off by the small cultivable area, and the scarcity of water in the populous habitats, with the continuing increase of the population –especially in the Central Highlands– highlights one of the primary constraints on economic and social development. The cities and regions extending along the Yemeni coastline of approximately 2,000 km, from the Town of Meidi in the North to the Town of Hawf (Al-Mahra) in the East are a strategic component and an essential element for coming out of this problem on one hand, and for the accomplishment of Yemen's economic and social goals in the next quarter of the century on the other. By developing those cities and regions we can arrive at a population and geographical balance that will alleviate the present urban concentration and migration to urban areas that has already burdened the available services and facilities.

1.1.1.2 Accelerating the Wheel of Industrialization

Industrialization and accelerating industrial development should be a strategic option and determinant of economic development in Yemen over the next period, in order to achieve the desired goals and to ensure moving from the status of a country of low income to the rank of middle income economies with rapid growth by 2025. The goals of the industrial sector focus on the need to broaden, improve and diversify the industrial base, to improve the quality of industrial products and to develop new pioneering industries that benefit from the country's comparative advantage in natural resources and labor and that open broad horizons for the improvement of income and employment.

The ability to "improve the product", by means of a national system for innovation

is considered essential for increasing value added, achieving economic diversification and creating new productive job opportunities, in addition to encouraging small and medium size industries. Similarly, the appropriate technology for Yemeni industry needs to be identified, and preparation of a strategy for transferring, adopting and producing what can be generated locally, especially in water desalination, fishing, preserving and marketing fish products, improving seed breeds, irrigation and using fertilizers (biotechnology). The acceleration of industrial development also requires Government support and backing for the establishment of industrial estates and furnishing them with facilities and services, providing land for the large industrial projects, which will help reduce the high production costs, and improving the capability and competitiveness of Yemeni industries.

1.1.1.3 Promotion of Extraction Industries

Yemen possesses a reasonable wealth of oil and gas estimated at 5.7 Billion barrels of proven oil reserves and around 14 trillion cubic feet of natural gas. Benefiting from these resources calls for expansion of excavation and exploration work to cover all of Yemen, including the marine areas, especially after the signing of the Yemeni – Saudi Border Agreement. This will enable the oil sector to play a major role in stimulating growth in the national economy.

It is also imperative to speed up the exploitation of natural gas locally and to primarily take advantage of its use in power generation. Shifting to power generated by natural gas reduces the cost of electricity, reinforces generated electric power and encourages setting up industries that require considerable power in their operations such as steel and aluminum smelting and petrochemical plants. In light of increased reserves of gas, an integrated and long-term plan needs to be drawn up for exporting gas to world markets, in addition to expanding utilization of liquefied natural gas (LNG) for household purposes (especially in the rural areas) and in workshops, farms and even in the large plants. Policies to develop the mining sector seek to stimulate local and private investment in excavation and exploitation. It is possible to develop the production of minerals, rocks and building materials and to exploit them for the production of cement, cement bricks, glass, paint, ceramic products and red bricks. This sector could also be a source of foreign currency earnings and can create many job opportunities, and contribute to the rejuvenation of rural areas, especially if plants are set up to increase value-added and produce new products relating to these activities, by means of transferring and adopting the appropriate technology.

1.1.1.4 Developing and Rationalizing Agriculture

The Future Vision for Agriculture should be built on the basis of a review of the functions and roles of this sector, given the factors that govern its activities and the orientation towards rationalizing the use of scarce water resources.

The agriculture sector uses between 90 – 93% of water resources with an irrigation efficiency that does not exceed 40%. Irrigated as well as rain-fed agriculture, in general, is characterized by low productivity, due to several reasons, of which the most significant is the widespread dispersion of

landholdings. The expansion of Qat cultivation and the dependence of the rural economy on the crop in those areas where it is cultivated constitute additional challenges that lead to the depletion of resources.

Regardless of the quality of the agricultural products, which face strong competition, a part of the surplus value comes from the low charge on water. The relatively high returns of irrigated crops leads to neglect of rain-fed agriculture and to increased competition for groundwater. This results in falling water tables, deterioration of water quality, retraction of production of basic agricultural products. Accelerated growth of the industrial and urban sectors leads also to the reallocation of waters in their favor, at the expense of neglecting large sections of rural areas and agricultural land. As a consequence, the options available are limited among pursuing groundwater to further depths, the transfer of water between basins, or else resorting to desalination of sea water at high costs, which will seriously affect the economic feasibility of population activities and the living and health conditions of the people, especially small farmers and those with low incomes. Thus, food security and water security become a national challenge that requires the exertion of focused and arduous efforts.

Therefore, a plan must be adopted for the development of agricultural production and for allowing some time for the economy and the society to start adapting to the new conditions. This plan should include redirecting agricultural production and turning to activities that generate non-farm income and supporting pro-women activities, whether in the rural or urban areas. This would require the expansion of water harvesting, improving traditional irrigation and introducing modern irrigation techniques to raise the efficiency of water use. Providing alternatives for the cultivation of Qat is paramount, in order to reduce water depletion while at the same time realizing economic returns. The cultivation of coffee, potatoes and other crops that are cost efficient and have export markets can represent those alternatives, in addition to the protected production of some vegetables.

Although there are some who would long for achieving an overall and general goal for the elimination of the Qat tree and to live in a Yemen which is free of Qat. However, a more realistic goal should be finding the balance between the development of the society on one hand, and controlling the spread of Qat and the reduction of its adverse effects, on the other. This can be achieved by adopting gradual measures in the demand and supply sides to contain the spread of Qat consumption and cultivation first, and then to gradually reduce Qat cultivated areas and the magnitude of consumption, by depending on the cooperation of all – individuals, groups and institutions.

1.1.1.5 Balanced Exploitation of Fisheries

The Fisheries sector is regarded as one of the most important among the promising economic sectors. There are large reserves of fish resources, thanks to the advantageous marine location, the long coastline, the territorial waters that extend on the Red Sea, the Arabian Sea and the Gulf of Aden, apart from the coastlines of the many islands in these waters. Due to the labor-intensive nature of traditional fishing activities and the availability of warm waters throughout the year, the establishment of modern culture farms for fish and marine life, which have a high

commercial value and for which there are lucrative markets in both Europe and the United States may be promoted. To accomplish this, attention should be given to research and studies in fisheries, to support existing centers and laboratories and establishing others in the various coastal areas of the country. Focus should also be given to modern technologies in culture breeding, fishing, refrigeration, storage, canning and marketing of fish products, in order to raise productivity and improve quality and competitiveness. Setting up "commercial incubators" in this field would lead to the development of this sector and in keeping with the international developments.

1.1.1.6 Exploiting the Potentials in Tourism

Yemen is considered among the countries that are rich in tourism resources and treasures, and which have yet to be exploited. This makes Yemen fit to become an important country in the region for tourism. The development of the tourism sector opens up wide prospects for alleviating unemployment, where the potentials for Yemen allow for the development of cultural, historical, environmental, aestivation, coastal and island tourism, in addition to mountain climbing and desert scouting. Therefore, over the next period, Yemen will witness the concomitance of the Government undertaking to complete some of the infrastructure projects with diligent activity towards setting up various private tourism projects, such as hotels, restaurant, tourism villages and complexes, diving centers and tourist transport projects. In the event that this promising sector is exploited, the number of tourists will rise from the 73,000 in 2000 to an estimated two million tourists in 2025 (by an annual growth rate that exceeds the world's average) and eventually revenues will rise up to an estimated \$ 2 – 3 billion.

1.1.1.7 Globalization and the Orientation towards Exports

It is impossible for Yemen to oppose or stand against the tumultuous winds of change, especially those of globalization. On the contrary, it would have to work, collectively, with the advanced and developing countries in order for globalization to accomplish growth, higher standards of living and new opportunities for all.

Globalization is associated with a world economy that is oriented towards information, the expansion of the role of science and technology in production and services to improve competitiveness and the export of manufactured products, rather than exporting raw materials, in order to increase the national wealth and job opportunities. This kind of economy is characterized by the growth of expenditures for acquiring information, in all its form, including research, development and transfer of technology such as information technology and communication, in addition to concern for intellectual property rights.

Given the limitations of the domestic market, the importance of trade and its link with economic growth becomes apparent, whereby trade becomes a source for growth and a method for enhancing productivity and adherence to professional values. The orientation towards exports must be a strategic option and a stimulus for the desired economic growth. The development of exports should become the number one issue that concerns the economy and all the groups within the society, not just an issue that concerns a particular sector. This would require people's appreciation and comprehension of variables become part of their behavior.

Yemen may be able to benefit from the agreements on free trade areas, and incite the movement towards free trade with the Gulf Cooperation Council and the East African countries. Those regions represent a natural market and an inlet for Yemeni manufactured exports to the heart of Africa, in addition to the States of the Indian Ocean. The flow of foreign investments into the country is also associated with globalization. States that achieve high growth rates obtain much of the FDIs while the share of the less fortunate states is minimal, including Yemen, where the share of foreign investments (excluding the oil companies) did not exceed 1% of the total licensed projects during 1992-2000. Therefore, and before inviting foreign investments, the Yemenis, themselves, should first be persuaded to invest in the country, by means of providing the required infrastructure and setting up the appropriate investment environment. An environment free from bureaucratic red tape, corruption and disputes over land ownership, along with ensuring clean, fair and quick litigation proceedings, and firm protection of rights including intellectual property rights. After that, there will be no need for government efforts to promote investments in the country, as Yemeni emigrants and Yemeni expatriates overseas, throughout the world, will be the first to rush towards pumping their capital funds, which are estimated to amount to \$ 20 – 30 billion, for investment in Yemen.

1.1.1.8 Exploiting the Geographic Location and Supporting the Role of the Free Zones

Free Zones represent one of the promising sectors for economic growth in Yemen, due to the strategic geographic location of Yemen. After the unification of Yemen, the Yemeni Government persisted in the development of the national economy, in linking it with the world economy and diversifying sources of income. Developing exports and making use of the comparative advantage, which the country enjoys, especially the strategic location of the Port of Aden are priority areas. Despite the fact that implementing the first phase of the project represented an essential and important step, in the course of attracting more investments, however, there is more that needs to be done to revive the role of the Port of Aden, especially in light of competition among the various free zones in the region. The relationships with other free zones, especially those in the neighboring countries must be strengthened, with a view towards seeking coordination and integration, so as to achieve prosperity and growth in the activities of all these zones, in particular with due consideration of the New World Order.

The geography and population of Yemen provides a suitable climate for investing in the establishment of various economic activities in the various regions. Government's policies, plans and programs encourage establishing other free zones (in Socotra, Al-Hodeidah and Al-Mukalla) in accordance with the promising investment opportunities in these zones. Yemen can become a regional and international center for trade, industry, investment, transit, storage and shipping activities. This would secure an increase in output, income and the creation of job opportunities for Yemeni labor. On the other hand, technology parks and incubators suitable for Yemen should be set up, especially for fisheries, agricultural and mining industries, especially after such mechanisms have become possible and inexpensive.

1.1.2 Requirements and Conditions for Economic Growth

1.1.2.1 Partnership Between Government and Private Sector

The achievement of the objectives of the Vision is very closely concomitant with the new roles for the Government and for the private sector. The strategy for future action is based on the role of the private sector as an engine of economic growth, which requires improving the efficiency of the resource utilization, reinforcing competitiveness and the participation and the empowerment of the local and foreign private sector to implement several projects, including infrastructure projects, by means of applying build, operate, transfer (BOT) and build, operate, own (BOO) systems..

The Government's role in undertaking infrastructure projects, improvement of financial intermediaries, maintaining low inflation, stabilizing the exchange rate, all of which are essential and necessary conditions for the economy and the society, and for attracting investments and for the growth and expansion of the private sector.

1.1.2.2 Modernizing the Public Administration

In order to ensure that the national economy performs its functions properly and effectively, and to create the conducive climate for attracting investments, it is imperative to overcome the difficulties that hinder the private sector and restrict its activities. Modernizing and restructuring the public administration and its various institutions, in a manner that will be useful for the new roles of the Government and which will reinforce its regulatory role is key. The roles and tasks of the government do not need more laws and regulations, but they do need work towards reviewing and improving the existing ones, in addition to simplifying procedures, freezing sources of corruption, putting an end to the neglect and inefficiency of employees. The gradual orientation towards an E-Government, by means of using information and communication technology would improve the performance in all Government agencies as well as facilitate dealings of citizens with them. There should also be progress towards delegating authorities to the administrative units in the Governorates and the districts – especially after the issuance of the Law of Local Authorities – which should be granted sufficient authority to enable them to manage the affairs of the local communities.

A just and honest judiciary is also considered a guarantee for achieving people's security and the country's well being. Therefore, a prerequisite to strengthening the investment climate and rejuvenating the economy would be ensuring protection of rights and property. To achieve this objective, the execution of the judicial reforms, which aim to improve the performance of the judiciary, to simplify litigation procedures, speed up the execution of court rulings by the law enforcement agencies and the recording procedures of the Real Estate Register.

1.1.2.3 Economic Growth and Alleviation of Poverty

The period of the First Five-Year Plan saw noticeable improvement in the performance of the national economy, which reflected positively in a number of economic indicators.

However, the growth realized during that period, estimated to average at about 5.5% per annum, was not enough to raise the standard of living, reduce unemployment and generate productive job opportunities, to the extent of ensuring long-term sustainable economic growth.

The comprehensive solution to such an enigma rests on pursuing the appropriate strategy designed to achieve sustainable economic development, with the provision of job opportunities, an equitable distribution of income, an increase of social expenditures (e.g. education and health), and prioritization and expansion of projects for poverty reduction. Yemen's Strategic Vision aims at halving food poverty by 2015, and its complete elimination, with the decline of relative poverty to 10% by 2025.

Since 1995, the Government, with the support of Yemen development partners, took the initiative of creating a Social Safety Net, to include the Social Welfare Fund, the Public Works Project, the Social Fund for Development, the Productive Family and Community Development Centers and a significant number of other Government and non-government programs and projects. Within this framework, the Strategic Vision aims to create productive job opportunities by means of adopting numerous approaches. The first and most important is to create a broad base for small investments, in order to enable all social groups in the society to set up their own businesses or to provide job opportunities for such categories. The Net also seeks to direct attention towards community programs, which are based on the participation and contribution of the people in the preparation and implementation of local projects. The idea of business incubators can be introduced as an effective mechanism for the creation of productive job opportunities and the development of the various regions of Yemen, subject to the comparative advantage of each region. It is also imperative to focus on the most deprived groups based on a criteria that ensures that deprived people benefit and that there is equity in distribution in the governorates and districts.

1.1.2.4 Environment Protection

Environmental issues have become a cause for arousing concern of both officials and the public. The Government realizes that the conservation of the environment is not just the issue of the day, but rather it is more tied to the future, in the short and long-terms and touches on the fate of the forthcoming generations. In recognition of the relationship between the environment and development, and of the importance of sound environment management, it is imperative to work towards reinforcing awareness, directing attention to research and development in this field and enhancing official and non-government environment work. The priorities of environment activities are summed up in supporting water management, preventing the pollution of water basins, halting the deterioration of land and rangeland resources, regulating waste management and industrial effects,

management of the coastline and pollution of the marine environment, and studying the impact of climatic change on environment and on desertification, in addition to the protection of agriculture terraces and biodiversity in the protected zones.

It is imperative to enter into the environmental industry, to direct attention to this new sector, to set up the specialized facilities for recycling and simple rural wastewater treatment plants, and to produce products that help to protect the environment.

1.2 Directions and Objectives of the Strategic Vision in the Social Field

Human Development aims to build human capital, and raise their standards of living, economically, intellectually and culturally, by means of formation of productive human capacities and broadening the available options for enabling the society, as a whole and individually, to have access to a source of livelihood. It should also lead to the realization of a suitable and decent life, and to participation in political, economic and social decision making, under a system, in which security and stability are prevalent, and under social justice that ensures freedom and equity and an environment that is optimally exploited to ensure that resources are conserved and renewable. Hence, the aims and ambitions of human development, as embodied in the Strategic Vision emanates from the realization of the following specific policies and objectives:

1.2.1 Population

The Strategic Vision aspires to create a set of interconnected structures and policies, all of which contribute to dealing with the population challenge, in the different aspects of life. It aims at gradually reducing the present rate of population growth to 2.1% and to arrive to a population of 33.6 million inhabitants by 2025. The Vision also aims for controlling the factors of internal migration and to redirect such migration to the coastal growth areas, whereby the percentage of the urban population would rise to about 60%.

Children represent an essential link in the social contract, for which the family and the society together are responsible. The normal situation is exemplified by the children who are found amidst families that surround them with care and warmth and which implant in their children self-confidence, and then within a society that provides them with suitable education and health facilities to support their social upbringing. Youth are confronted by many challenges. Therefore, it is imperative to develop the youth and young people's capacities and potentials and to make them better able to pave their own paths, depend on themselves, help their families and build their country. As for the handicapped and the elderly, in order to ensure that they are cared for, to reduce the hardships of life on them, to shield them from poverty and becoming marginalized and to provide them with the required care, it is imperative to maintain deep social solidarity, in keeping with the teachings of our righteous religion, and our instilled customs and traditions, even under the economic and social changes that the society is undergoing.

The efforts also focus on narrowing the existing gaps between men and women, whether in education, health, or in providing greater chances for women to participate in political, economic and social activities. Women should become full partners with men in carrying the burdens and harvesting the fruits of development, with a view towards realizing the principle of "**women are the siblings of men**", without prejudice and with respect to the consistent gender differences legally and in accordance with Islamic jurisdiction. This orientation aims for increasing the participation of the women in all facets of economic activity and to raise their participation rate in the labor force from 22.7% to 50% by 2025.

1.2.2 **Health**

The large population growth led to increasing the strain on the limited capacities of the health sector, and accordingly to the poor quality of health services and the spread of some diseases and epidemics. The sector also suffers from having inappropriate management systems, which are not in harmony with the times, and from having financial resources that do not meet the needs of the health programs. Public and private investment is considered the primary and basic input for the development of the various preventive, primary and therapeutic health services, in order to achieve social development and to prepare the human beings for acquiring the knowledge, expertise and technical skills that qualify them for production, performance, creativity and innovation.

Raising the health situation of the population can be achieved by means of spreading and improving health services, especially in the rural areas. Yemen's Strategic Vision aims at increasing health service coverage to about 90% by 2025, with focus on primary health care, reproductive health, immunization and raising health awareness. Maternal and infant mortality rates should also be reduced to 65 and 31 deaths respectively by 2025. The Strategic Vision aims to have Yemen declared free from the prevalent and endemic diseases, such as malaria, schistosomiasis, tuberculosis and intestinal parasites.

1.2.3 **Education**

Eliminating Illiteracy and Enhancing Adult Education

The needs and aspirations of the Yemeni society can never be fully achieved, except after illiteracy has been eliminated, by means of directed educational programs that seek to improve the life of the individuals and to empower them to enjoy their rights and reinforce their confidence, capacities and respect for productive work. The Strategic Vision essentially focuses on combating illiteracy in order to reduce it to less than 10% of the population by 2025.

Achieving Education for All

Despite the expansion of education over the last decades, and considering the base it took off from, enrollment in basic education is still modest at 61.4%, with wide gaps between urban and the rural areas (57.4% and 85.4%, respectively) and between females and males (43.9% and 77.2%, respectively). In girls education, the Strategic Vision aims to spread and guarantee the education of all girls, especially in rural areas, reduce the gap between boys and girls in order that girls enrollment in basic education reaches 95% by the year 2025. Applying compulsory basic education, increasing awareness on the importance of education for girls, increasing the absorption capacity of girls' schools and limiting drop out are key policies.

Yemen's Strategic Vision also aims to introduce rudimentary changes in the educational systems, in terms of structures and curricula, until these systems are able to keep pace with scientific and technological developments and with the needs of development. Accordingly, the Strategic Vision takes off from a starting point in the area of information technology (IT), wherein many countries were able to accomplish great strides and achieve advanced levels that gradually prepare them to deal with the elements of IT. Since schools represent the proper inlets to the age of IT, and while advanced countries have been able to provide a computer for each student, to seek to

be likewise in the case of Yemen which looks to eliminate illiteracy and generalize basic education over the next quarter of a century, would be illogical.

While such goal may look impossible to realize, and in order to keep up with the times in light of the available resources, it is possible to set up schools for IT that draw the alert students and provide the required teaching and training in this field.

1.3 Directions and Objectives of the Strategic Vision in the Field of Science and Technology

The basis for a science and technology system already exists in Yemen. It only needs restructuring and an improved framework, to provide the appropriate legislative and legal framework for it, and to direct the education and training system towards this end. It also requires support and reinforcement to transform it to a national system for innovation, which should be the foundation for the real development of the Yemeni economy, in terms of diversification, increasing growth rates, generating productive job opportunities therein, and its entry into the new world economy that is based on the knowledge. Yemen's Strategic Vision aims for the transformation of the fundamentals of Yemen's science and technology base, to a national system for innovation in accordance with the following perspective:

1.3.1 Formulation of a National Strategy for Science and Technology

This strategy ensures the transformation of the existing science and technology system to a national system for innovation, by means of activating the relationship between education and training, research and development, production and services activities, and scientific and technological activities. Such relationships should consider the resources and needs, such as in the areas of maintenance, measurements, setting standards and external marketing. This strategy may be prepared during the first years of the Second Five-Year Plan in order to establish the structure of the system and setting up an agency that coordinates, implements and follows up on the improvement of the strategy.

1.3.2 Education and Training

Vocational and Technical Education and Training

High unemployment, high population growth, and high internal migration, all require that special attention be given to rejuvenating, broadening the base and improving the areas of technical education and training. To increase the number of students in this kind of education requires directing a certain percentage of the output of basic and secondary education towards vocational training and technical education and to the community colleges. Emphasis should also be clear on the integration and flexibility of the educational facilities and channels, whereby the vocational training centers would receive around 120,000 students and the absorption capacity of the technical institutes and the community colleges is raised to about 105,000 male and female students by 2025.

The aim of this kind of education and training is to prepare a technically qualified labor force that contributes to achieving comprehensive development and to strike a balance with the needs for economic growth and the promising sectors which the Strategic Vision focuses on. In addition, such approach encourages the establishment of small and medium enterprise in all forms, especially those that rely on innovation.

University Education

University education witnessed large expansion in the last two decades. The number of universities mounted to 7 government and 8 private universities in 2000, and the number of registered students stood at 184,000, of which 45,000 are female students. Faculty members reached 3,200 of whom 80% are Yemenis. Nonetheless, poor structures and traditional content characterize university education. The enhancement of university education requires improving its responsiveness to the needs of the society and of development, and its ability to keep pace with the advances in the fields the humanities and applied sciences and with the changes and challenges of the times.

Yemen's Strategic Vision strives to ensure linking higher education to the needs of the society, whereby its graduates are transformed from job seekers to generators of job opportunities. This can be accomplished by means of adopting a multitude of measures such as: (a) setting up university institutes that absorb a limited number of outstanding students and which supports the Yemeni Innovation System and offers scientific and technological specialization compatible with the Economy of the 21st Century; (b) increase the percentage of students specializing in the fields of Science and Technology; and (c) setting up technology incubators in universities and business incubators in the vocational training and technical education institutes and in the community colleges.

1.3.3 Scientific Research and Development

The fundamentals and foundations for scientific research and development do exist in Yemen, which are spread out in some of the centers, institutions and universities. The activities of these institutions differ, in terms of type of activity, its size and effectiveness. Most of research and development is still in its embryonic stages and needs to be developed further to be more effective. Yemen's Strategic Vision anticipates an increase in the number of these institutes and in the allocations to them. They will be also given more support in order to have a more active role with greater coordination amongst them. More important is that they should be linked with the production and service sectors to become among the effective components within the Yemeni Innovation System and to assist in establishing an economy that rests on the know-how. Moreover, there is a need to promote the undertaking of scientific studies and research in the universities, including those that represent requirements for higher education degrees.

Support can also be given to investment funds for small and medium size industries, which depend on the findings and outcomes of research and development. Venture capital funds and banks can also be set up for financing the application of research findings in industry, agriculture and services. Business incubators and technology incubators are considered practical mechanisms that must be set up in the various regions of Yemen and across different production and service sectors.

1.3.4 Technology Transfer and Absorption

Stimulating economically related scientific and technological development and establishing research and development institutions enhance the national capacity to absorb the appropriate technologies. It is imperative to give attention to every method of technology transfer, whether through training or by setting up strategic partnerships with companies that possess such technology. It can be also encouraged by means of joint ventures or through attracting foreign direct investment, especially in the manufacturing of natural resources or agricultural goods. It is also important to reinforce the ability to negotiate and enter into contracts for the transfer of technology. "Product improvement", "inverse engineering" and all other methods are also considered among the major mechanisms for accomplishing the objectives of technology transfer and absorption.

1.3.5 Scientific and Technological Services

The provision of science and technology services that meet the needs of the Strategic Vision, requires setting up a favorable environment, exemplified by the availability of information and information networks in all industrial, agricultural, scientific, technological and cultural fields. It also requires modern and rapid techniques for disseminating information, such as television, the Internet and compact disks. Furthermore, it needs support to measurements and standardization, and making the role of their relevant agencies effective in improving the quality and reliability of local products and services. Finally, Arab, regional and international cooperation in science, technology and networking deserves special attention, in view of its great importance.

1.4 Directions and Objectives of the Strategic Vision in the Cultural Field

Yemen enjoys a long and diversified cultural track record, with roots that go back to distinguished ancient civilizations, of which the most significant were the Kingdoms of Saba, Ma'en and Himyar. Those civilizations blended positively with the righteous religion of Islam, which entered Yemen peacefully in the 7th Century, when the Yemenis rushed to convert by tribes and as individuals. This cultural heritage continued to grow and become updated as the ages passed. Its influence even extended to other areas of the world, through old and modern migrations, which went on to reflect the original Yemeni identity and its cultural and civilized heritage wherever it went.

The most apparent traits of Yemeni culture are the devotion to the Islamic religion and the faith in Allah and loyalty to the Prophet, the love for the homeland, solidarity, mercy to each other, hospitality to the guest, championing the weak, desire to work and to excel in work, love of commerce, quest for knowledge, and search for the new, from all of which became manifested in intellectual and cultural openness, with the preservation of the Yemeni identity, originality and distinctiveness.

Yemen's Strategic Vision aims to build and develop the institutions that are able to achieve cultural breakthroughs and to transfer culture from marginal attention to a driving element of development. Culture should be an area for innovation, production, attracting investment and creation of job opportunities, and a gateway for communication with the modern world. This orientation does not, in any case, conflict with preserving the historical and cultural heritage, that is exemplified by the substantive and traditionally passed down heritage, folklore heritage, architectural, literary, scholarly and artistic influences, nor with the devotion to the Yemeni cultural identity and with engraining all the values of good, amity, cooperation, tolerance, generosity, care and protection of the homeland into the hearts, minds and behavior of the forthcoming generations.

1.4.1 The Cultural Dimension of Development

The accomplishment of the objectives and goals of the Strategic Vision in culture requires giving special attention to the cultural dimension of development. This development should be settled, by means of having the people take an active part in it and increasing their awareness on development. Development should interact with religious beliefs and cultural values, and should employ inherited and acquired culture, resources and capabilities to transform human beings to participants in the production of knowledge and expertise. The diversified climate, terrain and cultural sites can also be exploited, along with the multiple and different customs, traditions and arts. Also, the substantive and non-substantive kinds of heritage can bring about new additions and innovations, and accordingly integrates the population with development and interacts with the new and the old creatively, for the interest of man and the progress of mankind. It implants a new understanding of originality that supports creativity, and which exhumes the spirit of perseverance, work and the reward for output and innovation.

Accordingly, culture becomes an element of sustainable development, and the rational use of natural, human and ethereal resources. Engraining and deepening cultural

freedom is an integral part of political freedom and the freedom of expression, and an organic component of democracy and human rights, which sets the climate for creativity and innovation and which ensures the positive interaction with globalization and the communication revolution.

1.4.2 Culture, Literature and Artistic Diversity

Cultural diversity is reinforced by means of motivating the different governorates to develop their contributions and enrich the Yemeni common culture, within an Arab and Islamic culture that opens up to foreign cultural experiences. The rejuvenation of Yemeni culture should be in support of an Arab Islamic culture, which is open to, and interacts with the world. This can prevent the cultural preponderance that accompanies globalization, on one hand, and leads to the diversification of a creative world culture on the other.

Cultural diversification in Yemen shall become a manifestation of tolerance that absorbs and is enhanced by the heritage of local communities, and which creates new common grounds that accepts coexistence and solidarity, on the basis of equality, non-violence and the elimination of tyranny.

Differences that create strife and destroy the attributes of national unity and fraternal links within a common loyalty to Allah, and then to the homeland and unity are unacceptable.

To sustain this diversity, it becomes necessary to guarantee all the freedoms and rights of expression, creativity, writing and publication. In this respect, attention must be given to encouraging artistic production, in all its forms, such as novels, short stories, theater and cinema, fine arts, music, scientific research and educational production, besides continuing to encourage poetry and literature, in view of the cultural role they have played since antiquity.

1.4.3 Broadening the Concept of Innovation

Innovation is not just confined to literature and artistic fields, but also includes all aspects of life and all areas of knowledge. It works to engrain the values of production, deep thinking, the sound management of resources and communities and amity for change. It also entails the improvement of cultural activities to enhance the quality of output and the provision of job opportunities, especially in the publication of books. Therefore, this would need spreading public libraries beginning with the Capital Secretariat and the governorate capitals, establishing school libraries, holding school cultural contests, giving attention to children's culture by means of implementing the Yemeni Children's Library Project, establishing children's cultural centers, and providing suitable children's books. It is also important to consider the role of television and radio programs in encouraging reading and reviving the connection with intellectuals.

Innovation also requires activating the role of the theater, the cinema, and television, as well as the improvement of their production base; encouraging the local, Arab and

foreign private sector to invest in these fields; accelerating the establishment of school theater, teaching young children about the theater and developing a taste for it that helps discovering talents and capabilities in playwriting and acting. Attention to the development of traditional skills is considered essential to preserve the architecture of the Yemeni home, in terms of its functions and decorations, and avoiding unnecessary change. Introducing new skills, for which there is a local and/or foreign market and to train local labor, especially women in these skills is very key in the strategy.

It is imperative to spread the use of communication means (compact disks) for presenting cultural material, especially those of large size and high cost, and spread new cultural material that is unavailable in the local market. They may be also used for highlighting the Yemeni diversified cultural heritage, Yemen's natural and tourism site potentials and those derived from archeological ruins, the diversified terrain and climate, and from the components of substantive and intangible cultural heritage, such as, handicrafts, customs and traditions. Word, color, song and picture can do spreading culture.

1.4.4 Science and Technology Transfer

Culture can never develop and achieve the aims of the Strategic Vision for catapulting development, unless it works towards the transfer of knowledge and technology, especially by means of education for all, improvement of higher education, teaching science and technology, improving its methods, attention to scientific research, spreading information centers, introducing communication technologies and giving attention to translation to and from foreign languages.

1.4.5 Maintenance of Culture

It is imperative to spread "maintenance culture" and to apply it as an approach for the rationalization of the use of resources. Resources should be dealt with prudently and creatively. To spread awareness on the need to maintain machinery, equipment and other accomplishments, to preserve national identity, substantive and intangible heritage, and to tone the determination to find creative solutions to our problems is the path for future. This would include elimination of bad customs and traditions, such as overindulgence and prodigality, and all the social behaviors, which lead to the depletion and destruction of resources and potentials of the society. The role of culture is also obvious in the elimination of blood feuds and the imposition of the rule of law and resorting to religious jurisdiction as a basis for governing the relationship of the individual with other groups and the state.

1.4.6 Perception of Women's Role

The creative output of this culture should radiate with ideals that work towards changing the inferior social views of women, which are part of the mistaken cultural heritage of the society. Accordingly, women should be given their proper place as effective and equal partners to men in terms of rights and responsibilities, in accordance with religious jurisdiction and the law. Involving women in cultural production and expanding their chances for education and their roles in building up the society will give quick returns, in terms of expanding the production and creativity base, improve health and education, and contribute effectively in controlling

population growth.

1.4.7 The Qat Problem

Qat is engrained in the heart of the culture and heritage of the society. It has become a semi complete culture of its own. Over the next quarter of a century, we can not ignore such an important problem as Qat, in all its various aspects. It must be put up for continued and open dialogue on the harms arising out of its increased spread and its social, health and environmental effects, and accordingly consideration and searches should be made for acceptable alternatives to Qat.

1.4.8 Sectoral Linkages

Culture and cultural production is considered an outcome of the interaction and interconnection of several sectors related to handicrafts, architecture, decorations, fine arts and tourism, as well as the theater, schools, universities, television and the radio. Coordination and cooperation between these sectors will lead to the development of the productive base, stimulation of creativity and innovations and promotion of marketing and competition domestically and overseas.

For example, the development of tourism requires the orientation towards reviving the ancient caravan routes, such as the Frankincense Trail, the Silk Trail, the Pilgrimage Trail, and the other trails.

Achieving the aims of cultural development calls for reviewing and activating the roles of cultural institutions, to enable them to contribute effectively to a cultural renaissance that is hoped for in Yemen's Strategic Vision. Equally important is setting forth new policies for offering incentives for cultural output and linking awards with output and creativity. It is also necessary to support the participation of civil society in cultural production and sponsoring innovators, and to encourage the private sector to invest in culture and set up prizes that motivate cultural production. Organizing festivals can also mobilize every cultural or artistic field and stimulate the cultural environment.

1.5 Directions and Objectives of the Strategic Vision in the Political Field

The cultural renaissance of Yemen over the next period requires the reinforcement of gains and accomplishments that the country realized. It also sees proceeding forward with the political system and the democratic experience in order to take off towards more advanced stages until the establishment of a mature and stable democratic state and society. For this purpose, and on the political side, Yemen's Strategic Vision seeks to have Yemen transformed from **a young democracy to a stable and mature democracy**, where political pluralism, the peaceful transition of authority and the respect for human rights become the society's engrained and strong mechanisms for the management of government and the realization of political progress for the society as a whole.

This Vision is based on the consistencies and platitudes which were agreed upon unanimously in the programs of all the political parties and factions, as exemplified by:

- Adherence to Islam, considering it to be the main foundation for all rules of conduct.
- Adherence to the republic and the Principles of the September and October Revolutions.
- Safeguarding the unification of the territories and people of Yemen and deeply instill national unity.
- Establishing the modern Yemeni State on the basis of and with adherence to democracy.

For the achievement of the major political objectives of the society, Yemen's Strategic Vision should rest on the following main pillars:

1.5.1 Reinforcing Democratic Practice and Political Participation

This pillar is based on the reinforcement of democracy, on political pluralism as a form of government, and on democracy and the peaceful transition of power. This approach entails ingraining the constitutional right of voting; nomination; establishment of, and membership in associations, unions, political parties and organizations; the sound application of laws relating to political parties, elections, the provision of equal opportunities for political parties and organizations to enable them to perform their political, social and cultural roles within the society, and in representing and activating the role of constructive and responsible opposition as a guarantee for the continuation of the democratic course. This approach is supported by continuous review and improved regulations and methods for managing elections to arrive to an advanced and integrated elections system, which will secure optimal popular participation, keep pace with the developments and improvements and which will be manifested in a free choice.

On the other hand, the participation of women in political activity has become an important factor for the acceleration of political progress and development. Accordingly, over the next period, efforts must be focused to setup a suitable climate

for the reinforcement of the role of women and their contribution to public life and in the society, and for women to take leadership positions and posts, by means of encouraging and empowering them to exercise all their legal, social and political rights, which are guaranteed by the Constitution, starting with the right to nominate and vote.

1.5.2 General Freedoms and Human Rights

The government's respect for, and commitment to, general freedoms and human rights has become an essential yardstick that reflects the level of political maturity and the progress of the country. Therefore, it is basic that the legislation and laws, which guarantee the rights of the citizens and their general freedoms are issued, and that all the facilities that ensure that they will be able to enjoy them and exercise them freely and be able to obtain all the requirements of the rights of citizenship are provided accordingly.

1.5.3 Good Administration and Transparency

The Government is confronted with the pressure to manage government more efficiently and at lower cost, by means of a small decentralized and innovative administrative apparatus, besides the necessity of providing the right conditions for competition and sense of responsibility, which should be accompanied by accountability. Management transparency and combating corruption have also become requirements for good governance, and among the requirements for economic and social development. The use of modern technologies in management -especially target-oriented management, management strategies, the use of information technologies in managerial development- helps towards reaching the E-government, which raises the efficiency of management and enhances its transparency.

1.5.4 Decentralization and Local Authority

Efforts have been exerted by the Government to instill democracy and reinforce popular participation, to protect the rights granted by the law to the citizens in electing their representatives in the local councils, and to activate the roles of these councils in the future. Exercising authorities granted by the Law of Local Authorities, in planning and executing projects and programs at the local level requires the application of administrative and financial decentralization, which came to activate the role of the citizens and to expand their participation in development.

This represents a mechanism for the stability of the population in their regions and for clarifying the relationship of the local authorities with the Government at the central level.

1.5.5 Civil Society

Democracy is not just based on political pluralism, but rather also on the institutions of civil society. To reinforce the integrated relationship between the government and the society, it is imperative to encourage the society to organize itself, by means of setting up professional, labor, and public organizations, institutions and federations, etc. It is also important to activate their role in all political, cultural, social and economic fields. Development of the legislation and the provision of the conditions

and factors that are adequate to ensure the independence of these institutions will enhance their contribution in the development of the society and instill democratic practice and create an advanced and democratic Yemeni society.

1.5.6 Political Awareness and Traditions for Political Practice

The dissemination of constitutional, juristic, and legal rights within the society represents an essential condition that enables the citizens to know their rights and to undertake their responsibilities. The awareness of citizens leads to instilling democratic practice and traditions, within the institutions of Government, and also within the political parties and organizations, within the unions, associations and organizations, and other institutions of civil society, to carry out the duty of oversight over the execution of laws and legislation. It is imperative to note that the creation of a high level of awareness requires raising the forthcoming generations on the concepts of democracy, instilling in them democratic values and practices and incorporating them in the educational curricula accordingly.

1.5.7 Foreign Policy

The political stability and development and the economic progress of countries in the age of globalization and economic blocs has become linked to their ability to create positive interaction with their regional and international spheres, based on reciprocal economic interests and benefits. In fact, the essential principle is to use foreign policy as an important instrument and vehicle for serving economic issues and for reinforcing the country's ability to be competitive and to search for new markets and to develop exports. Taking off from this, the foreign policy will be directed towards achieving political stability, development and economic progress for the country, and towards activating the role of Yemen in regional economic blocs and to work towards enlivening common Arab activities, on the basis of solidarity, cooperation and integration, and to direct attention to the reinforcement of relations with neighbor states, especially the members of the Gulf Cooperation Council and the countries of the Horn of Africa, in addition to the improvement of Yemen's relations with all international government and non- governmental organizations that are concerned with humanitarian issues and human rights.

Annex 2: Long term annual mean for weather elements

Station	Temperature	Relative Humidity	Rainfall (mm)	WIND	
				Speed (KT)	Direction
ADEN	29.4	66	40.1	10	E
AL-GHAIDAH	27.0	63	20.1	8.4	SE
AL_SADDAH	19.6	41	817.6	5.4	S
ATAQ	27.9	31	46.3	9.4	SE
DHAMAR	16.8	43	425.7	7.7	E
HODEIDAH	29.4	74	80.8	8.4	S
IBB	19.9	59	954.4	7.1	S
MARIB	28.3	26	44.0	10.4	NE
MOKALA	27.6	71	63.3	6.9	SE
SA'DAH	21.5	39	160.5	8.8	S-E
SANA'A	19.0	40	57.7	6.4	NE
SEIYOUN	27.8	39	235.6	4.7	NE
SOCOTRA	27.5	67	629.3	18.5	NE-SW
TAIZ	21.6	62	568.9	6.9	S-SE

Source: Civil Aviation and Meteorology Authority, 2013

Annex 3: Continental watersheds, catchments, their sizes and average rainfall

Continental Watersheds	Catchment Name	Area in Km2	Average rainfall mm/y	
Red Sea (Tihama) Catchment	northern tihama catchments, (wadi hayran, abs, harad,....etc.)	8800	250	
	Wadi Mawr	8100	158/400	
	Wadi Surdud	2700	113/350	
	Wadi Siham	4900	93.5/570	
	Wadi Rima	2700	543	
	Wadi Zabid	4700	223	
	wadi Nakhlah, Dumim,etc.	1500	421	
	Wadi Resyan	2000	445.5	
	Wadi Mawza	1500	250	
	Total Area	36900		
	Al Rub' Al Khali Catchment	Wadi Najran	4400	
		Al-rub Alkhali catchment (w. Amlah, Khubb, Qu'aff, northeast wadis....etc)	84100	140
		Total Area	88500	
	Arabian Sea Catchment	Ramalt Al-Sabatayn catchments (W. Harib, W. Al Aqman...etc.)	9100	150
Wadi Al-jawf		14000	150	
Wadi Adhanah		12600	200	
Wadi Bayhan		3600	75	
Wadi Markhah		3900	65	
Wadi Hammam		1850	54/78	
Wadi Nissab		1800	69	
Wadi Hadramawt		21000		
Total Area				

Annex 3 (Continue): Continental watersheds, catchments, their sizes and average rainfall

Gulf of Aden Catchment	Wadi Tuban	6500	55/450
	Wadi Bana	8000	75/650
	Wadi Hassan	3500	70/200
	Wadi Rabwa (Suhaybiyah)	1900	34
	Wadi Ahwar	6400	261
	Wadi Maifa'ah	8600	239
	Wadi Hajar	9300	225
	Mukalla catchments	5000	69
	Total Area	57000	
Grand total		393750	

Source: Food and Agriculture Organization (FAO), 1997

Annex 4: Total performance indicators of water and sanitation in urban areas during the years of the Third Five-Year Plan 2006–2010

Nr	Indicators	Unit of measurement	Base year	The third five-year plan				
			2005	2006	2007	2008	2009	2010 Expected
1	Total population within facility service areas	Person	6,313,281	6,595,939	6,838,480	7,089,533	7,330,317	7,262,901
2	Total water production	³ m	128,447,320	133,898,237	137,823,478	139,783,198	140,370,798	169,713,969
3	Total water consumption	³ m	82,810,560	88,342,430	91,307,950	95,509,834	96,727,565	121,302,983
4	Loss ratio	%	36%	34%	34%	32%	31%	29%
5	Total number of water connections	Connection	496,302	517,693	540,390	569,618	598,826	643,253
6	Total number of sewer connections	Connection	245,707	263,311	282,516	306,683	319,738	340,740
7	Number of people benefiting from water services	Person	3,626,113	3,784,061	3,934,690	4,137,213	4,350,024	4,583,667
8	Number of people benefiting from sanitation services	Person	1,797,307	1,948,391	2,097,070	2,271,818	2,376,254	2,491,483
9	Population coverage rate of water supply services	capita	57%	57%	58%	58%	59%	63%
10	ratio supplC Population coverage sanitation services	capita	28%	30%	31%	32%	32%	34%
11	per capita share of water Average	liter per day	63	65	64	64	62	74

Source: The Ministry of Water and Environment, 2012

Annex 5: Summary table of the most important results and indicators of population projections (2005–2025) by CSO (2010)

The median age of the population			Average age of the population			population less than 15 years (%)			Years needed to double the population	Sex Ratio%	Total Population (0000)			Vital Indicators			Infant mortality rate	Life expectancy at birth (years)			Indicators of fertility			Years	Nr. of the Alternati	Fertility assumptions	Mortality assumptions	Mortality assumptions (life expectancy at birth)
Both Sexes	Females	Males	Both Sexes	Females	Males	Both Sexes	Females	Males			Both Sexes	Females	Males	Annual population growth rate (%)	Crude death rate (000)	Crude birth rate (000)		Both Sexes	Females	Males	Net reproduction rate	Gross reproduction rate	Total fertility rate for women					
15.8	16.1	15.5	21.9	22.0	21.8	45.0	44.4	45.7	23.3	104.0	19,682	9,648	10,034	3.1	9.0	39.7	77.20	61.1	62.0	60.2	2.47	2.97	6.1	2004	Census Dec 2004			
15.9	16.1	15.7	21.9	22.0	21.8	45.0	44.5	45.4		104.0	19,983	9,794	10,189				77.20	61.1	62.0	60.2				2005	The base year 2005			
17.0	17.2	16.9	22.1	22.3	21.9	42.4	42.1	42.6	24.1	103.7	23,154	11,364	11,790	2.90	8.9	37.9	72.10	62.0	62.9	61.1	2.23	2.86	5.5	2010	1	Medium fertility	Deaths Medium	Deaths medium (expected average life
18.1	18.2	18.0	22.6	22.8	22.4	40.9	40.8	41.1	25.2	103.6	26,687	13,106	13,581	2.78	8.1	35.9	68.29	63.0	63.9	62.1	1.98	2.39	4.9	2015				
19.0	19.1	18.8	23.4	23.6	23.1	40.4	40.2	40.6	28.1	103.6	30,411	14,939	15,472	2.49	7.3	32.2	64.13	64.0	65.0	63.1	1.74	2.10	4.3	2020				
19.8	20.0	19.6	24.4	24.7	24.2	37.8	37.6	38.0	33.5	103.6	34,045	16,724	17,321	2.09	6.8	27.7	60.39	65.0	65.9	64.1	1.50	1.80	3.7	2025				
17.0	17.1	16.8	22.1	22.3	21.9	42.4	42.2	42.7	23.6	103.7	23,190	11,385	11,805	2.96	9.0	38.6	72.10	62.0	62.9	61.1	2.27	2.73	5.6	2010	2	High fertility		
17.9	18.1	17.8	22.5	22.7	22.2	41.3	41.1	41.4	24.2	103.6	26,854	13,189	13,665	2.89	8.2	37.1	68.29	63.0	63.9	62.1	2.06	2.49	5.1	2015				
18.6	18.7	18.5	23.1	23.4	22.8	41.2	41.0	41.4	26.4	103.6	30,830	15,145	15,685	2.65	7.4	33.9	64.13	64.0	65.0	63.1	1.86	2.24	4.6	2020				
19.1	19.3	18.9	24.0	24.3	23.7	39.2	39.0	39.4	30.3	103.6	34,861	17,124	17,737	2.31	6.9	30.0	60.39	65.0	65.9	64.1	1.66	2.00	4.1	2025				
17.1	17.2	16.9	22.1	22.3	22.0	42.3	42.0	42.5	24.6	103.7	23,119	11,347	11,772	2.84	8.9	37.3	72.10	62.0	62.9	61.1	2.19	2.63	5.4	2010	3	Low fertility		
18.2	18.4	18.1	22.7	23.0	22.5	40.6	40.4	40.7	26.3	103.6	26,519	13,024	13,495	2.66	8.0	34.6	68.29	63.0	63.9	62.1	1.90	2.29	4.7	2015				
19.3	19.4	19.2	23.6	23.9	23.3	39.5	39.3	39.8	30.3	103.6	29,988	14,732	15,256	2.31	7.2	30.3	64.13	64.0	65.0	63.1	1.62	1.95	4.0	2020				
20.5	20.7	20.4	24.9	25.2	24.6	36.4	36.2	36.6	37.6	103.5	33,221	16,322	16,899	1.86	6.7	25.3	60.39	65.0	65.9	64.1	1.34	1.61	3.3	2025				
17.0	17.2	16.9	22.1	22.3	21.9	42.4	42.2	42.6	23.7	103.8	23,187	11,380	11,807	2.96	8.4	37.9	67.09	63.3	64.2	62.4	2.23	2.86	5.5	2010	4	Medium fertility	Deaths High	Deaths high (life expectancy is high)
18.1	18.2	17.9	22.6	22.8	22.4	41.0	40.8	41.2	24.4	103.7	26,833	13,175	13,658	2.87	7.1	35.8	58.24	65.5	66.4	64.7	1.98	2.39	4.9	2015				
18.9	19.0	18.8	23.3	23.7	23.1	40.6	40.3	40.8	26.8	103.7	30,752	15,098	15,654	2.61	5.9	32.0	49.94	67.7	68.6	66.9	1.74	2.10	4.3	2020				
19.7	19.9	19.5	24.5	24.7	24.2	38.1	37.8	38.3	31.1	103.7	34,669	17,018	17,651	2.25	5.0	27.5	41.86	70.0	70.9	69.1	1.50	1.80	3.7	2025				
17.0	17.2	17.8	22.1	22.3	21.9	42.5	42.2	42.7	23.2	103.8	23,222	11,397	11,825	3.01	8.4	38.6	67.09	63.3	64.2	62.4	2.27	2.73	5.6	2010	5	High fertility		
17.9	18.0	17.8	22.5	22.7	22.2	41.4	41.2	41.5	23.5	103.7	27,000	13,256	13,744	2.98	7.2	37.0	58.24	65.5	66.4	64.7	2.06	2.49	5.1	2015				
18.5	18.7	18.4	23.1	23.4	22.8	41.4	41.1	41.6	25.2	103.7	31,175	15,305	15,870	2.78	6.0	33.8	49.94	67.7	68.6	66.9	1.86	2.24	4.6	2020				
19.0	19.2	18.8	24.0	24.3	23.7	39.4	39.2	39.7	28.3	103.7	35,503	17,425	18,078	2.47	5.1	29.8	41.86	70.0	70.9	69.1	1.66	2.00	4.1	2025				
17.0	17.2	16.9	22.1	22.3	22.0	42.3	42.1	42.5	24.1	103.8	23,151	11,362	11,789	2.90	8.3	37.3	67.09	63.3	64.2	62.4	2.19	2.63	5.4	2010	6	Low fertility		
18.2	18.3	18.1	22.7	22.9	22,47	40.6	40.5	40.8	25.5	103.7	26,663	13,092	13,571	2.75	7.0	34.5	58.24	65.5	66.4	64.7	1.90	2.29	4.7	2015				
19.3	19.4	19.1	23.6	23.9	23.3	39.7	39.5	40.0	28.8	103.7	30,322	14,888	15,434	2.43	5.9	30.2	49.94	67.7	68.6	66.9	1.62	1.95	4.0	2020				
20.4	20.6	20.3	24.9	25.2	24.6	36.6	36.4	36.9	34.8	103.7	33,823	16,606	17,217	2.01	5.0	25.1	41.86	70.0	70.9	69.1	1.34	1.61	3.3	2025				

Annex 6: List of decision-makers and experts interviewed

No.	Name	Position	Institution	Date of the Interview	Duration of the interview (in minutes)
1	Mohammed Lutf Al-Eryani	Former Minister	Ministry of Water & Environment	21.07.2011	55
2	Abdulrahman Fadhl Al-Eryani	Former Minister	Ministry of Water & Environment	12.02.2012	54
3	Abdulkader Hanash	Deputy Minister	Ministry of Water & Environment	09.01.2012	22
4	Salem Bashoaib	Chairman	National Water Resources Authority	05.02.2012	32
5	Mahmoud Sultan	Head of Planning and Researches	National Water Resources Authority	16.01.2012	43
6	Nori Jamal	GD. of Coordination and Follow-up	Ministry of Water & Environment	10.01.2012	90
7	Abdul Wahed Al-Hamdi	GD. of Irrigation Structures	Ministry of Agriculture and Irrigation	15.01.2012	10
8	Abdulkarim Al-Sabri	GD. of On-farm Irrigation	Ministry of Agriculture & Irrigation	08.02.2012	70
9	Ezz Addin Al-Gunied	GD. of Agricultural Land Reclamation	Ministry of Agriculture & Irrigation	14.01.2012	20
10	Fadhl Ali Al-Nozaily	Deputy Director	Water & Environment Centre, Sana'a University	06.02.2012	50
11	Abdulla Noman	Water Expert	Water & Environment Centre, Sana'a University	08.01.2012	54
12	Khaled Al-Selwi	Head of Modern Irrigation Systems Unit	Groundwater & Soil Conservation Project	08.01.2012	25
13	Ali Hasan	Head of Groundwater Irrigation Unit	Ministry of Agriculture & Irrigation	14.01.2012	22

Annex 7: Questions asked to the interviewees during the semi-structured interviews

A) Water sector

1) Decision-makers in the water sector

Past

- For centuries, Yemenis lived under limited water resources but faced no problems resulting from a water shortage. What has changed and caused the current situation? What have been main turning points in this regard?

Current situation

Technical aspects

- Given that the government has been supporting several intervention measures to enhance water resources, how do you evaluate the impact and potential of each of the following technical interventions?
 - o Modern irrigation systems
 - o Water harvesting structures (including small and large dams)
 - o Desalination
 - o Wastewater reuse

Strategic and institutional aspects

- How do you evaluate the National Water Sector Strategy & Investment Programme (NWSSIP) 2004–2009 and its implementation?
- Why—or if at all—is the existing legal foundation for water resources management in Yemen adequate to support and maintain the sustainability of its water resources?
- How do you evaluate the application of water law and its by-laws?
- What are your views on the existing institutional structure for managing water resources?
- Are there any contradictions or overlap between the tasks of the Ministry of Agriculture & Irrigation and the Ministry of Water & Environment? What could be the solution from your point of view?

Future

- How do you envision the water resources situation of the country in the year 2025?
- Talking about water resources sustainability and considering the steep growth in population, what should be the future direction to meet the increasing water demand supposing that the country reaches a point when all feasible alternatives are applied for efficiently exploiting each water drop to its full economic value?
- What, according to you, should be the strategies for containing and reducing qat agriculture and expansion in Yemen?

2) Water and wastewater experts

- What are the major current plans and policies in the water sector?
- Are there any policies, strategies or plans presently being developed in the water or irrigation sector?

- What do you think of the technical interventions initiated by the government, such as modern irrigation systems, water harvesting, desalination, wastewater management, etc?
- Which intervention initiative is yet to yield its full potential in solving the existing problem of water shortage in Yemen, and why?
- Why do you think existing regulations have failed to help to control groundwater depletion?
- Are there any run-offs that still flow into the sea? In which wadis and at what intervals? Are there any data on the water quantities of these run-offs?
- After applying all the available technologies and optimally using every drop of water in the country and considering the steady rise in population, what do you think should be the future direction to meet the increasing demand?
- What is the average per capita water consumption in rural and urban areas?
- Are there any governmental interventions to enhance groundwater recharge?
- How much wastewater is produced in Yemen? Is it fully treated and reused?
- What are the main constraints to fully and adequately reuse wastewater in future?
- How much industrial wastewater is produced in Yemen? Is it reused?
- Are there water losses from the urban water system? How much water is lost?
- Could you shed some light on the coverage of Yemen's water and sanitation networks in percentage terms?

B) Irrigation sector

1) Modern conveyance and on-farm irrigation experts

- Are there any policies, strategies or plans currently in development in the irrigation sector?
- How do you evaluate the present technical interventions, i.e. modern irrigation systems to increase irrigation efficiency?
- What are the hindrances to scaling out these interventions? How to overcome these hindrances?
- What are the main reasons for the conflict between the MAI and MoWE? What could be the solution?
- Do you think there are other alternatives that can be used to increase irrigation efficiency?
- What do you think of the utilization of economic tools to influence irrigation practices and increase efficiency?
- How do you think the situation (availability) of irrigation water will be by 2025?
- What will be the future of agriculture in Yemen if the current situation persists?
- Are modern irrigation alternatives accepted by farmers? If not, why?
- Considering the technical and financial capacities, how many hectares you think can be covered using modern irrigation annually?
- Do you think that the currently adopted technology is the best for the Yemeni situation, or are there some other technologies that should be introduced?
- How many cubic meters of water does one hectare of agricultural land in Yemen need on average? Is water consumption per hectare increasing? If yes, why?

2) Harvesting structures experts

- There is controversy centring on the programmes of small dams' construction. How do you evaluate these programme? What are the reasons for such controversy?
- Which type(s) of harvesting structure still hold potential for Yemen? Why?
- Do you think that the implementation of these structures can be expedited? Why? How?
- Currently, there is support for creating some large dams in Yemen. What is your opinion about these large dams' potential in Yemen?
- Is there any run-off that still flows into the sea? In which wadis (valleys) and at what intervals? Are there any available data on the water quantities of such run-off?
- How many water harvesting structures does Yemen have? What is the total capacity of these structures?

Annex 8: List of institutions and organizations visited and contacted during the data collection phase

The following authorities were visited:

- Ministry of Water & Environment
- Ministry of Agriculture & Irrigation
- National Water Resources Authority
- Water & Environment Centre, Sana'a University
- Central Statistics Authority, Ministry of Planning & International Cooperation
- National Information Center
- Groundwater & Soil Conservation Project, Ministry of Agriculture & Irrigation

Other international organizations contacted:

- German Development Bank (KfW), Yemen
- German Society for International Cooperation (GIZ), Yemen
- World Bank (WB)

Annex 9: Projected population, rural and urban water demand for each governorate

The capita city of Sana'a

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (daily lpcd)	Rural Water Demand (daily lpcd)	Total Water Demand (daily lpcd)
1986	0	427	427			
1994	0	972	972	41796	0	41796
1995	0	1045	1045	44935	0	44935
1996	0	1120	1120	48160	0	48160
1997	0	1200	1200	51600	0	51600
1998	0	1284	1284	55212	0	55212
1999	0	1373	1373	59039	0	59039
2000	0	1488	1488	63984	0	63984
2001	0	1590	1590	68370	0	68370
2002	0	1699	1699	73057	0	73057
2003	0	1834	1834	78862	0	78862
2004	40	1707	1747	73401	1600	75001
2005	42	1802	1844	77486	1680	79166
2006	44	1902	1946	81786	1760	83546
2007	46	1960	2006	84280	1840	86120
2008	47	2020	2067	86860	1880	88740
2009	46	1976	2022	84968	1840	86808
2010	48	2295	2344	98701	1936	100637
2011	50	2411	2461	103658	1995	105653
2012	51	2532	2583	108864	2055	110919
2013	53	2659	2712	114331	2118	116449
2014	55	2792	2847	120073	2183	122255
2015	56	2933	2989	126103	2249	128352
2016	58	3080	3138	132436	2317	134753
2017	60	3235	3294	139087	2388	141475
2018	62	3397	3459	146072	2461	148533
2019	63	3568	3631	153408	2536	155943
2020	65	3747	3812	161112	2613	163725
2021	67	3935	4002	169203	2693	171895
2022	69	4133	4202	177700	2775	180475
2023	71	4340	4412	186624	2859	189483
2024	74	4558	4632	195997	2946	198943
2025	76	4787	4863	205840	3036	208876

Sana'a governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	1166	71	1237			
1994	1774	112	1886	4816	70960	75776
1995	1810	114	1924	4902	72400	77302
1996	1865	118	1983	5074	74600	79674
1997	1921	122	2043	5246	76840	82086
1998	1979	126	2105	5418	79160	84578
1999	2037	130	2167	5590	81480	87070
2000	1326	26	1352	1118	53040	54158
2001	1367	26	1393	1118	54680	55798
2002	1411	27	1438	1161	56440	57601
2003	1093	21	1114	903	43720	44623
2004	893	25	918	1075	35720	36795
2005	912	25	937	1075	36480	37555
2006	931	26	957	1118	37240	38358
2007	959	27	986	1161	38360	39521
2008	989	28	1017	1204	39560	40764
2009	1019	28	1047	1204	40760	41964
2010	938	15	953	662	37510	38172
2011	892	14	906	582	35681	36262
2012	849	12	860	511	33940	34451
2013	807	10	818	448	32285	32734
2014	768	9	777	394	30711	31104
2015	730	8	738	346	29213	29559
2016	695	7	702	304	27788	28092
2017	661	6	667	267	26433	26699
2018	629	5	634	234	25144	25378
2019	598	5	603	206	23917	24123
2020	569	4	573	180	22751	22931
2021	541	4	545	158	21641	21800
2022	515	3	518	139	20586	20725
2023	490	3	492	122	19582	19704
2024	466	2	468	107	18627	18734
2025	443	2	445	94	17718	17813

Aden governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	33583	293336	327			
1994	39	411	450	40689	1560	42249
1995	39	427	466	42273	1560	43833
1996	39	440	479	43560	1560	45120
1997	39	454	493	44946	1560	46506
1998	40	469	509	46431	1600	48031
1999	39	484	523	47916	1560	49476
2000	9	494	503	48906	360	49266
2001	9	509	518	50391	360	50751
2002	10	526	536	52074	400	52474
2003	10	548	558	54252	400	54652
2004	0	589	589	58311	0	58311
2005	0	611	611	60489	0	60489
2006	0	634	634	62766	0	62766
2007	0	654	654	64746	0	64746
2008	0	674	674	66726	0	66726
2009	0	684	684	67716	0	67716
2010		712	712	70468	0	70468
2011		737	737	72978	0	72978
2012		763	763	75577	0	75577
2013		791	791	78269	0	78269
2014		819	819	81057	0	81057
2015		848	848	83944	0	83944
2016		878	878	86935	0	86935
2017		909	909	90031	0	90031
2018		942	942	93238	0	93238
2019		975	975	96559	0	96559
2020		1010	1010	99999	0	99999
2021		1046	1046	103560	0	103560
2022		1083	1083	107249	0	107249
2023		1122	1122	111069	0	111069
2024		1162	1162	115026	0	115026
2025		1203	1203	119123	0	119123

Taiz governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	1208109	211525	1419634			
1994	1685	380	2065	8056	67400	75456
1995	1709	396	2105	8395	68360	76755
1996	1744	414	2158	8777	69760	78537
1997	1780	434	2214	9201	71200	80401
1998	1815	454	2269	9625	72600	82225
1999	1852	474	2326	10049	74080	84129
2000	1782	513	2295	10876	71280	82156
2001	1834	528	2362	11194	73360	84554
2002	1889	544	2433	11533	75560	87093
2003	1966	566	2532	11999	78640	90639
2004	1858	536	2394	11363	74320	85683
2005	1903	549	2452	11639	76120	87759
2006	1950	563	2513	11936	78000	89936
2007	2009	579	2588	12275	80360	92635
2008	2071	597	2668	12656	82840	95496
2009	2116	610	2726	12932	84640	97572
2010	2083	647	2730	13709	83321	97030
2011	2110	666	2777	14126	84411	98538
2012	2138	687	2825	14556	85516	100072
2013	2166	708	2873	15000	86635	101635
2014	2194	729	2923	15456	87769	103225
2015	2223	751	2974	15927	88917	104844
2016	2252	774	3026	16412	90080	106493
2017	2281	798	3079	16912	91259	108171
2018	2311	822	3133	17427	92453	109880
2019	2342	847	3189	17958	93663	111621
2020	2372	873	3245	18505	94889	113393
2021	2403	899	3303	19068	96130	115198
2022	2435	927	3362	19649	97388	117037
2023	2467	955	3422	20247	98662	118910
2024	2499	984	3483	20864	99953	120817
2025	2532	1014	3546	21499	101261	122761

Hodiedah governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	756635	295438	1052			
1994	1038	549	1587	25254	41520	66774
1995	1102	602	1704	27692	44080	71772
1996	1133	640	1773	29440	45320	74760
1997	1164	679	1843	31234	46560	77794
1998	1197	720	1917	33120	47880	81000
1999	1230	764	1994	35144	49200	84344
2000	1198	744	1942	34224	47920	82144
2001	1236	767	2003	35282	49440	84722
2002	1275	792	2067	36432	51000	87432
2003	1330	826	2156	37996	53200	91196
2004	1408	750	2158	34500	56320	90820
2005	1442	786	2228	36156	57680	93836
2006	1488	811	2299	37306	59520	96826
2007	1534	836	2370	38456	61360	99816
2008	1581	861	2442	39606	63240	102846
2009	1599	871	2470	40066	63960	104026
2010	1647	921	2567	42343	65866	108209
2011	1693	944	2637	43415	67736	111151
2012	1741	968	2709	44514	69659	114174
2013	1791	992	2783	45641	71638	117279
2014	1842	1017	2859	46797	73672	120468
2015	1894	1043	2937	47981	75764	123745
2016	1948	1069	3017	49196	77915	127111
2017	2003	1097	3100	50441	80127	130569
2018	2060	1124	3184	51718	82403	134121
2019	2119	1153	3271	53028	84743	137770
2020	2179	1182	3361	54370	87149	141519
2021	2241	1212	3452	55746	89624	145370
2022	2304	1243	3547	57158	92169	149326
2023	2370	1274	3644	58604	94786	153390
2024	2437	1306	3743	60088	97477	157565
2025	2506	1339	3845	61609	100245	161854

Lahj governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	437615	20770	458			
1994	568	32	600	1728	22720	24448
1995	573	33	606	1782	22920	24702
1996	583	34	617	1836	23320	25156
1997	595	35	630	1890	23800	25690
1998	605	37	642	1998	24200	26198
1999	618	38	656	2052	24720	26772
2000	621	28	649	1512	24840	26352
2001	634	29	663	1566	25360	26926
2002	649	29	678	1566	25960	27526
2003	670	30	700	1620	26800	28420
2004	673	63	736	3402	26920	30322
2005	677	64	741	3456	27080	30536
2006	695	66	761	3564	27800	31364
2007	716	67	783	3618	28640	32258
2008	738	70	808	3780	29520	33300
2009	754	71	825	3834	30160	33994
2010	748	71	820	3849	29935	33784
2011	762	76	838	4091	30479	34570
2012	776	81	856	4349	31033	35381
2013	790	86	876	4622	31596	36218
2014	804	91	895	4913	32170	37083
2015	819	97	916	5222	32755	37976
2016	834	103	937	5550	33349	38900
2017	849	109	958	5899	33955	39855
2018	864	116	980	6270	34572	40842
2019	880	123	1003	6665	35200	41865
2020	896	131	1027	7084	35839	42923
2021	912	139	1052	7530	36490	44020
2022	929	148	1077	8003	37153	45156
2023	946	158	1103	8507	37828	46334
2024	963	167	1130	9042	38515	47556
2025	980	178	1158	9610	39214	48825

Ibb governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	1133050	121564	1255			
1994	1573	232	1805	13920	62920	76840
1995	1596	242	1838	14520	63840	78360
1996	1628	255	1883	15300	65120	80420
1997	1659	268	1927	16080	66360	82440
1998	1693	281	1974	16860	67720	84580
1999	1725	295	2020	17700	69000	86700
2000	1726	292	2018	17520	69040	86560
2001	1773	300	2073	18000	70920	88920
2002	1823	308	2131	18480	72920	91400
2003	1893	320	2213	19200	75720	94920
2004	1762	370	2132	22200	70480	92680
2005	1801	384	2185	23040	72040	95080
2006	1844	394	2238	23640	73760	97400
2007	1900	406	2306	24360	76000	100360
2008	1959	418	2377	25080	78360	103440
2009	1996	425	2421	25500	79840	105340
2010	1986	448	2434	26887	79421	106309
2011	2014	467	2480	28013	80541	108554
2012	2042	486	2528	29185	81676	110861
2013	2071	507	2577	30407	82828	113234
2014	2100	528	2628	31679	83996	115675
2015	2129	550	2680	33005	85180	118185
2016	2160	573	2733	34386	86381	120767
2017	2190	597	2787	35825	87599	123424
2018	2221	622	2843	37325	88834	126158
2019	2252	648	2900	38887	90086	128973
2020	2284	675	2959	40514	91356	131871
2021	2316	704	3020	42210	92644	134854
2022	2349	733	3082	43977	93950	137927
2023	2382	764	3145	45817	95275	141092
2024	2415	796	3211	47735	96618	144353
2025	2450	829	3278	49732	97980	147713

Abyan governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	243277	35964	279			
1994	315	71	386	8946	12600	21546
1995	321	77	398	9702	12840	22542
1996	328	83	411	10458	13120	23578
1997	333	89	422	11214	13320	24534
1998	340	95	435	11970	13600	25570
1999	347	102	449	12852	13880	26732
2000	332	87	419	10962	13280	24242
2001	342	89	431	11214	13680	24894
2002	352	92	444	11592	14080	25672
2003	366	96	462	12096	14640	26736
2004	334	99	433	12474	13360	25834
2005	329	114	443	14364	13160	27524
2006	337	117	454	14742	13480	28222
2007	348	120	468	15120	13920	29040
2008	358	124	482	15624	14320	29944
2009	369	127	496	16002	14760	30762
2010	356	128	485	16172	14259	30430
2011	359	133	491	16714	14344	31059
2012	361	137	498	17275	14431	31706
2013	363	142	505	17855	14518	32372
2014	365	146	512	18454	14605	33059
2015	367	151	519	19073	14693	33766
2016	370	156	526	19713	14781	34494
2017	372	162	533	20374	14870	35244
2018	374	167	541	21058	14960	36018
2019	376	173	549	21764	15050	36814
2020	379	179	557	22494	15140	37635
2021	381	185	565	23249	15231	38481
2022	383	191	574	24029	15323	39352
2023	385	197	582	24835	15415	40251
2024	388	204	591	25669	15508	41177
2025	390	211	601	26530	15601	42131

Dhamar governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	641384	57439	699			
1994	895	105	1000	6930	35800	42730
1995	904	109	1013	7194	36160	43354
1996	922	114	1036	7524	36880	44404
1997	939	119	1058	7854	37560	45414
1998	957	125	1082	8250	38280	46530
1999	976	130	1106	8580	39040	47620
2000	1057	142	1199	9372	42280	51652
2001	1088	146	1234	9636	43520	53156
2002	1119	150	1269	9900	44760	54660
2003	1164	156	1320	10296	46560	56856
2004	1144	186	1330	12276	45760	58036
2005	1179	192	1371	12672	47160	59832
2006	1214	197	1411	13002	48560	61562
2007	1251	203	1454	13398	50040	63438
2008	1290	209	1499	13794	51600	65394
2009	1302	211	1513	13926	52080	66006
2010	1355	233	1588	15380	54203	69583
2011	1392	245	1637	16184	55687	71871
2012	1430	258	1688	17031	57211	74242
2013	1469	272	1741	17922	58777	76699
2014	1510	286	1795	18860	60385	79245
2015	1551	301	1852	19847	62038	81885
2016	1593	316	1910	20885	63736	84621
2017	1637	333	1970	21978	65480	87458
2018	1682	350	2032	23128	67272	90400
2019	1728	369	2097	24338	69113	93451
2020	1775	388	2163	25612	71005	96616
2021	1824	408	2232	26952	72948	99900
2022	1874	430	2303	28362	74944	103306
2023	1925	452	2377	29846	76995	106841
2024	1978	476	2453	31408	79103	110510
2025	2032	501	2532	33051	81267	114318

Shabwah governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	175323	17001	192			
1994	322	39	361	2262	12880	15142
1995	346	43	389	2494	13840	16334
1996	370	47	417	2726	14800	17526
1997	393	52	445	3016	15720	18736
1998	419	56	475	3248	16760	20008
1999	445	61	506	3538	17800	21338
2000	402	52	454	3016	16080	19096
2001	415	54	469	3132	16600	19732
2002	428	55	483	3190	17120	20310
2003	446	58	504	3364	17840	21204
2004	396	74	470	4292	15840	20132
2005	406	76	482	4408	16240	20648
2006	416	78	494	4524	16640	21164
2007	429	80	509	4640	17160	21800
2008	442	82	524	4756	17680	22436
2009	452	84	536	4872	18080	22952
2010	455	90	545	5243	18203	23446
2011	462	95	556	5500	18460	23960
2012	468	99	568	5771	18720	24491
2013	475	104	579	6055	18984	25039
2014	481	110	591	6352	19252	25604
2015	488	115	603	6665	19523	26188
2016	495	121	616	6992	19799	26791
2017	502	126	628	7336	20078	27414
2018	509	133	642	7697	20361	28058
2019	516	139	655	8075	20648	28723
2020	523	146	670	8472	20939	29411
2021	531	153	684	8889	21234	30123
2022	538	161	699	9326	21534	30860
2023	546	169	715	9785	21837	31622
2024	554	177	731	10266	22145	32411
2025	561	186	747	10771	22457	33228

Hajjah governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	662482	57472	720			
1994	1150	111	1261	4218	46000	50218
1995	1207	118	1325	4484	48280	52764
1996	1264	125	1389	4750	50560	55310
1997	1325	132	1457	5016	53000	58016
1998	1388	140	1528	5320	55520	60840
1999	1452	148	1600	5624	58080	63704
2000	1225	135	1360	5130	49000	54130
2001	1264	139	1403	5282	50560	55842
2002	1305	144	1449	5472	52200	57672
2003	1362	150	1512	5700	54480	60180
2004	1340	140	1480	5320	53600	58920
2005	1381	144	1525	5472	55240	60712
2006	1422	148	1570	5624	56880	62504
2007	1466	152	1618	5776	58640	64416
2008	1510	157	1667	5966	60400	66366
2009	1524	158	1682	6004	60960	66964
2010	1493	162	1655	6156	59722	65878
2011	1513	165	1678	6268	60503	66771
2012	1532	168	1700	6382	61295	67677
2013	1552	171	1723	6498	62097	68595
2014	1573	174	1747	6616	62910	69525
2015	1593	177	1771	6736	63733	70469
2016	1614	180	1795	6858	64567	71425
2017	1635	184	1819	6983	65411	72394
2018	1657	187	1844	7110	66267	73377
2019	1678	190	1869	7239	67134	74373
2020	1700	194	1894	7370	68013	75383
2021	1723	197	1920	7504	68903	76407
2022	1745	201	1946	7641	69804	77445
2023	1768	205	1973	7779	70718	78497
2024	1791	208	2000	7921	71643	79564
2025	1815	212	2027	8065	72581	80645

Al-Baydha governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	254633	40802	295			
1994	392	78	470	3822	15680	19502
1995	407	83	490	4067	16280	20347
1996	421	88	509	4312	16840	21152
1997	436	93	529	4557	17440	21997
1998	451	99	550	4851	18040	22891
1999	467	104	571	5096	18680	23776
2000	467	95	562	4655	18680	23335
2001	481	98	579	4802	19240	24042
2002	496	101	597	4949	19840	24789
2003	516	106	622	5194	20640	25834
2004	469	108	577	5292	18760	24052
2005	481	111	592	5439	19240	24679
2006	492	113	605	5537	19680	25217
2007	507	116	623	5684	20280	25964
2008	522	120	642	5880	20880	26760
2009	533	122	655	5978	21320	27298
2010	541	124	665	6096	21634	27730
2011	550	128	678	6250	22005	28255
2012	560	131	690	6408	22382	28790
2013	569	134	703	6570	22766	29336
2014	579	137	716	6737	23156	29893
2015	589	141	730	6907	23553	30460
2016	599	145	743	7082	23957	31039
2017	609	148	757	7261	24368	31629
2018	620	152	772	7445	24785	32231
2019	630	156	786	7634	25210	32844
2020	641	160	801	7827	25643	33470
2021	652	164	816	8025	26082	34107
2022	663	168	831	8228	26530	34758
2023	675	172	847	8437	26984	35421
2024	686	177	863	8650	27447	36097
2025	698	181	879	8869	27918	36787

Hadhramout governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	388925	148170	537			
1994	488	243	731	17982	19520	37502
1995	486	250	736	18500	19440	37940
1996	491	262	753	19388	19640	39028
1997	497	275	772	20350	19880	40230
1998	502	289	791	21386	20080	41466
1999	507	303	810	22422	20280	42702
2000	558	315	873	23310	22320	45630
2001	568	321	889	23754	22720	46474
2002	580	327	907	24198	23200	47398
2003	598	337	935	24938	23920	48858
2004	578	451	1029	33374	23120	56494
2005	569	491	1060	36334	22760	59094
2006	587	506	1093	37444	23480	60924
2007	605	521	1126	38554	24200	62754
2008	623	537	1160	39738	24920	64658
2009	635	546	1181	40404	25400	65804
2010	639	594	1234	43978	25579	69557
2011	651	631	1282	46697	26044	72741
2012	663	670	1333	49585	26517	76101
2013	675	712	1386	52651	26998	79649
2014	687	755	1443	55907	27489	83395
2015	700	802	1502	59364	27988	87352
2016	712	852	1564	63035	28496	91531
2017	725	904	1630	66933	29014	95946
2018	739	960	1699	71072	29541	100612
2019	752	1020	1772	75466	30077	105544
2020	766	1083	1848	80133	30624	110756
2021	779	1150	1929	85088	31180	116268
2022	794	1221	2015	90350	31746	122096
2023	808	1296	2105	95937	32323	128259
2024	823	1377	2199	101869	32910	134779
2025	838	1462	2299	108168	33508	141676

Sa'dah governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	289257	33853	323			
1994	432	58	490	3364	17280	20644
1995	446	61	507	3538	17840	21378
1996	459	64	523	3712	18360	22072
1997	474	67	541	3886	18960	22846
1998	488	69	557	4002	19520	23522
1999	502	72	574	4176	20080	24256
2000	521	74	595	4292	20840	25132
2001	537	77	614	4466	21480	25946
2002	554	79	633	4582	22160	26742
2003	577	82	659	4756	23080	27836
2004	588	107	695	6206	23520	29726
2005	609	111	720	6438	24360	30798
2006	631	115	746	6670	25240	31910
2007	651	118	769	6844	26040	32884
2008	671	122	793	7076	26840	33916
2009	669	121	790	7018	26760	33778
2010	698	133	831	7691	27930	35621
2011	720	140	859	8118	28781	36898
2012	741	148	889	8568	29657	38225
2013	764	156	920	9043	30561	39604
2014	787	165	952	9545	31491	41036
2015	811	174	985	10075	32450	42525
2016	836	183	1019	10634	33439	44072
2017	861	194	1055	11224	34457	45681
2018	888	204	1092	11847	35506	47353
2019	915	216	1130	12504	36588	49091
2020	943	228	1170	13198	37702	50900
2021	971	240	1211	13930	38850	52780
2022	1001	253	1254	14703	40033	54736
2023	1031	268	1299	15519	41252	56771
2024	1063	282	1345	16380	42509	58888
2025	1095	298	1393	17288	43803	61092

Al-Mahweet governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	245178	15667	261			
1994	353	26	379	1274	14120	15394
1995	360	27	387	1323	14400	15723
1996	368	28	396	1372	14720	16092
1997	377	30	407	1470	15080	16550
1998	386	31	417	1519	15440	16959
1999	396	32	428	1568	15840	17408
2000	417	33	450	1617	16680	18297
2001	429	34	463	1666	17160	18826
2002	441	35	476	1715	17640	19355
2003	458	37	495	1813	18320	20133
2004	459	37	496	1813	18360	20173
2005	472	37	509	1813	18880	20693
2006	485	38	523	1862	19400	21262
2007	499	39	538	1911	19960	21871
2008	515	40	555	1960	20600	22560
2009	522	41	563	2009	20880	22889
2010	539	43	582	2107	21579	23686
2011	554	44	598	2169	22169	24338
2012	569	46	615	2232	22776	25009
2013	585	47	632	2298	23399	25698
2014	601	48	649	2366	24040	26406
2015	617	50	667	2435	24698	27133
2016	634	51	686	2507	25374	27881
2017	652	53	704	2581	26068	28649
2018	670	54	724	2657	26782	29438
2019	688	56	744	2735	27515	30249
2020	707	57	764	2815	28268	31083
2021	726	59	785	2898	29041	31939
2022	746	61	807	2984	29836	32819
2023	766	63	829	3071	30652	33724
2024	787	65	852	3162	31491	34653
2025	809	66	875	3255	32353	35608

Al-Maharah governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	30560	13665	44			
1994	39	19	58	1406	1560	2966
1995	39	19	58	1406	1560	2966
1996	40	19	59	1406	1600	3006
1997	41	20	61	1480	1640	3120
1998	41	20	61	1480	1640	3120
1999	43	21	64	1554	1720	3274
2000	46	24	70	1776	1840	3616
2001	47	24	71	1776	1880	3656
2002	49	25	74	1850	1960	3810
2003	51	26	77	1924	2040	3964
2004	51	37	88	2738	2040	4778
2005	54	39	93	2886	2160	5046
2006	56	41	97	3034	2240	5274
2007	57	41	98	3034	2280	5314
2008	59	43	102	3182	2360	5542
2009	58	42	100	3108	2320	5428
2010	62	48	110	3522	2479	6002
2011	64	51	115	3763	2557	6320
2012	66	54	120	4019	2638	6657
2013	68	58	126	4294	2721	7014
2014	70	62	132	4587	2806	7393
2015	72	66	139	4900	2895	7794
2016	75	71	145	5234	2986	8220
2017	77	76	153	5591	3080	8671
2018	79	81	160	5972	3177	9149
2019	82	86	168	6380	3277	9657
2020	85	92	177	6815	3380	10195
2021	87	98	186	7280	3487	10767
2022	90	105	195	7777	3596	11373
2023	93	112	205	8307	3710	12017
2024	96	120	216	8874	3826	12701
2025	99	128	227	9480	3947	13426

Ma'reb governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	85956	9370	95			
1994	165	21	186	1218	6600	7818
1995	172	22	194	1276	6880	8156
1996	181	24	205	1392	7240	8632
1997	190	26	216	1508	7600	9108
1998	202	27	229	1566	8080	9646
1999	211	29	240	1682	8440	10122
2000	199	27	226	1566	7960	9526
2001	205	28	233	1624	8200	9824
2002	212	29	241	1682	8480	10162
2003	221	30	251	1740	8840	10580
2004	207	32	239	1856	8280	10136
2005	212	33	245	1914	8480	10394
2006	218	33	251	1914	8720	10634
2007	224	34	258	1972	8960	10932
2008	231	35	266	2030	9240	11270
2009	235	36	271	2088	9400	11488
2010	239	37	276	2174	9558	11733
2011	244	39	282	2245	9742	11987
2012	248	40	288	2318	9929	12247
2013	253	41	294	2394	10119	12513
2014	258	43	300	2471	10313	12784
2015	263	44	307	2552	10511	13063
2016	268	45	313	2635	10713	13347
2017	273	47	320	2720	10918	13638
2018	278	48	327	2809	11127	13936
2019	284	50	334	2900	11341	14241
2020	289	52	341	2994	11558	14553
2021	295	53	348	3092	11780	14872
2022	300	55	355	3192	12006	15198
2023	306	57	363	3296	12236	15533
2024	312	59	370	3403	12471	15874
2025	318	61	378	3514	12710	16224

Al-Jawf governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	33564	9198	43			
1994	144	28	172	1624	5760	7384
1995	154	30	184	1740	6160	7900
1996	170	34	204	1972	6800	8772
1997	187	37	224	2146	7480	9626
1998	205	41	246	2378	8200	10578
1999	225	44	269	2552	9000	11552
2000	378	54	432	3132	15120	18252
2001	390	56	446	3248	15600	18848
2002	403	58	461	3364	16120	19484
2003	420	60	480	3480	16800	20280
2004	386	58	444	3364	15440	18804
2005	395	59	454	3422	15800	19222
2006	404	60	464	3480	16160	19640
2007	417	62	479	3596	16680	20276
2008	429	64	493	3712	17160	20872
2009	437	65	502	3770	17480	21250
2010	588	78	666	4506	23533	28039
2011	637	82	719	4761	25493	30254
2012	690	87	777	5030	27616	32646
2013	748	92	840	5314	29916	35231
2014	810	97	907	5615	32408	38023
2015	878	102	980	5932	35107	41039
2016	951	108	1059	6268	38031	44299
2017	1030	114	1144	6622	41199	47821
2018	1116	121	1236	6997	44630	51626
2019	1209	127	1336	7392	48347	55739
2020	1309	135	1444	7810	52374	60184
2021	1418	142	1561	8252	56736	64987
2022	1537	150	1687	8718	61461	70179
2023	1664	159	1823	9211	66580	75791
2024	1803	168	1971	9732	72125	81857
2025	1953	177	2131	10282	78132	88415

Amran governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	0	0	0			
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	827	128	955	6272	33080	39352
2001	860	133	993	6517	34400	40917
2002	894	138	1032	6762	35760	42522
2003	939	145	1084	7105	37560	44665
2004	728	150	878	7350	29120	36470
2005	742	152	894	7448	29680	37128
2006	755	155	910	7595	30200	37795
2007	778	159	937	7791	31120	38911
2008	801	164	965	8036	32040	40076
2009	831	170	1001	8330	33240	41570
2010	777	176	952	8601	31067	39668
2011	769	181	950	8862	30758	39620
2012	761	186	948	9132	30452	39584
2013	754	192	946	9411	30149	39559
2014	746	198	944	9697	29849	39546
2015	739	204	943	9992	29552	39544
2016	731	210	942	10297	29258	39555
2017	724	217	941	10610	28967	39577
2018	717	223	940	10933	28679	39612
2019	710	230	940	11266	28393	39660
2020	703	237	940	11610	28111	39720
2021	696	244	940	11963	27831	39794
2022	689	252	940	12327	27554	39881
2023	682	259	941	12703	27280	39983
2024	675	267	942	13090	27008	40098
2025	668	275	944	13488	26740	40228

Al-Dhal'a governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	0	0	0			
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	359	43	402	1161	14360	15521
2001	370	44	414	1188	14800	15988
2002	381	46	427	1242	15240	16482
2003	396	47	443	1269	15840	17109
2004	408	62	470	1674	16320	17994
2005	423	64	487	1728	16920	18648
2006	437	66	503	1782	17480	19262
2007	451	68	519	1836	18040	19876
2008	464	70	534	1890	18560	20450
2009	466	71	537	1917	18640	20557
2010	491	81	572	2194	19642	21835
2011	507	87	593	2341	20260	22601
2012	522	93	615	2498	20898	23396
2013	539	99	638	2666	21556	24222
2014	556	105	661	2845	22235	25080
2015	573	112	686	3036	22935	25971
2016	591	120	711	3240	23657	26897
2017	610	128	738	3458	24402	27859
2018	629	137	766	3690	25170	28860
2019	649	146	795	3938	25963	29900
2020	670	156	825	4202	26780	30982
2021	691	166	857	4484	27623	32108
2022	712	177	890	4785	28493	33278
2023	735	189	924	5107	29390	34497
2024	758	202	960	5450	30316	35765
2025	782	215	997	5816	31270	37086

Raymah governorate

Year	Rural Population (000)	Urban Population (000)	Total Population (000)	Urban Water Demand (lpcd)	Rural Water Demand (lpcd)	Total Water Demand (lpcd)
1986	0	0	0			
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	0	0	0	0
2003	377	7	384	462	15080	15542
2004	391	4	395	264	15640	15904
2005	402	4	406	264	16096	16360
2006	414	4	418	264	16560	16824
2007	427	4	431	264	17080	17344
2008	440	4	444	264	17600	17864
2009	444	4	448	264	17760	18024
2010	461	3	465	225	18453	18678
2011	474	3	478	212	18977	19188
2012	488	3	491	199	19516	19715
2013	502	3	505	188	20070	20258
2014	516	3	519	177	20640	20816
2015	531	3	533	167	21226	21392
2016	546	2	548	157	21828	21985
2017	561	2	563	148	22448	22596
2018	577	2	579	139	23086	23225
2019	594	2	596	131	23741	23872
2020	610	2	612	123	24415	24539
2021	628	2	629	116	25109	25225
2022	646	2	647	109	25822	25931
2023	664	2	665	103	26555	26658
2024	683	1	684	97	27309	27406
2025	702	1	703	91	28084	28176

Annex 10: Yemeni standards of water quality

Annex 10 -1: Yemeni standards of water quality used for drinking

Parameter	Unit	Maximum Value
Physical Characteristics		
Colour		15
Turbidity	NTU	5
Temperature	°C	25
PH		6.5-9
Conductivity	(µmhos/cm)	2500
Chemical Characteristics		
Total Dissolved Solids	mg/l	1500
Total Hardness	--	500
Bicarbonate	--	500
Chloride	--	600
Sulphate	--	400
Calcium	--	200
Magnesium	--	30-150
Sodium	--	400
Potassium a	--	12
Iron	--	1
Manganiz	--	0.2
Copper	--	1
Zink	--	15
Aluminum	--	0.2
Nickel	--	0.02
Toxic Organic Pollutants		
Parathion	mg/l	0.035
Endrin	--	0.0002
Lindane	--	0.004
Methoxychlor	--	0.1
Toxaphene	--	0.002
Malathion	--	0.19
Dimethoate	--	0.002
Diazinon	--	0.02
HexachlorCyclohexan	--	0.04
Acetic Acid	--	0.1
Propionic Acid	--	0.01
Toxicants		
Lead	mg/l	0.05
Selenium	--	0.01
Arsenic	--	0.01
Chromium	--	0.05
Cyanide	--	0.1
Cadmium	--	0.005
Mercury	--	0.001
Barium	--	0.5-1.0
Silver	--	0.01-0.1

Annex 10-1: (cont.)

Fluorine	--	1.5-0.5
Antimony	--	0.005
Barium	--	0.3-0.1
Total trihalomethanes c	µg	150
Chemical Pollutants		
Nitrate	mg/l	10-50
Ammonium	--	0.3-0.05
Nitrite	--	2
Phosphate	--	0.5
Radioactive material		
Beta emitters	Becquerel (Bq)	0.1
Alfa emitters	--	1
Microbiological contaminants		
Faecal Coliforms	Cell/100 ml	10-15

Source: Environmental Protection Authority (2009)

- a) 30 mg/l if Sulphate is 250 mg/l and more and 150 mg/l if the Sulphate is less than 250 mg/l
- b) Total pesticides must not exceed 0.1 mg/l
- c) Includes the following: Chloroform, Bromoform, Bromide, Chloromethane, Dibromochloromethane.

Annex 10-2: Yemeni standards of water quality used for irrigation

Parameter	Symbol	Unit	Limit Allowed
Salt content			
-Electrical conductivity	ECw	(mmhos/cm)	0.7-4
-Total Dissolved Solids	TDS	mg/l	450-3000
Infiltration			
-Sodium adsorption	Adj-SAR	Ratio	6-9
-Electrical conductivity	ECw	(mmhos/cm)	less than 0.5
Ion toxicity			
-Sodium	Na		
Surface irrigation		Adj-SAR*	3-9
Sprinkler Irrigation		mEq/l	less than 3
-Chloride	Cl		
Surface irrigation		mEq/l	4-10
Sprinkler Irrigation		mEq/l	less than 3
-Boron	B	Mg/l	0.7-2
Miscellaneous Effects			
-Nitrogen	N	Mg/l	5-30
-Bicarbonates	HCO ₃	mEq/l	1.5-8.5
Sprinkler Irrigation			
-pH	pH		6.5-8.4

* Maximum concentrations are put according to good water consumption experiences (1000m³/acrs/year). Only if water consumption exceeds the mentioned ration, it is recommended to reduce maximum concentration according to the same ratio.

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