Chapter 1

Introduction
INTRODUCTION

"We made from water every living thing."(Qur-An, Surat Al Anbiyaa, verse: 30). "And among His signs is this: thou seest the earth humble; but when we send down Rain to it, it is stirred to life and yield increase." (Qur-An, Surat Fussilate, verse: 39).

Water has been considered as an essential element for human survival and for that matter for the entire living organism. Former President of the United States of America, John Kennedy, is said to have said, "Anybody who can solve the problems of Water will be worthy of two Nobel Prizes. One for peace and one for science." (Grigg, 1985). Biswas (1998) indicated that human history could be written in terms of interactions and interrelations between humans and water. A quick review of water activities around the global clearly indicates that this resource has rapidly become one of the critical elements in determining local, national and regional growth.

Water Availability

Water resources, while renewable, are limited. Water scarcity has recently been considered to be a major concern of those who are already facing the crisis. The main problem emerging in many parts of the world is water scarcity. Water has always been a scarce resource in the arid countries where one of the constraints to development has been water. The situation has progressively worsened in terms of adequate quantity and desired quality of water. It is also recognized that the problems of water resource are not merely of regional or national concern but are of worldwide concern. Many regions are facing water shortage such as the Middle East, Africa, South Asia and other parts of the world as well.

The increasing population will have a direct and significant impact on future water availability, use and quality. The growth rate of the population in the developing countries exceeds 2% per year, and in some parts of Africa, Asia and the Middle East, it exceeds 3% per year.
The global trend of high growth rate of population indicates that over 90 percent of future population increase will be in developing countries, where access to clean water and sanitation services are inadequate. The rapid population growth phenomenon makes the Arab countries one of regions with high rates of population growth in the world (2.5 - 3.8%). In Yemen according to the population projection for 1999, the total resident population was estimated at 17.7 million inhabitants, with annual population growth rate of 3.5 percent (Statistical Year - Book, 1999). By the end of year 2013, the population in the country projected to get doubled.

Because the total amount of fresh water is fixed, these growing populations will continuously reduce the water availability per capita. In Africa, the increasing population is seen as a single factor, than any other, for creating the pressure on present and future demand on water resources. Many people in eastern and western African countries, for example, Botswana, Malawi, Zambia, Zimbabwe and Ethiopia are recently facing serious famines. The issues of droughts and famines were among the main agenda of the “World Summit on Sustainable Development” which was held by the United Nations in Johannesburg in South Africa, during August 26 - September 4, 2002. The agenda of the conference included important issues such as environment, natural resources and global warming.

The Middle East region has been facing serious condition of water availability particularly in the arid areas. The low level of rainfall and high temperatures characterize the region. Rainfall is low in most of the region, but it is highly variable seasonally and annually. Average monthly rainfall ranges from 0 mm to 200 mm in January and 0 mm to 500 mm in July for the Middle East region as a whole (Watson et al., 1998). Many countries of the region depend on water supplies from outside their political boundaries.
The Arab region is characterized by its water resources scarcity. Large portions of the region are in arid and semi-arid where rainfall is low. About 67 percent of the land area receives rainfall less than 100 mm/yr; 15 percent between 100-300 mm/yr, and 19 percent of the land area receives more than 300 mm/yr. (League of the Arab States, 1995). Two-thirds of the population in the Arab countries is dependent on water carried by rivers originating in neighboring states (Modzin, 1996). The available surface water was estimated at about 204.62 billion cubic meters (BCM) and ground water availability for agricultural and municipal uses was estimated at about 35 BCM (League of Arab States, 1994). The countries of the Arabian Peninsula do not have reliable sources of surface water. They depend either on groundwater or on desalination for their water supply. Big desalination plants were built in the area, especially in the Gulf States. According to Abdul Razzaq (1995) problems that contribute to overall water shortages in the Arabian Peninsula include: (1) insufficient surface runoff to recharge aquifers or sustain irrigation requirements; (2) full development of renewable shallow groundwater alluvial aquifers; (3) extensive mining of deep fossil groundwater resources; (4) seawater intrusion into fresh water aquifers in coastal areas and (5) pollution of shallow aquifers. In addition to these, poor management practices due to inadequate planning and institutional arrangement, as well as lack of training programs result in poor monitoring and utilization of water resources in the area.

Yemen, being in the arid regions of the world, is vulnerable to changes in water availability. Water shortage, already a problem in the country, is unlikely to be reduced and may exacerbated by climate change. The country faces such severe water shortages that it could be classified as one of the water-scarce countries in the world. The situation is expected to worsen in the near future because of increases in demand resulting from changing life styles, economic development
and population growth. The reduction of water availability would sharpen competition among user activities, including agriculture. Agriculture is the fundamental economy in Yemen (despite the recent discovery of oil in 1980s). Farming, terrace farming in particular, depends entirely on the nature of the rainy season, a situation that makes the economy of the country vulnerable to any climate change. Therefore, any change in the patterns of rainfall may cause serious problems to the country. About two thirds of the population lives in rural areas and derives its main income from agriculture. The economic situation of this majority group is influenced heavily by the scarcity of water resources, which is expected to support the cultivation of approximately 1.1 million hectares, most of it depending on rainfall.

Yemen has predominantly arid to semi-arid climatic conditions with rainy seasons mainly during spring and summer (pre-monsoon and monsoon seasons) and with high temperatures prevailing all through the year in low altitude zones. The country experiences wide fluctuation in rainfall. Annual rainfall increases from less than 100 mm along the Red Sea coast (Tihama coastal plain) to about 500-1500 mm in the central highlands, particularly around Ibb area (1917.7 mm). However, in the further east the rainfall decreases and reaches 100 mm/yr in the Rub al Khali area. Natural water resources are mainly represented by seasonal runoff carried by streams (wadis) and by groundwater. Other sources of water are springs, including hot springs. The country is devoid of perennial rivers and lakes. The country experiences chronic water shortages. There is substantial imbalance between the available water resources and the demand. Total annual renewable water resources were estimated at 2500 million cubic meters (MCM), with surface water amounting to 1000 MCM and groundwater contributing the remainder 1500 MCM. (Statistical Year Book, 1999).
Water Demand

The demand for fresh water has been increasing at a fast rate since the beginning of the twentieth century. In several parts of the world, water demands are fast approaching the limits of available resources. Increasing population and increasing demand in the agricultural, industrial, and hydropower sectors will put additional stress on the water resources. In the Middle East, as a result of rapid increase in the income of some countries, resulting in high living standards, the demand for water has increased. Hence, many countries in the region are experiencing chronic water shortage. In the Arab countries, as a result of population growth associated with industrial, social, and cultural developments, the demand for water has increased in traditional water use (domestic, industrial, and agricultural). In 1990, for example, the total of Arab countries' water usage was estimated at about 157.7 BCM, this amount was allocated into agricultural usage 143.3 BCM (91%), domestic usage 8.4 billion meters (5%), and industrial usage 6.0 BCM (4%) (League of Arab States, 1994).

In the Arabian Peninsula, demand had increased from about 6 BCM to about 23 BCM during 1980-1990 (Abdul Razzaq, 1995). Based on that rate, according to the same source, total water demand is expected to reach 35.4 BCM by the year 2010. In Yemen, total annual renewable water resources, as mentioned earlier, were estimated at 2500 MCM in 1995. At the same year, total water consumption was estimated at about 3200 MCM. Thus, the water deficit between renewable water resources and water consumption was 700 MCM. According to the National Water Resources Authority (NWRA) (1998), the water deficit is expected to increase to more than 920 MCM by the year 2005. The water deficit has mainly been met by the accelerated use of ground water resources. Thousands of wells have been drilled to supply water for agriculture and to meet the water demand of the ever-increasing population, particularly in urban centers. However, the
uncontrolled pumping of ground water has resulted in declining water tables and increasing water salinity in the coastal areas where seawater has intruded into the fresh water aquifers. In addition, ground water in some areas has been subjected to pollution. The over-pumping of ground water will result in more problems than it is expected to solve, as in case of a number of major cities, which are now required to look at different areas for their water need.

Water availability is an essential component of agricultural productivity. The limited water supplies constrain present agricultural productivity and threaten the food security of many developing countries. Agriculture consumes more fresh water than any other human activity. Worldwide about 87 percent of the fresh water is consumed by agriculture (Biswas, 1998). In India, for example, 96 percent of water is consumed in agriculture (Patwardhan, 1999). In the Middle East, agricultural production is highly dependent on irrigation because rainfall is low and highly variable. Therefore, the increased water demand for agriculture is putting more pressure on available water resources. 41 percent of the region’s agricultural lands are irrigated. In some countries, however, up to 89 percent of the agricultural lands are irrigated (Watson, et al. 1998). In the Arab region countries such as Egypt, Saudi Arabia, Yemen, Libya and Tunis use between 80-90 per cent of their total water usage for agricultural purpose. In Yemen, according to NWRA (1998), 93 percent of the total country’s consumption of water was for irrigation. Domestic use consumed about 6 percent and the rest was consumed by other economic activities including industries.

As demand for all type of traditional use (domestic, industrial and agricultural) increase, the signs of conflict between the various beneficiaries are becoming increasingly evident in most parts of the world. The issue of climatic change adds a new dimension to the problem of water supply and demand.
Developing countries are highly vulnerable to climate change because many are located in arid and semi-arid regions in the world. Water storage, already a problem in many countries of the arid region, is unlikely to be reduced and may be exacerbated by climate change. With the continuous increase in the demand for the water over the entire world, the need for planning of the water resources, development and management has become important. Hence, the research in this study attempts to contribute in this direction of water resources management, which is not only crucial for the study area but also for the country as a whole.

Rationale of the Study

Wadi Zabid basin (the study area), with a catchment area of 5257 km², is the second largest stream that drains to the Red Sea. The Tihama Plain part of the study area is one of the most promising areas for the recent and future agricultural development in Yemen. Due to its agricultural potential and the richness of water resources, compared to other regions, this part of the study area is considered to be one of the agricultural heartlands of the country. However, the water resources have been improperly managed. There are reduction in total runoff, as a result of variation in climate conditions, and increasing demand for agricultural activities that has been placing more pressure on water resources. The declining water table levels at alarming rates and increasing salinity, particularly in the coastal zones, could have an impact on water quality. In some areas, groundwater is contaminated with salt as a result of seawater intrusion into freshwater aquifers. All these call for the need of proper management of water resources of the study area for which knowledge of the basin characteristics particularly related to hydrology and terrain conditions of the wadi is essential.
Objectives of the Study

Several studies have been conducted on the issues of water resources development and management. Policies and recommendations have been made at the regional and national level. However, the Wadi Zabid basin (the study area) has not been studied separately in terms of wadi-specific integral water resources management. Moreover, with recent additions of hydrological data for sufficiently large period becoming available it is necessary to have a fresh look at available water resources and revise the earlier estimates and plan in light of the recent information. The author, therefore, thought of studying the surface water resources of Wadi Zabid basin with the following objectives:

1. To assess the total of the water resources of Wadi Zabid.
2. To understand and analyze the pattern of water resource utilization.
3. To look into spatial variation in the pattern of utilization particularly in agricultural sector.
4. To assess the validity of present utilization.
5. To evaluate optimal utilization pattern.
6. To identify and minimize the gap between optimal and present utilization.
7. To formulate a regional policy for water resources for the area under consideration.

Data Base and Methodology

The primary and secondary data collection was the first stage. The first trip to the study area was arranged during Nov. 1998 and Feb. 1999 in order to collect secondary data on meteorological and hydrological variables, regional topographical and other maps necessary for the research project. In addition Aerial - photographs for selected areas across the basin, population census, and agricultural statistics were collected during the first visit. The second trip was arranged during Feb. 2001 to May 2001 in order to carry out fieldwork that included questionnaire survey, data collection for hydrological
aspects, conducting interviews, and collecting information about the socio-economic activities.

Since the overall objective of the present study is to evaluate the availability of water resources of the study area, and then to consider the optimum utilization, the research methodology has been formulated to serve this main objective. The research work has been carried out in three parts such as (A) climatic and hydrologic analysis, (B) terrain analysis, and (C) water resource availability-need analysis.

A. Climatic and Hydrologic Analysis

The analysis focused on variables, such as sunshine, temperature, wind speed, evaporation and air humidity besides rainfall. The basin has six rainfall stations and two full-fledged meteorological stations. Data from these stations formed the base for the climate analysis. For example, rainfall data for the period of 30 years (1970-1999) has been used for the rainfall analysis.

Since the primary objective of this analysis is to assess the water availability, more concern has been given to the rainfall analysis, particularly, the rainfall analysis in space and time in order to estimate the areal mean rainfall and volume of available water. Isohyetal method, and Thiessen polygon were employed in order to calculate the average rainfall over the basin. Discharge data for the period of 28 years (1970 – 1997) has been analyzed. The discharge data has been obtained from Al Kolah gauge station located on the site where Wadi Zabid enters the Tihama coastal plain.

B. Terrain Analysis

Terrain is one of the principal basin characteristics affecting stream flow. The morphological set up of the basin largely determines the water resource occurrence, distribution and management. The analysis of the terrain has been divided into three parts:
(1) Physiographical analysis, (2) Slope analysis, and (3) drainage network analysis.

**Part I: Physiographical Analysis**

Based on topographical sheets (1:50,000) Digital Elevation Model (DEM) was developed for the Wadi Zabid basin.

**Part II: Slope Analysis**

The slope of a drainage basin is an important variable, which not only shapes the geometry of the basin but also determines the development and management practices in the basin. Hence, the slope analysis of the Wadi Zabid basin was carried out. Topographical sheets (1:50,000) and aerial photographs (1:60,000) formed the data based of this analysis. GIS software has been used for the analysis and drawing the base maps necessary for the research.

**Part III: Drainage Network Analysis**

The Topographical sheets of (1: 50,000) formed the database for the analysis. The parameters worked out include stream order, stream number, bifurcation ration, circularity ratio, drainage density and frequency distribution besides the stream profiles and Shreve order diagrams. For the purpose of detail analysis, the Wadi Zabid basin has been divided into 8 sub-basins of the fifth and sixth stream order.

**C. Water Requirements Analysis**

Water availability for agriculture as well as domestic is a major concern in the study area. The analysis of water need, therefore, focused on these two aspects of water uses. Questionnaire / Interview method was employed in order to gather information about the perception of end-users of the resources.
Arrangement of the text

The present work has been divided into eight chapters. A brief description of each one is given below:

Chapter I: Introduction

The chapter opens with a short introductory section on the importance of water for the human survival. The chapter discusses the availability and demand aspects of the water resources starting with the global view and goes down to the regional and national levels. Further, it shows that increased population and increasing demand in the agricultural, industrial and hydropower sector will put additional stress on water resources. Moreover, climatic change represents an important additional stress on the water resources already affected by increasing demands, improper management practices and lastly the pollution. The chapter concludes with the call for urgent need for water development and management, particularly in the developing countries, which have high rate of population growth and are highly vulnerable to climatic change. In addition to this, the chapter contains the rationale of the study, the main objectives of the study and the methodology.

Chapter II: Literature Review

The chapter opens with the introductory section of the historical consideration about water as a natural and critical need for mankind. The discussions about the various aspects of water resources include topics like the availability, demands and causes of the increasing demands. Other issue includes the international growing concern about the issue of water resources development and management. The discussion goes down to the national level and Yemen has been the focus in order to show the water situation in the country as well as in the study area. The chapter concludes with a brief review of previous work done in hydrology and water resources development in the country and the study area as well.
Chapter III: Description of the study area

In this chapter, the introduction to the study area has been given. The contents of the chapter include area and location, physiography, geological setting, soils and natural vegetation.

Chapter IV: General Climatic Conditions

This chapter is devoted to analysis of the general climatic characteristics of the study area. The climatic parameters analyzed in this chapter include sunshine, temperature, wind speed, humidity, evaporation and rainfall. Special emphasis has been given to the analysis of rainfall, as the main objective of the present study is to assess the availability of water resources in the study area.

Chapter V: Terrain Analysis

This chapter deals with terrain conditions. The chapter opens with introductory section of the importance of terrain analysis in the study of hydrology. The variables related to physiography are analyzed with the help of DEM and drainage network. Slopes analysis also form part of this chapter. The DEM map, diagrams, slope aspect maps along with geomorphological sketches, and table support the discussion.

Chapter VI: Quantification of Water Resources

The aim of this chapter is to analyze and determine the amount of available water that can be utilized in optimum ways. The analysis mainly focuses on spatial temporal distribution of rainfall, quantification of volume of rainfall and estimations of runoff.

Chapter VII: Water Requirements

In this chapter, the water requirements for different water usages (domestic and agricultural) have been analyzed. Variables such as area of the districts, population, and crops have been considered and analyzed in order to understand the total need and the future demands.
Chapter VIII: Discussion, Conclusion and Recommendations

The last chapter deals with constrains and limitations faced by the region in the water resource management. It also covers the topic such as region wise characteristics of the terrain, which have been responsible for the low level of agricultural extension. An attempt has been made to suggest various means and methods of enhancing the scope of water resource management through the technique of rainwater harvesting.