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M.SC. THESIS

A STUDY ON THE AVAILABLE OPTIONS FOR MITIGATING WATER SCARCITY IN THE HEBRON DISTRICT, PALESTINE

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A STUDY ON THE AVAILABLE OPTIONS FOR MITIGATING WATER SCARCITY IN THE HEBRON DISTRICT, PALESTINE

دراسة عن الخيارات المتاحة لتخفيف ندرة المياه في محافظة الخليل، فلسطين

Submitted by
Khalil Tumar

This thesis was prepared under the main supervision of Dr. Maher Abu-Madi and has been approved by all members of the examination committee.

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SUMMARY

Water is the soul of life, and many communities will face the problem of water scarcity in the coming years. Water scarcity is the lack of available water resources, which lead to a gap in the coverage of demands in an area.

Many countries are working continuously to reduce water scarcity. Palestine is one of the areas that suffer from water scarcity significantly in the Middle East. The Israeli occupation, is a major cause of the growing problem of water scarcity in Palestine. Hebron district suffers significantly from water scarcity compared to other districts in Palestine. This danger threatens Hebron entity from all aspects of life (domestic, agricultural and industrial).

The main aim of this research is to study the available options of water resources covering both local resources and nonconventional sources in the Hebron District that can mitigate water scarcity in the district to create a state of balance between demand and supply based on scientific facts.

The method that has been followed is by calculating the value of the Falkenmark index, based on the amount of water available, and the amount needed for domestic, agricultural and industrial water use, at the current situation and the future situation at 2035.

It was found that the current total water required to satisfy a person's needs for domestic, agricultural and industrial sectors is (42.42 Mcm/yr), and the current renewable water resources in Hebron District per person for domestic, agricultural and industrial sectors is (10.97 Mcm/yr).

Generally, it was found that Hebron district experience absolute scarcity. And it was found that the available options to mitigate water scarcity in the Hebron District were: water right, water demand management, rainwater harvesting, reduction of water leaks and thefts and treated wastewater reuse. And it was found that when integrated these available options all together will create a state of balance between demand and supply. The result showed that the total water required to satisfy a person's needs for domestic, agricultural and industrial sectors at 2035 will be (48.22 Mcm/yr), and the Future renewable water resources in Hebron District due to integrated available options all together will be (86.10 Mcm/yr). The results show a lack of management for water sector in Hebron District.

This research has shown that the political situation resulting from the Israeli occupation, is the main problem that impede applying of these options.

الخلاصة

الماء هو روح الحياة. وندرة المياه هي من بين المشاكل الرئيسية التي يواجهها العديد من المجتمعات والعالم في السنوات المقبلة. ندرة المياه هي عدم وجود موارد المائية المتاحة، مما يؤدي إلى وجود فجوة في تغطية مطالب في المنطقة.

تعمل دول كثيرة بشكل مستمر للحد من ندرة المياه. فلسطين من المناطق التي تعاني من شح المياه بشكل كبير في منطقة الشرق الأوسط. الاحتلال الإسرائيلي، سببا رئيسيا في تفاقم مشكلة ندرة المياه في فلسطين. محافظة الخليل تعاني بشكل كبير من ندرة المياه بالمقارنة مع مناطق أخرى في فلسطين. هذا الخطر يهدد كيان الخليل من كافة جوانب الحياة (المنزلية والزراعية والصناعية).

الهدف الرئيسي من هذا البحث هو دراسة الخيارات المتاحة للموارد المائية التي تشمل كلا من الموارد المحلية ومصادر غير تقليدية في محافظة الخليل التي يمكن أن تخفف ندرة المياه في المنطقة، لخلق حالة من التوازن بين العرض والطلب على أساس الحقائق العلمية.

الطريقة التي اتبعت هي عن طريق حساب قيمة المؤشر فالكينمارك، استنادا إلى كمية المياه المتاحة، وكمية المياه اللازمة للاستخدام المنزلي والزراعي والصناعي، عن الوضع الحالي والوضع المستقبلي في عام 2035.

وقد تبين أن إجمالي المياه الحالية اللازمة لتلبية احتياجات الفرد للقطاعات المنزلية والزراعية والصناعية هي (42.42 مليون متر مكعب / سنة)، والموارد المائية المتجددة الحالية في منطقة الخليل للشخص الواحد للقطاعات المنزلية والزراعية والصناعية هي (10.97 مليون متر مكعب / سنة).

بشكل عام، وجد أن محافظة الخليل تعاني ندرة مطلقة. وتبين أن الخيارات المتاحة للتخفيف من ندرة المياه في منطقة الخليل هي: الحق في المياه، وإدارة الطلب على المياه، وتجميع مياه الأمطار، والحد من تسرب المياه والسرقات، وإعادة استخدام مياه الصرف الصحي المعالجة. وتبين أنه عندما تدمج هذه الخيارات المتاحه جميعا سيخلق حالة من التوازن بين العرض والطلب. وأظهرت النتائج بأن مجموع كميات المياه اللازمة لتلبية احتياجات الفرد للقطاعات المنزلية والزراعية والصناعية في 2035 ستكون (48.22 مليون متر مكعب / سنة)، والموارد المائية المتجددة المستقبلية في منطقة الخليل بسبب تكامل الخيارات المتاحة جميعا ستكون (86.10 مليون متر مكعب / سنة). أظهرت النتائج عدم وجود إدارة لقطاع المياه في محافظة الخليل.

وقد أظهرت هذه الدراسة أن الوضع السياسي الناتج عن الاحتلال الإسرائيلي، هو المشكلة الرئيسية التي تعيق تطبيق هذه الخيارات.

DEDICATION

To my parents,

To my lovely wife,

To my heart "Kareem",

To soul of my daughter "Roqia",

To my family,

To my friends,

ACKNOWLEDGEMENTS

My greatest thanks for my supervisor Dr. Maher Abu-Madi, for his continued follow and guidance.

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My Special thanks to the West Bank Water Department, Palestinian Water Authority, Water Sector Regulatory Council, the Palestinian Central Bureau of Statistics, Ministry of Agriculture, Ministry of National Economy, Ministry of Local Government, Action Against Hunger, American Near East Refugee Aid, Palestinian Hydrology Group, all Municipalities of the district.

I would like to thank my thesis examination committee Dr. Rashed Al-Sa`ed and Dr. Nidal Mahmoud.

LIST OF ABBREVIATIONS

ACF	Action Against Hunger
ANERA	American Near East Refugee Aid
EQA	Environmental Quality Authority
HG	Hydrology Group
ICA	Israeli Civil Administration
JWC	Joint Water Committee
JWU	Jerusalem Water Undertaking
L.	Liters
L/C/D	Liters per capita per day
Mcm	Million cubic meters
MoA	Ministry of Agriculture
MoH	Ministry of Health
MoLG	Ministry of Local Government
MoNE	Ministry of National Economy
MWH	Montgomery Watson Harza Engineering Company
PAI	Population Action International
PCBS	Palestinian Central Bureau of Statistics
PWA	Palestinian Water Authority
SPSS	Statistical Package for the Social Sciences
TWB	The World Bank
UNOHCHR	United Nation Office of the High Commissioner for Human Rights
WBWD	West Bank Water Department
WHO	World Health Organization
WSRC	Water Sector Regulatory Council
Yr	Year

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CHAPTER ONE
INTRODUCTION

1.1 Overview

Palestine is located in the Middle East, in the east Mediterranean zone. “Lack of access to adequate, safe, and clean water has been a longstanding problem for the Palestinian population. Though exacerbated in recent years by the impact of drought-induced water scarcity, the problem arises principally because of Israeli water policies and practices which discriminate against the Palestinian population. This discrimination has resulted in widespread violations of the right to an adequate standard of living, which includes the human rights to water, to adequate food and housing, and the right to work and to health of the Palestinian population” (Amnesty International, 2009). Water resources in Palestine are limited, and controlled by Israeli occupation, which deprived the Palestinians from their legal share of water.

Water is the most important issues in the negotiations between the Palestinian and Israeli sides, but no progress has been made. In the second Oslo agreement of September 1995, Israel recognized Palestinian water rights. But it was postponed until after the "final status negotiations" (Jayyousi et al., 2009).

Water is the significant feature in the population/resource equation where water resources in Palestine are limited due to both natural and artificial constraints and the country's population has continued to rise. A high rate of natural population growth, has transformed into an imbalance condition between population and water. Hebron District is the most areas that suffer from this problem. This thesis focuses on the water scarcity in Hebron District, the primarily study the available options for mitigating water scarcity.

The more essential and “doable” elements of a sustainable water solutions were discussed in this research are: water right, new supplies of water, water harvesting, reuse of wastewater in the agricultural sector, reduction of water demands and reduce water leak and thefts.

1.2 Statement of the Problem

Water scarcity is described as a major challenge facing the world. “When an individual does not have access to safe and affordable water to satisfy her or his needs for drinking, washing or their livelihoods we call that person water insecure. When a large number of people in an area are water insecure for a significant period of time, then we can call that area water scarce” (Rijsberman, 2005). Population growth is a major contributor to water scarcity.

The increase in water demand and competition for water for domestic, agricultural and industrial use, increases with population growth. Most of the countries in the Middle East and North Africa (MENA) region cannot meet their current water demand. The path of future population growth will impact water scarcity (PAI, 2011).

Population growth will increase the need for food, which highly depend on water for food production, hence the scarcity of water and hunger are closely interlinked agricultural productivity (PAI, 2011).

Growing population contributes to the demand on water for industrial purposes, which is determined by the demographic factors including family size, composition and age structure. The amount of water each person uses is expected to increase as incomes grow and consumption increases (PAI, 2011).

Population growth and prosperity could cause many of people subjected to water scarcity, and this is reflected on the different aspects of life (PAI, 2011).
Hebron's population expected to continue to rise, the gap between water supply and demand threatens to widen significantly, because Israeli occupation are controlled of water resources , that will exacerbate this gap .

1.3 Research Questions

The main research question this research aims to answer is:

- What available options can contribute to mitigating the water scarcity in the Hebron District?

Other questions which this research aims to answer are:

1. How much is the water stress indicator in the Hebron District?
2. How can each of these available options options contribute to augmenting water availability?
3. What are the obstacles and challenges for applying these options?
4. What are the effective solutions to apply these options?

1.4 Aim and Objectives

The main aim of this research is to study the available options that can mitigate water scarcity in the Hebron District.

The specific objectives are:

1. To determine the water stress indicator in the Hebron District.
2. To identify and assessment of the available options for mitigating water scarcity in the Hebron District.
3. To determine the amount of water resulting from each option.
4. To identify obstacles and challenges that impede applying of these options and propose suitable solutions.

1.5 Significance of the Study

This study will be a great effort to discuss the options available water resources which include both local resources and non conventional sources in the Hebron District. This study contributes to mitigation water scarcity, to create a state of balance between demand and supply based on scientific facts. The results of this study provide information for further research in this field.

1.6 Approach and Methodology

Research approach and methodology adopted in this study are based on multiple methods. Scientific papers were reviewed on water scarcity, water right, rainwater harvesting, treated wastewater reuse, water demand management and Reduction of water leaks and thefts. Interviews were held with representatives of the water sector in the district. The collected data was used to determine the quantities of water that will be obtained from each option.

The work will be as follows:

- Studying the available options in the Hebron District.
- Making direct meetings and distributing questionnaires.
- Analyzing collected data by questionnaires using the computerized analysis programs.
- Making the required calculations.
- Studying potential for the implementation of the available options and the possibility to integrate them.
- Studying the problems that impede applying these options and propose suitable solutions.
- Making the results and recommendations.

1.7 Hypothesis

The main hypothesis of this research is " water scarcity in the Hebron District is due to the Israeli occupation". The other hypothesis are:

- Non conventional water resources can contribute substantially to augmenting water availability.
- Integrating the available options mitigates water scarcity in the Hebron District.
- Political situation resulting from the Israeli occupation, is the main problem that impede applying available options for mitigating water scarcity in the district.

1.8 Thesis Outline

This thesis consists of six chapters. Chapter One provides an introduction of the research. Chapter Two describes the study area which is the Hebron District, Palestine. Chapter Three presents the literature review on the subject. Chapter Four describes the approach and methodology. Chapter Five focuses on the results and discussion. Finally, Chapter Six presents the conclusions and recommendations.

CHAPTER TWO
STUDY AREA: THE HEBRON DISTRICT

2.1 Location

Palestine is located on eastern coast of the Mediterranean Sea and west of the Jordan River Valley. Located in the heart of the Middle East and up between West Asia and North Africa to have occurred and the Sinai peninsula at the confluence of the two continents point. Extends between latitudes 29.30 and 33.15 north, between latitudes 34.15 and 35.40 East Longitude, with an area 26.990 km^2. It is bordered to the west of the Mediterranean, on the east by Syria and Jordan, Lebanon at the north, to the south by Egypt and the Gulf of Aqaba. It became under Israeli occupation, after the Israeli occupation displacement of hundreds of thousands of Palestinians from their homeland in 1948.

Israel continued to confiscate Palestinian lands, after the Oslo Accords became the control of Palestinian self-rule in the West Bank and Gaza Strip.

In the southern area of the West Bank, lies Hebron district. It is a mountainous area with an average height of 800 m with respect to sea level, as shown in Figure 2.1.

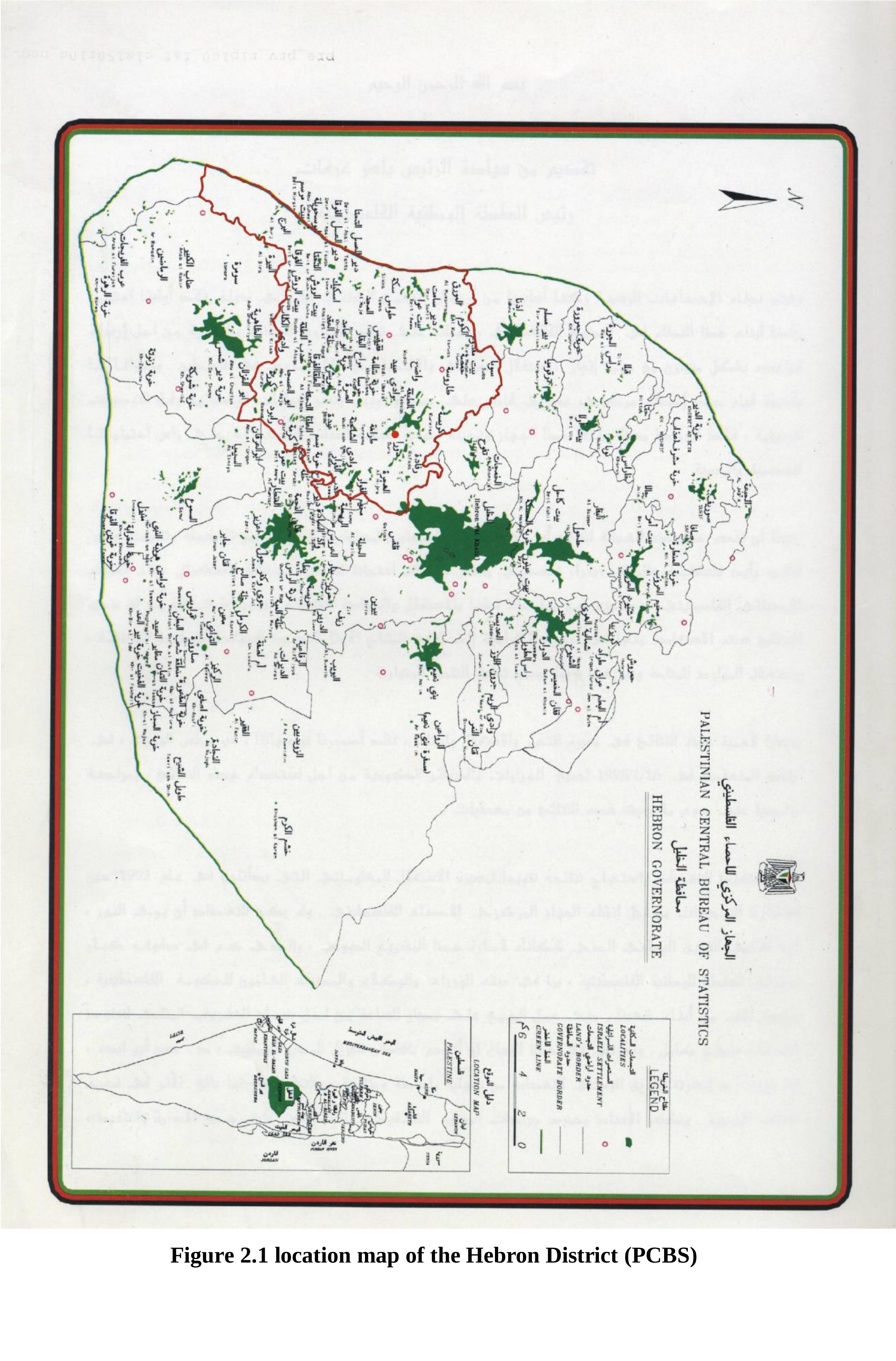

Figure 2.1 location map of the Hebron District (PCBS)

2.2 Climate

There are two types of climate in Hebron district, the first Mediterranean climate: which prevails most areas of the district, which is characterized as a rainy relatively warm winters and hot dry summers, and the second desert climate: which prevails the eastern slopes of the mountains of Hebron and the coast of the Dead Sea, which is characterized by a warm winter and high temperatures and drought summer (PCBS, 2010).

2.3 Temperature

The average maximum and minimum temperature in summer are 26.6 and 16.4 ^{o}C, respectively and in winter is (12.1, 5.2), the relative humidity is (71.25%) (Palestinian Metrological Department, 2007).

2.4 Land Use

The area of Hebron district is around 997square kilometers, which represent about 17.6% of the West Bank area, of which 257.6 km^2 agricultural land. (PCBS, 2010). Agriculture is one of the most important crafts practiced by the population in the Hebron district, Cultivated area has reached 338,400 Dunums at year 2006/2007 (PCBS, 2010).

2.5 Demography

The Hebron district includes 97 localities (Annex 1), the number of population in mid-2014 in the Hebron district 684,247 inhabitants. (PCBS, 2014). Reached the proportion of Palestinian refugees living in the Hebron district 17.9% of the total population of the district the end of 2007. The population density reached mid-2009 in the district 582.7 persons/km^2, (PCBS, 2010). Future population needs to be estimated through 2035. Future growth rates estimated by the PCBS and presented in their 2010 study were used. The population growth rates vary between 1.3 and 4.1 percent per annum (Table 2-1). These growth rate assumptions are based on 5-year increments and vary depending on the size of population center.

Table 2-1 Future Population Growth Rates Source: PCBS, 2010

Locality Class	Annual Population Growth Rate (%)				
	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
Large Village	3.4	3.2	3.0	2.7	2.5
Main City	2.9	2.7	2.3	2.0	1.8
Medium Village	3.7	3.5	3.2	3.0	2.8
Refugee Camp	2.0	1.8	1.6	1.5	1.3
Small Village	4.0	3.8	3.6	3.3	3.1

The Palestinian population in the Study Area is estimated to increase from approximately 684,247 in 2014 to 1,118,662 in 2035 by depending on the following equation (Equ.1). This represents a substantial population growth (Table 2-2).

Future population equation:

$P_n = P_{t+1} * (1 + r)^n$ ………………………………………………………….. (Eqn. 1)

where

P_n = the number of future population

P_{t+1} = the number of present population

r = annual population growth rate (%)

n = year numbers

Table 2-2 Projected Future Population

District	Projected Future Population				
	2015	2020	2025	2030	2035
Hebron	697,211	802,145	907,201	1,012,094	1,118,662

2.6 Water situation in Hebron District

2.6.1 Water resources

- **The history of water in the West Bank**

"Prior to 1967, Israel had developed the water resources to which it had access and established a national water carrier, Mekorot, that conveyed water from existing sources of supply to the various centres of demand from agricultural, municipal and industrial customers. Following the 1967 War, Israel took control of water resources, and developed wells, throughout the West Bank, together with a water supply network serving settlements that linked into the Mekorot network. Palestinian water rights in the West Bank were abrogated, including from the Jordan river", (TWB, 2009).

"The amount that Mekorot supplies to the settlements is unofficially estimated at some 75 MCM, of which 44 MCM is produced from wells controlled by Israel or settlers within the West Bank. Economic disparities between West Bank and Israel are large – in 2005, Israel's

Gross National Income (GNI) per capita was almost eighteen times the Palestinian GNI per capita. Water resources availability in the two neighbors is likewise far apart, with fresh water per capita in Israel about four times that of West Bank. Whereas Israel is known for efficient water infrastructure and management, Palestinians are struggling to attain the most basic level of infrastructure and services of a low income country", (TWB, 2009).

- **Article 40 of the Oslo Accords**

With the continuation of negotiations between Israel and the Palestine Liberation Organization in the early 1990s, it resulted in the Oslo Accords, and was the establishment of the Palestinian Authority (PA) in 1994, with jurisdiction over parts of the West Bank and Gaza Strip. Negotiations on a permanent status agreement which include allocation of water resources were deferred, but were to be concluded by 1999. However, by 2000 no progress had been achieved, (Amnesty International, 2009).

First bilateral agreement between the Palestinians and Israelis was the Declaration of Principles signed on September 13, 1993 (Oslo I). "According to this agreement, the Permanent Palestinian-Israeli Committee would discuss water resource issues for Economic Cooperation", (Jayyousi et al., 2009).

Second bilateral agreement was signed on September 18, 1995 (Oslo II). "Article 40 of the Agreement, was the basis for water sector planning and project implementation. This binding agreement regarding water and wastewater became the basis for water sector planning during the "interim period" and until the final agreement was reached", (Jayyousi et al., 2009).

"The agreement states that the interim period should not exceed 5 years from the date of the signing of Oslo II, or September 2000. 'Principle One' of the water section of Oslo II is the most significant element of the agreement. It states, "Israel recognizes the Palestinian water rights in the West Bank". These rights will be settled in the permanent status agreement after the final negotiations", (Jayyousi et al., 2009).

"Afinal status negotiation has not yet taken place. This has left Palestinians with a suboptimal yield and a forced reliance on water purchased from the Israeli company Mekorot", (Jayyousi et al., 2009).

Table 2-3 shows the groundwater allocations for both sides according to Oslo agreement and the consumption figures in 2012 from the three shared groundwater aquifers (West Bank area only) (PWA, 2011).

Table 2-3 Water allocation according to Oslo agreement and utilization in 2012 (PWA,2011).

Use	Oslo Agreement (MCM)				Utilization 2012 (MCM)			
	WAB	NEAB	EAB	Total	WAB	NEAB	EAB	Total
Israel	340	103	40	483	≈411**	≈103**	150*	664
Palestine	22	42	54	118	28	23	53	104
Additional Quantity for Palestinian Development	--	--	78	78	--	--	0	0
Basin Total	362	145	172		439	126	203	

* This includes 100 MCM from Dead Sea springs, which Israel prevents Palestinians from developing
** Since there are no updated figures from Israeli side, the figures of 2011 are used here

- **Groundwater resources**

The amount of the mountain aquifer that access for Palestinians does not exceed one fifth of the resources. Israel abstracts about 80% of the "estimated potential" of the aquifers that underlie both the West Bank and Israel. Excessive withdrawal of groundwater from deep wells with low water recharge causing danger to the aquifer, which leads to a reduction in water available to Palestinians through the shallower wells (TWB, 2009).

The main source of water for the Palestinians in the West Bank is groundwater, which provide more than 90% of fresh water supply for various purposes (PWA, 2011).

There are three groundwater basins in the West Bank: the western, the northeastern, and the eastern basin. These basins are semi-completely controlled by the Israeli water supply company of Mekorot (PWA, 2011).

Western Aquifer Basin: which is the largest basin and the most important among the West Bank Aquifer basins. The annual yield (362- 400) MCM per year. The Palestinians utilization is 25MCM/y. Whereas Israelis utilization is (340-430) MCM/Y, and in some years it reaches more than 520 MCM/Y. The main aquifer system in this basin is the upper and lower Cenomanian aquifers (PWA, 2011).

Northeastern Aquifer Basin: Most of the recharge areas of this basin are located within the West Bank boundaries and it has an annual yield of 100- 145 MCM. The Palestinians utilization is about 20 MCM/Y, Whereas Israelis utilization is 103 MCM/Y. The aquifer system in this basin includes the shallow Eocene Aquifer, Upper and Lower Cenomanian Aquifers (PWA, 2011).

Eastern Aquifer Basin: The basin is divided into three main sub-aquifers, namely the Mountainous Heights, Northeastern Tip and Jordan Valley. The annual yield of this basin varies from 145 to 185 MCM. The Palestinians utilization is about 42 MCM/Y, Whereas Israelis utilization is 50 MCM/Y from wells in addition to 100 MCM/y from Dead Sea Springs (PWA, 2011).

Figure 2.2 is a map illustrating the water resources in the West Bank in the three basins (PWA, 2012).

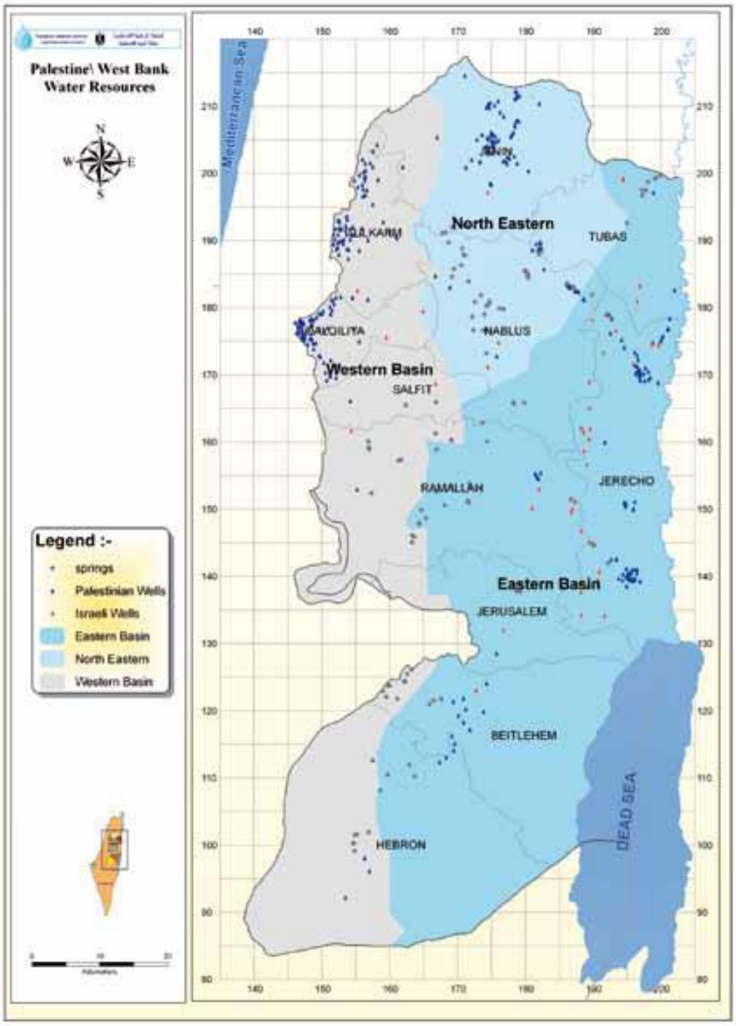

Figure 2.2 Water Resources in the West Bank (PWA, 2012)

- **Rainfall**

The average annual rainfall in the West Bank between 700 mm in the western part to less than 100 mm in the east. The average annual rainfall for the hydrological year (September 2011 – August 2012) for the entire West Bank was about 518 mm (PWA, 2011).

Rainfall is between November and April in Hebron district. And precipitation increase in the .mountains. The annual quantity of rainfall in Hebron district in 2007 was 447.8 mm (PCBS, 2008).

- **Surface water resources**

The main Surface water resources is the Jordan River which is the only permanent river in the whole Palestine, and ephemeral wadis flowing towards three basic directions: towards the Mediterranean (West Bank and Gaza Strip), towards the Jordan Valley and towards the Dead Sea (PWA, 2012).

- **The Jordan River**

The Jordan flows north to south from an altitude of 2200 meters above sea level to end at the Dead Sea at an altitude of ± 425 meters below sea level. It is shared among five riparian countries: Palestine, Jordan, Syria, Lebanon and Israel, with the latter using most of the water (PWA, 2012).

The estimated quantity of water flowing into the Lower Jordan River and discharging into the Dead Sea is about 1400 MCM/y. This amount decreased during the past six decades and is presently no more than 30 MCM/y, this is due mainly to diverting by Israel of more than 500 million cubic meters through the National Israel Water Carrier, as far south as the Negev, in addition to the construction of many dams on the upper reaches of the river. Natural factors such as evaporation also had an adverse impact on Jordan River flows (PWA, 2012).

- **Wadis**

The important potential source of water is Surface water which flowing into wadis during the rainy season. The estimated annual flow of flood water through wadis in the West Bank is about 165 MCM/y. The average flow of flood water at 2011/2012 season reached 179 MCM/y. The West Bank wadis are classified into eastern (toward the Jordan Valley and towards the Dead Sea) and western (towards the Mediterranean) by the direction of flow (PWA, 2012).

Figure 2.3 show the direction of flow, and Table 2-4 recognize the major Hebron District surface catchments.

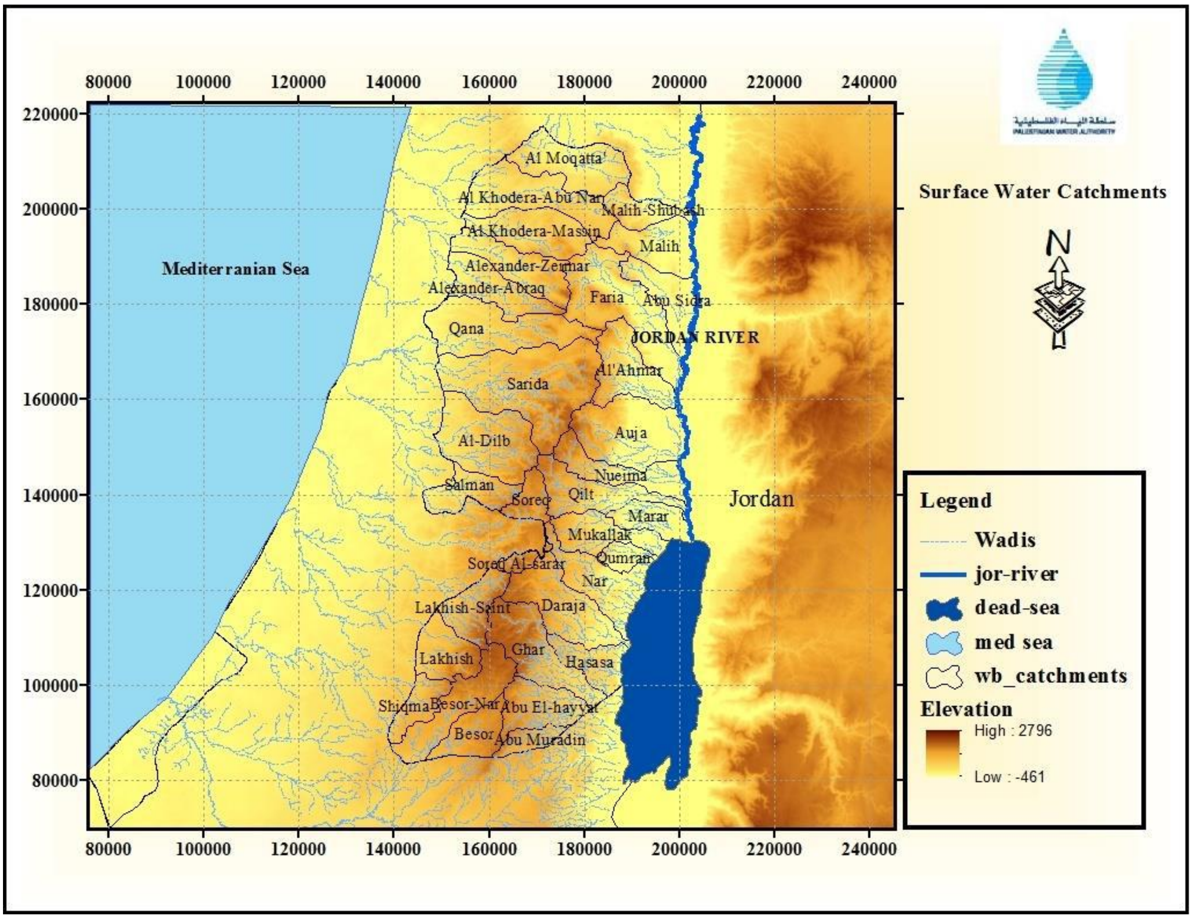

Figure 2.3 Surface water catchments and wadis (PWA, 2012)

Table 2-4 Estimated discharge Hebron District wadis, 2011/2012 season (PWA, 2012)

No.	Flow Direction	Catchment	Average Runoff (MCM)	2012 Estimated Runoff (MCM)
1	Eatern Wadis Flowing towards the Dead Sea	Hasasa	0.50	0.85
2		Ghar	6.50	6.67
3		Abu El-hayyat	2.40	2.50
4		Abu Muradin	0.50	0.50
Total			9.90	10.52

2.6.2 Water Supply

The Palestinians abstract is less than 15% of the “estimated potential” of those three aquifers. In 2010, the abstraction of the Mountain Aquifer did not exceed 98 MCM, which is 29 MCM from the North-Eastern Aquifer, 25 MCM from the Western Aquifer and 44 MCM from the Eastern Aquifer (PWA, 2012).

The reasons that reduced the Palestinians abstraction from all three aquifers over the last decade were: Israeli controls over the available resources, the severe restrictions imposed by JWC and ICA on Palestinian development water projects, and the adverse impact of the drought phenomenon that caused a gradual decrease in rainfall recharge rates into groundwater systems. In order to overcome the water shortages, Palestinians purchased amounts of water from the Israeli national water company “Mekorot” (PWA, 2012).

According to the Palestinian Bureau of Statistics, the per capita amount of water supplied in Hebron is about 16.87 Mcm/yr, with a population of about 684,247, leading to a daily allocation per capita of 67.55 l/c/d. The Palestinians can supply only about 6.70 Mcm/yr from their own resources, (PCBS, 2008); the rest are purchased from "Mekorot".

The main existing sources of potable water that originate in the Study Area are deep water wells that tap the underlying Eastern and Western Aquifers. Only four existing wells located in the Study Areas are currently tapping the Western Aquifer, (MWH, 2012). The annual quantities provided from both resources for Hebron district in 2010 are demonstrated in Table 2-5 (PWA, 2012).

Table 2-5 Total Local and Purchased Water in Hebron District in 2010 (PWA,2012).

District	Total Local and Purchased Water				
	Local Resources (MCM)	Percent (%)	Purchased Water (MCM)	Percent (%)	Total Resources (MCM)
Hebron	7.702	39	12.230	61	19.932

2.6.3 Existing Water Supply Infrastructure in Hebron district

The water system of the Hebron district consists of groundwater wells, pump stations, bulk and municipal reservoirs, bulk transmission pipelines, and municipal water distribution networks.

The majority of the Palestinian population in the Study Area is connected to the water system through service connections. The existing water infrastructure has been built as a centralized system in various stages, and various system elements are mutually interconnected (MWH, 2012).

The primary source of water for the Study Area is groundwater withdrawn from deep water wells which tap the underlying aquifer. Substantial volumes of water are also delivered to the Study Area through service connections from "Mekorot", the Israeli water utility (MWH, 2012).

Water infrastructure in the Study Area is controlled by both Palestinian and Israeli authorities. There are two bulk water conveyance systems in the Study Area: one that serves Palestinian communities only, which is managed by PWA; and one that serves Israeli settlements and some Palestinian communities, which is managed by Mekorot. While there are numerous system connections and interdependencies, the Palestinian and Israeli-controlled systems are operated somewhat independently. However, the two systems are interconnected, which makes it difficult in some cases to demarcate the two. This has resulted in overall system inefficiencies in the past. As of today, the Palestinian consumers in the Study Area depend primarily on water provided by "Mekorot" (MWH, 2012).

Most demand centers are located at higher elevations than supply wells, thus booster pump stations are located downstream of all supply wells. There are a few bulk system reservoirs located along the main transmission system and some communities have municipal (local) storage reservoirs. The total storage capacity within the Study Area is approximately 79,000 CM. Communities are served via metered service connections. Many of these service connections are connected directly to the distribution networks without storage (MWH, 2012).

2.6.4 Water network coverage

The total served populations with a water network in Hebron District is more than 95%. These populations are distributed over different types of localities: urban areas, rural areas and camps. Water network coverage is available for all camps and urban areas. Rural areas (villages) are served up to 96%, and the rest are still need piped networks (PWA, 2011).

2.6.5 Water Demand

Water demand for the Study Area is divided into three categories: domestic, industrial, and agricultural irrigation. Domestic demands are intended to cover water usage by individuals. Industrial water demand is any water not used for drinking water or irrigation use, but instead for industrial and non-industrial purposes. Agricultural demands intended to cover water used for irrigation.

It was adopted the World Health Organization standard for the amount needed for drinking and other household uses per capita water and which is set at 150 L/C/D (WHO, 2008), in accounting the demand for water in the Hebron District. Considering the most recent population consensus for mid-2014 was 684,247 inhabitants, the needed amount of water is about 37.46 Mcm/yr.

Industrial facilities are also major users of water in Hebron district, with the principal water-using industries being stone cutting, leather tanning and animal Husbandry. Actual industrial demand data is not accounted for separately in PWA consumption data; the industrial water demand are based on "FINAL REPORT of WATER MASTER PLAN FOR THE SOUTHERN WEST BANK MAY, 2012 performed by MWH under the funding and direction of the United States Agency for International Development (USAID), Contract Number 294-I-00-08-00202-00, Task Order No. 2." of stone cutting facilities and livestock. Stone cutting firms are the largest industrial users of water, many of which are located throughout the Hebron District. Master plan showed that the average use per stone cutting firm ranged from 150 to 400 cubic meters per month (CM/month). Based on this master plan, it is assumed that stone cutting facilities consume 4,000 CM/yr per facility, Data collected identified a total of 287 stone cutting firms in the Hebron District. Also Based on this master plan, there are 459 leather shoe manufacturing facilities in Hebron District in 2011, they assumed each of these leather shoe facilities has a demand of 400 CM/yr. Water demand from animal husbandry is determined by the number of livestock regarding to the Master plan, the total animal husbandry consumption in 2010 is assumed to be 2.0 MCM/yr. Considering the above data the industrial water demand will be 3.33 Mcm/yr.

Actual agricultural demand data of irrigated Cultivated Area of vegetables is based on the amount of water required by each crop annually was collected from Hebron Agricultural Directorate in Ministry of Agriculture, and the Cultivated Area of Vegetables in Hebron District by Crop from Palestinian Central Bureau of Statistics, 2008. Agricultural Statistics, 2006/2007.

Table 2-6 shows the amount of water required by each crop annually which Obtained from Ministry of Agriculture as mentioned in Annex-4 (MoA, 2015).

Table 2-6 Amount of water required by each crop annually

Crop	Amount of water required (m3/Dunums)	
	Plastic House	Exposed
Kidney bean	655	356
Tomato	920	365
Cucumber	842	513
Squash	No data	400
Eggplant	No data	919
Onion	No data	313
Cauliflower	No data	464
Spinach	No data	140
Broad bean	No data	133
Hot Pepper	726	No data

Table 2-7 shows Area of Vegetables in Hebron District by Crop, 2006/2007 (Pcbs, 2008).

Table 2-7 Area of Vegetables in Hebron District by Crop, 2006/2007

Crop	Amount of water required (Dunums)	
	Plastic House	Exposed
Kidney bean	54	150
Tomato	145	335
Cucumber	464	54
Squash	-	388
Eggplant	-	68
Onion	-	193
Cauliflower	-	1,171

Spinach	-	232
Broad bean	-	120
Hot Pepper	-	50

Considering the above data the agricultural water demand will be 1.63 Mcm/yr.

2.6.6 Water leak

Water loss is a known problem throughout the West Bank and is known to occur at both the bulk and municipal distribution systems. Water loss in the bulk system occurs between water sold by PWA and the municipalities, and has been estimated at 20 percent for year 2010, additional water losses at the municipal system (i.e., water loss between municipalities and customers) have been reported to exceed 35 percent of production (PWA, 2010).

2.6.7 Water thefts

Water may also be lost in the system through illegal connections to the pipeline, unmetered connections, and leakage from aging infrastructure. This lead to a daily allocation per capita of 30.40 l/c/d and less (MWH, 2012).

2.7 Wastewater Treatment and Reuse in Hebron district

While the water supply systems have been extended into nearly all communities of Hebron district, the area is lagging significantly in development of wastewater collection and treatment systems. Just the Hebron city 183,312 person (PSPC, 2011) has wastewater collection systems in place which serves approximately 85 percent of the city area, while the other 15 percent is not covered due to difficult topography. The collected wastewater is discharged into wadi As Samen untreated. The untreated wastewater then meanders towards the southwest and ultimately reaches the border between the West Bank and Palestinian territories occupied in 1948 by the Israeli occupation. Field measurements conducted by MWH in 2011 indicate that summer flows of untreated wastewater through Wadi Al Samen range between 7,000 and 12,000 CM/day (MWH, 2011).

Most of other communities in Hebron district do not have wastewater collection systems at all, and the households rely primarily on seepage pits or direct discharge into nearby streams. In many areas, untreated wastewater flows through open environment, where it poses health risks.

2.8 Rainwater Harvesting for Residential Use in Hebron district

Rainwater harvesting has a long history in the area, and many Palestinian houses in the Hebron district are currently fitted with rainwater collection systems and underground cisterns. Some of these systems were built centuries ago. Existing rainwater harvesting systems typically collect rain from the house roof or paved areas near the house and route collected water into an underground cistern (Figure 2.4). Currently, such systems do not include water treatment and removal of debris from emptied cistern is periodically required.

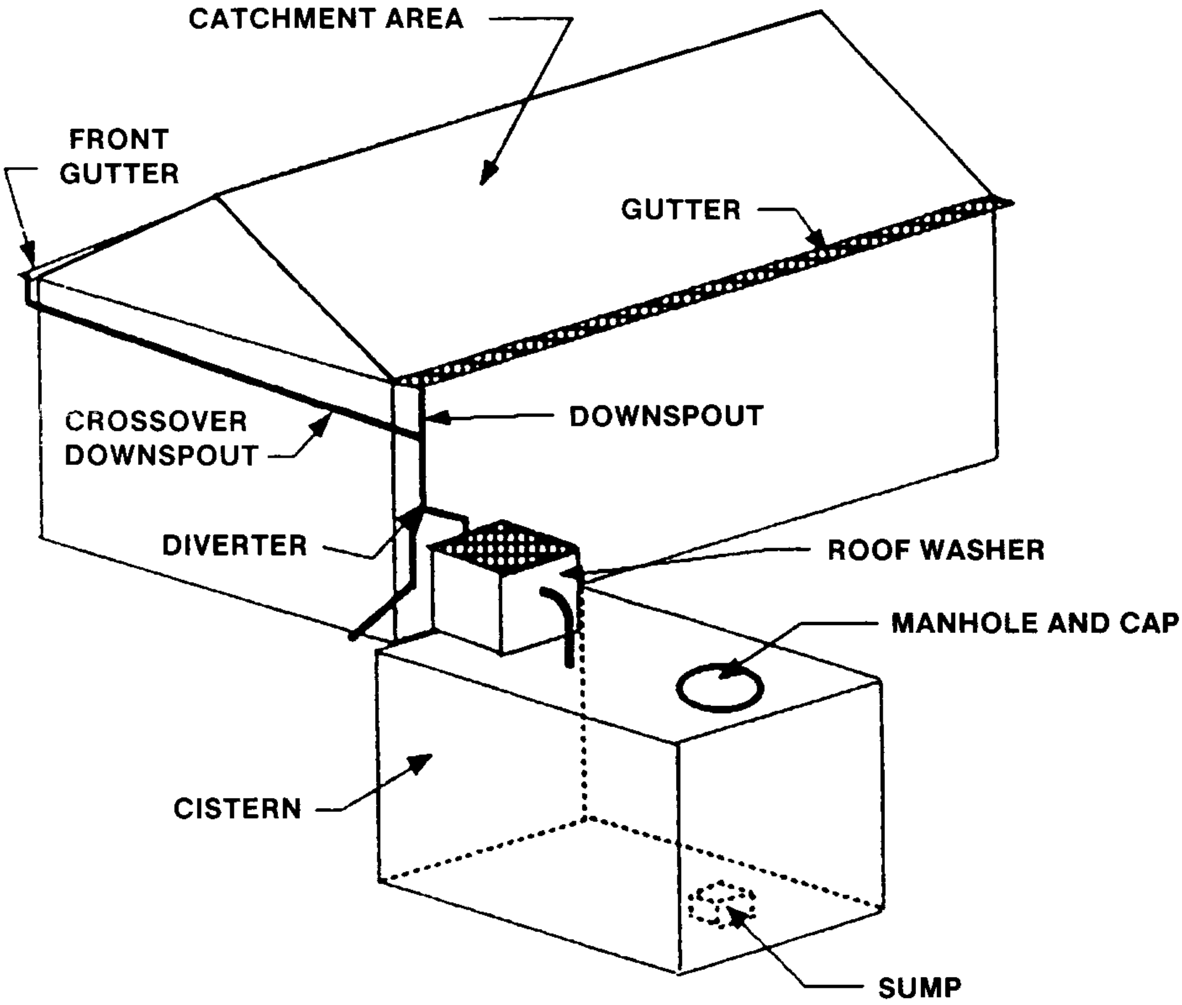

Figure 2.4 Ground water cistern (www.ca.uky.edu)

Rainwater harvested from roofs or paved areas is typically polluted by dust, bird feces, or airborne pollution and may require treatment for potable use.

The amount of water collected by rainwater harvesting systems is restricted by the amount of rainfall, available rainwater collection area, and capacity of underground cisterns.

Most of the storage tanks in Palestine are:

i. Square/Rectangular shaped cisterns

ii. Pear shaped cisterns (conventional).

Usually, concrete cisterns are the most common types of cisterns. The recommended cistern volume is:

i. Single square/rectangular shaped cistern ranging from 50 to 70 cubic meters.

ii. For double square/rectangular shaped cistern ranging from 100 to 120 cubic meters.

iii. The recommended capacity for a pear shaped cistern is between 50-70 cubic meters. (Abdul-Hamid, 2008)

Rainwater harvesting project for large scale could be implemented by Storm water enhancement project across communities in the Study Area by local municipalities, with particular focus on rural and urban population residing in single-family homes. The systems would allow storm water to percolate below the surface and replenish the underlying Eastern Aquifer. In doing so, overall recharge of the Eastern Aquifer would be increased and sustainability of the wells tapping it would be improved.

Almost all the water flowing to Hebron District watersheds comes from the relatively high rainfall areas of the Mountains. The annual volume of precipitation at the study area is 390.72 MCM. As 4.04% of the annual volume of precipitation runs in the wadis as runoff, this means that the volume of annual runoff in this watershed is 15.78 MCM (Awadallah et al., 2005).

2.9 Assumptions Used in Determining Future Water Demand

2.9.1 Future Domestic Water Demand

Currently, the water supplies are not sufficient to meet the water demands. It is expected that water demands will increase in the future as more water supplies become available. water demand per person is expected to increase over time as the water infrastructure improves and becomes more developed, increasing the standard of living and reliability of water delivery. Therefore, the domestic water demand rate is assumed to increase from 150 l/c/d in 2014 to

217.5 l/c/d in 2035. These water consumption rates are based on the assumption that the water loss percentages will decrease.

2.9.2 Future Industrial Demand

Projected industrial demands is assumed to be 6 Mcm/yr.

2.9.3 Future Agricultural Demand

Projected agricultural demands are based on agricultural base year consumption, regarding to the direct meeting with the ministry of agriculture.

2.9.4 Future Water right

The water supply for each person will be 100 liter (UN (OHCHR) , 2010).

2.9.5 Future Rainwater Harvesting

The volume of annual runoff in this watershed is 15.78 MCM (Awadallah et al., 2005).

2.9.6 Future wastewater reuse

Wastewater collection and treatment systems will serve approximately 50 percent of Hebron District so that the flow of untreated wastewater through Wadi Al Samen will be 15.70 Mcm/yr regarding to the data from (MWH, 2011).

2.9.7 Future water demand management

The water consumption will be decrease of more than 50% by introducing a combination of domestic water management options regarding to Nazer et al. (2010). So that the amount of water will be saved with respect to 100 liter / capita / day regarding to (UN (OHCHR) , 2010) is 20.42 Mcm/yr.

2.9.8 Projected Water Loss

Water loss is expected to be less prevalent in the future as leak reduction measures are implemented. A 10 percent water loss goal for the system by 2035. So that the amount of water that will be saved is 6.90 Mcm/yr.

CHAPTER THREE
LITERATURE REVIEW

This chapter is the literature review on water scarcity definition, Falkenmark water stress indicator, Water right, rainwater harvesting, treated wastewater reuse, water demand management and Reduction of water leaks and thefts.

3.1 Water scarcity

Water insecure is defined as: when an individual does not have access to safe and affordable water to satisfy her or his needs for drinking, washing or their livelihoods. Water scarce is defined as: when a large number of people in an area are water insecure for a significant period of time (Rijsberman, 2005).

"Water scarcity refers to the relative shortage of water in a water supply system that may lead to restrictions on consumption" (El Kharraz et al., 2012).

"If we know how much water is needed to satisfy a person's needs then the water availability per person can serve as a measure of scarcity" (Rijsberman, 2005).

3.2 Water scarcity indicators

3.2.1 The Falkenmark Water Stress Indicator

"According to Falkenmark et. al (1989), they proposed 1700 m^3 of renewable water resources per capita per year as the threshold, based on estimates of water requirements in the household, agricultural, industrial and energy sectors and the needs of the environment. Countries whose renewable water supplies cannot sustain this figure are said to experience water stress. When supply falls below 1000 m3 a country experiences water scarcity, and below 500 m^3, absolute scarcity" (Rijsberman, 2005).

3.2.2 The Water Resources Vulnerability Index

Raskin et al. (1997) use Shiklomanov's (1991) basic data on water resource availability, but replace water demand with water withdrawals the total annual withdrawals as a percent of available water resources to present scarcity in what is referred to as a Water Resources Vulnerability Index. Water withdrawals are defined as the amount of water taken out of rivers, streams or groundwater aquifers to satisfy human needs for water. They suggest that a country is water scarce if annual withdrawals are between 20 and 40% of annual supply, and severely water scarce if this figure exceeds 40% (Rijsberman, 2005).

3.2.3 Physical and economic scarcity Indicators

Physically water scarce is called when countries that will not be able to meet the estimated water demands in 2025, even after accounting for future adaptive capacity. Economically water scarce is called when countries that have sufficient renewable resources, but would have to make very significant investment in water infrastructure to make these resources available to people (Rijsberman, 2005).

3.2.4 Water Poverty Index

Sullivan et al. (2003) developed the ‘‘Water Poverty Index’’ that attempts to reflect both the physical availability of water, the degree to which humans are served by that water and the maintenance of ecological integrity (Rijsberman, 2005).

3.3 Water right

- UN (OHCHR) (2010) show that “the water supply for each person must be sufficient and continuous to cover personal and domestic uses, which comprise water for drinking, washing clothes, food preparation and personal and household hygiene. Other domestic water uses, such as water for swimming pools or gardening, do not fall within the scope of the right to water. The right to water therefore covers access to water to sustain life and health and to meet basic needs and does not entitle individuals to an unlimited amount of water.
- According to WHO, 150 L/C/D (WHO, 2008), are needed to ensure that most basic needs are met and few health concerns arise. Access to 20-25 litres per person per day represents a minimum, but this amount raises health concerns because it is insufficient to meet basic hygiene and consumption requirements. These amounts are indicative as they might depend on a particular context and might differ for some groups depending on their health status, work, climate conditions or other factors”.
- Jayyousi et al. (2009) show that the first bilateral agreement between the Palestinians and Israelis was the Declaration of Principles signed on September 13, 1993 (Oslo I). Second bilateral agreement was signed on September 18, 1995 (Oslo II). He showed that Article 40 of the Agreement, was the basis for water sector planning and project

implementation. This binding agreement regarding water and wastewater became the basis for water sector planning during the “interim period”. He showed that the agreement states that the interim period should not exceed 5 years from the date of the signing of Oslo II, or September 2000. And he showed that final status negotiation has not yet taken place, this has left Palestinians with a suboptimal yield and a forced reliance on water purchased from Mekorot.

- Article (5) of Palestinian Water Law (2014) about the right to water access show that “every person has the right to obtain his needs of suitable quality drinking water for utilization at specific prices set in accordance with the Tariff Regulation issued by the Cabinet of Ministers”.

3.4 Rainwater harvesting

- PHG (2003) analyzed water samples from thirty cisterns in Hebron district, of which 12 were collected from the Yatta area and 18 were collected from the Arab Ramadeen area. The samples were collected from household, public and school cisterns. It was found that the pH of some water samples is mostly alkaline. Also it was found that the water is aerobic with DO values of 4.8-6.62 mg/l. Water salinity values were low. Turbidity analysis showed that 6 samples have turbidity values greater than 5 NTU.
- Al-Khatib and Orabi (2004) have a study of the biological characteristic of drinking water in three villages in Ramallah District by testing the total coliforms in samples were collocated from rain-fed cisterns. The results show that 87% of tested samples were highly contaminated, 10.5% had low contamination and only 2.5% were not contaminated.
- Abdul-Hamid (2008) has a study of physical, chemical and biological characteristics for the quality of roof-top harvested rainwater which is used for domestic and drinking purposes in the middle area of the West Bank and the factors affecting it were assessed through wet season surveillance (from Nov., 2005 to April, 2006). The study conducted in Kubar and Abu Shekheidim villages in Ramallah district. The quality of harvested rainwater was assessed for 7 cisterns. The results showed that the samples were alkaline with pH values above 8. This is postulated to the alkaline dust from soil and rock type in this area which is mainly lime and delomite. Also, the results showed that rainwater have very low concentration of TDS of less than 68 mg/l for fresh water samples and below136 mg/l for harvested ones. The turbidity had varied remarkably for the same cistern over time. Some samples had turbidity above 10 NTU while its values went

down after storage then raised again due to the nature of rainfall based on atmospheric conditions; Turbidity test showed that fresh and harvested rainwater mostly did not comply with the Palestinian standards and WHO guidelines (exceeds 5 NTU) due to debris from badly managed rooftops. Also most harvested rainwater samples were found aerobic with DO values range above 6 mg/l while fresh water was more aerobic with DO more than 8.5 mg/l. Total and fecal coliforms were absent in fresh rainwater but its detected respectively in 100% and 86% of the tested harvested rainwater samples; so that the pollution came after storage due to bad management of the whole system and/ or from leakage from nearest cesspits. Samples of harvested rainwater showed low concentration of ions as Ca^{++}, Na^{+}, Cl^{-} and total hardness while the results showed the NO_3 concentration varied from cistern to another. This is might be due to several factors like the status of rooftop and the distance from cesspits. In the cisterns which are closer than 10 m from cesspits, the NO_3 concentration was rather high probably due to ammonium leakage from these cesspits. Also, the results showed harvested rainwater is not contaminated with heavy metals like Cr, Zn and Pb as the measured values fell within the PS41 and WHO guidelines.

- Al-Khatib and Al- Salaymeh (2008) have a study of physical, chemical and biological parameters for the water quality of 100 cisterns in Hebron city through the period from December, 2007 till April, 2008. All the results of physical parameters are within the acceptable limits of WHO, EPA and Palestinian standards except turbidity which exceed these limits in 24 % of the cases. The percentage of contamination of total coliform and faecal coliform was 95% and 57%, respectively. The chemical parameters exceed the standards by different percentages (calcium 47%, magnesium 32%), other parameters give results below the maximum contaminant levels.
- Shadeed and Lange (2010) have a study of Rainwater harvesting to alleviate water scarcity in dry conditions: A case study in Faria Catchment, Palestine Treated, to evaluate the potential for rainwater harvesting in the arid to semi-arid Faria Catchment, in the West Bank, Palestine. The analysis shows that there is a theoretical potential for harvesting an additional 4×10^6 m^3 of surface water over the entire catchment.
- Traboulsi and Traboulsi (2015) have a study of Rooftop level rainwater harvesting system in Lebanon, the results showed that if widely adopted in Lebanon, this technique can be an important alternative to increase available domestic water and sustain groundwater and Lebanon could harvest around 23 Mcm of rainwater a year and thus cover around 70% of the current deficit in the domestic water supply estimated

at 33 Mcm. The proposed rainwater harvesting system is intended to collect and store rainwater in the already existing roof water tanks. It is far cheaper than the ordinary rainwater harvesting systems as it eliminates the need for a special ground or underground storage tank, submersible pump, first flush diverter and other less expensive materials. It could harvest as much as 196 m^3 a year if installed on a rooftop of 400 m^2 and receives an average yearly rainfall of 765 mm like the city of Beirut in Lebanon.

Figure 3.1 Schematic diagrams for rainwater harvesting systems (Traboulsi and Traboulsi, 2015)

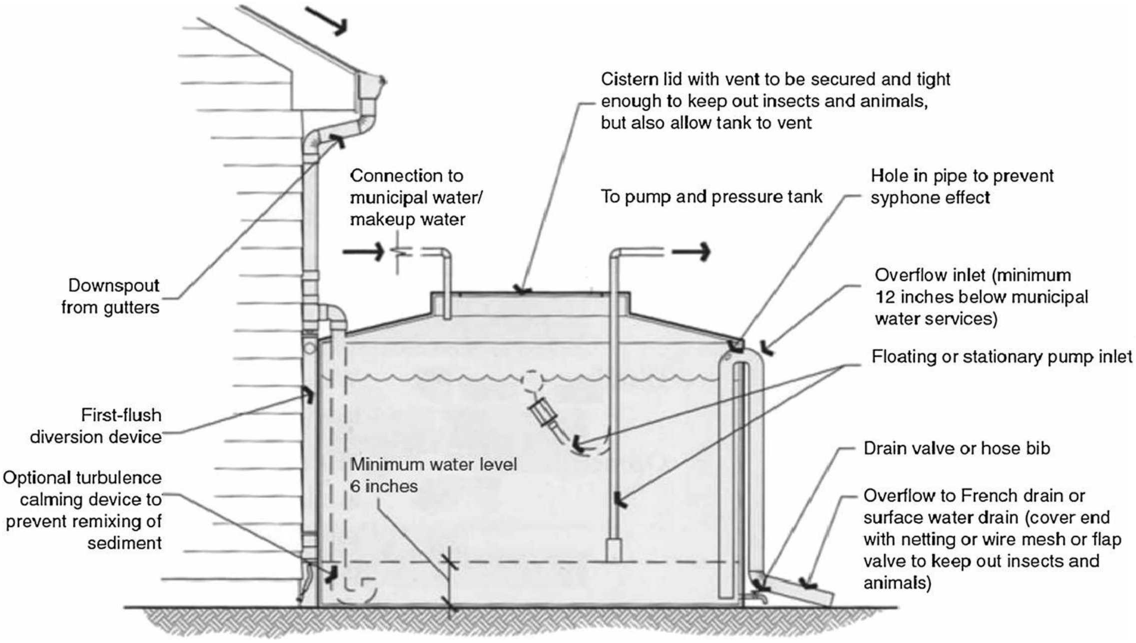

Figure 3.2 The plumbing diagram for a rainwater harvesting system (Traboulsi and Traboulsi, 2015)

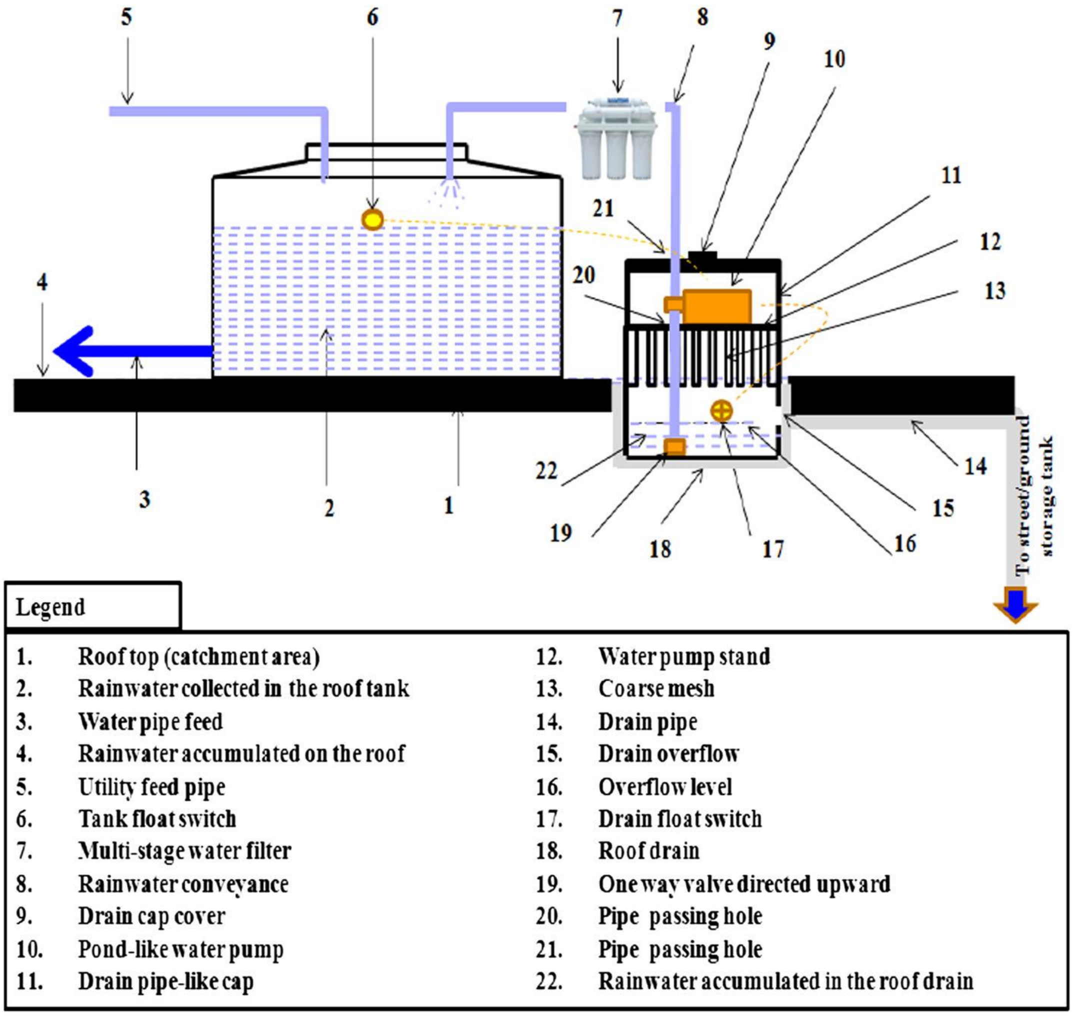

Figure 3.3 Rooftop level rainwater harvesting system (Traboulsi and Traboulsi, 2015)

3.5 Treated wastewater reuse

There is a critical lack of wastewater system in the Hebron district . Most domestic sewage is disposed of into unlined cesspits or septic tanks, or directly discharged to the environment without treatment. Reuse of treated (reclaimed) wastewater has great potential to alleviate limited Water resources. There are many study to implementing wastewater reuse.

- McNeill et al. (2009) have study reusing treated wastewater in agricultural irrigation in the West Bank town of Tubas to get A sustainable approach. The result showed that the town of Tubas and neighboring communities do not have any infrastructure for centralized collection and treatment of wastewater. The current utilization of cesspits for wastewater disposal has a negative impact on the underlying groundwater resources, so the construction of a wastewater collection network and treatment plant is imperative. The area is heavily reliant on agriculture, but suffers from water scarcity. The reuse of treated wastewater can greatly improve environmental conditions and enhance agricultural activities. Successful implementation of the reuse project requires proper engineering design as well as consideration of social and cultural factors. A detailed survey of public opinion and development of an education plan to encourage acceptance of treated wastewater by farmers and consumers will improve stakeholder participation.
- Al-Sa`ed and Arafat (2012) have a study of The Role of Public Awareness Towards Sustainable Use of Treated Wastewater in Agricultural Irrigation, for three targeted group Students, women and farmers in three villages Anza, Beit Dajan and West Bani Zaid in west bank. The researcher found that about 91% of students showed knowledge about wastewater definition, while 88% know about wastewater definition before conducting workshops. The majority of farmers agrees and supports the idea of constructing a WWTP in their villages where the workshops was promote and increase their willingness to reusing treated wastewater for agriculture. The research concludes that training and public awareness programs must be conducted to raise the knowldgment about the wastewater treated uses in order to ensure the sustainability of WWTP, and wastewater-related topics have to be introduced throughout school curriculum in Palestine to be learned for the students in all school grades.
- Al-Zboon and Al-Ananzeh (2008) have a study on Performance of wastewater treatment plants in Jordan and suitability for reuse, characteristics of wastewater for four wastewater treatment plants were determined. Characterization of wastewater was evaluated in terms of measuring BOD, COD, TSS, TDS, NH_4 and DO for the influent

and the effluent wastewater from the selected plants. The quality of the treated wastewater was compared with Jordanian standards. Results indicate that municipal wastewater in Jordan contains high concentrations of pollutants such as BOD, COD, TSS and NH_4; therefore it is classified as a strong waste. The performance of the four treatment plants was evaluated. Conventional and modified activated sludge show good performance, while low water quality is produced by stabilization ponds. The effluent from activated sludge treatment plants complies with Jordanian standards for restricted use. Before reuse, effluent wastewater needs advanced treatment to prevent its impact on human health and the environment.

- Shibao et al. (2015) have a study on method of domestic wastewater treatment through new-type multi-layer artificial wetland. This paper introduces a new-type multi-layer artificial wetland for treatment of domestic sewage, and analyzes the removing effects of COD_{Cr}, BOD_5, NH_3-N, TN and TP in this approach. The results indicate that when hydraulic loading reaches approximately 0.44 $m^3/(m^2$ d) and hydraulic retaining duration reaches 3 days, the effect of removing COD_{Cr}, BOD_5, NH_3-N, TN and TP from the wetland is relatively good, and the average removing rate achieves 90.6%, 87.9%, 66.7%, 63.4 and 92.6% respectively, and the effluent COD_{Cr} reaches approximately 14.1~30.8 mg/L, BOD_5 reaches approximately 8.2~13.1 mg/L,NH_3-N reaches approximately 9.9~19.6 mg/L, TN reaches approximately 17.3~28.7 mg/L and TP reaches less than 1.2 mg/L. Thus the effluent exceeds farmland irrigation water quality standards (GB5084-2005). Such factors as planting density, temperature variation and influent contaminant concentration have relatively great correlation with efficiency of wetland treatment. Generally speaking, when the temperature is higher than 24°C, the higher planting density and lower contaminant concentration reaches, the better effect of the treatment would realize.
- Anwaruddin et al. (2014) have a study on Constructed Wetland of Lepironia Articulata for Household Greywater Treatment, the main purpose of this study was to investigate the grey water loading characteristics, provide appropriate on site mini wetland and to measure the effectiveness of the wetland treatment system. The grey water samples were collected from the effluent of single house, at influent, pre-treatment model (particle material), mini wetland model (plant tube sedge Lepironia Articulata), and control model (without plant) at two sampling period. The concentrations of parameters in the influence of raw grey water were 309 mg/L of BOD, 1103 mg/L of COD, 153 mg/L of SS, 3.83 mg/L of AN, and 132 NTU of turbidity. The mini wetland model

shows high removal performance of 81.42 % BOD, 84.57 % COD, 39.83 % AN, 54.70 % SS, and 45.01 % turbidity. Generally, the results show that the constructed mini wetland was effective to remove contaminants and suitable for treatment of grey water sources.

3.6 Water demand management

To mitigate water scarcity we need to make some basic changes in water management. There are many study about Water demand management.

- Nazer (2009) has a study on A Strategy for Sustainable Water Management in the West Bank, Palestine, by discussing Three scenarios; the "do-nothing" scenario which assumes that the existing water availability will encounter no change due to the existing political situation which allows the Israelis to restrict the water availability while the population is increasing, thereby increasing the water demand. The "water stress" scenario assumes that the water availability will increase due to improved negotiations between Palestinians and Israelis; however, population growth and the development and improvements in the social, commercial, industrial and environmental sectors will increase the demand for water. The "sustainable water use" scenario proposes a strategy for the sustainable water management. She conclude that, Under both the "do-nothing" and "water stress" scenarios there is an increasing gap between water availability and water demand. The gap between water availability and water demand from Palestinians in the West Bank can be closed by gradually introducing water management alternatives that increase the availability (through rain-water harvesting) and reduce the demand through water conservation options as well as re-use options. The proposed alternatives in the industrial sectors proved to be financially feasible on the basis of the existing water price. In the domestic sector the proposed methods were financially infeasible because of the high investment required for the new interventions. However, the social benefits gained from improved health and social life, not included in the calculations, may justify these investments. In the agricultural sector the proposed methods were financially infeasible because of existing low prices for agriculture. Increasing water prices in the agricultural sector will motivate farmers to use treated used-water for irrigation. Legislation and regulations regarding the introduction of these alternatives is an important supporting tool. Awareness and education about water scarcity and potential methods for dealing with it is crucial to achieve effective management.

- Al-Ansari et al. (2014) have study Water Demand Management in Jordan. A sample of 15-year complete record for water consumption was investigated. The results showed that water deficit is increasing with time. To overcome the water deficit between supply and demand, it is believed that water demand management program should be adopted. Such a program will help reduce water use and water loss through the distribution supply net, prevent pollution and waste water disposal in nature, make efficient use of available water resources, plan for future new water resources prudently, and finally impose a real cost for water supply that would be acceptable. Water demand management program will redefine water allocation priorities (such as reducing agricultural water use), and help develop new technologies for use of non-conventional water resources (example waste-water recycling). To protect public health and the environment, water quality degradation should be reversed. In addition to the above, public awareness program is to be put in action. It is noteworthy to mention that public awareness program is to be adopted which will make people aware of the seriousness of the problem so that they can contribute to solving it by changing the water consumption pattern.
- Nazer et al. (2010) have study A Financial, Environmental and Social Evaluation of Domestic Water Management Options in the West Bank, Palestine, the aim of this study to evaluate domestic water management options suitable for Palestinian conditions that contribute to achieving water sufficiency in the domestic water use in the house of tomorrow. A number of options were evaluated economically, environmentally and socially using the concept of life cycle impact assessment (LCIA). Results of the study showed that by introducing a combination of domestic water management options, a substantial decrease in the water consumption of more than 50% can be achieved, thereby reducing the pressure on the scarce water resources. The annual environmental impact of the in-house water use can be reduced in the range of 8%, when using low-flow shower head to 38% when using rainwater harvesting systems. Some of the options (faucet aerators, low-flow shower heads and dual flush toilets) were found to be financially attractive with a payback period of less than their expected lives, others (rainwater harvesting, gray water reuse and dry toilets) were found to be financially unattractive because of the high investment. In the social context, it was found that introducing such options can improve the quality of life of those not having enough water. There is already a popular willingness to take part in water conservation in the domestic sector in the West Bank. The strongest driving force

for using water conservation measures is the awareness that water is a scarce resource. It was concluded that, theoretically, the house of tomorrow can be largely independent in terms of water and sanitation. Education and awareness campaigns in the context of water management with a focus on non-traditional options are key to achieve such a house.

3.7 Reduction of water leaks and thefts

- Frauendorfer and Liemberger (2010) have a study of the Issues and Challenges of Reducing Non-Revenue Water (NRW). The main objective of this discussion paper is to provide the basis for a substantive dialogue on NRW between key decision makers at the municipal level, including local government officials, management of water utilities, civil society, and other stakeholders. It aims to raise awareness on key issues surrounding NRW, including the magnitude of the NRW problem in Asian cities, reasons why NRW management is often not practiced, international terminologies and methodologies for improving NRW management, and the importance of using appropriate performance indicators. The result of the paper showed that One of the problems that can be addressed is the lack of NRW management in engineering curricula at colleges and universities.
- Joaquim et al. (2015) have a study of Locating leaks in water distribution networks with simulated annealing and graph theory, this paper presented a methodology that uses a hydraulic model of the water distribution networks to quickly and economically identify probable leaky pipes. This methodology is based on pressure measurements and explores the exchange of information between an optimization model and the hydraulic simulation of the water distribution networks in steady state conditions. The pressure transducer placement was carried out by a novel tool based on the graph theory concepts, specifically developed to select the monitoring nodes, demonstrating the ability to gather the necessary information for the leak location methodology to work. The optimization model used to identify the leaky pipes was solved by a simulated annealing algorithm, a reliable, fast, and easy to implement method. The results obtained with a single or with two simultaneous leaks at different locations showed that are very encouraging. The implementation of the methodology does not affect the regular activity of the water distribution networks and it was able to help active leakage control activities. Results showed that, in general, the methodology

identified a small number of pipes, confining the on-field works to a considerably reduced extension of the water distribution networks.

CHAPTER FOUR
APPROACH AND METHODOLOGY

This chapter presents the research methodology. This chapter discusses the methodology adopted in the data collection phase and data analysis procedures.

4.1 Research Approach

Research approach and methodology adopted in this study was based on multiple methods. Scientific papers were reviewed on water scarcity, water right, rainwater harvesting, treated wastewater reuse, water demand management and Reduction of water leaks and thefts. Interviews were held with representatives of the water sector in the district like Palestinian Water Authority, West Bank Water Department, Ministry of Agriculture and municipalities as an aid to reveal essential primary data. The collected data was used to determine the quantities of water that will obtain from each option.

The survey was conducted to re-confirm the results and to provide additional solutions to enhance the situation.

The key steps in the research approach process shown below:

(1) How much is the water stress indicator in the Hebron District?

By calculating water required to satisfy a person's needs in the household, agricultural and industrial sectors in Hebron District, and calculating water availability per person for household, agricultural and industrial sectors in Hebron District, then by subtract water availability from water required will get the :

"Falkenmark water stress indicator (The current situation)"

(2) What options are available in the Hebron district can contribute in mitigating the water scarcity?

The available options in Hebron District that can contribute in mitigating the water scarcity are: water right, rainwater harvesting, treated wastewater reuse, water demand management and Reduce water leaks and thefts. Water quantity produced by applying these option in ideal situation will be calculated and will be added to the available water in Hebron District to check how much water stress indicator will get better.

criteria / Available Options	Quantity (Mcm)
Water right	
Rainwater harvesting	
Treated wastewater reuse	
Water demand management	
Reduction of water leaks and thefts	

(3) How can each of these options contribute to augmenting water availability?

Water quantity produced by applying these option in real situation taking into consideration political situation, Economical situation, Environmental situation, Social situation and Technical availability, will be calculated, and will be added to the available water in Hebron District to check how much water stress indicator will be at 2035.

"Falkenmark water stress indicator (Due to Water right)".
"Falkenmark water stress indicator (Due to Rainwater harvesting)".
"Falkenmark water stress indicator (Due to Treated wastewater reuse)".
"Falkenmark water stress indicator (Due to Water demand management)".
"Falkenmark water stress indicator (Due to Reduction of water leaks and thefts)".
"Falkenmark water stress indicator (Due to Integrate Available Options all together)".

(4) Carry out survey

4.1. Identifying the main causes of water scarcity and the weight of effect

Main causes	**Weight of effect %**										
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**	***remarks***
Water resources											
Water supplied quantity											
Water consumption quantity											
rate of natural population growth											
Pollution											
Infrastructures											

Political situation											
Economical situation											
Financial situation											
others, (please specify)…….											

4.2. Arranging the most effective available options to mitigate water scarcity in the District

effective solutions	**Rank**	**Describe**
To reach a solution to the Palestinian-Israeli conflict on the water right		
Using rainwater harvesting system		
Collecting wastewater, treating and reuse		
Improving water demand management		
Improving institutional expertise and needs		
Improving water infrastructures and efficiency		
Reducing water leak		
Reducing water thefts		
Protecting natural water resources		
Water demand management to Reduce excessive water consumption (excluding drinking water)		
Others, please specify		

4.3. Determine problems that influence applying available options to mitigate water scarcity in the District, and the weight of effect

Main Problems	**Weight of effect %**										
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**	***remarks***
Water price											
Political											
Social											
Economical											
Financial											
Institutional											
Management											
Technical and experts											
Infrastructures											
others, (please specify)…….											

4.2 Data Collection

Data were collected through scientific papers and books. and It has been also collecting data used to calculate the amount of water from several sources, mainly the Palestinian Water Authority, the West Bank Water Department and the Palestinian Ministry of Agriculture. meetings were held with officials of these institutions to get the relevant information topics and identify problems and causes of the problem and possible solutions.

The field-study consisted of a survey (questionnaire) of twenty five institutions which responsible of water sector in the region. A list of these institutions, are mentioned in Annex-2. Interviews were held with representatives of the water sector in the district like Palestinian Water Authority, West Bank Water Department, Ministry of Agriculture and Municipalities as an aid to reveal essential primary data.

The questions asked aimed to gather information on:

- The available options to mitigate water scarcity in Hebron District.
- Effective solutions to mitigate water scarcity
- Problems that influence applying available options to mitigate water scarcity in the District.

4.3 Analytical Procedures

Analysis was adopted in this research in general by calculating the value of the Falkenmark index, based on the available amount of water, and the amount of the required water for domestic, agricultural and industrial use, for the present situation and the future situation in 2035.

The formula used for determine Falkenmark Index :

"The water stress indicator = water availability per person for domestic, agricultural and industrial sectors".

For the present situation: Falkenmark Index was calculated based on the current renewable water resources in Hebron District, with respect to the current water required to satisfy a person's needs in the household, agricultural and industrial sectors.

For the future situation in 2035: Falkenmark Index was calculated based on:

- The current renewable water resources in Hebron District without applying the available options for mitigating water scarcity, with respect to the future water required to satisfy a person's needs in the household, agricultural and industrial sectors.

– The Future renewable water resources in Hebron District by applying the available options for mitigating water scarcity each alone, with respect to the future water required to satisfy a person's needs in the household, agricultural and industrial sectors.
– The Future renewable water resources in Hebron District by applying the Integrated available options for mitigating water scarcity, with respect to the future water required to satisfy a person's needs in the household, agricultural and industrial sectors.

The aggregated data from the surveys and questionnaires is used to determine the main causes of water scarcity, the best available options to mitigate water scarcity and the problems that influence applying available options to mitigate water scarcity.

CHAPTER FIVE
RESULTS AND DISCUSSION

This chapter discusses the results of current water stress indicator in the Hebron District, the results of the water stress indicator after applying the available options. The results of the questionnaires are discussed in the next section.

5.1 The Falkenmark water stress indicator in the Hebron District (The current situation)

The water stress indicator = water availability per person for household, agricultural and industrial sectors.

Water required to satisfy Hebron district needs in the household sector = {150 (L/c/d (WHO, 2008)) x 684247 (capita at 2014) x 365 (d/yr) x 1^{-9} (Mcm/L)} = **37.46 Mcm/yr**.

Water required to satisfy Hebron district needs in agricultural sector = **1.63 Mcm/yr**, (MoA, 2015).

Water required to satisfy Hebron district needs in industrial sector = **3.33 Mcm/yr**, (MWH, 2012).

Total water required to satisfy Hebron district needs in the household, agricultural and industrial sectors = **42.42 Mcm/yr.**

Water availability for household, agricultural and industrial sectors in Hebron district regarding to (PWA, 2012) after deducting water loss and water thefts = **10.97 Mcm/yr**

➔ The current renewable water resources in Hebron District = **(16.03 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

5.2 The Falkenmark water stress indicator in the Hebron District at 2035 without applying the available options for mitigating water scarcity in Hebron District

Water required to satisfy Hebron district needs in the household sector = {217.5 (L/c/d) x 1118662 (capita at 2035) x 365 (d/yr) x 1^{-9} (Mcm/L)} = **88.81 Mcm/yr**

Water required to satisfy Hebron district needs in agricultural sector = **1.63 Mcm/yr**, (MoA, 2015).

Water required to satisfy Hebron district needs in industrial sector = **6 Mcm/yr**, (MWH, 2012).

Total water required to satisfy Hebron district needs in the household, agricultural and industrial sectors at 2035 = **96.44 Mcm/yr**

Water availability for household, agricultural and industrial sectors in Hebron district regarding to (PWA, 2012) after deducting water loss and water thefts = **10.97 Mcm/yr**

➔ The Future renewable water resources in Hebron District (without applying the available options) = **(9.81 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

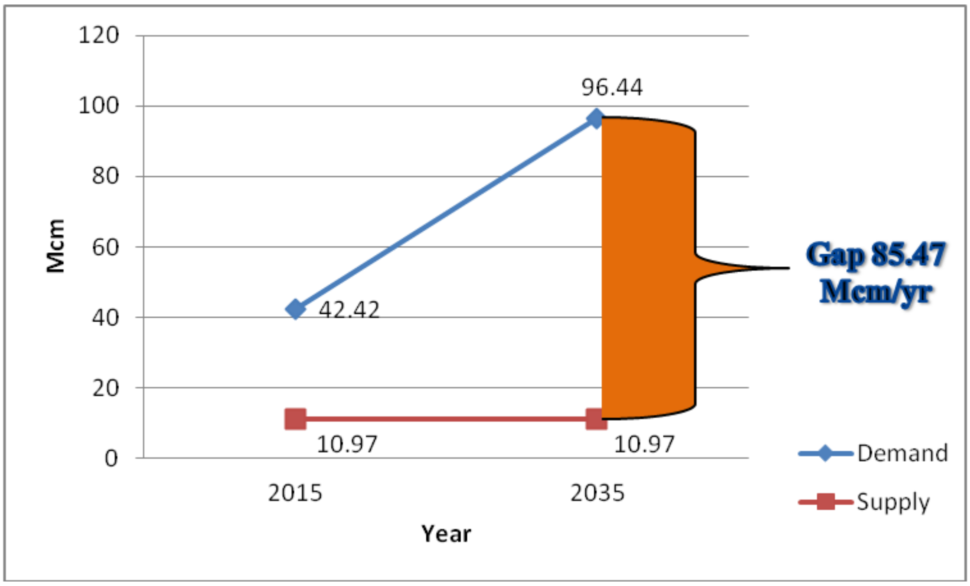

Figure 5.1 Future water demand and Future water supply (Mcm/year) "without applying the available options"

5.3 The Falkenmark water stress indicator in the Hebron District at 2035 if we applied the available options for mitigating water scarcity in Hebron District

Water required to satisfy Hebron district needs in the household sector = {217.5 (L/c/d) x 1118662 (capita at 2035) x 365 (d/yr) x 1^{-9} (Mcm/L)} = **88.81 Mcm/yr**

Water required to satisfy Hebron district needs in agricultural sector = **1.63 Mcm/yr**, (MoA, 2015).

Water required to satisfy Hebron district needs in industrial sector = **6 Mcm/yr**, (MWH, 2012).

Total water required to satisfy Hebron district needs in the household, agricultural and industrial sectors at 2035 = **96.44 Mcm/yr**

5.4.1 water right

Water availability for household, agricultural and industrial sectors due to water right and 10% water loss at 2035 = 36.75 Mcm/yr

➔ The Future renewable water resources in Hebron District due to water right = **(32.85 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

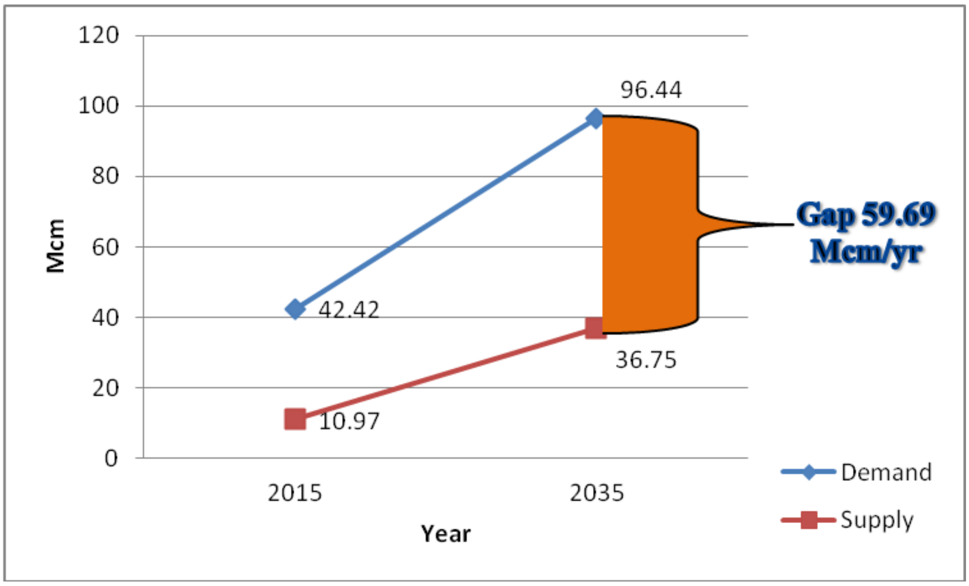

Figure 5.2 Future water demand and Future water supply (Mcm/year) "due to water right"

5.4.2 Rainwater harvesting

Water availability for household, agricultural and industrial sectors due to rainwater harvesting at 2035 in addition to water supplied = 15.78 + 10.97 = 32.65 Mcm/yr

➔ The Future renewable water resources in Hebron District due to rainwater harvesting = **(29.19 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

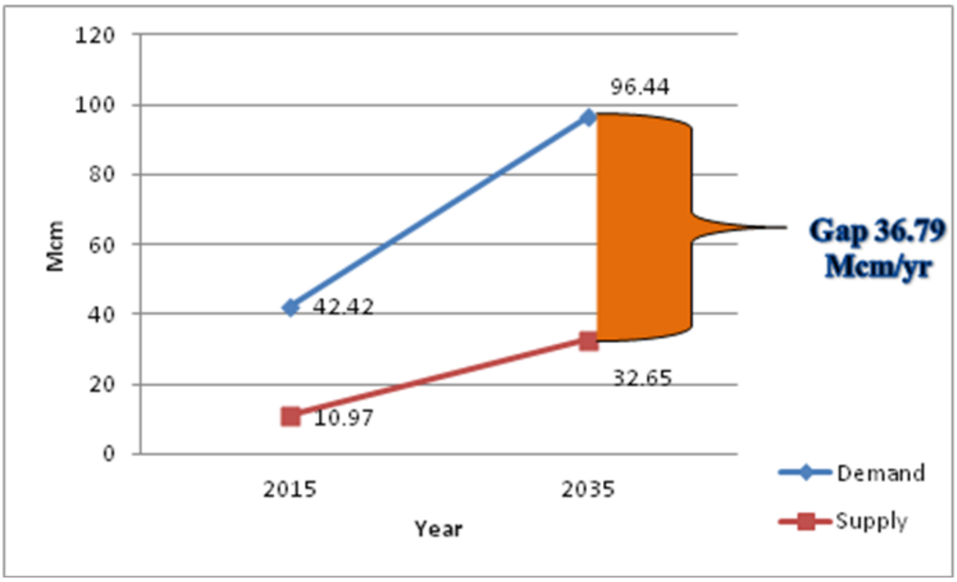

Figure 5.3 Future water demand and Future water supply (Mcm/year) "due to rainwater harvesting"

5.4.3 treated wastewater reuse

Water availability for household, agricultural and industrial sectors due to treated wastewater reuse at 2035 in addition to water supplied = 15.70 + 10.97 = 26.67 Mcm/yr

➔ The Future renewable water resources in Hebron District due to wastewater reuse = **(23.84 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

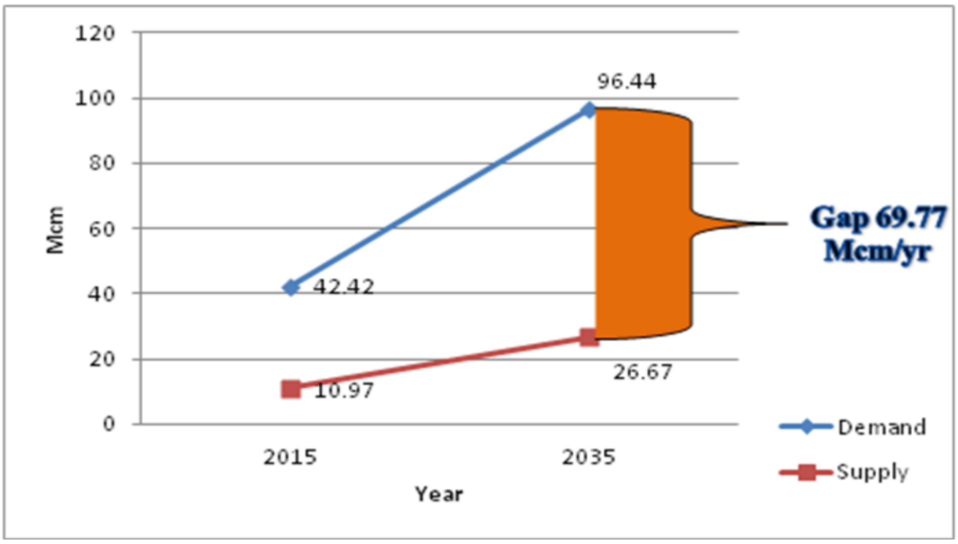

Figure 5.4 Future water demand and Future water supply (Mcm/year) "due to wastewater reuse"

5.4.4 water demand management

Total water required to satisfy Hebron district needs in the household, agricultural and industrial sectors at 2035 = 96.44 Mcm/yr.

Water conservation measures, a substantial decrease in the water consumption of more than 50%, Nazer et al. (2010).

➔ Total water required to satisfy Hebron district needs in the household, agricultural and industrial sectors at 2035 = 50% x 96.44 = 48.22 Mcm/yr.

Water availability per person for household, agricultural and industrial sectors at 2035 is the water supplied = 10.97 Mcm/yr

➔ The Future renewable water resources in Hebron District due to water demand management = **(9.81 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

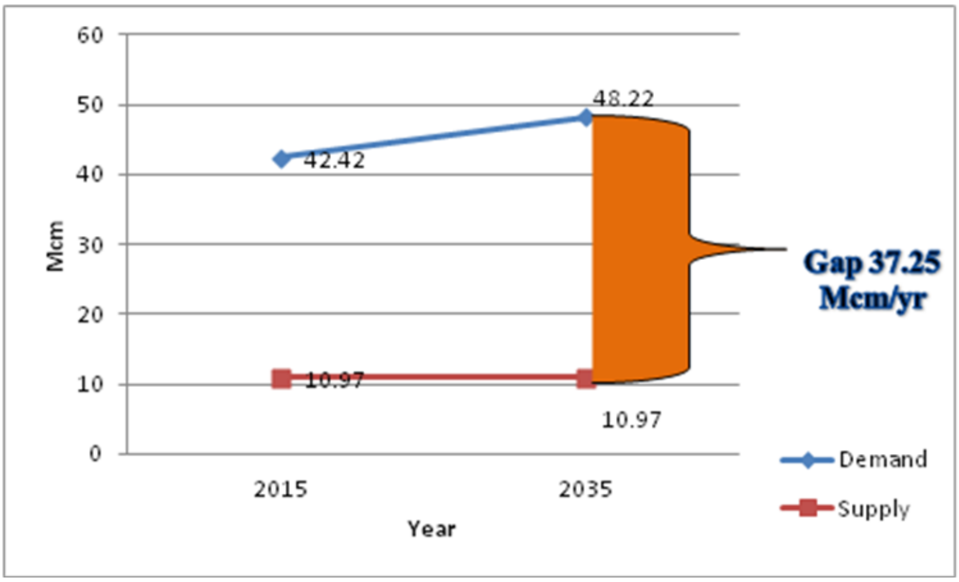

Figure 5.5 Future water demand and Future water supply (Mcm/year) "due to water demand management"

5.4.5 Reduction of water leaks and thefts.

Water availability for household, agricultural and industrial sectors due to Reduce water leaks and thefts at 2035 in addition to water supplied =6.90 + 10.97 = 17.87 Mcm/yr

➔ The Future renewable water resources in Hebron District due to Reduce water leaks and thefts = **(15.97 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

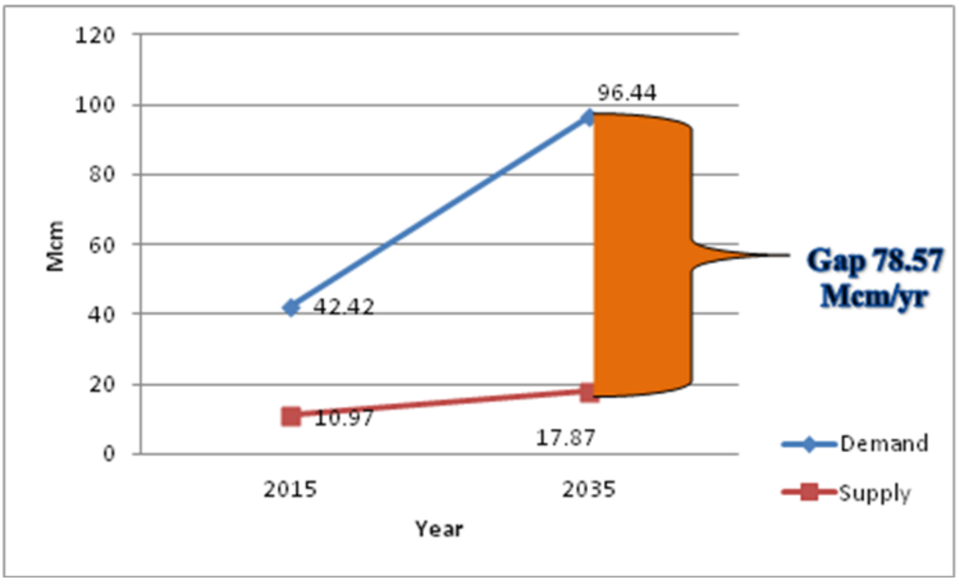

Figure 5.6 Future water demand and Future water supply (Mcm/year) "due to Reduce water leaks and thefts"

5.4.6 Integrate Available Options all together

Water availability for household, agricultural and industrial sectors due to Integrate Available Options all together at 2035 = 36.75 + 15.78 + 15.70 + 10.97 + 6.90 = 86.10 Mcm/yr

➔ The Future renewable water resources in Hebron District due to Integrate Available Options all together = **(85.41 cm/c/y)** which is below 500 cm/c/y. According to Falkenmark et. al (1989), Hebron District experience **absolute scarcity**.

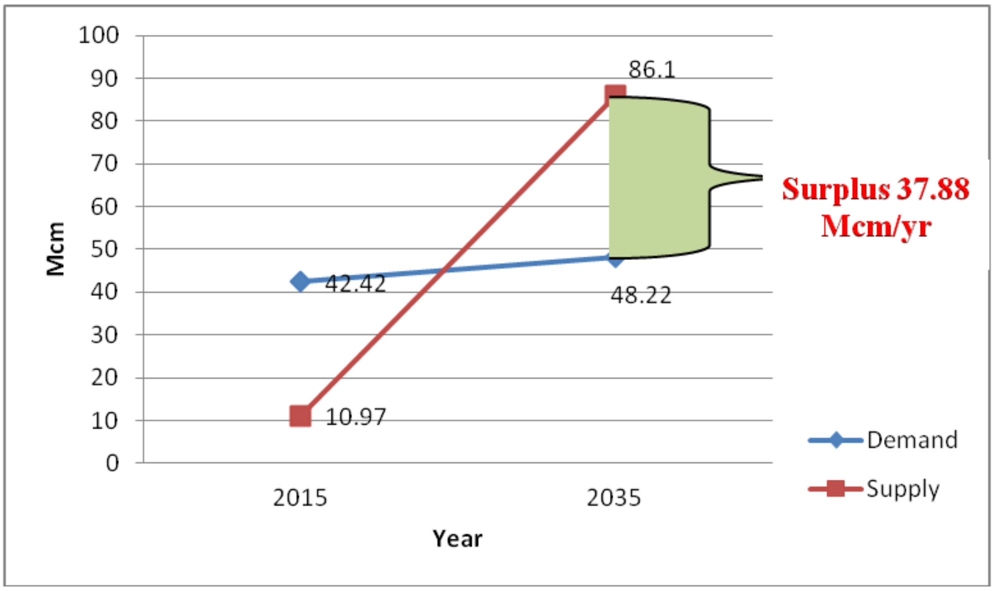

Figure 5.7 Future water demand and Future water supply (Mcm/year) "due to Integrate Available Options all together"

5.4 Questionnaire Analysis

As outlined in Chapter 4, 25 questionnaires were distributed among responsible of water sector in the region to obtain indicator values of the main causes of water scarcity, most effective available options to mitigate water scarcity in the District and The problems that influence applying possible options to mitigate water scarcity in the District. Results of the survey showed that:

5.4.1 "Is Water scarcity experienced by people?", the responses showed that:

- Irregular access of water.
- Lack in the amount of supplied water , especially in summer.
- Interruption of access to water to some neighbourhoods for a period of 3-4 months in the summer.
- Presence of awareness programs from some institutions gave citizens a look at the presence of water scarcity.
- make a complaint to institutions and municipalities about lack of provided water.
- Protests of some citizens in some areas for lack of supplied water in summer.
- Weakness of water pressure in the network during the summer.
- Not being able to irrigate crops.
  - The high price of meter cube of supplied water through tankers which up to 45 NIS.
  - Factories are supplied with water through tankers.

- People believed that the water available but can’t be obtained.

5.4.2 “Are the institutions directly confronted with water scarcity?”, the responses showed :

- PWA:
    - Water resource management and follow-up water supply to communities in the district.
    - Intervention in the development of distribution policies if possible during the seasons were there excess demand for water like summer.
- WBWD:
    - Wholesale water distribution to local councils and municipalities according to the justice according to the quantities available within the distribution programs.
- MoA:
    - Through the construction of wells for collecting rain water, and restoration of old wells.
    - Through water harvesting projects in agricultural areas.
    - Rehabilitation of springs.
    - Construction of earth dams (such as the Bani Naim Dam and Bait Al-Rosh dam).
- EQA:
    - Indirectly through environmental approval requests in terms of: the amount of water used, its source, its use, and the extent of the impact of the project on groundwater.
- MoNE:
    - Working to provide water to the factories in reasonable quantities for the development of the industrial sector, especially the stone factories.
- MOLG:
    - Through coordination between local councils and the Department of Water, and study the needs of the local councils for sufficient quantities to population.
- HG:
    - Awareness to change the behaviour of the individual in dealing with water.
    - Improved the available water sources such as springs.
    - Wastewater reuse.

- Rehabilitation of water networks to reduce leaks.
- working on a variety of activities such as ingathering wells for schools and areas.

- ANERA:
  - Implementation of projects of drinking water systems and rainwater drainage systems.

- ACF:
  - Development of alternative sources such as partial dependence on rain water.
  - restoration the old networks to reduce leaks.

- Municipalities:
  - Working to increase the amount of water supplied from PWA.
  - Prevent agricultural subscriptions.
  - Establish reservoirs and main pipes to control the distribution of water in a fair.
  - Securing water tanks to be sold to citizens at affordable prices.
  - Establish Water pumps for a fair distribution of water.
  - Making a program for the distribution of water to all districts.
  - Bring the media to highlight the problem.

- WSRC**:**
  - Indirectly to ensure justice in the distribution and monitoring on prices.

5.4.3 "The Main Problem of water scarcity", the responses showed that:

- Water agreement between the Israelis and the Palestinians did not take into account the natural increase in the population.
- Israelis control on the sources, constraints and obstacles to the development of sources and digging wells.
- Weak management of the water sector by the PWA and WBWD.
- Distribution of water supplied by the PWA to the areas is unfair.
- Inaction of the PWA in the provision of other sources and mismanagement.
- There are some areas on one line of the grid leads to the non-arrival of quantity supplied as a result of losses along the grid.
- The lack of wastewater treatment plants and the lack of sanitation networks for all areas.
- Not using the methods of water harvesting.

- Lack of surface water availability.
- Lack of commitment by the municipalities in the distribution programs provided by the WBWD.
- Mismanagement of the municipalities and local councils for the springs in the region.
- The high percentage of losses as a result of weakness and the old age of infrastructure.
- Infringements on transmission and distribution lines.
- Increasing the population.
- Competition among the population to get water, especially in the economic activities
- Increased demand for water compared to the quantity of water supplied to citizens especially in the summer.
- Lack of domestic wells for all homes.
- The lack of rainfall and fluctuating precipitation.
- Environmental and climatic reasons.

5.4.4 “The main causes of water scarcity and the weight of effect”, the responses showed that water supplied quantity and the political situation are the main causes of the water scarcity in the district with weight of (90%), then water resources with weight of (80%),then water consumption quantity and Economical situation with weight of (55%), then rate of natural population growth, Infrastructures and Financial situation with weight of (50%), the last is Pollution with weight of (30%). The Table (5-1) and Figure (5.1), showed the results obtained from SPSS.

Table 5-1 Statistics for Identify the main causes of water scarcity Hebron District and the weight of effect (Source Questionnaire)

		Water resources	Water supplied quantity	Water consumption quantity	rate of natural population growth	Pollution	Infrastructures	Political situation	Economical situation	Financial situation
No	Valid	24	25	24	25	25	25	24	22	25
	Missing	1	0	1	0	0	0	1	3	0
Median		80.00	90.00	55.00	50.00	30.00	50.00	90.00	55.00	50.00

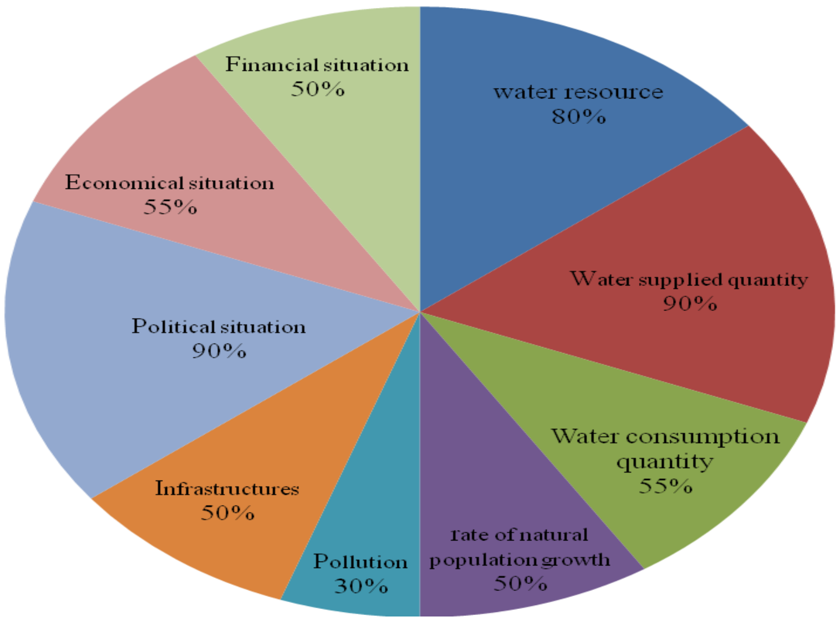

Figure 5.8 The main causes of water scarcity in Hebron District and the weight of effect (Source Questionnaire)

5.4.5 "The most effective available options to mitigate water scarcity in the District", the responses showed that To reach a solution to the Palestinian-Israeli conflict on the water right is Most effective available options to mitigate water scarcity in Hebron District, then Improving water demand management and Improving water infrastructures and efficiency, then using rainwater harvesting system, Reducing water leak and Reducing water thefts, then collecting, treating and reuse wastewater, improving institutional expertise and needs and Protecting natural water resources, the last is Water demand management to Reduce excessive water consumption (excluding drinking water). The table (5-2) and Figure (5.2), showed the results obtained from SPSS.

Table 5-2 Statistics for Arranging the most effective available options to mitigate water scarcity in Hebron District (Source Questionnaire)

		To reach a solution to the Palestinian-Israeli conflict on the water right	Using rainwater harvesting system	Collecting wastewater, treatment and reuse	Improving water demand management	Improving institutional expertise and needs	Improving water infrastructures and efficiency	Reducing water leak	Reducing water thefts	Protecting natural water resources	Water demand management to Reduce excessive water consumption (excluding drinking water)
N	Valid	25	24	25	25	25	24	24	25	25	24
	Missing	0	1	0	0	0	1	1	0	0	1
Median		10	7	6	8	6	8	7	7	6	4.5

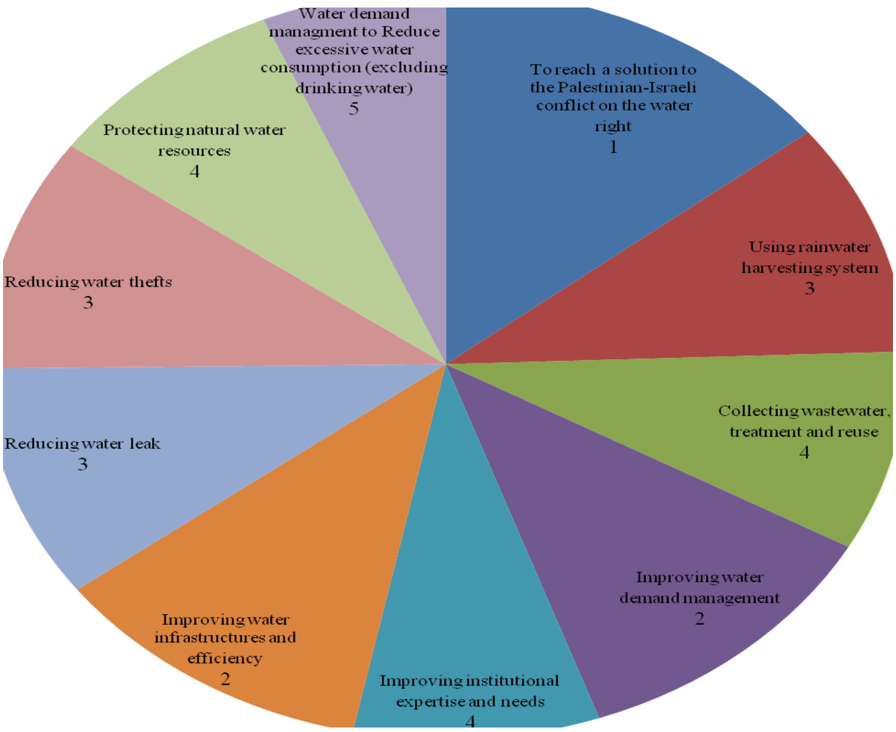

Figure 5.9 The most effective available options to mitigate water scarcity in Hebron District (Source Questionnaire)

5.4.6 "Problems that influence applying available options to mitigate water scarcity in the District, and the weight of effect", the responses showed that Political is the main problem that influence applying possible options to mitigate water scarcity in the District with weight of (90%), then water Management with weight of (70%), then economical, technical and experts and infrastructures with weight of (60%), then Social and Institutional with weight of (50%), the last is Water price with weight of (45%). The table (5-3) and Figure (5.3), showed the results obtained from SPSS.

Table 5-3 Statistics problems that influence applying available options to mitigate water scarcity in Hebron District, and the weight of effect (Source Questionnaire)

		Water price	Political problems	Social problems	Economical problems	Institutional problems	Water management problem	Technicians and specialists problem	Infrastructures problems
N	Valid	24	25	25	25	25	25	25	25
	Missing	1	0	0	0	0	0	0	0
Median		45.00	90.00	50.00	60.00	50.00	70.00	60.00	60.00

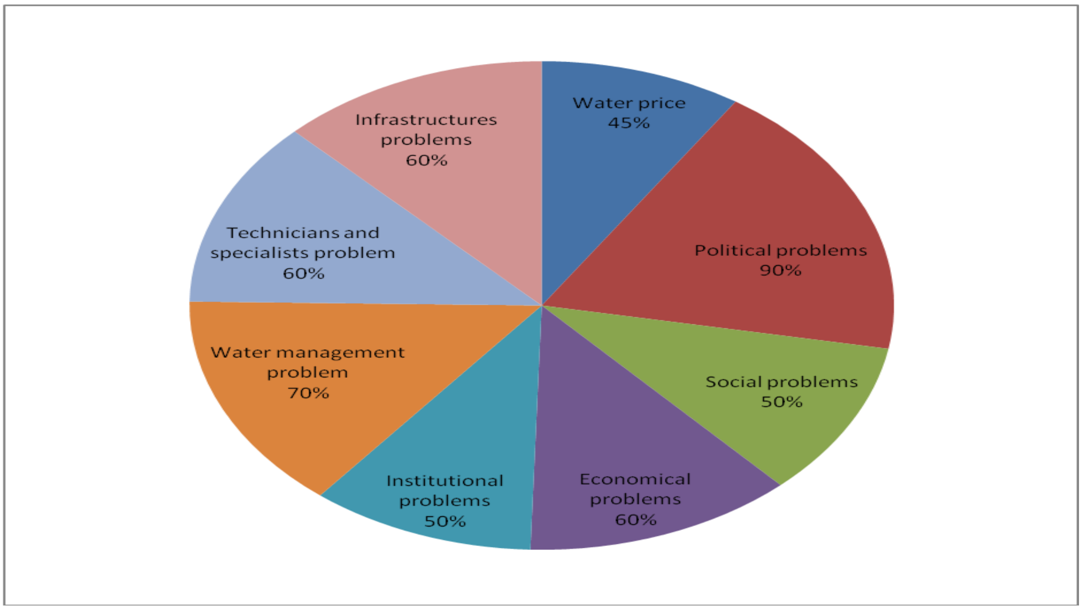

Figure 5.10 The problems that influence applying available options to mitigate water scarcity in Hebron District (Source Questionnaire)

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Hebron district experience absolute scarcity of water for domestic, agricultural and Industrial use.

The result showed that the available options to mitigate water scarcity in Hebron District were: water right by reach a solution to the Palestinian-Israeli conflict on the water, Improving water demand management, using rainwater harvesting system, Reducing water leaks and thefts, Wastewater collection and treatment and reuse. By integrating these Available Options all together will create a state of balance between demand and supply.

It was found that the current total water required to satisfy a person's needs for domestic, agricultural and industrial sectors is (42.42 Mcm/yr), and the current renewable water resources in Hebron District per person for domestic, agricultural and industrial sectors is (10.97 Mcm/yr).

The result showed that the total water required to satisfy a person's needs for domestic, agricultural and industrial sectors at 2035 will be (48.22 Mcm/yr), and the Future renewable water resources in Hebron District due to Integrated available options all together will be (86.10 Mcm/yr). The results show a lack of management for water sector in Hebron District.

This research has shown that the political situation resulting from the Israeli occupation, is the main problem that impede applying of these available options.

6.2 Recommendations

It is apparent from this research that the integrating the Available Options all together will create a state of balance between demand and supply in the future.

To achieve that, the following recommendations are derived:

- Effort at the global, international, regional and local level to obtain water rights from the Israeli occupier.
- Coordination of efforts between the private and public institutions, and develop an action plan to mitigate the water scarcity on the national level.
- Increase awareness among citizens of the importance of water and conservation.

- Unify efforts between municipalities for establishing joint water council in the district.
- Make tariffs prices of sale water according to consumption and sector.
- Establish a water transmission line from the areas that is available with a large amount of water.
- Establishment of dams on the streams of valleys.
- Support Individual projects related to water harvesting and water collecting.
- Create regulations to force citizens to build domestic wells to collect rainwater

6.3 Further Research

In this study, it was discuss the available options to mitigate the water scarcity in the Hebron district. There is a need for more research to obtain additional information. Other research which would concentrate on certain issues mentioned throughout this study, may be as follows:

- Study on the economic part for the available options to mitigate water scarcity in Hebron District.
- Study on the amount of water that flows into valleys in Hebron District.
- Study on the points of leakage in water networks in Hebron District.
- study on the appropriate types of wastewater treatment plants in Hebron District.

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APPENDIX 1

Hebron district localities

1	Hebron (al-Khalil)
2	Bani Na'im
3	ad-Dhahiriya
4	Dura
5	Halhul
6	Idhna
7	Sa'ir
8	as-Samu
9	Tarqumiyah
10	Yatta
11	Beit Awwa
12	Beit Kahil
13	Beit Ula
14	Beit Ummar
15	Deir Sammit
16	Kharas
17	Nuba
18	ash-Shuyukh
19	Surif
20	Taffuh
21	Anab al-Kabir
22	Arab al-Ka'abneh
23	Beit 'Amra
24	Beit Einun
25	Beit Maqdum
26	Beit ar-Rush al-Tahta
27	al-Burj
28	Beit Mirsim
29	Beit ar-Rush al-Fauqa
30	al-Buweib
31	Deir al-'Asal al-Fauqa
32	Deir al-'Asal al-Tahta
33	Deir Razih
34	ad-Deirat
35	Fuqeiqis
36	Hadab al-Alaqa
37	Hadab al-Fawwar
38	al-Heila
39	Hitta
40	Hureiz
41	Imneizil
42	Imreish

43	Karma
44	al-Karmil
45	Khallet Edar
46	Khallet al-Aqed
47	Khalet al-Maiyya
48	at-Tabaqa
49	Umm Lasafa
50	Wadi Ubeid
51	Khallet al-Masafer
52	Khashem
53	al-Daraj
54	Khallet Salih
55	Khirbet Safa
56	Khirbet Salama
57	Khirbat al-Simia
58	Khirbet Zanuta
59	Khursa
60	al-Kum
61	Kurza
62	Kuseis
63	al-Majd
64	Marah al-Baqqar
65	Masafer Yatta
66	an-Najada
67	Rabud
68	al-Ramadin
69	ar-Rihiya
70	Sahel Wadi Elma
71	Sikka
72	Shuyukh
73	al-Arrub
74	as-Sura
75	Tarrama
76	at-Tuwani
77	Umm Ashoqan
78	Umm al-Butm
79	Umm al-Khair
80	Wadi al-Amayer
81	Wadi al-Kilab
82	Wadi ash-Shajina
83	Zif
84	Qila
85	Jala
86	Hamrush
87	Khirbet ad-Deir

88	Arab al-Fureijat
89	al-Baqa
90	Al Bowereh
91	Qalqas
92	Qla'a Zeta
93	Wadi al Hussein
94	ad-Duwwara
95	al-Uddeisa
96	al-Arroub
97	Fawwar

APPENDIX 2

List of Institutions

Action Against Hunger (ACF)

Al Dahrieh municipality

Alshyoukh municipality

American Near East Refugee Aid (ANERA)

Baninaim municipality

Beit Kahil village council

Beit Ula municipality

Dura municipality

Environmental Quality Authority (EQA)

Halhul municipality

Hebron municipality

Hydrology Group (HG)

Idna municipality

Kharas municipality

Ministry of Agriculture (MoA)

Ministry of Local Government (MoLG)

Ministry of National Economy (MoNE)

Nuba municipality

Palestinian Water Authority (PWA)

Sier municipality

Surif municipality

Tarqumiya municipality

West Bank Water Department (WBWD)

Water Sector Regulatory Council (WSRC)

Yatta municipality

APPENDIX 3

Questioner English Form

1.FIRST SECTION: GENERAL INFORMATION

Name of the institution: **…………………………………………………..**		
based in	*City: …………….*	
represented by:	*(please insert your name):*	*…………………………………..*
Function you hold in the institution ……………………………………...		

1.1. Do you think that water scarcity is “experienced” by the people living in your region?

Yes □ No □

Please comment

……………………………...
....
....……

1.2. Is the institution you represent directly confronted with water scarcity?

Yes □ No □

If yes;

How?...……...............

....………...

2. SECOND SECTION: WATER SCARCITY: MAIN PROBLEMS AND CAUSES

2.1. What are the Main Problem of water scarcity?

…………….………...

....…......................

....

2.2. Identifying the main causes of water scarcity

In relation with your experiences and activities, which of these causes do you think are the most relevant? Please tick under the weight of impact

Main causes	Weight of effect %										
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**	***remarks***
Water resources											
Water supplied quantity											
Water consumption quantity											
rate of natural population growth											
Pollution											
Infrastructures											
Political situation											
Economical situation											
Financial situation											
others, (please specify)…….											

3. THIRD SECTION: AVAILABLE SOLUTIONS

3.1 Which of the following is the best effective solutions for applying the possible options to mitigate water scarcity in the District ? And how can affect it?
Please give ranks between (1 – 10), (give best solution Rank No. (10))

effective solutions	Rank	Remarks
To reach a solution to the Palestinian-Israeli conflict on the water right		
Using rainwater harvesting system		
Collecting wastewater, treating and reuse		
Improving water demand management		
Improving institutional expertise and needs		
Improving water infrastructures and efficiency		
Reducing water leak		
Reducing water thefts		
Protecting natural water resources		
Water demand management to Reduce excessive water consumption (excluding drinking water)		
Others, please specify		

3.2 which of the following problems influence applying possible options to mitigate water scarcity in the District ?
Please tick under the weight of impact

Main Problems	**Weight of effect %**										
	0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**	***remarks***
Water price											
Political											
Social											
Economical											
Financial											
Institutional											
Management											
Technical and experts											
Infrastructures											
others, (please specify)…….											

4. LAST SECTION: ADDITIONAL INFORMATION
If you have any additional information that could be important for the research, please write it here:

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Questioner Arabic Form

القسم الأول :معلومات عامة

اسم المؤسسة ....
مقرها في مدينة : .... **ممثلة :(يرجى إدراج اسمك)**..
الوظيفة التي تمثلها في المؤسسة ....

1.1 هل تعتقد أن ندرة المياه "ملاحظة" من قبل الناس الذين يعيشون في المنطقة؟

نعم □ لا□

يرجى التعليق

....
....
....

2.1 هل المؤسسة التي تمثلها تتعامل بشكل مباشر مع ندرة المياه؟

نعم □ لا □

اذا نعم؛

كيف؟...
....
....

القسم الثاني :ندرة المياه المشاكل والأسباب

1.2 **ما هي المشاكل الرئيسة لندرة المياه؟**

....

....

2.2 **تحديد الأسباب الرئيسة لندرة المياه**

من خلال خبراتكم وأنشطتكم، أي من هذه الأسباب في رأيكم هي الأكثر تأثير؟ يرجى وضع علامة قيمة التأثير

الأسباب الرئيسة	مقدار التأثير %										ملاحظات
	0- 10	10- 20	20- 30	30- 40	40- 50	50- 60	60- 70	70- 80	80- 90	90- 100	
مصادر المياه											
كمية المياه المزودة											
كمية استهلاك المياه											
معدل النمو الطبيعي للسكان											
التلوث											
البنى التحتية											
الوضع السياسي											
الوضع الاقتصادي											
الحالة المالية											
أخرى، (يرجى التحديد)											

القسم الثالث :ندرة المياه : الحلول المتاحة

1.3 أي من الخيارات التالية هو أفضل الحلول الفعالة للتخفيف من ندرة المياه في المنطقة؟ وكيف يمكن أن تؤثر عليه؟

يرجى إعطاء الرتب بين (1-10)، (إعطاء أفضل الحلول المرتبة رقم (10))

الخيارات المحتملة	المرتبة	ملاحظات
الوصول إلى حل في الصراع الفلسطيني-الإسرائيلي للحصول على الحقوق المائية		
استخدام نظام حصاد مياه الأمطار		
تجميع مياه الصرف الصحي ومعالجتها وإعادة استخدامها		
تحسين إدارة الطلب على المياه		
تحسين الخبرات والاحتياجات المؤسسية		
تحسين كفاءة البنية التحتية للمياه		
الحد من تسرب المياه		
الحد من سرقة المياه		
حماية الموارد المائية الطبيعية		
إدارة الطلب على المياه للحد من استهلاك المياه المفرط (باستثناء مياه الشرب)		
آخرى، (يرجى التحديد)		

2.3 أي من المشاكل التالية تؤثر على تطبيق الخيارات المحتملة للتخفيف من ندرة المياه في المنطقة؟

يرجى وضع علامة تحت مدى التأثير

المشكلة الرئيسة	مقدار التأثير %										ملاحظات
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
سعر المياه											
المشاكل السياسية											
المشاكل الاجتماعية											
المشاكل الاقتصادية											
مشاكل مؤسساتية											
مشكلة إدارة المياه											
مشكلة التقنيين وذوي الاختصاص											
مشكلة البنى التحتية											
آخرى، (يرجى التحديد)											

القسم الأخير : معلومات اضافية

إذا كان لديك أي معلومات إضافية يمكن أن تكون مهمة للبحث، يرجى الكتابة هنا:

....

....

....

....