An-Najah National University
Faculty of Graduate Studies

The Use of Water Evaluation and Planning "WEAP" Program as a Planning Tool for Jerusalem Water Undertaking "JWU" Service Area

By

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DEDICATION

This thesis is dedicated to my wonderful parents; you have raised me to be the person I am today; you have been with me every step of the way, through good times and bad. Thank you for all the unconditional love, guidance, and support that you have always given me, helping me to succeed and instilling in me the confidence that I am capable of doing anything I put my mind to. Thank you for everything.

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I express my thanks and appreciation to my family for their understanding, motivation and patience. Lastly, but in no sense the last, I am thankful to all colleagues and friends who made my stay at the university a memorable and valuable experience.

الإقـــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

The Use of Water Evaluation and Planning "WEAP" Program as a Planning Tool for Jerusalem Water Undertaking "JWU" Service Area

استخدام برنامج (WEAP) كأداة للتخطيط في المنطقة المخدومة من مصلحة مياه القدس في رام الله والبيرة

اقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء مـا تمـت الإشارة إليه حيثما ورد، وان هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل أية درجة علمية أو بحث علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

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THE USE OF WATER EVALUATION AND PLANNING "WEAP" PROGRAM AS A PLANNING TOOL FOR JERUSALEM WATER UNDERTAKING "JWU" SERVICE AREA

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ABSTRACT

Water shortage is one of the real challenges facing the Palestinian people. Our fast growing population, urbanization, and the expansion of development and economic activities in Ramallah and Al-Bireh district exert pressure on available water resources. This study attempts to develop an integrated water resources management for the area which is served by Jerusalem Water Undertaking (JWU), by using (WEAP) model. WEAP model allows the simulation and analysis of various water allocations, the concept of regional utilities and its impact on water management was evaluated.

The study methodology consists of two components (1) data gathering and reviews (2) WEAP Model that aided to evaluate water resources management options for the study area.

Three management options for JWU are investigated. The three options which were developed into WEAP and tested as follows:

Option 1: pumping water from Eastern Aquifer Basin

Option 2: pumping water from Western Aquifer Basin

Option 3: pumping water from Both Aquifer Basins

The results obtained in this study show that the service area of the central water utility should be connected together to allow better management of the available water resources. Results also show that the estimated future water needs for the service area of the central water utility is 40 MCM by the end of year 2025.

The results reveal that applying a demand management program and involvement the private sector resulted in decreasing the water demand by about 14 MCM by the end of year 2025.

Pumping water from both eastern and western aquifer basins as in option 3 is the most economic option because the average cost is 27.7 U.S. cents per m^3. While in option 2 when the unmet demand was covered from western aquifer basin is the most expensive option with estimated cost 29.7 U.S. cents. In option 1 the estimated cost is 28.6 U.S. cents.

CHAPTER ONE

INTRODUCTION

1.1. General Introduction

Water shortage is one of the real challenges facing many countries in the Middle East region. The West Bank, Palestine, is a unique place where water scarcity accompanied by the largely fluctuating political events and conflicts result in a complex matrix of interrelations that need careful and intelligent ways of adaptation and management.

Following the Oslo I (1993) and the Oslo II (1995) Peace accords between the Palestinian Libration Organization and Israel, the concern was to accommodate the anticipated stage of rapid transformation that would be the result of accelerated economic, physical, and social developments and urbanization. In addition to the uncertainties of climate change and the transboundary nature of the hydrologic regime, the threat was that these anticipated rapid developments would create pressure on available water resources. At that time, the shortage of administrative, legislative, and technical planning expertise on the Palestinian side even increase the effect of that threat.

Therefore, Demand Management appears to be one of the main alternatives to control high increase in the demand until there is a political solution to the water issues with Israel.

However, successful management of water requires systematic, comprehensive, and coordinated approaches that will provide decisionrelevant information at an affordable cost to water managers. Management of water resources will require approaches that will need more-and better quality-information about the current and potential future states of the water resources systems we manage. Therefore, to meet the growing information needs of water management and water resources research, efficient modeling techniques are required that have high power for long and short term assessment in order to be able to devise smart decisions.

Scenarios are self consistent story-lines of how a future system might evolve over time in a particular socio- economic setting and under a particular set of policy and technology conditions. Using WEAP, scenarios can be built and then compared to assess their impact. All scenarios start from a common year, for which the model Current Account data are established (SEI, 2005).

In this study we want to focus on the establishment of the central utility. The objective of this study is to guarantee the expansion of JWU services in an administratively unified and well-managed water utility for both Jerusalem, and Ramallah & Al-Bireh governorates to ensure the provision of safe and cost effective water for all the population in the area.

WEAP model as a water planning and evaluation tool that has gained some credence in recent times but it has not been established as praxis in current water policy and decision-making frameworks. The results of this study are hoped to provide insights into potential uses of WEAP that will benefit for scenarios and planning evaluation schemes in areas where water resources are already highly stressed. In other words, planning tools in general will provide techniques to improve water resources management by providing reliable assessment in a risk avert manner (Arafat, 2007).

This thesis was successfully crafted to fulfill the following goals: to investigate the impact of different "what if" questions that are posed to enhance multiple water resources management problems; to develop a framework; to action to be taken in decision making process, and to evaluate the applicability of WEAP on real-life tasks related to water resources issues in Palestine.

The general structure of the thesis is as follows. Chapter I introduce the research and provide general explanation, justification, and background about the research objectives, research contributions, research motivations. Chapter II provides a review of the related literature and IWRM basic principles, general view about WEAP software and why to choose it in the modeling. Chapter III shows a general view of water resources in the study area; geographical location, climate change and rainfall in the area. Chapter IV details the methodology. Chapter V demonstrates the applicability of water evaluation and planning (WEAP) model in designing the Current Account and model setup, Chapter VI represents the main scenario and the other three options which are developed, and discussing the output results for these suggested scenarios. Finally, chapter VII summarizes the findings of the research, and presents conclusions and recommendations.

1.2. Research Objective

This study attempts to develop an integrated water resources management for the service area of Jerusalem Water Undertaking (JWU) by using WEAP model. This model allows the simulation and analysis of various water allocations; evaluate the existing conditions and other expected future scenarios taking into account different operating policies, costs, and factors that affect demand such as demand management strategies, alternative supply sources and hydrologic assumptions.

The concept of regional utilities and its impact on water management was evaluated taking JWU as a case study. Also, the proposed research will evaluate the plausibility of WEAP as complementary or an alternative to the traditional techniques used to solve management problems for water resources systems.

Research Motivations

The research is motivated by the following issues:

1. The fast growing population, urbanization and the expansion of development and economic activities that exert pressure on available water resources.
2. Importance of understanding the extent of the existing problems in the water sector;
3. Decision makers lack a tool that can aid them in planning and management.

CHAPTER TWO

LITERATURE REVIEW

2.1. General

Many regions are facing formidable freshwater management challenges. Allocation of limited water resources, environmental quality and policies for sustainable water use are issues of increasing concern. Conventional supply-oriented simulation models are not always adequate. Over the last decade, an integrated approach to water development has emerged to achieve social equity, sustainable environment, and the economic efficiency, makes identifying and implementing effective solutions much easier and allocates water strategically improving the efficiency in water use.

To achieve the required integrated water resources model, WEAP software is used since WEAP is known for its special capabilities and abilities to realize management goals. WEAP is a microcomputer tool for integrated water resources planning that attempts to assist rather than substitute for the skilled planner. It provides a comprehensive, flexible and user-friendly framework for planning and policy analysis. A growing number of water professionals are finding WEAP to be a useful addition to their toolbox of models, databases, spreadsheets and other software. WEAP is a central component of Decision Support System (DSS), providing a framework that is accessible to strategic planners, stakeholders and decision-makers.

2.2. Water Management

2.2.1. IWRM Basic Principles

Integrated Water Resources Management (IWRM) is a participatory planning and implementation process, based on sound science that brings stakeholders together to determine how to meet society's long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits. IWRM helps to protect the world's environment, foster economic growth and sustainable agricultural development, promote democratic participation in governance, and improve human health (www.usaid.gov).

Figure 1 show that how the IWRM is a participatory and coordinated process, it brings all water users together to emphasize social and economic welfare and equity and it is protecting the environment in trying to achieving equitable allocation of water resources.

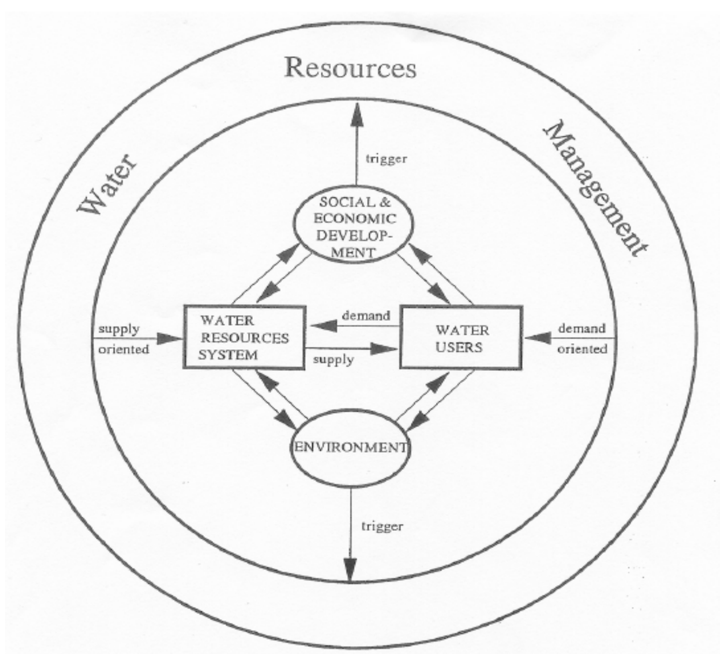

Figure 1: Schematic Representation of IWRM

According to Global Water Partnership (2000) IWRM is defined as "a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000).

Some of the principal components of IWRM are:

- **Managing water resources at the basin or watershed scale**. This includes integrating land and water, upstream and downstream, groundwater such as the western and eastern aquifer basins, surface water, and coastal resources.
- **Optimizing supply.** This involves conducting assessments of surface and groundwater supplies, analyzing water balances and evaluating the environmental impacts of distribution and use options such as the water supplied by JWU.
- **Managing demand.** This includes adopting cost recovery policies, utilizing water-efficient technologies, and establishing decentralized water management authorities.
- **Providing equitable access to water resources** through participatory and transparent governance and management. This may include support for effective water users' associations, involvement of marginalized groups. This will happen at regulatory levels such as Palestinian Water Authority (PWA) level.
- **Establishing improved and integrated policy, regulatory, and institutional frameworks.** Examples are implementation of the

Polluter-pays principle, water quality norms and standards, and market-based regulatory mechanisms.

- **Utilizing an intersectoral approach to decision-making**, where authority for managing water resources is employed responsibly and stakeholders have a share in the process like a ministry of agricultural (www.usaid.gov).

2.2.2. Decision Support Systems (DSS) Tools

2.2.2.1. Water Management and Decision Making

Problems in water management all revolve around few main issues: i.e. the spatial and temporal uneven distribution of water resources as well as the bad quality of the water available. These features may furthermore be exacerbated by the growing population, the development and the climate change. The primary purpose of water resources management is, thus, to assure and improve the allocation, preserve water quality, cope with extreme events such as floods and mitigate droughts, and with inter-annual variability of water supply especially in the Mediterranean Area (www.feem-web.it).

New strategies and instruments have been developed to lead to a more sustainable use and allocation of water resources: for instance desalination, water re-use and harvesting (i.e. usually through small scale collection and storage systems) or via different systems of tariffs aiming to improve efficiency in water use.

The "best" strategy to adopt is often the result of a long process which involves different and competing interests. Given the complexity of the water assessment and planning/decision process, a significant role could be played by the adoption of Decision Support System (DSS) tools.

2.2.2.2. What is Decision Support Systems (DSS)?

In broad sense a Decision Support Systems (DSS) is a combination of the tool and the process of structuring problems, thus, aiding decisions. In strict sense the concept refers to a wide range of computer-based tools developed to support planning and decision processes. WEAP is a central component of this Decision Support Systems (DSS), providing a framework that is accessible to strategic planners, stakeholders and decision-makers (www.feem-web.it).

Decision Support Systems (DSS) tools usually integrate three components:

- **Data management system** which collects, organizes, and processes data and information and facilitates access and elaboration of time series of raw data.
- **A variety of models** and/or techniques and methods for decision analysis through which perform different analysis
- **Customized user interface** to facilitates the interaction with the system and support the communication and analysis of the models' outputs;

The basic functions of a Decision Support Systems (DSS) include:

- **Identify and structure** the problem, and define a consistent preference structure in terms of criteria, objectives, and constraints.
- **Design alternatives** that provide solutions to the problem as posed.
- **Select** preferred solutions from the set of alternatives based on the preference structure (www.feem-web.it).

2.2.2.3. Why Use and Develop DSS?

The integration of different type of knowledge (e.g. local and expert knowledge), disciplines and perspectives in the development of effective management strategies is facilitated by the development and adoption of a DSS which helps make basic elements of the decision process (i.e. criteria, objectives, constraints) more explicit:

- Decision Support Systems (DSS) helps multidisciplinary team involved in the analysis of a common problem to establish a common language and think in a structured way.
- The graphical features of a Decision Support Systems (DSS) support communication between stakeholders with different backgrounds. Visual aids help in fostering public participation and are particularly enhanced features of Deliberation Support Tools while web-based Group Decision Support Systems support collaborative decision making;

- Optimization and simulation models help in the analysis of possible trade-offs and conflict situation for the identification of the most suitable within a set of alternative options.
- Geographic Information System (GIS) components help in the spatial visualization of measures and impacts and facilitate the problem assessment by providing important information, for instance, for the allocation of water management infrastructures.
- In general, a Decision Support Systems (DSS) helps at least in documenting the decision process that leads to the choice of a particular option thus contributes to its increasing transparency and fairness.

2.2.2.4. Water Management Models

Different models are developed for water resources management. There are two basis types of optimization approach: hydrology inferred optimization models that optimize allocations based on hydrologic specifications and economic optimization models that optimize allocations based on economic considerations. Other criteria, such as equity or environmental quality can also be used. Following are some models with a brief description of their suitability to achieve our needs from modeling:

Water Evaluation and Planning System (WEAP): WEAP is a general multi-purpose, multi-reservoir simulation program which determines the optimal allocation of water for each time-step according to demand priorities and supply preference. It operates at a monthly time step on the basic principle of water balance accounting (SEI, 2008)**.**

The model can represent any water resource system incorporating natural inflows, precipitation, evaporation, and evapotranspiration as input data. Operational features that can be represented include storage and release of water by reservoirs, physical discharge controls at reservoirs outlets, water flow in channels, consumptive demands, and hydropower release. These operational features can be specified as steady-state or time-varying.

In addition, WEAP allows users to develop their own set of variables and equations to further refine and adapt the analysis to local constraints and conditions with possible data exchange with other software such as excel (SEI, 2005).

The Water Allocation System Model (WAS): It is an annual steady state model with extraction from water sources limited to annual renewable amounts. Seasonal variation and multiyear issues are not modeled. It is assumed that each source of supply has an annual renewable and a constant extraction cost per cubic meter up to that amount. Different sources can be drawn on the same water resources (e.g. the same river or aquifer).agricultural demands are treated in a very simple mean. WAS model can be applied to regions larger or smaller than an actual country and optimizes allocation based on economic considerations. It treats demand as a function of price by representing demand by the demand curve (Fisher, 2005).

Water Rights Analysis Package (WARP) simulates management of the water resources of a river basin or multiple-basin region under a priority-based water allocation system availability and reliability for specified water use requirements. Basin-wide impact of water resources development projects and management strategies may be evaluated. The software package is generalized for application to any river\reservoir system, with input files being developed for the particular river basin of concern (www. ceprofs.tamu.edu).

MODSIM_DSS: is a simulation model that can be obtained free of charge. The model can simulate physical operation of reservoirs and water demand. The data sets can be developed for daily, weekly, and monthly time steps.
It is generalized river basin decision support system and network flow model developed at Colorado State University designed to meet the growing demands and pressure on river basin manager. It has been linked with stream-aquifer models for analysis of the conjunctive use of groundwater and surface water resources, as well as water quality simulation models for assessing the effectiveness of pollution control strategies. It can be used with GIS for managing the intensive spatial data base requirements of river basin management. Results of the network

optimization are presented in useful graphical plots. (http://modsim.engr.colostate.edu).

2.2.3. Water Resources Management in the Area

The Palestinian Water Authority (PWA) and the National Water Council (NWC) are in charge of implementing any water management strategy. The PWA is the central water authority. It is responsible for strategic planning, monitoring and oversight, policy implementation, regulation, water rights negotiations, ensuring the equitable utilization and sustainable management of Palestinian water resources. The local ministries, utilities and water users associations are responsible for the actual implementation of the PWA national water plan. While the PWA is effectively the primary water agency, the NWC is officially the highest body within the Palestinian Authority regarding water issues.

Water supply management is shared by Israeli Authorities and the Palestinian Water Authority (PWA). The proposed water projects must be approved by the Joint Water Committee (JWC)[1]; a procedure that obstructs and delays water development projects, since they are subject to Israeli approval.

The bad economic situation restrains water development projects, since that Palestinian economy is highly dependent on donors and can't afford by

[1] JWC was established as a part of the OsloII agreement and it is composed of equal number of representatives from each side of Palestinians and Israelis

itself development projects; in addition to that projects are unsustainable due to the inefficient implementation of "full cost recovery" principle.

Many communities don’t have piped water network, lack of storage facilities and high rate of losses magnifies the problem resulting in a very poor infrastructure, beside the repeated Israeli aggressions on the infrastructure causing huge damage.

There is a significant lack of water management due to political constrains, economic factors, and others that restrict development. This encourages the adaptation of the methodology of Water Resources Management which offers the best means to moderate the situation integrate various needs against available resources, help in achieve a sustainable development, and ensure better balance between efficiency sustainability and equity needs in water allocations.

2.2.3.1. Regional Water Utilities

Palestinian Water Authority (PWA) intends to combine all the segregated networks and water committees throughout West Bank and that is based on the idea of reducing duplication of work and increasing the possibilities to improve water supply.

Within a comprehensive planning process the principles for the institutional reform within the water sector have been defined as follows (PWA, 2004):

- Regulation of the water sector by only one responsible body (PWA), with the separation of the institutional responsibility for policy and regulatory functions from those of service delivery;
- Establishment of three regional water utilities in the West Bank and one in Gaza
- Private sector participation in funding and implementation of water projects.

Four Regional Water Supply Utilities are planned to be created to deliver water to the different end users. The supply area is fractionized geographically;

- Northern Utility (Nablus, Jenin, Tulkarem, Qalqilia, Salfit and Tubas Governorates),
- Central Utility (Jerusalem, Ramallah and Al-Bireh and Jericho Governorates)
- Southern Utility (Hebron and Bethlehem Governorates)
- Coastal Utility (Gaza Strip Governorates)

Within the new institutional framework an autonomous Palestinian Bulk Water Supply Utility is planned to be set up which will be responsible for the management of all trans-regional bulk water supply systems and activities.

In this study we want to focus on the establishment of the central utility. The objective of this study is to guarantee the expansion of JWU services in an administratively unified and well-managed water utility for both Jerusalem, and Ramallah & Al-Bireh governorates to ensure the provision of safe and cost effective water services for all the population in the area.

2.2.3.2. Previous Water Studies in West Bank

Many studies were carried out in order to assess and evaluate water availability, and to develop demand supply system. Following are some studies that are conducted that can enrich this study.

National Water Plan (2000)

The National Water Plan (NWP) is a strategic document developed to provide guidance for development of the Palestinian water sector. The document provides important insight to the Palestinian vision for water sector growth. It includes description of the legal and institutional framework, the tariff structure, the basis for water rights, general management strategies, and a detailed investment plan (PWA, 2000).

West Bank Integrated Resources Management Plan (2003)

This study provides an overall strategy and vision for water sector development integrating all available resources and requirement of all water sectors stakeholders. The study represents a guideline for the water sector development. It outlines PWA goals, objectives and polices for the water sector, and provides master planning detail to guide water infrastructure development (CH2MHILL[2], 2003).

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[2] CH2MHILL is a global project delivery firm providing strategically integrated services to public and private sector clients in water resources, water and wastewater facilities design, construction and operations, environmental, telecommunications and transportation services as well as related infrastructure.

Water Sector Strategic Planning Study (2000)

The study builds upon the resource analysis and supply and demand estimations presented by CDM/Morganti. It provides a comprehensive database of projects to be implemented in order to meet anticipated water demand through 2020. In addition; this study asserts specific goals, objectives, policies, and priorities recommended for adoption by the Palestinian water sector (Carl Bro International, 2000).

Article 40 (Water Resources) of the Oslo Accords

Article 40 of Oslo II Agreement, signed in September, 1995, is 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. It states "recognizes the Palestinian water rights in the West Bank". These rights will be settled in the permanent status agreement after the final negotiations.

2.3. The WEAP Approach

2.3.1. Background

The Water Evaluation and Planning version 21 (WEAP 21) Integrating Water Resources Management (IWRM) model seamlessly integrates water supplies generated through watershed- scale hydrologic processes with a water management model driven by water demands and environmental requirements and is governed by the natural watershed and physical network of reservoirs, canals and diversions.

The WEAP model was developed by the Stockholm Environment Institute (SEI) and can be downloaded from www.weap21.org. It is a general multi-purpose, multi- reservoir simulation program which determines the optimal allocation of water for each time step on the basic principle of water balance accounting.

The model provides a comprehensive flexible and user-friendly framework for planning and policy analysis. WEAP has an integrated approach of simulating both the natural inflows and engineered components of water system. This allows the planner access to a comprehensive view of the factors that must be considered in managing water resources for present and future use. This enables us to predict the outcomes of the whole system under different scenarios, and carry out comparisons between the different alternatives to evaluate a full range of water development and management options (SEI, 2005).

2.3.2. Why to Use WEAP?

Based upon the following criteria, WEAP was selected to perform water resources management modeling, since it meets the criteria requirements such as:

- WEAP can be used at different levels spatially and temporarily;
- Easy to use with a friendly interface;
- Recently, WEAP received a great deal of attention where it is being applied at national and international levels;

- Capable to simulate hydrology, groundwater utilization, surface groundwater interactions, and wastewater treatment.
- Capable to build and compare scenarios.
- priority –based water allocation system
- Enable stakeholders to get involved in management procedures through interactive data-driven model. This will increase public awareness and acceptance.
- WEAP can handle Variable time step.
- Enable users to have interactive control over data input, editing, model operation and output display.

2.3.3. WEAP Applications

There are many case studies that are supported by WEAP Applications all over the world that can be downloaded from the site (www.weap21.org), such as:

Effects of Climate Change on Ecosystem Services in California (2001-2004): WEAP was used to identify and evaluate the likely impacts of climate change on the provision of aquatic ecosystem services (e.g., water for agriculture, recreation, hydropower generation, water for municipal and industrial use, habitat function and health, biodiversity, water purification) in the San Francisco Bay Basin and Watershed.

Water and Environment in the Rio San Juan: WEAP was used in an integrated water resources assessment of the Rio San Juan basin in Mexico, including the industrial center of Monterey. The study included the development of a supply and demand balance for the watershed, and the identification of alternative water development strategies and their environmental implications. The analysis also estimated the true cost of water in the region, reflecting opportunity costs, marginal costs, and scarcity costs.

Developing an integrated water resources management model for Al-Far' a catchments: in Arafat thesis (2007),WEAP was used to evaluate the existing scenario and other expected future scenarios taking into account different operating policies, costs, and factors that demand management strategies, alternative supply sources and hydrologic assumptions.

Four scenarios were proposed in this research, and these are:

1. The do-no-thing scenario.
2. Establishing wastewater treatment plant (WWTP) in the catchments to reuse water from agricultural and domestic sites.
3. Project a population growth of 3.5% taking into account that all the assumptions in the existing scenario are applied here too.
4. Using new techniques in agriculture to increase the supply up to 30%.

After studying all the proposed scenarios, it was noticed that all of them are successful to control and manage the water consumption in the region, but the most effective scenario is to use new techniques in agriculture, also it would be great if two options or more than one scenario are combined together.

Developing a Sustainable Management Options for the West Bank Water Resources: in Abu Hantash thesis (2007), WEAP was used for the development an integrated water resource management model to help of assess water resource management options under various conditions and scenarios which in turn will help to identify and implement effective solutions to many water-related problems that the West Bank is experiencing. In this study, a questionnaire was distributed to explore Palestinian priorities and concerns related to water uses.

Three scenarios were used in this study to ensure adequate and sustainable supplies of water. These scenarios are:

1. Current state of occupation and closure scenario.
2. Two-consolidated states when peace process moves on scenario.
3. Independent state of Palestine scenario.

WEAP output showed that management cannot take place properly if the existing situation continues while implementation of water resource management aspects can take place only when peace prevails.

WEAP as Water Management Decision Support System Tool on Tulkarem district in Haddad et al, 2007: The project was done to test the applicability and suitability of WEAP as water management Decision Support Systems tool (DSS) on Tulkarem district. The applicability of WEAP as a Decision Support Systems (DSS) in this case study is also aimed to be used to sustain the future planning, yield, reliability and risks, and associated costs of the Tulkarem district water resources system management taking into consideration various water resources constraints, competitive uses, and priorities.

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA

3.1. Historical Background

Until late 1950s, the population of Ramallah and Al-Bireh cities depended almost entirely on cisterns for drinking water with the exception of a few local springs. Following the war of 1948 and the resulting influx of Palestinian refugees into the area, the need to increase the water supply in the region became vital. Thus, Ramallah and Al-Bireh Water Company were established to deal with this burden (JWU, 2000).

The new company planned to draw on Ein-Fara springs northeast of Jerusalem and succeeded in concluding an agreement with Arab East Jerusalem Municipality. In 1963, the Jordanian government concluded an agreement with the International Development Agency (IDA) to develop drinking water projects in some parts of the Kingdom. The government decided to utilize the groundwater resources in Ein Samia well field, 20 km northeast of Ramallah, and initiated construction in what later became known as the Ein-Samia Water Project (JWU, 2009).

Pursuant to the respective agreement between the Jordanian government and IDA, the funding law of JWU was issued in 1966 with a mandate to develop new water resources and control all water projects in the area with the responsibility of providing the population with potable water. According to this law, JWU was established as a non-profit, independent, civil organization run by a Board of Directions.

Since 1967 occupation, the Israeli Military Authorities subjected all works and projects pertinent to water and water resources to its direct control through the Military Order No.92/1967. The mentioned order prevented any organization or undertaking from the execution of any work connected to management, maintenance and development of water resources without obtaining prior approvals and licenses from these Authorities. In 1982 the Israeli Occupation Authorities dissolved the city councils of Ramallah and Al-Bireh cities, thus, disabling JWU Board of Directors from performing its duties.

In the wake of the rule of the Palestinian National Authority (PNA), The Palestinian Water Authority (PWA) was established in 1995 assuming the regulation powers of the water sector in Palestine.

As a result of the presidential decree that changed the name of Ramallah and Al-Bireh Governorate, the Board decided in 1998 to change the name of JWU (Ramallah District) to Jerusalem Water Undertaking (Ramallah and Al-Bireh District).

The JWU located in Ramallah-Al Bireh Governorate of the Palestinian Territories. The Governorate includes the major central urban area, the twin cities of Ramallah and Al-Bireh, eight other cities /towns, more than 35 villages and five refuge camps and the northern part of Jerusalem. The served area of JWU extends over 600 km^2, provides water to almost

288,000 inhabitants. The length of the distribution network at present is approximately 1000 km made up from steel and ductile iron pipes (JWU, 2009).Figure 2 depicts the general location for the study area.

The mission of JWU is to provide the community in the service area now and in the future with reliable water services at an affordable price in order to improve the quality of life; contribute to the fulfillment of national water strategies; and manage in a professional manner that sustain JWU while maintaining its independence and accountability (JWU, 2009).

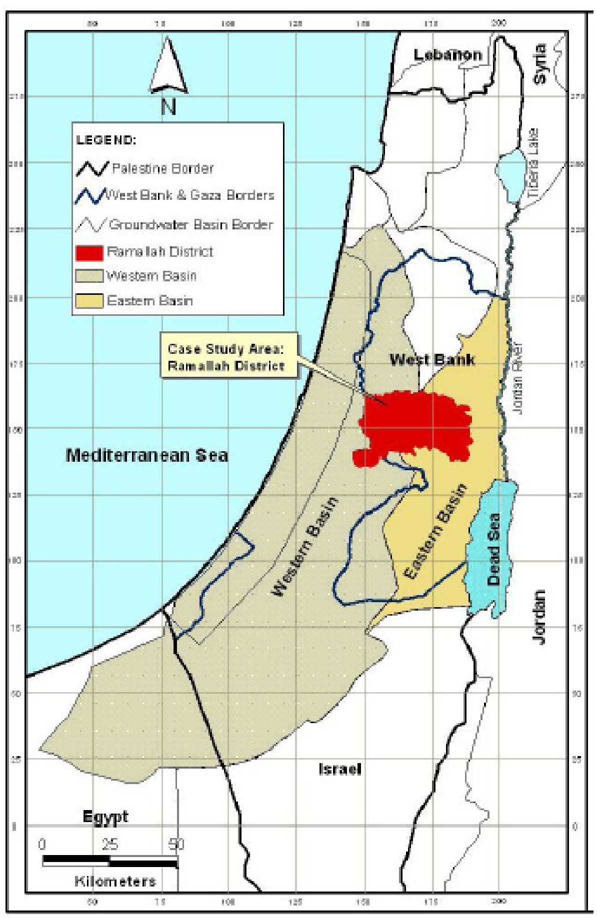


Figure 2: General Location Map for the Study Area, (HWE, 2009)

3.2. Location and Landuse

The Ramallah-Al Bireh District is located in the middle part of the West Bank, and the twin cities of Ramallah and Al-Bireh are located on a chain of Palestine central mountains. This district extends from the Jerusalem district in the south to Nablus district in the north and from Jericho district in the east to the 1948 borderline between Israel and West Bank from the west, as shown in Figure 2. The two cities are 860 meters above sea level, and have a moderate climate, which allows them to be a center for tourist attraction. From Figure 2, it is clear that Ramallah- Al Bireh District is underlined by two major aquifer basins: the Western and Eastern basins (HWE, 2009).

Due to restrictions imposed by Israelis, the average Palestinian built-up areas are very limited. The average population density reaches 400 person/km^2. It is considered very high when compared to those in the Israeli areas. Also, there are 24 settlements in Ramallah-Al Bireh Governorate, occupying approximately 30.27 km^2 of the Governorate's land which form 3.54% of the total Governorate area (HWE, 2009).

The study area is divided by Oslo II interim agreement into three areas, Area A, Area B, and Area C which are differentiated by a different level of control by the Palestinians as follows: (ARIJ, 1996)

"Area A" which includes Ramallah and Al-Bireh cities and covers 1,957 hectares (2.3%) of the district's land.

"Area B" is the populated villages and refugee camps. It accounts for approximately 22,429 hectares (26.6%) of the total area of Ramallah district.

"Area C" which covers 71.1% of the district's land and includes areas of Israeli settlements, closed military areas, and military bases.

Functionally, there are eight major land use classes within the Ramallah District boundaries, serving both the Israelis and Palestinians. These are Palestinian built up areas, Israeli settlement, closed military areas and bases, nature reserves, forests, cultivated areas, and industrial areas. The Ramallah District occupies approximately 14.5% of the West Bank and 13.6% of Palestine (Gaza Strip and West Bank). Currently only 4.35% of the Ramallah District is inhabited by Palestinian built up areas, while approximately 20.3% is occupied by either Israeli settlements, nature reserves or closed military areas (ARIJ, 1996).

3.3. Topography and Climate

3.3.1. Topography

The topography of Ramallah district can be divided into three parts: the eastern slopes, mountain crests and western slopes. The eastern slopes are located between the Jordan Valley and the mountains. They are characterized by steep slopes which contribute to forming young wadis such as wadi El-Maquk. Mountain crests form the watershed line and separate the eastern and western slopes. Elevation ranges on average between 750 and 800 meters above sea level. Western slopes, characterized by gentle slopes, and have elevation ranges between 250 and 500 meters above sea level. The highest point in Ramallah District is 1022 m above sea level at Tal A'sur, figure 3 shows the topographic map for the study area (HWE, 2009).

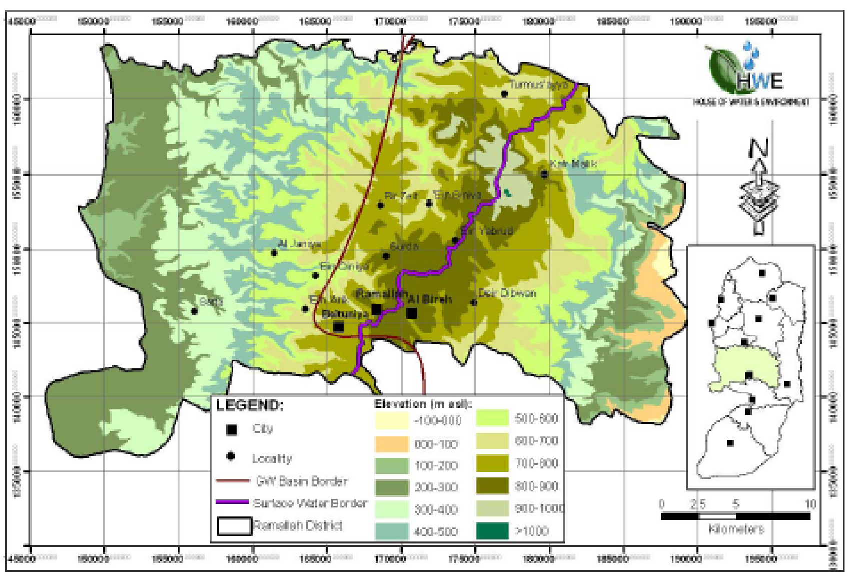


Figure 3: Topographic Map, (HWE, 2009)

Two main drainage systems are distinguished in Ramallah district the first system runs to the west towards the Mediterranean such as wadi Sarida, wadi El-Shamiyah, wadi Salman and wadi El-Kabeir. The second system runs to the east towards the Jordan River such as wadi El-Maquk and wadi El-Ein. Figure 4 shows the drainage systems in Ramallah-Al Bireh District.

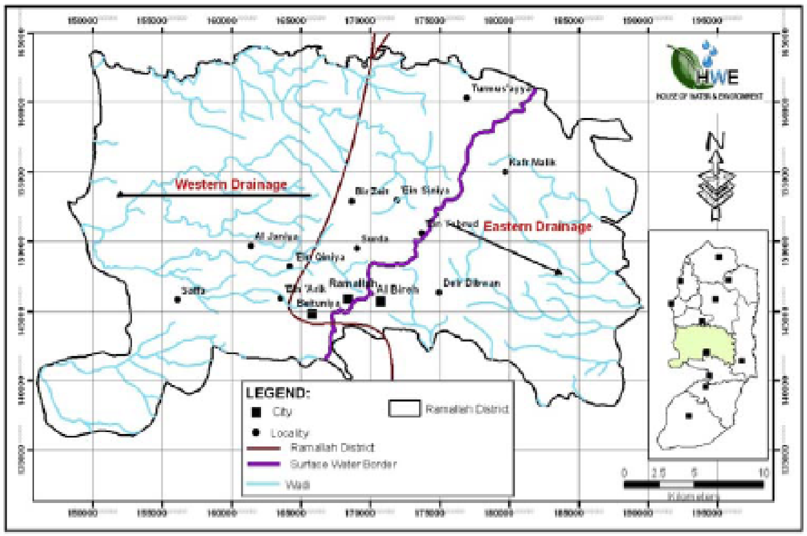


Figure 4: Drainage Systems in Ramallah-Al Bireh District, (HWE, 2009)

3.3.2. Climate

Ramallah-Al Bireh District is highly influenced by the Mediterranean climate, which is characterized by long, hot, dry summers and short, cool, rainy winters. Rainfall is limited to the winter and spring months, mostly between November and May; summer is completely dry. Snow and hail, although uncommon, may occur anywhere in the area especially over the mountains crests. In general, the distribution of rainfall is strongly influenced by the topography, with higher rainfall in the hills and mountains. Rainfall in the area also shows considerable inter-seasonal variation. The rainy days are estimated between 40-70 days per year. The annual quantity of rainfall in Ramallah- Al bireh district in 2007 was 543.9 mm (PCBS, 2007).

Ramallah-Al Bireh has lower temperatures than other places in the West Bank since it is part of the hill Regions, with a mean annual temperature of 17.1 ºC, as stated by the PCBS in 2007. The maximum annual average temperature is 21.4ºC whereas the minimum annual average temperature is 13.1ºC (PCBS, 2007). January is the coldest month with an average temperature of 6-12 ºC, while August is the hottest with an average temperature of 22-27 ºC (HWE, 2009).

The average annual relative humidity in Ramallah-Al Bireh District was 57% in 2007 and reaches its highest rates during the months of January and February. For the extreme maximum relative humidity, the highest value was 100% registered for (January–April) in Ramallah Station (PCBS, 2007).

In winter season, the wind move in a general west-east direction with an average daily wind speed of 16.0 km/hour in December, but during summer they are northern west and northern east, hot & dry with an average wind speed of 18.6 km/hour in August (PCBS, 2007).

Generally, rainfall is considered as the main component of precipitation in West Bank. There are more than 80 rainfall stations distributed geographically from northern to southern parts of the West Bank. The average annual rainfall in the eastern part of the district varies from 200 to 450 mm. In the western part of the district, the average annual rainfall is higher than the eastern part; it varies from 350 to 550 mm. In the mountains the average annual rainfall heights vary from 550 to 700 mm (HWE, 2009).

3.4. Soil

The soil types in Ramallah-Al Bireh Governorate are: (HWE, 2009)

- Terra Rosa type (70% of the Governorate): The parent material is dolomite and hard limestone. This soil is deep in hill tops (2 meters) and shallow in slopy mountainous areas (0.5 meter). In Ramallah, approximately 58,504 hectares consist of Terra Rosa, Brown and Pale Rendzina (about 40% of these soils are rocky).
- Brown Lithosols (8% of the Governorate): These soils characterize the eastern slopes of the district and are mainly found on steep to moderate rocky and eroded slopes. Brown lithosols are found in pockets among the rocks. These types of soil association cover an area of about 6,866 hectares of the Governorate.
- Grumusols: it is a soil type association which covers approximately 817 hectares of the district. It is found in areas with smooth to gently sloping topography. The soil is formed from fine textured alluvial or aeolien sediments. Nowadays, what appears is segetal vegetation of the Prosopis farcata- Scolymus maculates association.
- Many other types of soil are present in the Governorate such as Loessial Arid Brown Soil and Loessial Serozems.

3.5. Socio-Economic Characteristics

3.5.1. Demography and Population

Demographic trends in Ramallah District, as is the case of other districts in the West Bank, have been closely related to the political situation.

According to the population statistics estimated by the Palestinian Bureau of Statistics (PBS) for the Palestinian cities, towns and villages in 2007, the total population in the Ramallah District was estimated at 279,730 people, while the population in 1994 was estimated at 176,154 people, the difference between two numbers represents the stage of rapid transformation that would be the result of accelerated economic, physical and social development and urbanization after Oslo agreements (ARIJ, 1996).

3.5.2. Economy

By the beginning of the twentieth century (in 1908), Ramallah was declared a city and had an elected municipality. Ramallah area is composed of two main sectors: the lower city of Ramallah and the city of Al-Bireh. The two cities have become to an important financial administrative and cultural center in Palestine during the previous years. They are the main centers for tens of banks and the insurance companies.

Ramallah-Al Bireh District became the economic center in the West Bank Recently, it had developed at a high rate where many new commercial centers and housing projects have been constructed and many investors established their own business.

There are different economic activities in Ramallah-Al Bireh District, ranging from agricultural to commercial and industrial activities. Regarding agricultural activities, the total cultivated areas in the district had been reduced and replaced by residential ones. On the other hand, the most dominant economic activity is the manufacturing industry, such as food, furniture, soap and paper industry as well the manufacture of pharmaceuticals. However, the industry is mainly dependent on the political situation since Israel is still responsible for providing the raw materials needed (HWE, 2009).

Finally, it is worth mentioning that the socio- economic condition would heavily affect not only the affordability of the customers but also the collection rate which it turns will affect the ability of JWU to provide better services.

3.6. Water Resources

3.6.1. Groundwater Wells

The groundwater wells, supplying domestic water to the people in Ramallah district, are controlled by JWU, Mekorot and Jerusalem Municipality as follow:

(a)Wells owned by the Jerusalem Water Undertaking (JWU)

The Jerusalem Water Undertaking (JWU) owns five wells at E'in-Samia area to the east of Ramallah city. Ein Samia's wells are located in the eastern aquifer of the West Bank at depth of 60-600 meter below ground surface. It is noticed that there is a decrease in the productivity of the Ein Samia wells that supply to the Jerusalem Water Undertaking, the productivity of these wells was about 2.6 MCM in year 2007.

Two more wells were drilled in Ein Senia area, but none of them produced economical quantities.

(b) Israeli Sources

A large quantity of water is purchased from Israeli sources and from Jerusalem municipality to supplement the low water production of E'in-samia wells. The Israeli water company, Mekorot controls over Shebtin wells No.4 and No.5 in the Ramallah District. These wells located to the west of the groundwater shed and tap the upper Cenomanian aquifer system.

Mekorot is also responsible for supplying domestic water to 22 villages and 6 Israeli settlements with Ramallah District through West Bank Water Department (WBWD) and distributed by JWU and WBWD.

Purchased water from Jerusalem Municipality is another Israeli source that is injected into the JWU water supply system at 2 locations; North of Shu'fat and Entrance of Hizma.

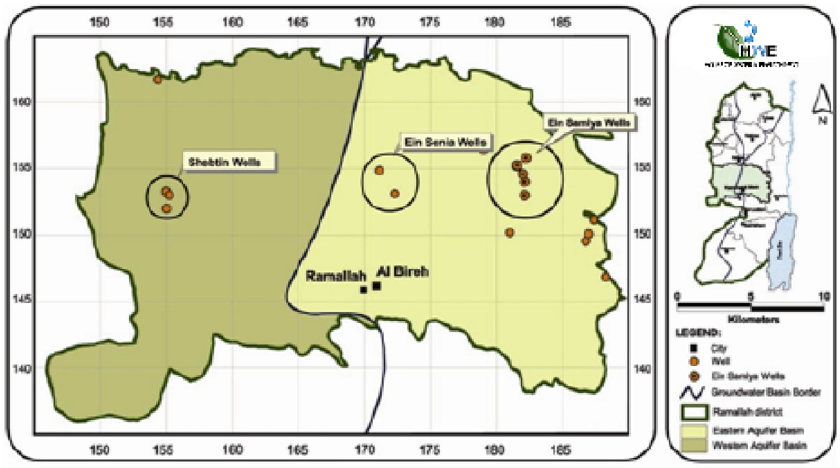


Figure 5: Ein Samia Wells and Other Wells in Ramallah-Al Bireh District, (HWE, 2009)

3.6.2. Springs

The total number of springs in Ramallah-Al Bireh District is 78 springs spreading in the Eastern and Western basins, with an annual average discharge of 11.56 liters/sec, of which 38 are minor springs with an average discharge not exceeding 0.01 liters/sec (Note: these springs are intermittent). The two major springs in the district are the Auja and Samiya springs located in Ramallah and Kafr Malek, with an annual average discharge of 9.45 and 0.58 liters/sec respectively. Springs are used for different purposes, such as agricultural use and domestic use in the areas lacking of municipal water, whereas many springs are useless (HWE, 2009).

The major springs in the study area are Ajjul, Harrasheh, Delbeh, Delba, Arik Fuqa, Arik Tahta and Zarqa springs.

3.6.3. Rainwater Harvesting

Cisterns are widely used as a supplementary source of water supply in Ramallah district. Most Palestinians use the rooftops of their houses as a catchment area to collect rainwater during winter time. The average capacity of the existing cisterns is 70 m^3. This source of water is very important to Palestinians all over the West Bank but more important to those who are not connected to a water distribution system and where there is a shortage of water during the summer.

CHAPTER FOUR

METHODOLOGY

4.1. Methodology

WEAP will be used to build an IWRM model taking JWU as a case study. This was carried out after preparing needed maps such as JWU service area location within West Bank then collecting the required data such as volumes of water supplied to the service area.

The following summarizes the main steps that were followed:

- Data collection to define the current situation of the water system.
- Review of available data and previous studies on water management.
- Develop future management scenarios related to the population growth, supply and demand changes for JWU area.
- Building the IWRM model using WEAP and illustrating its output.
- The final results of the modeling study have been formulated in the form of figures, tables and maps
- Forecast the behavior of the water system on the basis of assumed or envisaged scenarios of water availability and demands.
- Evaluate the impacts of the actions, by observing and making a Comparative Analysis based on certain criteria of the results from the different scenarios. This means that WEAP is used here as a DSS tool.
- Based on the above comparative analysis, a set of management practices and recommendations will be developed.

In order to achieve the main goals of this research, it is necessary to make the following steps;

1. Prepare the required information and all the input data for WEAP software to develop an integrated water resources management (IWRM) model,

2. Be a good decision maker to decide what the suggested scenarios will be after studying the JWU area and what it needs to address water scarcity since this will help in evaluating the existing water management scenarios and other expected future scenarios taking into account different operating policies, and factors that affect demand such as demand management strategies,

3. Get the output results and study their accuracy and check if they are close to the truth in order to test and evaluate the use of WEAP as water demand management tool and check if it can use them in solving IWRM problems using data and conditions of this case study and undertake the needed calibration. Figure 6 summarizes the methodology used in this research.

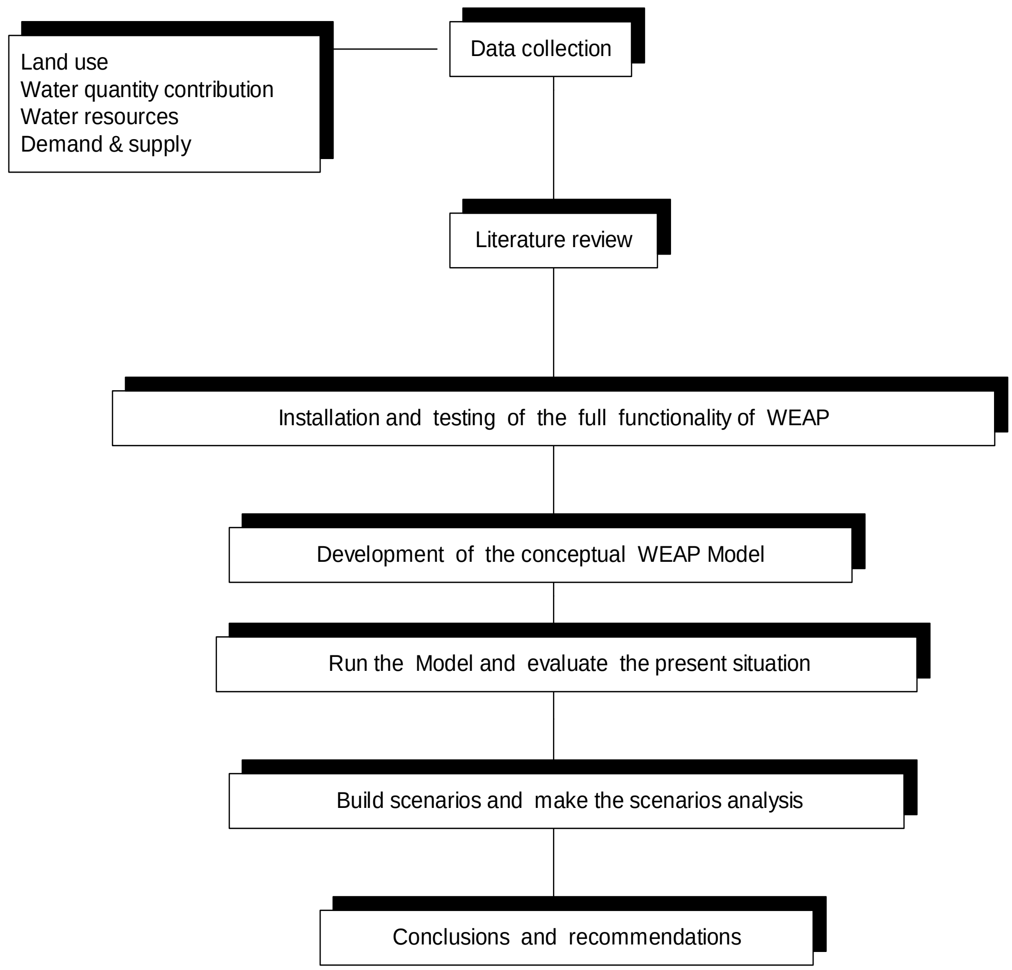


Figure 6: The Methodology of This Research

CHAPTER FIVE

MODELING DEMAND AND SUPPLY USING WEAP

5.1. Introduction

Palestinian water managers face significant challenges in providing sufficient water supplies to meet Palestinian domestic needs at present and in the future, and to support agricultural and industrial growth. Increasing water demand must be managed and met. Palestinians must have a model that evaluates the variety of options available to them to manage future water demand and develop supplies. Modeling becomes an essential tool in water management. It plays a significant role in fulfilling the core tasks of water management.

The major steps in using WEAP to evaluate water management options under different scenarios for the Jerusalem Water Undertaking 'JWU' are:

- Identification of model domain, time frame and system components and configuration.
- Establishing the current accounts that provide a snapshot of actual water demand resources and supplies for the system.
- Establishing the reference scenario that represents the changes that are likely to occur in the future in absence of any new policy measure.
- Building scenarios based on different sets of future trends and factors that affect demand supply.
- Evaluating the scenarios with regard to criteria including adequacy of water resources, costs, benefits and environmental impacts.

5.2. Model Algorithm

In order to verify the model, the algorithms behind the different scenarios were reviewed.

WEAP operates on the basic principle of water balance for every node and link in the system on a monthly time step subject to demand priorities, supply preferences, mass balance and other constraints. Mass balance equations are the foundation of WEAP monthly water accounting: total inflows minus total outflows equal to net change in storage if any. Every node and link in WEAP has a mass balance equation and some have additional equations which constrain their flows (e.g., outflows from an aquifer cannot exceed its maximum withdrawal, link losses are a fraction of flow, etc.)

Annual Demand in WEAP: The monthly demand represents the amount of water needed by the demand site for its use on monthly basis. A demand site's (DS) for water is calculated as the sum of the demands for all demand sites' bottom –level branches (Br).

$$Annual\ Demand = Total\ Activity\ Level \times Water\ Use\ Rate \quad \cdots\cdots\cdots \quad (1)$$

Monthly Supply Requirement: The supply requirement is the actual amount needed from the supply sources. The supply requirement takes the demand and adjusts it to account for internal reuse, demand site management strategies for reducing demand, and internal losses. These three adjustment fractions are part of the input data for the model.

$$Monthly\ Supply\ \mathrm{Re}quirment = \frac{Monthly\ Demand \times \left(1 - \mathrm{Re}use\ Rate\right) \times \left(1 - DSM\ Savings\right)}{1 - Loss\ Rate} \quad \cdots\cdots \quad (2)$$

Supply and Resources: Given the monthly supply requirement established from the definitions of the system demand, the supply and resources section determines the amounts, availability and allocation of supplies.

Transmission Links: Transmission links deliver water from supply nodes to satisfy final demand at demand sites. In addition, they deliver wastewater outflows from demand sites and wastewater treatment plants to other demand sites for reuse. The amount delivered to the demand site equals the amount withdrawn from the source minus any losses. Losses refer to the evaporative and a percentage of the flow passing through a transmission link.

$$Trans.\ Link\ Outflow = Trans.\ Link\ Inflow - Trans.\ Link\ Loss \quad \cdots\cdots\cdots \quad (3)$$

Priorities for Water Allocation: competing demand sites and catchments are allocated water according to their demand priorities. These priorities are useful in representing a system of water rights, and are also important during a water shortage, in which case higher priorities are satisfied as fully as possible before lower priorities are considered.

Supply Preference: if a demand site is connected to more than one supply source, choices for supply, that supply is preferred to be used, may be ranked using supply preferences. In the model groundwater is set to be with highest preference since it is more reliable and has better quality.

Using the demand priorities and supply preferences, WEAP determines the allocation order to follow when allocating the water. The allocation order represents the actual calculation order used by WEAP for allocating water. All transmission links with the same allocation order are handled at the same time. For example, flows through transmission links with allocation order 1 are computed, while temporarily holding the flows in other transmission links with higher allocation orders at zero flow, and so on.

Return flow links transmit wastewater from demand sites to destinations that are either wastewater treatment plants or receiving bodies of water. The amount that flows into the link is a fraction of that demand site return flow.

5.3. Establishing the Current Accounts in WEAP

The current accounts represent the basic definition of the water system, as it currently exists. In our case, the year 2007 is selected as the current year since it is the last published data by PWA when the work started. The model simulation period is taken from 2007-2025.

5.3.1. Identifying Current Water Uses

Existing water uses can be classified according to the following: Municipal and industrial (domestic, industrial) water demands.

Annual water demands are the requirements for final water services. Activity Levels are used as a measure of social and economic activity, and the water use rate is the average annual water need per unit of activity. Figure 7 depicts the five domestic demand sites in study area.

Domestic demand: the population census obtained from PCBS is shown in Table 1.

Table 1: The Domestic Demand Sites in the Study Area

Zone	Annual activity level (population)	Annual Use Rate (m^3/ Person)	Losses %
Zone 1	104437	55	24
Zone2	67312	55	22
Zone 3	35128	46.6	21
Zone 4	27973	38.8	21
Zone5	22904	34.8	19

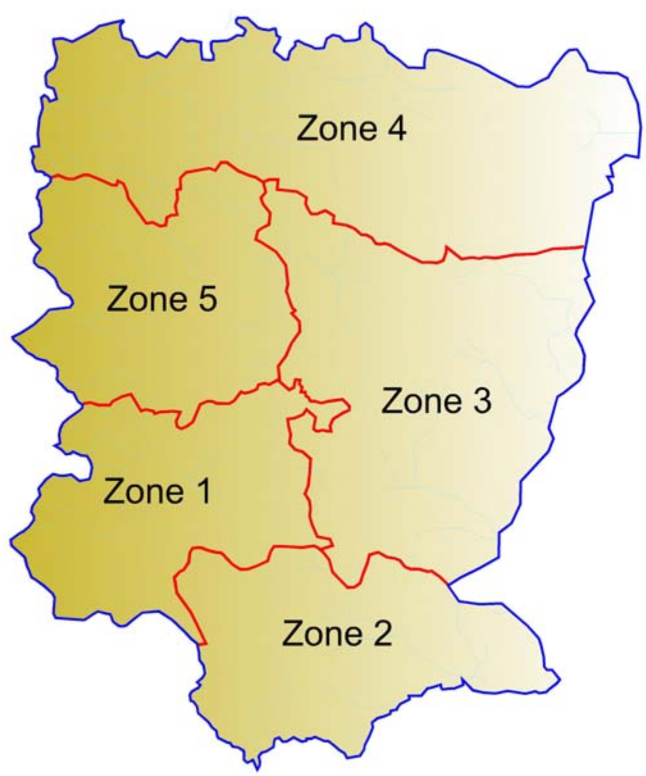


Figure 7: The Domestic Demand Sites in the Study Area

5.3.2. Identifying Current Basic Water Needs

Domestic Water Needs

All people, whatever their stage of development and their social and economic conditions, have the right to have the access to drinking water in quantities and of a quality equal to their basic needs.(UN,1997).

In terms of quantity and quality, four basic human needs are identified: drinking water for survival, water for human hygiene, water for sanitation services and modest household needs for preparing food.

Considering drinking water and sanitation needs only suggests that the amount of clean water required to maintain adequate human health is about 100 L/c/d, and 150 L/c/d is necessary to provide for some average acceptable quality of life.

5.4. Existing Water Supply and Distribution System

5.4.1. Water Production Facilities

5.4.1.1. Origin of Supply

The service area of the JWU is presently supplied by drinking water from the three following sources:

1. JWU own water wells at Ein Samia, located in the north-east of the service area;
2. Purchased water from the Israeli company, Mekorot, which is pumped into the system through Ramallah Pumping Station located

at the south-west of the service area and Um Safa and Al-Jib locations; and

3. Purchased water from Jerusalem Municipality that is injected into the JWU water supply system at 2 locations:
   - North of Shu'fat (Jerusalem 1); and
   - Entrance of Hizma (Jerusalem 2).

JWU owns and operates currently 4 wells with an equipped capacity of 520 m^3/h and an actual production representing almost 18% of the total water supplied to the service area. The remaining quantity is purchased from Mekorot and Jerusalem municipality. It is evident that the first priority for JWU is to reduce as much as possible the water purchased and increase the capacity of its own resources. Table 2 below shows the present water resources in the area.

Table 2: Present Water Resources within JWU Service Area

Location of Source	Connection Diameter (mm)	Controlled by
Ein Samia	-	JWU
Beitunia	400	Mekerot
Shufat (JM1)	150	Jerusalem Municipality
Hizma (JM2)	75	Jerusalem Municipality
Al Jib	50	Mekorot
Um Safa	50	Mekorot

Source: JWU, September 2008

5.4.1.2. Production Facilities

The JWU has drilled about seven wells in the eastern aquifer, four of which are operated near the Ein Samia spring east of Kufr Malik village. The rest are either dry or not functioning.

Well No. 1

Well No. 1 was drilled in 1964 with an average production capacity of 100 m^3/h in normal winters. Its water table fluctuates between wet and dry seasons, thus the discharge usually drops to half in summer seasons. There are two submersible pumps installed in the well. One pump is used to pump water when the water level in the well is high and second pump is used when the water level is low. In good rainy seasons, both pumps could be used together for a short period.

Well No. 2

Well No. 2 was first drilled in 1965 with a production capacity of 45 m^3/h. By the year 1991, the discharge of the well fell to about 34 m^3/h. deviation in the vertical alignment of the borehole and its small diameter were amongst the technical problems that prevented its possible rehabilitation. Therefore, JWU approached the German Government to finance the drilling of a new substitute well. The drilling of the substitute well No. 2 began in 1996 at an adjacent location and equipped with a vertical, turbine pump. JWU purchased a stand-by electric motor for this unit. The unit is in excellent condition. The completed new well is 250 m deep and produces 165 m^3/h from the upper aquifer of Cenomanian age. Its water table lies at 170 m below ground level.

Well No. 3

Well No.3 was drilled and equipped with a vertical, turbine pump in 1980 and taps the Lower Aquifer down to a depth of 526 m. In 1996, this unit was overhauled through the GTZ project. The old 8" column pipe was replaced by 10" pipe. The electric motor was replaced with a larger one. The electric control panel was modified and renewed. The unit is in a very good condition. Since its rehabilitation, it has the second largest yield amongst all JWU wells at 180 m^3/h.

<u>Well No. 4</u>

Well No. 4 was drilled in 1990. Although, it is the deepest well (616m deep), and its production capacity does not exceed an average quantity of 1000 m^3/d from the lower aquifer. The reason for this low productivity seems to be due to a complicated hydro-geological situation. A deep throwing fault system lies between well No. 4 and the other wells. Most probably, this fault acts as a semi - barrier indicated by a small drop. It decreases the wells recharge considerably.

5.4.1.3. Operation of Supply

Priority is given to the production from water resources owned by JWU, which are Ein Samia wells. These wells produced in 1998 around 3.5 MCM, but in 2007 the production reduced to 2.64 MCM.

The additional water requirements are given by the external resources

1. The main water resources purchased are from Mekorot at Beitunia reservoir where around 10.47 MCM were purchased in 2007.
2. The second external water resources are purchased from Jerusalem Municipality and produce some 1 MCM a year. They are entered into the system at Shu'fat and Hizma. These resources are used

mainly for local consumption and are operated in a way to minimize the volumes purchased.

3. The third external water resources purchased produce some 57,000 m^3 a year, and are located in Um Safa and Al Jib. These sources, which were introduced in 1997, are used of local consumption, and are operated in a way that minimizes the abstraction form these resources.

Table 3 presents the volumes entered into the system, for every source in 2007. From the table Ein Samia wells produced about 2.64 MCM in year 2007, also we can see that JWU purchased about 10.97 MCM from Mekorot Company in addition to 18,810 m^3 and 39,075 m^3 which were pumped into the system through Um Safa and Al-Jeeb.

The table shows that 850,506 m^3 and 193,702 m^3 were purchased from Jerusalem municipality and entered the system through Bitunia and Shufat.

Table 3: Monthly Volumes in m^3 Entered in the System in the Year 2007, for Every Source

Month	Produced	Purchased					Total (m^3)
	Ein Samia (m^3)	Bitunia (m^3)	Shu'fat (m^3)	Hizma (m^3)	Um Safa (m^3)	Al Jib (m^3)	
January	167,274	796,255	80,772	15,001	1,390	3,390	1,064,082
February	148,986	831,449	57,623	11,715	830	3,391	953,994
March	176,160	833,926	65,966	12,885	1,120	3,400	1,093,457
April	199,570	863,887	69,351	10,230	1,300	3,400	1,147,738
May	245,493	979,446	66,048	14,762	1,800	3,566	1,311,115
June	261,782	971,923	80,586	20,283	1,790	3,566	1,339,930
July	278,495	1,016,925	78,211	19,972	1,950	3,906	1,399,459
August	275,877	895,354	76,559	15,978	2,050	3,905	1,369,723
September	253,407	962,701	64,960	20,223	1,420	2,645	1,305,356
October	249,128	1,005,116	87,229	17,611	2,270	2,645	1,363,999
November	208,888	827,511	57,149	15,351	1,860	2,631	1,213,390
December	180,723	992,275	66,052	19,961	1,030	2,631	1,162,402
Total	**2,645,783**	**10,976,768**	**850,506**	**193,702**	**18,810**	**39,076**	**14,724,645**

Source: JWU operation Engineer, Bassam Sawalhi, September 2009

5.4.2. Transmission and Distribution Facilities

The JWU water supply system covers the major part of the cities and villages of Ramallah-Al Bireh Governorate. The network shown on Figure 8 (General Layout of Main Facilities) extends:

– North to the border of Ramallah-Al Bireh Governorate and south to Beit Hanina village;

– West to the Al Mazra'a Al Qibliyeh village and east to Ein Samia village.

Ramallah water supply network is not very old with nearly 70% of the pipe length less than 22 years old and some sections of the main transmission lines are around 40 years old. Pipes were laid in a random way without adherence to standard specifications. Laying the pipes was usually done piece by piece according to connection requirements and no standards were used for the construction of the network. The total length of systems, transmission and distribution, reached 1000 km.

The main issues for operating the distribution system can be summarized in the following:

1. The distribution system as mentioned earlier consists of different networks that are directly connected to the transmission lines. Most of these networks are connected to the transmission lines from different entrance points. This would create operational and hydraulic difficulties in controlling the flow and the pressure. Additionally, the cost of controlling a system with several entrance points is higher than that with one entrance point.

2. The lack of standard operation procedures in the past for laying of pipes, installation of manholes, and maintenance of water meters has made the regular operation and maintenance (O&M) of the system inherently problematic.
3. Major political and administrative constraints are imposed on the expansion and upgrading of the distribution system. These constraints are attributed to the fact that part of the distribution system lies in areas B and C that are still under the Israeli control.
4. The lack of awareness of some consumers creates problems in operating and managing the distribution network and increases the Unaccounted for Water (UFW) ultimately causing higher unit water cost.

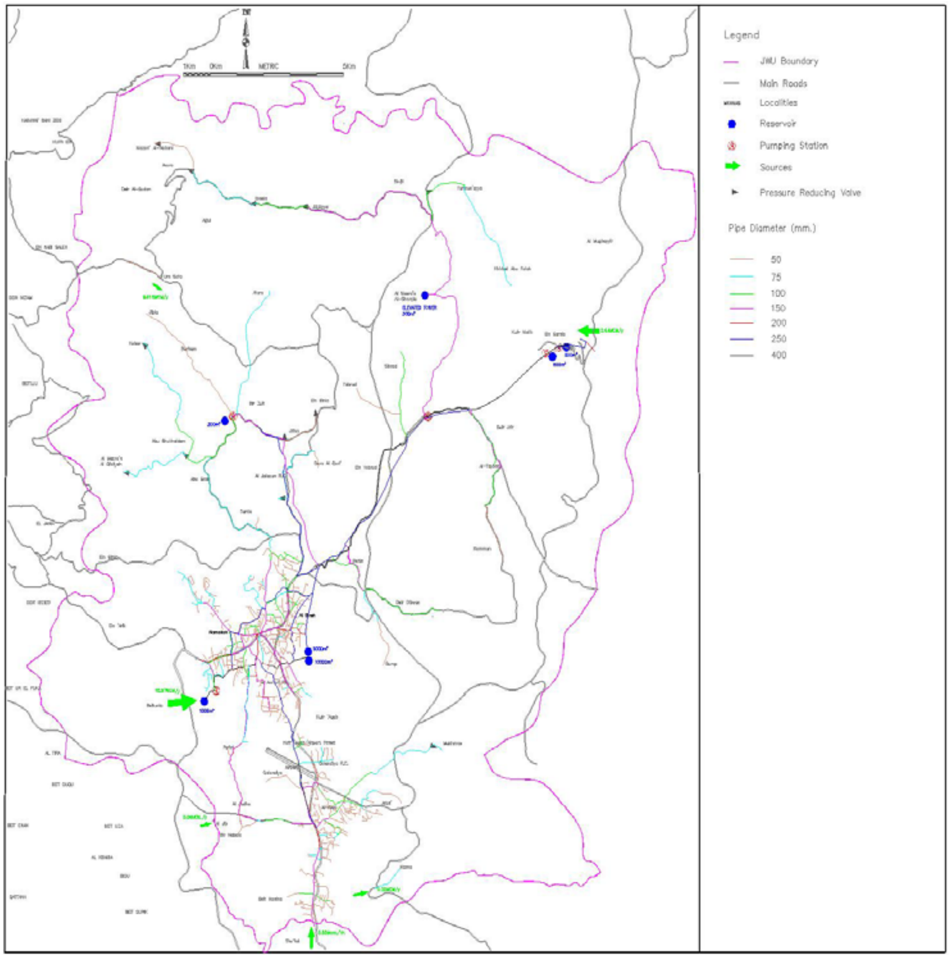


Figure 8: General Layout of Main Facilities
Source: JWU, September 2008

5.4.3. Storage Capacities

There is no inter-seasonal storage capacity in the system but only several balancing reservoirs. The number of these reservoirs is limited to 8 reservoirs.

Three reservoirs are under external control. One of these reservoirs, which is called Ramallah reservoir (or Beitunia-Mekorot), is controlled by Mekorot. Another one (Beitunia Municipality) is operated by Beitunia

Municipality, whereas the third one (Bir Zeit) is operated by Bir Zeit Municipality. The other five reservoirs are completely operated by JWU.

5.5. Water Quality

The aim of JWU is to ensure the supply of clean and hygienically safe water to its consumers and to stay vigilant in case of any water quality problems. JWU regularly samples and tests its supplied water at sources and at different locations of the distribution system.

Water produced from Ein Samia wells is tested and analyzed from both Chemical and Bacteriological aspects. Specific Chemical tests are performed twice a year and include major cations, anions, trace elements and surfactant content. In addition to these tests, there are number of routine Chemical and Physical tests that are performed on water produced from Ein Samia wells on weekly basis such as turbidity, conductivity and chlorine content.

Regarding the distribution network, there are number of tests that are performed on a routine basis such as turbidity, conductivity, and Chlorine content. In addition, Bacteriological tests are carried out on daily basis and cover the whole distribution system of JWU. For this purpose, the service area of JWU is divided into four zones depending on the source of water supply. Each zone of the four is further divided into sub-zones, depending on the number of consumers, and a number of bacteriological tests are assigned and performed in each zone accordingly.

Additionally, the Palestinian Water Authority performs from time to time its own quality tests on JWU sources. The Government's Health Department also performs biological tests from consumers'dwellings. Previously, all tests and analysis were carried out by the Center for Environment and Occupational Health Sciences of Bir-Zeit University. Presently, all routine tests are carried out by JWU. Sampling for all types of tests is as well the responsibility of JWU.

So far and without considering few isolated incidents, water supplied by JWU has proven to be hygienically safe and complies with the internationally recognized quality standards.

5.5.1. Physical Quality

The physical parameters include temperature, odour, taste, colour and turbidity.

The analytical results for the physical quality parameters showed that the water supplied by JWU is of high quality. The analytical results for turbidity at the water sources are presented in Table 4.

Table 4: Water Turbidity

Location	Value (NTU)
Well No. 6	3.05
Well No. 1	5.68
Well No. 2	0.68
Well No. 3	1.55
Well No. 4	0.58
Ramallah Station	1.3
Stadard Value according to WHO Guidelines	1-5

Source: JWU, 2009

5.5.2. Chemical Quality

The chemical characteristics for all water sources along with corresponding WHO Standards are presented in Table 5.

Table 5: Chemical Characteristics of the Water Sources

Source	Hardness * mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	HCO3 mg/L	SO4 mg/L	NO3 mg/L	TDS mg/L
Shufat Connection	334	71	38	92	4	174	234	66	4	589
Ramallah Station	339	73	38	82	3	161	234	62	4	560
Hizma Connection	315	72	33	90	3	147	234	58	12	543
Ein Samia 1	223	58	19	30	4	38	210	14	10	289
Ein Samia 2	188	52	14	32	3	45	190	13	4	273
Ein Samia 3	249	50	30	29	2	45	222	12	4	302
Ein Samia 4	266	57	26	29	2	44	234	12	2	309
Ein Samia 6	216	50	22	29	3	40	181	14	11	267
WHO Guidelines	**	**	**	LT200	**	250	**	250	50	1000

Source: JWU, 2009 * JWU Water lies in the category of medium to hard water
LT = less than ** No WHO Guideline Value

A comparison between these results and WHO standards shows that the water supplied by JWU is of high quality.

5.5.3. Bacteriological Quality

For JWU sources, routine Bacteriological tests are performed on a monthly basis or as needed. So far, the results of these tests comply with WHO Guideline Values as shown in table 6.

Table 6: Bacteriological Tests Results

Number of Tests	Number of Tests with Zero Colony Detected*	Number of Tests with more than Zero Colony Detected*
610	**606**	**4**

Source: JWU, 2009

WHO Guideline Value for Total Coliform: TC must not present in 95% of the total number of samples taken throughout any 12 months period. The result indicates that the quality of the supplied water through the distribution system of JWU is well within WHO Guideline Value with regard to the detection of total coliform colonies in the drinking water.

5.6. Input Parameters in WEAP

The initial tasks in the modeling with WEAP are to set the main components of the system; area location catchment size supply and demand location, basins or groundwater source or any other external source of water.

Then, the current supply and demand data explained above will be entered to be integrated and used within WEAP. Figure 9 shows a schematic representation of WEAP input basic parameters.

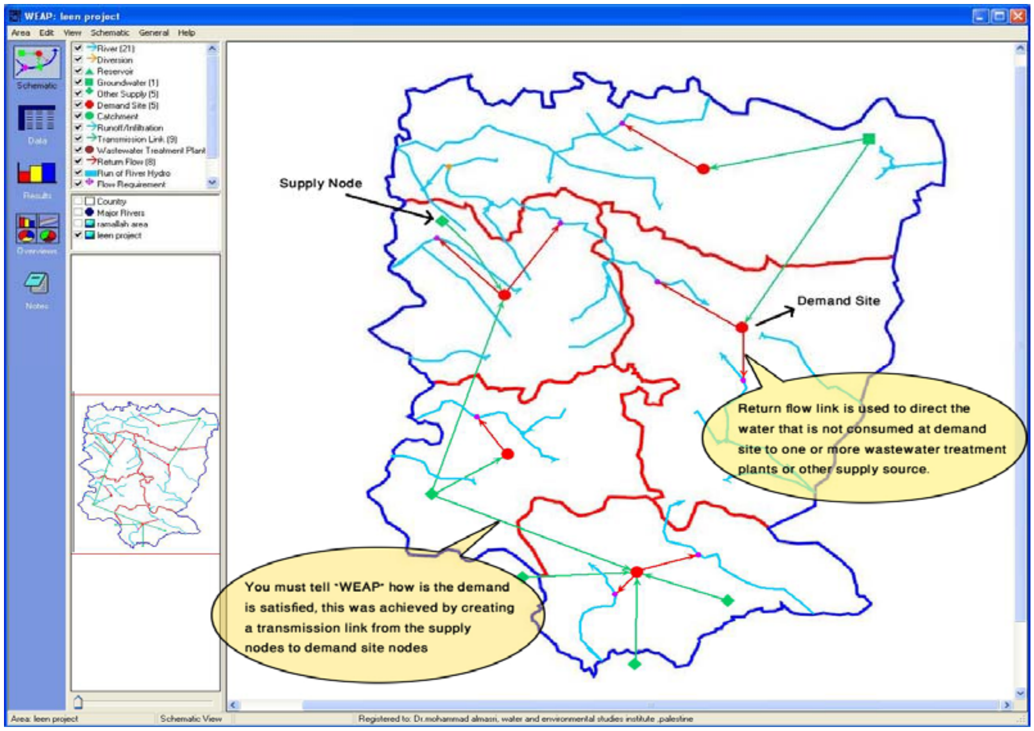


Figure 9: Schematic Representation of WEAP Input Parameter

Water Demands: currently three options exist to input and calculate water demands within WEAP:

(1) **Standard water use method** is the simplest case, the user determines an appropriate activity level (e.g. persons, households, hectares of land) for each disaggregated level and multiples these by an appropriate annual water use rate for each activity which was mentioned in table 1.

(2) **FAO crop requirements approach** is typically used to represent agricultural demand nodes. This approach assumes for each demand site a set of simplified hydrological and agro-hydrological processes.

This approach is not applicable in our project because we haven't a agricultural demand site.

(3) **Direct method** in which demands can be directly read into WEAP from a file.

Water demands were entered as 5 municipal demand sites classified according to Jerusalem Water Undertaking service area using the Standard Water Use Method. Figure 10 shows the demand data entry table in WEAP. This data includes the population in each demand site; the annual water use rate in m³ per person and losses, the values were mentioned in table 1.

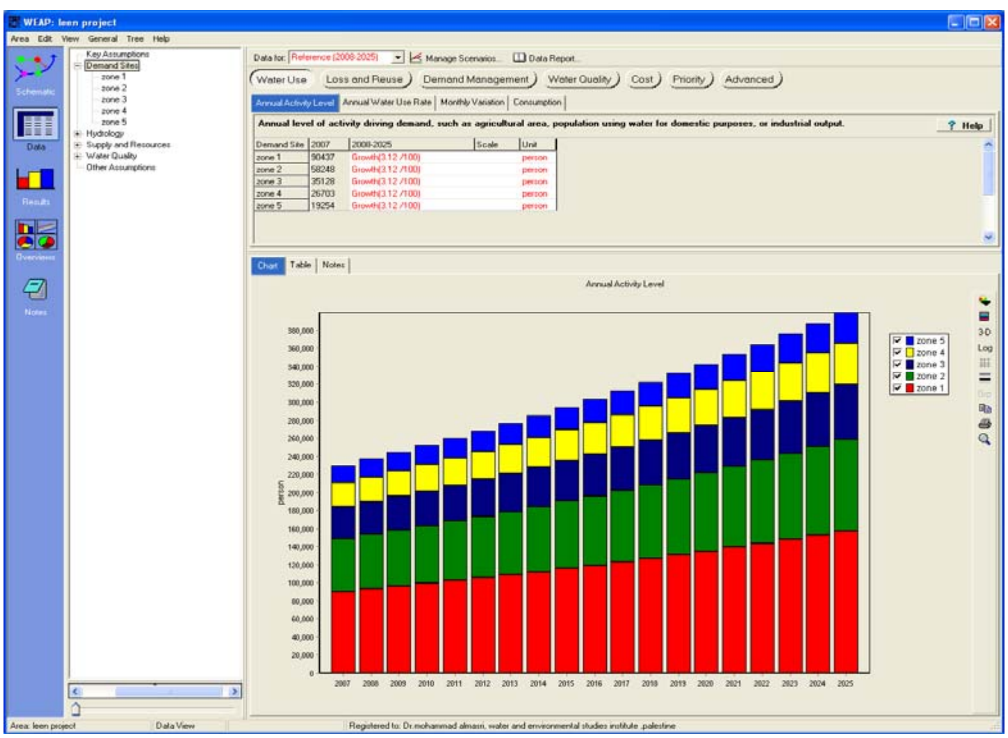


Figure 10: Example of Demand Data Entry Table in WEAP

Supply elements were defined. Data related to groundwater (recharge rate, its initial storage, and the maximum withdrawals allowed according to annual renewal), the storage capacity is unlimited. The safe yield is 172 MCM/Y as agreed upon Oslo agreement. Other supply parameter used in WEAP to represent supplies other than groundwater such as Mekorot and Jerusalem municipality inflows are entered.

There is a need to tell WEAP how the demand is satisfied. This was achieved by connecting a supply source to each demand site through creating a transmission link from the supply nodes to demand nodes. Transmission links carry water from local supply to demand sites subject to losses and physical capacity.

Then set the priorities. Priorities can range from 1 to 99, with 1 being the highest priority and 99 the lowest. These priorities are useful in representing a system of water rights, and are also important during a water shortage, in which case higher priorities are satisfied as fully as possible before lower priorities are considered. If priorities are the same, shortages will be equally shared.

Each demand site with multiple sources can specify its preference for a source, due to economic, environmental, historical, legal or political reasons, by entering supply preference for each source linked to each demand site.

You can restrict the supply from a source, to model contractual or physical capacity limitations, or merely to match observations by entering the maximum flow volume on transmission link rules/ maximum flow volume in WEAP.

The transmission losses refer to the evaporative and leakage losses as water is carried by canals and conduits to demand sites and catchments. This loss rate is specified as a percentage of the flow passing through a transmission link.

A return flow link is used to direct the water that is not consumed at demand site to one or more wastewater treatment plants or other supply sources.

CHAPTER SIX

DEVELOPMENT OF SCENARIOS, MANAGEMENT OPTIONS AND RESULTS

6.1. Introduction

In this chapter scenarios are constructed consisting of alternative sets of assumptions or policies. By using WEAP, the scenarios and the management options are evaluated with regards to water sufficiency, costs and benefits. All scenarios start from a common year, for which the model current accounts data are established. Scenarios are used to explore the model with enormous range of "what if" questions. These scenarios in WEAP encompass any factor that can change over time, including those factors that may change because of particular policy interventions, and those that reflect different socio- economic assumption.

6.2. Establishing the Reference Scenario

PWA intends to combine all the segregated networks and water committees throughout West Bank and that is based on the idea of reducing duplication of work and increasing the possibilities to improve water supply.

Within a comprehensive planning process the principles for the institutional reform within the water sector have been defined as follows (PWA, 2004):

- Regulation of the water sector by only one responsible body (PWA), with the separation of the institutional responsibility for policy and regulatory functions from those of service delivery;

- Establishment of three regional water utilities in the West Bank and one in Gaza
- Private sector participation in funding and implementation of water projects.

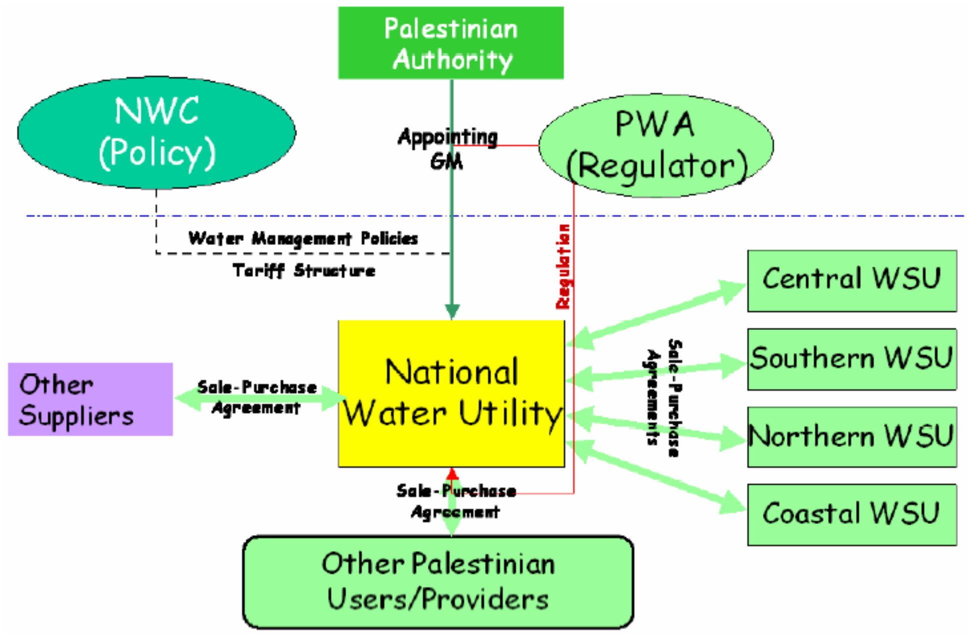
Four Regional Water Supply Utilities are planned to be created to deliver water to the different end users. The supply area is fractionized geographically; (Barghouti, 2006)

- Northern Utility (Nablus, Jenin, Tulkarem, Qalqilia, Salfit and Tubas Governorates),
- Central Utility (Jerusalem, Ramallah and Al-Bireh and Jericho Governorates)
- Southern Utility (Hebron and Bethlehem Governorates)
- Coastal Utility (Gaza Strip Governorates)

Within the new institutional framework an autonomous Palestinian Bulk Water Supply Utility is planned to be set up which will be responsible for the management of all trans-regional water supply systems and activities (Barghouti, 2006).

The Water Supply Utility would be licensed by PWA to operate water production facilities, purchase portable water from national and international suppliers, convey the water to local municipal and industrial water distribution systems; the operation, maintenance and management of those local water distribution facilities will be progressively taken over by the four planned Regional Water Supply Utilities as requested by the water law (Barghouti, 2006).

Figure 11 below show the future institutional organization of the water sector.



* WSU = Water Supply Utility

Figure 11: Future Institutional Organization of the Water Sector, (Jaas, 2006)

This scenario represents the previous vision of (PWA) to manage and organize the water sector, so our main scenario will be the development of the JWU bulk utility which is the central inland.

The service area of the proposed central utility comprises Jerusalem, Ramallah / Al Bireh Governorates. The service area would cover about 1,160 km² and would consist of 106 localities. An orderly expansion of the territory, operations and administrative structure of present JWU requires that the communities will be brought under the Utility in phases. Therefore, the expanded JWU in consultation with the PWA should be entitled to set the pace for the expansion.

This scenario will examine and discuss the establishment of the central utility to guarantee the expansion of JWU services in an administratively unified and well-managed water and sanitation utility for both Jerusalem, and Ramallah & Al-Bireh governorates that ensure the provision of safe and cost effective water services for all the population in the area.

It will be assumed that a charter company type of corporation would be established based on the amended JWU law. The company would evolve from the present JWU and be owned by the participating municipalities (local councils). The company (expanded JWU) should be governed by a representative body, the general assembly and a managing body, the Board of Directors.

The JWU will also develop the regional organization and link the expanded areas to the physical and financial systems of the JWU. This is a major task and requires substantial investment in manpower, land facilities and equipment. The JWU will formulate an implementation strategy based on the actual situation in the local authorities in different sectors and prepare an institution- building project based on that strategy.

The extension of the JWU services to new areas would also give the JWU an opportunity to re-organize the functions of its staff and hence improve the productivity. However, this may require increasing automation and streamlining the duties and functions of the staff.

At the same time it means that the unaccounted for water should, on priority basis, be as low as possible in the areas where the water consumption is the highest. The unaccounted for water (UFW) is about 25% in the service area of the JWU and probably this figure is still higher in the other project communities as shown in table 1, hence there is a need to start a project to reduce water losses and further reduce the dependency on foreign sources of water. This is not only important to the expanded utility, but to the nation as a whole.

The centralized system creates an opportunity to the extended utility to 'privatize' some activities, so the effect of privatization will be checked in the later sections.

6.2.1. Demand Projection

These demand projections represent the changes that are likely to occur in the future, in absence of any new policy measure. Base case scenario is with population growth at a rate of 3.2% (PCBS, 2003). Population census that is represented in WEAP by the annual activity level is shown in Table 7.

Historic demand figures can not be used to forecast future demand since it has been artificially constrained by non market forces. The current allocations between Palestine and Israel aggrieve Palestinian water rights.

Present per capita consumption is below WHO standards. So WHO standards will be used to project future demand. Population increase is the major parameter affecting future water needs, not only for domestic uses, but also for other uses such as industrial uses. Figure 12 below show the proposed central utility. Detailed description of the characteristics of these zones is shown in Appendices

Table 7: Domestic Demand Sites in the Expanded Area

Zone	Annual activity level (population)	Losses %
Zone 1	104,437	15
Zone2	67,312	15
Zone 3	35,128	15
Zone 4	27,973	15
Zone5	22,904	15
Eastern Jerusalem	100,000	15
Northern Ramallah	63,750	15
Southern Ramallah	26,066	15

Figure 12: Central Utility Area

Applying this scenario to WEAP and keeping the supply quantities which were discussed in the previous chapter in table 3 as current, the run results show that water demand will grow due to the increase in population as shown in Figure 13. In Figure 14 the unmet demand will grow dramatically because of the limited supply and increased population. This ensures the role of JWU in developing new water resources and securing water to the JWU area.

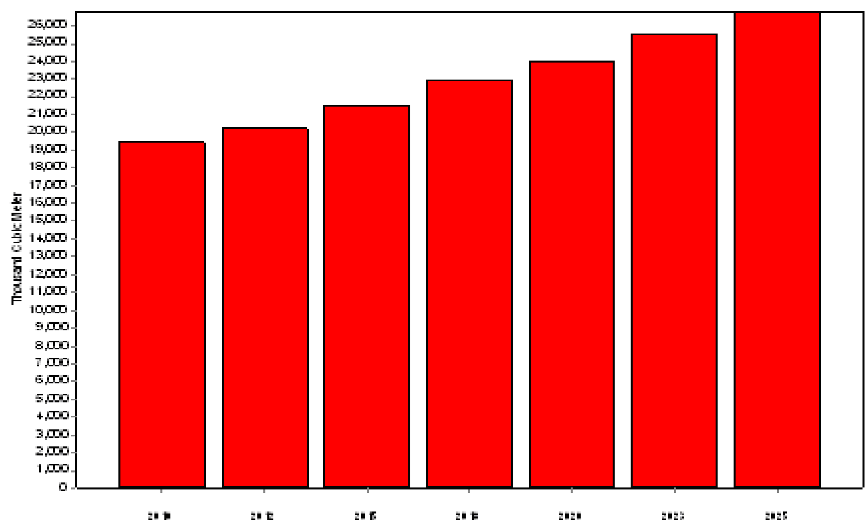


Figure 13: Water Demand (Reference Scenario)

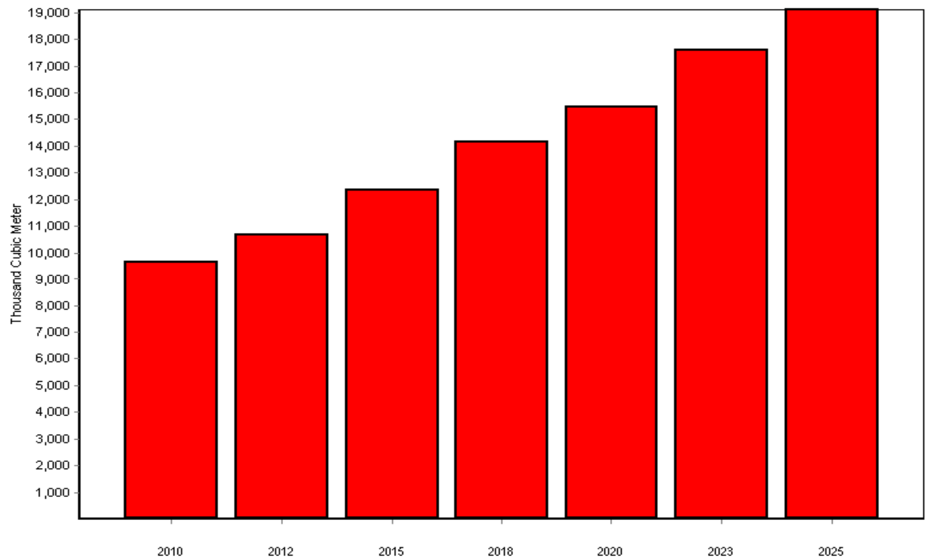


Figure 14: Unmet Demand (Reference Scenario)

6.3. Establishing the Main Scenario and Management Options

The service area of the proposed central utility comprises Jerusalem, Ramallah & Al Bireh Governorates. Most of the water supplied to project area (about 80%) of the total volume is purchased from Mekorot. The Jerusalem water undertaking (JWU) is distributing this water to networks. In similar manner various other agencies like WBWD within the planned operation area of the new utility are doing the same. To reduce dependency on foreign sources of water such as Mekorot Company there is an urgent need of developing new resources inside the project area to cover the water supply requirements which is expected to increase due to expanding the service area. These new sources will be one of the following:

1. Eastern Aquifer Basin
2. Western Aquifer Basin
3. Both Aquifer Basins

So the aim is to calculate the future volumes to be mobilized and how they will be spatially distributed for each alternative and evaluate the performance of each distribution system and determine the resources where these volumes will be abstracted, taking into account the cost of producing water from the aquifer and the distribution cost. Water unit cost will be the main factor in the option preference and in the best option selection. This unit cost will be affected highly by the cost of producing water from the Aquifer basin and the distribution cost.

Accordingly, three options will be developed, populated into WEAP, and tested that are as follows:

Option 1: pumping water from Eastern Aquifer Basin

Option 2: pumping water from Western Aquifer Basin

Option 3: pumping water from Both Aquifer Basins

Those options are formulated by considering a set of alternative assumptions about future impacts of the adopted policies. In each option we will investigate the possibility of pumping the water needed due to the expansion in the service area from each source: Eastern Aquifer Basin, Western Aquifer Basin or Both Aquifer Basins. In the main scenario we will assume that no peace agreement can be reached but that economic prosperity prevails, kindled by international donors. This results in fairly stable conditions in the region. Water availability for JWU service area will be checked for the source but the quantity of water is assumed to be enough and there is no problem with quantities. Following is a description of the assumptions that will be applied for each option, where a questioner was distributed to different stakeholders by Abu-Hantash in year 2007 and these assumptions represents the average values of there responses.

- The assessment of future Population has been carried out using the PCBS (2007) census results as a base for the end of the year 2007 and then applying the following population growth rates:

Table 8: Population Projection

years	Population growth %
2007-2010	3.2
2010-2015	3.0
2015-2020	2.5
2020-	2

- Municipal demand will be at the average WHO standards 150L/C/d and the industrial demand will be increased to reach 10.5 percent of total municipal demand, this figure is the average between WHO standards (16 percent of the total municipal demand) and the current demand which is 7 percent of the total municipal demand (CH2MHILLM, 2003).
- It was assumed that all communities with the district will have wastewater collection, treatment and reuse systems by the end of year 2025.

- The analytical results for the physical, chemical and bacteriological quality parameters shows that the water supplied by JWU is of high quality.
- Consumer education and awareness level would affect the water use and practices, which could result in water demand reduction. In this case it was assumed that there is an increase in education and awareness to a level that will result in an efficient demand management program, which can save 15% of domestic demand.
- Applying conservation measures and improving water infrastructure was assumed to be reflected in unaccounted for water rates reduction that losses will not exceed 15 percent at the end of 2025.
- Private sector will be engaged in water development activities to achieve development progress. This would enable projects sustainability, this can save water as much as 10 percent.
- The unit cost of water considers the cost of producing water from aquifers in addition to pumping those waters to the different zones. As a component of the water supply systems, pumping will be required to transport water in pipes that cannot flow by gravity. Pumping will be also required to transfer water from each source to the different zones.
- The cost of producing water which includes the investment cost and the cost of pumping water to the ground elevation at the well site was calculated for the eastern and Western Aquifers Basin according to the water sector strategic planning study that took all the West Bank as the study area as follows:

- Eastern Aquifer: 0.35 $/m³
- Western Aquifer: 0.4 $/m³

- The average conveyance cost between demand sites is calculated as following:

$$P = Q * H * \gamma$$

- P = Power transmitted to the fluid by the pump in Watt.
- Q = Flow in m^3/s.
- H = Energy or pressure loss expressed in m.
- γ = 9810 m^2/s
- The cost of each KW is .1 $

Then

$$\text{Cost} = .1\left(\$/_{kwatt}\right) * \left(\frac{9810 * Q\left(m^3/_s\right) * 10^6 * H(m)}{1000 * 24 * 365 * 60 * 60}\right)$$

So the cost of conveyance water in US Dollar is equal to:

$$\text{Cost} = .03 * Q * H$$

While Q in MCM/year and H expressed in m. The elevation of each zone is shown in the Appendices.

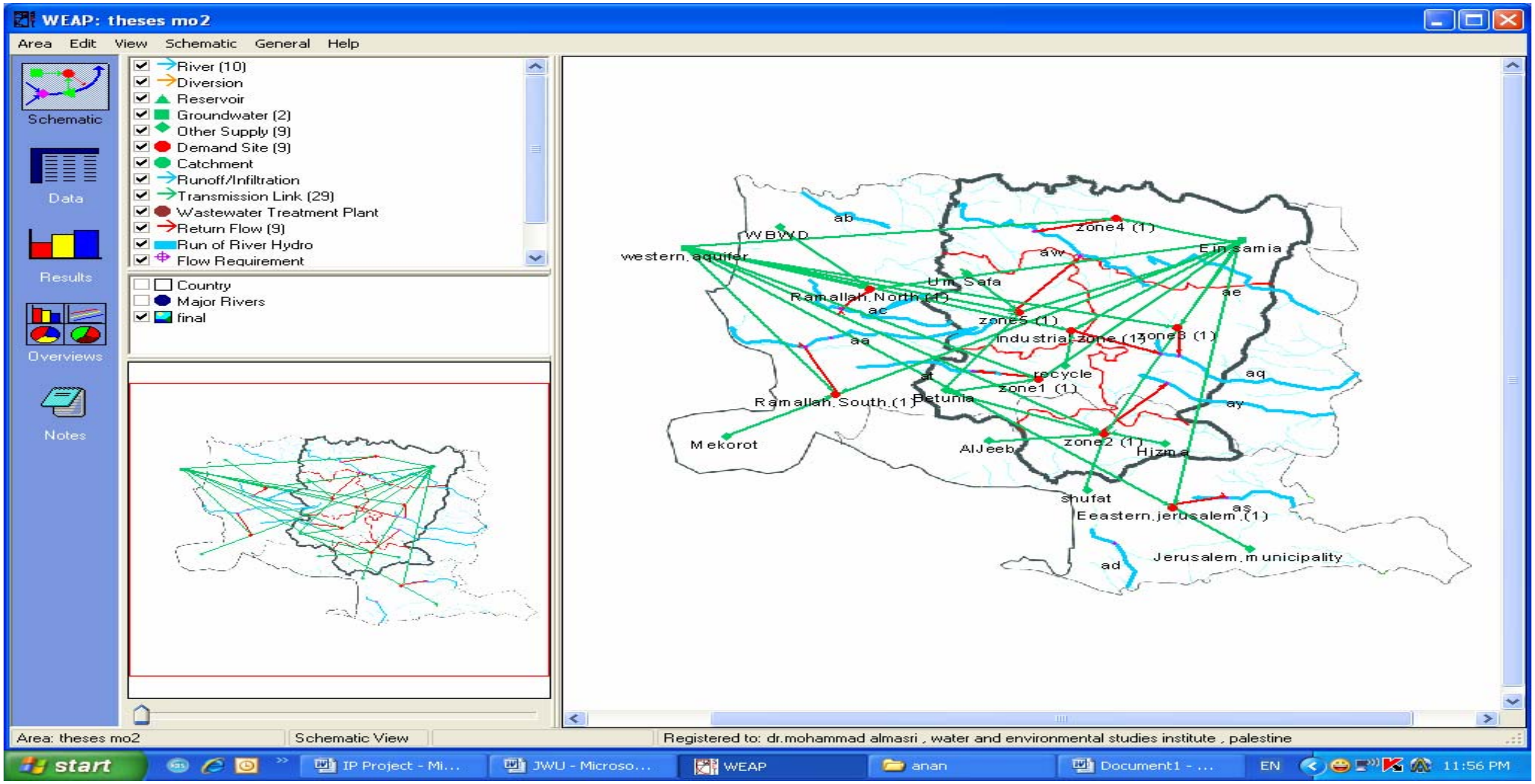


Figure 15: Conceptual WEAP Model

6.4. Results and Discussion

The results obtained from various WEAP Runs under various management options mentioned in the previous section are summarized, discussed, and presented in the following section:

6.4.1. Supply Delivered

Predicted water demand is about 40 MCM as shown in figures 16 and 17, the quantities delivered to the JWU area about 34 MCM by the end of year 2025 the source of these quantities was varies according to the three options, see figures 18, 19 and 20

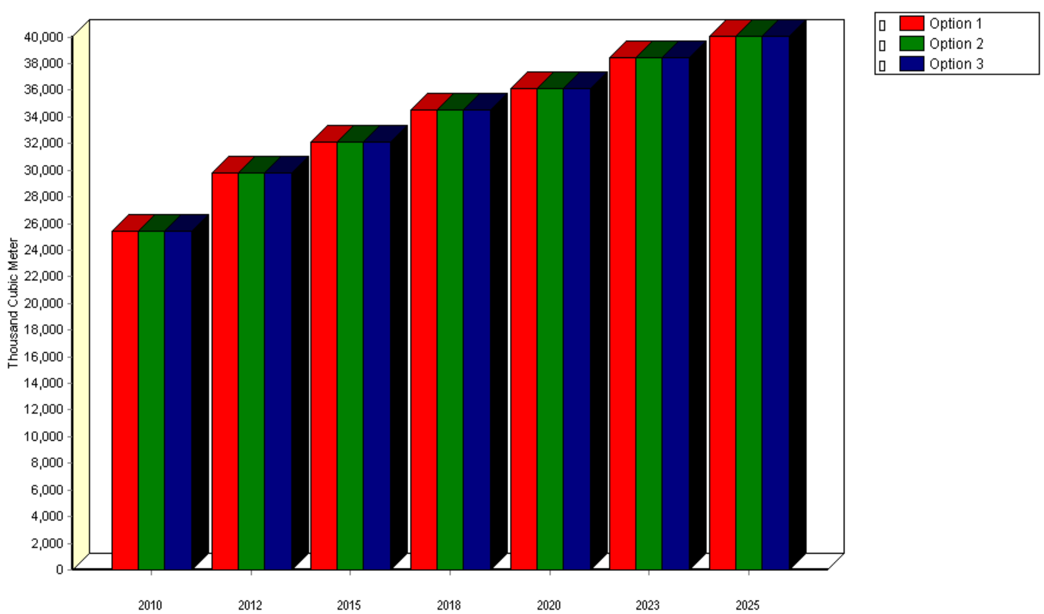


Figure 16: Predicted Water Demand

In figure 16 the water demand will be increased due to the increasing in population. Figure 17 shows the difference between the water demand and the supply requirement, this difference represent the losses, reuse and Demand Saving Management.

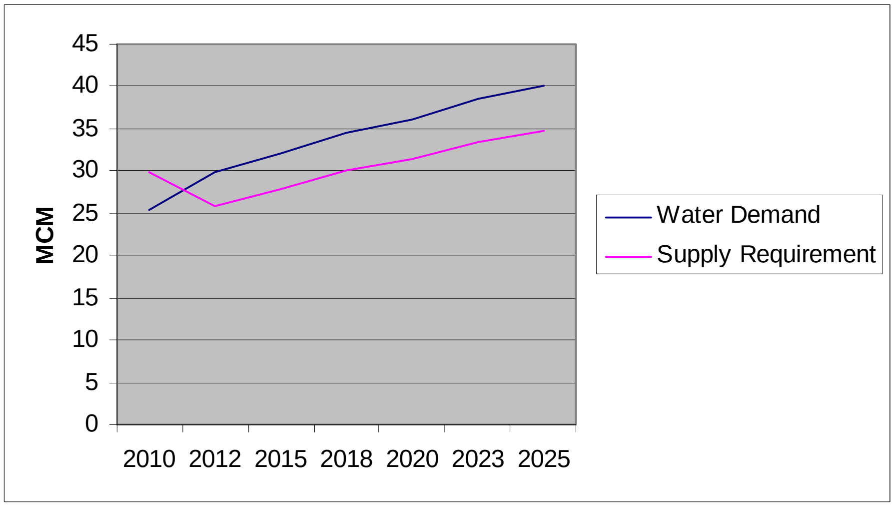


Figure 17: Predicted Water Demand and Supply Requirement

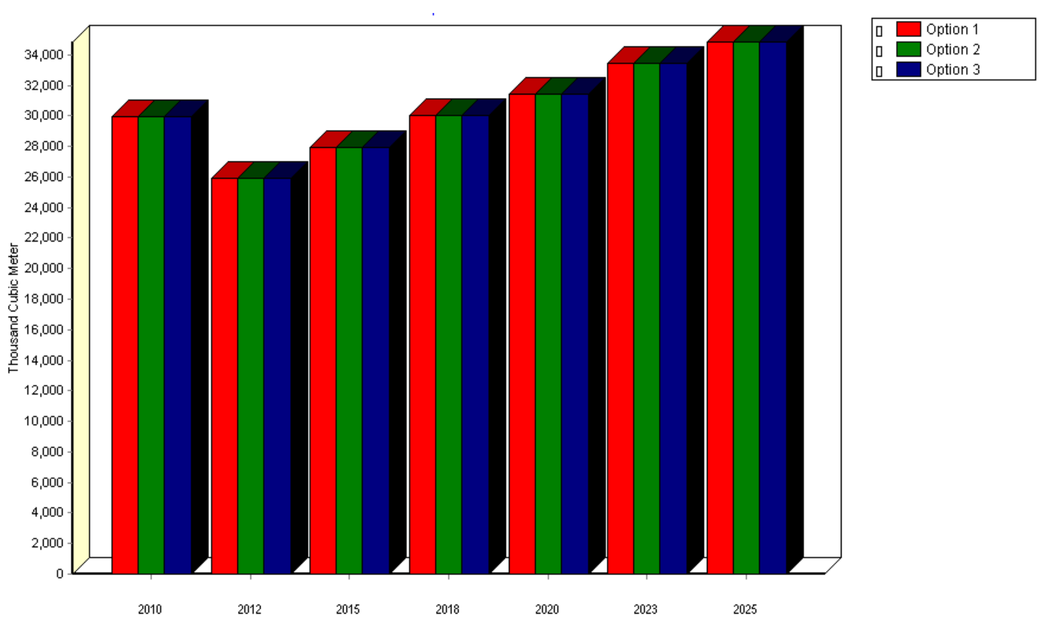


Figure 18: Water Delivered to the Demand Sites from all Sources

In figure 18 it is noticed that the water delivered to the area will be decreased by year 2012 because in this year we will start in applying the demand management program, so the supply requirement will be decreased then it will start to increase again due to population increase. Figure 19 shows that the largest amount of water was abstracted from Ein Samia in Option 1 to cover the future demand. The amount was 21 MCM by the end of year 2025. In Option 2, all future needs of water were covered from Western Aquifer in addition to the current amounts abstracted from Ein Samia (2.65MCM) and the amounts of water purchased from Mekorot (13MCM).

However, only 15 MCM were abstracted from Ein Samia in Option 3 and the rest of water needs were supplied by Western Aquifer.

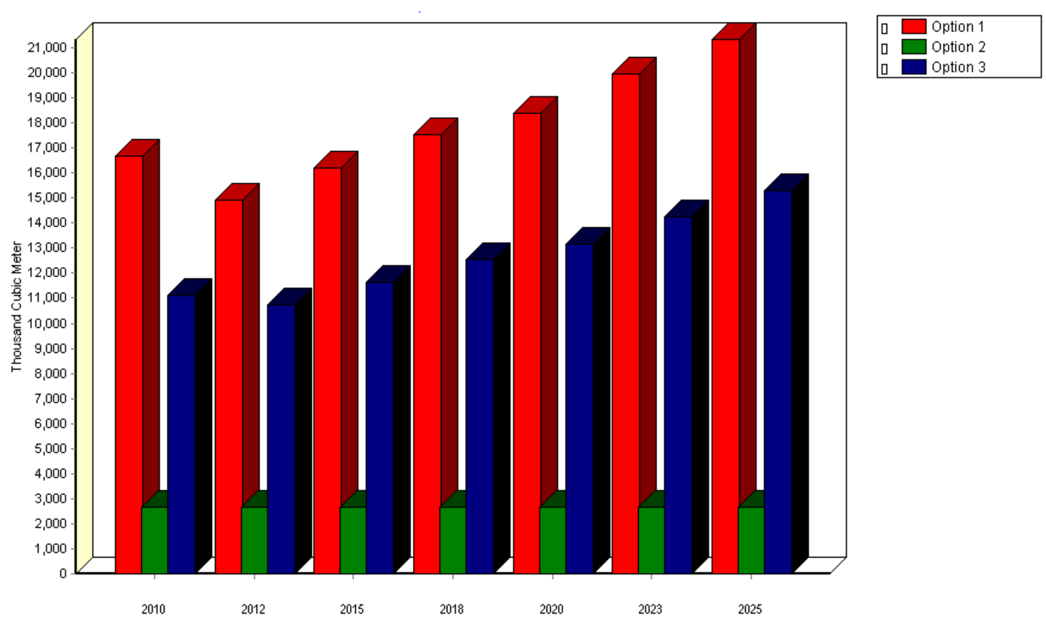


Figure 19: Water Delivered to the Area from Ein Samia in three Options

In Figure 20, Option 1 indicates 0 MCM usage of water from Western Aquifer. Because all future needs of water are covered by Ein Samia.

Option 2 shows that all future needs of water are supplied by Western Aquifer. And it is estimated to be 19 MCM in addition to the current amounts from Mekorot and Ein Samia.

While the amounts abstracted from Western Aquifer are reduced to 6 MCM in option 3. Because the rest of water need are supposed to be abstracted from Ein Samia.

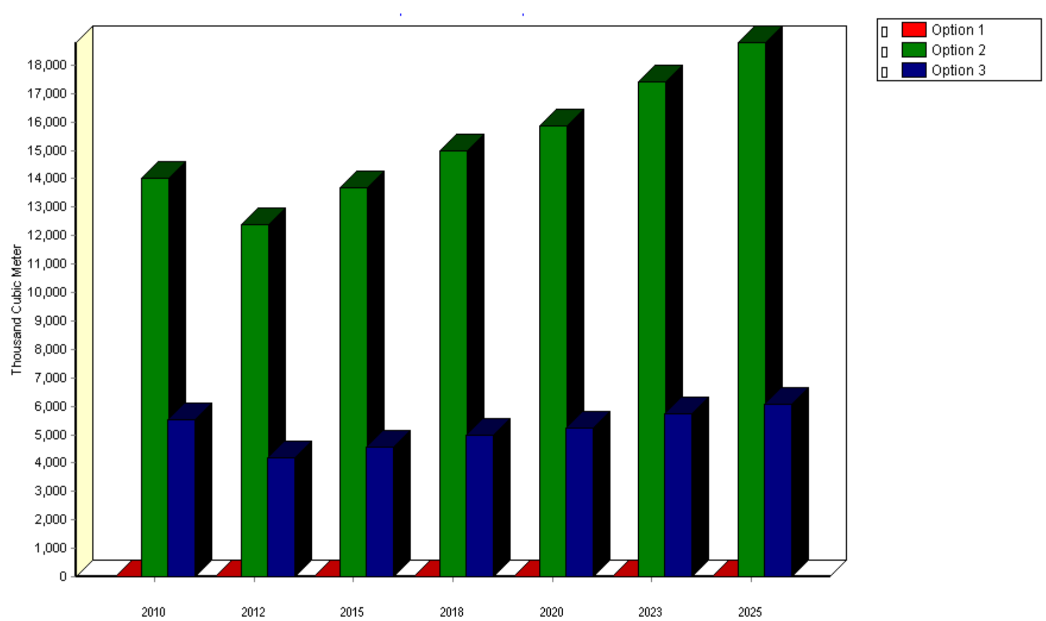


Figure 20: Water Delivered to the Area from Western Aquifer in three Options

The quantities abstracted from Ein Samia wells in option 1 are about 21 MCM by the end of year 2025, the other quantities needed was covered from Mekorot and it is about 13 MCM by the end of year 2025, while the quantities abstracted from western aquifer in this option are zero as shown in figure 21 below.

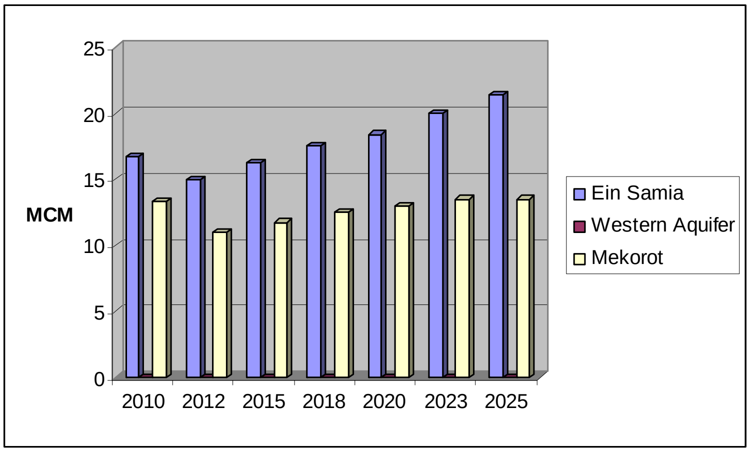


Figure 21: Water Delivered to the Area from Different Sources in Option 1

In figure 22 below it was noticed that in option 2 the additional water needed to cover the future demand was abstracted from western aquifer (18 MCM by the end of 2025) in addition to the current quantities which are purchased from Mekorot and pumped from Ein Samia wells and are estimated to be 13 MCM and 2.65 MCM by the end of 2025 respectively.

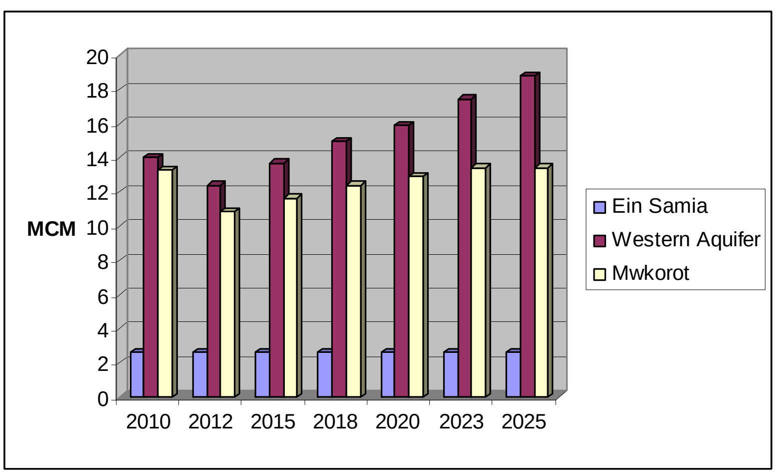


Figure 22: Water Delivered to the Area from Different Sources in Option 2

In option 3 the water needed to meet the future demand was covered from both aquifers, 15 MCM from Ein Samia and 6 MCM from Western Aquifer, in addition to the current amount of 13 MCM purchased from Mekorot. Figure 23 represents that.

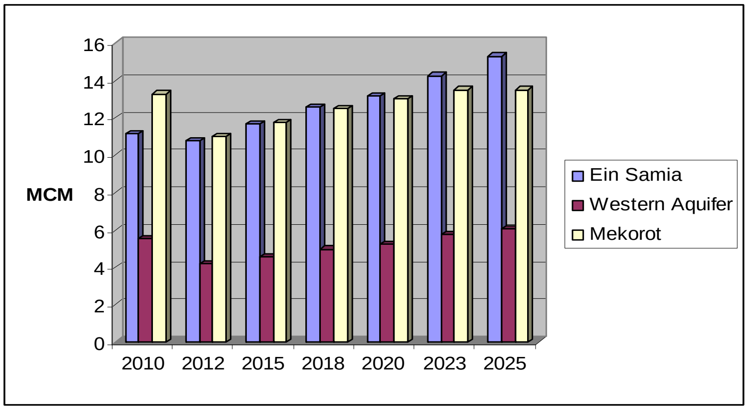


Figure 23: Water Delivered to the Area from Different Sources in option 3

The table below summarizes the water delivered to the area from all sources.

Table 9: The Total Quantities Delivered to the Area in Year 2025

Option #	Source		
	Eastern Aquifer MCM/ Yr	Western Aquifer MCM/Yr	Mekorot MCM/Yr
Option 1	21	0	13
Option 2	2.65	18	13
Option 3	15	6	13

6.4.2. Unmet Demand

The unmet demand in all demand sites is zero in the three options because all water requirements were covered in each option from different sources.

6.4.3. Water Requirement

In this section the effect of applying a water management program and private sector participation on water requirement will be investigated. Figure 24 below shows that applying the demand management program can save water as much as 8 MCM by the end of year 2025, these amounts of water can be developed for other purposes. The demand management here assumes to be a demand management program to increase user awareness to use water saving technologies, save water by optimizing its use and protect it from pollution.

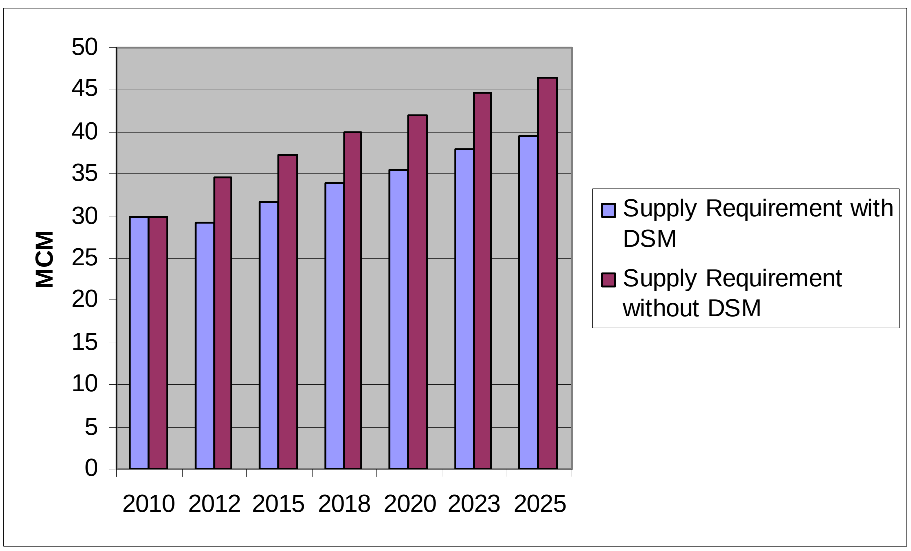


Figure 24: The Effect of Applying a Demand Side Management Programs on Supply Requirement

The centralized system creates an opportunity to the extended utility to 'privatize' some activities, such as meter reading and billing and later also part of maintenance and even operations like a management contracts at short time and build and operate then transfer (BOT) within the next 20 years, if deemed appropriate. This would enable the utility to concentrate its efforts to the main mission of the utility, i.e. serving the population in the most economic manner. The effect of private sector participation is shown in figure 25 below; the Figure shows that the participation of private sector can save more than 6 MCM by the end of year 2025.

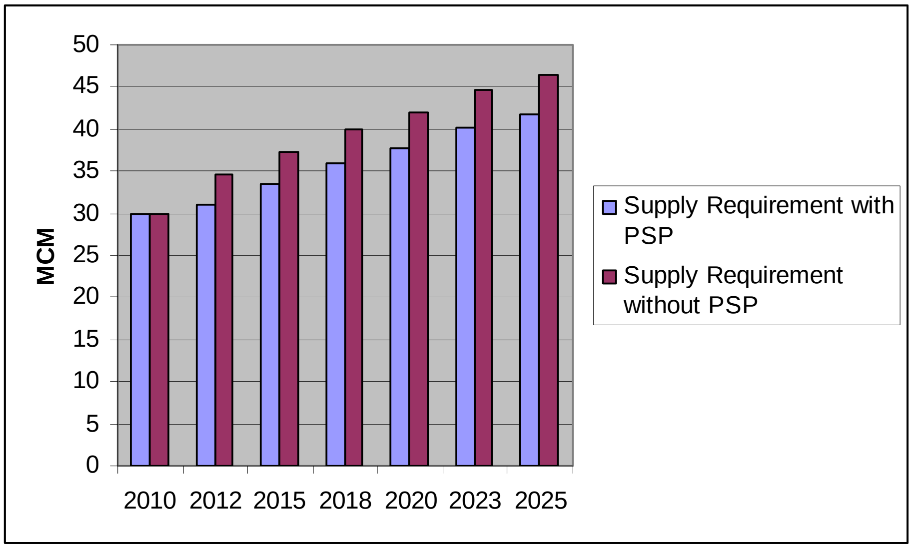


Figure 25: The Effect of Private Sector Participation on Supply Requirement

Figure 26 below represents the total supply requirement after applying the demand management program and participation with private sector.

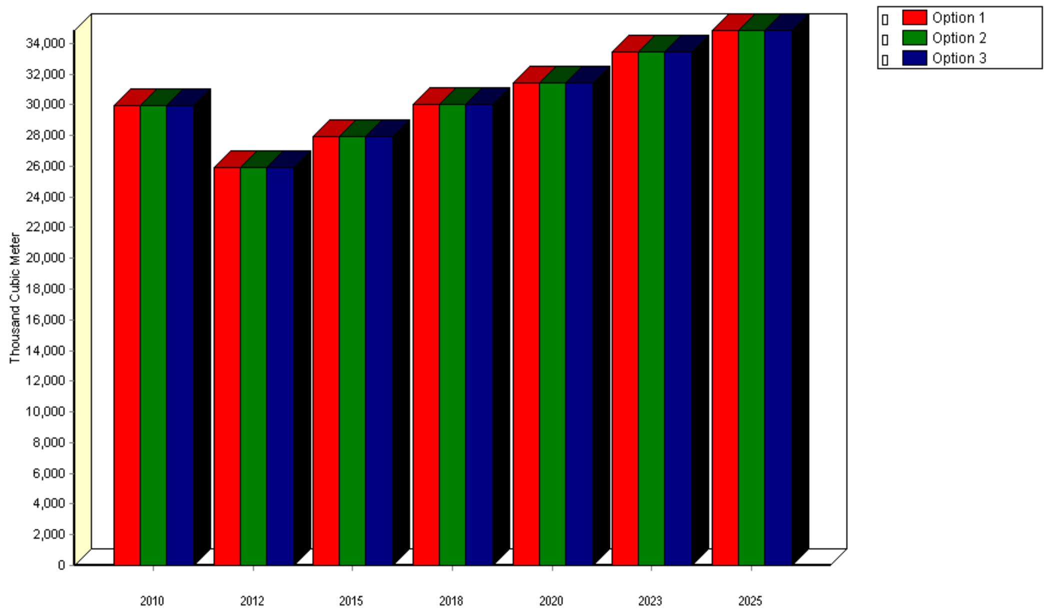


Figure 26: Predicted Total Supply Requirement

6.4.4. Coverage

In the three options all water required in all zones were met. The coverage reaches 100% in all demand sites.

6.4.5. The Cost of Water Conveyance

The unit cost of water considers the cost of producing water from aquifers in addition to the cost of conveyance water between demand sites. As a component of the water supply systems, pumping will be required to transport water in pipes that cannot flow by gravity. Pumping will be also required to transfer water from each source to the different zones. This cost will play a big role in deciding which option is more suitable for implementation in our study.

The cost of conveyance the water between demand sites in each option was calculated. A comparison between these options shows that all of these options are successful to control and cover the unmet demand in the region, but it was concluded that pumping water from both aquifers as in option 3 is the most economic choice because the average cost is 27.7 U.S. cents per m³. While in option 2 when the unmet demand was covered from western aquifer is the most expensive option due to the high differences in elevations between Ein Samia wells and other regions. The estimated cost in option 2 was 29.7 US cents.

However, option 1 show that the cost is 28.6 US cents when all demand is met by Ein Samia.

The comparison between the average costs in the three options was shown in table 10 and figure 27 below.

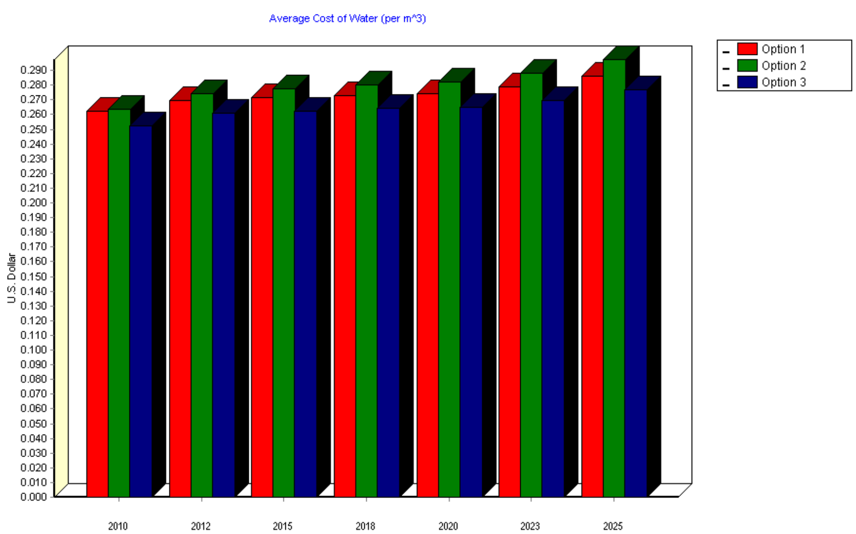


Figure 27: the Average Cost of Conveying the Water in $per m³ for the Three Options

Table 10: The Average Cost of Conveying the Water in the Three Options

Option #	1	2	3
Cost US. Cent /m^3	28.6	29.7	27.7

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The concept of regional utilities and its impact on water management was taken into account by taking JWU as a case study. This concept combines all the segregated networks and water committees throughout West Bank into three regional utilities.

To achieve this goal, WEAP software is used to build an IWRM model taking JWU service area, examine alternative water development and management strategies. WEAP is known for its special capabilities and abilities to realize management goals. WEAP is a central component of DSS, providing a framework that is accessible to strategic planners, stakeholders and decision-makers.

Three management options for JWU are investigated. The three options which were developed into WEAP and tested as follows:

Option 1: pumping water from Eastern Aquifer Basin

Option 2: pumping water from Western Aquifer Basin

Option 3: pumping water from Both Aquifer Basins

The main conclusions can be summarized in the following points:

1. The service area of the central water utility should be connected together to allow better management of the available water resources.
2. The estimated future water needs for the service area of the central water utility is 40 MCM by the year 2025.

3. The three options considered different potential sources. Results showed that eastern aquifer gives the minimum pumping cost while the pumping from both aquifer basins minimizes the conveyance cost for the total service area.
4. Based on the outcome results, there are no significant differences between providing water directly to consumers in different localities or on bulk basis to different localities within the service area.
5. Applying a demand management program resulted in a decrease of water demand and can save up to 8 MCM in year 2025.
6. Privatize some activities or making a management contracts with the private sector can save about 6 MCM by the end of the year 2025.
7. Pumping water from both aquifers is the most economic choice with an average conveyance cost of U.S. $ 27.7/ m^3 which means that the saving in conveyance cost is 360,000 U.S. $ between option 1 and option 3.
8. The cost of pumping water from eastern aquifer is 28.6 U.S. cent per m^3, while the cost of pumping water from the western aquifer is 29.7 U.S. cent per m^3.

7.2. Recommendations

1. The concept of regional utilities and its impact on water management was taken into account by taking JWU as a case study. It is recommended that further studies to be conducted to consider the other two proposed regional utilities in the Northern and southern parts of the West Bank.

2. Further research is needed to investigate the legal and institutional aspects of the concept of regional water utilities.

3. Although no significant differences between providing water directly to consumers in different localities or on bulk basis to different localities within the service area were found, it is recommended that Central Water Utility to consider supplying water by bulk to different localities. This will assure the equity between different localities and is seen to increase the collection efficiency of the utility.

4. Demand management programs are highly recommended to be applied. This will not only reduce the water losses but will also increase the ability of the utility to provide better services to the customers.

5. The involvement of the private sector through leases or management contract is seen necessary especially at the beginning of the establishment of the utility.

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APPENDIX
CHARACTERISTICS OF THE ZONES

Main Characteristics of each Community in the Demand Zones

District	Locality	zone	Estimated Population 2007	Lowest Point Elevation (m)	Highest Point Elevation (m)	UFW Rate	Water Supplied 1998 (m3/y)	Water Supplied 1998 (1) (m3/h)	Institutions Demand Dispatching Factor	Water Supplied 1998 (2) (m3/h)	Water Supplied 1998 (2) (m3/Y)	Water Supplied 2007 (2) (m3/Y)	Annual Water Use Rate (m3/C/Y)
RAMALLAH	Beittunia (bulk meter)	1	19,761			0%	378,597	43.22		43.22			
RAMALLAH	Beir Zeit (bulk meter)	5	4,529			0%	102,393	11.69		11.69			
RAMALLAH	Ein Samia					0%	0	0					
RAMALLAH	Institutions					32.11%	790,009	90.18					
RAMALLAH	Qadura R.C	1	0	855	865	22%	18,851	2.15	0.002	2.35	20,559		
RAMALLAH	Al Bireh North West	1	38,202	850	880	23%	125,266	14.30	0.014	15.60	136,614		
RAMALLAH	Ramallah South West	1		690	830	27%	387,100	44.19	0.044	48.19	422,166		
RAMALLAH	Ramallah Center	1	27,460	830	870	25%	204,569	23.35	0.023	25.47	223,101		
RAMALLAH	Ramallah North	1		700	880	24%	374,301	42.73	0.043	46.60	408,208		
RAMALLAH	Al Bireh Center / North East	1	5,000	850	880	20%	352,013	40.18	0.040	43.82	383,900		
RAMALLAH	Al Bireh South	1		790	870	26%	297,581	33.97	0.034	37.05	324,538		
RAMALLAH	Ramallah - Al Bireh	1	2,000	855	865	27%	402,318	45.93	0.046	50.09	438,763		
RAMALLAH	Ramallah South West	1		800	850	24%	586,493	66.95	0.067	73.02	639,622		
RAMALLAH	Am'ari R.C	1	5,014	830	840	27%	124,855	14.25	0.014	15.54	136,165		
RAMALLAH	Um Al	1	7,000	720	860	23%	341,395	38.97	0.039	42.50	372,321		

	Sharayet												
RAMALLAH	Sha'ab Kassab + Dura Al Qari'	1		820	880	21%	85,524	9.76	0.010	10.65	93,271		
Total			104,437							454.09	3,977,836.36	5,857,241.00	56.08
JERUSALEM	Qalandiya R.C	2	8,831	730	790	27%	188,949	15.57	0.016	16.98	148,749		
JERUSALEM	Start of Beit Hanina	2		720	770	27%	366,642	22.75	0.023	19.81	173,536		
JERUSALEM	Beit Hanina	2	1,071	670	760	30%	405,307	20.60	0.021	20.47	179,317		
JERUSALEM	Bir Nabala	2	5,000	710	770	24%	236,603	27.01	0.027	29.46	258,036		
JERUSALEM	Kufr 'Aqab / Airport Street	2		740	800	24%	94,271	10.76	0.011	11.74	102,811		
JERUSALEM	Al Ram / Accross from the Airport	2		700	750	18%	135,613	15.48	0.016	16.88	147,898		
JERUSALEM	Kufr 'Aqab	2	5,000	780	850	24%	210,199	20.00	0.020	21.81	191,071		
JERUSALEM	After the Airport / Across from Al Ram	2		740	780	21%	28,886	3.30	0.003	3.60	31,503		
JERUSALEM	Al Ram / Across from Zone 39	2		750	780	24%	264,171	21.34	0.021	23.27	203,873		
JERUSALEM	Al Ram left of the main road	2		730	760	24%	252,325	25.80	0.026	28.14	246,481		
JERUSALEM	Al Ram right of the main road	2	500	640	780	26%	208,378	19.97	0.020	21.78	190,784		
RAMALLAH	Wad Al Nus	2		700	740	18%	72,529	8.28	0.008	9.03	79,100		
JERUSALEM	Al Dahia / Al Uma	2	22,359	750	770	24%	247,799	15.24	0.015	16.62	145,596		

	College												
JERUSALEM	Al Dahia / Center	2	2,500	720	760	22%	146,271	10.70	0.011	11.67	102,223		
JERUSALEM	Qalandiya Village	2	3,500	760	780	18%	21,473	2.45	0.002	2.67	23,418		
JERUSALEM	Al Judira	2	2,276	710	780	18%	47,971	5.48	0.006	5.97	52,316		
JERUSALEM	Jaba'	2	3,183	600	760	21%	59,011	6.74	0.007	7.35	64,357		
JERUSALEM	Hizma*	2	6,271	550	640	19%	119,049	13.59	0.014	14.82	129,834		
JERUSALEM	Rafat	2	2,374	750	830	19%	100,368	5.46	0.005	5.95	52,162		
JERUSALEM	Mukhmas	2	1,447	520	630	20%	82,121	9.37	0.009	10.22	89,560		
RAMALLAH	Dura Al Qari'	2	3,000	700	780	18%	36,183	4.13	0.004	4.50	39,461		
Total			67,312							302.75	2,652,085.95	3,905,101.00	58.01
RAMALLAH	Ein Yabrud	3	2,999	700	810	17%	120,249	13.73	0.014	14.97	131,142		
RAMALLAH	Burqa	3	2,090	690	790	20%	39,299	4.49	0.005	4.89	42,859		
RAMALLAH	Al Jalazun R.C	3	7,813	700	810	29%	165,742	18.92	0.019	20.63	180,756		
RAMALLAH	Yabrud	3	644	640	800	18%	13,305	1.52	0.002	1.66	14,510		
RAMALLAH	Deir Bibwan	3	5,252	720	850	18%	221,705	25.31	0.025	27.60	241,789		
RAMALLAH	Beitin	3	2,143	850	910	23%	105,127	12.00	0.012	13.09	114,650		
RAMALLAH	Deir Jrir	3	3,986	730	900	20%	69,874	7.98	0.008	8.70	76,203		
RAMALLAH	Al Taybeh	3	1,452	770	800	25%	63,519	7.25	0.007	7.91	69,273		
RAMALLAH	Rammun	3	2,626	700	830	18%	76,873	8.78	0.009	9.57	83,837		
RAMALLAH	Silwad	3	6,123	790	880	25%	144,697	16.52	0.017	18.01	157,805		
Total			35,128							127.03	1,112,824.85	1,638,601.00	46.65
RAMALLAH	Kufr Malik	4	2,787	660	800	18%	76,335	8.71	0.009	9.50	83,250		
RAMALLAH	Al Mazra'a Al Sharqia	4	4,495	900	930	22%	154,468	17.63	0.018	19.23	168,461		
RAMALLAH	Sinjil	4	5,236	690	850	22%	107,724	12.30	0.012	13.41	117,483		
RAMALLAH	Turmus'ayya	4	3,736	660	700	23%	114,991	13.13	0.013	14.32	125,408		
RAMALLAH	Abu Falah	4	3,996	700	790	22%	64,247	7.33	0.007	8.00	70,067		
RAMALLAH	Jiljiliyya	4	741	680	830	20%	30,458	3.48	0.003	3.79	33,217		
RAMALLAH	Ibwein	4	3,119	600	700	20%	44,469	5.08	0.005	5.54	48,497		
RAMALLAH	Arura	4	2,087	500	600	21%	45,842	5.23	0.005	5.71	49,994		

RAMALLAH	Mazari' Al Nubani	4	1,776	460	500	20%	34,561	3.95	0.004	4.30	37,692		
			27,973							83.80	734,069.24	1,080,895.00	38.64
RAMALLAH	Jifna	5	1,716	660	740	19%	54,774	6.25	0.006	6.82	59,736		
RAMALLAH	Ein Sinia	5	711	650	700	21%	35,175	4.02	0.004	4.38	38,361		
RAMALLAH	Atara	5	2,270	710	820	21%	43,261	4.94	0.005	5.39	47,180		
RAMALLAH	Surda	5	1,031	790	830	20%	44,504	5.08	0.005	5.54	48,535		
RAMALLAH	Burham	5	616	600	680	19%	13,586	1.55	0.002	1.69	14,817		
RAMALLAH	Abu Qash	5	1,404	690	780	16%	37,012	4.23	0.004	4.61	40,365		
RAMALLAH	Jibia	5	148	590	650	15%	3,695	0.42	0.000	0.46	4,030		
RAMALLAH	Um Safa*	5	612	600	690	19%	13,068	1.49	0.001	1.63	14,252		
RAMALLAH	Al Maza'a Al Qibliyeh	5	6,190	690	770	19%	58,758	6.71	0.007	7.32	64,081		
RAMALLAH	Abu Shukheidem	5		700	750	18%	35,029	4.00	0.004	4.36	38,202		
RAMALLAH	Kobar	5	3,677	600	680	18%	63,838	7.29	0.007	7.95	69,621		
Total			22,904							61.82	541,583.82	797,465.00	34.82
	Total		**234,750**				**9,991,571**	**1,140.59**		**1,029.50**	**9,018,400.21**	**14,724,645.00**	

جامعة النجاح الوطنية
كلية الدراسات العليا

استخدام برنامج (WEAP) كأداة للتخطيط في المنطقة المخدومة من مصلحة مياه القدس في رام الله والبيرة

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إشراف
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قدمت هذه الأطروحة لمتطلبات درجة الماجستير في هندسة المياه والبيئة بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس، فلسطين
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الملـــخــــص

إن النقص الحاد في مصادر المياه هو من أهم التحديات التي تواجه منطقة الشرق الأوسط بشكل عام وفلسطين بشكل خاص ،فالتزايد المستمر في عدد السكان والنشاط الإقتصادي والتطور الذي شهدته محافظة رام الله والبيرة في السنوات الأخيرة أحدث ضغط كبير على المصادر المائية الموجودة في هذه المنطقة لذلك كان لابد من تطوير نموذج نظام لإدارة مصادر المياه في المنطقة التي تخدمها مصلحة مياه رام الله والقدس وفحص امكانية تزويد المنطقة عن طريق مؤسسة اقليمية تقدم الخدمات بالجملة وتقييم الخيارات المتاحة للمساعدة على اتخاذ القرارات.

تكونت منهجية الدراسة مما يلي (1) جمع البيانات اللازمة ومراجعتها (2) تطوير نموذج نظام لإدارة مصادر المياه في منطقة محافظة رام الله والبيرة باستخدام برنامج WEAP يهدف لمحاكاة الواقع ودراسة وتقييم الخيارات المختلفة ويعمل كنظام مساعد وداعم لاتخاذ القرارات.

بعد الإنتهاء من بناء النموذج، تم افتراض ثلاث خيارات إدارية مستقبلية لتزويد منطقة الدراسة بحاجاتها من المياه وكانت الخيارات على النحو الآتي:

- ضخ المياه من الحوض الشرقي
- ضخ المياه من الحوض الغربي
- ضخ المياه من كلا الحوضين (الشرقي والغربي)

تشير النتائج التي حصلنا عليها الى أنه يمكننا إنشاء مصلحة مياه الوسط لتكون مؤسسة تقدم خدمات المياه في وسط الضفة الغربية وذلك بهدف ادارة مصادر المياه بشكل أفضل، تشير الدراسة أيضا الى حاجة الفلسطينيين في هذة المنطقة لتطوير مصادر اضافية لسد الإحتياجات المائية تقارب 40 مليون متر مكعب في نهاية عام 2025.

خلصت الدراسة أيضا الى أن تطبيق برنامج توعية لإدارة الطلب على المياه وعقد شراكات مع القطاع الخاص يمكن أن يساهم في توفير حوالي 14 مليون متر مكعب من المياه في نهاية عام 2025. كما أشارت الدراسة الى أن الإحتياجات المائية المستقبلية عن طريق ضخ المياه من آبار عين سامية ومن الحوض الغربي في آن واحد هي الطريقة الأفضل من وجهة نظر اقتصادية حيث بلغت تكلفة هذا الخيار 27.7 سنت أمريكي، في حين كان الخيار الثاني وهو ضخ المياه من الحوض الغربي هو الخيار الأغلى ثمنا حيث بلغت تكلفته 29.7 سنت أمريكي أما تكلفة ضخ المياه من الحوض الشرقي بلغت 28.6 سنت أمريكي.