The Islamic University of Gaza
Deanship of Post Graduated Studies
Faculty of Engineering
Civil Engineering Department

الجامعة الإسلامية بغزة
عمادة الدراسات العليا
كُلية الهندسة
قسم الهندسة المدنية

The Potential Allocation of Water Resources in The Gaza Governorate

إمكانية إعادة توزيع مصادر المياه في محافظة غزة

Mohammed J. A. Aloul

Supervised by:
Dr.Husam Al-Najar
Associate prof. of Environmental engineering

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Abstract

Gaza Governorate is considered the center of the Gaza Strip and its most populous area. Gaza governorate has limited water resources and mainly depends on the aquifers whose water is considered, by international reports, not valid for use in 2020. In contrast, the water consumption of the population and agriculture continues to grow. The relevant authorities are planning to implement a range of projects to provide unconventional water resources to decrease withdrawals from the aquifers.

This study aims at identifying and reallocating resources of water and types of water demand in Gaza in order to study the impact of new water resources projects on the aquifers and the amount of domestic water demand balance in the period from 2014 to 2030.

In this study, WEAP Model (2015) was used to examine the impact of the four scenarios on the aquifers (Zero Action, Desalination Scenario, Recharge of Treatment Waste Water Scenario, and Combination of Scenarios 2 and 3) through the modeling of existing and projected water resources and water demand for each scenario during the period of the study.

The total water consumption demand in 2014 was 27 MCM covering 606,749 capita and is expected to increase gradually to reach 46 MCM to serve 1,050,000 capita in 2030 according to normal population growth (3.5% annually).

The total agricultural area is 34,508 donum and it is divided to 4 main crops: field crops, vegetables, fruits and citrus, which consume around 18.5 MCM every year.

The best-case scenario is the fourth scenario, which combines water desalination and wastewater reuse as a non-conventional water resource. This scenario will reduce the abstract from the aquifer and will provide the quantity of water needed for domestic consumption.

According to the Fourth Scenario, which is a combination of Scenarios 2 and 3, ground water decreased from 22.4 MCM to 10.5 MCM in 2014, and the net balance will reach its best in 2022 when there are not any deficits at all and will reach 4.6 MCM. Then, it will decrease again to reach -6.4 MCM in 2030.

The amount of domestic water demand balance in scenario 4 will reach 16 MCM in 2022 which means that there will be a surplus of amounts in domestic water, but it will decrease in 2030 without deficits to reach 12 MCM.

الملخص

تعتبر محافظة غزة المركز الرئيسي لقطاع غزة وأكثر المحافظات تعدادا للسكان، وتصنف بأنها محدودة الموارد المائية حيث تعتمد بشكل رئيسي على مياه الخزان الجوفي والتي ستصبح غير صالحة للاستخدام في عام 2020 حسب التقارير الدولية. وفي المقابل فإن استهلاك السكان و الزراعة للمياه في ازدياد مستمر، والسلطات المختصة تخطط لتنفيذ مجموعة من المشاريع لتوفير مصادر مياه غير تقليدية لوقف السحب من الخزان الجوفي.

تهدف هذه الدراسة الى اعادة توزيع مصادر المياه في محافظة غزة وذلك من خلال سيناريوهات تدرس تأثير مشاريع مصادر المياه الجديدة على الخزان الجوفي وعلى طلب المياه السكانية في الفترة من 2014 وحتى 2030.

تم استخدام WEAP Model 2015 لدراسة تأثير الأربع سيناريوهات على الخزان الجوفي وهي (1.الوضع القائم 2.تحلية المياه 3. معالجة المياه العادمة 4.الجمع بين سيناريو2 و سيناريو3) وذلك عن طريق نمذجة مصادر المياه القائمة والمتوقعة لكل سيناريو والاستهلاك السكاني والزراعي للمياه خلال فترة الدراسة. وتم استخدام برنامج Microsoft Excel للحصول على كمية العجز او الفائض في كمية المياه المطلوبة والغير متوفرة للاستخدام السكاني.

وحسب النتائج فإن مساحة الأراضي الزراعية في محافظة غزة 34508 دونم ومقسمة الى أربع أقسام رئيسية وهي (المحاصيل الحقلية، الخضروات، الفواكه، والحمضيات) واجمالي الاستهلاك المائي 18.5 مليون متر مكعب سنويا. وحسب معدل نمو السكان في محافظة غزة 3.5% فإن عدد السكان سيزداد من 606,749 في عام 2014 الى 1,050,000 في عام 2030.

وحسب النتائج فإن أفضل سيناريو هو السيناريو الرابع والذي تم فيه الجمع بين تحلية المياه و حقن المياه العادمة المعالجة في الخزان الجوفي كمصدر غير تقليدي للمياه سيخفف من السحب الجائر من الخزان الجوفي وسيوفر كمية المياه المطلوبة للاستهلاك السكاني. حساب التوازن في كميات المياه للخزان الجوفي يوضح بأن العجز في عام 2014 سيبلغ 10.5 مليون متر مكعب أما في عام 2022 فسيكون فائض 4.6 مليون متر مكعب ليعاود العجز في الرجوع ويصل في عام 2030 6.4 مليون متر مكعب. أما العجز في كمية المياه غير الملباة للاستهلاك السكاني 4.5 مليون متر مكعب وينخفض حتى يصبح فائض في عام 2022 يصل الى 16 مليون متر مكعب ويعاود الانخفاض بشكل بسيط ليصل في عام 2030 الى 12 مليون متر مكعب.

Dedication

This research is dedicated to:

The memory of my **father***, may Allah grant him mercy...*

My **mother** *for her love, pray, and continuous sacrifices...*

My beloved **wife** *for her support and encouragement...*

My lovely twins ...

To all of my brothers and sisters...

To all of my **friends** *and* **colleagues***...*

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All admirations and glory are due to ALLAH for all the support granted to me. This effort would not be reached without God's limitless guidance and support.

I would like to take this opportunity to sincerely thank all individuals who have helped me in this research. Especially my supervisor (Dr. Husam Al-Najar) for his encouragement, continuous support, treasured assistance and his vision which inspired this research.

I could not forget the role of my friends for their help, encouragement, constructive feedback and positive challenging. Finally, my most appreciations are to my parents, wife, brothers and sisters for their full support, encouragement and patience that give me the power all life.

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LIST OF ABBREVIATIONS AND UNITS

AMSL	Above Mean Sea Level
AWWA	American Water Works Association
CMWU	Coastal Municipality Water Utility
CWR	Crop Water Requirement
CMS	Cubic Meter Seconed
ET	Evapotranspiration
FAO	Food & Agricultural Organization
FAO	Food and Agriculture Organization
GCDP	Construction of the Gaza Central Desalination Plant
GIS	Geographic Information System
IWR	Irrigation water requirement
IWRM	Integrated Water Resources Management
IWRP	Integrated Water Resources Planning
Kc	Crop coefficient
l/c.d	Liter per Capita per Day
MCM	Million cubic meter
MCM	Million cubic meter
mm	Millimeter
mm/yr	Millimeter per year
MoA	Ministry of Agriculture
OASIS	Operational Analysis and Simulation of Integrated Systems
OCHA	United Nations Office for the Coordination of Humanitarian
OCL	Operational Control Language
OSP	Occupied State of Palestine
PAPP	Programme of Assistance to the Palestinian People
PCBS	Palestinian Central Bureau of Statistics
PWA	Palestinian Water Authority

RO	Reverse Osmosis
STLV	Short-term Low Volume Seawater Desalination Plant.
T	Temperature (°C)
UNCT	United Nations Country Team
UNDP	United Nations Development Programme
UNESCAP	United Nations, Economic and Social Commission for Asia and the
UNESCO	United Nations Educational, Scientific and Cultural Organization
WAM	Water Availability Model
WEAP	Water Evaluation and Planning System
WFP	World Food Program
WHO	World Health Organization
WWTP	Waste Water Treatment Plan

Chapter 1

Introduction

Chapter Introduction

1.1. Background

The Gaza Strip is one of the most densely populated places on earth, with a total area of 365 km^2 and a population of approximately 1.8 million. Since the July 2014 Crisis 1.2 million have no or limited access to water (UNDP, 2014). Recently, problems in Gaza water supply and sanitation have reached crisis levels, largely connected to the deteriorating economic, political and security situation. The closures led to dramatic deterioration in service provision, and the utility has been living from hand to mouth (WB, 2009).

Groundwater is the main source of water for Gaza Strip and provides more than 90% of all water supplies. The main aquifer systems can be divided into four distinct units; the Western Aquifer Basin, the North-eastern Aquifer Basin and the Eastern Aquifer Basin for the West Bank, and the Coastal Aquifer for Gaza, where the groundwater is available at much shallower depth (PWA, 2012).

The Gaza Governorate is among the areas with the scarcest recharge water resources with average water consumption in 2013/2014 of 78 l/c/d of bad water quality exceeding the recommended standards. This is far below the per capita water resources available in other countries in the Middle East and in the world, constraining economic development, and resulting in health negative impacts. More than half of the available groundwater is used for irrigation (52%), while the remaining is used for domestic water supply and industry (PWA, 2014).

Coastal Aquifer in the Gaza Strip receives an annual average recharge of 50-60 MCM/y mainly from rainfall, while the annual extraction rate of this aquifer complex is estimated at about 178.8 MCM. These unsustainably high rates of extraction have led to lowering the groundwater level, the gradual intrusion of seawater and up coning of saline groundwater.

Tests have indicated high salinity levels of more than 1,500 ppm chloride, making significant parts of the aquifer unsuitable for drinking water as shown in Figure 1.1, domestic applications and for many irrigated crops (PWA, 2012).

The Gaza Strip’s aquifer is being over-abstracted, producing more than 100 MCM annual deficits in ground water balance. The water quality has been deteriorating due to seepage of sewage water leading to high nitrate concentration as shown in Figure 1.2 and salinity has increased due to seawater intrusion (UNDP, 2012)

Access to clean drinking water is essential not only for human health, but also to the economic and municipal development of a society. Water scarcity in Palestine continues to be the cause of political conflict and additional costs while ensuring an adequate amount of clean water remains extremely difficult. Moreover, the Occupied State of Palestine (OSP) suffers from exceptional circumstances under the Israeli occupation that denies the Palestinians from their rights and restricts their access to water resources. This struggle that the Palestinians face within the water supply process is continuously increasing under the growing population and water demands (PWA, 2012).

95% of Gaza's water supply is contaminated with unacceptable high levels of either nitrate (NO_3) or chloride (Cl), posing significant health risks to Gaza's 1.8 million residents. Average consumption in the Gaza Strip of 90 liters per capita per day (l/c/d) falls below the standard of 100 l/c/d recommended by WHO, but with unacceptable water quality (PWA, 2014)

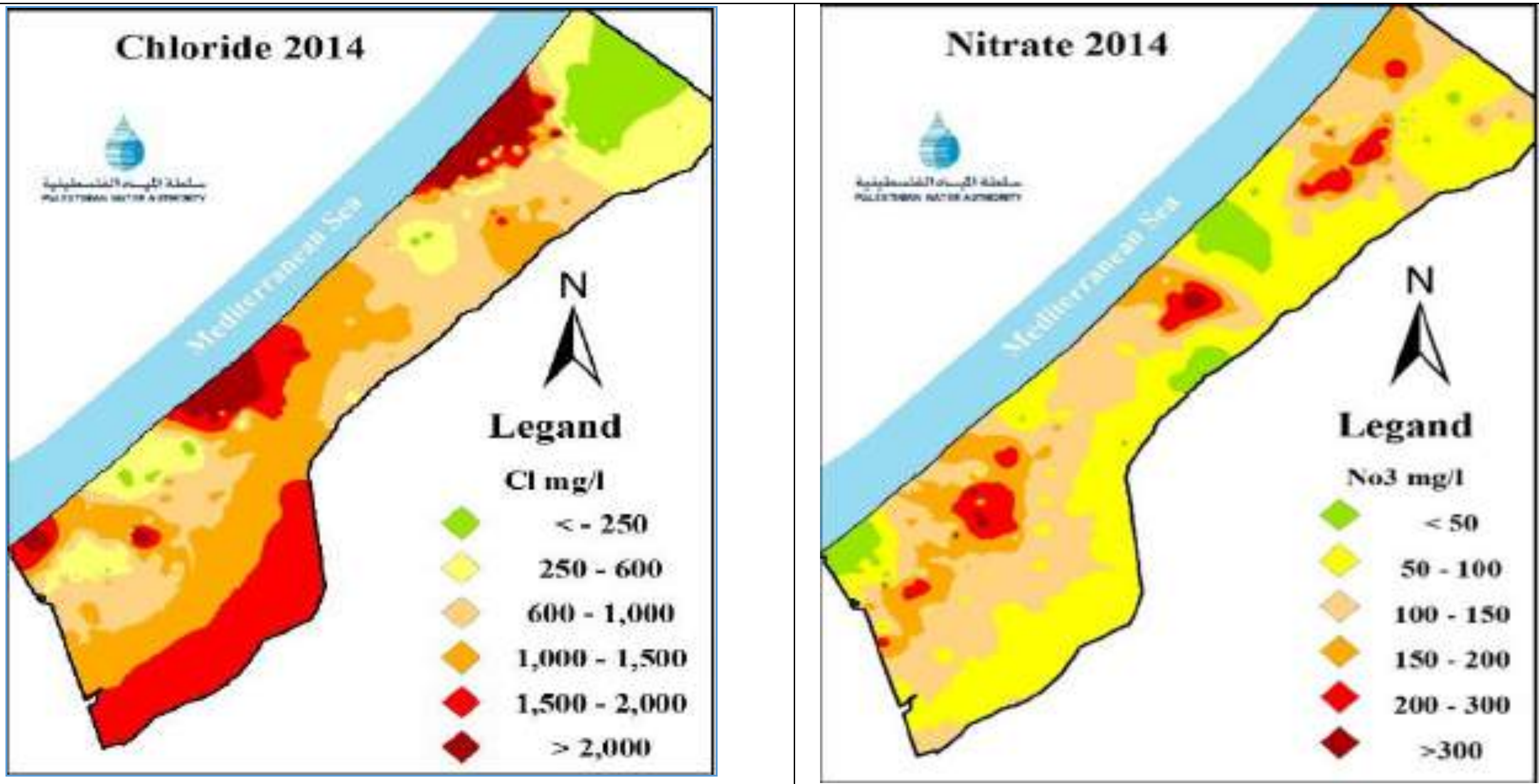


Figure 1.1: Chloride and Nitrate Concentration contour for the year 2014 (Source: CMWU, 2016).

1.2.Problem Statement

There is a clear deterioration in groundwater quality in the Gaza Governorate. Total amount of water produced in the Gaza city during 2014 about 27 MCM/y rate of 123 L/C/D from quantity produced. Considering the low efficiency of the drinking water network (63%) The rate of consumption per capita become 77 L/C/D.

In Gaza City, 95% of the produced water quality does not meet the international standards for the use of drinking because of salinity of the water due to the sea water intrusion on most wells located within this effect.

However continue relying on groundwater as the only source to meet the different demand of water is expected to increase the salinity of groundwater to record levels makes it difficult to benefit even for domestic use. (PWA, 2014).

1.3.Research Objectives

The research work is intended to achieve the following objectives:

1. Identification the current situation for water deficiency in Gaza Governorate.
2. Study the main factors affect water resources.
3. Identify the main non-conventional water resources for Gaza Governorate.
4. Study the influence of urban, agriculture area to water distribution system.
5. Propose water resources allocation scenarios to minimize the water crisis in Gaza Governorate.

1.4.Thesis structure

The basic structure of the thesis is organized in six chapters, as follows:

Chapter one "Introduction"

It provides a background on Gaza Governorate water crisis, summary on the problem statement, research.

Chapter Two " Literature Review"

It summarizes the literature reviews along with background information related to of water resources allocation, water allocation models and water resources management.

Chapter Three "Study Area"

It describes the study area geographically with briefing about its water resources and crisis, non-conventional water recourses, water demand, domestic and agriculture demand.

Chapter Four "Research Methodology"

It deals with the methodology used to achieve the objectives of the study, starting from assessing the deficit of water resources spatially ground water balance using WEAP model to see the scenario effects on ground water, and amount of unmet water domestic through four scenarios and conducting a comparison between these scenarios.

Chapter Five "Results and Discussions"

It explains the findings, results and discussion using non-conventional water resources domestic water demand on ground water balance deficit and amount of unmet water domestic through four scenarios. And try to find the optimum scenario.

Chapter Six "Conclusion and Recommendations"

It provides a brief summary on research findings as a conclusion, follows by future recommendations on the best practices.

Chapter 2

Literature Review

Chapter 2. Literature Review

2.1.Water Allocation

The simplest definition of water allocation is the sharing of water among users. A useful working definition would be that water allocation is the combination of actions which enable water users and water uses to take or to receive water for beneficial purposes according to a recognized system of rights and priorities.

Water allocation is about optimizing the benefits of water to society under all physical condition. While technical inputs provide vital information for decision making, water allocation decisions must satisfy consideration of equity, fairness, productivity, economic benefit and the interest of all sectors of society as they rely on water. And these decisions must be made in such a way that future generation will continue to receive adequate water resources for their needs. (UNESCAP, 2000).

Water allocation systems serve to equitably apportion water resources among users; protect existing water users from having their supplies diminished by new users; govern the sharing of limited water during droughts when supplies are inadequate to meet all needs; and facilitate efficient water use. Effective water allocation becomes particularly important as demands exceed reliable supplies. As water demands increase with population and economic growth, water allocation systems must be expanded and refined. (Ralph,2013)

2.1.1. Objectives and principles of water allocation

The overall objective of water allocation is to maximize the benefits of water to society. However, this general objective implies other more specific objectives that can be classified as social, economic and environmental in nature as shown in Table 2.1. As can be seen in this table, for each classification there is a corresponding principle: equity, efficiency and sustainability.

Table 2.1: Objectives and principles of water allocation (UNESCAP,2000)

Objective	Principle	Outcome
Social Objective -	Equity	Provide for essential social needs: • Clean drinking water • Water for sanitation • Food security
Economic Objective	Efficiency	Maximize economic value of production: • Agriculture and industrial development • Power generation • Regional development • Local economic
Environmental Objective	Sustainability	Maintain environmental quality: • Maintain water quality • Support instream habitat and life • Aesthetic and natural values

Equity means the fair sharing of water resources within river basins, at the local, national, and international levels. Equity needs to be applied among current water users, among existing and future users, and between consumers of water and the environment. Since equity is the state, quality, or ideal of being just, impartial, and fair, and different people may have different perceptions for the same allocation, it is important to have pre-agreed rules or processes for the allocation of water, especially under the situations where water is scarce.

Efficiency is the economic use of water resources, with particular attention paid to demand management, the financially sustainable use of water resources, and the fair compensation for water transfers at all geographical levels. Efficiency is not so easy to achieve, because the allocation of water to users relates to the physical delivery or transport of water to the demanding points of use. Many factors are involved in water transfers, one of which is the conflict with equitable water rights. For example, a group of farmers should have permits to use certain amounts of water for agricultural irrigation. However, agriculture is often a low profit use; some water for irrigation will be transferred to some industrial uses if policy makers decide to achieve an efficiency-based allocation of water. In this case, farmers should receive fair compensation for their losses.

Sustainability advocates the environmentally sound use of land and water resources. This implies that today's utilization of water resources should not expand to such an extent that water resources may not be usable for all of the time or some of the time in the future (Savenije and Van der Zaag, 2000).

2.1.2. Elements of water allocation

Water allocation does not mean merely the right of certain users to abstract water from sources but also involves other aspects. Table 2.2 lists a number of activities involved in a comprehensive and modern water allocation scheme.

Table 2.2: Elements of water allocation (UNESCAP, 2000).

Element	Description
Legal basis	Water rights and the legal and regulatory framework for water use
Institutional base	Government and non-government responsibilities and agencies which promote and oversee the beneficial use of water
Technical base	The monitoring, assessment and modeling of water and its behavior, water quality and the environment
Financial and economic aspects	The determination of costs and recognition of benefits that accompany the rights to use water, facilitating the trading of water
Public good	The means for ensuring social, environmental and other objectives for water
Participation	Mechanisms for coordination among organization and for enabling community participation in support of their interests
Structural and development base	Structural works which supply water and are operated, and the enterprises which use water

2.1.3. Water allocation policies and mechanisms

Different points of departure call for different kind of reforms. In water allocation policies four questions: (i) what do we know about water allocation?; (ii) what do we need for water allocation reforms?; (iii) what are the challenges related to such reforms?; and (iv) what is the role of water economics?, understanding the political processes that drive water demand at various scales is crucial to gaining knowledge of water allocation.

What is needed for water allocation reform is practical guidance in the form of tools to support water allocation decisions, substantiated with system knowledge of water availability, responsibilities and regulations. By applying flexible mechanisms water can be reallocated when appropriate.

Deriving from the above, different steps of a water allocation reform comprise three dynamic dimensions: (i) knowledge of the water hydrological system; (ii) economic assessment; and (iii) political process. The major challenges related to such water allocation reforms stem from a weak knowledge-base, unclear political objectives, varied interests of stakeholders, inadequate implementation and policy incoherence. The main roles of water economics were highlighted, for example, showing the potential water productivity gain of water reallocation among regions, users and generations.

Mechanisms for water reallocation between end-users Water rights, permits and entitlements, as well as allocation mechanisms, provide security and predictability in an uncertain world. Their aim is to reduce risk. But there is a trade-off between reliability and the amount of water one can use –the more secure the smaller the flow. How can water allocation systems better deal with uncertain inflows while maximizing beneficial use? There are various types of water transfer mechanisms. High value users can compensate low-value water users for the temporary right to use their water traded on the water market.

The creation of water banks, by means of a public intermediary between sellers and buyers, is an attempt to improve the reliability of water markets. A dry-year option is a contingent contract between a buyer (who needs a high reliability of supply) and a seller that gives the buyer the right, but not the obligation, to use water owned by the seller. Risk can also be transferred differentially between the interested sectors by paying a premium for transferring the supply risk.(UNESCO,2012)

2.1.4. Water allocation procedure

A general comprehensive water allocation procedure at the operational level is proposed in Figure 2.1. This procedure starts with setting objectives under certain regulations and institutions governing water rights policy and water allocation mechanisms. Then physical and social investigations, together with hydrological modeling, water quality modeling, economic analysis, and social analysis should be carried out to have a comprehensive water resources assessment. The water resources assessment phase generates the possible options for water allocation. Then a water allocation plan can be obtained by evaluating the possible options utilizing certain criteria considering the factors of water availability, need, cost and benefit.

After a plan is made, and its proposals are agreed upon by the representatives of water users and others, it needs to be implemented. To evaluate the performance of the plan, monitoring and reporting are required. Each feedback in this process can provide more highlights in the next iteration. The water allocation plan made at the operational level determines the water flow or volumes for distribution at the local level. (Wang,2005)

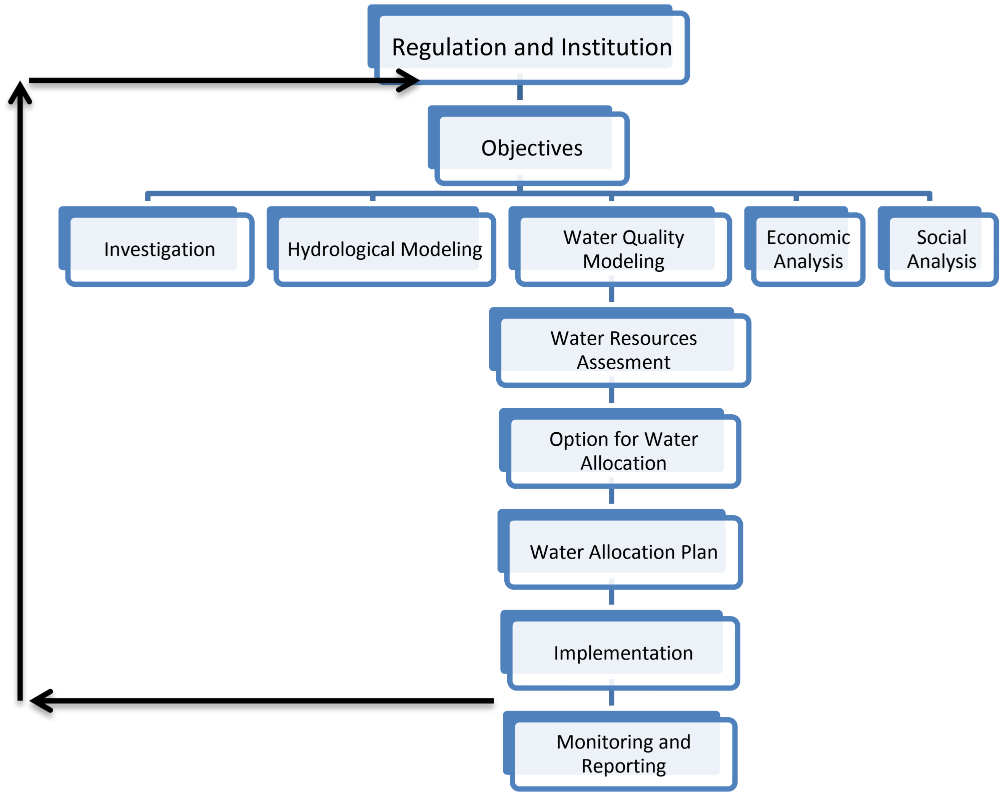


Figure 2.1: Water Allocation Planning Procedure at the Operational Level.(Wang,2005)

2.1.5. Water allocation mechanisms

People in various nations, regions, and local communities have developed their own sets of institutions and practices governing the sharing of water. These water allocation systems have evolved historically and continue to change. Hierarchies of water allocation systems in the U.S. and many other countries generally have the following components or features.

The waters of international rivers and aquifers are allocated between nations based on international law, customs, treaties, and agreements

Water allocation mechanisms typically vary greatly between ground-water and surface-water. From a water law perspective, ground and surface water are usually treated as separate resources. The extent to which the important hydrologic and water management interconnections are recognized varies between geographical regions.

The institutional mechanisms of water allocation are typically viewed from policy, legal، economic, and social perspectives. However, hydrologic science and engineering are also important aspects of developing and maintaining water allocation systems. (Ralph, 2013)

Particularly Water Allocation Models are being widely used in order to assess the impacts of future development trends, water management strategies, climate change, etc on the availability of water resources. For instance a Statewide Water Availability Model (WAM) has been developed in order to assess the impacts of different water management decisions on the availability of water in the different watersheds of Texas (Wurbs, 2005).

2.1.6. Water allocation plans

may be made at three levels from national to local. At the level of water rights, a water allocation plan deals with the interacting obligations of water users and the regulatory authorities.

It may indicate the cumulative rights that are intended to be issued, and it may include

the criteria for management at other levels. At the operational level, a water allocation plan is concerned with shorter-term, usually annual, management of reservoir storage, river flows, and diversions. At the local level, the distribution rules and priorities are set out (UNESCAP,2000).

2.1.7. Water Resources Management Modeling

Modeling of water conditions in a given area is a simplified description of the real system to assist calculations and predictions used to estimate the amount of water that is needed to meet the existing and projected demands under potential availability and demand scenarios, and determine what interventions are necessary, as well as when and where, and their cost.

Models can represent the important interdependencies and interactions among the various control structures and users of a water system; in addition they can help identify the decisions that best meet any particular objective and assumptions (Loucks and Beek, 2005).

The two principal approaches to modeling are simulation of water resources behavior based on a set of rules governing water allocations and infrastructure operation; and optimization of allocations based on an objective function and accompanying constraints. Simulation models address what if questions. Their input data define the components of the water system and their configuration and the resulting outputs can identify the variations of multiple system performance indicator values. Simulation works only when there are a relatively few alternatives to be evaluated.

Optimization models are based on objective functions of unknown decision variables that are to be maximized or minimized. The constraints of the model contain decision variables that are unknown and parameters whose values are assumed known. Constraints are expressed as equations and inequalities (Loucks, 2005).

2.2. Water Allocation Models

2.2.1. WEAP Model

The Water Evaluation and Planning System (WEAP) developed by the Stockholm Environment Institute's Boston Center (Tellus Institute) is a water balance software program that was designed to assist water management decision makers in evaluating water policies and developing sustainable water resource management plans.

The Water Evaluation and Planning System (WEAP) aims to incorporate these values into a practical tool for water resources planning. WEAP is distinguished by its integrated approach to simulating water systems and by its policy orientation. WEAP places the demand side of the equation--water use patterns, equipment efficiencies, re-use, prices, hydropower energy demand, and allocation--on an equal footing with the supply side--streamflow, groundwater, reservoirs and water transfers. WEAP is a laboratory for examining alternative water development and management strategies.

WEAP is comprehensive, straightforward and easy-to-use, and attempts to assist rather than substitute for the skilled planner. As a database, WEAP provides a system for maintaining water demand and supply information. As a forecasting tool, WEAP simulates water demand, supply, flows, and storage, and pollution generation, treatment and discharge. As a policy analysis tool, WEAP evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems.

WEAP is applicable to municipal and agricultural systems, single sub-basins or complex river systems. Moreover, WEAP can address a wide range of issues, e.g., sectoral demand analyses, water conservation, water rights and allocation priorities, groundwater and streamflow simulations, reservoir operations, hydropower generation and energy demands, pollution tracking, ecosystem requirements, and project benefit-cost analyses.

WEAP applications generally include several steps. The study definition sets up the time frame, spatial boundary, system components and configuration of the problem. The Current Accounts provide a snapshot of actual water demand, pollution loads, resources and supplies for the system. Alternative sets of future assumptions are based on policies, costs, technological development and other factors that affect demand, pollution, supply and hydrology. Scenarios are constructed consisting of alternative sets of assumptions or policies. Finally, the scenarios are evaluated with regard to water sufficiency, costs and benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables. (WEAP,2015)

2.2.2. AQUARIUS Model

AQUARIUS is driven by an economic efficiency criterion that calls for reallocating stream flows among traditional and nontraditional uses, subject to specified constraints, until the net marginal economic returns in all water uses are equal. This equality occurs because, if marginal values differ and demand curves are downward sloping, a higher-valued use can theoretically afford to purchase water from a lower-valued use, paying a price that exceeds the water's value in the lower-valued use. Transfers from lower-valued to higher-valued uses continue until the advantages of trade are eliminated, that is, until marginal values are equal and an optimal allocation is reached. We adopted an economic criterion for determining an optimum primarily because economic demands have traditionally played a key role in water allocation decisions and because economic value estimates for some nontraditional water uses are now becoming available. (Thomas,2002)

2.2.3. CALSIM Model

The California Water Resources Simulation Model was developed by the California State Department of Water Resources .The model is used to simulate existing and potential water allocation and reservoir operating policies and constraints that balance water use among competing interests. Policies and priorities are implemented through the use of user-defined weights applied to the flows in the system. Simulation cycles at different temporal scales allow the successive implementation of constraints. The model can simulate the operation of relatively complex environmental requirements and various state and federal regulations (Quinn et al., 2004).

2.2.4. Water Ware Model

Water Ware is a decision support system based on linked simulation models that utilize data from an embedded GIS, monitoring data including real-time data acquisition, and an expert system. The system uses a multimedia user interface with Internet access, a hybrid GIS with hierarchical map layers, object databases, time series analysis, reporting functions, an embedded expert system for estimation, classification and impact assessment tasks, and a hypermedia help- and explain system. The system integrates the inputs and outputs for a rainfall-runoff model, an irrigation water demand estimation model, a water resources allocation model, a water quality model, and groundwater flows and pollution model (Fedra, 2002).

2.2.5. OASIS Model

Operational Analysis and Simulation of Integrated Systems (OASIS) developed by Hydrologics, Inc. is a general purpose water simulation model. Simulation is accomplished by solving a linear optimization model subject to a set of goals and constraints for every time step within a planning period. OASIS uses an object-oriented graphical user interface to set up a model, similar to ModSim. A river basin is defined as a network of nodes and arcs using an object-oriented graphical user interface. Oasis uses Microsoft Access for static data storage, and HEC-DSS for time series data. The Operational Control Language (OCL). (Hydrologics, 2009)

2.2.6. RiverWare Model

River Ware is a reservoir and river system operation and planning model. Site specific models can be created in RiverWare using a graphical user interface by selecting reservoir, reach confluence and other objects. Data for each object is either imported from files or input by the user.

RiverWare is capable of modeling short-term (hourly to daily) operations and scheduling, mid-term (weekly) operations and planning, and long-term (monthly) policy and planning. Operating policies are created using a constraint editor or a rule-based editor depending on the solution method used. The user constructs an operating policy for a river network and supplies it to the model.

RiverWare has the capability of modeling multipurpose reservoir uses consumptive use for water users, and simple groundwater and surface water return flows. Water quality parameters including temperature, total dissolved solids and dissolved oxygen can be modeled in reservoirs and reaches. Reservoirs can be modeled as simple, well-mixed or as a two layer model. Additionally, water quality routing methods are available with or without dispersion (Carron et al., 2000).

2.3. Water Resources Management

2.3.1. Integrated Water Resources Management

The concept of integrated water resources management (IWRM) has been developing since the beginning of the eighties. IWRM is the response to the growing pressure on our water resources systems caused by growing population and socio-economic developments. Water shortages and deteriorating water quality have forced many countries in the world to reconsider their options with respect to the management of their water resources. As a result water resources management (WRM) has been undergoing a change worldwide, moving from a mainly supply-oriented, engineering-biased approach towards a demand-oriented, multi-sectoral approach, often labelled integrated water resources management.

In international meetings, opinions are converging to a consensus about the implications of IWRM. This is best reflected in the Dublin Principles of 1992 which have been universally accepted as the base for IWRM. The concept of IWRM makes us move away from top-down 'water master planning which focuses on water availability and development, towards 'comprehensive water policy planning' which addresses the interaction between different sub-sectors, seeks to establish priorities, considers institutional requirements and deals with the building of management capacity.

IWRM considers the use of the resources in relation to social and economic activities and functions. These also determine the need for laws and regulations for the sustainable use of the water resources. Infrastructure made available, in relation to regulatory measures and mechanisms, will allow for effective use of the resource, taking due account of the environmental carrying capacity. (Daniel, 2005)

2.3.2. IWRP Framework

there is no complete definition of IWRP, there are a series of characteristics of IWRP that have evolved over time to be typical of the planning process. Figure 2.2 presents an overview of IWRP. This figure illustrates that IWRP begins with a careful consideration of both supply-side and demand-side planning and that the process is highly interconnected.

System reliability is also shown to be a central component of IWRP. The output of the planning process is both a plan and a mechanism to evaluate the plan. The figure also indicates that public input is required. As noted elsewhere in this document, public input is needed at all stages of planning. (AWWA, 2001)

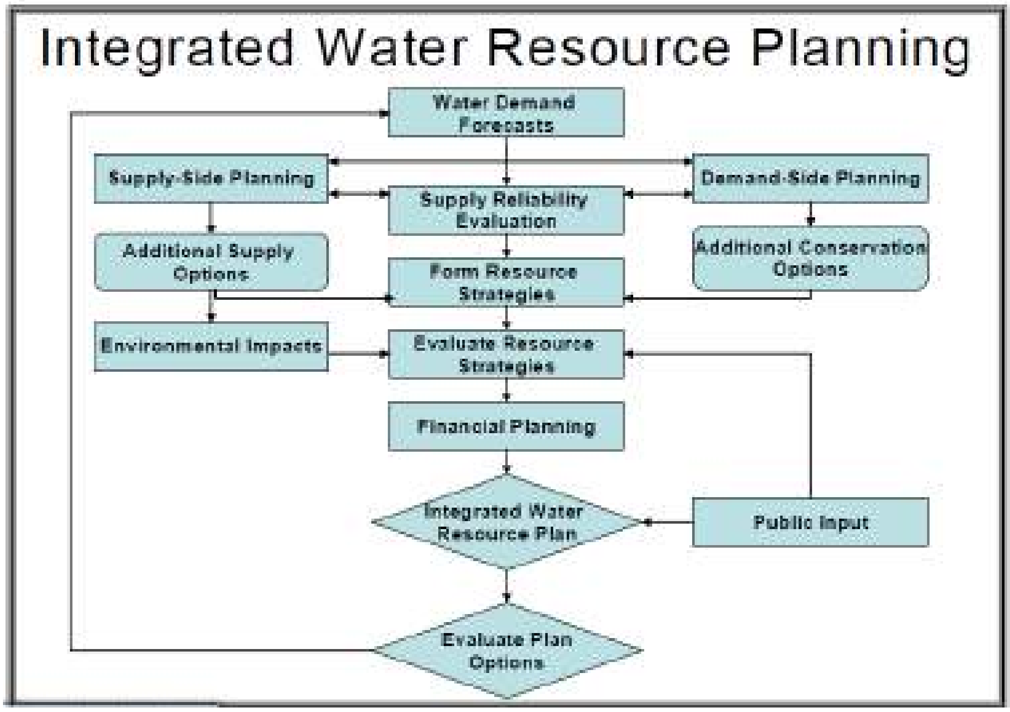


Figure 2.2: Water Allocation Planning Procedure at the Operational Level (AWWA, 2001)

Chapter 3

Study Area

Chapter 3. Study Area

3.1.Geographic Data

3.1.1. Gaza Strip

Gaza Strip is an elongated zone located at southeastern coast of Palestine with coordination of Latitude N 31° 26' 25" and Longitude E 34° 23' 34". The area is bounded by the Mediterranean in the west, the 1948 cease-fire line in the north and east and by Egypt in the south. The total area of the Gaza strip is 365 km^2 with approximately 40 km long and the width varies from 8 km in the north to 14 km in the south. Gaza Strip is divided geographically into five governorates: Northern, Gaza, Mid Zone, Khan Yunis, and Rafah. As shown in figure 3.1. (UNEP, 2003)

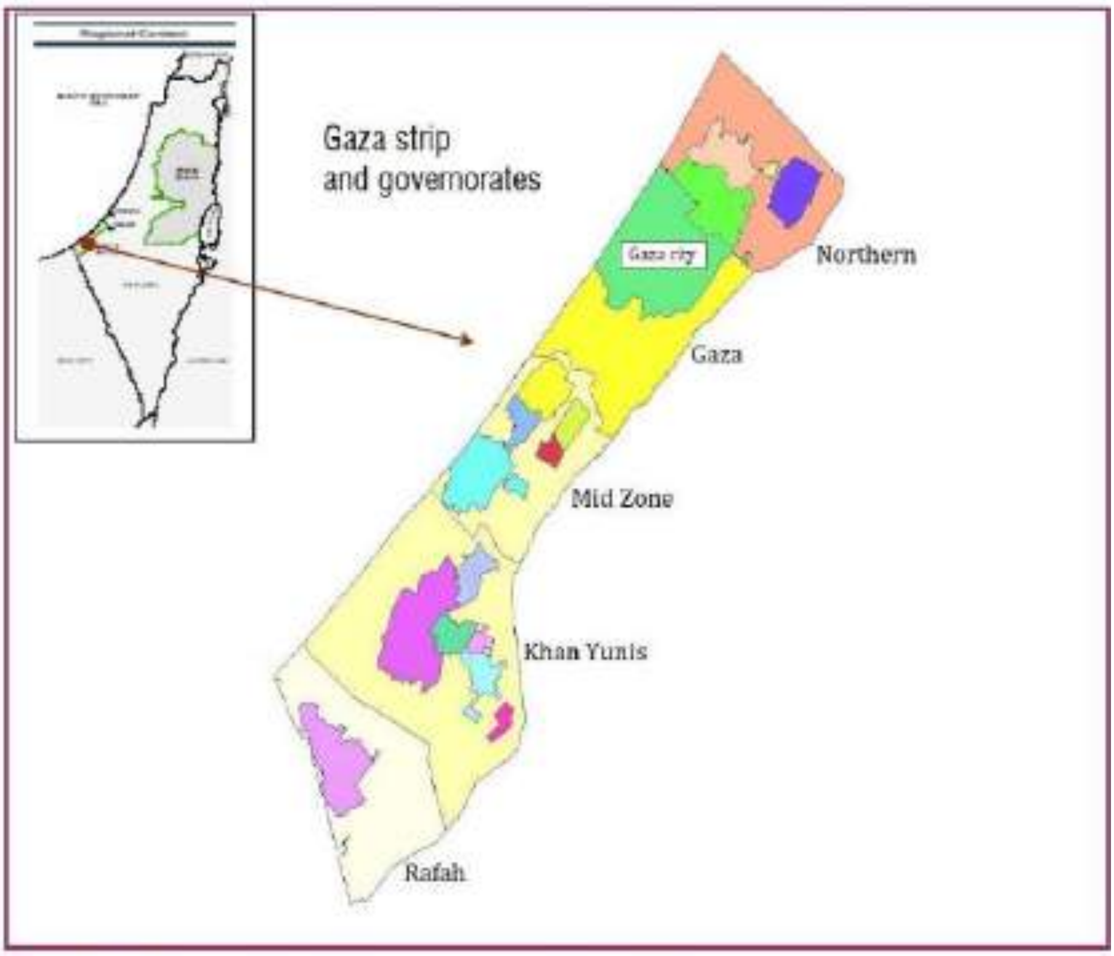


Figure 3.1: Gaza strip and its governorates (UNEP,2003)

3.1.2. Gaza Governorate

Central Gaza is situated on a low-lying and round hill with an elevation of 45 feet (14 m) above sea level. Its coordinates: 31° 30' 0" North, 34° 28' 0" East. Much of the modern city is built along the plain below the hill, especially to the north and east, forming Gaza's suburbs. The beach and the port of Gaza are located 3 kilometers (1.9 mi) west of the city's nucleus and the space in between is entirely built up on low-lying hills.

Gaza is composed of fifteen districts outside of the Old City as shown in figure 3.2 and listed in the table below table 3.1 and table 3.2.

Table 3.1: Estimated Population and Percentage Distribution of Population in Gaza Strip and Gaza Governorate (Mid-Year 2010-2014)

Region	2010		2011		2012		2013		2014	
	Number	%	Number	%	Number	%	Number	%	Number	%
Gaza Strip	1,535,120	37.9	1,588,692	38.1	1,644,293	38.3	1,701,437	38.5	1,760,037	38.7
Gaza	534,558	13.2	551,833	13.3	569,715	13.3	588,033	13.3	606,749	13.3

Table 3.2: Gaza Governorate Districts (GMS, 2016)

	District	Population (2015)	Percentage %
1.	Al-Judeide	58,899	9.7
2.	Al-Turukman	55,366	9.1
3.	Tuffah	38,519	6.3
4.	Sheikh Radwan	52,862	8.7
5.	Al-Awda	5,090	0.8
6.	Al-Nasser	59,120	9.7
7.	Zeitoun	79,842	13.2
8.	Sheikh Ijlin	16,156	2.7
9.	Tel al-Hawa	12,497	2.1
10.	Al-Sabra	37,507	6.2
11.	Rimal	65,209	10.7

	District	Population (2015)	Percentage %
12.	Old City	19,775	3.3
13.	Al-Shati Camp	45,415	7.5
14.	Al-Blakhia	7,066	1.2
15.	Al-Daraj	53,426	8.8
	Total	606,749	100.0

Figure 3.2: Gaza Governorate Districts Map (OCHA, 2012)

3.1.3. Population

The population density in Gaza Strip 4,822 capita/km^2 and in Gaza Governorate 8,199 capita/km^2 at mid-year 2014. As shown in table 3.3.

The Annual growth rate of the Palestinian population was 2.9% in Palestine in 2014, and 3.5% in Gaza Strip. The average household size in in Gaza Strip is 5.8 capita. (PCBS,2014)

Table 3.3: Population Density in Gaza Strip and Gaza Governorate Mid-Year,2014

Region /Governorate	Area (km^2)	Population Mid-Year 2014	Population Density (Capita/km^2)
Gaza Strip	365	1,760,037	4,822
Gaza	74	606,749	8,199

3.1.4. Climate

The Gaza Strip is located in the transitional zone between the arid desert climate of the Sinai Peninsula and the semi humid Mediterranean climate along the coast. The following is a climatological summary in the project area for the period from 1981 to 2012 as shown in table 3.4.

3.1.5. Temperature

As shown in table 3.4 the average daily mean temperature in the Gaza Strip ranges between 25.8^{0C} in summer to 13.4^{0C} in winter. The hottest month is August with an average temperature of 25 to 28^{0C} and the coldest month is January with average temperature of 12 to 14^{0C}. (EMCC, 2014)

3.1.6. Humidity

The relative humidity fluctuates between 60% and 85%. See table 3.4 The highest humidity in June and July and accounted for 74%. (Al-Najar, 2011)

Table 3.4: Gaza Strip average of ten years monthly metrological data (Al-Najar, 2011)

Month	Temperature		Humidity (%)	Wind Spd (km/d)	Sun shine (hrs/d)	Solar Rad. (MJ/m^2/d)	ET$_o$ (mm/d)
	Max	Min					
Jan.	17.8±2	10.7±1	64±5	281±27	4.8±1.4	9.9±1.5	2.5±0.4
Feb.	18.1±2	11.2±1	67±4	278±15	6.2±1.7	13.4±1.9	1.8±0.3
March	19.8±2	13.2±3	68±5	262±22	7.6±1.0	17.7±1.2	3.4±0.4
April	22.5±3	16.7±3	67±6	250±14	8.2±1.3	20.9±1.7	4.3±0.3
May	24.4±2	19.2±3	71±4	230±12	9.8±1.0	24.5±1.5	4.9±0.2
June	27.0±2	21.7±2	74±6	238±15	9.8±1.2	24.8±1.6	5.2±0.3
July	29.4±2	23.9±4	74±4	233±13	10.5±0.5	25.6±1.0	5.7±0.2
Aug.	29.4±3	24.6±3	71±4	238±16	10.5±0.5	24.6±1.1	5.6±0.2
Sept.	28.7±4	23.1±3	69±6	250±30	9.6±0.9	21.3±1.4	5.0±0.3
Oct.	26.3±3	20.4±2	68±3	257±26	8.2±1.7	16.6±2.1	3.9±0.4
Nov.	23.0±3	16.1±2	61±3	262±15	6.0±1.8	11.6±2.4	3.2±0.4
Dec.	19.2±2	12.6±2	65±5	262±22	3.9±1.1	8.5±1.3	2.4±0.5

3.1.7. Wind

In summer, sea breeze blow all day and land breeze blows at night. Wind speed reaches its maximum value at noon period and decrease during night. During the winter, most of the wind blow from the Southwest and the average wind speed is 4.2 m/s. In summer, strong winds blow regularly at certain hours, and the daily average wind speed is 3.9 m/s and come from the Northwest direction. Storms have been observed in winter with maximum hourly wind speed of 18 m/s. as shown in table 3.4.(EMCC, 2014)

3.1.8. Soils and Land Use

Near the Gaza Strip coast, the soils are sandy, characterized by high infiltration and low water retention. In some coastal areas, underlying clay layers may ultimately control the infiltration rate during prolonged winter rains. Rapid infiltration makes this area suitable for grapes, dates and other crops requiring well-drained soils. The underlying clay or loamy soils of lower infiltration do not pose a problem for agriculture. In fact, in some areas where the sand layer is thin, the sand is often removed to take advantage of the water retention characteristics of these soils. Wadi

Gaza, the low point that serves as conduit for surface water drainage toward the Mediterranean, has transported finer soils. Thus this area has finer soils than are usually found close to the coast.

Silt and clay content generally increases with distance from the coast, increasing the soil's ability to retain water. The quantity of organic matter also generally increases with distance from the coast, making the soil suitable for a wide variety of crops including citrus, olives, and vegetables. (Anan, 2008)

Gaza Strip has alluvial, sandy and loess soils as shown in figure 3.4. Major crops include vegetables, strawberry, citrus, guava, dates, field crops, and almonds. Groundwater salinity and pollution are serious problems affecting crop production. (CIRD, 2011)

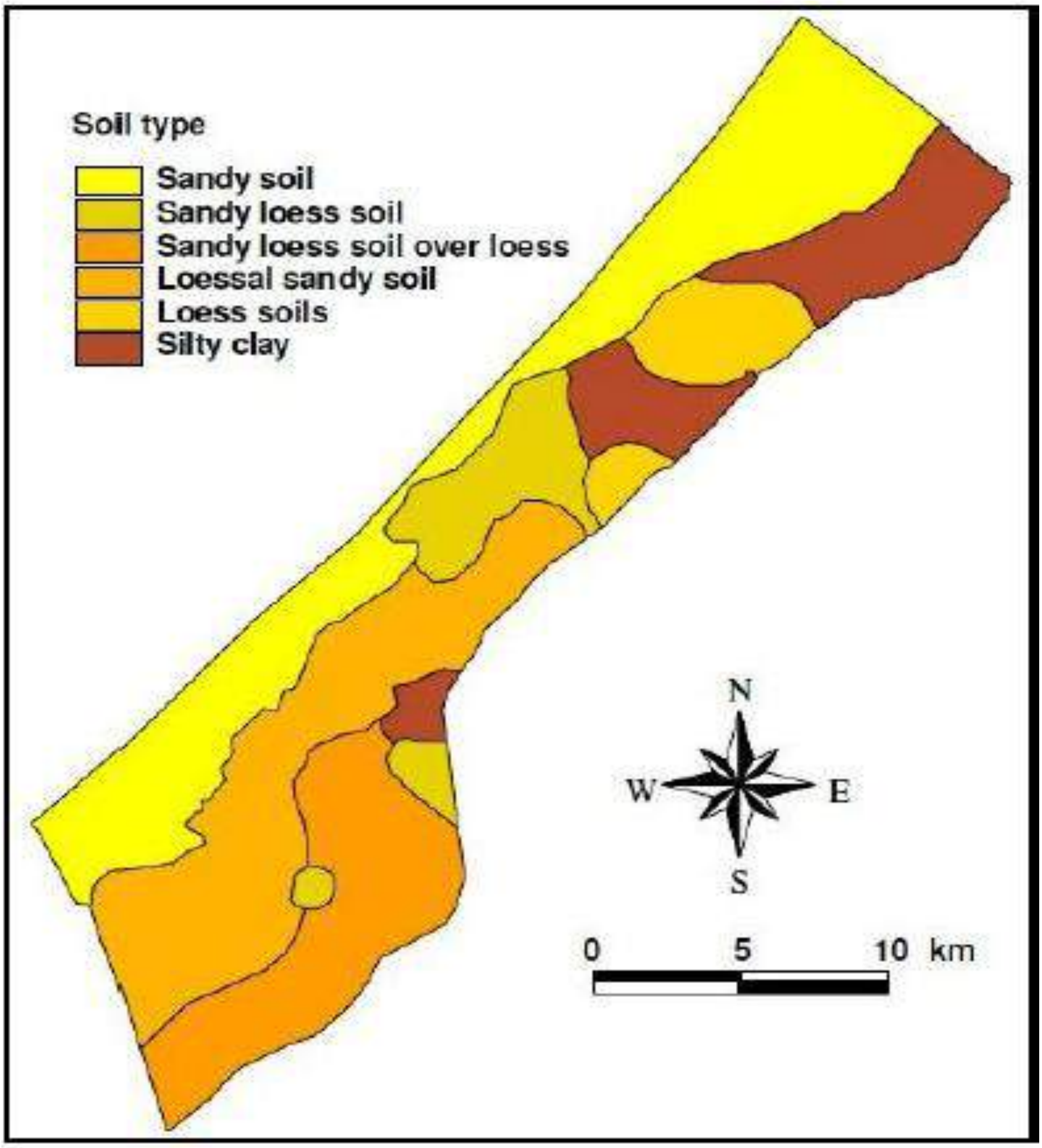


Figure 3.3: Soil Types of Gaza Strip (PWA, 2003)

In Gaza Governorate as shown in figure 3.5 the agriculture land distributed all over the governorate districts.

The agriculture lands divided to four types in Gaza Governorate. Field Crops, Vegetables, Fruits, Citrus. And the total area of them 34,508 donum. The largest type is fruits with 15,161 donum, and the smallest type is field crops with 5,820 donum.

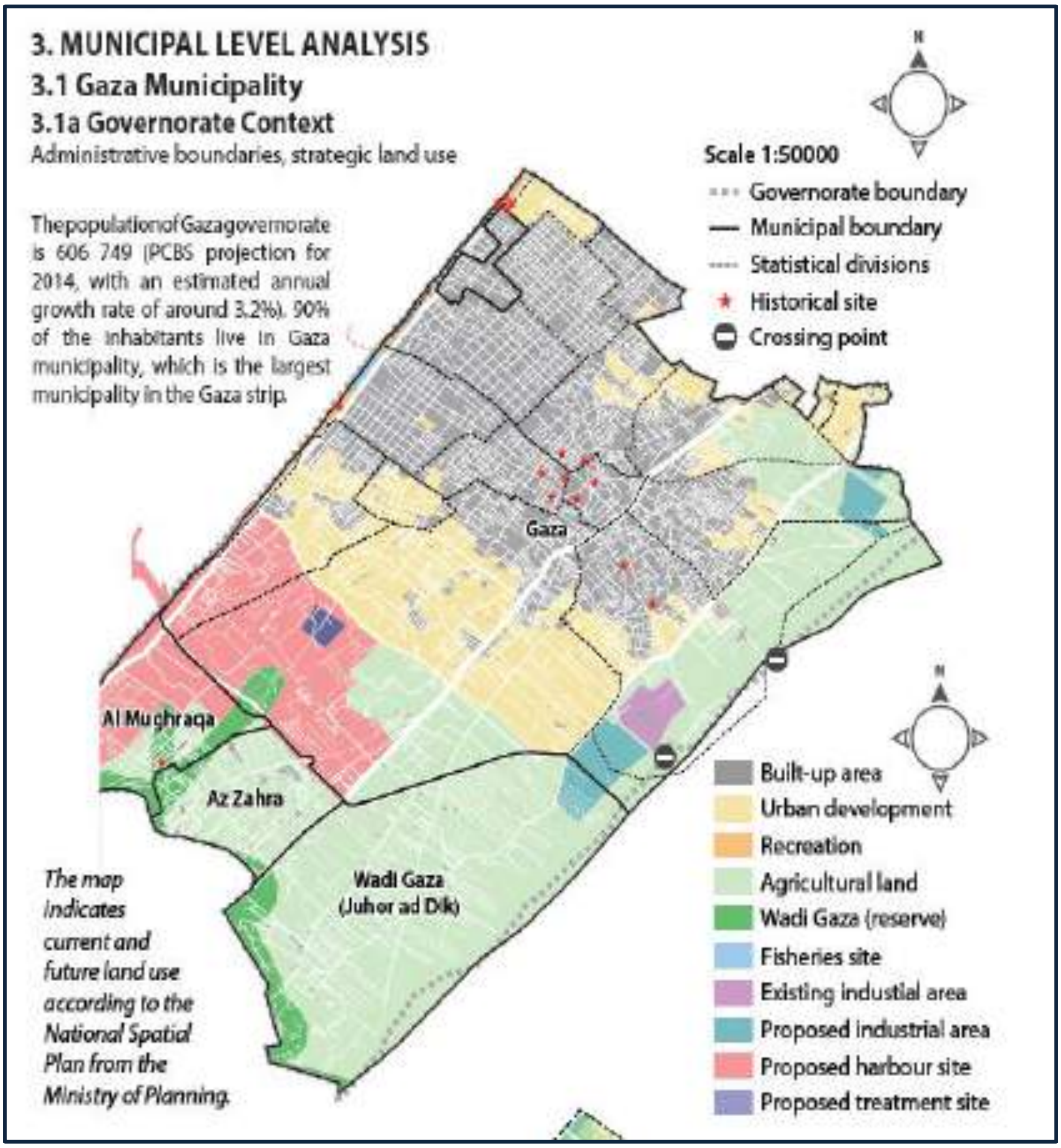


Figure 3.4: Gaza Municipality, Administrative boundaries Strategic Land Used (UN,2014)

3.2. Water resources in Gaza Strip

3.2.1. Rainfall and Recharge

In the Gaza Strip, the average normal rainfall is calculated over the period 1981-2010 for 8 stations as shown in figure 3.6. Clear increases in rainfall totals for the hydrological year of 2011/2012 compared to 2010/2011. (PWA, 2012)

In the season 2011/2012 the average annual rainfall over the Gaza Strip is estimated at about 372 mm, while the long term annual average rainfall in Gaza is 327 mm.

The annual rainfall in 2011/2012 has exceeded the normal seasonal average at all stations. In contrast, annual rainfall was low during the 2010/2011 season, averaging only 225 mm for the Gaza Strip. Rainfall is unevenly distributed; it varies considerably, decreasing from the north to the south with large fluctuations from year to year. (PWA, 2012)

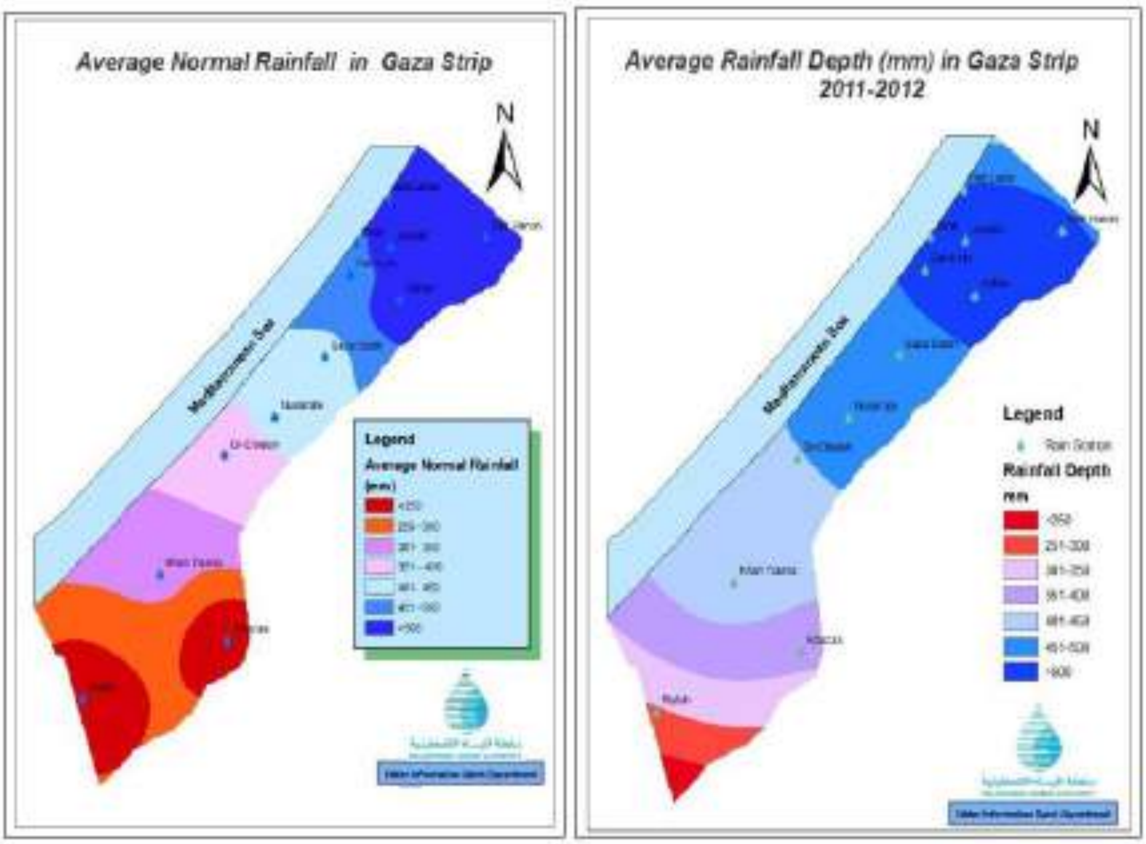


Figure 3.5: Rainfall Contour maps for the Gaza Strip, 2010/2011 season and long term average. (PWA, 2012)

The winter is the rainy season, which stretches from October up to March. Rainfall is the main source of recharge for groundwater. The rate of rainfall is varying in the Gaza Strip and ranges between 160 mm/year in the south to about 400 mm/year in the north, while the long term average rainfall rate in all over the Gaza Strip is about 317 mm/year (CMWU, 2011). For the last ten years, between 2001 and 2011, the average annual rainfall of Gaza strip ranged between 220 mm/year to 520 mm/yea. (MOA, 2011).

Rainfall shows considerable spatial and temporal variation, with annual average rainfall of 327 mm/y in Gaza Strip. During the 2013/2014 season (1 Sept. 2013 to 11 May 2014) the total average rainfall was significantly higher than average in Gaza Strip at 442.0 mm/y. This translates into a rainfall volume of 162 MCM/y in Gaza; out of this total about 76 MCM are estimated to have recharged the groundwater systems in the Gaza Strip (PCBS, Environment Day, 2014).

Total monthly rainfall for Gaza districts for season 2013/2014. Al-Remal Station 544 mm, Al-Shate Station 454 mm and Al-Tofah Station 560.8 mm. (PMA, 2014)

3.2.2. Groundwater resources

The Coastal Aquifer is the only source of water in the Gaza Strip, with the thickness of the water bearing strata ranging from several meters in the east and south-east to about 120-150 m in the western regions and along the coast. The aquifer consists mainly of sand and gravel sand and sandstone (Kerkar) intercalated with clay and silt. Hard and non-productive layers of clay and marl with low permeability (Sakia Formation) with a thickness of about 800-1000 m are situated below the coastal aquifer. The yearly recharge volume, equaled to the sustainable yield for this limited volume aquifer, is in the range of 55-60 MCM/yr. The Palestinian utilization from this aquifer in Gaza Strip is about 185 MCM in 2012. From around 200 wells distributed all over Gaza Strip as shown in figure 3.9.

The water level declines in most of the monitoring wells have continued with the same magnitude and attitude of the year 2012 as well as the previous years. Generally, the magnitude as well as the attitude of groundwater level decline changes from area to another based on; location of the monitoring wells, hydrogeological characteristics of the water bearing formation, production rates in the vicinity of the monitoring wells and the production duration. The significant water level decline has been recorded in the two cones of depression areas that located in the north and south of Gaza Strip as a result of high density of domestic wells that are pumping continuously with high pumping rates. The influence of the cone of depressions affects all the monitoring wells surrounding, with different degree of influence. The water level decline in Rafah area is significantly high reflecting the low aquifer potential as well as its low recharge water amounts compared to the pumped quantity.(PWA, 2015)

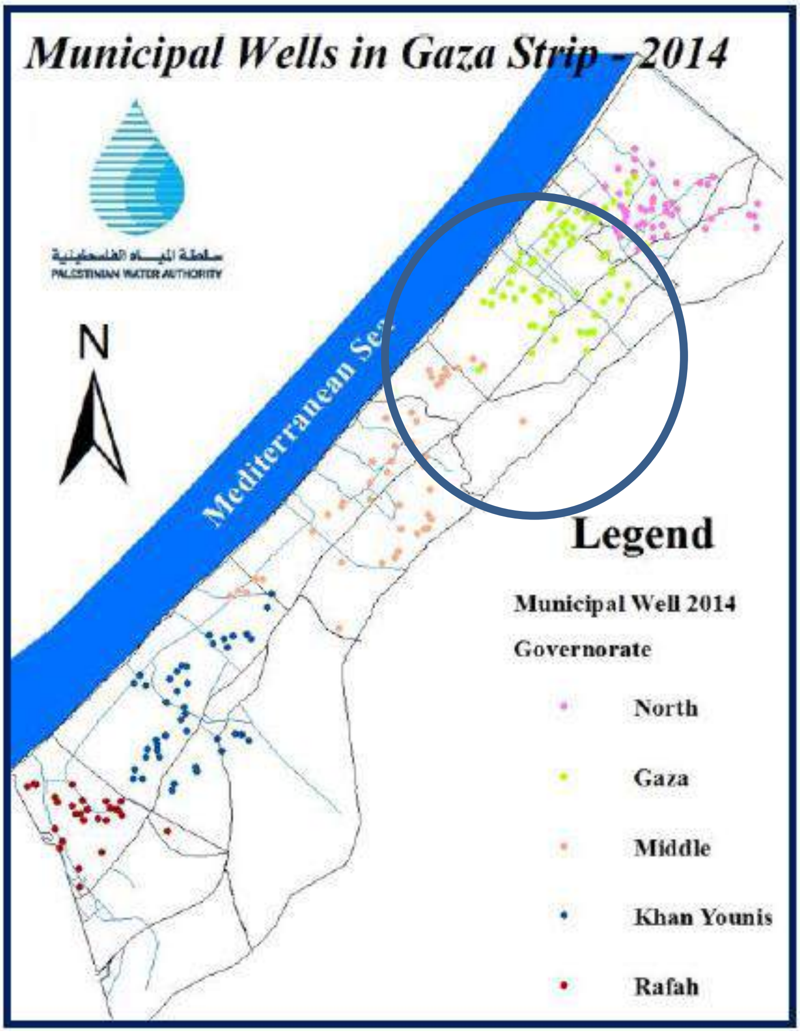


Figure 3.6: Municipal Wells in Gaza Strip 2014. (PWA, 2015)

3.2.3. Water resources in Gaza Governorate.

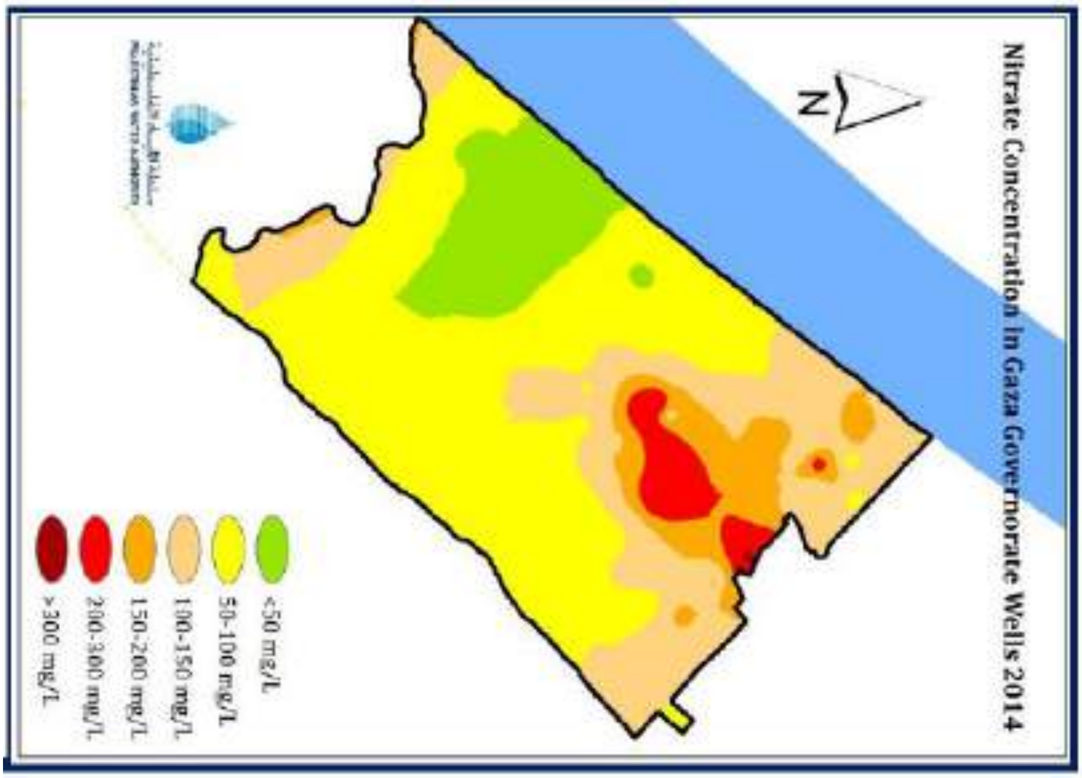
Gaza Governorate served by groundwater through 77 municipal wells; three of them owned and operated by UNRWA. Gaza Governorate considered as a central economical and industrial city in Gaza Strip; hence, the water demand in this area is more than the other municipalities in Gaza Strip, which led to a negative impact on groundwater quality and its degradation. Total groundwater production in 2014 was 27,024,755 m3. Hence, a theoretical consumption per capita is 123.3 l/c/d from the total water produced, while the calculated system efficiency is about 63% that mean the actual per capita water consumption is 77.6 l/c/d as shown in Annex 1 *(PWA, 2015).*

3.2.4. Groundwater Quality

Depending on the results of the groundwater chemical analyses carried out twice a year by both Ministry of Health Lab (MOH) and Coastal Municipal Water Utility (CMWU) for about 200 domestic water wells in Gaza Strip, PWA has evaluated these results through preparing contour maps as well as graphs for the main ions such as Chloride as salinity indicator and Nitrate as pollution reference. (PWA,2014)

According to the latest results of chemical analyzes of the element of chloride compound nitrates to 2014, was drawn contour maps to illustrate the current status of water quality in Gaza City as shown in figure 3.9, a contrast in general also reflect the quality of water that is pumped from the various municipal wells in Gaza City, which in turn link to all citizens through water networks.

As a result of pumping operations and continued from Gaza Municipality wells caused a sharp fall in the groundwater level, which in turn led to a sharp deterioration in water quality private chloride element, so we find through a contour map of the element of chloride to 2014, the majority of the province is characterized by very poor quality and the situation came to what looks like a catastrophic situation in the concentration of chloride hand, especially in the western region stretching from the far north west of the city and even the south, and deeply into the city from the coastal strip reached more than 7 km away, where we find that the concentration of chloride is at record rates and unprecedented reached more than 12,000 mg/l due to seawater intrusion with groundwater. (PWA, 2015)



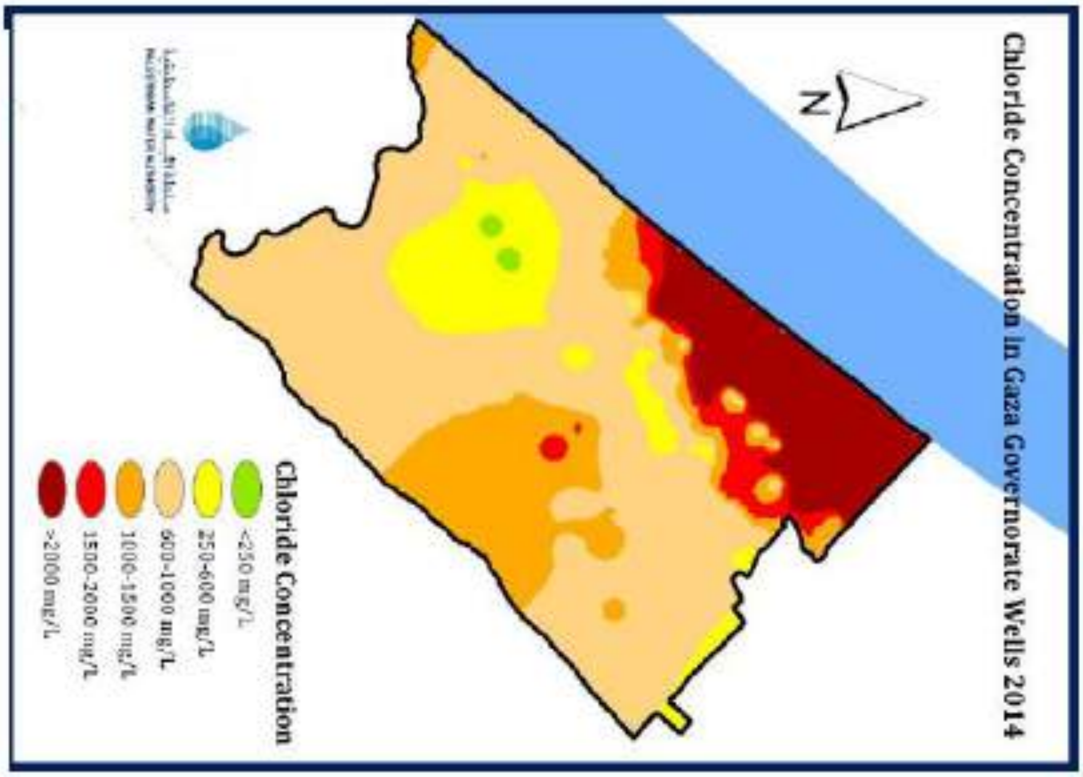


Figure 3.7: Chloride and Nitrate Contour Map for Gaza Governorate 2014 (PWA,2015)

3.2.5. Surface water (Wadis)

In the Gaza Strip, the major wadis originate east of the border where Israel is blocking the natural flow for irrigation purposes. This makes the wadis dry except in years of heavy rainfall. Because the topography in Gaza is flat and land is scarce, the scope for storing and using any remaining surface water is very limited. (PWA, 2012)

Wadi Gaza- It originates at the eastern upstream where Israel is trapping the natural flow. This action dries the Wadi, except in very wet years, making the use of any remaining surface water resources is very limited. The annual average flow of this wadi is about 20 MCM/y. (PWA, 2012)

3.2.6. Non-conventional water Recourses

3.2.6.1. Desalinated Water

Construction of Gaza Short-term Low Volume (STLV) Seawater Desalination Plant

The project of the establishment of the above mentioned STLV seawater desalination plant is comprised of four main components,

1. Reverse Osmosis (RO) plant: This is the main component of the project. This plant is located on the shore of the Beit Lahia while it is going to serve some of Gaza city neighborhoods, namely, Beach camp, Western Al Nasser, Sheikh Radwan and Western Tal Al Hawa. The production of this plant will be around 10,000 cubic meters per day and this is equivalent to a yearly production of 3.7 MCM of desalinated water per year. The quality of the desalinated plant should be 50 ppm Cl.
2. Blending Reservoir: This reservoir is located in Gaza city. The purpose behind constructing this reservoir is blending the desalinated water with water abstracted from municipal wells. Size of this reservoir is 5000 cubic meters.
3. Carrier Line: 18" HDPE from the desalination plant to the blending reservoir. Length: 7500 meters.
4. Water Networks Re-routing Installations: (i) 2500 meter pipeline from the water wells to the blending tank and (ii) 2000 meter pipeline to connect the blending tank with the existing networks. (PWA, 2015).

Construction of the Gaza Central Desalination Plant (GCDP) – Stage 1

The long term plan for the GCDP is to have a total production capacity of 110 MCM per year. However, the current project is to establish the first stage of the plant which is with a production capacity of 55 MCM per year.

The GCDP is planned to be located on the shore of Deir Al-Balah. The total area of land assigned for the plant is around 800 donums (for stage 1 and 2). However, 5 donums are already occupied by the southern short term low volume (STLV) seawater desalination plant. The GCDP is planned to be designed based on Reverse Osmosis (RO) technology. (PWA, 2015)

3.2.6.2. Treated wastewater reuse

Wastewater Treatment Plants in the Gaza Strip

In the Gaza Strip, there are three main treatment plants and one temporary plant for collecting and treating wastewater to treat it to the level allowed to be dumped to the sea and to not pollute the aquifer in case of infiltration Except for the north WWTP which infiltrates to the eastern lagoons These treatment plants are placed along the Gaza Strip (North, Gaza, Rafah and Khanyounis).

The locations of these treatment plants were chosen during the times of the Israeli occupation of the Gaza Strip; however, the regional contour of Ministry of Planning suggests establishing three central treatment plants near the eastern armistice line as shown in figure 3.11. The current treatment plants still do not meet the standards of treating wastewater in Gaza and this is due to the frequent closure of Gaza crossings that hinder the required periodical maintenance. Moreover, the population growth without a proper expansion of the treatment plants has caused a problem since the wastewater production rate is increasing. (CMWU,2011)

The largest Palestinian wastewater treatment plants (WWTPs) are located in the Gaza Strip, more specifically in Beit Lahiya, Gaza and Rafah. While, in Khan Younis the existing plant is just collection pond with partially treatment. It's worth mentioning that; there is no treatment facility in the Middle area and a total of 3.7 MCM/Y of its raw wastewater is diverted to the Wadi Gaza. The total treated wastewater (treated partially) from Gaza, Khan Younis, and Rafah WWTP’s are discharged to the sea around 30 MCM/y. Around 8.4 MCM/y of partially treated in

Beit Lahia WWTP is infiltrated into the groundwater. Accordingly the wastewater flow in Gaza Strip is around 42MCM/Yr.

All the existing WWTPs in Gaza Strip are function at moderate efficiency rates (45-70%); they also operate above their actual capacity and are in need of upgrade and maintenance. As shown above, 71% of all the partially treated wastewater in Gaza Strip is discharged to the environment (Wadi Gaza and the sea). (PWA,2012)

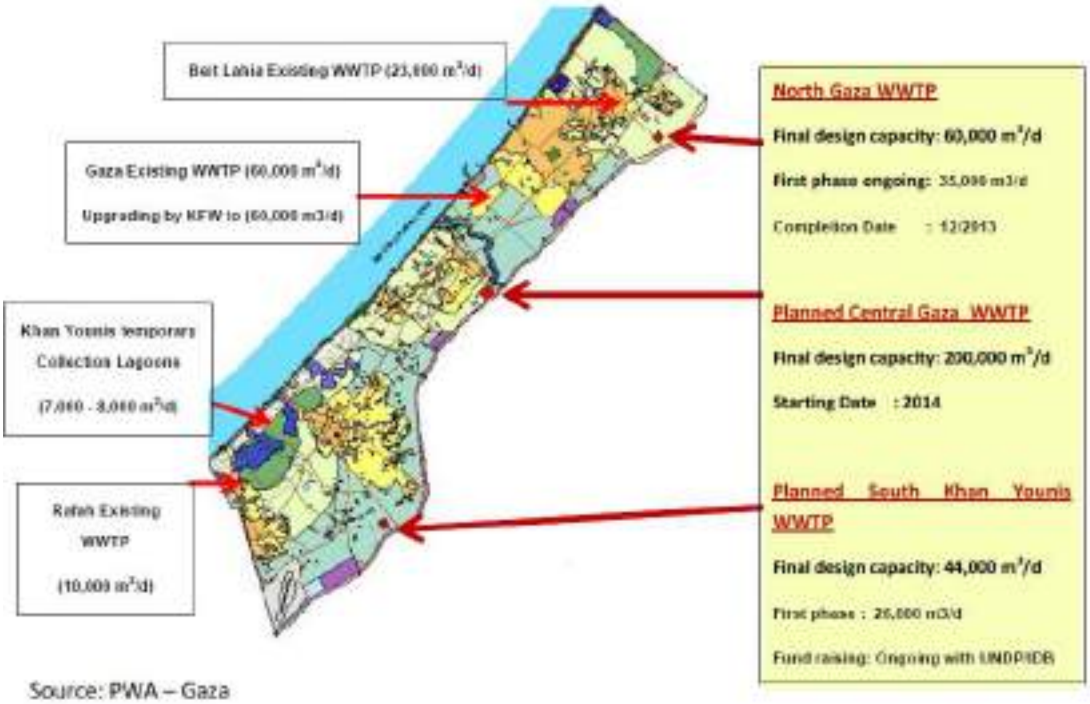


Figure 3.8: Gaza Strip wastewater treatment plants.

Sheikh Ajleen Treatment Plant

The plant was established in 1979 with an infiltration basin next to it and by the year 1986 the United Nations Development Program (UNDP) established another two infiltration basin to develop the plant. The plant also was developed in 1996 by the Municipality of Gaza and UNRWA in order to recharge 12,000 cubic meters per day. In 1998 the plant was rehabilitated and its capacity was enlarged to recharge 35,000 cubic meters per day in order to accommodate population growth till the year 2005, this was done by USAID in collaboration with PWA. A part of the treated WW was pumped to the infiltration basins and another part was pumped to the sea. In 2009 the water pumped to the plant increased to 60,000 cubic meters per day and this exceeds the plant capacity. After the year 2005 many people seized the plant infiltration basins and turned them into agricultural lands, thus the semi-treated WW was pumped to the sea (without getting treated) as the treatment plant was overloaded.

CMWU, in collaboration with KFW, has drawn the required plans to develop the plant and its pumping stations. The project's total cost is 15 Million USD and expected to absorb 90,000 Cubic Meters of wastewater in order to be treated according to the international standards. This is part of project of establishing central treatment plant with initial cost up to 70 Million Euros. (CMWU, 2011)

3.2.6.3. Purchase Water (Mekorot)

As of Oslo II, 5 MCM/year of drinking water are imported into Gaza through the Israeli water company Mekorot, which Gaza has to pay for. According to the Oslo II Agreement, water supply from Israel should increase by an additional 5 MCM of desalinated water annually (Israeli-Palestinian Interim Agreement on the West Bank and Gaza Strip, Annex III: Protocol Concerning Civil Affairs) but so far the delivery of this water is pending and Mekorot has not started pumping this water, despite a letter from the PWA to do so.

Palestinians utilize only 15% of water from the ground water aquifers, while Israelis, including settlers, utilize the remainder, 85%. The Gaza Strip utilizes approximately 18% of the coastal aquifer, Israel the remainder - 82%. (PCBS, World Water Day, 2014).

3.2.6.4. Storm Water Harvesting

The Gaza City having two Storm water reservoirs, which are:

Sheikh Radwan Reservoir

It serves its own catchment of about 9000 dunums and it receives over flow from Waqf reservoir, which serves a catchment of 9500 dunums. The storage capacity of Sheikh Radwan reservoir is about 560,000 m^3. (Ghabayen and Nassar, 2013)

The Sheikh Radwan Reservoir is one of the largest storm water collection reservoir in the Gaza Strip. The collected water is usually discharged directly to the sea due to impermeable soil profile beneath the reservoir bottom. The artificial storm water recharge is found to be one of the feasible options to compensate for the Gaza aquifer deficit. (Metcalf & Eddy, 2003).

The Shiekh Radwan Reservoir is located northwest of Gaza City (figure 3.17). It has a surface area of 88000 m^2. The site is almost flat and the bottom of the reservoir is elevated at about +16 m MSL. The reservoir receives about 2.5×106 m3 annually from a catchment area of about 25 km^2 (PWA, 2011). The sides of the reservoir are supported by gabion walls. The capacity on the reservoir is 560,000 m^3.

Figure 3.9: Shiekh Radwan Reservoir is located northwest of Gaza City.

Waqf Reservoir

It is located at a low point in the Asqoula area of the city and receives storm water flows from the adjacent streets and developed areas. Waqf reservoir, serves a catchment of 9500 dunums. The storage capacity of this reservoir is about 34,000 m3. (Ghabayen and Nassar,2013)

3.3. Water demand

3.3.1. Domestic demand

3.3.1.1. Population growth

As shown in figure 3.12 the estimated population of Palestinians in State at the end of 2014 was 4.62 million: 2.83 million in the West Bank 61.2% and 1.79 million 38.8% in Gaza Strip. The highest population was in Hebron with 15.1% of the total population, followed by Gaza governorate with 13.4% and the Jerusalem population with 9.0%. Jericho and Al Aghwar had the lowest population rate of 1.1%. (PCBS,2014)

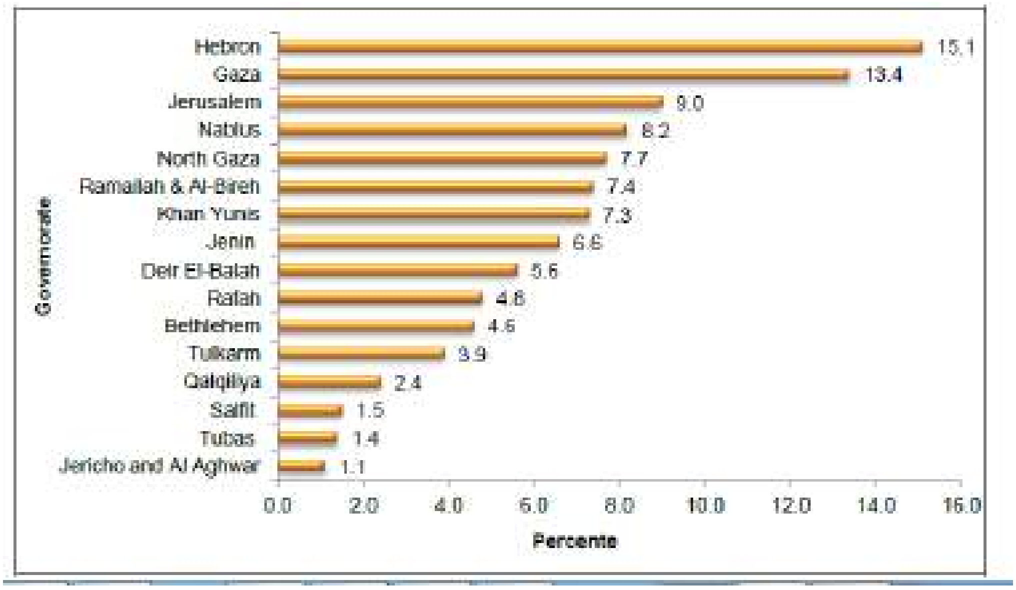


Figure 3.10: Percentage Distribution of Population in Palestine by Governorate, End 2014 (PCBS, 2014)

3.3.1.2. Growth Rate in State of Palestine

The population growth rate increase and reach 3.5% in Gaza Strip. It is anticipated that this growth rate will remain stable over the coming five years since the mortality rate is declining and fertility rates remain high, despite a tendency to slow. This will therefore require appropriate economic and social policies to deal with the population increase in coming years. (PCBS,2014)

Table3.5: Number of Population Gaza Strip (2000-2015) (SPCBS, 2014)

Year	2000	2001	2002	2003	2004	2005	2006
Population	395,760	407,745	419,963	432,546	445,645	459,851	474,509
Year	2007	2008	2009	2010	2011	2012	2013
Population	489,642	504,047	519,027	534,558	551,833	569,715	588,033
Year	2014	2015					
Population	606,749	625,824					

3.3.1.3. Domestic Water Consumption

The total water supplied for domestic use in Gaza governorate was about 27.024 MCM in 2014. Where, 96 % (25.94 MCM) of that water is supplied from groundwater through 77 water wells. While the remaining 4 % (1.08 MCM) is supplied from Mekorot. This mean that the daily average per capita water production is 123 L/C/D.

Taking in consideration the network distribution system efficiency (63%), the total water consumption was 17.024 MCM in 2014. This means that the daily average per capita water consumption is 78 l/c/d. (PWA, 2015)

Where the Gaza Strip total production is 88.466 MCM and the total consumption 52.062 MCM. Based on that, the per capita consumption ranged between 90 l/c/d in the Northern Governorate in spite of its low system efficiency (50%) as indication of high groundwater production quantities and 73 l/c/d in Khan Younis Governorate. The maximum production was recorded in the Northern Governorate of 180 l/c/d while the lowest is 120 l/c/d in the Khan Younis and Rafah Governorates (table.3.7). (PWA, 2012)

Table 3.6: Domestic Water Supply in Gaza Strip-2014 (PWA, 2012)

Governorate	Total Production	Total Consumption	System Efficiency	L/C/D Production	L/C/D Consumption
North	23,389,963	11,664,340	50%	180	90
Gaza	27,024,755	17,024,755	63%	123	78
Middle	13,636,819	8,287,506	61%	137	83
KhanYounis	14,702,700	8,997,143	61%	120	73
Rafah	9,712,729	6,089,174	63%	120	75
Total	88,466,966	52,062,918	58.9%	135.4	79.8

Today 90% of water from the aquifer is not safe for drinking without treatment. Availability of clean water is thus limited for most Gazans with average consumption of 70 to 90 litres per person per day (depending on the season), below the global WHO standard of 100 litres per person per day. (UNCT, 2012)

3.3.2. Agriculture Demand

During the agricultural year 2009/2010, cultivated land area constituted 75,154 dunums in Gaza Strip which is 20.6% of the total area of Gaza Strip . (PCBS and MoA, 2011).

The agricultural sector in Gaza Strip in average consumes around 80 million cubic meters annually from the groundwater wells. There is absence of direct measurement of water withdrawal for agriculture as most of the agricultural wells distributed all over Gaza Strip are unmetered , not functioning well or not installed absolutely, All amounts of water used for this purpose come from groundwater wells. (PWA, 2012)

Gaza Strip is one of the places where the exploitation level of recourses exceeds the carrying capacity of the environment. This is especially true for the water and land resources, which are under high pressure and subject to sever overexploitation, pollution and degradation.

The municipal water supplied within the Gaza Strip area is recorded monthly while agricultural usage cannot be measured due to the lack of meters, and non-functioning meters on existing wells are being estimated annually. Agricultural water use and water use productivity are not always available at the country level. This is mainly due to the complexity of the assessment methods and to the absence of direct measurement of water withdrawal for agriculture. The Agricultural sector in the Gaza Strip on an average consumes around 75-80 million cubic meters of water annually. (Adwan, 2014)

3.3.2.1. Agricultural pattern - Gaza Governorate

It is grown in the western area of the city (Sheikh Ajleen) area where the soil is sandy grapes, olives, figs, apples, nuts and vegetable crops.

Is cultivated in the Moghraqa area and Zaitoon neighborhood citrus and palm trees and greenery area. The eastern region where the clay soil is cultivated olives ,vegetables ,rain-fed crops and cereal crops. Agricultural areas are limited to in the Gaza Governorate following areas: Moghraqa-Sheikh Ajleen-Zaitoon-Joher Dike-East Line. As shown in figure 3.14. The detailed type of Gaza Governorate agriculture is shown in Annex 2.

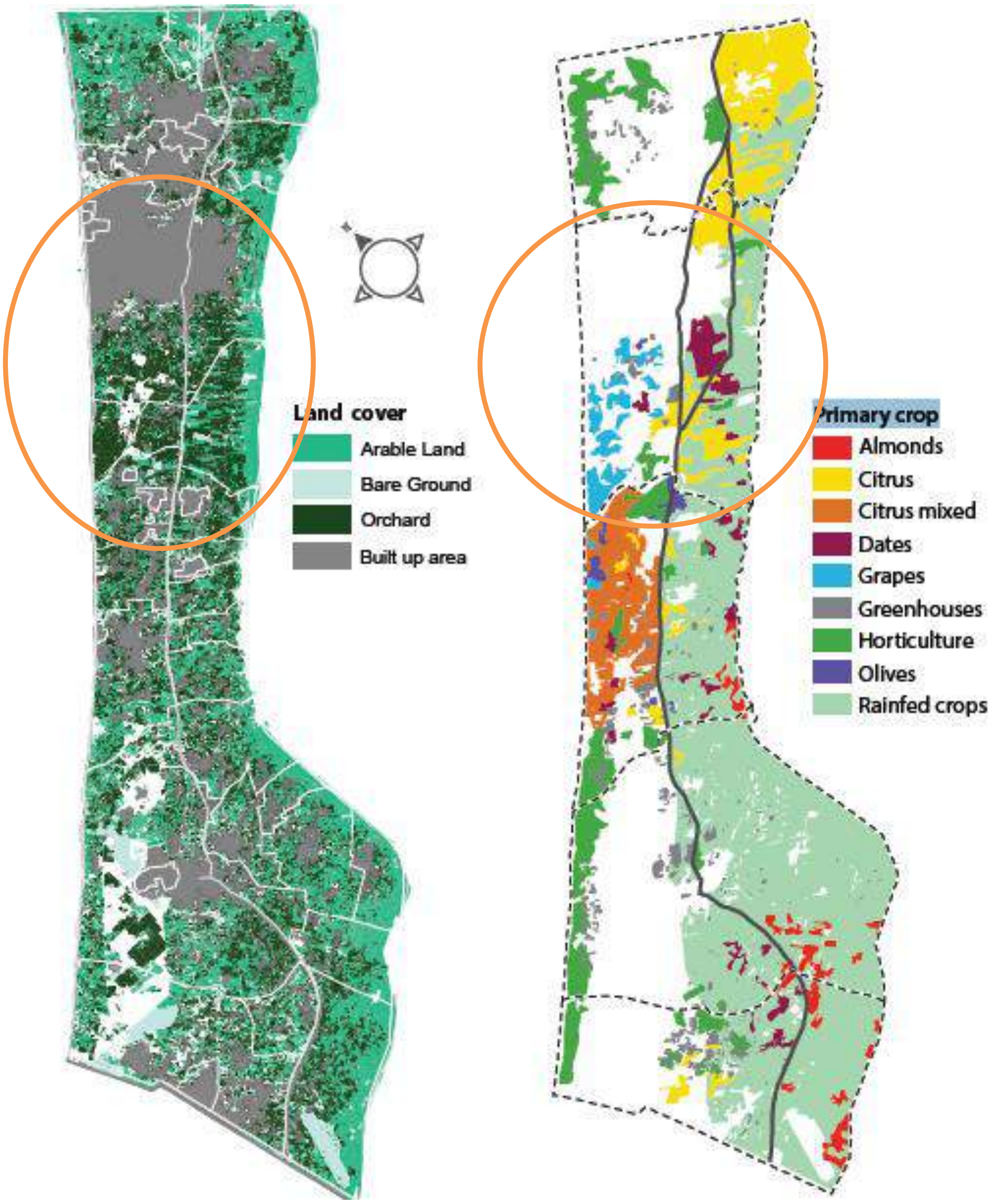


Figure 3.11: Map of Land Cover – Agriculture /Bare Land. Based on ECHO of Agriculture Damage

Map of Land Cover – Agriculture /Bare Land. Based on ECHO of Agriculture Damage	Map Showing Primary Crops and their Location. Data Obtained from UNRWA

Chapter 4

Research Methodology

Chapter 4. Research Methodology

4.1. Data Collection

The data in this research was collected using a variety of methods and tools to reach accurate and detailed information in order to get results that touch reality. Gathering information was depending on the official reports exported from the relevant institutions and previous scientific researches. The various information collected shows water consumption and water resources for Gaza City.

4.2. WEAP Model

WEAP ("Water Evaluation And Planning" system) is a user-friendly software tool that takes an integrated approach to water resources planning.

4.2.1. Overview

WEAP is a software 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. This introduction presents WEAP's purpose, approach, and structure; a detailed technical description of WEAP capabilities is available in a separate publication.

4.2.2. WEAP operates in many capacities

Water balance database: WEAP provides a system for maintaining water demand and supply information.

Scenario generation tool: WEAP simulates water demand, supply, runoff, stream flows, storage, pollution generation, treatment and discharge and instream water quality.

Policy analysis tool: WEAP evaluates a full range of water development and management options, and takes account of multiple and competing uses of water systems.

4.2.3. WEAP Approach

WEAP operates on the basic principle of a water balance and can be applied to municipal and agricultural systems, a single watershed or complex transboundary river basin systems. Moreover, WEAP can simulate a broad range of natural and engineered components of these systems, including rainfall runoff, baseflow, and groundwater recharge from precipitation; sectoral demand analyses; water conservation; water rights and allocation priorities, reservoir operations; hydropower generation; pollution tracking and water quality; vulnerability assessments; and ecosystem requirements. A financial analysis module also allows the user to investigate cost-benefit comparisons for projects.

4.2.4. WEAP applications generally include several steps

Study definition: The time frame, spatial boundaries, system components, and configuration of the problem are established.

Current accounts: A snapshot of actual water demand, pollution loads, resources and supplies for the system are developed. This can be viewed as a calibration step in the development of an application.

Scenarios: A set of alternative assumptions about future impacts of policies, costs, and climate, for example, on water demand, supply, hydrology, and pollution can be explored. (Possible scenario opportunities are presented in the next section.)

Evaluation: The scenarios are evaluated with regard to water sufficiency, costs and benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables.

4.3. Getting Started WEAP - The Schematic View

The design of WEAP is guided by a number of methodological considerations: an integrated and comprehensive planning framework; use of scenario analyses in understanding the effects of different development choices; Demand-management capability; Environmental assessment capability; and Ease-of-use.

The Schematic View is the starting point for all activities in WEAP. A central feature of WEAP is its easy-to-use "drag and drop" graphical interface used to describe and visualize the physical features of the water supply and demand system. This spatial layout is called the schematic. You can create, edit and view it in the Schematic View. GIS layers can be added to provide clarity and impact.

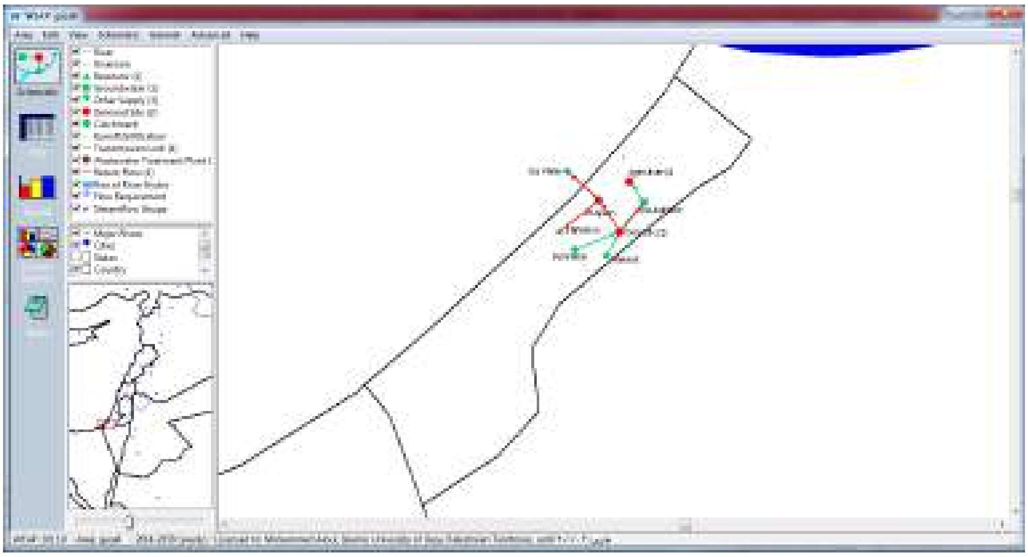


Figure 4.1: Interface of WEAP Model for Gaza Governorate.

Demand

Demand analysis in WEAP is a disaggregated, end-use based approach for modeling the requirements for water consumption in an Area. Using WEAP you can apply economic, demographic and water-use information to construct alternative scenarios that examine how total and disaggregated consumption of water evolve over time in all sectors of the economy.

The following types of data are often useful:

- ✓ Basic water requirements data, categorized by sector and/or specific water users
- ✓ Existing water use studies for the study area, and data from national, state, county or municipal agencies
- ✓ Population projections for cities and towns, production activity level projections for industry and agriculture
- ✓ Water consumption (water consumed by a demand site that is lost to the system, lost to evaporation, embodied in products, or otherwise unaccounted for)

Note: Agricultural irrigation demands can either be calculated using activity levels and water use rates as described above, or by simulating catchment processes such as evapotranspiration, runoff, infiltration and irrigation demands. See Overview of Catchment Calculation Methods for more information.

Supply and Resources Overview

Supply and Resources include the following subsections:

- ✓ **Transmission Links**: transmission links carry water from local and river supplies to demand sites, subject to losses and physical capacity, contractual and other constraints.
- ✓ **Rivers and Diversions**: surface inflows to rivers, properties and operation of reservoirs and run-of-river hydropower facilities, instream flow requirements, surface water-groundwater interaction, and streamflow gauges.
- ✓ **Groundwater**: aquifer properties, storage and natural recharge..
- ✓ **Local Reservoirs**: reservoirs not on a river.
- ✓ **Other Supplies**: e.g., surface sources that are not modeled in your WEAP application, such as inter-basin transfers or desalination.
- ✓ **Return Flows**: wastewater from demand sites can be routed to one or more wastewater treatment plants, rivers, groundwater nodes or other supply sources; treated effluent from wastewater treatment plants can be routed to one or more rivers, groundwater nodes or other supply sources.

Results View

The Results View is a general purpose reporting tool for reviewing the results of your scenario calculations in either chart or table form, or displayed on your schematic. Monthly or yearly results can be displayed for any time period within the study horizon. The reports are available either as graphs, tables or maps and can be saved as text, graphic or spreadsheet files. You may customize each report by changing: the list of nodes displayed (e.g., demand sites), scenarios, time period, graph type, unit, gridlines, color, or background image.

4.4.Scenarios Development

The study will evaluate water management options for Gaza Governorate using WEAP. This model will help to identify management options under different scenarios which in turn will help as a decision support tool to identify the best options concerning water management in Gaza governorate. The following scenarios represent the most important water management options that will be developed and analyzed in this study:

1. Zero Action Scenario.
2. Desalination Scenario.
3. Recharge of Waste Water Treatment Scenario.
4. Combination of Scenario 2 and Scenario3

4.4.1. Scenario Number 1 (Zero Action)

Description of Scenario

The Zero Action scenario is the base scenario that extrapolates historical trends to provide a baseline for the studied period. The objective of a Zero Action scenario is to help in learning what could occur if the current trend continues and to understand the opportunities, pressures, and vulnerabilities that this might bring.

This scenario is based on the assumption that the irrigated land and water use efficiency will follow the same trend as in the last ten year. There will be no major change in prevailing agriculture practices.

The main features of the this scenario are :

- ✓ Time horizon 2014-2030.
- ✓ Population Growth Rate 3.5%.
- ✓ Per capita water demand 120l/c/d.
- ✓ Water distribution system losses 35%.
- ✓ Water supply from ground water wells only.
- ✓ Water demand include domestic and agriculture.

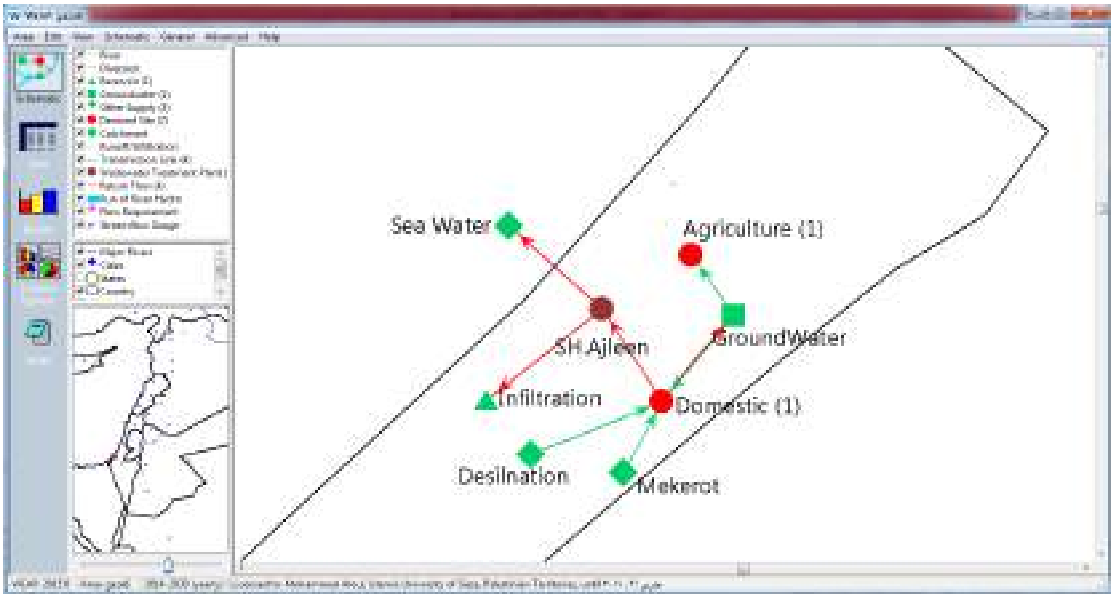


Figure 4.2: Water Resources and Water Demand at WEAP Model.

4.4.2. Scenario Number 2 (Desalination Scenario)

Description of Scenario

This scenario is studying the impact of use desalination plants as a source of water supply to the Gaza Governorate and the impact of use this source on the aquifer. A small desalination plant STLV will be construct in 2018 with 4MCM capacity.

According to Palestinian Water Authority, a central desalination plant in the Middle region is expected to be ready to work with the beginning of 2022 year. Production capacity will be 55 MCM, where Gaza Governorate share expected 19 MCM, according to the proportion of the population in Gaza City from Gaza Strip.

The main features of the this scenario are:

- ✓ Time horizon 2014-2030
- ✓ Water supply from ground water wells and desalination plant, STLV plant capacity 4 MCM/y starting work 2018, GCDP plant capacity 55 MCM/yr starting work 2022 and Gaza Governorate portion 19 MCM/yr.
- ✓ Water demand include domestic and agriculture

4.4.3. Scenario Number 3 (Recharge of Treatment Waste Water Scenario)

Description of Scenario

This scenario is studying the effect of wastewater treatment and infiltration it to the aquifer during the study period.

Sheikh Ejleen Waste Water plant with capacity 60,000 M3/d discharge the waste water completely to the sea. through this scenario 20,000 M3/d Waste Water will be treated , infiltrated to the aquifer and measured its impact on the aquifer during study period

The main features of the this scenario are :

- ✓ Time horizon 2014-2030
- ✓ Water supply from ground water wells.
- ✓ Sheikh Ejleen WWP will work as WWTP with 60,000 M3/d capacity. And 20,000 M3/d of this amount will infiltrate to ground water.
- ✓ Water demand include domestic and agriculture.

4.4.4. Scenario Number 4 (Combination of Scenario 2 and Scenario3)

Description of Scenario

This scenario is studying the effect of Combination of Scenario 2 and Scenario3 including water desalination and recharge of treatment wastewater on the aquifer during the study period.

The main features of the this scenario are :

- ✓ Time horizon 2014-2030
- ✓ Water supply from ground water wells and desalination plant, STLV plant capacity 4 MCM/y starting work 2018, GCDP plant capacity 55 MCM/yr starting work 2022 and Gaza Governorate portion 19 MCM/yr.
- ✓ Sheikh Ejleen WWP will work as WWTP with 60,000 m^3/d capacity. And 20,000 m^3/d of this amount will infiltrate to ground water.
- ✓ Water demand include domestic and agriculture.

Chapter 5

Results and Discussion

Chapter 5. Results and Discussion

5.1. Water Demand on Gaza City

water demand in Gaza City is divided into three types, domestic, agricultural and industrial. The main demands of water are domestic and agricultural while the lowest is industrial. It has been estimated in some reports 3% of the domestic demand, however, this is inaccurate and needs a special study to determine the types of industries and water consumption for it. As a result, just the domestic and agricultural demand has been accounted.

5.1.1. Domestic Water Demand

Based on reports gathered from the Palestinian Central Bureau of Statistics, proportion and population expected for coming years is estimated 3.5%. Furthermore, the daily water demand for capita rate is calculated by 120 L/C/D. as shown in Figure 5.1.

The total population of Gaza Governorate is 627,200, 477,900, 884,700 and 1,050,800 capita for the years 2015, 2020, 2025 and 2030 respectively. Considering constant growth rate of 3.5% from 2015 to 2030 and constant water demand 120 L/C/D. the domestic demand accounted for 27.7, 33, 39.2 and 46.5 MCMfor years 2015, 2020, 2025 and 2030.

Table 5.1: Gaza Governorate population growth and domestic demand.

Year	Population Growth	Population (Capita)	Domestic Demand MCM
2015	3.5 %	627,200	27.7
2020	3.5 %	744,900	33
2025	3.5 %	884,700	39.2
2030	3.5 %	1,050,800	46.5

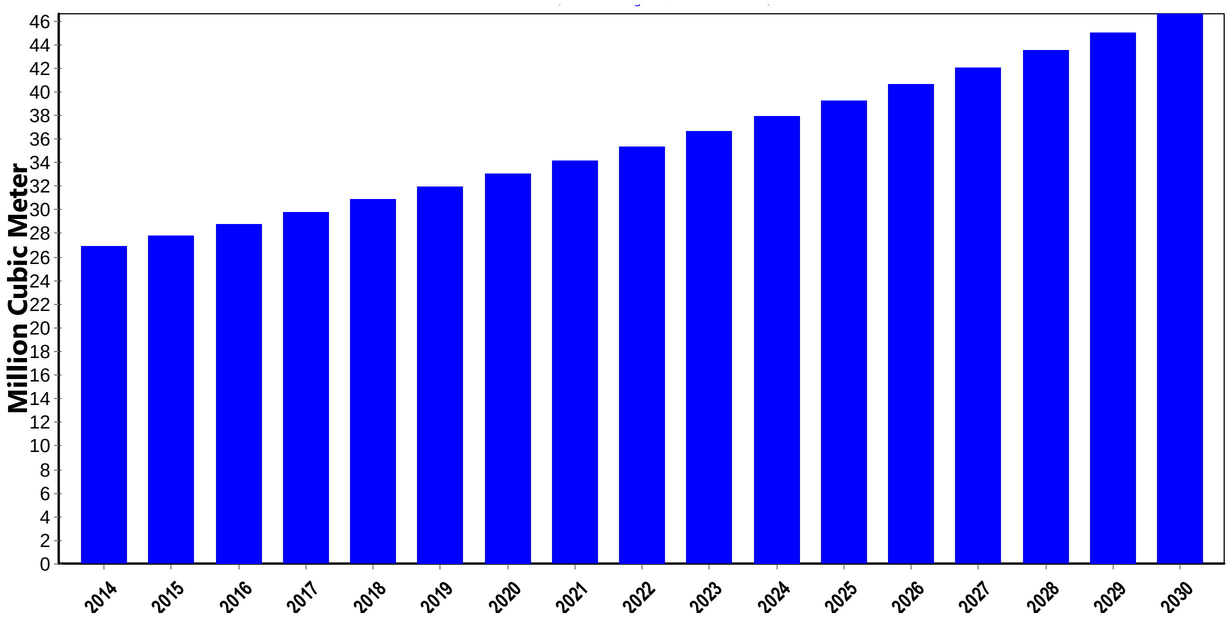


Figure 5.1: Domestic Water Demand from 2014yr. to 2030 yr. for Gaza Governorate.

5.1.2. Agriculture Water Demand

Agricultural lands in Gaza City are limited and increasable in the coming years because of the limitation of the land , populations need more residential lands, and there are several other factors affected on agricultural sector. As a result, it was considered that the area of agriculture land will not change, and types of crops remain constant during the study period and during the scenarios that will be studied in this research. Through the report by the Ministry of Agriculture, researcher obtain the area of agricultural land in Gaza City and the types of agriculture used in the city, which is divided into four types of crops field crops, vegetables, fruits and Citrus besides the annual consumption rate per donum obtained for different types of crops. According to the tables below 5.2, the researcher calculates the amount of yearly water consumption for agriculture land.

Where the total area of Gaza city 72,471 donum the proportion of utilized space in the agriculture 47.61% which equivalent of 34,508 donum were distributed according to the following table 5.2.

Table 5.2: Area of crop type in Gaza Governorate (MOA,2013)

Crops	Area (donum)	Water Consumption (MCM)
field crops	5,820	2.40
vegetables	8,644	3.60
fruits	15,161	8.10
Citrus	4883	4.40
Total	34,508	18.50

5.2.Zero Action Scenario

5.2.1. Introduction

The first scenario examines the aquifer and the quantities of deficit behavior in the demand for water in Gaza City in case of depending on the aquifer as the only source of water until 2030. The researcher note that the amount of the deficit will reach in 2030 to 41.4 MCM if we relying only on the aquifer water source.

5.2.2. Domestic and Agriculture Demand

Population water consumption is linked to the rate of population growth in Gaza City, which is estimated at 3.5% in the year. As shown in Table 5.7, the consumption of the population in 2015 an is estimated 627,200 capita and the amount of water which is needed for the population is estimated at 27.7 MCM. Agriculture water demand 18.54 MCM, then the total water demand 46.24 MCM.

It is expected that the number of people will up in the year 2030 to 1,050,800 capita and quantities of water domestic needed is 46.56 MCM. Agriculture water demand 18.54 MCM, then the total water demand 65.04 MCM. As shown in figure 5.3.

Domestic and Agriculture water demand in Gaza Governorate from 2015 to 2030.

Table 5.3: Domestic and Agriculture water demand in Gaza Governorate from 2015 to 2030.

Years	Domestic Demand MCM	Agriculture Demand MCM					Total Demand MCM
		field crops	Veget.	fruits	Citrus	Total	
2015	27.7	2.46	3.61	8.1	4.4	18.54	46.24
2020	33	2.46	3.61	8.1	4.4	18.54	51.54
2025	39.2	2.46	3.61	8.1	4.4	18.54	57.74
2030	46.5	2.46	3.61	8.1	4.4	18.54	65.04

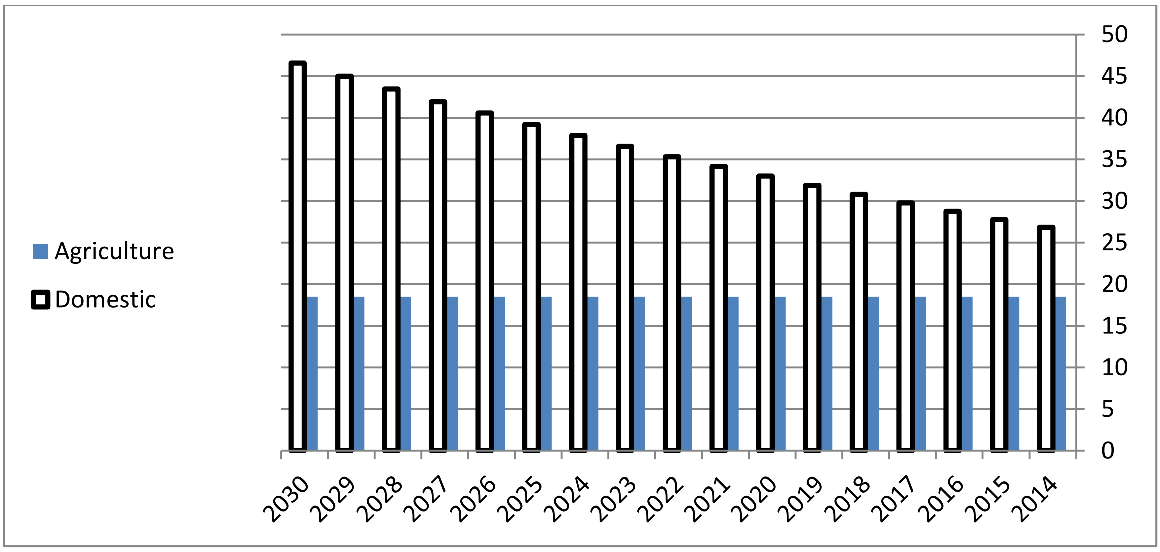


Figure 5.2: Domestic and Agriculture Water Demand from 2014 to 2030.

Regarding to the agricultural water consumption, researcher assumed that agricultural land will remain constant and it's area equal 34,508 dunum and thus the agricultural water consumption rate will reach 18.5 MCM yearly.

Table 5.4: Ground Water Net Balance in Scenario 1

Water Balance		Years	
		2014	**2030**
Inflow (MCM)	Infiltration Rainfall	10	10
	Return Flows	9.1	9.1
	Lateral Flow	4	4
Net Ground Inflow (MCM)		23.1	23.1
Out Flow (MCM)	Domestic Wells	27	46
	Agriculture Wells	18.5	18.5
Net Ground Water Out Flow (MCM)		45.5	64.5
Net Balance (MCM)		**-22.4**	**-41.4**

As shown in Table 5.8 water balance in Zero Action scenario showed that the net ground water inflow 23.1 MCM at 2014 and 2030, but the net ground water out flow reach 45.5 MCM in 2014 and 64.5 MCM in 2030. So the deficit will increase from 2014 year with -22.4 MCM to reach -42.4 in year 2030. As a result, from WEAP Model as shown in figure 5.4 ground water storage decrease and salinization issue because of unbalance between the aquifer recharge amount and the discharge amount.

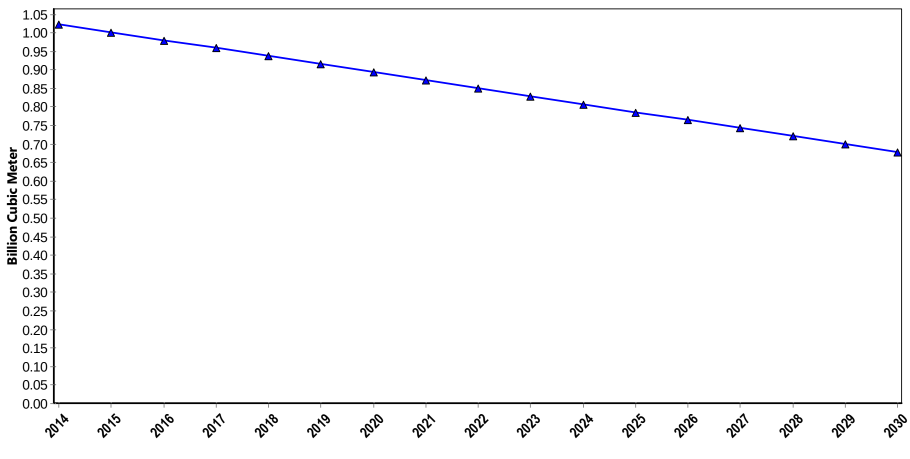


Figure 5.3: Ground Water Storage Decreasing at Scenario 1 from WEAP Model.

5.2.3. Domestic Water Demand Balance

In Table 5.9 we note at 2014 the amount of domestic water demand balance is 9.5 MCM. Furthermore, it will raise to 16.1MCM in 2030 if we assume that the efficiency of the network will remain fixed 65% and that the only water source is an underground reservoir.

We also note that the daily consumption of water per capita in year 2014 is 79 liters per day, and will arrive to 76.5 liters per day in 2030 which is much less than the recommendations of the World Health Organization that reaches from 100 to 150 liters per day.

Table 5.5: Water Domestic Water Demand Balance at Scenario 1

Years	**2014**	**2030**
Population	606,749	1,050,000
Total water production MCM	27	46
System Efficiency %	65%	65%
Total Water Consumption MCM	17.5	30
L /c/d Consumption	79	79
Domestic Water Demand Balance MCM	**-9.5**	**-16**

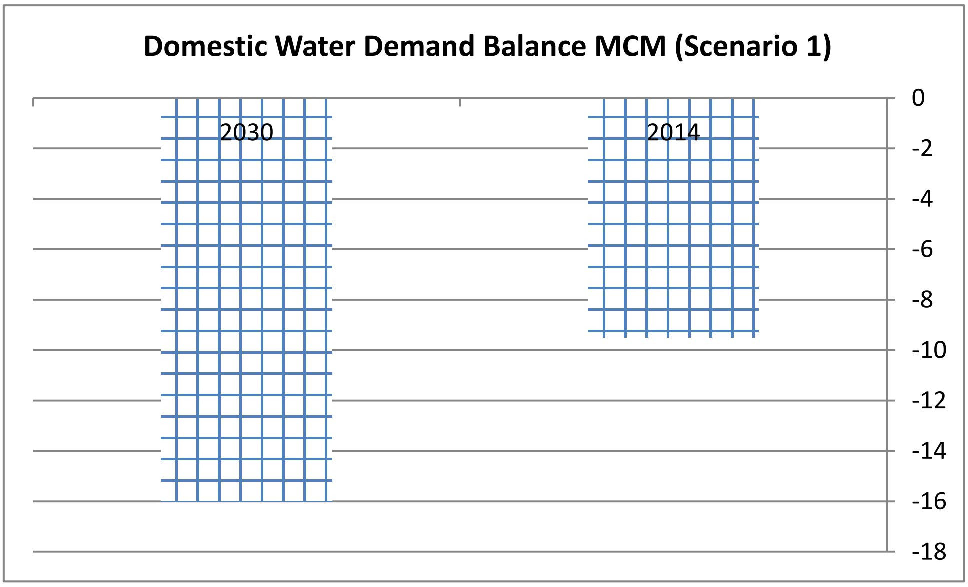


Figure 5.4: Domestic Water Demand Balance at Scenario 1 for years 2014 and 2030.

5.3. Scenario 2 (Desalination Scenario)

5.3.1. Introduction

This scenario is studying the effect of non-conventional water resources on the aquifer, and the deficit on water domestic demand by using desalination water and purchasing Mekorot. As shown in figure 5.6 the STLV Desalination plant will start working at 2018 with 4 MCM/yr capacity, and GCDP will work at 2022 with 19 MCM/yr capacity, this data will input to WEAP model.

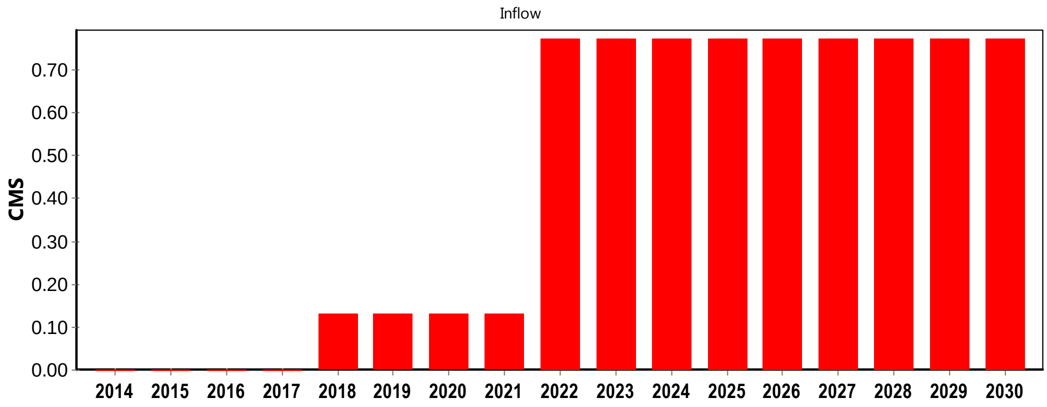


Figure 5.5: Water Desalination Inflow Supply for Scenario 2

5.3.2. Domestic and Agriculture Demand

Population and agricultural water consumption will remain according to what has been explained in the first scenario.

5.3.3. Water Balance for Ground Water (Scenario 2)

Through this scenario as shown in table 5.10 the net ground water inflow 23.1 MCM for every years from 2014 to 2030. And the net ground water out flow 45.5,49,53.5 and 64.5 MCM at years 2014, 2018, 2022 and 2030 respectively. The non-conventional water recourses are 5 MCM yearly of water from Mekorot company will be supplied. Also, STLV desalination plant in Gaza City will work at full capacity in 2018 with a capacity of 4 MCM/yr. While the Central Desalination Plant GCDP will work at full capacity in 2022 with a capacity of 55 MCM/yr Gaza City share will be 19 MCM/yr.

Table 5.6: Ground Water Net Balance in Scenario 2

Water Balance		**Years**			
		2014	**2018**	**2022**	**2030**
Inflow (MCM)	Infiltration Rainfall	10	10	10	10
	Return Flows	9.1	9.1	9.1	9.1
	Lateral Flow	4	4	4	4
Net Ground Inflow (MCM)		23.1	23.1	23.1	23.1
Out Flow (MCM)	Domestic Wells	27	30.5	35	46
	Agriculture Wells	18.5	18.5	18.5	18.5
Net Ground Water Out Flow (MCM)		45.5	49	53.5	64.5
Water Deficit MCM		-22.4	-25.9	-30.4	-41.4
Non-Conventional Water Recourses					
Purchase Water (MEKOROT)		5	5	5	5
STLV Desalination plant at year 2018			4	4	4
GCDP at year 2022				19	19
Net Balance (MCM)		**-17.4**	**-16.9**	**-2.4**	**-13.4**

Table 5.10 we note that after using desalination plants and water purchasing to Gaza City , the amount of the deficit in the aquifer declined significantly because the population consumption reliance on alternative sources of water. Moreover, this will affect positively on the quality of water in the aquifer as a result of lack of pumping. This was evident in the middle of the time period of the study. In 2022 the deficit reaches to -2.4 MCM but then increases up to 13.4 MCM in 2030.

Also we note that the amount of the deficit reached its lowest level in 2022 with the use of all options for up to -2.4 MCM. However, this deficit increased again in the last period of time and reached -13.4MCM in 2030. This requires the provision of new alternatives to feed the aquifer or mitigate aquifer pumping.

As a result, from WEAP Model as shown in figure 5.7 ground water storage decrease to the middle of the time period and salinization issue because of using non-conventional water recourses, then the decline return to increase at the last time period because increase in domestic water demand without any increase in water resources.

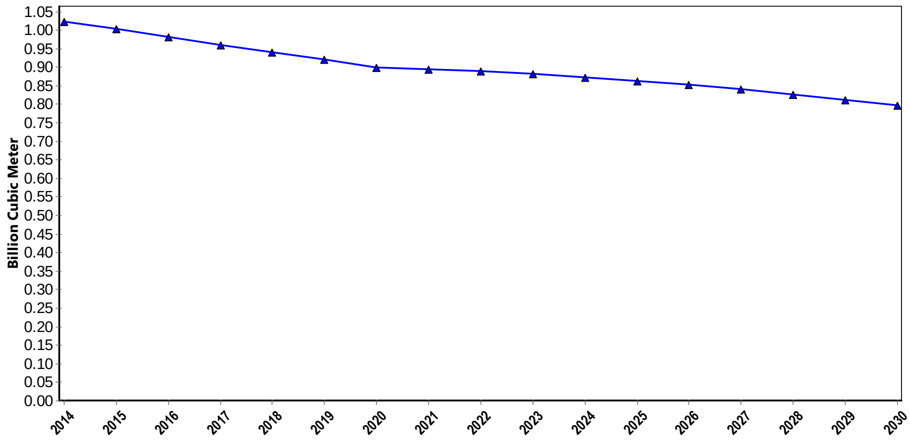


Figure 5.6: Ground Water Storage Decreasing at Scenario 2

5.3.4. Water Domestic Demand Balance

Table 5.11 shows the amount of domestic water demand balance or surplus in the water supplied for domestic consumption. In 2014 , the amount of domestic water demand balance decreased from -9.5 MCM to -4.5 MCM due to using the non-conventional water resources.

In 2022, although the use of non-conventional sources of water, the amount of water supplied will increase to +16 MCM. That means the use of alternative sources will reduce the discharge of the aquifer, which will improve the quality of the aquifer water.

In 2030, the increase in the amount of water supplied decreased to +12 MCM which means that after several years we must look for alternative sources either to feed the aquifer or to increase water supplied for domestic consumption.

Table 5.7: Water Domestic Demand Balance at Scenario 2

Years	**2014**	**2018**	**2022**	**2030**
Population	606,749	695,400	798,000	1,050,000
Total water production MCM	27	30.5	35	46
System Efficiency %	65%	65%	65%	65%
Total Water Consumption MCM	17.5	20	23	30
L /c/d Consumption	79	79	79	79
Water Domestic Demand Balance Before Non-Conventional Recourses MCM	-9.5	-10.5	-12	-16
Non-Conventional Water Recourses				
Purchase Water (MEKOROT)	5	5	5	5
STLV Desalination plant at year 2018	-	4	4	4
GCDP at year 2022	-	-	19	19
Water Domestic Demand Balance After Non-Conventional Recourses MCM	**-4.5**	**-1.5**	**+16**	**+12**

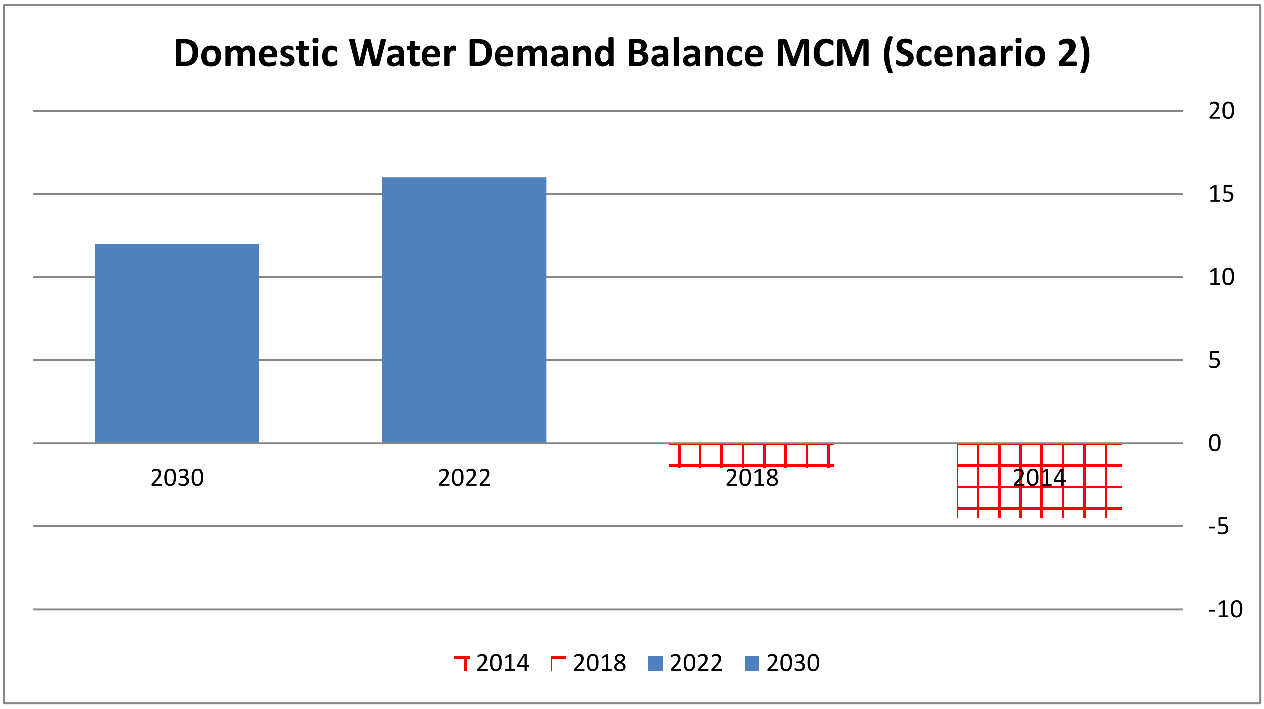


Figure 5.7: Domestic Water Demand Balance at Scenario 2

5.4. Scenario 3 (Recharge of Treatment Waste Water Scenario)

5.4.1. Introduction

This scenario will study the effect of non-conventional water resources on the aquifer and the deficit to fit the water demand for population using the wastewater treatment and infiltration to the aquifer

5.4.2. Domestic and Agriculture Demand

Population and agricultural water consumption will remain according to what has been explained in the first scenario.

5.4.3. Water Balance for Ground Water (Scenario 3)

Through this scenario 20,000 m^3 resulting from Sheikh Ejleen water plant (daily capacity 60,000 m^3) will subject to an advanced processing until it becomes valid for infiltration to the aquifer with capacity of 20,000 cubic meters per day or the equivalent of 7 MCM/yr.

As shown in table 5.12 the amount of the deficit in the aquifer decreased in 2014 from -22.4 MCM to -15.4 MCM. However, this deficit returned to grow steadily with time up to 2030 from -41.4 MCM to -34.4 MCM, because the deficit still increase the groundwater storage decreasing as a result from WEAP model as shown in figure 5.9. So this require the provision of other non-conventional water resources to reduce the deficit in the aquifer.

Table 5.8: Ground Water Net Balance in Scenario 3

Water Balance		Year			
		2014	2018	2022	2030
Inflow (MCM)	Infiltration Rainfall	10	10	10	10
	Return Flows	9.1	9.1	9.1	9.1
	Lateral Flow	4	4	4	4
Net Ground Inflow (MCM)		23.1	23.1	23.1	23.1
Out Flow (MCM)	Domestic Wells	27	30.5	35	46
	Agriculture Wells	18.5	18.5	18.5	18.5
Net Ground Water Out Flow (MCM)		45.5	49	53.5	64.5
Water Deficit MCM		-22.4	-25.9	-30.4	-41.4
Non-Conventional Water Recourses					
Recharge of SH. Ejleen Treatment Waste Water MCM		7	7	7	7
Net Balance (MCM)		-15.4	-18.9	-23.4	-34.4

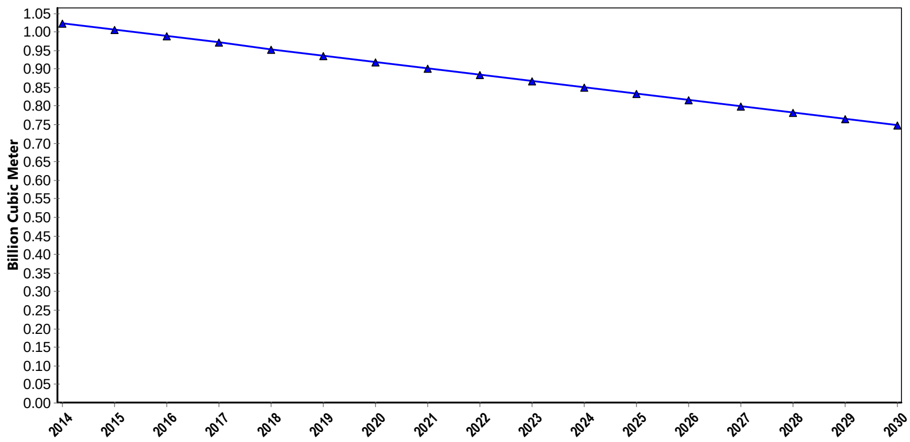


Figure 5.8: Ground Water Storage Decreasing at Scenario 3

5.4.4. Domestic Water Demand Balance

Through this scenario, as shown in table 5.13 treated wastewater will infiltration to the aquifer. However, this source does not affect to the amount of domestic water demand balance for domestic consumption. As a result, the amount of domestic water demand balance remains fixed -9.5 MCM in 2014 and reaches -16 MCM in 2030, As shown in figure 5.10. Therefore, it is necessary to provide non-conventional water resources for domestic demand to decrease discharging from water wells.

Table 5.9: Water Domestic Demand Balance at Scenario 3

Years	2014	2018	2022	2030
Population	606,749	695,400	798,000	1,050,000
Total water production MCM	27	30.5	35	46
System Efficiency %	65%	65%	65%	65%
Total Water Consumption MCM	17.5	20	23	30
L /c/d Consumption	79	79	79	79
Domestic Water Demand Balance Before Non-Conventional Recourses MCM	-9.5	-10.5	-12	-16
Non-Conventional Water Recourses				
Recharge of SH. Ejleen Treatment Waste Water MCM	0	0	0	0
Domestic Water Demand Balance After Non-Conventional Recourses MCM	-9.5	-10.5	-12	-16

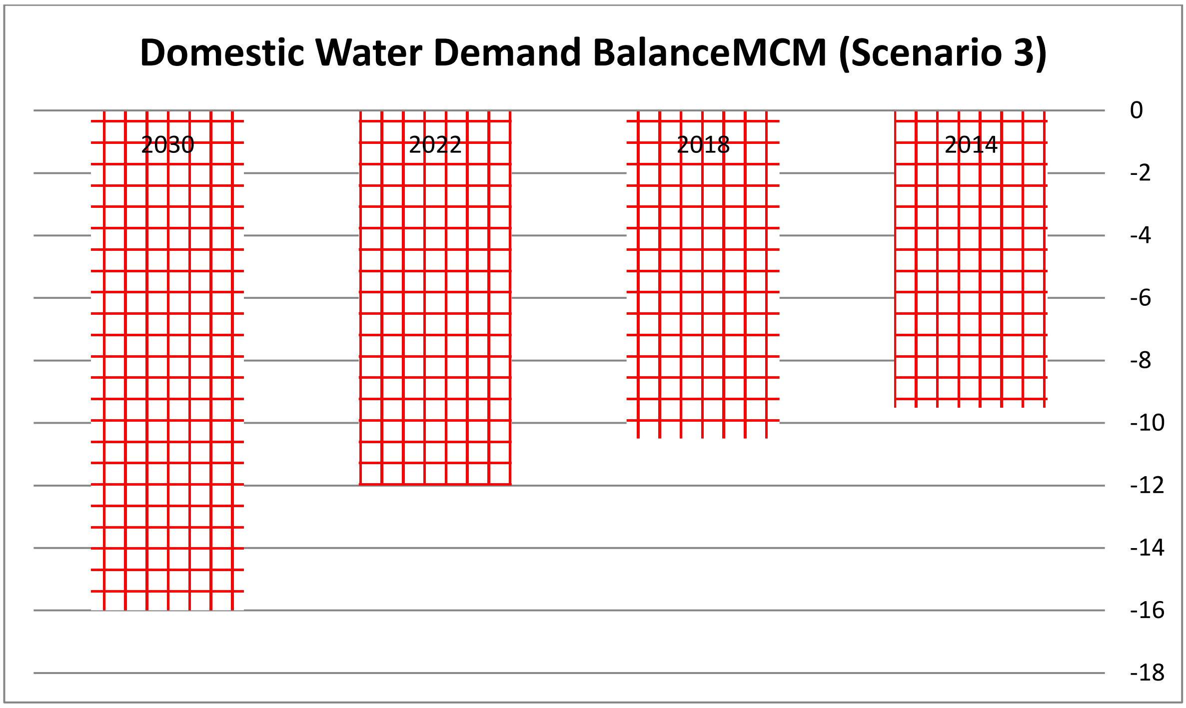


Figure 5.9: Water Domestic Demand Balance at Scenario 3

5.5.Scenario 4 (Combination of Scenario 2 and Scenario3)

5.5.1. Introduction

This scenario will study the effect of non-conventional water resources on the aquifer and the deficit of domestic water demand balance of population use, by combining between the results of the second scenario using desalination and the third scenario which is wastewater treatment and infiltration it to the aquifer.

5.5.2. Domestic and Agriculture Demand

Population and agricultural water consumption will remain according to what has been explained in the first scenario .

5.5.3. Water Balance for Ground Water (Scenario 4)

In this scenario, as shown in table 5.14 the deficit less significantly in 2014 from -22.4 MCM to -10.5 MCM because of merging between scenario 2 and 3. As a result, the aquifer reaching the best level in 2022, where the deficit is over and appeared surplus in the aquifer +4.6. Also, due to the increased water domestic demand, the deficit in the aquifer returned increase to -6.4 MCM in 2030.

So as shown in figure 5.11 as a result from WEAP Model the decline of ground water storage decrease.

Here is an indication that it should be continue to provide new non-conventional resources to increase aquifer water level and to decrease water aquifer net balance.

Table 5.10: Ground Water Net Balance in Scenario 4

Water Balance		**Year**			
		2014	2018	2022	2030
Inflow (MCM)	Infiltration Rainfall	10	10	10	10
	Return Flows	9.1	9.1	9.1	9.1
	Lateral Flow	4	4	4	4
Net Ground Inflow (MCM)		23.1	23.1	23.1	23.1
Out Flow (MCM)	Domestic Wells	27	30.5	35	46
	Agriculture Wells	18.5	18.5	18.5	18.5
Net Ground Water Out Flow (MCM)		45.5	49	53.5	64.5
Water Deficit MCM		-22.4	-25.9	-30.4	-41.4
Non-Conventional Water Recourses					
Purchase Water (MEKOROT)		5	5	5	5
STLV Desalination plant at year 2018			4	4	4
GCDP at year 2022				19	19
Recharge of SH. Ejleen Treatment Waste Water MCM		7	7	7	7
Net Balance (MCM)		**-10.5**	**-9.9**	**+4.6**	**-6.4**

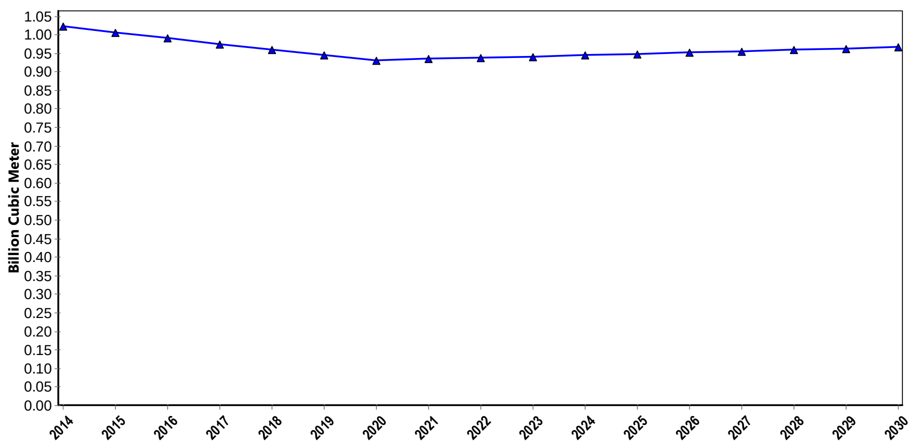


Figure 5.10: Ground Water Storage Decreasing at Scenario 4

5.5.4. Domestic Water Demand Balance

AS shown in table 5.15 in this scenario the domestic water demand balance before non-conventional resources is -9.5, -10.5, -12 and -16 MCM for years 2014, 2018, 2022 and 2030 respectively. Then after using non-conventional water resources (Purchase Water, Desalination and Recharge of Treatment Waste Water) the domestic water demand balance become -4.5, -1.5, +16 and +12 respectively, as shown in figure 5.12. The amount of domestic water demand balance or surplus in the amount of supplied water for population consumption equal to the same value in scenario No. 2. This results is expected because the amount of treated wastewater will be in filtered into the aquifer directly.

Table 5.11: Domestic Water Demand Balance at Scenario 4

Years	2014	2018	2022	2030
Population	606,749	695,400	798,000	1,050,000
Total water production MCM	27	30.5	35	46
System Efficiency %	65%	65%	65%	65%
Total Water Consumption MCM	17.5	20	23	30
L /c/d Consumption	79	79	79	79
Domestic Water Demand Balance Before Non-Conventional Recourses MCM	-9.5	-10.5	-12	-16
Non-Conventional Water Recourses				
Purchase Water (MEKOROT)	5	5	5	5
STLV Desalination plant at year 2018	-	4	4	4
GCDP at year 2022	-	-	19	19
Recharge of SH. Ejleen Treatment Waste Water MCM	-	-	-	-
Domestic Water Demand Balance After Non-Conventional Recourses MCM	-4.5	-1.5	+16	+12

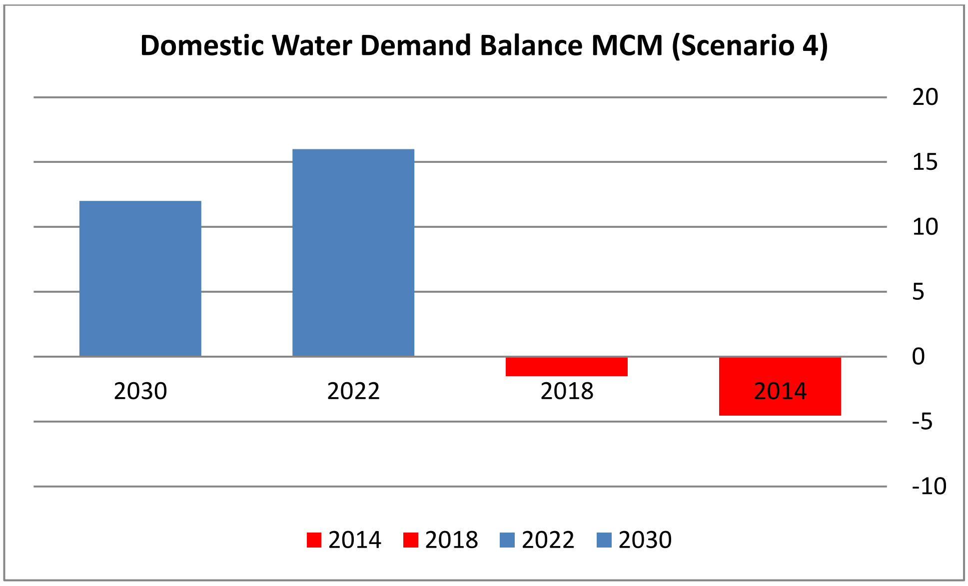


Figure 5.11: Domestic Water Demand Balance at Scenario 4

5.6. Comparison of Scenarios

5.6.1. Water Balance for Ground Water

Through comparison of different scenarios (Scenario 1,2,3 and Scenario 4) in 2030 as shown in table 5.16, the net ground inflow 23.1MCM and the net ground outflow 64.5 MCM. So the water deficit is 64.5 MCM. it is evident that the best-case scenario in terms of impact on the amount of water in the aquifer is Scenario 4, which was a combination of desalination and waste water treatment. From results it is demonstrated that in scenario 4 no deficit, but there is a surplus estimated at +6.4 MCM. Scenario 2 ranked in the second place, where it took the lowest deficit which is estimated -13.4 MCM .The highest amount in the deficit was in the scenario No.1,it reached -41.4 MCM and this result is expected because of not using any non-conventional water source and relying only on the aquifer water.

As shown in figure 5.13 from WEAP Model the decline of ground water storage comparison shown the best scenario is combination scenario number 4, and the worst scenarios is number 1 zero action scenario.

Table 5.12: Ground Water Net Balance, Comparison between Scenarios.

Net Balance		**Scenarios**			
		Sc.1	Sc.2	Sc.3	Sc.4
		2030	2030	2030	2030
Inflow (MCM)	Infiltration Rainfall	10	10	10	10
	Return Flows	9.1	9.1	9.1	9.1
	Lateral Flow	4	4	4	4
Net Ground Inflow (MCM)		23.1	23.1	23.1	23.1
Out Flow (MCM)	Domestic Wells	46	46	46	46
	Agriculture Wells	18.5	18.5	18.5	18.5
Net Ground Water Out Flow (MCM)		64.5	64.5	64.5	64.5
Water Deficit MCM		-41.4	-41.4	-41.4	-41.4
Non-Conventional Water Recourses					
Purchase Water (MEKOROT)		-	5	-	5
STLV Desalination plant at year 2018		-	4	-	4
GCDP at year 2022		-	19	-	19
Recharge of SH. Ejleen Treatment Waste Water MCM		-	-	7	7
Net Balance (MCM)		**-41.4**	**-13.4**	**-34.4**	**+6.4**

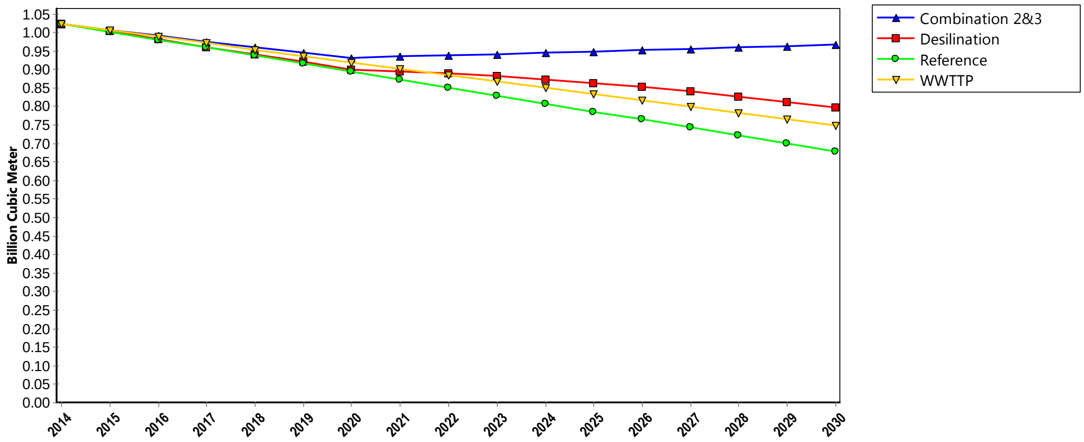


Figure 5.12: Ground Water Storage , Comparison between Scenarios.

5.6.2. Domestic Water Demand Balance

As shown in table 5.17 by comprising between the different scenarios in 2030 which is related to the amount of domestic water demand balance, domestic water demand balance before non-conventional recourses -16 MCM and the domestic water demand balance after non-conventional recourses -16, +12, -16 and +12 MCM at 2030 years. From figure 5.14 we see the best-case scenarios are No. 2 and Scenario 4. Because it have been relying on desalinated water where is the surplus in the amount of domestic water supplied to amount +12 MCM while the deficit in scenario No.1, which not include non-conventional water resource. As well as scenario No. 3, which depends on the waste water treatment infiltration to the aquifer.

Table 5.13: Domestic Water Demand Balance, Comparison between Scenarios.

Scenarios	Sc.1	Sc.2	Sc.3	Sc.4
Years	2030	2030	2030	2030
Population	1,050,000	1,050,000	1,050,000	1,050,000
Total water production MCM	46	46	46	46
System Efficiency %	65%	65%	65%	65%
Total Water Consumption MCM	30	30	30	30
L /c/d Consumption	79	79	79	79
Domestic Water Demand Balance Before Non-Conventional Recourses MCM	-16	-16	-16	-16
Non-Conventional Water Recourses				
Purchase Water (MEKOROT)	-	5	-	5
STLV Desalination plant at year 2018	-	4	-	4
GCDP at year 2022	-	19	-	19
Recharge of SH. Ejleen Treatment Waste Water MCM	-	-	-	-
Domestic Water Demand Balance After Non-Conventional Recourses MCM	-16	+12	-16	+12

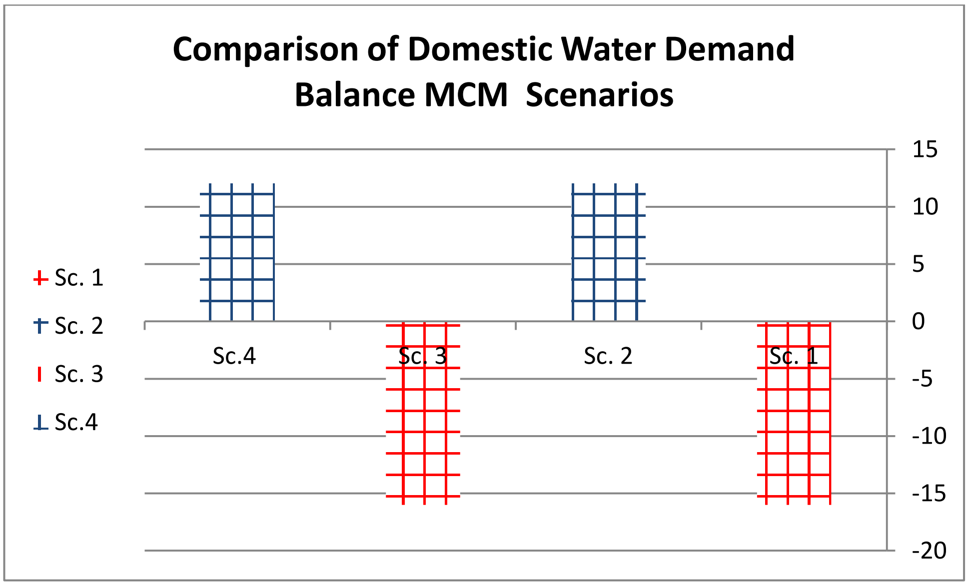


Figure 5.13: Domestic Water Demand Balance, Comparison between Scenarios in 2030.

Chapter 6

Conclusions And Recommendations

Chapter 6. Conclusions And Recommendations

6.1. Conclusions

The following points conclude the main outcome from this research:

1. Gaza Governorate depend on groundwater wells as a main water resources, in 2014 there are 77 municipal wells including 3 for UNRWA wells.
2. Water Desalination, Purchase water from (MEKOROT) and Recharge of Treatment Waste Water considered as non-conventional water resources for Gaza Governorate.
3. Water Desalination plan depends on two plant during study period, the first station STLV with 4 MCM/y capacity and expect to work on 2018. The second is a central plant called GCDP with 55 MCM/y capacity and will serve Gaza Strip and the Gaza Governorate portion is 19 MCM/y and it's planned to operate at year 2022.
4. Sh. Ejleen is the only Waste Water Treatment Plant in Gaza Governorate through study period and its capacity 60,000 m^3/d (20MCM/y). all of them pumped to the sea. The research scenario is to advance treatment for 20,000 m^3/d (7MCM/y) and infiltration them to the ground water.
5. The total water production at 2014 is 27 MCM to cover 606,749 capita and expected to increase gradually to reach 46 MCM to serve 1,050,000 capita at 2030 according to normal population growth (3.5% annual).
6. The total agriculture area is 34,508 donum and it's distributed to 4 main crops, field crops, vegetables, fruits and Citrus. All of them consumption 18.5 MCM yearly.
7. Four Scenarios are proposed to find the effect of non-conventional water resources on the amount of aquifer deficit and to decrease the amount of domestic water demand Balance, the scenarios are (Zero Action Scenario, Desalination Scenario, Recharge of Treatment Waste Water Scenario, and Combination of Scenario 2 and Scenario3).
8. The results of first scenario (Zero Action Scenario) shows that the deficit in water balance for ground water at 2014 reach -22.4 MCM and expected to reach -41.4 MCM. And the amount of domestic water demand balance -9.5 MCM at 2014 and expected to reach -16 MCM at 2030.

9. Second scenario (Desalination Scenario) results, After using desalination plants and (MEKOROT) water the deficit on ground water decrease but still exists. The net balance of aquifer at 2014reach -17.4 MCM and decrease at 2022 from -41.4 MCM to -13.4 MCM. The lowest deficit -2.4 MCM at 2022 year.
10. The amount of domestic water demand balance in scenario 2 reach -4.5 MCM at year 2014 but at year 2022 there is a surplus reach to +12 MCM at year of 2030.
11. Third Scenario (Recharge of Treatment Waste Water Scenario), ground water deficit reach to -15.4 MCM at 2014 year and increase to reach –34.4 MCM at 2030 year. And the domestic water demand balance increase from year 2014 to reach to -16 MCM at 2030 year.
12. Fourth Scenario (Combination of Scenario 2 and Scenario3), ground water deficit decrease from -22.4 MCM to -10.5 MCM at year 2014, and the net balance reach to the best situation at year 2022 when no deficit and reach +4.6 MCM. Then back to decrease to reach -6.4 MCM at 2030 year.
13. The amount of domestic water demand balance in scenario 4 reach +16 MCM at 2022 and that's mean there is a surplus of amounts in water domestic, but it back to decrease at 2030 year with no deficit to reach +12 MCM.
14. With a comparison between the four scenarios, the best scenario for net ground water balance in scenario 4, but regarding to domestic water demand balance the best scenarios are 2 and 4.
15. In case of improving system water efficiency the defect in water balance will decrease in all scenarios.

6.2. Recommendations

Based on above results and conclusion, the following recommendations might be considered for future:

Those responsible for the water sector must integrate between water desalination and recharge of treatment waste water as a non-conventional water resources.

Because of the high increase in water demand in the light of the great deficit in the aquifer must search for non-conventional resources include increase the water levels in the aquifer and increase the amount of water to meet the growing need in the domestic water demand.

The Researcher recommends to prepare a study which is focusing on the study of the financial cost and the interest of the four scenarios in order to get the most appropriate possible scenario marketed to international donors with the help of model WEAP

The researcher recommends the preparation of the study include desalinated water mixing with aquifer water technology to get to the appropriate water quality for the domestic water in order to reduce the cost of desalination use only.

The researcher recommends to prepare a study to explain the reason behind the loss in water network and mechanisms necessary to follow in order to reduce losses and increase network efficiency..

Researcher recommended to prepare a study showing the different types of industries and the quantities of water consumption for each industry in Gaza province .

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Annex

Annex 1: Water wells for Gaza Governorate (PWA, 2015).

Well Name	Well No.	Q	Total Depth	Chloride (CL)	Nitrate (NO_3)	Attitude Trends of (CL) up to 2014	(CL) Projections for 2020	(CL) Projections for 2025
		m^3/hr	m	mg/l	mg/l		mg/l	mg/l
UNRWA 1 - Shat 1	R/161	55	40	8049	189	Seawater Intrusion	13000	17000
UNRWA 2 - Shat 2	R/299	70	42	10369	128	Seawater Intrusion	16000	20000
UNRWA 3 - Shat 3	R/300	100	60	9561	116	Seawater Intrusion	15000	20000
Sh.R 1 A	R/162LA	140	101	7206	115	Seawater Intrusion	12000	18000
Sh.R 1 B	R/162LB	140	96.5	7135	111	Seawater Intrusion	12000	18000
Sh.R-Haleema	Sh.R.2	N.A	N.A	302	180	New Well	New Well	New Well
Sh.R. 3A	R/162BA	65	68.5	3234	258	Seawater Intrusion	5700	8000
Sh.R. 4A	R/162CA	55	71	2179	191	Seawater Intrusion	5000	7500
Sh.R 5	R/162D	74	60	12283	109.1	Seawater Intrusion	18000	22000
Sh.R 7	R/162H	170	103	576	206	Steady	1000	2000
Sh.R 7A	R/162HA	130	85	598	125	Steady	1000	2000
Sh.R 8A	E/154A	77	66	5237	87	Seawater Intrusion	7000	9000
Sh.R 9	E/157	200	85	738	80	Seawater Intrusion	3750	6500

Well Name	Well No.	Q	Total Depth	Chloride (CL)	Nitrate (NO_3)	Attitude Trends of (CL) up to 2014	(CL) Projections for 2020	(CL) Projections for 2025
		m^3/hr	m	mg/l	mg/l		mg/l	mg/l
Sh.R 10	D/68	150	80	668	113	Seawater Intrusion	2250	3750
Sh.R 11	D/69	75	77	366	109	Increase	1750	3250
Sh.R 12	D/70	200	90	141	146	Steady	550	1500
Sh.R 13	R/162G	210	100	2179	137	Seawater Intrusion	6000	10500
Sh.R 14	E/185	50	71	858	130	New Well	New Well	New Well
Sh.R 15	D/71	200	77	105	147	Steady	550	1500
Sh.R 16	D/72	175	67	105	139	Steady	700	1750
Sh.R.17	Sh.R.17	60	65	1076	101	Seawater Intrusion	3000	5000
Sh.Eg 2	R/254	60	72	569	62	Increase	1500	3000
Sh.Eg 3	R/265	50	75	3937	55	Seawater Intrusion	7000	10000
Sh.Eg 4A	R/113A	70	65	5062	85	Seawater Intrusion	8500	11000
Sh.Eg 5	R/277	55	69.5	591	59	Increase	2250	5000
Sh.Eg 6	R/280	65	70	387	66	Increase	2000	4200
Sh.Eg 7	R/293	50	67	422	104	Steady	1100	1900
Sh.Eg 8	R/343	40	53	5858	70	Seawater Intrusion	11000	16000
Sh.Eg 9	R/345	40	57	1226	41	Seawater Intrusion	5500	10000

Well Name	Well No.	Q	Total Depth	Chloride (CL)	Nitrate (NO_3)	Attitude Trends of (CL) up to 2014	(CL) Projections for 2020	(CL) Projections for 2025
		m^3/hr	m	mg/l	mg/l		mg/l	mg/l
Al Safa 1	R/25B	210	93	645	214	Increase	800	1000
Al Safa 2	R/25A	120	66.5	569	134	Increase	700	800
Al Safa 3	R/25C	170	80	1078	61	Increase	1250	1350
Al Safa 4	R/25D	230	80	880	51	Increase	1000	1150
Al Safa 5 - Zimmo	Q/68	210	100	253	61	Increase	350	400
Shijaia 2	R/75	220	72	872	142	Increase	1000	1100
Shijaia 3	R/74	80	70	851	148	Increase	950	1050
Shijaia 4	R/66B	N.A	62	654	177	Increase	880	1000
Shijaia 5 - Al Al Halal	R/309	60	90	1118	53	Steady	1250	1350
Shijaia 6 - Al Muntar	R/312	60	106	897	78	Steady	1050	1200
Shijaia 7 - Al Sahiana -Tunis	Shijaia 7	60	57.5	780	85	Increase	1100	1300
Shijaia 8 - Al Tawfeeq	R/341	50	90	1060	81	Steady	1150	1250
Shijaia 9 - Adle - Rayan	Shijaia 9	N.A	N.A	1160	55.1	Increase	1450	1750
Shijaia 10 - Al Batesh	R/349	50	99.4	819	67	Increase	1100	1400
Shijaia 11 - Al Qastal	R/398	50	70	1090	79	New Well	New Well	New Well

Well Name	Well No.	Q	Total Depth	Chloride (CL)	Nitrate (NO_3)	Attitude Trends of (CL) up to 2014	(CL) Projections for 2020	(CL) Projections for 2025
		m^3/hr	m	mg/l	mg/l		mg/l	mg/l
Shijaia 11 - Al Muntar 2	R/394	50	86	N.A	N.A	New Well	New Well	New Well
Shijaia 13 - Al Motasem	Shijaia 13	N.A	N.A	815	83	New Well	New Well	New Well
Shijaia 14 - Surani 2	Shijaia 14	N.A	N.A	605	71	New Well	New Well	New Well
Al Daraj 2 - Al Basa	R/311	60	70	942	295	Steady	1050	1200
Al Daraj 2 - Al Yarmouk	Al Daraj 2	N.A	N.A	429	189	Steady	600	750
Al Tufah 1- Al Qutta'a	Al Tufah 1	N.A	N.A	443	314	Steady	650	800
Al Tufah 3- Al Shorafa	R/346	50	68	548	322	Steady	680	800
Zatoun 1	R/310	60	63	575	85	Steady	650	750
Zatoun 2	R/305	60	60	824	139	Increase	1100	1400
Zatoun 3 - Al Talteeni	F/225	50.0	60.0	1005	105	Increase	1450	1750
Zatoun 4	R/342	50	55	844	141	Increase	1400	2000
Zatoun 5 Dola	R/344	50.0	57.0	1582	128	Increase	2250	2750
Sabra 1- Doghmush	R/306	60	61	534	128	Steady	1750	4000

Well Name	Well No.	Q	Total Depth	Chloride (CL)	Nitrate (NO_3)	Attitude Trends of (CL) up to 2014	(CL) Projections for 2020	(CL) Projections for 2025
		m^3/hr	m	mg/l	mg/l		mg/l	mg/l
Sabra 2-AlDieri	R/307	60	55.5	471	251	Increase	900	1500
Sabra 3-Shibabar	R/308	60	59.5	527	241	Steady	950	1400
Sabra 4-Said SIAM	R/375	50	68	583	287	Steady	800	1100
Sabra 5-Azam	R/357	50	67	605	133	Increase	1250	1800
Sabra 6 - Asalam Clinc Abu Baker	Sabra 6	40/50	70	959	167	New Well	New Well	New Well
Remal 1 - Al Jundi	R/313	60	62	576	147	Increase	2750	5000
Remal 2 - Kamal Naser	R/314	60	73.5	2461	151	Seawater Intrusion	4200	5800
Remal 3 - Tafteesh	R/338	60	56	7638	130	Seawater Intrusion	11500	15000
Remal 4 - Bekdar	R/317	N.A	59.5	6538	147	Seawater Intrusion	12000	16000
Remal 5 - Al Thawra	R/316	60	64.5	654	153	Increase	3000	5500
Remal 6 - Aghadeer Al Rahma	R/354	50	74	2371	161.9	Seawater Intrusion	8500	13000

Well Name	Well No.	Q	Total Depth	Chloride (CL)	Nitrate (NO_3)	Attitude Trends of (CL) up to 2014	(CL) Projections for 2020	(CL) Projections for 2025
		m^3/hr	m	mg/l	mg/l		mg/l	mg/l
Remal 7 - Palestine	R/348	50	71	499	163	Steady	2500	5000
Remal 8 - Al Etisalate Al Nassrah	R/347	40	45	9983	92	Seawater Intrusion	15000	20000
Remal 9 - Ahmed Shawqi	R/353	40	58.5	548	137	Increase	2700	5500
Remal 10 - Khalil Al Wazeer	R/352	50	67	415	161	Steady	2000	5000

Annex 2 Agriculture water demand

2.1 Area and water consumption of field crops cultivated in Gaza Governorate, agricultural season 2012/2013 (MOA, 2013)

Field Crops Type		Area (donum)	Water consumption (m^3/ donum.yr)	Total water consumption m^3/yr
Wheat	قمح	3,200	450	1,440,000
Barley	شعير	1,000	350	350,000
Onion crusty	بصل يابس	160	395	63,200
garlic	ثوم	120	371	44,520
Potatos	بطاطس	1,150	421	484,150
Dry Homs	حمص جاف	30	450	13,500
Trefoil	برسيم	30	660	19,800
Biqia	بيقيا	10	500	5,000
Lupin	ترمس	20	350	7,000
Others (sugar cane)	أخرى (قصب السكر)	100	400	40,000
		5,820		2,467,170

2.2 Area and water consumption of vegetables cultivated in Gaza Governorate ,agricultural season 2012/2013 (MOA, 2013)

Vegetables type		Area (donum)	Water consumption (m^3/ donum.yr)	Total water consumption m^3/yr
Tomato greenhouses	بندورة دفيئات	180	858	154,440
Tomatoes field	بندورة مكشوفة	1,350	587	792,450
Koussa is covered	كوسا مغطى	600	425	255,000
Koussa field	كوسا مكشوف	520	201	104,520
Greenhouses cucumber	خيار دفيئات	170	420	71,400
Covered cucumber	خيار مغطى	100	380	38,000
cucumber field	خيار مكشوف	900	350	315,000
Eggplant greenhouses	باذنجان دفيئات	2	658	1,316
Eggplant field	باذنجان مكشوف	400	517	206,800
pepper field	فلفل مكشوف	350	517	180,950
Peppers greenhouses	فلفل حلو دفيئات	2	713	1,426
Molokhia greenhouses	ملوخية دفيئات	10	517	5,170
Molokhia field	ملوخية مكشوفة	600	216	129,600
Watermelon field	بطيخ مكشوف	400	599	239,600
Cantaloupe field	شمام مكشوف	100	269	26,900
lettuce	خس	460	376	172,960
Chick-pea	بازيلاء	100	503	50,300
Green Bean	فول اخضر	110	354	38,940

spinach	سبانخ	200	391	78,200
boil	سلق	200	301	60,200
radish	فجل	20	131	2,620
Attract	لفت	170	167	28,390
cabbage	ملفوف	450	226	101,700
a flower	زهرة	450	241	108,450
Okra field	بامية مكشوف	230	350	80,500
Vqos field	فقوس مكشوف	50	253	12,650
parsley	بقدونس	120	520	62,400
Atom field	ذرة مكشوف	350	747	261,450
Beating	قرع	40	448	17,920
Taro	قلقاس	10	1052	10,520
		8,644		3,609,772

2.3 Area and water consumption of fruits cultivated in Gaza Governorate, agricultural season 2012/2013 (MOA, 2013)

Fruits Type		Area (donum)	Water consumption (m^3/ donum.yr)	Total water consumption m^3/yr
Olive	زيتون	7,359	550	4,047,450
Guava	جوافة	190	920	174,800
Date	بلح	885	850	752,250
Almond	لوز	100	300	30,000
Grape	عنب	4,872	500	2,436,000
Fig	تين	535	150	80,250
Peach	خوخ	260	450	117,000
Apricot	مشمش	200	450	90,000
Apple	تفاح	105	650	68,250
Pomegranate	رمان	280	150	42,000
Mango	مانجا	200	850	170,000
Aloe	بالمتر صبر الطولي	45	-	0
Others	أخرى	130	450	58,500
		15,161		8,066,500

2.4 season 2012/2013 (MOA, 2013)

Citrus Type		Area (donum)	Water consumption (m^3/ donum.yr)	Total water consumption m^3/yr
Falensia orange	فلنسيا	440	900	396,000
Shamoty orange	شموطى	160	900	144,000
Lemon	ليمون	2370	900	2,133,000
Grapefruit	جريب فروت	180	900	162,000
Naval orange	صرة أبو	425	900	382,500
Clement	كلمنتينا	85	900	76,500
Poppy	مخال	930	900	837,000
French orange	فرنساوى	90	900	81,000
Pamplemousse	بوملي	13	900	11,700
Others	أخرى	190	900	171,000
		4883		4,394,700