KTH Land and Water
Resources Engineering

Prospects of Water Desalination in the Gaza Strip

Mahmoud Ismail

Stockholm 2003

TRITA-LWR Master of Science Thesis
ISSN 1651-064X
LWR-EX-04-10

Prospects of Water Desalination in the Gaza Strip

Mahmoud Ismail

mshaban2001@hotmail.com

Supervisor:

Associate Professor, Jan-Erik Gustafsson

Department of Land and Water Resources Engineering, KTH

Stockholm 2003

Department of Land and

Water Resources Engineering

Royal Institute of Technology

TRITA-LWR Master of Science Thesis

DEDICATION

I would like to dedicate this work to every one in my lovely family, wife, daughters, and sons

ACKNOWLEDGMENTS

I would like to express my deep appreciation to my supervisor, Associate Prof. Jan-Erik Gustafsson, for his advice and continuous support through out the thesis work. I also acknowledge, with gratitude, my boss Mr. Nabil Al Sharif, Chairman of the Palestinian Water Authority who gave me the opportunity to enrol in the master program in Sweden. Thanks are forward to SIDA for their financial support during my thesis work. I would like to appreciate all EESI program lecturers and supporting staff, especially Mr. Jan-Erik Gustafsson, Director of the program and the program coordinator and Mrs. Christina Ek. I wish to extend a special thank to all my EESI 2002-2003 classmate for their warm friendship and a lovely memorable time in Sweden. I would like to thank Miss Rebheih Suleiman for her continuous help during the study period.

I owed to my colleague, Mr. Rebhy El Sheikh for his faithful advice and encouragement during the thesis preparation. Special thanks are to Mr. Sami Hamdan for his cooperation during questionnaires analysis and valuable information. Much gratitude is extended to heads of the water departments at municipalities who helped me in distributing the questionnaire to water consumers. I also would like to extend my thanks to all interviewees from water professionals and water enterprises for their time and effort during questionnaire interviews. I wish to acknowledge all water consumers time consuming and concern for filling the questionnaires.

My greatest thanks are to my lovely wife, daughters, and sons for their patience, encouragements and continuous support during my study in Stockholm and also during research preparation.

Mahmoud Ismail

Stockholm, December 2003

ACRONYMS AND ABBREVIATIONS

CDM	Camp Dresser and McKee International.
CAMP	Coastal Aquifer Management Program
CMWU	Coastal Municipal Water Utility
M^3/day	Cubic meters per day
GRWC	Gaza Regional Water Carrier
GSWDP	Gaza Sea Water Desalination Plant
GDP	Gross Domestic Product
l/c/d	Liter per capita per day
LEKA	Lyonnaise des Eaux and Khatib and Alami
MCM/yr	Milllion Cubic Meter per year
Mg/L	Millgrams per Liter
MUSD	Million United States Dollar
NWP	National Water Plan
NIS	New Israeli Shekel
O&M	Operation and Maintenance
PCBS	Palestinian Central Bureau of Statistics
PNA	Palestinian National Authority
PWA	Palestinian Water Authority
ppm	part per million = (Mg/L)
RO	Reverse Osmosis
SPSS	Statistical Package for Social Science
PT	The Palestinian Territories (West Bank and Gaza Strip)
TDS	Total Dissolved Solids
UNRWA	United Nations Relief and Works Agency
USAID	United State Agency for International Development
WHO	World Health Organization

***:** The currency equivalent as of October 7, 2003 was US$1=4.4 New Isreali Shekel

ABSTRACT

This study evaluates prospects of water desalination in the Gaza strip with special emphasize on the large scale Gaza Sea Water Desalination Plant (GSWDP) that has committed to be funded by USAID.

Groundwater, which is the only resource for water in the Gaza Strip, has already been exploited. Water demand much exceeds water supply. Seawater intrusion and inefficient sewer system also added more serious environmental problems. GSWDP as a large-scale seawater desalination beside the existing desalination plants have been brought as a strategic option to be adopted by the Palestinian Water Authority to overcome water shortage and provide an alternative water source

Seawater and/or brackish water desalination is a reliable and effective to improve the water quality and add more quantity to meet the World Health Organization (WHO) or the local standards for drinking water and create a sustainable life for the people in the Gaza Strip. Three brackish desalination plants already exist and other two seawater desalination plants are under construction. In the last three years, 25 small-scale RO brackish desalination units have been constructed by the private sector. In addition seven vendors were exist.

Two types of questionnaires were administered to both water consumers and water professionals. Results from water consumer questionnaires indicate that only 9% the people in the Gaza Strip used the municipal water for drinking purposes while 90% used desalinated water from different sources. 21% of population have their own in houses RO units for drinking purpose mainly.

The study has concluded that desalination applications are crucial in the near future for people in the Gaza Strip .It will solve partially the crisis of unavailable acceptable drinking water. Individual with GDP of US$400 can afford 1.53 to 2.1US$ extra of the current municipal water tariffs. In the same sake poor families with seven family members and average monthly income of US$340 can afford up to US$0.84 /M3 of desalinated water. Smart setting tariff structure with cross subsidiary has to be adopted by PWA in order to protect the poor.

Recommended minimum values of chemical elements such as calcium are to be available in the drinking water that produced from commercial RO desalination units and RO in houses as well.
Public Participation is also recommended to be involved in the desalination projects life cycle.

Table of Content

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1

1. INTRODUCTION

Water desalination has become the famous technical process to solve the shortage in water resources with accepted water quality. By the time rapid progress in desalination equipment technology has reduced the cost of produced cubic meter. Water is one the main components for sustainable life on this planet. It comprises about 70% of human body. The ever-increasing population creates an increased pressure on water demand that affects directly the socio-economic development. More than two billions of people over the world have no access for regular supply of potable water. In the developing countries 10,000 to 20,000 people die every day from preventable water-related diseases. The available fresh water gives us the opportunity to get a sustainable life on this planet. However in areas like Gaza potable water for domestic use is rare and forms a crisis.

By the beginning of 1960's, the use of desalination to deliver water to consumers was a challenge for decision making due cost constraints. The rapid progress in desalination technology and high competition between the water enterprise industries has made it more economic. Today, the water scarcity areas of the world are being driven towards using desalination technology due to the decrease in the available fresh water.

Water in the Middle East region is still one of the main causes of conflicts between trans boundary countries. Part of the Arab –Israeli dispute is the water issue. The lack of available fresh water resources increases the gap towards finding out solutions to the Palestinian -Israeli water problems. Both parties are interested in looking for developing non-conventional water resources such as reuse of treated wastewater or desalination to overcome the growth water demand for socio-economic development.

Desalination as a source for potable water can relieve water shortages mainly in dry regions along seacoasts. But it will be more costly in cities far from a seacoast or in mountains. Thus, desalination is still considered as the only realistic and best technological hope for dealing with fresh water shortages. Over the past forty years, its uses have grown, particularly in the Middle East with two-thirds of the world's 7500 desalination plants (El Bana, H., 2000). For example, about 82% of the Unite Arab Emirates domestic water is supplied from desalination (CIA, 2003). However, it is often too expensive for most developing countries.

Desalination has become a component of the strategic plan of the Palestinian Water Authority, since the projected domestic water demand by year 2020 is about 182 MCM/year (PWA, CAMP 2001). In Palestine, the experience in desalination is new. The first RO –plant was constructed in Deir El Balah in 1993 as a pilot project. Two RO plants exist in Khanyunis as well. Both areas are a part of the Gaza Strip. People in Gaza has become aware of the deterioration of the quality of the municipal water supply, so they have started to install RO domestic units to solve their problem individually. PWA according to its policy decided to increase the non-conventional water resources through adoption of desalination options.

1.1 Background

The Gaza Strip (GS) is facing a challenge by deficient and unbalance in the municipal water supply-demand equation. Currently, groundwater is still the main resource for water supply for all people in the Gaza Strip. The extraction from coastal aquifer is almost twice the available recharge that has resulted in dropping the water level by 20-30 cm per year (PWA, Data bank 2003). Seawater intrusion deteriorated the quality of aquifers beside the overuse of fertilizers and pesticides in the agricultural activities. The overall water deficit is estimated at 50-60 MCM/year (PWA, CAMP 2001). This serious problem will aggravate by the time. It is accompanied with a rapid growth of population, and inadequate sewerage systems contaminate the groundwater. Securing potable water for domestic use is becoming a heavy target on the PWA.

Desalination as non-conventional water resource offers the only viable option for meeting the growing demand for potable water for Gaza people. Water desalination also could play a big role to mitigate the adverse environmental impacts associated with lack of fresh water for at least drinking purposes and over abstraction from the aquifer as well. In the early nineties different the Palestinian parties due to political reasons were objected the idea of desalination. Water desalination projects are supposed to cover the deficit after allocating the Palestinians water rights. However, small desalination plants (1250-5000 M^3/day) were agreed upon to be constructed in the late nineties to help people drink acceptable water quality.

Traditionally, people believe that the desalination option is costly. But due to the rapid progress in the last five years in the desalination process and the technology development has reduced the capital and operation costs especially for large-scale desalination plants. Large-scale desalination has more and more become available option.

According to Oslo II, Article (40) of Annex III in the Interim Peace Agreement between Israelis and Palestinians, the United States Government gave commitment to the Palestinians to address the issue of desalination of brackish or sea water in the Gaza Strip (Oslo II, Article40, 1995). The result of this commitment is on the way by construction of a large-scale seawater desalination facility with a capacity at phase (I) at 60,000 M^3/day. It will increase to 150,000 M^3/day in the final phase by 2020. The project assumed to be a Design/Build/Operate contract was procured according to the U.S Federal Acquisition Regulation. The awarding contract was decided by mid-2003. But due to the political situation it was postponed. In parallel, efforts were done through support from French Government to start with Design, Built, and Operate seawater desalination plant at North Gaza with final capacity at 5000 M^3/day. The Austrian government did the same support to Design, Built, and Operate for short time a seawater desalination plant with final capacity at 1200 M^3/day to serve people in middle area of Gaza strip.

1.2 Problem definition

The Gaza Strip (GS) has an area of 365 Km^2, (approximately 45 Km in length and 7 to 12 Km in width) situated in the southern part of the Mediterranean Sea of the Palestinian coastal plan. It consists of five governorates, North, Gaza, Middle, Khanyunis, and Rafah. The population count in year 2002 was at 1299403 inhabitants, while the fertility rate is estimated at 3%-3.5% and average member per family is at 6.9% (PCBS, 2003).

Ground water is the major source for water supply for domestic and agricultural use and it has already being exploited. Rainfall with an average of 330 mm/year, which is the main conventional source, became insufficient to refresh the groundwater system. By year 2002, the available yield of ground water is about 91 MCM/year while the total abstraction for domestic and agricultural purposes is 153 MCM/year (PWA, CAMP 2000). This result is affected in negative way the quality and the quantity of the municipal water that pumped to the consumers. More than16 municipalities and 9 Village councils in the Gaza Strip manage their own water supply system. The average total water production for domestic use was by year 2002 at 62 MCM /year (PWA, LEKA 2003). These quantities were pumped from 117 municipal water wells. Only 18% of these wells meet the WHO standards of drinking water, while the other wells have average nitrate concentrations (NO_3) above 45 ppm and average chlorine concentrations (CL) is 250 ppm. By the year 2002 the average water consumption over whole the Gaza Strip was estimated at 90 l/c/d.

The quality of the municipal water had been almost completely deteriorated. The Palestinian Water Authority (PWA) perceives water desalination as the principle approach to alleviate the water problem and provide people in Gaza with accepted water quality.

1.3 Objectives of the study

This study aims to evaluate prospects of water desalination in the Gaza strip and its impact on the quantity and the quality of the municipal supply. It will also examine the affordability of the consumers of the water produced by desalination with a special emphasis on the Gaza Sea Water Desalination Plant (GSWDP). At present, the role of increased desalination on the total water supply provision is not clear so far. In addition, the impact of the desalination on consumer's willingness to pay for water has not been investigated.

The objectives are:

- To evaluate to what extent water desalination could contribute to minimize the deficit in the quantity of the municipal water supply.
- To what degree could water desalination contribute in improving the quality of the municipal drinking water?
- Could water desalination be a sustainable option for all people in the Gaza Strip **or** will it only cover areas since long have suffered from using deteriorated water quality.
- To examine if water desalination is an accepted option to the people in the Gaza Strip in terms of affordability and willingness to pay.
- Examine whether the people in the Gaza Strip can afford for the desalination.
- Explore the political status of desalination option and the effect of it on the Palestinian-Israeli water dispute.

1.4 Research Methodology

This research started with a literature review focused on water resources and desalination in general, and the management of the municipal water supply in particular. A multi method approach has been applied in the study. Data have been collected from structured questionnaires for the key water professionals and a structured questionnaire for water consumers. Field visits to existing desalination plants were carried out and discussion meetings with RO suppliers were also held. In total 50 interview questionnaires for key water professionals from different institutions were addressed. 47 of professionals gave response to the questionnaire while three were apologized. The questionnaire has included three main parts of questions to explore findings related to political, socio-economic and technical aspects of feasibility of the adoption of the desalination option. The interview questionnaires were distributed and meeting with interviewees were conducted to give more elaboration and explanation for the questions.

A questionnaire for water consumers was distributed by hand to 525 consumers in the Gaza Strip. The number of return respondents was 480. After cleaning and checking of inaccurate responses, the final number of the study sample became 428 questionnaires. The response rate of consumer questionnaires is 89.2%. The questionnaires have been analysed by using the Statistical Package for Social Science (SPSS). Triangulation method was applied to validate generated data. Reliability test also was done by using the Statistical Package for Social Science (SPSS) to check the questionnaire respondent's performance.

Most of the questions included are of rating scaling type Likert Scale questionnaire that is particularly useful in scientific assessment of people perceptions. The questionnaire has been distributed in rural and urban areas in proportion to the number of households in each area. . The total number of water households in the Gaza Strip by the year 2002 was approximately 100,000 households. The households have been selected randomly from different categories of the society such as teachers, labours, housewives, governmental employees, and private sector employees.

.

CHAPTER 2

2. DESCRIPTION OF THE STUDY AREA

2.1 Population and Geography

2.1.1 History

As a result of the Israeli-Arab conflict in 1948, many Palestinians were enforced to leave their homes to neighbouring countries such as Syria, Lebanon, Egypt, and Jordan. Part of them resettled in other Palestinian areas: the Gaza strip and the West Bank. Nowadays they form two Palestinian Territories (P T). They constitute about 22.8% of the total area of historical Palestine 27,009Km^2 (Abu Mailai, Y., 1993).

Figure 1 Palestine map, the Gaza Strip and the West Bank (*Source: PWA, Data bank 2003*)

As a consequence of war June 1967 Israel had occupied the whole Gaza Strip and the West Bank. Israeli Military Order No.2 of June 1967 stated that all water resources in the newly occupied Palestinian Territories were to be owned by the state of Israel (UNEP 2003, p. 20). Few months later, the Israeli government issued military orders towards the establishment of a Civil Administration. The Israeli Civil Administration (ICA) of the Israeli government became responsible for all aspects of government within the occupied territories. In some cases local governments administered and managed some daily routine work for the local people under control of Israeli officials. The Civil Administration was in theory responsible for all aspects of public health, and controls water resources including issuing well abstraction licenses. However, United Nations Relief and Works Agency (UNRAW) has the responsibility for many public health functions in the refugee camps (PWA, CDM 1993).

According to OSLO agreement between the Arab countries and Israel (1993), the Palestinian National Authority (PNA) was given responsibility for the ruling of the Gaza Strip and the West Bank (WB) after the Israeli withdrawal from Palestinian Territories. In 1996 a Presidential Decree was issued to establish the Palestinian Water Authority (PWA) according to the By-Laws No 2 1996.

2.1.2 Population

The Palestinian Central Bureau of Statistics (PCBS) conducted the last national population census for Palestine in 1997. By the year 1997 the total population for Palestine (the Gaza Strip and the West Bank) was 2.9 millions. The total population of the Gaza strip (appendix 10) was estimated in the year 2002 at 1,299,403 inhabitants and the fertility rate was estimated at 3-3.5% (PCBS, 1999). This rate plays a big role in the planning and management of water resources. More than 67.5% was registered as refugees, living in eight refugee camps where the standard of living is very poor.

The economic situation in the GS in particular and in Palestine in general is directly affected by the political situation. Israeli procedures like closures, prohibition of export and import from and to the Palestinian area are other significant factors that have resulted in a deceasing trend of the income per capita. The Gross Domestic Product (GDP) has dropped to US$ 600 per capita by year in 2002 and it was expected to be much less than this figure due to the continuous instability of the political situation. Figure (2) refers to projected population of the Gaza Strip (PCBS, 1999).

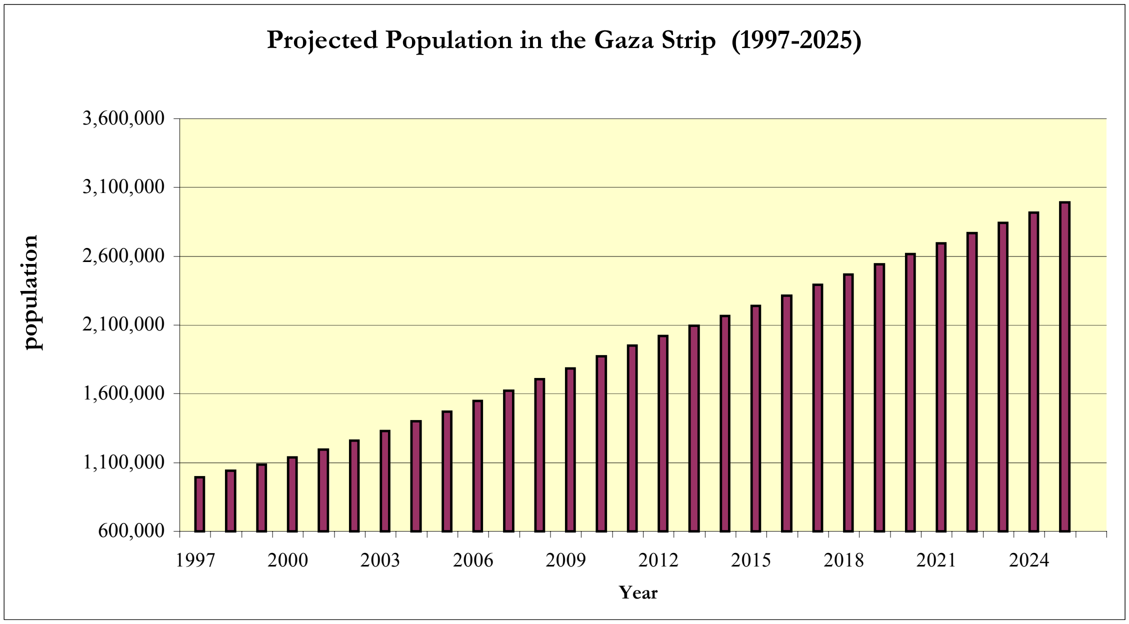


Figure 2 Projection populations in the Gaza Strip 1997 to 2025 (*Source: PCBS, 1999)*

2.1.3 Geography

Gaza Strip is located on the southeastern shore of the Mediterranean Sea, bordered by Israel to the east and north, Egypt to south. The total area is estimated at 365Km^2. Its length along the coast is 45km and width ranges from 5 to 12 Km. After Israeli occupation to Gaza Strip in 1967, many Israeli settlements have been constructed on the Palestinians lands and these form about 30% of the whole area of the Gaza Strip. Sand dunes are dominant along the shoreline with elevations up to 40 m above mean sea level, while a brown clay (mix with) loamy soil extends at east Gaza city and at north-eastern of Gaza Strip. Three Wadis are crossing Beit Hanoun, Gaza, Salga areas forming the hydrological feature of the area. Wadi has a river cross-section and shape. Water flows in the Wadi seasonally. In the winter season, water flows into those Wadis. The Wadi Gaza is the biggest one. It runs in the central part of the Gaza Strip and discharges into the Mediterranean Sea. Israel has retained and changed the course of the three Wadis and they became dry Wadis (MOPIC**,** EPD 1994).

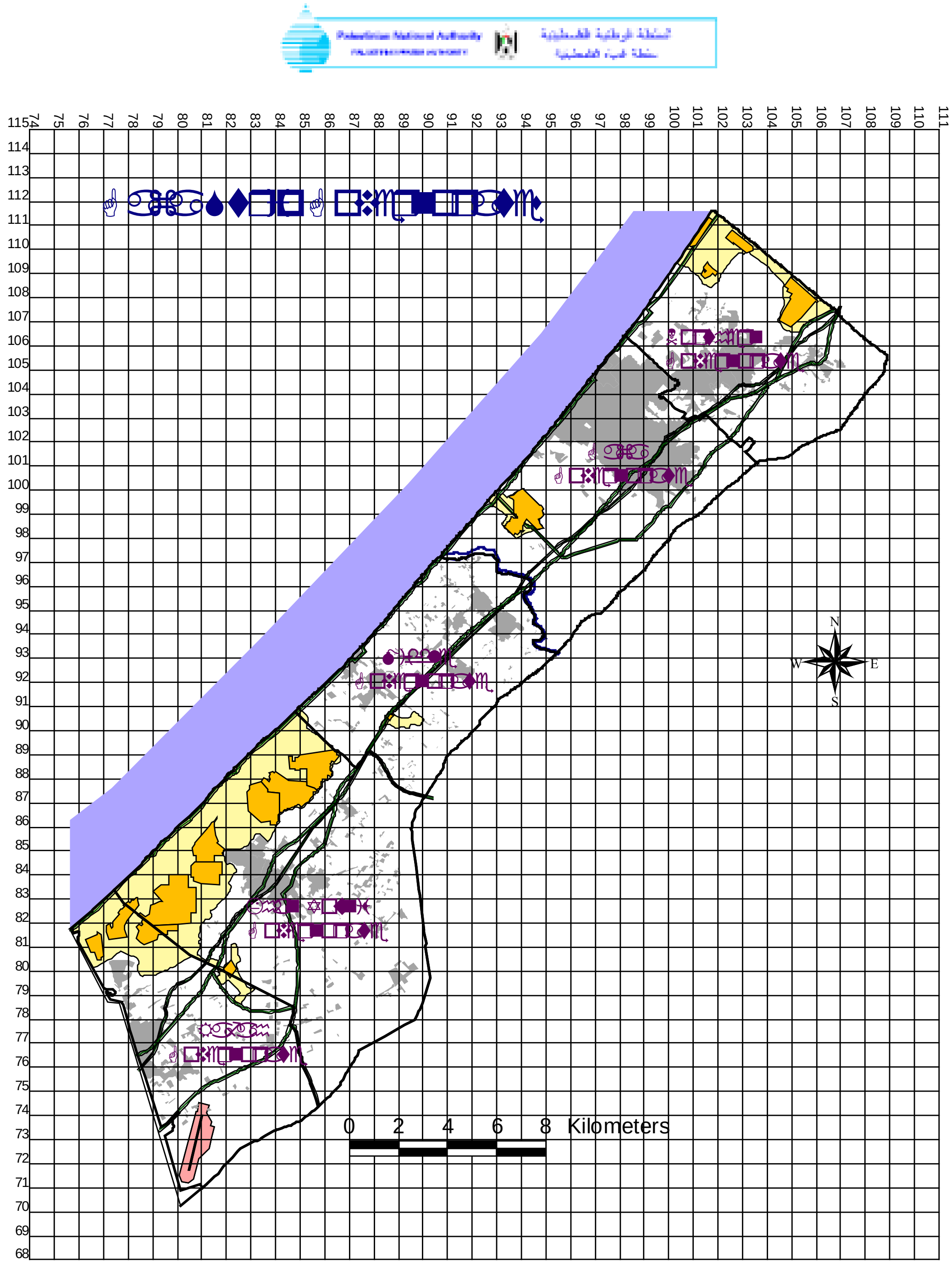


Figure 3 Gaza Strip –the study area map *(Source: PWA, Data bank 2003)*

- **Climate and rainfall**

Gaza strip has a semi –arid Mediterranean climate, with mean temperature varying from 12-14 ºC in January, to 26-28 ºC in August. Rainfall is the main source of almost all water in GS. According to the available historical data at PWA, the average rainfall ranges from 400mm/yr in north to 200mm/yr in south. The peak of rainfall is taking place during December and January. The rainy days range from 45 to 50 days (Abu Safia, Y., 1995). The average annual volume of rainfall is about 110-115 MCM/yr, and the potential recharge is between 40 to 46 MCM/yr (PWA, Data bank 2003). Average annual evaporation in Gaza is 1300 mm from open space; evapotranspiration is estimated at 80% of this value. (Appendix 1) is adopted from CDM (1993) report which gives average monthly temperature, rainfall, and evaporation for Gaza town based on the period 1931-1960

2.2 Surface Water

Three small Wadis are distributed over the Gaza Strip but all of them are considered as dry. Since 1967, many studies reported that the amount of surface water flowing in the three Wadis crossing the Gaza Strip became negligible due to Israeli barriers. Quantities decreased from 20MCM/yr to 2 MCM/yr or less (EPD, MOPIC. 1994) because Israel is located upstream areas and it controlled the course of them.

The type of soil also affects storm water infiltration in the Gaza strip. Surface runoff usually occurs when the rainfall intensity is higher than the rate of infiltration of water in soil. The coastal plan of Gaza which is close to sea is composed of moseys of sandy soil, while the north and eastern part has clayey layer. So infiltration conditions are most likely to occur on the coastal parts.

2.3 Ground Water

Ground water is the main resource of water for Gaza people. Two aquifers systems exist in the Palestinians Territories. Part of the coastal aquifer is in the Gaza Strip and part of the mountain aquifer system is in the West Bank. Near the coast, the aquifer is divided into several sub aquifers by different layers of clay and silt. The coastal aquifer thickness is about 120-160 m near the coast to less than 10 meter along the eastern boarder. The upper layer of the aquifer contains fresh water. The groundwater moves from east to west to the sea. Due to over abstraction, in balance in supply- demand equation occurs. (PWA, CAMP 2000) report shows that there has been a continuous drop in the groundwater levels in the last twenty years all over the Gaza Strip. This has been reflected in the increase of the salinity of the groundwater. The chloride content (CL) ranges between 200-300Mg/L in the northern part and over 400-1200 Mg/L in the southern part especially in Khanyunis governorate. The concentration of nitrates is also generally high. Although the north area has a low level of chloride, it has a high nitrate concentration (NO_3). These serious problems add more pressure to decision makers and water planners, thus making the exploration of fresh water to be a very complicated task.

> *PWA,(2000) the National Water Plan reported: "the coastal aquifer holds approximately $5x10^9$ M^3 of ground water of different quality. However, only 1.4-x109 m^3 of this is "freshwater", with chloride content of less than 500 Mg/L. This means that approximately 70% of the aquifer is brackish or saline and the rest 30% is fresh water".*

The renewable amount of groundwater is about 91 MCM by year 2000 from which 40 to 46 MCM comes from direct infiltration of rainfall. The remaining amount (51 MCM) comes from irrigation return flow, leakage from non-sewered areas and brackish trans-boundary flow that crosses the eastern side of the Gaza Strip (PWA, 2000). The total amount of groundwater abstraction including 5 MCM/year from Mekerot was 153 MCM by the year2002, for domestic and agricultural (62 MCM/year and 91 MCM/year respectively. Total recharge was at 91MCM and the total deficit in the water budget of 62 MCM by the year 2002.

The negative result in water balance of Gaza resulted into a continuous decline in the ground water levels of about 20-25 cm year per year. Using large amounts of fertilizers and pesticides in agricultural activities and lack of sewage networks were both increasing the concentration of nitrate ions in groundwater. Nitrates have reached above 250 Mg/L in some areas reflected in an aggravated deterioration of water quality. Salinity represented in chloride concentration also increased dramatically to above 1000 Mg/L due to the high groundwater abstraction rates. Salinity originates from both seawater intrusion and deep saline groundwater (up coning).

2.4 Municipal Water Supply

2.4.1 Municipal and industrial water

Gaza Strip has a severe crisis on water resources due to the increase of demand on water for both domestic and agriculture purposes. Municipalities and village councils are responsible for delivering water to domestic and industrial customers. The management of water systems have been developed by the time. The level of unaccounted for-water due to many illegal connections is likely to be improved. The domestic water demand in 1990 was estimated at 25MCM/yr, while 75MCM/yr was used for irrigation (CDM, 1993**)**. By year 2002**,** average per capita consumption for both domestic and industrial overall the Gaza Strip was estimated at 91 l/c/d including the livestock (PWA, LEKA 2003). The industrial consumption is relatively low (no actual readings). Since 1996, the average physical losses were estimated at 50%. So the actual production for domestic use was in some areas about 120 l/c/d. Still there are weaknesses and difficulties of managing the water system in the Gaza Strip.

The total number of water households by year 2002 is 99588 households (PWA, LEKA, 2003). The strategy of PWA is to reach 150 l/c/d for domestic use by year 2020, which is equal to the minimum requirement per capita according to WHO standards. Between 1998 and 1999 nine village councils have been established. These village councils were not fully included in the World Bank project activities for the service improvement of water and waste water (Gaza I). On sake of service, PWA has offered some additional support to those village councils through other projects mainly in the field of constructing new water networks, drilling new water wells and upgrading existing wells.

To overcome the water deficit in the future, many scenarios and solutions have been proposed by or to the PWA such as reuse of treated wastewater for agriculture, imported water from neighbouring countries. Transportation of water from Turkey through water tanker ships was another option. Local alternatives such as brackish and/or seawater desalination has been focused on, but all of these options are depending mainly on the socio-economic criteria. Consequences of water resources scarcity and lower level of water quality has imposed on the Palestinian decision makers to adopt desalination option.

2.4.2 Quantitative aspect

Ground water is the main source in Gaza Strip for municipal water supply. Most of the GS municipalities have their own water wells. The total number of municipal wells is at 117 water wells. The total production by the year 2002 was estimated at 62.7 MCM/year. This figure includes 5 MCM /year that are pumped from the Israeli settlements through Israel water utility (Mekerot). Not less than 98 % of the people in Gaza Strip have access to municipal water supply.

Three pilot RO brackish water desalination plants exist; two have been managed and operated by Khanyunis municipality and the third by Deir El Balah municipality. The main function of those plants was to secure a very limited quantity (100 to 150 M^3/hr) of accepted water for drinking purposes either by pumping directly in the networks or by direct filling from the plants. These plants are operated about 8 hours a day because of cost reasons.

Per capita water of each customer in the Strip has increased from 72 l/c/d in year 1996 to 91 l/c/d by year 2002. Before a lunching the World Bank project (Gaza I), the average system efficiency of water networks was estimated at 50%. Leak detection campaign has been carried out for most of the water networks followed by refurbishment works. This result has been in minimizing the water losses from 46% to 37%by year 2002. More details are in table (1).

Table (1) Quantities of the municipal water supply in the Gaza Strip from 1996 to 2002

Year	Population inhabitant	*Water sources (MCM/year)			Water production MCM/year	Water consumption l/c/d	System efficiency	No. of house connections	
		Mekerot	Municipal	Private				Water	Waste water
1996	961,981	5,0	41,3	0.3	46,6	72	54%	75,906	18,000
1997	995,650	5,4	42,4	1,0	48,8	76	56%	80,458	33,870
1998	1,030,498	5,8	46,5	1,2	53,5	83	58%	84,507	36,922
1999	1,066,566	4,3	50,6	0.9	55,8	88	61%	89,512	32,140
2000	1,103,895	4,0	52,5	0.6	57,1	87	61%	94,884	47,695
2001	1,142,532	3,5	55,1	0.6	59,2	91	64%	97,118	50,089
**2002	1,182,520	3,6	58,2	0.9	62,7	91	63%	99,588	55,096

Source: PWA- Consumer Affairs Department (2003)

**These numbers and quantities represent16 municipalities*
***The total population of the whole of the GS by year 2002 is at 1,299,403 inhabitants*

2.4.3 Qualitative aspect

- **Salinity (Chloride)**

As mentioned above, most of municipalities in the GS depend mainly on the ground water for service delivery. The current water supply in general has high level of chlorides (CL). Chloride levels in drinking water wells have shown dramatic increases in the last twenty years. The salinity levels vary relatively from low level 50-60Mg/L, as in the northern area of the Strip to very high levels reaching to 800-1200 Mg/L as at Gaza and Khanyunis. Figure (4) shows chloride concentration in the municipal water wells.

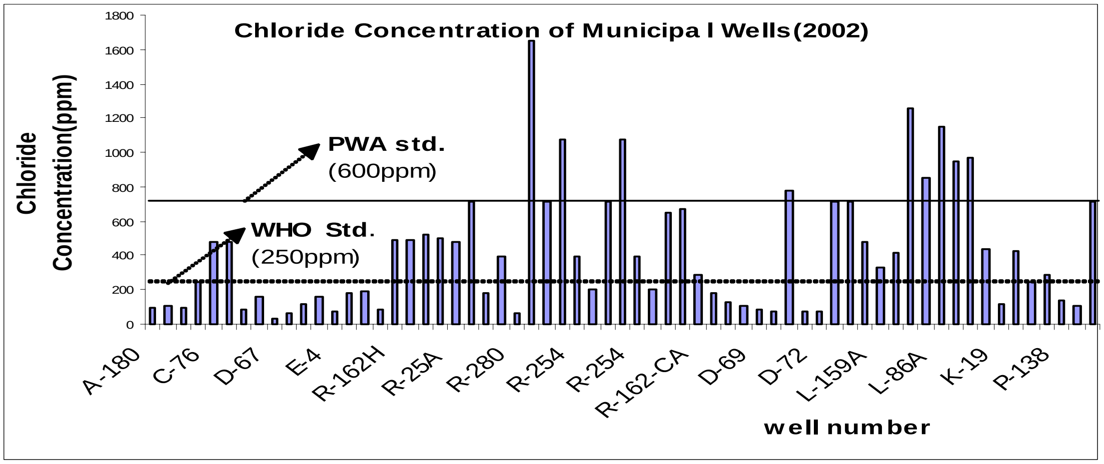


Figure (4) Average values of annual chloride concentrations of the municipal water wells in the year 2002 *(Source: PWA, Data Bank 2003)*

This is a result of continues over pumping from aquifer at high rates. Seawater intrusions into aquifers and brackish water are the main reasons of the high salinity**.**

- **Nitrate levels**

A significant increase in nitrate contents (NO_3) is widely recorded. The available data at PWA indicate that the groundwater is being contaminated by untreated domestic wastewater. Uncontrolled use of pesticides and fertilizers in agriculture add more load to the increase of nitrate in groundwater. Nitrate concentration reaches in some areas a rate of 150-400Mg/L. Figure (5) shows nitrate concentration in some municipal water wells.

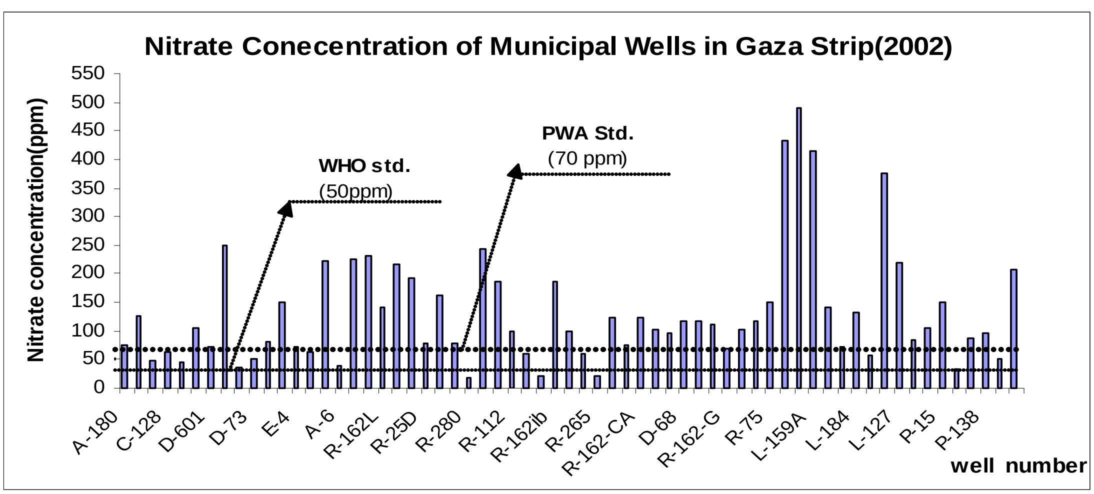


Figure (5) Average values of annual nitrate concentrations of the municipal water wells in the year 2002 (Source: PWA, Data bank 2003)

- **Fluorides**

The higher level of fluoride contamination affects directly the health of people especially the infants. It is also a limiting factor for the quality of municipal water. In southern part of Gaza Strip mainly in Khanyunis area, reports recorded high contents of fluoride exceeding 1.0 Mg/L. This contaminant may cause disorders such as mottling of teeth but les frequently. Generally the quality of the drinking water wells is exceeding the World Health Organization (WHO) standards.

Based on the above information the lack of fresh water in Gaza imposed the Palestinian Water Authority to elevate the standards of some chemical elements. For example, the limit of chloride concentration can be accepted up to 600 Mg/L compared with 250 Mg/l according to WHO. Nitrate concentration may reach 70Mg/L compared with 45 Mg/l according to WHO. If those standard values of the water quality are applied on the water quality of the domestic wells in terms of CL and NO_3 concentrations, only 23% of the total wells will be accepted for drinking water usage according to the Palestinian standards compared with 18% according to WHO standards. To solve this serious problem, some people in Gaza as individual have installed house RO units or relied on vended water to have their own needs for drinking purposes mainly.

2.4.4 Current price of municipal water and tariff structure

At present, 16 municipalities and nine village councils are responsible for water supply in the Gaza Strip. Water tariffs for domestic and industrial supply vary from one municipality to another. Each municipality has its own water tariff based on its own local water sources. In general the average tariff is around US\$0.3/M^3. The water charge has a fixed price for the first block, which ranges from 10 to 15 M^3/month, and other two or three blocks follow it. The water bill is issued every second months. The political situation and weakness of economy and job opportunities affect directly the collection efficiency at the municipalities. Mekerot, the Israeli water utility sells about 5 MCM annually to the Gaza Strip at price of around US\$ 0.55/$M^{3.}$ This price of cubic meter is supposed to increase by time.. Different tariff structures (or blocks) all over the Gaza Strip is listed in table (2).

Table (2) Tariffs structure of domestic water of the Gaza Strip municipalities

Municipality	Fixed Charge if Quantity in M³	Slide (or block) number and quantities in (M^3)					
		Slide 1	**Slide 2**	**Slide 3**	**Slide 4**	**Slide 5**	**Slide 6**
		0 to 10	**11 to 20**	**21 to 30**	**31 to 40**	**41 to 50**	**Over**
Gaza	6	0.3 NIS/M³	0.5 NIS/M³		0.9 NIS/M³		
Rafah	30		15.3 NIS			1.5 NIS/M³	2 NIS/M³
K. Yunis	40		40 NIS			1.5 NIS/M³	2 NIS/M³
B.Suhyla	18	18 NIS	2 NIS/M³	2.2 NIS/M³		2.5 NIS/M³	
Big Abassan	18	18 NIS	e		2 NIS/M³		
New Abassan	15	15 NIS			2 NIS/M³		
Khuzaa	16	16 NIS	1.7 NIS/M³	1.8 NIS/M³		2 NIS/M³	
Qurarah	25	25 NIS			1.2 NIS/M³		
D.Balah	15	15 NIS		1.2 NIS/M³		1.75 NIS/M³	
Zwaidah	27	27 NIS		2.7 NIS/M³			
Nussierat	16	16 NIS	1.8 NIS/M³	1.9 NIS/M³		2 NIS/M³	
Maghazi	17	17 NIS	1.8 NIS/M³	1.9 NIS/M³		2 NIS/M³	
Buraij	17	17 NIS	1.8 NIS/M³	1.9 NIS/M³		2 NIS/M³	
Jabalia	40		40 NIS/M³			0.8 NIS/M³	
Beit Lahia	30		30 NIS/M³			0.8 NIS/M³	
Beit Hanoun	30		30 NIS/M³			0.8 NIS/M³	

Source: PWA, Consumer Affairs Department (2003)

NIS: New Israeli Shekels (US$1= 4.4 NIS)

2.5 Projected Water Demand

Population growth and socio-economic development are limiting the water demand for different water users. In Gaza Strip, rapid increase of population growth and high numbers of Palestinian returnees after the Oslo agreement of peace in the Middle East, economic development as well have increased the pressure on water resources. This resulted by over pumping from the aquifer. Drop in groundwater level has been recorded. Water pricing has been affected directly by the quality of water that is delivered to customers such as water delivered from Mekerot.

2.5.1 Domestic water demand

The population in 2020 is estimated to be 2,600,000 inhabitants. This means that population will be doubled every twenty years. Per capita water consumption over all the Gaza Strip ranges from 70 l/c/d to 130 l/c/d according to available water source in each municipality. The main problem is the deterioration of quality of water delivered for domestic and industrial purposes. This severe problem is growing with rapid increase in the population. At same time, more than 25 Israeli water wells in the settlements in Gaza Strip produce 5-7 MCM/year used by 5000 to 7000 Israeli settlers (CIA, 2003). This means that each Israeli settler consumes 275 l/c/d.

According to the master plan, the municipal (domestic and industrial) demand would grow from 55 MCM in year 2000 to 100MCM in 2005. By 2020, the projected demand for domestic will be at 182 MCM assuming that consumers are presently receiving only 2/3 of the water they demand, and the growth rate in population is continuous at a rate of 3.5%. The system efficiency will be targeted at 80%. (PWA, CAPM 2000-Volume 1.pp.3-18). Table (3) indicates the projected demand of municipal uses up to 2020.

Table (3) Projection municipal water demand for the Gaza Strip

Year	2000	2005	2010	2015	2020
Demand (MCM)	55	100	125	152	182

Source: PWA, CAPM (2000).

Industry in Gaza is composed of very small factories and workshops. The water consumption for industry was estimated at 3 MCM in year 2000. The high percentage of salinity and nitrate in the municipal water will likely be a serious constraint for development of food industry.

2.5.2 Agricultural water demand

Agricultural water demand for food requirements is the heavy user in the Gaza Strip. There are more than 4,000 water wells pumping approximately 91 MCM /year for agricultural use in year 2000. According to table (4) the agricultural water demand is projected to decrease from 91 MCM/yr to 80 MCM/year 2020 provided that change will occur on the irrigated rain fed agricultural land area in the Gaza Strip. This result is due to the growth in land use of urban areas, which is expanding on account of agricultural land. The farmers in this case have to change their crop pattern based on the available water. Intensive agriculture is also required due lack of land (PWA, CAPM 2000-Vol. 1.pp.3-18)

Table (4) Projected agriculture water demand in the Gaza Strip

Year	2000	2005	2010	2015	2020
Demand (MCM)	91	92	88	86	80

Source: PWA, CAMP (2000)

2.5.3 Overall future water demand in the Gaza Strip

The overall projected water demand in Gaza Strip was estimated to increase from about 146 MCM in year 2000 to about 262 MCM by year 2020. This includes domestic and industrial demands at water supply source and agriculture use as well.

According to the Water National Plan (PWA, 2000) and the (PWA, CAMP 2000) reports, there is dramatic increase in the water balance by year 2020. Table 5 illustrates over all water demand in domestic and agriculture sectors and the gap in water resources for both to the year 2020 without incorporating the management options (PWA, CAPM 2000)

Table (5) Overall projection water demand in the Gaza Strip

Year	**Population (inhabitant)**	**Agriculture water demand**	**Domestic& industrial water demand**	**Total demand**	**Available resources**	**Gap**
2000	1167359	91	55	146	109	**-37**
2005	1472333	92	100	192	131	**-61**
2010	1871144	88	125	213	137	**-76**
2015	2241206	86	152	238	145	**-93**
2020	2617823	80	182	262	155	**-107**

Source: PWA, CAPM (2000)
All figures in MCM/ year.

The projected overall water demands for both domestic and agriculture as mentioned in table 6 is about 262 MCM/year and the available water resources by year 2020 is at 155 MCM/year. Accordingly, the water deficit will be at 107MCM/year. The deficit will result in more declining in the groundwater level and the continuous deterioration in the water quality of the aquifer due to seawater intrusion and up-coning saline water from deep aquifer. These impacts will add to more threats to overall development and sustainability. Table (6) explains in details the development in water resources for the period 2000 to 2020. (PWA, 2000).

Table (6) Water resources development in the Gaza Strip 2000 to 2020.

Water Resource	Year				
	2000	**2005**	**2010**	**2015**	**2020**
Coastal aquifer**	55	92	100	119	148
Brackish groundwater	51	35	32	20	0
Wastewater re-use	0	23	34	48	63
Israel/ Mekerot	5	10	10	10	10
Desalination	**0**	**24**	**47**	**55**	**57**
Storm water recharge	3	4	5	6	7
Transfer from West Bank	0	0	0	0	0
Total	**114**	**188**	**228**	**258**	**285**

Source: PWA, (2000)
*** All figures in MCM/year*

With reference to values in tables (5) and (6) the overall projected demand is estimated at 262 MCM by year 2020. The resources development plan will be at 285 MCM by the same year, which means no deficit, will occur by 2020. Thus the conclusion is that the desalination as a resource is essential to be adopted and developed in order to bridge the gap. The target of PWA is to reach up per capita consumption 150 litre by 2020, the total investments to implement the strategy of PWA in the Gaza Strip according National Water Plan (NWP) was estimated at 1503 MUS$ by year 2020.

CHAPTER 3

3. INSTITUTIONAL SET UP

3.1 Role and Responsibility of Palestinian Water Authority

On 26 April 1995, the Palestinian Authority established the Palestinian Water Authority (PWA). The PWA derives its authority from By- Law No. 2 of 1996, and Law No. 3 of 2002 according to which PWA is the official body that regulates, and is responsible for overall water resources in the West Bank, and the Gaza Strip (UNEP 2003, pp. 22-24). The mission of PWA is *to ensure equitable utilization and sustainable management and development of the Palestinian Water Resources.*

PWA is an autonomous institution confirmed by the Legislative Council of the Palestinian National Authority. It is the overall water agency for both the Palestinian West Bank and Gaza Strip. The main activities that PWA has to achieve are:

1. Strategic planning for water resources in Palestine
2. Develop, enhance, and allocate water resources among the various users.
3. Optimal way to manage, protect, and to conserve the limited water resources
4. Secure the rights of access to water of good quality for both present and future generations at cost that can they afford.
5. Monitoring and protection of water resources through monitoring programs improving water resources management
6. Improving water supply delivery systems
7. Improving the sewage collection
8. Regulation to maximize the benefit from the use of water resources and avoid a conflict of interest if any.

3.2 Palestinian Water Authority Strategy

The strategy statement is to secure an environmentally sound and sustainable development of water resources through efficient and equitable water management. The key elements of the Water Management Strategy are (PWA, 1999.pp.6-7): -

1. Secure Palestinian water rights
2. Strengthen national policies and regulations
3. Build institutional capacity and develop human resources

4. Regulate and coordinate integrated water supply and waste water investments and operations
5. Enforce pollution control and protection of water resources.
6. Promote public awareness and participation
7. Promote regional and international cooperation

3.3 National Water Council

Based on Article 8 of Water Law No.2 1996, the National Water Council (NWC) comprises 13 members as follow:

1. Chairman of the Palestinian National Authority (Chairman of the council).
2. Minister of Agriculture
3. Minister of Finance
4. Minister of Local Government
5. Minister of Health
6. Minister of Planning and International Cooperation
7. Chairman of Environmental Authority
8. Chairman of the Palestinian Water Authority
9. Al Quads Governor
10. Representative of Local Authorities Union
11. Representative of the Palestinian Universities
12. Representative of Water Unions and Societies
13. Representative of Water Utilities

The member of Palestinian Water Authority (PWA) is working as a secretariat for the NWC (see appendix 2). The main duties of NWC according to the water law- Article 9 (PWA, 1996) are:

1. Develop and manage the water resources in order to meet present and future water needs in an environmental sounding way.
2. Endorse the Palestinian water policy
3. Endorse the tariff structure policy
4. Setting the policy for development and utilization of the water resources in Palestine in coordination with relevant parties.
5. Enhancement of the cooperation in water sectors on regional and international level.
6. Identify the required budget for implementation of water projects.

3.4 The National Water Policy

1. Access to water must be available to all Palestinian people with accepted water quality and quantity at costs that they can afford.
2. All water resources should be the property of the state.
3. The Palestinian water policy is based on the principle of sustainable development of all the available water resources including wastewater.
4. The Palestinians will pursue their interest in connection with obtaining the right of water resources shared with their neighbours.
5. The development and management of water resources must be coordinated at a national level and at appropriate local levels.
6. Development and investment in domestic, industrial, and agricultural sectors must be compatible with the available water resources.
7. The public must participate in all the water management and project phases.

3.5 Regulatory Framework for Water Industry

Regulation aims to organize the relation between services providers, users, and authorities to optimise the benefits of water resources use. Regulation should include three functions according to (Al-Jamal, K& Shublag, M., 2000.pp6-7) which are:

1. Economic regulation,
2. Environmental regulation, and
3. Water quality regulation.

The Palestinian Regulatory Framework has been developed in addition to the strategic institutional set up for the water sector in Palestine as shown in appendix 2 (Al-Jamal, K. & Shoblak, M. 2000). The main players according to the framework are:

1. The National Water Council (NWC).
2. Palestinian Water Authority (PWA)
3. Ministry Of Health (MOH).
4. Ministry of Environmental Affairs
5. Services Utilities

3.6 Formation of Coastal Municipal Water Utility

Since 1996, the water sector has been managed and operated by fragmented 16 municipalities spreading all over the Gaza Strip. According to the agreement between the World Bank and PWA through Gaza (I) project, it was agreed that the end of the project would create the water utility in the Gaza Strip keeping in mind that other three utilities should be created under other programs in the West Bank.

In Gaza Strip, the Coastal Municipal Water Utility (CMWU) is assumed to be created by support from the World Bank to local municipalities and village councils. Each of the participating representatives of localized utilities has been given a membership in the board of the CMWU according to its assets. The role of CMWU will be the overall water management for Gaza. But due to the deterioration in the political situation since September 2000 the project has been delayed.

Until the CMWU becomes fully functioning, the PWA will have a significant role in the context of the development of the desalination facility. The role of PWA is to provide the land for the desalination facilities available, getting necessary permissions, guidance in the requirement of the facility, and to provide the local staff that will cooperate throughout the development and construction of the facility. The main function of CMWU will ensure that the water resources within Gaza Strip are systematically managed and operated in a cost-effective manner. The CMWU will operate and maintain the whole water facilities such as wells, pump stations, the regional carrier, desalination plants, and the water distribution and wastewater collection networks. It will eventually be the owner of the whole water facility network including the Gaza Sea Water Desalination Plant (GSWDP) and will be responsible for the O&M of this plant once the USAID three years operation and maintenance (O&M) commitment is finished.

3.6.1 The Service Management Contract (Gaza I)

The level of service of the 16 municipalities was below the standards technically, financially as well as administratively. In July 1996 PWA has succeeded to have a soft loan from the World Bank of at US$ 25 million. PWA has signed a Service Management Contact (SMC) for four years with the international operator Lyonnaise des **E**aux (SUEZ), which is a joint company, owned by the French company and in joint venture with a regional consultant **K**hatib & **A**lami (LEKA). The first priority was to improve the level of services in water and wastewater sector since it was below the standards. Second priority was to create four autonomous regional water and wastewater utilities, one in the Gaza Strip and three in the West Bank to replace the fragmented institutions.

The main objectives of Gaza I project were:

1. Hiring an international operator- Lyonnaise des Eaux, Khatib &Alami (LEKA) under a four years management contract to implement a service improvement program.
2. Improve the water quality and quantity delivered by municipalities
3. Enhance the capability of the water institutions that suffer from weakness of structure
4. Built up a sustainable framework for future services delivery
5. Avoid the fragmentation of the water sector among the 16 municipalities in the Gaza Strip through creation of Coastal Municipal Water Utility (CMWU).

The contract was the first of its kind in a World Bank funded project in the Middle East. (Saghir, et al., 2000). The project has achieved significant improvement in the water quality and increased the quantity of water supplied to the consumers from 70 l/c/d in 1996 to 91 l/c/d in 2002, reduced the un-accounted–for water from 50% to under 30%, replaced about 30,000 service connections, and repaired more than 50,000 water meters. On sake of quality, the water disinfections efficiency reached 100%. (World Bank 2003, pp. 25-27). The project was assumed to be finished on August 31, 2000, and to start with project Gaza (II) where the Municipal Coastal water utility MCWU should be functioning. But due to the deterioration of the political situation since September 2000, the preparation of the Gaza II project suffered extended delays. Consequently, PWA with the support of the World Bank extended LEAK's Service Management Contract several times (September 2000 to August 2003) in order to ensure the continuity of the services delivery. The total cost of Gaza (I) (original contract and extension contract) was at 31MUS$.

3.6.2 Gaza Water and Sanitation Services Project-Gaza II

The World Bank will financially support the establishment of the Coastal Municipal Water Utility (CMWU) that will undertake the development of the structure of water and wastewater sector in the Gaza Strip. This was agreed between the PWA and the World Bank by the end of the management contract project Gaza (I) to establish Gaza (II) project, which aims to the following based on the World Bank report (World Bank 2003):

1. Strengthening the capability of the PWA as a regulator for the water sector
2. Encourage the role of private sector participation.

It was assumed that LEKA will finish the Service Management Contract (SMC) by the August 31, 2000 and a fully international operator was assumed to replace it. Unfortunately, Request For Proposal (RFP) to attract proposals from the pre-qualified bidders in June 2003 had failed. This is problem as due to the political situation. Most of the large planned project such as the Gaza Sea Water

Desalination Plant (GSWDP), the Gaza Regional Water Carrier (GRWC) and others have been funded by the donors had the condition of PWA success in establishing the CMWU and nominated private operator to run the water sector in the Gaza Strip.

3.6.3 The current situation

The PWA and due to wish full transparency take a decision to stop the money extension of LEKA's contract by the end of September 2003. The World Bank (WB) agreed to finance Gaza Emergency Water Project with about 1.4 MUS$ for eight months beyond the end of LEKA activities provided that PWA as matter of principle is committed to tender a new proposal for hiring a new operator by a Management Contract (MC) for three years. This could be extended to additional four years if needed. PWA and the WB would do their best to attract a private management contractor. Table (7) illustrates the progress of water and wastewater structure and management in the Gaza strip.

Table (7) Summery of the historical progress in the structure of water management and operation in the Gaza Strip

Period / Responsibility	**Previous**					**Ongoing**	**Forecasting**		
	Before 1967	**1967 - 1994**	**1994-1996**	**1996-2000**	**2000-03**	**Sep03-May04**	**June04 –May 07**	**June07 – May 15**	**June 2015-?**
Regulator	—	ICA	—	PWA (created in1996) NWC (created in 1996)	PWA NWC (not activated)	PWA NWC (not activated)	PWA NWC (assumed to be active)	PWA NWC	PWA NWC
Management	M&VC	M&VC	M&VC	M&VC **LEKA**	M&VC **LEKA**	M&VC	MC (International Consultant)	CMWU	CMWU
Operator	M&VC	M&VC	M&VC	M&VC **LEKA**	M&VC **LEKA**	M&VC	CMWU (assumed to be created during this period)	IO (assumed to be nominated)	!!
Technical Assistance	—	ICA	WRAP	LEKA (4-years service contract)-creation of CMWU	LEKA (extension of service contract)	**LMU &LTT** (replaced LEKA)	MC (International Consultant)	IO (assumed to be nominated)	!!

Abbreviations:

1. Municipalities &Village Councils **(M&VC)**
2. Water Resources Acting Program (**WRAP**)
5. National Water Council **(NWC)**
7. Project Management Unit & Local Technical Team (**LMU &LTT**)
9. Coastal Municipal Water Utility (**CMWU**)

2.Israeli Civil Administration **(ICA)**
4.Palestinian Water Authority (**PWA**)
6.Lyonnaise Des Eaux Khatib and Alami (**LEKA)**
8.Management Contract **(MC)**
10.International Operator (**IO**)

CHAPTER 4

4. DESALIANTION AS A NEW RESOURCE

4.1 Need for Desalination in the Gaza Strip

The increasing demand on fresh water is continues to supply the worlds growing cities is becoming more and more crucial. The estimated amount of renewable fresh water is 40,000 cubic kilometers. Out of this amount, only 10% is withdrawn and 5% is consumed. The problem is that the resources are not evenly distributed geographically and seasonally. Figure (6) shows the global water on the earth.

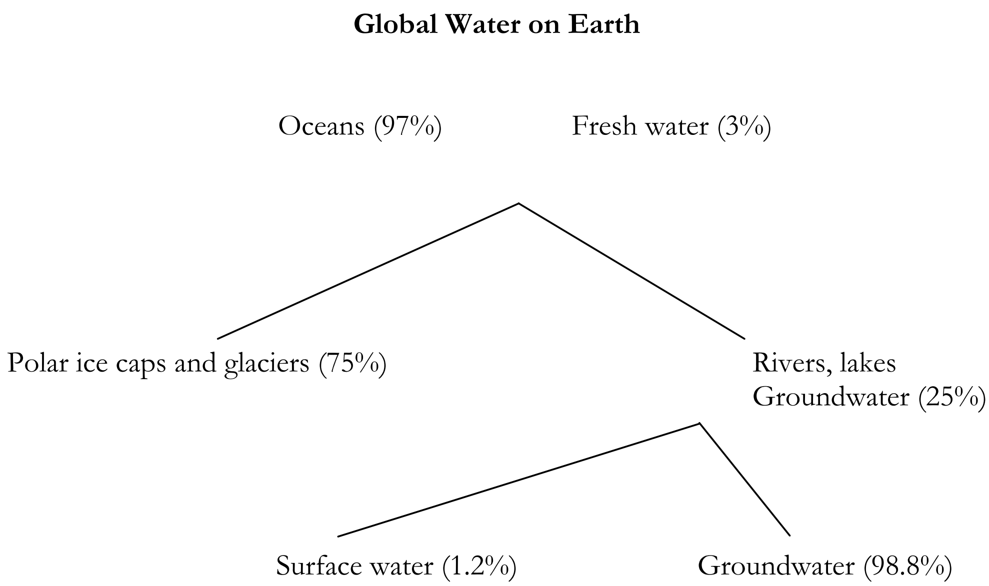


Figure (6) Distribution of water on earth *(Source: Goodman, A.S., 1984)*

> Goodman, A. S., (1984) *explained, "The distribution of water over the earth, he indicates that much of groundwater is located far from points of needs. Population intensities and water availability often are not compatible. The water resource planner is thus challenged to overcome the problem".*

The Middle East in general and Palestine in particular, lies under the pressure of water crisis due to the rapid increase of population and economic growth. Conventional resources such as rainfall are not sufficient to cover the water demand, so desalination technology as one of non-conventional resource has become a vital resource for water projects. Management, planning, development, and

implementation of such projects are complex tasks that need full integration with other sectors such as, environment, ecology, economy, social, legislation, and technology.
As pointed out in chapter two resources deterioration has made desalination a new interesting option for water supply.

People have by them selves taken initiative to start installation of RO in house units, because of the deterioration in water quality. The wide usage of vended desalinated water is common now that aims to secure potable water to at least to meet of their drinking needs. The progress in desalination technology and the high competition in the manufacturing of membrane over the world have made it easily to deal with. In the GS, more than 25 RO desalination plants (licensed and unlicensed) of private investors have been constructed in the last three years. (Ismail M 2003, pp. 14-15) and seven water vendors based on desalinated water also exist.

4.2 Desalination Concept

Desalination is a physical process that aims to remove dissolved minerals from either brackish ground water or seawater (El Bana, H., 2000, p 110). About 97 per cent of water on the earth is in salty seas or oceans. The process aims to produce water with a quality that is accepted for domestic use or others such as industrial or agricultural use. The produced water is divided into two streams, one as potable water with a low Total Dissolved Solids (TDS) and the second with high percentage of dissolved salts (brine). The need for desalination as an alternative option is to secure water for drinking purposes. But desalination is not capable to other needs in for example the development in industry or tourism activities. Recent researchers and scientists are talking about the uses of biotechnology in desalination in the coming years. (El Bana, H., 2000, p.125).

Most of desalination projects spread along the coastal areas are located where water scarcity often occurs. The first plant to desalt seawater was registered in 1675(IHE-UNESCO 2003). In the 1872, Swedish engineer Carlos Wilson built the first industrial desalination plant. Till now, it is still producing 22.5 cubic meters of potable water a day (IHE-UNESCO 2003). During the last 20 years there has been an explosive growth of desalination plants as shown in figure (7). Most of this growth has been constructed in the oil rich Middle East countries and was based on distillation technology (EC 1993, p 22).

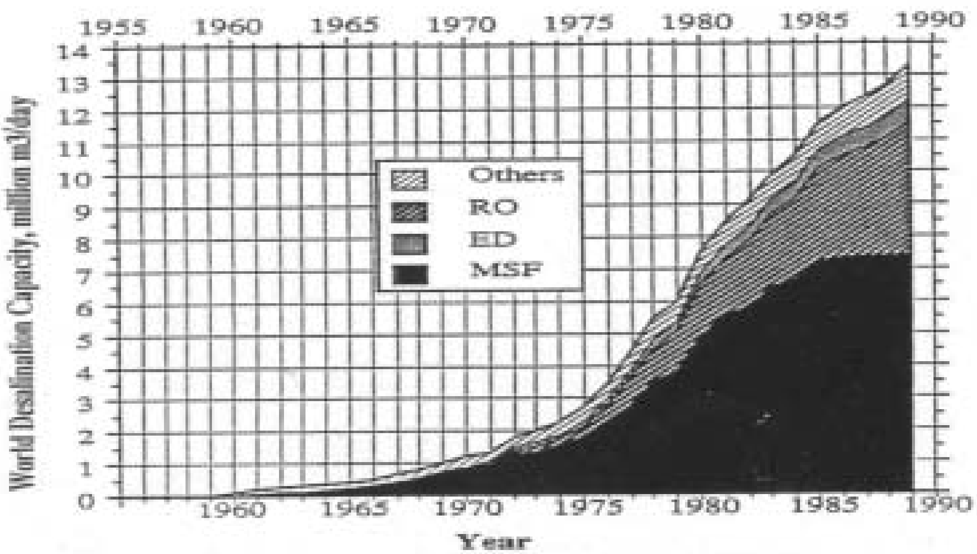


Figure (7) Growth of world desalination capacity by process *(Source: EC, 1993)*

In general, desalination plants with lower cost are to be found close to electricity plants or where fuel or energy is cheap.

> *Johansson, K. (2003) argues: "Desalination is an energy-intensive process which can use a variety of low-temperature heat sources, including solar energy, or electricity. The choice generally depends on the relative economic values of fresh water and particular fuels"*

The main goals of water desalination are:

- To increase the available quantity of potable water to consumers.
- To reduce the over-pumping from the groundwater.

The water desalination can be accomplished by different techniques that can be classified under three main processes (El Bana, H., 2000).

1. Thermal processes
2. Membrane processes
3. Other processes

Table (8) Classifying the desalination process according the used technology

Desalination Process		
1-Thermal processes	***2-Membrane processes***	***3-Other process***
Multistage Flush distillation (MSF)	Reverse Osmosis (RO)	Ion Exchange
Multiple Effects Distillation (MED)	Electro Dialysis (ED)	Membrane Distillation
Vapor Compression (VC)		Freezing separation
		Solar Distillation
		Nuclear desalination

Source: El Bana, H., (2000)

4.3 Types of Desalination Processes

4.3.1 Thermal desalination processes

- Multi-Stage Flash (MSF) distillation

This is a process where seawater is heated to its boiling temperature and passing it to a series of heat exchange stages and flows into large chamber in which the pressure is low. The low pressure causes some of water to flash (turn quickly) into steam. The steam is condensed into salt-free water. The seawater passes through several distillation chambers. Each chamber has lower pressure than the previous chamber, the final water is so pure that it is tasteless, and some salt must be tossed back to give it flavour (World Book, 2000).

- Multiple Effect Distillation (MED)

In this process, vapour produced by an external heating steam source is passed through several evaporators (effects) in series under successively lower pressures, and using the vapour produced in each effect as a heat source for the next. MED plants are typically built of units ranging from 2,000 to 20,000 M^3/day. Lower operating temperatures (70^{o}C) reduce potential for scaling and energy consumption, but require large heat transfer areas, which add to the physical size of the plant and increase capital costs.

- Vapour Compression (VC)

Vapour compression distillation is a process in which a mechanically driven heat pump is employed to recycle the latent heat.

4.3.2 Membrane-Based processes

They are used in two commercially important desalting processes. Each utilises the ability of membranes to selectively separate salts and water, however they differ in the nature of the physical process applied.

- Reverse Osmosis (RO).

RO is a widely used method for desalting seawater by using a pressure driven techniques. Water is forced to flow through small pores under high pressure through semi-permeable membranes or filters, while salt is rejected. The pressure differential must be high enough to overcome the natural tendency of water to move from the low salt concentration side of a membrane to the high concentration side, as defined by osmotic pressure. Pre-treatment is important in RO because the membranes must remain clean. Therefore larger particles are filtered and often multiple stages of membranes are used. No heating is necessary but the major energy requirements come from pressure. Small pores require high pressure and consequently more energy. The quality produced depends on pressure, salinity of source and efficiency of the membranes. Development of more efficient membranes and energy recovery devices has significantly improved the operating cost of RO plants in the past decade and great potential growth in seawater desalination has been recorded. Figure (8) shows schematic layout of a RO plant (EC, 1993).

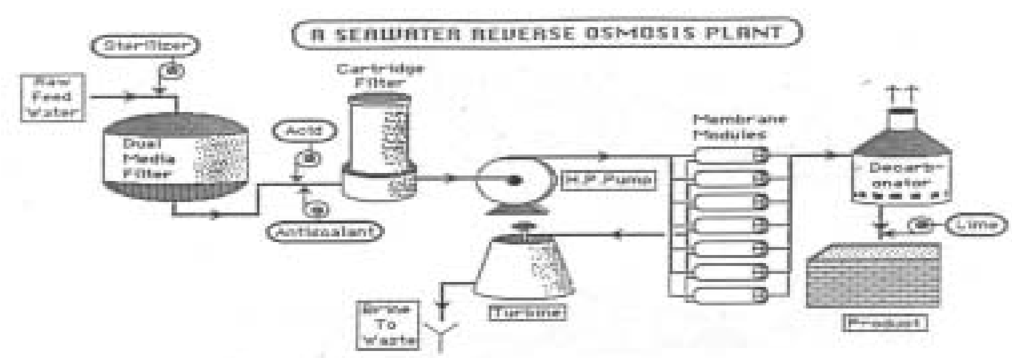


Figure (8) Schematic of the Reverse Osmosis RO *(Source: EC, 1993)*

The disadvantages of reverse osmosis technology compared to thermal technologies include sensitivity to the pre-treatment system capability and operator capability. Both of these disadvantages can be easily overcome with sufficient pre-treatment design and operating training programs.

- Electro dialysis (ED)

Electro dialysis is mainly used to desalt brackish groundwater (slightly salt). The process of electro dialysis is based on the fact that salt water breaks up electrically to sodium and chloride. It uses a large chamber divided into many compartment by stacks of thin plastic sheets called membrane. Two types of membranes are used, one type allows only positive ions (sodium ions) to pass through it and the other lets only negative ions (chloride ions).

> *Johanson, K., (2003) argues: The major technologies in use are the multi-stage flash (MSF) distillation process using steam, and reverse osmosis (RO) driven by electric pumps. A minority of plants use multi-effect distillation (MED) or vapour compression (VC). MSF-RO hybrid plants exploit the best features of each technology for different quality products (MSF gives purer water than RO).*

4.3.3 Other Processes

- Freezing Process

Other desalting processes are also being studied. During the 1970's, several plants were experimented with freezing as a method of desalination. When seawater freezes, the ice crystals that are produced form pure water in solid form. The salt is separated and trapped between the ice crystals.

The main problem lies in separating the ice crystals from the salt. This is usually done by washing off the salt with fresh water. The ice is then melted and becomes fresh liquid water. High costs and engineering problems have prevented the commercial use of freezing as a desalting method (World Book, 2000)

- Solar distillation

A very simple process that could be used to have potable water is by solar distillation. It can be done simply by filing a basin with seawater and covering it with sloping plastic or glass sheets. The collecting solar energy turns seawater into vapour and very salt water; the vapour will condense on the surface of the plastic sheet and be collected in special basin. This type of distillation produces a little water and it doesn't work in lack of sun, even though it is expensive and less efficient compared with other desalination process (World Book, 2000).

- Nuclear distillation

Application of nuclear power for desalination was used with beginning of 1960 by various national nuclear agencies. Nuclear reactors have some general characteristics, which differ, from conventional energy sources. The prospects of using nuclear energy for seawater desalination in a large scale are attractive since desalination is an energy intensive process. The heat from nuclear reactor and/or the electricity produced by such plants can be used at a desalination facility. The safety, regulatory and environmental concerns in nuclear desalination were those related directly to nuclear power plants.

4.4 Existing Desalination Plants in the Gaza Strip

In the beginning of the nineties, three pilot Reverse Osmosis (RO) desalination plants constructed as brackish water desalination, one plant in Deir El Balah and two plants in Khanyunis. The average production per plant is about (30 to 40) M^3/hour. Those plants aim to improve the public health of people and to secure partially accepted water for drinkable use in their areas. By time the efficiency of the plants have decreased due to the increase of salinity of the brackish water well and lack of experience of local staff in operation and maintenance. However, using of desalination water as an alternative source for drinkable use has developed and increased as type of investment projects of the private sector.

4.4.1 Public plants

- Deir El Balah RO desalination plant

In June 1993, the Israeli Civil Administration erected a pilot RO brackish water desalination plant for Deir El Balah municipality (Middle of Gaza Strip) by an American funding, and implemented by EMS a subsidiary of an Israeli water company (Mekerot) at a turnkey contract cost of 650,000 US$. The function of the plant was to desalinate brackish water with a capacity of $60M^3$ /hr at recovery rate of 75%. The brine is pumped to the sea (EC 1993, pp. 13-22). The produced water is pumped for people at southern part of the city, besides one free filling point in front of the plant for consumers. Today, the productivity of the plant has decreased to $25M^3$/hr with high cost in O&M. It forms a high financial load on the budget of the municipality due to high cost per cubic meter production (Site Visit, October 2003).

- Khanyunis municipality RO plant (I)

In May 1997, Khanyunis municipality had received a grant from the Italian Government through Italian Developing Program. The Italian company CISS has designed and built a RO brackish water desalination plant nearby the existing municipal well. The total capacity of this plant is estimated at $55M^3$ /hr. The turnkey contact cost of the plant was at US$ 500,000. The plant aims to pump water to parts of the city that suffer from lack of potable water according to an allocated distribution system. In addition, free filling taps are spreading around the plant. Trucks with desalinated water are distributing water to other areas as well. The brine is pumped to the sea. (Site visit, October 2003).

- Khanyunis municipality RO plant (II)

In July 1998, Khanyunis municipality had received another grant from Italian Government through Italian Developing Program. The Italian company CISS also this time designed and built a RO brackish water desalination plant nearby the existing municipal well. The total capacity of the plant is estimated at $80M^3$ /hr. The turnkey contact cost of the plant was at US$250,000 (Site visit, October 2003). The plant is used in the same manner as the RO plant (I).

- North Gaza RO plant

The Palestinian National Authority (PNA) has received a grant from the French Government to build a RO seawater desalination plant. This project was designed to serve the people in El Shati refugee camp (80,000 inhabitants) and the area nearby who are suffering from the deterioration of water quality and bad environmental health.

In April 1999, Degremont (French company) had started the works for design and building the North RO seawater desalination plant close to the beach. The plant was designed to two phases, phase (I) is to produce 1250 M^3 /day to be increased to $5000M^3$/day in phase (II). The design of the plant was based on the use of beach wells. According to the contract between the PWA and Degremont, the total production cost was estimated at US$ 0.94 per cubic meter (PWA, Degremont 1998, pp. 2-10).
The site of the plant is nearby the Palestinian- Israeli boarder, and during Intifadah, the site became unsafe for continuing the work. In December 2000, the work in the plant was frozen and the percentage of accomplished work is about 80%. Completion of the remaining works is conditioned with improvement of the security conditions on site (Site visit, October 2003).

- Middle Area RO plant

By 1998, Palestinian National Authority has received a grant from Austrian Government for design and construction of seawater desalination plant to serve people in Middle area in general and Deir El Balah and Zwaydah in particular (65000 inhabitants). The design capacity is to produce 600 M^3/day for phase (I) and to be increased up to 1200 M^3/day in phase II (PWA, Vinzenz Trugina. 2000).
The function of the project is to pump the produced water from the plant to about 13 water shops covering two intensive residential areas through a separate water network. In addition, extend the service to other far areas that are in bad need for potable water. The source of seawater comes from two existing beach wells close to the shore. The brine is discharged to the sea. The construction of the

plant had been launched in July 2000, and the elementary handover was in December 2002(Site visit, October 2003).

4.4.2 Private RO desalination units

- RO houses units

Due to the deterioration of the quality of municipal water supply in the Gaza Strip people has become more aware of impact of potable water on the public health. They try to solve their problems by installing small RO house units. By the beginning 1996, enterprises in the water sector have started to import small and feasible RO desalinated units with small capacity (120-240 liters/day) that provide people with their needs (drinking and cooking) purposes. This idea has spread on a wide range and been adopted by many users such as, clinics, schools, small institutions, children centers, and so on. Due to the progress in the RO manufacturing and high competition in the market, the average cost of small units with capacity 120 l/c/d has dropped from US$500 in 1997 to US$250 in 2002.

In some cases this method has constraints related to human health aspects since there is no adjustment or control on the quality of water produced at output whether it contains the chemical elements required for hygienic purpose. Table (9) shows types and costs of RO devices that are available in Gaza's market (PHG 2002, p18).

Table (9) Different types and prices of RO domestic units available in the local market

Filter Type	**Made in**	**Cost in US$**
1. King 2000	USA	270
2. U.S Filter (Amatic Company)	USA	300
3. Flowmatic filters	USA	290
4. World water	USA	320
5. Aqua water	Taiwan	245
6. TGI	USA	؟
7. White Snow	Made in USA but assembled in Korea	300
8. Best Life- pure water	Made in USA but assembled in Korea	250
9. D.Q	Made in USA but assembled in Korea	from 280-700 according to type
10. D. Fisher		320
11. Espa Max		240
12. Water Fresh		270
13. Bio ceramic		265
14. Kemflo Filter		280
15. Universal		600
10. D. Fisher		320

Source: PHG, (2002)

- Small RO for commercial investments

The phenomenon of increasing the investments in construction of RO desalinations plants has developed in the Gaza Strip since 1998. This is due to the poor quality of the municipal water delivered for domestics use. Chemical analysis of municipal water wells shows few of the municipal water wells having potable water for drinking according to the WHO standards. Between 1999 and 2003, the total number of RO private desalination plants for commercial use was 25, in addition to seven vendors. Tables (10) and (11) show the details of small scale RO private desalinated units and water vendors in the Gaza Strip.

Table (10) Commercial RO private desalination plants in the local market.

No.	Plant Name	Governorate	Source of row water	Design capacity M^3/day	Quantity sold M^3/day	Brine discharge	TDS (Mg/L)
1	**Al methali**	**North**	brackish well	96	96	irrigated gardens	**51**
2	**Al khayria1**		municipal water	12	12	Municipal network	**22**
3	**Al karama**		municipal water	20	10	NA	**NA**
4	**Al gadir**		municipal water	30	20	Municipal network	**100**
5	**Yaffa**		brackish well	96	40	Municipal network	**NA**
6	**Al ain safi**		brackish well	90	40	irrigated gardens	**65**
7	**Al Ain**	**Gaza**	brackish well	40	30	Municipal network	**46**
8	**Al khayria2**		municipal water	12	12	Municipal network	**78**
9	**Al khayria3**		municipal water	12	12	Municipal network	**187**
10	**Salsabil**		brackish well	20	10	irrigated gardens	**205**
11	**Sehaa**		municipal water	10	6	Municipal network	**51**
12	**Al janoub**		brackish well	60	40	Wadi Gaza	**183**
13	**Al kemma**		municipal water	12	12	Municipal network	**35**
14	**Al fardaws**		brackish well	100	60	Municipal network	**60**
15	**Al sahib**		brackish well	100	40	Municipal network	**57**
16	**Al sabra**		brackish well	20	10	Municipal network	**83**
17	**Akwa**		brackish well	1200	120-80	Municipal network	**260**
18	**Al khayria4**		municipal water	12	12	Municipal network	**76**
19	**Al khawthar**		brackish well	40	20	Municipal network	**75**
20	**Al shalal**	**Middle**	municipal water	12	12	Municipal network	**40**
21	**Al khayria5**		brackish well	12	12	irrigated gardens	**NA**
22	**Al furat**		brackish well	50	20	Wadi Gaza	**120**
23	**Al westa**		brackish well	12	12	irrigated gardens	**185**
24	**Zamzum**	**Rafah**	brackish well	20	10	Municipal network	**37**
25	**Al furat**		municipal water	20	10	Municipal network	42

Source: Ismail, M., (2003)

***NA**: not available*

Table (11) Existing of the water vendors in the Gaza Strip water market

No	Vendor name	Location	Source of desalination water	Sold water (M^3/day)	TDS (Mg/L)
1	Mecca	Gaza	Industrial zone RO plant	12	**270**
2	Al ain	Gaza	Al ain RO plant	40	**80**
3	Al nabaa	Gaza	Khanyunis municipality RO plant	12	**140**
4	Al faoumi	Gaza	Al Methali RO plant	8	**110**
5	Al saffa	Rafah	Khanyunis municipality RO plant	6	**145**
6	Al marwa	Rafah	Khanyunis municipality RO plant	4	**140**
7	Al madina/Hanin	Rafah	Khanyunis municipality RO plant	5	**150**

Source: Ismail, M.(2003)

This huge number of plants located in a tiny area like Gaza Strip reflects the level of awareness of people regarding the requests needed for accepted water. Venders extend their services to water customers by using trucks, or installing small stainless steel tanks in front of shops. Unfortunately, those huge numbers of tanks need intensive efforts for monitoring and control. The selling price of this water is about 1.0 NIS per 20 liter (US$ 0.2). Those small plants comprise a challenge in marketing the production of the large-scale desalination projects and it has adverse impact on the environment regarding discharging the brine into the sewerage system. PWA in cooperation with Ministry of Health is available to issue licenses for those plants

The results of chemical analysis for selected RO plants in table (13) indicate a wide range of values of the chemical elements where no recommended minimum values for each element or compound exist. Tables (12) and (13) point out chemical and physical analysis of water sample that produced from private RO and the recommended values as guideline for users.

Table (12) Physical and chemical analysis of water produced from private RO plants in the Gaza Strip

Plant Name	Chemical; Elements/Compound												
	Turbid.	Colour	PH	E.C	T.D.S	NO3	CL-	SO4	Alkal.	Hardness	Ca++	Mg++	K+	Na+
Al Ain	<5	<5	6.96	75	**46**	6.02	21.3	1	17.3	33.1	5.5	4.6	0.2	9
Mecca	<5	<5	6.9	161	**100**	12.8	35.4	5	19.8	49.7	4.1	9.6	0.2	24
Ammer	<5	<5	5.51	97	**60**	12.2	21.3	1	17.3	36.8	8.1	4	0.3	9
Salsabil	<5	<5	6.22	401	**205**	2.2	14.2	1	17.3	27.6	5.7	3.3	0	6
Sehaa	<5	<5	5.64	82.2	**51**	17.8	14.3	1.88	16.4	24.6	2.55	4.42	0.7	11.5
Al janoub	<5	<5	6.72	274	**153**	9.4	64.4	7	32.8	25.6	4.3	3.6	0.4	43
Al chalal	<5	<5	6.21	65	**40**	22.7	14.3	2	19.1	20.7	1.76	3.9	0.3	9
Al furat	<5	<5	5.46	67.8	**42**	10.7	14.3	1	8.2	18.6	4.4	2	0.1	12
Al saada	<5	<5	5.7	176	**109**	44.5	58	5.8	62.8	31	4.5	4.7	0.6	65
Al gema	<5	<5	6.54	86.6	**53.7**	6.4	21.4	0.8	33.4	24.5	7.7	1.3	0.9	8

Fardaws	<5	<5	5.79	167	**103**	31.7	28.5	1.5	25	55.1	5.2	10.2	0.6	20
Al shaaba	<5	<5	5.89	92.2	**57.2**	15	13.9	1.2	13.9	18.5	3.4	2.4	1	14.2
Al sabra	<5	<5	6.05	135	**83**	52.7	14.3	3	16.4	22.6	3.4	3.41	2.8	23
Akwa	<5	<5	7.89	389	**238**	16.3	83.5	6.14	61	49.4	6	8.4	0.3	70
Al khayria	<5	<5	7.01	36	**22.3**	13.8	7.16	1	19.1	24.6	2.55	4.4	0.7	5.5
Hijazi	<5	<5	5.7	69	**42**	14.5	14.3	2	10.9	14.4	2.1	2.2	0.1	12
Thuhair	<5	<5	7.73	200	**124**	29.3	43	6.5	32.8	47.2	10.2	5.3	0.3	24.3

Source: Ministry of Health (2003).

Table (13) Physical and chemical maximum and/or recommended values of drinking water according PWA and WHO standards

Materials	**Turbid.**	**Colour**	**pH**	**E.C**	**T.D.S**	**NO2**	**NO3**	**CL-**	**SO4**	**Alkal.**	**Hardn.**	**Ca++**	**Mg++**	**K+**	**Na+**
Measurement unit	NTU		units	Micromho /Cm	Mg/L	Mg/Las NO_2	Mg/L as NO_3	Mg/Las CL	Mg/L as SO4	Mg/Las HCO_3	Mg/Las $CaCO_3$	Mg/Las Ca	Mg/L as Mg	Mg/L as K	Mg/L as Na
PWA*(max.)	<4	max 15	6.5 to 8.5		**1500**	0.1	70	600	400	400	600	100-200	150	12	200
WHO**	5-50	5-25	7- 8.5	1200-3300	**500-1500**	Nil	45-90	250-600	250-400	200-450	200-500	80-200	50-150	0.5-5	0.0-200

**Source: PWA, (2000).* ***Source: WHO, (1985)*

4.5 Desalination plants in Some Countries

Desalination plants have been experienced in many countries. More than 120 countries are nowadays using desalination. The total number of desalination units all over the world is estimated at 13,600 units producing around 26 MCM/day (El Bana, H., 2000, pp. 110-120).

World Water Council, 3rd World Water Forum reported that the Middle East countries are suffering from water scarcity and thereby using water desalination option for domestic use (World Water Council, 2002 p.19).

Table (14) Current source of the municipal water supply in the water scarce countries

Country	**Source water for municipal use**		
	Surface water %	**Groundwater %**	**Desalination %**
Malta*	0	35	65
Jordan	0	100	0
Yemen	0	100	<1
Bahrain	0	60	40
Kuwait	0	For dilution	~100
Qatar	0	0	~100
Saudi Arabia	0	50	50
Libya	0	98	2

**Outside the region, but a good Mediterranean example.*

*** Source: World Water Council (2002)*

As having potable water for drinking purposes is necessary for human health, many countries have seen a trend to use bottled and vendor water for drinking.

Gleick, P. et al. (2002, p.13) illustrate in Table (15) examples from countries that use bottled and vended water for drinking purposes in urban and rural areas.

Table (15) Bottled and Vended Water: Urban and Rural Areas (WHO 2000).

Country	Year	Source of water	Percentage of the urban Population that consumes Bottled or vended water	Percentage of the rural population that consumes bottled or vended water
Angola	1996	Tanker Truck	25.2	0.8
Cambodia	1998	Vendor	16	3.5
Chad	1997	Vendor	31.5	0.5
Dominican	1996	Bottled water	37	6.3
Ecuador	1990	Tanker Truck	16	7
Eritrea	1995	Tanker Truck	30.5	1.4
Guatemala	1999	Bottled water	25.5	7.1
Haiti	1994	Bottled water	26	0.3
Jordan	1997	Tanker Truck	1	10.6
Libya	1995	Tanker Truck	6.8	13.9
Mauritania	1996	Vendor	53	0.9
Niger	1998	Vendor	26.4	1.9
Oman	1993	Bottled water	39.5	42
Syria	1997	Tanker Truck	4.1	11.3
Turkey	1998	Bottled water	14.9	1
Yemen	1997	Bottled water	14.6	0.1

Sources: WHO, (2000)

4.6 Proposed Gaza Sea Water Desalination Plant

The Feasibility Study (PWA, CDM 2003) reports that the United States (US) Government is working to fulfill future needs has been established in accordance with the provisions of Article 40, Interim Agreement between Palestine and Israel. The agreement aims to strengthen cooperation already established by the Israeli- Palestinian-American Water Committee. So the US addresses the issue of.

brackish or seawater desalination in the Gaza Strip. On this sake, United State Agency for International Development (USAID) has been committed to the Palestinian National Authority to give a grant for designing, constructing, and supervising the RO Gaza Sea Water Desalination Plant (GSWDP). The production capacity of phase (I) is estimated at 60,000 M^3/day (~ 20 MCM/year) and the plant is assumed to be in operation by the year 2005. But now, and because of political conditions, this date may be postponed. The production phases are estimated according to the PWA, CAMP report (2001) as follows:

Phase 1: 60,000 M^3/day in operation by 2005

Phase 2: 60,000 M^3/day in operation by 2008

Phase 3: 20,000 M^3/day in operation by 2014

Phase 4: 10,000 M^3/day in operation by 2018

The target final capacity shall be 150,000M^3/day (~55MCM/year) by the year 2020. Seawater intake shall be employed for the feed water to the plant. Samples were collected from the Mediterranean Sea close to the proposed site intake one Km far from the shore. Figure (9) shows location of existing and proposed RO seawater and brackish water desalination plants in the Gaza Strip

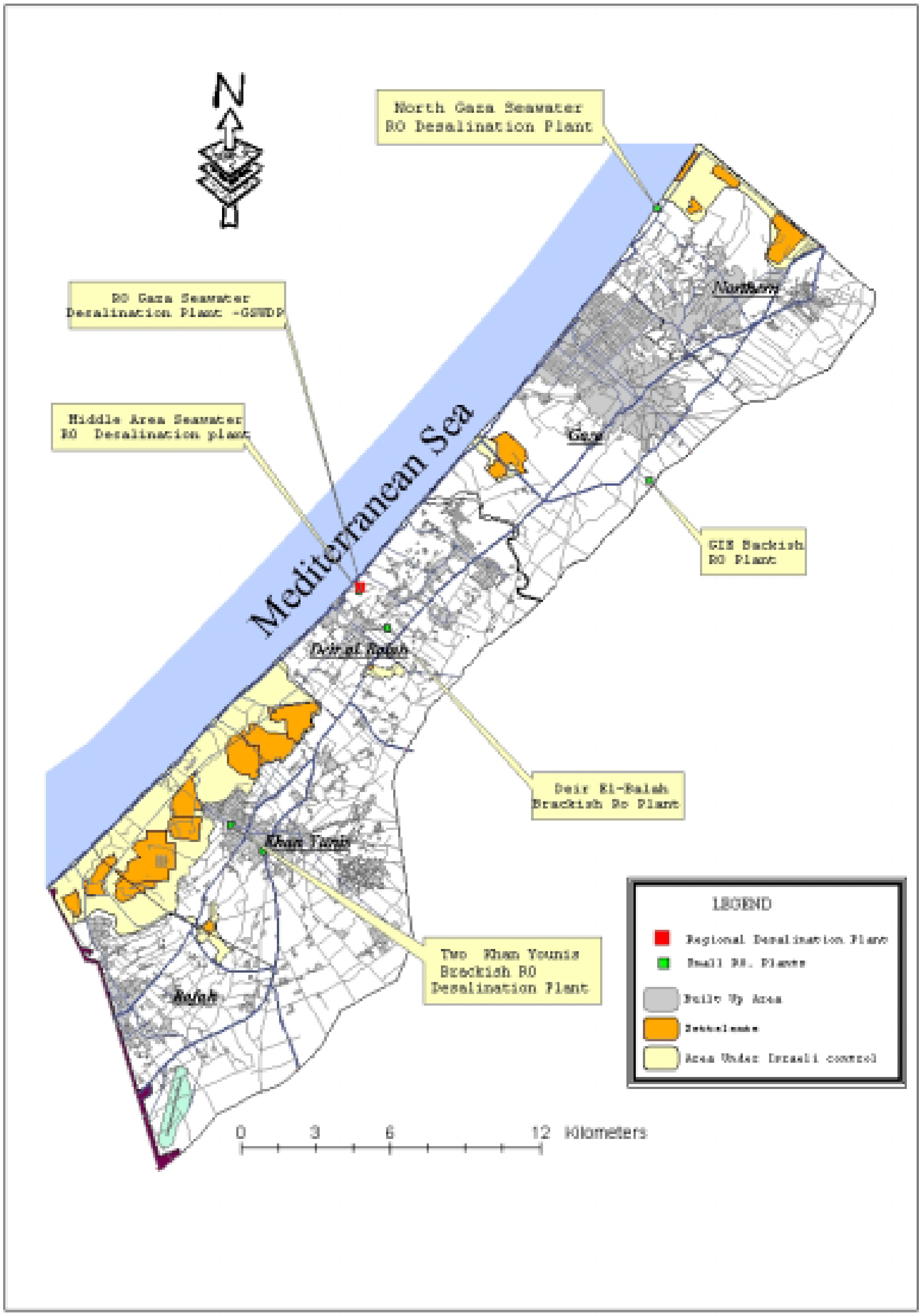


Figure (9) Location of desalination plants in Gaza Governorates *(Source: PWA, Data Bank 2003)*

The average TDS was 36,000 to 40000 Mg/L and the average chloride was 18,000 to 20,000 Mg/L. By the end of the construction phase of the GSWDP, the turnkey American contractor will carry out the responsibility for Operation for three years in a contract with UASID, then the operation contract will be shifted to the Municipal Coastal Water Utility (MCWU) in stead of USAID for a possible period of seven years. Since the operation cost of the plant will be a load on the MCWU during this extended operation contract, the World Bank as part of its obligations in Gaza 2 project is expected to financially support the CMWU. This large-scale plant will serve all people in Gaza Strip through the Gaza Regional Carrier. The site of the plant lies in the middle area of the strip, with total land area at 27,000 M^2.

According to (PWA, CDM 2003) and master plan study, the *operation and maintenance* costs will be US**$** 0.54/$M^3$ in the first phase and is estimated to drop to US$ 0.42/M^3 when the final phase is completed based on energy costs of US$0.055/KWh. The master plan study argues, that the tariff structure is designed not only to encourage the water conservation but also to allow an appropriate rate to support the expansion of desalination facilities.

4.6.1 Feasibility of Gaza Sea Water Desalination Plant

According to the Feasibility Study (PWA, CDM 2003), USAID signed a contract number LAG-I-00-99-00017, Task Order. No. 807 with Development Alternative, Inc. (DAI) to conduct feasibility study prepares bidding documents and contracts for the design, construction and operation of the GSWDP. The feasibility study includes the technical and financial evaluation, and issues associated with the design, construction and operation of GSWDP facility in the Gaza Strip. The project will be contracted as a Designed, Built and Operated (DBO) contract funded by USAID. The contractor will also enter into a 3 years Operation and Maintenance (O&M) contract with USAID and will be extended to additional 7 years with the Palestinian Coastal Municipal Water Utility (CMWU). The estimated cost of phase (I) is at 60MUS$. It will be a grant from USAID. The design capacity is estimated to produce 60,000 M3/day of desalinated water from sea using reverse osmosis technology (RO). And, it will be expanded to 150,000 MCM/day by year 2020.

The quality of raw water from Mediterranean Sea is approximately 40,000Mg/L as total dissolved solids (TDS). The produced water must meet salinity level (TDS) of 350 Mg/L, Chloride levels of 250 Mg/L, and to meet the World Health Organization (WHO) standards for other water quality constituents. The source of power for the proposed plant is from the new 140 MW thermal power plant via the Gaza West Grid Substation, located about 11 Km from the plant site. The anticipated power cost is about US$0.052-US$0.055/KWh for the facility. The land is being provided by the PWA and is located about 650m from the sea.

4.6.2 Summary of Gaza Sea Water Desalination Plant facilities

The project components include a sea water intake, a brine rejection outfall, two pumping stations, storage facilities, and 2 Km pipeline to connect with Gaza Regional Carrier. Parts of infrastructure will be built to match the final capacity of 150,000M^3/day.

In September 2001 (Metcalf &Eddy) through CAMP activities prepared the Gaza Desalination Master Plan as part of their contract with USAID for the benefit of PWA. The feasibility study in the master plan assumed the followings (PWA, CDM 2003): -

- Sea water desalination plant recovery is 40%
- Feed water is approximately 40,000 Mg/L as TDS
- Product water is specified to be 350 Mg/L as TDS and 250 Mg/L as chlorides
- Seawater open intake 1km far from the shore.
- RO is the most recommended technology
- Pre-treatment and post treatment (chlorination, coagulation, filtration, dechloronation, antiscalant) are required
- Two pass system to achieve the chloride level of 250 Mg/L, seawater membrane for first pass (47% recovery) and brackish water membrane in the second pass (90% recovery).
- Energy recovery of 35% was assumed by using work exchanger technology.

4.6.3 Cost of cubic meter of desalinated Water

By beginning of 1960^S, water desalination technology has been started to be as an alternative conventional water resource. The main challenging at that time was the high cost of produced water. The limiting factor that is still affecting the price of cubic meter is the power cost and the water quality of the produced water.

In the last decay, a rapid progress and high competition has happened in the RO desalination technique and technology. The main aim of that is to decrease the power consumption. New researches and figures argue that to produce one cubic meter of desalinated water 3.5 KWh or less are needed.

The following main factors that affect the cost of desalinated water:

1. Contract scheme and its conditions (Lease Contract, BOT, BOOT, Concession Contract,)

2. Plant capacity
3. Type of technology
4. Energy cost
5. Contract period
6. Salinity of feed water
7. Quality of the product
8. Special site considerations (integration with source of power supply)
9. Cost of capital (loans, bank interest,)

In the Feasibility study report (PWA, CDM 2003 p77) submitted by USAID to PWA, the sections related to capital cost, operation and maintenance cost, and financial analysis of GSWDP were intentionally left blank.

> *PWA, CDM. (2003). The feasibility study argues that the privatised projects for large scale facilities awarded over the last few years indicate desalinated water from very large co-generation thermal plants is being sold for US$0.70-US$0.73 /M^3 while desalinated water from small to large single purpose seawater RO plants is being sold for US$0.50-US$0.73 /M^3 (ARI, 2001).*

Regarding water desalination market, Israel signed a Build, Operate, and Transfer (BOT) contract with the international French water company VIVENDI to construct the RO seawater desalination plant at Ashkelon/Israel, with a capacity of 100 MCM/year at production cost at US$0.527/$M^3$.

Thus the energy consumption is the main a limiting factor in the economic feasibility in the determination of the cost of cubic meter of desalinated water. Energy devices are critical to the cost effectiveness of today's seawater desalination plants. Those devices aim to lower the net high- pressure power consumption. Since GSWDP will not be a co-generation power plant, power costs are significant. The facility (GSWDP) will be empowered by the new Gaza 140 MW thermal power plant. The bulk of operation costs of the facility are in the energy costs, assessed to as high as 72% of total O&M costs. The master plan indicates those costs based on fixed units of cost of power at US$0.055/Kwh of consumption.

> *Wayne, O., (1999:pp.4-6) argues: "The average price of desalinated sea water is one-tenth of what it was twenty years ago, dropping dramatically from US$ 5.5 per cubic meter in 1970 to US$0.55 in 1999, including interest, capital recovery and O&M. Today's cost of construction of a reverse osmosis desalination facility*

remains constant at about MUS$ 3 per million cubic per year yield (hence, a 100 million cubic meter per year sea water desalination plant will cost about MUS$300 to construct), regardless where it is built in the world. Construction is modular, and can be built incrementally to the capacity needed".

For purposes of rough simulation of cost elements, table (16) presents t*wo-point views* of desalination consultants (Wade and Wilf) regarding the cost components of water desalination plants. It can be concluded that the average production cost is most likely less than US$0.75/$M^3$ (table 16).

Table (16) the items cost of cubic meter produced by Reverse Osmosis RO

Cost component (US$/$M^3$)	**Wade**[1]	**Wilf**[2]
Electric Power	0.10	0.25
Operation / Maintenance	0.13	0.06
Spares	0.03	-
Chemicals	0.05	0.06
Membranes	0.10	0.05
Capital	0.34	0.32
Total	**0.75**	**0.74**

Source: IHE- UNESCO, 2003

Assumptions:

1) Energy 3.5 KWh/m3 Power 0.03 US$/KWh

2) Energy 4.2 KWh/m3 Power 0.06 US$/KWh

The estimated cost of a potable cubic meter produced from the RO Sea water desalination plant at the Middle Area plant according to the Trugina study (Austrian consultant) and submitted to PWA-Gaza was found at US$0.9 /$M^3$. More details are in table (17).

Table (17) the items cost of the RO seawater desalination plant at Deir El Balah.

Potable water costs	
Design Basis:	**Values**
Production	600 M^3/day
Operation time	23 hours /day
Water recovery	40%
Feed water	Sea water
TDS	41 000 Mg/L
Product water quality	< 1000 Mg/L
Cost Basis	
Item cost	**Costs per cubic meter product. Water in**

	(US$/$M^3$)
Electric Power	0.43
Chemicals	0.10
Filter cartridges	0.10
Membrane replacement	0.08
Spares parts	0.07
Personal costs	0.20
Total	**0.90**

Source: PWA, Trugina (2000)

4.6.4 Environmental Impacts of GSWDP'

The proposed desalination plant is a recommendation of the master plan (2000) which has done through the Integrated Aquifer Management Plan (IAMP). The objective was to recover and sustain the coastal aquifer by 2020.

4.7 Contractual Quality of Desalination Plants in the Gaza Strip

In the last decade, the Palestinian Water Authority has signed agreements with both Austria and France governments to build two seawater desalination plants 600 and 1250 m3/day respectively in addition to a Memorandum Of Understanding (MOU) with USAID to build a 60,000 M^3/day seawater desalination plant. The contractual guarantee values of water produced from the three seawater desalination plants are listed in table (18).

Table (18) The Guarantee values of water produced from desalination plants in the Gaza Strip

No.	**Parameter**	**Guarantee values**		
		RO Austria*	**RO French****	**USAID*****
1.	Turbidity (NTU)	5		0.1 maximum
2.	pH	7 – 8.5		7-8
3.	Temperature			Maximum increase of 5 C above ambient seawater temperature
4.	T.D.S (Mg/L)	<500 – max1000	400	350, with penalties over 400
5.	Chloride (Mg/L)	200		250
6.	Sulphate (Mg/L)	<250		Other water quality constituents according WHO standards.
7.	Nitrate (Mg/L)	<50		
8.	Alkalinity (ppm $CaCO_3$)	30 – 100		
9.	Hardness (ppm $CaCO_3$	50 – 200		
10.	Langlier Saturation	+0.1 - +0.3		

11.	Residual Chlorine (Mg/L)	0.3 – 1		
	Total water production: Phase I / phase II	**600/1200 M3/day**	**1250/5000 M³/day**	**60000/150000 M³/day**

Source: Feasibility Study (PWA, CDM 2003.pp2-57).
** Contract agreement between PWA & Trugina (Austrian consultant), Sep 2000.*
***Contract agreement between PWA & Degremont (French Company), March 12th 1998.*

4.8 Linkage with Proposed Gaza Water Regional Carrier

A regional water carrier is going to be linked with GSWDP in order to effectively utilize the water produced from the plant at a rate of 20MCM/ year in phase (I) up to 55MCM by year 2020). In addition to other good quality water sources available in the GS, such as water from local aquifer, 10 MCM/year from Mekerot (Article 40), and other sources from outside will be distributed using the Gaza Water Regional Carrier.
Figure (10) shows location of existing and proposed RO seawater and brackish water desalination plants in the Gaza Strip.

PWA is planning to construct the Gaza Regional Water Carrier (GRWC) serving the Gaza Strip from north to south with the necessary loops for distribution in the different cities and villages. The pipe will range in diameter from 1.25m to 0.25 metres at the distribution loops. It corporates blending reservoirs in addition to boosting stations pumping water to storage tanks which in turns supply water to the distribution system. This will allow almost equal water quality to be distributed all over the Gaza Strip and will facilitate a more effective tariff system. The total length of the carrier will be around 91 Km. It will be equipped with Supervisory Control And Data Acquisition system (SCADA) connected to a central room for monitoring the different parameters and controlling flows at the different nodes. The system will be operated using telemetry facilities. The total estimated cost of the project is around 90 MUS$ out of them 60 MUS$ are committed as a grant by USAID which will be used to implement a basic part of the project. The bidding process has been started during the year 2003 as a turnkey contract scheme. It is worth to mention that since most of the water quantities entering this carrier will be from the desalination plant, the project has to be completed later by the time the desalination facilities are completed. Other wise the system cannot be operated in a feasible and a practical way with the water from other available sources only (PWA, CAMP, Vol.2 .2003). Appendix (3) shows the route of the Gaza Regional Water Carrier (GRWC) with the desalination facilities.

CHAPTER 5

5. SURVEY RESULTS AND DISCUSSIONS

A questionnaire for the water consumers all over the Gaza Strip (appendix1) was distributed as a percentage of the population count (appendix 3). Interview questionnaires (appendix 2) also were carried out with the water professionals from different institutions in the Gaza Strip.

5.1 Results of Water Consumer Questionnaire

5.1.1 Sample size

525 Questionnaires were administered to explore the opinion of people that use municipal water for domestic use. It was designed in Arabic Language to be understood easily by the target population. The questionnaire was developed according to initial responds from the customers. It covered both urban and rural areas in the Gaza Strip. 480 consumers responded to questionnaire. The questionnaires were cleaned and checked for inaccurate responds. The net size of the study sample was 428 questionnaires.

The water departments in municipalities and village councils gave help in distributing the questionnaires to consumers coming to pay their water bills. In addition some questionnaires were distributed randomly for different categories of the society like teachers, workers, employees, and housewives. The response rate of the study sample was 91.42%. Because of having some incomplete or inaccurate questionnaires, they were cleaned and some of them were omitted to facilitate the statistical analysis.

5.1.2 Reliability analysis

A random sample of 35 consumer questionnaires was returned to the same water consumers in order to check the questionnaires reliability instrument. The target consumers were asked to fill the questionnaires again after two weeks. The reliability of questionnaires tested by using the Statistical Package for Social Sciences (SPSS). The result shows that the reliability of the instrument equals 0.85, which is acceptable (Okasha M., 2002, pp.137-150). .

5.1.3 Results of water consumers questionnaires

Questionnaires were administered with 428 respondents 35.5% out of them were in the age category (36-45) years old with males as the majority 84.3%. Detailed results of the age and sex categories are given in appendices 7.1 and 7.2. The study sample of living area category indicates that 35.3% of respondents live in the Gaza Governorate since it has the biggest population count (appendix 7.3). 55.6% of respondents hold Bachelors or above while 7.0% hold elementary education (appendix 7.4).

36.2% of consumers have 7-9 family members as shown in (appendix 7.5). The study sample indicates that 74.1% have a month family income between 1200 to 1800 New Israeli Shekels (NIS), while only 1.4% has above 4000 NIS as seen in (Appendix 7.6).

Regarding the water sources, results indicate that 93.67% use a municipal source. More details are found in (appendix 7.7). 46.1 % of the consumers were not satisfied with the municipal water quantities while 49.1% were satisfied as shown in (Appendix 7.8).

77.6% of consumers shown that they are not satisfied with the quality of water that is delivered by municipalities for drinking purposes while 4.2% of them were completely not satisfied with it. On the contrary a total of 17.1% were either completely satisfied or satisfied with it. The results are shown in (Appendix 7.9)

Because of the bad municipal water quality some people in the Gaza Strip started to look for alternative sources for drinking water. This is represented in the tendency to purchase bottled water, desalinated water from water shops or vendors or the installation of domestic RO units. Others who are satisfied with the quality of municipal water or do not have the financial resources to purchase alternative drinking water kept using the tap water. As a link to the question regarding the quality of water, the result in table (19) indicate that 50.2% of consumers are using water shops (vended water) that sell the water produced from private desalination plants. 21% of study sample have their own RO house unit.

Table (19) Distribution of the study sample by category of purchased water for drinking purposes

	Type of water source	Frequency	Percent	Valid %	Cumulative%
Valid (complete answer)	*Bottled*	18.0	4.2	5.0	5.0
	Water shops	215.0	50.2	59.6	64.5
	RO house unit	90.0	21.0	24.9	89.5
	Tap water	38.0	8.9	10.5	100.0
	Total	361.0	84.3	100.0	
Missing (no answer)	*System*	67.0	15.7		
Total		428.0	100.0		

Due to bad quality 22% of consumers paid for purchased water within the category 21-30 NIS /month, while 9.8% of them pay more than 45NIS/month for drinking purpose in addition to the municipal water bill. More details are shown in appendix (7.10).

In order to have a comprehensive idea about the link between costs of drinking water purchased with the municipal water bill. Appendix (7.11) indicates that 37.6% pay more than 60 NIS/ two months, while 12.1% pay less than 20 NIS/two months. The majority, which represents 66.8%, pay more than 45 NIS per two months.

Because of the anticipated higher costs with water expected from GSWDP as a non-conventional water source compared with the costs of municipal water, the customers' willingness to pay was examined. Table (20) shows that 56.5% of consumers are not willing to-pay additional cost to have desalinated water from GSWDP, while the rest accept the additional cost.

Table (20) Distribution of study sample by category of willingness to pay

	Response	Frequency	Percent	Valid %	Cumulative%
	Yes	186.0	43.5	43.5	43.5
Valid	***No***	242.0	56.5	56.5	100.0
	Total	428.0	100.0	100.0	

Out of the 43.5% of respondents who accepted to pay additional cost in order to have desalinated water 90.86% are ready to pay additional (1-25%) to the municipal water bill as shown in Table (21).

Table (21) Distribution of study sample by category of value to be added on the municipal bill

	% exstra on water bill	Frequency	Percent	Valid %	Cumulative%
	1-25%	169	39.5	90.86	90.86
Valid	*26-50%*	14	3.5	8.06	98.93
	51-75%	1	0.23	0.53	99.54
	76-100%	1	0.23	0.53	100.00
	Total	185	43.21	100.00	
Missing	*System*	243	56.54		
Total		428	100.00		

5.1.4 Discussion of water consumer questionnaires

It is clear the respondents with university degree or above representing 55.6% are aware to some extent of the water problems in the Gaza Strip and its effect on their health. 74.1% of consumers have a family income less than 1800 NIS. Although 93.7% of consumers used municipal sources for domestic purposes, they were not satisfied with the quantity of municipal water. In addition, more than 77.7% of people were not satisfied with the municipal water quality, and out of those 50.2% and 4.2% are using vended and bottled water respectively, while 21% of respondents have their own RO house units. Most of them are paying about 30 NIS per month to purchase water for drinking purposes (appendix 7.6). The results indicate directly that there are problems in the municipal water supply both in quality and quantity.

Regarding the municipal water bill, answers showed that 66.8% pay average of 60 NIS per two months for the municipal water bill, which represents around 2% of their average monthly income. About 25 NIS/month is paid in addition to the municipal bill to purchase sweet water for drinking purposes, which represents 2% of their monthly income. The total paid represents 2.8% to 4.16% of their average monthly income (1200 to 1800 NIS/month). This means that the poor customer can afford a total of 55 NIS /month and will be capable to afford the same amount if he is provided by 70 l/c/day from the desalination plant if it constructed based on average cost of GSWDP at US$0.75 per M^3. This was investigated with the consumers in case of building the GSWDP. It was found that 56.5% of respondents couldn't afford to pay in case of operation of the GSWDP, while 43.5 % are willing to pay. Out of the later category it was found that 90.86% are willing to pay 1-25% extra on the municipal water bill.

A general reaction of water consumers in relation to the level of water service indicated that 55.1% suffer from the water quality and quantity problems. 14.5% of consumers have problem with the quality while 30.4% suffer form deteriorated water quantity. Table 22 shows results of water consumer opinion.

Table22: Distribution of survey sample by category of perceived water problems.

	Type of water problem	Frequency	Percent	Valid %	Cumulative%
Valid	*Quantity*	130.0	30.4	30.4	30.4
	Quality	62.0	14.5	14.5	44.9
	Both	236.0	55.1	55.1	100.0
	Total	428.0	100.0	100.0	

5.2. Results of Interview Questionnaires

5.2.1 Sample size and questionnaire design

Interview questionnaires were carried out with 50 water professionals representing most of water related institutions such as PWA staff, universities, NGO's, consultants, water enterprises, donors representatives. The list of professionals contacted is given in appendix 8. Three of them apologized to fill the questionnaire. The net size of questionnaires sample is 47. The questionnaire was divided into three parts, the first part was related to political issues, the second part covered technical matters, and the third one was relevant to socio-economic issues. This is, because the desalination option for Palestinians is considered to have the political, social, and economic dimensions. In the early of the nineties, the Palestinian politicians to avoid any weaknesses in their negotiation standings until water rights are gained as a result from the negotiations with Israel rejected the desalination option. With and because the dispute on water was postponed to later stages according to Oslo Agreement on the peace process in the Middle East, the Palestinian Water Authority has adopted the desalination option in its Water National Plan (PWA, 2000).

5.2.2 Results of questionnaires

The results of the interview with water questionnaire are given in appendix (9). ***Part I*** concerning the political issues, 48.9% of water professionals believed that the desalination option was a PWA demand while 42.6% believed that it was a donor's dictation (appendix 9.1). As most of the desalination projects in Gaza are grants from donors, 48.9% and 19.1% of professionals agreed and strongly agreed respectively that fund for the desalination projects were conditional (appendix 9.2). PWA commitments and obligations towards donors mean that consultants, contractors, and material are to be imported from the donor's countries or the water sector is to be managed and operated by a fully private international operator. It was found that 55.3% and 17% of professionals agreed and strongly agreed respectively that there were obligations from PWA side towards donors (appendix 9.3).

Concerning the impacts of the desalination projects on the Palestinians rights in final the Palestinians-Israeli negotiations about water rights, results indicate that about, 38.3% and 34% of respondents strongly agreed and agreed respectively that it will affect their water rights, while 14.9% disagreed on that (appendix 9.4).

> *Singapore, Conference (March 21, 2001): concluded: "Desalination holds the solution to a looming shortage of clean water identified as a potential source of conflict in many parts of the world, experts said at a global conference, Singapore".*

In Part II, technical issues were raised concerning the deterioration of water quality and quantity of municipal water. The professionals evaluated the alternative resources. It was noticed that 42.6% and 34% of professionals strongly disagreed and disagreed respectively that small RO house desalination units will be a permanent solution (appendix 9.5).

In relation to the big scale desalination as an alterative resource, 80.9 % of respondents agreed that the GSWDP, which is committed to be funded by USAID is necessary to improve both water quality and quantity as indicated in appendix (9.6).

The main objective of GSWDP (appendix 9.7) according to the opinion of professionals as given by 59.6% of professionals is to secure potable water as a top priority. On the other hand 27.7% of them indicated that USAID are investing in this project for the purpose of solving the Palestinian- Israeli water disputes.

Regarding whether the guarantee values of the water quality that will be produced from GSWDP has been assigned, 46.8% of professionals said yes while 44.7% of them have no idea and the rest answered negatively (appendix 9.8). Regarding the survival of small-scale RO plants, in the presence of GSWDP, 40.4% agreed and 23.4% disagreed on that (appendix 9.9).

Whether GSWDP will have a positive impact on the quality and quantity of water that specified for agriculture purposes, 61.7% of professionals agreed while 23.4% strongly agreed (appendix 9.10). About the sustainability of large-scale desalination such as GSWDP, 51.1% of respondents agreed that GSWDP could be a sustainable option, while 21.3% disagreed (appendix 9.11). Since GSWDP when erected and operated will be the principal water source for domestic purposes, 61.7% of respondents agreed that an emergency plan should be available in case of shutdown of the plant due to political or operational reasons while 31.9% strongly agreed on the same point (appendix 9.12).

Part III, of the questionnaire which is concerned in socio-economic issues indicate that 53.2% of professionals have no idea about water tariff of water to be produced from GSWDP, while 27.7% of them do not know if a tariff structure has been assigned (appendix 9.13).
Regarding whether production cost of a cubic meter from GSWDP has been assigned, 44.7% of respondents had no idea while 25.5% answered positively but gave different figures (Appendices 9.14 and 9.14.1).

Concerning affordability of people to pay for desalinated water from GSWDP, 70.2% said yes they could afford for it, while 21.3% said they couldn't (appendix 9.15). As to willingness to pay, 61.7% of professionals agreed that people are willing to pay, while 10.6% of them disagreed (appendix 9.16)

Questions concerning the availability of procedures to enforce people to pay indicate that 51.1% of professionals do not see such procedures available, while 29.8% said yes and the rest (19.1%) have no idea (appendix 9.17). Investigation on the presence of a clear policy at PWA to protect the poor through for example a cross- subsidiary show that 42.6% Of respondents did not have an idea, while 36.2% of them answered negatively and the rest (21.3%) said yes there is (appendix 9.18).

About the level of public involvement in GSWPD project, 40.4% of respondents said that the public had not been involved while 34% of them said yes and the rest (25.5%) answered by having no idea (appendix 9.19). Out of the 34% positive answers, 14.9% were engaged in the initial assessment stage and 8.5% ere engaged in the study preparation while the rest representing 10.6% was involved in the whole process (appendix 9.19.1). For the recommended contract type on operation and maintenance (O&M) 66% of respondents recommended the public- private partnership while 21% of them supported private sector involvement. In addition 6.4% prefers the public sector involvement. More details are shown in appendix 9.20

5.2.3 Discussion of Interviewees Questionnaires

- **Point views of interviewees concerning part one (political issues)**

By beginning of 1990's, the desalination option was rejected from the Palestinian side to avoid any significant impact on their water rights. According to Oslo II, Article (40) of Cairo Agreement1995, between the Palestinians and Israelis, this states that Israel recognizes the Palestinians water rights in West Bank (Oslo II, Article (40) 1995:pp. 213–218). Due to delay in implementing Article 40, PWA has adopted the desalination option in its strategy in order to meet the growth in economy and to secure future generations need for water. Based on this, this thesis work has given attention to GSWDP as a large-scale project in Gaza. 48.9% of respondents agreed that PWA initiated the desalinisation option. 48.9% of them agreed that grants from donors for desalination were conditional. 55.3% and 17% of respondents agreed and strongly agreed respectively that there were obligations from PWA side against donors. 72.3% of the respondents believed that desalination projects would affect the Palestinian water rights, that it could replace their water rights in the final negotiations with Israel.

- **Pointed views of interviewees concerning part two (technical issues)**

People in Gaza have become aware of water problems concerning quality and quantity issues. 80.9% of professionals believed that desalination was necessary to improve both quality and quantity. Only 14.9% hold contrary view. The Gaza Sea Water Desalination Plant (GSWDP) is the largest desalination project that has been offered to PWA. 59.6% of interviewees believed that to secure potable water was the main objectives of the project, while 27.7% (relatively high figure) answered it would solve Israel –Palestinian water dispute. Regarding the quality of produced water from THE GSWDP, 46.8% of the professionals knew the quality of the product while 44.7% did not.

These interviews reveal that there was weakness in the involvement of the professionals in the project. Interviewees said that GSWDP would have a positive impact on agriculture. From a sustainability point view, 63.9% of respondents agreed and strongly agreed that GSWDP is a good sustainability life. 93.6% of professionals agreed that there should be an emergency plan for the projects.

- **Opinion of water professional concerning part three (socio-economic issues)**

Water desalination projects in general and the GSWDP in particular have direct impacts on the living conditions of the Palestinians. Thus tariff and pricing structure of the produced water is important for consumers. To set up a fair structure, public awareness programs are essential in the various GSWDP phases. 53.2% of the professionals haven't got any ideas about the water tariff system. Moreover 27.7% of them said tariffs have not been assigned. About cost of cubic meter from the GSWDP, 44.7% and 29.8% of professionals haven't any ideas or didn't know about the cost, the rest 25.5% stated they knew the cost. However most of lost category gave different figure of cost ranges varying US$0.4 to US$1.2/M^3. The above result indicates clearly that professionals have not presented the cost of cubic meter clearly to the public.

Desalination in general has a high cost of produced water compared with other conventional water resources. Affordability is also important to be tested by consumers. As a consequence to this, 70.2% of professionals said yes, people would afford, while 21.3% gave negative answers. 68.1% of interviewees agreed that people are willing to pay for desalinated water, while 17% of them gave negative answer.

The Conclusion here showed that professionals had a positive opinion that water consumers would afford and are willing to pay for the desalinated water.

It is known that desalination projects need high capital investments and also have high cost for operation and maintenance. So the tariff collection efficiency is essential to make such projects viable. In this sense, 51.1 % of professionals said there weren't clear procedures from the PWA side to enforce people to pay, and 19.1% of respondents had no idea if there were clear enforcement procedures or not. On the same sake 36.2% of the professionals said they did not know of any policy to protect poor people from the high tariffs.

As desalinated water as a product affects most people life. Public participation is a vital component to push such projects towards a success. The results showed that 34% of professionals said yes, while 40.4% said no to the question if the public were involved in the planning phase of GSWDP and the rest of them 25.5% have not any idea. It must conclude that there has been a serious lack of public involvement. And out of 34% who said yes, 14.9% of them claimed that the public were involved in the initial process, while only 10.6% of them said the public were involved in the whole process.

The type of Operation and Maintenance (O&M) of a desalination plant in general is a decisive factor in identifying cost per cubic meter. In general, large companies or firms with long experience are most capable to manage these projects. The decision of O&M type usually comprises a part of contract and should be known by beginning of the construction of the project. 66% of professionals recommended a contract type of the public-private partnership model, while 21.3% recommended private sector participation. The same value 6.4% was given to either public or public-public partnership contract

5.3 Future Scenarios

There is major fresh water scarcity problem facing the region, which includes mainly Palestine, Israel, and Jordan. No sustainable solution or agreement can be achieved without the involvement or taking into consideration Syria, Lebanon, and Egypt or even Turkey under the umbrella of international committees like the UN or the European Union or USA as well. The trans-boundary water problems between the Palestinian and Israel affect directly the progress in peace between Arabs and Israel to reach its final status. Peace cannot prevail among the countries in the region without having a just and satisfactory solution to all parties. Water issue is one the main factors in reaching that regional settlement.

Wayne, O., (1999). The white paper argues: "water rights issues promise to be very difficult to resolve between Israel and Palestinians and also between Israel and Syria, but would be much easier if there were large, new amounts of *fresh water available. The peace process in region can be made easier by large-scale seawater desalination. In fact, their need to be neither water shortage nor water disputes, the matter is economic, not political"*

To ensure what is mentioned above, Israelis and Palestinians both have adopted the desalination projects in their master plans as urgent solutions to secure water for their people. Israel has launched a seawater desalination program to produce more than 500 MCM/year by 2010(Wayne Owens1999). The first large-scale RO seawater desalination plant with capacity of 100 MCM/ years is under construction in Ashkelon (south of Israel) nearby the northern part of the Gaza Strip (see figure 1).

On same the road, the Palestinians are also considering a 55 MCM Gaza RO Seawater Desalination Plant (GSWDP). For Palestinians, although water rights are not resolved with the Israelis, desalination options are still critical to their water rights issues in future. It should be indicated that *the West Bank* is still suffering from lack of drinking water as well. The construction of a seawater desalination plant in the Gaza Strip with capacity 50- 100 MCM/year to serve the West Bank is also another future option provided that a geographical link can be made available between Gaza and the west Bank in coordination with the Israelis.

On the other hand water in Gaza also suffers from high nitrate content. Nitrate removal has been introduced to PWA as an alternative of non-conventional water resource for improving the water quality in the Gaza Strip. This option has not found the required funding sources.

CHAPTER 6

6. EVALUATION

After the questionnaires have been administered for the water professionals and water consumers, it has been noticed that there is a new attitude of water consumers towards desalination projects in general and large-scale desalination in particular. The people are ready to pay an extra charge of their water bill to get better quality and more quantity of water. In the Gaza Strip, individuals, groups and municipalities to solve temporary problems of salty water and to let the people having access on fresh water for drinking at least, now they practise the water desalination plants.

6.1 Role of Desalination in Water Supply

However, desalination solution is a strategic option for Gaza people because it will postpone the problem of deficit in freshwater and the continuous exploiting of the aquifer. Large-scale desalination could be more attractive since it has positive impact on water resources in general and covers the gab in the water budget in particular. Also it plays a big role in decreasing the water shortage and can improve the water services in both quantitative and qualitative aspects. The initial capacity of the GSWDP is 60,000M^3/day, which equals to about 20 MCM/year. Moreover, the final capacity of the French plant is 5000 M^3/day; in addition to 1200 M^3/day will be produced from Austrian plant. By assuming that the three plants will be in full operation by year 2005, the total capacity produced from these three plants will be 66,200 M^3/day, which is equivalent to 24MCM/year. The total domestic water use will be 100 MCM/year by year 2005 (PWA, CAMP 2000). This means that the total additional quantities from desalination will cover about 24% of the domestic needs by year 2005. It is recommended that the sweet water that will be produced from desalination (24MCM/year) should be used for drinking purposes to the possible extend till enough water resources for full domestic use be available presumably. This can be achieved through a proper management of water distribution.

By year 2020, the total production in the final phase of the GSWDP is 150,000M^3/day that is equal to 55MCM/year. At the same time, the total domestic water consumption is estimated at 182 MCM/year by year 2020. To achieve water balance as for a long-term strategy, other new water resources are needed such as import of water, artificial recharge of groundwater and reuse of treated wastewater.

6.2 Economic Analysis

At present, the water sector in the Gaza Strip is operated and managed by the municipalities who have their own water sources and distribution systems. Each municipality has its own tariff structure. In general, the maximum tariff charged to domestic users is about 1 to 1.6 NIS/M^3, which is US$0.23/$M^3$ to US$0.36/$M^3$. This means that the average tariff is US$0.3/ M^3. The World Bank estimated the Gross Domestic Product (GDP) in the Gaza Strip at US$860 per capita in 1994. Due to Intifada and the unstable political situation, the income per capita was dropped to US$600 per year 2002, and 60% of the population have fallen below the poverty line (CIA, 2003). Recently, it is reasonable to assume that the GDP in the Gaza Strip is at US $400 per capita per year. The following calculations test the individual capability to afford for water that is produced from the GSWDP and as per family as well:

- **As per individuals**

Average cost of the current municipal water tariffs	US$0.3/$M^3$
Gross Domestic Product (GDP) /2002	US $400 /individual/year
3% -4% of annual income is paid for the water bill (assumption)	
Cost of the municipal water bill	US$12 to US$16/year
Per individual water consumption	70 l/c/d
Total individual water consumption	25.5 M^3 /year
Cost of M^3	US$0.47 to US$0.63

The result that individual with annual income (US $400) can afford 1.56 % to 2.1% extra of the current municipal water tariffs.

- **As per family**

Average family members (questionnaires results)	7 members
Average family income (questionnaires results)	1500NIS/month
	=US$340/month
Per capita water consumption	70 l/c/d
Total water consumption per family	178.5M^3/year
Family already paid (questionnaires results):	
❑ For the municipal water bill	30NIS/month
❑ For purchasing a potable water for drinking	25NIS/month
❑ Total is paid by family for water	55NIS/month
	=US$150/year
Total cost is to be paid for water (municipal & potable)	US$0.84/ M^3

From above it can be conclude that people with a family with 7 members and a monthly income of US$340 and a rate of water consumption of 70 l/c/d are already charge at US$0.84/$M^3$

The estimated cost of cubic meter that produced from GSWDP in phase (I) is at US$0.54/$M^3$ and can drop to US$0.42/$M^3$ at the final phase (PWA, CDM 2003). Consequence with this figure, the consumer shall charge for the production and pumping of the cubic meter around US$ 0.75. So families can afford for the water produced from GSWDP. The PWA to protect poor people should adopt a smart tariff setting and cross-subsidies through lowering the first slid in the water tariff system. Al-Ghuraiz (2002) report argued that people in the Gaza Strip could afford to pay up to US$ 0.7 per cubic meter with accepted water quality.

6.3 Social Analysis

The Gaza Strip has over 30 years passed through unstable political conditions due to the Israeli occupation, which reflected directly on the social life. People practised a type of challenging life. The economy of the strip is linked directly with Israel. The standard of living in the Strip is deteriorating due to boarder closures and curfew restrictions. As a result, the number of unemployed people increases. Other requirements such as housing, health care, water and wastewater services are mostly below the minimum international standards.
The municipal water pumped to people in Gaza has high concentration of chloride and nitrate that exceeds the international standards. High range of nitrate concentration in water affects directly the infant's health. More than 50% of the population of Gaza are under 15 years of age (PCBS 2003, p. 14). So water quality in terms of nitrate and chloride has significant negative impacts on the standards of living and development.

The responsibility of the PWA with relevant Palestinian institutions is to provide water with accepted quantity and quality of water at affordable price as apart of human needs. This can be achieved through desalination project such as GSWDP provided that the public should be involved.

> *Gleick P. H., (2003) concluded "Governments must establish clear guidelines that ensure fair access to water regardless of income, protect the environment, ensure transparency, and include affected parties in decision-making efforts".*

6.4 Willingness to pay

Willingness to pay is a type of valuation technique for non-market goods. Different survey methods are available for generating willingness to pay data. A contingent valuation approach is still the most common being used.

> *Healey, A. and Chisholm, D., (1999, p. 56) argue: "For traded commodities, the money valuation of welfare gains or losses is generally observable via prices paid in day- to- day transactions for goods and services. However, for non-traded goods, including health care, the trade-offs that appropriately reflect the money value that people attach to specified improvements in welfare are usually non-observable in market transactions".*

The municipal and industrial water demand would grow from 55MCM at year 2000 to 100 MCM at year 2005 and to about 182 MCM by year 2020 assuming that the growth rate of population is 3% per year and the water tariffs remain low (NWP, 2000). Socio-economic indicators are essential in water development and planning projects such as desalination. The cost of cubic meter produced from desalination affects affordability and willingness to pay of the consumers. Due to the adverse effects of the polluted water on their health, results from consumer questionnaires concluded that about 43.5% of people are willing to pay extra on the municipal water bill to get accepted water quality.

6.5 Public Awareness and Participation

Environmental education programs and public awareness activities in the water projects are important in water management. It is a mean of informing people and educating water users about the serious problems in general and the crisis of water resources in the Gaza Strip in particular either in quantity or in quality. Successful awareness campaign through community participation will conserve and protect more water from over-exploitation and pollution that could alleviate the gap in water shortage and improve the quality. Awareness can be achieved by changing the undesirable behaviour of the people such as misuse and damage of the water meters, making illegal connections and overuse of limited water resources. The need for awareness in water is due to:

- Over-exploitation and pollution of water resources
- Insufficient source and/or supply to meet demand.
- Lack of empowerment within the community and indifference regarding water issues.

Many governmental organizations and civil society organizations like universities, schools, women centres, farmers, and the water private voluntary organizations can make efficient contribution. They can be involved in the public awareness campaigns and each one of the groups should have a specific role to reach efficient use of water.

Successful awareness can be done in its three levels, firstly is awareness, secondly is involvement, and the thirdly is participation (Castensson et al. 1988). All these activities can play a big role in large-scale projects such as GSWDP, because it has significant impacts on social, economic, environmental, and ecosystem. Since lack of water resources in Gaza comprises a serious problem, awareness program must be done in parallel with the progress of any project phases. Data of the water shortage should be available to the people to understand the situation and to encourage them towards water conservation and protection.

Stockholder's participation working with users and other interested- groups are vital in terms of building support for reforms, monitoring, and enforcement of manipulating users. Top-down, technocratic approaches in municipal water supply management are generally unsuccessful. Same importance should be given to ensure that community participation is involved in all project phases, identification, preparation, implementation, monitoring, and evaluation. Effective sharing of community leads to social sustainability.

CHAPTER 7

7. CONCLUSIONS AND RECOMMENDATIONS

1. Gaza aquifer is the backbone of water resource for supplying water to the people in the Gaza Strip. Developing and managing the water resources is a crucial and essential target for decision makers.
2. Gaza Strip in particular suffers from water shortage and poor water quality, so desalination as a reliable source of fresh water is essential to be adopted by the Palestinians to meet future needs in a sustainable way.
3. Integration on local level between the three regulatory parties (Palestinian Water Authority, Ministry of Health and Environment Quality Authority) is crucial and vital in order to regulate and organize the desalination industry. More over cooperation, data exchange and experience are required between neighbour countries.
4. Desalination projects need high capital investment; in this sake integrated cooperation between public and private sector is highly recommended in order to increase the efficiency of water supply operational conditions, which will reflect positively on customers.
5. A feasibility study of GSWDP concludes that Gaza desalination facility project (GSWDP) is financially viable.
6. According to economic analysis results, low-income individuals can afford to pay 1.56% to 2.1% extra the current municipal tariff. In this sake a family with 7 members and average monthly income at US$340/month can afford US$0.84 /M3 of desalinated water at consumption rate 70 l/c/d.
7. PWA as a regulator of water sector has to develop clear regulations, guidelines, and contract conditions in order to organize the water market, specially the quality of desalinated water.
8. Proper institution with effective legislations and policies should stimulate improvements in minimizing unaccounted for water and increasing the delivery efficiency.
9. Training and capacity building in desalination industry are essential for local staff mainly on Operation and Maintenance (O&M), and should be extendable to cope with any progress in the desalination market.
10. To make the desalination industry more successful, PWA should be engaged in a process of institutions development in order to cope with any progress in international desalination technology, economic, and regulatory information.
11. More attention should be given to the effect of brine that is pumped from both RO house units and the private brackish water desalination plants into the sewerage networks to avoid any

reaction with the concrete manholes and asbestos or steel pipes. In addition it should be noted that sewerage pipes diameters might be under design regarding uncontrolled quantities of brine discharged from the domestic or private desalination units.

12. Since the principle of desalination process depends mainly on using some chemical materials, while problems are sometimes faced with Israel who restricts the entry of such materials to Gaza from their security viewpoint, this creates a risk on the operation of desalination plants. In this case, USAID should secure or obligate Israel to allow for the entry of chemicals required for operation of the proposed plant.
13. Gaza Strip with semi arid climate has a potential of solar energy (200Watt/M^2) that could be utilized for small-scale water desalination as an environmental friendly source of energy.
14. It was clearly reached that cost of cubic meter produced from GSWDP, which is a very important indicator, wasn't analysed and presented clearly by USAID to part of water professionals and the public.
15. The West Bank, the other part of Palestine (inland area) suffers also from water shortage, so a desalination plant could be build at Gaza Sea in order to meet future needs of people there.
16. Some parts of the Gaza Strip have less chloride ions but suffer from high percentage of nitrates concentration (over than 100ppm), so nitrate removal technology should be adopted as a pilot scheme with more research to be practiced in future.
17. It is recommended by the professionals to employ a private operator for the operation and maintenance of desalination plants. Accordingly regulations and contractual conditions should be prepared thoroughly in order to avoid monopoly and negative impacts on the tariff.
18. More research should be practiced also to find out recommended minimum values of the chemical constituents such as magnesium, calcium and others.
19. Further studies are recommended to be elaborated on the use of desalinated treated wastewater for domestic use as an alternative resource. In addition more elaboration on the effect of desalination on the marine life on one hand and the tourism on the other hand should be considered since Gaza is a small crowded area with a limited coast length.

References

Abu Mailah, Y., 1993. *Water Balance in Palestine, 1993. 1st Scientific conference "Towards a new view of modern problematic issues in the Gaza Strip"*.

Abu Safia, Y., 1995. *Water Status in Palestine*.

Al-Ghuraiz, Y., 2002. *Water Pricing for Domestic Use in the Gaza Strip*. The Islamic University, Gaza, October 2002, pp. 118-122.

Al-jamal, K. & Shoblak, M., 2000. *Institutional Reforms Towards Sustainable Water Sector*. Unpublished Paper, March 2000, pp. 6-7

Camp Dresser and McKee International (CDM). 1993. *Strategic Action for Development of the Environmental Health Sector in the Gaza Strip*. PWA, CDM. UNRWA, Gaza. June 1993.

Castensson, R., et al., 1988. *Water Awareness in Planning and Decision-.Making.* Synthesis Document. International Seminar at Sweden, Skokloster.

Central Intellectual Agency (CIA). 2003. *World Fact Book- The Gaza Strip-Economy.*

[WWW document]. http:// www.cia.gov/cia/publications/factbook/print/gz.html. Visited on 23, 24 November 2003.

El Bana H., 2000. *Desalination Technology.* El Dar El Amelia, Alexandria, Egypt, (Arabic version). 2000, pp. 110-120

Environmental Planning Directorate (EPD) and Ministry of Planning and International cooperation (MOPIC). 1994. *Gaza Environmental Profile, Part I, Inventory of Resources.*

European Community (EC). 1993. *Prospects for Brackish Water Desalination in Gaza*. The Commission of the European Communities-Director General for External Relations. March 1993.pp.13-22.

Gleick, P et al., 2002. *The New Economy of Water: The risk and benefits of Globalisation and privatisation of Fresh Water.* Pacific Institute for Studies in Development, Environment, and Security. Oakland, California. 2002.p.13.

Gleik, P. H., 2003. *The New Economy of Water: The Risks and Benefits of Globalization and Privatization of Fresh Water.* [WWW document].

http://www.pacinst.org/reports/new_economy_overview.htm. Visited on 2 December 2003

Goodman, A., S., 1984. *Principles of Water Resources Planning.* Prentice-Hall, Inc., Englewood Cliffs, New Jersey.1984, p. 10.

Healey, A., and Chisholm D., 1999. *Willingness to Pay as a Measure of the Benefits of Mental Health Care*.J. The Journal of Mental Health Policy and Economics. Vol. 2. 1999, p. 56.

Institute for Water Education (IHE) and UNESCO. 2003. *Membrane technology in drinking water & industrial water treatment, Principles, Design& Application.* Unpublished documents training course, Amman, Jordan. 12-16 October 2003, pp. 39-44.

Ismail M., 2003. *Facts and Challenging of Desalination in the Gaza Strip*. PWA. (Arabic Version). Gaza. 2003, pp. 13-17.

Johanson, K., 2003. *Nuclear Desalination***.** [W WW document].
By: Karl Johanson (karljohanson@shaw.ca)
http://groups.google.com/groups?desalination.access on 11 October 2003.

Ministry of Health. 2003*. Chemical analysis of desalinated water*. Environmental Health Department , Gaza. August 2003.

Okasha, M., 2002*. Statistical Package for Social Sciences In Data Analysis (SPSS).* Gaza. March 2002,pp. 137-150.

Oslo II, Article 40. 1995*. Water Agreement*: Water *and Sewage, Principles1, 2,3.* PWA, Gaza. September 18, 1995, pp. 213-216.

Palestinian Central Bureau of Statistics (PCBS). 1999. *Population in the Palestinian Territory, 1997-2025*. Ramallah, Palestine.

Palestinian Central Bureau of Statistics (PCBS). 2003. *Palestinian 2002 in Numbers.* Ramallah, May 2003,p. 14.

Palestinian Hydrology Group for Water and Environmental (PHG). 2002. *Qualitative Use of Home Reverse Osmosis Filters of some Areas in Gaza Strip***.** PHG. Gaza. May 2002, p. 18.

Palestinian Water Authority (PWA). 1996. *Water Law No. 2, Establishment of the Palestinian Water Authority.* (Article 8 and Article 9). PWA, 1996.

Palestinian Water Authority (PWA) and Degremont. 1998. *Desalination Plant***,** *Process Description and Contract Agreement*. Degremont (French Company). Gaza, March 1998,pp. 2-10.

Palestinian Water Authority (PWA). 1999*. Strategy for Water Management in Palestine***.** PWA. March 1999, pp. 6,7.

Palestinian Water Authority (PWA), 2000. *The National Water Plan.* PWA, Palestine,

Palestinian Water Authority (PWA). 2000. *Standards of Drinking Water for Gaza Strip*. PWA. Gaza, July 2000, pp. 4-7.

Palestinian Water Authority (PWA). 2000. *Water Resources and Management Issues (Gaza Strip*). PWA. Gaza.2000.

Palestinian Water Authority (PWA) and Coastal Aquifer Management Programme (CAMP). 2000*. Integrated Aquifer Management Plan (Task-3).* PWA, CAMP. Volume 1. Gaza. May 2000.

Palestinian Water Authority (PWA) and Coastal Aquifer Management Programme (CAMP).

2001. *Gaze desalination master plan*. PWA, CAMP. Gaza. September 2001.

Palestinian Water Authority (PWA) and Coastal Aquifer Management Programme (CAMP). 2003. *Basis of Design Report and Design Criteria For Gaza Regional Water Carries. (Task-26).* PWA, CAMP. Vol. 2. Gaza. January 2003, pp. 3-1 to 3-7.

Palestinian Water Authority (PWA) and Camp Dresser and McKee International (CDM). 2003. *Gaza Sea Water Desalination Plant, Feasibility Study*. PWA, CDM. Vol.1, Final Report, Gaza February 2003.pp 6-57.

Palestinian Water Authority (PWA)/Consumer Affairs Department. 2003. *Water Tariff at Municipalities of the Gaza Strip*. PWA, Gaza 2003.

Palestinian Water Authority (PWA)/Data Bank Department. 2003. *Yearly Data Books.* PWA. Gaza. January 2003.

Palestinian Water Authority (PWA) and Lyonnaise des Eaux, Khatib &Alami (LEKA). 2003. *Financial Data for the fiscal year 2002*. PWA, LEKA. Yearly report. Gaza, January 2003.

Palestinian Water Authority (PWA) and Sustainable Management of the West Bank and Gaza Aquifer (SUSMAQ) .2003. *Management Options Report- Water Security and Links with Water Policy in Palestine (Final Draft)*. PWA, SUSMAQ. Version 0.3. December 2003, p. 90.

Palestinian Water Authority (PWA) and Vinzenz Trugina. 2000. *Progress Report*. PWA, Trugina (Austrian consultant). Gaza, September 2000.

Rudge, D., 2003. *Israel Building World's Biggest Desalination Plant*. [W WW document]. http://groups.google.com/groups?desalination.access on 30 September, 2003

Saghir. Jamal, et al., 2000. *Urban water and Sanitation in the Middle East and North Africa Region: The Way Forward*. The World Bank, Middle East and North Africa Region Infrastructure Development Group, January 2000, pp. 15.

Singapore Conference 2001. *Water Technology on Line*. [W WW document]. By: mo201a@nospamyahoo.com. March 21 2001 http://www.watertechonline.com/news.asp? Access on 20 December 2003.

United Nations Environment Programme (UNEP). 2003. *Desk Study on the Environment in the occupied Palestinian Territories*. UNEP, 2003,pp. 20-24.

Wayne O., 1999. *Solving the Problem of Fresh Water Scarcity in Israel, Jordan, Gaza, and the West Bank- A white paper*. Center for Middle East Peace and Economic Cooperation. Second edition, November 1999, pp. 4-6.

World Health Organization (WHO). 1985. *Guidelines for Drinking Water Quality*. *Vol.3* Geneva.

Bank. 2003. *World Bank Report on Impact of Intifada*. West Bank and Gaza Update, The World Bank Group. April-June 2003, pp. 25-27.

World Book. 2000. *Desalination.* CD Book Millennium

World Water Council. 2002. *Water Vision for the Twenty-first Century in the Arab World*. 3rd World Water Forum. Edited by Abu-Zeid. M., and Atef, H, A., 2002 p. 19.

List of Appendices

Appendix 1: Data of 25 years regarding the climate in the Gaza Strip; Gaza town.

Month	Average temperature (^oC)	Average evaporation (mm)	Gaza town average rainfall (mm)
January	13.6	63.4	83.3
February	14	73.1	55.3
March	15.8	94.1	41.2
April	18	116.4	8.9
May	21.3	133.4	3.7
June	23.8	135.5	0
July	25.7	137.8	0
August	26.2	137.8	0
September	25.2	124.9	0.7
October	22.9	113.7	15.6
November	19.8	91	70.9
December	15.4	78.7	91.8
Annual	**20.1**	**1299.8**	**371**

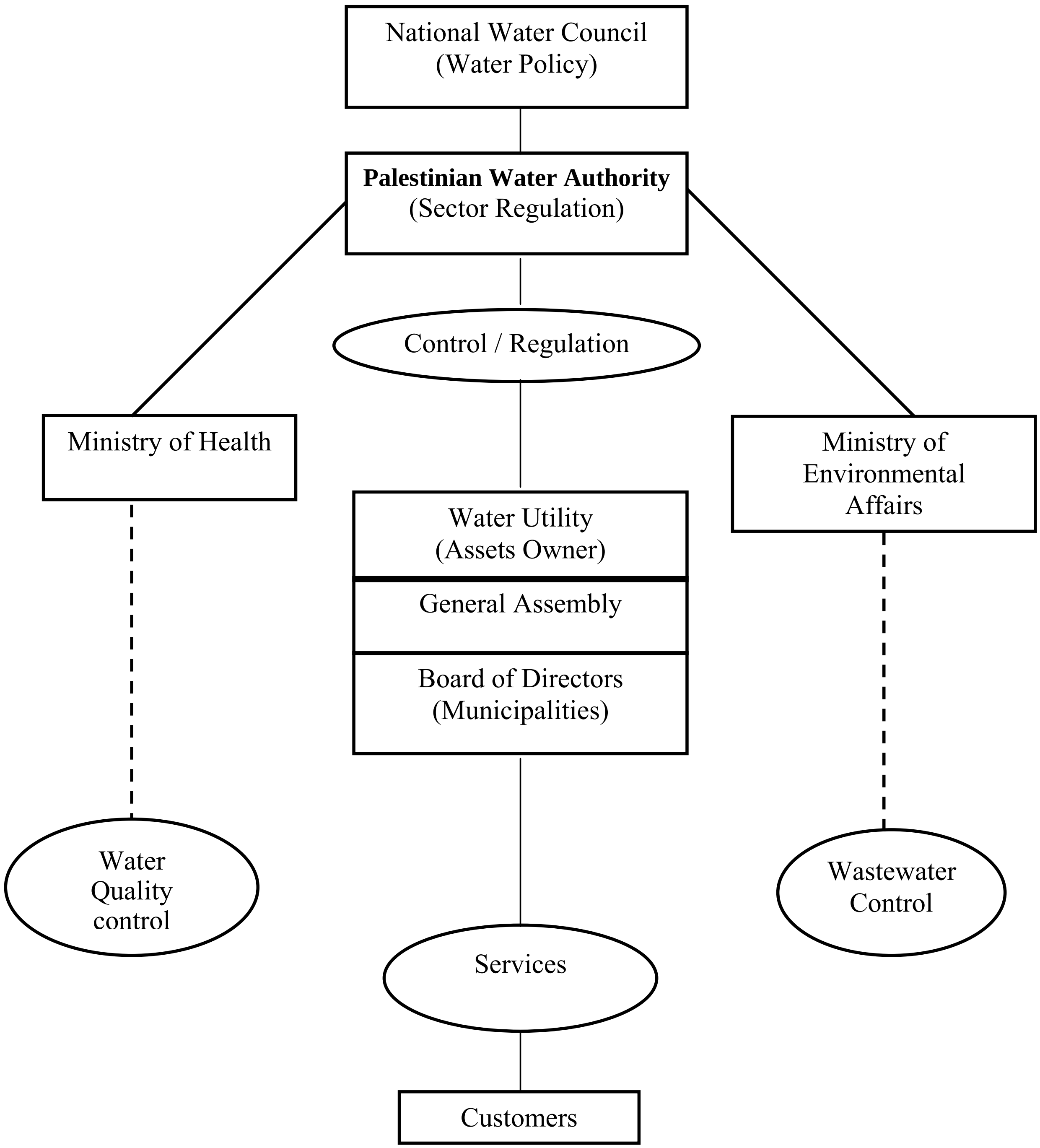
Source: Israel Metrological Service: Atlas of Israel, (1985)

Other climatic data concerning the Gaza town:

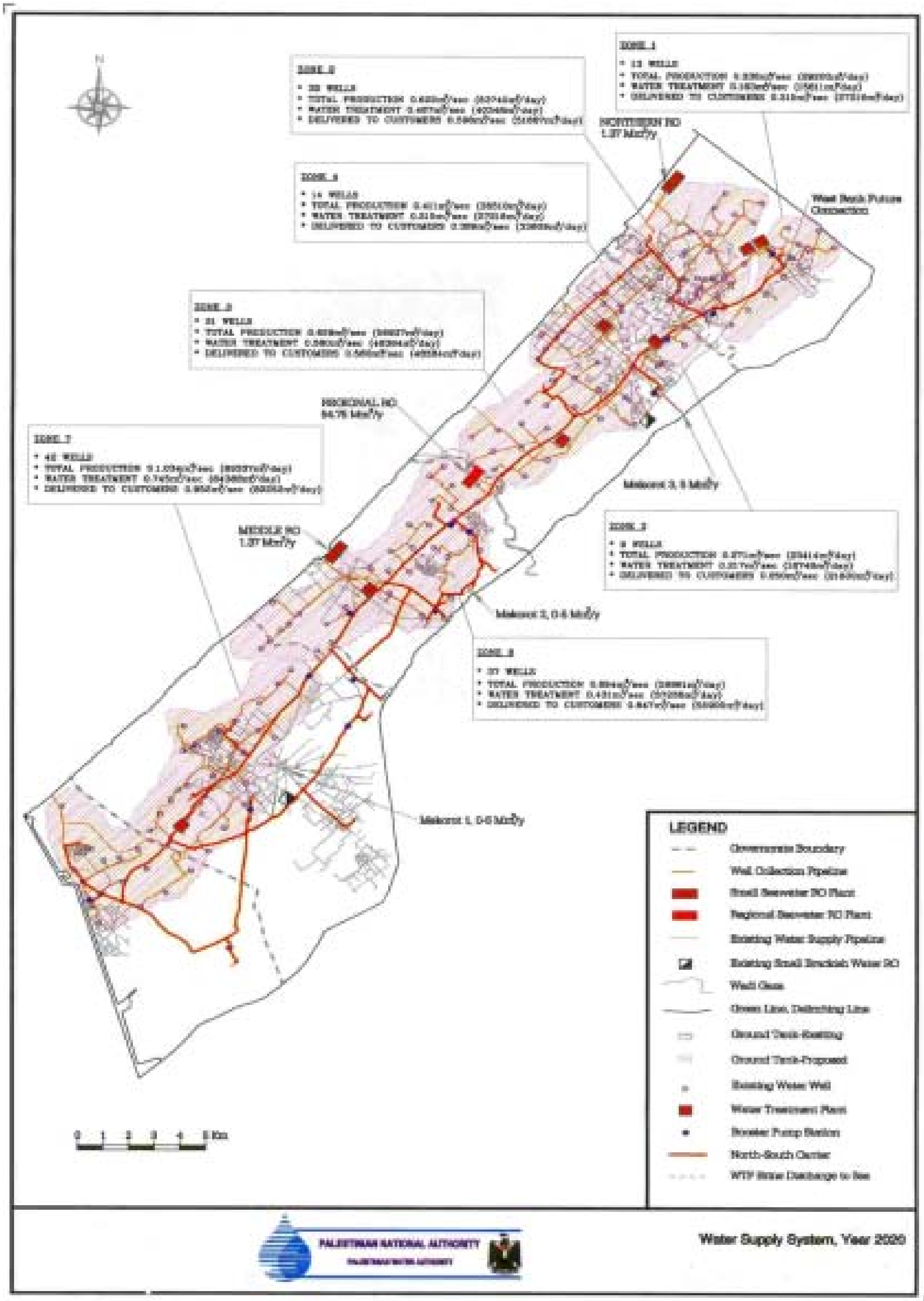
- Mean annual rainfall 200 – 400Mm
- Mean annual evaporation from open water surface 1200-1400Mm
- Mean daily relative humidity 70-75%
- Mean annual temperature 19-21 ^oC
- Mean annual solar radiation (incidents on horizontal surface) in kg cal/cm^2/year 189-195

Potential solar energy is 200 Watt/M$^{2.}$

Appendix 2: Strategic institutional set up for the water sector in Palestine



Appendix3: Route of the Gaza Water Regional Carrier (Source: PWA. Data Bank 2003)



Appendix 4: Questionnaire for Water Consumer

Questionnaire for Water Consumer

Dear, Mrs, Mr:. ……………………………………………………………………**Water consumer**

The Gaza Strip has severe water problems. The urban development and the population growth of Gaza increase the pressure on the existing water resources, which have been already exploited. Access to potable water for drinking purposes has become not easy. The Palestinian Water Authority and according its policy has adopted a desalination option as an alternative resource to bridge the gap in the water balance and to secure potable water for domestic use.

Through grants from France and Austria, the Palestinian Water Authority has been started in constructing of two RO seawater desalination plants with initial capacity at (1250 and 600) M3/day- respectively. In addition, the USAID committed to design, built, and operate a seawater desalination plant with capacity at 60000M^3/day-phase I. Those desalination projects aim to provide people with potable water for domestic use.

This questionnaire aims to investigate the prospects of water desalination projects in water supply in terms of quantity, quality, and to test the affordability as well. All the information that gained will be used for the research and to the public later.

1. General Information
1.1 Name of respondent (optional): **Date:**
1.2 Age (year): □18-24 □25-35 □36-45 □46-55 □>55
1.3 Gender: □Male □Female
1.4 Place of living (Governorate): □North □Gaza □Middle □Khanyounis □Rafah
1.5 Educational: □Primary □Secondary/Diploma □University / above
1.6 Number of family's member: □ Member

1.7 Average income in NIS /month (1 US$=4.4 New Israeli Shekel)
□Less than 1200 □1200 – 1800 □1800 – 2700 □2700 – 4000
□More than 4000

2. Which type of water source do you use for domestic use?
□Municipal □Private well □Agricultural well □Others

3. Are you satisfied with water quantity that delivered by the municipality for domestic use?
□Completely satisfied □Satisfied □Don't know □Not satisfied
□Completely not satisfied

4. Are you satisfied with the quality of municipal water for drinking use?
□Completely satisfied □Satisfied □Don't know □Not satisfied
□Completely not satisfied
4.1 Which type of water do you use for drinking?
□Bottled □Water shops □ RO House unit □ Municipal water

4.2 In case you purchase water for drinking purposes, how much in average do you pay (in NIS/ month)?
□1-10 □11-20 □21-30 □31-45 □>45

5. How much do you pay for municipal water bill in NIS per period (2 months)?
□1-15 □16-25 □26-44 □45-60 □>60

6. The Palestinian Water Authority strategy has adopted desalination projects in order to alleviate the water problems in Gaza.
In your opinion which problems could be solved by desalination?
□Quantity problem □Quality problem □Both

7. PWA has received a commitment from USAID to design, construct, and operate Gaza Sea Water Desalination Plant (GSWDP) with capacity at 60000 M^3/day- phase (I). This mainly aims to provide people with desalinated water for domestic use.
After accomplished of the project, are you willing to pay additional cost for existing bill?
□Yes □No

7.1 If yes, how much extra as percentage of municipal water bill are you willing to pay for desalinated water?
□1-25% □26-50% □51-75% □76-100%

Other comments: …………………………………………………………………………….
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your cooperation;

Appendix 5: Interview Questionnaires for Water Professionals

Interview Questionnaire for Water Professionals

PWA has received a commitment from USAID to finance RO Gaza Sea Water Desalination Plant (GSWDP). The design capacity is estimated at 60,000 M^3/d for phase I, and expected to be expanded to 150,000M^3/d for final phase. The project will be Design, Built, and Operate (DBO) for three years contract. The contractor shall entire into seven years contract for operation and maintenance with Coastal Municipal Water Utility (CMWU). The produced water is assumed to pump to the people through Gaza Regional Water Carrier (GRWC). Two small scale RO seawater desalination plants with capacities at 600 M^3/day and 1250 M^3/day –phase I were funded by Austrian and French governments respectively. Three RO desalination plants exist and being operated by municipalities. In addition, a large numbers of private RO plants with wide range of capacity (20 - 1200 M^3/day), as wells as, a huge number of RO house units are existing as well.

This interview will be used for MSc thesis at KTH, the Royal Institute of Technology- Sweden. The thesis is focused on the Gaza Strip, which has severe water problems. The growth in urbanization and socio- economic development increases the pressure on the existing water resources, which have been already exploited. Water desalination is an alternative option to bridge the gap in the water balance and to secure potable water for people in Gaza Strip.

This interview aims to envisage the prospects of water desalination in water supply in many dimensions such as quantity, quality, and to abstract idea about willingness- to pay as well

Personal information (optional)**:**
Name of respondent: ***Title:***
Institution: ***Email address:***

Questions:

Part one: Political questions
1. Was the desalination option chosen by PWA according to its policy and goals; or supply driven option from donors?
□PWA demand □Donors supply □No idea
2. Do you agree that funds for desalination projects from donor agencies (UASID, France, Austria, and others) were conditional?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree
3. Do you think that there were obligations from PWA side towards donors?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree
4. Do you agree that large-scale desalination projects such as GSWDP will affect the Palestinian water rights in the final negotiation in water dispute with Israel?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree

Part II: Technical questions
5. Do you agree that the existing municipal and private desalination plants and small RO units at houses, schools, and clinics could be a permanent solution to solve water quality problem?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree
6. Do you think that large scale desalination project such, as GSWDP is a necessary to improve the quality and the quantity of municipal water supply for long term?
□Necessaryy □Don't know □Not necessary
7. What is the main objective of GSWDP?
□Secure potable water for customers
□Conserve and protect water resources
□Partially solving (alleviate) Israeli/Palestinian water dispute
□Others……………………………………………………………………………
8. Was the quality of water from GSWDP determined and presented to PWA?
□Yes □No □No idea
9. Last three years, many small private desalination units have been constructed, in addition to existing municipal RO plants. In your opinion do you agree that these plants can be survived in the presence of GSWDP?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree

10. Do you agree that the use of GSWDP will have positive impact on the quantity and quality of the irrigation water?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree

11. Do you agree that large-scale RO desalination projects are a sustainable option for all aspects of, social, economical, political, and environmental?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree
12. Since Gaza Strip to some extend is politically unstable, do you agree that there should be an emergency plan to precede in the project phases?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree

Part III: Socio-economic questions
13. Was tariff structure of water produced from GSWDP assigned?
□Yes □No □No idea

14. Was the production cost of one cubic meter of desalinated water from GSWDP assigned and presented to PWA or customers?
□Yes □No □No idea
14.1 If yes, how much is it in US dollar?
…………………………………………………………………………………………………..

15. Affordability is a key factor in the success of desalination options, do you believe that people will afford?
□Yes □No □No idea
16. Willing to pay is essential to success of such projects, do you agree that people willing to pay?
□Strongly agree □Agree □Don't know □Disagree □Strongly disagree
17. Desalination projects need large investments, so collection efficiency of bills is essential for financial stability. Is there any clear procedure to enforce people to pay?
□Yes □No □No idea
18. Is there any policy at PWA to protect people with low income or hard case?
□Yes □No □No idea
19. Did the public participate in decision-making process of GSWDP?
□Yes □No □No idea
19.1 If the answer is yes, at what stage(s) were they involved?
□initial assessment □study preparation □in the whole process
20. Which type of contract could be more practical for operation and maintenance of GSWDP from a socio economic point of view?
□public sector □ public - public partnership □public-private partnership
□private sector

More comments do you want to add? ....
………………………………………………………………………………………………….
…………………………………………………………………………………………………..

Thank you for your cooperation;

Sincerely yours
Mahmoud Ismail

Appendix 6: Distribution of questionnaires in each municipality of the Gaza Strip

Place	Frequency	Percent	Valid%	Cumulative%
Jabalia	49	11.45	11.45	11.45
Beit lahia	17	3.97	3.97	15.42
Beit hanoun	11	2.57	2.57	17.99
Om al nassr	4	0.93	0.93	18.92
Gaza	144	33.64	33.64	52.56
A lzhra	4	0.93	0.93	53.49
Al moghragah	2	0.46	0.46	53.95
Wadi Gaza	1	0.23	0.23	54.18
Deir el balah	17	3.97	3.97	58.15
Al Nasserite	19	4.43	4.43	62.58
Al buraij	10	2.33	2.33	64.91
Al maghazi	7	1.63	1.63	66.54
Zawydah	4	0.93	0.93	67.47
Wadi salga	2	0.46	0.46	67.93
Al musadar	1	0.23	0.23	68.16
Khanyunis	58	13.55	13.55	81.71
Bani suhila	9	2.1	2.1	83.81
Big abasan a	5	1.16	1.16	84.97
New abasan	2	0.46	0.46	85.43
Al qarrara	5	1.16	1.16	86.59
Khuzaa	3	0.7	0.7	87.29
Al fakhari	2	0.46	0.46	87.75
Rafah	45	10.51	10.51	98.26
Al shoka	5	1.16	1.16	99.42
Al nasser	2	0.46	0.46	100%
Total	428.0	100.0	100.0	

Appendix 7: Results of water consumer questionnaires

Appendix 7.1

Question 1.2: Citizen age

Age range	Frequency	Percent	Valid %	Cumulative%
18-24	44.0	**10.3**	10.3	10.3
25-35	129.0	**30.1**	30.1	40.4
36-45	152.0	**35.5**	35.5	75.9
46-55	74.0	**17.3**	17.3	93.2
More than 55	29.0	**6.8**	6.8	100.0
Total	428.0	100.0	100.0	

Appendix 7.2

Question 1.3: Citizen sex

Sex	Frequency	Percent	Valid %	Cumulative%
Male	361.0	**84.3**	84.3	84.3
Female	67.0	**15.7**	15.7	100.0
Total	428.0	100.0	100.0	

Appendix 7.3

Question 1.4: Place of living

Governorate	Frequency	Percent	Valid %	Cumulative%
North Gaza	81.0	**18.9**	18.9	18.9
Gaza	151.0	**35.3**	35.3	54.2
Middle zone	60.0	**14.0**	14.0	68.2
Khanyounis	84.0	**19.6**	19.6	87.9
Rafah	52.0	**12.1**	12.1	100.0
Total	428.0	100.0	100.0	

Appendix 7.4

Question 1.5: Education status

Education degree	Frequency	Percent	Valid %	Cumulative%
Elementary	30	**7.0**	7.0	7.0
Secondary	160	**37.4**	37.4	44.4
Bsc. or above	238	**55.6**	55.6	100.0
Total	428.0	100.0	100.0	

Appendix 7.5

Question 1.6: Family members

Family members	Frequency	Percent	Valid %	Cumulative%
1-3	48.0	**11.2**	11.2	11.2
4-6	130.0	**30.4**	30.4	41.6
7-9	155.0	**36.2**	36.2	77.8
10 or more	95.0	**22.2**	22.2	100.0
Total	428.0	100.0	100.0	

Appendix 7.6

Question 1.7: Average family income in NIS/month

Income (NIS/month)	Frequency	Percent	Valid %	Cumulative%
Less than 1200	160.0	**37.4**	37.4	37.4
1200-1800	157.0	**36.7**	36.7	74.1
1800-2700	74.0	**17.3**	17.3	91.4
2700-4000	31.0	**7.2**	7.2	98.6
More than 4000	6.0	**1.4**	1.4	100.0
Total	428.0	100.0	100.0	

Appendix 7.7

Question 2: Water sources

Water source	Frequency	Percent	Valid %	Cumulative%
Municipal	401.0	**93.7**	93.7	93.7
Private well	14.0	**3.3**	3.3	97.0
Agricultural well	5.0	**1.2**	1.2	98.1
Others	8.0	**1.9**	1.9	100.0
Total	428.0	100.0	100.0	

Appendix 7.8

Question 3: Water quantity problem

Ranking	Frequency	Percent	Valid %	Cumulative%
Completely satisfied	36.0	**8.4**	8.4	8.4
Satisfied	174.0	**40.7**	40.7	49.1
Don't know	21.0	**4.9**	4.9	54.0
Not satisfied	192.0	**44.9**	44.9	98.8
Completely not satisfied	5.0	**1.2**	1.2	100.0
Total	428.0	100.0	100.0	

Appendix 7.9

Question 4: Water quality problem

Ranking	Frequency	Percent	Valid %	Cumulative%
Completely satisfied	11.0	**2.6**	2.6	2.6
Satisfied	62.0	**14.5**	14.5	17.1
Don't know	23.0	**5.4**	5.4	22.4
Not satisfied	314.0	**73.4**	73.4	95.8
Completely not satisfied	18.0	**4.2**	4.2	100.0
Total	428.0	100.0	100.0	

Appendix 7.10

Question 4.2: Amount of purchased water for drinking purposes (NIS per month)

Shekel/month	Frequency	Percent	Valid %	Cumulative%
1-10	95	**22.2**	26.5	26.5
11-20	83	**19.4**	23.2	49.7
21-30	94	**22**	26.3	76
31-45	44	**10.3**	12.3	88.3
>45	42	**9.8**	11.7	100
Total	358	83.6		
Missing	70			
	428			

Appendix 7.11

Question 5: A mount of municipal water bill in (NIS per two month)*

NIS/two months	Frequency	Percent	Valid %	Cumulative%
1-15	16.0	3.7	3.7	3.7
16-25	36.0	8.4	8.4	12.1
26-44	90.0	21	21	33.2
45-60	125.0	29.2	29.2	62.4
>60	161.0	37.6	37.6	100
Total	358	100	100	

** In the Gaza strip people pay their water bell every two months.*

Appendix 7.12

Question 6: Type of water problems

Water problems	Frequency	Percent	Vali%	Cumulative%
Quantity	130.0	**30.4**	30.4	30.4
Quality	62.0	**14.5**	14.5	44.9
Both	236.0	**55.1**	55.1	100.0
Total	428.0	100.0	100.0	

Appendix 7.13

Question 7: willingness to pay

Response	Frequency	Percent	Valid %	Cumulative%
Yes	186.0	**43.5**	43.5	43.5
No	242.0	**56.5**	56.5	100.0
Total	428.0	100.0	100.0	

Appendix 7.14

Question 7.1: % Amount to be added on the municipal water bill in (NIS)

% To be added to bill	Frequency	Percent	Valid %	Cumulative%
1-25%	169.0	**39.48**	90.86	90.86
26-50%	15.0	**3.5**	8.06	98.93
51-75%	1.0	**0.23**	0.53	99.54
76-100%	1.0	**0.23**	0.53	100
Sub total	186.0	**43.2**	100.0	
Missing (no answer)	242.0	**56.54**		
Total	428.0	100.0		

Appendix 8: List of water professionals (name, work, and position)

No.	Institution	Name	Position
1.	PAW/ World Bank	Khairy Al Jamal	Director of PMU (World Bank Project)
2.	PWA	Nahed Ghana	Chairman Assistance
3.	PWA	Ahmad Yaqobi	Director of Water Resources Depart.
4.	PWA	Sami Hamdan	Manager of Data Bank
5.	PWA	Munther Shublag	Deputy Director of PMU (WB-project)
6.	PWA	Mohamad Ahmad	Manager of inspection depart.
7.	PWA	Rebhy EL Sheikh	Director of Technical department
8.	PWA	Sadi Ali	Director of Swedish Project
9.	PWA	Majid Ghnam	Coordinator project
10	PWA	Maher El Najar	Coordinator project
11	PWA	Nehad Khatib	Coordinator project
12	Ministry Of Planning &International Cooperation (MOPIC)	Emad Shaath	Director
13	Ministry Of Planning &International Cooperation (MOPIC)	Mahmoud Sheikh Deep	Project Manager
14	Ministry of Local Governorate	Sufian Abu Sammra	Director of Technical Depart.
15	Ministry of Local Governorate	Khalil Ka Ismail	Manager of SMDM project
16	Beit Hanoun Municipality	Ramadan Naim	Manager of Water Depart.
17	Beit Lahia Municipality	Jaber Kaseeh	Manager of Water Depart.
18	Gaza Municipality	Hazim Tarazi	Director of water &Waste water Depart.
19	Gaza Municipality	Abu El Rahim abu Ghomboz	Director of Environment &Health Depart.
20	Nasserite Municipality	Khalil Ah.Ismail	Manager of water &Waste water Dep.
21	Khanyunis Municipality	Usuf El Hahj	Director of water &Waste water Dep.
22	Rafah Municipality	Ashraf Ghnaim	Manager of water &Waste water Dep.
23	Ministry Of Health	Ahmad Abu Al Nasser	Director Manager
24	Ministry of Agriculture	Shehada Wahdan	
25	Metcalf & Eddy (CAMP)	Haider Noori	Chief of Party
26	Metcalf & Eddy (CAMP)	Nabil Awad	Civil Engineer
27	Metcalf & Eddy (CAMP)	Farid Ashour	Environ. Engineer
28	USAID	-	-
29	USAID	Paul Stephey	Project Manager
30	ANERA	Salah Saqqa	Director
31	UNRWA	-	-
32	LEKA	Imad Ilian	Task Manager
33	LEKA	Ramiz Al Madhoun	Task Manager
34	LEKA	Marwan Bardaweel	Task Manager
35	LEKA	Omar Shatat	Task Manager
36	LEKA	Mahjed Zakout	Maintenance Engineer
37	Local Consultants TECC Environmental Quality Authority	Samir Mannah Baha El Falojy	General Manger Engineer
38	Environmental Quality Authority	Zaher Salem	Engineer
39	Environmental Quality Authority	Husam Zakoit	Engineer
40	Palestinian Hydrology Group (PHG)	Riyad Jinanah	Area Manager

41	Universities/Azhar	Mustafa el Baba	MSc
42	Universities/Azhar	Mohammad abu Jabal	MSc
43	Islamic University	Abed El Majeed Nassar	PHD
44	Islamic University	Yusuf al Ghreez	MSc
45	Deir El Balah Desalination /Trugena	Mazen abu Sammrah	Consultant Engineer
46	Deir El Balah Desalination Operator	Ibrahim Elswity	Operation Engineer
47	Vendors/ Akoa	Walid Abu Shaban	Manager of plant

Appendix 9: Results of interview questionnaires with water professionals

Appendix 9.1

Part (I): Political questions

Question 1: whether desalination option was chosen by PWA or donors?

Category	Frequency	Percent	Valid Percent	Cumulative Percent
PWA demand	23	**48.9**	48.9	48.9
Donors supply	20	**42.6**	42.6	91.5
No idea	4	**8.5**	8.5	100.0
Total	47	100.0	100.0	

Appendix 9.2

Question 2: Was fund from donors conditional?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	9.0	**19.1**	19.1	19.1
Agree	23.0	**48.9**	48.9	68.1
Don't know	6.0	**12.8**	12.8	80.9
Disagree	6.0	**12.8**	12.8	93.6
Strongly disagree	3.0	**6.4**	6.4	100.0
Total	47.0	100.0	100.0	

Appendix 9.3

Question 3: Were there obligations from PWA side?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	8	**17**	17	17
Agree	26	**55.3**	55.3	72.3
Don't know	8	**17**	17	889.4
Disagree	3	**6.4**	6.4	95.7
Strongly disagree	2	**4.3**	4.3	100.0
Total	47.0	100.0	100.0	

Appendix 9.4

Question 4: Will the desalination affect the Palestinians water rights?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	18.0	**38.3**	38.3	38.3
Agree	16.0	**34.0**	34.0	72.3
Don't know	3.0	**6.4**	6.4	78.7
Disagree	7.0	**14.9**	14.9	93.6
Strongly disagree	3.0	**6.4**	6.4	100.0
Total	47.0	100.0	100.0	

Appendix 9.5
Part (II): Technical questions

Question 5: Are exist small scale desalination plants/units a permanent solution?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	3.0	6.4	6.4	6.4
Agree	7.0	14.9	14.9	21.3
Don't know	1.0	2.1	2.1	23.4
Disagree	20.0	42.6	42.6	66.0
Strongly disagree	16.0	34.0	34.0	100.0
Total	47.0	100.0	100.0	

Appendix 9.6

Question 6: Does GSWDP a necessary to improve municipal water quality & quantity?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Necessary	38.0	80.9	80.9	80.9
Don't know	2.0	4.3	4.3	85.1
Not necessary	7.0	14.9	14.9	100.0
Total	47.0	100.0	100.0	

Appendix 9.7

Question 7: What is the main objective of GSWDP?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Secure potable water	28.0	59.6	59.6	59.6
Conserve w. resources	5.0	10.6	10.6	70.2
Solving water dispute	13.0	27.7	27.7	97.9
Others	1.0	2.1	2.1	100.0
Total	47.0	100.0	100.0	

Appendix 9.8

Question 8: Has water quality from GSWDP been assigned?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	22.0	46.8	46.8	46.8
No	4.0	8.5	8.5	55.3
No idea	21.0	44.7	44.7	100.0
Total	47.0	100.0	100.0	

Appendix 9.9

Question 9: Can small-scale desalination plants be survive in the presence of GSWDP?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	3.0	6.4	6.4	6.4
Agree	19.0	40.4	40.4	46.8
Don't know	10.0	21.3	21.3	68.1
Disagree	11.0	23.4	23.4	91.5
Strongly disagree	4.0	8.5	8.5	100.0
Total	47.0	100.0	100.0	

Appendix 9.10

Question 10: Has GSWDP a positive impact on agriculture?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	11.0	23.4	23.4	23.4
Agree	29.0	61.7	61.7	85.1
Don't know	1.0	2.1	2.1	87.2
Disagree	4.0	8.5	8.5	95.7
Strongly disagree	2.0	4.3	4.3	100.0
Total	47.0	100.0	100.0	

Appendix 9.11

Question 11: Can large-scale desalination be a sustainable option?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	6.0	**12.8**	12.8	12.8
Agree	24.0	**51.1**	51.1	63.8
Don't know	1.0	**2.1**	2.1	66.0
Disagree	10.0	**21.3**	21.3	87.2
Strongly disagree	6.0	**12.8**	12.8	100.0
Total	47.0	100.0	100.0	

Appendix 9.12

Question 12: Is there an emergency plan for GSWDP?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	15.0	**31.9**	31.9	31.9
Agree	29.0	**61.7**	61.7	93.6
Don't know	2.0	**4.3**	4.3	97.9
Disagree	1.0	**2.1**	2.1	100.0
Strongly disagree	0.0	**0.0**	0.0	
Total	47.0	100.0	100.0	

Appendix 9.13

Part (III): Socio-economic questions

Question 13: Was water tariff from GSWDP assigned?

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	9.0	19.1	19.1	19.1
No	13.0	27.7	27.7	46.8
No idea	25.0	53.2	53.2	100.0
Total	47.0	100.0	100.0	

Appendix 9.14

Question 14: Has cost of cubic metre that produced from GSWDP been assigned?

Response	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	12.0	**25.5**	25.5	25.5
No	14.0	**29.8**	29.8	55.3
No idea	21.0	**44.7**	44.7	100.0
Total	47.0	100.0	100.0	

Appendix 9.14.1

Question 14.1: If yes, how much does desalinated water cost?

Cost in US$/M³	Frequency	Percent	Valid Percent	Cumulative Percent
0.0(no answer)	38.0	**80.9**	80.9	80.9
0.4	1.0	**2.1**	2.1	83.0
0.5	2.0	**4.3**	4.3	87.2
0.6	2.0	**4.3**	4.3	91.5
0.6	1.0	**2.1**	2.1	93.6
0.7	1.0	**2.1**	2.1	95.7
1.0	1.0	**2.1**	2.1	97.9
1.2	1.0	**2.1**	2.1	100.0
Total	47.0	100.0	100.0	

Appendix 9.15

Question 15: Can people afford for desalinated water?

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	33.0	**70.2**	70.2	70.2
No	10.0	**21.3**	21.3	91.5
No idea	4.0	**8.5**	8.5	100.0
Total	47.0	100.0	100.0	

Appendix 9.16

Question 16: Are people willing to pay?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Strongly agree	3.0	**6.4**	6.4	6.4
Agree	29.0	**61.7**	61.7	68.1
Don't know	7.0	**14.9**	14.9	83.0
Disagree	5.0	**10.6**	10.6	93.6
Strongly disagree	3.0	**6.4**	6.4	100.0
Total	47.0	100.0	100.0	

Appendix 9.17

Question 17: Are there procedures to enforce people to pay?

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	14.0	**29.8**	29.8	29.8
No	24.0	**51.1**	51.1	80.9
No idea	9.0	**19.1**	19.1	100.0
Total	47.0	100.0	100.0	

Appendix 9.18

Question 18: Is there any policy at PWA to protect poor people?

Answer	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	10.0	**21.3**	21.3	21.3
No	17.0	**36.2**	36.2	57.4
No idea	20.0	**42.6**	42.6	100.0
Total	47.0	100.0	100.0	

Appendix 9.19

Question 19: Whether public were involved in the project stages?

Ranking	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	16.0	**34.0**	34.0	34.0
No	19.0	**40.4**	40.4	74.5
No idea	12.0	**25.5**	25.5	100.0
Total	47.0	100.0	100.0	

Appendix 9.19.1

Question 19.1: If yes, to which stages did public involve?

Process stage	Frequency	Percent	Valid Percent	Cumulative Percent
0.00(said No in previous question)	31.0	**66.0**	66.0	66.0
Initial assessment	7.0	**14.9**	14.9	80.9
Study preparation	4.0	**8.5**	8.5	89.4
In the whole process	5.0	**10.6**	10.6	100.0
Total	47.0	100.0	100.0	

Appendix 9.20

Question 20: Which type of contract is fit for O&M of GSWDP?

Type of contract	Frequency	Percent	Valid Percent	Cumulative Percent
Public sector	3.0	**6.4**	6.4	6.4
Public - public partnership	3.0	**6.4**	6.4	12.8
Public - private partnership	31.0	**66.0**	66.0	78.7
Private sector	10.0	**21.3**	21.3	100.0
Total	47.0	100.0	100.0	

Appendix 10: Population count of the Gaza Strip municipalities

No.	Governorate	City/Village	Population in 1997	Total Population in 1997	*Population in 2002	Total Population in 2002
1	**North**	Jabalia	113213	**185604**	149784	**245250**
2		Beit Lahia	38228		50576	
3		Beit Hanoun	25405		33612	
4		Om Al Nassr	8758		11278	
5	**Gaza**	Gaza	351914	**366267**	439112	**459045**
6		Al Zhra(new)	8500		12629	
7		Al Moghragah	3590		4480	
8		Wadi Gaza	2263		2824	
9	**Deir El balah**	Deir El balah	42611	**144814**	52111	**182292**
10		Al Nasserite	44452		56449	
11		Al Buraij	25028		31783	
12		Al Maghazi	16756		21278	
13		Al Zawydah	10683		13566	
14		Wadi Salga	3215		4583	
15		Al Musadar	1869		2522	
16	**Khanyunis**	Khanyunis	133566	**195474**	176602	**256384**
17		Bani Suhila	22892		28761	
18		Big Abasan	13297		16706	
19		Al Qarrara	12435		15624	
20		New abasan	3938		4948	
21		Khuzaa	6751		8482	
22		Al Fakhari	2595		5261	
23	**Rafah**	Rafah	110064	**125592**	136003	**156432**
24		Al Shoka	11584		14519	
25		Al nasser	3944		5910	
	Total		**1017551**	**1017751**	**1299403**	**1299403**

Source: *PCBS (1999)*

*Population of Gaza Strip cities& villages at 2002 is calculated at rate of growth of 3% per year