

*Economics of Using Desalinated Sea Water and Brackish  
Water in Supplementary Irrigation*

**By**

**Somea Ibrahim Khoder**

B.Sc. Civil Engineering, Syria

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
In  
**Irrigation and Hydraulics  
Engineering**

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT**

**2012**

*Economics of Using Desalinated Sea Water and Brackish  
Water in Supplementary Irrigation*

**By**

**Somea Ibrahim Khoder**

B.Sc. Civil Engineering, Syria

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
In  
**Irrigation and Hydraulics  
Engineering**

**Supervised by:**

**Prof. Khaled Hussein Hamed**

Professor of Hydraulics  
Irrigation and Hydraulics Dept.,  
Cairo University

**Dr. Hesham Bekhit Mohamed**

Associate Professor  
Irrigation and Hydraulics Dept.,  
Cairo University

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT**

2012

*Economics of Using Desalinated Seawater and Brackish  
Water in Supplementary Irrigation*

**By**

**Somea Ibrahim Khoder**

B.Sc. Civil Engineering, Syria

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
In Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
In  
**Irrigation and Hydraulics  
Engineering**

**Approved by the:**  
**Examining committee:**

**Prof. Khaled Hussein Hamed**

Irrigation and Hydraulics Dept., Cairo University (Main Advisor)

**Prof. Sameh Mohamed Abdel-Gawad**

Irrigation and Hydraulics Dept., Cairo University (Member)

**Prof. Osama Khairy Saleh**

Faculty of Engineering, Zagazig University (Member)

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT**

**2012**

**Engineer:** Somea Ibrahim Khoder

**Date of Birth:** 6<sup>th</sup>/Jan /1981

**Nationality:** Syrian

**E-mail:** soma-cp1981@hotmail.com

**Phone:** 01099219196

**Address:** Mahmoud Sami Baroudi Street / Giza

**Registration Date:** 1 /10/2009

**Awarding Date:** / /

**Degree:** Masters.

**Department:** Irrigation and Hydraulics

**Supervisors:** Prof. Khaled Hussein Hamed,  
Dr. Hesham Bekhit Mohamed



<b>Examiners:</b>	Prof. Khaled Hussein Hamed	Maine supervisor
	Prof. Sameh Mohamed Abdel-Gawad	Member
	Prof. Osama Khairy Saleh	Member

**Title of Thesis:** Economics of Using Desalinated Seawater and Brackish Water in Supplementary Irrigation

**Key Words:** desalination, RO, ED, MED, supplementary irrigation, CROPWAT.

**Summary.** At present, about 40% of the world's population is suffering from serious water shortages. This is because of the rapid increase of population, and pollution that limit the use of fresh water resources. In addition, according to IPCC the rainfall and water resources will decrease significantly because of climate change. Concerns about the sustainability of freshwater supplies are fostering the interest in desalination as a one possible solution to the increased water demand especially in agriculture sector. This study investigates the economics of using the desalinated salt water and brackish water especially in supplementary irrigation. To find an optimum solution linking the economic cost of the desalination plant technology with the economic return of water used in supplementary irrigation by finding breakeven curves for each crop and analysis for change variables. Desalination presents the main opportunity to meet the increased demand and reduce the food gap by providing freshwater not only from the sea, but also from brackish groundwater. This research offers solution to cover loss in cost due to reduction of water, using supplement irrigation.

## **ACKNOWLEDGMENT**

I express my sincere gratitude to Prof. Khaled Hussein Hamed and Dr. Hesham Bekhit Mohamed, my supervisors, whose invaluable guidance and insightful suggestions from the initial to the last stage have greatly contributed to this study.

I appreciate enormously the help of all staff members of Cairo University, Irrigation and Hydraulics Dept., who were my first advisers by guiding me during my first steps in Cairo University. I would like to express my grateful recognition to my close friends and colleagues, their support gave me the energy and the courage required to accomplish this research. I extend my appreciation and blessings to all of those who supported me in any respect during this study.

I would like to express my deepest gratitude to my family, my father, my sisters and brothers.

Finally, this work is dedicated to the spirit of my mother, and Jasmine's land, cradle of civilization my home SYRIA.

Somea

## **ABSTRACT**

Only 6 percent of all the Earth's water is fresh, while 94 percent is salt water from the oceans. At present, about 40% of the world's population is suffering from serious water shortages. This is because of the rapid increase of population and pollution that limit the use of fresh water resources. In addition, according to the Intergovernmental Panel on Climate Change (IPCC) the rainfall and water resources will decrease significantly in the Arab countries because of the expected increase in temperature that will lead to increasing evaporation losses, losses in soil moisture, and decrease in the groundwater levels. Concerns about the sustainability of freshwater supplies are fostering the interest in desalination as a one possible solution to increase water demand. It is expected that the agricultural sector will be significantly affected and the water availability for this sector will be decreased. In the Arab Region, desalination presents the main opportunity to meet the increased demand and reduce the food gap by providing freshwater not only from the sea, but also from brackish groundwater. This study investigates the economics of using the desalinated sea water and brackish water especially in supplementary irrigation to find a solution linking the economic cost of the desalination plant technology used in the region with the economic return of water used in supplementary irrigation. This has been achieved by studying the economics of using the desalinated water in supplementary irrigation and the influence of variables change (cultivated area, maximum yield, feed salinity, and crop sale price) on the cost by calculating breakeven curve for every crop.

First, cost equations of desalination are fitted as a function of capacity and degree of feed salinity using regression analysis by using Excel. Next, yield reduction under stress of water shortage is studied for different stages of growth, and its influence on the loss of profit was assessed by using the CROPWAT program. Finally, breakeven curves for each crop are established and compared. This research offers a solution to cover loss in profit due to lack of sufficient water resources, using supplementary irrigation. Desalination offers a good benefit, especially for large capacity and large

area of relatively profitable crops. Future studies must focus on reduction the cost of desalination.

# TABLE OF CONTENTS

<b>TITLE</b>	<b>PAGE</b>
<b>ACKNOWLEDGEMENT</b>	I
<b>ABSTRACT</b>	II
<b>TABLE OF CONTENTS</b>	IV
<b>LIST OF FIGURES</b>	VI
<b>LIST OF TABLES</b>	VIII
<b>LIST OF SYMBOLS</b>	X
<b>CHAPTER 1: INTRODUCTION</b>	
1-1 General	1
1-2 Problem Definition	2
1-3 Research Objectives	3
1-4 Outlines of the Thesis	3
<b>CHAPTER 2: DESALINATION PROCESSES</b>	
2-1 Introduction	6
2-2 Definition of Desalination Technology	6
2-3 Parameters of Quality of Water	7
2-4 Overview and Classification of Desalination Processes	8
2-5 Elements of Economic Calculations	12
2.5.1 Direct Capital Cost	13
2.5.2 Indirect Capital Cost	14
2.5.3 Operating Cost	15
2.6 Comparison of Distillation and Membrane Process	17
2-7 Factors Affecting Technology Selection	18
2-8 Description of Some Desalination Process	21
2-8-1 Reverse Osmosis	21
2-8-2 Electrodialysis	24
2.8.3 Multi Effect Distillation	26
<b>CHAPTER 3: Supplementary Irrigation</b>	
3-1 Introduction	29
3-2 Computation of The Crop Water Requirements:	29
3-3 Crop Coefficient (Kc)	31



3-4 Yield Response Factor ( $K_y$ )	31
3-5 Maximum Yield ( $Y_m$ )	33
3-6 Actual Yield ( $Y_a$ )	33
3-7 Water Stress Coefficient ( $K_s$ )	34
3-8 Supplementary Irrigation	35
<b>CHAPTER 4: Literature Review</b>	
4-1 Introduction	37
4-2 Previous researches for desalination	37
4-3 General remark	43
4-4 Desalination profile in Egypt	44
4-5 Desalination in agriculture sector	46
<b>CHAPTER 5 : Methodology</b>	
5-1 Introduction	49
5-2 Available Data for Desalination	49
5-3 Regression Analysis	52
5-4 Irrigation Requirement Calculation by CROPWAT 8.0	58
5-5 Desalination for Supplementary Irrigation	59
<b>CHAPTER 6: Application and Results Analysis</b>	
6-1 Introduction	62
6-2 Study Area	62
6-2-1 General Description	62
6-2-2 Water Resources	63
6-2-3 Water Balance	63
6-3 Model Application	63
6-4 Sensitivity Analysis	71
<b>CHAPTER 7: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS</b>	82
7-1 Summary	82
7-2 Conclusions	82
7-3 Recommendations	83
<b>REFERENCES</b>	85
<b>APPENDICES</b>	87

## LIST OF FIGURES

<b>N0.</b>	<b>TITLE</b>	<b>PAGE</b>
1.	Fig (2-1) Definition of various desalination processes.	7
2.	Fig (2-2) Energy classification of desalination process.	11
3.	Fig (2-3) Global desalination plant capacity by technology.	12
4.	Fig (2-4) Cost elements of desalination processes.	17
5.	Fig (2-5) Description of RO process.	23
6.	Fig (2-6) Basic illustration of Electrodialysis processes	26
7.	Fig (2-7) Basic illustration of the MED process	28
8.	Fig(3-1) Generalized relationship between relative yield decrease (1 - Ya/Ym) and relative Evapotranspiration.	32
9.	Fig (3-2) Soil water balance.	34
10.	Fig(4-1) Estimation of profit changes according to operation conditions	39
11.	Fig (4-2) Installation capacities	46
12.	Fig (5-1) Illustrate methodology	50
13.	Fig (5-2) Type of desalination technology uses in study	51
14.	Fig (5-3) Relationship cost & capacity for RO – BW (1000-3000)	53
15.	Fig (5-4) Relationship cost & capacity for RO – BW (3000-5000)	54
16.	Fig (5-5) Relationship cost & capacity for RO – BW (5000-10000)	55
17.	Fig (5-6) Relationship cost & capacity for RO –HBW (10000-25000) SW (25000-47000)	56
18.	Fig (5-7) Relationship cost & capacity for EDR- BW(500-5000)	57
19.	Fig (5-8) Relationship cost & capacity for MED- BW (500-5000)	58
20.	Fig (5-9) Relationship of Cost & Capacity for all studied processes	59
21.	Fig (5-10) Flowchart illustrate crops relationships	61
22.	Fig (6-1) Breakeven points for (cotton crop) between water costs versus available water.	65
23.	Fig (6-2) Breakeven points for wheat between water costs versus available water.	67
24.	Fig (6-3) Breakeven points for Banana between water costs versus available water	69
25.	Fig (6-4) Breakeven points for tomato between water costs versus available water	69

<b>N0.</b>	<b>TITLE</b>	<b>PAGE</b>
26.	Fig (6-5) Breakeven points for Roselle between water costs versus available water.	70
27.	Fig (6-6) Sensitivity analysis for cotton due to a) Price change, b) maximum yield, c) feed salinity	73
28.	Fig (6-7) Influence change cultivated area on cotton crop a) area=1 ha, b) area=100ha, c) area=500 ha.	74
29.	Fig (6-8) Sensitivity analysis for wheat due to a) change price, b) maximum yield) Feed salinity	75
30.	Fig (6-9) Influence change cultivated area on wheat crop a) area=1 ha, b) area=100ha, c) area=500 ha.	76
31.	Fig (6-10) Sensitivity analysis Banana crop due to a) price change, b) maximum yield, c) feed salinity	77
32.	Fig (6-11) Influence change cultivated area on banana crop a) area=1 ha, b) area=100ha, c) area=500 ha.	78
33.	Fig (6-12) Sensitivity analysis for tomato crop due to a) Change price, b) maximum yield , c) feed salinity	79
34.	Fig (6-13) Influence change cultivated area on tomato crop a) area=1 ha, b) area=100ha, c) area=500 ha.	80
35.	Fig (6-14) Sensitivity analysis Roselle crop due to a) change price b) maximum yield , c) feed salinity	81
36.	Fig (6-15) Influence change cultivated area on Roselle crop a) area=1 ha, b) area=100ha, c) area=500 ha.	82

## LIST OF TABLES

NO.	TITLE	PAGE
1.	Table (1-1) Water salinity classification	1
2.	Table (2-1) Quality categories for water salinity.	9
3.	Table (2-2) comparison of distillation and membrane processes advantages and disadvantages	19
4.	Table (2-3) Percent recovery of feed water	21
5.	Table (4-1) Capacity of desalination unit and cost of water produced	40
6.	Table (4-2) Type of energy supply system and cost of water produced	41
7.	Table (4-3) Thermal methods and cost of water produced (per m <sup>3</sup> )	42
8.	Table (4-4) Membrane (RO) methods and water desalination cost (per m <sup>3</sup> )	43
9.	Table (4-5) Water demand and desalination capacity in the Red Sea and South Sinai.	45
10.	Table (4-6) Red Sea modern desalination units.	46
11.	Table (5-1) Ranges feed water salinity before desalination :	51
12.	Table(5-2) Allowable range of the feed water salinity for each processes	52
13.	Table (5-3)Fitting cost RO – brackish water (1000-3000 ppm)	53
14.	Table (5-4) Fitting criteria of equations for RO – brackish water (1000-3000 ppm)	53
15.	Table (5-5) Fitting cost data RO – brackish water (3000-5000 ppm).	54
16.	Table (5-6) Fitting criteria of equations for RO – brackish water (3000-5000ppm)	54
17.	Table (5-7) Fitting cost RO – brackish water (5000-10,000 ppm)	55
18.	Table (5-8) Fitting criteria of equations for RO– brackish water (5000-10,000 ppm)	55
19.	Table (5-9) Fitting cost RO – high brackish water (10,000-25,000 ppm) & sea water (25,000-45,000 ppm).	56
20.	Table (5-10) Fitting criteria of equations for RO– high brackish water (10,000-25,000 ppm) & sea water (25,000-45,000 ppm).	56
21.	Table (5-11) Fitting cost ED –brackish water (500-5000 ppm)	57

<b>N0.</b>	<b>TITLE</b>	<b>PAGE</b>
22.	Table (5-12) Fitting criteria of equations ED –brackish water (500-5000 ppm)	57
23.	Table (5-13) Fitting cost MED –brackish water (500-5000 ppm).	58
24.	Table (5-14) Fitting criteria of equations MED –brackish water (500-5000 ppm)	58
25.	Table (6-1) Breakeven cost computations for cotton.	65
26.	Table (6-2) Data required for calculations SI, BEP for cotton crop.	65
27.	Table (6-3) Criteria salinity for cotton crop.	66
28.	Table (6-4) Breakeven cost computations for wheat.	67
29.	Table (6-5) Data required for calculations SI, BEP for wheat crop.	67
30.	Table (6-6) Criteria salinity for wheat crop.	68
31.	Table (6-7) Breakeven cost computations for banana.	68
32.	Table (6-8) Data required for calculations SI, BEP for Banana crop.	69
33.	Table (6-9) Criteria of salinity for Banana crop.	69
34.	Table (6-10) Breakeven cost computations for tomato.	70
35.	Table (6-11) Data required for calculations SI, BEP for tomato crop.	70
36.	Table (6-12) Criteria of salinity for tomato crop.	70
37.	Table (6-13) Breakeven cost computations for Roselle.	71
38.	Table (6-14) Data required for calculations SI, BEP for Roselle crop	71
39.	Table (6-15) Salinity criteria for Roselle crop	71

## LIST OF SYMBOLS, AND ABBREVIATIONS

### Symbols

<b><i>BEP</i></b>	Breakeven point(\$/m <sup>3</sup> )
<b><i>C</i></b>	Capacity (m <sup>3</sup> /day)
<b><i>CG</i></b>	Crop gain due to water deficit in each stage
<b><i>CG max</i></b>	Maximum crop gain due to ET <sub>max</sub>
<b><i>CWR</i></b>	Crop water requirements (m <sup>3</sup> )
<b><i>Dr</i></b>	Root zone depletion [mm].
<b><i>ea</i></b>	Actual vapors pressure [kPa],
<b><i>es- ea</i></b>	Saturation vapour pressure deficits [kPa],
<b><i>es</i></b>	Saturation vapors pressure [kPa],
<b><i>ET0</i></b>	The reference evaporation (mm/day)
<b><i>Eta</i></b>	Actual crop evapotranspiration (mm/day)
<b><i>ETc</i></b>	(ET <sub>max</sub> ) is daily evapotranspiration (Et <sub>c</sub> in mm) of crop under irrigation or Maximum evapotranspiration.
<b><i>Etm</i></b>	crop evapotranspiration for standard conditions (no water stress) (mm/day)
<b><i>ETm</i></b>	Refers to conditions when water is adequate for unrestricted growth and development.
<b><i>G</i></b>	Soil heat flux density [MJ m <sup>-2</sup> day <sup>-1</sup> ],
<b><i>ha</i></b>	Hectare ( area unit)
<b><i>Ks</i></b>	A dimensionless transpiration reduction factor dependent on available soil water [0 - 1].
<b><i>n</i></b>	The number of data
<b><i>p</i></b>	Fraction of TAW that a crop can extract from the root zone without suffering water stress.
<b><i>Q mix</i></b>	The amount of water that is mixed with salt water to get proper salinity of plant. (m <sup>3</sup> /day).
<b><i>RAW</i></b>	Readily available water
<b><i>Rn</i></b>	Net radiation at the crop surface [MJ m <sup>-2</sup> day <sup>-1</sup> ],
<b><i>SI</i></b>	Supplementary irrigation (m <sup>3</sup> )
<b><i>T</i></b>	Air temperature at 2 m height above ground level [°C],
<b><i>TAW</i></b>	Total available soil water in the root zone [mm].
<b><i>U2</i></b>	Wind speed at 2 m height [m s <sup>-1</sup> ],
<b><i>Ya</i></b>	Actual crop yield (ton/hectare)
<b><i>Ym</i></b>	Maximum expected crop yield for standard conditions(ton/hectare)

$Y_{cal}$	Predicted data
$Y_{obs}$	Observed data
$YR$	Yield reduction
$lp$	Length of growing period in days
$\gamma$	Psychrometric constant ([kPa °C <sup>-1</sup> ].)
$\Delta$	Slop vapour pressure curve [kPa °C <sup>-1</sup> ],

## Abbreviations

<b>ABVC</b>	Absorption Vapor Compression
<b>ADVC</b>	Adsorption Vapor Compression
<b>BW</b>	Brackish water
<b>CVC</b>	Chemical Vapor Compression
<b>ED</b>	Electro-Dialysis
<b>FAO</b>	Food and Agriculture Organization
<b>HDH</b>	Humidification - Dehumidification
<b>HBW</b>	High brackish water
<b>IDA</b>	International Desalination Association
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>MED</b>	Multi Effect Desalination
<b>MEE</b>	Multi Effect Evaporation
<b>MSF</b>	Multi Stage Flash
<b>MVC</b>	Mechanical Vapor Compression
<b>RO</b>	Reverse Osmosis
<b>SEE</b>	Single Effect Evaporation
<b>TDS</b>	Total dissolved solids
<b>TVC</b>	Thermal Vapor Compression

# CHAPTER ONE

## Introduction

### 1-1 General:

As a result of increasing population growth, some Arab countries with relatively existing sufficient water resources (such as Lebanon, Egypt, Morocco, Syria) will suffer from severe water problems and will join the countries under the water poverty limit by the year 2050. Also, the Inter-governmental Panel on Climate Change (IPCC) has noticed that the rainfall and water resources will decrease significantly in the Arab countries by the year 2050 (IPCC, 2009). IPCC (Inter-governmental Panel on Climate Change) suggested that the expected increase in temperature will lead to increase in evaporation losses, loss in soil moisture, and decrease in groundwater levels. As a result of the future shortage in water resources in these Arab countries, it is expected that the agricultural sector will be significantly affected and water availability for this sector will decrease. Accordingly, the development of non-conventional water resources such as desalination of both sea water and brackish water is of great importance in meeting the water needs of the Arab countries.

Desalination of sea water and brackish groundwater for public drinking water supply is adopted in many parts of the world in areas where the demand is increasing beyond the supply. A seawater desalination process separates saline seawater into two streams: a fresh water stream containing a low concentration of dissolved salts and a concentrated brine stream. Salt water is divided on the basis of the total amount of water-soluble salts in parts per million as shown in Table (1-1).

Table (1-1) Water salinity classification

<b>Fresh water</b>	<b>Brackish water</b>	<b>salt water</b>	<b>Brine Water</b>
<500 ppm	500-20,000 ppm	20,000-50,000 ppm	>50,000 ppm

There are many techniques used for the desalination of sea water, including thermal methods, flash evaporation method, multi-stage distillation, multi-effect distillation



using solar energy, steam distillation, and membranes methods (e.g., electric power methods sorting membrane dialysis and reverse electricdialysis). The technology used for desalination depends on the quality of the water source and the desired degree of desalination of produced water. The salinity of seawater ranges from 20,000 to 50,000 ppm, and the salinity of the brackish groundwater ranges from 500 to 20,000 ppm. In order to select the adequate technology to desalinate water, consideration should be taken into accounts, which are:

- The quality of feed water source and the concentration of total dissolved solids ( TDS)
- Sources of energy available, such as oil, electricity, gas, or renewable sources (e.g., wind, solar energy).
- Desalination plant to be close to the usage area.
- Expected uses of water (industrial, agriculture, domestic ...etc).

### **1-2 Problem Definition:**

Concerns about the sustainability of freshwater supplies are fostering the interest in desalination as one possible solution to the increased water demand. Sandia National Laboratories announced that more than 70 billion dollars will be spent worldwide over the next 20 years to design and build new desalination plants and facilities. In the Arab Region, desalination presents the main opportunity to meet the increased demand and reduce the food gap by providing freshwater not only from the sea, but also from brackish groundwater. Unfortunately, previous studies did not thoroughly investigate the economics of using the desalinated salt water and brackish water especially in supplementary irrigation. Accordingly, this study aimed at providing some efforts in this regard.

### **1-3 Research Objectives:**

The main objective of this research is to link the economic cost of the desalination plant technologies used in the region with the economic return of water used in supplementary irrigation. This could be obtained by achieving the following specific objectives:

- Establishing a relation between the cost of desalination process and the capacity of feed salinity for different desalination techniques in the region.
- Examining the economics of using desalinated sea water and brackish water in supplementary irrigation, for different crops.
- Deriving curves that represent breakeven between the amounts of available water with the cost of water, for getting optimum profit for each crop. Therefore assessing the feasibility of using desalination for supplementary irrigation.

### **1-4 Outlines of the Thesis:**

This thesis consists of seven chapters, the details of each chapter and their interrelations are as follows:

#### **• Chapter (1): Introduction**

This Chapter presents general information about the research point, problem definition, objectives and the thesis contents.

#### **• Chapter (2): Desalination Processes**

This chapter covers the definition of desalination, overview of desalination technologies, types of desalination processes, factors affecting technology selections and product cost, elements of economic calculations, advantages and disadvantages of each type of technology, ranges of salinity of sea water and brackish water, and limits of product salinity for different uses in each sector (municipal, agriculture, industrial.....etc ).

- **Chapter (3): Supplementary Irrigation**

This chapter illustrates information about crops, factors affecting crop water requirements and supplementary irrigation, yield reduction based on CROPWAT computer program, and equations developed in previous studies.

- **Chapter (4): Literature Review:**

This chapter gives a review of previous studies related to desalination processes as well as supplementary irrigation.

- **Chapter (5): Methodology:**

This chapter describes the methodology used in this research:

1. Compiling all available data about methods and techniques of desalination and their cost. This is conducted by using internet resources and communication with different desalination companies in Egypt.
2. Constructing cost curves for each desalination technique showing the cost of desalination as a function of the quantity of water and the degree of feed salinity.
3. A synthetic analysis is conducted to study the economics of using desalinated water in the supplementary irrigation. In this analysis different crops will be selected and the feasibility for preventing yield loss by using supplementary irrigation will be evaluated at different levels of supplementary water requirements.
4. Effect of the price, maximum yield, and the amount of reduction of water as decision variables on the economic return is also studied.

- **Chapter (6): Application and Results Analysis:**

This chapter presents the results of analysis:

- Establish curves that can be used to relate the cost of desalination to the quantity of water for each degree of feed salinity.

- Provide a decision tool that could examine the economics of using desalinated salt water or brackish water in supplementary irrigation.

- **Chapter (7): Conclusions and Recommendations :**

This chapter gives the main study conclusions, general remarks, and recommendations for future research.