University of Bahrain
Deanship of Scientific Research

THE AGRICULTURAL WATER ALLOCATION ISSUES IN THE KINGDOM OF BAHRAIN

By
Anisa Ahmed Salman Khalaf

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER IN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Kingdom of Bahrain

2006

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DECLARATION

I declare that this work is the result of my own investigation and that it has not already been accepted in substance for any degree, nor is it being currently submitted for any degree.

Signed :.....Anisa..... **Date:**.....16th January.07

Anisa Ahmed Salman Khalaf (candidate)

The Thesis defense committee considers the Thesis titled

THE AGRICULTURAL WATER ALLOCATION ISSUES IN THE KINGDOM OF BAHRAIN

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Submitted by Anisa Ahmed Salman Khalaf to the Deanship of Scientific Research satisfactory and acceptable for the Master of Science degree in Environment and Sustainable Development.

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* Dr. Mohanned S. Al-Sheriadeh, was the supervisor of the above titled thesis.

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Abstract

Groundwater is the only traditional water resources in Bahrain. It is a trans-boundary source. The aquifer outcrops in central Arabian Peninsula and discharges partly in Bahrain. The over-exploited of this scarce resource for many years has led to the deterioration of its quantity and quality to an alarming level. Most of the over-exploitation is attributed to agriculture sector. Meanwhile, the government tries to ease the dependency on groundwater by water desalination. This policy of increasing the supply has been confronted by the high cost of desalination and the increased demand. An alternative water source has arose recently that could reduce the dependency on groundwater, it is the treated wastewater. The high cost of desalinated water and the promising treated wastewater shifted gears in the use of groundwater for agriculture in Bahrain. However, the diversion of part of groundwater from agriculture could lead to other implications on farmers including jobs and social structure. The research herein addresses the issue of water management from the perspective of groundwater uses for agriculture sector. A questionnaire was prepared and distributed to 125 farmers on the basis of one-on-one meetings or interviews. Results of the questionnaire have indicated that the young Bahrainis are not taking over farming from old generation, have no objections for the use of treated wastewater for agriculture and thus farming is becoming more and more unattractive profession. Farmers are still using unwise agricultural practices like old irrigation systems and plantation of water consuming crops. The results illustrated that there is a good opportunity for the diversion of groundwater to other uses with little implications on farmers in the long run. These opportunities will sustain the available groundwater and environmental sustainability as a whole.

Table of Contents

		Page
Chapter 1 Introduction		**1**
1.0	Introduction	1
1.1	Problem Identification	6
1.2	Importance of the Problem	6
1.3	Objectives of the Study	6
1.4	Methodology of the Study	7
Chapter 2 Natural Setting and Water Resources		**9**
2.0	Natural Setting and Water Resources	9
2.1	Location	10
2.2	Topography, Geology and Surface Relief	11
2.3	Climate	13
2.4	Water Resources in Bahrain	14
2.5	Groundwater Resources	14
	2.5.1 The Hydrogeologic Setting	14
	2.5.2 Groundwater Flow	16
	2.5.3 Groundwater Quality	19
	2.5.4 Groundwater Recharge	21
	2.5.5 Springs	22
	2.5.6 Groundwater Abstraction	22
	2.5.7 Impact of Groundwater Abstraction	24
2.6	Desalinated Water	28
2.7	Treated Wastewater	30
2.8	Cost of Production	32
Chapter 3 Water Usage		**36**
3.0	Water Usage	37
3.1	Agricultural Use	38
	3.1.1 Agricultural Soil	38
	3.1.2 Planted Crops	38
	3.1.3 Irrigation Methods	42
	3.1.4 Irrigation Efficiency	42
	3.1.5 Reforms in the Agricultural Sector	43
3.2	Domestic Uses	44
	3.2.1 Population	44
	3.2.2 Domestic Water Use	45

3.3 Industrial Uses 47
3.4 Groundwater Balance 47
3.5 Water Resources Management 48
3.5.1 Water Resources Planning 49
3.5.2 Water Policies 50
3.5.3 Demand Managemement 51
3.5.3.1 Water Saving Technology 52
3.5.3.2 Water Pricing 54
3.5.3.3 Water Allocation Changes 54
3.6 Supply Management 55
3.6.1 Groundwater Recharge 55
3.6.2 Water Legislation 56
3.6.3 Enforcement and Evaluation of Legislation 58
3.6.4 Recent Legislation 59
3.6.5 Water Institution Reform 59
3.6.6 Development of Human Resources 60
3.7 Socio-Economic Evolvement in Bahrain 60

Chapter 4 Survey and Analysis **62**
4.0 Questionnaire Background 63
4.1 Description of the Questionnaire 66
4.2 Questions and Data 66
4.3 Survey Results 67
4.4 Conclusions and Recommendations 91

Appendix A : Questionnaire for evaluating formers Views on Agriculture in Bahrain **95**

List of Figures and Photos

	Page
Figure 1.1. Kingdom of Bahrain location map.	8
Figure 2.1. Various administrative divisions and cities of Kingdom of Bahrain.	10
Figure 2.2. Simplified lithological logs for borehole 1116, located in Abu-Jarjur well field.	12
Figure 2.3. Bahrain average temperature (°C), 1946-2004.	13
Figure 2.4. Bahrain means precipitation (mm), 1946-2004.	14
Figure 2.5. Hydrogeological cross section showing the C aquifer system in Bahrain.	16
Figure 2.6. Regional hydrogeological cross section Bahrain and Dammam Domes.	18
Figure 2.7. Effect of groundwater salinity due to abstraction.	19
Figure 2.8. Changes in the Dammam aquifer potentiometer levels in Bahrain, 1925-2001.	25
Figure 2.9. Changes in the Dammam aquifer salinity in Bahrain, 1925-2001.	26
Figure 2.10. Effect of groundwater salinity due to abstraction, 1965-2005.	27
Figure 2.11. Effect of groundwater salinity due to abstraction, 1990-2002.	27
Figure 2.12. Locations of desalination plants.	29
Figure 3.1. Geographical location of groundwater wells in the Kingdom of Bahrain.	35
Figure 3.2. Dammam aquifer abstraction by various sectors in Bahrain, 1952-2003.	36
Figure 3.3. Development of agricultural lands.	37
Photo 3.1. Production of eggplants.	39
Photo 3.2. Vegetable gardens.	40
Photo 3.3. Pumping station for irrigation.	40
Photo 3.4. Low efficiency gravity irrigation.	41
Photo 3.5. Greenhouse.	41

List of Tables

	Page
Table 2.1. The effect of Dammam-Neogene abstractions on the springs water discharge and number of wells from1924- 2005.	22
Table 2.2. Groundwater abstraction from Dammam-Neogene and Rus-Umm Er Radhuma aquifers for various uses.	23
Table 2.3. Bahrain desalination plants and their associated production capacity.	28
Table 2.4. Bahrain annual water production and blending ratio of distillate to groundwater resources in the period from 1980 to 2001.	30
Table 2.5. Average flow of raw sewage to TWPCC.	31
Table 2.6. Average wastewater inflow to TWPCC.	31
Table 2.7. Properties of tertiary treated effluent from TWPCC, 1991.	32
Table 3.1. Planted areas to various crops.	39
Table 3.2. Land under vegetables and forage crops using old methods of water -flooding and new methods between 1985-1991 in hectares.	42
Table 3.3. Rate of growth of Bahrain population.	44
Table 3.4. Water production and consumption for municipal purposes, 2005.	46
Table 3.5. Groundwater balance in Bahrain, 2002.	48
Table 3.6. Water tariff adopted by the Ministry of Electricity and Water.	54
Questionnaire:	
Table 4.1. Farms places.	68
Table 4.2. Nationality of the farm owners.	69
Table 4.3. Farm ownership.	69
Table 4.4. Adequacy of farm revenue.	69
Table 4.5. Willingness to sell the farm.	70
Table 4.6. Periods of farmers practicing farming.	71

Table 4.7. Having other job besides farming. 72

Table 4.8. Is the farmer's children helping in agriculture? 72

Table 4.9. Farmer owning a pickup. 72

Table 4.10. Willingness of the farmer to change farming. 73

Table 4.11. Farmer owning a house. 73

Table 4.12. Built a house recently. 74

Table 4.13. No of rooms. 74

Table 4.14. Farmers' living or residence places in Bahrain. 75

Table 4.15. Farmer's nationality. 76

Table 4.16. Period of farm ownership. 77

Table 4.17. Farms survey results and analysis, 2004-Source of irrigation water. 78

Table 4.18. How much the farmer pays per cubic meter of groundwater used? 78

Table 4.19. Farm leasing. 79

Table 4.20. Willingness to use treated sewage effluent. 79

Table 4.21. Willingness to use treated wastewater effluent once groundwater source ceased. 80

Table 4.22. Willingness to use treated wastewater effluent once it is subsidized. 80

Table 4.23. Systems of irrigation. 81

Table 4.24. Interviewer observation of a salty layer on top of dry soil. 81

Table 4.25. The farmer's observation of soil salinity. 81

Table 4.26. Soil salinity treatment methods. 82

Table 4.27. The interviewer's observations regarding the salinization of soil. 82

Table 4.28. Problems of groundwater in Bahrain. 83

Table 4.29. Reasons for the problems of groundwater in Bahrain. 83

Table 4.30. Raising cattle or having livestock in the farm. 84

Table 4.31. Type and number of cattle heads in the farm. 84

Table 4.32. Presence of storage ponds or swimming pools in the farm. 85

Table 4.33. Presence of swimming pools in the farm. 86

Table 4.34. Farming problems in Bahrain. 87

Table 4.35. Crops that farmers plant in Bahrain. 88

Table 4.36. Farm products selling places. 89

Table 4.37. Purpose of practicing farming in Bahrain. 89

Table 4.38. Farmers acceptance to plant cash crops. 90

Table 4.39. Where the government can support? 90

CHAPTER 1 INTRODUCTION

1.0 INTRODUCTION

Globally, fresh water distribution varies significantly. While certain countries have abundance of fresh water, others are not so fortunate. Water crises threaten lives, sustainable development and even may disrupt peace and security of countries. The primary factors that led to increasing pressure on water resources include, among others, population growth and rapid urbanization, changing lifestyles, and economic development (Al-Noaimi, 1999). Due to the interrelated nature of these factors, water issue in recent time is dealt with in cross-sectoral way, through which health, livelihoods, economic development and peace and security are considered interrelated issues.

In small island states, like Bahrain, the availability of fresh water is critically crucial as it represents the main constraint against the economic development. The natural setting of Bahrain in an arid region exacerbates the issue of freshwater, the annual precipitation is low (less than 70mm) (Civil Aviation Affairs, 2004) and the potential evapotranspiration is high. No surface runoff exits in Bahrain and up till the late seventies of last century the only water resource was groundwater, mainly from an aquifer called locally "Dammam", (Al-Noaimi, 1999). It is part of an extensive regional aquifer system, called the Eastern Arabia Aquifer. This system extends from central Saudi Arabia, where it outcrops and discharges at the eastern Saudi Arabia and Bahrain. The rate of annual groundwater underflow to Bahrain is estimated at 112 million cubic meters (Zubari, 2004). This groundwater underflow is considered the safe yield for sustainable groundwater development in Bahrain (Al-Noaimi, 1999).

Since the discovery of oil in the thirties of last century, groundwater withdrawal has increased appreciably as a result of the sustained economic and industrial development, the increase in population growth and continual changing of lifestyle. For example, as reported by a number of investigators the abstracted groundwater from Dammam aquifer have risen from 63.2 MCM in 1952 to about 218 MCM in 2001 (Al-Noaimi, 1999). This has led over the years to a sharp

decrease in the peizometric level of groundwater of more than 4 m between 1965 and 1992, an increase of seawater intrusion and saline water up-flow from deeper aquifers, and a deterioration of more than half of the original groundwater reservoir in both quality and quantity (Al-Noaimi, 1999).

The water use in Bahrain is distributed among agricultural, municipal and industrial uses. Agriculture is still consuming about two third of Bahrain's groundwater resources, followed by municipal uses (27%) and industrial uses (3%). Since mid-seventies and as a result of increase in demands, groundwater supplies have been augmented with desalinated water. The ratio of desalinated water to groundwater has risen from 0.08% in 1980 to 2.20% in 2005 (Table 4). This dramatic increase in ratio makes the unit cost of producing water in Bahrain more and more expensive (present cost is about BD 0.661). If it continues to rise in the same way it may become formidable in the years to come.

In the past, when the population of Bahrain was low in number, the groundwater pumping was much less than the sustained safe yield. The gross national income was low and, hence, the argument of water use for agriculture was justified and could be understood. At present, the situation has changed and the policy of using groundwater for agriculture has to be revisited and perhaps modified. In the past agriculture share in the Bahrain economy was second after pearl, but since the discovery of oil it has dropped continuously. In recent years it does not constitute more than 0.46% of the gross national product (CIO, 2001). At the same time the use of water for agriculture has led to degradation of other components of the environmental system (e.g., the loss of Nabih Island plam trees and the cease of flow to springs). Now, the wise practice in Bahrain's agriculture requires decision-makers to make a trade of between groundwater use for agriculture and other environmental and socio-economic components. These decisions should take advantage of the opportunities exist at present such as the country income from oil or other sectors of economy and the presence of other non-conventional water sources like treated wastewater.

The income generated from oil or other sectors of economy like banking and services could encourage the diversion from locally produced agricultural products to imports. This policy saves groundwater, reduces costs of producing desalinated water and improves other components of the environment. However, this could lead to socio-economic implications on the Bahraini society like farmers lose their jobs, social structure disruptions, and urbanization increases.

Another non-conventional source, which has entered Bahrain's water pool recently, is the treated wastewater. It is estimated by many (ACE, 1997; Al-Ansari, 2004; Murad, 2004) that by 2010 the annual treated wastewater diverted to agriculture will reach about 73 million cubic meters. The cost of the tertiary treated wastewater, about BD 0.275, is low in comparison with other sources in Bahrain. Though the salinity of this wastewater is better than many of the groundwater resources in Bahrain, its usage will depend on the farmer acceptability and its content of disease-free causing pathogens.

On the basis of the above, it is believed that the quantity of groundwater used for agriculture could be conserved by diverting part of it from agriculture to other more urgent uses like municipal ones. However, implications from this diversion on the farmers should be assessed. This work tries to investigate and explore such implications. In this way, the concept of integrated water resources management or wise water allocation is approached from the water user (the demand side) rather than the supply side.

Zubari (2005) has conducted extensive research work on the groundwater aquifer system in the kingdom of Bahrain for the past years within the field of aquifer structure and hydraulic modeling. His work contributed significantly in the understanding of the hydraulic behavior of such important groundwater system.

Zubari's work were concentrated on the modeling and investigating Rus-Umm Er Radhuma formation using modern hydraulic modeling techniques (Zubari, 2005).

(Zubari, 2006), discussed the general policy of groundwater development and management, from the supply augmentation effort, explained on the thoughts behind groundwater resources deterioration and the replacement of groundwater agricultural dependency to tertiary treated wastewater that will help in conservation efforts of the groundwater.

Furthermore, he discussed the scenarios that the Kingdom water authorities have laid down since 1980 for the implementation of water management scheme with the following objectives:

(1) to control and decrease the abstraction rates from the Dammam aquifer by expanding industrial sector; (2) to lower the potentiometric levels in the brackish water zones and decrease the vertical hydraulic gradients between the Dammam aquifer and its underlying brackish water zones in order to reduce their upward migration and salinization of the aquifer (GDC, 1980a, 1983); and (3) to reduce the risk of shutting down desalination plants in the case of oil spills in the Arabian Gulf waters (as was the case in the first and second Gulf wars).

He also discussed the demand management and conservation efforts history in addition to the existing institutional and legislative framework in regards to the groundwater in the Kingdom discussing the details of such policies.

He proposed an alternative water policy towards groundwater resources sustainability and protection. In order to investigate groundwater sustainability in Bahrain for the period from 2002 to 2010, assuming three scenarios as:
Baseline Scenario I - supply augmentation and stabilization of agricultural water demands;
Scenario II – supply augmentation and demand management in the agricultural sector;
Scenario III – supply augmentation and unrestricted agricultural sector water demands.

He concluded that the second scenario was preferred and constitutes an appropriate base of an alternative strategy to secure sustainable development for

groundwater resources in the near future 2010, depending on the effective implementation by the government especially in the agricultural sector. On the other hand, failure to achieve the set targets of restricting the agricultural water demand would lead to the continuation of the chronic deficit and result in the deterioration of both the quantity and the groundwater supplies.

1.1 PROBLEM IDENTIFICATION

The increase of uncontrolled abstraction of groundwater and the migration of farmers from agriculture.

1.2 IMPORTANCE OF THE PROBLEM

In order for the government to preset policies that meets the water demands, additional water desalination plants needs to be revisited for the following reasons:

- The Kingdom economy improvement.
- Imposing restrictions on the alleviating water demand to help lowering the government subsidy on the water production.
- Potentials and opportunities of groundwater conservation in agriculture.
- Alarming decline of groundwater piezometric levels, desertification.

1.3 OBJECTIVES OF THE STUDY

The main study objectives are:

- To discuss the groundwater situation qualitatively and quantitively and its implications on the agricultural sectors in the Kingdom of Bahrain.
- To assess the effectiveness of management of regulations undertaken recently by the water authorities.
- To measure farmers willingness to use alternatives such as the TSE.
- To recommend alternatives to agriculture.

1.4 METHODOLOGY OF THE STUDY

To fulfill the above objectives a questionnaire was prepared and distributed. On one-on-one meetings with farmers and landowners in the kingdom of Bahrain were concluded. The main purpose of such meetings was to seek guidance of the farmers' perspectives and perceptions on the key issues related to the present use of water in agriculture, identify the problems and explore the opportunities for water conservation in agriculture.

The overall objective of the present study is to address water sustainability in Bahrain from the perspective of the effectiveness and the payoff of water used in agriculture. The reason that triggered this study is the diversion of two-third of the scarce water resources to the agriculture sector that contributes very little to the national economy.

The research comprises of the introduction chapter and the following chapters:

Chapter 2 discusses the natural settings and water resources of the Kingdom of Bahrain. The topography, geology and the surface relief, the Dammam aquifer and its lithological and hydrogeological aspects are presented. Furthermore, the chapter touches on the climatic settings and the water resource system as a whole is reviewed (Figure 1.1).

Chapter 3 describes the water usages, including municipal, industrial, and agricultural with a particular emphasis on agricultural usages, describing the various irrigation methods implemented by the agriculture sector. In addition, statistical analysis of the water usages over years during the period 1950 to 2002 was also addressed. Furthermore, the chapter briefly discuses the water planning and management issues as set by the government.

Chapter 4 addresses water sustainability in the kingdom of Bahrain from the perspective of the effectiveness and the payoff of water used in agriculture. In this chapter, a statistical analysis of the survey study that was carried out during

the year 2004. The results were analyzed and recommendations and guidelines were proposed. Survey results revealed that agriculture is a diminishing profession without government subsidy. The study calls for reassessment of the agriculture sector as a contributor to the GNP and diverts attention to the importation of the agriculture products which proved to be more beneficial to the Kingdom economy.

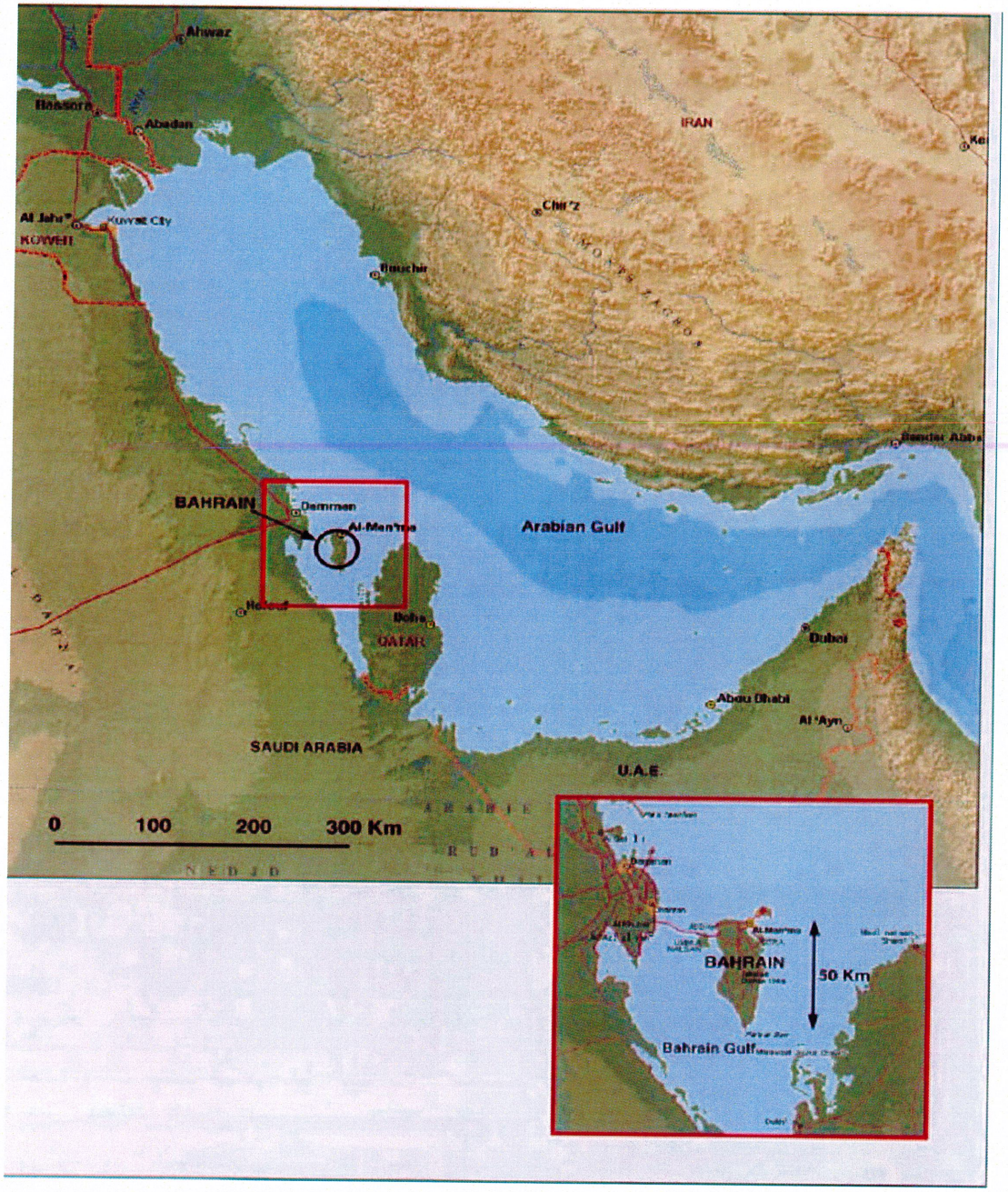


Figure 1.1. Kingdom of Bahrain location map, (Sogreah ,2001).

CHAPTER 2 NATURAL SETTINGS AND WATER RESOURCES

2.0 NATURAL SETTINGS AND WATER RESOURCES

2.1 LOCATION

The Kingdom of Bahrain is an archipelago of thirty-six small islands with a total area of approximately 710.90 km^2 and a population of 650,000 (Statistical Abstract, 2001). It is located midway down the Arabian Gulf, approximately 24 km east of Saudi Arabia sea-board and to the north coast of the State of Qatar at the 26° latitude North (Figure 2.1).



Figure2.1: Various administrative divisions and cities of Kingdom of Bahrain.

The largest in size amongst the islands in the archipelago is the Bahrain Island which the kingdom named after with 84.6% of the total area. The capital, Manama is located at the northeastern part of Bahrain Island. The majority of the population occupies Manama, which serves economical and social activities. The Kingdom is organized into 12 administrative units; Manama, Muharraq, Hidd, Jiddhafs, and the Northern area, Sitra, the Central area, Isa Town, Riffa, Madinat Hamad and the Eastern area including the Hawar Islands.

2.2 TOPOGRAPHY, GEOLOGY AND SURFACE RELIEF

There are six principal islands in the Bahrain archipelago. Those islands are situated mainly in a low-lying area of the Arabian Gulf. With the exception of the northwestern narrow coastal strips of fertile land, most of the Kingdom islands are comprised of limestone strata covered with saline arid sand. The main island is formed of an oval shaped nucleus made of Eocenic calcareous rock surrounded by an assemblage of more recent loose rock (Al-Noaimi, 1999).

The Dome of Bahrain dominates the geology and the topography of the island. This is large unreeling concavity infiltrating in a north-south direction. The highest point in altitude is Jabel Al Dukhan at 134 m above sea level. More than 50% of the island elevations are within 20 m above mean sea level. The natural appearance of the surface of the island of Bahrain's "natural landscape" is divided into five morphological areas which are; the coastal plains, the major rural plains, the areas of rocky grooves, the internal pool and the mid hills (MoHM&E 1990, Sogreah 2001). It is surrounded by sedimentary hills and the coastal zone area is basically formed of sedimentary clay. In general, the soils of middle hill areas are of high quality and depth. These areas have natural drainage slopes which during heavy rainfall periods produce a series of ponds. Soil particles of these temporarily formed ponds are sedimented during heavy to moderate rainfall periods, whereas during the dry seasons they are eroded and more sediments are carried away by wind (Sogreah, 2001).

Despite the fact that Bahrain Island is relatively small, the different geomorphic and physiographic nature has diversified the soil types. The sediment on the island surface is an evident of the diversity of the origin and age of the soils. Sand dunes, Sabkhat, calcium, gypsum and surface rock soils are observed in different areas of Bahrain (Figure 2.2).

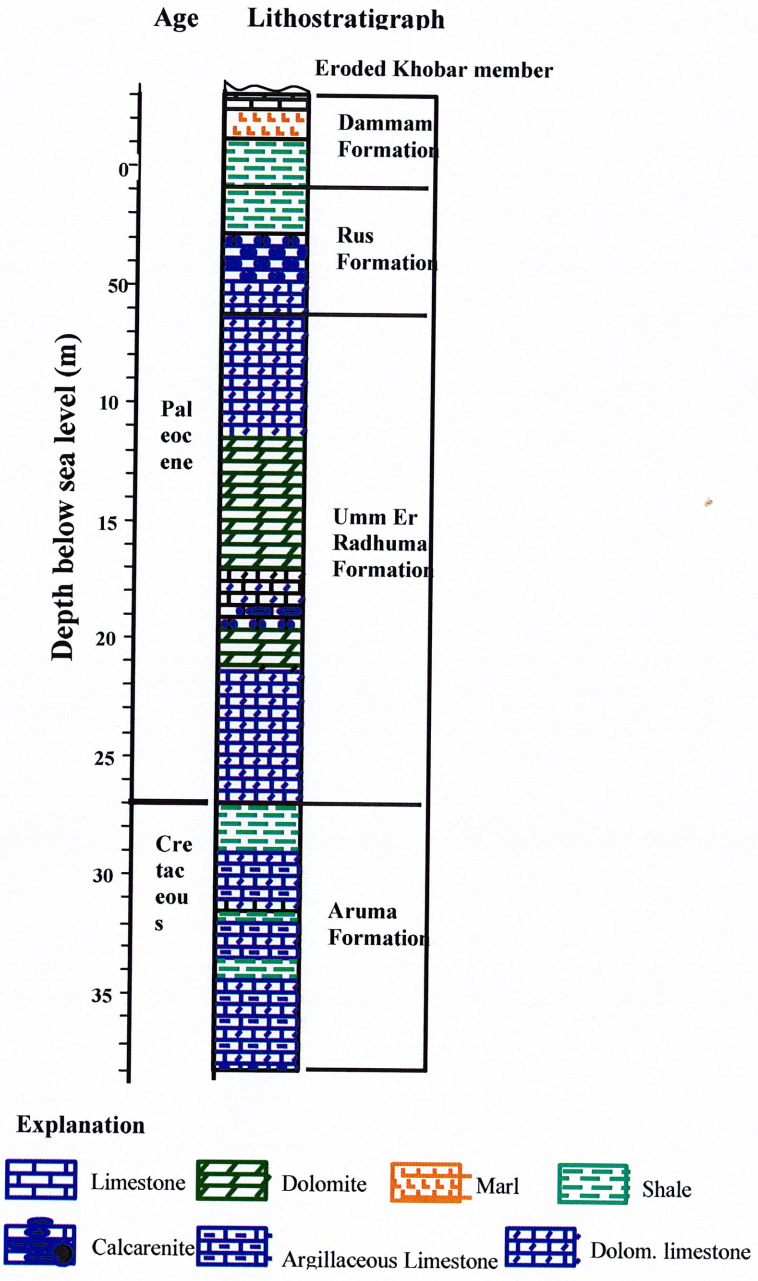


Figure 2.2. Simplified lithological logs for borehole 1116, located in Abu-Jarjur well field (Al-Shabani, 1999).

The agricultural present soils are mostly formed from the modern times marine sedimentations during the forth era "Quaternary". Generally speaking, the soils of agricultural area are sandy or sandy clay in the upper layers with consolidated sand and calcium carbonate or calcium sulfides at the lower layers. The low permeability of the lower layers is the reason for the presence of a shallow depth of groundwater at the coastal areas (Figure 2.2).

2.3 CLIMATE

Because of its location in an arid region, the climate of Bahrain is characterized by elevated summer temperatures and scanty and irregular winter rainfalls, the hottest months are July and August with a mean daily maximum of around 40°C (Figure 2.3). December, January and February are the winter months with a mean daily minimum of around 15°C. Humidity is usually high with mean daily maximum of about 85% throughout the year, and it drops to about 40% in May and June.

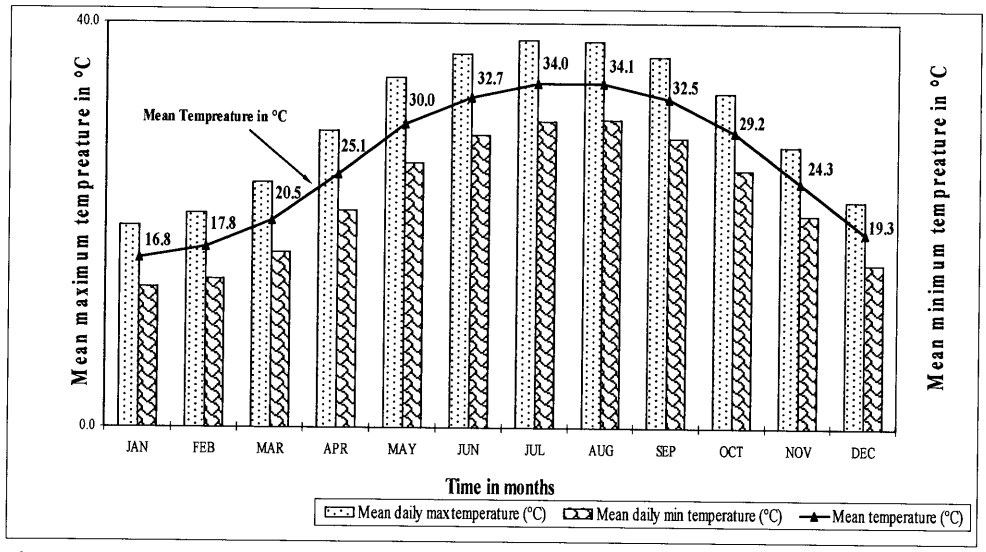


Figure 2.3. Bahrain average temperature (°C), 1946-2004 (Civil Aviation Affairs, Directorate of Meteorology, Muharraq, 2004)

During winter that extends from November to April the mean annual rainfall is about 70 mm (Figure 2.4), the dominant wind is northwesterly with an average

speed of about 5 m/s. Evaporation is high, its class A Pan peaks reach over 10 mm/day in July or on average around 210 mm per year (FAO,1997).

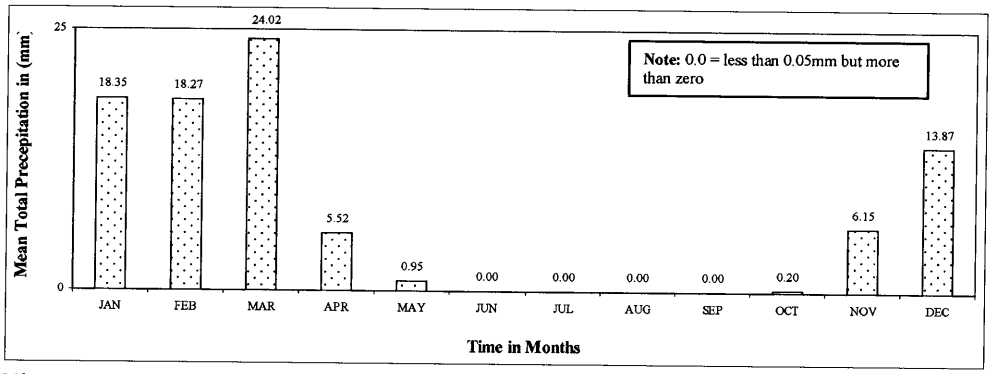


Figure 2.4. Bahrain means precipitation (mm), 1946-2004 (Civil Aviation Affairs-Directorate of Meteorology, Muharraq, 2004).

The potential evapotranspiration rate in the Kingdom average about 1850 mm/year and can peak to over 10 mm a day in some of summer months (Zubari et. al, 1996).

2.4 WATER RESOURCES IN BAHRAIN

No conventional surface water resources exist in Bahrain; the only conventional available resource is groundwater (Al-Noaimi 1999, Water Resources 2000). Non-conventional resources have entered the water pool recently; these are the desalinated seawater and reclaimed wastewater. Details of those resources are presented in the sections below.

2.5 GROUNDWATER RESOURCES

2.5.1 THE HYDROGEOLOGIC SETTING

The system which provides the groundwater resources in Bahrain is the three zones system of the Palaeocene to Eocene sedimentary rocks, locally termed as A, B and C. Hydrogeologically, it is divided into two aquifer systems: Dammam-Neogene and Rus-Umm Er Radhuma. In Bahrain, they represent a small part of the extensive regional aquifer system, known as the Eastern Arabian Aquifer system, which extends from central Saudi Arabia where it outcrops to the Arabia

Gulf waters of Bahrain, southern Qatar and Kuwait where it mainly discharges (Figure 2.6).

The Dammam-Neogene aquifer system consists of A and B zones, in which A represents Alat aquifer (15-25 m) and B represents Khobar aquifer (40-49 m). Zone C is two aquifer system; Rus and Um Er Radhuma (Water Resources 2000, Zubari, 2004).

The top Alat aquifer is comprised of crystallized dolomitic limestone at the upper parts and changes into chalky dolomitic limestone with increasing depth. Alat is unconfined in the western parts and in the direction of central areas of the main Bahrain Island, it becomes confined in the northern and northeastern parts of Bahrain as it is overlaid by the impermeable Neogene claystone formation (10-60 m), and underlain by semi-permeable marl deposits (9-15 m). On average, it has a low hydraulic conductivity (14 m/day). The transmissivity is in the order of 350 m^2/d, and the storage coefficient of the confined parts varies between $1.3x10^{-4}$ and $5.3x10^{-4}$ (Al-Noaimi, 1999).

Underlain the marl deposits lie the Khobar aquifer; it is comprised of a highly fractured limestone and dolomite formations. It is unconfined in northern central parts at A'ali and Salmabad areas, and in the southeastern and western parts of Bahrain like Hamalah. In the islands of Muharraq, Umm Naasan, Jida and Hawar, the aquifer is confined on the top by about 13 m depth of marl. The Khobar aquifer is characterized by good hydraulic properties, on average the transmissivity ranges between 1000 to 41000 m^2/day, the conductivity ranges between 16 to 900 m/d and the storage coefficient is in the range of $5x10^{-5}$ (Al-Noaimi, 1999). Shale beds of Sharks Tooth Shale (8-20 m) underlie the Dammam aquifer system, in addition to the anhydrite and shale deposits on the top of the Rus formation.

The aquifer system C (Rus and Um Er Radhuma) is comprised of fractured chalky dolomitic limestone with subsidiary shale and anhydrite intercalation in its upper section. The thickness of Rus is between 60-150 m and that of Um Er

Radhuma varies between 115-350 m. The anhydrite of Rus formation section in the central and eastern areas of Bahrain is subjected to solution, and led to collapses in the overlying formations and the vertical movement of the saline water it contains to the overlying Dammam aquifer in those areas. The mean conductivity of this aquifer is 25 m/day, the transmissivity ranges between 1210 to 48000 m^2/day and the storage coefficient in the confined part is $2.26x10^{-4}$ and 0.25 to 0.3 in the unconfined part. Refer to Figure 2.5 for simplified schematic presentation of these aquifers.

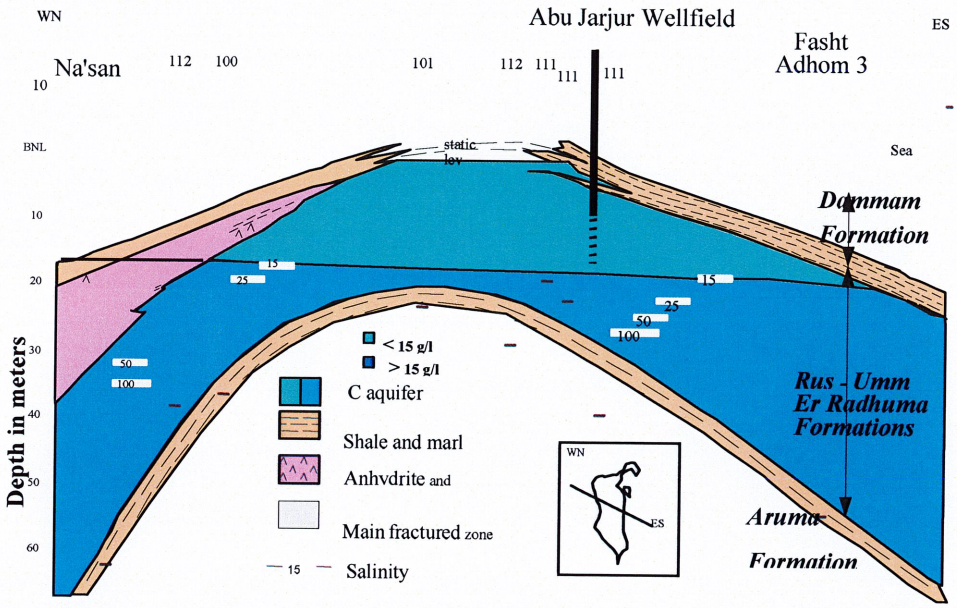


Figure 2.5. Hydrogeological cross section showing the C aquifer system in Bahrain, (Modified after GDC 1983), Al-Shabani (1999), Sogreah (2001), WRD (2005).

2.5.2 GROUNDWATER FLOW

The groundwater flow in the Alat aquifer follows the Eastern Arabian Aquifer System flow direction, from west to east. The piezometric levels are deceasing eastwards. However, there are exceptions in places where upflow from the deeper Rus-Umm Er Radhuma aquifer exists (A'ali and Salmabad areas) or when seawater intrusion occurs (Sitra area). No data is available on the historical steady state peizometric levels of the Alat aquifer, however, recent work indicated a loss

of 1 to 3 meters of piezometric level in the period between 1924 to 1990 (Al-Noaimi, 1999).

Contrary to Alat aquifer much data is available for Khobar aquifer piezometric levels. The backward analysis of this data by GDC in 1980 showed that the piezometric level in Khobar aquifer in 1924 was less than Alat by 0.5 m, and thus upflow was not occurring between these aquifers in the past. Recent studies by Zubari (1987) indicated that the piezometric levels in both aquifers were equal in 1953. Excessive abstractions from Khobar aquifer were regard as the cause for this decline in groundwater levels. The 1979 data showed that the piezometric level declined by 4 to 5 meters in Khobar aquifer, and it resulted in the decline of water flow in natural springs, more khobar aquifer salinisation due to the upflow from deeper Rus-Umm Er Radhuma aquifer and seawater intrusion at Sitra, Askar and Door areas (GDC, 1979). A further one-meter decline was noticed in 1990 analysis of khobar aquifer piezometric level, however, it was also noticed that the level reached an alarming zero value in many places and led to the reversal of regional flow in the northwestern coastal villages and the salinization of their abstraction wells. The same conclusion could be drawn for the east and southeastern areas of Muharraq wells, where the decline has resulted in seawater intrusion, and for Sitra Island and Bahrain southeastern areas where the deep upflow balanced the decline in piezometric level (Al-Noaimi, 1999).

In spite of the above it was noticed by many researchers (Al-Noaimi 1999, Zubari et. al., 2004) that Khobar aquifer piezometirc level response to a reduction in abstraction is fast, and the aquifer could recover quickly. Zubari (2004) attributed the reason to the aquifer high conductivity due to the fractured nature of the aquifer formation.

For Rus-Umm Er Radhuma aquifer it seems that the piezometric levels are inconsistent with the Arabian Regional flow system. They are high in central and southern areas of Bahrain Main Island, and decrease outward. Because the piezometric levels in this aquifer are higher than the upper ones and because the anhydrite rock capping it has undergone excessive dissolution and collapsing the

water in it is moving upward to the upper Dammam aquifer, leading to the increase of salinity in this aquifer (Figure 2.6).

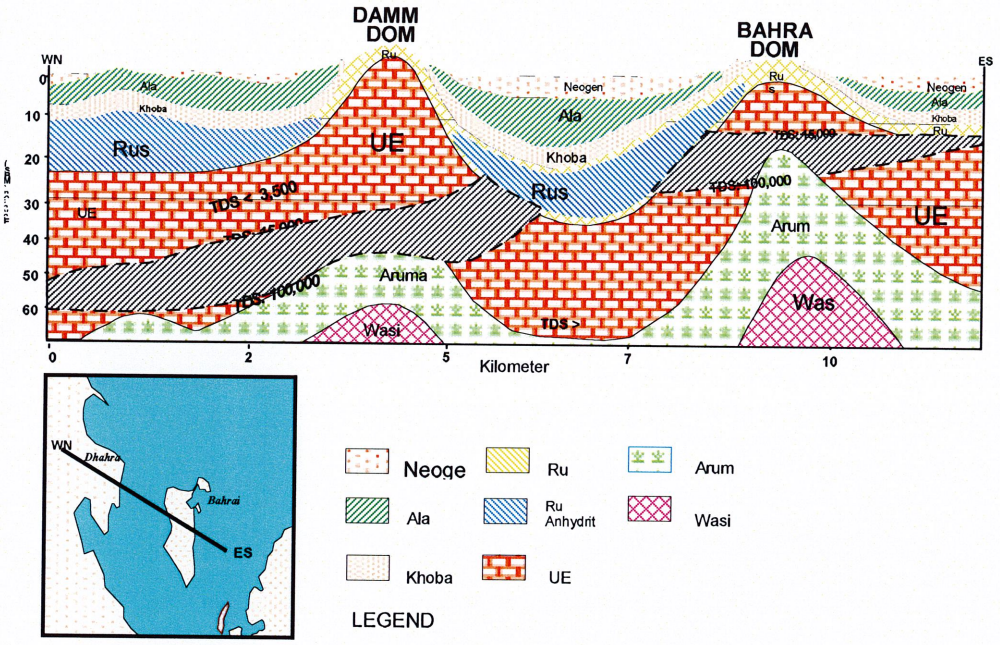


Figure 2.6. Regional Hydrogeological cross section Bahrain and Dammam Domes (Al-Shabani, 1999).

Until mid-eighties abstraction from Rus-Umm Er Radhuma aquifer was restricted to industrial uses. Recently, the aquifer has been pumped for drinking purposes; this water is desalinated and treated via Ras Abu Jarjour plant for potable uses. Recent figures shows a 2.1 m decline in the piezometric level of this aquifer (Al-Noaimi, 1999). Therefore, water in this aquifer is becoming increasingly important for drinking purposes.

2.5.3 GROUNDWATER QUALITY

Groundwater quality in Bahrain is historically poor when compared to the 1500 ppm WHO permissible guideline for drinking purposes. A number of water types are interplaying to produce this elevated concentration. The first is the deep high salinity water, the second is the very old rainfall water (more than 14,500 years), and third is the seawater that intrudes through the coastal formations (Al-Noaimi, 1999).

The salinity of Dammam aquifer is typically in the range of 2,200 to 2,500 ppm in places like Budaiya, Duraz and the upper western areas of El-Hamalah, Jesra and Junabiah. Pockets of elevated salinity exist in those areas, but the increase of salinity in this aquifer follows the piezomtric gradient of the Regional Arabian Aquifer System flow (Al-Noaimi, 1999).

In places like Sitra Island and south of Askar, Jawa, Al-Door the Dammam aquifer salinity is in range of 5000 to more than 20000 ppm (GDC, 1979). This is attributed to seawater intrusion that encouraged the aquifer at a rate of 100 m per year in the years from 1924 to 1980 (Figure 2.7).

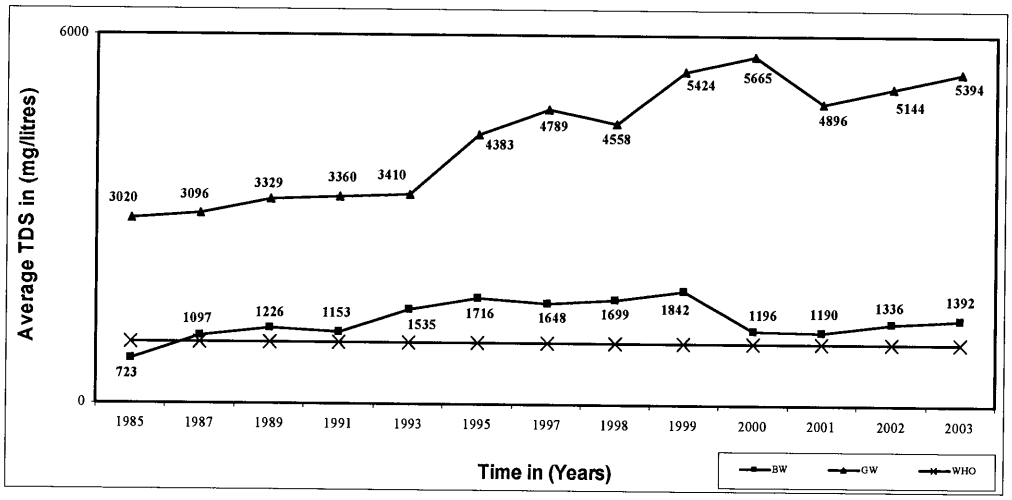


Figure 2.7. Effect of groundwater salinity due to abstraction (Ministry of Electricity and Water - Water Transmission Directorate (2003).

The rise in salinity exacerbates in villages south and southeastern of Saar inclination like Bouri, Aali, and Salmabad. The salinity changes from 3200 ppm west of the drift to more than 10000 ppm east of it. Many researchers (Al-Noaimi, 1999; Zubari, 2004) attributed the reason of this salinity change to the dissolution and collapsing of the anhydrite formations capping of Rus-Umm Er Radhuma aquifer, which made both aquifers: Dammam and Rus-Umm Er Radhuma in a direct hydraulic contact. The deterioration of Khobar aquifer water quality has resulted in the loss of agricultural lands in north central areas of A'ali, Salmabad and Bouri to housing and industrial activities.

Further deterioration to Khobar aquifer water quality is noticed in the southern and southwestern areas of Bahrain, near Al Mumtallah, Al Wasmieyah, and Al Jasaar, where the salinity has reached in some areas more than 10000 ppm. As mentioned above, the most probable explanation to this increase is the seawater intrusion (Al-Noaimi, 1999).

Alat aquifer water quality is naturally poor; in the range of 2600 to 4500 ppm. On the basis of the Water Resources Directorate files it is higher than that of the Khobar aquifer salinity by 200 to 650 ppm. In contrary to Khobar aquifer the historical data on Alat aquifer water quality does not allow a full understanding of the water quality trend over the years.

In summary, the water quality in Khobar aquifer has a witnessed noticeable deterioration since the pre-development era in 1965. Comparisons of iso-salinity maps between 1965 and 1992 were conducted by Al-Noaimi (1999) and were updated by Zubari (2004). These comparisons have indicated that most areas in Bahrain have been plagued by the water quality deterioration of the main aquifer "Khobar". In Al-Noaimi's comparisons, it was concluded that the salinity increased between 5000 and 10000 in the south of Sittra Island, 6000 to 15000 ppm in Hidd and the Dry Dock, 2000 to 6000 ppm in the northern central areas of A'ali, Salmabad and Shakhoura, and 500 to 2500 ppm in the western coast of Bahrain that extends from Hamalah to Zallaq. Zubari (2004) has further indicated

that the salinity reached more than 4000 ppm in many areas of Bahrain, a value that precludes the domestic and agricultural direct uses of water.

Water quality distribution in Rus-Umm Er Radhuma aquifer is more complicated. It ranges between 2000 ppm to more than 80000 ppm. The 2000 ppm salinity waters are very few and restricted to outcropping areas of Rus formation in Bahrain. Aging studies attributed the origin of these waters to recent rainfalls. From water balance point of view they are considered of little value because they form small lenses of sweet waters floating on a much more saline or brackish water. Apart from these lenses the water salinity of water in Rus aquifer and the upper parts of Umm Er Radhuma aquifer is in the range 7000 to 15000 ppm. The lower parts of Umm Er Radhuma aquifer is highly saline connate water; in the range of 50000 to 100000 ppm. Because abstraction from this aquifer is little, the water quality experienced no change (Al-Noaimi, 1999).

2.5.4 GROUNDWATER RECHARGE

Groundwater recharge comes from different sources; the rainfall that infiltrates through the exposed unconfined layers of some aquifers, the irrigation return flow from agricultural areas and the up-flow that leaks to the upper aquifers through eroded or fractured formations in between, and through underflow of water flowing to Bahrain from outside or regional system.

Many scholars consider rainfall water and the return flow from irrigated areas negligible. According to Al-Noaimi (1999), the annual rainfall recharge through the exposed upper Khobar aquifer was estimated at 0.1 million cubic meters (MCM), and through the exposed Alat aquifer to 0.18 MCM (possibly including the irrigation return flow). However, it was estimated that the annual Rus aquifer rainfall recharge is to 0.5 MCM (GDC, 1979).

The underflow of water coming from Saudi Arabia is considered the prime source of water recharge to Dammam-Neogene aquifer. This was estimated at 83 to 90 MCM annually (GDC, 1979) and at 112 MCM on average (Al-Noaimi, 1999).

2.5.5 SPRINGS

Historically, natural springs were abundant in Bahrain, in particular marine springs in areas east and east north of Bahrain like Sitra and Muharraq, and to fewer numbers in areas along the north coast like Sanabis, Barbar and El Deraz. Terrestrial springs existed in a number of areas like Sitra, Nuweidrat, Sanad, Tubli, Maqsha'a, Karraneh, A'ali and Manama.

Total flow from springs was estimated by a number of investigators as given in Table 1. Springs waters are originated to a large extent from Dammam-Neogene aquifer, as it is evident from relation between continual over-exploitation of this aquifer and the decline of flow in these springs (Table 2.2). It was also indicated that continual groundwater abstraction at rates witnessed in the early nineties of last century would result in the loss of all springs by 1995 (Zubari, 2004). Almost all springs were non-productive after 1995.

Table 2.1. The effect of Dammam-Neogene abstractions on the springs' water discharge in MCM/Y and number of wells from 1924- 2005, modified after (Al-Noaimi, 1999).

Description	Years							
	Heim 1924	**Bapco 1953**	**Sutcliff 1966**	**Italconsult 1971**	**GDC 1979**	**WRD 1987**	**WRD 1990**	**WRD 2005**
Wells abstraction		63.2	113.6	125.1	138.1	179.91	187.32	
Terrestrial springs flow	70	41.4	28	23	8.1	4.0	1.5	
Marine springs flow	13	9.6	9.6	6	6.6	3.1	3.5	
No. of wells		280	780	980	1307	1803	1890	2040

2.5.6 GROUNDWATER ABSTRACTION

The total annual abstraction from groundwater has increased a steadily due to the rapid increase of Bahrain population and the rise in the standard of living since the discovery of oil in the thirties of the last century. The abstraction was at about 65 MCM in 1953, increased on an average of 3.1% per year to reach 146.1 MCM in 1979 (Table 2.2). During this period abstractions were almost confined to Dammam-Neogene aquifer (about 98%), agriculture demands used up about three fourth of the total abstraction.

In the eighties, the rate of increase in abstraction was almost doubled to reach 6.7% per year and the total abstraction reached 219.32 MCM in 1990 (Table 2.2). The share of Dammam-Neogene to the total abstraction reduced to about 85% and the share of agriculture declined to about 60%. Noticeably, the municipal share during this period has doubled if compared with the period prior to 1980.

In the nineties, the rate of annual increase in abstraction has reduced to about half (1.4%) in comparison with the period between 1953 and 1979. The Dammam-Neogene aquifer share remains high at 85% and the agriculture demand continued to consume about 60% of the total annual abstraction.

Table 2.2. Groundwater abstraction from Dammam-Neogene and Rus-Umm Er Radhuma aquifers in MCM/Y for various uses (Al-Noaimi, 1999).

Source/Aquifer	**Annual abstraction**						
	Bapco 1953	**Sutcliff 1966**	**Italconsult 1971**	**GDC 1979**	**WRD 1985**	**WRD 1990**	**WRD* 2002**
Dammam-Neogene							
• Agricultural uses	48	89	96	90	99.9	124.66	141.86
• Municipal uses	5.1	16.45	20.9	41.1	47.4	56.8	53.87
• Industrial uses	10.1	8.15	8.2	7	4.9	5.86	5.26
Dammam-Neogene abst	63.2	113.6	125.1	138.1	152.2	187.32	200.99
Rus-Umm Er Radhuma							
• Agricultural uses	----	----	----	----	2.52	5	1
• Municipal uses	----	----	----	----	25.7	23	29.33
• Industrial uses	2	2	2	8	4.6	4	5
Rus-Umm Er Radhuma abstraction	2	2	2	8	32.82	32	35.33
Total Abstraction	**65.2**	**115.6**	**127.1**	**146.1**	**185.02**	**219.32**	**236.32**
Dammam-Neogene / total abstraction ratio (%)	96.9	98.3	98.4	94.5	82.3	85.4	85.0
Agriculture / total abst ratio (%)	73.6	77.0	75.5	61.6	55.4	59.1	60.5
Municipal / total abstraction ratio (%)	7.8	14.2	16.4	28.1	39.5	36.4	35.2

WRD = Water Resources Directorate.

* These figures are corrected and updated after (Al-Noaimi, 1999).

2.5.7 IMPACT OF GROUNDWATER ABSTRACTION

The over-exploitation of Dammam-Neogene aquifer, probably since the thirties of the last century, has resulted in the continual decline of groundwater piezometric levels, the loss of all springs' flow and the rise of groundwater salinity. Zubari (2004) compared two piezometric maps of Dammam aquifer; one for 1925 when the aquifer is believed was at steady state (abstraction equals safe yield), and the other for 2001 (Figure 2.8). By comparison, he observed that piezometric levels have dropped from values of 1 to 6 m above sea level to values below sea level in many parts of Bahrain. Similar comparison was conducted by Al-Noaimi (1999). He recorded an average drop of 4 to 5 m. In conclusion, the piezometric level in the main aquifer "Dammam" dropped significantly to a value that requires immediate action.

The below-described situation has resulted in an appreciable rise up of salinity in Dammam aquifer. Similarly, Zubari (2004) compared the change in Dammam aquifer salinity for the two years: 1965 and 2001 (Figure 2.9). He concluded that the salinity is increasing at an accelerated rate. This increase in the salinity is attributed to the seawater intrusion, the up-flow from deeper aquifers "Rus-Umm Er Radhuma" and irrigation return flow.

Al-Noaimi (1999) gave more elaboration on the causes of the salinity rise up. He reported that the salinity in Sitra area was first noticed in the early forties at the time when the refinery increased its production capacity from 25000 to115000 barrel a day and the associated increase in groundwater abstraction in the vicinity of Sitra. The salinity rose between 5000 to 10000 ppm during the period from 1965 to 1990. The salinity increased from about 2000 to 6000 ppm during the same period in other areas like A'ali, Salmabad and the north central parts of Bahrain. This increase is caused by the up-flow through the eroded anhydrite layer between Dammam and Rus-Umm Er Radhuma aquifers. In Bahrain western areas from Al Hamallah till Zallaq, the salinity rose between 500 to 2500 ppm during the same period.

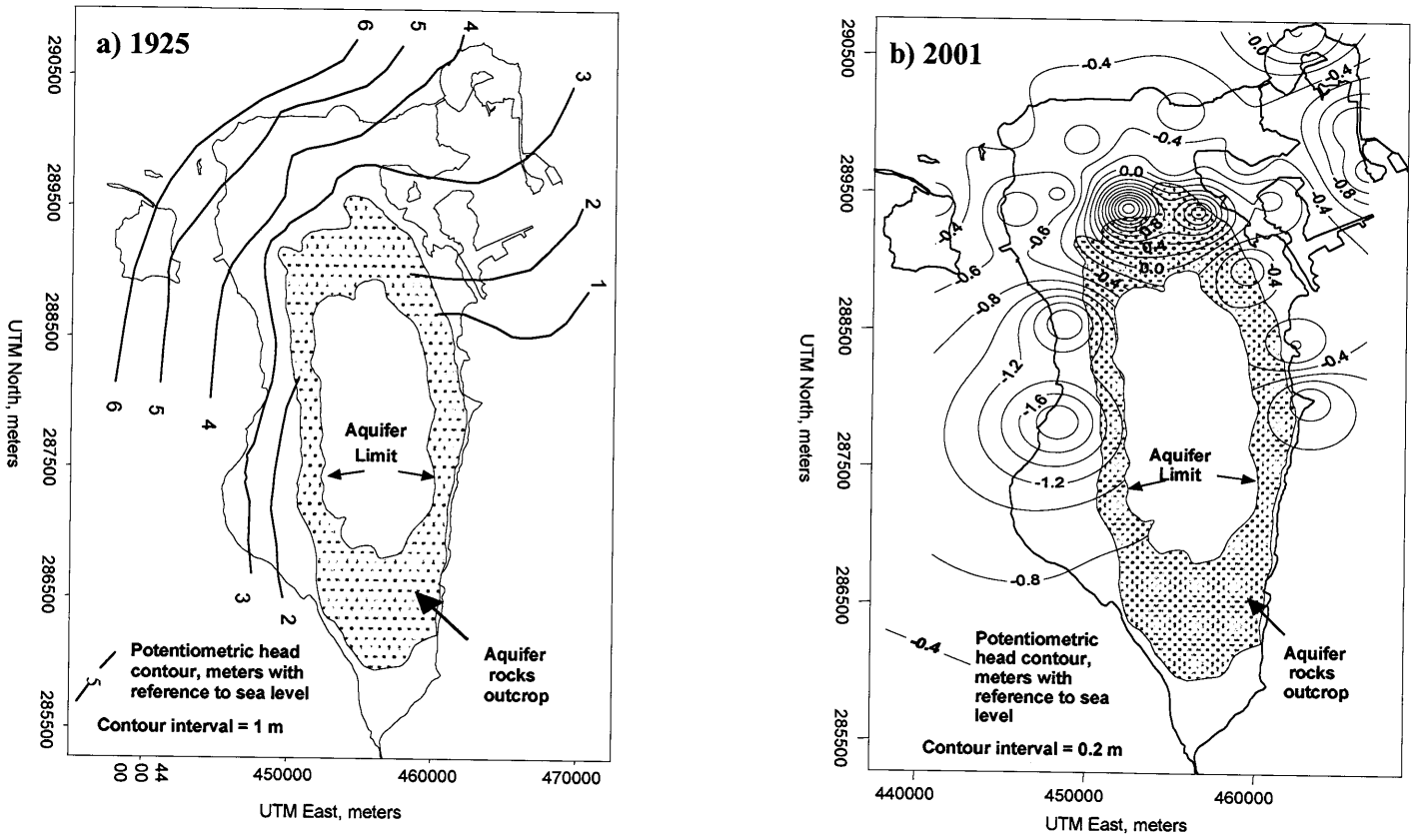


Figure 2.8. Changes in the Dammam aquifer potentiometric levels in Bahrain, 1925 (GDC, 1980) and 2001 with permission (Zubari, 2004).

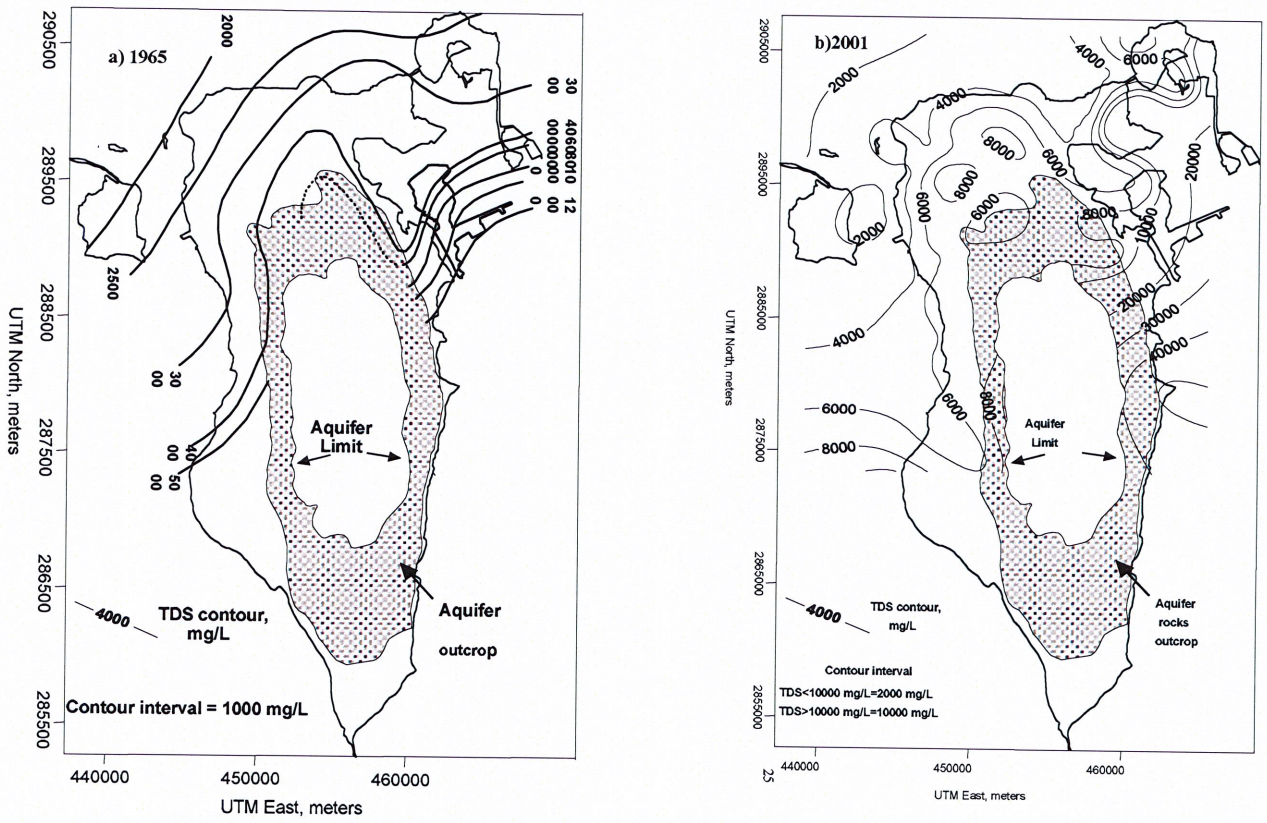


Figure 2.9. Changes in the Dammam aquifer salinity levels in Bahrain, 1965 (Al-Noaimi, 1993) and 2001, with permission (Zubari, 2004).

The deterioration level of groundwater in the Dammam aquifer over the years was clearly evident in the sharp rise of salinity of water of Bahrain springs before they were ceased (Al-Noaimi, 1999). Zubari (2004) presented a clear relationship between groundwater abstraction and salinity in an observation well in Muharraq. Figures 2.10 and 2.11 represent the salinity in one well (Sitra) and average salinity of wells in Bahrain. The figures indicate a sharp rise in the salinity, in particular in the second half of the nineties.

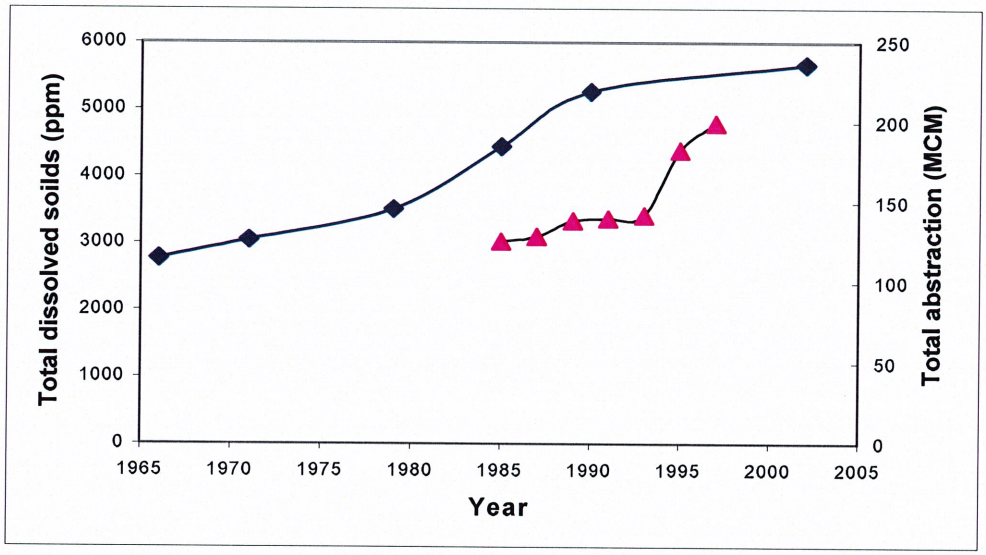


Figure 2.10. Effect of groundwater salinity due to abstraction, Ministry of Electricity and Water-Water Transmission Directorate (2003).

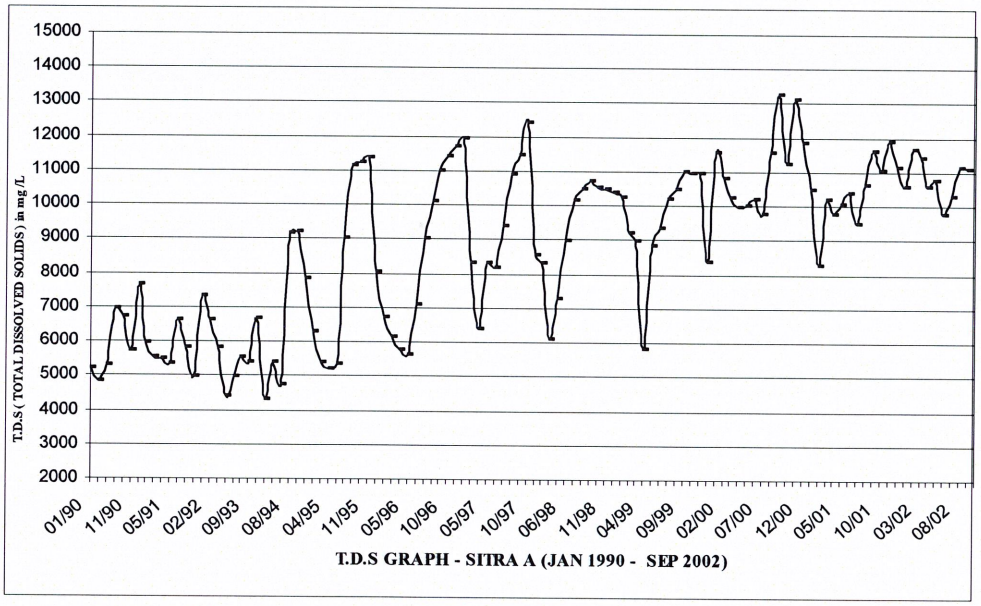


Figure 2.11. Effect of groundwater salinity due to abstraction, Ministry of Electricity and Water-Water Transmission Directorate (2002).

2.6 DESALINATED WATER

To overcome the deterioration of groundwater quality and the further lowering of peizometric levels in the Dammam-Neogene aquifer, the government decided in the mid-seventies to augment domestic and industrial water supply by brackish and seawater desalination. A number of plants were constructed (Figure 2.12), and some are still under construction. Table 2.3 gives a summary of these plants and their capacities, in addition to the date of their commissioning Swar (2001).

Table 2.3. Bahrain desalination plants and their associated production capacity Swar (2001).

Serial No.	Plant	Date of Commissioning	Desalination Method	Capacity (Million Gallons/Day)	Source of Raw Water
1	Sitra	1975	Multistage-Flash evaporation (MSF)	25 (41.4)**	Seawater
2	Ras Abu-Jarjur	1984	Reverse Osmosis	10 (16.6)	Groundwater
3	Al-Dur	1990	Reverse Osmosis	10(16.6)	
4a	Al-Hidd Phase 1	2000	Multistage-Flash evaporation (MSF)	30(49.7)	Seawater
4b	Al-Hidd Phase 2	2005	Multistage-Flash evaporation (MSF)	30(49.7)	Seawater
4c	Al-Hidd Phase 3	2010	Multistage-Flash evaporation (MSF)	30(49.7)	Seawater
5	Alba	*	Multistage-Flash evaporation (MSF)	10 (16.6??)	Seawater

* The expected commissioning date is unknown
** Numbers in parenthesis are in MCM per year

Table 2.4 shows the continual increase of desalination share in Bahrain water pool and how the ratio has risen from 0.08 in 1980 to 1.96 in 2002. However, it was 2.20 in 2005 (MoE&W, 2006). This increase in ratio reflects the increasing cost of meeting domestic water demand in Bahrain.



Figure 2.12. Locations of Desalination plants (Geomatec, 2005).

Table 2.4. Bahrain annual water production and blending ratio of distillate to groundwater resources in the period from 1980 to 2005 (Water Transmission Directorate, 2005)

Year	Total Groundwater		Total Distillate water		Blending Ratio Distillate water over Groundwater
	(MG/Y)	MCM/Y	(MG/Y)	MCM/Y	
1980	9023.55	40.97	721.57	3.28	0.08
1981	10902.3	49.50	878.98	3.99	0.08
1982	12149.1	55.16	1192.81	5.42	0.01
1983	12345.2	56.05	1372.42	6.23	0.11
1984	12721.5	57.76	2873.04	13.04	0.23
1985	8174.64	37.11	9438.8	42.85	1.15
1986	7782.48	35.33	10913.22	49.55	1.40
1987	10083	45.78	9711.19	44.09	0.96
1988	9967.87	45.25	10824.36	49.14	1.09
1989	11279.7	51.21	10680.89	48.49	0.95
1990	10603.3	48.14	11917.3	54.10	1.12
1991	9749	44.26	12323	55.95	1.26
1992	9526.6	43.25	13620.88	61.84	1.43
1993	11738.8	53.29	12840.92	58.30	1.09
1994	11194.5	50.82	13151.38	59.71	1.17
1995	12022.1	54.58	11551.54	52.44	0.96
1996	11075.7	50.28	13052.75	59.26	1.18
1997	11865.8	53.87	12709.99	57.70	1.07
1998	11995.7	54.46	13207.87	59.96	1.10
1999	12183.1	55.31	13479.85	61.20	1.11
2000	10049.4	45.62	17880.72	81.18	1.78
2001	9941.51	45.13	19822.86	90.00	1.99
2002	10279.48	46.67	20107.77	91.30	1.96
2003	10424.81	47.33	21686.66	98.46	2.08
2004	10622.08	48.23	23254.56	105.58	2.19
2005	10964.22	49.78	24091.69	109.38	2.20

MG/Y = million gallons per year
MCM/Y = million cubic meter per year

2.7 TREATED WASTEWATER

As part of a plan to decrease the dependence of agriculture on groundwater the government of Bahrain commissioned in 1982 a wastewater treatment plant, named "Tubli Water Pollution Control Center (TWPCC)", with a design capacity of about 54,000 m^3/day in the first phase. The plant was later expanded in a

second phase to booster its capacity to 124,000m^3/day and to serve a population of about 450,000 capita. Recently, TWPCC was further expanded to increase the secondary treated raw wastewater to a volume in the range from 150,000 to 160,000 m^3/day, of which 35,000-42,000 m^3/day of the effluent is further tertiary treated in sand filters and disinfected by ozonation and chlorination. The tertiary treated wastewater is presently used for irrigation of agricultural areas in Hawrat A'ali, Buhayr, Adari, Tubli and Buri, whereas the secondary treated is disposed to the sea at Tubli Bay.

Table 2.5 illustrates the average wastewater production over the years from 1985 to 2015.

Table 2.5. Average flow of raw sewage to TWPCC (Al-Ansari, 2004).

Year	Flow (m^3/day)
1985	73,968
1990	115,926
1995	140,000
2000	159,595
2005	187,286
2010	219,783
2015	257,917

Table 2.6 shows the quantity of wastewater treated in TWPCC and the projected flow in 2005 and 2010. The quantity is increasing steadily and by the year 2010 it may become one of the main sources for irrigation in Bahrain.

Table 2.6. Average wastewater inflow at TWPCC (ACE 1990a, 1990b, 1997).

Year	1983	1985	1990	1992	1995	2000	2005	2010
Flow (MCM/Y)	22	27	42.3	44.9	51.1	52.9	58.4	73

The tertiary treated effluent from TWPCC can be considered of good quality in according to the Food and Agriculture Organization (FAO) guidelines of wastewater used for irrigation (Table 2.5). A part from microbial content the quality of this effluent is better than the groundwater quality of irrigation water in Bahrain (Table 2.7). The only fear from the use of this effluent in agriculture is related to its microbial content, in particular the presence of certain worms. To eliminate this fear, the government has incorporated certain modifications to the

sand filters and disinfections processes in the plant to reduce these worms (Murad, 2004).

Table 2.7. Properties of tertiary treated effluent from TWPCC, 1991.

Property	Unit	Tertiary effluent	FAO guideline value
PH	---	7.5	6.5-8.4
Electric Conductivity	dS/m	4.4	0.25-3.0
TDS	mg/l	2800	< 2000
Turbidity	NTU	0.2	---
BOD5	mg/l	1.3	---
COD	mg/l	42	---
SS	mg/l	1	< 100
Ca	mg/l	238	< 400
Mg	mg/l	122	< 61
Na	mg/l	729	< 460
SAR		9.5*	< 9
Cl	mg/l		< 350
NH4-N	mg/l	0.1	< 5
NO2-N	mg/l	0.004	---
NO3-N	mg/l	3.6	< 10
PO4	mg/l		< 2.0
SO4	mg/l	501	---
Boron	mg/l	0.8	< 1
Fe	mg/l	0.2	< 5
Zn	mg/l	0.3	< 2.0
Pb	mg/l	<0.001	< 5
Faecal Coliforms/100ml		0-2.5	< 100

* Calculated from sodium, calcium and magnesium concentrations

In conclusion, the tertiary treated effluent from TWPCC could reduce the agricultural water demand in Bahrain and may soon become the main part of Bahrain water pool. Also, its use in agriculture requires good public awareness and training on the part of government and farmers.

2.8 COST OF PRODUCTION

The cost of producing desalinated water in Bahrain varies according to the entries of the cost function including, the cost of energy; and the governmental policies like the water subsidy policy. According to the Ministry of Electricity and Water (1992) the unit cost (1 unit = $1m^3$), excluding the cost of construction, of producing desalinated water in Sitra plant (Figure 2.12) in the period between

1985 and 1991 was between BD 0.25 to BD 0.35, and for Ras Abujarjur plant was between BD 0.39 and BD 0.48.

Similarly, Abdulgafar (1999) estimated the average unit cost of producing desalinated water in Bahrain in the period between 1992 and 1997 to BD 0.275. In a report presented to ESCWA in 1995, Bushnaaq (1995) estimated that the actual unit cost, including the construction cost, of producing desalinated water in Bahrain to BD 0.661 (1994 prices).

The above costs exclude the cost of extraction of groundwater, and the cost of water distribution to customers. The ministry in the same period estimated the unit cost of water extraction from groundwater to about BD 0.026 and the unit cost of water distribution to about BD 0.095.

For wastewater, ACE (1990) estimated the unit cost of tertiary treated wastewater to BD 0.119, and for secondary treated wastewater to BD 0.062. The unit cost of distribution to farms was estimated on the basis of 1990 prices to BD 0.012.

From the above presentation, it is concluded that water desalination is very expensive as compared to others from groundwater and wastewater. Given the fact that groundwater is scarce in Bahrain, the water resources management in Bahrain should be considered on the basis of opportunity cost.

CHAPTER 3 WATER USAGES

3.0 WATER USAGES

Historically, groundwater has been used in the Kingdom for both agriculture and municipal requirements. Natural freshwater springs used to flow freely in the northern part of the kingdom and in other scattered areas, but with the increased groundwater pumping the spring flows ceased and pumping wells become the normal means of water supply. Therefore, groundwater and seawater become the only water sources to meet all water needs in Bahrain. Figure 3.1 presents the groundwater wells distributed among different areas of the Kingdom under the full responsibility of Ministry of electricity and Water.

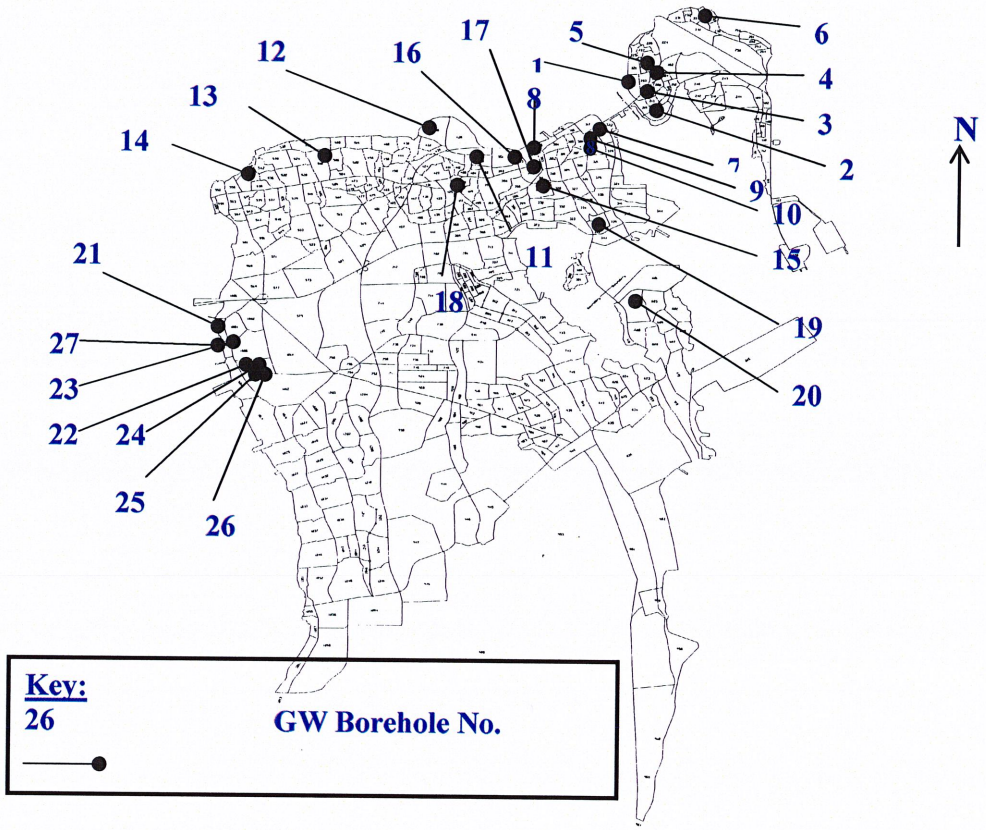


Figure 3.1. Geographical location of groundwater wells in the Kingdom of Bahrain (2002).

The total abstractions from Dammam aquifer has increased from about 63 MCM in 1952 (Bapco, 1953) to about 113 MCM in 1966 (Stucliff, 1966), and have

reached around 125 MCM in the early 1970's (Italconsult, 1971). It later rose slightly to approximately 138 MCM in 1997/1980 (GDC, 1980). The latest abstraction from the aquifer recorded in 2002 was about of 201 MCM (WRD, 2002), of which about 79.58%, 26.80%, and 2.62%, were for the agriculture, domestic and industrial sectors, respectively (Figure 14).

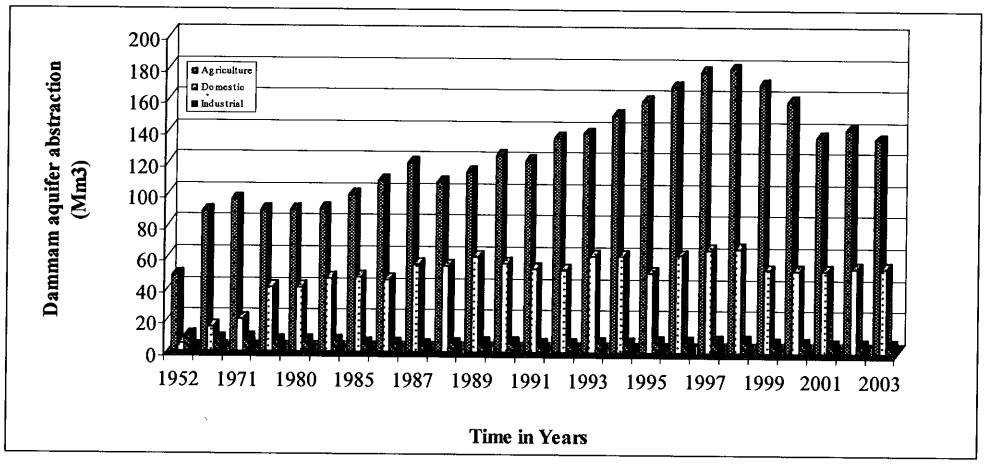


Figure 3.2. Dammam aquifer abstraction by various sectors in Bahrain (1952-2003). (Water Resources Directorate, 2003).

3.1 AGRICULTURAL USES

Before the discovery of oil in the thirties of last century Bahrain economy was dependant on fishing, pearl fetching and agriculture. Accordingly, city centers flourished along the coastline and agriculture existed in the northern parts where the free flowing springs provided the necessary irrigation water. Date palms cultivation was the most sources of trades and for the use on the local and export use.

After the discovery of oil the importance of agriculture declined as the source of wealth changed to oil exportation. This resulted in the transformation of traditional agriculture work force to other newly emerged sectors like trade and industry, and this had resulted in the changes of people food consumption habits and standard of livings. By the 1980s, a significant number of palm trees were replaced by new kinds of agricultural activities, including vegetable gardens, nurseries for trees and flowers, poultry production, and dairy farms.

Bahrain's agricultural area was reduced from 6,460 hectares in 1956 to 4096 hectares in 1991, with a decline of about 36.6%. However, the cultivated land shrunk from 3793 hectares in 1966 to 1535 hectares in 1974 (40.5%) and increased again to 3056 hectares in 1991 (Al-Noaimi, 1999). The number of the skilled farmers declined progressively after 1975 due to the attraction to other types of jobs and the high wages of other professions. In spite of these consequences, the government policy in the 1980's was to encourage the domestic production of crops through programs such as free distribution of seeds, technical assistance in adopting new and more efficient irrigation technologies and low-interest credit. Therefore, these programs have contributed to significant increases in the irrigated land and the production of eggs, milk, and vegetables. Figure 3.3 gives the general trend of irrigated and cultivated areas in Bahrain over the last three decades (Zubari et. al, 1996).

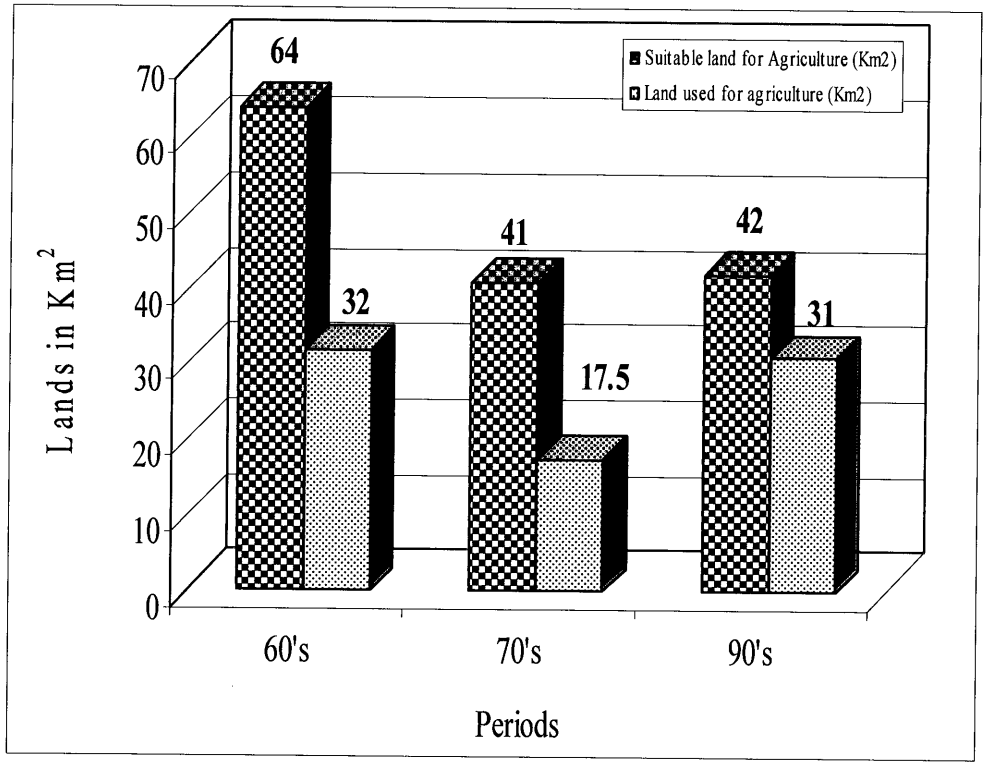


Figure 3.3. Development of agricultural lands (Zubari et. al, 1996).

Many factors limit the expansion of agriculture sector in Bahrain (Al-Noaimi, 1999) including:

- The natural constraints of the limited cultivated land, the poor soil water holding capacity and the unavailability of a good quality irrigation water.
- The root zone is shallow due to the presence of an impermeable lime layer at about 1.2 to 2 meters below surface. These causes a salinity build up in the soil to the extent that retards the plants growth.
- The encroachment of housing, industry and other urban developments into the agricultural land.
- The absence or the weak enactment and enforcement of laws and byelaws that protect those working in agriculture.
- The low wages or incomes of those working in agriculture sector compared to those working in other sectors.
- The small area of farms limits the use of mechanization and improved the methods of farming.

The above factors have reduced the share of agriculture in the GDP to less than 0.46% according to 2001 records. Similarly, the workforce in agriculture dropped from 12.4% in 1971 to 5.3% in 1981, and to 2.1% in 1990 (Al-Noaimi, 1999).

3.1.1 AGRICULTURAL SOIL

The soil of agricultural land in Bahrain is loamy-sand. It is characterized by poor organic matter content and weak water holding capacity, in the range of 2-6%. The root zone depth is shallow in the range of 1.2 to 2 meters, it is underlain by impermeable layer of lime that precludes water from seeping downwards, and thus allows saline irrigation water to accumulate in the root zone and forms a salt crust on soil surface at times of drying up.

3.1.2 PLANTED CROPS

The main crops planted in the Kingdom of Bahrain are date palm, vegetables, forage crops and to a little extent some types of fruits. The cropping area in Bahrain has witnessed a number of changes in the period between 1974 to 1991, all crops area had increased since 1974, in particular vegetables that witnessed

the highest increase of about 141% as shown in Table 3.1. These increases were a result of the increase in the use of protected agriculture, new methods of irrigation and the reuse of treated wastewater in the irrigation of forage crops (Al-Noaimi, 1999). Sample photos (3.1 to 3.5) are provided hereafter to demonstrate the crop types in the Kingdom.

In addition to the above, Bahrain produces other products like dairy, eggs and meat.

Table 3.1. Planted areas to various crops (Al-Noaimi, 1999).

Year	Crop/Area (Hectare)		
	Palm/Fruits	Vegetables	Fodder crops
1974	880	340	310
1978	780	410	320
1982	----	488	315.9
1985	----	576	307
1986	983	834.7	311.8
1988	----	835	426.8
1991	-----	819.9	430.8



Photo 3.1. Production of eggplants (Sogreah, 2001)



Photo 3.2. Vegetable gardens (Sogreah, 2001)



Photo 3.3. Pumping station for irrigation (Sogreah, 2001)



Photo 3.4. Low efficiency gravity irrigation (Sogreah, 001)



Photo 3.5. Green house (Sogreah, 2001)

3.1.3 IRRIGATION METHODS

Though the soil infiltration rate and irrigation water salinity is high, old methods of water flooding still dominate the irrigation methods in Bahrain. Water flooding methods consume more water than needed as a result of the low soil holding capacity and the shallow root zone which produces water logging. Table 3.2 and photos 3.1-3.5 shows areas under various crops irrigated by water flooding.

In the early eighties, the government encouraged farmers through financial support and other incentives to adopt new methods of irrigation. Consequently, the area of irrigated land with new methods of irrigation such drip systems has increased (Table 3.2). The lands cultivated with vegetables using new methods of irrigation was increased from 9.6% in 1985 to 46.88% in 1991. While for forage crops it increased from zero to 27.39% for the same period.

Table 3.2. Land under vegetables and forage crops using old methods of water flooding and new methods (1985-1991) in Hectares (Al-Noaimi, 1999).

Crop / Irrigation method	Vegetables			Forage crops		
	1985	1988	1991	1985	1988	1991
Water flooding	520.66	535	435.48	307	312.1	312.8
New methods	55.34	310	384.42	0	114.1	118
Total	576	835	819.9	307	426.2	430.8

Expansion of new methods of irrigation to palms and fruits are confined to new farms. Old farms are still using old irrigation methods because the old trees roots are not adapted to new methods of irrigation. Land under forage crops is still using the old irrigation methods and efforts should be directed to change this situation since the water consumption of these crops is high.

3.1.4 IRRIGATION EFFICIENCY

Irrigation efficiency is a critical measure of irrigation performance in terms of the water needed to irrigate a field, farm, basin, district, or an entire watershed. In the context of satisfying quality food supply which is needed to meet the demand of

the rising population growth. "Irrigation efficiency" is a basic engineering term used in irrigation science to characterize irrigation performance, evaluate irrigation water use, and to promote better or improved use of water resources, particularly those used in agriculture and turf/landscape management.

Irrigation efficiency is defined in terms of a) the irrigation system performance, b) the uniformity of the water application and c) the response of the crop to irrigation. Each of these irrigation efficiency measures is interrelated and varies with scale and time.

In Bahrain, the introduction of the new irrigation methods had led to the production of more diversified crops with small quantities and small economic value. However, new irrigation methods contributed to the conservation of ground water and hence contributed in reducing the depletion of the already exhausted aquifers. The new irrigation technologies will contribute to the achievement of the sustainable water resources concept.

3.1.5 REFORMS IN THE AGRICULTURE SECTOR

In an attempt to reduce the consumption from the groundwater resources and in particular from the agricultural sector, despite its low contribution in the GNP, only 0.46% (CIO, 2001), the water resources authorities had introduced a more stringent regulations for water well drilling. An Amiri Decree No. 12 was issued 1997 and at the same time, different programs were initiated to enhance the usage efficiency as follows:

- Installation of water meters on production wells and impose tariff on groundwater.
- Start the program of replacing the forge alfalfa, which is the biggest consumer of water by different forge that are of less water requirement.
- Start a program of improving the efficiency of the irrigation systems.

These programs were expected to reduce the groundwater usage for agriculture to about 50 MCM/Y by the year 2002 in contrast with 178 MCM in the year 1997

(Al-Mansour, 1998). However, this target was not met due to various reasons among which are the delays in:

- The enforcement of the water resources regulations and policies; and
- The construction of the TSE network.

3.2 DOMESTIC USES

3.2.1 POPULATION

Bahrain population reached a total of 650,604 capita in 2001, of which 62.35% are Bahraini nationals (Figure 3.3). The population growth rate between 1991 and 2001 for Bahrainis was 2.5%, which is lower than the previous growth rate of 2.91%. This decrease in the population growth rate is a result of rise in educational levels and the increase of average marital age of Bahrainis (Al-Noaimi, 1999). The population was expected to increase by more than 20,000 inhabitants between 2001 and 2002, of which 62.18% are Bahrainis (CIO, 2001). Using the high growth rate the total population for the years 2005, 2010, 2015, 2020, and 2025 is expected to reach 724,645 (CIO, 2006), 717,000, 766,000, 816,000 and 863,000, respectively (UNSPD, 1997).

The Bahrain total population increases steadily, but at different growth rates due to influx trend of non-Bahrainis which is affected by the economic growth. (Figure 3.4 and Table 3.3).Due to the increase in the oil prices associated with the expansion in the oil sector, the rate of growth of the non-Bahraini population was relatively high in the early eighties. Another observation is the reduction of Bahraini growth rate after the nineties due to the reasons mentioned in the first paragraph of 3.2.1.

Table 3.3. Rate of growth of Bahrain population (CIO census, 2001).

Time period	1941-1950	1950-1959	1959-1965	1965-1971	1971-1981	1981-1991	1991-2001
Bahraini	2.31	2.91	3.39	3.55	2.95	2.91	2.5
Non-Bahraini	1.64	3.07	8.21	0.22	11.48	4.8	3.0
Total	2.19	2.94	4.29	2.82	4.96	3.55	2.7

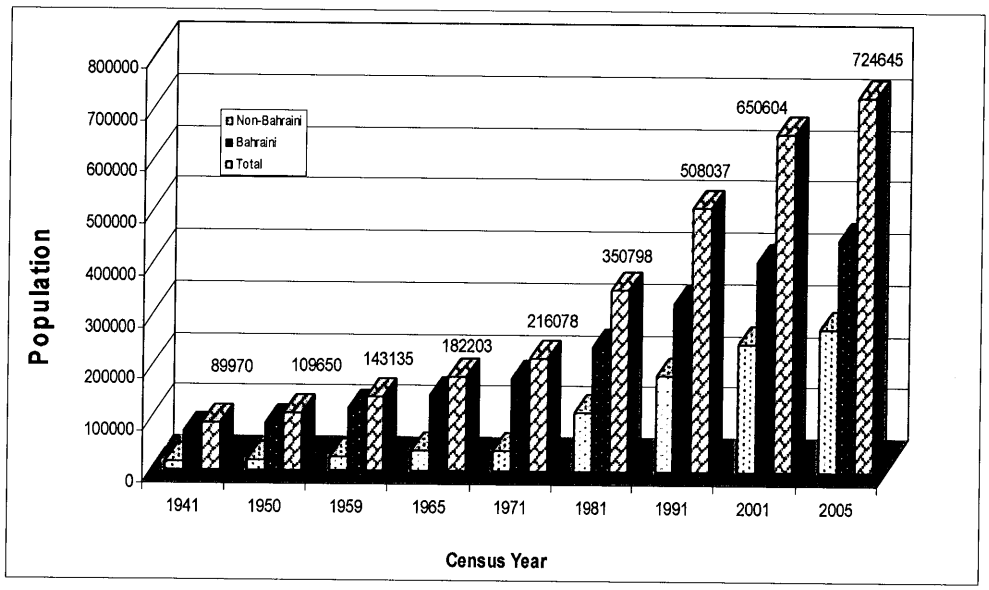


Figure 3.4. Population census in Bahrain (1941-2005), (Modified after Central Informatics Organization).

The Bahraini community can be considered young; the age distribution of Bahrainis in the range of 15-19 years, as per the census of 2001, and the estimated population by CIO for the year 2005, it is clear that this range of the population will form 11% of the workforce entering the market, thus 42.4% of Bahrainis are between 15 to 44 years old, whereas the elderly of more than 65 years old represents only 3.7%.

The increase of population and the transformation of economy from agriculture-based to oil, trade and services have induced more urbanization and migration of villagers to urban centers for the sake of better life. The urbanized population increased from 56% in 1941 to about 88% in 1991, of which more than 50% lives in the cities of Manama (23.6%), Muharraq (14.1%) and Rifa'a (12.3%). Because Bahrain is a small country and the economy and population are growing fast one can easily observe that the intermingling of industrial and residential areas in many parts of the country (Mac Donald, 1994).

3.2.2 DOMESTIC WATER USE

Prior to 1975, groundwater was the only source for domestic purposes in Bahrain, since then it has been augmented by desalinated water.

Table 3.4. Water production and consumption for municipal purposes.

Years	Total Production*		Population	Per Capita Consumption	
	(MG/Y)	(MCM/Y)		(G/d)	(Liter/d)
1980	9745.1	44.2	326346	81.8	371
1981	11781.3	53.5	350798	92.0	418
1982	13341.9	60.6	366728	99.7	453
1983	13717.7	62.3	380120	98.9	449
1984	15594.6	70.8	394034	108.4	492
1985	17613.4	80.0	408493	118.1	536
1986	18695.7	84.9	423520	120.9	549
1987	19794.2	89.9	439138	123.5	561
1988	20792.2	94.4	455372	125.1	568
1989	21960.6	99.7	472249	127.4	578
1990	22520.6	102.2	489794	126.0	572
1991	22072.0	100.2	508037	119.0	540
1992	23147.5	105.1	521846	121.5	552
1993	24579.8	111.6	536035	125.6	570
1994	24345.9	110.5	550614	121.1	550
1995	23573.6	107.0	565594	114.2	518
1996	24128.5	109.5	580987	113.8	517
1997	24575.8	111.6	596802	112.8	512
1998	25203.6	114.4	613054	112.6	511
1999	25663.0	116.5	629752	111.6	507
2000	27930.1	126.8	646911	118.3	537
2001	29764.4	135.1	650604	125.3	569
2002	30387.3	138.0	672123*	123.9	562
2003	32111.5	145.77	689418*	123.8	563
2004	33876.6	153.79	707160*	127.5	580
2005	35055.9	159.14	724645*	131.2	596

*(Updated after Swar, 2001, Water Transmission Department and personal communication collected from Central Informatics Organization (CIO), 2006.

The daily per capita consumption over the years is given in Table 3.4. The per capita consumption increased steadily before the mid-eighties and stabilized to an average of 550 liter/day since then.

3.3 INDUSTRIAL USES

Economic activities that are based on oil replaced the fishing and agriculture activities. Oil industry brought more wealth to the country and induced accelerated development in all aspects of life. At the beginning, industries, excluding oil refining, were simple in nature like food processing and beverages. Large scale and modern industries like the production of aluminum, primary and secondary, steel forming, petrochemicals and others emerged over the last three decades.

Those new industries increased the demand on water. Up to early seventies the industrial demand was met from Dammam-Neogene aquifer. From 1971 to 1990 it was met equally by both Dammam-Neogene and Rus-Umm Er Radhuma aquifers, and after mid eighties the desalinated water augmented the industrial demand, but mixed with groundwater. In the year 2003, the industrial consumption reached to 5.04 MCM (2.58%) of the total groundwater consumed from Dammam-Neogene aquifer.

3.4 GROUNDWATER BALANCE

Standing upon water deficit for the year 2002, the calculations is based on the following equation (Al-Noaimi, 1999):

Change of storage = Total Inflows – Total Outflows

Result revealed as detailed in Table 3.5 below that -125.71 MCM is the annual water deficit calculated with an increase of 31% during the period from 1992-2002 of that calculated by Al-Noaimi (1999) (-96.04 MCM for the year 1992).

Table 3.5. Groundwater Balance in Bahrain, 2002.

Component Inflow/Outflow	Average annual rate, Inflow/Outflow (MCM)
Inflow:	
• Recharge by under-flow (aquifer safe yield)	112.00
• Recharge by rainfall on outcrop and irrigation return flows	0.28
Total inflow	**112.28**
Outflow:	
• Agricultural uses (wells abstraction)	141.86
• Municipal uses (wells abstraction)	53.87
• Industrial uses (wells abstraction)	5.26
• shallow water lagoons	17.60
• Sabkha natural discharge (salty waters)	14.00
• Natural springs discharge	5.40
Total outflow	**237.99**
Total inflow – Total outflow	**-125.71 (water budget deficit)**

3.5 WATER RESOURCES MANAGEMENT

Water resources management is an important issue for policy makers. However, without changing the consumers' practices in water consumption, the sustainable water resources management is impossible. In certain situations, decreasing the quantity of water used is important. On the other hand the increase in the water use may have rose in situations like preserving wet ecosystems such as marshes, rivers and estuaries or perhaps lowering the contamination levels in particular areas (El-Kady et. al 2002, GWMATE 2003).

Storage of water is important as climate variability impact the balance between demand with supply. Groundwater is by far the largest store of freshwater on the earth. However, when the pumped groundwater from an aquifer exceeds the natural recharge (rainfall), the groundwater levels decline and the storage is depleted. Groundwater recharge occurs only in the wet seasons. Despite the fact that the Dammam aquifer which extends from the Saudi peninsula has its outcrop at the eastern province and gets replenished by the rain fall over that area

.However Bahrain part of the aquifer is being constantly depleted beyond the replenishment rate (Zubari, 2004).

The trends are increasingly moving towards utilizing the TSE excess as part of the management aquifer regimes to replenish depleted aquifers. Currently about 15,000 m^3/day is being pumped to the sea as TSE network have not been fully constructed (Al-Aradi, 2006). In demand management, diversified methods usually are sought for such as limiting the well depth, building awareness and using modern agriculture techniques.

3.5.1 WATER RESOURCES PLANNING

Bahrain has formulated a land use plan for the year 2000 and beyond. There is a clear management policy in allocating land for industries, housing development, oil and gas processing, recreational and cultural activities, agriculture, public utilities, communications, ports and airports, road network and quarry activities.

In addition, Bahrain's sustainable development policy contains six main priority issues, one of which is terrestrial and marine resources (Figure 3.5).

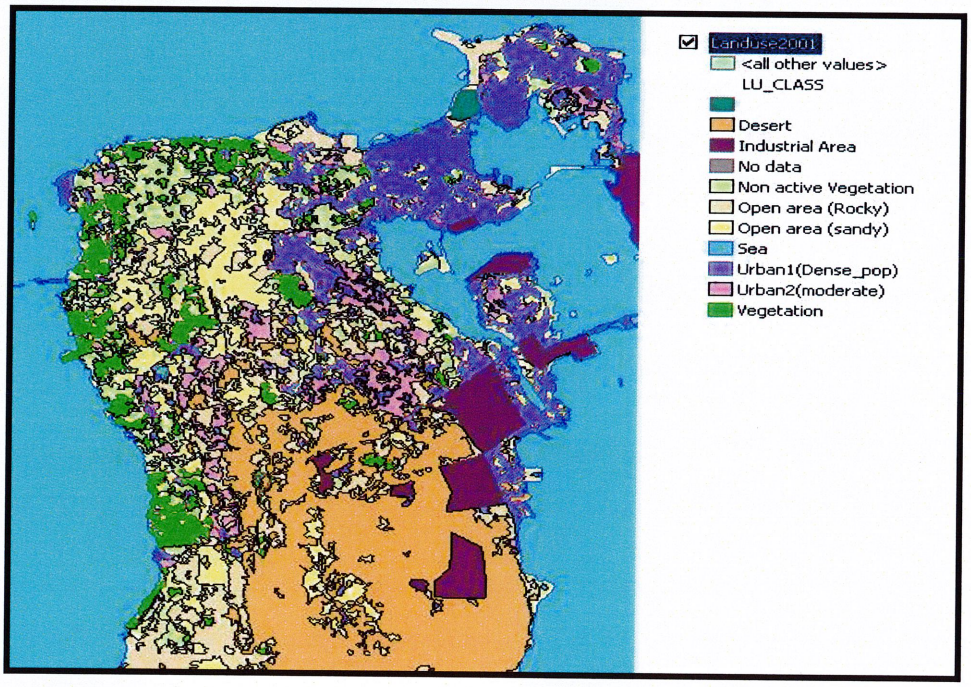


Figure 3.5. Kingdom of Bahrain land use (Geomatec, 2001).

3.5.2 WATER POLICIES

Several policy tools can help influence the water use in Bahrain. Regulation, pricing, investments, institution building are examples of such tools.

Awareness rising can also help create a social pressure on the government and other water users. It can support a drive for policy changes in favor of better water management and build a political environment toward water sustainability and conservation.

The groundwater resources are depleting due to an increased abstraction and limited recharge. This has motivated the Directorate of Water Resources to consider every attempt to control the excess of water use. An Amiri Decree No. 12 (1980) has been enacted to protect the available water resources, stop the drilling of new wells, and control water use and groundwater quality in terms of TDS.

The government has implemented a management scheme for the abstraction of groundwater from Dammam aquifer for the industrial sector and was directed to meet the required demand from the highly saline (brackish) Rusumradhma aquifer. To meet the needs for the rapid development in the industrial sector, to reduce and control the abstraction from Dammam aquifer, groundwater can be pumped from the Rusumradhma aquifer. The use of the groundwater of Rusumradhma aquifer will assist in maintaining the piezometric level in the latter aquifer and as reduce the upward migration of the brackish water into the Dammam aquifer (GDC, 1980, 1983).

Many ministerial orders were issued to protect the natural water resources from further salinization and deterioration, including the Ministerial Order No. 23 (1980) and Ministerial Order No. 4 (1983)..etc, such significant Ministerial Order No. 23 negative impacts will eventually dictate a very expensive remedies at later stage on Bahrain government related to natural resources (Swar, 2001).

These orders were underpinned by the weak enforcement and implementations execution which was lacking the political backing to adapt the water well taxation, this in turn adversely affected the efforts of ground water conservations.

The efforts in 1980-1984 periods have been confronted by an ever increasing number in well drilling from 1084 to 1213, respectively (Swar, 2001).

In spite of the above measures which were meant to reduce the pumpage rate of groundwater, the pumping rate has increased by the year 1985 to around 150 MCM/year (Figure 3.2).

3.5.3 DEMAND MANAGEMENT

In most rapidly growing cities, a particular challenge will need to meet the escalating water demand in the face of competing political, and socioeconomical issues and limited financial resources for technological development and essential infrastructure (Abdel-Magid et. al, 1994). In addition, to the arid climate in Bahrain has a significant role in the water shortage problem.

To achieve the sustainable management of water resources in Bahrain, new approaches should be examined, and if necessary, new water resource development and management plans should be developed, in association with detailed field surveys that could consider the stakeholders participation. Hence, a cultural change is essential to ensure the sustainable management of water resources (Al-Alawi, 1999).

The Ministry of Electricity and Water has adopted water distribution management as a mean towards water conservation in two directions. First, through water distribution system management and second, through the on-going public awareness programs (Al-Mansour 1992, 1998).

The water distribution network deficiencies associated with the increase of the high level of unaccounted for water (UFW) that is defined as the wastage through the network itself, are due to the following reasons:

- The use of the non-standard materials in networks.
- Continuous damage caused by works of other authorities to the water distribution system like sewer and electrical cabling.
- High level of leakage (Khalaf, 1998).
- High static pressures.
- Poor registration and identification of high consumers.
- Rapid deterioration of the network elements and features due to various water quality supplied through the distribution network.
- Irrigation.
- Age of the network elements (Khalaf, 2002).
- Poor workmanship.
- Others.

In general, the tariff rate, conservation technology, use of Geographical Information System (GIS), the Customer Services System (CSS), Network Analysis Modeling Techniques (NWAMT) and supportive trainings are some of the tools to activate the demand management (Khalaf, 2004).

3.5.3.1 WATER SAVING TECHNOLOGIES

Communication channels are used to provide basic information. TV programs, radio commercials and outdoor media reinforce the messages of the campaign awareness groups. The following are some suggested tools to promote water saving technologies:

- Distribution of Conservation kits to the public. The kits contain a displacement bag (0.5 gallon) for the toilet tank, dye tablets to test for leaks, a flow restrictor and an instruction sheet.
- Make effective use of the Internet, mass media, newspapers, magazines, brochures and these can be successful when distributed to the right places and right people. Therefore, displaying racks at nurseries, libraries, community centers, municipalities, schools, hospitals, clinics and

plumber's associations, depending on the topic of the brochure. Outreach events like festivals and shopping malls. In addition to these means, mailing brochures within water bills to Ministry of Electricity and Water's customers. Water bills are popular means of communication and are used to ensure better information dissemination and community involvement.

- Involving a marketing agency, for example, UNICEF's Social Mobilization Program.
- Making sure that educational material works and continuous updating of such materials.
- Training facilitators and motivators. Updating teachers through water conservation workshops and latest technologies in addition to Development Workshop to train people in the field of development communications. In this way a "pool of pepole" is formed and can be employed by water sector whenever required. Trainees could be from nongovernmental organizations (NGOs) the government and freelance.
- Effective use of water meter installation programs for all types of premises, followed by a maintenance program along with the pricing measures.
- Subsidies/free appliances, for example, free high-efficiency showerheads, faucet aerators and other devices.
- Mandatory non-domestic water-saving devices.
- Metering the irrigation system and improving the efficiency by the use of dripping systems in irrigation.
- Political support together with support from community leaders, and religious leaders can give an effective boost to social norms.
- Nurseries to promote low water-use plants.
- Integrating water issues in school programs and curriculum and extending it to international events.
- Introducing the concept of supplied area pressure regimes that vary area wise through the 24 hours supply. During the 24 hours of the day, the area water tank is subjected to normal, restriction, and boosting periods (Khalaf, 1998).

3.5.3.2 WATER PRICING

At early 1980's, the water pricing rose to BD 1.5 per month (Al-Noaimi, 1999). This was a fixed rate applied to all the residential areas in Bahrain. Following this situation and at 1985, the water meters installation program took place to cover all type of consumers starting with the high consumers.

The water meters installation program was implemented with introduce a new escalating pricing system that was defined as "Licermental Block System" (Al-Noaimi, 1999). Accordingly, a remarkable reduction in water consumption was achieved. Table 3.6 shows the tariffs for the various types of water on a monthly basis.

Table 3.6. Water tariff adopted by the Ministry of Electricity and Water.(Al-Noaimi, 1999)

Tariff	Type of Water	Range in m^3/month	Cost in Fils/m^3
Past Tariff up to April 1992	Blended Water	1-50	45
		51-100	110
		101- and above	200
	Groundwater	1-50	30
		51-100	35
		101- and above	85
New Tariff after April 1992	Blended Water	1-60	25
		61-100	80
		101- and above	200
	Groundwater	1-60	20
		61-100	25
		101- and above	85

Note: US$ 1=378 Fills
Water Production Cost = 400 Fils

In 1992, the tariff on the blended water was reduced by the government to lower the burden on the citizens, specially those majorities with limited or medium incomes (Table 3.6).

3.5.3.3 WATER ALLOCATION CHANGES

During the last decade, the water supply of the Kingdom has grown from least effective management to almost total management, from natural groundwater to

desalinated water and from a declining natural resource to a stabilizing and potentially improving situation. It is expected to be more effective once the Government's plan to re-use the treated sewage effluent (TSE) is successfully implemented (Twort et. al , 1994).

3.6 SUPPLY MANAGEMENT

3.6.1 GROUNDWATER RECHARGE

Managed Aquifer Recharge (MAR) has the potential to be a key component in many integrated water management systems; providing storage, and in some cases, water treatment. Over all, treated wastewater and storm water are increasingly being used as water sources for MAR. Artificial recharge of treated water is being studied (Al-Ansari, 2004). Demand for water also needs to be managed to balance the recharge to the aquifer. Demand management can take many forms including; more efficient use, limiting the depth of wells, education, moving to a lower water use economy (e.g. away from conventional irrigation systems).

Aquifer recharge and AQUIFER STORAGE AND RECOVERY (ASR) wells are used to replenish water in an aquifer for subsequent use. While an aquifer recharge well is used only to replenish the water in an aquifer, ASR wells are used to achieve two objectives: (1) storing water in the ground and (2) recovering the stored water (from the same well) for a beneficial use. Both of these types of wells, however, may have secondary objectives, such as subsidence control and prevention of saltwater intrusion into freshwater aquifers.

Aquifer recharge and ASR wells are found in areas of the U.S. that have high population density and proximity to intensive agriculture; dependence and increasing demand on ground water for drinking water and agriculture; and/or limited ground or surface water availability. ASR wells are also found in areas that have no freshwater drinking water supplies, or in coastal areas where saltwater intrusion into freshwater aquifers is an issue.

Aquifer recharge and ASR well injectate consists of potable drinking water (from a drinking water plant), ground water (treated or untreated), and surface water (treated or untreated). Water injected into aquifer recharge and ASR wells is typically treated to meet primary and secondary drinking water standards. This is done to protect the host aquifer and to ensure that the quality of the ground water to be recovered is adequate for subsequent use. In addition, most regulatory agencies require the injectate in aquifer recharge and ASR wells to meet drinking water standards in order to prevent degradation of ambient ground water quality. However, it should be noted that, in some instances, constituents have been measured at concentrations slightly above drinking water standards. Aquifer recharge and ASR wells are drilled to various depths depending on the depth of the receiving aquifer. They may inject into confined, semi-confined, or unconfined aquifers, although most of these wells inject into semi-confined aquifers that have been partially dewatered due to over pumping (USA EPA, 1999).

Moreover, in the early 1990s, artificial recharge is considered by the water authorities in Bahrain to augment depleting groundwater resources and to improve their deteriorating quality. Two pilot projects for rainfall collection into retention basins and its recharge into the Dammam aquifer via recharge wells are being carried out and are still under investigation and evaluation. However, the unreliability of rainfall from year to year and its spatial inconsistency hinders the proper evaluation of these schemes (Zubari, 2004).

However, the Dammam aquifer geological formation conditions may require extensive investigations and modeling to stand upon the suitability of such techniques in recharging by TSE, such techniques may help in reviving the depleted resource.

3.6.2 WATER LEGISLATION

To maximize the utilization of available water resource without causing environmental imbalances, scientific plans for water resource management should be implemented. Integrated water management calls for formulating a

central authority concerned with water policies and plans in addition to activities and programs amongst authorities related to water usage and prioritizing water demand sectors utilizations (Zubari, 2006).

In fact the planning towards water resources management is a complex issue as it requires the consideration of all environmental, social and economic elements and requires the collaboration of multi specialized entities in the Kingdom. The risk on water management will increase drastically as the water resources becomes scares due to natural hazards such as draughts, earthquakes and from the human being misused.

The success or failure of water management plans is related to the efficiency and authority of the administrative and legislative structure to confront the challenges. The "Administrative Structure" is defined as a group of systems, establishments, authorities, administrative organizations, technical organizations and organizational structures. Not forgetting those whom are trained to set out strategic plans for the water resources and those who should execute, implement and monitor such plans to optimize the availability of water resources.

The legislative structure refers to the system of the water legislations, laws, byelaws which are targeted to organize and optimize the utilization of water resources in addition to its conservations, including the organizational and law boundaries responsible for the follow up of the execution of these legislation and laws.

The recent directions in water management dictate that the proper management has to rest on a modern water legislation that controls the utilization of water resources ensuring the equity of distribution to achieve the maximum benefit from these resources. Hence, the completion of the administrative and legislative structures is required in Bahrain (Zubari, 2006).

In the past the water demand was limited, the need to regulations was not justified, and the concept of the community water rights was the norm, which

means that the water source is shared among the community. This concept led to utilizing natural spring's water and the large water bodies to meet the agricultural needs.

The distribution and utilization of water among the agriculture fields were carried out based on personnel initiatives or under the directives of the village mayors without a direct interference from the government. This logic of handling water resource was also applicable for the municipal sector use through utilization groundwater pumping well waters spread all over the Kingdom which were termed as "ayoon ". The government involvement was limited to drilling and equipping these wells in addition to the building of bathrooms and drainage collectors (Al-Noaimi, 1999).

With the increase on water demand, a new concept was developed which related water ownership to the landownership and was called "owned water use right privately". This concept has given the right to the landowners to utilize the water without any restrictions. This type of ownership had a major role in the water shortage problem and led the Kingdom to issue a water legislation that assumes the government involvement in the water utilization and distribution within the framework of the public interest without provoking in to the personal ownership. This was in the years 1933 (Swar, 2001), when the first water legislation was issued targeting water storage protection against waste and pollution emphasizing public health issues. Most wells at that time were naturally flowing and swamps were encountered due to the flowing water.

3.6.3 ENFORCEMENTE AND EVALUATION OF LEGISLATION

Despite of the Amiri Decree No 12/1980 regarding the organization of groundwater usage and its associated edicts and decrees considered as legislative carrying the nature of modernized directives in preserving the water resources, the major draw backs were the failure to enforce its implementations; this is quite evident in the difficult water situation. The only Decree that was efficiently enforced was in 1986 which had the most effect to reduce the use of drinking

water is the ministerial order No. 19 of 1986 regarding the amendment to desalinate water tariff for both residential and non-residential (Swar, 2001).

3.6.4 RECENT LEGISLATION

To satisfy the growing demands for various sectors (agriculture, municipal and industrial), which continue to increase much faster than the capacity of existing desalination plants new plants are constructed. Accordingly, this led to accelerate the deterioration of the groundwater due to the excessive pumping. Hence, to confront this critical situation, the Council of Ministers in its session of 19/5/1994 approved the recommendation for a daily consumption ceiling of 70 MGPD. The maximum groundwater abstraction was, therefore, limited to about 33 MGPD (Al-Mansour, 1998).

3.6.5 WATER INSTITUTION REFORMS

It is extremely difficult to deal with the water resources within a centralized framework, although from the management context, the central management is the most effective to deal with the shortage water problem and other complex water planning issues. This is attributed to the diversity of water resources and its uses.

Currently, management directions are focusing on findings in an agreeable understanding to the water resources from a centralized point of view. Without disturbing the decentralized water authorities in all stages of meeting their objectives, a gap-close system needs to be in place.

In Bahrain, there are a number of organizations and authorities that deal with water resources. Some are concerned with the development and preservation of these resources while others are responsible for the management, operation and the maintenance of water facilities as well as the production and distribution. Other authorities are concerned with collection of water data.

The liaison responsibility in between these authorities is the sole responsibility of the Water Resources Board that is incharge of drawing the strategic water policies for the Kingdom of Bahrain and outlining the liaison framework between the various authorities involved in the development and usage of water.

3.6.6 DEVELOPMENT OF HUMAN RESOURCES

The building of training organizations that are able to carry out complex duties in the water fields has become one of the most important and urgent issues that should be addressed by water authorities.

The formulation of such training organizations requires the creation of scientific, academic, and technical capacities at different levels. While the re-training will help in maintaining the human capacities to enable it to be in-line with the modern development in the field of water and their individuals should be trained on advanced automation and its implementation to suit the local conditions (Khalaf, 1998).

At the senior levels, water resources authorities are considering the preparation of scientific capacities. The problem remains with two ends: first, the insufficient preparation of the human capacities at the levels of technicians and inspectors, second, the unavailability of tailored made training for the development of the human resources.

3.7 SOCIO-ECONOMICS EVOLVEMENT IN BAHRAIN

Although oil was discovered in 1902, large-scale drilling and processing did not take place until the 1930s, just when the world pearl market was collapsing. Oil discovery brought improved education and health care to Bahrain. It also brought a remarkable escalated standard of living.

Bahrain diversified level of development took advantage of the oil boom which happened in Saudi Arabia and other neighboring countries, and made Bahrain the Gulf's main trading. As the price of oil went through the stratosphere during the

1970s and 1980s, the country economy grew accordingly. Bahrain diversified its economy and created some of the region's best education and health systems.

CHAPTER 4 SURVEY AND ANALYSIS

4.0 QUESTIONNAIRE BACKGROUND

The overall objective of the present study is to address water sustainability in Bahrain from the perspective of the effectiveness and the payoff of groundwater used in agriculture. The reason that triggered this study is the diversion of two-third of the scarce water resources to the agriculture sector that contributes very little to the national economy, other alternatives should also be considered.

The collection of field data represents a good approach to learn about the farmer's views on the agricultural practices in Bahrain, and to explore potentials of groundwater conservation. The purpose of the questionnaire was to explore the potentials and opportunities of groundwater conservation. This objective, we believe, is noble since the over-exploitation of groundwater for agriculture has led to severe consequences on various components of the environment in Bahrain. The continuation of such deterioration threatens the sustainable use of the water resources.

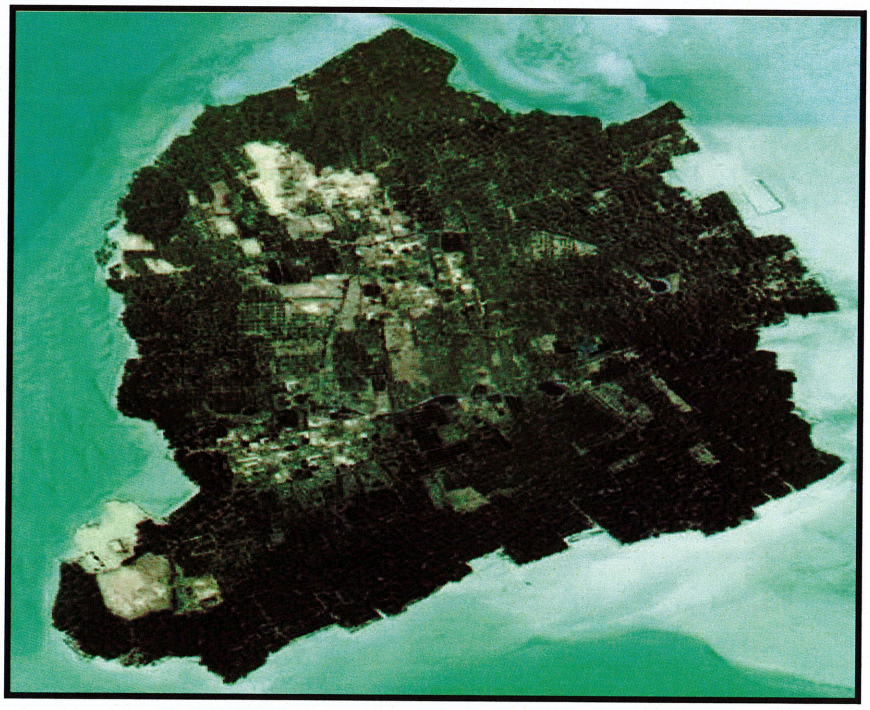


Figure 4.1a. A remote sensing image for Nabih Saleh Island (1954) (Geomatec, 2004)

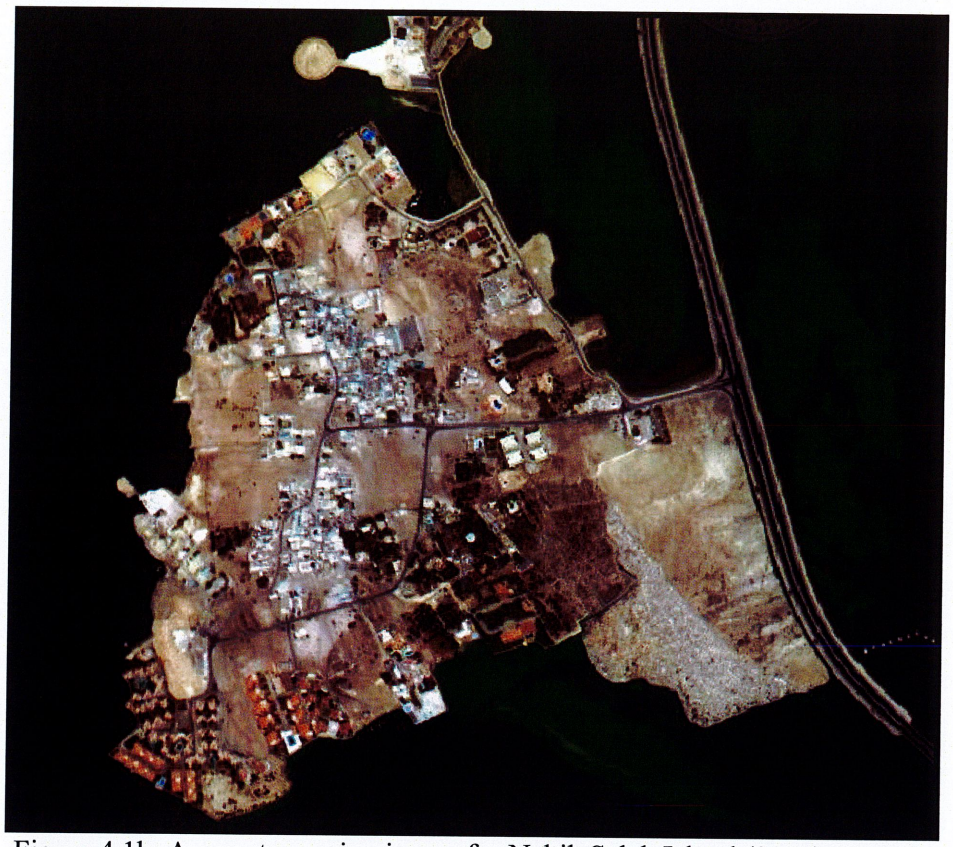


Figure 4.1b. A remote sensing image for Nabih Saleh Island (2004) (Geomatec, 2004)

A desktop study was conducted to determine the total number and distribution of farms in Bahrain that could be considered as a representative sample for the distribution of the questionnaire. Accordingly, it was decided that 120 questionnaires could satisfy the purpose. The questionnaire was distributed in areas of Bahrain where farms exist and in number that is proportional to number of farms in the targeted area. Figure 4.2 shows the number of questionnaires distributed in the targeted areas.



Legend

Area Serial No.	Locality name (No.)
1	Sanad (2)
2	Jurdab (4)
3	Jid Ali (2)
4	Al Kawarah (2)
5	Tubli (1)
6	Alzinj (5)
7	Alqadem (11)
8	Karaneh (21)
9	Jid Alhaj (5)
10	Bahrain Fort (4)
11	Janusan (5)
12	Barbar (7)
13	Alderaz (4)
14	Banijamra (8)
15	Almarkh (3)
16	Alqrayeh (1)
17	Sar (4)
18	Aljanabeah (11)

Figure 4.2. Location of surveyed farms-December 2004-Land satellite image (Geomatec, 2004)

4.1 DESCRIPTION OF THE QUESTIONNAIRE:

Each questionnaire is dubbed as "Questionnaire for evaluating farmers views on agriculture in Bahrain". Though the title is general, the questions are targeted on the purpose of exploring the options to conserve the use of groundwater. The questionnaire consists of the followings:

The first part of the questionnaire included:

- Questionnaire serial number, the number of the groundwater well in the farm, and the farm number as designated by ACE Al Moayyed Company.
- Farm location and area in m^2.
- The farmer nationality, whether Bahraini or Non Bahraini.
- How the farmer owned the farm.

The second part contains the main questions. A description of the questionnaire and its answers are given below.

4.2 QUESTIONS AND DATA

The questions first measured the farmer age and experience in the farming profession, and the owner socio-economic factors that tied him to farming. Second, they explore the owner's agricultural problems with regard to the irrigation water sources and the farmer's willingness to change to other sources like treated wastewater. Third, they identify other uses of water in the farm like livestock and cattle raising. Fourth, they test the owner satisfaction with his work in agriculture and ultimately the possibility of changing the profession.

For the sampling method to attain regional coverage of agricultural areas in Bahrain the questionnaires were distributed randomly within the sampled region and systematically among regions. The selected regions were determined after consultation with Ministry of Municipality and Agriculture. To make sure that all questionnaires be responded to, and for more reliability in the answers, one-on-one meetings were conducted with farmers in their farms.

Using this transparent and clearly defined set of questions as explained above, this exercise provided very useful insights on the groundwater uses for agriculture in Bahrain that researchers, policy-makers at different levels of the government can benefit from. Furthermore, it suggests options towards sustainability of groundwater.

Because it is the first time to know about the farmers views in Bahrain and to scrutinize the questionnaire questions a genuine start of 10 farmers were first interviewed in their farms that are located in the western part of the Bahrain in Karzakan, Dumistan and Malkiya villages. The questionnaire at that time consisted of 33 questions. These questions were found short of certain elements and some questions were unclear. Accordingly, the questions were revised and increased in number to become 42. The revised questionnaire was distributed again to the targeted farms and the responses were used in the analysis. (See Appendix A for a copy of the questionnaire).

After completing the interviews, the survey revealed a good blend of different types of farmers, owners' nationalities and their status of work in the farm (ownership, leasing, rental, and workmanship). The responses were then analysed by a statistical package "SPSS", Statistical Package for the Social Sciences, version 12.0.1 for Windows. The results are presented and discussed hereafter.

4.3 SURVEY RESULTS

Before displaying the results it is advisable for the reader to keep in mind that the interviewed farmers are old in age and have very little education or illiterate. The questions were asked in a number of ways to get the proper answers and the responses may not be as accurate as one could expect from educated people.

Place of the farm

The total number of farms is 120 because five were found converted to residential area. The selected farms are in the top third area of the main island "Bahrain", namely: Alqrayeh, Janosan, Bani Jamra, Alderaz, Barbar, Belad Alqadeem, Alzenj, Aljanbeah, Sar, Almarkh, Alkawarah, Tubli, Jid Ali, Karaneh, Bahrain Fort, Abosaiba, Aleker and Albudayea (Table 4.1 and Figure 4.3). The areas

covered are representative of Bahrain farming regions. The highest percentage of distributed questionnaires was in Karaneh village (18.3%) and the lowest was in Alqadam and Tubli areas.

Table 4.1. Farms places.

Area	Area Code	Frequency (NOs.)	%
Alqrayeh	1	3	2.5
Janosan	2	8	6.7
Bani Jamra	3	8	6.7
Alderaz	4	4	3.3
Barbar	5	8	6.7
Belad Alqadeem	6	11	9.2
Alzenj	7	5	4.2
Aljanbeah	8	11	9.2
Sar	9	4	3.3
Almarkh	10	3	2.5
Alkawarah	11	2	1.7
Tubli	12	1	0.8
Jid Ali	13	2	1.7
Jurdab	14	4	3.3
Sanad	15	2	1.7
Jid Alhaj	16	5	4.2
Karaneh	17	21	17.5
Bahrain Fort	18	4	3.3
Abosaiba	19	4	3.3
Aleker	20	5	4.2
Albudayea	21	4	3.3
Alqadam	22	1	0.8
Total		**120**	**100**

Nationality of the farm owners

As shown in Table 4.2, 95% (114) of the farms are either owned by Bahrainis or under the government custody as per the endowment laws. This fact provides more justification for the result of this work. The high percentage of ownership by Bahrainis gives more insights into the way agriculture is run and managed in Bahrain. Bahrainis are still interested in agriculture though other sectors are presently more rewarding than agriculture. The rest 5% of non-Bahraini are from GCC nationalities, of which the majority are Kuwaitis.

Table 4.2. Nationality of the farm owners.

Nationality	Frequency (Nos.)	%
Bahraini	114	95
Non-Bahraini	6	5
Total	**120**	**100**

Farm ownership way

As shown in Table 4.3, 65.8% (79) of the farms were inherited. This may explain the fact that Bahrainis are still working in agriculture though other professions are more rewarding; therefore agriculture becomes part of the family culture. Farmers require a strong encouragement to change to other professions.

Table 4.3. Farm ownership way.

	Frequency (Nos.)	%
Farm inherited (Yes)	79	65.8
Farm inherited (No)	41	34.2
	120	**100**

Adequacy of farm revenue

It was perceived that 91% (110) of farm's revenues are not sufficient to satisfy the farmers' basic needs (Table 4.4). Therefore, farmers tend to work other jobs besides agriculture. The problem of low revenues is attributed to the small size of the farm.

Table 4.4. Adequacy of farm revenue.

	Frequency (Nos.)	%
Farm revenues sufficient (No)	110	91
Farm revenues sufficient (Yes)	10	9
Total	**120**	**100**

Willingness to sell the land

About 93.3% (114) of farmers were not willing to sell their farms, for a number of reasons: (a) most farmers are old in age and value the land differently than young aged ones. Old age farmers show a loyalty to agriculture and land; (b) the believe among the elderly farmers in Bahrain that agriculture represents the most secure income in life and once land is sold this income will be lost and (c) the

majority of farmers are living in their farms and once they sell them they will loose their home shelter (Table 4.5).

In general, the sale value of the farm in the market is based on the farm's crops, trees, date palm trees, cattle, and poultry production, and the availability of groundwater well (s). Therefore, the farm is subjected to sale once appropriate conditions such as are met:

- Subdivision of farm due to farmer's death.
- Farmer retirement.
- Groundwater deterioration.
- Low product income.
- Intentional desertification by landowner due to market prices.

Intentional desertification had led the government to enact the law of "Green belt" that conserves the green land from being converted into residential areas. Only a leisure pursuit for some of these farmers, the hidden price for the farm itself as a residential land and not as a farm, a future asset (Table 4.5).

Table 4.5. Willingness to sell.

	Frequency (Nos.)	**%**
Willing to sell (No)	112	93.3
Willingness to sell (Yes)	6	6.7
Total	**120**	**100**

Question 6: If the answer of question 5 is "Yes", what are the domineering factors from your perception?

The answers of question 5 revealed that an insignificant percentage, 6.7%, of the farmers answered with "Yes". However, this low percentage had included farmers with small lands or interest diverted farmers.

Periods of farmers practicing farming

A little more than 75% (91) of the farmers are practicing agriculture for more than 20 years (Table 4.6). This means that the younger generation is practicing other more rewarding professions and agriculture is not very much attractive to them.

A direct relationship could be drawn between the age of the farmer and the period of practicing farming. The understanding of this result leads to the fact that the range of the periods the farmers were practicing farming play an important role in perceiving the future of farming as a profession within the Bahraini society based on a demographical basis. The older generations are attached to farming as a source of living and not willing to switch to other professions.

The new generations are deterring this profession. It is important to study all associated parameters that have influenced this profession from a socioeconomic prospective. The low incomes and better work opportunities due to oil discoveries, changing of living standards, education, economic development, and weak subsidy from the government to the agricultural sector have negatively impacted the farming profession. Therefore, apparently, farming is a diminishing profession in Bahrain.

Table 4.6. Periods of farmers practicing farming.

Periods practicing farming in (range of years)	**Frequency (NOs.)**	**%**
1-5	2	1.7
6-10	9	7.5
11-15	9	7.5
16-20	9	7.5
> 20	91	75.8
Total	**120**	**100**

Having other job besides farming

About 70% (83) of farmers are not working in other jobs besides farming (Table 4.7). The majority of farmers are living on low income because the revenues they receive from agriculture are not satisfying their basic needs as it was revealed in question 4. However, they may supplement their income from agriculture by working as pickup drivers as it will be revealed in subsequent questions. The other about 30% (37) of farmers supplement their revenues from agriculture by working other jobs other than driving. Those farmers belong to younger generation of Bahrainis who are capable of working and need to increase their

incomes to be compatible with others in Bahrain who are of the same age and work in other professions.

Table 4.7. Having other job besides farming.

	Frequency (Nos.)	%
Working other job besides farming (Yes)	37	30.8
Working other job besides farming (No)	83	69.2
Total	**120**	**100**

Are his children helping him in farming

Almost 8.3% (10) did not answer. However, 75% (90) of the respondents receive no help from their children in their work in agriculture. The answer did not surprise us, as it was articulated before. Younger generations are inclined to more financially rewarding professions. Another reason may be children can not spare time for helping their fathers in agriculture (Table 4.8).

Table 4.8. Are his children helping him in agriculture?

	Frequency (Nos.)	%
Children helping in farming (Yes)	20	16.7
Children helping in farming (No)	90	75
Not applicable	10	8.3
Total	**120**	**100**

Owning a pickup

Eleven farmers did not answer this question. About 70% (83) of farmers own pickups. Farmers need pickups for two purposes: selling their products in the markets or nearby areas and during the times of no harvest they use the pickups in other purposes to supplement their income from agriculture (Table 4.9).

Table 4.9. Owning a pickup.

	Frequency (Nos.)	%
Owning pickup (Yes)	83	69.2
Owning pickup (No)	26	21.7
Not applicable	11	9.2
Total	**120**	**100**

Willingness to change farming

A little more than 50% (62) are willing to move from farming (Table 4.10). The answer to this question came as a surprise to us because as it was revealed in question 7 the majority of farmers (more than 70% of the farmers) are practicing agriculture for than 20 years. Generally, farmers with this long experience should be reluctant to change to other professions. Considering the answers to question 7 and 11, it is concluded that only 20% of long-time experience farmers are willing to move from farming, the other 30% are short-time experience farmers and those can easily move from farming.

Table 4.10. Willingness to change farming.

	Frequency (Nos.)	**%**
Willingness to change farming (No)	55	45.8
Willingness to change farming (Yes)	62	51.7
Not applicable	3	2.5
Total	**120**	**100**

Owning a house

The majority of farmers (89%) own private houses (Table 4.11). However, this does not indicate the income of the farmers. The majority of them belong to the long experience category. They build their houses over different stages in time. They started with few rooms and add more rooms as they need them.

Table 4.11. Owning a house.

	Frequency (Nos.)	**%**
Owning a house (No)	11	9.2
Owning a house (Yes)	107	89.2
Sub-Total	**118**	**98.3**
Not applicable	2	1.7
Total	**120**	**100**

Build a house recently

Five farmers did not answer. About one-fourth of the farmers (29) built their houses recently, i.e. their houses are new. Again, it is concluded that the farming income may not reflect the ability of farmer to build a house (Table 4.12).

Table 4.12. Built a house recently.

	Frequency (Nos.)	%
Built recently (Yes)	29	24.2
Built recently (No)	86	71.7
Sub-Total	**115**	**95.8**
Not applicable	5	4.2
Total	**120**	**100**

In case the answer to question 13 is yes, No of rooms

Of the thirty farmers who built their houses recently 10% of their houses have 7 rooms, 5% have 6 rooms, 5% have 5 rooms and 2.5% have 4 rooms (Table 4.13). This indicates that farmers have large families and/or have grown sons, who are working and living with them. If the farmer is capable of building a large house and having working sons it will be obvious that his income from farming combined with other complementary work is good. This answer does not contradict with the answer in question 14.

Table 4.13. No of rooms.

No. of rooms	Frequency	%
4	3	10
5	6	20
6	6	20
7	12	40
> 8	3	10
Total	30	100
No having new house	90	75
Total	**120**	**100**

Place of residence

Combining the farm location in question 1 with farmer residence place as answered in this question, one might conclude that the majority of the farmers tend to live in the area of their farms location. There is a good correlation between the farm location and place of farmer residence (Table 4.14 and Figure 4.3). In Karaneh village, where 18% (22) of surveyed farms are located, 20% (24) of farmers live there. The same could be applied in other places.

Aljanbeah village might be an exception of the above correlation. Out of the 11 farms surveyed, only 3 farmers live in the same area. This may be due to the fact

that the majority of the farms in this area are owned by non Bahrainis or by landlords who are not working by themselves in farming. These farms might be also leased to others (Bahraini farmers).

In general, farmers are either living in the same areas where their farms are located or in nearby villages. Few farmers live in distant villages and vicinities. Such cases may need further investigations to define the real reasons behind having farm locations elsewhere from the farmers' residence areas.

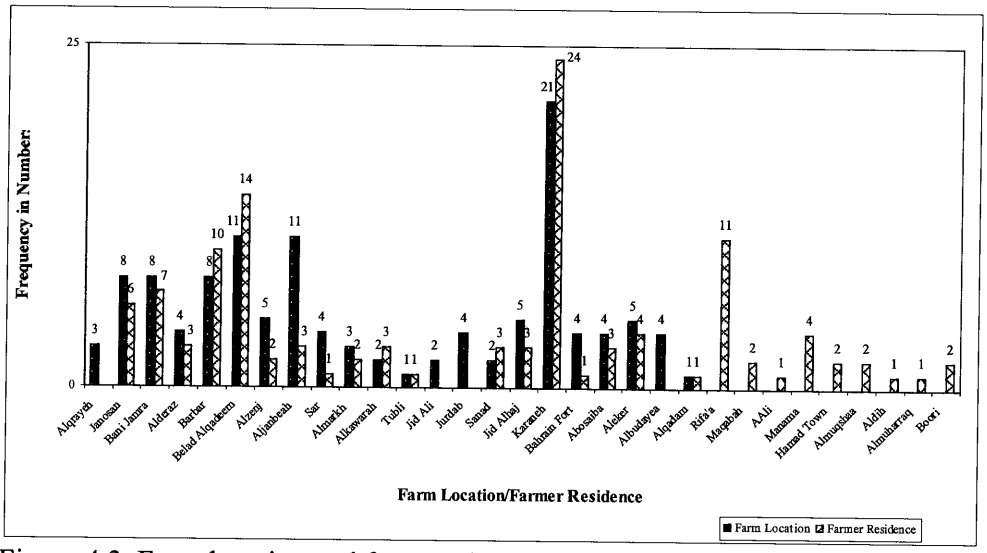


Figure 4.3. Farm location and farmer place of residence.

Table 4.14. Farmers' living or residence places in Bahrain.

Area	Farm Location		Farmer Residence	
	Frequency (N0.)	%	Frequency (N0.)	%
Alqrayeh	3	2.5		
Janosan	8	6.6	6	5.0
Bani Jamra	8	6.7	7	5.8
Alderaz	4	3.3	3	2.5
Barbar	8	6.6	10	8.3
Belad Alqadeem	11	9.2	14	11.7
Alzenj	5	4.2	2	1.7
Aljanbeah	11	9.2	3	2.5
Sar	4	3.3	1	0.8
Almarkh	3	2.5	2	1.7
Alkawarah	2	1.7	3	2.5
Tubli	1	0.8	1	0.8
Jid Ali	2	1.7		

Jurdab	4	3.3		
Sanad	2	1.7	3	2.5
Jid Alhaj	5	4.2	3	2.5
Karaneh	21	17.5	24	20.0
Bahrain Fort	4	3.3	1	0.8
Abosaiba	4	3.3	3	2.5
Aleker	5	4.2	4	3.3
Albudayea	4	3.3		
Alqadam	1	0.8	1	0.8
Rifa'a			11	9.2
Maqabah			2	1.7
AAli			1	0.8
Manama			4	3.3
Hamad Town			2	1.7
Almuqshaa			2	1.7
Aldaih			1	0.8
Almuharraq			1	0.8
Boori			2	1.7
Total	**120**	**100**	**120**	**100**

Farmer's nationality

About two-third (64.2%) of farmers are Bahraini nationality and very few are non-Bahraini (5%). About one-third of farmers (30.8%) did not answer this question because it is optional, and those farmers might have of other nationalities other than Bahraini and this explains their reluctantcy to answer.

Table 4.15. Farmer's nationality.

	Frequency (Nos.)	**%**
Bahraini	77	64.2
Non-Bahraini	6	5.0
Sub- Total	**83**	**69.2**
No answer	37	30.8
Total	**120**	**100**

Period of farm ownership

About 70% of farmers own their farms for more than 20 years (Table 4.16). This indicates that farms are inherited from one generation to another (Question 3).

Combining the answer of this question with that of question 7 confirms this conclusion, and further confirms that old farmers adhere to their land though they are not satisfied with the revenues they obtain from agriculture (question 4). However, one should take note of the contradiction in question 11 (Table 4.16 and Figure 4.4). It is apparent that although 91% of the farmers were not satisfied with the revenues, still 51.7 % of the farmers were willing to change farming and the remaining 45.8% will diversified their income sources to satisfy the basic needs.

Table 4.16. Period of farm ownership.

Range of periods (Years)	Frequency (Nos.)	%
1-5	2	1.7
6-10	8	6.7
11-15	12	10.0
16-20	11	9.2
> 20	83	69.2
Sub-Total	**116**	**96.7**
No Answer	4	3.3
Total	**120**	**100**

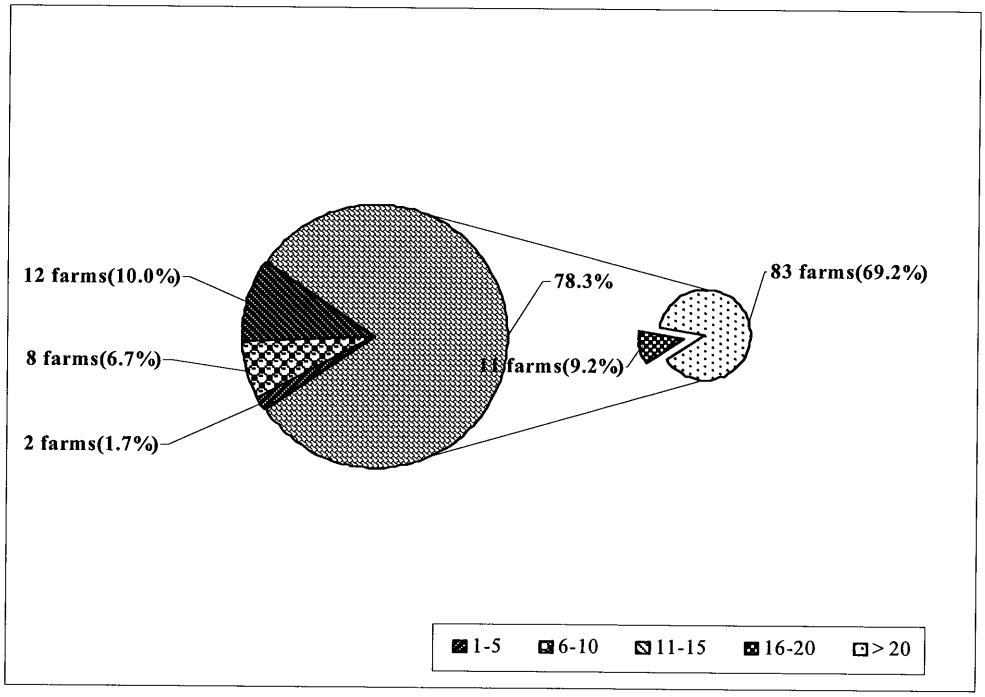


Figure 4.4. Period of farm ownership in years.

The source of irrigation water in the farm

Almost all the farms surveyed use groundwater as a source of irrigation (Table 4.17).

Table 4.17. Farms survey results and analysis, 2004-Source of irrigation water.

	Frequency (Nos.)	%
Groundwater	119	99.2
TSE	0	0
Not Answer	1	0.8
Total	**120**	**100**

If the source of irrigation is groundwater, Farmer payment per cubic meter used

Farmers are not paying for the water consumed in agriculture (Table 4.18). It is also believed that those who did not answer this question are not paying for water. This gives an indication of the difficulty of controlling the consumption of groundwater for agriculture in Bahrain and contradicts with the government policy of increasing the supply to match the demand.

Table 4.18. How much the farmer pays per cubic meter of groundwater used?

	Frequency (Nos.)	%
Pay for groundwater (No)	103	85.8
Pay for groundwater (Yes)	0	0
Not answered	17	14.2
Total	**120**	**100**

Farm leasing

This question was a little tricky to farmers and firstly they were hesitant to answer, but once it was explained that the purpose is to rationalize the use of groundwater for irrigation and give the land some relief time from agriculture they agreed to answer. In spite of this, 70% (84) of farmers are not willing to accept leasing the government, while 27.5% (33) are willing to lease the government (Table 4.19). Though the answer makes it difficult to rationalize the use of irrigation for agriculture, it is understandable because most of the farmers are old and those typically adhere to land and agriculture. However, the farmers

may have a fear that land could be utilized for other activities once it has not used for agriculture.

Table 4.19. Farm leasing.

	Frequency (Nos.)	%
Lease the farm (No)	84	70
Lease the farm (Yes)	33	27.5
Sub-Total	**117**	**97.5**
No answer	3	2.5
Total	**120**	**100**

Willingness of farmers to use treated sewage effluent

Only two farmers, as indicated in Table 4.20, did not accept the use of TSE. The first farmer raises chickens in the farm and the second can accept TSE under one condition, that is, if groundwater is no longer available. The vast majority of farmers (about 98%) accept using TSE for irrigation, if provided.

Table 4.20. Willingness to use treated sewage effluent.

	Frequency (Nos.)	%
Are you willing to use TSE if given? (No)	2	1.7
Are you willing to use TSE if given? (Yes)	117	97.5
Sub-Total	**119**	**99.2**
No answer	1	0.8
Total	**120**	**100**

The reasons of not using the TSE

Answer to this question is given in question 21 above.

If the present groundwater resource ceased, would he use treated wastewater for irrigation?

On the basis of the preceding two questions the answer to this question becomes known. About 99.2% (Table 4.21) will use treated wastewater once groundwater ceased.

Table 4.21. Willingness to use treated wastewater effluent once groundwater source ceased.

	Frequency (Nos.)	**%**
If the present groundwater ceased, would you use treated wastewater for irrigation? (No)	1	0.8
If the present groundwater ceased, would you use treated wastewater for irrigation? (Yes)	119	99.2
Total	**120**	**100**

Willing to use treated wastewater effluent once it is subsidized

Although the groundwater is currently free, the answers to the question were based on the farmers' awareness of the groundwater scarcity.

All farmers without exceptions accept treated wastewater effluent if it is subsidized. It is noted that the concept of "Subsidence" itself might gives the farmers the false, impression that farming may become a profit generation profession (Table 4.22). This might be important point as it can be used as an opportunity to trade off between groundwater and TSE.

Table 4.22. Willingness to use treated wastewater effluent once it is subsidized.

	Frequency (Nos.)	**%**
If the farmer is given a subsidence to use treated wastewater, would you use it? (Yes)	120	100

Systems of irrigation

This question was raised to evaluate if water is used rationally in the farm. New irrigation systems rationalize the use of water; on the contrary, old ones do not (Table 4.23). About 46% still use the old systems and very few (6%) use the modern systems. However, the farms that have mixed of the two are observed to be more than the old systems. It is concluded that modern irrigation that rationalizes the use of water for irrigation is not widely spread in Bahrain.

Table 4.23. Systems of irrigation.

	Frequency (Nos.)	%
Modern Irrigation Systems	7	5.8
Old Systems	55	45.8
Mixed Irrigation Systems	57	47.5
Sub-Total	**119**	**99.2**
No answer	1	0.8
Total	**120**	**100**

Interviewer observation of a salty layer on top of dry soil

About 40% of farmers observed that their farms have clear salty layers on top of soil when it is dry (Table 4.24), confirming the farmers' thoughts measured in question 27. Thus, some farmers are aware of the relation between the existence of salt layer on top of soil and the high salinity of irrigation water and soil.

Table 4.24. Interviewer observation of a salty layer on top of dry soil.

	Frequency (Nos.)	%
Salt on top of dry soil (No)	72	60
Salt on top of dry soil (Yes)	47	39.2
Sub-Total	**119**	**99.2**
No answer	1	0.8
Total	**120**	**100**

The farmer's observation of soil salinity

The farmers' observations came comparable with the interviewer answers in Tables 4.24 (39% and 37, respectively).

Table 4.25. The farmer's observation of soil salinity.

	Frequency (Nos.)	%
Salinized soil (NO)	63	52.5
Salinized soil (Yes)	45	37.5
No answer	9	7.5
Sub-Total	**117**	**97.5**
Not Applicable	3	2.5
Total	**120**	**100**

Soil salinization is a direct consequence of high content of salt, of irrigation water. Over-exploitation of groundwater has brought more saline water from the deeper strata into the irrigation water, and over the years the usage of this water leads to soil salinaization.

Soil salinity treatment methods

Normal treatment methods stated by the farmers regarding soil salinity highlighted the level of awareness farmers reached to tackle this problem and the experience they gained in soil salinity management. Of those observed the salinization in their farms' soil about 30% solve it by flooding with sweet water before the plantation of new crops which 15% by adding soil additives like animal manure. Though the manure can't be considered a solution by itself, but some farmers think it is (Table 4.26).

Table 4.26. Soil salinity treatment methods

	Frequency (Nos.)	**%**
Water washing	35	29.2
Soil & additives	18	15.0
Sub-Total	**53**	**44.2**
Not observed salinized soil	67	55.8
Total	**120**	**100**

The interviewer observations regarding the salinization of soil

The interviewer observations of salty layer on top of soil (Table 4.27), came comparable with those of the farmers observations presented in Table 4.25.

Table 4.27: The interviewer observations regarding the salinization of soil.

	Frequency (Nos.)	**%**
Soil Salinization (Yes)	50	41.7
Soil Salinization (No)	55	45.8
No answer	10	8.3
Sub-Total	**115**	**95.8**
Not Applicable	5	4.2
Total	**120**	**100**

Problems of groundwater in Bahrain (Farmer)

As indicated in Table 4.28, about two-third (64.2%) of the interviewed farmers are aware of the problems of groundwater in Bahrain.

Table 4.28. Problems of groundwater in Bahrain

	Frequency (Nos.)	%
Know the problems of groundwater (No)	43	35.8
Know the problems of groundwater (Yes)	77	64.2
Total	**120**	**100**

Reasons for the problems of groundwater in Bahrain

The answers to this question are classified as shown in Table 4.29. It seems that the problems are mostly of dredging and reclamation (35%), over-exploitation of groundwater (about 16%) or other problems (about 13%). A high percentage of farmers (35.8%) did not answer this question for reasons that they could perhaps do not know or not willing to answer. The answer of dredging and reclamation cause groundwater deterioration surprised us because it was not expected by us that this large extent of groundwater deterioration could be easily related to the dredging and reclamation as the farmers stated. This may suggest that many farmers are not really aware of the causes of groundwater deteriorations. Hence, groundwater awareness program is essential for the farmers.

Table 4.29. Reasons for the problems of groundwater in Bahrain.

	Frequency (Nos.)	%
Over exploitation	19	15.8
Dredging & reclamation	42	35.0
Others	16	13.3
Sub-Total	**77**	**64.2**
Not Applicable	43	35.8
Total	**120**	**100**

Raising cattle or having livestock in the farm

The majority of farmers (about 57%) raise cattle in their farms for the production of meat, milk, eggs, and other products (Table 4.30). In general, these farmers plant forage crops in addition to other crops for livestock or cattle raising

purposes. Raising cattle is a way of increasing farmer's income. Therefore, those farmers who complaint in question 4 of the low revenues from farming can raise livestock or cattle to boost their revenues. Though livestock does not require much water, their food (e.g., alfalfa) requires huge amounts of irrigation water.

Table 4.30. Raising cattle or having livestock in the farm.

	Frequency (Nos.)	**%**
Raise cattle (No)	47	39.2
Raise cattle (Yes)	68	56.7
Sub-Total	**115**	**95.8**
Not Applicable	5	4.2
Total	**120**	**100**

Type and number of cattle heads in the farms

Out of 68 farmers who raise cattle or livestock in their farms Table 4.31, 44 (64%) (Table 33) raise cows and/or 60 (88%) raise sheep and goats. Of those raising cows more than 82% have more than 5 of them and of those raising sheep and goats more than 92% have more than 6 of them, this indicate the commercial purpose behind raising livestock in the farms and the need for cattle raising to boost farming revenues.

Table 4.31. Type and number of cattle heads in the farms

Cattle Type	***Number statistics***		
Cows	**Number range**	**Frequency (Nos.)**	**%**
	1-2	4	9
	3-4	4	9
	5-7	13	30
	>7	23	52
	Total	**44**	**100**
Sheeps and Goats	***Number statistics***		
	Number Range	**Frequency (Nos.)**	**%**
	1-5	5	8
	6-10	5	8
	11-15	9	15
	>15	41	69
	Total	**60**	**100**

The farmers' perspective of raising cattle in the farms, as explained by them, is given below:

Sheeps are affordable money-wise, easier in raising, less vulnerable to diseases with less vaccines and medical care requirements, they require less space for grazing and are much needed during the holy occasions like in Ramadan or Ashora, for instance.

Cows are more milk and manure-producing animals than sheeps; manure could be used as fertilizer in the farm or could easily be sold. Cows are more vulnerable to diseases and taking care of them is more expansive than sheep. In addition, they require wider space for grazing. For feeding cows, alfalfa is planted and this turns out to be water-consuming product. This last fact could explains a direct relation between cattle raising and water consumption in the farms.

Presence of irrigation pools in the farm

As illustrated in Table 4.32, about 80% of farms have irrigation pools. The irrigation pools are small in size (2 m width, 2 m length and 1 m height) and are used for storing irrigation water temporarily before diverting it to plants and for crops washing before shipping to markets.

Table 4.32. Presence of irrigation pools in the farm.

	Frequency (Nos.)	**%**
Irrigation pool (No)	12	10
Irrigation pool (Yes)	95	79.2
No answer	10	8.3
Sub-Total	**117**	**97.5**
Not Applicable	3	2.5
Total	**120**	**100**

Presence of swimming pools in the farm

About one third (31%) of surveyed farms have swimming pools, Table 4.33. This indicates that a large volumes of irrigation water are being used for leisure and recreational purposes, this contradicts with the issue of groundwater scarcity in Bahrain and the unwise uses of this scarce resource.

Table 4.33. Presence of swimming pools in the farm.

	Frequency (Nos.)	%
Has a swimming pool (No)	80	66.7
Has a swimming pool (Yes)	37	30.8
Sub-Total	**117**	**97.5**
Not Applicable	3	2.5
Total	**120**	**100**

The dimensions of the swimming pool (LxWxH), and its use

This question to cross-check and to specify the possible use of the pool.

Farming problems in Bahrain

Five farmers did not respond to this question. The farmers answer to this question came in different texts as it is an open one. The answers were put in categories as shown in Table 4.34. Three-fourth of farmers (72.5%) complained of the low water quality and quantity, 75.8% complained of manpower shortage, and 74.2% complained of foreign products competition. About half (49.2%) complained of the weak governmental support, 40% of the high price of pesticides and 22.5% of the low market prices. The answers indicated that farmers, in general, are not satisfied with the irrigation water quality and quantity, with the workforce shortage and with the foreign products competition. Though their complaints are justifiable, for water quality and quantity, no other source is available in, Bahrain; nothing could be done about it. For foreign product competition the local product prices are acceptable to them as answered in this question and the quantity of their products can not satisfy the local demand.

It seems from farmers' answers that agriculture is profit-making profession per unit planted area. Comparing this answer with that in question 4 it becomes obvious that product prices are satisfactory, but because the area of the farm is small the total revenues become low. However, cattle raising could compensate the revenue shortage.

Table 4.34. Farming problems in Bahrain

Farming problem	**Frequency (Nos.)**	**%**
Pesticides purchasing (Yes)	48	40
Pesticides purchasing (No)	72	60
Total	**120**	**100**
Low market prices (Yes)	27	22.5
Low market prices (No)	93	77.5
Total	**120**	**100**
Weak governmental support (Yes)	59	49.2
Weak governmental support (No)	61	50.8
Total	**120**	**100**
Low water quantity and quality (Yes)	87	72.5
Low water quantity and quality (No)	33	27.5
Total	**120**	**100**
Manpower shortage (Yes)	91	75.8
Manpower shortage (No)	29	24.2
Total	**120**	**100**
Foreign products competition (Yes)	89	74.2
Foreign products competition (No)	31	25.8
Total	**120**	**100**

Crops that farmer's plant in Bahrain

A number of crops are planted Bahrain. Date palm trees are planted in 53.3% of the surveyed farms. They are used as a fence around the farm or a decorative tree. Date palm trees can grow in sandy, gravelly or stony soils of the desert, as well as the coastal areas of the country and can tolerate high salinity levels.

Two other crops that farmers mostly plant presently are vegetable (85%) and forage crops (53.3%) (Table 4.35). Fresh vegetables have good prices in the market and forage crops are used to feed cattle raised in the farm and the products can be sold easily in very good prices.

Fruits are not common in Bahrain for a simple reason. Imported fruits are is available with good prices. They are imported from many places over the world and competing with these is difficult.

Flowers are not common in Bahrain, 18.3% and the reason could be the same as fruits, but most importantly, we believe, the reason is the low experience of Bahraini farmers. Flowers could provide good cash money. Governmental support in the form of capacity building could encourage farmers to plant flowers and thus increase the farmers' revenues from agriculture, and to conserve water. Flowers could be irrigated by desalinated wastewater.

Table 4.35. Crops that farmer's plant in Bahrain.

Planting Crops	**Frequency (Nos.)**	**%**
Palm Trees (Yes)	64	53.3
Palm Trees (No)	56	46.7
Total	**120**	**100**
Fruits (Yes)	26	21.7
Fruits (No)	94	78.3
Total	**120**	**100**
Vegetables (Yes)	102	85
Vegetables (No)	18	15
Total	**120**	**100**
Forage (Yes)	64	53.3
Forage (No)	56	46.7
Total	**120**	**100**
Flowers (Yes)	22	18.3
Flowers (No)	98	81.7
Total	**120**	**100**

Farm products selling places

Many farmers sell their crops in the central market (66.7%), whereas about 10.8% sell their crops in the nearby villages or in the neighborhoods. About 5% sell their farm products on farm. Surprisingly, 15% of farmers use the farm products for their own consumption (Table 4.36). This could apply to farms raising livestock, in particular.

Table 4.36. Farm products selling places

	Frequency (Nos.)	%
Central market	80	66.7
Nearby villages	13	10.8
Self consumption	18	15
In the farm	6	5
Sub-Total	**117**	**97.5**
Not Applicable	3	2.5
Total	**120**	**100**

Purpose of practicing farming in Bahrain

About half (47.5% or 110) of farmers who responded to this question practice farming for living while 15.8% as a supplement to their incomes from other sources, 11.7% as a hobby and 6.7% for other purposes (Table 4.37).

Table 4.37. Purpose of practicing farming in Bahrain

	Frequency (Nos.)	%
Living	57	47.5
Hobby	14	11.7
Income increase	19	15.8
Others	8	6.7
No answer	10	8.3
Change	2	1.7
Sub-Total	**110**	**91.7**
Not Applicable	10	8.3
Total	**120**	**100**

Farmers acceptance to plant cash crops

About 74% of the 105 farmers who answered this question are not willing to plant cash crops like flowers, for example. I think the reasons behind this high percentage are the age of the farmers, who, as shown previously, are old in age and can't accept change easily; and these new crops need training and experience and without which the farmers are afraid to try. In spite of this high percentage, I strongly think that farmers, if supported and trained they would accept planting these new crops, because at the end of the day farmers would like to increase their farm revenues (Table 4.38).

Table 4.38. Farmers acceptance to plant cash crops.

	Frequency (Nos.)	%
Willing to plant cash crops (No)	89	74.2
Willing to plant cash crops (Yes)	16	13.3
No answer	10	8.3
Sub-Total	**115**	**95.8**
Not Applicable	5	4.2
Total	**120**	**100**

Where the government can support

As shown in Table 4.39 very few responded to this question. It seems that farmers are frustrated with the governmental promises of supporting them. Moreover, they believe that the government has different plans other than agriculture.

Table 4.39. Where the government can support.

	Frequency (Nos.)	%
Training	2	1.7
Provide seeds	3	2.5
Others	7	5.8
No answer	11	9.2
Sub-Total	**23**	**19.2**
Not Applicable	97	80.8
Total	**120**	**100**

4.4 CONCLUSIONS AND RECOMMENDATIONS:

On the basis of the questionnaire results the following conclusions are made:

1. Though the non-Bahrainis own a good percentage of farms in Bahrain, most farms are still owned by Bahrainis. As an observation during the survey, the non-Bahraini share of land property is expected to increase due to present trends of Bahraini economy (Table 4.2).
2. Current Bahraini farmers mostly inherited the farm from previous generations. The present farmers are old in age and work in farming for more than 20 years. The younger generation is not taking over farming from the older generation or even helping. Other professions are preferred for the young generation. In conclusion, the farming profession in the Kingdom of Bahrain is diminishing and it is expected in the coming decades that it will suffer badly, unless measures and strategies are set to revive it (Tables 4.3, 4.6, 4.8, 4.9 and 4.10).
3. The majority of the interviewed farmers are not willing to sell their farms, because they value the land and most of them live in the farm, itself. Furthermore, they are not willing to lease it to the government as it could be used for other purposes (Tables 4.5 and 4.19).
4. About half of interviewed farmers are willing to move from farming because of problems of low revenues compared to other professions, workforce shortage, and degradation of irrigation water quality and quantity (Tables 4.10 and 4.29).
5. Farmers in many instances raise livestock or take other jobs like pickup drivers besides farming to increase their income (Tables 4.9, 4.3 and 4.3).
6. Though groundwater resource is scarce in Bahrain, it is not in many occasions treated in a proper manner. Evidences of this include:

    (a) Farmers don't pay for irrigation water, modern irrigation systems are not used widely spread, farmers are still planting water consuming crops (vegetable and forage crops).

(b) Farmers are not fully aware of the causes of the high salinity of groundwater; some farmers are still using irrigation water for recreational purposes (swimming pools).

(c) Some farmers practice farming as a hobby or as a source of to increase their.

(d) The absence of government capacity training programmes that target the wise use of irrigation water in cash crops like flowers that require less water.

(e) Farmers do not practice modern agricultural methods such as the hydroponics that allows the reuse of water for more than 25 times to overcome the water scarcity problem, (Zubari, 2006).

7. There is a good opportunity for using treated wastewater instead of groundwater in irrigation. Farmers are willing to use treated wastewater, even without any governmental support in the form of subsidies.
8. Except for small size farms, farming is a profitable profession in the Kingdom of Bahrain.Young educated generation may prefer to work in other professions that might be more rewarding.
9. Farmers are aware of the groundwater problems in Bahrain, but the majority of them stated unrealistic reasons for the causes, this indicates that their answers might be polarized or biased, or their level of awareness is not high.

Therefore, the following recommendations could be stated:

1. From the perspective of interviewed farmers treated wastewater is a strong alternative for part of groundwater as a source of irrigation. The balance from groundwater could be diverted to municipal and industrial uses. This will enhance the opportunity cost of groundwater as a scarce resource, and turn over the governmental policy of meeting demand by more supply.
2. Because agriculture, as it seems from the questionnaire responses, is an extinct profession in Bahrain. The present governmental plans of distributing treated wastewater to farms need rethinking or revisiting.

Alternatively, the plans could be shifted to irrigate decorative trees in streets, public gardens, making greenbelts and the alike.

3. Because the cost of irrigation by groundwater is approaching the cost of desalinated water and due to the socio-economic impacts on farmers leaving the profession, are deemed negligible in the short term (old people who practice agriculture currently will be substituted by new generation), it will be no longer acceptable in the short run to use groundwater for the production of meat, milk etc or crops production. Imports will evidently substitute the local products with much lesser costs on the Bahraini economy. Products in Bahrain might be restricted to that which needs to be sold fresh.
4. Effective public awareness campaigns are needed for the utilization of treated wastewater. These campaigns should target the users of this water or the public at large.
5. It is highly recommended that a regional approach for the management of the transboundary groundwater aquifer system be in place amongst the GCC countries sharing such resources, a mechanism to carry out this work proposed to be structured in the following way:

   A steering committee composing of the national water authorities in the GCC countries, a coordination unit based on the GCC higher supreme headquarters and an adhoc scientific committee for scientific evaluation and orientation.
6. Realistically, it will be wise to redirect the utilization of water resources and in particular the TSE to serve the industry rather than the agriculture, which should be limited to beatification, landscaping and dates industries and in accordance with WHO limitations for the use of TSE.
7. Debatable Issues:

   A debate about the issue of the continuity of agriculture against developing the industry in the kingdom arose as a result of the regional move towards the industry of consumables and commodities in lieu of the investment in agricultural industry for many reasons that we have identified in the questioner and due to the current conditions around the region as:

- The unsuitability of soil to produce valuable crops that can increase the GNP share from its current (0.46%)
- About two third of the kingdom area is occupied by oil field
- The scarcity of water for irrigation, taking into account the WHO regulations and guidelines for the use of TSE for human consumption crops
- Being an oil producing country, like others around us, light industries related to oil such as petrochemical and others are more profitable and can reduce the alarming unemployment rate.
- The small industries can also contribute to the development of the economic situation, such as consumable.
- Food processing industries are also in need especially in white meats as we currently import most of it from neighboring countries.
- The kingdom has the trainable human resources that have proven successful in the industry rather in agriculture, ALBA is a good example.
- It would be wiser to exchange agriculture crops with light industry with agricultural based economies
- The globalization dictates that we should excel in the oil byproducts industries and to increase the GNP share in the services and banking sectors rather than the agriculture.
- A good practice would be to increase the plantation of date palms of good quality, starting a date industry, the soil and weather conditions are most suitable for date palms.

This debate is left now to the specialized authorities to expand and study carefully from its economical point of view to arrive into a practical paradigm that is executable.

APPENDIX – A

"QUESTIONNAIRE FOR EVALUATING FARMERS VIEWS ON AGRICULTURE IN BAHRAIN"



"QUESTIONNAIRE FOR EVALUATING FARMERS VIEWS ON AGRICULTURE IN BAHRAIN"

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أن الاستبانة اداناه هي مخصصة لملاك المزارع و المزارعين البحرينين في مملكة البحرين و الغرض منها اخذ المشورة و الاستفادة من وجهة نظركم بالامور المتعلقة بقطاع الزراعة مثل التحديات التي تواجهها الزراعة و كيفية الاستفادة من الفرص لصالحها أن هذه الاستبانة تشكل جزء من بحث ماجستير بجامعة البحرين و ان المعلومات المأخوذه ستظل سرية و ستستخدم للبحث العلمي فقط و ستستغرق بضع دقائق من وقتك وشكرا لتعاونكم لانجاح هذه الدراسة.

رقم الاستبيان:.....

رقم البئر:.....

رقم المزرعة:.....

1. موقع المزرعة..... مساحة المزرعة.....م2
2. مالك المزرعة بحريني غير بحريني
3. هل المزرعة موروثة؟ نعم لا
4. هل عائدات الزراعة كافية للعيش؟ نعم لا
5. هل مستعد للبيع؟ نعم لا
6. إذا كانت الإجابة لسؤال 5 بنعم, فما هو السبب في رأيك؟

.....

.....

7. ما هي مدة خدمتك في المهنة (الزراعة)؟..... سنة
8. هل تعمل عمل آخر بالإضافة لعمل المزرعة؟ نعم لا
9. هل يساعدك أبنائك في الزراعة؟ نعم لا
10. هل تملك بيك اب؟؟ نعم لا
11. إذا أعطيت عمل آخر هل تغير عمل الزراعة؟ نعم لا
12. هل تملك بيت؟ نعم لا

13. هل بيتك جديد ؟ نعم لا

14. إذا كانت الإجابة لسؤال 13 بنعم, فما هو عدد الحجر (الغر ف)؟..... غرفة

15. في أي منطقة تسكن في البحرين؟ .....

16. ما هي جنسيتك (لغير البحريني)؟ (اختياري) .....

17. ما هي مدة ملكيتك للمزرعة؟.....سنوات

18. ما هو مصدر ماء الري؟ مياه جوفية مياه مجاري معالجة

19.إذا كانت وسيلة الري هي المياه الجوفية, كم تدفع للمياه الجوفية؟

20. هل تؤجر مزرعتك للحكومة مقابل أن تبقى الأرض دون استخدام؟ نعم لا

21. إذا تم تزويدك بمياه المجاري المعالجة هل تستخدمها؟ نعم لا

22. إذا كانت الإجابة لسؤال 21 بلا, لماذا؟

.....

.....

23. إذا توقفت المياه الجوفية, هل ستستخدم مياه المجاري المعالجة كبديل لها للري؟ نعم لا

24. إذا كنت ستحصل على دعم لاستخدامك مياه المجاري المعالجة, هل تقبل؟ نعم لا

25. ما هي طريقة الري المستخدمة؟ حديثة قديمة

26. هل لاحظت طبقة ملحية بيضاء على سطح التربة عند جفافها؟ نعم لا

27. هل تعتقد الأرض متملحه (للمزارع) ؟ نعم لا

28. إذا كانت الإجابة لسؤال 27 بنعم, فكيف يتم معالجتها؟

.....

.....

29. ملاحظتك الشخصية : نعم لا

30. هل لديك علم بمشاكل المياه الجوفية في البحرين؟ نعم لا

31.إذا كانت الإجابة لسؤال 30 بنعم, أذكر منها؟

.....

.....

32. هل يوجد ماشية في المزرعة؟ نعم لا

33. كم رأس من الماشية في المزرعة؟

.....

34. هل توجد بركة للري في المزرعة؟ نعم لا

ا

ا35. هل توجد بركة للسباحة؟ نعم لا

36. حجم البركة (ط*ع*أ)؟و لمادا تستخدم؟

.....

.....

37. ما هي مشاكلك في الزراعة؟

.....

.....

38. ما هي أنوع المحاصيل التي عادة ما تزرعها؟

.....

.....

39. أين تبيع منتجات المزرعة؟

.....

40. ما هو دافعك للعمل في الزراعة؟

.....

.....

41. هل تقبل أن تغير المحاصيل المزروعة بمحاصيل أكثر عائد اقتصادي مثل الورود؟ نعم لا

42. إذا كانت الإجابة لسؤال 41 بنعم, ما هو المطلوب لتحولك إلى هذه الزراعات؟ تدريب , توفير البدور

شكرا مسبقا لتعاونكم ووقتكم الثمين

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الخلاصة

لقد كان المصدر المائي الوحيد في البحرين هو المياه الجوفية والذي مصدره عبر الحدود المشتركة مع شبة الجزيرة العربية, يصب جزيء منه في البحرين وبسبب كثرة الاستخراج لسنوات عدة تدهورت نوعية و كمية المياه إلى مراحل تنذر بالخطر ولقد كان السبب الرئيسي في كثرة ألاستخراج هو الزراعة والتي لازالت ليومنا هذا تستنفذ ثلثي المياه الجوفية المستخرجة ولم تألو الحكومة جهدا في تلك الأثناء بمحاولة الاستعاضة بالمياه المحلاة و لكنها اصطدمت بواقع ارتفاع تكلفة الإنتاج و بالزيادة في مستويات الاستهلاك و التي بلغت في عام 2002 حوالي 150% من المياه الجوفية المستخرجة. مما قد يؤدي على المدى البعيد لارتفاع التكلفة بمستويات لا تمكن الحكومة من تحملها, وقد بدا في القريب استخدام بديل للتقليل من استهلاك المياه الجوفية وهو مياه المجاري المعالجة التي قد يصل إنتاجها إلى 73 مليون متر مكعب حتى عام 2010 وقد أدى ارتفاع كلفة المياه المحلاة و مياه المجاري المعالجة إلى الضغط على المياه الجوفية و عموما فأن تحويل جزء من المياه الجوفية عن الزراعة قد ينتج عنه تعقيدات في مهنة الفلاحة و تأزم الوضع الاجتماعي للمزارعين.

إن البحث الذي بين يديك يناقش هذا البحث الإدارة المائية المتكاملة من ناحية استخدامات المياه للزراعة وقد استهدف تعريف التعقيدات الناتجة من التحول في استخدامات المياه للزراعة ومدى تأثيرها و الفرص المتوافرة لاستخدام البدائل المتاحة مثل المياه المحلاة و مياه المجاري المعالجة ولتحقيق هذا الغرض فقد تم تصميم و استخدام إستبانه تم ملئها بمقابلة 125 مزارع أو مالك ارض زراعية وجها لوجه و لقد تم اختيار المزارع بطريقة منظمة حسب الأعداد و حسب المناطق و باختيار عشوائي.

أظهرت النتائج بأن الجيل الشاب من المزارعين لا يفضل الاستمرار في هذه المهنة لانعدام الحافز و عدم وضوح المستقبل و بالعكس أظهر المزارعين الأكبر سنا تمسكا بها, وقد أبدى المزارعون استعدادهم لإحلال المياه الجوفية بمياه المجاري المعالجة كما أظهرت الدراسة بأن المزارعين لازالوا يستخدمون طرق الري التقليدية مثل الري بالتغمير و زراعة المحاصيل المستهلكة للماء مثل البرسيم و غيره, و بالخلاصة فإن الفرص متاحة لتحويل استخدام المياه الجوفية إلى استخدامات أخرى و بقليل من الضرر على المزارعين على المدى الطويل.

وبسبب تقاعس الجيل الجديد عن العمل في الزراعة و عدم الممانعة باستخدام المياه المعالجة للزراعة وبالاستفادة من هذه الفرص فأننا سنتمكن من ترشيد استخدام المياه الجوفية مما يحقق للمصادر المائية الاستدامة البيئية في المملكة.