Chemical and Biological Environmental Parameters of the Major Springs in Wadi Kufrinja Basin

By

Thair Muhammad Al-Momani

Supervisor

Prof. Dr. Muhammad Shatanawi

Co-Supervisor

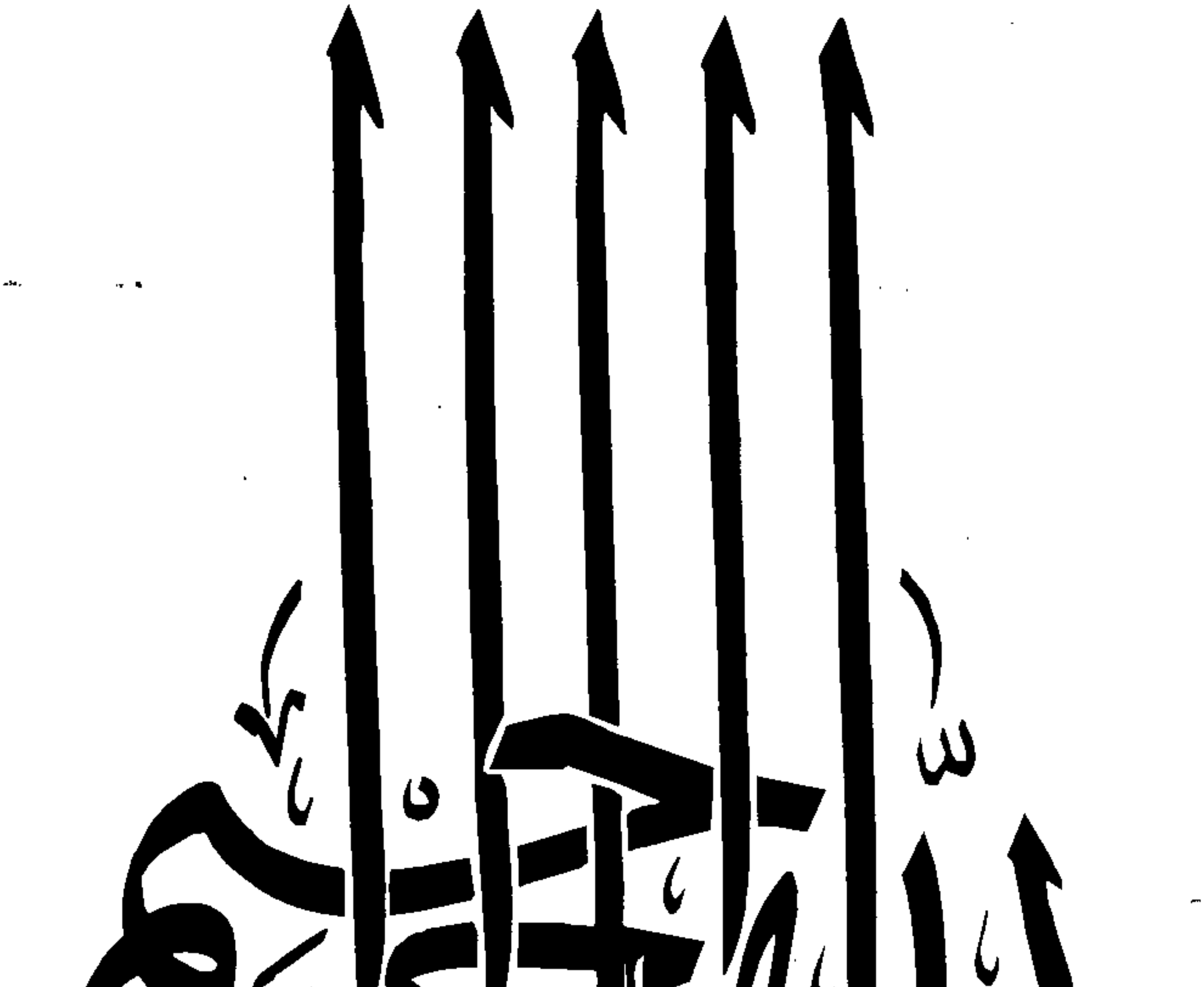
Dr. Omar Rimawi

عميد كلية الدراسات العليا

Submitted in Partial Fulfillment of the Requirments for the
Degree of Master of Science in
Environmental Science and Management

Faculty of Graduate Studies
University of Jordan

December 1997


بسم الله الرحمن الرحيم

This thesis was successfully defended and approved on 21 December 1997

Examination Committee | **Signature**

1. Dr. Muhammad Shatanawi

Prof. of Irrigation Engineering, Director of Water and Environmental Research and Study Center

2. Dr. Omar Rimawi

Associate Prof. of Hydrology, Faculty of Science

3. Dr. Manar Fayyad, Member

Prof. of Water Chemistry, Water and Environmental Research and Study Center

4. Dr. Radwan Al-Weshah, Member

Assistant Prof. of Hydrology and Water Resource Faculty of Engineering

5. Dr. Rakad Ayed Ta'any, Member

Head of Surface Water Department - Water Resources Studies Dept.-Ministry of Water and Irrigation

Dedication

TO MY GREAT MOTHER WHO SUPPORTS ME AND LIGHTS MY LIFE SINCE MY BIRTH TO THIS DATE

AND

TO MY GREAT FATHER AND MY SINCERE BROTHER AHMAD

Acknowledgement

My deepest and profound acknowledgements are to my supervisor Prof. Dr. Muhammad Shatnawi and co-supervisor Dr. Omar Rimawi for there continuous support, fruitful suggestions and constructive criticism during this work. There immeasurable help will never be forgotten.

I am deeply appreciate to the examining committee, prof. D. Manar Fayyad, Dr. Radwan Al-Weshah and Dr. Rakad Ta'any for their helpful suggestions and their valuable comments for this work.

Special thanks are attributed to the staff members of the Ministry of Water and Irrigation and Water Authority particularly the director and the staff of the Department of Water Resources Studies. In particular. Engineers Muhammad Al-Momani, Ali-Saad, Sameer Hawwamdeh, Geologist Ahmad al-Ziud, Esa Nsour, and My friend Jihad Al-Mahamid for their support during the preparation of this work.

Sincere thanks and appreciation go to the staff members and employees in the Water and Environmental Research & Study Center in the university of Jordan, specially Mr Awad Kayed. Many thanks are also attributed to all my friends including Abas&Loiey Al-Momani for their help, during this work.

My wormiest thanks to my parents, brothers, sisters also my uncle Khalid for their supports, encooragements and love through my life.

Thanks for all who helped me and are not mention in this acknowledgement.

Content

Subject	Page

Subject	Page

Chapter Three: Hydrology and Water Resources

Subject	Page

Chapter Four: Water Pollution and Environmental Issue Related to Water

Subject	Page

Chapter Five: Hydrochemistry

Subject	Page

List of Tables

Table		Page

Table	Page

Table	Page

List of Figures

Figure		Page

Figure		Page

Abstract

Chemical and Biological Environmental Parameters for the Major Springs in Wadi Kufrinja Basin

By

Thair Muhammad Al-Momani

Supervisor

Prof. Dr. Muhammad Shatanawi

Co-Supervisor

Dr. Omar Rimawi

The study area is located in the northwest of Jordan, with a distance about 75 km to the northwest of Amman . It extends between the Palestine Grid coordinates 207-226.75 E, and 184.9-196.5 N and cover an area of about 112.2 km^2. About 50000 inhabitants in the study area distributed in the upper part due to favorable condition of climatic condition, rainfall and availability of the springs water, which is the only source for water. This high population density leads to pollution of springs by cesspools and fertilizers used in agriculture.

The rocks of the upper cretaceous age (Cenomanian to Turanian), within Ajlun Group represents the main rock unit exposed in the study area.

The elevation of the study area changing rapidly from east to west towards the Jordan Valley, whereas, the altitude ranges between 1240 m (asl) in the eastern part to 220 m (bsl) in the Jordan valley. This area is dominated by the Red and Yellow Mediterranean soils.

The study shows that the average annual volume of rainfall is about 66.5 MCM and range between 43 MCM and 123 MCM. The calculated average volume of runoff is about 1.66 MCM which represent 2.5% from rainfall. The calculated actual evaporation is about 49.78 MCM, representing 74.7% of the average rainfall. The calculated direct recharge into the aquifer systems using the Water Budget Approach is about 15.3MCM /year which forms about 22.7% of the average annual rainfall.

There are about 25 springs in the study area of which 12 springs issue from Nau'r Aquifer system (A1/2), 13 springs issue from the Hummar Aquifer System (A4), and one spring issue from Wadi Sir Aquifer (A7). The total annual discharge of all springs is about 4.1 MCM.

In the study 46 water samples were collected in two periods, (September 1996, March 1997), in addition to 253 historical samples analyses from the archives of the Water Authority. All samples were subjected to hydrochemical analyses to evaluate the water quality. Different statistical methods have been used such as cluster analyses and factor analyses, project moment correlations expanded Durov and Piper diagram and other methods. The water was classified into one main group 0 according to Rimawi (1985) classifications. These groups were also subdivided into four subgroups that are group - 0a, group - 0b, group - 0c and group - 0d.

According to the majority of the chemical and physical analyses, the springs water was found to be good for drinking purposes except one spring due to the high concentration of NO3 which exceeds from the standards. Except the deep springs and these faraway from the building and population gathering, most of the samples were polluted with the coliform bacteria. The deterioration in water in the study area was mainly due to wide distribution of the cesspools and chemical fertilizer uses in the agriculture.

Chapter One

1- Introduction:

Limitation of water resources in Jordan is a national problem due to the steady increase in population as well as the increase in industrial and agricultural activities in the last few years. These has led to deterioration of water quality and pollution of water resources. Protection of the existing water resources from different pollution sources becomes a necessity for the country.

This study is about the water quality of the springs, which represent the only available water resource for Wadi Kufrinja basin. Wadi Kufrinja is located in the northern part of Jordan along the eastern high land of Ajlun, about 70km north of Amman. These springs are used for both domestic and irrigation purposes.

There has been an extension of urban areas and an increase in population in the upper basin and around the main springs. The wastewater from existing sewerage treatment plant and cesspools, as well as excess fertilizers used in agriculture, have conspired with the nature of the basin which has high permeable rocks and soil outcropping due to the fractured calcareous rocks and structure features to present a dangerous situation.

These issues have encouraged investigating the chemical and biological pollution and the water quality changes.

The sources of the chemical and biological pollution will be detected and evaluated. This will help the decision makers to plan the policies which will solve this problem and to protect this source of water from natural and human -made pollutants.

1-1 Location and Description of the Study Area

Wadi Kufrinja basin is located in northwest Jordan, along the mountainous high lands of Ajlun, with a distance of about 75km to the northwest of Amman city. It extends between the Palestine Grid coordinates 207-226.75 E, and 184.9-196.5N, and cover an area of about 112.2 square kilometer, Fig. (1.1). It is bounded by Wadi Yabis from the north, Wadi Rajib from the south, Wadi Zarqa River from east and Jordan River from the west. The area also includes small towns like, Ajlun, Ain-Jana, Anjara and Kufrinja and some small population groups. There are several wadies drains in the basin, the main wadi is Wadi Kufrinja and there are some wadies as tributary to this Wadi such as Wadi Muzeirib and Wadi El Haramiyyah. In the study area there are more than twenty five springs distributed in the basin. These springs are listed in Table (1.1), and most of them draining in Wadi Kufrinja. The topography of this basin is rather complex.

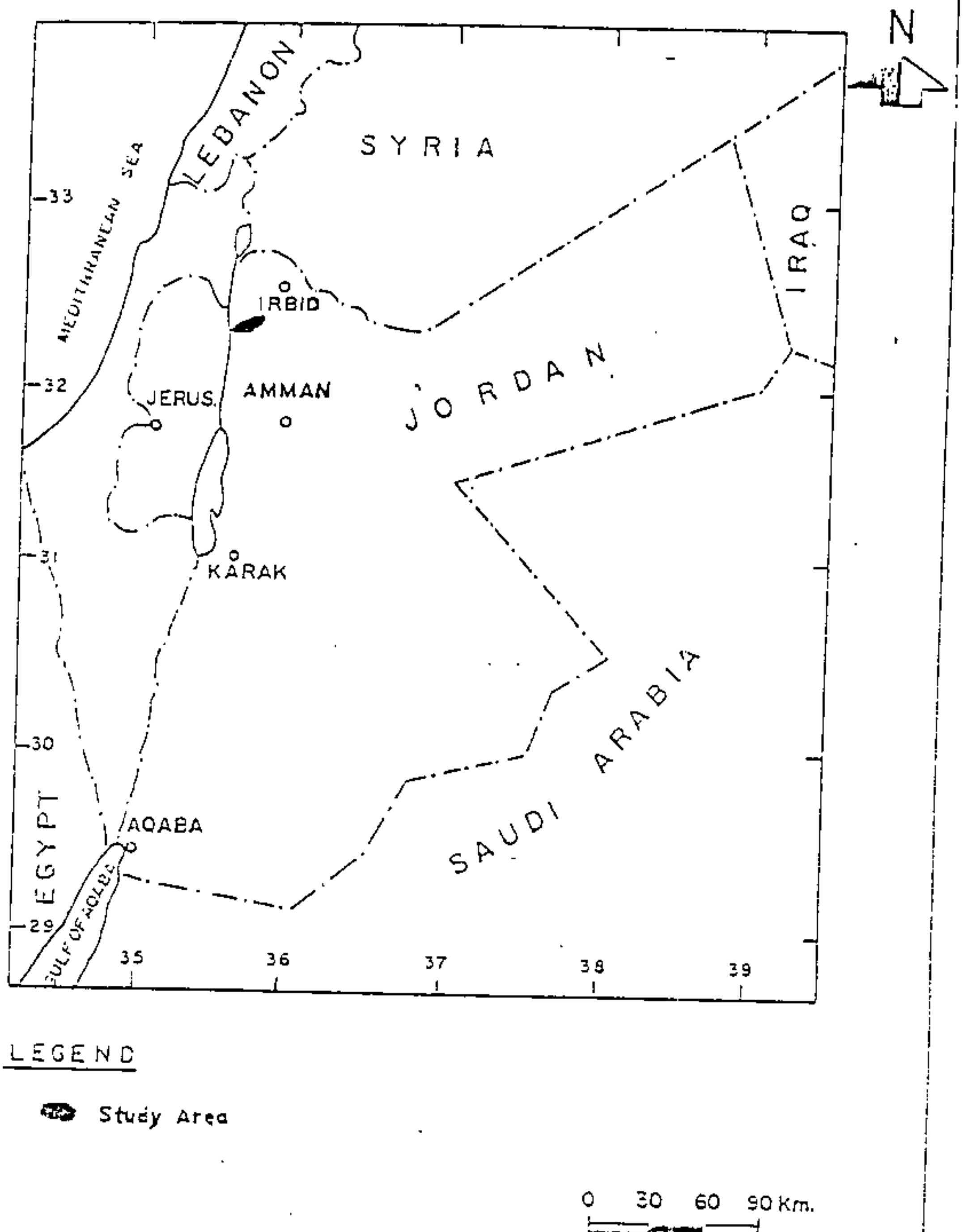


Fig.(1.1): The Location Map of the Study Area

It is changing rapidly from east to west towards the outlet of the basin and towards the wadi drains. Figure (1.2), illustrates the topographic map of Wadi Kufrinja basin. The altitude shows a sharp decrease from the eastern hills towards the Jordan Rift Valley in the west. The highest elevation in the basin is of 1240m (asl) located to the west of Souf town, where as the lowest point is-220m (bsl) located near the town of Kreimeh.

Table (1.1): Major Springs Located in the Wadi Kufrinja Basin

SPRING NAME	SPRING ID.NO	PG E	PG N	Altitude (m)	Aquifer Type
Et Teis	AJ0502	222	194.75	910	A4
El Harameyyah	AJ0504	221.5	194.1	890	A4
Barraneyyah	AJ0506	222.55	193.55	870	A4
Sharqeyyah	AJ0508	223	193.6	870	A4
El Fawwar	AJ0510	222.6	193.3	890	A4
Um Sarab	AJ0512	222.3	193.3	835	A4
El Balad(Ajlun)	AJ0516	220.9	193.4	771	A4
El Haddadeh	AJ0518	220.3	192.4	725	A1/2
El Qantara	AJ0520	220.1	192.1	680	A1/2
El Salous	AJ0524	222.7	190.95	880	A4
Abu Jabir	AJ0526	221.95	191.15	800	A4
El Balad(Anjara)	AJ0528	221.6	190.4	860	A4
Basset Khazaq	AJ0532	220.2	191.3	680	A4
Basset Afiya	AJ0534	220.2	191.9	675	A1/2
Qureiwah	AJ0536	219.9	191.8	675	A1/2
Basset Jatta	AJ0540	219.7	191.5	670	A1/2
El Bustan	AJ0544	218.4	190.8	675	A1/2
Basset Falah	AJ0546	218.2	190.9	640	A1/2
Deek	AJ0550	215.5	190.3	470	A1/2
El Balad(Kufrinja)	AJ0552	216.5	189.2	665	A4
Zaghadiyyah	AJ0558	215.25	190.7	495	A1/2
Um Hamdan	AJ0560	215.1	190.6	480	A1/2
El Aqdeh	AJ0564	215.1	187.9	680	A7/B2
El Birkeh	AJ0568	213	186.9	270	A1/2
Wadi El Haramiyyah	AJ0576	213.6	185.9	390	A4

WAJ,Open Files

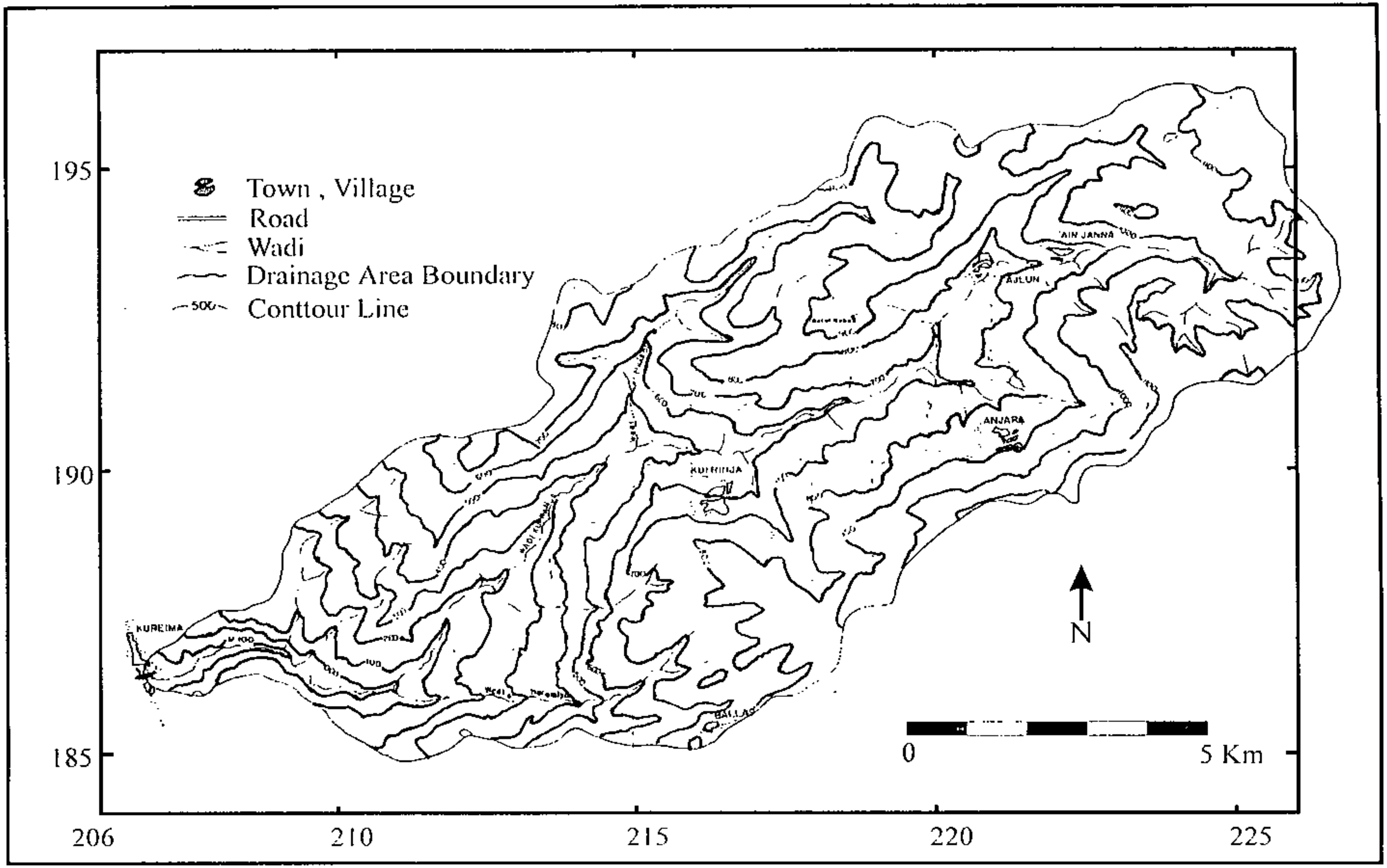


Fig (1.2) :Topographic Map of Wadi Kufrinja Basin

1-2 Literature Review

No detailed specified studies with similar objectives have been carried out on Wadi Kufrinja Basin. Although, the study area was investigated from different points of view for different purposes The following regional reports have been of great value in the course of this study.

MacDonald and Partner (1965) investigated the hydrology and water resources of the East Bank of Jordan in cooperation with Hunting Geological Surveys Limited. The study covered the southern, central and northern parts of the country. Wadi Kufrinja was part of their investigation. The study has put some recommendations for development of spring to be a source of water supply to the nearest towns and drilling exploratory or production wells in addition to conduction of small earth dams to conserve the surface water.

GTZ (1977), in cooperation with the natural resources Authority investigated the surface and ground water resources in Jordan and the study area was one part of the studied regions in the high lands.

EL-Naser (1987), evaluated the spring hydrographs in northern Jordan. He studied the main groundwater sources feeding springs using the semi-logarithmic plots of the flow-duration curves. It was observed that, the spring discharges increase during the winter months indicating the direct effects of precipitation on the recharge discharge patterns. |In addition to the calculation of the stored amounts of ground water, the aquifer characteristics and the water quality of the springs.

Water Authority of Jordan (WAJ) (1989) estimated the discharge of the springs in Wadi Kufrinja to be 4.01MCM /year from both the A4 and A1/2 aquifer systems.

Al-Zioud (1993), prepared a study about the surface water resources in Wadi Kufrinja catchment area. He studied the average annual volume of rainfall, the average runoff, the annual average infiltration rate, the calculated actual evaporation, and the hypsometric index of the basin. The spring water fit the standards for drinking purposes according to the World Health Organization and Jordan Standard. All springs for irrigation water are characterized by low sodium hazard and medium salinity hazard, except Ajlun and EL-Birkeh spring are classified as low sodium hazard and high salinity hazard.

Saad (1996), studied Rainfall-runoff relationships for urban, rural and desert sub-basin. He studied Wadi Kufrinja basin as a rural area, and calculated the average annual rainfall of the basin which ranged between less than 350 mm in the western lower areas to about 625 mm in the higher eastern areas of the basin. Also he calculated the mean total runoff volume of the basin to be 1.4 MCM and 5.8 MCM respectively.

1.3 Aim of the Study

This research were carried out to achieve the following objectives:

1. Evaluation of groundwater resources by investigating the different hydrologic parameters from the different aspects such as precipitation, evaporation, runoff and infiltration amount to illustrate the water budget.
2. Studying the hydrogeological situation of the different shallow aquifers, and different hydraulic characteristics of this aquifer.
3. Studying the water quality of the major springs of the study area of different seasons for chemical, physical and biological parameters.
4. Studying the long term temporal fluctuation of the chemical and physical parameters of the springs water in the study area.
5. Specification of the different pollutants and their possible sources.
6. Evaluation of the suitability of the water for both drinking and irrigation purposes.
7. Propose solution and alternatives for the protection of these resources from pollution.

1.4 Methodology

1.4.1 Field Work

46 representative water samples from 23 springs distributed in the study area and issue from different aquifers were collected in two time intervals; the first during September 1996 and the second during March 1997. Water samples were collected from each spring in two bottles; one for the biological testes (TC/FC) which sterilized by the autoclave, and the other for the chemical analysis. Prior to the collection, every bottle for the chemical analysis was rinsed with some water from the springs and filled completely. Some of the chemical and physical parameters were measured in the field by using protable equipment. These measurements are temperature, electrical conductivity and pH-value. These samples were then stored and kept cool until analyses were done and evaluated.

1.4.2 Laboratory Work

The laboratory work was totally done in the laboratories of the Water & Environmental Research and Study Center, of the University of Jordan. The analytical methods were performed according to the procedures mentioned in Standard Method for the Examination of Water and Wastewater (Greenberg, 1995) and manual of water analysis (Water & Environmental Research and Study Center,1990).

The interpretation of the data was carried out on personal computer using many programs for hydrochemical evaluation and statistical analysis such as (PC WATEQ (1988), GEO-500 (1986),GWW (1995)).

1.5 Vegetation

The type, density and diversity of vegetation is effected by many factors such as temperature, topography, rainfall, type of soil and human activities.

In the study area the rainfall, climatic region, temperature, and soil type in the upper part are differen from the lower part of the basin, and this causes huge diversity of the vegetation.

In the Wadi Kufrinja basin the following plant types are recognized Fig. (1.3) (Abu-Samur, 1984):

1. Pine Forest

This forest type covers the upper tributary of Wadi Ain Jana and some northern part of Ajlun town. It forms the best forest in Jordan and reaches a climax in some places (up to 10 meter such as ***Pinus halepensis***) and this is combined by low trees and shrub such as, ***Quercus Calliprinus, Pistacia Palestina, Cistus Salviaefoluis*** and ***Arbutus Andrachne***. These types grow up at heights over 900 m (asl).

2. Ever green Oak Forest

This forest types covers Ishtafina area, the northern and western part of Ajlun town, also it covers the eastern -west part of Wadi Kufrinja. The most dominant species in such forests is ***Quercus calliprinus*** combined by some shrubs such as ***Pistacia Palestina***, ***Crataegus azarolus and Anygdalus communis***. This forest is grown up on altitude over 700 m.

- The above mentioned two groups belong to Mediterranean region, which are characterized by (Abu Samur, 1984) (Al-Eisawi, 1995):

1)An annual rainfall exceedes 400 mm

2) A Terra Rosa soil (Red Mediterranean soil)

3) An altitude of over 700m.

3. Steppe Vegetation

This group belongs to the Irano - Turanian, and some time may be intruded with Mediterranean or Saharo-Arabian region. This group lies in the lower part of the basin toward the west in altitude ranging from 50-300 meter above sea level.

The vegetation is mainly of small shrub and bushes like those of ***Ziziphus lotus, Anabasis syriaca, Retama raetum.***

The region to which this group belongs is characterized by:

1- A mean annual rainfall between 200-400 mm.

2- The soil is Yellow Mediterranean with Rego soil.

3- The altitude is less than 400m above sea level

1.6 Soil :

The soil of Wadi Kufrinja is affected by environmental and human factors. The altitude from the see level is one of the most important factor that affect the distribution and the thickness of the soil, as well as other factors, such as the type of vegetation cover, percent of organic matter, and the dominant climatic condition of the basin, which is different in the lower part from the upper, in term of temperature, relative humility, wind speed and the amount of rainfall. The human impact is restricted in increasing the process of soil erosion as a result of continued cultivation. Due to these factors two types of soil were found in the study area these are:

1. Red Mediterranean Soils

This type of soil is dominant in the upper part of the basin and it is mixed with the lithosol (limestone) (Moorman 1959), even it doesn't cover more than 20% from the upper part of the basin. The continuous erosion of the soil and the steep slope for the basin which may reach 6%, as will as natural and human factors lead to increase these soils in the valley and depression which forms deeply developed Red Mediterranean soils.

This is characterized by poverty of horizon A by humus, the clay forms about 30%-50% which is formed as a result of limestone break down. It has a high permeability which allows the passage of rain to the groundwater and the dominant vegetation of this type of soil is Pinus and Oak forests.

2. Yellow Mediterranean Soil

This type of soil is dominant in the western part of the basin between the sea level and 400m above sea level (Abu Samur, 1984). This soil is different because of the climatic changes, since the amount of rainfall decreases towards the west, in addition to the vegetative cover changes. The Yellow Mediterranean Soils are transition between the Red Mediterranean Soils and the Yellow Soils which are situated in the Mediterranean arid zone with a rainfall from 250 to about 350 mm (Moorman, 1959).

This type of soil is characterized by low amount of organic matter, and as a result of these conditions, the soil is not suitable for agriculture, so they are considered as grazing areas. The dominant vegetation growing on that soil is mainly small shrubs and bushes such as ***Ziziphus lotus, Retama raetum.***

The lower part of Wadi Kufrinja near Kreimah town is covered by the complex soil of the Jordan Valley Fig. (1.4).

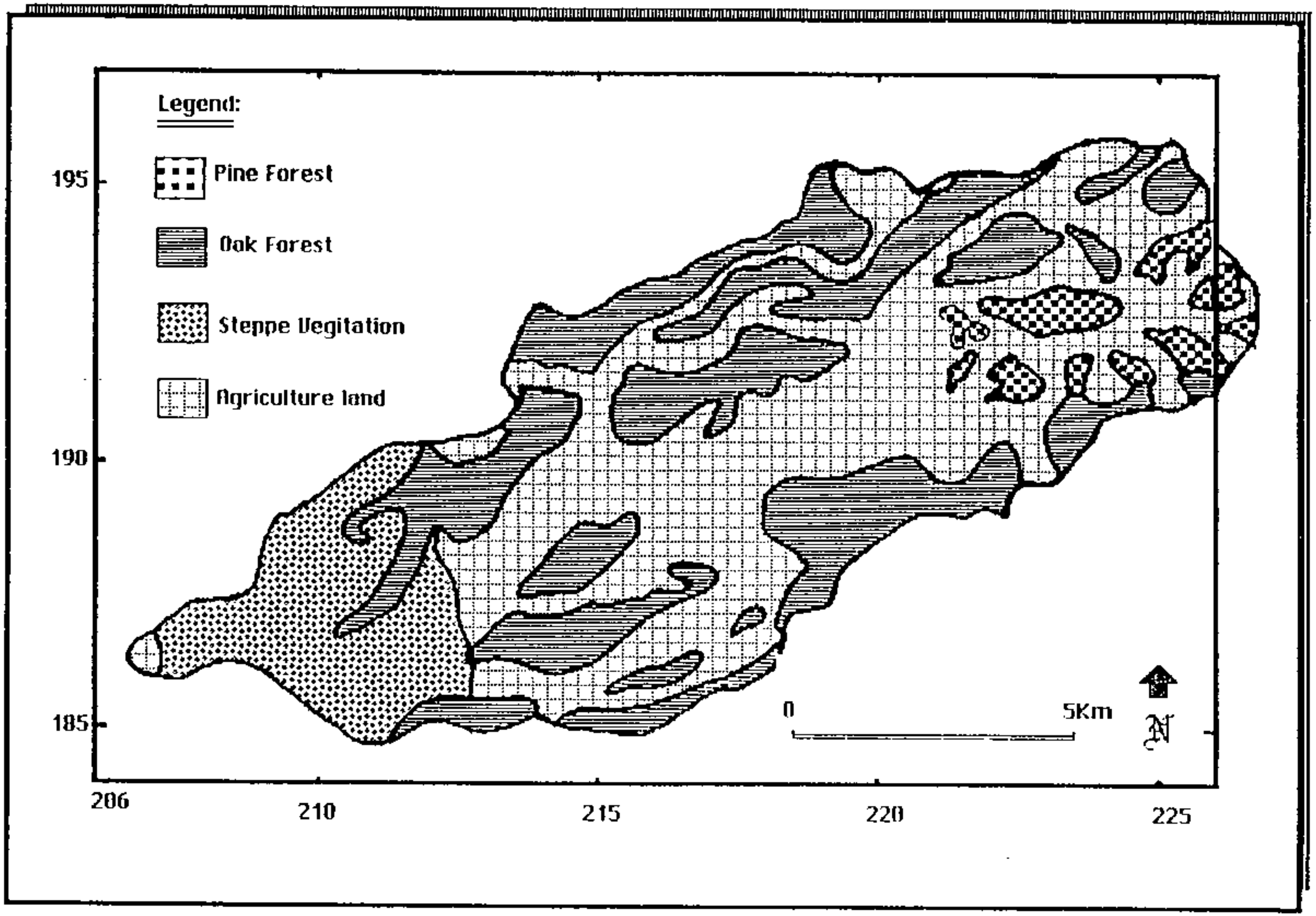


Fig.(1.3): Vegetation Distribution of Wadi Kufranja Basin (After Abu Samur, 1984)

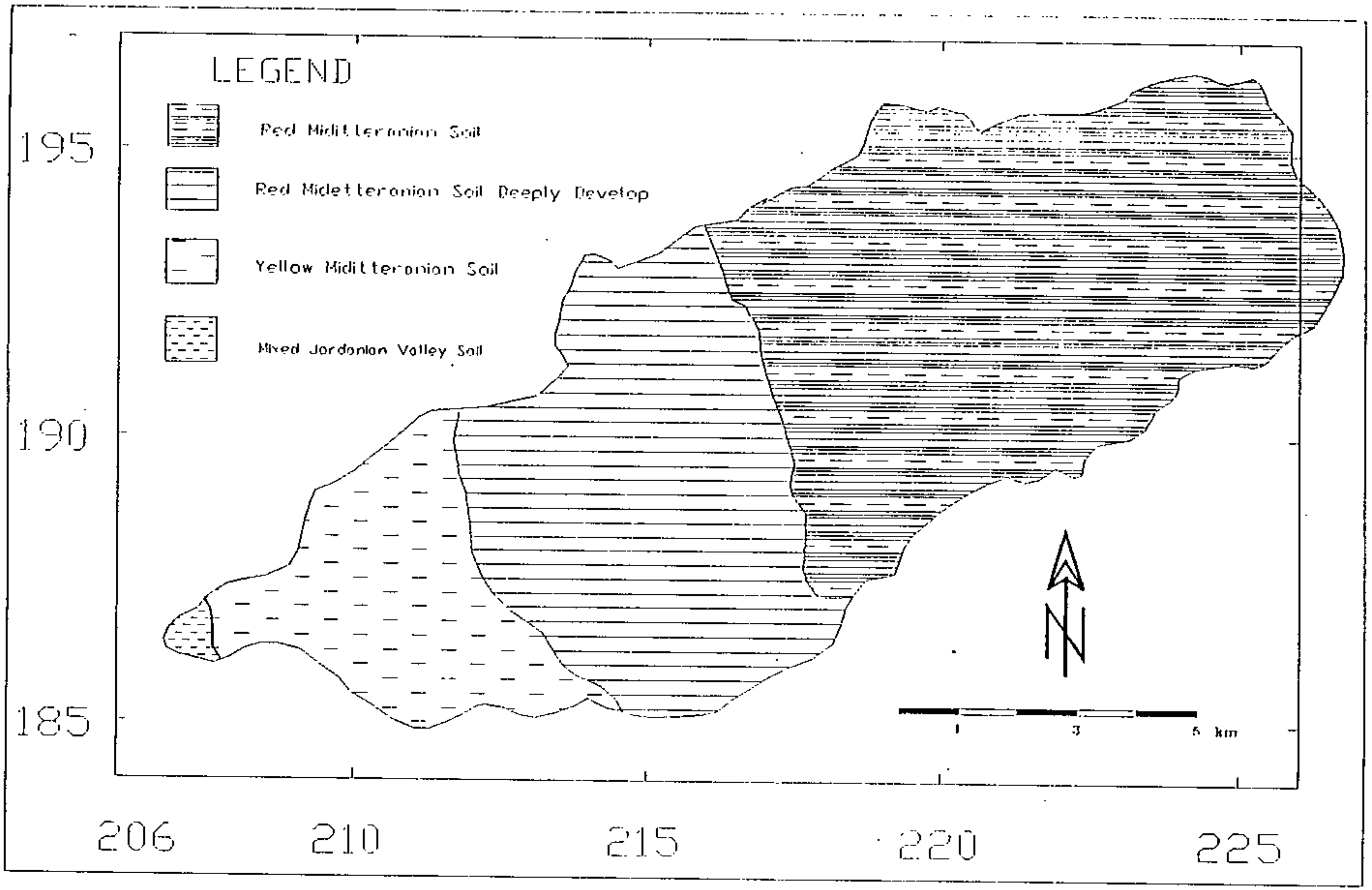


Fig.(1.4): The Type and Distribution of the Soil in Wadi Kufrinja Basin (National Atlas of Jordan, 1984)

Chapter two

Geology and Hydrogeology

2.1 Geology

2.1.1 Geological Setting.

The study area is covered by sedimentary rocks of Upper Cretaceous age. These sediments are composed of limestone, dolomitic limestone, marl, marly limestone and chert.

The geological map Fig. (2.1) shows the different rock units which crop out in the study area. Table (2.1) represents the nomenclatures of lithostratigraphic units used by many authors.

2.1.2 Stratigraphy

The Upper Cretaceous rocks are calcareous marine sediments which overlie disconformably the Kurnub Sandstone. The Upper Cretaceous sediments were divided by Quennell (1959) into two groups:-

The Ajlun Group (A) for the Lower part of Upper Cretaceous and the Balqa Group (B) for the Upper parts of the Upper Cretaceous.

Table (2.1) : Geological Succession and Aquifer Potentiality in Wadi Kufrinja Basin.

Era	Period	Epoch	Age	Quenul group (1951)	Masri (1963)	Bender unit (1974)	Thickness (Meter)	Brief description	Aquifer potentiality
Mecozoic	Cretaceous	Upper cretaceous	Campanian santonian	Balqa (B)	Amman (B2)	Phosphorite	—	Phosphorite chalk, silicified limestone & chert	Poor
			Coniasian		Wadi Gudran (B1)	Silicified limestone	20-25 M	Chalk & chalky marl	Poor
			Turonian	Ajlun (A)	Wadi sir (A7)	Massive limestone	70-90 M	Thinly bedded limestone , marly limestone with chert band	Fair-poor
			Cenomanian		Shueib (A5/A6)	Echinoidal limestone	65 M	Marly limestone & chalky marl	Poor
					Hummar (A4)		40-50 M	Dolomitic limestone	Good
					Fuheis (A3)	Nodular limestone	40-45 M	Marl, marly limestone & shale	Poor
					Naur (A1/A2)		120-160 M	Marl , limestone , dolomitic limestone & marlstone	Good

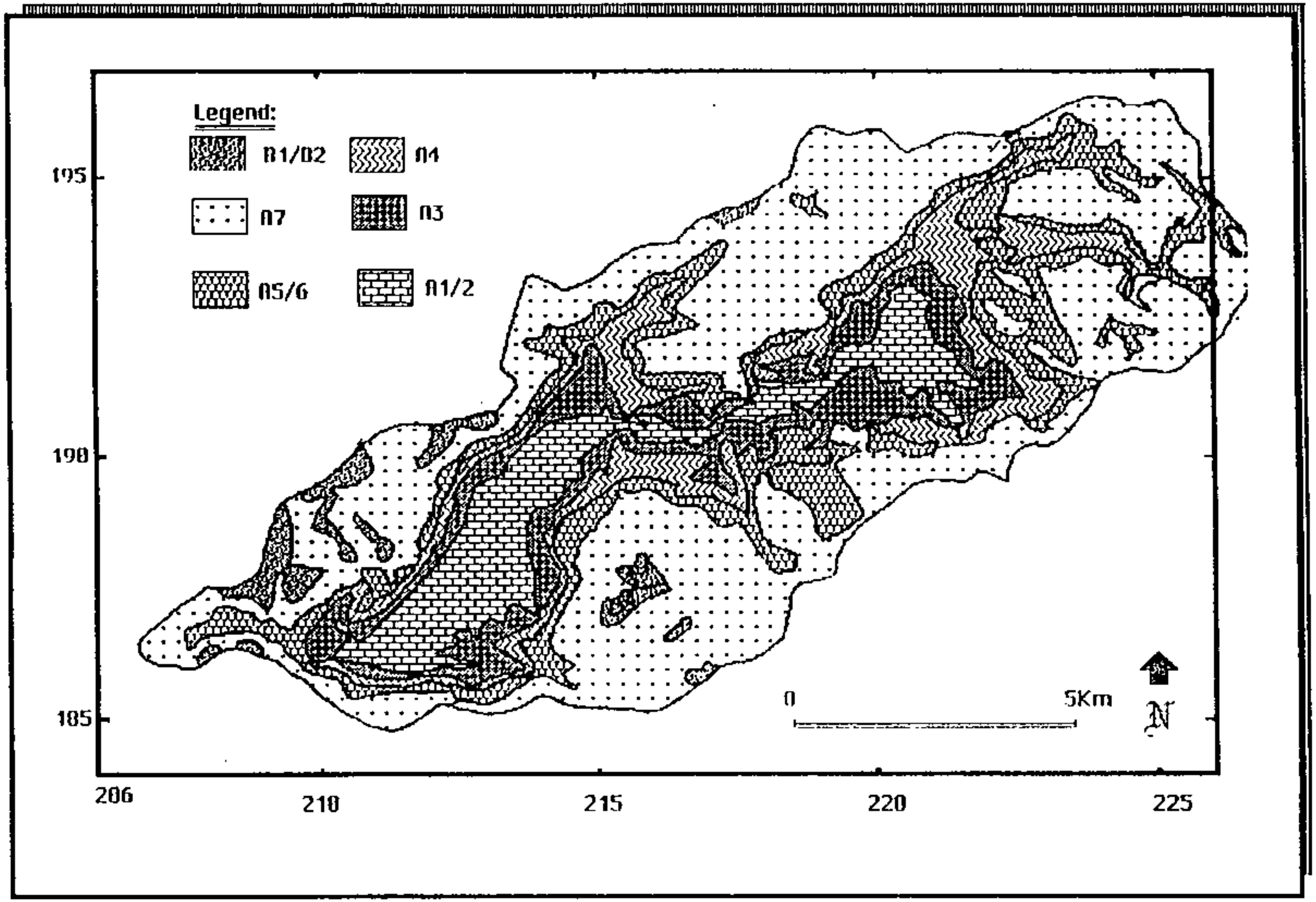


Fig.(2.1): Geological Map of the Study Area (After Mac Donald ,1965)

2.1.2.1 Ajlun Group :

This group includes all marine sediments of Cenomanian - Turonian age. It is represented by a sequence of carbonates overlying the Kurnub Sandstone and consists of alteration of limestone, dolomitic limestone, dolomite and marl. All Ajlun Groups have been distinguished over most of the study area. According to Masri (1963), the Ajlun group is divided into five lithilogical formations from bottom to top.

2.1.2.1 Nau'r Formation (A1/2)

This formation overlies the Kurnub Sandstone of the Early Cenomanian age (Mac Donald, 1965). This is equivalent to the lower part of Nodular Limestone Member. This formation consists of a sequence of grey limestone and dolomitic limestone with intercalation's of marl and shale in Wadi Kufrinja Basin.

This formation crops out in the lower parts of the basin and sometimes at the bed of the wadi. Nau'r Formation is considered as a good aquifer in the study area and has a thickness of 120-160m (Mac Donald, 1965)

2.1.2.1.2 Fuheis Formation (A3)

This formation is of Cenomanian age. It is composed of marl, interbedded with thin beds of limestone, with a thickness of about 40 meter in the basin (Momani, 1985).

Fuheis Formation forms the upper part of Nodular Limestone Unit. In the study area it is considered as an aquiclude forming the confining bed for the overlying Hummar Formation.

2.1.2.1.3 Hummar Formation (A4)

This formation consists of the alternating dolomite, dolomitic limestone and limestone of Upper Cenomanian age. The thickness of Hummar Formation in Wadi Kufrinja Basin is about 40-50 meter (Abdelhamid, 1995) and outcrops in different places and elevations in Kufrinja Basin. This formation is equivalent to the lower part of Echinoidal Limestone Member (Bender, 1974), and forms an important aquifer in the study area.

2.1.2.1.4 Shueib Formation (A5/6)

It is of Upper Cenomanian age, and consists of marly limestone and chalky marl. The thickness of this formation in the study area is about 65 meter where it is found - 2.5 km north of Ajlun (Abdelhamid, 1995) Shueib Formation is equivalent to the upper part of the Echinoidal Limestone Member (Bender, 1974) it is considered as an aquiclude, and it almost crops out in every part of the basin except small area in the north and middle part of the basin.

2.1.2.1.5 Wadi Sir Formation (A7)

This formation is of Turonian age, and is composed of massive limestone and marls with chert nodules.

It has high elevation in the study area mostly at more than 700m (asl) (Momani, 1985). Thickness of this formation is between 80-90 meters (Abed, 1981) and equivalent to the Massive Limestone Unit (Bender, 1974). Although this formation is a good to excellent aquifer in Jordan, it is considered as the recharge area to the lower aquifer except in the east middle part of the basin.

2.1.2.2 Balqa group :

Balqa Group overlies the Ajlun Group. The age of these rocks is ranging from Late Turonian to Early Oligocene, and it is dominantly composed of chalk, marls, cherts, silicified limestone and phosphates.

Masri (1963) subdivided this group into five formation (B1-B5), two of them occur in the study area at the higher elevation.

2.1.2.2.1 Ghudran Formation (B1)

This formation is underlain by Wadi-Sir Formation (A7) and is overlain by Amman Formation (B2) conformably of Santonian age and equivalent to the upper part of Massive Limestone Unit (Bender, 1974). It consists of sequence of chalk and chalky marl with sometimes beds of limestone. This formation is exposed at high elevations in the southern part of Wadi Kufrinja Basin, with a thickness of 10-20 meter (Momani 1995)

2.1.2.2.2 Amman Formation (B2)

This formation is of Campanian age, it consists of chert, limestone and phosphatic layers in the upper part. Amman Formation is equivalent to the Silicified Limestone and the Phosphorite Units (Bender, 1974). This formation is exposed at high elevations in the southern part of the basin. Hydrogeologically, this formations is exposed in the recharge area of lower aquifer.

2.2 Structure :

The structural features of Wadi - Kufrinja Basin are effected by the Jordan-Rift Valley. This represents the most conspicuous regional structure in Jordan, lead to depression of the west part of the basin associated with highly faulted and fracture, the Dome of Ajlun and the Anjara - Sakib Zone of anticline and syncline that lead to uplift the eastern part of the basin with extensive minor faults and fracture trend from SE to NW towards the graben (Abdelhamid, 1995). The disappearance of Balqa Group and clearing of broad valley depression in Ajlun area can be the result of this structural condition. Fig. (2.2) shows the structure of the Wadi Kufrinja Basin (Mac Donald, 1963).

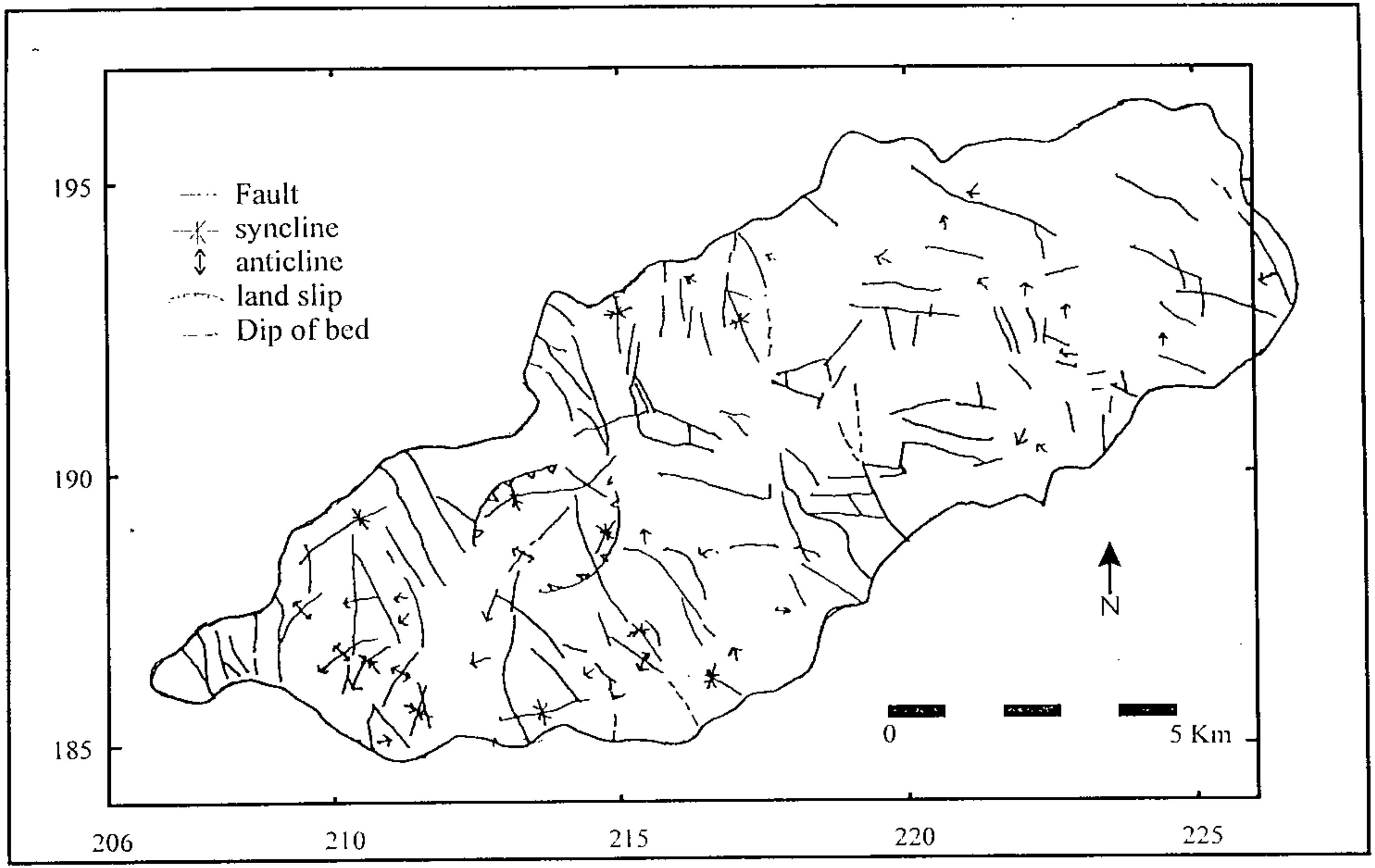


Fig (2.2) : Structural Map of the Study Area (After MacDonald 1965)

2.3 Hydrogeology:

2.3.1 General

In Wadi Kufrinja Basin the geological formations are hydrogeologically subdivided into lithostratigraphic units which form aquifers and aquiclude. An aquifer is a saturated bed, formation or group of formation which yield water in a sufficient quantity to be of consequence as a source of supply. Aquiclude is an impermeable formation which may contain water but is incapable of transmitting significant water quantities. Some aquifers, called unconfined aquifers, is one in which groundwater possesses a presure which is equal to the atmospheric presure. Other aquifers are termed artesian or confined aquifers occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata (Walton, 1991).

In the study area the hydrogeology is affected by geological structure (minor fault, fracture) related to the Jordan Valley Depression. This depression has increased the permeability and secondary porosity of the aquifers (Mac Donald, 1965)

The most important aquifers exposed in the study area are those of Upper Cretaceous age, consisting mainly of limestone and dolomitic limestone. Most of groundwater in the area is extracted by the springs in three aquifer systems, A4, A1/2 and A7 Formations and used for domestic and irrigation purposes.

The movement of the groundwater in the area towards the surface drain which is discharging to the Jordan valley, (WAJ, 1989).

2.3.2 Aquifer System.

The Upper Cretaceous rocks (Cenomanian to Turonian) within Ajlun Group represent the main aquifers in the study area. The Ajlun Group consists of alternating sequence of limestone, dolomitic limestone marl, marly limestone and chalky marl. In Wadi Kufrinja Basin, the Nau'r (A1-2) Hummar (A4), and Wadi - Sir (A7) Formations of Ajlun Group forms the main aquifers. The other formations of Ajlun Group Fuheis (A3) and Shueib (A5-6) are considered as aquiclude.

2.3.2.1 Nau'r Aquifer System.

This aquifer consists mainly of limestone and dolomitic limestone interbedded with marl and marly limestone. Two subunits are recognized within this aquifer, the lower part (A1) which consists of marls and the upper part (A2) consists of thick limestone layer. In this basin the limestone

/marl ratio of A1/2 formation increases forming a good aquifer (Mac Donald, 1965). It crops in the bed of Wadi Kufrinja and the lower part of the basin, of a total thickness ranging between 120-160m (Mac Donald, 1965). The hydraulic conductivity of the aquifer system is determined to be in the range of 0.002 to 2.7 m/day, with a specific capacity ranging between 0.24-288 m^3/day/m, and a transmissibility between 0.3-100 m^2/day.

2.3.2.2 Hummar Aquifer System.

The Hummar aquifer comprises a karstified limestone and dolomitic limestone with an average thickness of about 45m. The A4 aquifer is highly fractured and cavernous, sometimes it is interbedded with marl and marly limestone. It crops out in different places and elevation in the basin. The hydraulic conductivity of the Hummer aquifer is determined to be in the range of 0.076 to 65.1 m/day, with a specific capacity ranging between 0.24-1752 m^3/day/m and the transmissibility ranges between 3 to 315 m^2/day (Salem, 1984).

In general the Hummar and Nau'r Aquifer System is characterized by high permeability and highest infiltration rates, due to the minor faults and fractures related to the Jordan Valley Desperation and Ajlun Dome.

The two aquifer systems are the source of all water springs in the basin except one spring emerging from Wadi El - Sir (A7) Aquifer System (Table 1.1).

2.3.2.3 Wadi Sir Aquifer System.

This formation overlies the Shueib Formation. It consists of fractured limestone and dolomitic limestone. It is considered to be one of the most important groundwater aquifers in Jordan, but in the study area only one spring issues from the (A7) Formation because, the A7 is exposed in the higher elevation of the basin mostly more than 800m (asl) (Momani, 1985). Wadi Sir and Amman Formations in the study area are located above the saturated zone, and considered as the recharge area of the lower aquifers.

The thickness of this layer between 90 and 100 meter, (Abed, 1981). In general, the transmissibility of the A7 Aquifer System ranges between 0.160 to 100.000 m^2/day, the specific capacity ranges between0.24 to 600 m^3/day/m, and the hydraulic conductivity between 0.003 to 2808 m/day (Salem, 1984)

Chapter Three

Hydrology and Water Resources.

3.1 Hydrological Setting

Hydrology is an earth's science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their environmental relationships (Vissman et al, 1977).

The precipitation, storage, runoff and evaporation of the earth's water follow an unending sequence known as the hydrologic cycle. The hydrological network of the study area consists of 5 rainfall stations, two of them are located within the boundary of the basin, while three are located out of the basin, one station of runoff and two evaporation station out of the basin.

The coordinates and altitude of these stations are presented in (Table 3.1).

Table (3.1): Hydrometeorological Network of Wadi Kufrinja Basin

Station Name	PGE	PGN	Altitude (m)	Type of Station	Type of Recording
Ajlun	221	193.5	760	Rainfall	Daily&monthly
Kufrinja	216.4	189.4	640	Rainfall	Daily&monthly
Ibbin	226.8	196.5	1105	Rainfall	Daily
Ishtafina	220.4	196.5	920	Rainfall	Daily
Wahadneh	210.8	192.8	590	Rainfall	Daily
Wadi Kufrinja	206.8	186	-200	Runoff	Stream flow
Ras Munif	226.8	198.8	1150	Evaporation	Daily&Evaporation
Deir Alla	208.5	178	-224	Evaporation	Daily&Evaporation

3.2 Climate.

Wadi Kufrinja Basin belongs to the semi-arid Mediterranean climate. It is characterized by cold-wet weather in winter and hot dry weather in summer. According to Koppen classification, the study area is divided into three climatic regions. The upper part of the basin is located in the cool temperate rainy Mediterranean climatic region (Csb), the middle part in the warm temperate rainy Mediterranean climatic region (Csa), and the lower part to the warm steppe climate (Bsh) Fig. (3.1). In addition to that, Fig. (3.2) shows the agricultural regions in the study area according to rainfall. (National Atlas of Jordan, 1984).

Temperature is highly affected by the altitude and topography. It increases toward western part, while it decreases towards the eastern parts. January and August in the study area are the coldest and the hottest months, respectively. The long term average of temperature in the study area ranges between 14.15 ^{O}C in Ras-Munif Station which represents the upper part of the basin and 23.54 ^{O}C in the Deir Alla station which represents the lower part of the basin.

The relative humidity reaches its highest value during January, and it reaches its lowest value in May. The average annual relative humidity is

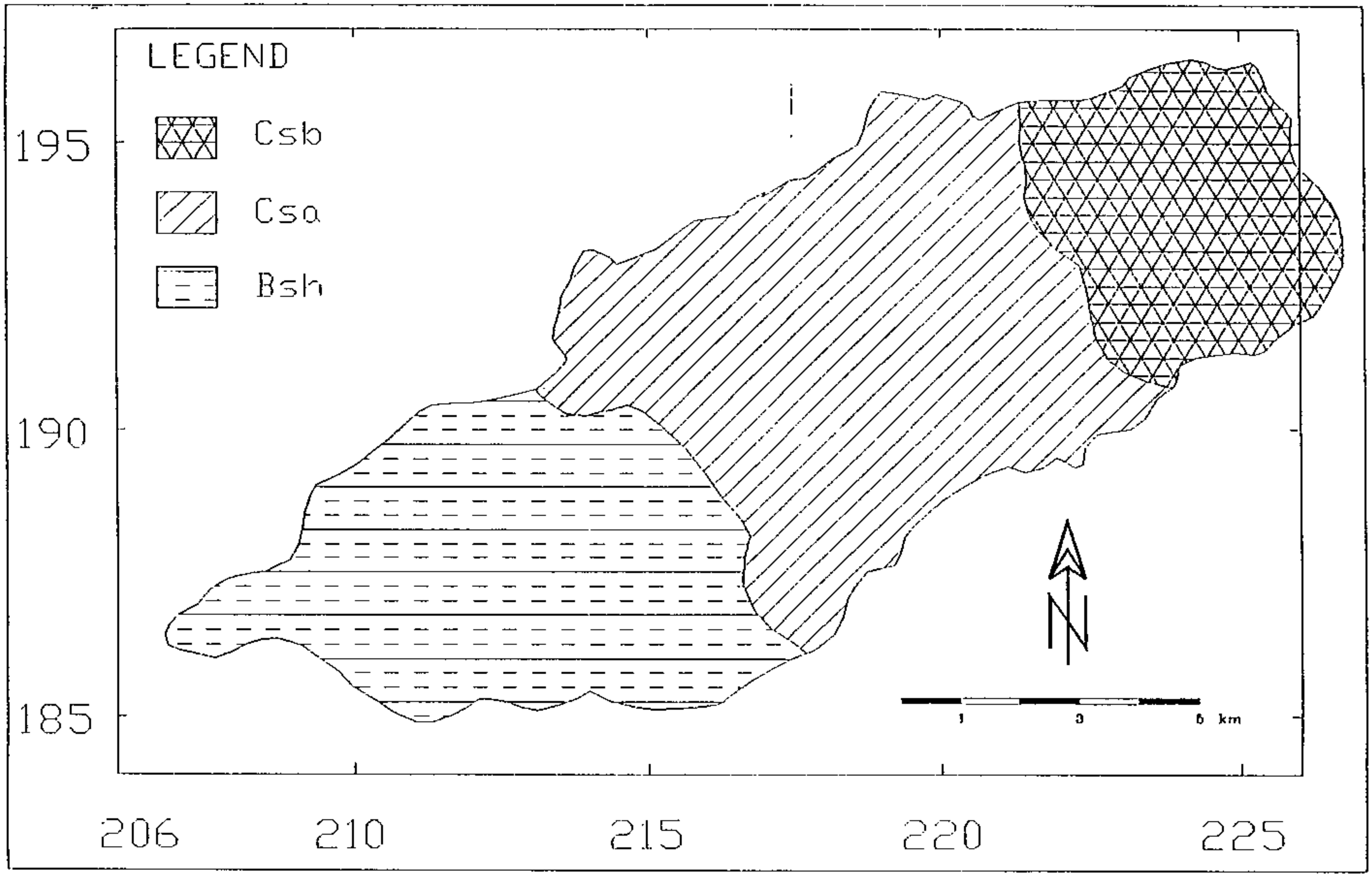


Fig.(3.1): The Climatic Region of Wadi Kufrinja According to Koppen (National Atlas of Jordan, 1984)

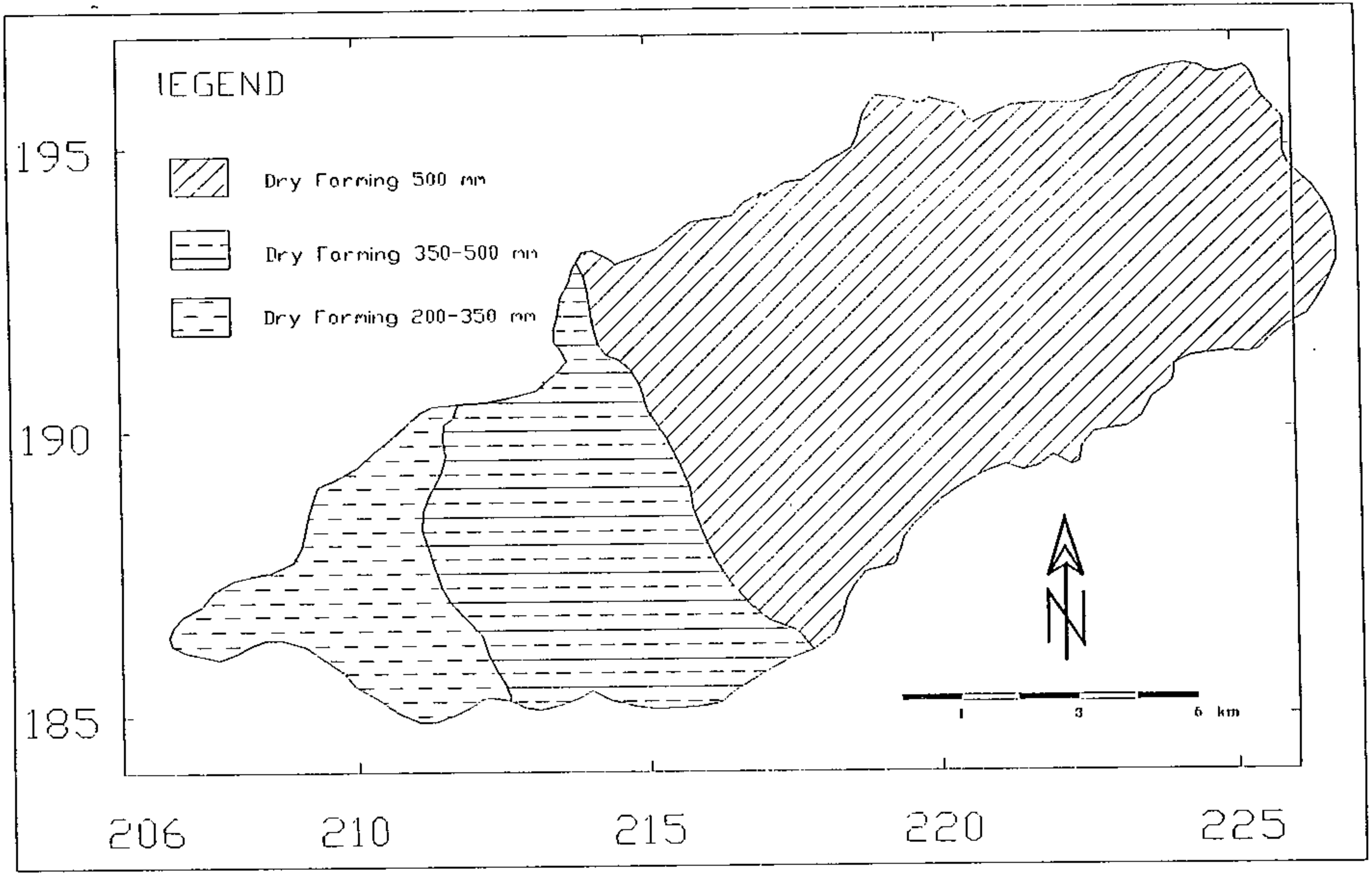


Fig.(3.2): Agricultural Regions of Wadi Kufrinja (National Atlas of Jordan, 1984)

64% for the upper part and 51% for the lower part of the basin, and the prevailing wind direction is west.

The climatological parameters of the study area for long period of time are summarized in Table (3.2).

Table (3.2): Climatological Parameters of Ras Munif & Deir Alla Stations

Parameter	Ras Munif	Deir Alla
Average Annual Temp °C	14.15	23.54
Average Annual Min Temp °C	10.1	17.42
Average Annual Max Temp °C	18.23	29.74
Average Annual Relative Humidity (%)	64	51
Average Annual Evap (Class A Pan)(mm/d)	5.9	6.24
Mean Annual Sunshine Hours	8.5	9.1
Mean Annual Rainfall (mm)	640	345

3.3 Precipitation

Precipitation is the discharge of water out of the atmosphere. It includes rain, snow, hail and sleet. It is the source of all water flowing in streams and in storage above and below ground (Hammar,1981). Two main factors are necessary in order for precipitation to occur. First a body of moist air, and second a means of lifting this body of air sufficiently for condensation and then precipitation to take place (Ward, 1967). Rainfall is considered the most importance element in the hydrological cycle, and as a source of water in the water budget.

The amount and distribution of rainfall in the study area is of special important in the appraisal of groundwater resources because the infiltration of precipitation is the main source of groundwater recharge. The rainfall occurs in winter months, October to early May, while the summer months, June to September are completely dry.

3.3.1 Precipitation - Gauging Network

The number of rainfall gauges necessary to determine the depth of precipitation on an area depends on size of the area, prevailing storm type, form of precipitation, topography and season. Prevailing storms are cyclonic (generally rainfall of low intensities over large areas), rather sparse network may be adequate. A more dense network will be required where storms are predominantly convective and are characterized by thunderstorms with high intensities and in uneven distribution (Taa'ny, 1986).

There are five rainfall gauging stations in the study area (Table 3.1), two stations, Ajlun and Kufrinja are located in the study area. Three stations, Ibbin, Ishtafina and Wahadneh are located out of the basin.

There are two types of rainfall gauges which are used in the study area to measure the rainfall. These are, the recording gauge and non - recording (daily rainfall) gauge. Two recording gauges and three daily gauges existed in the study area.

3.3.2-Determining the Mean Precipitation of the Study Area.

For most hydrologic analysis, it is important to know the areal distribution of precipitation. This can be calculated by different methods such as Arithmetic, Isohyetal and Thiessen methods.

The measured annual rainfall for the period of 31 years (64/65-94/95), of the stations located in the study area are presented in Table (3.3).

The most direct approach is to use the arithmetic average of gauged quantities. This procedure is satisfactory if gauges are uniformly distributed and the topography is flat. For the non uniform distribution of gauges, the mean annual rainfall over the study area were calculated by Isohyetal and Thiessen methods.

The Thiessen method subdivided the basin into polygonal sub areas using rain gauges . The sub areas are used as weights in estimating the watershed average depth. Isohyetal method is the most accurate method of averaging rainfall over an area. The first step is to plot the rain gauge locations on asuitable map and to record the rainfall amounts. Next, an interpolation between gauges is performed and rainfall amount at selected

Table (3.3): Annual Rainfall (mm) of the Rainfall Stations for the Period 1964/1965-1994/1995

WaterYear	Rainfall Station				
	Ishtafina	Wahadneh	Ibbin	Ajlun	Kufrinja
1964/1965	684	437	609	754	671
1965/1966	490	391	456	487	446
1966/1967	859	659	826	1024	884
1967/1968	473	326	479	579	515
1968/1969	614	431	762	925	722
1969/1970	794	341	750	641	511
1970/1971	720	404	598	710	635
1971/1972	609	471	553	606	635
1972/1973	306	220	302	292	343
1973/1974	727	554	605	722	751
1974/1975	513	394	446	427	514
1975/1976	510	435	439	521	507
1976/1977	548	393	425	541	545
1977/1978	559	266	405	465	426
1978/1979	359	278	270	382	367
1979/1980	937	663	818	863	919
1980/1981	528	410	288	581	654
1981/1982	471	139	422	533	532
1982/1983	599	535	726	807	781
1983/1984	445	278	447	496	490
1984/1985	517	287	570	631	558
1985/1986	461	338	400	475	546
1986/1987	754	454	561	776	715
1987/1988	635	416	454	750	699
1988/1989	471	342	554	572	552
1989/1990	488	424	553	620	525
1990/1991	474	358	494	547	570
1991/1992	1103	937	1166	1125	1136
1992/1993	684	452	614	682	703
1993/1994	457	288	485	483	410
1994/1995	582	412	620	663	608
Average	593	411	552	635	609

WAJ, Open files

increments are plotted . Identical depths from each interpolation are then connected to form isohytes. The areal average is the weighted average of depths between Isohyetal, that is the mean value between the Isohytes (Viessman et, al, 1977).

In the present study the two methods were applied, the annual volume of rainfall in the study area is 65.27 MCM and 64.45 MCM according to Thiessen polygons and Isohyetal method, respectively. The results of Thiessen technique are summarized in Table (3.4), and the area is represented by each station is shown in Fig. (3.3), and Table (3.5). Table (3.6) shows the rainfall volumes from rainfall Isohyetal map Fig. (3.5).

From the calculations of Thiessen polygons method the dry, normal and wet water years were selected. Then the values were plotted on a base map and the Isohyetal maps were drawn for the selected water years.

The water year 1991/1992 was selected as a wet water year,1994/1995 as a normal year and 1972/1973 as a dry water year Fig. (3.4,3.5,3.6). Fig. (3.7) represents the histogram of the mean monthly rainfall for each station in the study area.

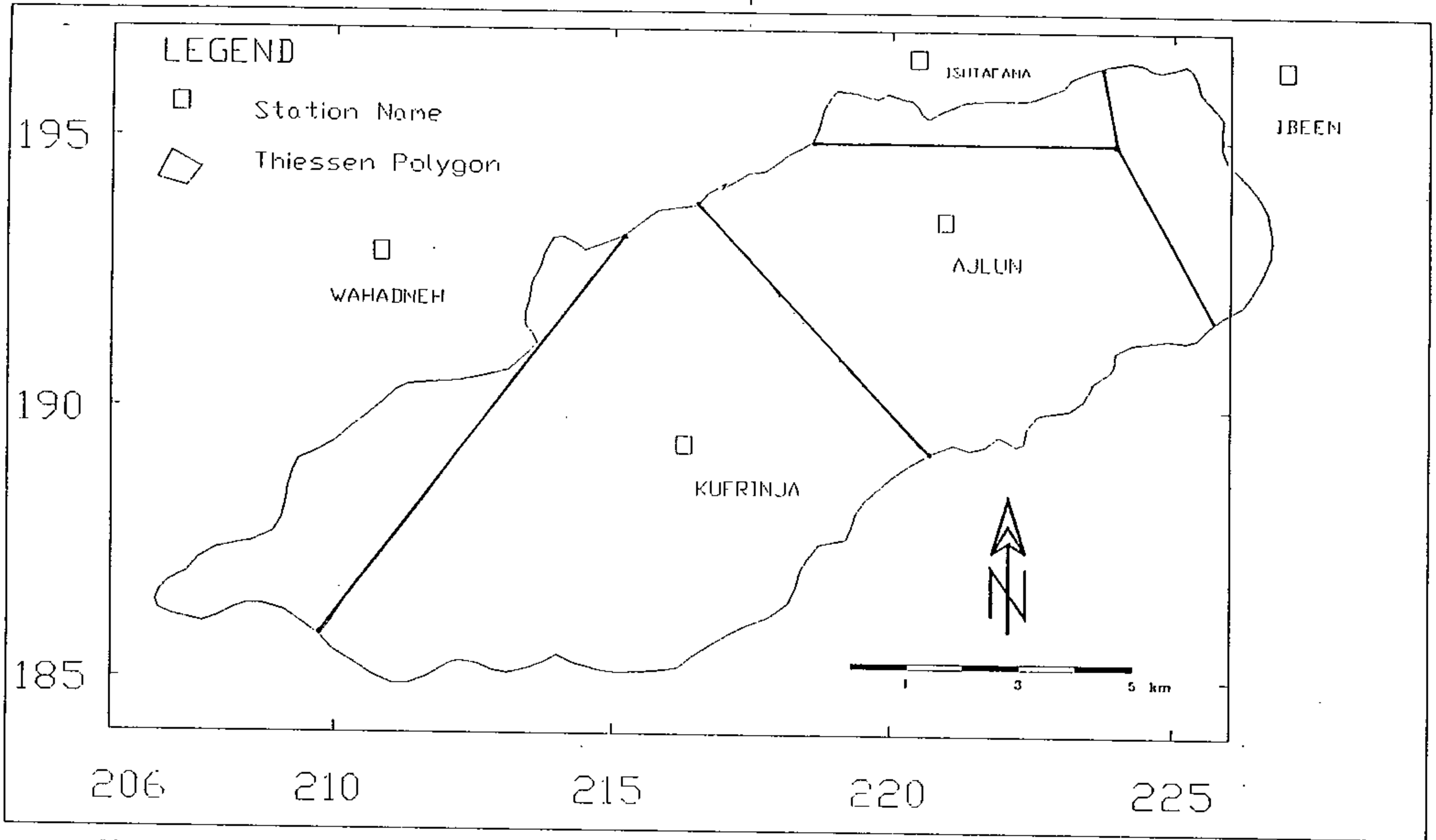


Fig.(3.3): Thiessen Polygons for the Study Area

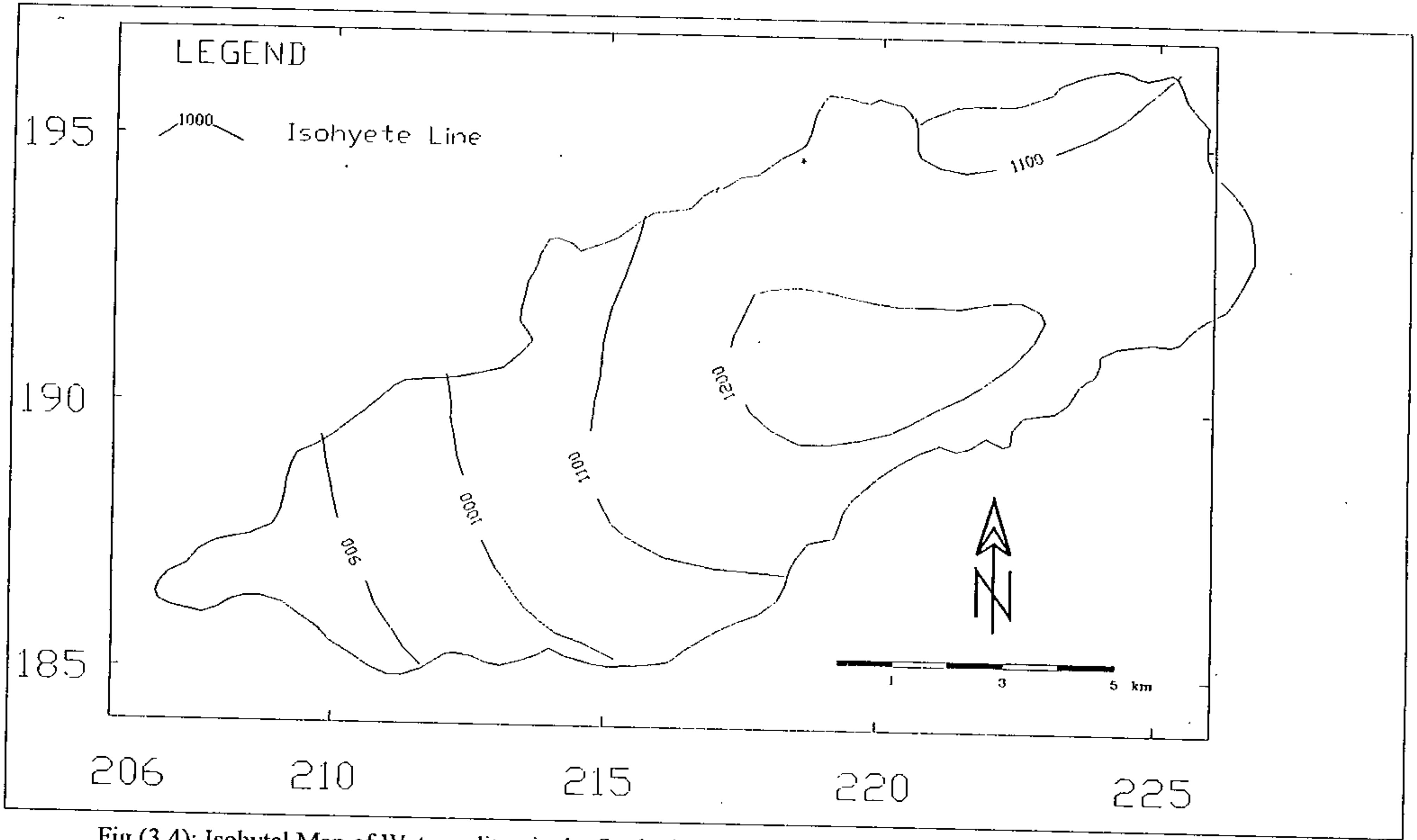


Fig.(3.4): Isohytal Map of Wet conditon in the Study Area

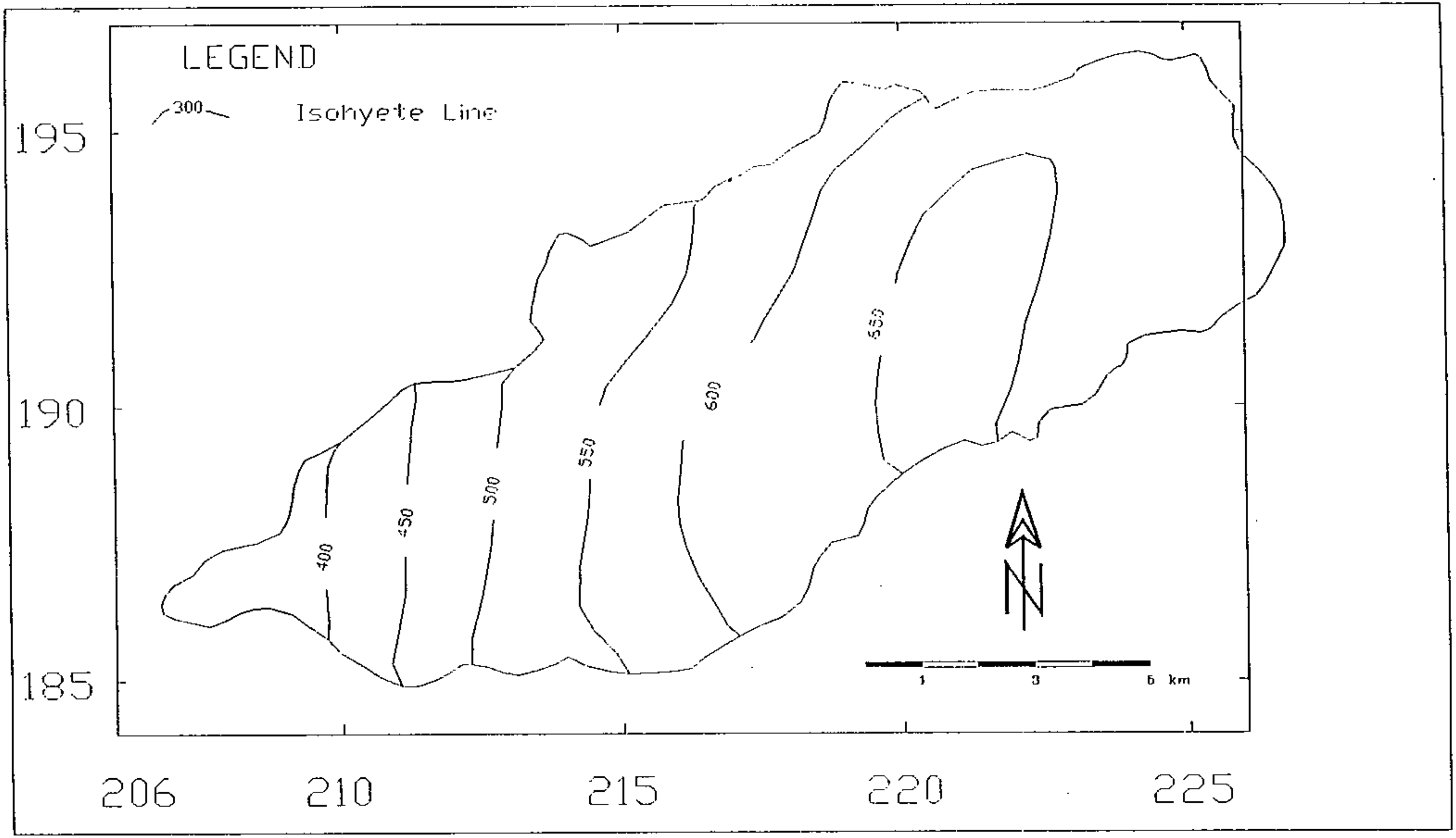


Fig.(3.5): Isohytal Map of Normal conditon in the Study Area

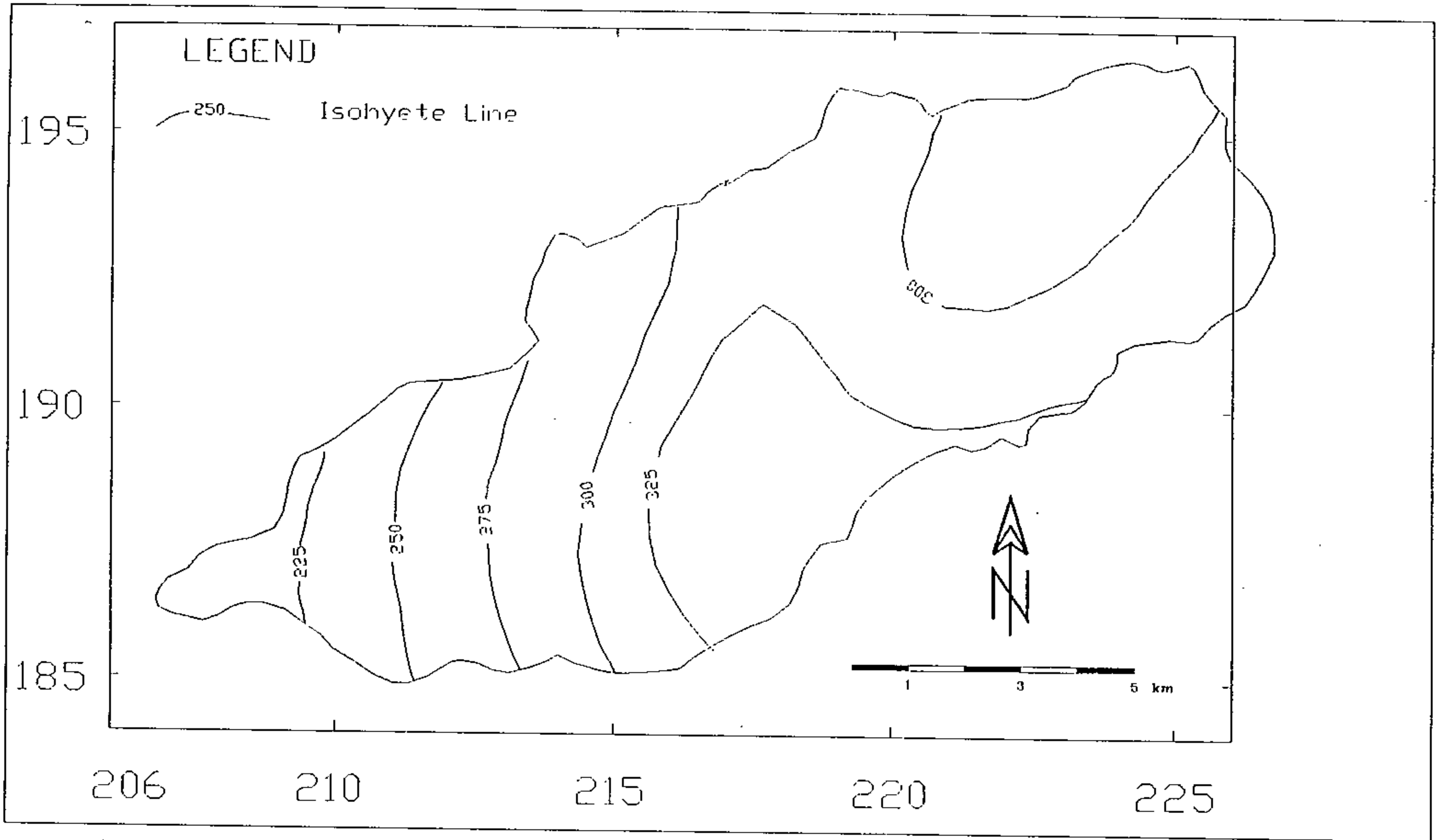


Fig.(3.6): Isohytal Map of Dry conditon in the Study Arca

Table (3.4): The Average Annual Rainfall over the Study Area Using Thiessen Polygons

Water Year	Weighted Rainfall (mm)					Weight Average	
	Ishtafeina	Wahadneh	Ibbin	Ajlun	Kufrinja	mm	MCM
1964/1965	31.70	67.77	40.71	220.42	294.83	655.43	73.54
1965/1966	22.71	60.64	30.48	142.37	195.97	452.16	50.73
1966/1967	39.81	102.20	55.21	299.35	388.42	885.00	99.30
1967/1968	21.92	50.56	32.02	169.26	226.29	500.05	56.11
1968/1969	28.46	66.84	50.94	270.41	317.24	733.88	82.34
1969/1970	36.80	52.88	50.13	187.39	224.53	551.73	61.90
1970/1971	33.37	62.65	39.97	207.56	279.02	622.57	69.85
1971/1972	28.22	73.04	36.97	177.16	279.02	594.40	66.69
1972/1973	14.18	34.12	20.19	85.36	150.71	304.56	34.17
1973/1974	33.69	85.91	40.44	211.07	329.98	701.10	78.66
1974/1975	23.78	61.10	29.81	124.83	225.85	465.37	52.21
1975/1976	23.64	67.46	29.34	152.31	222.77	495.52	55.60
1976/1977	25.40	60.95	28.41	158.15	239.47	512.38	57.49
1977/1978	25.91	41.25	27.07	135.94	187.18	417.35	46.83
1978/1979	16.64	43.11	18.05	111.67	161.26	350.73	39.35
1979/1980	43.43	102.82	54.68	252.29	403.80	857.01	96.16
1980/1981	24.47	63.58	19.25	169.85	287.36	564.52	63.34
1981/1982	21.83	21.56	28.21	155.81	233.76	461.17	51.74
1982/1983	27.76	82.97	48.53	235.91	343.17	738.34	82.84
1983/1984	20.62	43.11	29.88	145.00	215.30	453.92	50.93
1984/1985	23.96	44.51	38.10	184.46	245.18	536.22	60.16
1985/1986	21.37	52.42	26.74	138.86	239.91	479.29	53.78
1986/1987	34.94	70.41	37.50	226.85	314.17	683.87	76.73
1987/1988	29.43	64.51	30.35	219.25	307.14	650.68	73.01
1988/1989	21.83	53.04	37.03	167.22	242.55	521.66	58.53
1989/1990	22.62	65.75	36.97	181.25	230.68	537.27	60.28
1990/1991	21.97	55.52	33.02	159.91	250.45	520.87	58.44
1991/1992	51.12	145.31	77.94	328.88	499.15	1102.4	123.69
1992/1993	31.70	70.10	41.04	199.37	308.89	651.11	73.05
1993/1994	21.18	44.66	32.42	141.20	180.15	419.61	47.08
1994/1995	26.97	63.89	41.44	193.82	267.15	593.28	66.57
Average	27.47	63.70	36.87	185.59	267.46	581.08	65.20

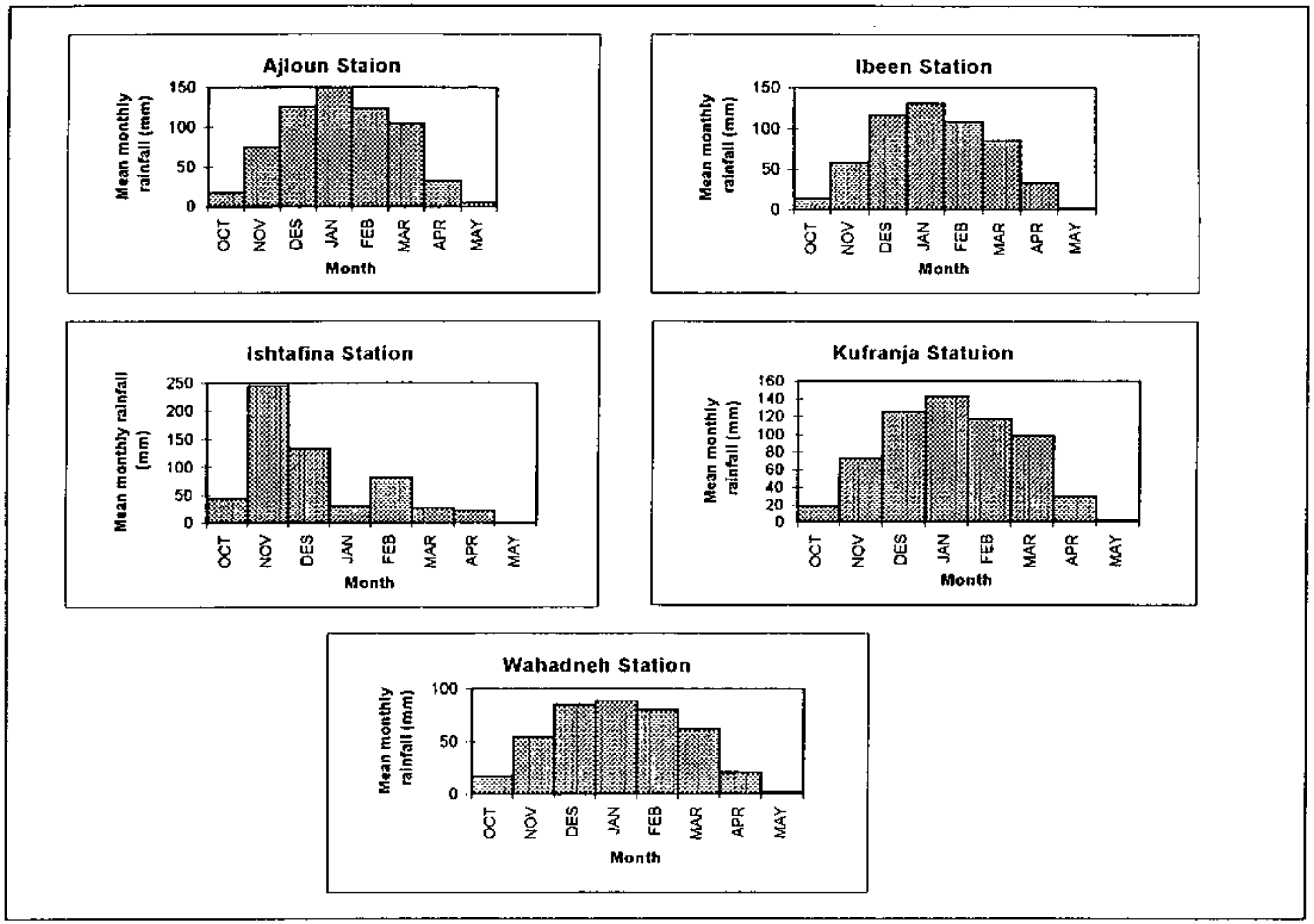


Fig. (3.7) Histograms Showing the Distribution of the Mean Monthly Rainfall for each Station in the Study Area.

From Isohyetal map of the normal water year (Fig. 3.5), it can be observed that the annual rainfall distribution over the study area ranges from less than 400 mm in the western parts to more than 600 mm in the eastern parts.

Generally, it can be concluded that the rainfall distribution over the study area is highly effected by the orography and topography where it decreases towards the west, while it increases towards the east and north east. On the other hand and according to Table (3. 3), histogram modeling has been drawn to show the average annual rainfall distribution within the study area for a period of 31 years. It can be noticed that the highest average annual rainfall of about 635 mm at Ajlun Station, and the lowest amounts as about 411 mm recorded in Wahadneh Station as shown in Fig.(3.8).

3.4 Runoff.

Runoff is that portion of precipitation which after falling on the ground surface finds its way into the stream channels without infiltrating into the soil and percolating down to the water table below. It is a measurable and very important element in the computation of the water balance in the area. It occurs during the rainy season from October to May.

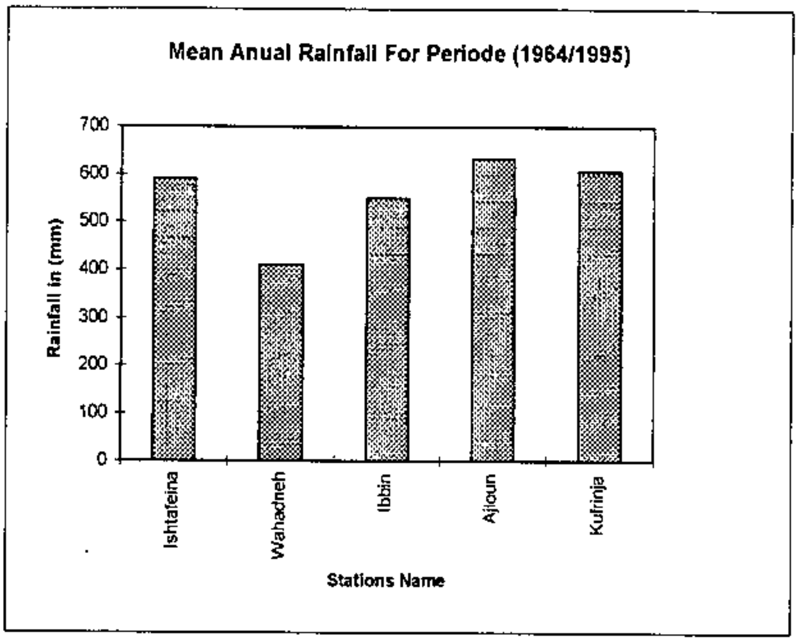


Fig. (3.8): Average Annual Rainfall Distribution in the Study Area for the Period of 64/65-94/95

Table (3.5) : Rainfall Annual Volumes (MCM) in the Study Area Calculated by Thiessen polygons method

Station name	Area (km^2)	Percentage To Total Area (%)	Average Annual Rainfall For The Period (64/65-94/95)	Volume (MCM)
Kufrinja	49.3	43.9	608.7	29.28
Ajlun	32.8	29.2	634.84	20.4
Wahadneh	17.4	15.5	410.7	7.14
Ibbin	7.5	6.7	551.5	4.15
Ishtafina	5.2	4.63	592.6	3.1
Average	112.2	100		65.27

Table (3.6) : The Rainfall Zones and the Average Annual Rainfall Volumes over the Study Area Using Isohyetal Method

Rainfall Zones	Area Covered Km^2	Mean Annual Rainfall	Annual Rainfall Volume (MCM)
>650	12.5	650	8.125
650-600	44.7	625	27.94
600-550	20.3	575	11.67
550-500	16.5	525	8.66
500-450	8.2	475	3.9
450-400	6	425	2.55
<400	4	400	1.6
Average	112.2		64.45

In the study area these water are directly discharged into Jordan Valley. Runoff is usually measured in stream flow gauging stations. One stream gauging station is present in the study area, and it is damaged by the floods of 1985. The continuous recorder was working throughout the period between 1973-1985, and some data of poor quality are available in the past before 1973 using the method of float measurement. Even the recent data is not precise, because of bad site where the station constructed, and to the silt problem (Sa'ad, 1996). The calculated average annual volume of runoff is about 5.17 MCM from the period between 1933-1985.

The present study for determining the volume of runoff data according to Al-Zioud (1993). He divided the water years to wet year (volumes of rainfall more than 70 MCM), normal year (rainfall volume between 60-70 MCM), and less than 60 MCM was considered a dry year. The relationship between available runoff data and volume of rainfall in the basin was studied, it were estimated that the runoff coefficient for wet, normal and dry year 7.3%, 2.5% and 0.76%, respectively. The runoff volume was obtained by multiplying the estimated runoff coefficient by the total rainfall volume. The average runoff volume was calculated to 2.53 MCM using runoff coefficient. Within the study area, the drainage systems are divided into perennial Wadies like Wadi Kufrinja and intermittent Wadies such as Wadi Haramiyah and Wadi Muzeirib. Fig. (3.9). The base flow of Wadi Kufrinja consists of springs discharge located in the basin, seepage, and from treated wastewater discharged from Kufrinja Treatment Plant. According to the base flow measurement carried out along the main channel of Wadi Kufrinja, the annual base flow ranges between 0.486 to 12.509 MCM, and the long term average annual base flow was found to be about 5.8MCM(WAJ, open files).

In addition to the springs as source of baseflow, after 1989 the Kufrinja Wastewater Treatment Plant supplies the baseflow of Wadi Kufrinja with about 1165m^3/day.

Table (3.7) shows the volume of runoff calculated by using Runoff coefficient, runoff, and baseflow from stream gauges stations (WAJ open files).

Table (3.7): Runoff and Baseflow Volumes in the Study Area Calculated and Measurement.

WaterYear	Runoff Calculated (MCM)	Runoff Measured (MCM)	Baseflow Measured (MCM)
1964/1965	5.37	x	x
1965/1966	0.37	x	x
1966/1967	7.25	x	x
1967/1968	0.404	x	x
1968/1969	6.01	x	x
1969/1970	1.55	x	x
1970/1971	1.75	x	x
1971/1972	1.67	x	x
1972/1973	0.25	x	x
1973/1974	5.74	1.395	5.781
1974/1975	0.38	0.741	4.88
1975/1976	0.4	0.458	0.486
1976/1977	0.42	0.067	0.655
1977/1978	0.34	0.189	0.743
1978/1979	0.28	x	x
1979/1980	7.02	x	x
1980/1981	1.58	2.205	12.509
1981/1982	0.37	2.585	10:041
1982/1983	6.05	x	x
1983/1984	0.37	0.756	4.775
1984/1985	1.5	3.783	12.328
1985/1986	0.39	x	x
1986/1987	5.6	x	x
1987/1988	5.33	x	x
1988/1989	0.42	x	x
1989/1990	1.51	x	x
1990/1991	0.42	x	x
1991/1992	9.03	x	x
1992/1993	5.33	x	x
1993/1994	0.34	x	x
1994/1995	1.66	x	x
Average	2.525	1.353	5.800

3.5. Evaporation

Evaporation is the process by which water is transferred from land and water masses of the earth to the atmosphere, by changing from liquid to vapor state (Vissman et al, 1977).

The combined evaporation from the surface of the ground and the transpiration from the vegetation covering the ground is called evapotranspiration. Evapotranspiration is dependent on many factors such as moisture, temperature, sun radiation, the density and Type of vegetation covering the area, geography, and on many other factors.

The simplest and most widespread method of obtaining a direct measurement from free water surface is to measure the loss from an evaporation pan. There are two evaporation stations available in the area, and are located at the boundary of Kufrinja basin using class A pan. These stations are Ras-Munif station which represents the upper part of the basin, with average evaporation of 5.9 mm/day, and Deir Alla represents the lower part of the basin with a long term average evaporation of 6.24 mm/day, Table (3.1 and 3.2). Empirical evaporation formulas make use of different factors such as temperature, humidity, and the moisture content of the soil. The average annual actual evaporation was computed by using the following Turc method (1954).

$$Et = P \Big/ \left[0.9 + \left(\frac{P}{F(t)} \right)^2 \right]^{1/2}$$

ET : Annual actual evaporation in mm.

P : precipitation in mm.

t : mean annual temperature for the wet season (C°)

F(t) : temperature function, where (t) is the average temperature in the range of - 5 to 20 C°

$F(t) = 300 + 25t + 0.05t^3$

Table (3.8) shows the evaporation amount in (mm) based on Turc method for wet, normal and dry years. The temperatures used for the calculation are dependent on daily temperature for water year recorded only in Ras-Munif and Deir Alla stations.

The difference in altitudes and temperature during the rainy months from November to April were taken into consideration.

Table (3.8):Area, Precipitation , Temperature , and Evaporation For

Wet , Normal , and Dry Year.

Wet Year (91/92)				**Evaporation**	
Stations	Area (km^2)	Weighted Precipitation (mm)	Temperature C°	Weightd Average (mm)	(MCM)
Kufrinja	49.3	499.15	9.97	235.29	26.4
Ajlun	32.8	328.88	9.1	149.15	16.7
Wahadneh	17.4	145.31	10.33	80.8	9.1
Ibbin	7.5	77.94	6.61	29.86	3.35
Isshtafina	5.2	51.12	7.94	22.13	2.48
Normal Year (94/95)				**Evaporation**	
Stations	Area (km^2)	Weighted Precipitation (mm)	Temperature C°	Weightd Average (mm)	(MCM)
Kufrinja	49.3	267.15	11.54	202.8	22.75
Ajlun	32.8	193.82	10.69	136.59	15.33
Wahadneh	17.4	63.89	11.9	56.8	6.4
Ibbin	7.5	41.44	8.24	27.64	3.1
Ishtafina	5.2	26.97	9.55	19.6	2.2
Dry Year(72/73)				**Evaporation**	
Stations	Area (km^2)	Weighted Precipitation (mm)	Temperature C°	Weightd Average (mm)	(MCM)
Kufrinja	49.3	150.71	12.53	141.6	15.89
Ajlun	32.8	85.36	11.68	81.8	9.18
Wahadneh	17.4	34.12	12.89	34.3	3.85
Ibbin	7.5	20.19	9.23	18.6	2.1
Ishtafina	5.2	14.28	10.54	13.3	1.5

It was found that the temperature gradient of the study area is 0.711, 0.71 and 0.723 C°/100m elevation for dry, normal and wets years respectively. The 1994/1995 was selected as a normal water year. Accordingly, the average annual evapotranspiration for the study area was found to be about 49.78 MCM. This value represent 74.78% of the total annual rainfall in the study area, Table (4.9).

3.5 Infiltration.

Infiltration is the flow of water into the ground through the earth surface. Many factors affect the infiltration rate such as, the type and extent of vegetal cover, the condition of surface crust, temperature rainfall intensity, physical properties of the soil, and on many other factors. There are no direct infiltration measurements in the study area. Generally, quantifying infiltrated volumes is not simple, a water budget approach was applied to estimate the average annual infiltration. The water budget of the basin is :

I= P-R-E

where

I : is the annual volume of infiltration (MCM)

P : Is the annual volume of precipitation (MCM)

R : Is the annual volume of Runoff (MCM)

E : is the annual volume of Evaporation (MCM)

In the present study, the seasonal water budget was calculated depending only on the water year from Nov. to Apr. The water balance equation was applied in the study area for the wet year (1991,1992), normal year (1994/1995) and dry year (1972/1973).

The average annual recharge to ground water was estimated to be about 15.13 MCM, which represent about 22.7 % of the total annual rainfall in the study area.

The wet, normal, and dry water budgets of the study area are presented in Table (3.9)

Table (3.9): Water Budget of Wet, Normal , and Dry Condition in MCM

Water year	Rainfall MCM)	Evaporation		Runoff		Infiltration	
		(MCM)	%	(MCM)	%	(MCM)	%
1991/1992(Wet)	123.69	58	46.89	9.03	7.3	56.66	45.8
1994/1995(Normal)	66.57	49.78	74.78	1.66	2.5	15.13	22.7
1972/1973(dry)	34.17	32.5	95.1	0.25	.0072	1.41	4.13

3.6 Water Resources.

The water resources in the study area are dependent only on the springs and are used for the municipal and irrigation purposes. The surface water is used for irrigation, no groundwater wells were drilled in Wadi Kufrinja Basin.

3.6.1 Surface Water

Surface water includes runoff and baseflow, both discharge to the Jordan Valley and used for irrigation in the summer season. The volume of runoff and baseflow is tabulated in Table (3.7).

3.6.2 Spring

A spring is a point through which groundwater emerges from an aquifer to the ground surface (Jacob, 1979). In the study area there are twenty five discharging spring emerging from the three aquifer systems, eleven from A1-2, thirteen from A4, and one from A7. The location of these springs are shown in Figure (3.10). These springs are used for drinking, domestic and agricultural uses. All these springs have records in the Water Authority files.

The largest spring in the study area from the discharging point of view is Qantara spring. It discharges at an average flow of about 139.3 m^3/hr, and the lowest spring is Wadi - El Haramiyah which flows at an average 1.9 m^3/hr. The minimum, maximum and average discharges of all springs in the basin are summarized in Table (3.10). The fluctuation of springs discharge is affected by precipitation, geological structure and topography. In general, spring discharge increases after rainfall storms in winter and spring season, and decreases in summer and autumn season.

Table (3.10): Minimum , Maximum and Average Discharge (MCM/year) of the Springs in the Study Area

SPRING NAME	Minimum Discharge (m^3/hr)	Maximum Discharge (m^3/hr)	Average Discharge (m^3/hr)	Average Discharge (MCM/Year)
Et Teis	0.18	6	1.35	0.0118
El Harameyyah	0	10.3	2.8	0.0252
Barraneyyah	0.8	15.9	3.58	0.0314
Sharqeyyah	0.8	68.4	7.99	0.0700
El Fawwar	0.72	193	18.42	0.1614
Um Sarab	0	36	12.584	0.1102
El Balad(Ajlun)	1.31	127	31.38	0.2749
El Haddadeh	1.08	12.8	4.51	0.0395
El Qantara	39.6	298	139.29	1.2202
El Salous	1.08	94	22.737	0.1992
Abu Jabir	0.29	25.5	5.33	0.0467
El Balad(Anjara)	0.72	25.5	4.16	0.0364
[3]Basset Khazaq	1.8	49.8	8.993	0.0788
Basset Afiya	5.05	52.8	17.28	0.1514
Qureiwah	4.01	37.5	12.04	0.1055
Basset Jatta	9.28	71	33.09	0.2899
El Bustan	1.08	11.3	3.956	0.0347
Basset Falah	1.3	49.8	12.58	0.1102
Deek	9.59	49.8	22.97	0.2012
El Balad(Kufrinja)	0.51	4.32	1.68	0.0147
Zaghadiyyah	3.52	137	18.78	0.1645
Um Hamdan	2	49.8	9.48	0.0830
El Aqdeh	9.28	52.8	22.31	0.1954
El Birkeh	17.9	116	44.24	0.3875
Wadi El Haramiyyah	1.08	5.05	1.9	0.0166

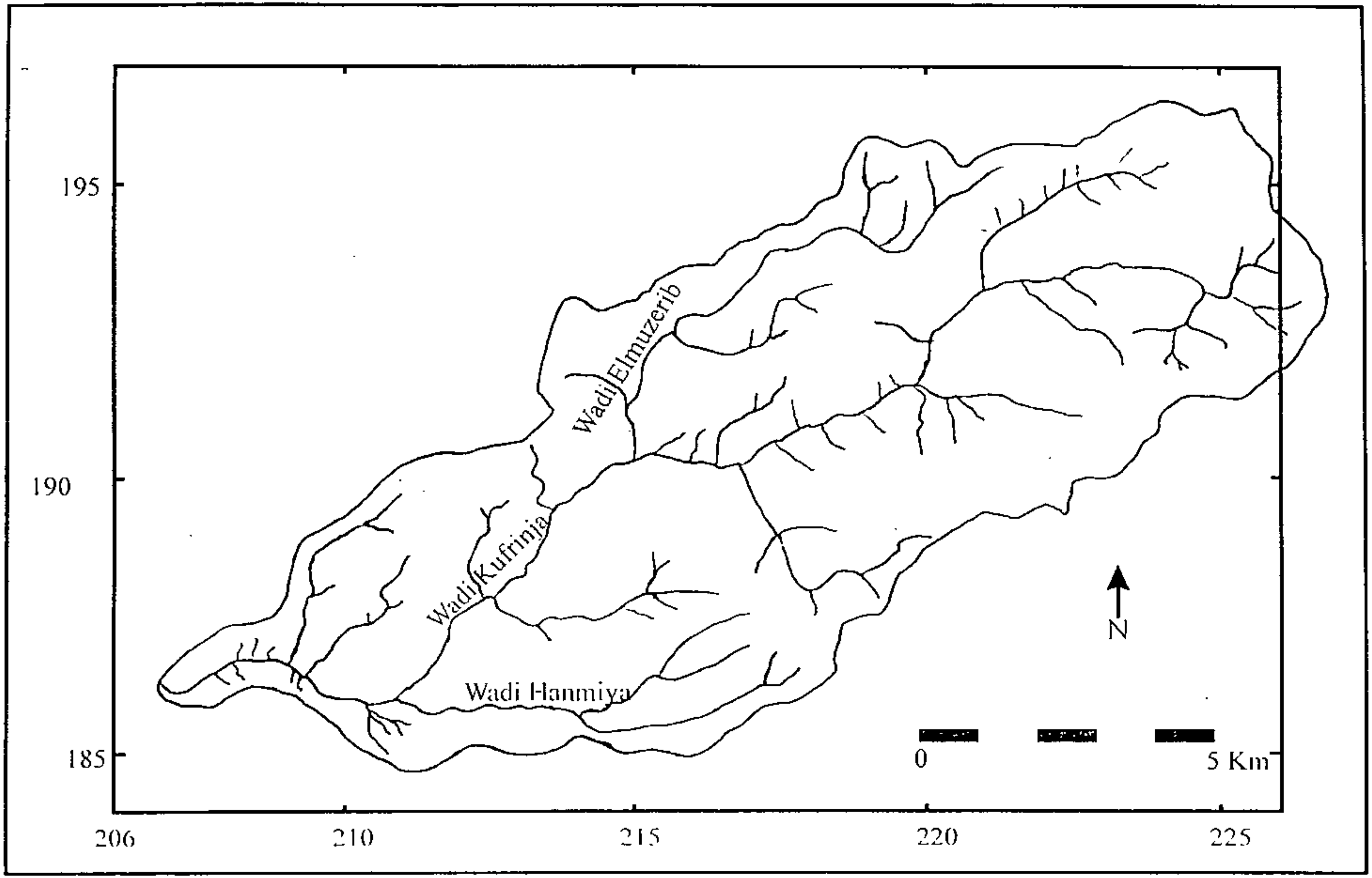


Fig (3.9) :Drainage Systems of Wadi Kufringa Basin

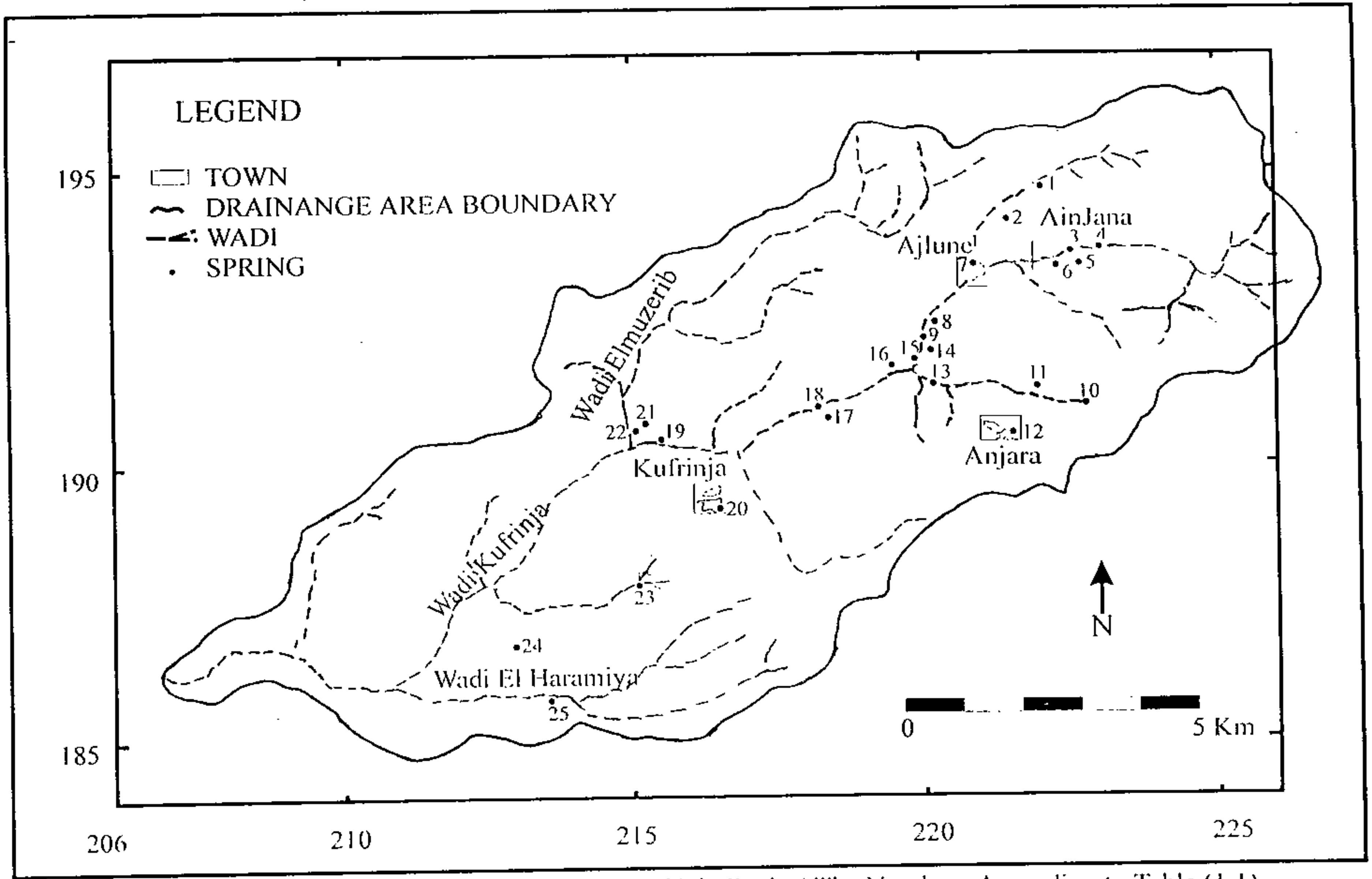


Fig (3.10) : The Location of Springs in Wadi Kufrinja Basin (The Numbers According to Table (1.1)

Chapter Four

Water Pollution and Environmental Issues Related to Water

4.1. Water

Water is essential to sustain life, and a satisfactory supply must be made available to consumers. Every effort should be made to achieve a drinking water quality. Protection of water supplies from contamination is the first line of defense. Source protection is almost invariably the best method of ensuring safe drinking water and is to be preferred to treating a contaminated water supply to render its suitability for consumption. Once a potentially hazardous situation has been recognized, the risk to health, the availability of alternative sources, and the availability of suitable remedial measures must be considered, so that a decision can be made about acceptability of the supply, (WHO, 1995).

Drinking water is charachterized as follows: (WHO, 1995) (National Jordanian Standard for drinking water, 1990)

1- It must not contain water borne pathogen
2- Its content of hazardous chemicals, turbidity, salinity smell and taste causative substances must be within the permissible limits.
3- Not to be corrosive and not to have dye substances.

4.1.1. Water Pollution

Pollution is the presence of materials in water that interfere unreasonably with one or more of its beneficial uses , (Lamb, 1985).

The sources of pollution are generally divided into two group:

1- Natural Pollution; is related to adverse weather condition, intense rain, decay of vegetation, dissolved minerals and other potential pollutants originatis from volcanic action, wind erosion, or other purely natural phenomena.

2- Artificial Pollution: this occurs as a result of man-made activities such as wastewater, agriculture and miscellaneous sources.

The pollution could be classified into biological, chemical and physical according to the type of potential pollutants, such as infections and toxic agent, oxygen demanded substances, suspended matter, heat ... etc. (Lamb, 1985).

4.1.2. Biological versus chemical contaminants

Pathogenic agents have several properties that distinguish them from chemical pollutants, (WHO, 1995):

- Pathogens are discrete and not in solution.

- Pathogens are often clumped or adherent to suspended solids in water, so that the likelihood of acquiring an infective dose cannot be predicted from their average concentration in water.
- The likelihood of a successful challenge by a pathogen, resulting in infection, depends upon the invasiveness and virulence of the pathogen, as well as upon the immunity of the individual.
- If infection is established, pathogens multiply in their host. Certain pathogenic bacteria are also able to multiply in food or beverages, thereby perpetuating or even increasing the chances of infection.
- Unlike many chemical agents, the dose response of pathogens is not cumulative.

Because of these properties there is no tolerable lower limit for pathogens. Thus water intended for consumption, for preparing food and drink, or for personal hygiene should thus contain no agents pathogenic for humans.

4.1.3. Water and Health

The relation between water quality and health occupies a niche of special important in the public perception. There is a strong and wide spread belief that water pollution problems must be closely related to human health effects. The relationship between water and health are divided into four categories, (Lamp, 1985):

1- Water as a direct vehicle for disease transmission.

Several infection diseases that probably can be transmitted directly by water, such as typhoid and paratyphoid fever and cholera ... etc. Basically these are diseases in which the pathogens are in water, such as bacteria, viruses and protozoa. The coliform group of bacteria is used to evaluate the microbiological quality of waters; the number present is interpreted as an indicator of the extent to which that water has been contaminated recently by human fecal discharges.

2- Water as a vector habitat in disease transmission.

Several important diseases are transmitted by organisms that require water as a habitat for at least part of their life cycles. The mosquito is best known and is responsible for transmitting some of the deadliest human diseases, including malaria, Yellow fever ... etc.

3- Water as a vehicle for transmitting toxic chemicals.

Water is an important vehicle for transmitting of potentially toxic and suspicious chemicals such as organic and inorganic toxcic materials to humans.

4-Beneficial health effects.

Many beneficial effects can occur from water and its constituent. The most obvious in satisfying our metabolic needs for water, without which life can continue only for a short time. Among several chemicals in water known or suspected to be beneficial to humans are, fluoride, iodine, calcium and magnesium, may produce benefit by offsetting the negative effects of sodium in hypertension and heart disease.

4.2 Population

The total population in the study area in 1994 was 45923 inhabitants which are aspected to reach about 50958 in 1997. (General Statistics Department, Jordan, 1994). About 67% of the population are residing in the Kufrinja and Anjara, and more than 98% of the population inhabiting in the upper part of the basin, due to the climate, rainfall and water availability. Population distributed around the water resources and springs lead to pollution of most springs especially from the cesspools. In addition , illegal and random buildings spreads near some springs lead to pollution of the springs, such as Deek spring which is located west of Kufrinja city adjacent of Wadi Kufrinja. This spring is polluted recently after building around this spring.

4.3 Water Uses

4.3.1 Drinking and Domestic Uses

A total of 1.7 MCM/year is the present amount of water used in the basin to satisfy domestic uses. The water supply network suffers from corrosion and damage which leads to losses that are estimated to be about 60%. Calculating the per capita domestic water use in the basin shows that it averages around 84l/day (Water Authority of Ajlun, open files, 1997).

Springs are the main source of water in the basin. About 70% of total water consumption for domestic uses comes from springs located in Wadi Yabis (Zugig and Tanure), and 30% from the springs located in the basin such as Qantara and Falah for Kufrinja town, Salous for Anjara town, and Sharqeyyah, Fawwar, UM Sarab for Ain-Jana town.

These springs are effected by the man-made activities such as, cesspools which affect most springs in the basin, fertilizer and from olive oil mills in the region.

Table (4.1), shows the chemical analyses of the water from pumping stations which are used as a source for domestic uses (Ministry of Health, Ajlun, 1997).

Table (4.1): Chemical Analyses of the Water from Pumping Stations in kufrinja Basin

Station Name	Turbidity	Color	pH	TDS	T.H	SO_4	Cl	F	NO_2	NO_3
Qantra	1.04	5	6.85	576	300	31.75	39.67	0.7	0	45.17
Anjara	.01	5	7.36	384	216	9.4	34.5	0.1	0	61.4
Salous	0.5	5	6.83	384	250	35.04	17.4	0.5	0	18.64
Tanure	0.5	5	6.76	512	310	31.75	38.67	0.7	0	45.77

This analyses fits the Jordan standard for drinking water (1991)

4.3.2 Irrigation water

Most of the population in the basin depends on the agriculture in winter and summer. The irrigated land in the basin is estimated to be about 7000 dunums. These areas are concentrated closed to the streams and springs. The period of irrigation starts from May till October each year. The amount of water used to irrigate fruits and different types of vegetables by channels (soil or concrete) having length of about 38km is 1.15 MCM/year (Water Authority, 1997). The water flows into channels by gravity and natural topography.

Agriculture is considered as a pollution source from the fertilizer added to agricultural lands such as nitrogen, phosphorus and potassium. These are transported into streams by runoff, irrigation return flows may contain high concentration of many chemical leached from the soil nutrients, suspended solids and runoff from farms. Animal wastes, which may add suspended matter, and wastes from olive oil mills are also potential sources of pollutian.

4.4 Wastewater

Wastewater is essentially water that has been fouled by communities through its use in the various daily activities such as cooking and washing. Domestic sewage is mainly composed of human body wastes and sludge. Industrial sewage comprises numerous and various chemicals including those toxic to human and nature.

Wastewater vary in charachter from community to community in response to many variables such as; the fractions derived from household wastes. Typical commercial activities commonly are viewed as relatively uniform in contributions per person per day, quality and quantity of the consumed water, the industrial practices, diets, and many other aspects of community life including its social customs. (Lamb, 1985).

Wastewater is extremely hazardous because of the number of diseases causing organisms and toxic matter that it contains. Managed disposal and reuse methods of the wastewater is essential for the removal of pathogens and toxic substances. This will protect the human lives and the environment, and prevent pollution of surface and groundwater. Also, the treated wastewater could be used to irrigate relatively large areas of cropped land. In the study area only domestic wastewater is available and no industrial wastewater. Domestic wastewater is either collected via cesspools or swerage systems that ends in wastewater treatment plants.

4.4.1 Wastewater Networks in the Study are

Combined sewers were constructed in the main towns in the basin, Ajlun, Kufrinja, Anjara, Ain-Jana since 1988. This network does not comes all the residences in the basin because the topography and the wide spread of buildings. In addition to this not all houses are connected to the network though they can make use of it. About 89.9% of Ajlun town, 80.4% of Ain-Jana, 75% of Anjara, and 57.7% of Kufrinja towns are connected to the sewer system. Besides, this network is not completely finalized, the oldest one is about 78km long, under construction is 20km, while 14km are suggested in 1997 budget.

4.4.2. Kufrinja wastewater treatment plant

This treatment plant was constructed in 1989 to serve different towns and villages in Ajlun governorate such as Kufrinja, Anjara, Ain-Jana and Ajlun town.

The designed capacity of this plant is 1920 m^3/day and 850mg/l BOD_5. The plant in 1996 was still hydraulically and organically under loaded with an average inflow 1517 m^3/day and BOD_5 is 803 mg/l. The effluent of this trickling filter- Imhof tank treatment plant has an average BOD_5 28.2 mg/l and COD is 145 mg/l Table (4-2).

Table (4-2): Kufrinja Wastewater Treatment Plant, Inflow and Outflow (1996)

Parameters	Influent	Effluent
flow m3/day	1517	1165
TDS in mg/l	1022	87.0
BOD_5 in mg/l	803	28.2
COD in mg/l	1355.3	145
TSS in mg/l	573.5	50.75
NH_4 in mg/l	100.3	38.75
PO_4 mg/l	-	29.9
Temp in C°	24	19.4
pH - Value	7.2	-

The COD and aammonia of the effluent is high. The effluent can be used for irrigation without any restriction because it is chlorinated before discharge along Wadi Kufrinja.

4.4.3 Cesspools

A cesspool is a covered chamber receiving all wastewater from a dwelling or dwellings. Cesspools are the main and most common disposal systems in the areas that lack wastewater collection network.

It is not only the economic status of the owner that determines the construction types of the pit and its capacity, but also availability of the land and number of dwellers. This system is characterized by low initial and maintenance cost because of the high permeability due to soil texture and the nature of the rocks which is karstic limestone and highly fractured. These conditions allow the infiltrated sewage water to reach the underlying water bodies.

4.5 Solidwaste Disposal Site

Solidwastes are all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted. The quality and quantity of the solidwastes depend mainly on the population habits and industrialization. In the study area there is one disposal site for solidwaste located west of Kufrinja town covering an area of about 70 dunum. Large portion of that site is difficult to be used because of the topography and the difficulty to reach the site. About 50 ton/day of solidwaste are discharged to the landfill collected from 16 municipality from Ajlun governorate.

Municipal dumps and landfills have long been recognized as potential sources of surface and groundwater pollution. Groundwater pollution occurs when the leachate of the disposed waste percolates down to the groundwater. The disposal site is located close to Wadi Kufrinja stream and this lead to pollution of the surface water by drawn waste during rainfall period.

In addition to this, hazards caused by the solidwaste on the human health through, direct exposure to pathogens, exposure to toxic and hazardous substances, and hazards by the potentiall methane explosion, gasses migration from landfill can result in extensive damage to vegetation and odor problems.

4.6 Selection of Water Sources

Before a new source for drinking-water supply is selected, it is important to ensure that:

1- The quality of the water is satisfactory or can be improved by treatment to make it suitable for drinking.

2- The source will yield enough water to meet the needs of the community.

3- Under normal abstraction conditions, the change in local water flow patterns will not cause any unacceptable deterioration in the quality of the water abstracted.

4- The water to be abstracted can be protected against pollution.

4.7 Protection of water sources

Water resources can be protected by:

1- Isolation of the watershed from human activity is an important mean of protecting a water way or aquifer from contamination, through immediate stop of the urban expansion over the reaching area.

2- Prevent or control the polluting activities in the area which may be a source of infection such as dumping of hazardous wastes, mining and quarrying, agricultural uses of fertilizers and pesticides, and limitations and regulations of recreational activities.

3- Sources of groundwater such as springs and wells should be sited and constructed so as to be protect them from surface drainage and flooding.

4- Animal husbandry should be controlled in such zone.

5- Monitoring and follow-up of the water quality.

Chapter Five

Hydrochemistry:

The chemical composition of water is affected by many sources such as, gases from the atmosphere, weathering of rocks and soil, dissolution / precipitation of minerals, adsorption or ion exchange and human activities. (Drever, 1982).

The chemical analyses of water aimed to determining the nature and importance of some the environmental factors which water may be exposed to in the hydrologic cycle.

The quality of water and suitability for various purposes deals with its chemical, physical and biological constituents. The aim of this study is to evaluate the water quality by studying the hydrochemistry of the twenty three springs located in the shallow aquifers in the study area in two periods; summer (September 1996) and winter(March 1997), to study the seasonal influence on the water quality . In addition historical data of the chemicals composition of the same springs were taken from the files of the Water Authority of Jordan.

The chemical analysis was performed for the major cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}), major anions (HCO_3^-, Cl^-, SO_4^{--}, NO_3^-) and minor ions (NH_4,PO_4). The physical analyses include measurements of temperature

(C°), electrical conductivity (EC) and pH- value. Biological analyses of total and fecal coliform were also conducted. Table (5-1), shows the analytical methods which were used in determination of different parameters. Statistical analyses for the samples were done by using IBM personal computer. The analyses help in identifing of the water genesis and the relationship of different parameters with each other. The analyses were all carried out at the Water & Environmental Research and Study Center, University of Jordan.

Table (5.1): Analytical Methods Used in the Determination of Various Parameters

Parameter	Method of Analysis
Temperature, EC, pH-value	Field multielectrod meter (Mettler Toledo)
NH_4^+	Ion selective electrode micro processor
Ca^{++}	Titration with Na_2-EDTA using Murexide indicator
Ca^{++} and Mg^{++}	Titration with Na_2-EDTA using Erochrome black-T indicator
Na^+, K^+	Flame photometer
$HCO3^-$	Titration with H_2SO_4 using bromocresol green indicator
$CO3^{--}$	Titration with H_2SO_4 using phenolphthalein indicator
$SO4^{--}$	Spectrophotometer, wave length (λ = 492 nm)
Cl^-	Titration with AgNO3 using potassium chromate as indicator
$NO3^-$	Spectrophotometeric, wave length (λ= 206 nm)
$PO4^{---}$	Spectrophotometer wave length (λ= 700 nm)
TC / FC MPN/100ml	multiple-tube fermentation

5.1 Field Measurements.

The field measurements included electrical conductivity (EC), temperature (C°), and pH. Table (5.2) shows the descriptive statistics of the measured value, and Table (5.3) shows the descriptive statistics for the historical data of pH and EC.

Table (5.2): Descriptive Statistics of the Field Measurements (Recent Data)

Variable	Minimum	Maximum	Mean	St.Dev	N
EC µS/cm	421	732	565.85	72.58	46
pH-Value	7.00	8.03	7.42	0.25	46
Temp C	16.40	27.23	20.43	3.06	46

Table (5.3): Descriptive Statistics of the Field Measurements (Historical Data)

Parameter	Minimum	Maximum	Mean	St.Dev	N
EC µS/cm	320	900	601.97	103.26	253
pH-Value	7.05	8.39	7.61	0.29	253

5.2 Laboratory Measurements.

The analyses of water samples were done at the laboratories of the Water and Environmental Research and Study Center, University of Jordan as follows:

1. Major cations and anions, in addition to PO_4, NH4, for all samples were determined. Table (5.4, 5.5), shows the statistical analyses of these variables for recent and historical data respectively.

Table (5.4): Descriptive Statistics of the Measured Major Ions (Recent Data)

Variable	Minimum	Maximum	Mean	St. Dev.	N
Ca mg/l	58	90	73.79	7.32	46
Mg mg/l	8.20	26.74	16.32	4.47	46
Na mg/l	4.21	41.01	17.40	7.81	46
K mg/l	0.18	19.31	2.84	3.41	46
Cl mg/l	21.08	67.45	35.29	10.17	46
PO4 mg/l	0.001	0.151	0.035	0.033	46
HCO3 mg/l	150	288.00	234.41	31.73	46
SO4 mg/l	10.50	42.72	21.66	6.84	46
NO3 mg/l	2.98	88.04	27.14	19.79	46
NH4 mg/L	all samples are Ammonium free				46

Table (5.5): Descriptive Statistics of the Measured Major Ions (Historical Data)

Parameter	Minimum	Maximum	Mean	St.Dev	N
Ca mg/l	36.4	120	79.52	13.69	253
Mg mg/l	3.37	47.96	18.32	7.73	253
Na mg/l	4.60	36.80	17.26	6.24	253
K mg/l	0.40	19.60	4.11	3.91	190
Cl mg/l	13.1	105.60	33.45	11.73	253
HCO3 mg/l	134.80	387.40	278.73	49.44	253
SO4 mg/l	1.40	61.90	14.31	10.75	253
NO3 mg/l	1.60	89.00	29.90	20.07	238

2. The determination of the biological total and fecal coliform for all samples, Table (5.6) shows their descriptive statistics.

Table (5.6): Descriptive Statistics of the Total and Fecal Coliform Analyses

Parameter	Minimum	Maximum	Mean	St. Dev	N
Total coliform MPN/100ml	0.00	≥ 2400	230.78	594.97	46
Fecal Coliform MPN/100ml	0.00	≥ 2400	128.09	425.40	46

5.3 Calculated Parameters.

Different Parameters were calculated based on the chemical analyses of the water samples.

5.3.1 Total dissolved solids (TDS mg/l) :

The total dissolved solids for all samples were calculated using the following equation (Appelo, 1993).

$$TDS\ mg/l = Ca^{++} + Mg^{++} + Na^{+} + K^{+} + SO_4^{--} + Cl^{-} + NO_3^{-} + 0.5HCO_3^{-}$$

Table (5.7), shows the descriptive statistics of TDS (mg/l) for the recent and historical data. The TDS ranges between 228.7 to 420.2 mg/l with a mean of 311.63 mg/l for the recent data and from 190.9 to 547.25 mg/l with a mean of 333.44 mg/l for the historical data.

5.3.2 Hardness.

The hardness of water is the concentration of metallic ions in the water which will react with a sodium soap to precipitate insoluble residue. Hardness is normally expressed as ppm CaCO3. It can be determined by substituting the concentration of Ca^{++} and Mg^{++}, expressed in mg/l in the expression,(Todd, 1980)

$$T.H = 2.5\,(Ca^{++}) + 4.1(Mg^{++})$$

Table (5.8), shows the descriptive statistics of TH for the recent and historical data. The T.H ranges between 189- 302 mg/l $CaCO_3$ with a mean 251.1 mg/l as Ca CO_3 for the recent data and between 133.8-381.4 mg/l as Ca CO_3 with a mean 273.76 mg/l as Ca CO_3 for the historical data.

Table (5.7): The Descriptive Statistics of the Total Hardness and Total Dissolved Solids for the Water Samples (Recent Data)

Parameter	Minimum	Maximum	Mean	St.Dev	N
Total hardness(mg/L) as Ca CO_3	188.72	302.06	251.13	26.62	46
Total dissolved solid (mg/L)	228.71	420.21	311.63	45.13	46

Table (5.8): The Descriptive Statistics of the Total Hardness and Total Dissolved Solids for the Water Samples (Historical Data)

Parameter	Minimum	Maximum	Mean	St.Dev	N
Total hardness(mg/L) as Ca CO_3	133.52	381.42	273.76	43.49	253
Total dissolved solid (mg/L)	170.86	547.25	333.44	61.73	253

5.3.3 Chemical Equilibrium and Saturation Index.

The rate of chemical reaction is related to the concentration of the constituents which are reacting, and the constituents of reaction products, according to the mass action law.

The law of mass action expresses the relation between the reactants and the products when the reaction is at equilibrium.

The law at equilibrium can be stated as follows :

$$K = \frac{\text{(active concentratioin of product)}}{\text{(active concentration of reactant)}}$$

Where K: is the thermodynamic equilibrium constant.

The activity of a given solution can be related to the activity coefficient by the following reaction (Freez & cherry, 1987).

$$A_i = \gamma_i M_i$$

Where A_i : is the activity of solute species, M_i the molarity and γ_i the activity coefficient.

The activity coefficient is calculated according to Debey- Hueckel equation (Drever, 1982):

$$\text{Log } \gamma i = \frac{-A \times Zi \times \sqrt{I}}{1 + B \times ai \times \sqrt{I}}$$

Where a: is the size of hydrated ion, A and B are constants that depend on the dielectric constant, density and temperature, I is the ionic strength of solution.

The used equation representing the degree of saturation of water with respect to a certain mineral is (Appelo, 1993)

$$SI = \text{Log (KIAP/KSP)}$$

Where:

SI : is the saturation index, KIAP is the ionic activity product of the appropriate ions, and KSP is the solubility product of the mineral.

By using the computer program PC-WATEQ, different saturation indices were obtained for the most common minerals. The common minerals such as calcite, dolomite, gypsum,.. etc. involved in the reaction between water and rock matrix of the aquifer systems are listed in Table (5.9)

The importance of the saturation indices is to determine the dissolution and /or precipitation process during the water rock interaction.

If

SI = 0, this means that the water is at equilibrium for a certain mineral.

SI > 0, this means that the water is oversaturated for a certain mineral, and the mineral will precipitate.

SI < 0, this means that the water is undersaturated for certain mineral, and the mineral will dissolve.

Table (5.10), shows the descriptive statistics for different calculated parameters for all analyzed samples recent and historical.

From this table the following points can be deduced.

- $SI_{anhydrite}$ and SI_{gypsum} for recent and historical data have low negative values, indicating that the water is under saturated with respect to gypsum and anhydrite. It is expected that, gypsum and anhydrite will not reach saturation due to the low content of gypsum in the aquifer matrix.
- The $SI_{calcite}$ ranges from – 0.24 to 0.59 and 0.19 to 1.27 for the recent and historical data respectively, and most water samples show

positive values indicating that water is over saturated with respect to calcite minerals.

- The $SI_{aragonite}$ ranges from –0.39 to 0.43 and from –0.34 to 1.12 for the recent and historical value respectively, and the majority of water sample have a ppositive values which also indicate that water is oversaturated with respect to aragonite.
- The $SI_{dolomite}$ range from – 0.74 to 0.78 for the recent data and between –0.18-2.1 for the historical data, half of the samples show positive values while the others show negative values. This means that the water is oversaturated with respect to dolomite in a part of the study area, while in the other part it is undersaturated.

Table (5.9): Dissociation Reactions and Equilibrium Constants for Minerals and their Enthalpies (Δ H)

Mineral	Dissolved Species	pK	(Δ H)
Anhydrite	$CaCO_4 \rightleftharpoons Ca^{++}{}_{(aq)} + SO_4^{--}{}_{(aq)}$	-4.548	-3.769
Aragonite	$CaCO_3 \rightleftharpoons Ca^{++}{}_{(aq)} + CO_3^{-}{}_{(aq)}$	-8.215	-2.959
Calcite	$CaCO_3 \rightleftharpoons Ca^{++}{}_{(aq)} + CO_3^{-}{}_{(aq)}$	-8.41	3.19
Dolomite	$CaMg(CO_3)_2 \rightleftharpoons Ca^{++}{}_{(aq)} + Mg^{++}{}_{(aq)} + 2CO_3^{++}{}_{(aq)}$	-17.02	-8.29
Gypsum	$CaSO_4.H_2O \rightleftharpoons Ca^{++}{}_{(aq)} + SO_4^{--}{}_{(aq)} + 2H_2O$	-4.759	0.261

Table (5.10): The Descriptive Statistics of the Calculated Saturation Indices

(Recent and Historical Data)

	Parameter	Minimum	Mxximum	Mean	St.Dev	N
Recent	SI-Anhydrit	-2.81	-2.22	-2.49	0.14	46
	SI-Aragonit	-0.39	0.43	-0.03	0.2	46
	SI-Calcite	-0.24	0.59	0.12	0.20	46
	SI-Dolomite	-0.74	0.78	-0.14	0.39	46
	SI-Gypsum	-2.98	-2.00	-2.25	0.17	46
Historical	SI-Anhydrite	-3.64	-2.02	-2.75	0.32	253
	SI-Aragonite	-0.34	1.12	0.26	0.27	253
	SI-Calcite	-0.19	1.27	0.4	0.28	253
	SI-Dolomite	-0.81	2.1	0.43	0.64	253
	SI-Gypsum	-3.37	-1.75	-2.48	0.32	253

5.4 Statistical Analysis :

The statistical analysis was performed on the different analyzed and calculated parameters. The correlation matrix represented the relationships between the different analysed parameters of the water sample. Also cluster and factor analysis were used for the determination of the water quality grouping.

5.4.1 Relationship between the Different Parameters of the Water Samples.

The different analyzed parameters of water samples, were subjected to product linear correlation analysis in order to distinguish the parameters which correlate to each other.

The relationship of the different constituents can be differentiated as follows:

Group (I): Chemical parameters with correlation coefficients greater than 0.9 (very high significant linear relationship)

Group (II): Chemical parameters with correlation coefficients between 0.85-0.9 (high significant linear relation ship)

Group (III): Chemical parameters with correlation coefficients between 0.8-.085 (significant relationship)

Group (IV): Chemical parameters with correlation coefficients between 0.7-0.8 (good correlation)

Group (V): Chemical parameters with correlation coefficients between 0.6-0.7 (Medium or acceptable correlation)

Group (VI): Chemical parameter with correlation coefficients between 0.5 – 0.6 (low correlation)

Group (VII): Chemical with correlation coefficients below 0.5(week to very week correlation)

The Parameters characteristics of each group for the recent data are as follow:

Group (I) parameters: > 0.9

Parameters			Correlation Coefficient
$SI_{aragonite}$	versus	$SI_{calcite}$	0.9998
Na mg/L	versus	SAR	0.9937
$SI_{aragonite}$	versus	$SI_{dolomite}$	0.9394
$SI_{calcite}$	versus	$SI_{dolomite}$	0.9397

SO4 mg/L	versus	$SI_{anhydrite}$	0.9332
pH-value	versus	$SI_{calcite}$	0.9309
pH-value	versus	$SI_{aragonite}$	0.9298
EC μ S/cm	versus	TDS mg/l	0.9228

Group (II) parameters : 0.85-0.9

Parameters			Correlation Coefficient
Cl mg/L	versus	Na mg/L	0.8970
Cl mg/L	versus	TDS mg/L	0.8915
FC colony/100ml	versus	TC colony/100ml	0.8768
Cl mg/L	versus	SAR	0.8649
EC μS/cm	versus	T.H	0.8592

Group (III) Parameters : 0.8-0.85

Parameters			Correlation Coefficient
pH-value	versus	SI-dolomite	0.8449
Na mg/L	versus	TDS mg/L	0.8279
HCO_3 mg/L	versus	T.H	0.8100

Group(V) Parameters : 0.7-0.8

Parameters			Correlation Coefficient
NO_3	versus	SAR	0.7714
SAR	versus	TDS mg/L	0.7680
EC μS/cm	versus	Cl mg/L	0.7507
NO_3 mg/L	versus	Na mg/L	0.7469
$SI_{anhydrite}$	versus	TDS mg/L	0.7350
Mg mg/L	versus	T.H	0.7287
Ca mg/L	versus	T.H	0.7234
EC μS/cm	versus	$SI_{anhydrite}$	0.7110
NO_3 mg/L	versus	CL mg/L	0.7103
TDS mg/L	versus	T.H	0.7028

Group (IV) Parameters : 0.6-0.7

Parameters			Correlation Coefficient
SO_4 mg/L	versus	TDS mg/L	0.6892
EC μS/cm	versus	Ca mg/L	0.6693
EC μS/cm	versus	SO_4 mg/L	0.6662
SO_4 mg/L	versus	Cl mg/L	0.6632
EC μS/cm	versus	Na mg/L	0.6539
SO_4 mg/L	versus	Na mg/L	0.6422
FC colony/100ml	versus	K mg/L	0.6395
HCO_3mg/L	versus	Mg mg/L	0.6335
K mg/L	versus	TDS mg/L	0.6296
Cl mg/L	versus	$SI_{anhydrite}$	0.6215
PO_4 mg/L	versus	K mg/L	0.6142
Ca mg/L	versus	TDS	0.6118
Na mg/L	versus	$SI_{anhydrite}$	0.6090

Group (VI) Parameters: 0.5-0.6

Parameters			Correlation Coefficient
SO_4 mg/L	versus	SAR	0.5943
EC μS/cm	versus	Mg mg/L	0.5788
EC μS/cm	versus	SAR	0.5711
EC μS/cm	versus	K	0.5584
SAR	versus	$SI_{anhydrite}$	0.5539
K mg/L	versus	$SI_{anhydrite}$	0.5457
HCO_3 mg/L	versus	Ca mg/L	0.5425
TC colony/100ml	versus	K mg/l	0.5373
ECμS/cm	versus	HCO_3	0.5367
T.H	versus	$SI_{anhydrite}$	0.5204
SO_4	versus	SI_{gypsum}	0.5126
SI_{gypsum}	versus	$SI_{anhydrite}$	0.5013

Table (5-10), shows the linear correlation matrix of the recent data, and Table (5-11) shows the linear correlation matrix for the historical data.

Table (5.11) : Correlation Matrix of the Measured and Calculated Variables (Recent Data)

	EC uS/cm	pH-value	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	PO4 mg/l	Tem C	HCO3mg/l	SO4 mg/l	NO3 mg/l	SI-anhy	SI-arag	SI-cal	SI-dol	SI-gyp	TCMPN/.1	FCMPN/.1	T.H	SAR	TDS
EC uS/cm	1																					
pH-value	-0.319	1																				
Ca mg/l	0.669	-0.245	1																			
Mg mg/l	0.579	-0.229	0.054	1																		
Na mg/l	0.654	-0.09	0.195	0.208	1																	
K mg/l	0.558	-0.247	0.486	-0.01	0.412	1																
Cl mg/l	0.751	-0.029	0.357	0.306	0.897	0.426	1															
PO4 mg/l	0.442	-0.258	0.357	0.133	0.299	0.614	0.31	1														
Tem C	0.052	-0.699	-0.174	0.143	0.172	0.072	-0.047	-0.04	1													
HCO3mg/l	0.537	-0.313	0.543	0.634	-0.158	0.161	-0.061	0.183	0.069	1												
SO4 mg/l	0.666	-0.208	0.218	0.431	0.642	0.473	0.663	0.396	0.229	0.112	1											
NO3 mg/l	0.326	0.048	0.159	-0.206	0.747	0.412	0.71	0.277	-0.078	-0.526	0.283	1										
SI-anhy	0.711	-0.38	0.43	0.326	0.609	0.546	0.622	0.449	0.315	0.192	0.933	0.313	1									
SI-arag	-0.128	0.929	0.013	-0.092	-0.121	-0.154	-0.038	-0.205	-0.658	0.022	-0.166	-0.099	-0.284	1								
SI-cal	-0.13	0.931	0.013	-0.096	-0.12	-0.153	-0.037	-0.203	-0.661	0.016	-0.166	-0.094	-0.285	1	1							
SI-dol	-0.011	0.845	-0.08	0.226	-0.059	-0.196	0.017	-0.205	-0.527	0.174	-0.035	-0.18	-0.2	0.939	0.938	1						
SI-gyp	0.276	-0.191	0.089	0.407	0.239	-0.212	0.343	0.111	-0.043	0.039	0.513	0.074	0.501	-0.226	-0.23	-0.11	1					
TCMPN/.1	0.313	-0.241	0.372	-0.111	0.168	0.537	0.132	0.274	0.208	0.153	0.14	0.207	0.259	-0.132	-0.14	-0.19	-0.311	1				
FCMPN/.1	0.374	-0.176	0.379	-0.157	0.256	0.64	0.187	0.267	0.212	0.135	0.193	0.257	0.295	-0.061	-0.06	-0.13	-0.506	0.877	1			
T.H	0.859	-0.326	0.723	0.729	0.277	0.326	0.457	0.337	-0.02	0.81	0.447	-0.033	0.52	-0.054	-0.06	0.101	0.343	0.178	0.151	1		
SAR	0.571	-0.052	0.116	0.138	0.994	0.372	0.865	0.261	0.176	-0.25	0.594	0.771	0.554	-0.114	-0.11	-0.07	0.206	0.148	0.236	0.175	1	
TDS	0.923	-0.224	0.612	0.41	0.828	0.63	0.892	0.485	0.035	0.26	0.689	0.622	0.735	-0.109	-0.11	-0.04	0.281	0.314	0.37	0.703	0.768	1

Table (5.12) : Correlation Matrix of the Measured and Calculated Variables (Historical Data)

	EC uS/cm	pH	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	HCO3mg/l	SO4 mg/l	NO3 mg/l	SI-anhy	SI-arag	SI-cal	SI-dol	SI-gyp	T.H	SAR	TDS
EC uS/cm	1.0000																	
pH	-0.1852	1.0000																
Ca mg/l	0.6323	-0.3955	1.0000															
Mg mg/l	0.5247	0.1208	-0.1321	1.0000														
Na mg/l	0.6771	0.0047	0.2763	0.3728	1.0000													
K mg/l	0.5335	-0.1509	0.4246	-0.0008	0.5005	1.0000												
Cl mg/l	0.7790	-0.0155	0.3266	0.4296	0.8352	0.5032	1.0000											
HCO3mg/l	0.6323	-0.2486	0.5810	0.5480	0.1622	0.1458	0.1622	1.0000										
SO4 mg/l	0.4708	-0.0145	0.1696	0.4129	0.5202	0.2732	0.5576	0.1239	1.0000									
NO3 mg/l	0.3722	-0.0254	0.2346	-0.0794	0.6183	0.5455	0.6000	-0.2699	0.2464	1.0000								
SI-anhy	0.4424	-0.1472	0.3555	0.1851	0.4454	0.3381	0.4704	0.1298	0.8651	0.2972	1.0000							
SI-arag	0.1283	0.8822	-0.0059	0.2519	0.1041	-0.0400	0.0841	0.1813	0.0458	-0.0777	-0.0458	1.0000						
SI-cal	0.1267	0.8833	-0.0084	0.2510	0.1040	-0.0399	0.0842	0.1785	0.0429	-0.0757	-0.0491	0.9991	1.0000					
SI-dol	0.2001	0.8414	-0.1663	0.5423	0.1694	-0.0742	0.1603	0.2580	0.1265	-0.1096	-0.0379	0.9358	0.9354	1.0000				
SI-gyp	0.4183	-0.1333	0.3490	0.1543	0.4471	0.3471	0.4651	0.0994	0.8320	0.3188	0.9760	-0.0456	-0.0487	-0.0466	1.0000			
T.H	0.8804	-0.2224	0.6890	0.6274	0.4897	0.3330	0.5707	0.8571	0.4351	0.1263	0.4146	0.1796	0.1769	0.2658	0.3870	1.0000		
SAR	0.5192	0.0500	0.1298	0.2495	0.9726	0.4597	0.7654	-0.0350	0.4385	0.6503	0.3691	0.0567	0.0574	0.1099	0.3790	0.2845	1.0000	
TDS	0.9111	-0.2113	0.6780	0.4543	0.7783	0.5886	0.7963	0.5647	0.5940	0.5235	0.5911	0.0878	0.0857	0.1342	0.5822	0.8648	0.6335	1.0000

5.4.2 Mathematical Relationship between the Different Parameters.

The different analyzed parameters of water samples were subjected to fit the following mathematical equations based on Geo-500 computer program :

Y = A+B*X

Y = A*exp (B+X)

Y = A* X^B

Y = A+B/X

Y = (1/(B*X+A))

Y = (X/(A+B*X))

Where

X: Represents the concentration of the independent variable (the cation and anions in mg/l and EC in μS/cm)

Y: Represents the concentration of dependent variable (the concentration of the cations and anions in mg/L and the EC in μS/cm)

B: Represents the slope of the line

A: A constant which intercepts the y-axis.

In order to determine the contribution of the different parameters to each other, the correlation coefficient of these parameters were computed. Consequently, the following conclusions can be drawn from these relations.

- Chloride and sodium have an effect on the salinity due to their high and good correlation coefficients with the EC as shown in Fig (5-1-a) and
- (5-1-b) respectively. The increase in sodium and chloride concentration increases the salinity.

  [Cl] = EC/(27.64 - 0.019*EC) R = 0.813

  [Na] = -6.91 + 0.69 * EC R = 0.686

  The correlation coefficient between EC and Cl is 0.813 and between EC and Na is 0.686. This indicates the direct contribution of the ions to the salinity of groundwater.

- Fig (5-1 c and d), shows the relationship between EC and Mg contents with a correlation coefficient 0.669 and between EC and Ca with correlation coefficient = 0.669 which indicates that Mg & Ca content has a medium contribution to salinity.

  [Mg] = EC/(52.58-0.028*EC) R = 0.637

  [Ca] = 35.6 * 0.0675 * EC R = 0.667

  This medium correlation indicates the dissolution of magnesium and calcium from dolomite and limestone from the different aquifer systems in the basin and influence on the salinity of water.

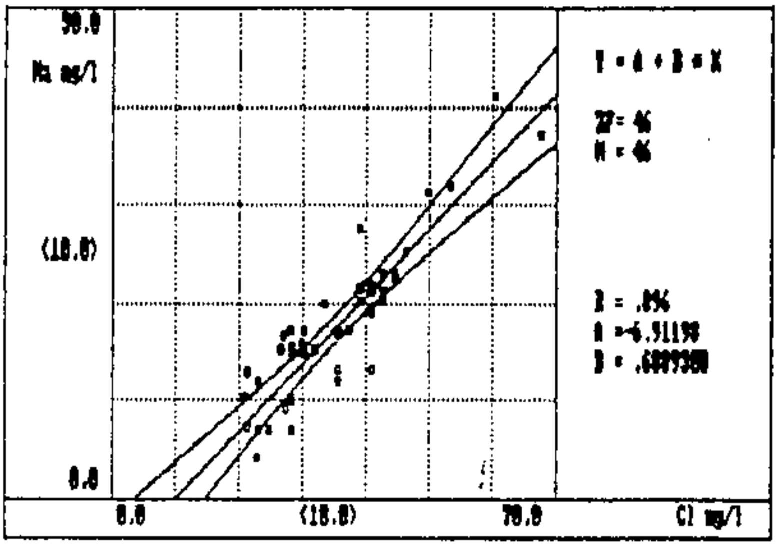


Fig.(5.2): The Relation Between Na (mg/l) and Cl (mg/l)

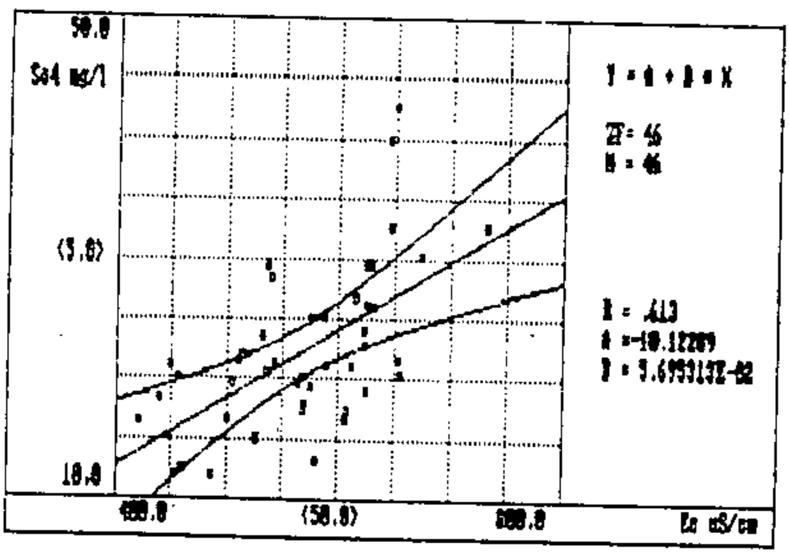


Fig.(5.3): The Relation Between EC (μs/cm) and SO_4 (mg/l)

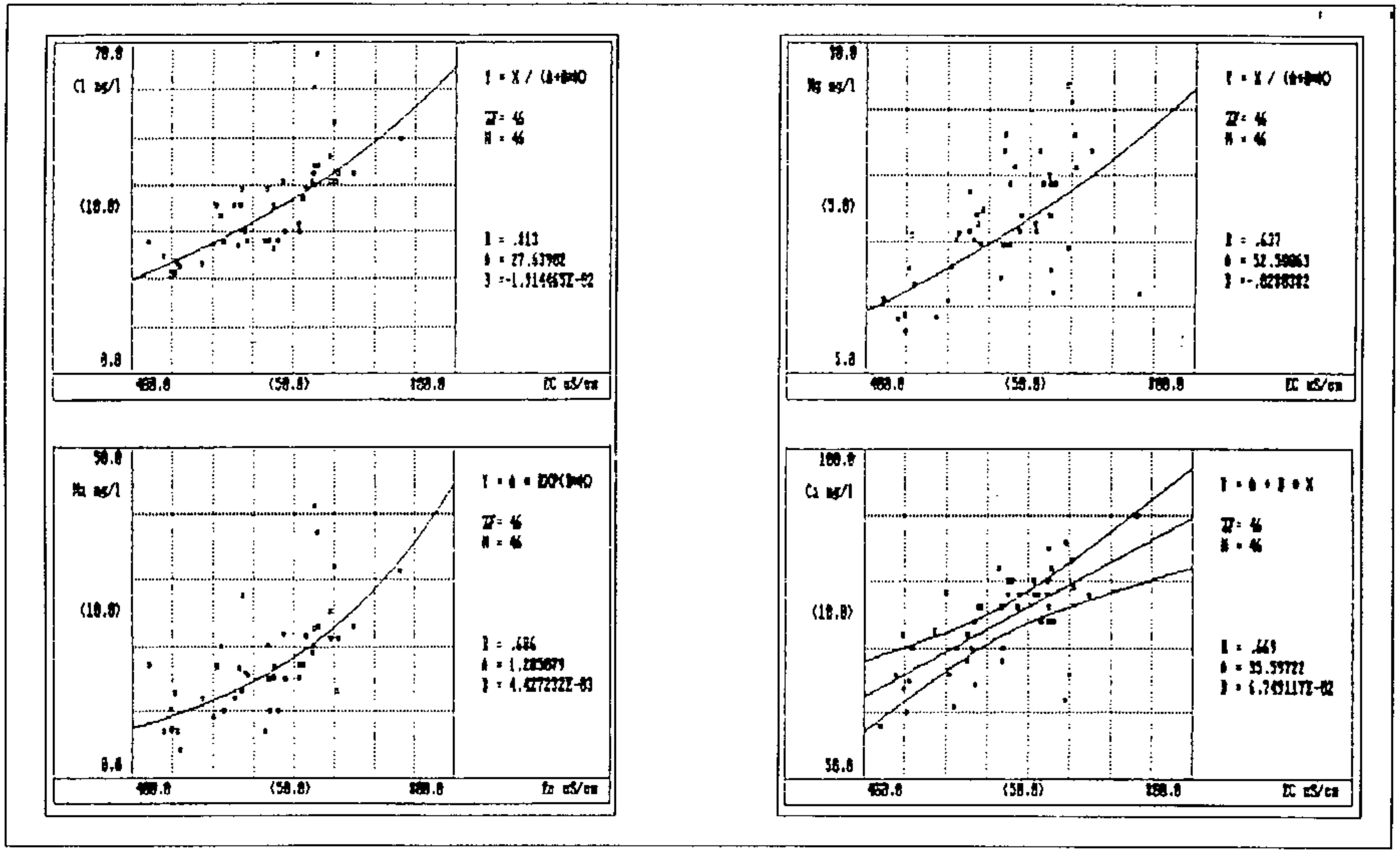


Fig.(5.1): Relationships Between Cl (mg/l) and EC (µs/cm) (a), Na (mg/l) and EC (µs/cm) (b), mg (mg/l) ad EC (µs/cm) (c), Ca (mg/l) and EC (µs/cm) (d)

Fig (5.2), shows the relationship between sodium and chloride with correlation coefficient of about 0.896

$[Na] = -6.911 + 0.689 * Cl$ $R = 0.896$

This high relationship indicated the interconnection between Na and Cl and their influence on the salinity of ground water.

Fig. (5.3) shows, the relationship between EC and SO4 content in water.

$[SO_4] = -10.123 + 0.097 * EC$ $R = 0.613$

With correlation coefficient of about 0.613. This indicates the effect of sulfate concentration on the salinity of groundwater.

Sulfate result from the dissolution of evaporite from the marl layers and from the pollution of the water with organic contaminant carried by the wastewater from the cesspool.

Fig. (5.4) shows the relationship between SI_{gypsum} and SO_4 as follows:

$$SI_{gypsum} = \frac{SO_4}{1.39 + .514 * SO_4} \qquad R = 0.642$$

With correlation coefficient of 0.642.

Fig. (5.5 a,b) shows the relationship between $SI_{calcite}$ and $SI_{dolomite}$, with correlation coefficient 0.912, and between pH and $SI_{calcite}$ with correlation coefficient 0.883. To determine the relationship between different

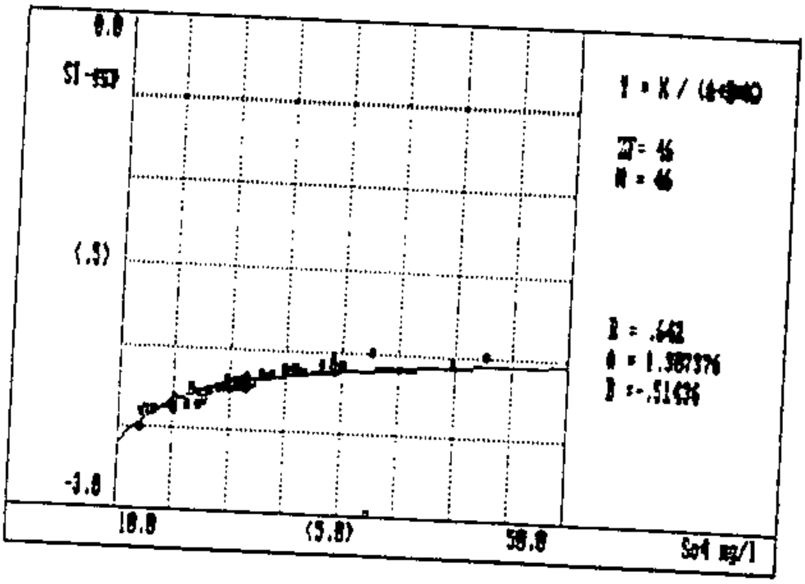


Fig.(5.4): The Relation Between SO_4 (mg/l) and SI_{gypsum}

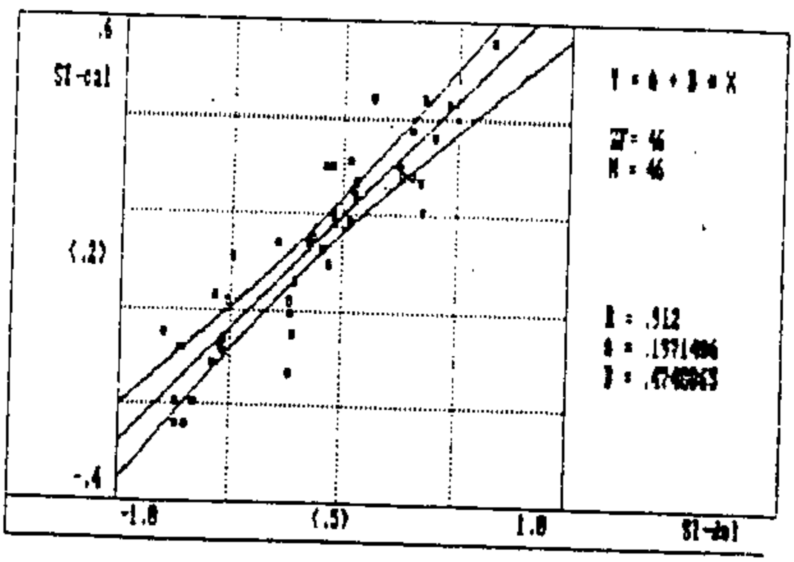


Fig.(5.5a): The Relation between $SI_{calcilte}$ and $SI_{dolomite}$

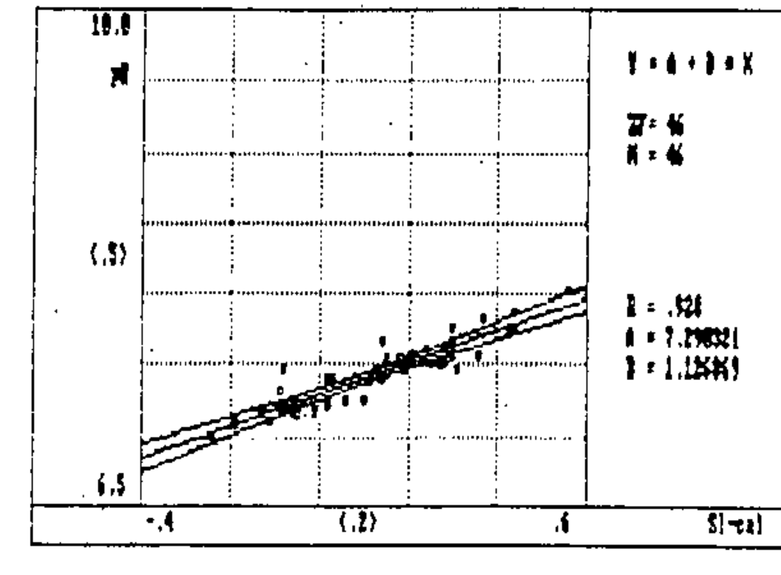


Fig.(5.5b): The Relation between pH and $SI_{calcite}$

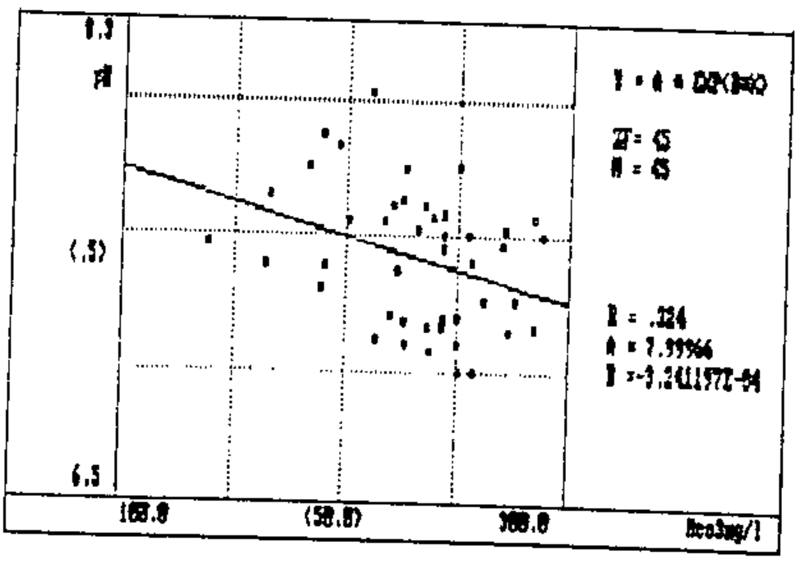


Fig.(5.6): The Relation Between pH and HCO_3 (mg/l) parameters of carbonate system, the variables are subjected to product linear correlation to show the correlation coefficient between these variables.

Fig (5.6) shows the relationship between pH and HCO_3 contents the analyzed water samples as :

$pH = 7.99 * EXP(-0.0032*HCO_3)$ $\qquad R = 0.324$

With correlation coefficient of about 0.324 which shows that bicarbonate concentration decreases with increasing pH-value.

- The correlation coefficient in the historical data approximately similar to the recent data correlation coefficient Fig. (5.7,a,b,c, and d), shows the correlation coefficient between Cl and EC is 0.779 between Na and EC is 0.677, between Ca and EC is 0.65 and between Mg and EC is 0.525 respectively.
- Fig (5-8,a,b,c,d), shows the relationship between SO_4 and EC, pH and $SI_{calcite}$, $SI_{calcite}$ and $SI_{dolomite}$ and between pH and HCO_3 with correlation coefficient is 0.47, 0.883, 0.935, and 0.254 respectively.

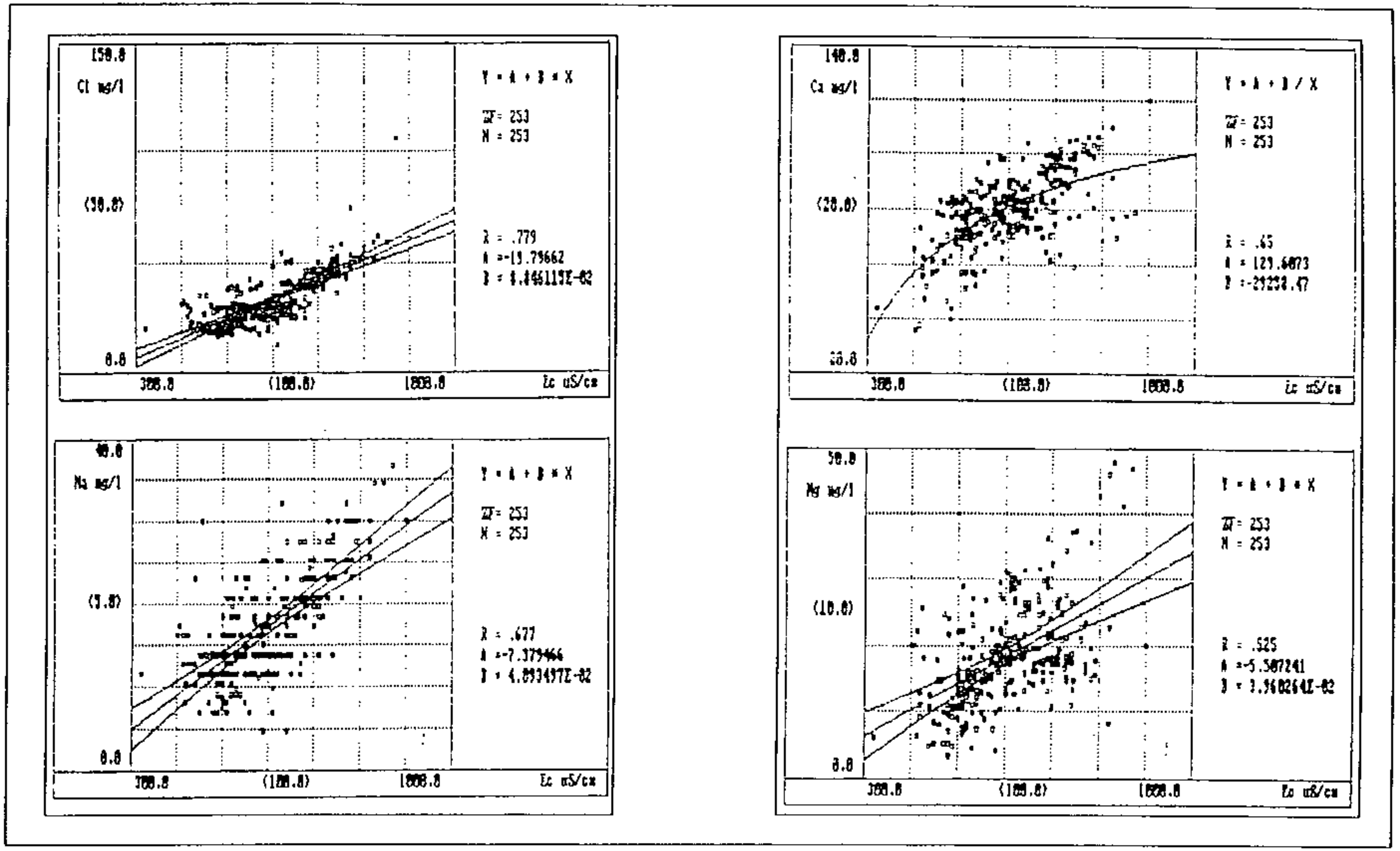


Fig.(5.7): Relationships Between Cl (mg/l) and EC (μs/cm) (a), Na (mg/l) and EC (μs/cm) (b), Ca (mg/l) and EC (μs/cm) (c), and Mg (mg/l) and EC (μs/cm) (d)

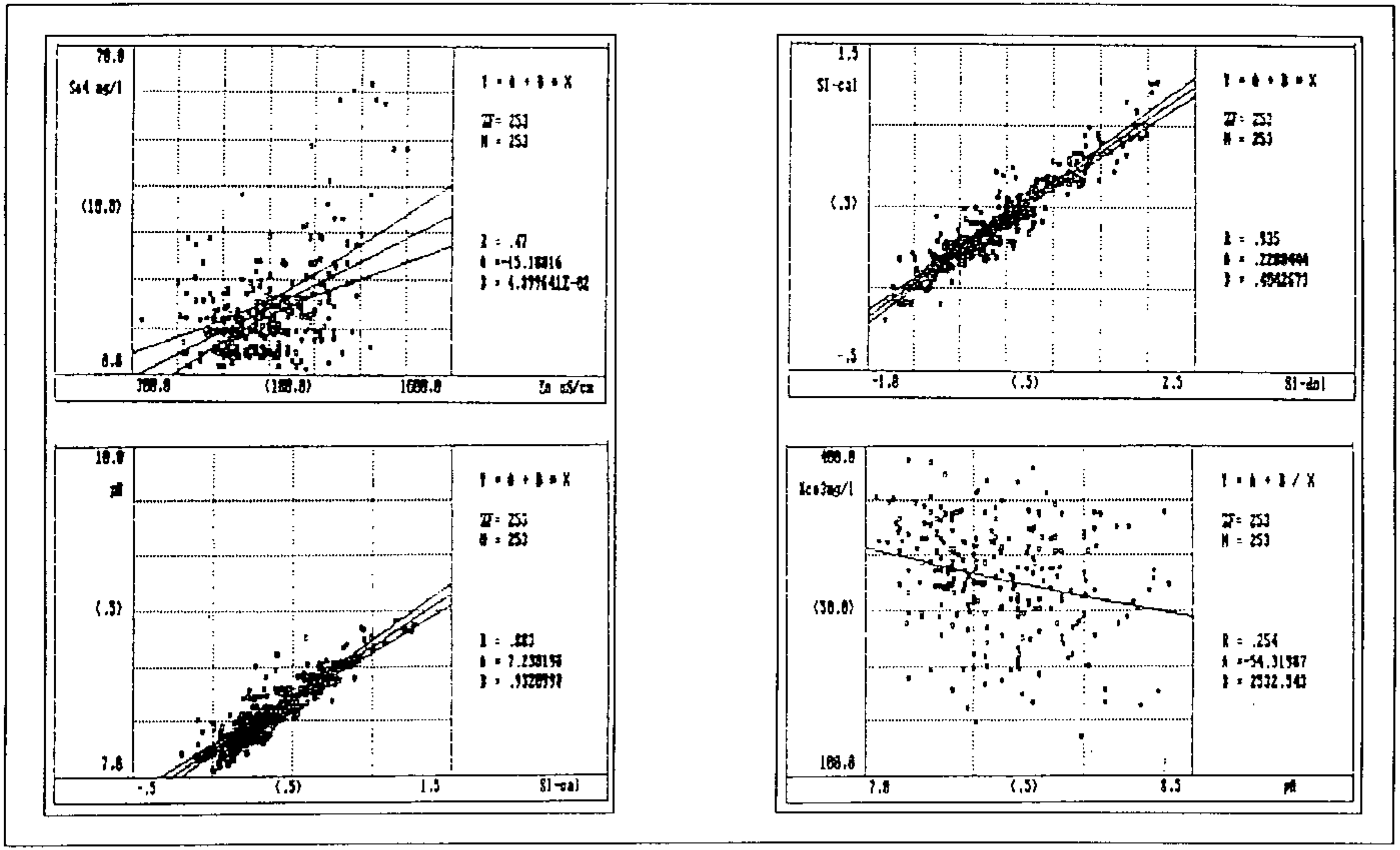


Fig.(5.8): Relationships Between SO_4 (mg/l) and EC (μs/cm) (a), pH and $SI_{calcite}$ (b), $SI_{calcite}$, and $SI_{dolomite}$ (c), pH and HCO_3 (mg/l) (d)

5.4.3 Cluster Analysis

The analyzed water sample were subjected to cluster analysis to facilitate the interpretation of their chemical characteristics. Cluster analysis involves the grouping of entities that are similar to one another in which a large quantities of data can be handled systematically (Davis, 1973).

Cluster analysis in this work was done by the Geo-500 (1988), computer program. In this study the water samples were clustered into four groups based on the water chemical composition (major cations and major anions) for the recent and historical data. Rimawi (1985) subdivided the water of Jordan into six main group (group 0,I,II,III,IV and V). The four clusters of recently analyzed samples and historical data compare well only with group 0 of Rimawi (1985).

This group of water is generally the source water for the different water groups. It originates from precipitation water which reaches the springs through infiltration into the carbonate rocks. This group is subdivided into four sub clusters (subgroups), group 0-a, 0-b, 0-c and 0-d. Fig (5.9) and (5.10) shows the bar diagram for the recent and historical data, respectively, for these subgroups.

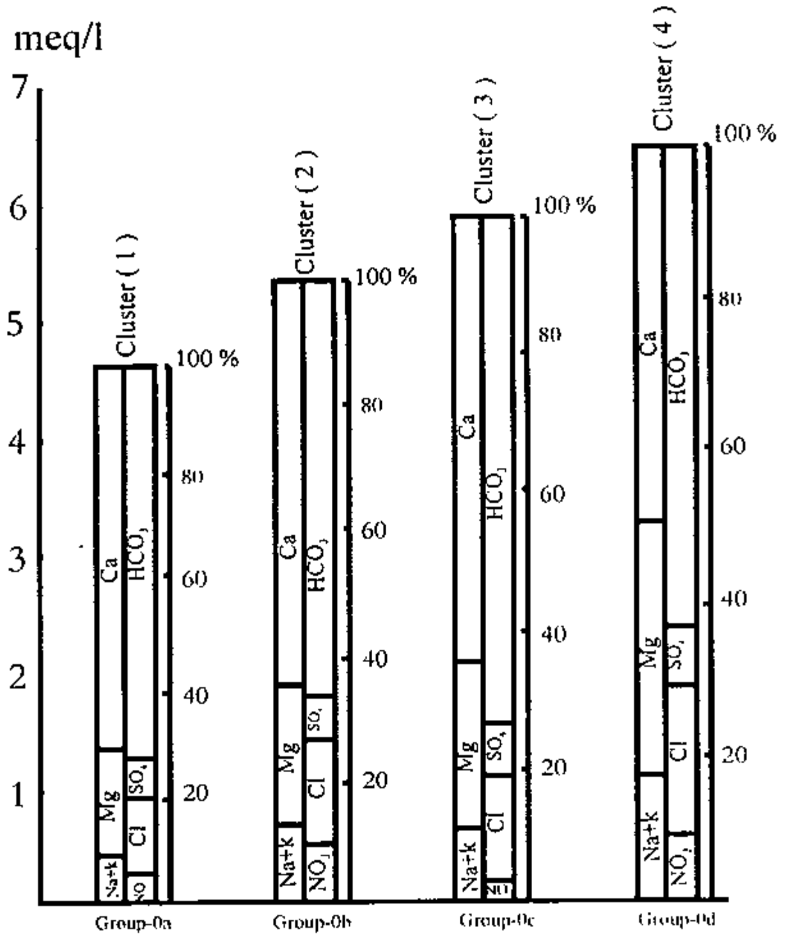


Fig. (5.9) Bar Diagram for The Study Samples Clusters

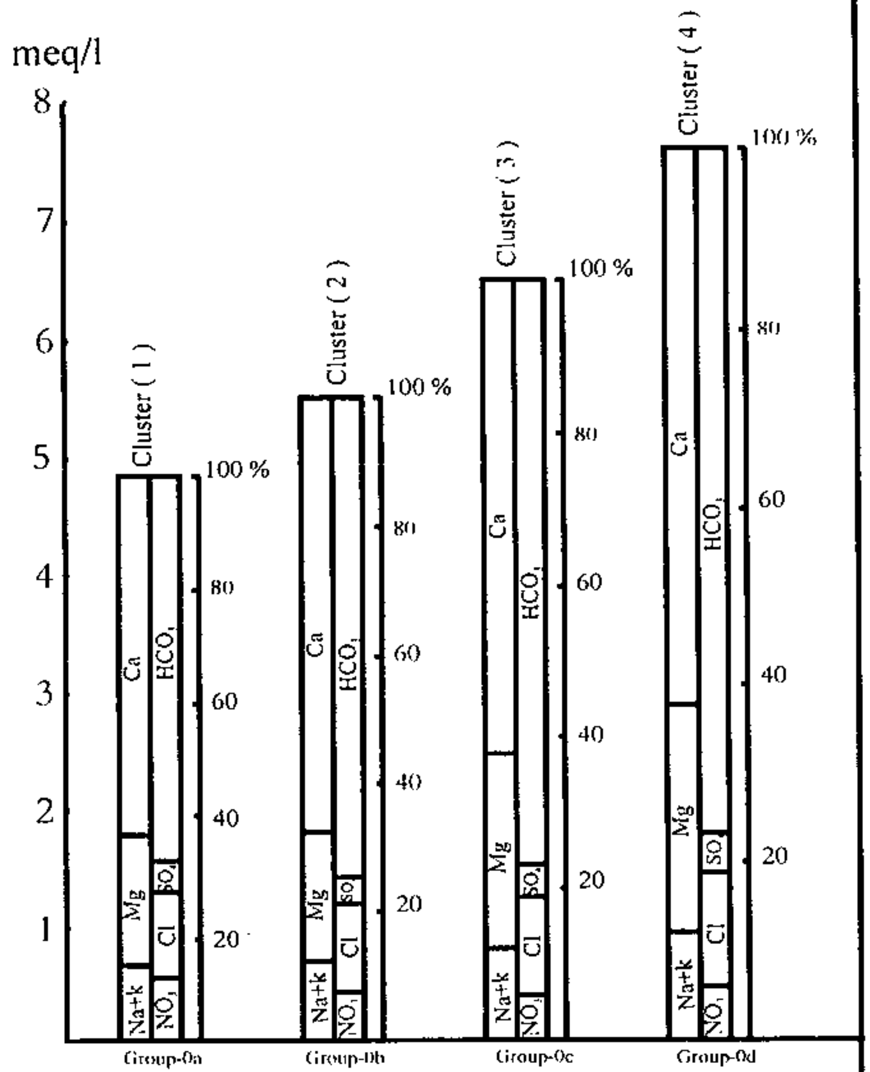


Fig. (5.10) Bar Diagram for The Historical Samples Clusters

5.4.3.1 Group 0-a.

15.2% of recent water samples fall within this cluster. The mean electrical conductivity reaches 446.43 μS/cm and pH-value 8.03. The historical data 11.5 % of the water samples fit within this group. The average electrical conductivity is 446.03 μS/cm and pH 7.76. In this water type calcium ion forms the major cation and bicarbonate ion is the major anion for the recent and historical data. The water of this group is the origin of all other water groups and it is attributed to precipitation water (Rimawi, 1985). The main characteristics of the recent data for this group are :

$Ca^{++} > Mg^{++} > (Na^{+} + K^{+})$

$HCO_3^{-} > Cl^{-} > SO_4^{--} > NO_3^{-}$

$HCO_3^{-} > Ca^{++}$

$(Na/Cl) < 1$

$((Cl-Na)/Mg) < 1.$

The characteristics of the historical data are similar to the recent data but different in NO_3 and SO_4.

The descriptive statistics of the hydrochemical and biological parameters of the recent analyses and historical analyses are shown in Table (5.13) and (5.14), respectively.

Table (5.13): Descriptive Statistic of Cluster No.1 (Recent Samples)

Variable	Minimum	Maximum	Mean	St.Dev	N
E-Coordinate	221.6	222.7	222.3	0.4	7
N-Coordinate	190.4	193.6	191.7	1.3	7
Altitude	800	880	851.4	35.8	7
EC μS/cm	421	459	446.4	12.9	7
pH-Value	7.2	8.03	7.6	0.3	7
Ca mg/l	58	72	64.9	5.0	7
Mg mg/l	8.2	15.4	11.1	2.5	7
Na mg/l	4.21	17.2	9.5	4.4	7
K mg/l	0.5	1.6	1.1	0.4	7
Cl mg/l	21.1	28.1	23.2	2.5	7
PO_4 mg/l	0.001	0.031	0.015	0.013	7
Temp C	16.4	23.2	20.1	2.9	7
HCO_3 mg/l	150	231	200.6	28.3	7
SO_4 mg/l	10.5	21.1	15.6	4.2	7
NO_3 mg/l	5.5	58.3	17.2	18.3	7
SI-Anhydrite	-2.8	-2.5	-2.6	0.1	7
SI-Aragonite	-0.2	0.4	0.02	0.2	7
SI-Calcite	-0.1	0.6	0.2	0.2	7
SI-Dolomite	-0.7	0.8	-0.2	0.5	7
SI-Gypsum	-2.5	-2.3	-2.4	0.1	7
T.C MPN/100ml	0.0	130	32.6	48.8	7
F.C MPN/100ml	0.00	23	7.6	9.9	7
T.H mg/l	188.7	225.4	207.7	14.7	7
SAR	0.1	0.5	0.3	0.1	7
TDS mg/l	228.7	262.6	242.9	11.8	7
Na/Cl	0.3	0.9	0.6	0.3	7
Cl-Na/Mg	0.03	0.5	0.3	0.2	7

Table (5.14): Descriptive Statistic of Cluster No.1 (Historical Samples)

Variable	Minimum	Maximum	Mean	St.Dev	N
EC μS/cm	320	510	446.1	38.2	29
pH-Value	7.4	8.3	7.8	0.2	29
Ca mg/l	36.4	82.8	60.1	12.5	29
Mg mg/l	4.9	25.5	13.5	6.2	29
Na mg/l	6.9	29.9	13.9	4.9	29
K mg/l	0.4	5.9	1.6	1.3	22
Cl mg/l	18.4	39.1	26.5	5.9	29
HCO_3 mg/l	134.8	262.3	198.9	31.6	29
SO_4 mg/l	1.9	28.8	12.6	7.7	29
NO_3 mg/l	2.0	82.3	32.9	21.7	25
SI-Anhydrite	-3.6	-2.4	-2.9	0.3	29
SI-Aragonite	-0.2	0.5	0.2	0.2	29
SI-Calcite	-0.1	0.7	0.3	0.2	29
SI-Dolomite	-0.7	1.2	0.2	0.5	29
SI-Gypsum	-3.4	-2.1	-2.6	0.3	29
T.H mg/l	133.5	279.8	205.3	25.4	29
SAR	0.2	0.8	0.4	0.1	29
TDS mg/l	170.9	408.5	255.5	41.3	29
Na/Cl	0.4	1.3	0.8	0.2	29
Cl-Na/Mg	-0.2	0.6	0.2	0.2	29

Table (5.15): Descriptive Statistic of Cluster No.2 (Recent Samples)

Variable	Minimum	Maximum	Mean	St.Dev	N
E-Coordinate	215.1	223	218.9	3.4	8
N-Coordinate	187.9	193.6	190.6	2.1	8
Altitude	470	870	715	141.9	8
EC µS/cm	487	536	513	15.2	8
pH-Value	7.3	7.8	7.6	0.2	8
Ca mg/l	61	78.2	69.1	5.4	8
Mg mg/l	9.3	18.8	14.3	3.2	8
Na mg/l	9.2	27.6	14.9	6.3	8
K mg/l	0.9	2.5	1.6	0.6	8
Cl mg/l	23.1	38.9	32.2	5.4	8
PO_4 mg/l	0.001	0.07	0.02	0.02	8
Temp C	16.7	23.2	19.1	2.6	8
HCO_3 mg/l	175.2	235	212.9	20.5	8
SO_4 mg/l	12	25.2	17.4	4.1	8
NO_3 mg/l	11.5	53.9	31.3	15.6	8
SI-Anhydrite	-2.7	-2.5	-2.6	0.1	8
SI-Aragonite	-0.2	0.3	0.06	0.2	8
SI-Calcite	-0.1	0.4	0.2	0.2	8
SI-Dolomite	-0.5	0.4	-0.01	0.3	8
SI-Gypsum	-2.4	-2.2	-2.3	0.1	8
T C MPN/100ml	0.0	350	57.9	118.9	8
F C MPN/100ml	0.00	26	7	8.2	8
T.H mg/l	214.3	247	231.2	12.6	8
SAR	0.3	0.8	0.4	0.2	8
TDS mg/l	252.8	326.1	287.3	21.3	8
Na/Cl	0.5	1.1	0.7	0.2	8
Cl-Na/Mg	-0.1	0.4	0.2	0.2	8

5.4.3.2 Group 0-b.

Calcium and bicarbonate are the dominate cation and anion respectively in this cluster for the recent and historical data.

About 17.4% of the recent and 27.3% of the historical data, fall in this cluster. The average electrical conductivity and pH of the recent data is 513 µS/cm and 7.59 and of the historical data the mean electrical conductivity was 523.19 µs/cm and the mean pH-value was 7.66. Table (5.15) and (5.16) show the descriptive statistics of this cluster for the recent and historical data respectively. The main characteristics of this cluster are similar to that of cluster (1).The only difference is in that NO_3 rates are greater than SO_4.

Table (5.16): Descriptive Statistic of Cluster No.2 (Historical Samples)

Variable	Minimum	Maximum	Mean	St.Dev	N
EC µS/cm	470	620	523.1	27.9	69
pH-Value	7.2	8.4	7.7	0.3	69
Ca mg/l	51.2	90.8	74.8	2.3	69
Mg mg/l	3.4	28.9	13.6	5.3	69
Na mg/l	6.9	25.3	13.9	4.4	69
K mg/l	0.4	9.0	2.2	1.7	45
Cl mg/l	17	54	26.8	7.3	69
HCO_3 mg/l	175	294	249.6	26.9	69
SO_4 mg/l	1.9	38.4	10.4	5.9	69
NO_3 mg/l	2.6	81.3	24.8	17.7	64
SI-Anhydrite	-3.5	-2.2	-2.9	0.3	69
SI-Aragonite	-0.3	1.1	0.3	0.3	69
SI-Calcite	-0.2	1.2	0.4	0.3	69
SI-Dolomite	-0.8	2.1	0.3	0.7	69
SI-Gypsum	-3.3	-1.9	-2.6	0.3	69
T.H mg/l	215.7	277.7	242.3	15.3	69
SAR	0.2	0.7	0.4	0.1	69
TDS mg/l	239	360.9	288.7	26	69
Na/Cl	0.4	1.3	0.8	0.2	69
Cl-Na/Mg	0.3	0.7	0.2	0.2	69

5.4.3.3 Group 0-c

In this cluster the dominante cation is calcium ion and it represents 64.4% of the total cation for recent data and 62.5% for the historical data, whereas bicarbonate ion is the major anion and represents 73.9% of total anions for recent data and 77.5% for the historical data. The average electrical conductivity has reached 561.58 µS/cm and pH- value 7.33 for recent data and 614.78 µS/cm and 7.56 for historical data. The characteristics of this cluster is similar to that of cluster 1. Descriptive statistics of the all parameters in the water samples which belong to this cluster are shown in Table (5.17) & (5.18) for the recent and historical data respectively.

Table (5.17): Descriptive Statistic of Cluster No.3 (Recent Sample)

Variable	Minimum	Maximum	Mean	St.Dev	N
E-Coordinate	215.1	222.6	218.2	3.4	12
N-Coordinate	187.9	194.8	191.7	2.0	12
Altitude	470	910	668.3	187.5	12
EC µS/cm	532	589	561.6	19.2	12
pH-Value	7.1	7.8	7.3	0.2	12
Ca mg/l	68	82	75.7	4.4	12
Mg mg/l	12.2	23.1	17.3	3.3	12
Na mg/l	7.1	20.2	14.3	3.6	12
K mg/l	0.2	8.2	1.9	2.4	12
Cl mg/l	26.6	39.1	30.5	3.9	12
PO_4 mg/l	0.007	0.081	0.032	0.021	12
Temp C	16.6	25.9	21.9	3.1	12
HCO_3 mg/l	226.6	284.3	254.8	18.5	12
SO_4 mg/l	13.2	25.3	20.3	3.4	12
NO_3 mg/l	2.9	33.5	13.8	9.4	12
SI-Anhydrite	-2.7	-2.4	-2.5	0.1	12
SI-Aragonite	-0.3	0.3	-0.1	0.2	12
SI-Calcite	-0.2	0.4	0.1	0.2	12
SI-Dolomite	-0.7	0.5	-0.2	0.4	12
SI-Gypsum	-2.4	-2.1	-2.2	0.1	12
T.CMPN/100ml	0.0	2400	248.1	685.9	12
FC MPN/100ml	0.0	540	56.1	153.7	12
T.H mg/l	236.8	284.6	260.0	12.5	12
SAR	0.2	0.6	0.4	0.1	12
TDS mg/l	278.9	335.3	301.2	15.3	12
Na/Cl	0.4	0.95	0.7	0.2	12
Cl-Na/Mg	0.03	0.5	0.2	0.1	12

5.4.3.4 Group 0-d

In this cluster also the calcium and bicarbonate are the dominant cation and anion for all analyzed sample. 41.3% for the recent data and 25.6% for the historical data belong to this cluster. It has an electrical conductivity average of 634.79 µS/cm and a pH average of 7.36 for the recent water sample, and 737.49 µS/cm and 7.58 , for the historical data.The main characteristics of this group(including recent and historical data) are :

$Ca^{++} > Mg^{++} > (Na^{+} + K^{+})$

$HCO_3^{-} > Cl^{-} > NO_3^{-} > SO_4^{--}$

$HCO_3^{-} > Ca^{++}$

(Na/Cl) < 1

((Cl-Na)/Mg) < 1.

Table (5.19) and (5.20) show the descriptive statistics of all parameters that belong to this cluster for recent and historical data.

Generally all the mentioned water groups can be classified as calcium-bicarbonate waters.

Table (5.18): Descriptive Statistic of Cluster No.3 (Historical Samples)

Variable	Minimum	Maximum	Mean	St.Dev	N
EC µS/cm	555	672	614.8	32.2	90
pH-Value	7.1	8.2	7.6	0.3	90
Ca mg/l	62	103.6	81.5	8.1	90
Mg mg/l	4.4	31.7	20.4	5.8	90
Na mg/l	4.6	32.2	15.9	4.9	90
K mg/l	0.4	8.2	3.1	1.9	64
Cl mg/l	13.1	50.4	30.3	7.0	90
HCO_3 mg/l	197.6	380	305.9	35.4	90
SO_4 mg/l	1.9	31.2	11.6	6.3	90
NO_3 mg/l	1.6	73.1	22.3	16.2	88
SI-Anhydrite	-3.6	-2.3	-2.8	0.3	90
SI-Aragonite	-0.2	0.9	0.3	0.2	90
SI-Calcite	-0.1	1	0.4	0.2	90
SI-Dolomite	-0.6	1.9	0.5	0.5	90
SI-Gypsum	-3.3	-2.1	-2.5	0.3	90
T.H mg/l	232.2	341.3	286.9	21.9	90
SAR	0.1	0.9	0.4	0.1	90
TDS mg/l	267.5	437.2	336.4	26.2	90
Na/Cl	0.3	1.6	0.8	0.2	90
Cl-Na/Mg	-0.3	0.6	0.1	0.1	90

Table (5.19): Descriptive Statistic of Cluster No.4 (Recent Samples)

Variable	Minimum	Maximum	Mean	St.Dev	N
E-Coordinate	213	221.5	219.4	2.4	19
N-Coordinate	186.9	194.1	191.5	1.9	19
Altitud	270	890	670.6	157	19
EC µS/cm	587	732	634.8	31.18	19
pH-Value	7	7.9	7.4	0.4	19
Ca mg/l	62	90	77.8	6.5	19
Mg mg/l	10.9	26.7	18.4	4.4	19
Na mg/l	13.2	41.0	23.3	7.3	19
K mg/l	0.5	19.3	4.6	4.4	19
Cl mg/l	30.2	67.5	44.1	8.8	19
PO_4 mg/l	0.001	0.15	0.1	0.04	19
Temp. C	16.6	27.2	20.2	3.2	19
HCO_3 mg/l	164.1	288	243.1	29.5	19
SO_4 mg/l	16.6	42.7	26.5	7.1	19
NO_3 mg/l	11.7	88.0	37.5	21.0	19
SI-Anhydrite	-2.6	-2.2	-2.4	0.1	19
SI-Aragonite	-0.4	0.3	-0.1	0.2	19
SI-Calcite	-0.2	0.4	0.1	0.2	19
SI-Dolomite	-0.7	0.4	-0.2	0.4	19
SI-Gypsum	-2.9	-2.0	-2.2	0.2	19
T.C MPN/100ml	0.0	2400	365.7	737.0	19
F.C MPN/100ml	0.0	2400	268.9	633.5	19
T.H mg/l	237.3	302.1	269.9	14.3	19
SAR	0.3	1.2	0.6	0.2	19
TDS mg/l	311.9	420.2	353.8	26.1	19
Na/Cl	0.5	1.1	0.8	0.1	19
Cl-Na/Mg	-0.1	0.3	0.2	0.1	19

Table (5.20): Descriptive Statistic of Cluster No.4 (Historical Samples)

Variable	Minimum	Maximum	Mean	St.Dev	N
EC µS/cm	680	900	737.5	49.8	65
pH-Value	7.05	8.4	7.6	0.3	65
Ca mg/l	59.2	120	90.6	12.8	65
Mg mg/l	8.3	47.9	22.8	9.1	65
Na mg/l	13.8	36.8	24.0	4.9	65
K mg/l	0.4	19.6	7.6	4.9	59
Cl mg/l	31.2	105.6	47.9	10.2	65
HCO_3 mg/l	220.8	387.4	307.4	31.5	65
SO_4 mg/l	1.4	61.9	23.1	15.1	65
NO_3 mg/l	9.8	89	44.6	18.8	62
SI-Anhydrit	-3.6	-2.0	-2.5	0.3	65
SI-Aragonit	-0.2	1.1	0.3	0.3	65
SI-Calcit	-0.1	1.3	0.5	0.3	65
SI-Dolomite	-0.5	2.1	0.6	0.7	65
SI-Gypsum	-3.3	-1.8	-2.3	0.3	65
T.H mg/l	266.3	381.9	319.5	26.3	65
SAR	0.3	0.8	0.6	0.1	65
TDS mg/l	342	547.5	411.6	38.4	65
Na/Cl	0.5	0.03	0.8	0.1	65
Cl-Na/Mg	0.9	0.6	0.2	0.1	65

5.4.4 Factor Analysis.

Factor analysis is a mathematical model which attempts to explain the correlation between a large set of variable in terms of smaller number of underlying factors. The factors are distinguished by a serial number 1, 2... n. The individual factors correlate differently with the original variables. The significance of the factor analysis is that any factor with high different factor loading gives an idea about the variables which depends on each other (Davis,1973)

The factor analysis used in this study was performed by using a computer statistical program (Geo-500,1988).

The data were analyzed in R-mode varimax factor rotation. It is concerned with an inter-relationship of variables, linear combination of the original variable. varimax - rotation : one factor will be declared only through one variable.

In this study three factors of the different chemical and physical variables were considered through varimax factor analysis for the historical and for the data collected during the completion of this study were distinguished. They include the major cations, major anions, fecal coliform and total coliform. Tables (5.21& 5.22). The interpretation of the different factors for the recent and historical data is explained below :

5.4.4.1 Varimax Rotation Factors:

Factor 1: Salinity Factor, EC, Cl, Na, SO_4, NO_3, K, Ca and Mg (positive relation)

Factor 2: pollution factor, TC, FC, K and EC (Positive relation)

Factor 3: Carbonate system factor, pH (negative relation), Ca, Mg, HCO_3 and EC (Positive relation)

Factor 1(salinity factor)

This factor has high loading on EC (electrical conductivity) and different variables which are in relation of the EC, such as Cl, Na, SO_4, NO_3, K, Ca and Mg. This factor explains about 30.9% (recent data) and 36.4% (historical data) of the total variance. Therefore, any increase in the concentration of the above mentioned variables will increase the electrical conductivity. However, by increasing the EC, which correlates positively with these variables, the concentration of Cl, Na, SO_4, K .... etc. will increase as it was in all groups of recent and historical data. Consequently, this factor indicates the salinity parameters, which are clearly observed by the cluster analysis of water group. This phenomena can be interpreted

Table (5.21): Varimax Rotation Factors Analysis (Recent Data)

Variable	Factor 1	Factor 2	Factor 3	Commun
Cl mg/l	0.9500			0.919
Na mg/l	0.9391			0.900
NO3 mg/l	0.7675			0.863
SO4 mg/l	0.7995			0.630
EC µS/cm	0.6607	0.3447	0.6286	0.951
FC MPN/100ml		0.9140		0.848
TC MPN/100ml		0.8942		0.801
K mg/l	0.4409	0.7035		0.711
Ca mg/l			0.5968	0.496
HCO3 mg/l			0.9389	0.933
Mg mg/l	0.3136		0.8371	0.850
pH			-0.4594	0.290
SS	3.7107	2.8656	2.6158	9.192
VA %	30.9222	23.8797	21.7984	76.600

Table (5.22): Varimax Rotation Factors Analysis (Historical Data)

Variable	Factor 1	Factor 2	Factor 3	Commun
NO3 mg/l	0.8931			0.860
Cl mg/l	0.8684			0.896
Na mg/l	0.8525			0.836
K mg/l	0.7651			0.689
EC µS/cm	0.6122	0.5640	0.4751	0.919
Mg mg/l		0.9300	0.6321	0.887
HCO3 mg/l		0.6844	0.6619	0.923
SO4 mg/l	0.5087	0.5414		0.557
Ca mg/l	0.3544	0.6421	0.8375	0.831
pH-value			-0.7614	0.541
SS	3.6428	2.2759	2.0194	7.936
VA %	36.4282	22.7592	20.1944	79.382

by the influence of dissolution processes or the natural water rock interaction

which plays a role in making the water reach its chemical composition. The composition of these waters is mainly attributed to the reaction of water with the carbonate rocks and clay mineral which are responsible for generation of new minerals, such as calcite, dolomite and gypsum which correlated with SO_4 positive.

Factor 2, (Pollution Factor)

The Pollution factor for the recent data explains about 23.9% of the total variance, and has no significance in the historical data. High positive relationship between TC and FC. This could attributed to the fact that FC is a subgroup of TC. Positive relation between both TC and FC with potassium as a pollution source, from the human activities, municipal waste water and fertilizer uses for agriculture, all of these variables show positive relationship with EC.

Factor-3 (Carbonate system factor)

This factor explains about 21 percent for the recent data and 20% in the historical data (factor 3 in table 5.20, 5.21). This factor shows positive relation of Ca, Mg and HCO_3, with negative relation of pH-value.

Therefore , there is a direct relationship between HCO_3 , Ca and Mg and reverse relationship between these variables and the pH value. This indicates that Mg, HCO_3 and Ca increases as pH- value decreases. On the other hand factor 2 in the historical data represent 22.7% of the total variance and is considered carbonate factor which contributes to salinity. This factor indicates the relationship between carbonate minerals (dissolution/ precipitation) and the sulfate minerals as gypsum.

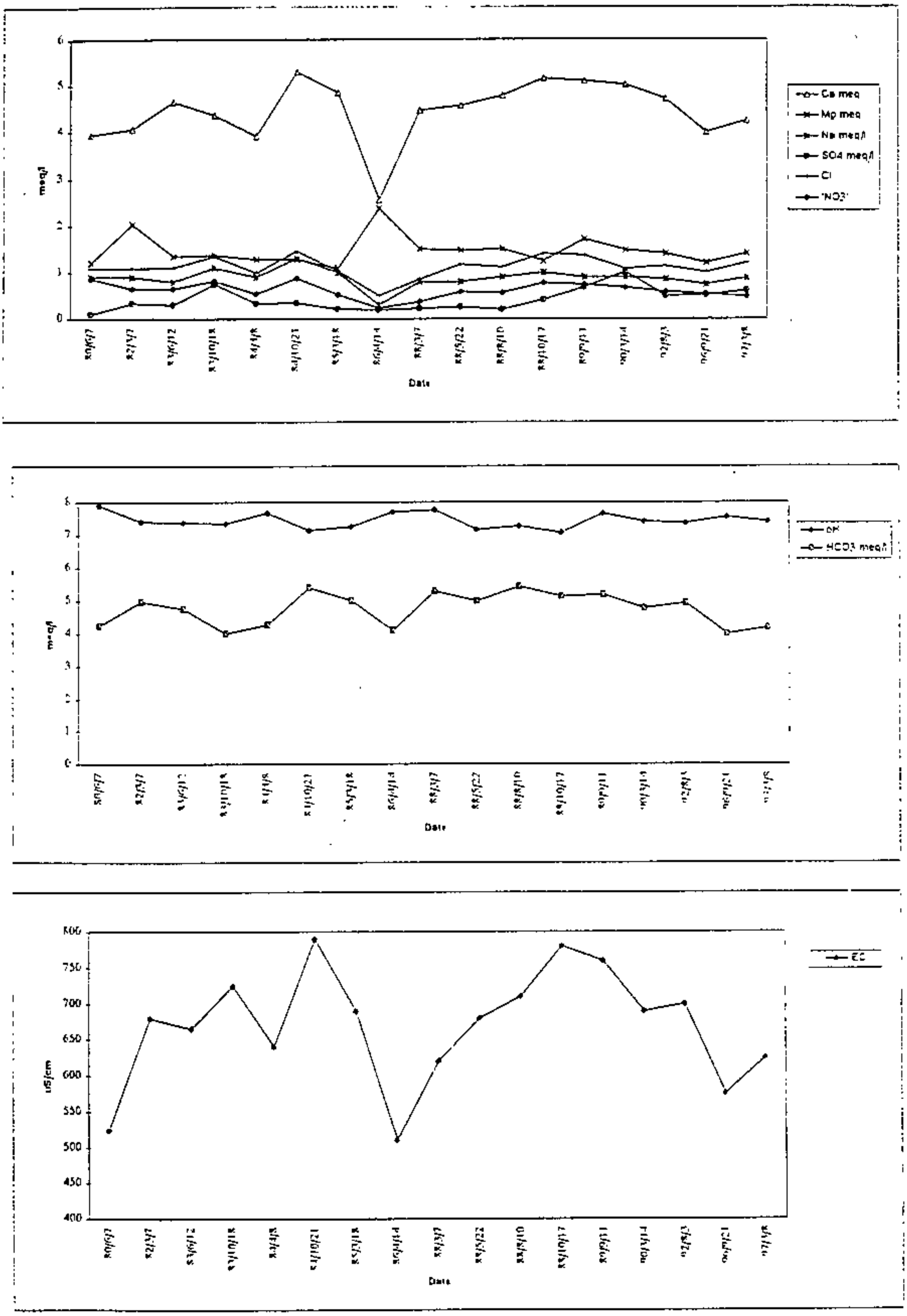
5.5 Temporal Fluctuation of the Different Chemical Parameters :

In order to show the seasonal fluctuation and change in the chemical composition of the group water, five springs have been selected, Ajlun and Anjara springs which are emerging from A4 aquifer, Qantara and Deek springs which are emerging from the A1-2 aquifer and Agdeh from A7 aquifer. The relation between electrical conductivity with time and also the relation of the major ions, sodium, chloride, calcium, magnesium, and sulfate with time will be discussed below.

5.5.1 Springs emerging from A1-2 aquifer systems.

These springs are Qantara (located in the Ajlun town), and Deek (located adjacent Wadi Kufrinja stream down stream of the Kufrinja town).

Fig (5-11, a, b) shows the fluctuation of the major ions, pH and EC as a function of time for the Qantara spring. It can be seen that all the ions maintain their original values which are < 5 meq/l, except during the year 1984. EC increased from 640 μS/cm in April to reach the maximum electrical conductivity of 790 μS/cm, and other ions such as Ca (5.3 meq/l), NO_3 (0.88 meq/l) Cl (1.45 meq/l) Na (1.3 meq/l) and K (0.4 meq/l) in October 1984. This is attributed to the irrigation return flow, high precipitation, combined with the wastewater from the cesspools in the Ajlun



.(5.11): Fluctuation of Major Anion (mg/l) With Time (a), pH and HCO_3 With Time (b), EC (μS/cm) With Time (c) for the Qantara Spring

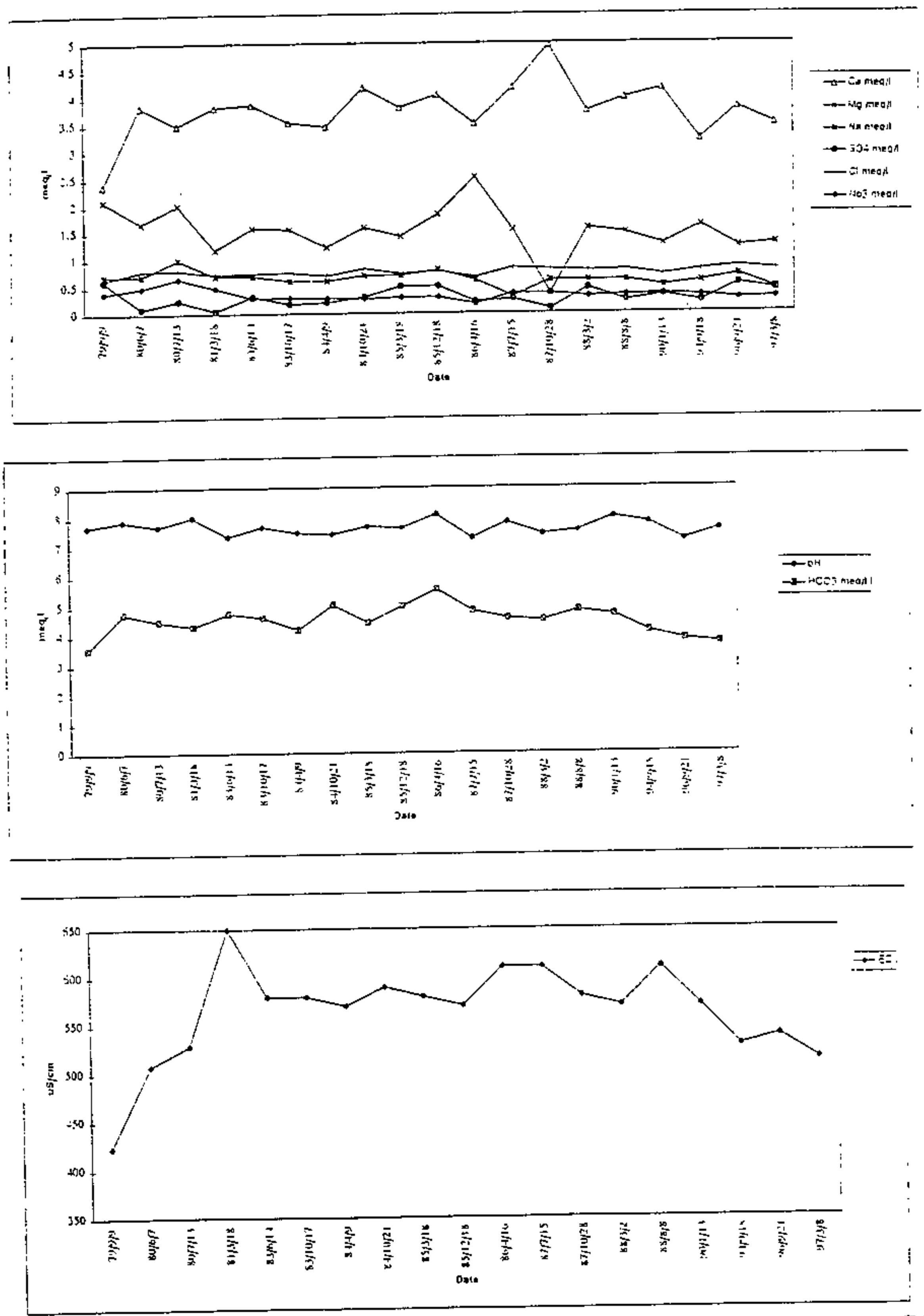


Fig.(5.12): Fluctuation of Major Anion (mg/l) With Time (a), pH and HCO_3 With Time (b), EC (μS/cm) With Time (c) for the Deek Spring town. The lowest value for the EC is 510 μS/cm in April 1986, and the same data represents the maximum value for the Mg ion (2.38 mg/l). Fig. (5.11, b) shows that the pH ranged between 7.14-7.9 and shows the inverse relation between pH and HCO_3.

The fluctuation of the Deek springs constituents are shown in Fig. (5-12, a, b, c). It can be seen that the bicarbonate ion represent the highest concentration of all ions in contrary SO_4 ion has the lowest concentration. Most of the ions concentration maintain their values between 0.1-1 meq/l such as NO3, SO4, Na and Cl. Fig (5-12, b) shows the behavior of the pH - value which ranges between 7.18-8.08 with the inverse relation with bicarbonate. The EC of water ranged from 423 μS/cm during the year 79/80 to value 650 μS/cm during the year 81/82 Fig. (5.12,c).

5.5.2 Springs Emerging from A4 Aquifer System.

These springs are Ajlun and Anjara. Ajlun spring is located in the center of Ajlun town. The behavior of the chemical composition of Ajlun spring is similar to the Qantara spring. From the Fig. (5.13, a) it can be seen that the maximum value of electrical conductivity 900 μS/cm was recorded in October 1984. In addition values of (6 meq/l) , (5.24 meq/l) (1.44 meq/l) were repated for Ca, HCO_3 and NO_3 respectively. The concentration of t Na,

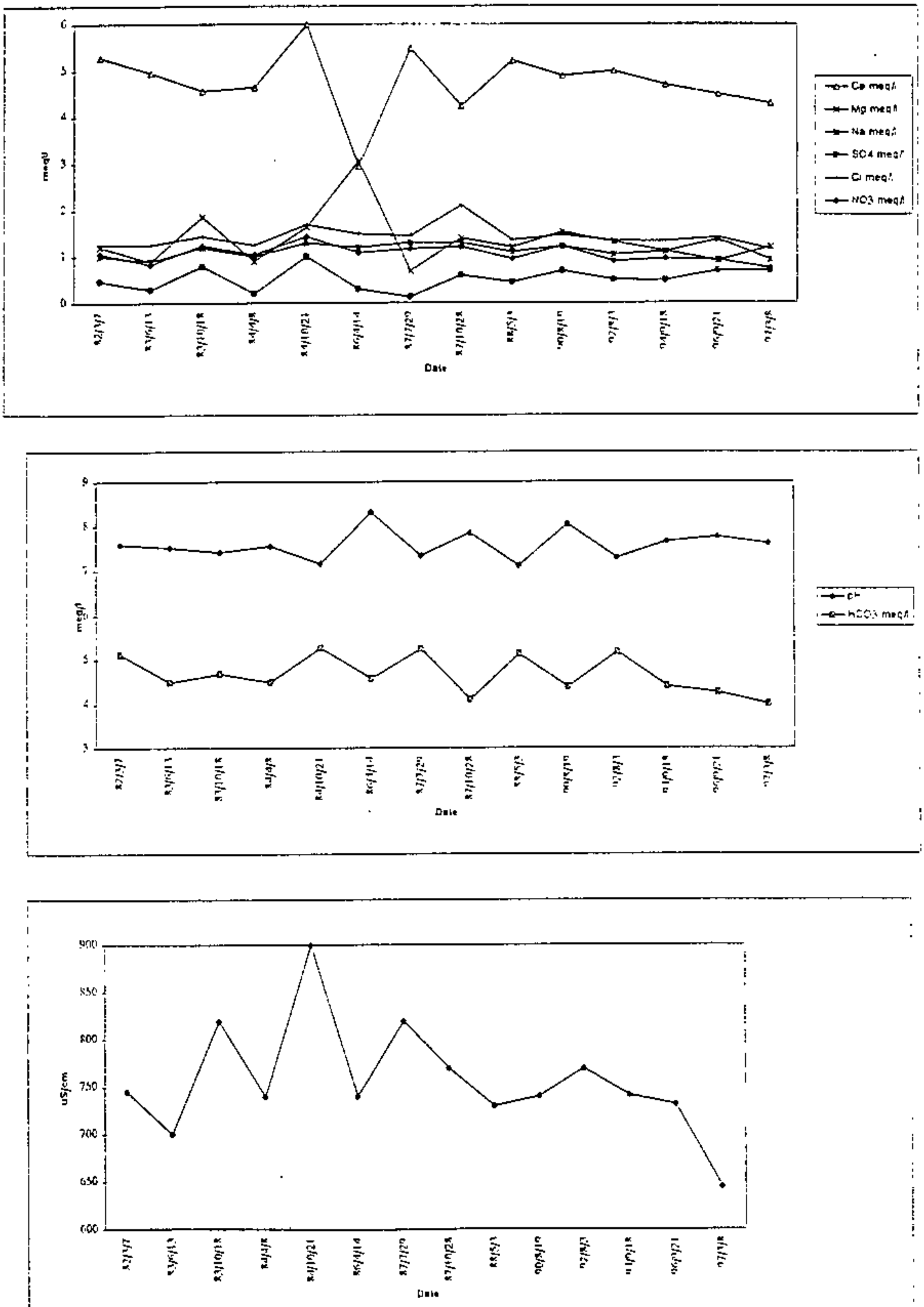


Fig.(5.13): Fluctuation of Major Anion (mg/l) With Time (a), pH and HCO_3 With Time (b), EC (μS/cm) With Time (c) for the Ajlun Spring

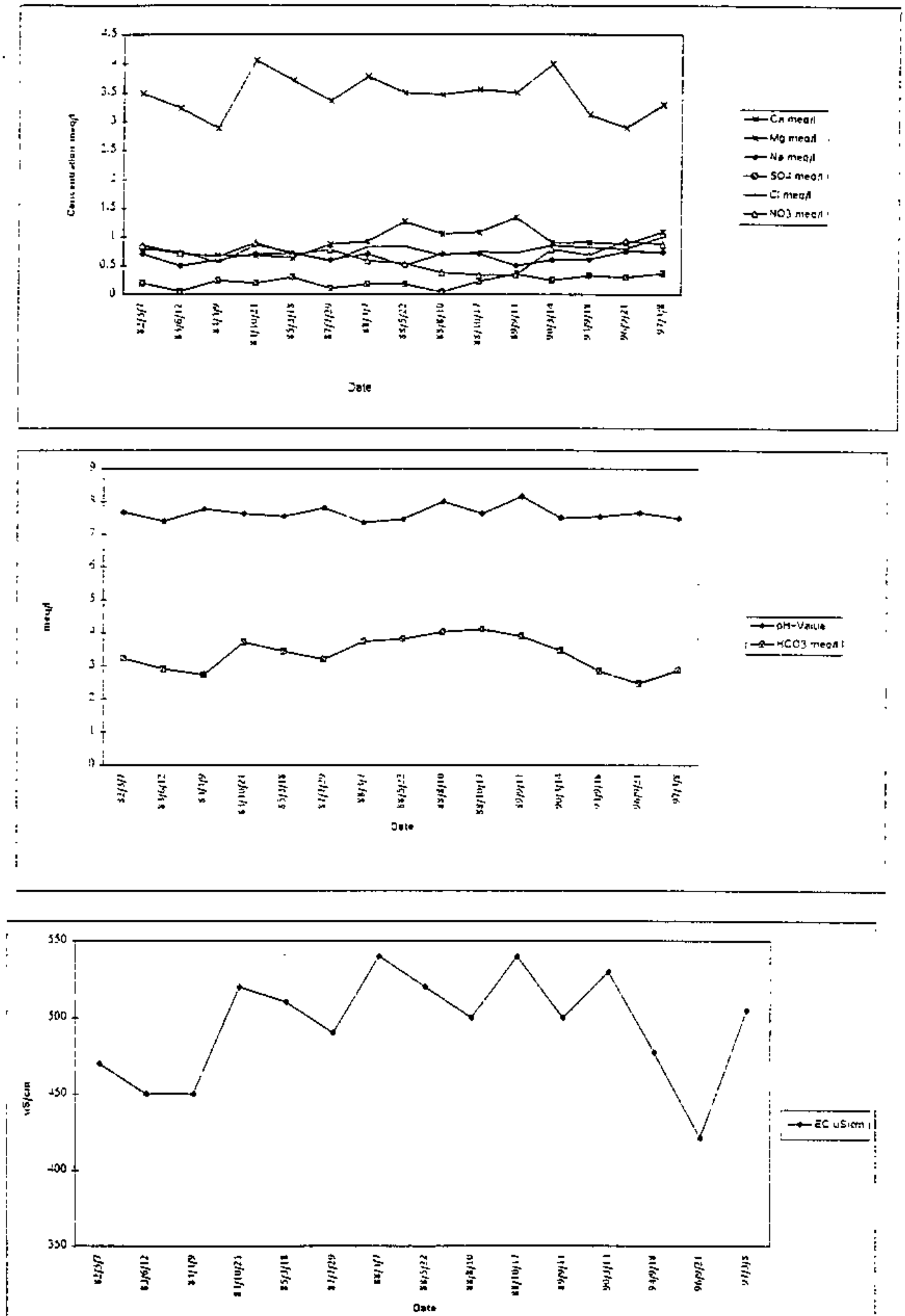


Fig.(5.14): Fluctuation of Major Anion (mg/l) With Time (a), pH and HCO_3 With Time (b), EC (μS/cm) With Time (c) for the Anjara Spring

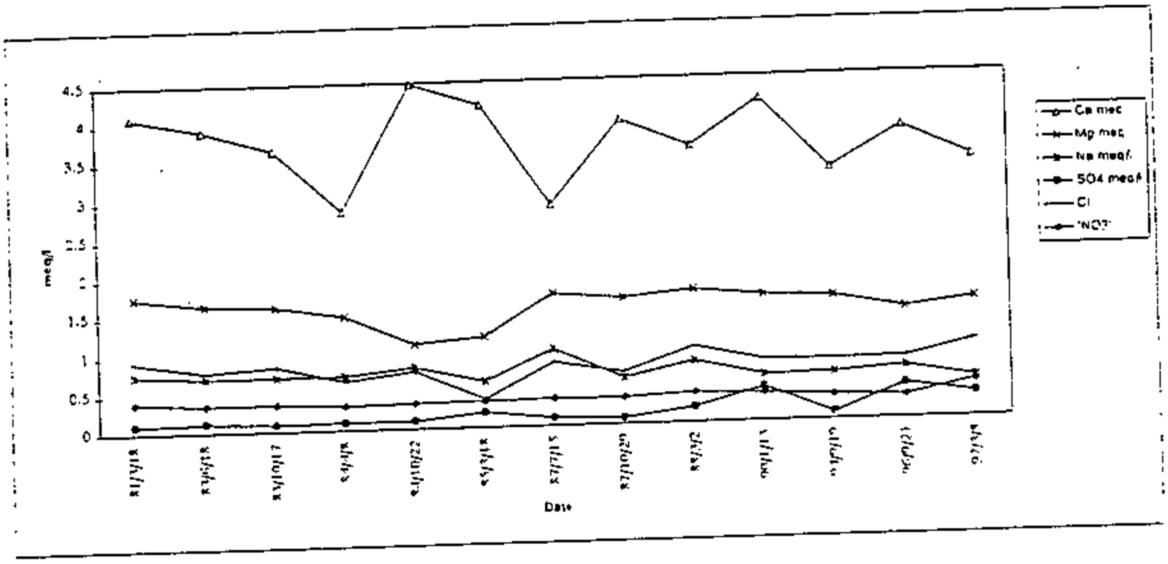
Cl, NO_3 and SO_4 ranges between 0.1 to 2.5 meq/l and the EC ranges between 645 μS/cm to 900 μS/cm Fig (5.13, c). The fluctuation is attributed the rainfall amount and stimulanearly to volume of infiltration.

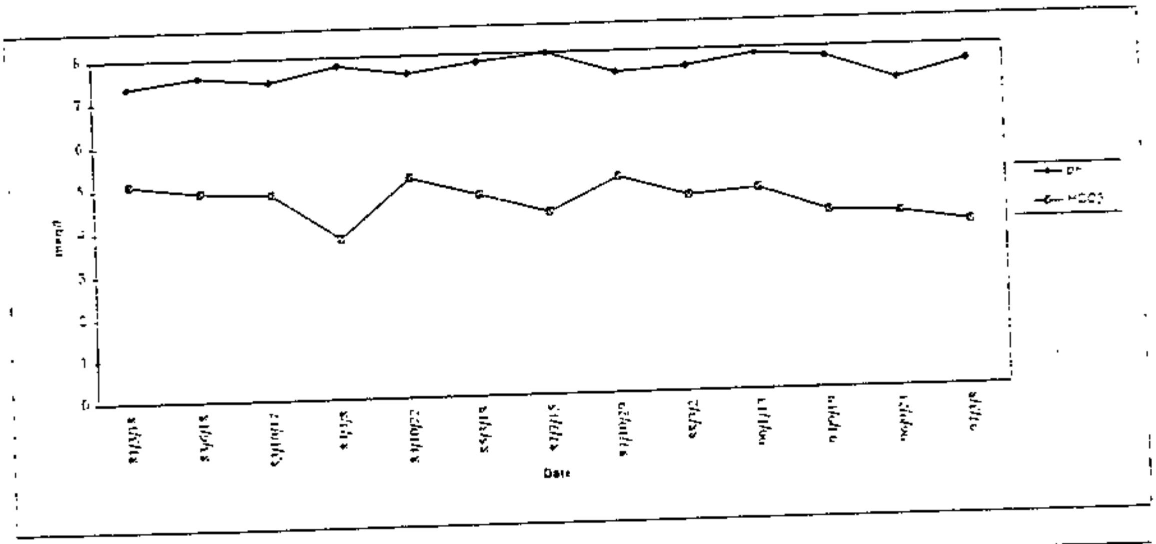
Fig. (5.13, b) shows the relation between pH and HCO_3 with time, pH ranges between 7.1 to 8.32.

Fig. (5.14, a) shows the fluctuation of the major ions as a function of time for the Anjara spring. It can be seen that all ions maintain constant values and pH ranges between 7.4 to 8.16 Fig. (5-14-b). The EC of water ranged between 7.4 to 8.16 Fig. (5.14, c).

5.5.3Spring Emerging from A7 Aquifer System.

One spring emerges from this aquifer system which is Aqdeh spring. This spring is similar to the previous springs. All major ions maintain their minimum concentrations ranging between 0.11 to 4.5 meq/l Fig. (5.15, a), and the pH value ranges between 7.2 to 7.99 Fig. (5.15, b) and Fig. (5. 15, c) shows the behavior of the EC, the minimum and maximum EC values are 525 and 660 μS /cm respectively.





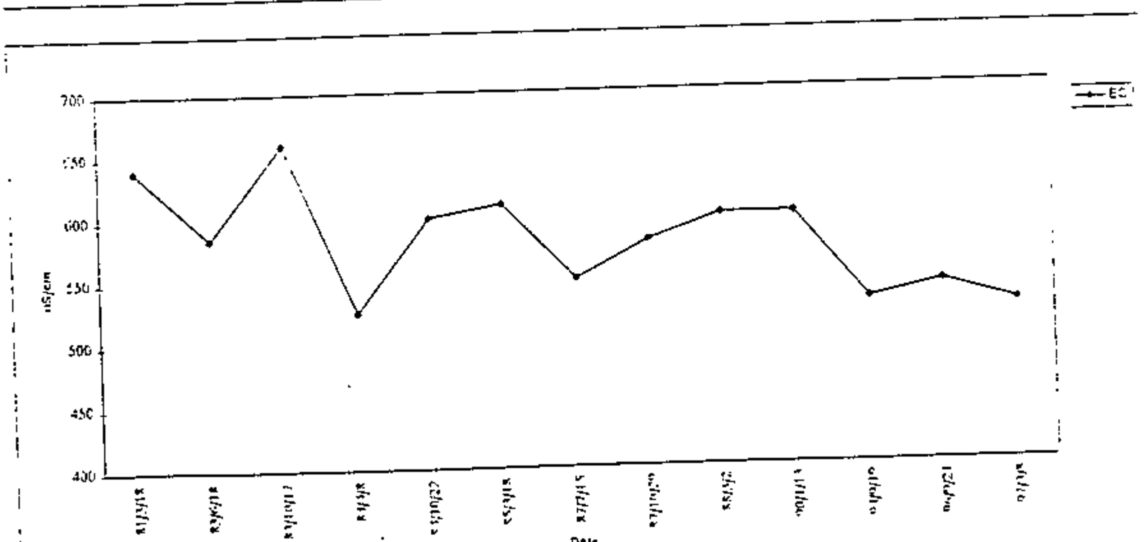


Fig.(5.15): Fluctuation of Major Anion (mg/l) With Time (a), pH and HCO_3 With Time (b), EC (µS/cm) with time (c) for the Aqdeh Spring

Chapter Six

Classification of the Water Samples and Quality Evaluation

6.1 Water Samples Classification

Different methods have been employed for studying the water quality variation by using many representation techniques. For studying the water quality variation, representation of hydrochemical data was performed in order to determine type of water and some of the processes involved in the chemical evaluation of springs water.

To represent data for interpretation some techniques were used, Piper diagram (Piper, 1944) and Durov diagram (Lloyed & Heathcote, 1985).

6.1.1. Classification of Water Quality Using Piper Diagram.

This classification was carried out by plotting the data on trilinear diagram (Piper, 1944), thereafter, they are assisted depending on Langguth classification (1966), Fig. (6.1), illustrates the classification of water types. This classification is based on the concentration of four major cations, sodium, potassium, calcium and magnesium, and the four major anions bicarbonate, sulfate, chloride and nitrate. Fig. (6-2,a, b), represents the Piper plotting of the samples for the two periods September 1996 and March 1997.

- First type(a):

Normal earth alkaline water with prevailing bicarbonate. This type represents around 91.3% of the total water samples in the study area. The chemistry of these water originates from the dissolution of carbonate rocks. The water is generally classified as Ca-HCO_3 water with low salinity and with the following ionic ratios:

Ca > Mg > (Na +K)

HCO3 > CI > SO4 > NO3 or in some cases

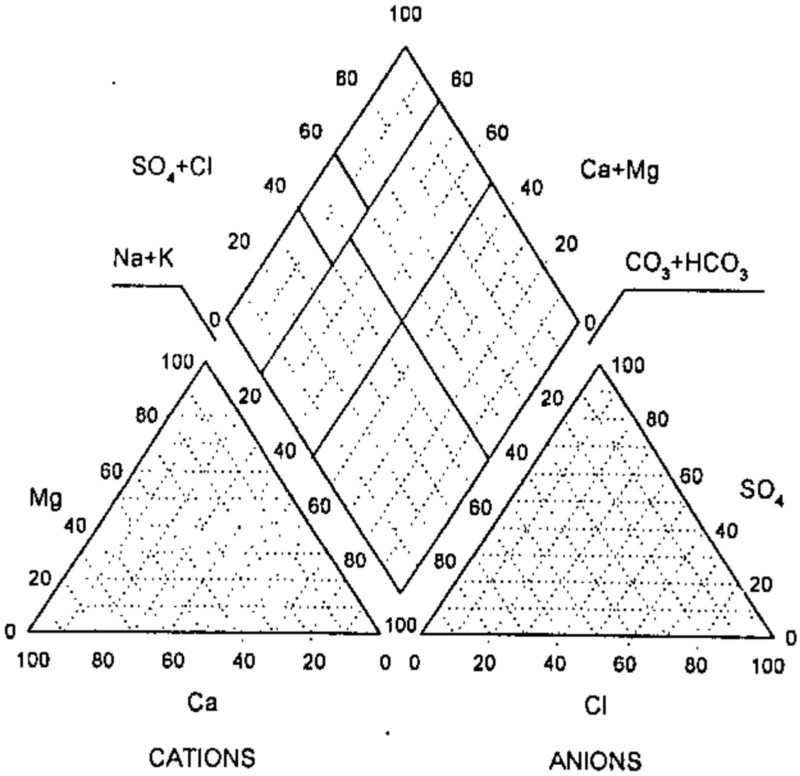
HCO3 > CI > NO3 > SO4

- Second type(d):

Alkaline earth water with increased portion of alkalis and prevailing bicarbonate. Around 8.7% of the water samples fall within this type especially those were collected from Ajlun and Haramiyah springs in the Ajlun town. The ionic ratios are similar to type one.

The Chemistry of this water type is governed by the dissolution of limestone and bituminous chalk.

Generally, the previous two types of water correspond to fresh ground water of contemporary recharge (Rimawi, 1985).



•Normal earth alkaline water:

a- With prevailing bicarbonate
b- With bicarbonate and sulfate (or chloride)
c- With prevailing sulfate (or chloride)

• Earth alkaline water with increased portion of alkalis:

d- With prevailing bicarbonate
e- With prevailing sulfate and chloride

•Alkaline water

f- With prevailing bicarbonate
g- With prevailing sulfate -chloride

Fig.(6-1): Classification of Groundwater According to Langguth (1966)

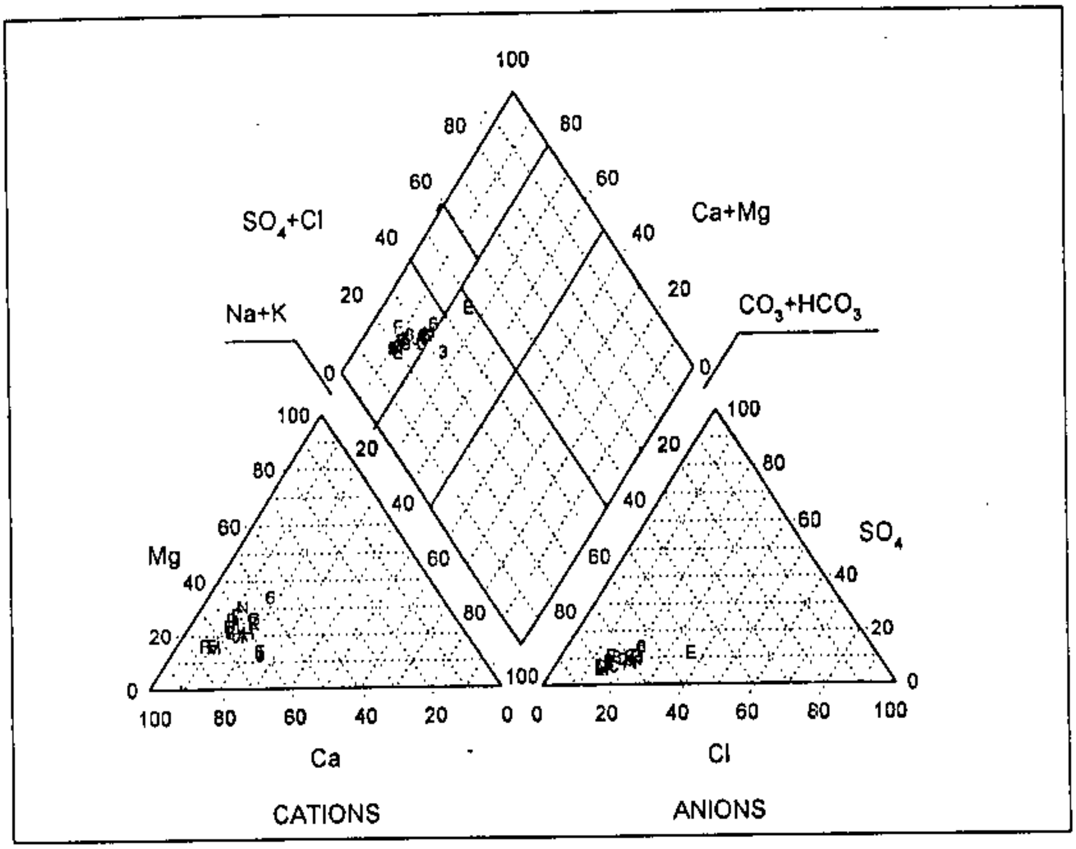


Fig.(6-2a):Trilinear Diagram of the Major Ions of the Water Samples Collected During September 1996

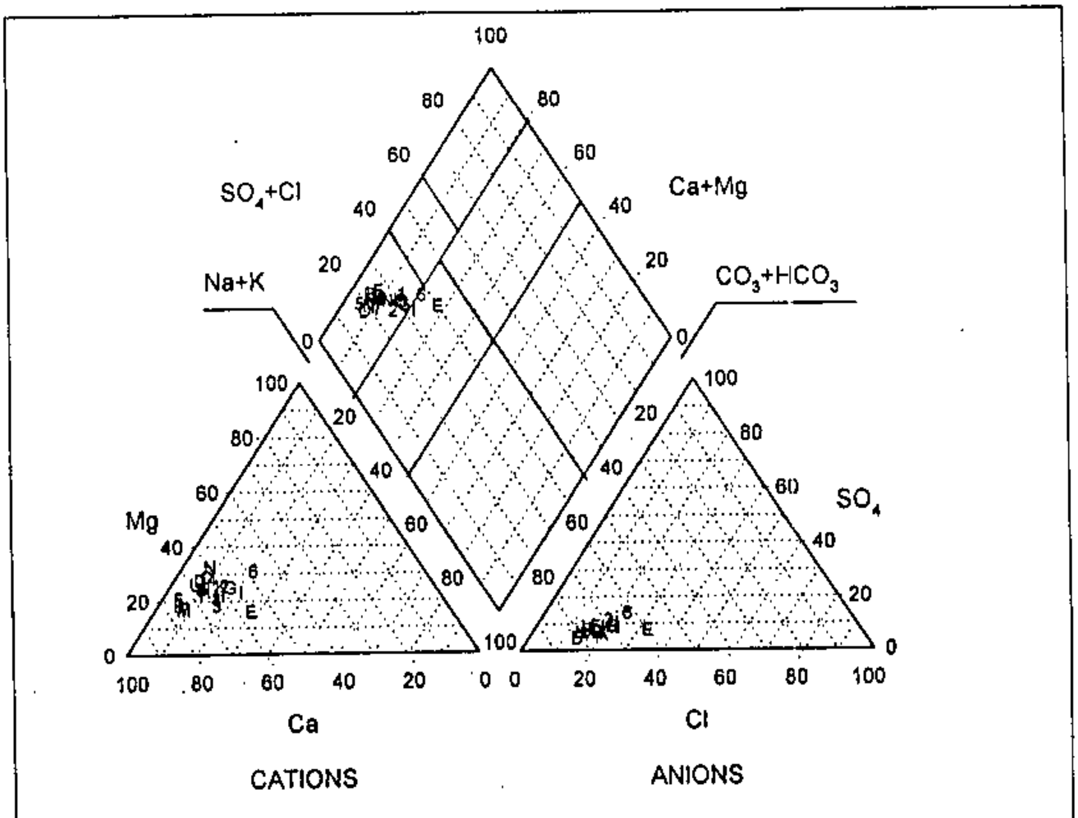


Fig.(6-2b):Trilinear Diagram of the Major Ions of the Water Samples Collected During March 1997

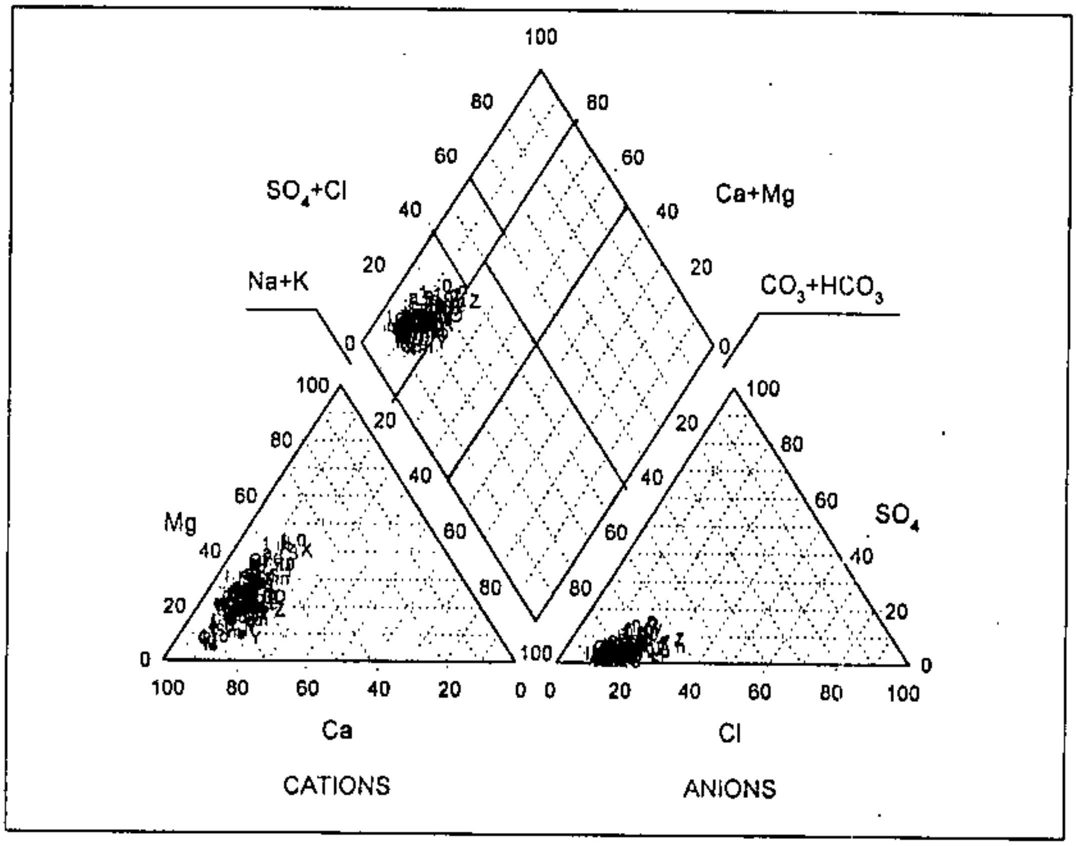


Fig.(6-3): Piper Trilinear Diagram of the Major Ions of Water Sample for all Historical Samples

6.1.2. Graphical Representation of Groundwater Samples on Durov Diagram.

Durov expanded diagram (1944), is based on the major cations (Ca, Mg, Na), and major anions (HCO3, Cl, SO4), where the total cations and anions together are considered as 100 percent. In order to explain the chemical processes during the reaction between the water and the rock matrix of the aquifer.

The cation and anion values are plotted in the appropriate triangle and projected into the square main nine fields. Water samples of two sample periods September 1996 and March 1997 were plotted on expanded Durov diagram (1944) Fig. (6.4 a, b). From the Fig. (6-4), about 95.7% of all sample fall in field (1).

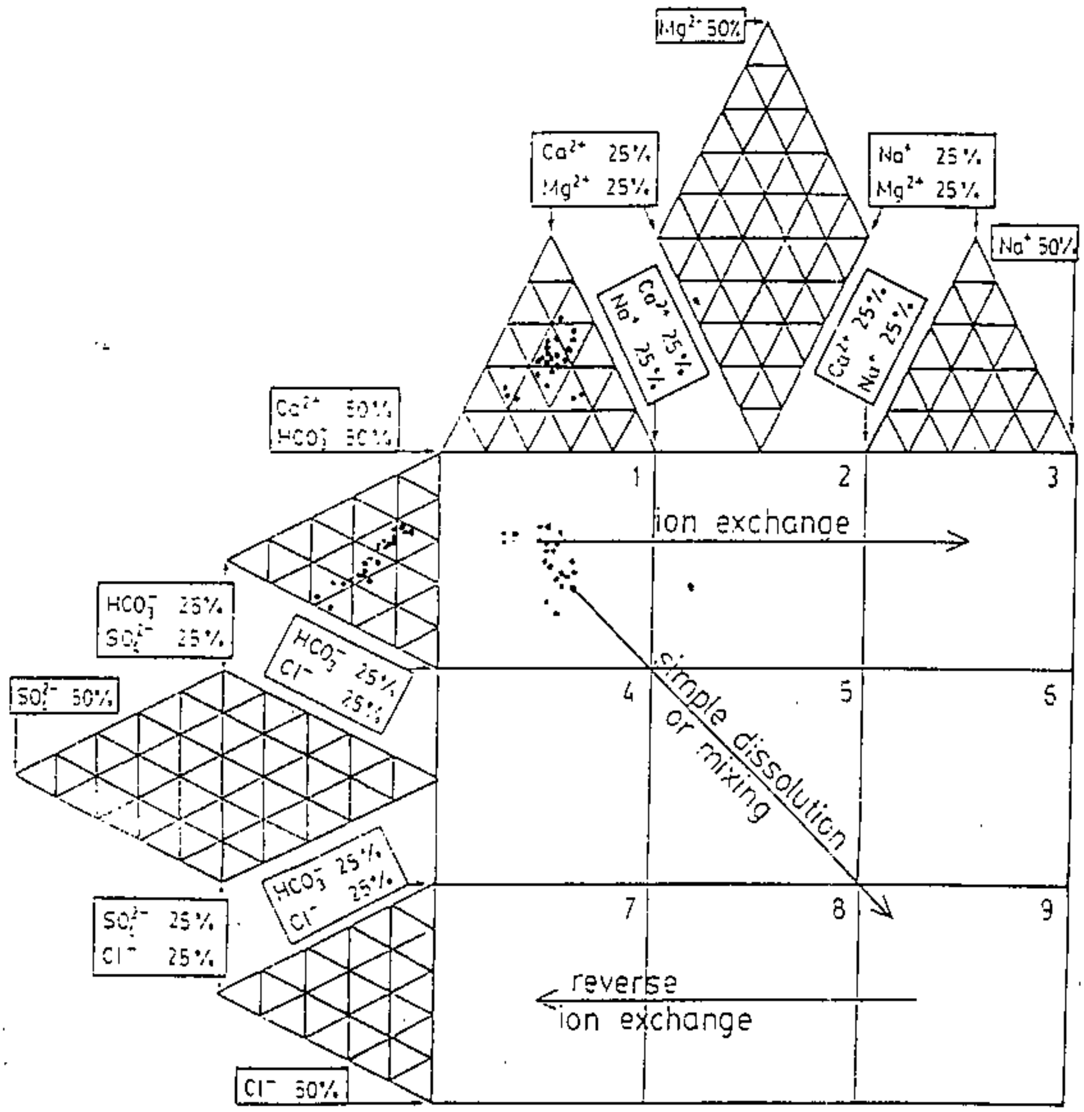


Fig.(6-4a): Expanded Durov Diagram for the Major Ions of the Water Samples Collected During September 1996

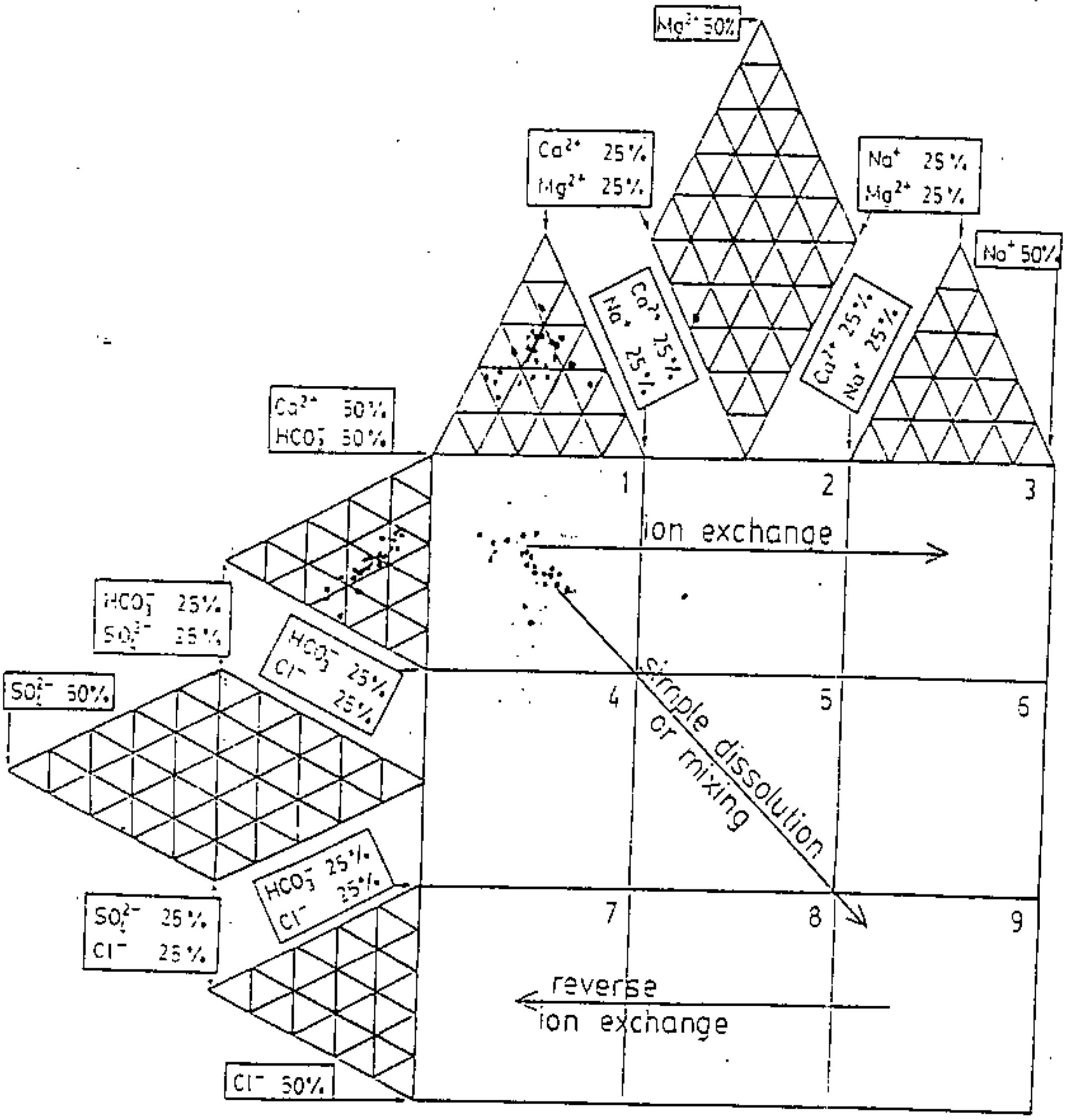


Fig.(6-4a): Expanded Durov Diagram for the Major Ions of the Water Samples Collected During March 1997

In this field HCO_3 and Ca^{++} are the dominant anions and cations respectively, indicating that the recharging water originate from limestone, dolomite and other carbonate rock.

- In Field (2) HCO_3 is the dominant anion and cations discriminate with Mg or Ca dominating. This indicates that waters are often associated with dolomite. One sample Birkeh spring fall in this field.

6.2 Water Quality Criteria

Water quality is the main factor which affects the suitability of water resources for various purposes. Several parameters were calculated to determine the suitability of the springs water quality for domestic and irrigation purposes, such as, hardness, soluble sodium percentage (SSP) and sodium adsorption ratio (SAR).

Both the calculated as well the measured parameters are compared to the standards of particular use. By this, the suitability of the water for any particular use is determined. The suitability and quality of the springs in the study area will be evaluated.

6.2.1. Domestic Water

Domestic water use encompasses the water supplied to housing areas, commercial districts, institutional facilities, and recreational facilities. The use of this water includes drinking, washing, bathing, culinary, waste removal, and yard watering. The quality of most of the water samples is defined to be suitable for human consumption and for all usual domestic purposes include personal hygiene(WHO,1995).

Short-term deviations above the guideline values do not necessarily mean that the water is unsuitable for consumption. The amount by which, and the period for which, any standard values can be exceeded without affecting public health depends upon the specific substances involved. Based on these guidelines the developing acceptable standards for drinking water vary from one country to another depending upon variety of geographical, socioeconomic, availability and nature of the water resources, usage, and the political situation.

Therefore, the Guidelines of the World Health Organization (WHO) differ from Jordanian Standards for Drinking Purposes, Jordanian Standards for Drinking Water (1990). For comparison the Jordanian Standard for Drinking Water (1990), and the WHO-Guideline(1995) are represented in Table (6.1) for evaluation process.

Table (6.1): Jordanian Standard and World Health Organization (WHO) Guidelines for Drinking Water (After WAJ, 1990), (WHO, 1995)

Parameters	Jordan Standard 1990	WHO Guidelines 1995	Source or Cause
Temp. °C	12-25	12-25	Earth's temperature or chemical reaction.
pH-value	6.5-9.0	6.5-8.5	Acids, PCO_2 lower, bicarbonate increase the pH-value.
Na (mg/l)	200-400	200	Dissolved from practically all rocks and soils, found also in sea water, brines and sewage.
Ca (mg/l)	75-200	75	Dissolved from all rocks and soils, but especially from limestone, dolomite and gypsum.
Mg (mg/L)	50-150	<125	Same as Ca. (Sedimentary rocks).
K (mg/L)	12	12	Sedimentary rocks. Wastes of man and livestock.
HCO3 (mg/L)	100-500	125-350	In most water, nearly all hardness is due to calcium and magnesium.
Cl (mg/L)	200-500	250	Dissolved from rocks and soils. Present in sewage, ancient brines and sea water.
SO_4 (mg/L)	200-500	250	Dissolved from rocks and soils containing gypsum, iron sulfides and other sulfur comp.
NO_3 (mg/L)	70	50	Decaying Organic, legume plants, sewage nitrate fertilizers.
TDS (mg/L)	500-1500	500-1000	Dissolved from rocks and soils. Includes organic matter.
Hardness (mg/L)		500	
Fecal coliform colony/100 ml	0	0	Wastes and residues of living organisms
Total coliform colony/100ml	0	0	Wastes and residues of living organisms

6.2.1.1. Chemical and Physical Quality Evaluation.

The suitability of the springs water for domestic purposes was determined by comparing the concentration of constituents with the Jordanian standards and WHO Guidelines for drinking water. Most of the springs water in the study area can be used for domestic purposes except the Haramiyah spring whereas the NO3 concentration is higher than both the WHO guideline and the Jordanian standard. The high concentration of nitrate is due to the wide spread of cesspools for the wastewater disposal around the springs and that is the main source pollution effect on the springs in the study area. Also the fertilizer use for the plants, in addition to about 15.2% of the total sample exceeded the WHO guideline but fit the Jordanian standards for drinking water.

In addition, the total hardness for the spring samples was also evaluated. All the springs in the study area fit the standards. This mean that the springs water is suitable from this point of view for drinking purposes.

According to the average values of the total hardness for the different water groups,the springs water is classified according to Sawyer and McCarty (1967), Table (6.2), illustrates the Sawyer and McCarty classification and Table (6.3), shows the classification of the different water groups based on their hardness.

Table (6.2): Classification of water based on hardness

(after Sawyer and McCarty, 1967)

Hardness as $CaCO_3$ mg/l	Water type
0-75	Soft
75-150	Moderately
150-300	Hard
>300	Very hard

Table (6.3) Classification of hardness for water group

cluster Number	Name of Group	Hardness as $CaCO_3$ mg/l		Water Class
		Recent data	Historical data	
1	Group – 0a	207.66	205	Hard
2	Group - 0b	231.24	242	Hard
3	Group – 0c	260	286	Hard
4	Group – 0d	269	319	Hard & very hard

6.2.1.2. Biological Quality Evaluation

The biological analysis of water is very important in order to detect the bacterial pollution, which causes different diseases. The untreated water possibly contain variable amounts of bacteria and viruses which may be considered as a reason for various diseases. Therefore, the biological analyses concering fecal and total coliform are essential for assessing the suitability of water for drinking purposes.

The coliform group of bacteria includes all aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod shaped bacteria that ferment lactose with gas production. (Schroeder, 1987). The term total coliform refers to coliform bacteria from feces of humans and warm-blooded animal, soil, or other origin and fecal coliform refers to coliform bacteria from human and warm – blooded animals feces.

The pathogens most frequently transmitted through water are those responsible for infections of the intestinal tract (Typhoid, paratyphoid fevers, dysentery, and cholera). Pathogenic microorganisms causing enteric diseases in human originate from fecal discharging of diseased persons. Consequently, water contaminated by fecal pollution is identified as being potentially dangerous by the presence of coliform bacteria. Hence, coliform bacteria are indicator organisms of fecal contamination and possible presence of pathogens (Viessman *et al*, 1993). In Ajlun district to where the study area belong the appearance of Typhoid diseases during year 1993 due to the drinking from the springs was reported.

Table (6.4), shows the distribution of typhoid cases according to consuming spring water (Kharabsheh, 1993)

Table (6.4): The Distribution of Typhoid Cases According to Consuming Spring Water (Kharabsheh, 1993)

Related	Number	Percent
Directly	64	52.5
Indirectly	21	17.2
Unrelated	30	24.6
Unknown	7	5.7
Total	122	100

Concentration of coliform bacteria are most often reported as the MPN (most probable number) per 100ml. Typically the MPN value is determined from the number of positive (lactose-fermenting) test in a set of five replicates made at three different dilution's (15 sample altogether). TC grow and producing acid and gas at 35°C within 48 hr of incubation, and FC grow and producing acid and gas after 22-26 hr of incubation at an elevated temperature of 44.5C°, where the nonfecal coliform do not grow at this temperature.

It is recommended by all standards that the long-term count of the total and fecal coliform must be zero. According to this it was found that 71.7% and 66.4% of the total samples are polluted with total and fecal coliform respectively. Thus treatment and/or disinfecting and coagulation before being used for drinking purposes as needed. The other samples which are free from both total and fecal coliform are mainly limited to the deep springs and faraway from building and population gathering. Considering the two springs: Ajlun and Qantara that are most important for different daily uses, located at the same line in Ajlun town near Wadi Kufrinja stream. These two springs are the most polluted springs in comparison with the springs included in the study area Ajlun spring discharging water to the Wadi Kufrinja, which is usually used for irrigation, while Qantara spring water is used for drinking in Kufrinja town. The source of pollution in Qantra and Ajlun springs are due to the surrounding cesspools which are not connected to the wastewater network, its closeness to the surface and from Wadi Kufrinja stream. Due to high pollution, the Qantara spring is closed most the year and this causes a great loss of water. This problem can be treated by efficient treatment and disinfection of water. Table (6.5) shows the total and fecal coliform from March to September during the year 1997 (Ministry of Health, 1997).

Table (6.5): Total and Fecal Coliform (MPN/100ml) for the Collected Samples During the Year 1997 (March to September)

	30/3/97	5/4/97	12/6/97	27/7/97	6/8/97	20/9/97
TC. MPN/100ml	17	33	170	1600	≥ 2400	13
FC. MPN/100ml	11	13	49	2600	≥ 2400	7.8

6.3. Evaluation of water for irrigation uses.

The suitability of groundwater for irrigation is dependent on the effect of its mineral constituents on both the plant and soil (Todd, 1980).

Water quality for irrigation can be determined and evaluated by calculated different parameters such as the sodium soluble percent of (SSP) and the sodium adsorption ratio (SAR).

Sodium salts in the water are much more objectionable than are salts of calcium and magnesium because of the tendency for sodium to cause defflocculations of the colloidal fraction of the soil, so develop an undesirable structure and reduce permeability. The sodium content is usually expressed in term of the soluble sodium percentage (SSP) which is defined as:

$$SSP = \frac{(Na + K)}{(Ca + Ma + Na + K)} \times 100\%$$

where, the ionic concentration are in milliequivalent per liter, Another parameter which is used in determining the suitability of water for irrigation purposes is the sodium adsorption ratio (SAR) which is calculated by the following formula:

$$SAR = \frac{Na}{\left((Ca + Mg)/2\right)^{1/2}}$$

Where the ion concentration are expressed in milliequivalent per liter, Table (6-6), shows the classification of irrigation water according to the soluble sodium percentage, (Todd, 1980). It was found that 89.2% of the springs were excellent and 10.8% of the spring are good for irrigation. Table (6-7), shows the calculated parameters of irrigation water for average different water group.

Table (6.6) : classification of irrigation water based on sodium percentage (Todd, 1980)

Water Class	sodium Percentage	EC us/cm
Excellent	< 20	< 250
Good	20 - 40	250 - 750
Permissible	40 - 60	750 - 2800
Doubtful	60 - 80	2000 - 3000
Unsuitable	> 80	> 3000

Table (6.7): Calculated Parameters for irrigation water for different water groups.

Name of Group	SAR		Na %		EC µs/cm	
	Recent	Historical	Recent	Historical	Recent	Historical
Group - 0a	0.29	0.42	9.57	13.28	446.43	446.03
Group - 0b	0.43	0.39	12.9	12.89	513	523.14
Group - 0c	0.39	0.41	11.35	11.53	561.58	614.78
Group - 0d	0.62	0.51	17.22	16.01	634.79	737.49

The United States Department of Agricultural has adopted an irrigation water classification based upon SAR in combination with EC. Gww 1995 Computer program was used for the EC-SAR classification of the all samples recent and historical. The classification of waters in the study area for irrigation purposes is shown in Fig (6-5) for the recent data and Fig. (6.6) for the historical data. These classes are discussed in the following.

The water samples having EC values between 250-750 μs/cm are defined as C2 (Medium Salinity Hazard) with S1 class (Low Sodium Hazard), the water sample located in such area is named as (C2-S1). It can be used for irrigation on all soils, all recent water samples collected belong to this group and includes 92.1% from the historical data.

The water sample having EC values between 750-2250 μs/cm are defined as C3 (High Salinity Hazard) and also with S1 class. This means that the water is of class (C3-S1). This group includes 7.9% from the historical data specially group 0-d, water samples.

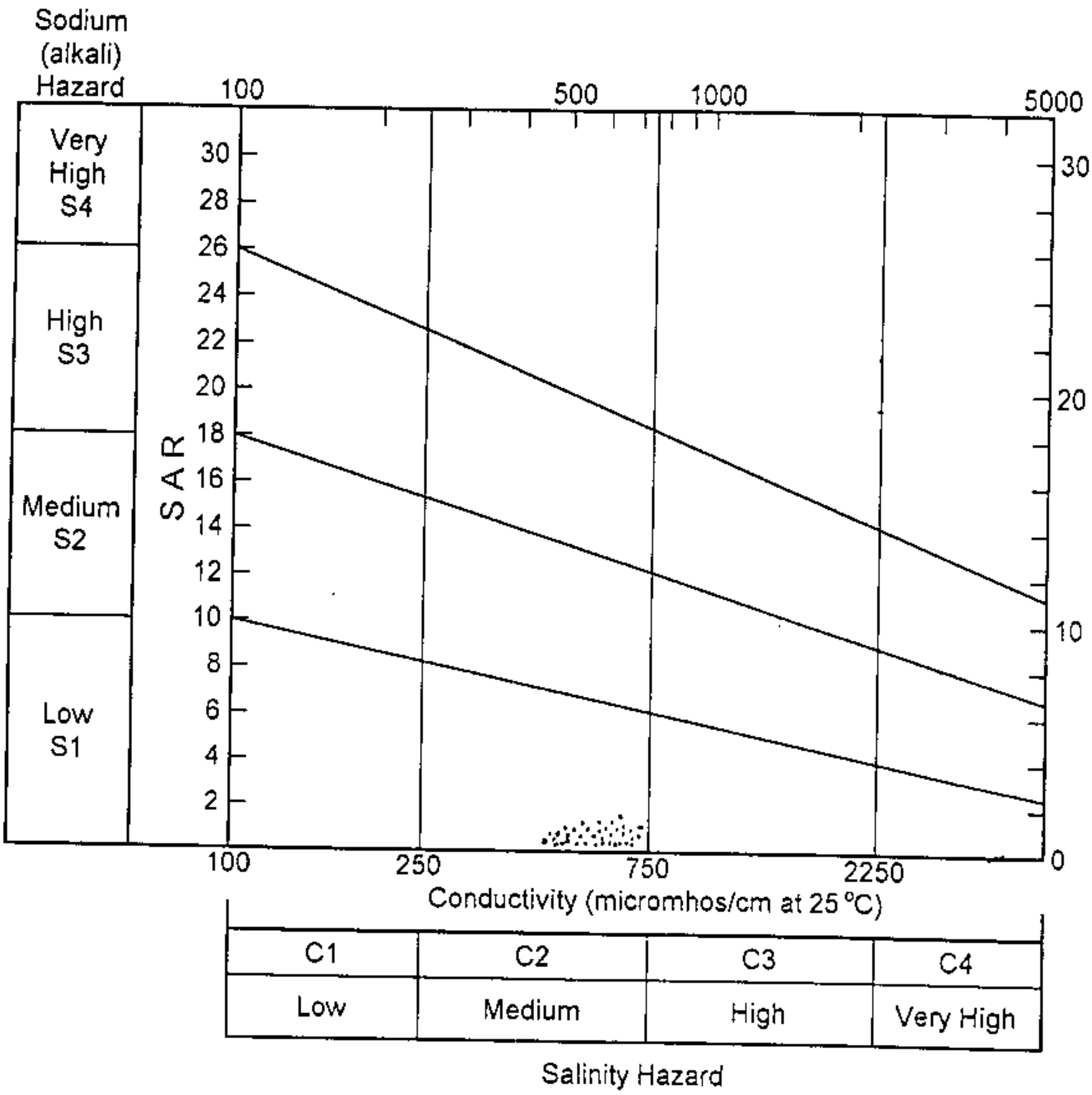


Fig.(6.5): Classification of irrigation water based on salinity and sodium adsorption ratio (SAR) (Recent sample)

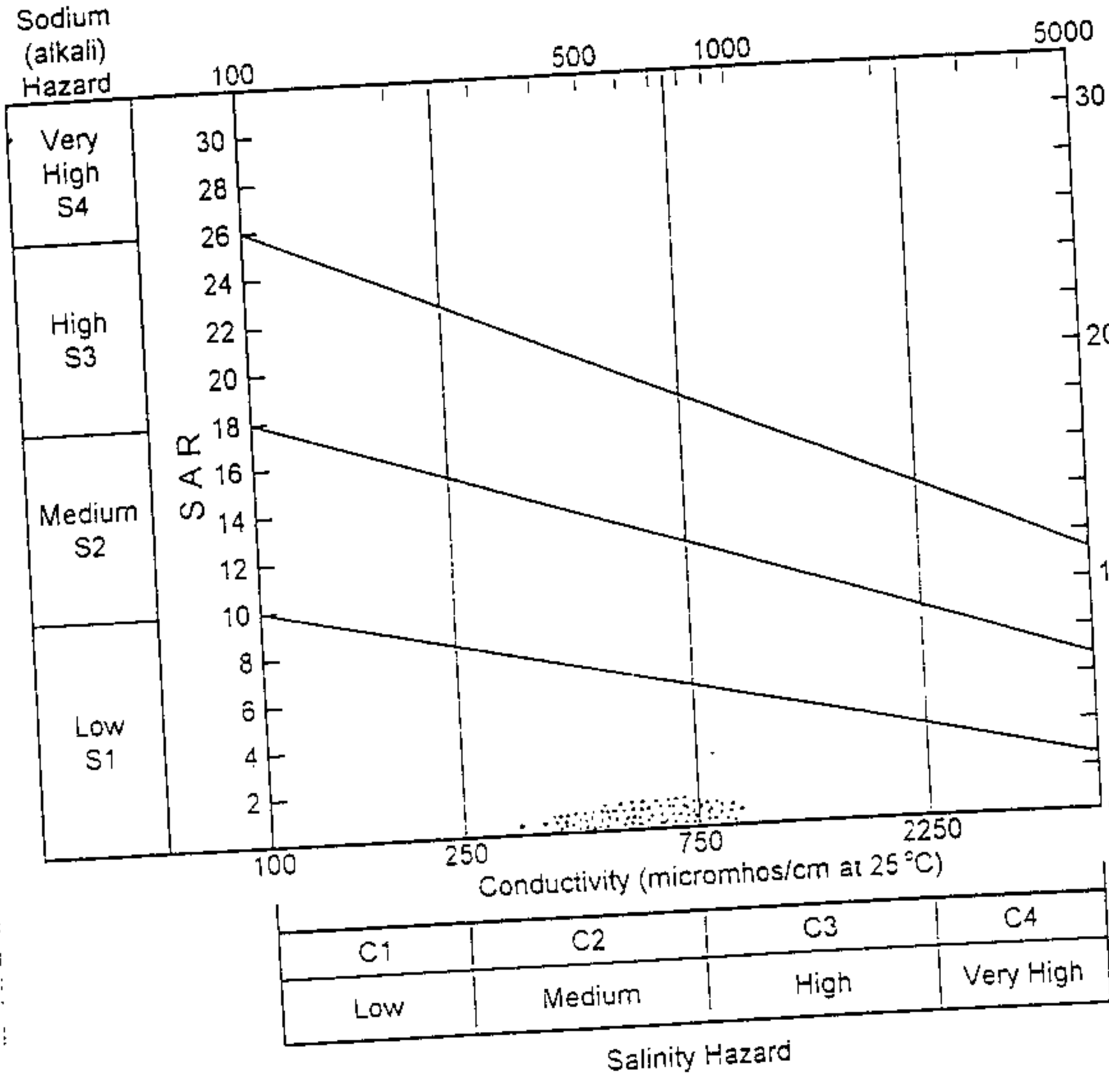


Fig.(6.6): Classification of irrigation water based on salinity and sodium adsorption ratio (SAR) (Historical sample)

Chapter Seven

Summary & Recommendation

7.1. Summary

- Topographically, the study area changes in elevation rapidly from east to west towards the Jordan Valley ,whereas the altitude ranges between 1240(asl) in the eastern part to 220m (bsl) in the Jordan Valley .
- The vegetation type in the study area belongs to the Mediterranean and Irano – Turanian region .
- Two types of soils were dominated in the study area which are the Red and Yellow Mediterranean soils .
- The rocks of the upper Cretaceous age (Cenomanian to Turonian) within Ajlun group represent the main rocks unit exposed in the study area .
- The study area includes two major aquifer systems which are Nau'r and Hummar Aquifer Systems.
- The study area is divided into three climatic zones, upper part is cool temperate rainy Mediterranean climatic region , the central part is warm temperate rainy Mediterranean climatic region and the lower part is warm steppe climatic region in the Jordan Valley.

- Rainfall occurs in the wet season which starting from Oct./Nov. and ends in Apr./May. From the Isohyetal maps for the wet, normal and dry year the followings can be concluded :

- The average amount of rainfall decreases from east to west towards the Jordan Valley depression .

- During the wet year condition the annual rainfall ranges from 1200 mm near Ajlun town to less than 900 mm near the lower reaches of the Kufrinja basin.

- During the normal year and dry year the annual rainfall range between (650-400mm) and (325-225 mm), respectively .

- The mean annual precipitation volume over the study area under normal condition was found to be around 66.57 MCM, of which 74.78% are lost due to evaporation, 2.5% as runoff, and 22.7% of the volume infiltrate through the subsoil's and strata to join the groundwater resources .

- The main water resources in Wadi Kufrinja basin are springs, surface water, and treated wastewater discharged from the Kufrinja treatment plant .

- There are 25 springs issue from different aquifers in the study area. Eleven springs issue from Nau'r Aquifer System (A1-2), thirteen springs from Hummar Aquifer System (A4) and only one spring issues from Wadi Sir Aquifer (A7) . They are used either for small scale irrigation or for drinking water purposes. The average discharge of these springs range between 1.08 and 139m^3/hr .

• The wastewater of households is disposed of in two ways; collection via sewerage systems and treated in Wastewater Treatment Plant, and the second is disposed directly in the cesspools .

• The chemical analyses of representative water samples include the major cations, major anions and the total and fecal coliform .

• Most of the water samples in the study area are oversaturated with respect to calcite, dolomite and aragonite, while they are under saturated with respect to gypsum and anhydrite .

• The different statistical analyses were made in order to get a best interpretation of the hydrochemical data using different methods. The results show that :

• The mathematical relationships between different parameters of the water samples (Recent & Historical) were determined and the following can be deduced :

• Sodium, chloride, magnesium and calcium are the major source of salinity in the water .

• Calcium and magnesium concentrations increase due to dissolution of carbonate and the ion exchange process in clay mineral .

• The analyzed water samples were subjected to cluster analysis and the water samples were classified into four subgroups; of the major group-0 of Rimawi's classification, and This group 0 is considered to be the source of water for the different water subgroups.

• The chemistry of group 0 (include recent and historical sample) , shows the following ionic ratio :

$Ca^{++} > Mg^{++} > (Na^{+} + K^{+})$

$HCO_3^{-} > Cl^{-} > SO_4^{--} > NO_3^{-}$ in some cases $NO_3 > SO_4$

$HCO_3^{-} > Ca^{++}$

$(Na/Cl) < 1$

$(Cl\text{-}Na)/Mg) < 1.$

• Varimax Factor rotation analyses is used in simplifying the interpretation of hydrochemical data. Three major factors were identified these are:

– Factor-1(Salinity factor) : EC, Cl, Na, SO4, NO3, K ,Ca and Mg (all are +ve)

– Factor-2 (Pollution factor) : TC, FC, K and EC (+ve)

– Factor-3 (Carbonate system factor) : pH(-Ve) , Ca , Mg , HCO3 and EC (+Ve) .

– The water quality can be classified by using the following techniques:

- Piper diagram classified the water quality of recent data as follows :

1- Earth Alkaline water type with prevailing bicarbonate (91.3%).

2-Alkaline earth water with increased portion of alkalis and prevailing bicarbonate (8.7%) .

- Durov diagrams illustrates the chemical composition of spring water is similar to that of precipitation water after the reacts on of water with the minerals constituting the aquifer matrix. Therefore, the chemistry of springs is characterized by the presence of Ca and HCO3 as the major cation and anion respectively .

- The chemical and physical quality evaluations, most of the springs water in the study area can be used for drinking purposes except one spring due to the high concentration of NO_3 exceeds both WHO guidelines and the Jordanian Standard for Drinking Purposes.

- All water samples were evaluated according to hardness and are classified to be hard to very hard.

- 67% of the total sample were contaminated with coliform bacteria and only the coliform free samples are those springs which are recharged from deep aquifer and faraway from the building and population gathering .

- For irrigation purposes, the water groups, in the study area are classified into two groups :

Group I : C2-S1 class

Group II : C3-S1 class .

Recommendation

- It is recommended to construct a dam before the confluence of Wadi Kufrinja Stream and effluent of the Kufrinja treatment plant, to get a benefit from the surface and flood water during winter.

- It is recommended to use the effluant of treated wastewater in irrigation and reforstation of the land which exposed to dreforstation especially the lower part of Wadi Kufrinja Basin.

- Stopping the Urban expansion and prohabition the building around the water resources and recharege area.

- It is recommended to finalize the sewage system network as soon as possible to protect the springs from pollution

- It is recommended to re-condition the stream flow gauging station of Wadi Kufrinja Basin.

References

- Abed, A.M. 1981. ***Geology of Jordan***. Al-Nanda Al-Islamiya Library, Jordan.

- Abedlhamid, G. 1995. ***The Geology of Jarash Area***. Natural Resources Authority, Amman, Jordan.

- Abu-Samur, H. 1984. *Vegetation Group of Wadi Kufrinja Basin*. University of Jordan, **12**(7): 15-22.

- Al-Esawi, D. 1995. *Vegetation of Jordan*. UNESCO, Cairo.

- Al-Zioud, A. 1993. *Surface Water Resources in Wadi Kufrinja Basin*. M.sc.Thesis, University of Jordan

- Appelo, C.A.J. and Postama. D. (1993). ***Geochemistry, Groundwater and Pollution***. A.A. Balkema, Rotter Dam.
- Bear, J. 1979. *Hydraulics*. McGraw-Hill Inc., New York

- Bender, F. 1974. ***Geology of Jordan***. Gebruder Borntager, Berline Strttgart.

- Davis, J. 1973. ***Statistics and Datal Analyses in Geology***, 2nd edition. John Wiley and Sons, New York.

- Drever, J.I. 1982. ***The Geochemistry of Natural Water***, 2nd edition, Prentic Hall Inc., New Jersey.

- El- Naser, H. 1987. *Evaluation of Spring Hydrograpth in Northern Jordan*. M.Sc. Thesis, University of Jordan, Amman.

- Freeze, R.A. and Cherry, J. A., 1979. ***Groundwater***. Prentic Hall Inc, New Jersey.
- Geo-500 (1986): Grafik and Statistik Fuer Geowissenschaften PIC-Gmbtt, Mvenchen.

- Greenberg, A. E. Cannors, S. S. and Jenkius, D. 1995. ***Standard Methods for the Examination of Water and Wastewater***. 16th edition. American Public Health Association, Washington.

- Hammar, M.J. and Mac kianan, K.A. 1981. ***Hydrology and Quality of Water Resources***. John Wiley and Sons, New York.

- Jordan National Geographic center. 1984. *National Atlas of Jordan, Climate and climateology*. Part.2. Amman

- Kharabsheh, S. 1993. *Epidemiology of Typhoid Fever with Emphasis on Jordan*. Ministry of Health. Amman.

- Lamp, J. C. 1985. ***Water Quality and its Control***. John Wiley and Sons. New York.

- Langguth, H.R. 1966. *Dei Grundwasserverhaltnisse Bereich des Velberter Sattels, Rheinisches Schiefergeberge, Der Mininester fur Ernahrung*. Landwirtschaft and Forsten, NRW, Dusseldrof.

- Lloyd, J.W. and Heathcote, J.A. 1985. ***Natural Inorganic Hydrochemistry in Relation to Groundwater***. Claredon Press, Oxford.

- Mac Donald, S.M. and Partner in Cooperation with Hunting Geological Surveys Limits. 1965. ***East Bank Water Resources***. London, Amman.

- Masri, M. 1963. *Report on the Geology of the Amman-Zerqa Area*. Unpublis. Report Central water Authority, Amman. 92PP.

- Meteorological Department of Jordan. 1988. ***Jordan Climatological Data Hand Book***. Amman.

- Minisry of Trade and Industry. *Jordanian Standards of Drinking Water*, No. 286. Amman, 1990.

- Momani, M.R. 1985. *Water Resources and their Uses in Northern Side Wadis of Jordan River*. Unpublished Report, WAJ, Amman, Jordan: p13.

- Moorman, F. 1959. *Report on the Soils of East Jordan.* No. 1132, Government of Jordan. Rome.

- Piper, A.M. 1944. *Graphics Procedure in Geochemical Interpretation of Water Analyses.* Trans American-Geophys Union, **25**: 914-928.

- Quennell, A.M. 1951. ***The geology and mineral resources of Trans Jordan.*** Colonial Geology and Mineral Resources, London.

- Rimawi, O. 1985. *Hydrogeochemistry and Isotope Hydrology of the Groundwater in North Jordan (North east at Mafraq, Dhuleil, Halabat, Azraq-Basins).* Ph.D. Thesis, Universit at Engereaicht und Dirch die Fakultat for Chemic, Biologei und Geuwissen-Schaftenam, Munchen.

- Rollins, L. 1988. PCWATEQ-*A computer Program Aids in Chemical Analysis of Ocean Waters, Lake Waters, Groundwater, Rainfall and Low-Temperature Hydrothermal Water.* 215 Cedar Lane, Wood Land.

- Saad, A.Y. 1996. *Rainfall-Runoff Relationships for Urban, Rural and Desert Sub-Basins, Jordan.* M.SC. Thesis, University of Jordan, Amman.

- Salem, H. S. 1984. *Hydrology and Hydrogeology of the area North of Zarqa River - Jordan.* MSC. Thesis, University of Jordan, Amman.

- Sawyer, C. N. and McCarty, P. L. 1967. *Chemistry and Sanitary Engineers*, 2nd edition. McGraw-Hill, New York.

- STASY (1986): Grafik und Statistik Fuer Geowissens Chuften. PIC-Gmbtt, Mvenchen.

- Ta'any, R. 1986. Surface water Resources in Azraq Basin. Unpubl, Report. Water Authority of Jordan.

- Todd, D. 1980. *Groundwater Hydrology.* 2nd edition. Prentic-Hall Inc., London.

- United Nations. 1994. *Groundwater Software For Windows (GWW)*, New York.

- Viessman, W. Knapp, J.W. Lewis, G.L. and Harbargn, T.E. 1977. ***Introduction to Hydrology***. Harper and Row, New York.

- Viessman, W. and Hammer, M.J. 1993. ***Water Supply and Pollution Control***. 5th edition. Harper Collins College Publishers, New York.

- WAJ, 1989. *Yarmouk Basin*, Resources Study Draft, Final Report, NRA, Amman.

- WAJ-Files, Water Authority of Jordan, Amman.

- Walton, W.C. 1991. ***Principles of Groundwater Engineering***. CRC Press, inc. Florida.

- Ward, R.C. 1967. ***Principles of Hydrology***. McGraw. Hill, New York.

- Water Research and Study Center. 1990. ***Manual of Water analyses,*** University of Jordan, Amman.

- World Health Organization (WHO). 1995. *Drinking Water Guidelines*. Amman.

الملخص

. التلوث البيولوجي والكيميائي للينابيع الواقعة في حوض وادي كفرنجه

إعداد

ثائر محمد احمد المومني

المشرف

أ.د محمد رشيد شطناوي

المشرف المشارك

د. عمر عبد الكريم الريماوي

تقع منطقة الدراسة في شمال غرب الأردن على بعد ٧٥كم شمال غرب مدينة عمان بين خطي طول ٢٠٧-٢٢٦ شرقاً وخطي عرض ١٨٤,٩-١٩٦,٤ شمالاً بمساحة مقدارها ١١٢,٢ كم٢ . يبلغ عدد سكان منطقة الدراسة حوالي٥٠٠٠٠ نسمة ينتشرون في الجزء الشرقي من منطقة الدراسة حيث وفرة المياه والمناخ المناسب وقربهم من الينابيع المصدر المائي الوحيد في منطقة الدراسة . تتكشف في المنطقة الصخور الرسوبية التابعة للكريتاسي الأعلى ضمن ما يسمى مجموعة عجلون ابتداءاً من طبقة عجلون الأولى والثانية (A1/2)حتى طبقة عجلون السابع(A7).

تتميز منطقة الدراسة بالتغير الشديد في الإرتفاع من الشرق الى الغرب بإتجاه وادي الأردن بين ارتفاعي ١٢٢٠م فوق مستوى سطح البحر الى ٢٤٠م تحت مستوى سطح البحر ، وتسود في منطقة الدراسة تربة البحر المتوسط الحمراء والصفراء.

اشارت الدراسة الى ان معدل كمية الأمطار السنوية الساقطة على الحوض حوالي ٦٦,٥م م٣، حيث تراوحت هذه الكمية خلال فترة التسجيل بين٣٤م م٣ الى ١٣٢م م ٣. تم حساب الموازنة المائية في منطقة الدراسة حيث وجد ان معدل التبخر الحقيقي والمحسوب عن طريق معادلة تيرك حوالي ٤٩,٧٨ م م٣ بما نسبتة ٧٤,٧٪ من معدل الأمطار الساقطة سنويا",ومعدل الفيضان السنوي حوالي ١,٦٦ابنسبة ٢,٥٪ من معدل كمية كمية الأمطار، كما قدرت كميات التغذية للطبقات المائية بإستخدام طريق الموازنة المائية حوالي ١٥,٣م م٣ بما نسبته ٢٢,٧٪ من معدل مجموع الأمطار الساقطة . يوجد في منطقة الدراسة حوالي ٢٥ نبعاً منها ١٢ نبعة تخرج من طبقة ناعور (A1/2), ١٣ نبعه تخرج من طبقة الحمر (A4) ، ونبعة

واحدة تخرج من طبقة وادي السير (A7)بمعدل تصريف سنوي طويل الأمد حوالي ٤,١ م م٣ سنوياً.

تكمن آلية العمل في دراسة هيدركيميائية لينابيع حوض وادي كفرنجه ، لذلك جمعت ٤٦ عينه من ٢٣ نبعه خلال فترتين (ايلول١٩٩٦ ، آذار ١٩٩٧) بالإضافة لذلك تمت دراسة نوعية المياه خلال الأعوام السابعة والتي قامت بتحليلها وزارة المياه والري . حيث تتم تحليل العينات كيماوياً وبيولوجياً ، ولتقييم نوعية المياه اخضعت نتائج هذه التحاليل لتحاليل احصائيه بإستخدام طرق التحليل العنقودي ، معاملات الارتباط العزومي واشكال دوروف وبايير وطرق أخرى.

صنفت المياه الى مجموعة واحدة اعتماداً الى تصنيف الريماوي (١٩٨٥)وهي مجموعة(o) وقد قسمت هذه المجموعة الى اربع مجموعات جزئية في (o-a.o-b,o-c,o-d). اظهر التقييم الكيماوي لمصادر المياه ان معظم العناصر الكيماوية تقع ضمن الحدود المسموح بها من خلال منظمة الصحة العالمية والمعايير الأردنية لمياه الشرب بإستثناء النترات حيث ان نبعة واحدة تحتوي على نسبة عالية تتجاوز الحد المسموح ، كما ان العينات التي تحتوي عن نسبة ضمن الحدود المسموحة تحتوي على نسب نترات عالية أصلاً . اما بالنسبة للتقييم البيولوجي لمصادر المياه لاستخدامات الشرب والمنزل ، أظهرت النتائج ان معظم الينابيع ما عدا الينابيع العميقة البعيدة عن التجمعات السكانية ملوثة ببكتيريا القولون البرازيه وتحتاج الى تعقيم / تخثير قبل استخدامها .

وهذا يمكن ان يعزى الى الاستخدام الواسع لحفر الامتصاص والمنتشرة بشكل كبير في منطقة الدراسة والى الاستعمال الواسع للأسمدة الكيماوية في الأعمال الزراعية .