UNIVERSITY BUSINESS ACADEMY IN NOVI SAD

FACULTY OF ECONOMICS AND ENGINEERING MANAGEMENT

IN NOVI SAD

D O C T O R A L D I S S E R T A T I O N

The problems of productive water wells in Ghadames area northwest Libya

Study in water geography

Supervisor

Jelena Bošković, Full Professor, PhD

Doctoral student

Adel Ahmad Auhida, M.Sc.

Novi Sad, 2020.

UNIVERSITY BUSINESS ACADEMY IN NOVI SAD

FACULTY OF ECONOMICS AND ENGINEERING MANAGEMENT

IN NOVI SAD

D O C T O R A L D I S S E R T A T I O N

The problems of productive water wells in Ghadames area northwest Libya

Study in water geography

Supervisor

Jelena Bošković, Full Professor, PhD

Doctoral student

Adel Ahmad Auhida, M.Sc.

Novi Sad, 2020.

UNIVERZITET PRIVREDNA AKADEMIJA U NOVOM SADU

D O K T O R S K A D I S E R T A C I J A

Problemi u proizvodnji bunarske vode u Gadamesu – područje severozapadne Libije

Studije iz geografije voda

Mentor

Prof. dr Jelena Bošković

Doktorand

Mr Adel Ahmad Auhida

Novi Sad, 2020.

UNIVERSITY BUSINESS ACADEMY IN NOVI SAD

Faculty of Economics and Engineering Management in Novi Sad

KEY WORD DOCUMENTATION

Document type:	Doctoral dissertation
Author:	M.Sc. Adel Ahmad Auhida
Menthor (title, first name, last name, position, institution)	Jelena Bošković, PhD, Full Professor Faculty of Economics and Engineering Management in Novi Sad, University Business Academy in Novi Sad.
Title:	The problems of productive water wells in Ghadames area northwest Libya
Language of text (script):	English language (latin script)
Physical description:	Enter number: Pages – 188 Chapters - 5 References - 52 Tables - 18 Figures – 89
Scientific/artistic field:	Industrial Engineering and Engineering Management Agronomy, technology and engineering management
Subject, Key words:	Hydro – chemical, well water, Ghadames Area, Lybia
Abstract (or resume) in the language of the text:	The current study explores the phenomena of sudden rise of salinity, lack of hydrostatic pressure and productivity decline in the water of some wells of deep underground reservoir in Kikla Formation, Ghadames Basin, Northwest Libya. A case study is conducted on some selected wells that have experienced these phenomena in Kiklah Formation. To learn more on the nature of these phenomena, the study focuses on their evolution, the main causes accounting for their occurrence, manifestations indicating them, field tests confirming their existence, and the steps required to avoid their occurrence. Basically, the study uses a descriptive approach to examine the natural, geological and hydrogeological characteristics of the

	region, identify the technical and operational specifications of the wells in the selected sites, and highlight problems associated with water resources in the region. The study also uses an analytical approach to provide detailed interpretations and representations of the results obtained from chemical analyses of water samples collected from thirteen wells within the boundaries of the study area as well as water samples for seven wells with significantly high levels of salinity. In general, the present study depends on the information from previous studies, field visits and laboratory tests. Statistically, results of the study are represented by a set of figures, tables, manuscripts and illustrations to facilitate the explanation and clarification of concepts related to the phenomena studied. The study draws many conclusions regarding the problems related to the selected wells, particularly with regard to design and specifications of processing, interpolation and declining productivity and efficiency and the low quality of water in the region. The study also finds out the key elements that cause and accelerate the spread of the phenomena of high salinity, lack of pressure and productivity decline in the wells. These elements include the technical reasons, design reasons and other reasons related to intensive exploitation. The study concludes a set of recommendations that relate to the removal of the layers and formations above the Kiklah aquifer during casing processes in future designs for wells in the region as the main source of the sudden rise of salinity. It is also recommended that exploitation of wells should be stopped as it has been reported as the main cause of sudden rise of salinity. Likewise, deterioration of water quality and pollution of water aquifer should be prevented by creating a network of surveillance to track water levels and quality periodically. There is also the need for coordination with neighboring countries exploiting the basin to modernize the well models in the basin regularly and follow the changes that occur in the wells quantitatively and qualitatively to ensure optimum utilization in the present and the future.
Defended: (The faculty service fills later.)	

Thesis Defend Board: (title, first name, last name, position, institution)	**Milena Žuža, Ph.D., Asociate Professor – President of the Commission** Megatrend University Belgrade, Faculty of Biofarming, Bačka Topola. Special topics: Biotechnology and Biochemical Engineering. **Jelena Bošković, Ph.D., Full Professor - Supervisor** University Business Academy in Novi Sad, Faculty of Economics and Engineering Management in Novi Sad. Special topics: Agronomy, Technology and Engineering Management. **Radivoj Prodanović, Ph.D., Assistant Professor - Member of the Commission** University Business Academy in Novi Sad, Faculty of Economics and Engineering Management in Novi Sad. Special topics: Agronomy, Technology and Engineering Management.
Note:	The author of doctoral dissertation has signed the following Statements: 1. Statement on the authority, 2. Statement that the printed and e-version of doctoral dissertation are identical and 3. Statement on copyright licenses. The paper and e-versions of Statements are held at the faculty.
UDC	556.18(612)(043.3)

UNIVERZITET PRIVREDNA AKADEMIJA U NOVOM SADU

Fakultet za ekonomiju i inženjerski menadžment u Novom Sadu

KLJUČNI PODACI O ZAVRŠNOM RADU

Vrsta rada:	Doktorska disertacija
Ime i prezime autora:	Mr Adel Ahmad Auhida
Mentor (titula, ime, prezime, zvanje, institucija)	Prof. dr Jelena Bošković, redovni profesor Univerzitet Privredna akademija u Novom Sadu Fakultet za ekonomiju i inženjerski menadžment u Novom Sadu
Naslov rada:	"Problemi u proizvodnji bunarske vode u Gadamesu – područje severozapadne Libije"
Jezik publikacije (pismo):	Engleski jezik – latinica
Fizički opis rada:	Uneti broj: Stranica - 209 Poglavlja - 5 Referenci - 52 Tabela - 18 Slika – 89
Naučna/umetnička oblast:	Industrijsko inženjerstvo i inženjerski menadžmet Agronomija, tehnologija i inženjerski menadžment
Predmetna odrednica, ključne reči:	Hidrohemikalije, bunarska voda, područje Gadamesa, Libija.
Izvod (apstrakt ili rezime) na jeziku završnog rada:	Aktuelna studija istražuje fenomene naglog porasta slanosti, nedostatka hidrostatskog pritiska i pada produktivnosti u vodi nekih bunara dubokog podzemnog rezervoara u formaciji Kikla, sliv Ghadames, severozapadna Libija. Studija slučaja se vrši na nekim odabranim bunarima, koji su ove pojave doživeli u formaciji Kiklah. Da bismo saznali više o prirodi ovih pojava, studija se usredsređuje na njihovu evoluciju, glavne uzroke koji objašnjavaju njihovu pojavu, manifestacije koje ih ukazuju, terenske testove koji potvrđuju njihovo postojanje i korake potrebne da se izbegne

	njihovo pojavljivanje. U osnovi, studija koristi opisni pristup da bi ispitala prirodne, geološke i hidrogeološke karakteristike regiona, identifikovala tehničke i operativne specifikacije bunara na odabranim lokacijama i ukazala na probleme povezane sa vodenim resursima u regionu. Studija takođe koristi analitički pristup da pruži detaljne interpretacije i prikaže rezultate dobijene hemijskim analizama uzoraka vode prikupljenih iz trinaest bunara u granicama područja istraživanja, kao i uzoraka vode za sedam bunara sa znatno visokim nivoom slanosti. Generalno, ova studija zavisi od informacija iz prethodnih studija, terenskih poseta i laboratorijskih testova. Statistički, rezultati studije predstavljeni su skupom slika, tabela, rukopisa i ilustracija, kako bi se olakšalo objašnjenje i pojašnjenje koncepata vezanih za proučavane pojave. Studija izvlači mnoge zaključke u vezi sa problemima, koji se odnose na odabrane bušotine, posebno u pogledu dizajna i specifikacija za obradu, interpolaciju i opadanje produktivnosti i efikasnosti i niskog kvaliteta vode u regionu. Studija takođe otkriva ključne elemente, koji uzrokuju i ubrzavaju širenje pojava visokog saliniteta, nedostatka pritiska i pada produktivnosti u bušotinama. Ovi elementi uključuju tehničke razloge, razloge dizajna i druge razloge povezane sa intenzivnom eksploatacijom. Studija zaključuje set preporuka koje se odnose na uklanjanje slojeva i formacija iznad vodonosnika Kiklah tokom procesa oblaganja budućih dizajna za bušotine u regionu kao glavnog izvora naglog porasta slanosti. Takođe, preporučuje se zaustavljanje eksploatacije bušotina, jer je to prijavljeno kao glavni uzrok naglog porasta slanosti. Isto tako, pogoršanje kvaliteta vode i zagađenje vodonosnog snabdevanja trebalo bi sprečiti stvaranjem mreže nadzora kako bi se periodično pratio vodostaj i kvalitet vode. Postoji i potreba za koordinacijom sa susednim zemljama koje koriste bazen za redovnu modernizaciju modela bušotina u slivu i praćenje promena koje se događaju u bušotinama kvantitativno i kvalitativno kako bi se osigurala optimalna upotreba u sadašnjosti i budućnosti.
Datum odbrane: (Popunjava naknadno odgovarajuća služba)	

Članovi komisije: (titula, ime, prezime, zvanje, institucija)	**Prof. dr Milena Žuža, vanredni profesor – predsednik komisije** Megatrend Univerzitet Beograd, Fakultet za biofarming, Bačka Topola. Uža naučna oblast: Biotehnologija i biohemijsko inženjerstvo. **Prof. dr Jelena Bošković, redovni profesor - mentor** Univerzitet Privredna akademija u Novom Sadu, Fakultet za ekonomiju i inženjerski menadžment u Novom Sadu. Uža naučna oblast: Agronomija, tehnologija i inženjerski menadžment. **Doc. dr Radivoj Prodanović – član komisije** Univerzitet Privredna akademija u Novom Sadu, Fakultet za ekonomiju i inženjerski menadžment u Novom Sadu. Uža naučna oblast: Agronomija, tehnologija i inženjerski menadžment.
Napomena:	Autor doktorske disertacije potpisao je sledeće Izjave: 1. Izjava o autorstvu, 2. Izjava o istovetnosti štampane i elektronske verzije doktorskog rada, 3. Izjava o korišćenju. Ove Izjave se čuvaju na fakultetu u štampanom i elektronskom obliku.
UDK	556.18(612)(043.3)

C O N T E N T S

Key Word Documentation
Ključni podaci o završnom radu
Dedication
Acknowledgements
List of Figures
List of Tables

CHAPTER I
1. INTRODUCTION 1
1.1. Background 1
1.2. Research Problem 3
1.3. Importance of the Study 4
1.4. Objectives of the Study 4
1.5. Research Hypotheses 5
1.6. Borders and Location of the Study Area 6
1.7. Methodology and Research Tools 7

CHAPTER II
2. GENERAL REVIEW AND THEORETICAL OUTLINES 9
2.1. Studies Providing an Inventory and Assessment of Water Capacity in Different Aquatic Areas 9
2.1.1. Systematic Studies 9
2.1.1.1. Hydro-Climatic Studies 9
2.1.1.2. Hydrogeological Studies 10
2.1.1.3. Studies Based on Exploration Wells 11
2.1.1.4. Studies Based on Hydraulic Properties of Water-Bearing Layers 11
2.1.1.5. Hydro-Chemical Studies 12
2.1.2. Assistive Technologies 12
2.1.2.1. Hydro-Geophysical Studies 12
2.1.2.2. Hydro-isotopic Studies 13
2.1.2.3. Hydro-Sensor Studies 13
2.1.2.4. Hydro-Information Studies 14
2.2. Documentation and Analysis of Basin Information and Systems 14
2.3. Terms and Concepts Used in the Assessment of Basins and Wells 15
2.3.1. Terms and Concepts of Aquifers 15
2.3.1.1. Groundwater Level 15
2.3.1.2. Porosity and Permeability 16
2.3.1.3. Water Free Movement and Water Restricted Movement 19

2.3.1.4. Aquifers 20
2.3.1.4.1. Unconfined Aquifer 21
2.3.1.4.2. Confined Aquifer 23
2.3.1.4.3. Semi-Confined Aquifer 24
2.3.1.5. Hydraulic Gradient 24
2.3.1.6. Natural Recharge of the Aquifer 25
2.4. Terms and Concepts of Test Pumping from Wells 29
2.4.1. Test pumping 29
2.4.2. Static Water Level (S.W.L) 30
2.4.3. Dynamic Water Level (D.W.L.) 30
2.4.4. Drawdown 31
2.4.4.1. Residual Drawdown 31
2.4.4.2. Well Yield or Discharge 32
2.4.4.3. Specific Capacity/Specific Yield 32
2.4.4.4. Specific Drawdown 33
2.4.5. Effective Radius of the Well 34
2.4.6. Well Performance Curve 35
2.4.7. Well Efficiency 36
2.4.8. Cone of Depression and Area of Influence 37
2.4.9. Well Loss 39
2.4.10. Well Interference Effects 42
2.4.11. Coefficient of Transmissivity 43
2.4.12. Storage Coefficient 43
2.4.13. Safety Coefficient 44
2.4.13.1. Exploitation Index 44
2.4.13.2. Final Consumption Index 44
2.4.14. Return to the Level of Groundwater (Water Level Recovery) 44
2.5. Pump Concepts 45
2.5.1. Pump Capacity 45
2.5.2. Pump Efficiency 45
2.5.3. Pump Pressure 45
2.5.4. Pump Performance Curve 45

CHAPTER III

3. PREVIOUS STUDIES 47
3.1. Major Previous Studies 47
3.2. Comment on Previous Studies 51
3.3. Utilization of Previous Studies 51

CHAPTER IV

3. NATURAL FEATURES OF THE STUDY AREA 53
4.1. Climate conditions 53
4.2. Effect of Natural Manifestations on the Water Situation in the Study Area 65
4.2.1. Impact of Location 65
4.2.2. Surface Manifestations and Topography Effect 66
4.2.3. Effect of Temperature 66
4.2.4. Effect of Wind 67
4.2.5. Effect of Rainfall 67
4.2.6. Effect of Soil 67
4.2.7. Effect of Vegetation 68
4.3. Geology and Lithostratigraphic Sequence of the Study Area 68
4.3.1. Rocks and Surface Sediments 68
4.3.2. Lithostratigraphic Sequence 69
4.3.2.1. Lithostratigraphic Sequence in Ghadames Basin and Surrounding Areas 69
4.3.2.2. Lithostratigraphic Sequence in the Study Area 71
4.4. Structural Geology 79
4.4.1. Geological Cross-sections 82
4.4.1.1. Geological Cross-section A-A′ (North-South) 82
4.4.1.2. Geological Cross-section B-B′ (North-West-South-East) 83
4.4.1.3. Geological Cross-section C-C′ (West - East) 87
4.5. Geological History of the Study Area 87
4.6. Hydrology of the Study Area 88
4.6.1. Main Aquifers in the Study Area 88
4.6.1.1. Shallow Aquifer Reservoir (Quaternary aquifer) 89
4.6.1.2. Upper Aquifer 89
4.6.1.3. Ain Tobi Aquifer 92
4.6.1.4. Kiklah Aquifer 92
4.6.1.5. Rass Hamia Aquifer 93
4.7. Specifications of Kiklah Aquifer 94
4.7.1. Hydraulic Properties of Kiklah Aquifer 94
4.7.2. Quality of Water in Kiklah Aquifer 94
4.7.3. Exploitation of Kiklah Aquifer 95
4.7.4. Feeding of Kiklah Aquifer 96
4.7.5. Water Movement in Kiklah Aquifer 96
4.7.6. Water Wells Provided by the Man-Made River System 97
4.8. Well Characteristics of the Study Area 100
4.8.1. Characteristics and Specifications of the Wells Selected for the Study 100
4.8.1.1. Criteria Considered When Selecting Wells 100
4.8.1.2. Technical and Hydrogeological Information of Selected Wells 101

4.8.2. Design and Completion Specifications for the Studied Wells 109
4.8.2.1. Information considered in the assessment and evaluation of the studied wells 109
4.8.2.2. Considerations of Design and Completion of the Studied Wells 110
4.8.2.3. Design, Implementation and Completion of Wells in the Study Area 110
4.8.2.4. Specifications of Cylindrical Core Samples Collected from Wells 115

CHAPTER V

5. HYDRO-CHEMICAL ANALYSIS OF KIKLAH AQUIFER IN THE STUDY AREA 123
5.1. Methodology of Hydro-Chemical Analysis of Water Samples from Selected Wells 123
5.2. Evaluation of Accuracy of Chemical Analysis of Water Samples 125
5.3. Chemical Classification of Water Quality of Kiklah Aquifer 132
5.4. Graphical Representation of the Results of Chemical Analysis of Water Samples Using Piper Diagram 133
5.5. Geographical Distribution of Chemical Components in Water Samples from Selected Wells 138
5.5.1. Mapping the Geographical distribution of pH 138
5.5.2. Mapping and Geographical Distribution of Total Dissolved Solids (T.D.S) 141
5.5.3. Mapping and Geographical Distribution of Sodium Ions 141
5.5.4. Mapping and Geographical Distribution of Calcium Ions 144
5.5.5. Mapping and Geographical Distribution of Magnesium Ions 146
5.5.6. Mapping and Geographical Distribution of Potassium Ions 146
5.5.7. Mapping and Geographical Distribution of Chlorine Ions 146
5.5.8. Mapping and Geographical Distribution of Bicarbonate Ions 146
5.5.9. Mapping and Geographical Distribution of Sulfate Ions 151
5.5.10. Mapping and Geographical Distribution of Nitrate Ions 154
5.5.11. Mapping and Geographical Distribution of Water Temperature 154
5.6. Hydrochemistry of High Salinity Wells in the Study Area 157
5.6.1. Wells With Highly Saline Water 157
5.6.2. Chemical Classification of High Salinity Well Water Samples 159
5.6.3. Contour Mapping and Geographical Distribution of Ions in High Salinity Wells 159
5.7. Phenomena of Sudden Salinity, Pressure Drop and Lack of Flow in Some Wells of the Study Area 166
5.7.1. Evolution of the Phenomena 166
5.7.2. Manifestations of Phenomenon of Salinity 168
5.7.3. Aspects of Studying the Phenomenon of Salinity 169
5.7.4. Field Tests Confirming The Phenomenon of Salinity 169

5.7.5. Causes of Phenomenon of High Salinity in Some Selected Wells 170
5.7.6. Considerations for Avoiding Phenomenon of high Salinity 171

6. CONCLUSION 173
7. RECOMMENDATIONS 177
8. REFERENCES 179
BIOGRAPHY 183

Dedication

To the MEMORY of my FATHER,

who always believed in my ability to be successful in the academic arena.

You are gone but your belief in me has made this journey possible.

May Allah grant you Jannah Firdaws.

Acknowledgements

First, I am grateful to Allah for the good health and wellbeing that were necessary to complete this thesis.

I would also like to express my sincere gratitude to my advisor Prof, Jelena Bošković, for her continuous support of my PhD study and related research, for her patience, motivation, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my PhD study.

Last but not the least, I would like to thank my family: my parents, my wife, who has been my companion and endured the ache of homesickness for three years, my children, my brothers and sisters.

The researcher

List of Figures

Figure (1): Distribution of water basins in Libya 3
Figure (2): Location of the study area 6
Figure (3): Studies necessary to limit the water potential of a groundwater basin 10
Figure (4): Water level corresponding to the upper limit of the saturated zone 16
Figure (5): Effect of topography of the Earth's surface on water level falling in the dry seasons, causing water to decrease in the course and the dryness of some wells 17
Figure (6): Movement of water from high pressure zones to low pressure zones in the form of twisted paths in the direction of the flow range 19
Figure (7): Free water movement and restricted water movement 20
Figure (8): Confined and non-confined aquifers 22
Figure (9): Nature of the Artesian wells 22
Figure (10-a): An illustration of a semi-restricted reservoir with a bottom-up leakage 23
Figure (10-b): An illustration of semi-restricted reservoir with a top-to-bottom leakage 24
Figure (11): Method of calculating the hydraulic gradient in the water-bearing formation 25
Figure (12): The groundwater flow system forming arches heading to the valleys dividing water flow into feeding areas and drainage areas 26
Figure (13): Groundwater recharge due to the movement of water from the unsaturated area to the gravitational saturated zone through the water level 27
Figure (14): Local, medium and regional systems of groundwater flow 27
Figure (15): Calculating the annual recharge of groundwater reservoir by the relationship between different treatments in both the feeding area and the discharge area 28
Figure (16): Test pumping from a pumping well and its effect on the water level and landing in the adjacent observation wells 29
Figure (17-A): Terms used in pumping tests: A well in a non-confined groundwater reservoir 31
Figure (17-B): Terms used in pumping tests: A well in a confined groundwater reservoir 31
Figure (18): Change in the specific productivity of the pumping well with the change 32
Figure (19): Curve of the relationship between the specific productivity, the transmissibility coefficient and the storage coefficient calculated from the equilibrium equation in pumping rate and time 33
Figure (20): Change in effective radius and depth of cone of depression after equal time intervals of pumping at a constant rate of full penetration well 34
Figure (21): Matching the well performance and pump performance curves 35
Figure (22): Method of calculating well efficiency 36
Figure (23): Effect of flux coefficient on the shape, depth and length of cone of depression taking into account that the pumping rate and other influencing factors in both cases are equal 39
Figure (24): Formation losses and well losses due to change of drop as productivity changes with continuous pumping in an unconfined aquifer 41
Figure (25): Analysis of gradual test pumping for the determination of loss of wells 41
Figure (26): Change in total drawdown (SW), well loss (CQ^n) and reservoir loss (BQ) with well productivity change 42

Figure (27): Surface of interference of three wells etched within the area of influence of each other in a water layer 43
Figure (28): Desert climate range of the study area compared to other climatic ranges in Libyan territory 53
Figure (29): Distribution of temperature in summer and winter in the study area compared to temperature within the Libyan territory 54
Figure (30): Temperature rate in Nalut 56
Figure (31): Temperature in Ghadames 57
Figure (32): Annual average of humidity of the study area and the Libyan territory 58
Figure (33): Average annual rainfall for the study area and the Libyan territory 60
Figure (34): Map of rain distribution of northwestern parts of Libya 61
Figure (35): Topography of the study area and the Libyan territory 63
Figure (36): Geological map of the study area 70
Figure (37): Geological map of the study area compared with other areas in Libya 71
Figure (38): South-North cross section of the western regions (Murzk-Hamada Al-Hamra-Western Mountain-Jafara) 72
Figure (39): Changes in the upper surface of Kiklah Formation in the study area 74
Figure (40): Changes in the lower surface of Kiklah Formation in the study area 75
Figure (41): Changes in the upper surface of Ain Tobi Formation in the study area 76
Figure (42): Changes in the upper surface of Yefirin Formation in the study area 77
Figure (43): Lithostratigraphic sequence and lithological description of geological formations of the study area 79
Figure (44): A Structural map of Ghadames Basin 81
Figure (45): Geological North-South cross section of the Ghadames area (Great Ghadames Fault) 82
Figure (46): A north-south geological cross section (A-A) in the study area 84
Figure (47): Geological cross-section from north-west to south-east (B-B′) in the study Area 85
Figure (48): Geological cross-section from west to east (C-C′) in the study area 86
Figure (49): Changes in the characteristics of the underground aquifers in the study area in the north-south direction 90
Figure (50): Change in the characteristics of the aquifers in the study area in the northwest direction to the southeast 91
Figure (51): Change in the characteristics of the underground aquifers in the study area in the direction from the northwest to the south-east 91
Figure (52): Regional system of groundwater movement and the northwestern part of Libya 97
Figure (53): Movable water tracks and quantities of the Man-Made River System 98
Figure (54): Well sites studied within the boundaries of the study area 103
Figure (55): Relationship between discharge and specific capacity of the selected wells in the study area 108
Figure (56): Self-flow of the well № (T/160/99) in Ghadames area 109
Figure (57): Old design of the exploratory well (T/1/0160/0/99) (Old specifications) 112
Figure (58): Structural design model of the old-fashioned piezometeric styling in the study area 113
Figure (59): Structural desing model of the production well with the new desing specifications in the study area 114

Figure (60): Structural Design model for the productive wells in the study area "New Specifications 115
Figure (61): Structural model of new-design piezometeric in the study area 116
Figure (62A): Cylindrical core sample of Ain Tobi Member/Sidi Assaid Formation at a depth of 378 meters in the well (Pz-7k) 120
Figure (62B): Cylindrical core sample of Ain Tobi Member/Sidi Assaid Formation at a depth of 377 meters in the well number (Pz-Zk) 121
Figure (62C): Cylindrical core sample of Ain Tobi Member/Sidi Assid Formation at a depth of 377 meters in the well number (PZ-Zk) 122
Figure (63): Location of the selected wells whose hydrochemistry was studied in the study area 124
Figure (64): Graph representation of test results of the balance of shipments of 12 wells with the exclusion of the highly saline well WG-10 in the study area 130
Figure (65): Relationship between (T.D.S.) and (E-C) in the water samples of the selected Wells 131
Figure (66): Percentages of the classification of selected wells according to the total dissolved solids (T.D.S.) in their water samples 134
Figure (67): Representation by Piper Scheme of the main concentrations of ions in the water samples of selected wells on Piper Diagram 136
Figure (68): Classification of selected wells according to their water chemical facies 137
Figure (69): Geographical contour map of distribution of pH in water samples of selected wells 140
Figure (70): Contour map of geographical distribution of T.D.S. in mg/L in water samples from selected wells 142
Figure (71): Contour map of geographical distribution of sodium ions in mg/L in water samples from selected wells 143
Figure (72): Contour map of geographical distribution of calcium ions in mg/L in water samples from selected wells 145
Figure (73): Contour map of geographical distribution of magnesium ions in mg/L in water samples from selected wells 148
Figure (74): Contour map of geographical distribution of potassium ions in mg/L in water samples from selected wells 149
Figure (75): Contour map of geographical distribution of chlorine ions in mg/L in water samples from selected wells 150
Figure (76): Contour map of geographical distribution of bicarbonate ions in mg/L in water samples from selected wells 152
Figure (77): Contour map of geographical distribution sulfate ions of in mg/L in water samples from selected wells 153
Figure (78): Contour map of geographical distribution nitrate ions of in mg/L in water samples from selected wells 155
Figure (79): Contour map of geographical distribution of temperatures in water samples from selected wells 156
Figure (80): Map of location of high salinity wells in the study area 158
Figure (81): Comparison between the values of total dissolved solids in high salinity Wells 160

Figure (82): Representation of the results of chemical analysis of highly saline wells on Piper Diagram 161
Figure (83): Map of the geographical distribution of sodium ion in mg/L in water samples from highly saline wells in the study area 162
Figure (84): Map of the geographical distribution of chlorine ion in mg/L in water samples from highly saline wells in the study area 163
Figure (85): Map of the geographical distribution of sulfate ion in mg/L in water samples from highly saline wells in the study area 164
Figure (86): Change in sodium concentrations in highly saline wells in the study area..... 165
Figure (87): Change in chlorine concentrations in highly saline wells in the study area 165
Figure (88): Change in the concentrations of sulfates in highly saline wells in the study area 166
Figure (89): The relationship between concentrations of sodium, chlorine and sulfate in highly saline wells in the study area..... 168

List of Tables

Table (1): Differences of porosity depending on the different types of rock 17
Table (2): Distribution of temperature and annual rate in the study area and adjacent areas 55
Table (3): Monthly average and annual rate of evaporation in Ghadames City 60
Table (4): Monthly rate of wind speed (m/s) in both Nalut and Ghadames 64
Table (5): Phases of the Man-Made River Project 98
Table (6): Classification of the wells selected for the study 104
Table (7): Technical and hydrological information on wells in the study area 105
Table (8): Description of a cylindrical core sample of Well number: PZ-6K 118
Table (9): Description of a cylindrical core sample of Well №: PZ-6K 119
Table (10): Description of a cylindrical core sample of Well №: PZ-7K 119
Table (11): Description of a cylindrical core sample of Well №: PZ-7K 120
Table (12): Results of chemical analysis of water samples from the selected wells (mg/L–ppm)... 127
Table (13): Results of calculations of the conversion of the concentrations of cations and ions into percentages in water samples from the selected wells 128
Table (14): Results of calculations of the conversion of the concentrations of cations and anions into percentages and results of charge balance in water samples from the selected wells 129
Table (15): Classification of water quality according to total dissolved salts concentration (T.D.S) 132
Table (16): Classification of selected wells according to the total dissolved solid (T.D.S.) in their water samples 132
Table (17): Statistical summary of the chemical quality classification of water samples according to chemical facies represented by Piper Diagram 138
Table (18): Summary of the distribution of nitrate ion in wells of the study area 154

CHAPTER I

1. *INTRODUCTIO*

1.1. *Background*

Libya has witnessed economic and cultural development in recent years, which leading to an increase of water consumption that has worsened the situation.

Water in Libya is limited , and restricted to groundwater. This situation needs accurate management, proper planning and continuous follow-up to ensure sustainable development. In addition, a scientific water policy, which will make proper water consumption the interest for future generations that should be adopted by setting scientific plans for how to optimally utilize it under an umbrella of conscious supervision, technical control and rationalization of consumption. In order to achieve this, the Libyan basins were divided into five water areas (General Water Authority ***GWA***, 2006) as shown by Figure (1). These areas correspond to a large extent with the geographic and geological distribution of the main water basins as follows:-

1. Western Region(The Jafara trough and also trough Al-Hamada Al-Hamra)
2. Middle precinct (East section of Al-Hamada Al-Hamra trough, Sirte trough)
3. Eastern Region (Green Mountain Basin)
4. Southern Region (Murzek Basin)
5. Al-Kufra area and Al- Sarir (Kufra Basin and Sarir Basin)

The present study focuses on Al-Hamada Al-Hamra Basin “Ghadames Trough ” in the northwestern part of Libya in the area between the (30. 00 and 30, 20) latitudes and the longitudes of 30° and 10° East, and both Tunisian-Algerian border in the west.

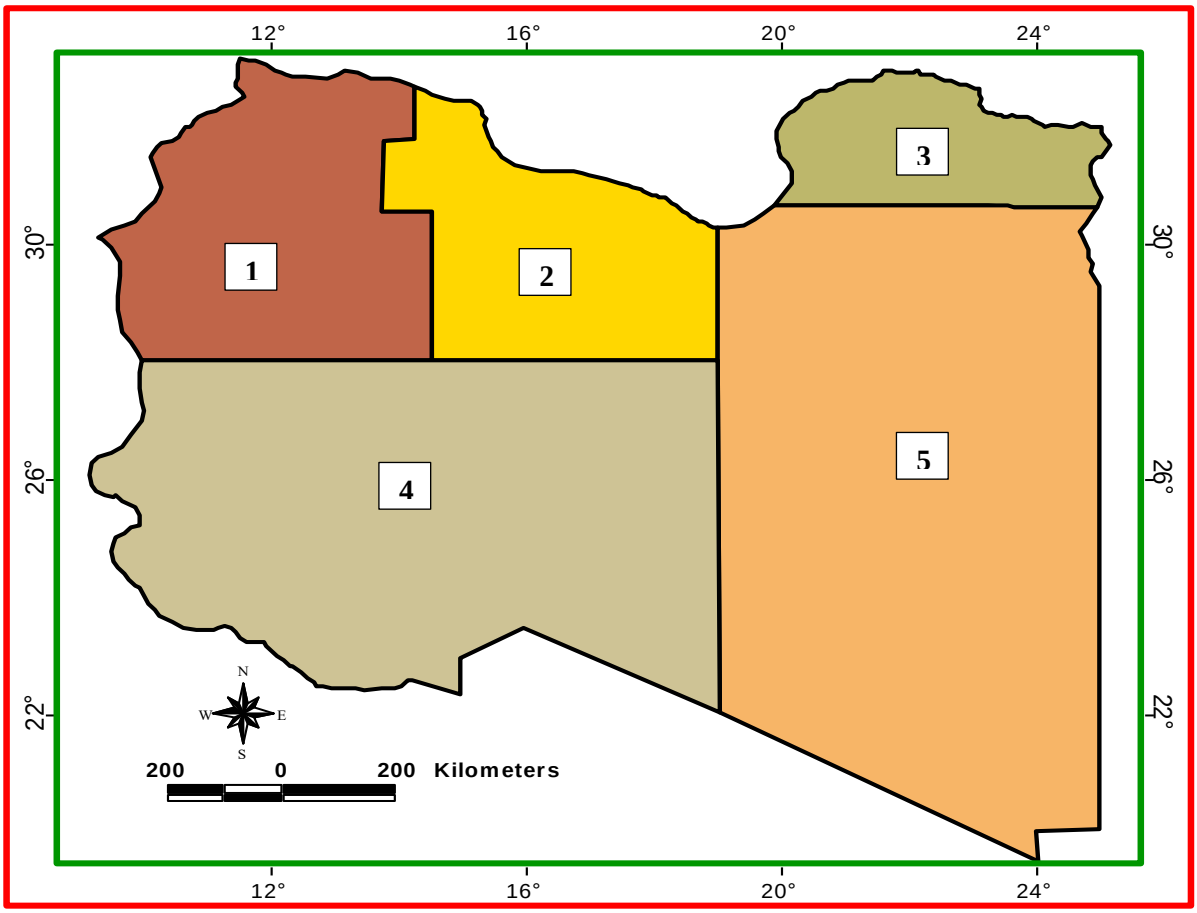
Ghadames Trough contains several underground reservoirs, such as the deep Kiklah aquifer, which is widely used in many areas within the basin currently. This reservoir is located at the depth of 500 meters. The thickness of water-bearing layers varies from region to region within the basin boundary. In some areas, the thickness reaches 500 meters, and more than 1000 meters deep . The level of static water ranges from several meters below the surface to about 40 meters above the surface (Al-Futtaisi et.al, 2007).

Total soluble salts in its water range between 800-1500 mg/L. In some areas the temperature of water in these wells reaches 400 °C (Radhi, M. 2006).

There is an important phenomenon connected with the exploratory digging of the borehole in the district . A sudden rise in water salinity is observed briefly during pumping from some wells that exploit the deep Kiklah aquifer exceeding the permissible limits and for the specified periods. This concentration reaches about 19,000 mg/L. Also, there is the lack of hydrostatic pressure in wells especially after being locked as well as disappearance of the artesian property with a low in considerable in productivity (Radhi, M. 2007).

Therefore, the current study is concerned with studying the reasons for the low quality of water, temporary increase in salinity, in addition to the sudden decline in productivity, and the lack of hydrostatic pressure in some wells that exploit the deep aquifer, depending on the review of the previous studies conducted on the region and their follow-ups, geological and hydrogeological qualities the diggs boreholes and the features it of , processing, design and completion, and conducting chemical analyzes of water samples and comparing them with previous analyses will enable the researcher to identify the causes of these phenomena, and the factors affecting the wells that are located nearby or the ones to be excavated in the future.

Figure (1):- Distribution of water basins in Libya



(Source:- General Water Authority, 2006, Tripoli, Libya)

1.2. Research Problem

The problem of the present study is related to a clear phenomenon, which is the percentage of a high percentage of salts in some exploited wells of the deep groundwater reservoir to from Kiklah in the Ghadames Basin. Total soluble salts in the water of some artesian and semi-artesian wells (in short pumping periods) exceed 70,000 mg/L, coincided with the lack of hydrostatic pressure and gradually decreasing productivity.

The utilization rates of this reservoir are significantly increasing, as a regional reservoir also exploited in Tunisia and Algeria . The phenomenon of high salinity is a temporary phenomenon that appears and disappears under certain conditions . Therefore, we must study it and know its causes and troubles , and the influence of the pumping amended on water quality . There is also a need to explain the relationship between sudden

salinity rise, low throughput, and hydrostatic pressure during operation and closure of these wells.

1.3. The importance

- The deep reservoir Kiklah in the Ghadames Basin is widely used particularly in the district of study and adjacent areas. And the degradation of water goodness and the low and the low productivity exploited wells pose a major threat the ezploitation of this reservoir , which requires monitoring and dealing with problems and suggesting solutions .
- The scarcity of monographs on the water qualitativy in the deep reservoir Kiklah in the Ghadames region as it did not effectively address theproblem of temporary salinity of water its careful analysis . Likewise , they did not provide any explanations for the reasons and limits for extension and its impact on other wells exploited in the area . Therefore this study is justified of drawing on the significance and monitored of water levels in the studied reservoir, analyzing water samples periodically, and assessing the quality and rates of pollution **.**
- It is also important to understand the hydraulic relationship between water-bearing layers in order to build future projects for water exploitation in the region. Moreover, there is a need to take care of high salinity aquifers, determine their depths, extension, completion and implementation of wells to prevent their leakage and negative impact on other layers.

1.4. Objectives Studying

The current study aims at

- reviewing the surface and subsurface geological studies and scrutinize of the skeletal attributes and stratigraphy in the southwestern part of Ghadames Basin, especially in the area between Ghadames, Derj and Senawen,
- identifying the hydrogeological properties of the natural water-bearing layers and their hydraulic characteristics, especially in the Kiklah deep aquifer,
- exclusively studying and appraisal the findings of the dig and characteristics of rock layers at different depths,

- exploring the geophysical records of scattered wells in the region, which appeared in the water as a phenomenon of temporary salinity, decreasing productivity and decline of hydrostatic pressure during periods of pumping and stopping,
- carrying out a review of the hydro-chemical study of water and identical the findings of its chemistry analysis with the findings analysis of some previous studies conducted by the General Authority for water in recent years,
- periodic water quality control and preparing maps, models and drawings that concern water quality and suitability for different purposes .
- attention to the relationship between the wells, monitored the spillover of the boulder and salt ,and specified the regime of the faults
- , and the mobility surveillance of water in Kiklah formation .
- drilling wells with a modern design ,through which layers of salt are known and isolated to prevent water leakage and contamination of Kiklah deep reservoir .

1.5. Research Hypotheses

During the pumping tests of many producing wells, exploration wells and some observation wells, it was found that there is high salt water in the first minutes from the pumping , in the addition to a lack of hydrostatic pressure , disappearance of artesian properties and low productivity after the locked . These phenomena represent a clear danger to the profiteering of groundwater trough in the region.

It was observed that the target wells to study their water are highly polluted, and there is possibly there's connection between emphasis of the salts and the existence of quagmires and salty springs and the penetration of some salty water from the deep groundwater layer , and thus water becomes polluted.

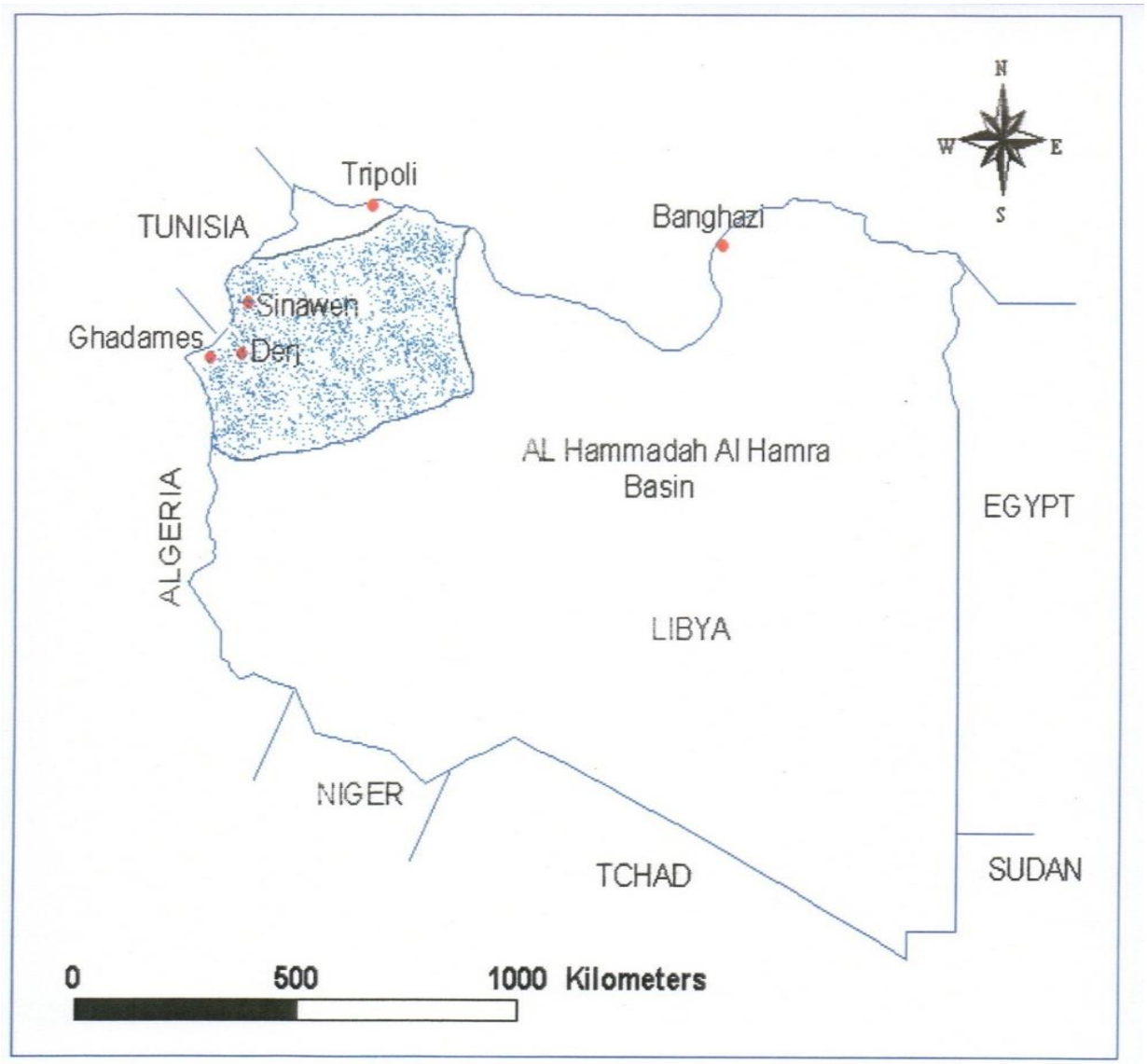
There may be a relationship between the appearance of emphasis high for salts in the water of some wells in the precinct , and the having of some sabkhas and saline springs, likewise the infiltration of saline water of the deep aquifer, and the deterioration and pollution of water . The design specifications for wells and equipment used in processing it , is one of the main problems experienced by wells in the region .

1.6. Location and Borders

The study targets the northwestern part of Libya, Ghadames and its outskirts and the boundaries of the region are as follows:-

- Between latitudes (31°, 10′ - 30°, 29′) N.
- Among meridians (11°, 00′) from direction east and the frontier Tunisia -Algeria from the west . This area covers a total area of approximately (20,000) km2..
- Figure (2) shows the site and boundary of the precinct in Libya.

Figure (2):-Site of the district



(Source:- Al-Futtaisi, et al. (2007). Technical Report on Field Visit to the Wells of Ghadames Basin. General Water Authority. Unpublished report, p. 4)

1.7. The methodology

The study depends on the descriptive analytical method. The methodology included the following points :-

1. The real characterization of the phenomenon of deteriorating water quality, sudden rise in salinity, lack of hydrostatic pressure, rapid decrease in productivity in some wells in the Ghadames basin, analysis and interpretation of the causes of these phenomena, and the reason for a decrease in the productivity of these wells.
2. Study of the geological and hydrological characteristics natural manifestations in the precinct of study, which whom to their large influenceto expiration boreholes.
3. Practical study of water produced boreholes in the district to establish the accurate signatory of the deep wells selected for the study, design specifications and technical and operational problems associated with them.
4. An attempt to clarify the relationship between the sudden salinity of well water and geological faults in the area, as well as the presence of swamps and salty springs and salt water infiltration from the deep reservoir.
5. Developing explanations and solutions to all the problems identified and formulating recommendations regarding the considerations, regulations and procedures required to transaction with the profound boreholes in the district of study the best way and to ensure the exploitation of optimal utilization.

In order to achieve this methodology, the following research tools have been adopted in the study:-

1. References, books and available manuals, which are concerned with the quantitative and qualitative problems of wells and their performance and the methodology used to address these problems.
2. Research studies dealing with the key constructs, concepts and terminology used in the present study.
3. Some reports and scientific articles that deal with the content of the hydraulic variables in the deep aquifers and the factors that control the flow of water and feeding rates.
4. Previous studies available on the region of study that are related to deep wells, especially the reports of General Water Authority on these wells, which include

the final reports of inventory and processing, updating, operation and periodic follow-up reports.

5. On-the-ground realizations in the district of study and sites of selected well to determine the water status of these wells and the problems experienced by them, as well as phenomena of declining performance in these wells.
6. Analysis of water samples collected from wells during field work to know the water quality and compare it with periodic analysis of the changes that occurred, such as the reasons for sudden salinity, rapid hydrostatic pressure shortage and low productivity.
7. Take into account the opinions the specialists and employees of General Water Authority in the Western Region, which had a great impact on answering many of the questions raised by researchers..
8. The use of specialized computer software available data, mapping , syllables and link models , as well as the drawing of hydro-chemical schemes and hydraulic variables.

CHAPTER II

2. GENERAL REVIEW AND THEORETICAL OUTLINES

2.1. Studies Providing an Inventory and Assessment of Water Capacity in Different Aquatic Areas

Hydrological studies have developed in the last decades, especially hydrological studies related to aquifers, which have become Independent science, deeming superficial water and subterranean water an whole science . This complementarity is expression on the interplay between surface water and groundwater.

Actually, the launch of the *International Hydrological Decade* by UNESCO in 1964 has been followed by the long-term *International Hydrological Program* in 1974, and decisions of the World Water Council in The Hague in 2000. With regard to water resource management, environmental, social, health and economic considerations must be taken into consideration, and a focus on protecting the chemical, physical and biological characteristics of water systems in basins through integrated studies based on scientific inclusion and modern technologies. (ACSAD, 2002).

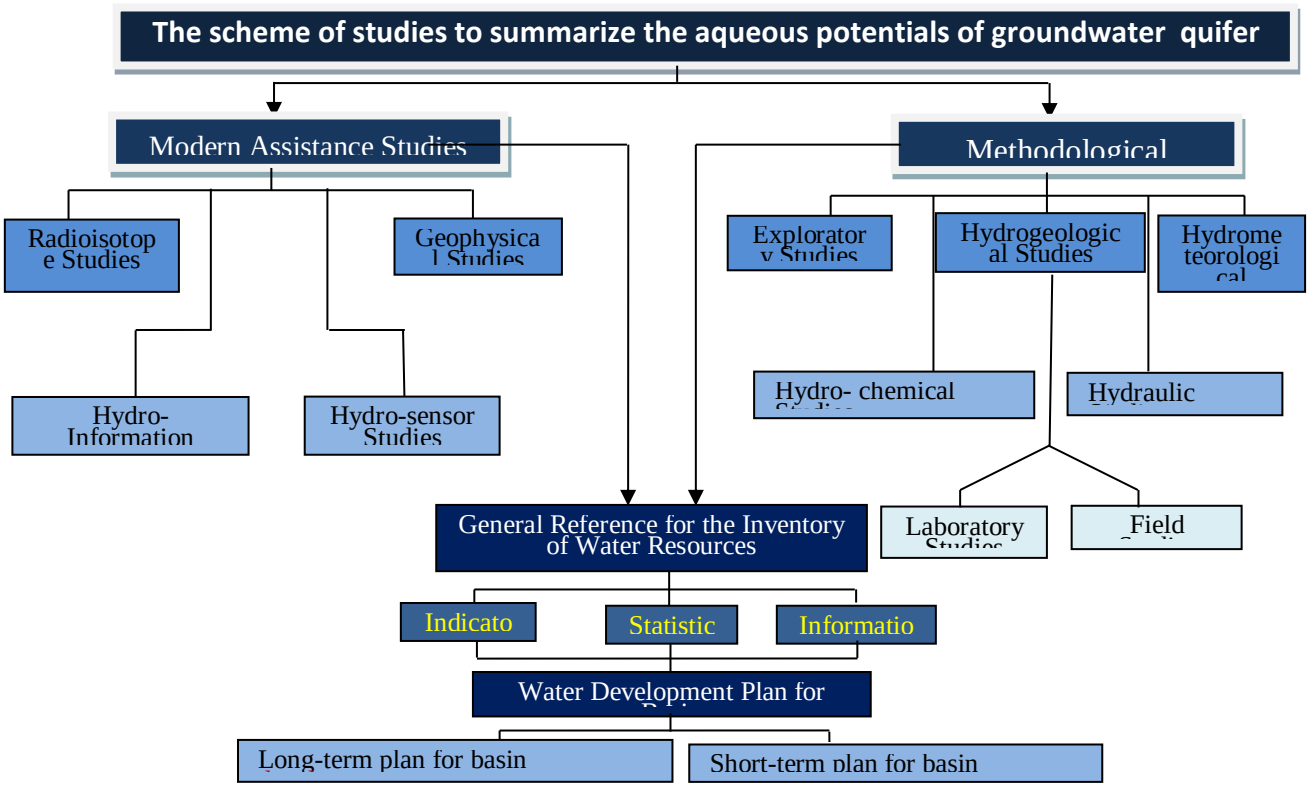
In this regard ,the scheme of studies to the aqueous potentials of the groundwater basin can be summarized as follows (Figure 3):-

2.1.1. Systematic Studies

2.1.1.1. *Hydro-Climatic Studies*

This study is concerned with the natural water cycle of the water basin, known as the water balance by measuring and analyzing climatic elements affecting the water potential of the underground water basin such as:- - precipitation, heat, humidity and evaporation rates, as well as soil moisture and surface hydrological sources. (Bogomulov, C., 1983).

Figure (3):- The scheme of studies to summarize the aqueous potentials of groundwater a quifer



(Source:- The researcher's work, depend on several data and some references)

In the beginning, a general network of monitoring stations is initially designed and implemented, including observation of various climatic elements that expand the monitoring stations connected to basins, aquifers, and development, investment and development projects of water resources in these basins (Bemoglov , C, 1983). Hydro-meteorological monitoring is inexpensive in comparison with the material costs and scientific and technical benefits of water resources in basins and aquifers, (ACSAD, 1985).

2.1.1.2. *Hydrogeological Studies*

These studies aim to determine the geological and hydrogeological characteristics of water-bearing aquifers in the groundwater basin. They are based on topographical maps, geological maps and aerial photographs. Hydrography studies are divided into two sections (Serafascaf , M., 1981):-

- The first section deals with field studies, in which the nature of subsurface layers, their extensions and depths are examined, as well as their rock structure, sub-surface and tectonic characteristics such as faults, fractures, cracks and caves.
- . The second section deals with laboratory studies that determine the stone properties of subsurface rocks, as well as the physical and chemical properties of aquifers.

Based on the field studies in addition to the above-mentioned laboratory studies, the hydrological map and hydrogeological cross-section of the aquifer and its explanatory notes will be prepared (Banana, M. E., 1998).

2.1.1.3. *Studies Based on Exploration Wells*

The preliminary results of the hydrogeological studies of the basin were It is accompanied by the identification of some sites for confirming and verifying information about the formation of subsurface basin layers, infrastructural and tectonic features, further to the features and attributes of rocks science and its cofigurations (Sakr, E., 1982).

2.1.1.4. *Studies Based on Hydraulic Properties of Water-Bearing Layers*

These studies are carried out through the pumping tests conducted on the exploration wells and Arbitrage in the exploration wells . And when we turn on pump is measured , and the hydraulic properties of each water layer in the shared underground basin are calculated , they include the drainage coefficient and the storage coefficient formation in the shared groundwater basin are measured and calculated, including the permeability coefficient and storage coefficient . (Khalil, E. M., 2005) :-

a. determine the annual natural revenue from the water, which reaches the water-bearing layers in the basin separately.

b. determine the distances between the productive wells within the basin, so that no overlap or interference between them affects the investment rates.

c. identify natural losses from evaporation and groundwater flow to the sea or to rivers.

d. determine the underground extension of the underground aquifers and means of communication among them, in addition to the identification of boundary contours for sites and hydrogeological ranges between these reservoirs (Khalil, E. M., 2005).

2.1.1.5. *Hydro-Chemical Studies*

The analysis is performed on water samples collected from wells that use aquifers in the basin. The results of these analyzes will give an integrated hydro-chemical study and we can represent these results on charts in order to monitor the changes that take place to qualitative of water for the nearby water basins . (Duradkha, K., 1988).

2.1.2. Assistive Technologies

The introduction of new assistive techniques in groundwater studies does not have any way of diminishing the value of systematic studies or dispense with any of them. On the contrary, this requires exercising them more accurately and in depth to provide a balance in information and its integration. The new techniques that will be exposed are tools or means of research assistance and speed, and can be used to fix the problems that can be solved by systematic studies.

Therefore, these methods are not original methods, but reflect the originality of methodological methods and this is what has been settled in the global scientific forums (Al-Salawi, M., 1986).

2.1.2.1. *Hydro-Geophysical Studies*

Geophysical techniques are used to support the hydrogeological studies of basins and are used for this purpose mainly through geophysical methods. (Resistive geophysics method or underground techniques), as well as the method of vibration and refraction and the method of gravity in some specific cases of breakdowns, fractures and karst. The application of these techniques leads to many geological conclusions that depict the geological picture beneath the surface in the basin and thus determine the water-bearing formations and their properties in water quality.(Banana, M.G ,1998) These conclusions include :-

- Identification of the contact surfaces between fresh groundwater and brackish groundwater .
- Define the subsurface and convex and concave layers, as well as faults and caves.
- Identification of the hydrogeological limits and separations of aquifers in basins.

2.1.2.2. *Hydro-isotopic Studies*

In recent decades, the ratio of radioisotopes in the water has increased due to the nuclear explosions that occurred in the world. This type of study can infer the relationship between the ratio of rainwater leakage and surface water to th earth interior the movement

of this water in the depths, the feeding and depletion systems , as well as the pollution rates of these water basins . (ACSAD, E. M., 2005).

Applications of water isotopes are particularly important in studying dry and semi-dry groundwater basins, due to the decrease or non-precipitation, high temperatures and high evaporation rates, in addition to a number of other factors that have negative effects on the water load of the isotopes and their development when leaking into layers Groundwater in the basin (ACSAD, 1985).

2.1.2.3. *Hydro-Sensor Studies*

Remote sensing techniques were widely used in the early 1970s to explore the sources of terrestrial wealth and terrestrial structures from space through the use of space images as a tool to solve difficult problems or give greater impetus to systematic studies.

These studies are used to value basin water by documenting hydrogeological basins and exploring surface indicators of groundwater presence, in addition to determining the optimal location for wells and completing subterranean waterways in breakdowns, fractures, and karst. Caverns, determining the sources of contamination of groundwater reservoirs and assessing the real of the water equilibrium in the reservoirs (Aboloqma, M., 1995).

It is noted that most remote sensing applications are linked to terrestrial and field-based studies in order to match the indicators of the sensory images with the ground reality to document the basis of the analysis. In addition to images from satellites, remote sensing is also used by flight to complement the information obtained from satellite imagery and to support conclusions about basin characteristics (World Water Council, 2000).

2.1.2.4.Hydro-Information Studies

These studies are carried out by entering information into the computer after completing the verification and documentation process, using specific programs that include electronic documents for this is intimation . On other side, this info is used to know the aggregate quantified of water is accessible, such like in the various sectors of groundwater basins,

and in advanced stages, water sports models have been developed that simulate the natural reality and reflect the positive Subterranean . (Water World Council, 2013).

2.2.Documentation and Analysis of Basins Information and Systems

The results of the different water studies of the groundwater basin are collected in the form from of maps including contour lines, and pictures .It describes the general characteristics of the aquifer and its relationship to neighboring basins. Therefore, these maps are combined with contour lines , curves and normal and atmospheric photographs , with a notebook containing indicators and statistics that have been accessed . In general this book includes the following basic maps (ACSAD, 2002) -:-

1. Map of hydrological basin or hydrological area, indicating basin boundaries, natural hydrographic network, precipitation, and leakage rates
2. Geological map showing water-bearing formations , and also parameters-the hydraulic .
3. Map of specific discharge of wells
4. Map of hydrochemical traits for groundwater layers in the reservoir .

These maps help to a large extent, investment and exploitation of the groundwater basin. It also help scholars abide by standards and methods which internationally . Figure (3):- The scheme of studies to summarize the aqueous potentials of groundwater aquifers. (Water World Council, 2013).

2.2. Terms and Concepts Used in the Assessment of Basins

2.3.1.*Terms and Concepts of Aquifers*

2.2.1.1. *Groundwater Level*

The level of groundwater or (filled region) is an important phenomenon for understanding groundwater in the water standard in the lakes. When try to see the water standard is almost impossible, but we can clarify it and study it on maps and images in many wells, because the cross section shows the upper part of it limit of the saturation zone, as shown by Figure (4). The water level maps show that this is not horizontal (Hamouda et al., 1989). There are many factors that make deck of the water standard unorganized , from where of the rains rates and the permeability of the subsurface layers

from one place to another. This leads to an imbalance in water leakage and thus the irregularity of groundwater movement (Al-Salawi, M., 1997).

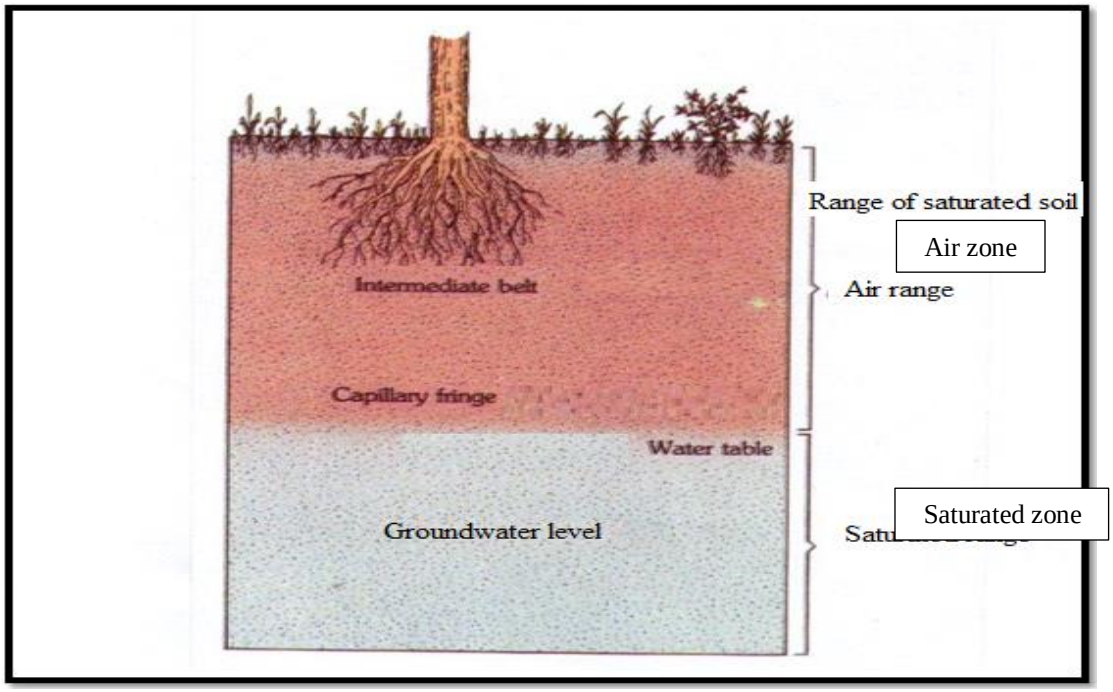
During dry seasons, the water level decreases, resulting in low water during the cycle and it becomes the dry (Figure 5) (Hamouda et al., 1989).

2.2.1.2. ***Porousness and Penetrativeness***

The volume of stored water and surface water varies by nature.

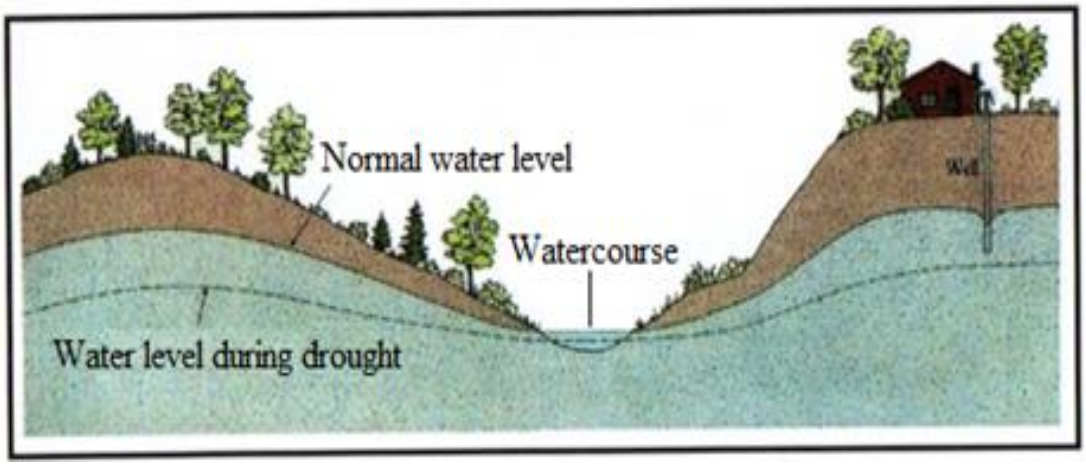
Subsurface configurations and layers , as water leaks into the ground due to gaps or openings in the sedimentary rocks or soil. These openings resemble sponge spaces, often called porous spaces . In general, porous size expense of these vacuums aggregate to vacuums in the boulder . These spaces are formed by gaps, cracks and fractures, as well as gaps resulting from decomposition affecting soluble rocks such as limestone (Dradkah, K., 1988). Table (1) shows the differences of porosity percentile (%) of the various types of rocks.

Figure (4):- Water level corresponding to the upper limit of the saturated zon



(Source:- Hamouda et al. (1989). Earth, Introduction to The nature Geology. Leaflets of Al-Fateh University , Tripoli , Libya)

Figure No. (5):- Terrain plays a prominent role in reducing the amount of groundwater, especially during droughts, which affects the drying of some wells.



(Source:- Hamouda et al. (1989). Earth, Introduction to The nature Geology. Leaflets of Al-Fateh University , Tripoli , Libya, p. 266)

Table (1):- Differences of porosity depending on the different types of rock

Type of rock	Porosity %
Non -solid materials	
Gravel	25-40
Sand	25-50
Silt	35-50
Clay	40-70
Rocks	
Fractured Basalt	5-50
Karstic limestone	5-50
Sand stone	5-30
Limestone, dolomite	0-20
Shale	0-10

(Source:- Dradkah, K. (1988). Hydrogeology of Groundwater. Dar al-Bashir for Printing and Publication, Amman, Jordan, p. 187)

Porosity varies widely according to rock types. Sedimentary rocks are often rich in pores. The shape and size The degree of homogeneity is determined by the number of grains, their pores and the rocks formed from them and the percentage of adhesives that act on the cemented material .

Rock porosity is usually reduced if the granules are close together, and their grains are irregular in shape and small in size and have an overmuch in the percentage of adhesives or solvents (Bogomulov, C., 1983).

Porosity is not the exact measure on which groundwater is obtained. The rock may be porous But the water is narrow and is not allowed to pass. Therefore, transmittance is the ability of water to pass through rock ducts (Banana, M. E., 1998).

The water moves in and the paths and directions are crooked and winding through small openings. The smaller the pores, the slower the movement of water. However, if the gaps are small, the water membrane attached to the granules touches each other and overlaps, producing a partial pull force that stabilizes the water content.

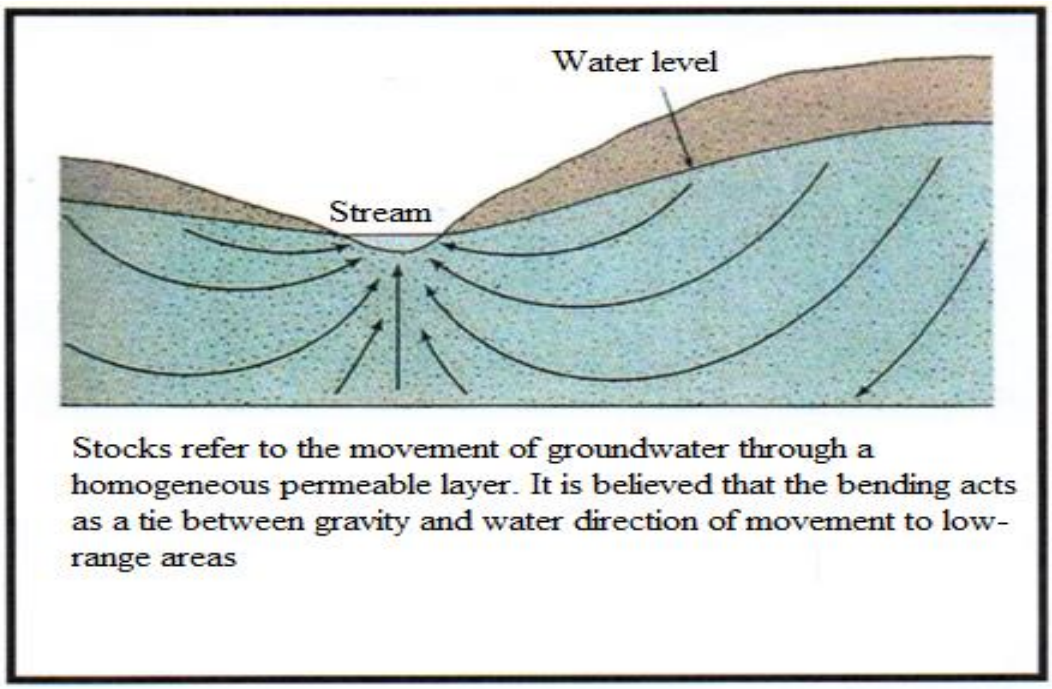
Next to porosity the rock must have high permeability to facilitate the movement of groundwater through rock granules. Many types of rock, such as clay, do not have high permeability, although they are considered porous and classified as non-aquatic. On the contrary, sand and gravel have larger pores and have higher permeability and are classified as aquifers. Some rocks also have high permeability to allow water to flow through them, even if they are nonporous, such as fractured basalt, and granite where cracking occurs. These splits are easy channels for water to pass through easily (Al-Talhi, J. A., 2004).

On this groundwork , rocks be zoning into cardinal genres in this field, the main ones are of which are porous rocks that resemble sandstone, non-porous rocks such as high-strength quartz . like that , it is evidently that if the properties of a rock are available (i.e., porosity and permeability), it becomes suitable for storage of vast amounts of groundwater, and it is also easy to draw water from it by pumping in abundant quantities of wells (Dradkha, K., 1988).

2.2.1.2. *Water Free Movement and Water Restricted Movement*

Groundwater relies on gravity, where water moves from areas with high water levels (high pressure zones) to areas with low water levels (low pressure zones) towards the end of a watercourse, and some water takes its way down the slopes of water levels directly, most of them follow a crooked path towards the stream, as indicated by Figure (6) below (Hamouda . 1989) .

Figure (6):- Movement of water from high pressure zones to low pressure zones in the form of crooked tracks of the flow range



(Source:- Hamoudah , (1989Land, chapeau to Nature Geology, leaflets of Al-Fateh University Compound , Tripoli, Libya , p. 267)

Groundwater is divided into two types according to its movement (Al-Talhi, J. A., 2004):-

a. ***Free Water***:- It is the water that restricts its movement only by gravity. Therefore, its upper water level is The vertical and follows the shape of the Earth's surface (Figure 7). Also, the dimension and proximity to the ground surface greatly influence by atmospheric changes.

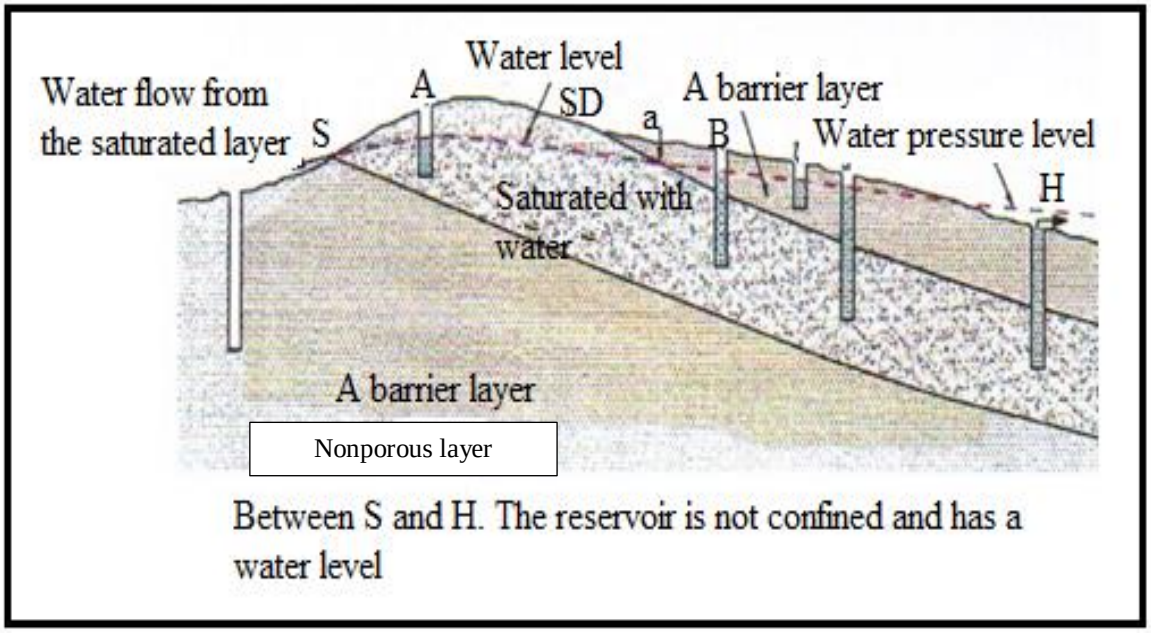
b. ***Restricted Water***:- It is the water controlled by the presence of an impermeable layer (non-porous) and not a passage either below or above it and it acts as an obstacle or impediment to its movement. The movement of this type of water may be subject to the presence of two stratas that rise from above and below. Also, the level of this type is

mainly is composed in conformity with the attributes of reservoir .It's be untouched by top of earth or climate.

2.2.1.3. *Aquifers*

Groundwater aquifers are porous and permeable rock layers that allow water to pass through, store and then give it back in economic quantities. This means that layers form a geological composition or group of configurations saturated with porous water, cracks and gaps that represent enough spaces to store water. Sometimes these spaces are original, such as gravel, sand, sediment, sand dunes, sandstone, or secondary spaces due to cracks or fractures resulting from resolution as in carbonate rocks. Sedimentary rocks, such as clay, hard limestone, and others, cannot be good layers carrying groundwater, unless there are many fractures in these rocks. In this case, they can store water. The same applies to igneous and metamorphic rocks with cracks and gaps. (Khalil, E. M., 2005).

Figure (7):- Free water movement and restricted water movement



(Source:- Al-Talhi, J. A. (2004). So as Not to Die Thirst. Institution Libya for deployment , Distributive and Proclamation , Tripoli, Libya, p. 52.)

"***Aquifer water layers***" as an expression is not an abstract scientific classification, but it has acquired an economic dimension due to its ability to produce water in economic quantities for use. Therefore, the aquifers are classified according to their storage capacity and productivity as follows (Al-Salawi, M., 1986) :-

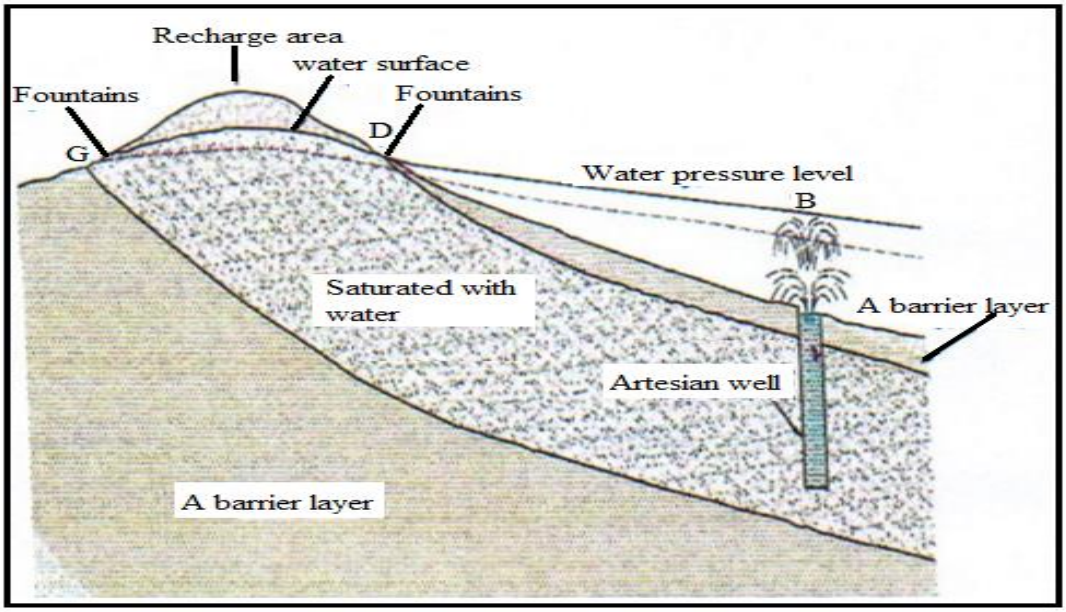
1. Magnitude of the porous voids contained in the aquifer of water specifies how broad accommodate this reservoir .
2. Depend on the permeability ratio of this reservoir in the district .
3. The aquifer feeding depends on factors , mostly outside the water bearing formation , such as the rainfall rate . The soil moisture, the leakage , In general , under the saturated layer of the underground reservoir there is an impermeable layer, which reservoir , and the most famous impermeable layers are clay , and solid limestone .

2.3.1.5.1. ***Unconfined Aquifer***

In this reservoir , where the pressure of water at this level is equivalent to atmospheric pressure, and this surface is variable according to the areas of nutrition and discharge. The lower layer of this reservoir is a confined or semi-confined layer as shown as shape (8). Water movement in underground reservoirs is free of movement. The main driving force behind this movement is gravity . (Khalil , E- M , 2005).

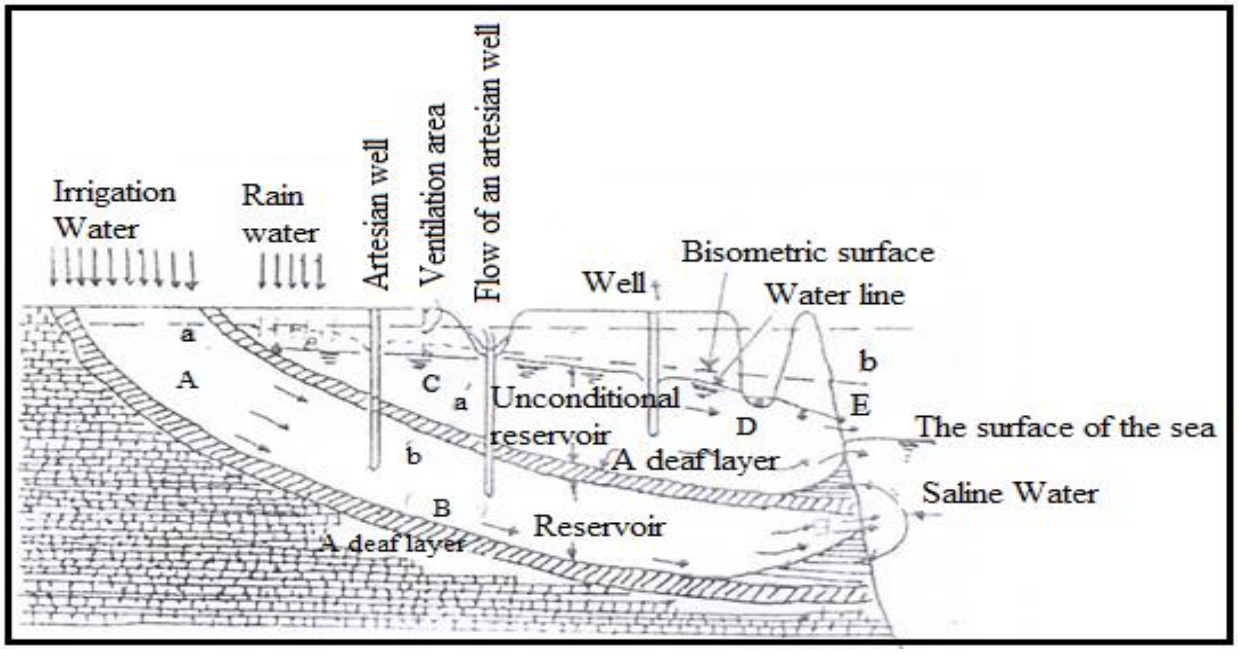
The Rainwater is the main nutrient for the water of these reservoirs by leaking through the layers of soil and subsurface rocks above these reservoirs . Likewise , the released surface water excess irrigation water can be a source of feeding these reservoirs through leakage and leaching (Figure 9) (Al-Talhi, J. A., 2004).

Figure (8):- Confined and non-confined aquif



(Source:- Al-Talhi, J. A., 2004. As Not To Die Thirst . Foundation Libya for dissemination , Apportionment and Declaration . Tripoli , Libya).

Figure (9):-The nature on which the Artesian wells



(Source:- Khalil, E. M., 2005). Groundwater and Wells. Dar Al-Kuttub AlAlamia for Publication and Distribution, 2nd ed. Cairo, Egypt.

2.3.1.5.2. Confined Aquifer

It is the reservoir in which the water-bearing layer, which is confined between two non-permeable layers filled with water, is completely intact. This reservoir does not have a free groundwater level but is characterized by a piezometeric surface level and pressure at any point in water is greater than atmospheric pressure.

The underground reservoir can be confined to one or several layers with a single slop . It can also take the basin form consisting of several layers of variable thickness and inclination in the form (10 a & 10b) . In any well, this reservior penetrates above the water reservior level , and this wellis called an artesian well . (Figure 9) (Al salawi , M , 1986).

Figure (10-a):- An illustration of a semi-restricted reservoir with a bottom-up leakage

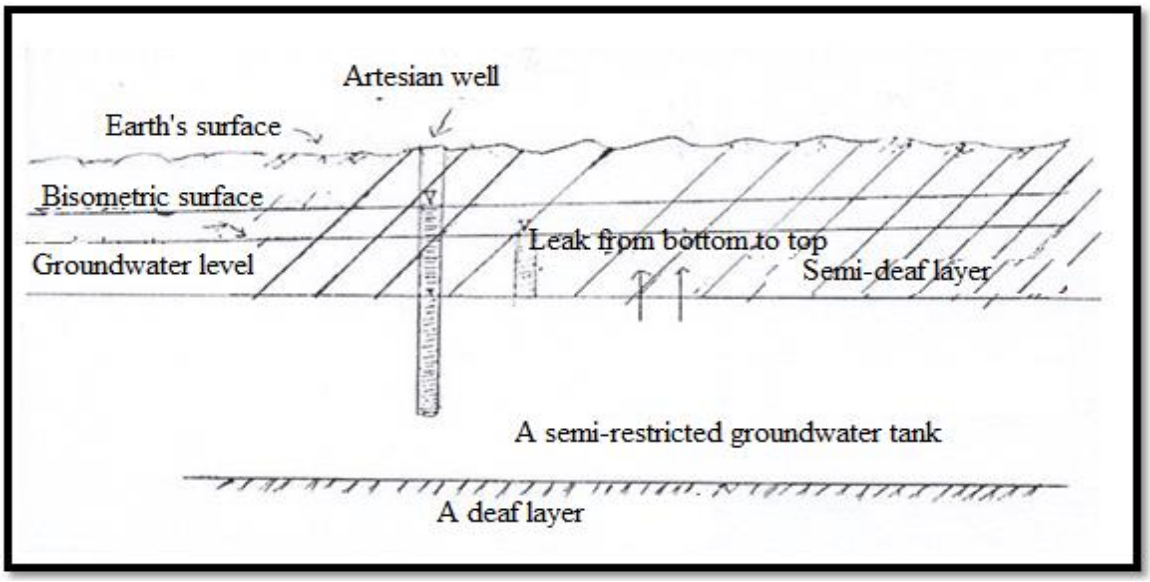
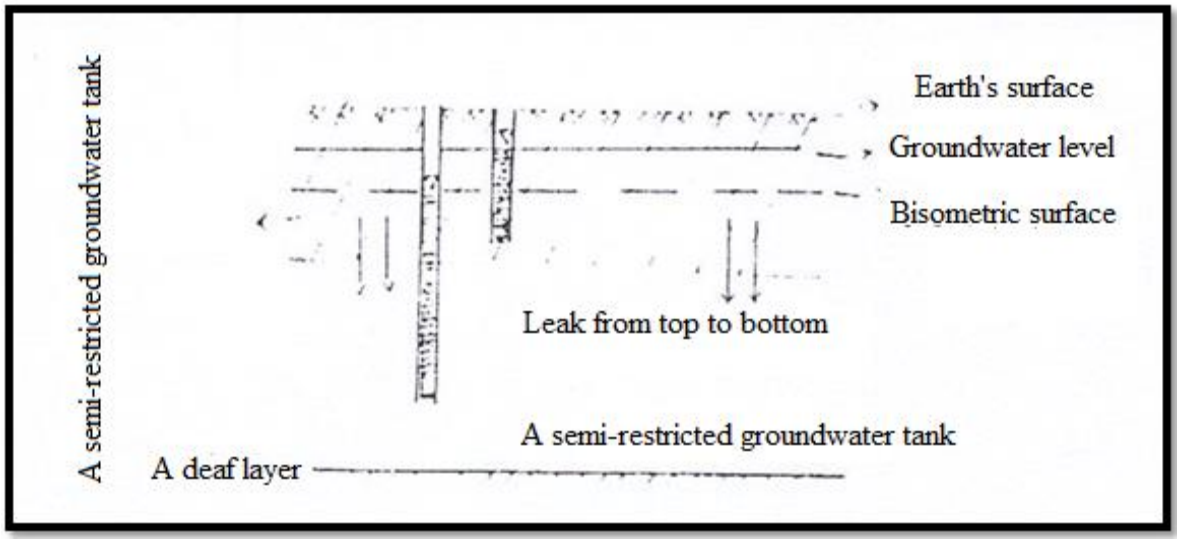


Figure (10-b):- An illustration of semi-restricted reservoir with a top-to-bottom leakage



(Source:- Al-Salawi, M., 1986). Groundwater between Theory and Practice. Publications of Dar Al-Jamahiriya. Tripoli, Libya)

2.3.1.5.2. Semi-Confined Aquifer

If the confined under the ground aquifer is flanked surrounded by a semi-deaf layer or two, in this case it is called a semi-restricted underground reservoir and its fed by fed by filtering rainwater that falls on the reservoir layers or the reservoir port in the feeding places, which is usually somewhat remote .The additional recharge can be by vertical leaching of groundwater or rainwater through the semi-deaf layers , which are at the top of semi-restricted underground reservoir (Al-Salawi, M., 1986).

2.3.1.6. Hydraulic Gradient

The hydraulic descending and pour of water in channels, feom the factors influencing the movement of groundwater. It expresses the height difference for the points of entry and exit of groundwater. It is expressed as (I) and is calculated from the following equation :-

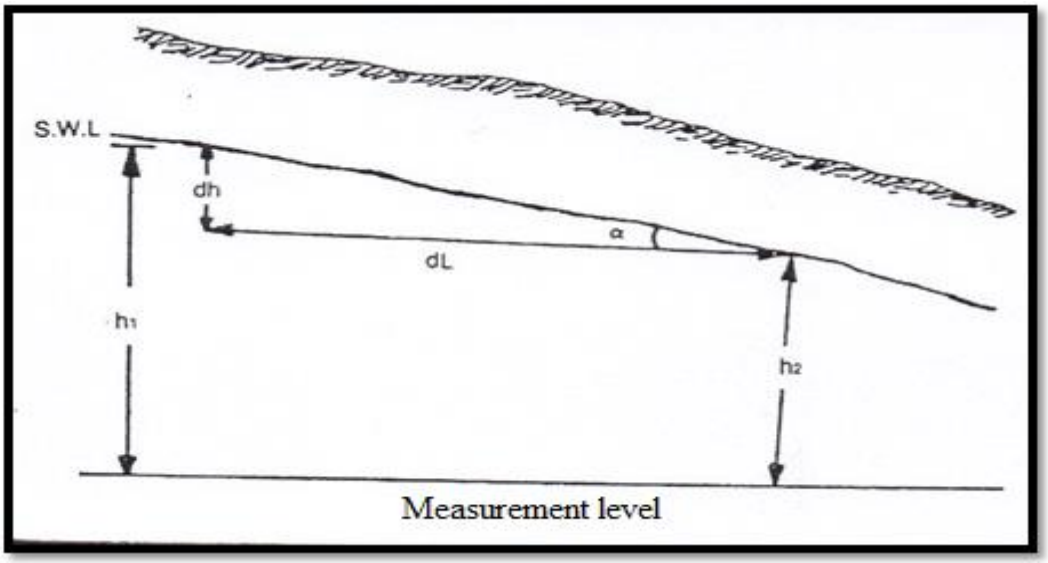
$$\boldsymbol{I = \frac{dh}{dl} = Tan\ \alpha}$$

The hydraulic tendency usually depends on the water rush from the loud pressure places to the low-wage pressure , as outlined in forma (11) (Dradkah , K., 1988).

2.3.1.7. Natural Recharge of the Aquifer

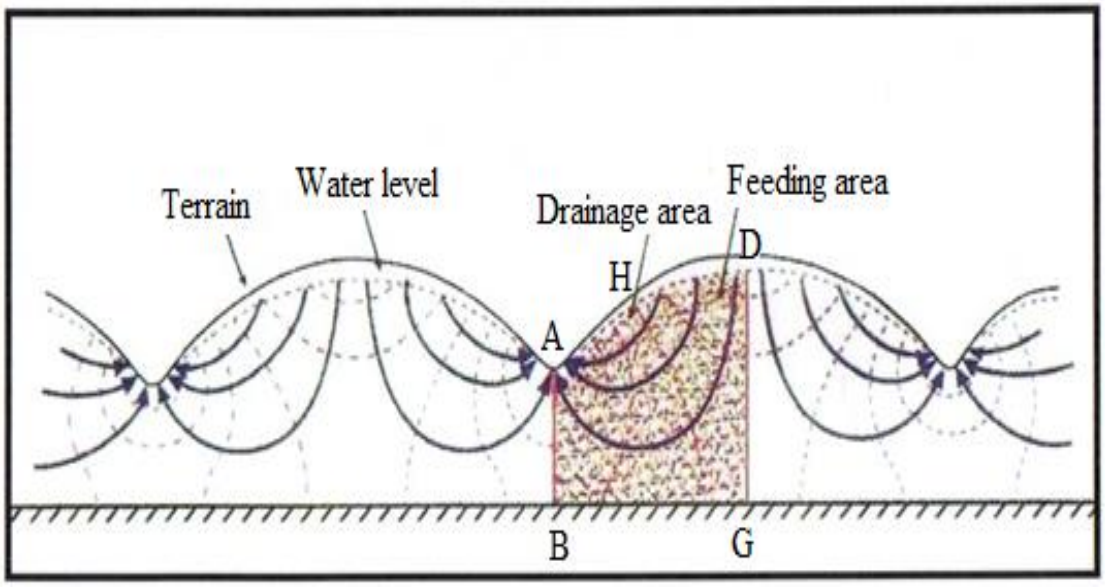
In highlands and lowlands , the groundwater descends that infiltrates soil and sub-surface rocks and spills to in the valleys in the movement of flow, vertical surfaces are created, from which the water flows away in the two directions, which are called the areas of dividing the groundwater, each of which is divided into a feeding area and a drainage area (Figure 12). The nutrition zone is defined as the area which the moving water and groundwater storage (Bogomulov, C., 1983) .

Figure (11):- Method of calculating the hydraulic gradient in the water-bearing formation



Source:- Dradkah, K., (1987). Hydrogeology of Groundwater. Dar Al Bashir for Printing and Publication. Amman, Jordan)

Figure (12):- The groundwater flow system forming arches heading to the valleys dividing water flow into feeding areas and drainage areas

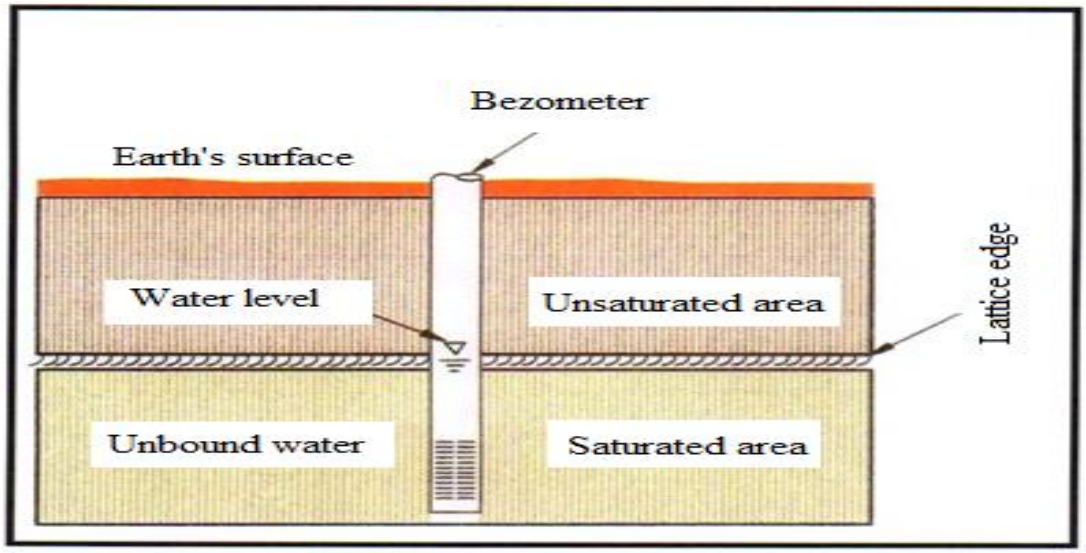


(Source Al-Talhi, J. A. (2004). So as Not to Die Thirst foundation Libya for dissemination, Apportionment and Declaration. Tripoli, Libya)

Accordingly, groundwater exceeds the capillary edge and reaches the saturated layer, format (13) shows which is the amount of natural feeding of groundwater. And the movement of water that seeps into the ground to feed the underground reservoirs is affected by both topography and geology in the precipitation region, thus creating local , secondary and regional systems of groundwater movement (Figure 14).

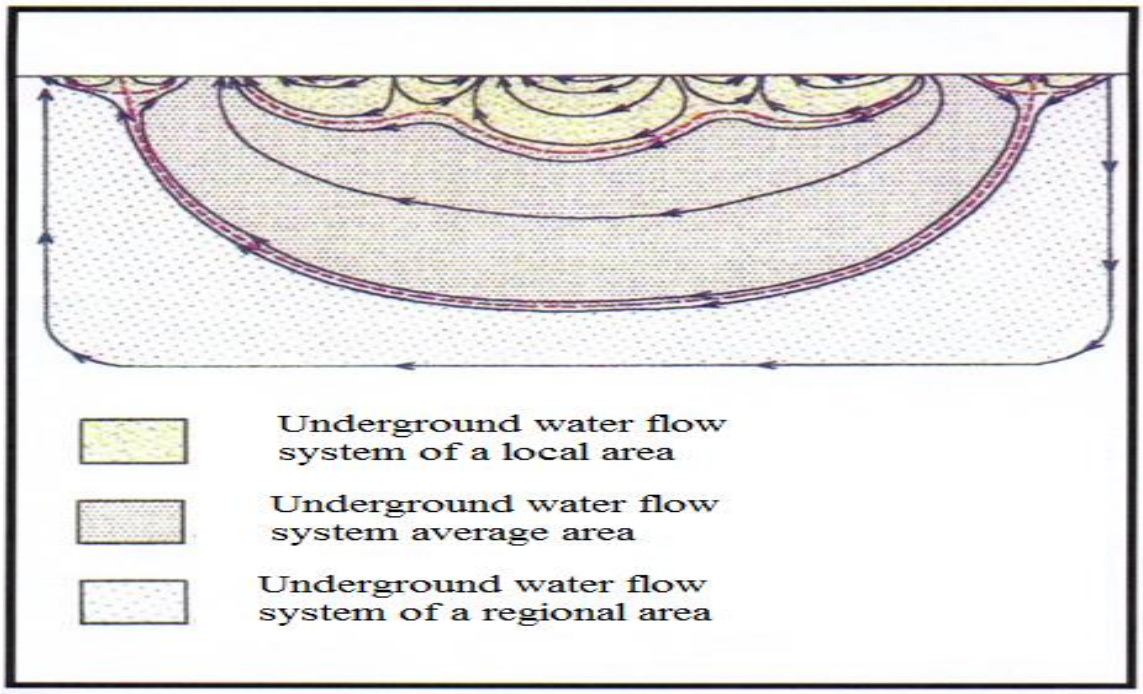
Any feeding or discharge of any free groundwater reservoir , such as the quadrant reservoir used by wells in the district of study, performs to a altered in the magnitude of reservoir stockpiling . This trigger to altitude level of the water surface in condition of nutrition and a drop in the discharge case .

Figure (13):- Groundwater nutrition the area to the saturated area , due to gravity through the water surface level



(Source:- Al-Talhi, J. A. (2004). So as Not to Die Thirst. Foundation Libya for dissemination Apportionment and Declaration . Tripoli, Libya)

Figure (14):- Local, medium and regional systems of groundwater flow



(Source:- ACSAD, 2002. Studying and Mapping of Natural Resources. Central Publications. Damascus, Syria, p 24)

The safe use of any aquifer requires the withdrawal to be within the annual recharge limit, which requires cognizance of the quantity of feeding , through which measurements

$$P = QS + R + ER$$

are made over a given time period for rainfall and runoff in the region of study. The following equations are usually applied to estimate the annual feeding quantity of any groundwater reservoir (Al-Talhi, J. A., 2004).

In the feeding area:-

where:-

P = annual rainfall rate (mm)

Qs = surface water of annual flow rate (mm)

R = annual average groundwater recharge (mm)

ER = mean annual amount of evaporation and output in feeding area (mm)

In the discharge area:- $\boxed{\mathbf{Q = QS + D + Ed}}$

where:-

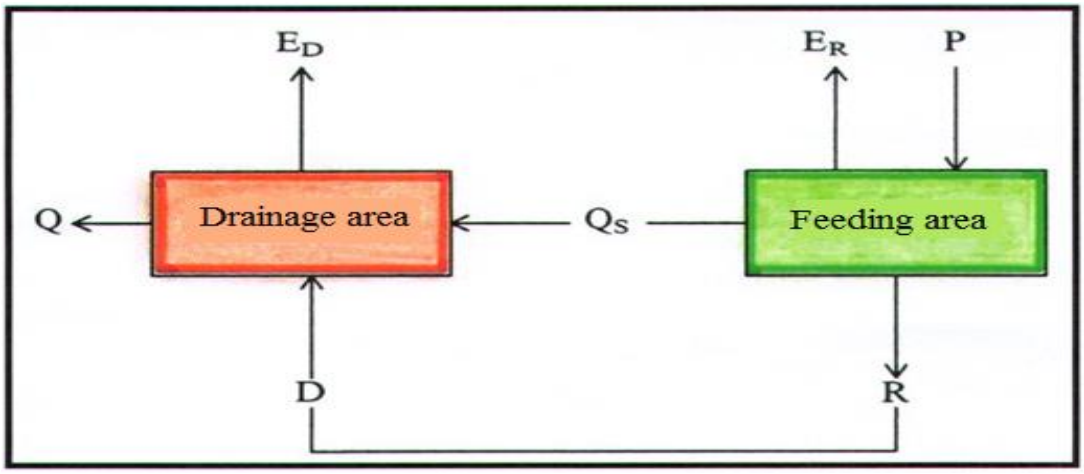
Q = annual flow rate

Qs = surface water of the annual groundwater rate

D = annual discharge rate of groundwater

Figure (15) shows concepts and determinants of these equations in the areas of nutrition and discharge.

Figure (15):- Calculating the annual recharge of groundwater reservoir by the relationship between different treatments in both the feeding area and the discharge area



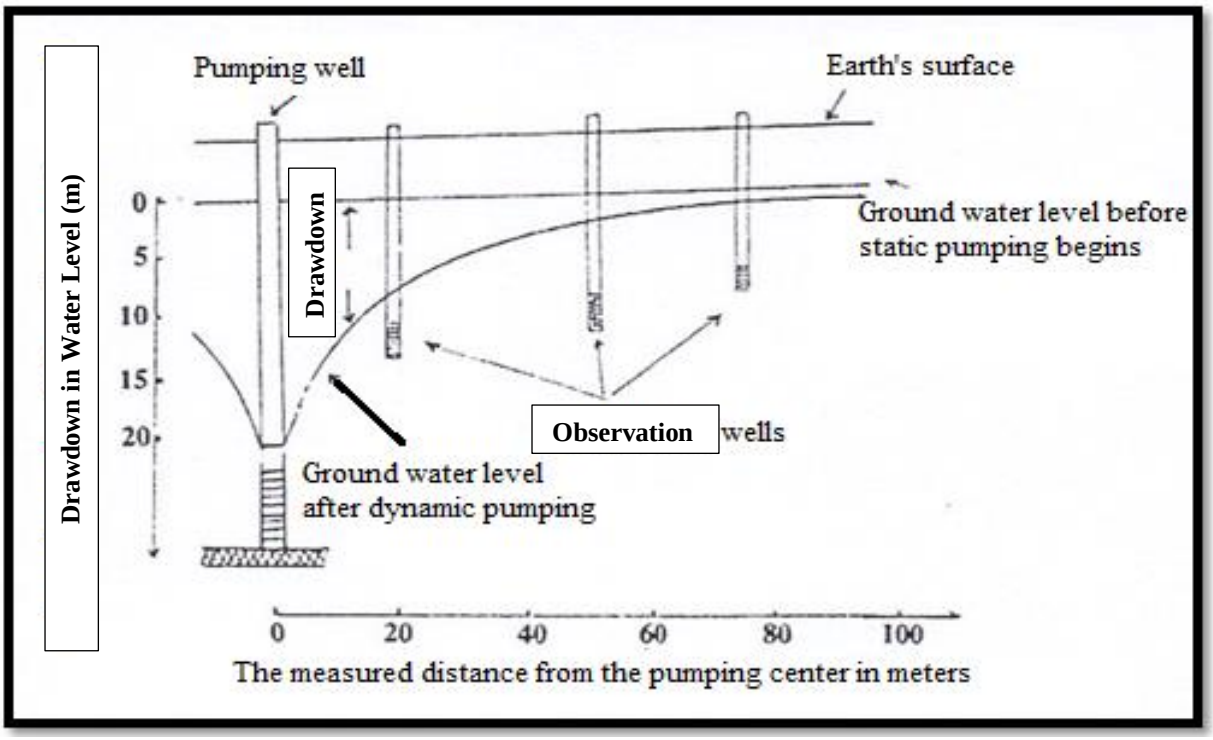
(Source:- Al-Talhi, J. A. (2004). So as Not to Die Thirst. Foundation Libya for dissemination Apportionment and Declaration . Tripoli, Libya)

2.4. Terms and Concepts of Test Pumping from Wells

2.4.1. Test pumping

Test pumping is the process of pumping water from a well equipped with a filter that penetrates into an underground reservoir for testing. Water is pumped by the well from the underground reservoir during a certain time and at a specific pumping rate, then the effect of landing in the test well . or in the main well itself, whereas wells others are located next to the main pumping well and at limited distances (Figure 16). Then compensation is manufacture from the worth of the reduction in the water table registered in the surveillance wells , also the worth of the spacing among these wells and the main pumping well , likewise the rates of water pumping or disposal of specific equations in order to calculate the hydraulic or hydrogeological transactions of the underground reservoir (Al-Salawi, M., 1986).

Figure (16):- Test pumping from a pumping well and its effect on the water level and landing in the adjacent observation wells



(Source:- Al-Salawi, M. (1986). Groundwater between Theory and Practice. Publications of Dar Al-Jamahiriya. Tripoli, Libya)

2.4.2. *Static water level(S.W.L)*

from it itself or before the pumping operations (Figure 17-a).The overall water level is generally utterance as the dimension between the water level inside the well and any likeness dot on the land surface . In cases of self-flow wells, this level is measured before opening the well for production (Khalil, E. M., 2005) .

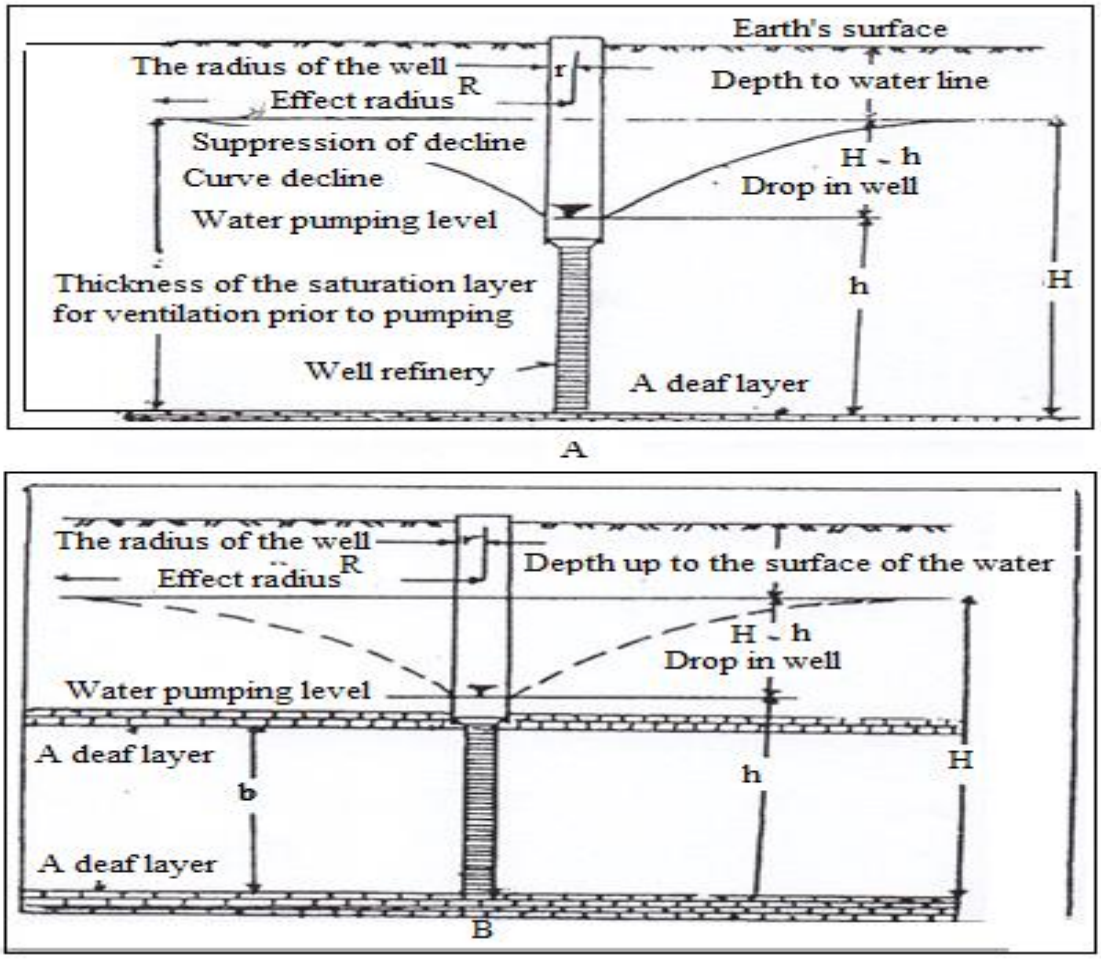
2.4.3. *Dynamic water level (D.W.L)*

The effective water surface is the water level of the well through pumping at a specific time or at that time of pumping, sometimes called Pumping Level. In the case of self-flowing wells, it is the level at which the well reaches when it is open (Figure 17-b) (Al-Salawi, M., 1986).

Figure (17A & 17B):- Terms used in injection tests

A. well in underground unconfined reservoir

B. well in a confined groundwater reservoir



(Source:- Al-Salawi, M., (1986). Groundwater between Theory and Practice. Dar Al-Jamahiriya for Publication. Tripoli, Libya)

2.4.4. Landing

Is process the groundwater is discharged from the well . The value of this drop can be calculated by subtracting the moving water level from the static water (Al-Salawi, M., (1986).

2.4.4.1.Residual Drawdown

After pumping stops, the water level ascend again to period of the pre-pumping (i.e., static water level). This process is referred to as the return process (recovery). The distance measured at point during the return the residual drawdown (Khalil, E. M., 2005).

2.4.4.2.Well productivity

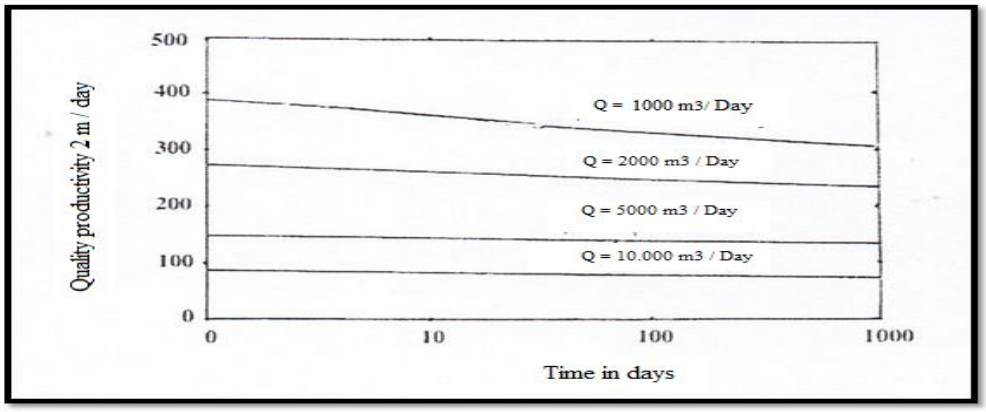
The productivity of a well is the quantity of water the disburse from the well in the unit of time expressed by pumping or self-flow. This rate is often expressed in cubic meters/hour, liter/sec, gallon/hour, or gallon/min (Todd, T. K., 1980).

2.4.4.3.Specific Capacity/Specific Yield

Specific the rate of productivity in relation to low at the same time and is symbolized by the symbol (*m*3/h/m), and calculated by dividing the productivity on the drawdown (Davis, S. N. 1999).

The well specific energy is the measure productivity of the well .note of the fact that productive amplitude reduce when intensify drag .The well data in Figure (18) shows this relationship or effect (Alsalawi , M . 1986).

Figure (18):- Change in the specific productivity of the pumping well with the change in pumping rate and time



(Source:- Jacob, C. E., 1946)

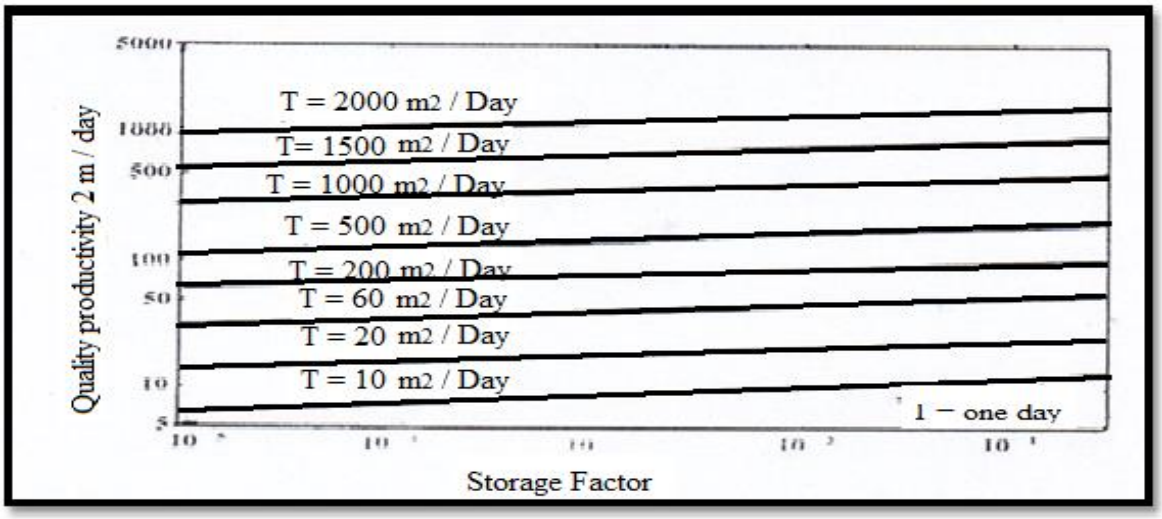
On Were the energy of the well fixed. Per pump process , if it plummeted on the water level normal in of the well . The reason is be either scroll factor or relegation as Figure (19) The relationship curve between specific productivity, pass factor and storage factor calculated from the non- compliance formula for a day of pumping for a well with a diameter of (30) centimeters , These curves give ease in evaluating and finding the value of the pass parameter in the wells under pumping . (Jacob, C. E., 1946).

2.4.4.4. Specific Drawdown

It is the ratio between the drag and the unloading that is

Specific Drawdown = Drawdown (m) ÷ Discharge (m^3/s)

Figure (19):- Curve of relationship between the productivity quality , pass factor and the storage factor calculated from the balance equation

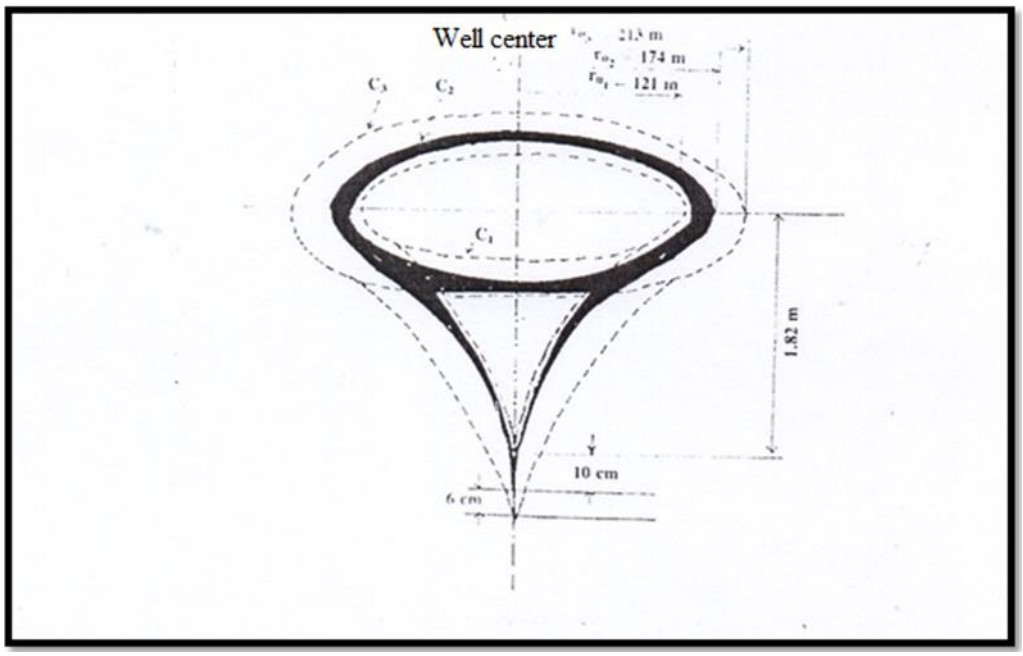


(Source:- Jacob, C. E., 1946)

2.4.5. Diameter half Influence of the borehole

The outer boundary of the cone of decline , called the cone radius and symbolized it with the symbol (r0), and its value is large for wells pumping restricted or artesian underground reservoirs. Free groundwater reservoirs are pumped , the smaller their value . As for the wells that pump from free groundwater reservoirs , their value will be smaller in value compared to the artesian wells, the radius of the impact of a well will get bigger as it increases and widens with artesian wells . So there is a huge benefit from Calculating the radius of the impact of the well , as it is used to the original well in order not to cause interference between them . (Figure 20). Generally, there is a great benefit of calculating the effective radius to the original well so that there is no overlap between them (Al-Salawi, M., 1986).

Figure (20):- The altered in half diameter Influence and depth of the cone of decline after equal time periods of pumping at a steady rate from a full penetration well . well (Source:- Al-Salawi, M., 1986).



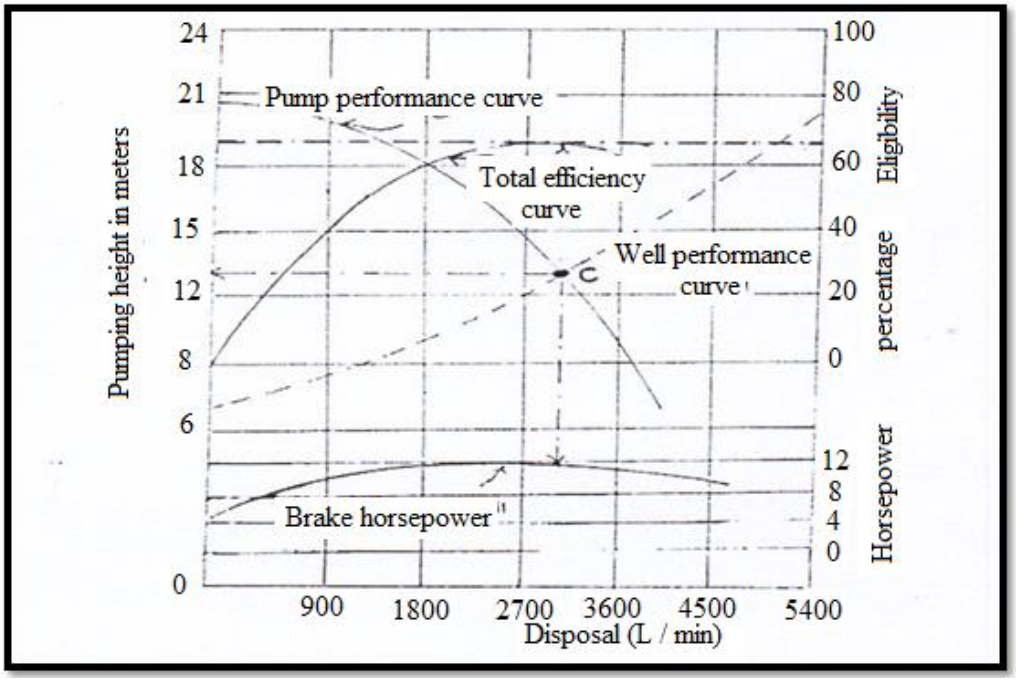
(Source:- Al-Salawi, M. (1986). Groundwater between Theory and Practice. Publications of Dar Al-Jamahiriya. Tripoli, Libya)

2.4.6. Well Performance

It is the curve the results from sketch of the limbic water, where the values of productivity or the discharge the well are placed on the x-axis .The depth is on the groundwater level it is placed on the y-axis .

The well performance curve is usually used in the selection of the pump that gives the desired behavior to the calculated total height with the maximum possible work efficiency, by matching the well performance curve with the pump performance curve, where the intersection point is the optimal selection point for the pump (Figure 21). At the point (C), for example, the pump can give an action (3150 L/min) for a total height of 13 meters and a working efficiency of up to 65% (Al-Salawi, M., 1986).

Figure (21):- Matching the well performance and pump performance curves



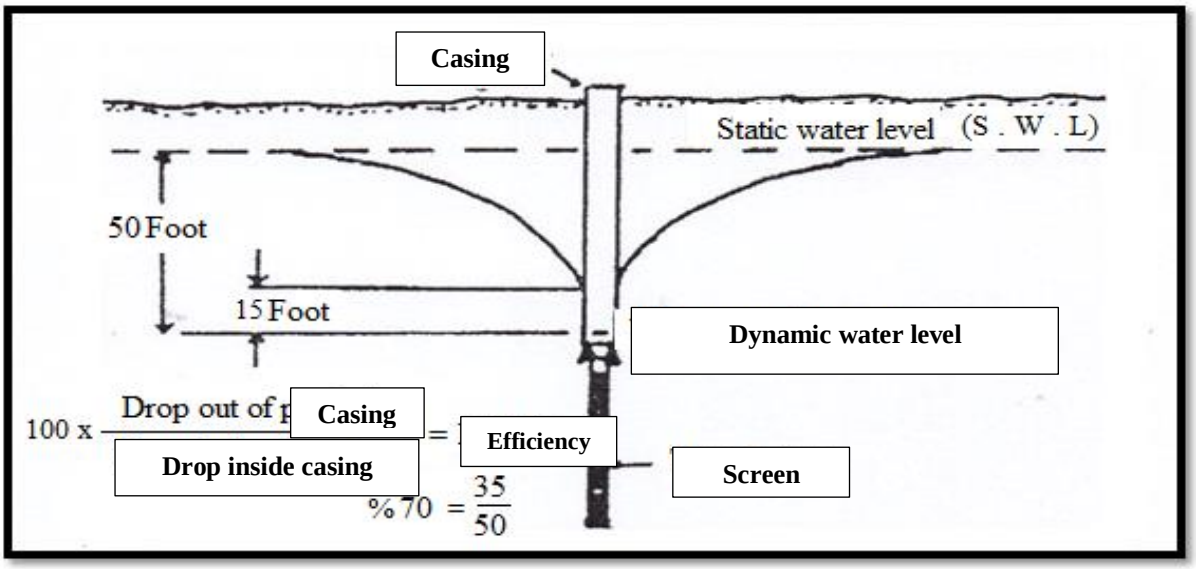
(Source :- Al-Salawi, M., 1986). Groundwater between Theory and Practice. Dar Al-Jamahiriya for Publication. Tripoli, Libya)

2.4.7. Well Efficiency

The well efficiency expressed by the percentage relegation and dig diameter inside the well . Figure (22) shows an example of the true well efficiency calculation. It is noted that in case of well efficiency (100%), the drop outside the casing of the drill directly should equal the drop inside . But often happens that , the water level inside the well is lower , can be investigation efficiency from (70-80%)for the borehole in the case of good design , as well as depend on relies on high quality materials in the creation and development of the well . (Khalil, E. M., 2005).

$$\text{Well efficiency} = \frac{\text{quantity of reduced of water level abroad wrapper}}{\text{quantity of reduced of water level inside wrapper}} \; 100$$

Figure (22):- Method of calculating well efficiency



(Source:- Khalil, E. M., 2005). Groundwater and Wells. Dar Al Kuttub Al-A'almia for Publication and Distribution. 2nd ed., Cairo, Egypt)

The competency of the well , this efficiency decreases with the specific capacity and reverse. Theoretical the specific capacity (Q/BQ), a number of hydraulic coefficients, such as the transmissibility coefficient and the storage factor, are evaluated. When these theoretical values of the specific capacity are compared with the measured value of the field (Q/SW), this gives the approximate efficiency of the well which can be calculated as follows (Khalil, E (Khalil, E. M., 2005) :-

$$EW = \frac{Q/SW}{Q/QB} \times 100 = \frac{BD}{SW} \times 100$$

where:-

Q = Productivity

EW = Well efficiency

BQ = reservoir loss

SW = total drawdown

The competence of the well is greatly affected by many variants , the most important of which are of working hours during the day, and the throughput and deep of borehole the efficiency of the pum wells, and the well when pumping , also pump from wells adjacent (Dradkha, K., 1988).

Another way in define the proficiency of the borehole is to identify, observe and monitor the rate of back of water in the well after pumping stopped. In the conditions of a large well loss, the rate of return is rapid, by leaking or draining water from the groundwater reservoir surrounding the well. There is an assumption proposed in define the proficiency of the borehole as follows (Jacob, C. E., 1946; Al-Salawi, M., 1997):-

If the If the pump stops pumping after an hour from the start of pumping, and the well was recovered (90%) or more of the resultant drawdown value after five minutes, a specific result can be reached . In towards to guarantee more effective of the well, it is required to determination ,observe and surveillance the ratio of return back on the water level of the well after the pumping stopped. In case the well loss is large, the rate of return is quick and thus the efficiency of the well decreases.

2.4.8. *Cone of Depression and District of Influence*

Once the pump water from the borehole , quantif of water that is drawn first is from the water reservoir surrounding the well directly , and with continued pumping , water is drawn from the reservoir over long distance. and farther from the well hole .

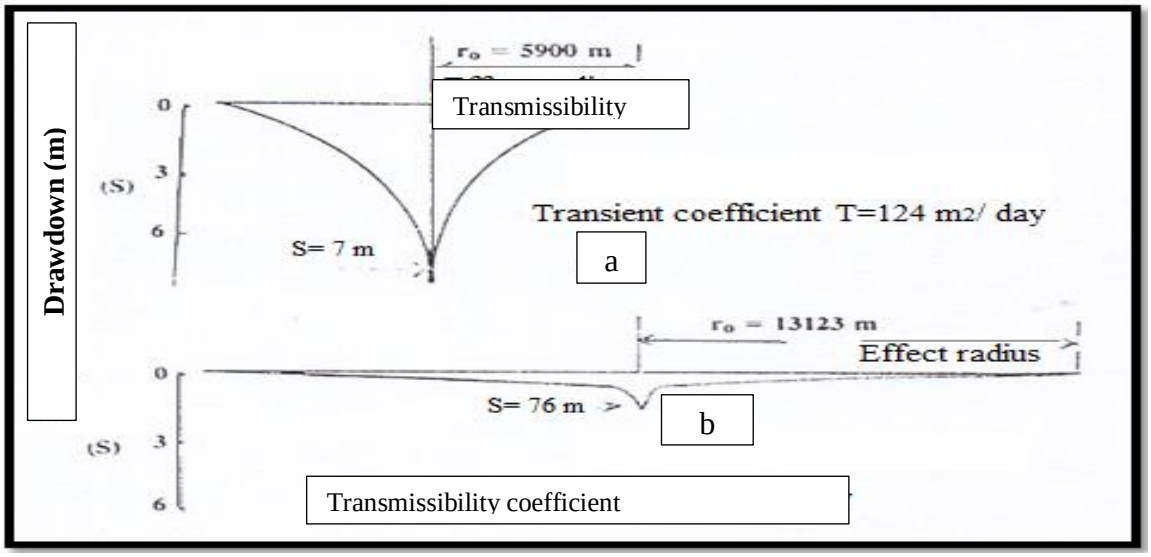
According to movement or flow of water inside porosities , the hydraulic orientation alter (spherically) with the variability of water activity , and the bigger fast the mobility of the water , the greater the hydraulic tilt as the flow approaches the center of the well , and as a result in the direction of the well and the surface takes the shape of an inverted cone and is called or known as Cone of depression . (ACSAD, 2002).

This cone is different in form and size due to the pumping , and the bearing layer characteristics of water or level feed to the groundwater reservoir within the well impact zone.It is also observed that after several hours of pumping, and take the precise measurements , increased relegation during periods of pumping and, in order to figure out the conic depth and in order to deduce the state of measurements of the funnel after stopped pumping and called this the state of stability . Figure (20) shows the change in the funnel after equal periods of time with the steady rate of pumping. Figure (23) also shows the impact of the difference in the transition factors or the shape and depth of the cone .

According to Figure (23-a), the well pumps a cavity reservoir diversion modulus and, consequently , the cone of depression and its sides have a sharp inclination and a small base. However, Figure (23-b) where the well pumps a underground reservoir with a large pass coefficient , and therefore the shape of the cone decreases and becomes shallow and has a large base and sides with a small slope. In all cases the drop of the scale water level at any dot on the norm of the conic of landing is called , the worth of the drop at this point . (Al-Salawi, M., 1986).

Figure (24) also shows how the decline values distributed along the cone on. This curve (curve of decline) Illustrate the water worth of adjacent boreholes in which the reservoir rocks are fully the variation between the underground water level explained earlier in the bending and the fixed level of the water account the valuable of the declining in the water (Dradkha, K., 1988).

Figure (23):- Effect of flux coefficient on the shape, depth and length of cone of depression taking into account that the pumping rate and other influencing factors in both cases are e



(Source:- (Al-Salawi, M., 1986). Groundwater between Theory and Practice. Dar Al-Jamahiriya for Publication. Tripoli, Libya. p. 110)

2.4.9.*Well Loss*

The reason for drop in the groundwater level in the wells during pumping to the vertical wastage , which includes formation losses , and well losses . The formation loss is usually taken as the downfall in underground water level in the water layer within the well .As to regarding the wastage of the well , it occurs when the water moves to the well through the cover gravel , filters , and cracks of the packing tubes , so it becomes a falling in the water layer . .

Figure (24) elucidate the formation loss and the well loss due to a change in drop the level of groundwater , and change in the productivity when pumping continues into the unconfined aqueous layer . It is noted that the level of decline (ho-hw) changes with the discharge (Q) and time (T) with continued pumping at a constant speed and for a

sufficient period of time that makes that drop change by a small percentage in the case of a free water layer (Khalil, E. M., 2005).

The meaning of this :- The determine how much of relegation in the well doesn't include the value of the logarithmic drop curve , but includes the resulting from the influx of groundwater through the refinery to the well , also to the outlet of the pump that pumps that water from the well .

$$S_W = BQ + CQ^n$$

Therefore, (SW) is calculated as follows (Jacob, C. E., 1946) :-

where:-

BQ = The wasted from groundwater influx in rock compositions

CQN = The wasted from the influx of groundwater from outside the well into it, through the well screen and then to executor of the pump which pumping water to the highest of the earth roof (Al-Salawi, M., 1986).

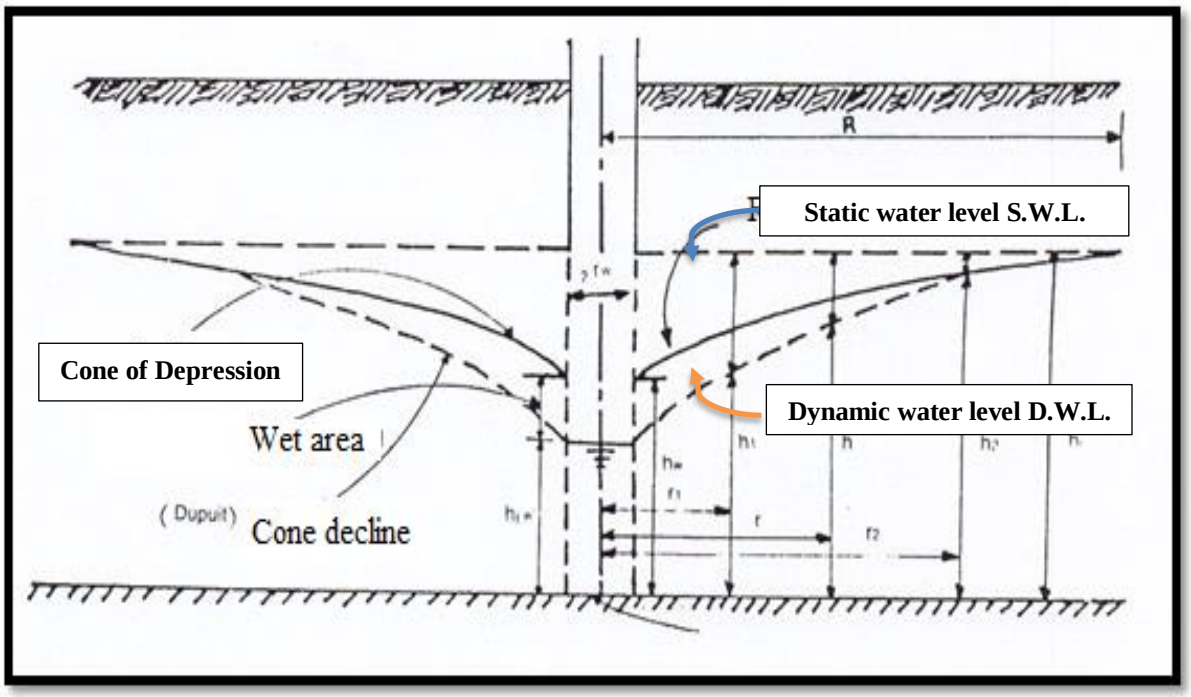
It is well-known the loss of the well an essential fraction of the aggregate landing rate when pumping evaluates are large . The loss of the well is usually determined by a gradual test pumping process and the conclusion of time and decreasing values. Thus, the partial drawdown value is calculated and the following calculation equation is applied :-

$$\mathbf{SW}/\ Q^n = \mathbf{B+C}\ Q^n$$

If we draw a graphic relationship between SW/Q^n and Q^n, as in Format (25), the suitable straight pipeline passed through these have the well modulus wastage (C) can be calculated by the across straight line regression .

The rate of the loss of the water-bearing aquifer (B) can be calculated at the intersection of the straight line with the line $Q^n = 0$ (Bogomulov, C., 19

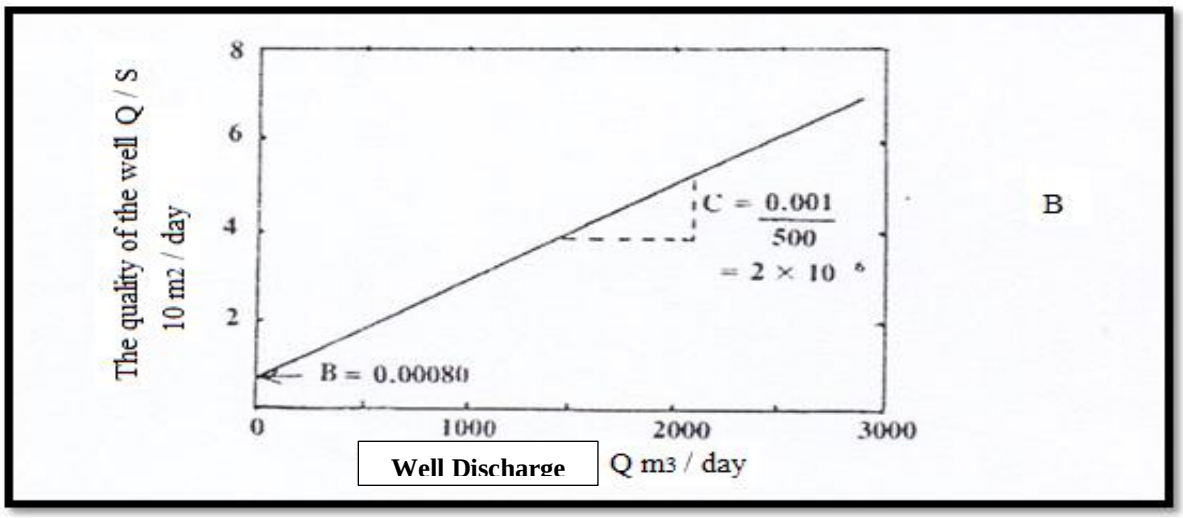
Figure (24):- Formation losses and well losses due to change of drop as productivity changes with continuous pumping in an unconfined aquifer



(Source:- Dradkha, K., (1988). Hydrogeology of Groundwater, Dar Al Bashir for Printing and Publication. Amman, Jordan).

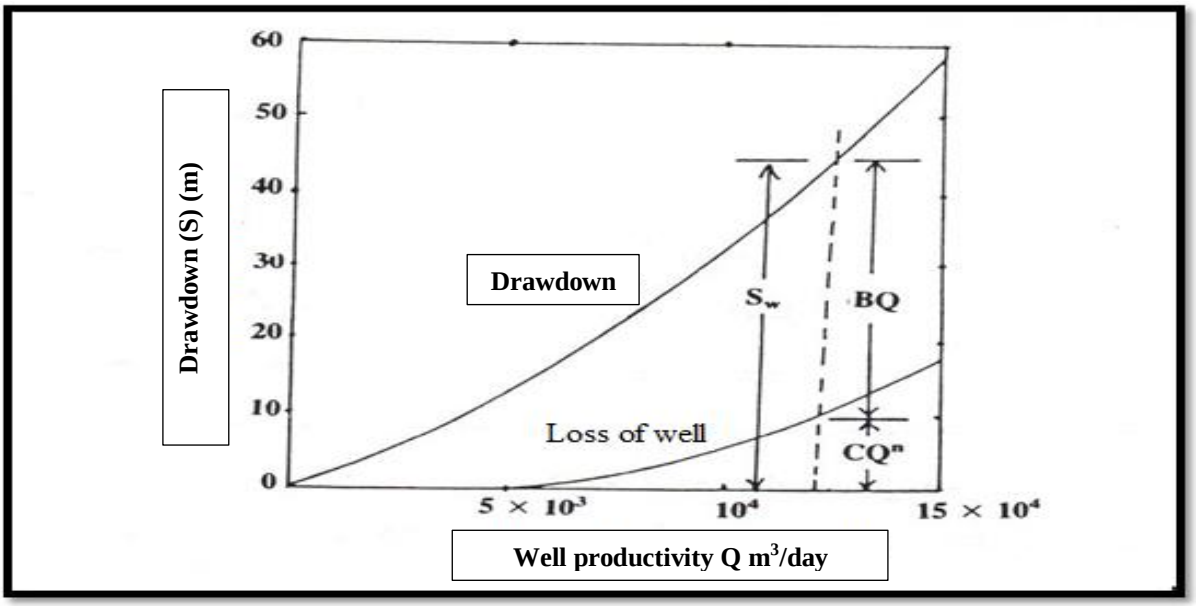
Figure (25 & 26) gives the total drawdown change (SW), well loss (CQ^N) and reservoir loss (BQ) with well productivity change.

Figure (25):- Analysis of gradual test pumping for the determination of loss of wells



(Source:- Todd, D. K., 1959)

Figure (26):- Change in total drawdown (SW), well loss (CQ ^{n}) and reservoir loss (BQ) with well productivity change



(Source(Al-Salawi, M., 1986). Groundwater between Theory and Practice. Dar Al-Jamahiriya for Publication. Tripoli, Libya.)

2.4.10 Well Interference Effects

In the instance of dug two or more wells within near distance, the level of groundwater will decrease quickly when pumping from these wells at the simultaneously and be a good productive condition in amongst boreholes if be space is long . likewise

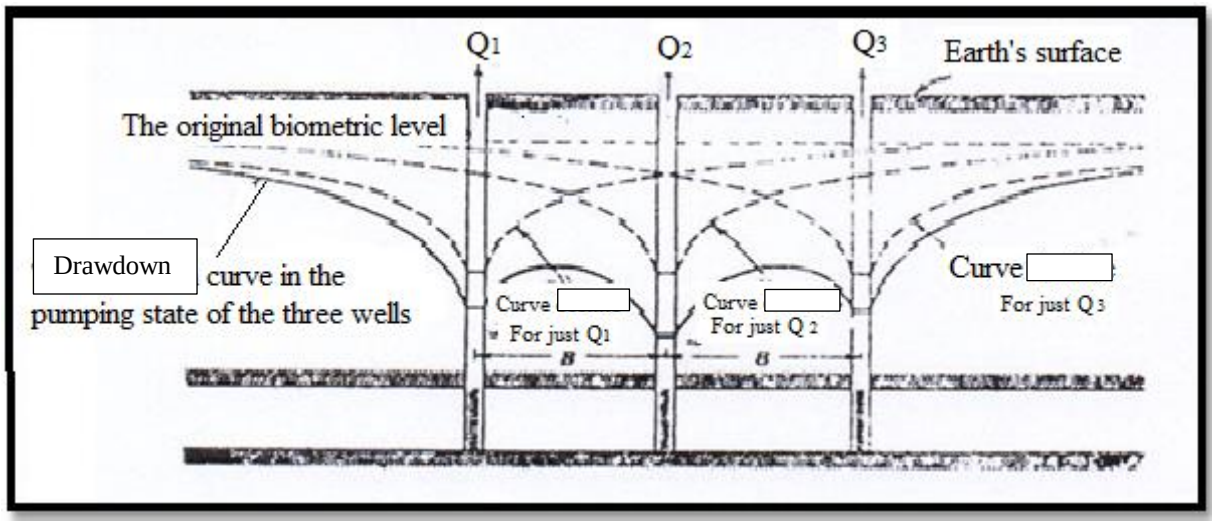
the cones of depression of these wells will overlap with each other. This incident is called the Interference between the well . figure (27) shows the overlap surface of three wells etched within the area of each other in a water layer (Dradkah, K., 1988).

If the cone of depression is followed by the wells dug into the aquifers, then the new state of the groundwater level resulting from the interference event can be identified. It should be noted that the safe exploitation of aquifers or the maintenance of wells requires that the appropriate distance between the pumping wells, should be chosen carefully, and their interference should be considered as having a negative implication on the standard of groundwater and aquifers. There is a rough rule in this area to avoid an overlap between wells, where the distance between any two pumping wells is not lower than double the valuable of the effective radius of each (Khalil, E ,M . 2005).

2.4.11. ***Coefficient of Transmissivity***

Transition modulus of a groundwater aquifer is the rate of water influx during a sub-set of the reservoir at a width of one foot under hydraulic pressure. The coefficient values range from less than 1,000 to more than 1 million gallons per day. And the storage coefficient clarify the amount of water that can be pumped , and these factors are of great importance in the pumping well at any time . (Banana, M. E., 1998) .

Figure (27):- Surface of interference of three wells etched within the area of influence of each other in a water layer



(Source: Khalil ,E , 2005)

2.4.12.Stockpiling Coefficient

Quantum of groundwater produced by a unit of horizontal sections , known as the retention coefficient , when the water level drops , a free underground reservoir is formed . As for the piezo-meteric , the reservoir is restricted . For example, if the water produced from a free groundwater reservoir is equivalent to (4) m^3 of water, it corresponds to a decrease in the level of groundwater at a rate of (2) meters over a horizontal area, equivalent to (10) m^2. Therefore, the storage factor in this case will be equal to (20%).

The storage coefficient in the field is estimated by test pumping operations. The storage coefficients of the free underground reservoirs range from a small fraction of the fractured rocks to 20% or 30% for rocks or non-solid materials with relatively regular granules. The following equation is used to calculate the warehousing modulus of the water-bearing layer during test pumping (Dradkha, K., 1988):-

$$\boxed{\mathbf{S = \frac{\mu \times T \times t}{1.8 + r2}}}$$

where

S = storage coefficient

μ = constant of the well

T = coefficient of transmissivity

t = start time of experiment

R = spacing the centralized of the pumping the well on the drawdown point

2.4.13. Safety Coefficient

Safety modulus of the groundwater reservoir is tariffed as the quantity of water that can be pumped from this aquifer without depletion of the underground stock. So as to prevent the wells of the exploited water from being exposed to this aquifer , as the pumping proceed display to risk on aquifer to the sea water intrusion or any other water from adjacent layers of undesirable quality modulus of the groundwater aquifer is tariffed as the quantity of water that can be pump. Therefore, a safety coefficient (S/A) is often taken during pumping operations from the well, where (S) refers to the qualitative behavior, while (A) refers to the area of the well section (Al-Salawi, M., 1986).

2.4.14. ***Exploitation Index***

It is It is the ratio percentile of the aggregate quantity every year from the groundwater layer divided by the aggregate quantity of renewal renewable water or annual natural feed that reaches the tank.

2.4.14.1. *Final Consumption Index*

It is the percentile proportion of the aggregate water expendable from groundwater reservoirs in the region over the aggregate renewable water from the natural resources of these reservoirs.

2.4.14.2.Repatriation to the Level of underground water (Water Level Restoring)

The groundwater level gradually begins to return to its original state after the cessation of infusion . The drawdown in the well can be calculated by measuring the return of the groundwater level after the pumping has stopped.

There is a rough base in this area regarding to the relationship between the comeback of the groundwater level and the competency of the well . If the pump stops pumping after an hour from the start of pumping, the well returns about 90% or more of the resulting drawdown after five minutes, indicating the inefficiency of the well (ACSAD, 1985).

2.5. Pump Concepts

2.5.1. Pump Capacity

Pump amplitude is the magnitude of water that is pumped or discharged into the unit of time and is usually measured in liters/sec or liter/min, liter/hour or cubic meter/hour.

2.5.2. Pump Efficiency

It's the proportion between the horsepower of the water (W h p) and the horsepower braking (b h p). (Khalil, E. M., 2005)

$$\mathbf{EP} = \frac{\mathbf{whp}}{\mathbf{bhp}}$$

where

Whp = the horsepower of water which is the power requisite to lift water to a specified distance.

Bhp = Fossil horse vigour, which is the vigour required to operate the pump in order to obtain certain values of pump productivity and total water lifting .

2.5.3. Pump Pressure

It is the pressure required to run the pump, and this pressure must be sufficient to give the force necessary for operation. At the same time it must be compatible with the required flow rate. There are special tables that link the maximum pressure of the pump (measured by bar) and the flow rates of the available pump types (measured in liters/min) in many practical applications and industry, (Khalil, E. M., 2005).

2.5.4. Pump Performance Curve

This curve clarify the relationship between the drainage rate and the pump ability and can be used in conjunction with a well performance curve in selecting the appropriate pump, where the intersection point of the two curves is the optimal selection point for the pump. The point (C) in Figure (21) represents the intersection point where the pump can give an action of 3150 L/min for a total height of 13 meters and a working efficiency of 65% with a horsepower of about 11 hp (Al-Salawi 1986).

CHAPTER III

3. *PREVIOUS STUDIES*

3.1.Major Previous Studies

The most important previous studies conducted on the region of study and its findings and recommendations can be summarized as follows:-

1. A regional hydrogeological study of the regions of Ghadames-Derj (Energo Project, 1976)

This study focused with the inventory of water and oil wells, that are the regions of Ghadames, Derj and Sinawen. The information obtained was used to identify the water-bearing layers and their geological and hydrogeological characteristics through a series of maps and information from a group of exploratory wells and observation wells scattered throughout the region.

The study found that geological variables and sub-surface structures domination the hydrogeological attributes of the region and have a large impact on the stretch of the groundwater layers. The most important aquifers in the region can be found in Nalut, Ain Tobi and Kiklah reservoirs, which differ in thickness, water quality and throughput of wells .

At eventually of the study, it was recommended that attention must be payed to these aquifers and to show them quantitatively and qualitatively, in addition to studying the sources of their nutrition, and the direction and velocity of water movement in their strata by digging more wells test and observation in Ghadames and surrounding areas.

2.A study titled " A study entitled "Applying of geophysical well registries in appraisal groundwater possible in Ghadames Basin-Al-Hamada Al-Hamra " (Senha, S. C., 1980)

The study was concerned with the use of the information obtained from the applications of geophysical well logging in (105 oil wells), and (40 water wells) in the area representing an area of about 170.000 square kilometers. After the study and evaluation of

water-bearing formations in the aquifers of the region, it's possible to obtain the presence of major water-bearing layers in the formations of Nalut, Kiklah and Rass Hamia. These layers are characterized by horizontal extension, and large thickness, which made it the best water sources in the region. In particular, the study recommended the use of information obtained in future water studies in the Ghadames basin and the use of their applications for development projects in the region.

2. *Regional Hydrogeological Study of Ghadames Basin (SRIVASTAVA, 1981)*

Such a study addressed the attributes of the deep aquifers in the basin, the sources of nutrition and the condition of exploit , additionally to the water equilibrium , the safe withdrawing, as well as the water situation and its quantitative and qualitative development. The project is based on a detailed study of hydro-climatic and hydro-chemical information in order to identification the volume and demands of groundwater development in the region and to conduct a comprehensive assessment of the water resources currently available in the region. The study determined the hydrogeological limits and extension of the Ghadames Basin.

A group of underground aqueducts with a geological age ranging from the Cambro-Ordovician to Holocene were found. These reservoirs extend into neighboring countries (Tunisia and Algeria) forming the so-called Northwest Desert Basin.

The study recommended the continuation of the detailed study of these reservoirs in terms of their extension, thickness, , and deepness, water qualitative productivity of the exploited wells and their sources of nutrition. As well as the need to provide integrated geological and hydro geological information to feed the mathematical model of the basin and to serve the purposes of agricultural development and projects targeted by Ghadames, Derj and Sinawen.

It also recommended the expansion of the drilling of productive wells, exploratory wells and observation wells, in order to periodically monitor the reservoirs exploited in the region quantitatively and qualitatively, especially of deep Kiklah reservoir, in addition to the development of studies related to the systems of aquifers in the basin and the concern in the utilization of radioactive isotope in studying the water qualitative of the water - bearing aquifers and determining their origin, age and sources of nutrition.

3. ***Studies carried out by the Engineering Consultant Office of Utilities of General Water Authority 1997*** **(**Geological and hydrogeological studies and a mathematical model for the water transfer project from Ghadames Basin to the coastal areas of the west Jafara Plain within the Ghadames-Zuwara- Alzawia system for the Man-Made River Project**)**

This study was based on the collection of information from the geological study, the stratigraphic sequence and the hydrogeological study of aquatic strata in aquifers where they focused on a reservoir as a whole, which is the purpose of its exploitation.

This reservoir was studied in detail in terms of extension, productivity, quality and hydraulic properties derived from the pumping experiments, drawdown rates and completion characteristics of the utilizing wells, as well as the computation of the suggested well fields that range between 700-800 meters deep. As further the specifications of their packaging,their productivity and the distances between them, and the cost of producing a cubic meter of water, in order to prepare these fields and design for the purpose of transferring water of a tub of Ghadames to the western coastal areas of Jafara Plain.

4. The latest Report of the Northern Desert Basin Study project (OSS, 2009)

This report is concerned with studying the northern desert basin between Libya, Tunisia and Algeria , and its details .

The total area of this basin is more than one million kilometers square, which divided into three sub-basins:- Ghadames, "an area of 250 thousand Kilometers in Libya, as is the eastern fraction of Tunisia and Algeria, thereby it is territory reach more than proximately 80,000 square kilometers ,and Algeriato in pelvis the western with an area of 700 thousand square kilometers.

The study included the two main aquifers in the basin:- the median caste of Kiklah composition and the ultimate vehicle caste (Nalut-Mazdah)in whence of the water possibilities of these compositions and the water situation in quantity and quality , as well as the water balance of the region and current and future utilization rates under the

development programs in the region. Based on the information available from three tests wells with a depth of 1000 meters in the deep aquifer in Kiklah Formation, in addition two wells with a depth of about 500 meters in the Nalut aquifer, calculation of hydrological transactions, water levels and pumping and from information the water situation in the region, some finding have been reported.

The fast lower in water levels due by it to over-exploitation with a significant periodic increase in water salinity this what outcomes of study confirmed on the jointly tub, which significantly threatens the sectorial exploitation of these water resources, of artesian wells and the drying of many water springs .

The study reached an integrated program and a future strategy by establishing a unified database and joint management between these countries to manage water resources for this common basin , and to set up a network for monitoring and analyzing information periodically , so that everyone can benefit from the information plan , and refer to it when studying the water basin , in light of the risks of unjust exploitation that threatens the future of water resources for that aquifer.

5. *Geological and Hydrogeological Study fraction of the South-West for tub Ghadames , North-West Libya (Radhi, M. A., et al, 2006).*

The southwestern fraction of the Ghadames pelvis one of the prioritized the concentrated of study , and it accounted an spillover of vast for low-level be marked by having of the most important faults (Ghadames crack) that extends in both directions- north -west- south- east . Through the sequence of interpretation of geophysical well loggings, correlation columns, geological cross-sections and maps prepared from water wells and oil wells through the exploratory drilling of the test wells, it was possible to study and know the geological characteristics of the region and its stratigraphic sequence, in addition to the hydrogeological variables and characteristics along the region of study, as well as ground reservoirs. Therefore a number of these reservoirs were identified:- Mizda, Tigirinnah, Nalut, Ain-Tobi, Kiklah and Rass Hamia

The study found that Kiklah Formation is the most important in terms of water potential and water quality. This reservoir is also a good source of water and is widely exploited, exposing it to many risks resulting from intensive and unfair exploitation. The study also pointed out lower productivity of the wells exploited, the high rates of decline

disappearance of artesian phenomenon from most wells. The study recommended several measures to avoid threats

preserving the water potential , and enacting laws that determine how, the organization of its resources among participating countries, the necessity of completing the basin study and the appropriate mathematical models to regulate its exploitation and exchange of information between them .

3.2. Comment on Previous Studies

By providing the researcher with previous studies, a number of conclusions and recommendations were reached, as follows:-

1. There was a lack of water studies related to the basin compared to the large extension of the basin within the borders of Libya, Tunisia and Algeria, especially with regard to problems related to the risks of salinity sudden temporary disappearance of hydrostatic pressure, and rapid decline in productivity when operating separated wells within the exploited aquifers in the basin, especially Kiklah aquifer.
2. These studies indicate that although of oil and gas wells in the region which dug contributed to the provision of geological and geophysical data and information, they did not take sufficient care to change the hydrogeological properties and risky phenomena and problems in these wells, even and that it found to be very limited.
3. Most studies did not care to study the geological formations of the deep underground reservoir as Kiklah and the salt layers in it , and it is certainly the reason for salinity that appears accompanying the water at the start of pumping , therefor when desiging and drilling wells ,high quality packaging materials and equipment must be used to ensure the isolation and locking of these layres in order to prevent leakage salt water , as well as periodic monitoring of the change water quality over time and continued pumping to irrigate current and future projects in the region .

3.3. Utilization of Previous Studies

The researcher benefited from previous studies as follows:-

1. Despite their lack of generality, previous studies provided the researcher with a database and information about wells scattered in the region, the problems caused by them and the main reasons for the quantitative and qualitative decline in the performance of these wells over time.
2. Reviewing previous studies, the researcher have given whole lot of findings also the proposals , and the problems of deep wells in the region of study, which benefited the researcher to a great extent in preparing, processing and implementing the proposed program in the current study.
3. It has given many indicators and important substantiation about on the attributes and designings of wells in the district of study, private in districts of extensive exploitation and its participation to the water equilibrium of the district t .
4. The researcher benefited of interpreting the results obtained in the exclusive and detailed study of the wells selected for the current study in the region and employing these results in developing solutions, recommendations, proposals and procedures for developing, investing and addressing problems related to the water of these wells in the future.
5. The researcher also hopes to provide explanations, solutions and procedures for sudden phenomena in the wells exploited in the region of study, such as salinity, disappearance of pressure and decrease of the productivity when operating and locking these wells. It stresses the need to limit the impact of these the phenomenon of district of study and adjacent areas. djacent areas.

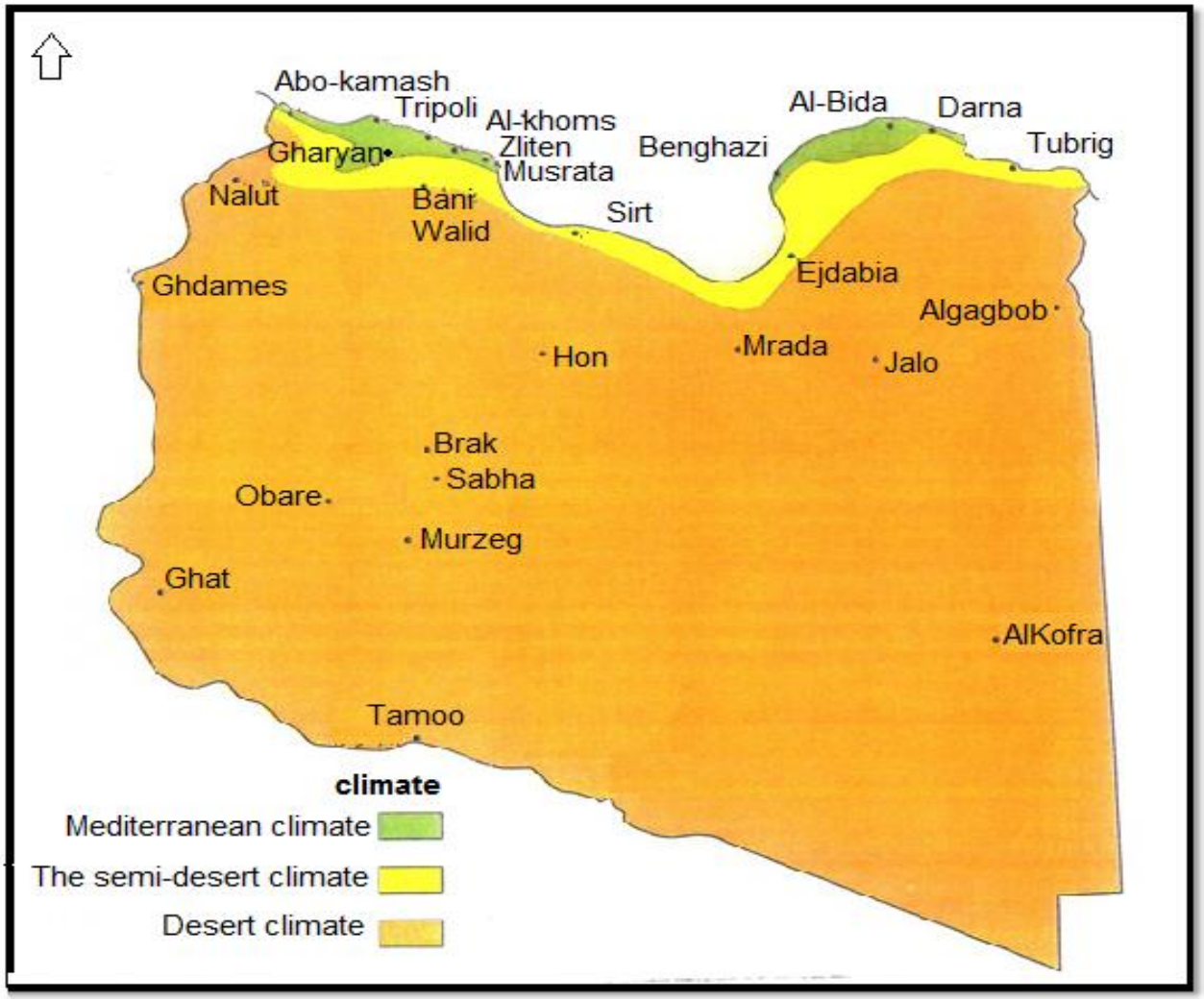
CHAPTER IV

4. *NATURAL FEATURES OF THE REGION OF STUDY*

4.1. *Climate conditions*

1. The region of study is characterized by desert climate (Figure 28). This climate has led to widespread drought and water scarcity in most parts of the region.(E.D , Atlas 1985)

Figure (28):- Desert climate range of the region of study compared to other climatic ranges in Libyan territory

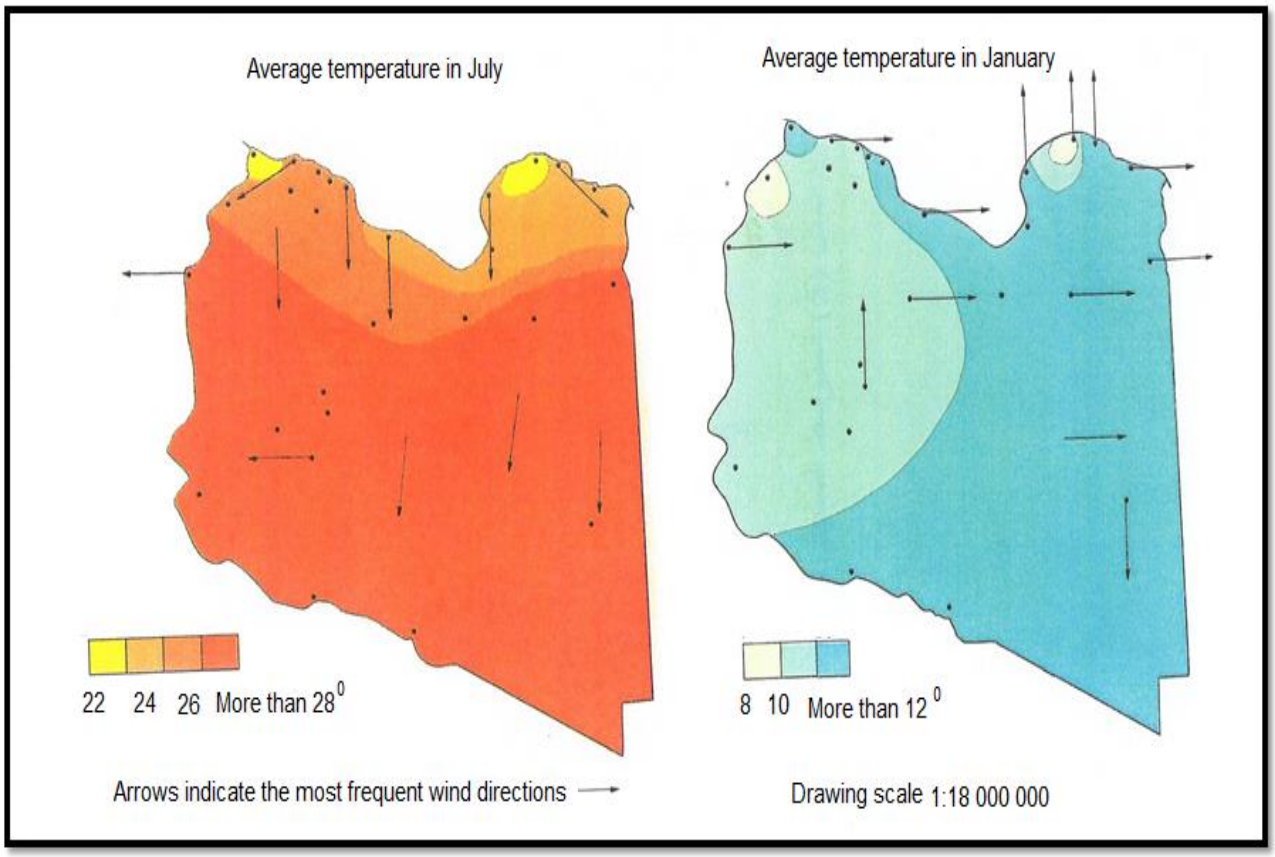


(Source:- General People's Committee for Education (1985). Educational Atlas. Elementary Level. Map Serve Publishing House, Stockholm, Sweden, p. 42.).

2. The temperature in the region varies markedly between night and day, and between summer and winter. The temperatures in the summer range between 28°-33°, while in winter it ranges between 9°-12° (Figure 29) , Table (2) shows the distribution of temperature and annual rate in the region of study and adjacent areas. Figures (30, 31) show the average temperatures in both Nalut and Ghadames, respectively (Al-Talhi , J. A,2004) .

3. Moisture is around 47% in Nalut , 43% in Sinaon , and 42% in Ghadames . And table(3) shows the average humidity in different places in the region (G.W.A, 1984) , as well as figure (32) shows the relative humidity of the region of study comparison to its neighboring areas .

Figure (29):- Allocation of heat and cold in summertime and wintertime within the Libyan territory



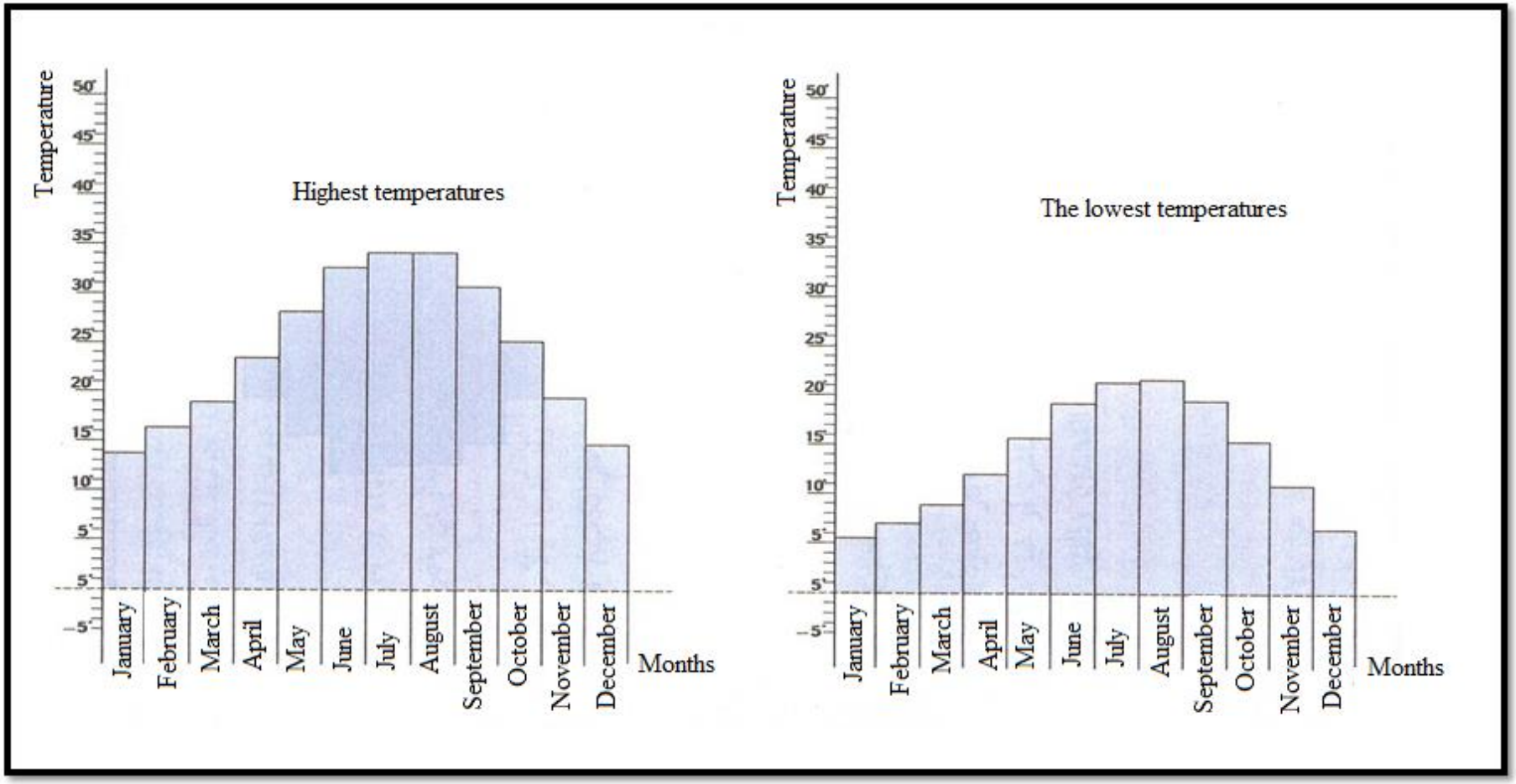
(Source:- Survey Department of the Planning Secretariat (1978). National Atlas of Jamahiriya. Tripoli - Libya, p 43)

Table (2):- Distribution of temperature and annual rate in the region of study and adjacent areas

The station	January	February	March	April	May	June	July	August	September	October	November	December	Annual rate
Nalut	13.2	14.3	19.3	23.8	28.2	33.2	35	4.3	31.6	26.6	21	14.3	24.6
	2.7	3.8	7.7	10.5	14.3	18.2	20.5	20	18.2	14.3	9.3	4.3	12
	8	9	13.5	17.1	21.2	25.7	27.7	27.1	25	20.5	15.1	9.3	18.3
	27.2	26	34	40	41	44.2	47	46	42	39.9	30.7	26.4	47
	-7	-3.3	0	2.8	6.6	8	10.3	11	9.6	6	1	-5	-7
Ghadamas	17	20.5	26.1	31.7	36.4	41.4	42.5	41.9	8.4	32.4	24.8	19.3	31
	2.3	4.2	8.4	12.7	18.3	22	22.9	21.9	18.5	14.9	9.3	4.4	13.4
	9.6	12.4	17.3	22.2	27.4	31.4	32.7	31.9	29	23.6	17.1	11.8	22.2
	32	33.9	41.3	48	52	55.2	53.4	52.4	50	48	39	30.4	55.2
	-6.5	-3.6	-1	3.8	6.8	14.1	15	13	10	3.5	1.4	-3.6	6.5
Senawen	15.8	18.6	23.3	29	33	38.8	40.1	39.3	35.7	29.5	22.4	17.1	28.5
	3.2	5	8.3	13.2	16.8	21.3	22.8	21.1	19.3	14.4	9.8	4.9	13.3
	9.5	11.8	15.8	21.1	24.9	30	31.4	30.1	27.5	21.9	16.1	11	20.9
	28.9	30.2	34.4	39.7	43.6	50.1	48.2	48	43	39.5	33.8	34	50.1
	-6.2	-2.5	1	3	8.1	8	15.6	12.5	12.5	2.7	1.1	-4	-5.2

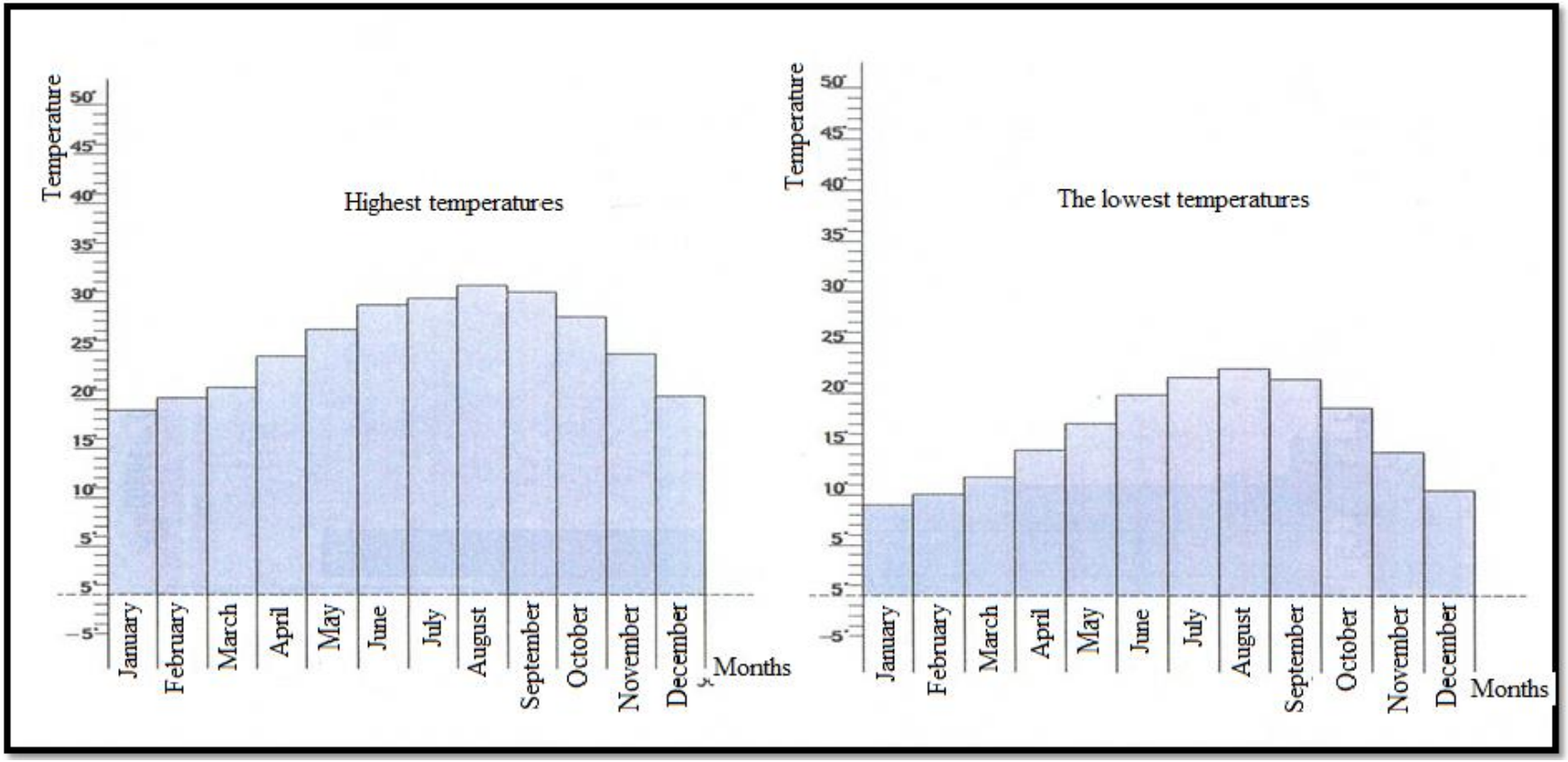
(Source:- Abuloqma, M. et al. (1995). A Study in the Geography of Libya. Foundation Al-Jamahiriya for Dissemination, Apportionment and Declaration . Tripoli, Libya, p 83.)

Figure (30):- Temperature rate in Nalut



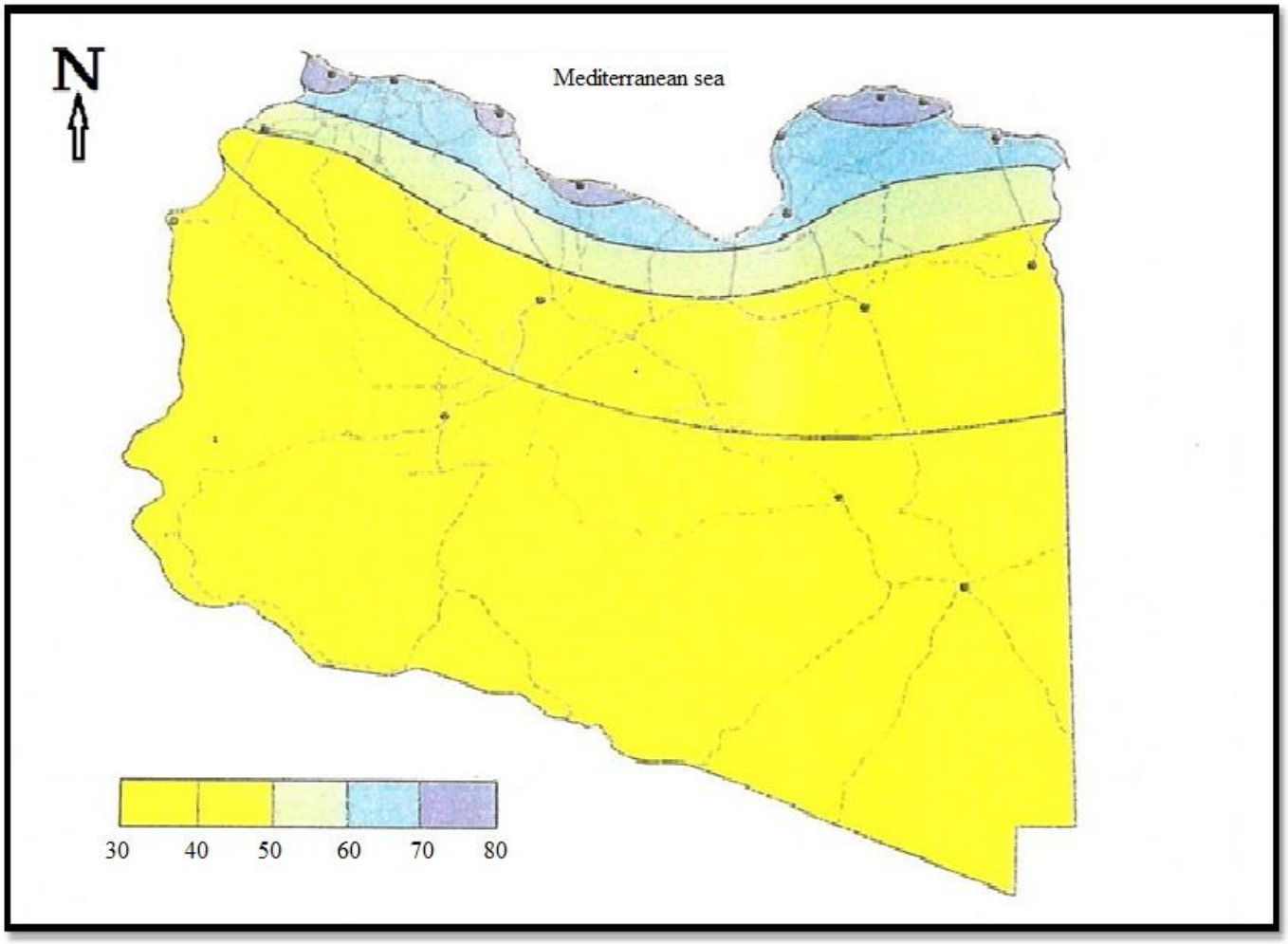
(Source:- Talhi, J. A., (2004). So That We Do Not Die Thirst. Foundation Al-Jamahiriya for Dissemination , Apportionment and Declaration. Tripoli, Libya, P 126)

Figure (31):- Temperature in Ghadames



(Source:- Talhi, J. A., (2004). So That We Do Not Die Thirst. Foundation Al-Jamahiriya for Dissemination , Apportionment and Declaration. Tripoli, Libya, p 125)

Figure (32):- The yearly medium of dampness in region of study and the Libyan territory



(Source:- Survey Department, Planning Secretariat (1978). National Atlas of Libya. Tripoli, Libya, p 43)

4. The increase in general temperatures in libya in the summer , and the desert climate prevailing in most regions , on reflected in the relatively high evaporation . It was also observed that the evaporation rate in the region was higher than average rainfall in many parts. Table (3) shows the average monthly and annual evaporation rate in Ghadames city, which the rate increases significantly in the summer as the temperature rises (Abuloqma, M., et al., 1995).

5. . Figure (33) shows the downpour rain median in the region of study comparative to other areas in Libya, whereas Figure (34) the northwestern parts of Libya and its rain. (General Water Authority, 1991). The ratio decline of raining as we go south. The ratio raining in Nalut as much as to 100 mm . The ratios of rainfall in Sinawen was up to 50 mm. The rainfall rates in Derj and Ghadames are between 20-50 mm. Rainfall rates ranged decrease in the southern half of the region ,between 5-10 mm. earlier raining ratios uppear in the study region and neighboring of it in the winter , and almost disappear in the summer .

6. From the previous geological studies and achieving of researcher's meidani in the region of study, the following features of surface manifestations were identified:-

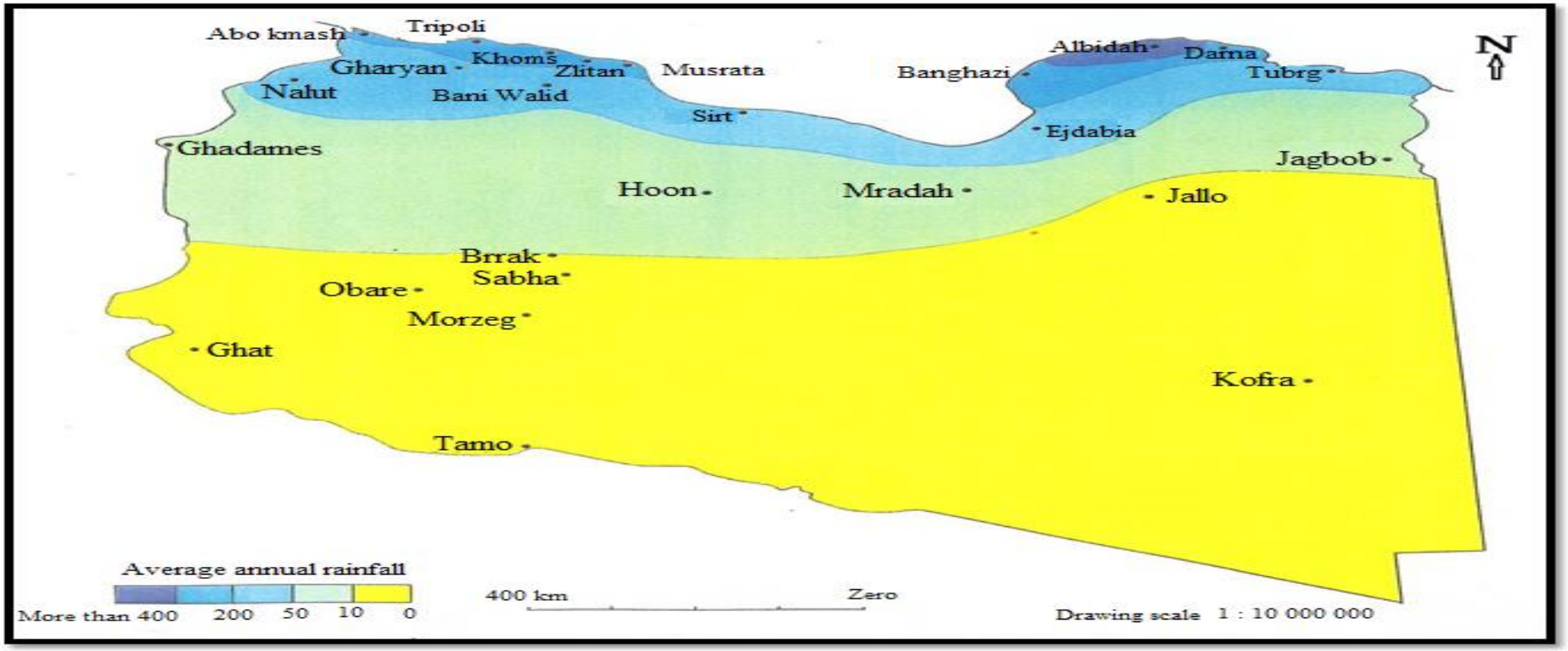
   a. Ghadames Basin is a sedimentary lower . It is fraction of Al-Hamada Al- Hamra Basin, which is it is bordered from the north by the chain of the north highlands , which has wave height around 650 to 720 meters, from the south is kergan mount, which height between 650 to 750 meters and spill over to the west and southwest in Tunisia and Algeria. while in the east is limited by the Sirte Basin .

Table (3):- Monthly average and annual rate of evaporation in Ghadames City

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual rate
	5.5	5.1	5.5	6.1	7.3	8.5	8.8	10.1	10.7	9.6	7.3	5.7	7.5

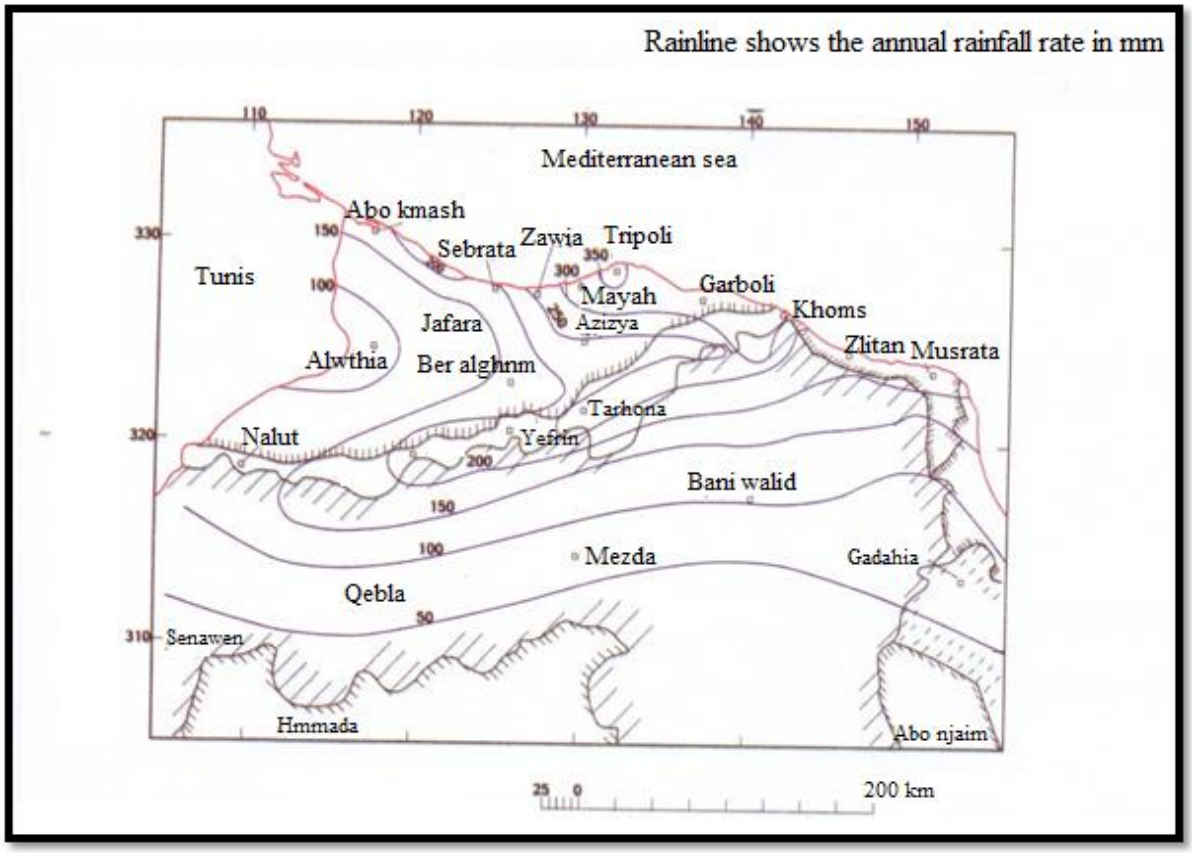
(Source:- The National Commission for Agriculture (1984). Libya Climate (Measurements and Indicators), Tripoli, Libya, p12.).

Figure (33):- Average annual rainfall for the region of study and the Libyan territory (Source:- Survey Dep



artment of the Planning Secretariat (1978). National Atlas of the Jamahiriya. Tripoli - Libya, p. 43)

Figure (34):- Map of rain distribution of northwestern parts of Libya



(Source:- General Water Authority (1991). Libya Rain Map, Documentation Center. Tripoli, Libya, p. 22.)

b. Ghadames Basin is determined in the west. Its altitude ranges from 300-525m, showing a range of valleys, depressions and belts of unconnected sand dunes taking the north-west and south-eastern tendency . The longitude of the girdle is about 50 km, whereas wid is about 1 km .

c. Most of the valleys in the region are dry. The most important were Wadi Tannarut, Wadi Awal and Wadi Memon. Drought season takes place after winter and for short periods due to low rainfall inside the frontiers of the region of study. These valleys take a north-west direction, where they transfer the sediment and the rock to the depressions and basins scattered throughout the region.

d. The region of study was marked by that there is a numerous of sabkhas , main ones are which is the "Majzem sabkha , which that constitute the largest marshes of the district, covering an area of about 100 kilometers square. It is extension lower inside Tunisian lands , about 30 km northeast of Ghadames .

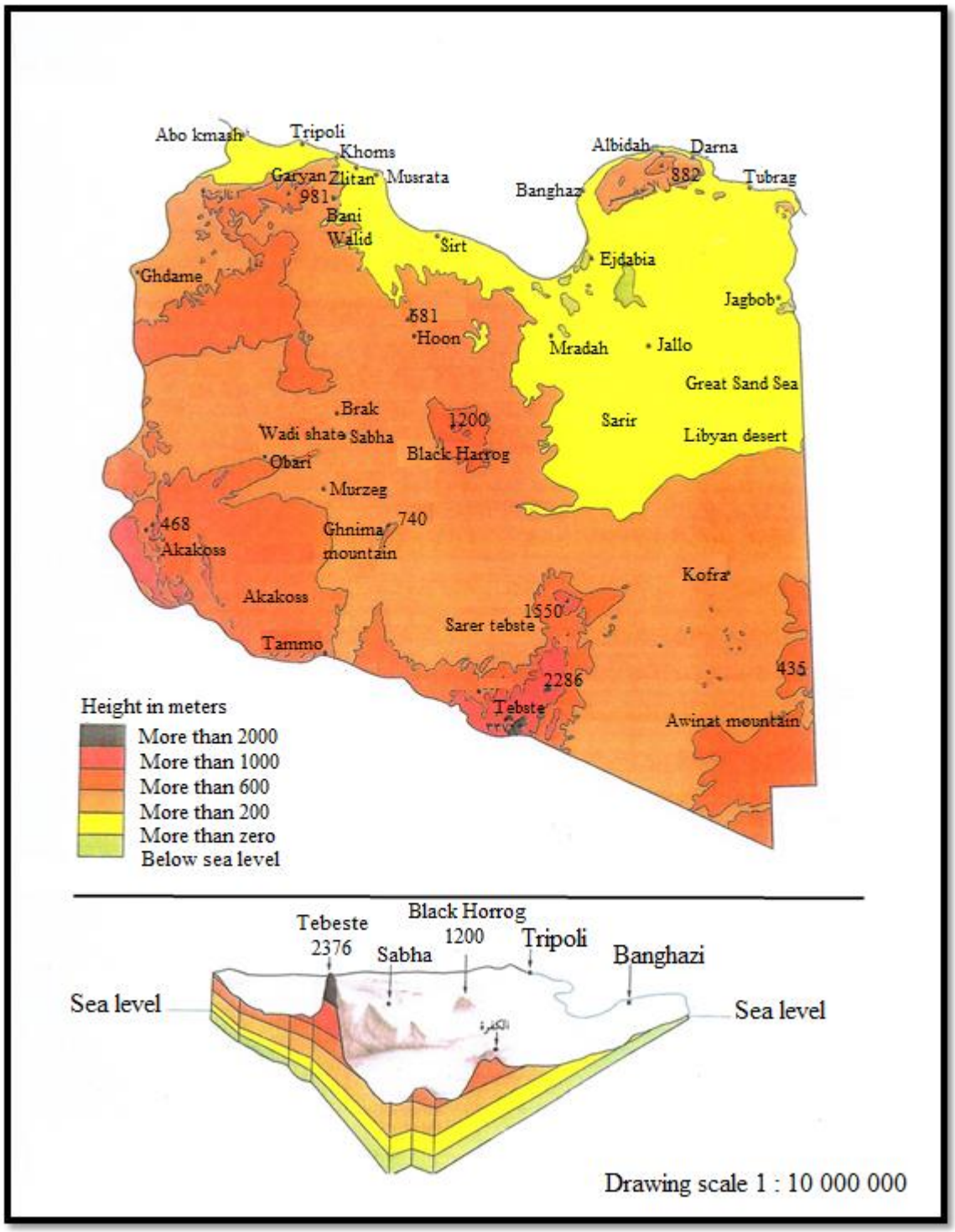
e. The region of study has some karstic advantages, which are closed, shallow and flatbed bottom, not more than 10 m in deep and to be the result of precipitate vaporize and decompose of carbonate sediments during the Oligocene and Miocene periods . The (Figure 35) which shows features of the district .

7. Wind in the district of study is classified into three categories according to the season and direction which comes frome it wind (grassroots Commission of Agriculture, 1984, 1984):-

- North West Winds through rainy winter
- North and North-Eastern winds in autumn
- Dry and hot wind (***gibli***) in summer

Of the factors that directly affect the wind, its velocity and trend inside the district of study is air the pressure and thus the downpour and its amounts . The allocation of barometric pressure varies from o period to another inside the frontier of the study region . Table (4) shows the monthly average of wind speed (m/sec) in both Nalut and Ghadames..

Figure (35):- Topography of the region of study and the Libyan territory



(Exporter :- The commission the grassroots of Education (1985). Educational Atlas. Elementary Level. Jean-Sirfs Publishing House, Stockholm, Sweden, p. 41)

8. Particularities in the district of study depend on their strength and content, and their resistance to water and air drift, as well as their effectiveness and water retention

capacity. The soil of the region of study is classified as dry land soil. It is characterized by certain characteristics,

almost all of which point out the dry case in this region .

There are a collection of points regarding to the soil of region , we will mention the most important :-

a . Most kinds of soils in the region are the kind of the sandy , with high permeable , low in in the ratio of organic matter and high carbonates , and it poorer of nutrients.

Table (4):- Monthly rate of wind speed (m/s) in both Nalut and Ghadames

Stations	January	February	March	April	May	June	July	August	Sep	Oct	Nov	Dec	Annual rate
Nalut	3.6	3.8	4.1	4.2	3	4.1	3.5	3.5	3.4	3.2	3.3	4.4	3.7
Ghadames	3	3.1	3.9	4.4	4	4.1	3.5	2.9	3.3	3.1	3.1	3.1	3.5

Source:- (Aboloqma, M., et al., 1995)

C . Soil in the region of study suffers from the problem of erosion in both air and water, due to its the earth, further the impact of climate elements of wind, rain, heat and humidity, to increase erosion rates in addition to some floods in the sloping areas.

d . There are many agents which had led to the high percentile of salts in the soil in some sections of the north and southwestern of the region of study . These involve , the height of the standard of groundwater during the capillary property , increase of evaporation rates and spread of she's in some parts of the region (General Water Authority, 1983). The low of rains and consecutive years of aridity was trigger to existence of the phenomenon as in the south-eastern section of the region. of the region.

e . It can be classified types of soil in the district of study to next (General Water Authority, 1983) :-

- Dry soil, with its brown structure, sandy strength and sandy silt, is spread in most parts of the region of study and less spread in the areas of marshes.
- Saline soil or marsh soil, which is spread in the form of lowlands, is characterized by lime sand, slightly tilted to alkalinity and contains saline crust.
- Sand dunes are mature, non-coherent, porous and fragile soil and often contain more than (85%) of the sand grains, while the clay content is not more than (10%) and

the rate of leakage is high and has the quality of ventilation for the expansion of pores and drainage speed water in addition to its extreme drift . This kind of soil was found in north of the district and some runs in the southeastern sections .

9 . The kinds of soil and their inferior fecundity , climate, topographic agents and location of the region of study within the dry desert climatic region characterized by low rainfall and high temperature, are all factors that reflect the condition of vegetation and natural plants and their in the region of study. Dry and modern soil, which has high salt content and low organic content, and lacks nutrient content, have also contributed to reducing the geographical area of this vegetation. However, the area is characterized by the existence of some natural plants away from the areas of marshes, which have a high capacity to withstand the conditions of drought, all belong to the region of Weeds Continental grass, in addition to a small amount of plants marshes, especially in the northwestern and southwestern sections region of the study (authority plenary water , 1983).

4.2. *The impact of normal in the zone of study*

From during studying with its metrics and in pointers, we can infer that that normal phenomena had a considerable influencing on

The water condition in the district , which may be summed as should read :-

4.2.1. *Impact of site*

Due to location this district within aerial volatility and uneven , especially in the southern section from it , and the less rainfall lessening the quantum of superficiality water on the upper of the earth and does not make up the sewer of water lasting or interim , such as flood or deep wadis , as well as the lack of water leaking to sub-surface layers to feed underground reservoirs(G. W. A 2006) .

4.2.2. *Surface Manifestations and Topography Effect*

1. The presence The presence of multiple slopes , as well as the presence of some sabkhas and most parts of the region lack high rates of rain and irregularity . This led to the absence of permanent waterways in the area , also the lack of benefit of water coming from the valleys of the neighboring highlands , which leaks or evaporates befor it arrivs the areas of exploitation . This led the population to rely on groundwater for all their purposes (Abulqma , M 1995) .

2. affect Sabkhas spread in many regions of study large largely on the quality of groundwater in these parts in terms of high salt content and low validity for exploitation (Hamid , W. F , 2006) .

3 . Water in the sand dunes was characterized by good quality but small quantities, and did not encourage exploitative of pond in the form of aquatic lensings in the shallow regions between these sand- dune and this phenomenon is obviousnt prese present in the northern and western regions (G. W. A , 1983) .

4.2.3. *Effect of Temperature*

All climatic elements are controlled by the temperature directly or indirectly . It also has a significant impact on the water situation and hydrogeology in various fragments of the region of study as follow :-

1. The temperature fluctuate from somewhere to another and also from one time to another and the difference in its yearly ratios within the region of study will control the air pressure , which is the other , controls the distribution of winds , its gusts times and directions , and this is all it reflects poorly in the ratios of rainfall , irregularity and fluctuation .
2. Heat is the trigger vaporizes water from water bodies scant in the district of study .The need to water augment for imperative with heats up of temperature in different fractions of the district of study.
3. The amount of water lost by evaporation from water bodies, irrigation water and soil is high. Thus, the rainwater leak into the ground to feed groundwater stocks was relatively little, which has had a passive effect on the water equilibrium of the aquifers in the region, where the water levels in these reservoirs have fallen due to intensive exploitation with low levels of nutrition (General committee of agriculture 1984) .

4.2.4. Effect of Wind

Wind has a major role in human life through its activities that affect the environment and its component and its apparent impact on water ,whether surface or groundwater in various places in the study district where :-

1. The wind Rainy of the northwest in the winter, plays an important role in terms of nutrition of reservoirs water in sporadic parts of the region.
2. The north and north-eastern winds tend to humidity in the atmosphere, which greatly reduces evaporation processes.
3. Dry and warm southern winds further the quantity of water lost through evaporation and reduce the relative humidity significantly in most parts of the region of study. This increases needs water for plants, increasing the number of periods of irrigation in large quantities. This in turn causes stress to the water-bearing layers, which causing a constant drawdown in water levels as a result of this continuous depletion (Aboloqma , M , 1995) .

4.2.5. Effect of Rainfall

It has already been pointed out that the region of study is within the dry desert range. These qualities have their implicat and their implications at the water ions situation of the region, which confirms the following:-

1. Insufficient rainfall, fluctuation and irregularity of the rainfall that contributes to the recharge of underground reservoirs was, usually much lower than the amount withdrawn from these reservoirs at present, which was causing a lot of problems including annual deficit nutrition of that aquifers .
2. The large decline in the water scale in almost all aquifers of the treated reservoirs in addition to the continuous increase in salinity of the water, which influence the hygiene of quantum and quality (G. W. A , 1991) .

4.2.6. ***Impact of Soil***

The soil in the study region has a great effect on the groundwater in the aquifers exploited due to high temperature and low rainfall. This effect is shown as follows :-

1. In many parts of the region, the soil is sandy with large pores and high permeability. It requires large quantities of water during frequent periods of irrigation because leak out of majority of the water used in irrigation, which plays positive role and helps to further the quantity of water leaks to nutrition the underground stock especially in the northern sections of the region of study.
2. Water leaking through the saline soil is salty, due it is packed with the purport of salts and influence of the sub-surface layers of water , which leads to pollution by salinity, and this is obviously emerge in the regions of the existence of swamps .
3. For the topsoil stone in district of study, the leakage is very slow because it is very low, which leads to the loss of a large amount of water by evaporation before the leak to the soil, often resulting in saline caste on above the roof of the earth , where their effects are poor on soil quality and water quality when leaking to feed underground stock (G. W. A , 1983) .

4.2.7. Effect of Vegetation

Vegetation and natural plants, although not concentrated in most parts of the region of study, have an effect on both evapotranspiration and it falling on the ground. Their role as a catalyst helps to reduce runoff and prevent floods if they occurred. It moreover make it easier offside of water inside the soil to replenish the aquifer and also has an effective effect "in mitigation soil corrosion " (Pallas. P , 1980).

4.3. Geology and Lithostratigraphic Sequence of the region of study

4.3.1. Rocks and Surface Sediments

Ghadames Basin contains several surface geological formations of marine sediments from the Upper Cretaceous to Paleocene, as well as Quaternary sediments in many areas in the basin.

The study of surface maps and outcrops in the region indicate the presence of sediments and formations that are scattered on the surface. The most important formations are as following (Industrial Research Center, 1979) :-

a. Qasr Tigirinnah Formation

This formation belongs to the Upper Cretaceous period, where rocks appear on the surface in the northern and southern parts of the region between Derj and Ghadames. It consists of limestone and dolomitic limestone with overlays of chalk.

b. Mizda Formation

This formation belongs to the Upper Cretaceous period and show on the roof in the northern and central sections of the region of study . It consists of limestone and dolomitic limestone with overlays of marl.

c. Teckbal Formation

This formation belongs to the Middle Jurassic Age, where rocks appear on the surface in some northern and southern parts of the region of study. It consists of clay deposits, sandstone and sand clay.

d. Zmam Formation

The geological age of this formation ranges from the Upper Cretaceous to the Paleocene, which show its crags appear on the roof in the east and southeastern sections and in the far northwestern section and some of the southern sections of the region of study . It consists of limestone and fossiliferous limestone with overlays of marl.

e. Quaternary Precipitates

They are wind deposits, and dunes and marsh deposits, as well as sediments of valleys, spread on the surface in many scattered portions of the district of study .And figure (36) shows geological maps, and format (37) is an interest the geological specificities for district of study compared to other areas in Libya.

4.3.2. ***Lithostratigraphic Sequence***

4.3.2.1.Lithostratigraphic Sequence in Ghadames Basin and Surrounding Areas

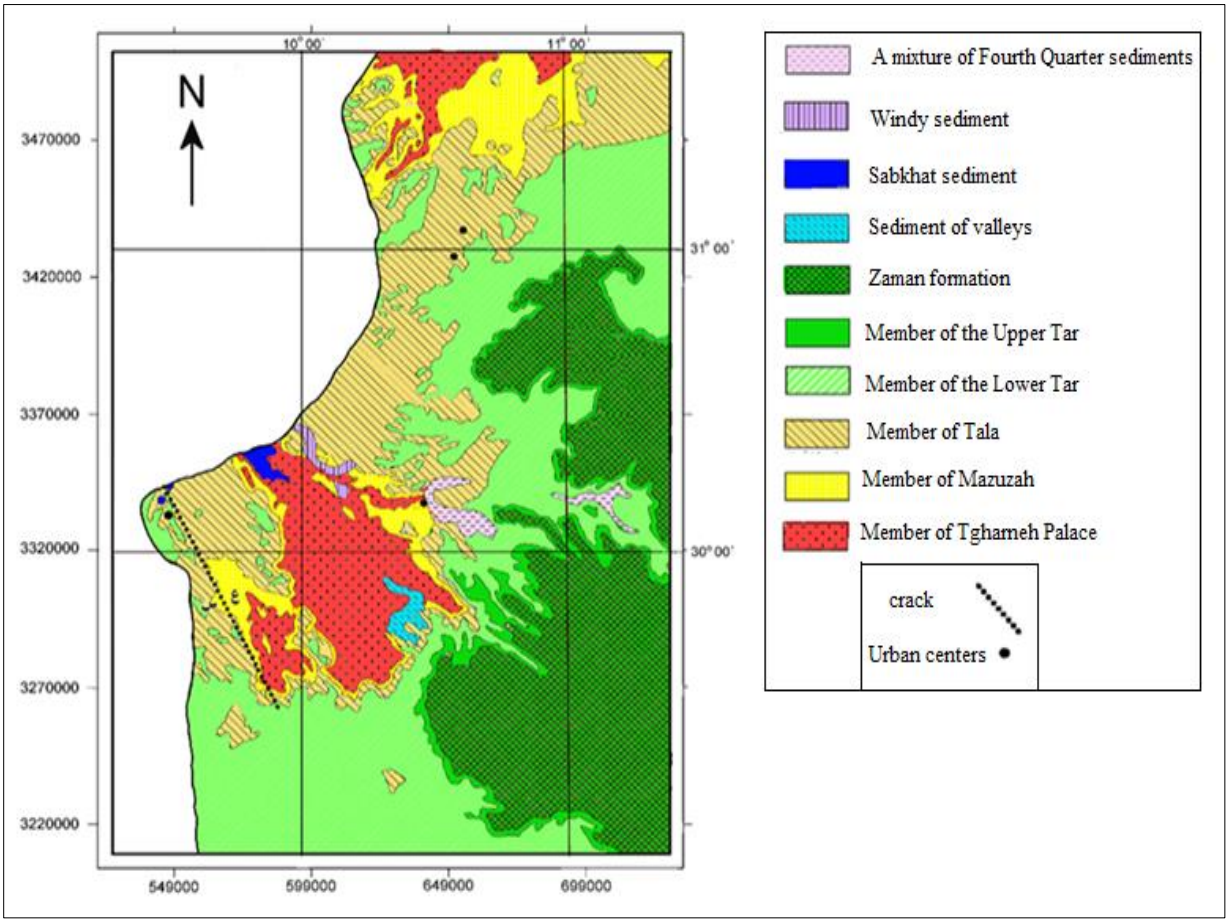
This sequence can be described as follows:-

Figure (38) shows a cross section extending in the south-north direction in west districts of Murzuk-Al-Hamada the Al-Hamra, Al-Jabal Al-Gharbi, Jafara, where the general pattern is observed and the rise and fall are shown as follows:-

1. A rise of norm composition (the vault) in the area of Mount Fazan, where deposits are bound to the sandstone of the Cambro-Ordovician age .
2. Fezan Mount in the north, which is representative it the Al-Hamada Al-Hamra Basin, is a syncline curve centered east-west and in thick formations of Paleozoic age.
3. A rise of basement as going south
4. Houn Basin represents the separation between Al-Hamada Al-Hamra Basin and Sirte Basin.

5. The entire area is covered by Mesozoic sediments with slow sea progress, forming continental and undersea sediments.
6. Al-Hamada Al Hamra Basin consists of thick deposits of the ancient and Paleozoic periods, overlaid with rocks from the Second Period, while the Paleocene cover the deposits of almost all the deck of Al-Hamada Al-Hamra Basin , save for its western side in the Ghadames area and the Far Eastern , in which the rooftop comprise of deposits chalky deposits and rocks.

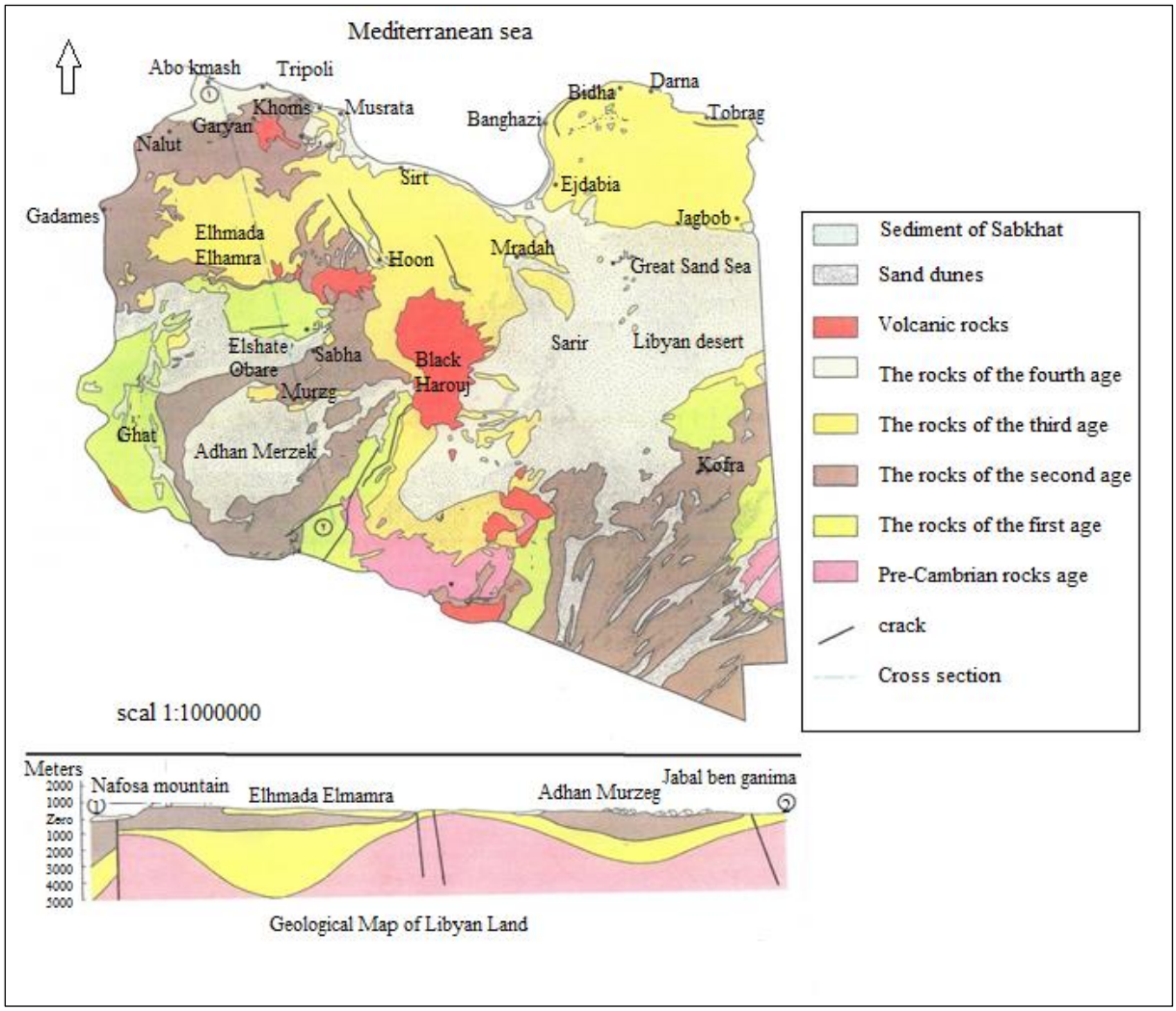
Format (36):- Geology map of the region of study



(Source:- Industrial Research Center (1979). Geological Map of Libya:- Ghadames and Al-Hamada Al-Hamra. Tripoli, Libya, p 5)

7. Formations of the second period are not thick of the continental deposits (especially sandstone) in the Triassic and Jurassic and nether chalky , whilst control by the marine nature of the Upper chalky and Paleocene (limestone , dolomitic) limestone, marl and shale) (Abuloqma, M., et al., 1995).

Figure (37):- Geological map of the region of study compared with further districts in Libya

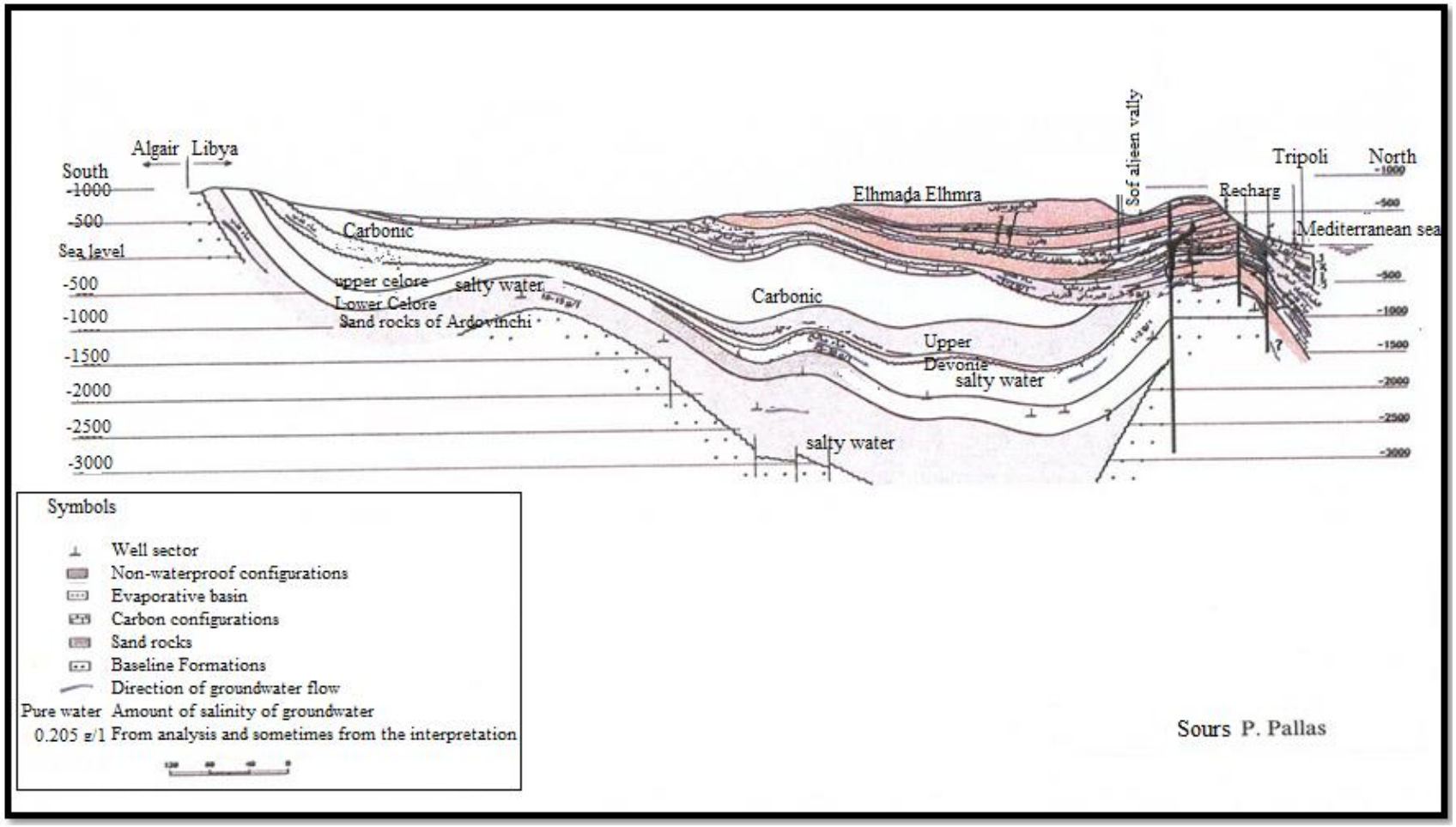


(Source:- General People's Committee of Education (1985). Educational Atlas. Elementary Level. Dar Map Serve for Printing and Publication. Stockholm, Sweden, p40)

4.3.2.2.Lithostratigraphic Sequence in the region of study

Through the information obtained from the drilling of test output wells and petroleum wells in the region, as well as the exploratory wells and water of Al-Wafa Gas Field in southeastern Ghadames, the was identified as follows :-

Figure (38):- South-North cross section of the western regions (Murzk-Hamada Al- Hamra-Western Mountain-Jafara)



(Source:- Pallas, P. et. al. (1993). Water Resources Utilization of Libya. General Water Authority. Tripoli, Libya

1. ***Teckbal Formation***

This formation belongs to the Middle Jurassic Age, consisting of a clay, sandstone and shale. The depth of this formation ranges between 1000-1100 meters while its thickness is between 60-180 meters.

2. ***Kiklah Formation***

The geological age of this formation ranges from Mid- and upper parts from cretaceous . It consists of sand, sandstone and calcareous sandstone with overlays of the formation varies from 300-1200 meters and the thickness is between 90-400 meters. This formation is divided into three members from the bottom up, and these members are (General Water Authority, 2002):-

a. Khashm Alzarzur Member

This member belongs to the Middle Jurassic period and ranges in thickness from 90-190 meters.

b. Shakshuk Member

This member belongs to the Middle Jurassic Age, with a thickness of 65-135 meters

c. Rajban Member

The geological age of this member ranges from the Upper Jurassic period to the Lower Cretaceous period, and its thickness ranges from 75-300 meters. Figures (39) and (40) for configuration Kiklah in the region of study.

3. ***Sidi Assid Formation***

This formation belongs to the Upper Cretaceous age and is divided into two members from the bottom up:

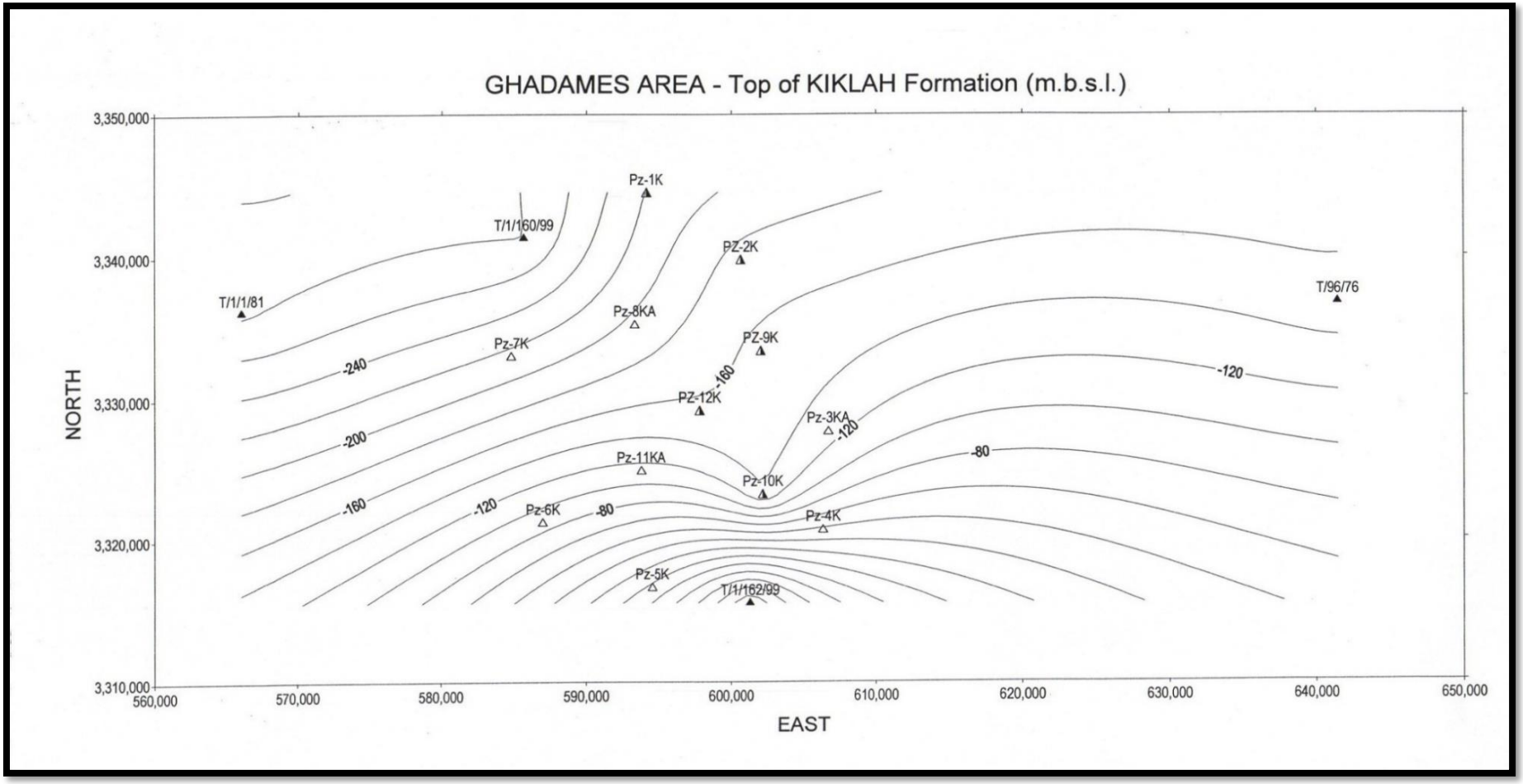
a. ***Ain Tobi Member***

This member is composed of both limestone, marly limestone and shale. Its thickness ranges from 20-150 meters. Figure (41) shows the alters in the top deck of Ain Tobi configuration in the district of study.

b. Yeferin Member

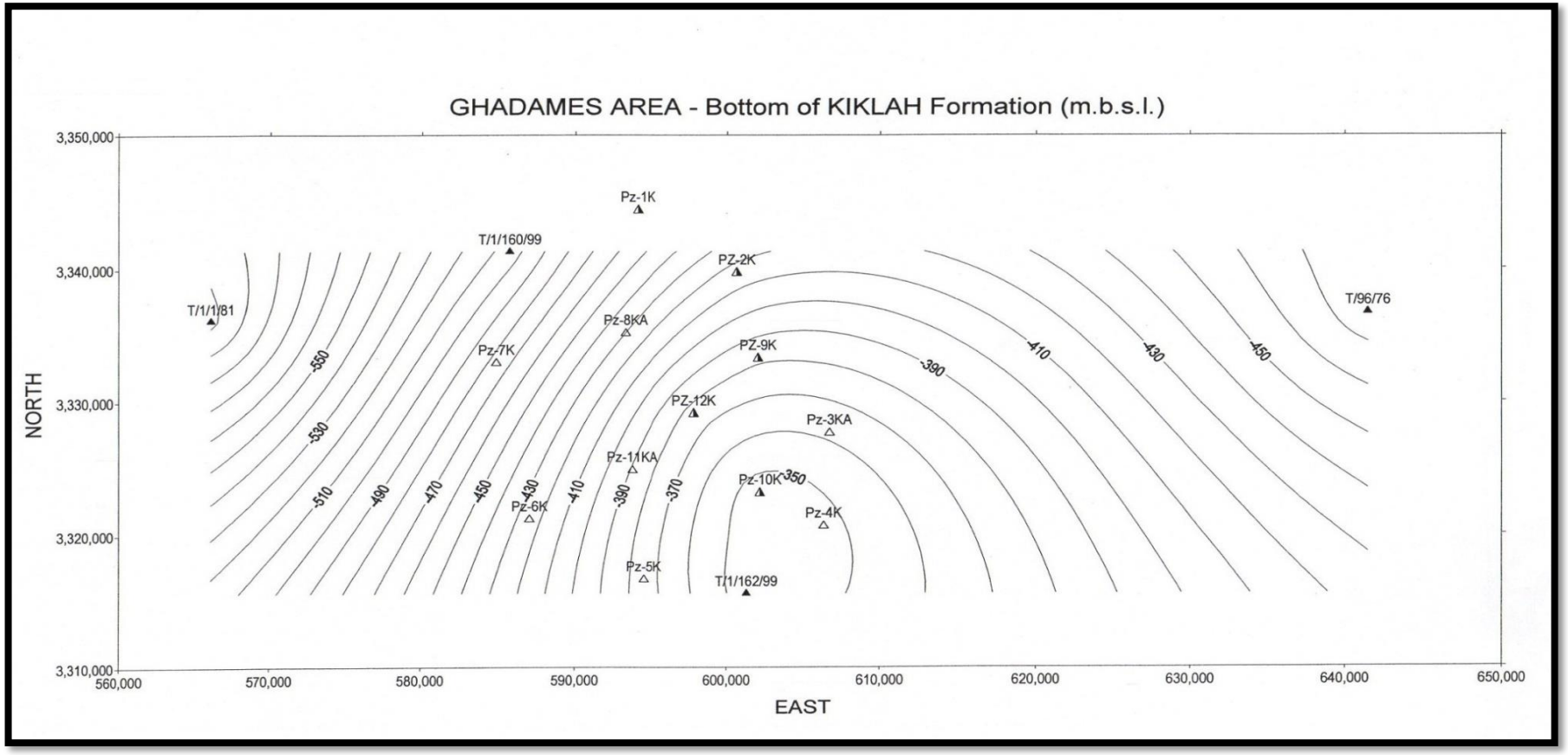
This member consists of marl, marly limestone and dolomitic limestone. Its thickness ranges from 90-170

Figure (39):- Variability in higher rooftop of Kiklah installation in the region of study



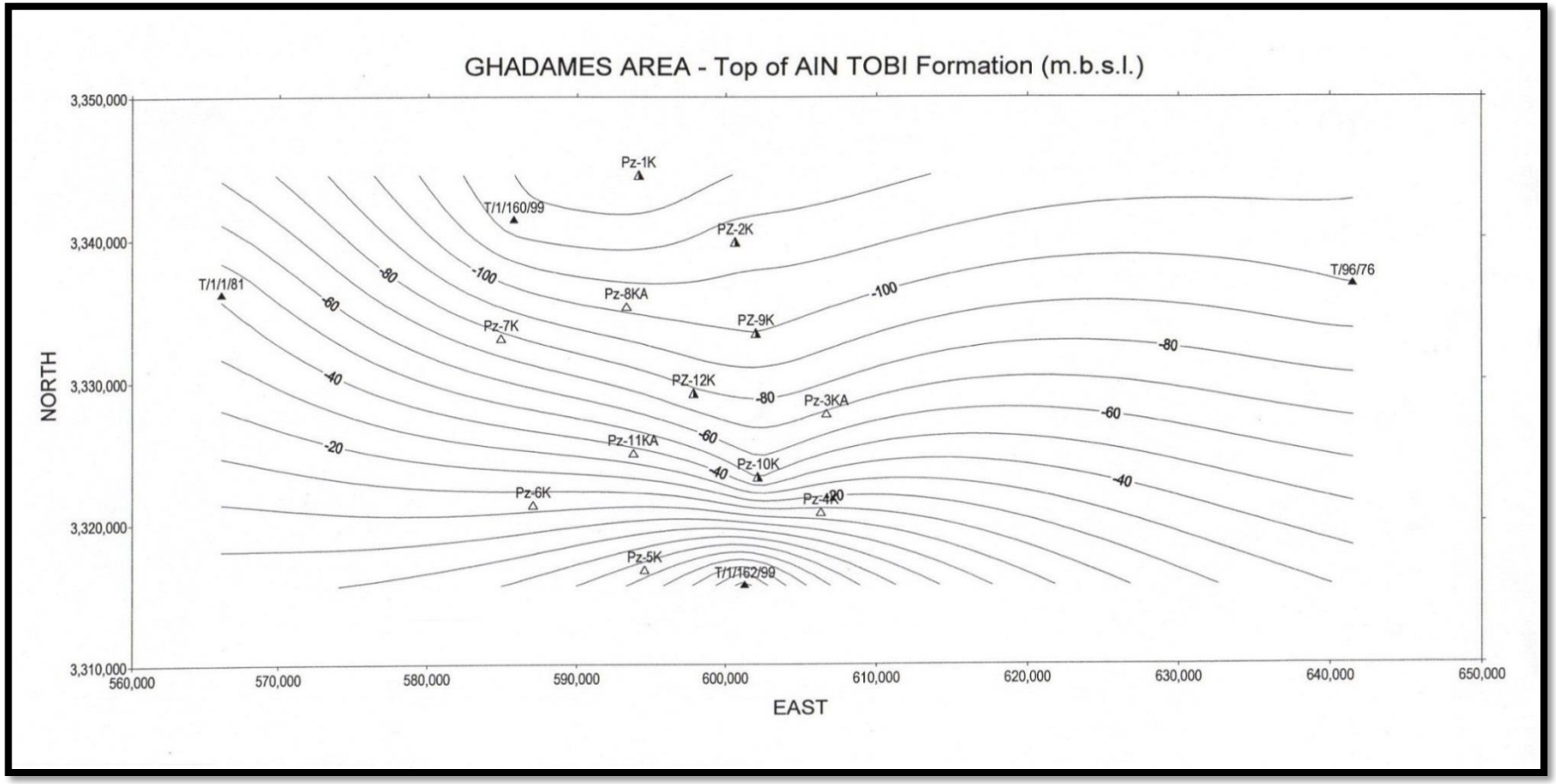
(Source:- TheResearcher's work depend onbased on the information of the final reports of drilling wells in Ghadames, prepared by General Water Authority, 2002).

Figure (40):- Changes in the lower surface of Kiklah Installation in the district of study



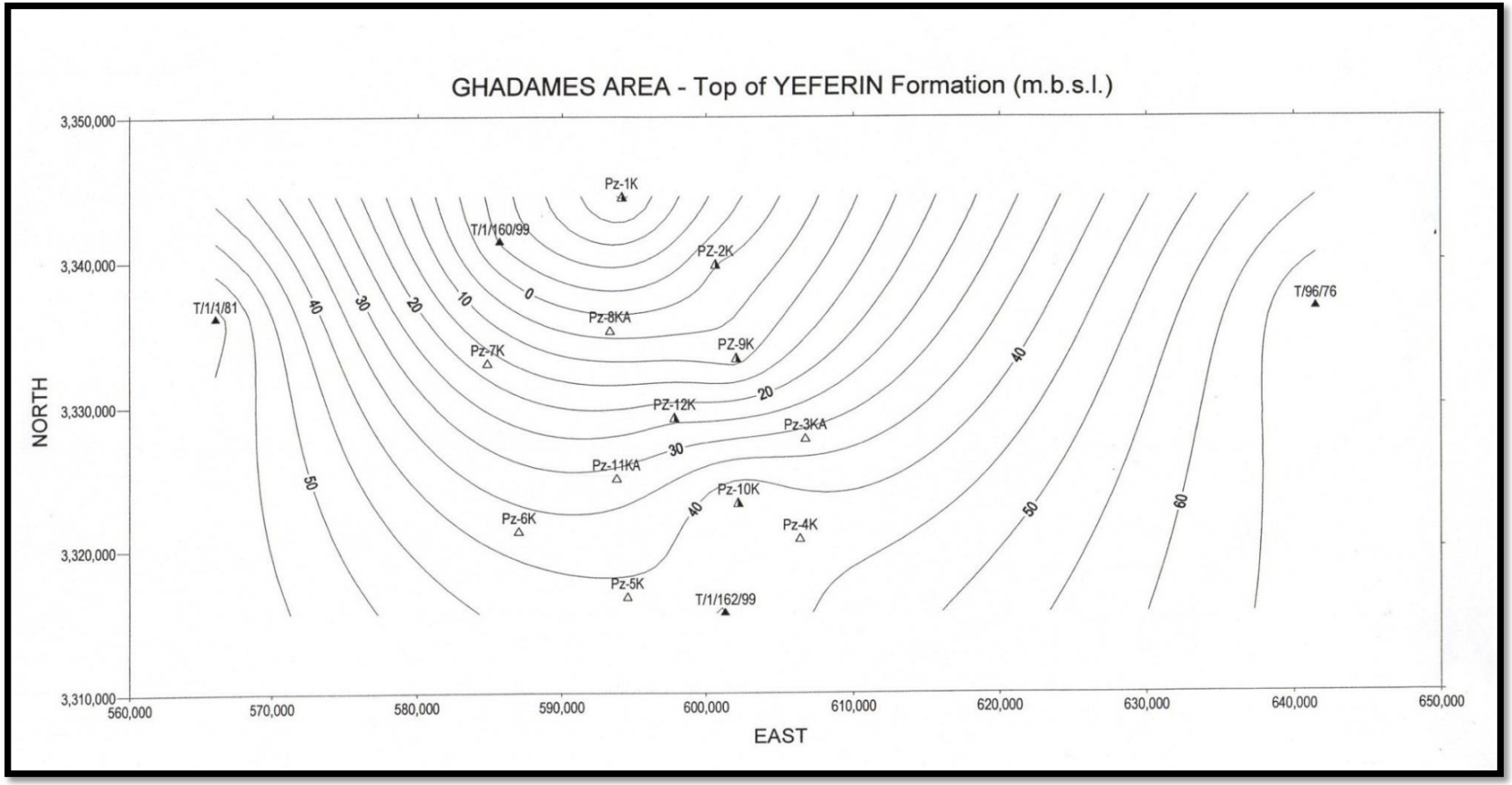
(Source:- TheResearcher's work depend onbased on the information of the final reports of drilling wells in Ghadames, prepared by General Water Authority, 2002).

Figure (41):- Changes in the upper deck of Ain Tobi configuration in the district of study



(Source:- Researcher's work depend on the information of the final reports of drilling wells in Ghadames, prepared by General Water Authority, 2002)

Figure (42):- Variability in higher rooftop of Yefrn installation in the district of study



(Source:- The researcher worked based on the information of the final reports of drilling wells in Ghadames, prepared by General Water Authority, 2002)

Figure (42) shows the alters in the top deck of Yfirn configuration in district of study.

4. *Nalot composition*

The geological era of this composition is the top chalky . It comprise of limestone with gypsum overlays.

5. Qasr Tigirinnah Formation

This formation belongs to the Upper Cretaceous period and consists of limestone and dolomitic limestone with overlays of chalk. Its thickness is between 40-260 meters.

6. Mizda Formation

This formation belongs to the Upper Cretaceous period and consists of limestone and dolomitic limestone with overlays of the marl and its thickness ranges from 20-180 meters. Mizda Formation is divided to two members:-

a. Member of the lower Almazoza (limestone)

b. Member of the upper Talah (limestone dolomite)

7. Zmam Formation

The geological age of this composition ranges from the top chalky era to the Paleocene (upper Cretaceous-Paleocene). This composition is composed of limestone and limestone fossil and overlaps with marl, ranging in thickness from 10 to 50 meters. Zmam Formation is divided into two members:-

a. Upper Tar Member

b. Lower Tar Member

Figure (43) shows the lithostratigraphic sequence and the lithological description of Ghadames Basin. In this study, attention will be given to the deep Kiklah aquifer, which is currently being exploited in large parts in the region and the problems that this reservoir suffers from under this exploitation.

Figure (43):- Lithostratigraphic sequence and lithological Sequence rocky stone and lithological the precinct of study

Depth (m)	Thickness (m)	System	Series	Formation		Log	Description
	10 - 50	Tertiary		Zmam			Limestone, fossiliferous limestone, alternating with Marl
100	20 - 180	CRETACEOUS	Upper	Mizda			Limestone, dolomitic limestone, with intercalation of marl
200	40 - 260			Qasr Tigrinnah			Limestone, dolomitic limestone, alternating with chalky
300	40 - 150			Nalut			Dolomite, dolomitic limestone, with gypsum
400	90 - 170			Sidi Assid	Yeffrin member		Marl, dolomitic limestone, marly limestone
500	20 - 150				Ain Tobi member		Limestone, marly limestone, shale
600	75 - 300		Lower	Kiklah	Rajban member		Sand, Sanstone, sandy limestone, conglomerate bed, clay
700	65 - 135				Shakshuk member		
800	90 - 190				Khashm Az Zarzur member		
900		JURASIC	Middle				
1000	60 - 180			Teckbal			Shale, sandstone, sandy clay
1100							

(Origin :- G W A , (2003). Digest of the outcomes of the study of the Northern Desert Basin Project. The Documentation Center, Tripoli, Libya, p 22.)

4.4 Structural Geology

Based on the previous studies, geological mapping of Libya by the Industrial Research Center of the Ghadames – Derj - Sinawen regions, information of wells dug in the region for the purpose of drilling for oil and test boreholes the structural features of the region of study are as follows:-

● Ghadames Basin is a wide concave curve (Synclinal).

● The general lean of the layers in this basin towards west , up to the circuit of circle supply 12 scores.

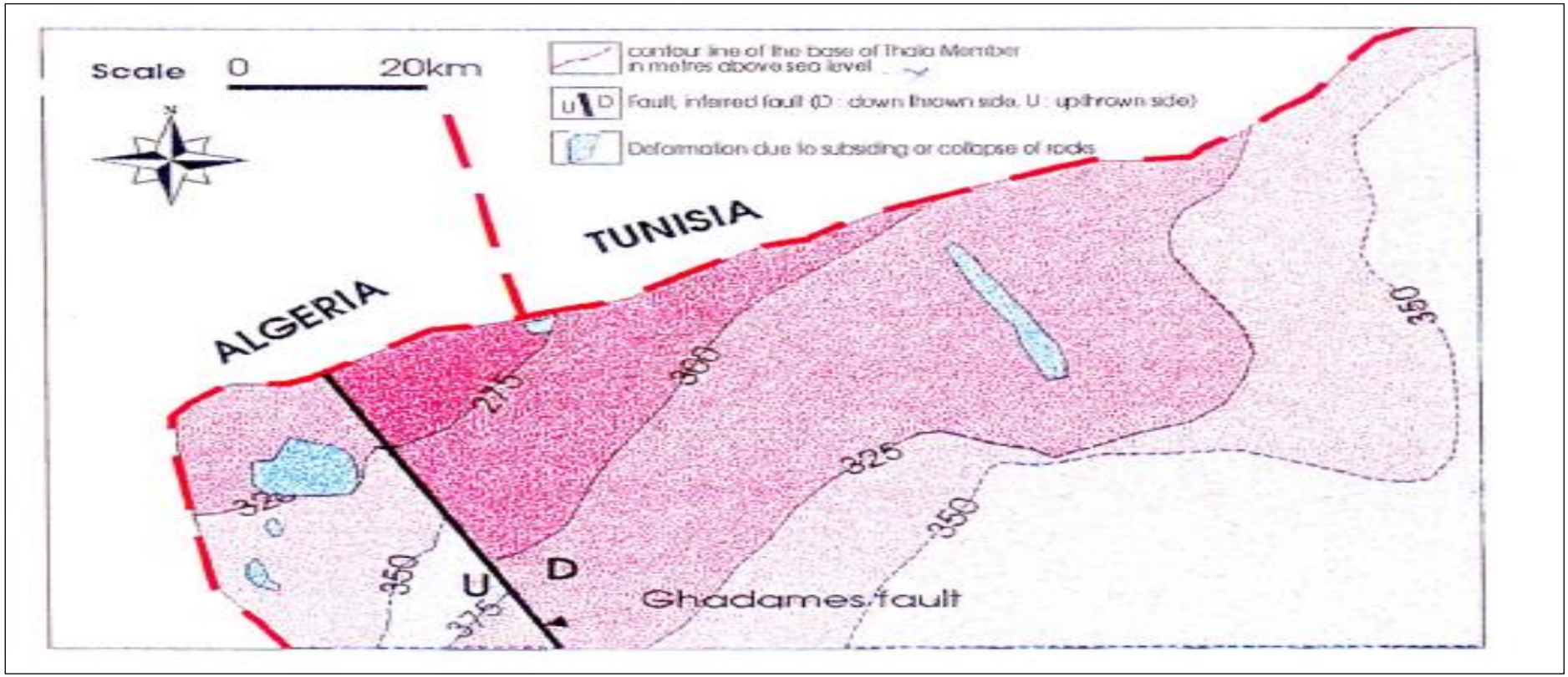
● The layers are skewed toward the southwestern in the zone .

● At the southern portion of the district , the strata are north-west oriented.

The main fault in the region, known as Ghadames Main Fault, is shown in the direction of northwest-south-east. This was identified as a field phenomenon, where Qasr Tigirinnah Formation appears next to the upper part of Mizda Formation (Tala Member), at the same level with Almazoza Formation disappearing, the vertical displacement of the crack is 60-70 meters (Radi and El-Akeel, 2006).

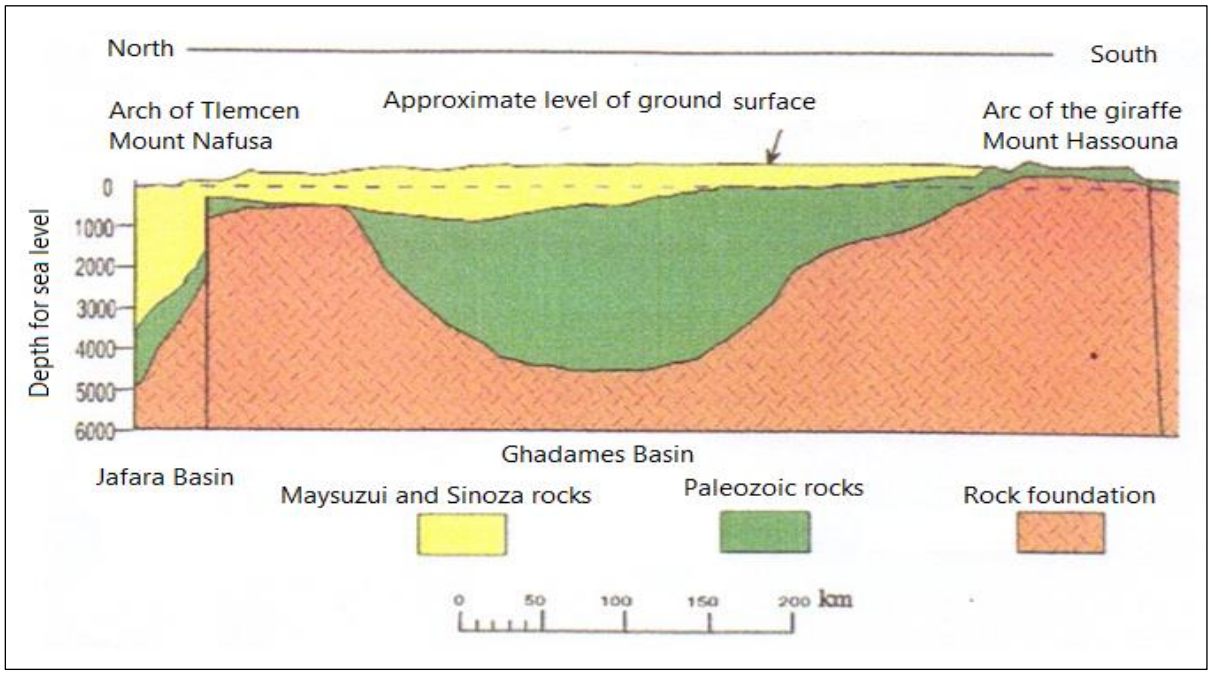
The area was exposed to other faults in the north-east-south-west direction, with parallel to Ghadames Main Fault, about 30 kilometers south-west of Al-Sabkha Majzem to form a large depression that extends to the south-west and is covered by the Sabkhat deposits. Figure (44) shows the structural map of Ghadames Basin, while Figure (45) shows a geological cross section of southeast of Ghadames area, which shows the main fault in Ghadames.

Figure (44):- A Structural map of Ghadames Basin



(Source:- Radi and El-Akeel (2006). Geology and Hydrogeology of the southwestern part of Ghadames Basin, northwest Libya. General Water Authority. Tripoli, Libya. p 9)

Figure (45):- Geological North-South cross section of the Ghadames area (Great Ghadames Fault)



(Source:- Serafascaf (1981). Hydrogeological Studies of Ghadames, Derj and Sinon, Northwest Libya. Documentation Center. General Water Authority. Tripoli, Libya:- p11)

4.4.1. Geological Cross-sections

In this study, the researcher prepared three geological cross-sections as follows:-

4.4.1.1.Geological Cross-section A-A' (North-South)

This cross-section passes through wells (T/158/89, WG16, WG10, D190, T/162, WSW6). In this cross-section, Upper Cretaceous deposits appear in the formations of Mezda, Qasr Tigrinnah, Nalut, Yefirin and Ain Tobi, at different depths of the surface and with a thickness of 300-500 meters.

The variation in thickness cause that the area is a wide depression that rises clearly on the northern and southern sides of the cross-section. Some formations appear while others disappear, especially under the influence of different erosion factors.

Kiklah Formation appears at a different depth and in a variable generated by of mistakes in the area. In the northern and at the well (T/158/89), the composition show up at a deepness almost 480 meters under the surface , and almost 200 meters thickness . In the well D190. The composition show up in a depth of about 550 meters with a thickness of more than 400 meters. In the south and at the well (WSW6), the formation appears at a depth of about 200 meters and a thickness of more than 400 meters. That is to say, the more we go

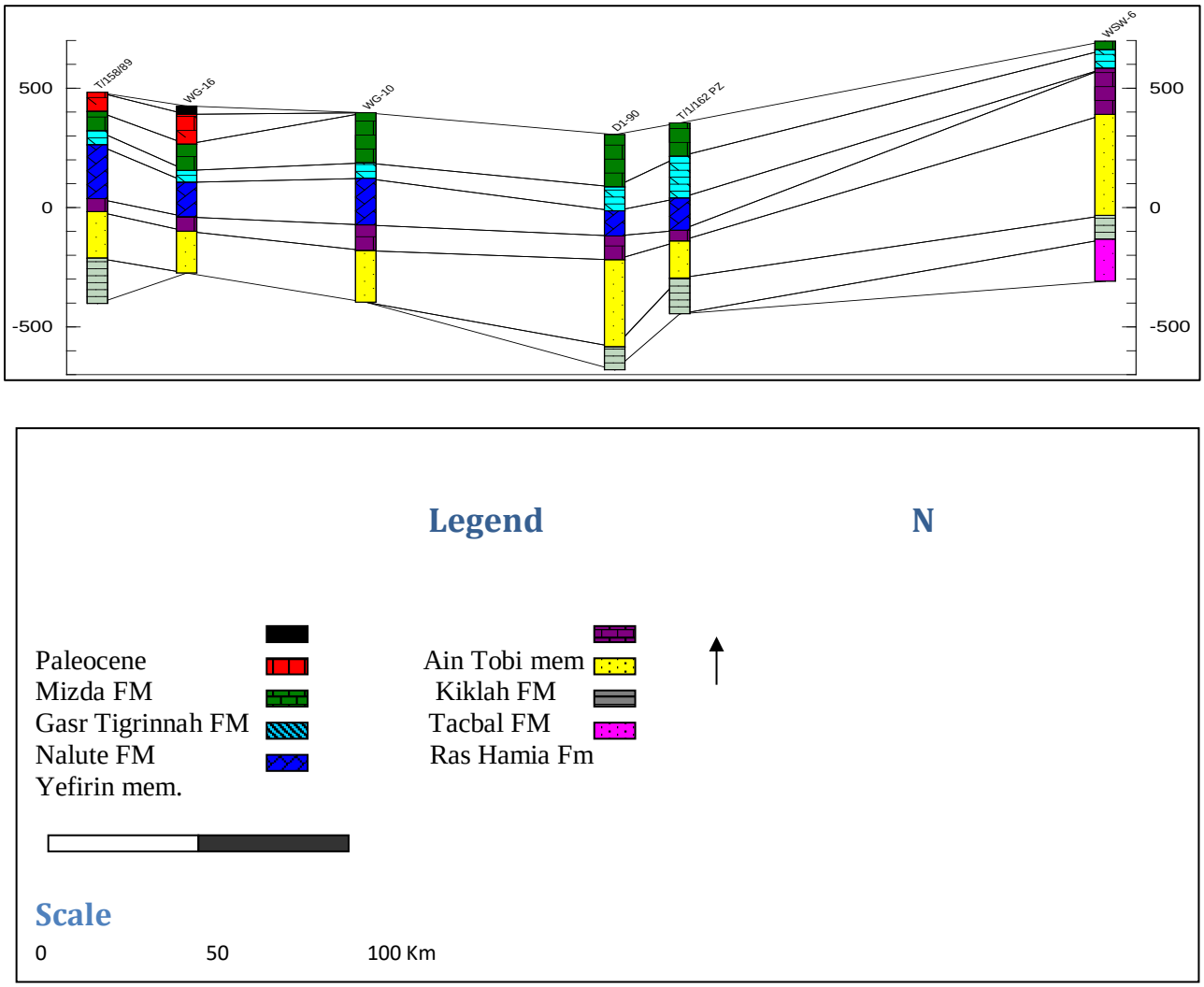
south, the denser it becomes. Overall, the largest thickness of the formation was observed at both the wells WSW6 and D1 GO, reaching about 400 m. Also, the full formation of the two wells (WG16) (WG10) was not fully penetrated. Figure (46) shows the geological Figure (46) shows the geological syllables (A, A')

Geological syllables (B-B')

This cross-section passes through wells (T/203/80, K90, T/162, T/162, T/159/89), where the following is clear:-

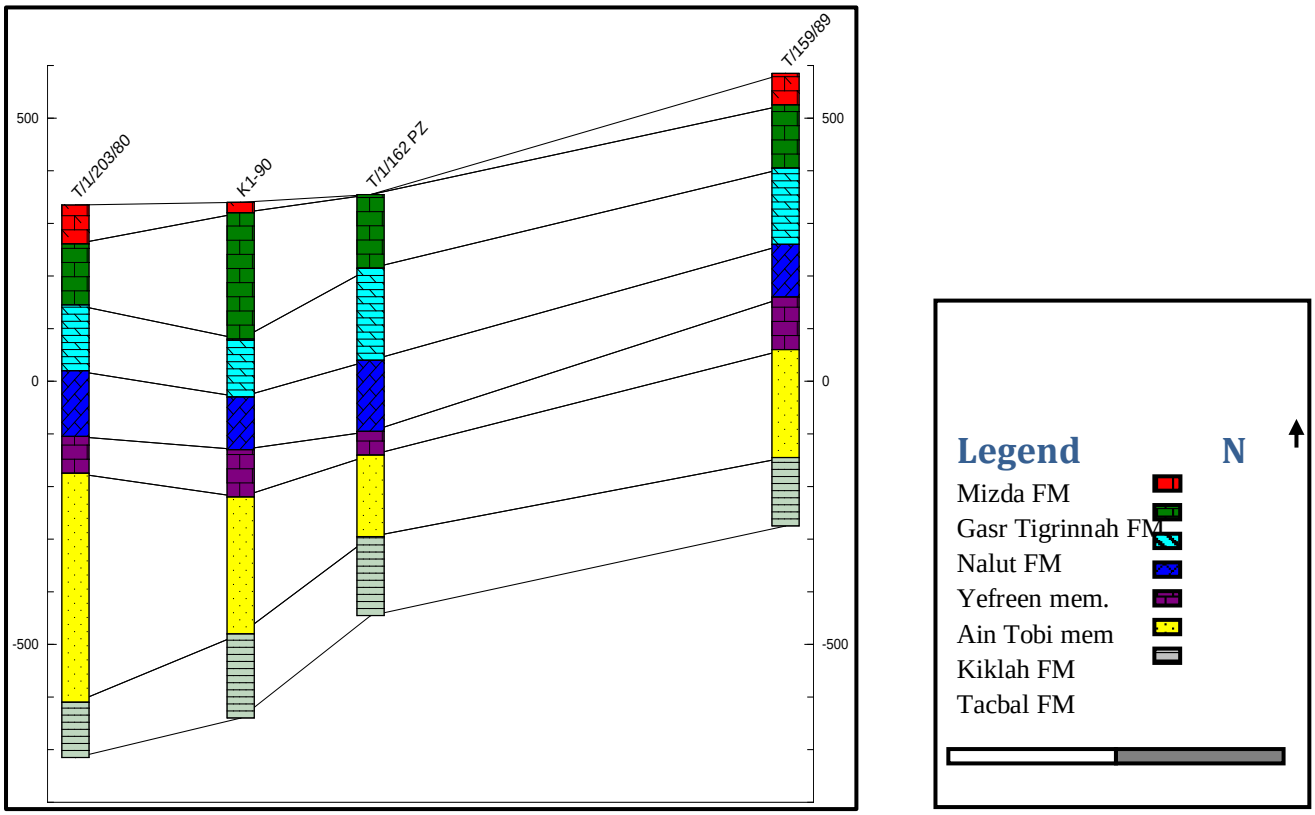
- Upper Cretaceous deposits appear on the rooftop and even a deepen of 400-500 meters from the rooftop . It sould be noted that there is a clear gap between the two wells K190 and T/162. The displacement of this fault is about 60 meters.
- The Lower Cretaceous sediments and Middle Jurassic deposits appear at different depths of the cross-section and are also uneven in nature. In the Well (T/ 203/80) of Ghadames, these compositions show at a deep of around 550 meters and a thickness of bypass400 meters .
- Thickness of these composition gradually decrease as we turn southeast, with deeply of almost 500 meters at the well (T/162) and thickness of around (160 meters).
- IN the well (T/159/89) the compositions show up at a deepen of around 550 meters , and with a thickness of around 190 meters. Format (47) clarify the geological cross section (B-B′) from the northeastern to the southwestern of the study region .

Figure (46):- A north-south geological syllables A-A′ at district of study



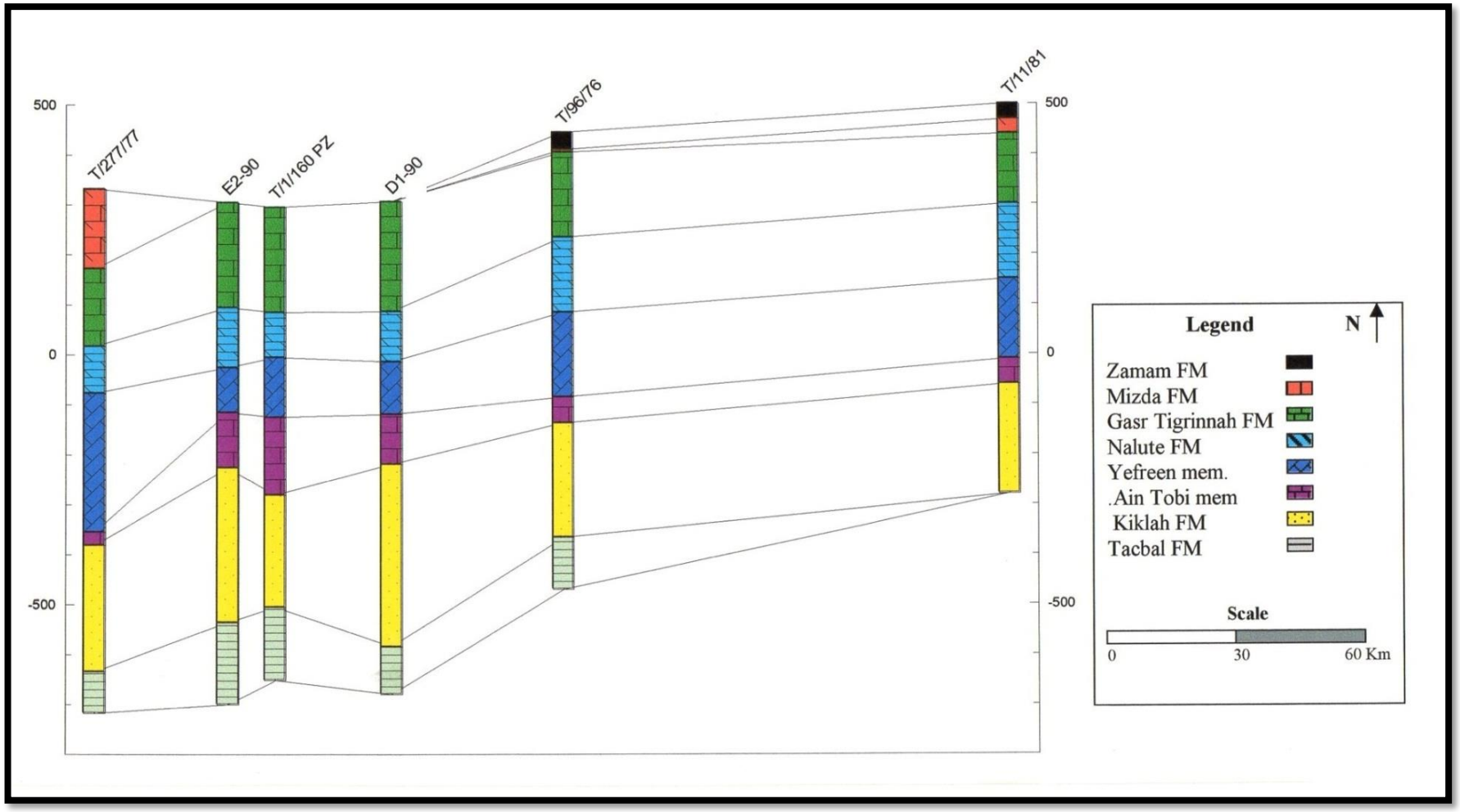
(Source:- Researcher's work depend on the information of the final reports of the studied wells, General Water Authority. (2016). Tripoli, Libya

Figure (47):- Geological cross-section from north-west to south-east (B-B′) in the region of study



(Source:- Researcher's work depend on the information of the final reports of the studied wells, General Water Authority. (2016). Tripoli, Libya.

Figure (48):- Geological incidental syllable from west to east (C-C′) in the district of study



(Source:- Researcher's work depend on the information of the final reports of the studied wells, General Water Authority. (2016). Tripoli, Libya.

4.4.1.2. Geological Cross-section C-C' (West - East)

This cross-section passes through wells (T/277/77, E290, T/160, D190, T/96/76 and T/11/81). All the wells that have been penetrated into the section represent sediments of the upper Cretaceous period starting from the surface with a thickness of 400-600 meters. This section is characterized by a number of faults in the central sector. This is evidenced by the appearance of rocks of Mizda Formation in the well (T/277/77). At other times, rocks of Qasr Tigrinnah Formation are also revealed in wells (D190, T/160). Kiklah Formation which represents the most important reservoir in the area, appears in the section at depths ranging from 550 to 700 meters . This thickness contrasts as we turn east. In general, the maximum thickness of this formation was observed at the well (D190), reaching more than 400 meters. Figure (48) shows the geological study cross section (C-C') from west to east in the study region .

4.5. Geologic History of the Study Region

Is bordered from the northern the highland northern ,and tub of Ghadames , which sprea southward shaped like of plateau to the area of Qirqaf, which separates it from Murzuk Basin. It extends westward within the borders of Algeria and Tunisia, and eastward to Houn Fault. It contains a series of geological formations from the Cambrian to the Paleocene period, interspersed with several periods in which some rocks completely disappear as a result of erosion in these periods. Through the researcher's fieldwork investigations, information and interpretations collected from cross-sections, the geological history of the region of study can be summarized by the following points:-

● Rocks belonging to the Cambrian, Ordovician, Silurian, Carbonic and , were mainly composed of continental sediments represented by sandstone, clay and sand, separated from the Precambrian rocks with a clear surface of unconformity, which was identified by some deep wells drilled south of Ghadames Basin. The presence of this surface indicates the continental conditions that prevailed in the region during these ages.

● The Mesozoic Era (from Jurassic to Upper Cretaceous ages) was characterized by the existence of sedimentary of rocks and their differences. During these ages, the sea immersed most parts of the region of study resulting in the deposition of thick layers of limestone, sand, clay and mixed sedimentary rocks and salts that vanish below the coverage of the boulders of the Cenozoic Era, the formations of Takbal, Kiklah, Sidi Assaid, Nalut, Qasr Tgrina and Mezdah .

● In late the geological ages of intermediate epochs, of cretaceous period, the conditions dominate in the study region , allowing for the formation of some continental sediments and the spread of areas affected by erosion.

● Before the started of the third epoch . preserve rock layers in the

district of study maintain their grounds of class regime and were not significantly affected by torsional movements , while they were greatly affected by various erosion factors conditions.

- At the beginning of the Tertiary period, the region of study, like most Libyan lands, was subjected to strong tectonic movements that resulted in changes in sea level and the origin of many folds, faults, fractures and cracks (most notably the main Ghadames fault) .
- In the centre the third epochs , the effect of the sea had rise in the study region . As a result, big marine deposit , actress by thick layers of the limestone ,the merle and petrified travertine , became wealthy in excavations (Zmam composition).
- At in late of the third epoch, the area was overshadowed by with sediments pelagic and superficial , outcome of the phased decrease of the sea . As a result , thin layers of clay , sand gravel were deposited , after which the region was subjected to multiple erosion periods .

4.6. Hydrology of the Study region

4.6.1. Major reservoirs in the Study region

Based on the researcher's fieldwork investigations, information and interpretations collected from three hydrogeological cross-sections (Figures 50, 51 and 52) selected to illustrate the geological, hydrological, hydraulic changes as well of the reservoirs in the study region ,and the final reports of the productive wells. Five main aquifers were identified as follows :-

3.6.1.1. Shallow Aquifer Reservoir (Quaternary aquifer)

This aquifer has the following features and characteristics:-

a. The lithological features of the aquifer is a sequence of limestone, gypsum and anhydrite with overlays of dolomite and marl. The depth of this reservoir ranges from 10-30 meters.

b. The productivity of wells that exploit this reservoir is very weak, so it is not considered trusted water origin .

c. The is poor and salty. The total amount of dissolved salts in water reaches to more than (5000 mg/L) due to the presence of gypsum and anhydrite interference.

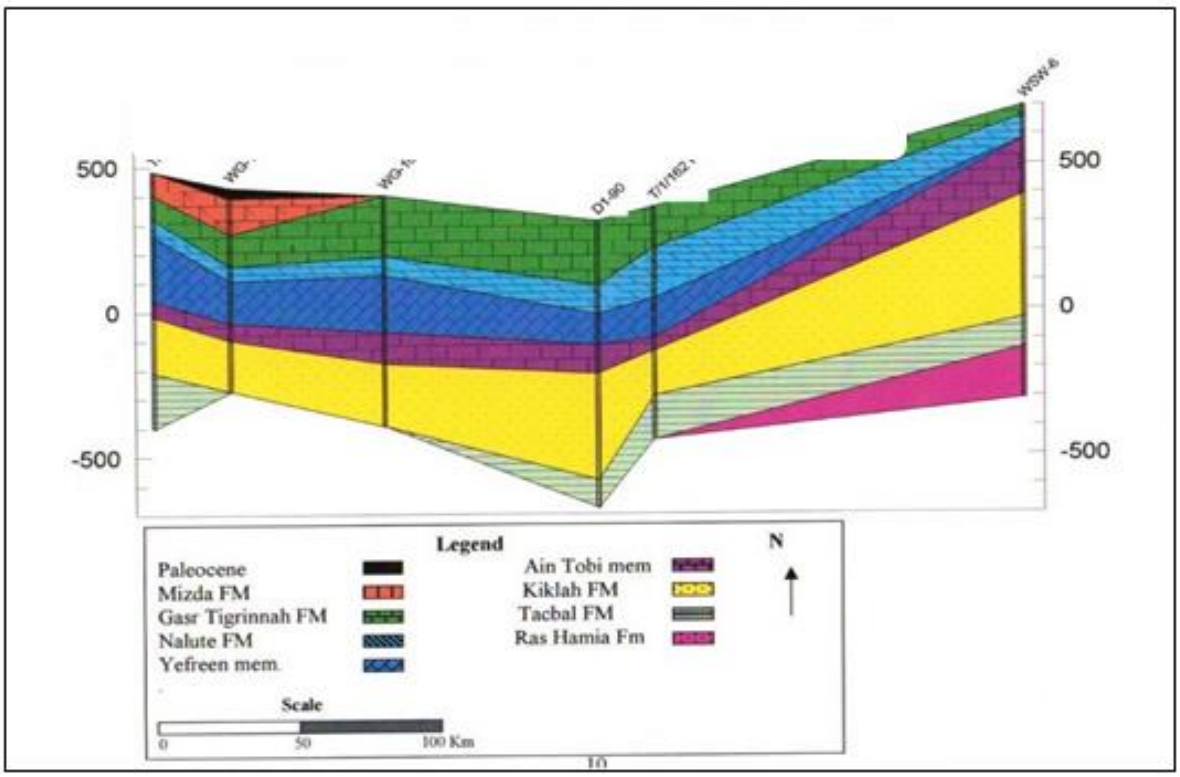
3.6.1.2. ***Upper Aquifer***

This aquifer has the following features and characteristics:-

1. The geological age of this aquifer ranges from the Upper Cretaceous to Paleocene.
2. This aquifer includes the formations of the Zamzam, Mezda, Qasr Tigrinnah and Nalut.
3. The lithological features of this aquifer is a sequence of limestone, dolomite, marly limestone, dolomite, with overlays of gypsum, clay and marl.
4. This aquifer is located at different depths in the region. The depth ranges between 100-320 meters in the areas of Derj and Sinawn. It becomes deeper as we go south until reaching the Ghadames area, which ranges between 300-450 meters under the roof of the earth.
5. The thickness of this aquifer ranges between 100-250 meters.
6. Most of the wells drilled to exploit this aquifer are located in the southwest of Ghadames with a self-flowing phenomenon (i.e., Artesian). Standard the water range from couple of meters under the rooftop ground to 10 meters over rooftop the land .
7. The productivity The productivity of wells in this aquifer ranges from (20-40 m3/h) in Ghadames area. This productivity is gradually increasing to (10-15 m3/h) in some areas north of Ghadames, while productivity is gradually decreasing in areas south of Ghadames .
8. The average drawdown due to the withdrawal of the tank ranges from 5-10 m.
9. The amount of dissolved solids in the used well of reservoir ranges from (2000-600 mg/L). This salinity increases as the ratio of gypsum layers increases in the reservoir structure.
10. The transmissibility rate ranges between (50 m^2/day) to (2000 m^2/day) according to the percentage of cracks and gaps of petrified lime in the formative of the water tank , as reveal by the statements of the numbers of productivity wells in the area (Final reports of productive wells, General Water Authority, 2016).

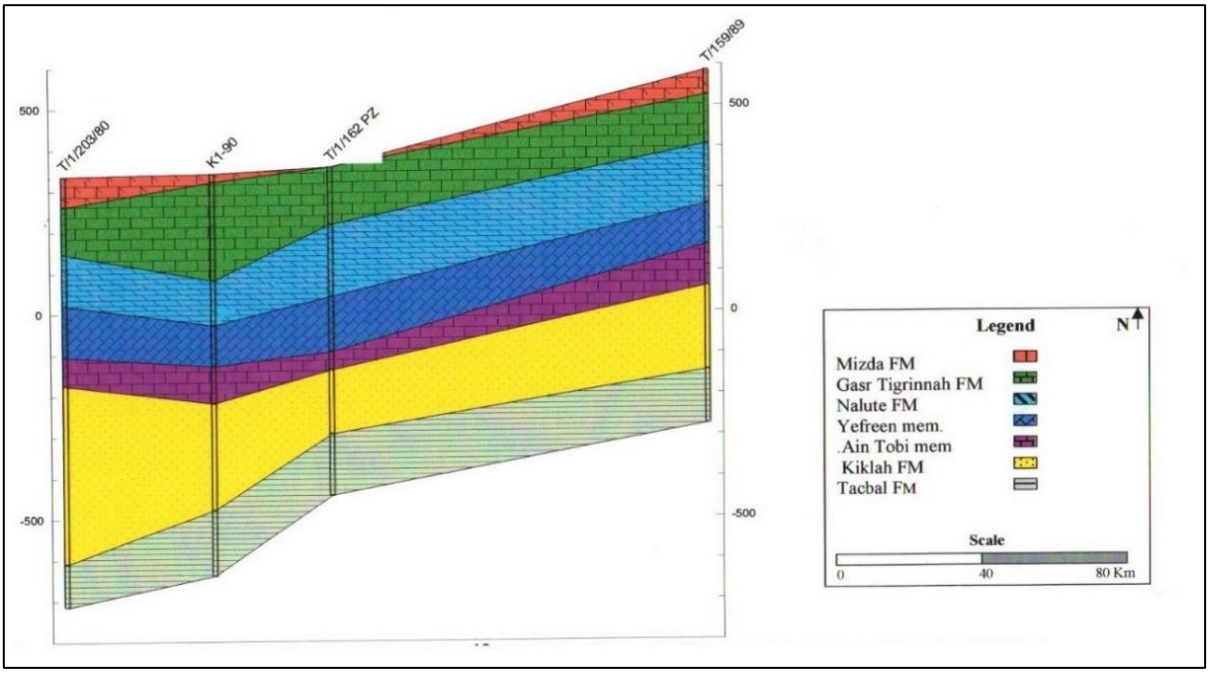
11. The currently exploited quantities of the reservoir, (457 million m3/year) in Tunisia, while estimated at (233 million m3/year) in Libya (General Water Authority, 2006).

Figure (49):- Discrepancy in attributes of the groundwater layers in the region study in the north-south direction



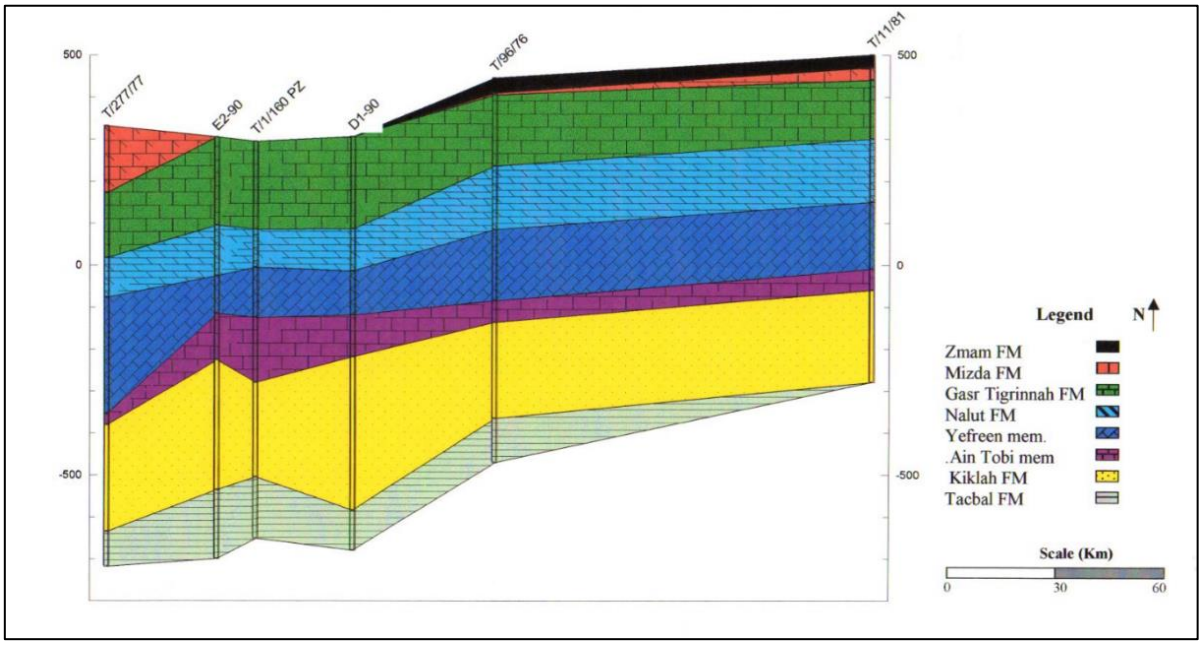
(Source:- Researcher's work depend on information of the final reports of the drilling of the studied wells. General Water Authority, 2006)

Figure (50):- The water and its attribute the distinct in the northwestern trend to the south-eastern



(Source:- Researcher's work depend on information of the final statements drilled of the studied wells G. W. A , 2016)

Format (51):- The water and its attribute the distinct in the thrust from the northwest to the south-east



(Source:- Researcher's work depend on information of the final reports of the drilling of the studied wells. General Water Authority, 2016)

3.6.1.3.Ain Tobi Aquifer

This aquifer has the following features and characteristics:-

a. This aquifer belongs to the Upper Cretaceous Age.

b. The lithological The lithological traits of this ground reservoir is a series of limestone and dolomitic limestone with overlays of oil shale-based and merle .

c. The deepness median of the underground water is between 45-150 m.

d. The thickening of the reservoir different from one region to another in the district of study . This thickness ranges from 25 to 150 meters.

e. Well water withdrawn from this aquifer is highly saline and, therefore, limited in use.

3.6.1.4.The underground water layer Kiklah

This is the principal reservoir underground and the region of study . It has the following characteristics:-

1. The lithological structure of the aquifer is a sequence of sand and sandstone with overlays of sandstone, limestone, clay, conglomerates and silt (deposits of continental environment).
2. Majority oil wells and water wells that were dug in the region of study proved that Kiklah aquifer is divided into three members from the bottom to the top (OSS, 2009):-
   - **a.** Khashim Zarzur Member (Early Middle Jurassic)
   - **b.** Shakshuk Member (Late Middle Jurassic)
   - **c.** Rajaban Member (Upper Jurassic to the Lower Cretaceous Period)
3. The depth of Kiklah aquifer varies from (3000-1200 meters) below the surface. This variation of depth was due to the presence of many faults in the area.
4. The geophysical well loggings and the drilling products and cuts of the drilled wells that utilize the groundwater reservoir in the various portions the region of study indicate that there is an overlap between the top of Kiklah aquifer with the Ain Tobi aquifer, whereas its lower part overlap with Takbal Formation.
5. The wells that exploit this groundwater layer that was situated in the north-eastern and south-western regions of the region of study are characterized by the self-water flow (Artisian), which ranges between 7-37 meters above the ground in Ghadames region .
6. The aquifer that was located in territories Al- Hamada Al-Hamra, and the western mountain its depth about from 210 to 350 meters under the roof of the earth.

7. The productivity of wells that exploit this aquifer are different from one part to another within the boundaries of the region of study where (General Water Authority, 2006):-
   a. The productivity ranges between (50-400 m^3/h) in Ghadames area.
   b. The productivity ranges between (40-70 m^3/h) in Hamada Al Hamra area.
   c. The productivity ranges between (20-35 m^3/h) in the district of northern heights chain.
8. Median the low in water plane in the underground a result of the utilization of wells is averaging between 7-10 meters in the Ghadames district .
9. In normal situations, be the salt water in the underground reservoir is ranging from (700-2000 mg/L) but it exceeds this number in some wells to reach more than that.
10. The aquifer water temperature ranges from (30°C - 40 °C).

4.6.1.5 Rass Hamia Aquifer

This aquifer represents the lower aquifer in the region of study and is characterized with the following characteristics (OSS, 2009):-

1. The geological era of this reservoir is the middle Triassic . .
2. The rock brown of the reservoir groundwater layer is a sequence of sandstone, clay sandstone, shale and clay with overlays of dolomite.
3. The depth of aquifer ranges from800-1000 meters under the roof of earth.
4. Thickness of Rass Hamia aquifer increases as it moves to north from the region of study, while gradually decreases in the south and south-western .
5. The district of study ranges interval 190-290 meters under the roof of the earth.
6. The production of the wells in this underground reservoir ranges with (18-40 m3/h) , as been there a decline 2 meters .
7. The quantum of salts range between 500- 700 mg/ L .
8. Temperature of the aquifer water ranges from (40-47 m).

In general, the oil wells and water wells were dug in the region, in Wafa Gas Field, prove that Rass Hamia aquifer represents a storage reservoir that can be exploited as another source of water next to the reservoir in Kiklah region, because of its water potential and quality of well water after intensifying studies on this aquifer as well as the preparation of mathematical models to exploit it.

3.7.Specifications of Kiklah Aquifer

3.7.1.*Quality of Water in Kiklah Aquifer*

The water of Kiklah aquifer is considered valid for all purposes whether for domestic, drinking or agriculture purposes, where the aquifer is characterized by its thickness and high prevalence , in addition to the homogeneity and water quality. The salinity in most wells ranges between 700-2000 mg/L. In some wells, there was an overlap with the upper aquifer (Ain Tobi), where water salinity was more than 10,000 mg/l, or with the lower reservoir, which was considered highly saline in some parts of the region as follows (Hamid, W. F., 2006):-

- In the area between Ghadames and Derj, the salinity is between 800-1800 mg/L.
- Salinity of the aquifer increases towards the north at times more than 500 mg/L .
- In the southeastern regions , the salinization of water up nearly 2000 mg/L .
- At district east , percentage salt in water ranges between (800-2600 mg/L) .
- In the western party region of the study exceed the saline of water (3000 mg/L).

In this regard, it is noteworthy that the amount of total dissolved solids (T.D.S.) changes from one well to the next , and at times in the same well from one duration to nextr in the water of Kiklah aquifer particular in the commissioning time of the wells . There are have two major factors influence on the water efficiency of this basin are the plane of high saline in the water of some wells, further case for is interferationof the water layer water with other underground aquifers, both upper and bottom, whose saline water seeps into the layers that were exploited for the reservoir underground .

4.7.3. *Utilization of Kiklah Reservoir*

The water in Kiklah reservoir is being used for all purposes, whether for drinking or agriculture. The quantities of water exploited in this aquifer were estimated by the(General Water Authority , 2006) as follows:-

1. (150 million m^3/year) within Libya in exchange for a withdraw of (0.5-1 m/year) in the western region between (1-5-1 m/year) in the eastern region.

2. The water of the aquifer faces several difficulties, as geographical difficulties, such as mountainous areas, plateaus and subkha. There are also hydraulic difficulties for deep wells, productivity, water salinity, and other difficulties related to exploitation rates.

This has been clearly demonstrated by the mathematical models prepared in the region, which explained many of the risks related to the aquifer as follows (OSS, 2009):-

1. Periodic increase in water.
2. The aquifer and disappearance of the artesian property (flow the subjective) in area of study.
3. Dryness and low productivity of most springs feeding from the reservoir.
4. The sudden rise of water salinity coincides with the lack of hydrostatic pressure and gradual decrease in productivity during the period of operation.

The wells did not return for self-flow only after injecting a quantity of water and then exit very salty water with the beginning of pumping. These risks and sudden phenomena require detailed studies of well designs that have emerged in these phenomena, in addition, hydro chemical analyses of the water of these wells to know the causes and consequences of these phenomena.

4.7.4. Feeding of Kiklah Aquifer

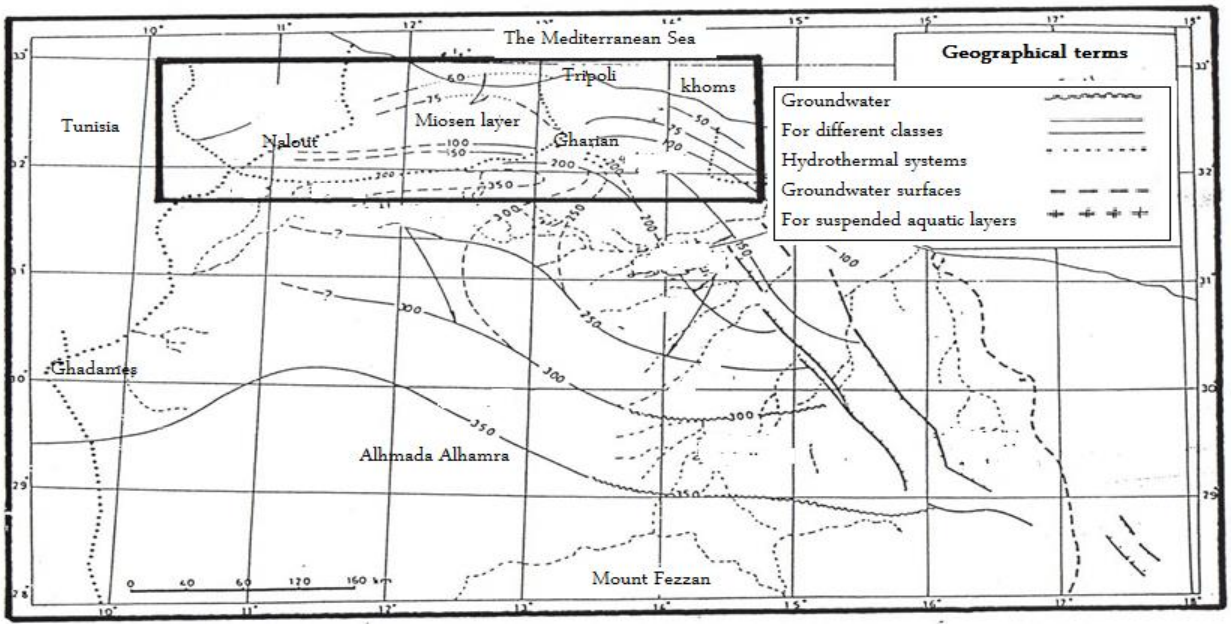
Studies that focused on the conditions of layer it did not arrive to rigorous identification of the amounts that nourish the aquifers in the region . However, these studies reached preliminary estimates and forecasts of the quantities of this nutrition, which indicated to percentage of the filtration factor for rainwater rate in the region, which ranges between (2-10%), namely 1/3 of the quantum of recharge water feeds the Kiklah deep aquifer (General Water Authority, 2006).

Also, studies indicated the importance of feeding the aquifers from adjacent water areas such as the Western Mountain, Al-Hamada Al-Hamra and west of the Sirte Basin. Basically, these areas were characterized by the active movement of water that transported sedimentary formations according to the hydrodynamic systems and hydraulic constants of water-bearing formations in aquifers in various segments the region of study (Serafascaf, M., 1980) .

4.7.5. The motion and vigour of water in Kiklah tub

The motion of underground water at the district of study is active in sedimentary formations only, depending on the prevailing hydrodynamic systems, especially constants of the water-bearing configurations the underground water in the district of study . at large , the groundwater influx the district of study have taken the south to north tendency across the variant sections , which in reality paradigms section of the regional order of groundwater mobility from the south to north and north-west, as illustrated in (Figure 52) (General Water Authority, 2006. pp. 56-57).

Figure (52):- Regional system of groundwater movement and the northwestern part of Libya

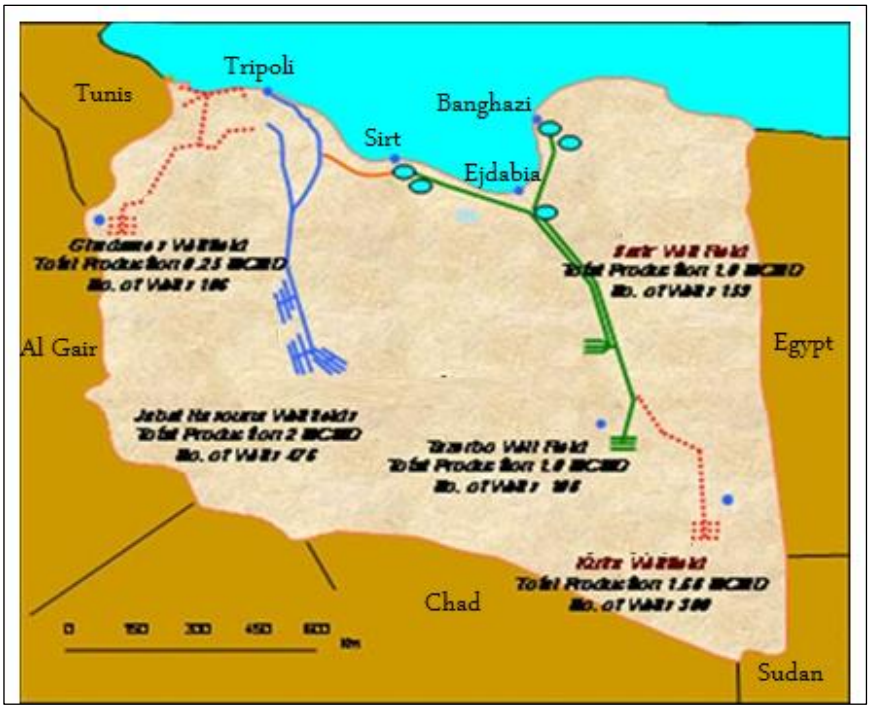


Source:- The artistic Committee for study the Water position in Libya (1999), Study of the Water Situation in Libya and the National Strategy for Water Resource Management (2000-2025), Strategic Report, Public Authority of Water. Documentation Center, Tripoli, Libya, p.53)

4.7.6. Water Wells Provided by the Man-Made River System

The previous studies and hydrogeological studies of Ghadames Basin were carried out by General Water Authority through the Engineering Consultant Office for Utilities in 1993. According to the results of exploratory drilling in the region and based on the information of many tested wells, it is estimated that (91 million m3/year) were produced from the area located between Ghadames and Derj to the coastal areas west of the Jafara Plain and the Western Mountain to meet the needs of the communities located like in the format (53) and Table (5).

Figure (53):- Movable water tracks and quantities of the Man-Made River System



(Source:- General Water Authority (2003), synopsis of the outcomes of the study of the Northern Desert Basin Project, and the Man-Made River System, Tripoli, Libya, p. 22

Table (5):-Stages of the Man-Made River Project

N.o	System	Quantity of water transported in cubic meters per day
1	Serer system-sirt-Tazrbo-Banghazi	2
2	Alhssawna system- jafara plain	2.5
3	Alkofra system – Tazrbo	1.68
4	Aljagbob system- Tubrg	0.120
5	Ghadames system-Zwara-Zawia	0.25
6	Gardabia system- sdada	Merg between (1-2) systems
Total		6.55

Source:- General Water Authority (2003), synopsis of outcomes the study of the Northern Desert Basin Project, and the Man-Made River System, Tripoli, Libya, p. 22)

These areas were lack drinking water sources (quality and quantity) as well as, water supplies needed for the establishment of agricultural projects, which are limited in these areas. Hence, some goals of water investment projects are:-

1. The continuity of water in existing projects and new sites shall be economically feasible.

2. These water investment projects should realization community developmental in the regions of which water is relocated Water , have to be exploitation projects relocated in the perspective of maintain and development of the ecological.
3. Identification of requirements water and storage size required for each draft also the species and pipelines and the capacity of pumping stations required and investment costs. The investment costs mentioned above should cover the following areas :-

a. Jafara Plain area (existing projects-new projects)
b. Areas affected by the coastal strip, which suffer from the imbalance in water supplies and seawater intrusion
c. Western Mountain Region (existing projects-support for private holdings)
d. The Man-Made River System area (new projects)

A water-well field which study of exploiting Kiklah aquifer, In which 106 wells to be drill and also where will be leave within 1,500 meters out every between the wells to prevent overlap a depth of 800 meters. .

Most of the drilled wells will be self-sufficient and the standard of water in these wells will be from 10 meters under the surface to 37+ meters over the roof of the earth with a productivity of 30 liters/second and with water quality of 900-1500 mg/L, ranging from 155-160 meters by 2060.

Twelve wells will be drilled observe the underground reservoir on deep 800 meters , also four wells to observe the underground reservoir Ain Toubi of a depth 600 meters. From the hydrogeological study of underground water findings below :-

1. The basin studied is a suitable water source for use, examination of the geophysical well logs of water wells and petrol wells, also the results of exploration digging of audition wells in the region shown that the layers of water in this basin represent aquifers that can be safely exploited.
2. Kiklah aquifer is the most important aquifer in the region in terminology of
   - Qualit and thickening of the reservoir ,
   - The deep and throughput of the wells which hacking into the reservoir
   - Existence Majority the water in the region under Artesian or semi-Artesian conditions

- The Man-Made River, between Ghadames and Derj , from where peculiarities and water efficiency .

Some of the wells that exploit Kiklah Formation in the region of study suffer from some problems related to the sudden rise in salinity, sudden drop in hydrostatic pressure and the disappearance of the self-flow phenomena with the apparent decrease in productivity, especially when the wells are closed and re-operated. These problems need to be studied and analyzed to them and avoid their negative effects.

And this conclusion is largely correspond with the findings of some previous of the region of study as follows :-

- Hydrogeological study of the district Ghadames , Daraj and Sinawon (Energy project ,1976)
- The hydrogeological study of the Ghadames Basin (Srivastava ,M. L , 1977)
- Report of the General Water Authority on the water situation in Libya (2006)
- The geological and hydrogeological study of the southwestren part of the Ghadames basin (Radi , Ala-aqil, 2006)
- Studies related to high salinity and quality deterioration in some wellsof the Ghadames basin (Radhi ,M, 2007) .

As well as , these conclusions fulfill the first hypothesis of the present study hypotheses related to the following phenomena :-

1- Sudden salinity of water .

2-Lack of hydrostatic pressure .

3- The disappearance of the artesian property .

4-Low of productivity .

4.8. Well properties of the region of Study

4.8.1. Properties and Specifications of the Wells Selected for the Study

To obtain a clear understanding of the hydrographic conditions and characteristics of Kiklah aquifer that was used intensively in the region. The information was collected from (24) specific wells with coordinates using the GPS device within the boundaries of the region of study. Table (7) below indicated the classification of wells that was based on their information in the present study.

4.8.1.1. ***Criteria Considered When Selecting Wells***

It has been of great importance for the researcher to ascertain the availability of technical information on sample wells in terms of:-

- design specifications, stages of drilling and completion,
- depths, subsurface thickness, class relay, rise from sea level,
- static water level, and dynamic water level,
- pump efficiency,
- productivity and specific capacity
- drawdown during pumping,
- calculations of the coefficients made during the pumping experiments,
- methods and stages of well development, and other information that represent the scientific basis in the study,
- Easy access to sample wells to conduct field studies and field measurements and the scientific basis in the study,

Basically, the selection of these wells was done in a manner that ensures representation of the variables that can occur in the layers of study with the continued and stopped pumping from these wells. The registration of information on these wells has been based on the final reports of construction, which were obtained from General Water Authority, in addition to some additional details from field survey studies and some previous studies on the area during the past 20 years. Serial numbers were given to the studied wells (1-24), because some wells were not numbered, while others had local names derived from the nearest site, with the original figure of the well, if any.

For the purpose of the study, wells with good productivity are selected, as they do not have problems during operation, flow or stopping. Some other samples wells in the region do not suffer from difficulties and problems during operation, flow or stopping, especially the phenomenon of sudden increase of salinization , and the considerable reduction in hydrostatic pressure with the decline of productivity when it lock and restart.

Based on the information and measurements of seven highly salinity wells, which suffer from many problems related to salinity, pressure and productivity, in order to compare and contrast with other wells in the region and use their information in the interpretation of variables related to wells due to intensive exploitation.

The study uses some wells that suffer from poor productivity or suffer from other technical or design problems in collecting information, binding, correlation, comparison and interpretation of some phenomena and effects on aquatic layers in Kiklah aquifer.

The use of information of some of the observation wells located in the area surrounding samples wells are important to monitor the quantitative and qualitative measurement of water wells and aquifer during the field work, record results and compare and interpret them.

Likewise, using the specifications of design, modernization and preparation of some wells in various district of productive wells in the district of study.

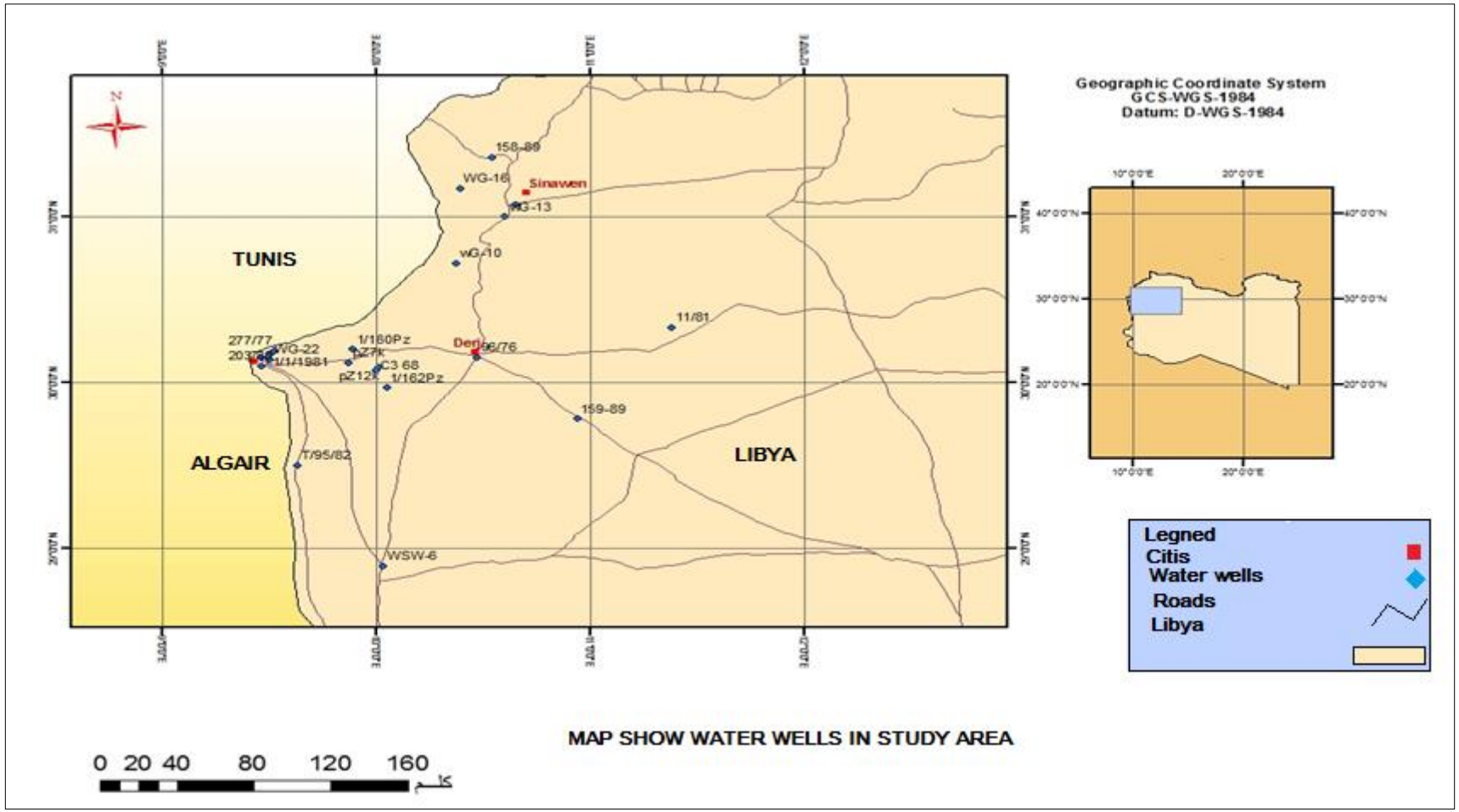
4.8.1.2.Technology available and hydrogeological for chosen boreholes

Table (7) shows the technical and hydrogeological information of the wells chosen for observe the following:-

1. The technical and hydrogeological information of selected wells include:-

- Well number,
- Location,
- Water level,
- Aggregate profound,
- Underground aquifer used,
- The area exploited by the groundwater layer,
- Water level,
- Productivity and specific capacity,
- Drawdown rates,
- Temperature,
- Transmissibility,
- Date of drilling and year of implementation.

Figure (54):- Well sites studied inside the boundaries the region of study



(Source:- The work of the researcher, based on the location altitude by using GPS device).

Table (6):- Classification of the wells selected for the study

Number of well	Type	Design	Exploiter aquifer
TI158189	Productive	Old	Kiklah
WG-16	Exploratory	Old	Kiklah
TI64/78	Productive	Old	Kiklah
WG-22	Productive	Old	Kiklah
DI-90	Oil	Oil	-
TI162/99PZ	Control	New	Kiklah
WSW6	Productive	Oil	-
TI276I77	Productive	Old	Kiklah
TI277I77	Productive	Old	Kiklah
TI1T1T81	Productive	Old	Kiklah
WG-10	Exploratory	Old	Kiklah
TI203I80	Productive	Old	Kiklah
E2-90	Oil	Old	-
TI60I99 PZ	Observation	Old	Kiklah
TI160I99 PD	Exploratory	Old	Kiklah
TI96I76	Productive	Old	Kiklah
TI11T81	Productive	Old	Kiklah
TI159T89	Productive	Old	Kiklah
K1-90	Oil	Oil	-
TI95I82	Productive	Old	Kiklah
C3-68	Productive	New	Kiklah
PZ-12K	Observation	New	Kiklah
Mejjezem sebkha	Sabkha(Ain al-thban)	-	-
Pz-7k	Observation	New	Kiklah

(Source:- Final reports of the drilling of wells that were studied and prepared by the General Water Authority. (2006). Documentation Center, Tripoli, Libya, p 17)

Table (7):- Technical and hydrological information on wells in the region of study

Well No.	Geographical						UTM		Location	High water level.	Total Depth	Aquifer	The top of the aquifer		The exploited area		water level		Productivity		ΔS	Quality productivity		temperature	Transmittance	Year of implementation	Date
	Easting			Northing			Easting	Northimg							from	To											
	gr	Min	Sec	Gr	Min	Sec				(m.a.s.i.)	(m)		(m.b.g.i)	(m.a.s.i.)	(m)	(m)	(m.b.g.i)	(m.a.s.i.)	(m^3/hr)	(i/s)		(m^3/hr/m)	(i/s/m)	(°C)	(m^2day)	(year)	
T/1/160PD	09	53	25	30	12	00	585698	3341331	Kiklah	294.59	800.00	Kiklah	575.00	-280.41	700.00	800.00	37.25	331.84	400.00	111.11	36.25	11.03	30.7	39	2195	2002	1/1/2003
T/1/1/160PZ	09	53	25	30	12	00			Kiklah	294.59	946.00	Kiklah	575.00	-280.41	700.00	80.00	37.00	331.59	158.00	43.89	4.00		10.97	39		2001	1/10/2003
T/1/162PZ	10	03	00	29	58	00	601285	3315542	Kiklah	354.70	800.00	Kiklah	495.00	-140.30	580.00	650.00	-16.90	337.80	120.00	33.333	-	-	-	36	-	2003	4/8/2003
T/276/77	09	27	30	30	08	45	544.143	335082	Kiklah	307.00	1000.00	Kiklah	645.00	338.00	759.00	925.00	31.00	338.00	337.00	93.61	21.00	16.05	4.46	40	7344	1980	24/10/1994
T/277/177	09	31	05	30	11	10	549874	3339570	Kiklah	332.00	1050.00	Kiklah	713.00	-381.00	770.00	1018.00	6.90	338.90	212.00	68.89	9.00	23.56	6.54	40	5184	1981	24/10/1994
WG-22	09	30	00	30	08	40	548156	3334945	Kiklah	331.00	1005.00	Kiklah	670.00	-339.00	770.00	950.00	12.90	343.90	144.00	40.00	0.80	14.70	50.00	40	1748	1975	6/15/1995
T/64/75	10	39	15	31	04	10	657819	3438525	Sinawin	435.00	975.00	Kiklah	575.00	-140.00	719.00	800.00	-117.90	317.10	99.70	27.69	3.69	27.02	7.51	32	1685	-	23/19/1994
T/96/76	10	28	08	30	09	10	641467	3336674	Deri	445.00	915.00	Kiklah	582.00	-13700	599.00	700.00	-100.20	344.80	110.00	30.56	7.31	16.00	4.18	37	1555	1976	24/10/1994
T/1/203/80	09	27	40	30	06	05	544430	3330158	Kiklah	335.00	1050.00	Kiklah	510.00	-175.000	733.00	948.00	12.90	347.90	191.00	53.06	9.00	21.22	5.90	41.4	6480	1981	24/10/1994
T/11/81	11	23	00	30	20	00	729137	3358179	E.DerI	597.74	8000.00	Kiklah	400.00	197.74	664.00	776.00	-283.30	314.44	49.00	13.61	3.00	16.33	4.54	41	1080	1983	16/10/1983
T/1/1/81	09	30	00	30	10	00	566048	3336116	Chadames	342.00	1013.00	Kiklah	625.00	-283.00	739.30	985.30	-2.15	339.85	133.00	36.94	-	-	-	-	-	1981	-
S.Mejzzem	278000			3355000			578805	33477	Chadames	-	-	Kiklah	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28/10/200
T/95/82	09	38	00	29	30	00	561391	3263598	Chadames	631.775	656.00	Kiklah	45.00	586.75	456.00	637.00	-289.00	342.75	-	-	-	-	-	-	-	-	-
T/158/89	10	32	36	31	21	26	646798	3470273	N.Sinawin	483.00	885.00	Kiklah	500.00	-17.00	502.00	694.00	-146.30	336.70	80.00	22.22	9.28	9.00	2.39	-	-	-	9/19/1989
T/159/89	10	46	27	29	46	41	687630	3295819	SE DerI	585.00	800.00	Kiklah	525.00	60.00	605.00	725.00	-252.70	332.30	82.80	23.00	5.80	14.28	3.97	35	6394	1990	-
WG-10	10	22	05	30	43	08	630996	3399297	SW Sinawin	397.418	794.00	Kiklah	578.00	-180.82	677.00	783.00	-104.50	292.68	72.00	20.00	10.90	-	1.83	27.3	-	1975	24/10/1994
WG-16	10	23	20	31	10	25	631883	3341512	Matreess	425.42	700.00	Kiklah	525.00	-99.58	570.00	667.00	-104.50	320.92	72.00	20.00	2.64	27.27	7.58	33	143	1974	29/3/2004
WG-13	10	37	40	31	2	40	-	-	Sinawin	432.729	740	Kiklah	580	-147.271	594	672	-114.5	318.229	72	20	9.58	7.5156575	2.0876827	33	389	1975	
WSW-6	10	1	36	28	53	10	-	-	wafa field	697.18	1006	Rashamia	820	-	826.5	989.3	-288.6	408.58	18	5	2.29			46	600	2002	-
C3-68	9	59	27	30	4	12	596999.5	3327069.4	Chadames	310.41	691.8	Kiklah	618	696			20.1	330.51		72.13				36.6	12273		
PZ-7K	9	55	43	30	6	5	584852.952	3333012.4	Chadames	350	766	Kiklah	526		862	753	-3.36	346.64	109					38.8		2007	5/2007
PZ-12K	10	0	52	30	5	23	597813.25	3329179.3	Chadames	312	920	Kiklah	492		678.48	634.2	15.92	327.92	70					36.7	1836	2006	5/2006
PZ/12A	10	0	52	30	5	23	597813.25	3329179.3	Chadames	312	456	Aintobi	398		446.9	417.47	9.33	321.33	0.4					26.7	7390	2006	4/2006
D1-90							307596	3335135	Chadames	285	1941	Oil Well					890										
K1-90							271563	3334	Chadames	340	2869	Oil Well	560														
E2-90									Chadames		2804	Oil Well				840											

(Source:- The researcher's work, based on the drilling reports prepared by the General Water Authority (2006). Documentation Center, Tripoli, Libya)

2. The well-studied sections indicate that the stratigraphic sequence of the penetrated units ranged from the Upper Jurassic period, represented by Takbal Formation, to the Paleocene, represented by Zmam composition.
3. The lithological description of the rocky cutting samples collected at each step and the stage of the drilling at each meter during drilling operations proved that the upper layers of the penetrating units were marine deposits of limestone, dolomitic limestone, marl and gypsum, while the intermediate layers in the sequence are overlaps of mixed marine sediments and continental sediments represented by limestone, clay, sand, evaporites and sandstone, while the bottom layers are represented by sediments of sandstone, limy sandstone, conglomerates and clay. However, Kiklah Formation is composed of fine sandstone, white to gray in colour, with overlays of clay and shale and in some areas it turns into a medium-grained sandstone, brown to light in colour.
4. Comparisons and rock correlations between the directions shown in Figures (54, 55, 56) indicate the following:-
   a. Surface of unconformity between Kiklah Formation and Takbal Formation.
   b. Surface of unconformity between Kiklah Formation and Ain Tobi Member, were represents the upper layer of Sidi Assid Formation.
   c. Surface of unconformity between Qasar Tigirinnah composition belongs to the top chalk era , and Mizda Formation which belongs to the Paleocene Age.
5. The depth of the studied wells ranges between 2869 meters in the well (K1-90) and 691 meters in the well (C3-68).
6. The thickness of Kiklah water layer, which is the major in the region of study , ranges between 155 meters in the well (T/162/99 pz) and 435 meters in the well (T/203/80).
7. By tracking the upper top layer of Kiklah underground reservoir in the studied wells (format 40), we find that the rooftop trend of the south of this line almost. This gradient estimated by 190 meters on top of sea level and 400 meters beneath sea level, by accord with the decline of the land .
8. Depth of the top surface of Kiklah aquifer at any of the studied well sites represents depths ranging from 400 meters in the eastern sections of the well (11/81). This deep further to reach 700 meters in the southwestern sections of the Well (WSW) 6 .
9. In the studied well according to sea level indicate that these levels take an irregular pattern. These levels in the region appear at levels higher than sea level and show up higher in the northern fraction of the region of study, specifically at the well

(T/160/99PZ), where with over height 370 meters over the sea level. The echelons be high too in the districts between the cities of Ghadames and Derj, terms up height to 340 meters over the sea level , with an increase of 370 meters above sea level. This level also rises in the area between the cities of Ghadames and Derj, which is approximately 340 meters above sea level. In general, the water levels are exhaustion of in the reservoir from northern to southern with rates between from 350 meters to 290 meters top of sea .

10. From the hydrogeological information , it was observed the height of water layers on the toproof of earth is approximately 37 meters with far a few kilometers north-eastern of the town Ghadames.

11. It takes start declining to 290 meters underground land the region of study . As well as it was observed that the water tiers of the artesian wells situated near the town Ghadames be above of land .

12. The productivity of the studied wells varies widely; it ranged from 400 m^3/h in the well (T/1/160/pd), and 49 m^3/h in the well (T/11/81).

13. The rate of drawdown (ΔS) estimated from 36.25 meters in the well (T/1/16pd) to 0.80 meters in the well (WG-22).

14. The transmissibility of the exploited layer is highly variable, ranging from 12273 m^2/day in well (C3-68) to 143 m^2/day in the well (WG-16). From the researcher's point of view, it's mostly due to different hydraulic qualities, hydrogeological determinants and changes in the lithological features of this layer from one area to another within the boundaries of the region of study.

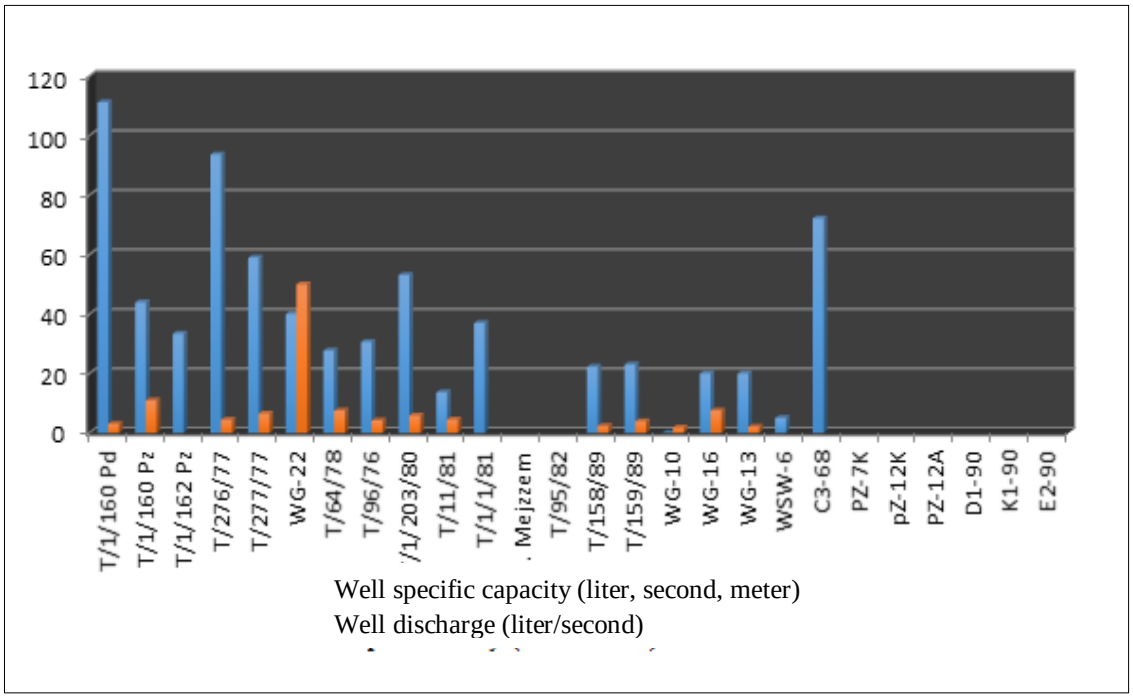
15. The measured water temperature in Kiklah aquifer ranges from 41.4 °C in the well (T/203/80), which is categorized as a hot water and 27.3 °C in the well (WG-10) and is classified as hot water of the water, and water productivity of studied wells ranged between 27.27 m3/hour/meter in well (WG-16) and 900 m3/hour/meter in well (T/158/89), which, from the researcher's perhaps return that to reasons follow :-

- Divergence in lithological feature and variab .
- Divergence in the quantifiable of water in the water tub and its nutrition rates .
- Space and expansion of the underground water stratum indoor the confines of the region of study.
- Structural subsurface changes.
- Change in the speed and direction of water movement in the aquifer.

▪ Change in the storage coefficient and the loss coefficient of the water-bearing formations.

16. Also, , it was noted that the specific capacity of boreholes step up with the reduction in the amount of their discharge, as illustrated by figure (55), this is manual of the high competence and the reason for the different boreholes efficiency the decline in the water level is the deterioration of water flow towards the well screen or the closure of the screen openings due to some sedimentation .

Figure (55):- Relationship between discharge and wells in the district of study



(Source:- Researcher's work depend on the findings of specimens of water for wells which selected to study.

17. All wells are drilled in the normal rotary drilling method with the direct pumping of the bentonite drilling fluid dissolved in water, with different properties of this fluid in terms of viscosity, density, weight and contents of the penetrating layer and the depths and stages of drilling.

18. All All wells in the area are drilled in several phases , so each phases of drilling has specifications that set it apart fromthe one before it . And diameter of the drilling hole ranges between (32- 17½) inches at the first of drilling , (8 ½) inches . At the ultimately of the dig phases by the needed deep .

19. All the drilled wells are fitted with a concrete slab to install the walls, and are fitted with surface protection pipes ranging in diameter from $18\frac{5}{8}$ –16 inches, and extending most of the time until the depth of 10 meters. Actually, it is manufactured from carbon black iron and ending at the required depth with a non-return valve diameter of 10 inches.

Figure (56) shows the self-flow, productivity and behavior of the piezometeric well (T/160/pppz) in Ghadames area.

Figure (56):- Self-flow of the well № (T/160/99) in Ghadames area

(Source:- a Photograph taken by the researcher during the fieldwork)

4.8.2. Design and Completion Specifications for the Studied Wells

4.8.2.1.Information considered in the assessment and evaluation of the studied wells

Taking into consideration the specifications according to which the design and completion of wells were studied (based on the final reports of General Water Authority), it was noted that these designs and: the descriptions relied on :-

● The findings of the sand and sandstone particle size distribution data obtained from the analysis using the sieve vibrator

● The nature and properties of the stratigraphy, rock formations, morphology and lithological description

● The total thickness of the water-bearing formations in Kiklah Formation and utilized by the studied wells

● The degree of cohesion of rock formations in Kiklah the reservoir underground in the various parts the region of study .

● Deep of the level of the saturated portion of the aquifer.

● Expected drawdown of water due to pumping or flow

● The productivity required for the well and its specific capacity

● Water quality and its corrosional effects on casing, screens and subsurface equipment.

4.8.2.2. Considerations of Design and Completion of the Studied Wells

Based on the previous variables, the researcher noticed that the wells in the region have been drilled according to the specifications of completion and structural design through the following elements:-

- Precise rocky description of layers and rock formation
- Stages of drilling, properties of drilling fluids used and measurements of each stage
- Problems and difficulties that are encountered during drilling and overcoming them.
- Results of geophysical measurements and their applications
- Specification and stages of casing

- Specifications of screens used
- Specifications of the gravel packing
- Calculation process of cementation
- Specification and stages of well development
- Results of pumping tests and their coefficients.

4.8.2.3.Design, Carrying out and accomplishment boreholes in the district of study

The study of the particularities of the studied wells studied show that salinity of some of these wells that exploit Kiklah Formation in Ghadames Basin. This coincides with the stop of the self-flow of the well after its closure due to the sudden drop in hydrostatic pressure. The researcher's possible explanation is that there is salinity or leakage of saline water from water-bearing formations above Kiklah Formation or Sabkhat scattered in some parts of the region, which led to the emergence of this remarkable of Kiklah reservoir .

Thus, the existing study pay specific particular attention to examining of the subsequent:-

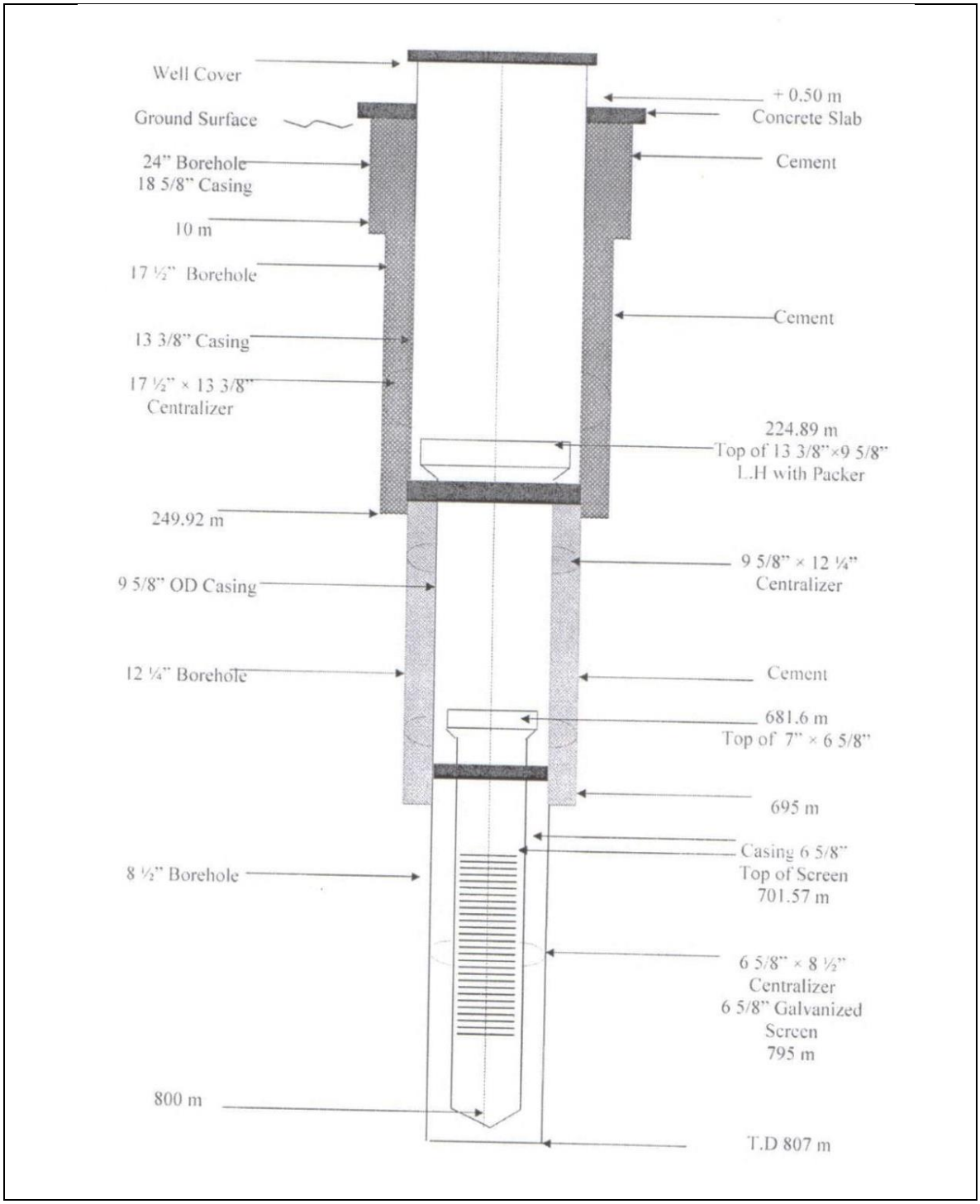
1. Rock sequence of the saline layers. Basically, the saline layers were studied in this sequence to identify the thickness, depth and extension of these layers in order to determine its effect on this phenomenon.
2. Compare the design of water wells that suffer from this phenomenon with the designs of other boreholes in the district in order towards appraisal the effect of structural design and the stages and steps of completion of the wells on the phenomenon mentioned.

Geological, hydrogeological, and structural design studies have shown that the studied wells penetrate a number of structures before penetrating Kiklah Formation. In other words, the formations were located above Kiklah Formation from top to base were the formations of Qasar Tigirinnah, Nalut and Sidi Assaid (members of Yefirin and Ain Tobi). Also, the rock samples collected through drilling showed that saline rocks such as gypsum-anhydrite-halite predominate in Sidi Assaid Formation, which overlies Kiklah Formation, especially Ain Tobi member.

General Water Authority (2006) has adopted modifications in the construction designs of newly drilled wells in the area. These amendments included a new design to address the specifications of the processes of completion in the old design, especially specifications of casing in order to avoid the effect of high salinity of the overlying saline water-bearing formations.

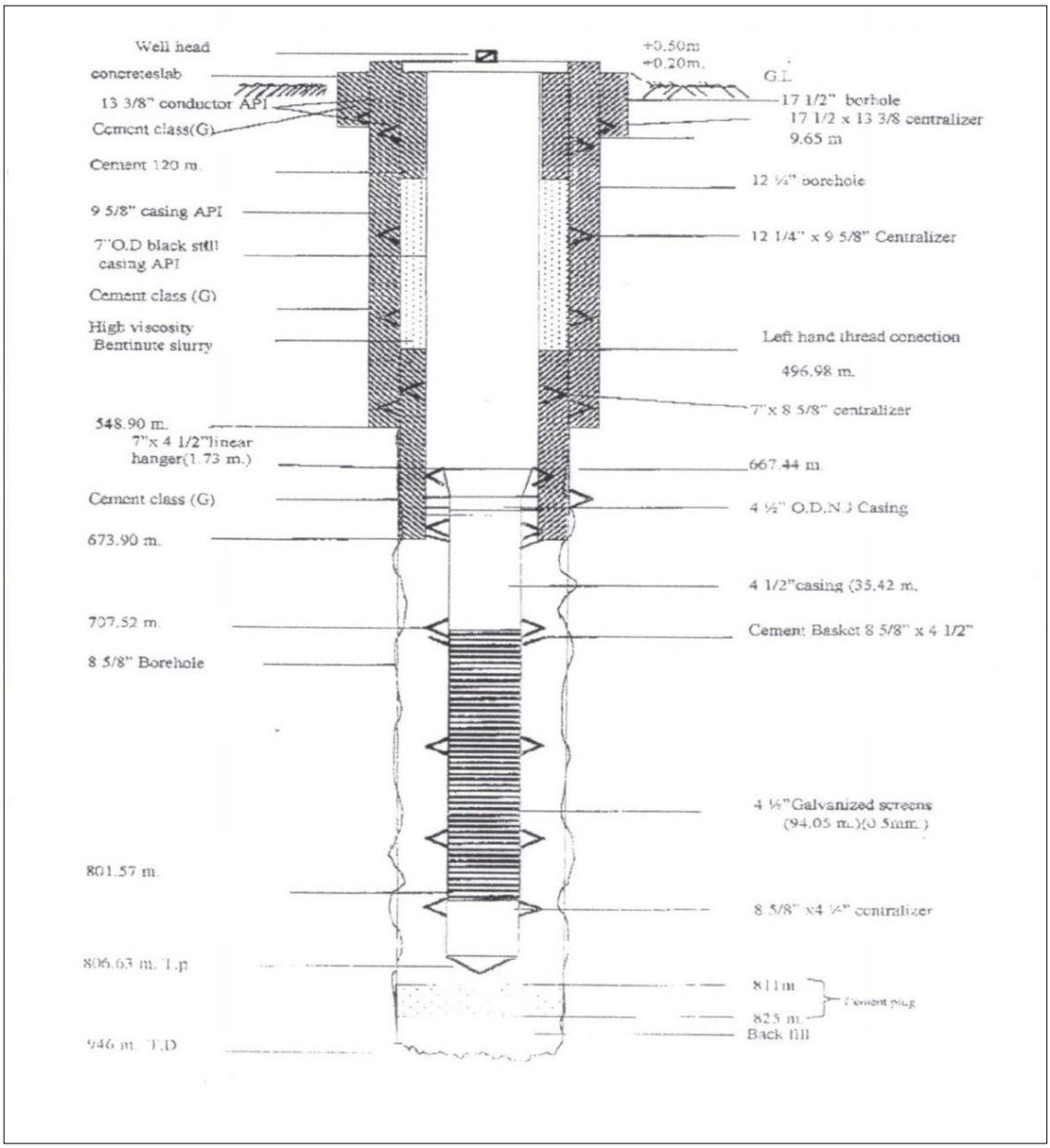
Accordingly, the current study describes and evaluates both the old and modern designs of wells drilled in the area (Figures 57, 58, 59, 60, 61).

Figure (57):- Design of the exploratory well (T/1/0160/0/99) (Old specifications)



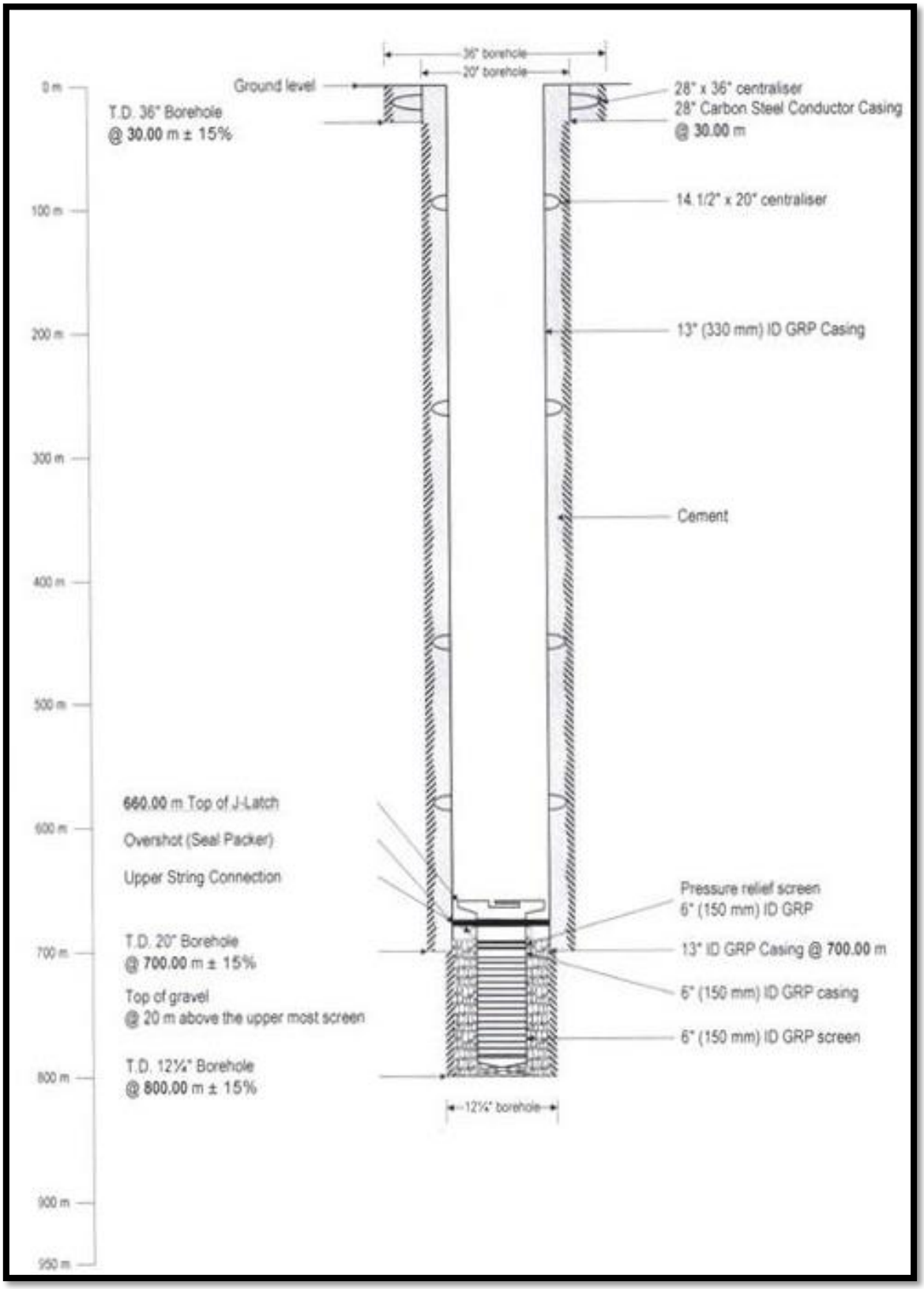
(Source:- General Water Authority, 1980, p13)

Figure (58):- Structural design model of the fashioned of old Al- bizometric the district of study



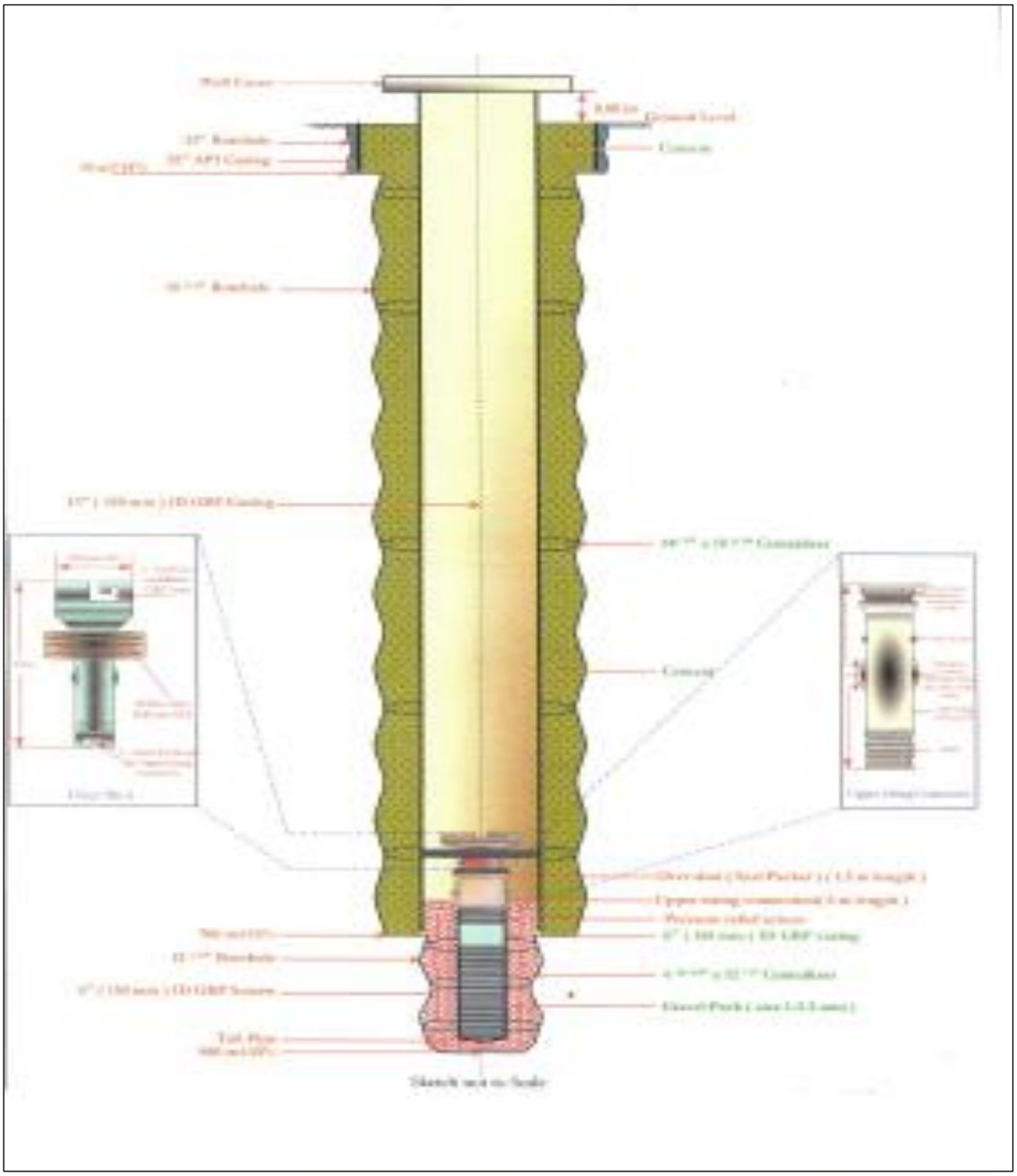
(Source:- Report of General Authority of Water, 1982)

Figure (59) :- Structural resolve paradigm of the productivity of well with the new design specifications in the region of study



(Issuer :- Report of G. A . W , 2010)

Figure (60):- Construction Designing paradigm for the productive boreholes in the district of study "brand-new descriptions"

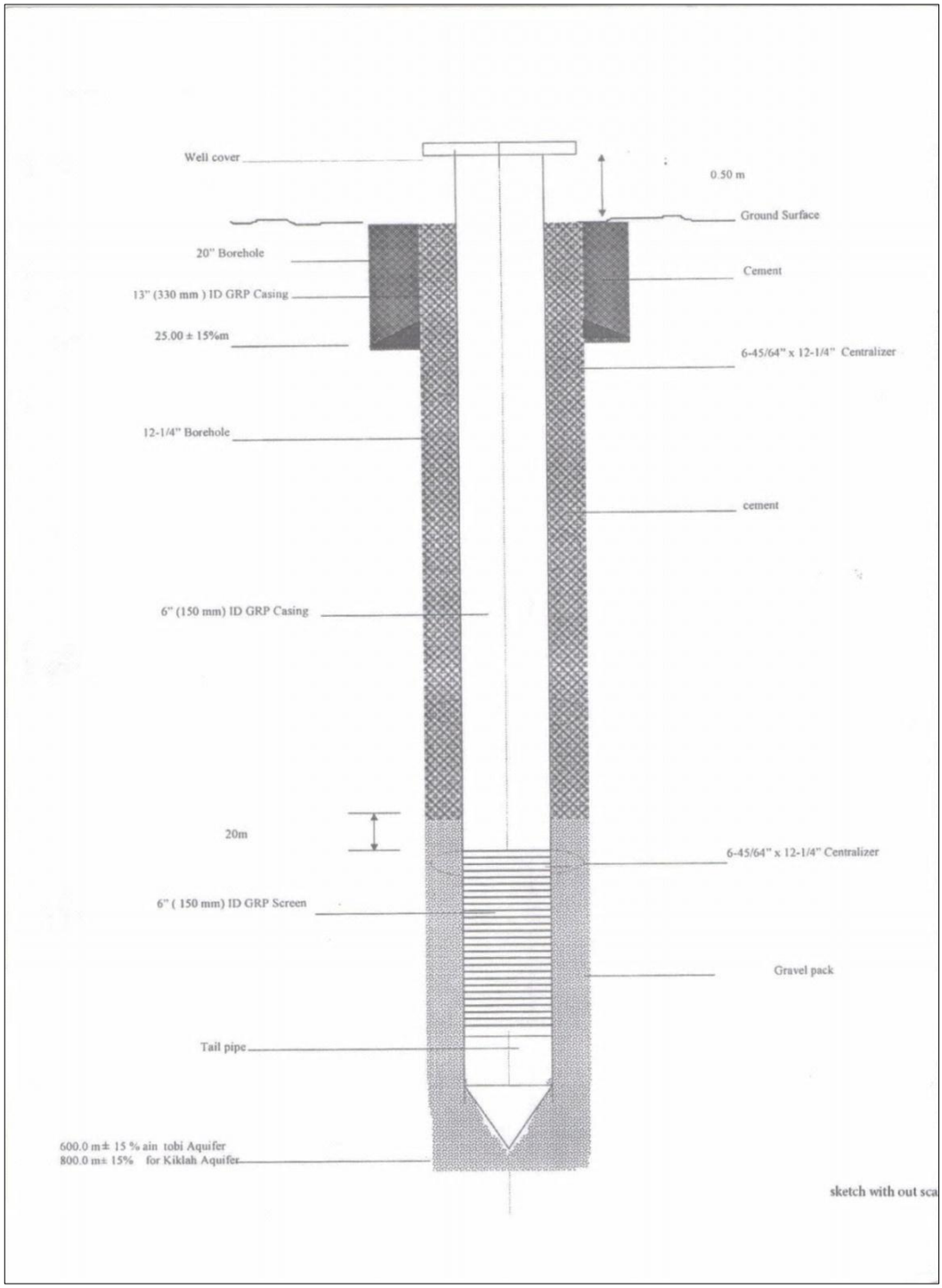


(Source:- Report of General Authority of Water, 2010:- p. 18)

4.8.2.4.Descriptions of the Cylinder specimens gathered from Wells

Collected number of cylinder specimens were gathered from some of the studied wells in order to identify the lithological features and the precise rock description of the constituent layers of the formations above Kiklah Formation,

Figure (61):- Structural Construction Designing new of Al- piezometric in the district of study



(Source:- Based on the specifications of wells developed by General Authority of Water, 2003:- p. 9)

especially Sidi Assaid Formation (Yefirin and Ain Tobi members). These core samples were collected at the following depths:-

1. 309-312 meters (well № Pz 6k)
2. 335-338 meters (well № Pz 7k)
3. 361-364 meters (well № Pz 6k)
4. 376-379 meters (well № Pz 7k)

Data tables (9, 10, 11, 12) below show the details of the depths at which some cylindrical core samples were collected along with rock description of these samples. From these spreadsheets it can be abstracted that:-

1. Overhead fraction of the tested formations consists of thin sequences, fine wavy wafers and gray anhydrite with silt and clay overlays. The anhydrite is converted in some depths into a white massive anhydrite within multiple fishers.
2. The central part of the tested formations consists of gypsum with overlays of of some organic sediments with a mixture of silt in some cracks and caves.
3. The lower part of the tested formations consists of thick layers of transparent crystalline rock salt with overlays of gypsum and reddish brown clay with many joints and cracks.
4. Formations tested in general were above Kiklah Formation. It represent the deposits of anhydrides (anhydrite-gypsum-halite) with many cracks, joints and spills, which are likely to be leaks from these formations to Kiklah Formation which is located below. This means that there is a hydraulic connection between these formations and the aquifer of Kiklah Formation.

Figures (62 A, 62 B, 62 C) show examples of cylindrical core samples collected from the selected wells from formations above Kiklah Formation.

Table (8):- Description of a cylindrical core sample

Well №:- PZ-6K

Location:- Ghadames Basin Well Field

Sample depth:- 361 m - 364 m

Depth (m)		Description Rock	Coverage ratio
From	**To**		
361	362.43	A reddish-brown clay-white anhydrite flakes turn into anhydrite below the sample	93%
362.43	362.72	A muddy green clay changing down to the grey at the bottom	
360.72	363.30	Anhydrite-light grey to grey -trimmed with crispy green and irregular at the top with white-coloured anhydrite at the bottom	
363.30	363.35	Salt rock - Transparent to semi-transparent – crystallized	
363.35	363.43	Clay stone - green grey ray - medium hardness	
363.43	363.52	Salt rock - Transparent to semi-transparent – mixed with granulated clay - brownish reddish	
363.52	363.65	Anhydrite - light grey - with wavy chips of clay stone	
363.65	364.00	Rock salt – transparent to semi-transparent – crystallized – brownish to red with clay intercolorations	

(Source:- Researcher's practice reliance on the specificities of the collected core specimens and the laboratory description)

Table (9):- Description of a cylindrical core sample

Well №:- PZ-6K

Location:- The Ghadames Basin Well Field

Sample depth:- 309 m - 312 m

Depth (m)		Description Rock	Coverage ratio
From	To		
309	309.75	Anhydrite - light grey in thin sequences	100%
309.75	3010.30	Anhydrite - light grey - wavy foils	
310.30	310.50	Anhydrite - light grey with thin foil	
310.50	311.05	Anhydrite - light grey with some white-massive	
311.05	311.58	Anhydrite - light grey - with ripples of mud	
311.58	311.82	Anhydrite- grey to medium grey -green.	
311.82	312.00	Anhydrite - light grey - irregular ripples and overlays of medium grey clay.	

(Source:- Scholar practice reliance on the specificities of the collected core specimens and the laboratory description)

Table (10):- Description of a cylindrical core sample

Well №:- PZ-7K

Location:- Ghadames Basin Well Field

Sample Depth:- 355 m - 338 m

Depth (m)		Description Rock	Coverage ratio
From	To		
335	335.48	Silt - green, dark grey	100%
335.48	335.61	Gypsum - light grey - flakes of mud	
335.61	336.06	Rock salt - medium grey - with a mixture of gypsum with the presence of capillaries filled with organic deposits with overlays of gypsum - light grey	
336.06	336.52	Anhydrite - light grey - with green colour in some of the upper parts and the presence of some cracks filled with clay	100%
336.52	338.00	Anhydrite - light grey - gypsum residue with a thinning stratum irregular in topside and lower parts of gypsum	

(Source:- Scholar practice reliance on the specificities of the collected core specimens and the laboratory description)

Table (11):- Description of a cylindrical core sample

Well №:- PZ-7K

Location:- Ghadames Basin Well Field

Sample depth:- 376 m - 379 m

Depth (m)		Description Rock	Coverage ratio
From	To	Transparent crystalline rock salt - with reddish brown clay parts and massive gypsum	100%
376	379		

(Source:- Scholar practice reliance on the specificities of the collected core specimens and the laboratory description)

Figure (62 A):- Cylindrical core sample of Ain Tobi Member Sidi Assaid composition at a deep of 378 meters in the well (Pz-7k)

(Source:- A photograph taken by the researcher during the fieldwork)

Figure (62 B):- Cylindrical core sample of Ain Tobi Member/ Sidi Assaid composition at a deep of 377 meters in the well number (PZ-Zk)

(Source:- A photograph taken by the researcher during the fieldwork)

Figure (62 C):- Cylindrical core sample of Ain Tobi Member/ Sidi Assid composition at a de of 377 meters in the well number (PZ-Zk)

(Source:- A photograph taken by the researcher during the fieldwork)

CHAPTER V

5. Hydro-Chemical analytical of Kiklah reservoir in the region of study

5.1. Methodological of Hydro-Chemical Analysis of Water Specimens from Selected Wells

This chapter submit a detailed analytical of water specimens chemical gathered from the selected 13 wells representing Kiklah aquifer, located within the boundaries of the region of study (Figure 63). In particular, 7 wells were closely examined as they had remarkably higher levels of salinity than other wells in the same area (See Figure 81).

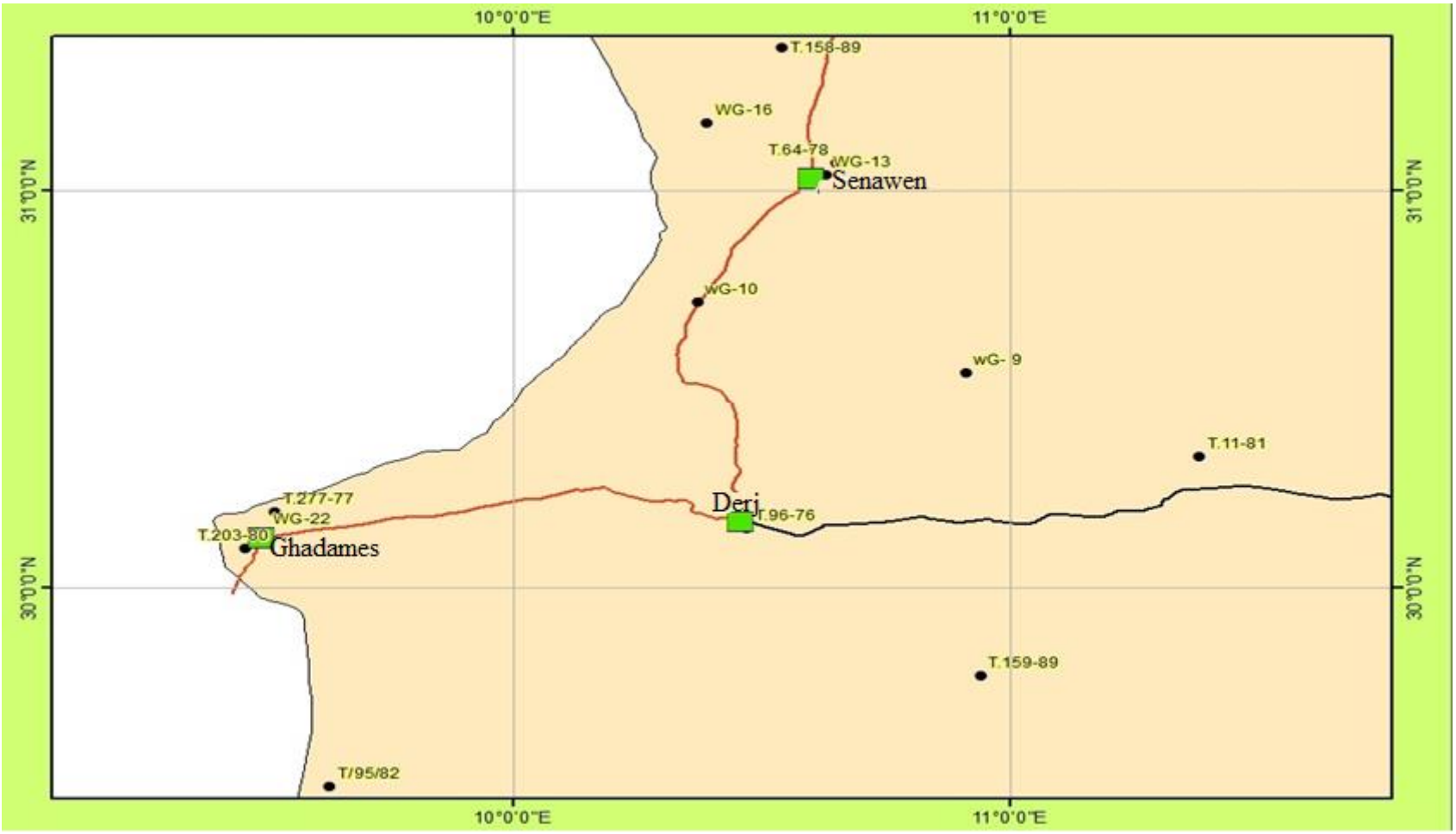
The hydro-chemical analysis of water samples in the present study is concerned with these aspects:-

1. The fundamental chemical specificities of water, which involve gross solute solids (T.D.S), electrical conductivity (E.C),hydrogen ion focus (pH), total water hardness (T.H), and water temperature (C°).
2. Main ionic analyses, which include the major cations of calcium (Ca^{++}), magnesium (Mg^{++}), (Na^{+} $K^{+)}$ and major anions, represented by chlorine (CL^{-}), sulfates (SO4), bicarbonate ($HCO3^{-}$) and carbonations $CO3^{--}$) and nitrates (NO3).

The findings of these analyses were utilized for the subsequent purposes :-

1. Appraising of quality water of Kiklah tub in district of study . .
2. Definition the nature ingredients of Kiklah tub in the region of study . .
3. Interpretation of the phenomena related to water chemistry in the aquifer in the light of hydro-chemical relations;

Figure (63):- Location of the selected wells whose hydrochemistry was studied in the region of study



(Source:- Researcher's work depend on location coordinates using GPS device)

Table (12) infra clarify the outcomes of chemical analysis of information obtained for water samples from the selected wells in mg/L (ppm).

5.2.*Assessment resolution of Chemical Analysis of Water Samples*

Ground water is an electrolytic solution, which means that the total charge of positive cations must electrically equal the sum of negative (ionic) charges. For this reason, analytical of the groundwater are usually conducted by testing a balance or equivalence. The electrical charge of dissolved ions in water is called a charge balance test . To determination the equilibrium of the shipments in the water lotion , the concentration of each soluble ion of the laboratory concentration unit is converted from (ppm) units to (epm) units.

It has been observed that the unsuccessful to test the equilibrium of charges in the data analyses of the main ions of water well № (WG-10) was associated the salinity of its water, which was close to (20000) mg/L (Schedule 13). The late of this chapter will address in detail the phenomenon of sudden rising salinity of some wells of the region of study that exploit the aquifer as a whole, including well № (WG-10).

Therefore, the total electrical equivalents of the cations should equal the sum of the ionic electrical equivalents in each water sample. However, obtaining high-resolution results may be difficult, because there are many variables during the analysis. Therefore, the results can be considered to an acceptable degree of accuracy if the percentage of the test balance shipments in the results of sample analysis (± 5%), as indicated by Deutsch (1997). In the present study, calculations were made to convert the main ion emphasis data for the well water specimens studied in Table (12) in milligrams/liter (ppm) to the electrical equivalents (epm) in Table (14) by using the following formula:-

$$\text{Charge Balance (\%)} = \frac{\text{Total cations (epm)} - \text{Total anions (epm)}}{\text{Total cations (epm)} + \text{Total anions (epm)}} \times 100$$

The test proved that the data of well water well samples (Table 14, Figure 64) are within the accepted range and can be trusted to a large extent, because these samples give a percentage to test the charge balance (%) within the permissible limits (± 5%) (Wg-10), whose main analysis of ionized data showed a significant imbalance in the charge balance (%) of charges (74.3%). This is also confirmed by the relationship between gross melted solids (TDS) and the electrical connectivity (EC) of the studied well water specimens

(Format 65), exception for the well (WG-10). This indicates that the electric conductivity can give an estimate of the acceptable concentrations of salts, which have been measured in these samples, as it can be relied upon as an indicator of another test, in addition to the charge balance (%) on the validity and accuracy of chemical analyses of water samples from chosen wells.

Table (12):- chemical outcomes of water specimens from the selected wells (mg/L – ppm)

Well №	Temperature C°	pH	E-C ms/cm	T.D.S. (mg/L)	T.H. (mg/L)	Cations (mg/L)				Anions (mg/L)			
						Mg ++	K+	Ca++	Na+	$NO3^-$	$HCO3^-$	SO4 -	Cl^-
T/1/203/80	14.4	7.91	1160	792	330	38	23	52	137	0.1	195	282	127
T/11/81	41	7.92	1466	1056	690	81.6	25	140	155	0	103	474	25
T/158/89	32.6	7.30	6589	5417	1770	165	52	432	610	0	171	601	1682
T/159/90	35	7.10	1170	986	560	57	19	130	67	0	146	386	133
T/2/277/77	40	7.50	3100	2887	916	173	11	155	296	6.7	244	927	403
T/64/78	32	7.50	1810	1262	455	47	27	70	201	0.9	201	227	347
T/96/76	37	7.90	1560	1330	385	62	110	0	110	0.9	19	357	163
T/95/82	38	7.80	1290	930	544	29	0	170	55	166	205	105	162
WG-10	27.3	7.40	23400	19198	2110	216	24	280	4851	0.3	181	490	800
WG-13	33	5.90	7450	5946	3230	427	40	58	704	0	85	246	2212
WG-16	33	7.40	9407	9980	1600	230	55	256	1359	0	330	2481	1356
WG-22	40	6.73	1320	942	360	45	20	65	165	0	295	254	200
WG-9	45.5	7.20	1400	1062	839	260	25	276	594	0.4	146	1380	952

Source:- researcher's work depend on virtue of the findings of chemical resolution of the gathered water specimens wells selected

Table (13):- Table (13):- Results to Diversion Emphasis of Cations and Ions into Percentages In Water Samples from the Selected Wells

Well №	Cations (mg/L %)			Anions (mg/L %)		
	Ca^{++}	Mg^{++}	$Na^{++}K^{+}$	$SO4^{+}$	Cl^{-}	$HCO3^{-}+CO3^{--}$
T/1/203/80	21.1	25.5	53.4	46.44	28.32	25.32
T/11/81	33.1	31.9	35.0	50.33	40.99	8.63
T/158/89	34.2	21.6	44.2	19.96	75.58	4.47
T/159/90	44.5	32.2	23.3	56.67	26.46	16.87
T/2/277/77	22.0	40.5	37.4	55.51	32.66	11.51
T/64/78	20.8	23.0	56.2	22.50	54.86	18.53
T/96/76	0.0	40.2	59.8	60.21	37.20	2.51
T/95/82	630	17.8	19.2	17.12	35.65	26.27
WG-13	4.1	50.4	45.4	7.44	90.54	2.02
WG-16	13.8	20.5	65.6	54.21	40.11	5.68
WG-22	21.8	24.9	53.4	33.57	53.72	30.17
WG-9	22.4	34.8	42.7	49.56	46.30	4.12
WG-10	5.8	7.4	86.9	28.57	63.14	8.32

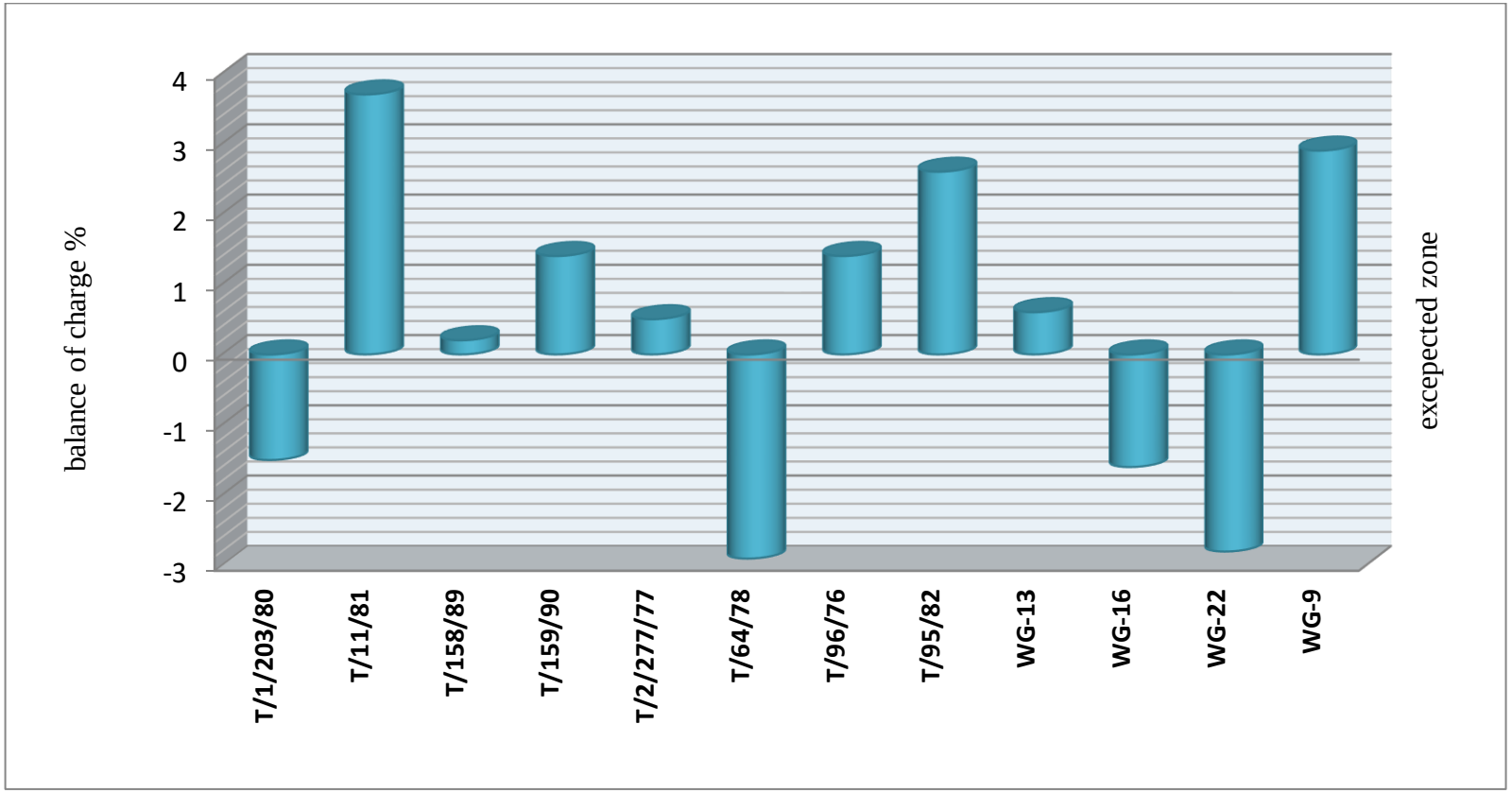
Source:- researcher's work depend on virtue of the findings of chemical resolution of the gathered water specimens of wells selected

Table (14):- Results of calculations of the diversion of the concentration of cations and anions to (epm-meg/L %) and results of shipments equilibrium for water specimens studied wells

Well №	Cations (epm-meq/L %)					Anions (epmmeg/L %)					Charge balance (%)
	Na^{+}	Ca^{++}	K^{+}	Mg^{++}	Total	$NO3^{-}$	$HCO3^{-}$	$SO4^{--}$	Cl^{-}	Total	
T/1/203/80	5.96	2.59	0.59	3.13	12.27	0.00	3.20	5.87	3.58	12.64	-1.5
T/11/81	6.74	6.89	0.64	6.72	21.08	0.00	1.69	9.86	8.03	19.59	3.7
T/158/89	26.52	21.55	1.33	13.58	62.98	0.00	2.80	12.51	47.38	62.69	0.2
T/159/90	2.91	6.48	0.49	4.69	14.57	0.00	2.39	8.03	3.75	14.17	1.4
T/2/277/77	12.87	7.37	0.28	14.24	35.12	0.11	4.00	19.29	11.35	34.75	0.5
T/64/78	8.74	3.49	0.69	3.87	16.79.	0.01	3.30	4.72	9.77	17.81	-2.9
T/96/76	4.78	0.00	2.81	5.10	12.70	0.01	0.31	7.43	4.59	12.34	1.4
T/95/82	2.39	8.48	0.20	2.39	13.46	2.68	3.36	2.19	4.56	12.79	2.6
WG-10	209.35	13.97	0.61	17.78	241.70	0.00	2.97	10.20	22.54	35.70	74.3
WG-13	30.61	2.89	1.02	35.14	69.67	0.00	1.39	5.12	62.31	68.82	0.6
WG-16	59.09	12.77	1.42	18.93	92.21	0.00	5.41	51.63	38.20	95.24	74.3
WG-22	7.17	3.24	0.77	3.70	14.89	0.00	4.84	5.29	5.63	15.76	-1.6
WG-9	25.83	13.77	0.43	21.40	61.43	0.01	2.39	28.72	26.83	57.95	-2.8

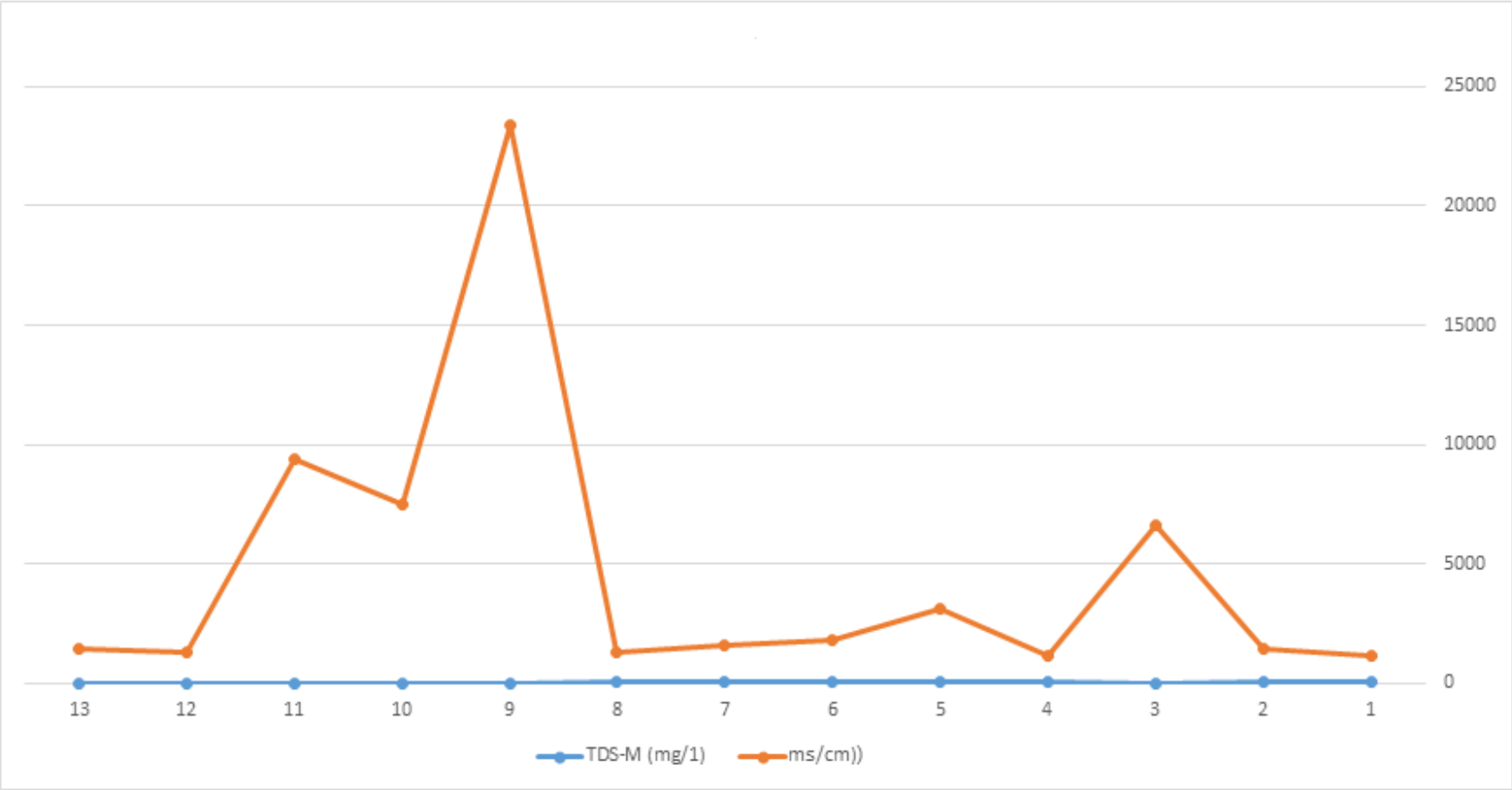
Source:- Researcher's work adopt on the outcomes of chemical analysis of the collected water specimens of the selected wells

Figure (64):- Graph the chart of audition results of the charge balance of the water of 12 wells with the exclusion of the highly saline well WG-10 in the region of study



(Source:- researcher's work depend on signing and drawing the findings of analyses from Table 16)

Figure (65):- Relationship between (T.D.S.) and (E-C) in the water specimens of the selected wells



Source:- Researcher's work depend on the findings of chemical analyses from Table (13)

5.3. Chemical Categorization of Water Qualitative of Kiklah Reservoir

There is no unified and delicate chemical categorization of the quality of groundwater. However, all classifications based on their different bases are based primarily on the quantity and quality of dissolved ions, because the presence of salts with high concentration in groundwater may limit their exploitation in various symptomatic the qualitative of these ions also ruled by the efficiency of water as the presence of an ion or more may have adverse effects on health or the environment.

Total dissolved solids (T.D.S) are indicators of water salinity. According to their from the selected wells are classified as fresh water, medium water salinity, saline water, and highly saline water, as shown in Table 15.

Table (15) :- Classification of water quality reliance on gross (T.D.S)

Water superbness	Gross of melted emphasis salts (T.D.S) (mg/L)
Fresh water	0-1000
Medium saline water	1000-10.000
Saline water	10.000-100.000
Highly saline water	Up to 100.000

Source:- (Davis and Dewiest, 1966)

According to the classification in Table (15) above, water samples from to the total dissolved solid (T.D.S.) , could discrimination to several table categories (Table 16).

Table (16):- Classification of selected wells according to the total dissolved solid (T.D.S.) in their water samples

Water quality	Well classifications according to the total dissolved solid (T.D.S.)			
	Fresh	Medium saline	Saline	Highly saline
number of Wells	3	9	1	0
Percentage (%)	23.1%	69.2%	7.7%	0%

Source:- Researcher's work depend on the results of T.D.S. in the studied water specimens from the selected wells

Thus, the water of the well-studied wells can be classified from fresh to medium saline water, except for wells of high salinity. Figure (81) shows locations of these wells.

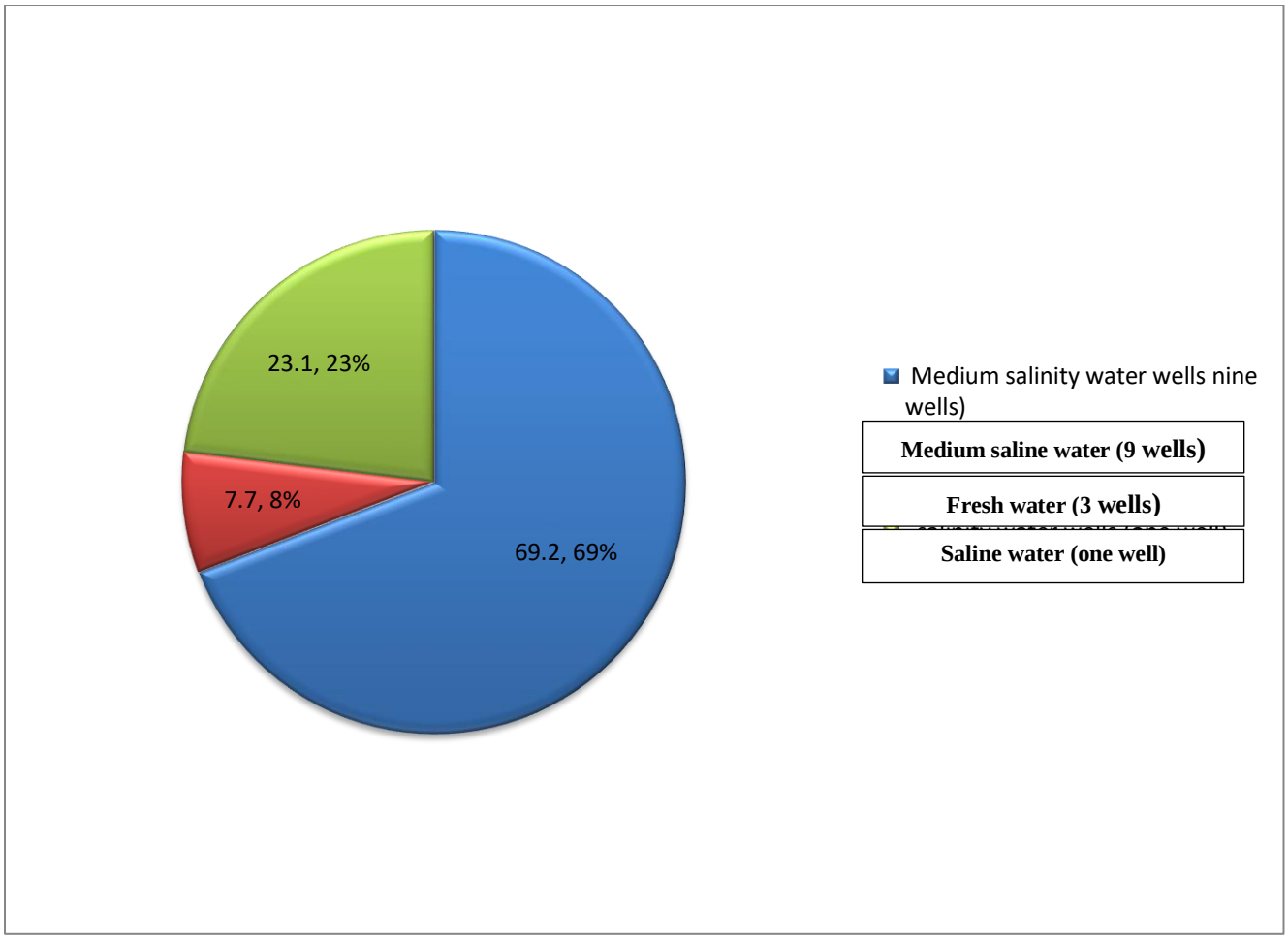
5.4. *The Graph Representation of Outcomes for Chemical Analyzing of Water Specimens Through Piper Graph*

The best sorts of the chart representation used of chemical analytical of groundwater and comparing its quality (Todd, 1980). This diagram expresses the concentration of each cation in the water specimens and electrons of the cations, which is dropped as a point on the left triangle representing each of the heads of calcium (Ca++), magnesium (Mg++) (Na+) and potassium (K+) , after that the percentages of equivalent data of anions on the right triangle are subtracted by the percentages , bicarbonate equivalents, then the extension of these points falls parallel to the upper edges as a single area at the intersection of this particular object. Thus, water samples of the selected wells are classified as moderate salty water in whence of efficiency, except for wells with high salinity and specific sites within the boundaries of the region of study.

The commonalities and dissimilarities in water qualitative are reflective the entire ion dissemination of the specimen. The resemblance and divergence in water quality can be show by representing a set of samples on this diagram. The chemically similar samples are clustered on the chart in convergent groups, while the chemically different samples are dispersed in different regions that divided into nine regions, which recognition the chemical efficiency of the sample water and its classified by ionic species dominant in water (Deutsch, 1997).

Generally , the graphic representativity of the material chemical analytical analysis of data according to the Piper scheme was done using the (Rock ware) where the ion concentration data were processed and converted from mg/L to electrolyte parameters per liter as well as converted to percentages in an automatic manner.

Figure (66):- Percentages of the classification of selected wells according to the total dissolved solids (T.D.S.) in their water samples



(Source:- Researcher's work depend on findings of concentration analyzing overall melted solids in water specimens and their proportion)

The (Na^+ Ca^{++} Cl^-) chemical Table (14) shows the outcomes of the transformation of the emphasis of cations and anions into percentages in water samples. Figure (68) shows the representation of these samples on the Piper chart.

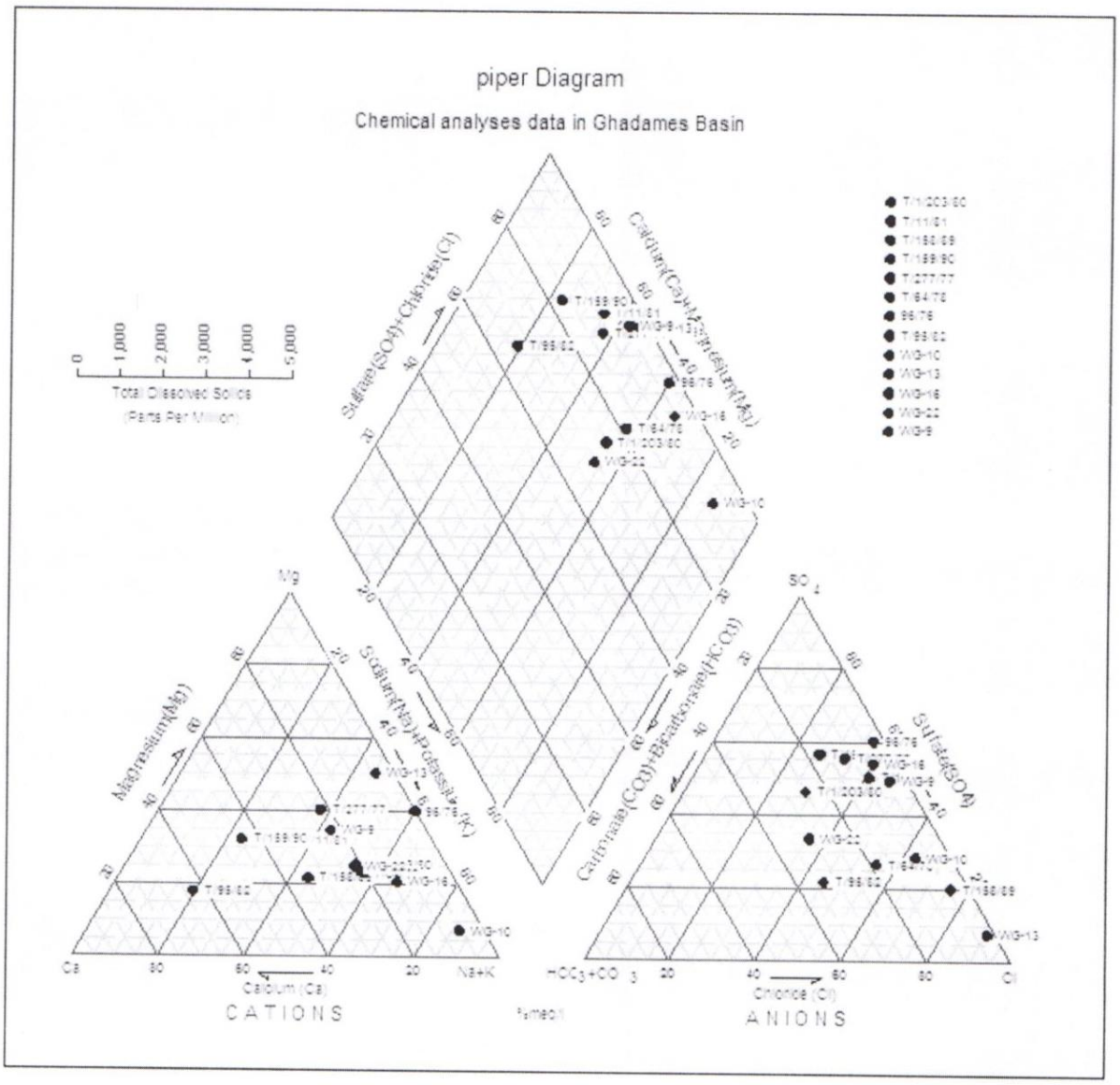
The chemical quality of the aquifers is characterized by significant variation in salinity levels. Actually, there are five chemical facies that can be distinguished in the water samples:- facies, where sodium ions, calcium and chlorine predominate and are relatively lacking in the rest of the other major ions. They are prevalent in eight wells:- T/1/203/80, T11/81, T/158/89, T/ 277/77, T/64/7, T/96/76, WG-9, and WG-13.

a. The (Na^+ Cl^-) chemical facies, which is dominated by sodium ions and chlorine, is dominant in the water specimens of the two wells (WG13), (WG10).
b. The (Ca^{++} $HCO3^-$ Cl^-) chemical facies in which calcium ions, bicarbonates and chlorine predominate and are represented by the well water sample of the well T/95/82.

c. The (Ca^{++} Cl^{-}) chemical facies, in which calcium ion and chlorine predominate, is represented by the water sample of the well T/159/90.

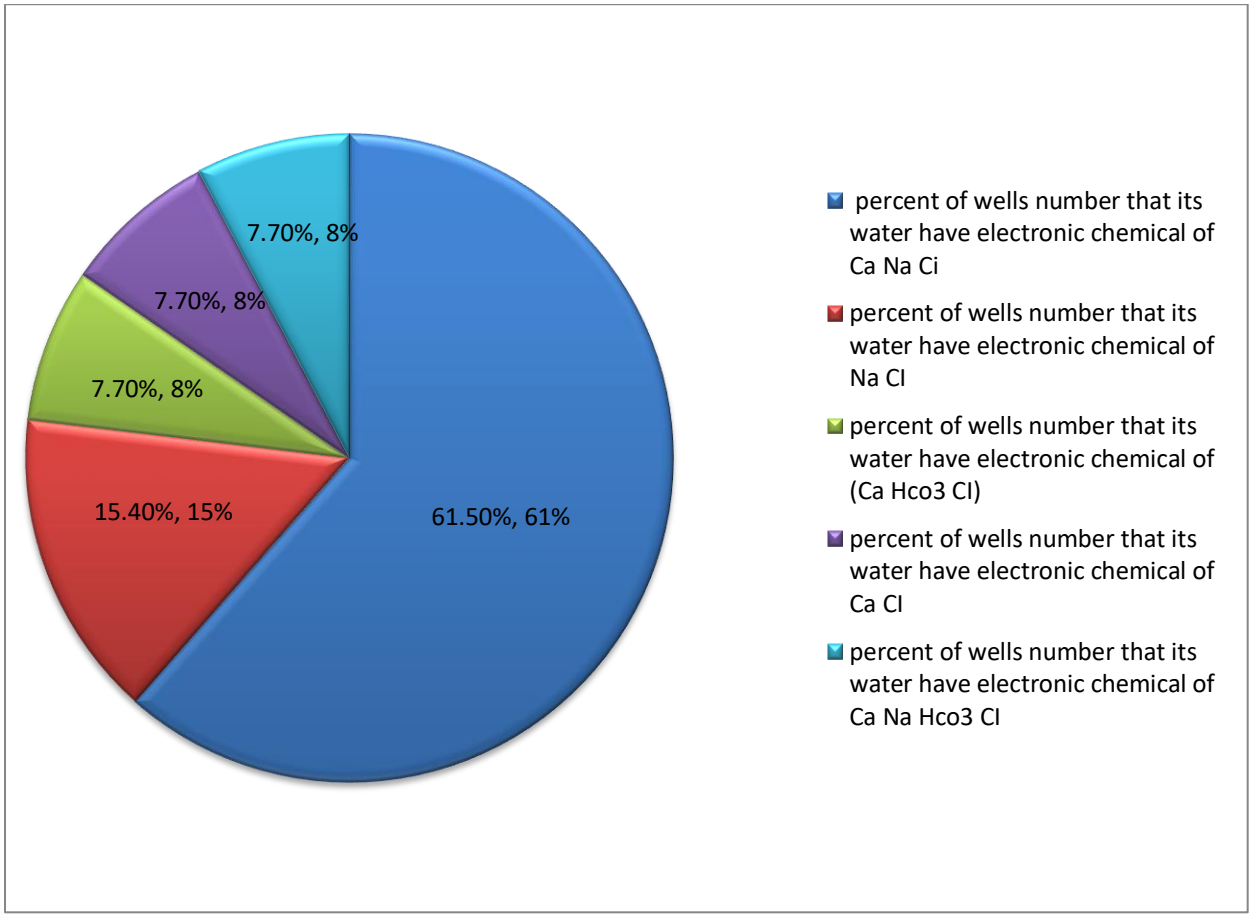
d. The (Na^{+} $HCO3^{-}$ Cl^{-} Ca^{++}) chemical facies, in which calcium, sodium, bicarbonate and chlorine ions predominate and representative from the water specimen for well WG-22 .

Figure (67):- Representative the chairman emphasis of ions in selected wells on Piper Diagram



(Source:- Researcher's work depend on data given in Table 14)

Figure (68):- Classification of selected wells according to their water chemical faces



(Source:- The researcher's work, based on findings of chemical analyses of water specimens and their classification into hydrochemical faces by Piper Diagram)

Table (17) shows the statistical summary of the chemical quality classification of water samples studied according to the above mentioned chemical facies, from which it can be deduce that a lot of the water of Kiklah reservoir is made up of water that is dominated by sodium, calcium and chlorine (Na^{+} Ca^{++}).

Table (17):- Statistical summary of the chemical quality classification of water samples according to chemical facies represented by Piper Diagram

Chemical facies in water of wells	Ca Na HCo3 CL	Ca CL	CaHCo3 CL	Na CL	Ca Na CL
Number of wells	1	1	1	2	8
Percentage of wells (%)	7.7	7.7	7.7	15.4	61.5

Source:- Researcher's work depend on classification of water faces by Piper Diagram **. .**

5.5.*Geographical Distribution of Chemical Components in Water*

Samples from Selected Wells

This part of the study includes a contour mapping process for the geographical distribution patterns of the main and the variations in the hydrochemical faces concerning to their distribute in the region of study. Contour mapping techniques for the modalities of geographical allocated the chemical constituents of selective wells incorporate :-

1. Chart of geographical allocation of pH .

2. The sketch of allocated map geographical for focusing of aggregate melt salts (T.D. S)

3. The sketch of geographical allocated of the cations, includes following :-

- The sketch of geographical allocated of calcium (Ca^{++})
- The sketch of geographical allocated of Mg^{++} (Mg^{++})
- The sketch of geographical allocated of sodium (Na^{+})
- The sketch of geographical allocated of potassium (K^{+})

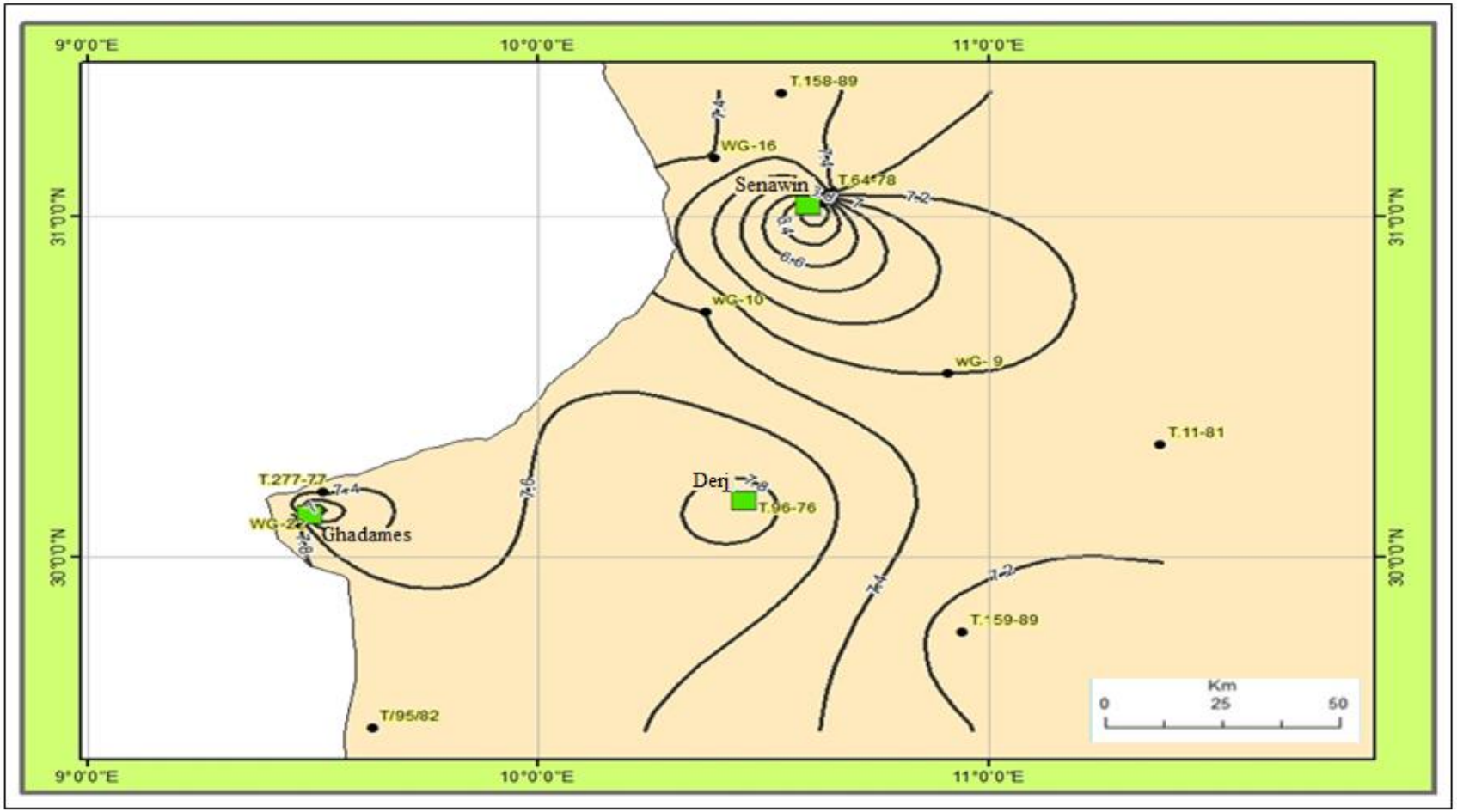
4. The sketch of geographical allocated of the anions, includes following :-

- The sketch of geographical allocated of chlorine (CL^{+})
- The sketch of geographical allocated of bicarbonate (HCO3)
- The shetch of geographical allocated of sulphate ($SO4^{--}$)
- The sketch of geographical allocated of nitrates (NO3)

5.1.1. The sketch of Geographical allocated of pH

Map of pH distribution of Kiklah reservoir in the region of study, as illustrated by Figure (70), shows that this distribution ranges between (5.90- 8.00). This relative variation in pH appears in three regions near the areas of Ghadames and Derj. It is believed that the relative increase in pH may be linked to the centers of urbanization and agriculture, indicating the possibility of contamination of water aquifer through human activities, especially as water levels are relatively near of surface like the well (T/ 96 /76) . However, the presence of the reservoir at depths of more than one meter below the surface requires more research and study of the artesian determinants for wells in these areas .

Figure (69):- Geographical distribution Contour map of pH in water samples of selected wells



(Source:- researcher's work, depend on the findings of chemical analyzing of water specimens and its representation in contour map)

The areas to the north of Ghadames and Derj, specifically at the well (WG13), the pH is reduced to 5.9. This sudden decrease is offset by a relative increase in concentrations of magnesium, chlorine, calcium, bicarbonate and sulfate, indicating the possibility of oxidation reactions of some solvents containing carbon or sulfate.

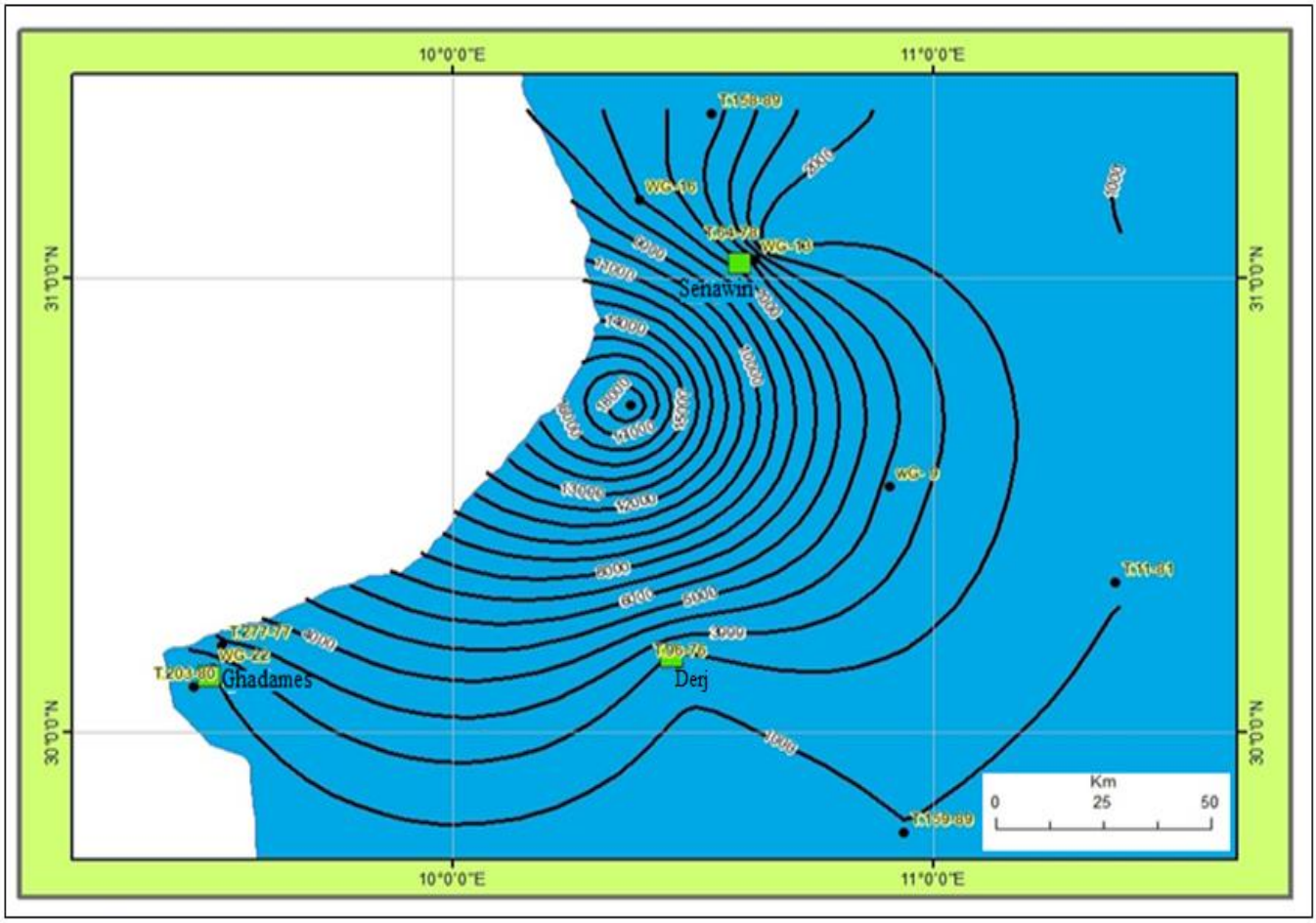
5.5.2. The sketch of allocated map geographical for focusing of aggregate melt salts (T.D. S)

In concerning to the geographical allocated map of aggregate melt salts (T.D.S.) in water sample wells, Figure (69) it shows the high salinity valuable about middle of the region of study, particularly at the well (WG-10), which is about 20000 mg/L, and from the slope in the southern extremities of the region which is (2000 mg/L), accompanied by relatively high concentrations of calcium ions and sulphates in the boreholes water with a largely decrease in water temperature compared to other wells surrounding it. It was thought that the reason for this decrease is the leakage of marshes by the cracks, caves, fractures and faults, or saline water leaking from aquifers above Kiklah aquifer, which is likely to leak from dissolved saline rocks and gypsum beds during its movement towards the aquifer. This was also indicated by cylindrical core samples.

5.5.2.*Map Geographical Distribution of Sodium Ions*

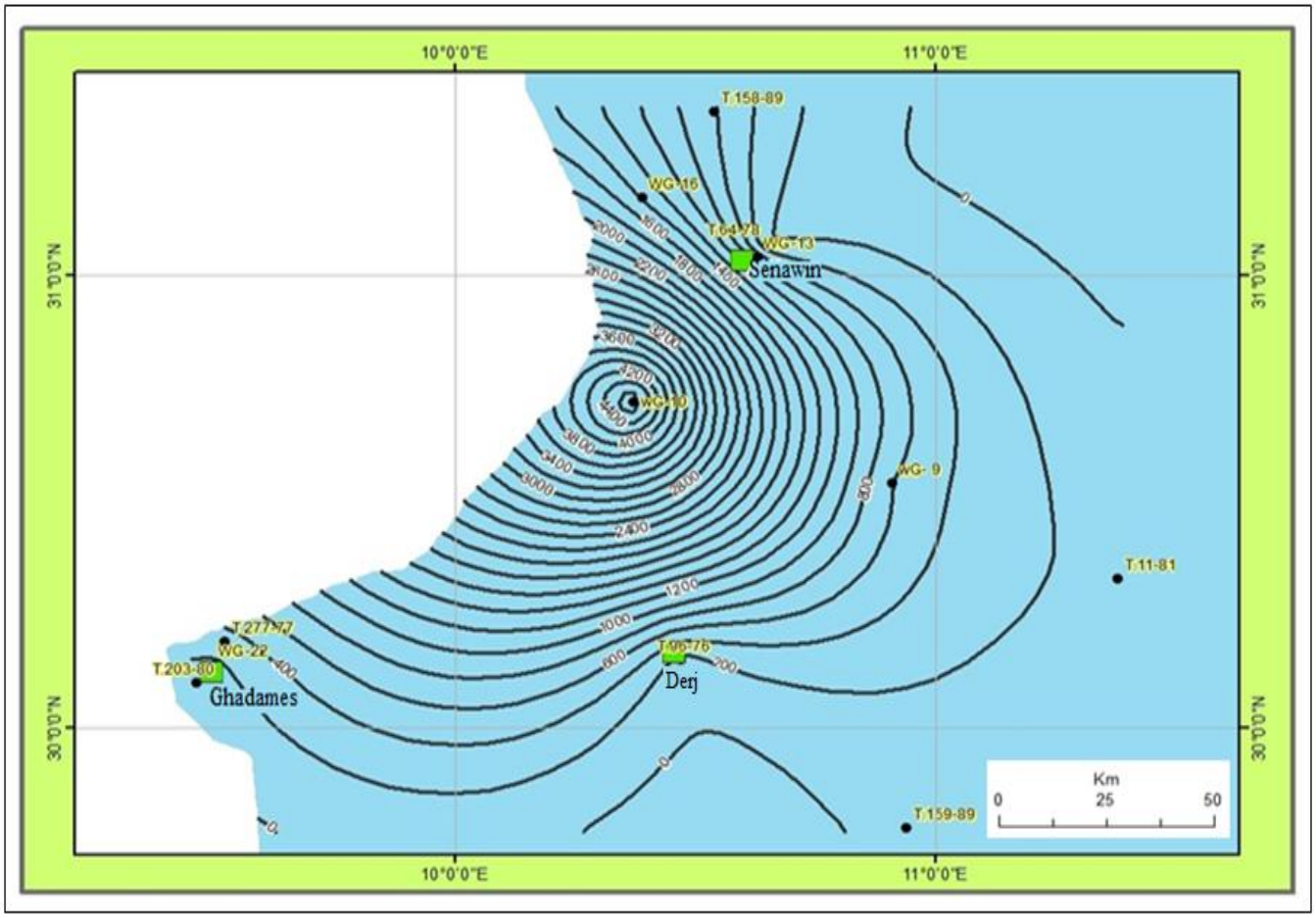
The geographical distribution of sodium ions refer to that the distribution stereotype of this ion is resemble to that of gross dissolved solids (T.D.S.) with the highest concentration reaching about 4700 mg/L at the center of the well (WG-10) (Figure 70).

Figure (70):- Geographical distribution Contour map of T.D.S. in mg/L in water samples from selected wells



(Source :- Researcher's work depend on the findings of chemical analysis of water specimens and representation it in contour map)

Figure (71):- geographical distribution Contour map of sodium ions in mg/L in water samples from selected wells



(Source:- Researcher's work depend on the findings of chemical analysis of water specimens and representation it in contour map)

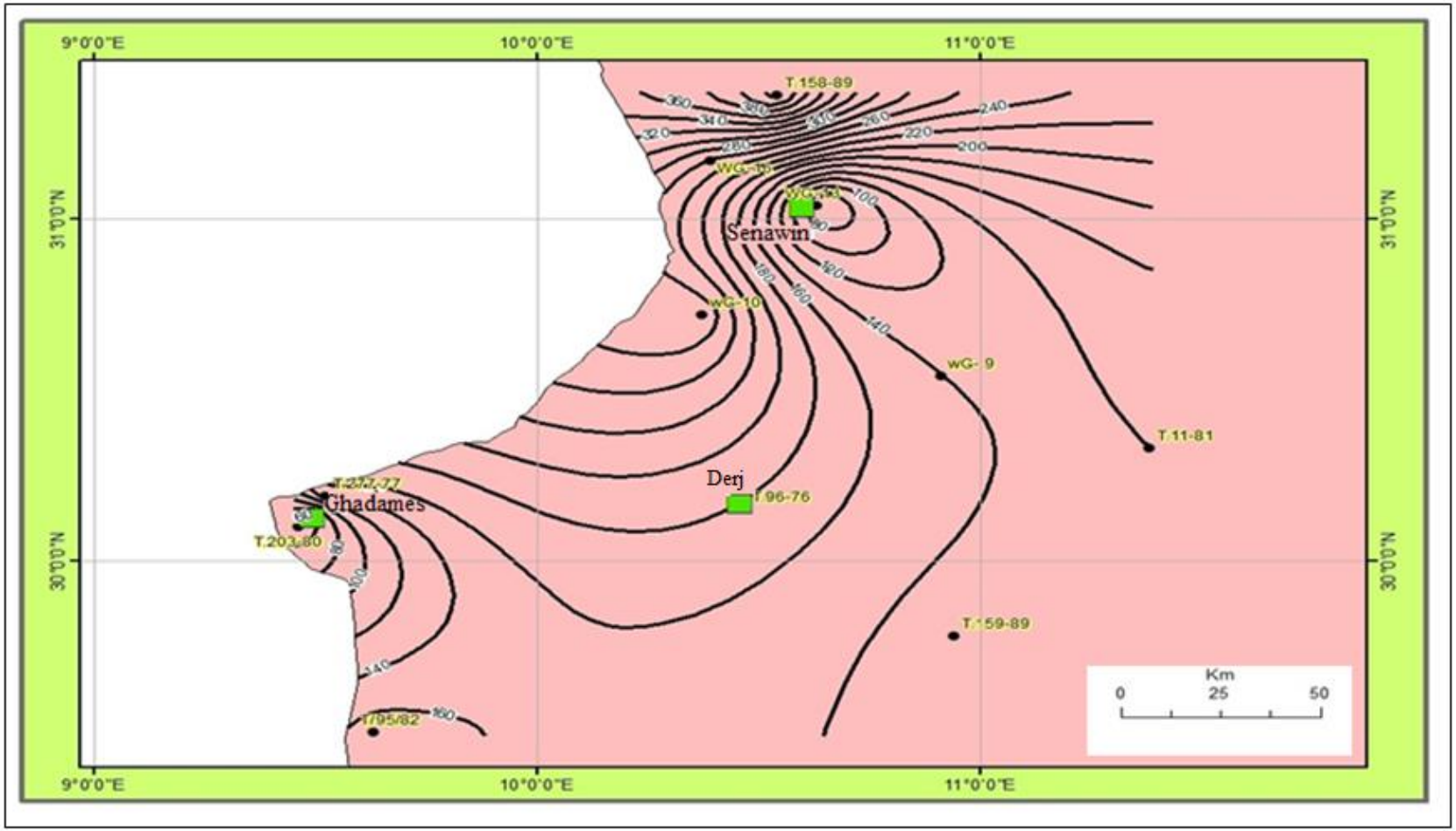
This concentration is reduced in all directions to a minimum value of 55 mg/L in the southern extremities of the region. of total dissolved solids (T.D.S.) .

5.5.4 *Mapping and Geographical Distribution of Calcium Ions*

The distribution of calcium ions in the groundwater in district of study indicates that this concentration is relatively low, as is the case for all aquifers consisting mainly of sandstone, despite the generally high values of total dissolved solids concentrations (Format 71) .

The ion emphasis of calcium does not exceed 200 mg/L in four wells, all located in the center and north of the region, (WG-9, WG-16, WG-10, and T/158/89). This concentration was very significant for other wells in the region, while in one well (Well No. WG-13), the concentration of calcium ion does not exceed 60 mg/L in its water sample.

Figure (72) geographical distribution Contour map of calcium ions in mg/L in water samples from selected wells



(Source:- Researcher's work depend on the findings of chemical analyzing of water specimens and its representation in contour map)

5.5.5 *Mapping and Geographical Distribution of Magnesium Ions*

The geographic distribution pattern of magnesium ion (mg/L) concentrations in the studied wells (Figure 73) is almost identical and largely similarity and the distribution of total dissolved solids as well aschlorine and sodium ion . It is also somewhat similarity to the geography distribution stereotype of calcium ion, and in general :-

1. Just in four wells, WG-9, WG-10, WG-16, WG-13, transcend the emphasis of calcium ion in its water more than (200) mg/L.
2. In the south parts of the region of study , magnesium ion concentrations decrease significantly to less than 30 mg/L in well T/203/80.

5.5.6. *Mapping and Geographical Distribution of Potassium Ions*

Format (74) represented the allocated of potassium did not exceed 56 mg/L except in one well, T/96/76, which is located near the city of Derj, where the concentration of potassium ion in its water reaches about (110) mg/L. The lowest concentration of this ion was observed in the water sample from the well T/95/82 in southernmost-west of the district , and which was 8 mg/L. Further , it there was been raising in the wells WG-16 and T/158/89 in north fraction of the district .

5,5.7. *Mapping and Geographical Distribution of Chlorine Ions*

The geographic distribution stereotype of chlorine ion in water wells is resemble to that of aggregate melt solids (T.D.S) and sodium ion distribution (Figure 74) Illustrate the maximum concentration of the high of concentrate for chlorination ions in simultaneous with the high in the concentrate .

5.5.8. *Mapping and Geographical Distribution of Bicarbonate Ions*

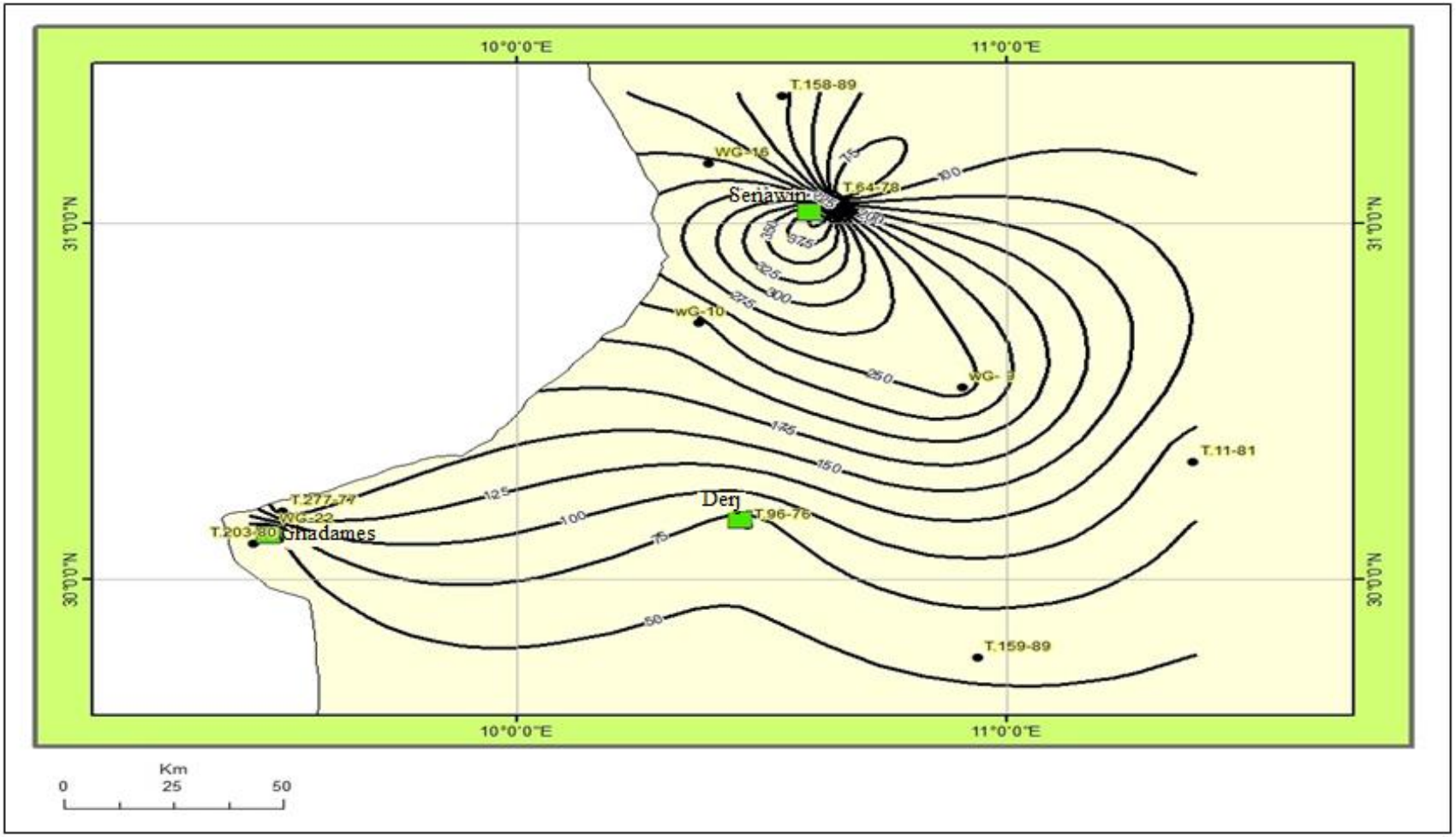
The distribution of bicarbonate ion concentration data in 11 wells in the region of study ranges between 100-330 mg/L and a mean concentration of 200 mg/L, while this

concentration is very low in Well № T/96/76, and Well № WG-13, 18 mg/L, 85 mg/L in the two wells, respectively.

In general, the geographic distribution map of the concentration of bicarbonate , in Figure (75) Illustrate pattern very similar to the calcium ion distribution pattern. It is a predictable pattern because calcium is present in carbonate metalwork , that melt in having of carbon dioxide, and become of this ion up to (19) mg/L at the well T/96/76, located near the city of Derj .

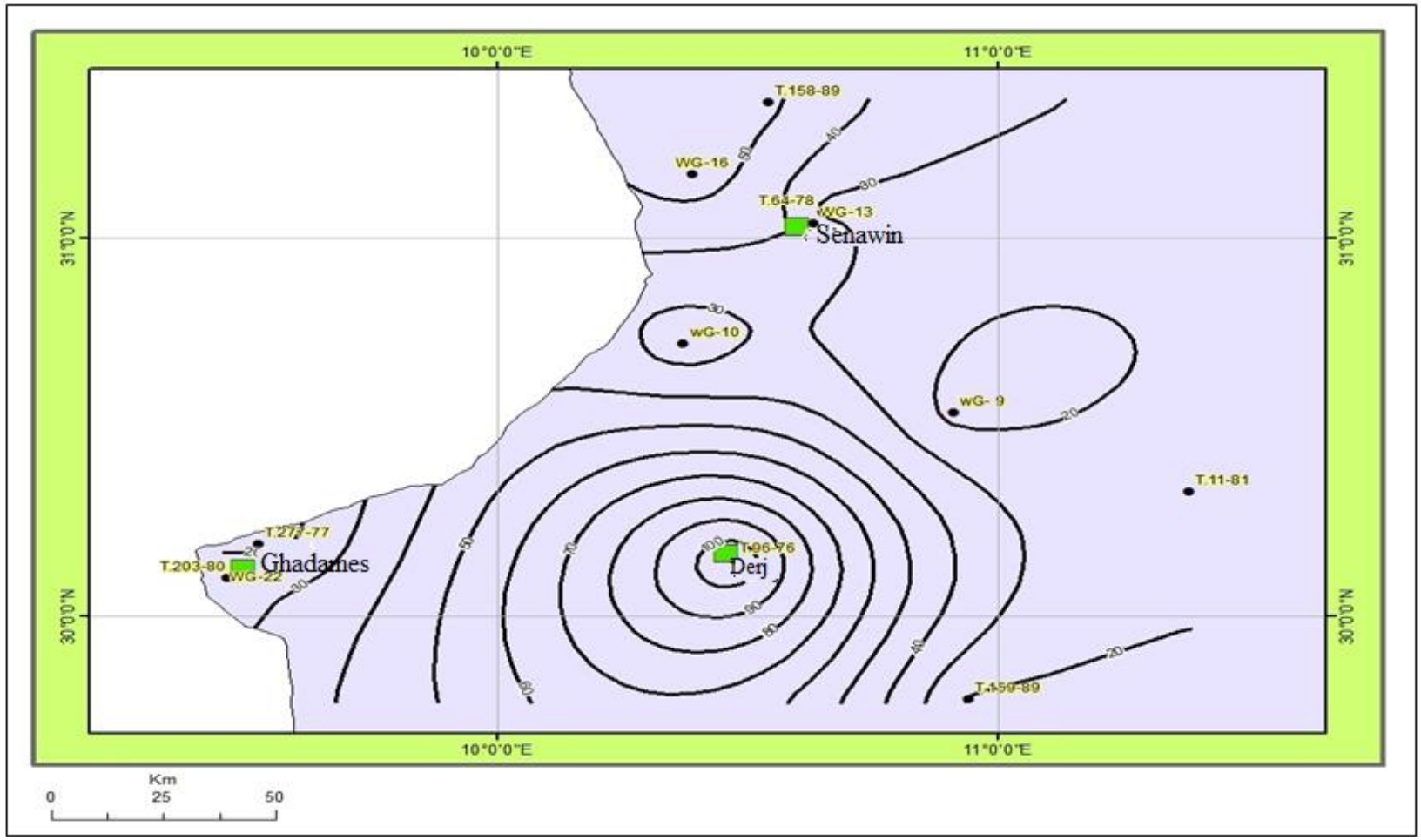
A decrease in both bicarbonate and calcium ion concentrations is also observed in this well offset by a relative increase in pH. On the other hand noted altitude in bicarbonates concentrate north of this well, where this concentration reaches its highest value which reached (30) mg/L at the well WG-16, in addition to that existence one borehole in bicarbonate ion is low, similar to the calcium ion, which reaches 85 mg/L, which is the well № WG-13 .

Figure (73):- Geographical distribution Contour map of magnesium ions in mg/L in water samples from selected wells



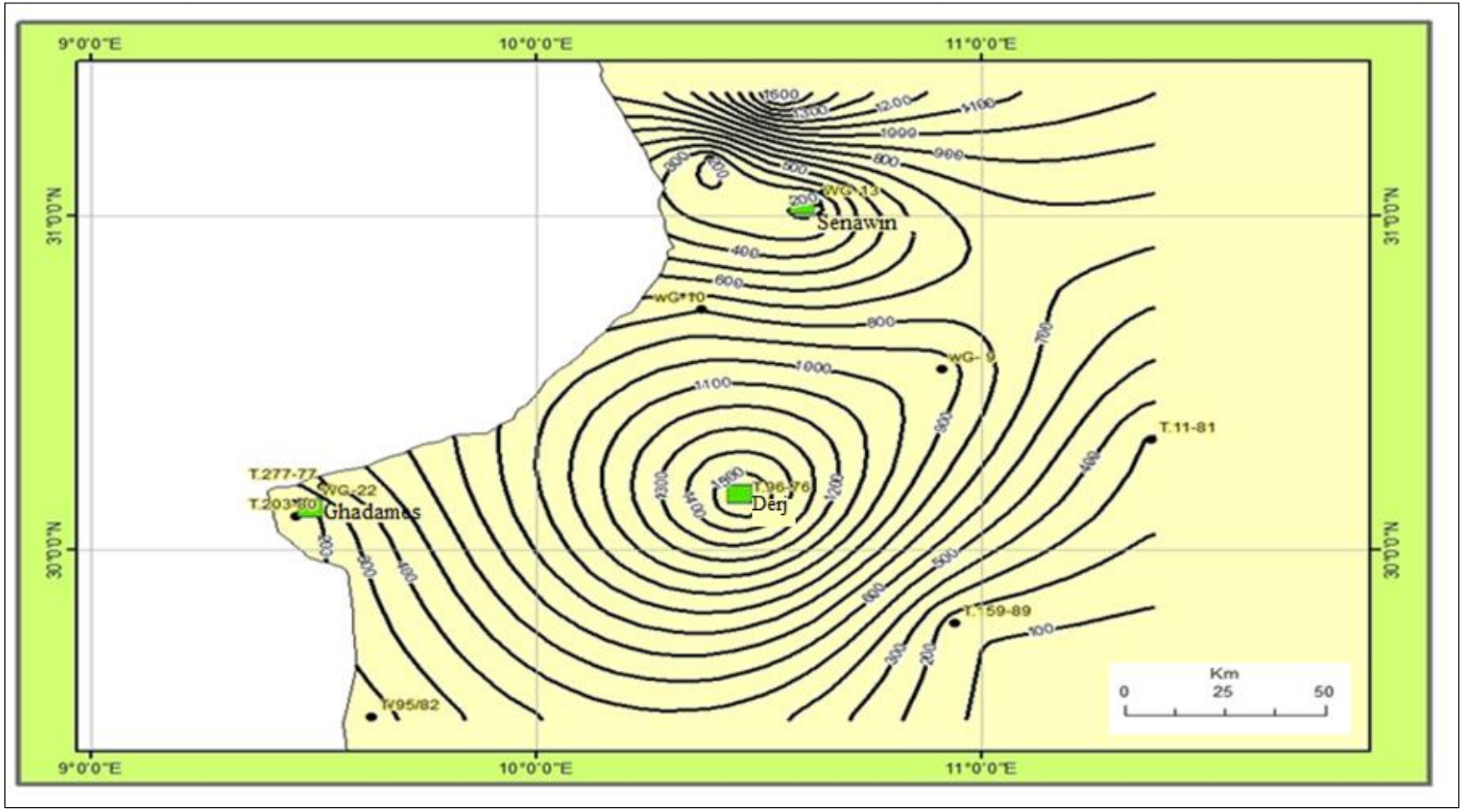
(Source:- (Source:- Researcher's work depend on the findings of chemical analysing of waters specimens and its representation in contour map)

Figure (74):- Geographical distribution Contour map of potassium ions in mg/L in water samples from selected wells



(Source (Source:- researcher's work, depend on the findings of chemical analysing of water specimens and representation it in a contour map)

Figure (75):- Geographical distribution Contour map of chlorine ions in mg/L in water samples from selected wells



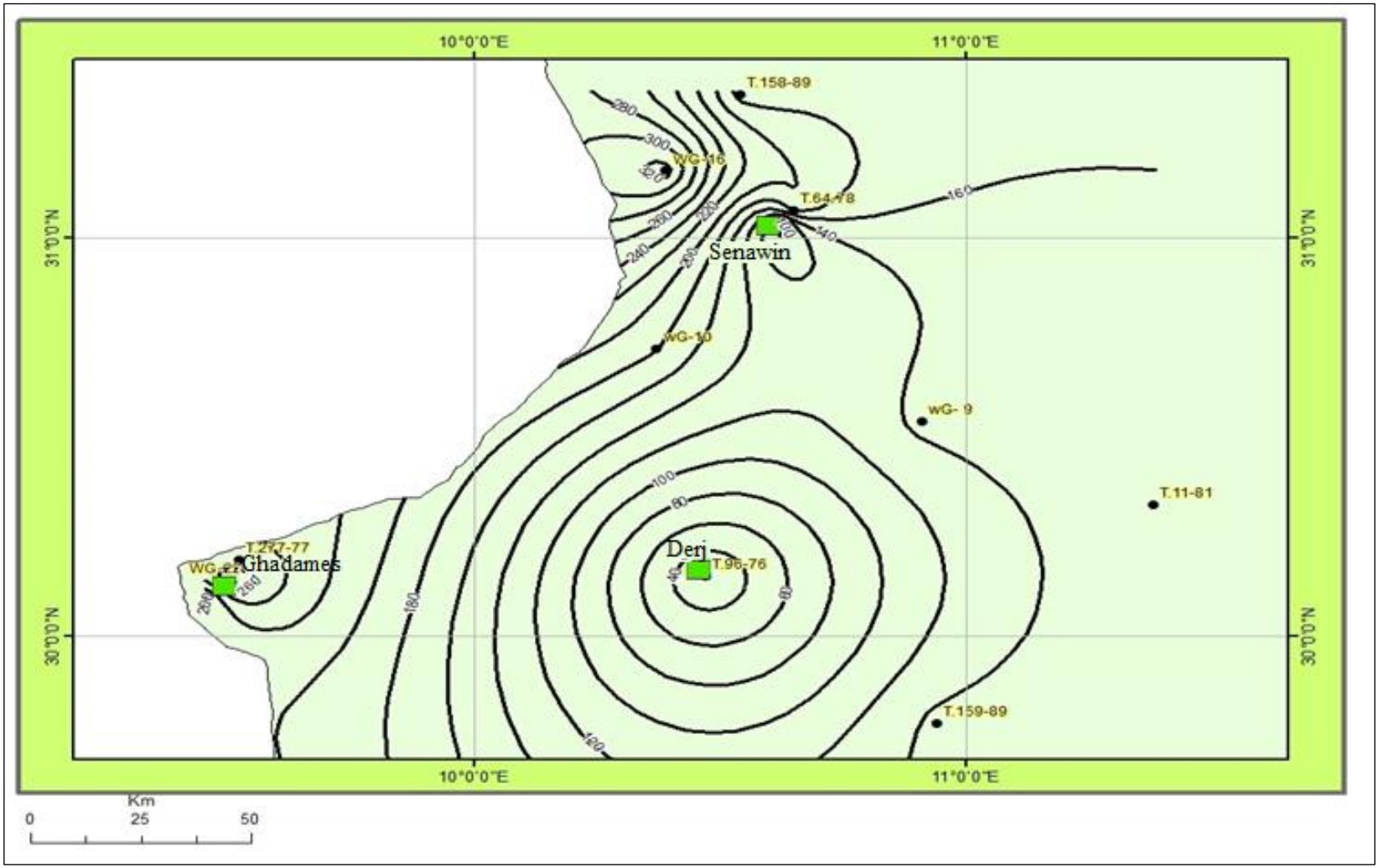
(Source:- Researcher's work depend on the finding of chemical analysing of water and representation it in contour map)

5.5.9. Mapping and Geographical Distribution of Sulfate Ions

Sulfate ion is usually produced in groundwater through the dissolution of gypsum minerals, such as gypsum and anhydrite found in the sedimentary layers of geological formations, or by oxidation of sulfate minerals that can also exist within these layers.

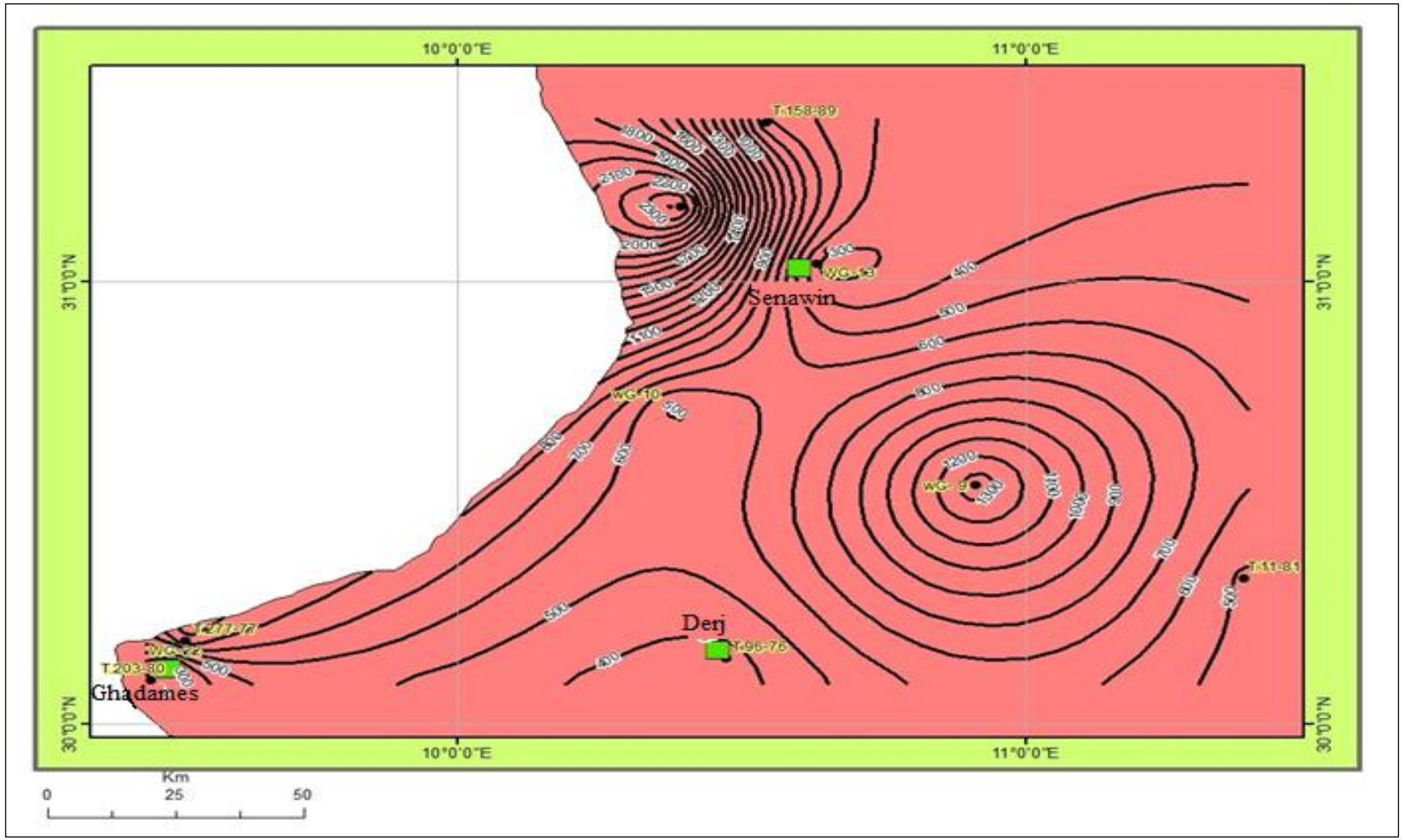
In the region of study, the concentration of sulfate ion is generally higher than other ions (Figure 78). It is approximately 100 mg/L in the well № WG-9, and 2500 mg/L in the well № WG-16. Except for these two wells, it is noted that the average concentration of sulfate ions in the area ranged to 500 mg/L. In addition, the geographical distribution of this ion indicates a large increase from east to west inside the boundaries the region of study.

Figure (76):- Geographical distribution Contour map of bicarbonate ions in mg/L in water samples from selected wells



(Source:- researcher's work depend on the findings of chemical analysing of water specimens and representation it in contour map

Figure (77):- Geographical distribution Contour map of sulfate ions in mg/L in water samples from selected wells



(Source:- researcher's work depend on the findings of chemical analyzing of water specimens and representation it in a contour map

5.5.10. Mapping and Geographical Distribution of Nitrate Ions

The presence of nitrates at relatively high concentrations is usually an indicator of contamination of groundwater through marsh waste or chemical manures for planting. The map of allocated of this ion in the district utilized of study refer that the concentration or disappearance of this ion in most wells were in the middle and northern sections , whereas in the south western sections this emphasis rises to a high level up to 166 mg/L in the well № T/95/82 .

Spreadsheet (18):- synopsis of the earmarked of nitrate ion in wells of the district of study .

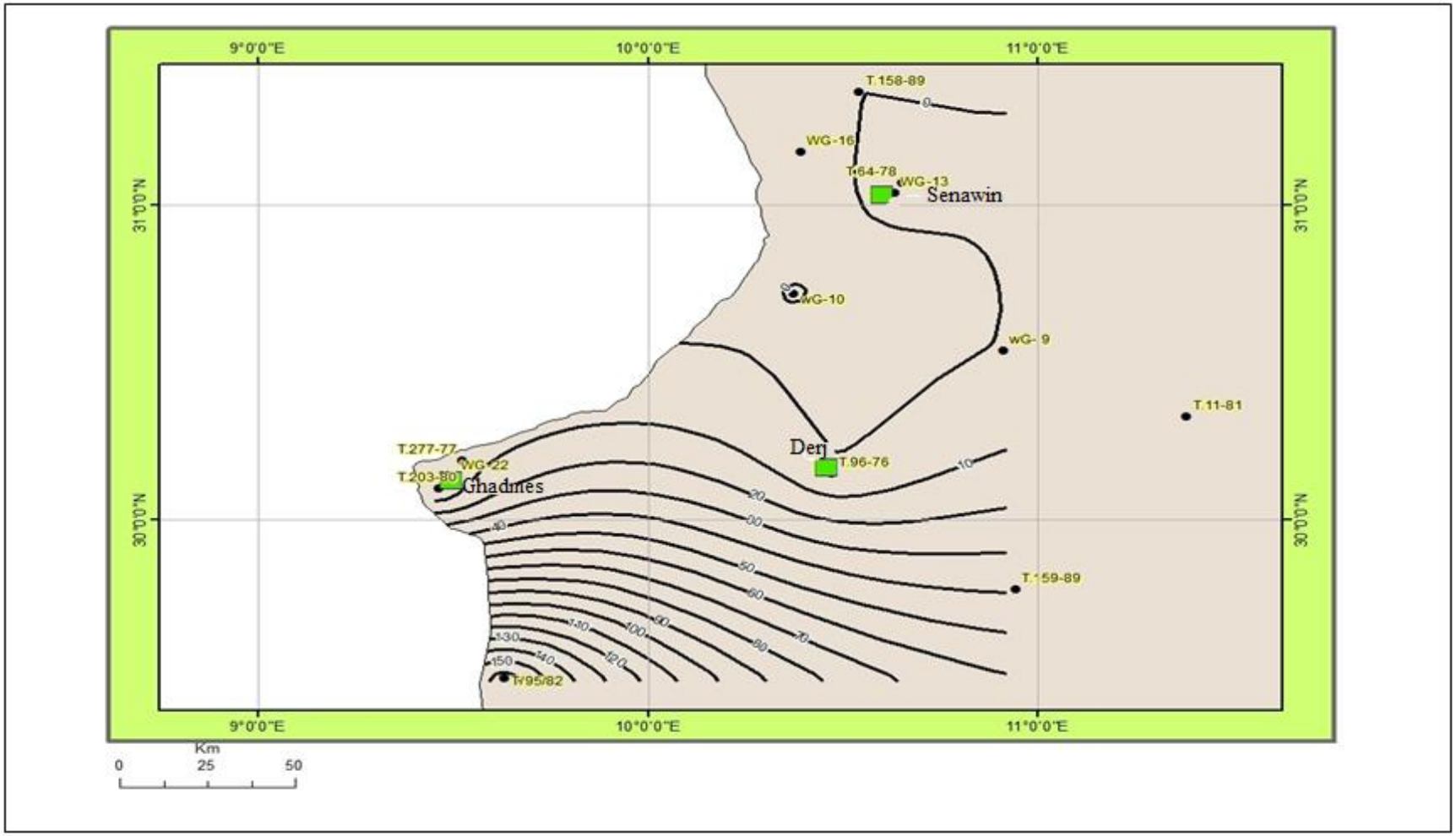
Nitrate ion concentrations	Concentration reaching (0166) mg/L	Concentration reaching (6.7) mg/L	Concentration not exceeding (1) mg/L	Concentration (0) mg/L
Number of Wells	1	1	5	6
Percentage (%)	7.6	7.6	38.6	46.2

Source:- researcher's work depend on chemical analysis of water samples from selected wells

5.5.11.*Mapping and Geographical Distribution of Water Temperature*

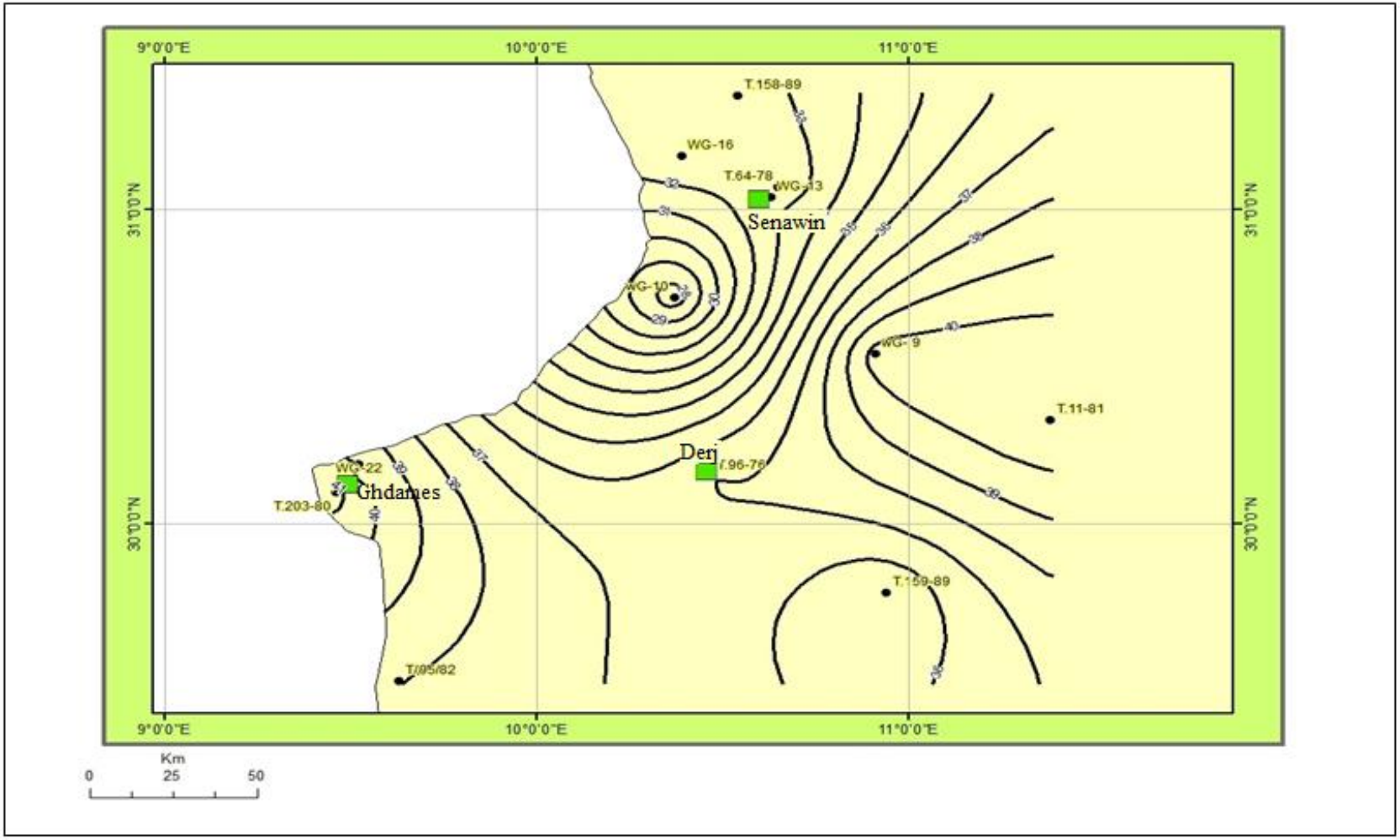
Temperature is an important factor in the hydro-chemical system of aquifer water, because it controls the mechanism and speed of all water-related chemical processes and reactions in these reservoirs, which include the dissolution of rock minerals and deposition of salts or metals that impact the quality of water, (Geothermal Gradient) and was also associated with tectonic movements and processes in any region.

Figure (78):- Geographical distribution Contour map of nitrate ions of in mg/L in water samples from selected wells



(Source:- researcher's work depend on the findings of chemical analysing of water specimens and representation it in contour map)

Figure (79):- Geographical distribution Contour map of temperatures in water samples from selected wells



(Source:- researcher's work depend on findings of chemical analysing of water specimens and representation it in contour map)

The map of temperature shown in (Figure 78) indicates a relative general increase of temperature, which reaches to 41.4 °C, while a relative decrease of high water temperature prevailed particular in districts of the centralized in Ghadames Basin. It is also noted that water temperature is relatively decreasing westbound ,in particular in the center and northern parts of the region.

5.6.*Hydrochemistry of High Salinity Wells in the region of study*

4.6.1. Wells With Highly Saline Water

Here is a list of the selected wells with high levels of salinity:-

a. Well № WG-13

b. Well № T/158/89

c. S. Mejezzem

d. Well № WG-10

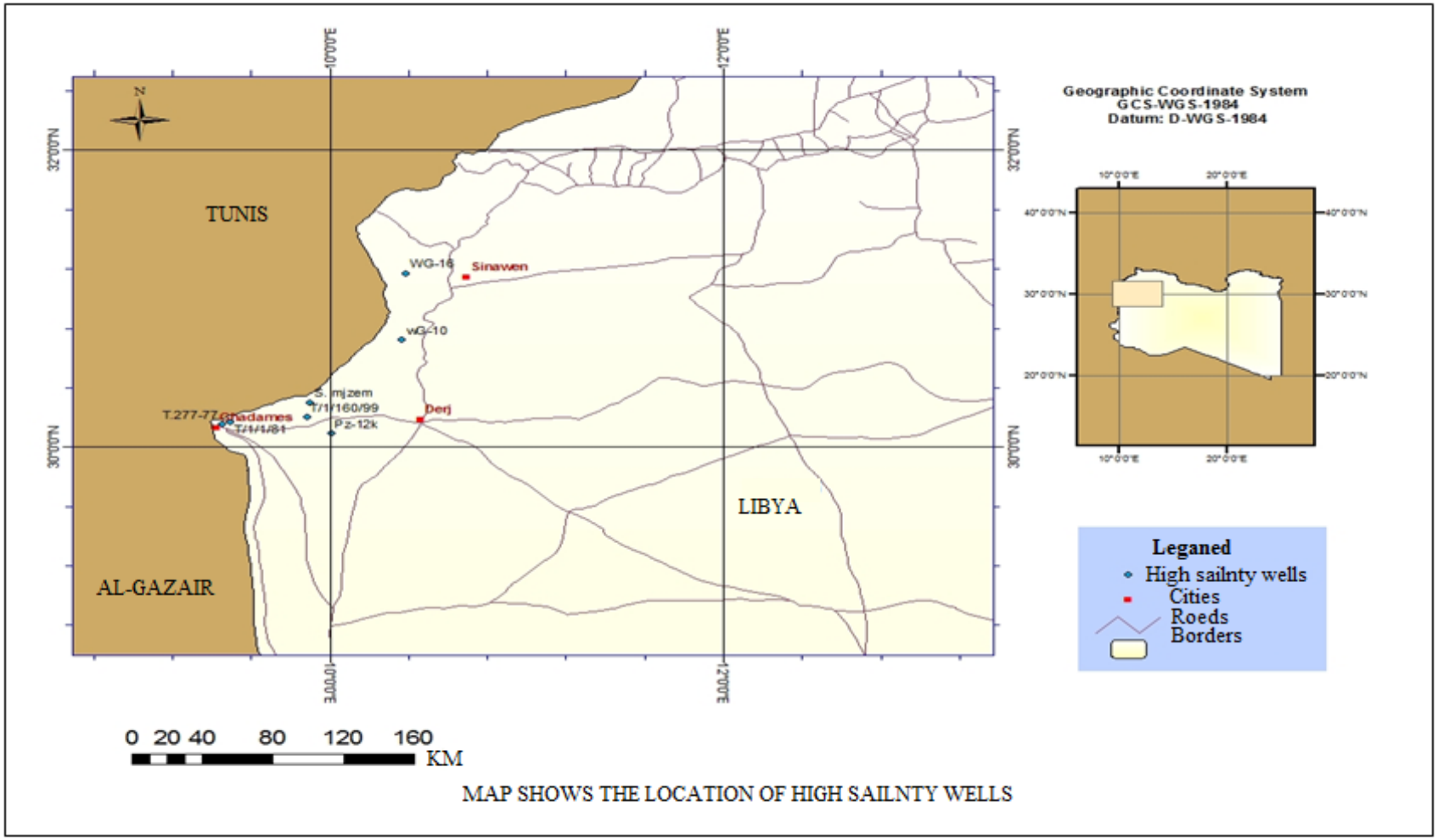
e. Well № WG-16

f. Well № T/277/77

g. Well № PZ-12A

clarify Format (79) the places of the high saline boreholes situated interior the frontiers the district of study .And clarify Table (12) the findings of chemical analysis of data for the water specimens of these wells in mg/L (ppm). Table (14) also clarifys the findings of these analyses in milli-equivalent per million (epm).

Figure (80):- Map of location of high salinity wells in the region of study



(Source:- Researcher's work depend on site coordinates of highly saline wells using a GPS device)

Format (81) clarify a comparative between the values for total melt salts (T.D.S.) in saline water wells.

5.6.2.*Chemical Classification of High Salinity Well Water Samples*

1. As categorizatied of the water specimens contained in Schedule (14), which is relied on aggregate melt salts (T.D.S), the water specimens of the mentioned wells are classified as saline and highly saline compared to water samples of other wells in the region, which take advantge of groundwater aquifer as a whole.
2. Quality of the water on the Anions triangle in Piper Diagram (Figure 83) refers to chlorine water with a significant proportion in some cases for presence of sulfates..
3. Quality the water on the cationic triangle in Piper Diagram most likely refers to the soda water in most cases.

4. Lozenge Piper shows that water samples are represented by the predominance of chlorides and sulfates.

4.6.3. *Contour Map-making and Geographical Allocation of Ions in High Salinity Wells*

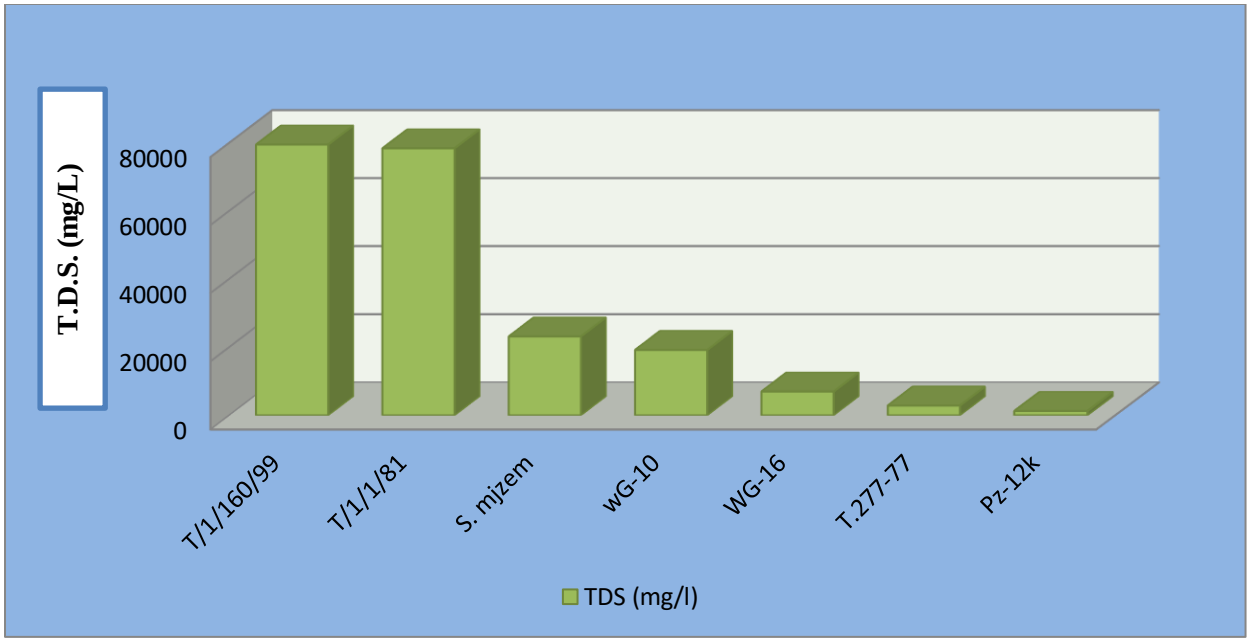
With respect to concentrations and geographical distribution of ions in highly saline water samples, Figures (84, 85, 86) show the contour mapping and geographical distribution of concentration values for sodium, chlorine and sulfate ions in selected wells. Change in concentrations of sodium ions, chlorine ions and sulfate ions in water samples reveals the following issues:-

1. These concentrations differ in diverse fractions from the district of the study.
2. There is a close relationship of natrium and chlorine, where the stereotype of geographical allocation of the ions is similar. There is also a linear relationship between the ions when comparing the change curve of each ion (Figures 87, 88).
3. The geographical distribution of sulfate ions is different from sodium ions and chlorine ions. The relative increase of the sulfate concentration change curve (Figure 88) indicates the highest concentration in the water sample (S.Mjezzem) and also the relative elevation in the well (WG-16).

These are the areas of the presence of Sabkhas and boulders within the frontiers the district of study. This is confirmed by (Figure 89), which illustrates the relationship between sodium, chlorine and sulfate concentrations in saline wells.

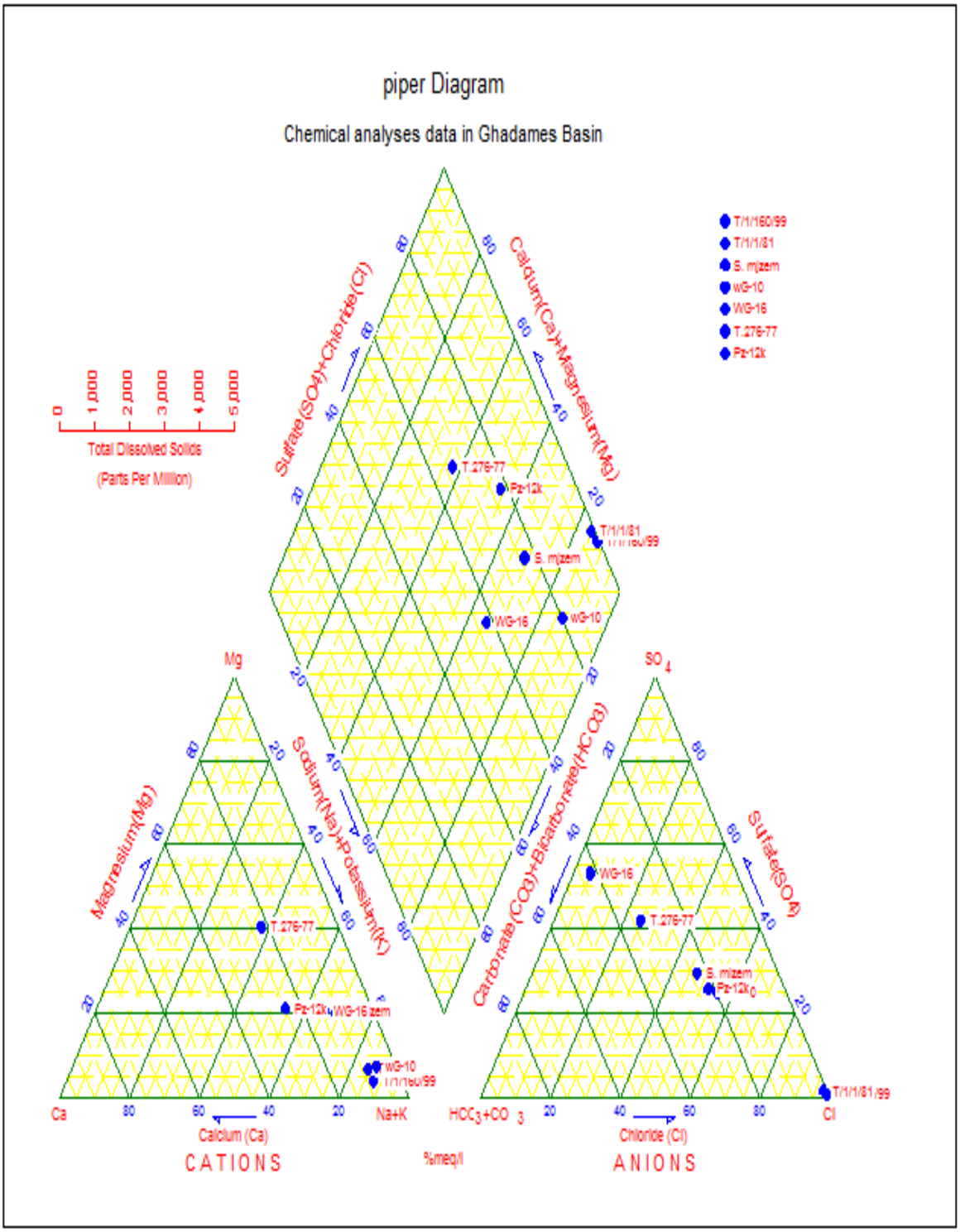
The sudden increase in salinity of these wells compared with further borehole in the district , concentrations of dissolved ions that lead to salinity, indicate the need to discuss this phenomenon and identify the causes of this sudden rise, and highlight the hydro-chemical and lithological relationship between Kiklah aquifer and the other aquifers above it in order to address this qualitative decline in the water of this important and widely used aquifer in Ghadames Basin.

Figure (81 Compared amongst of the aggregate valuable melt salts):- in highly saline wells



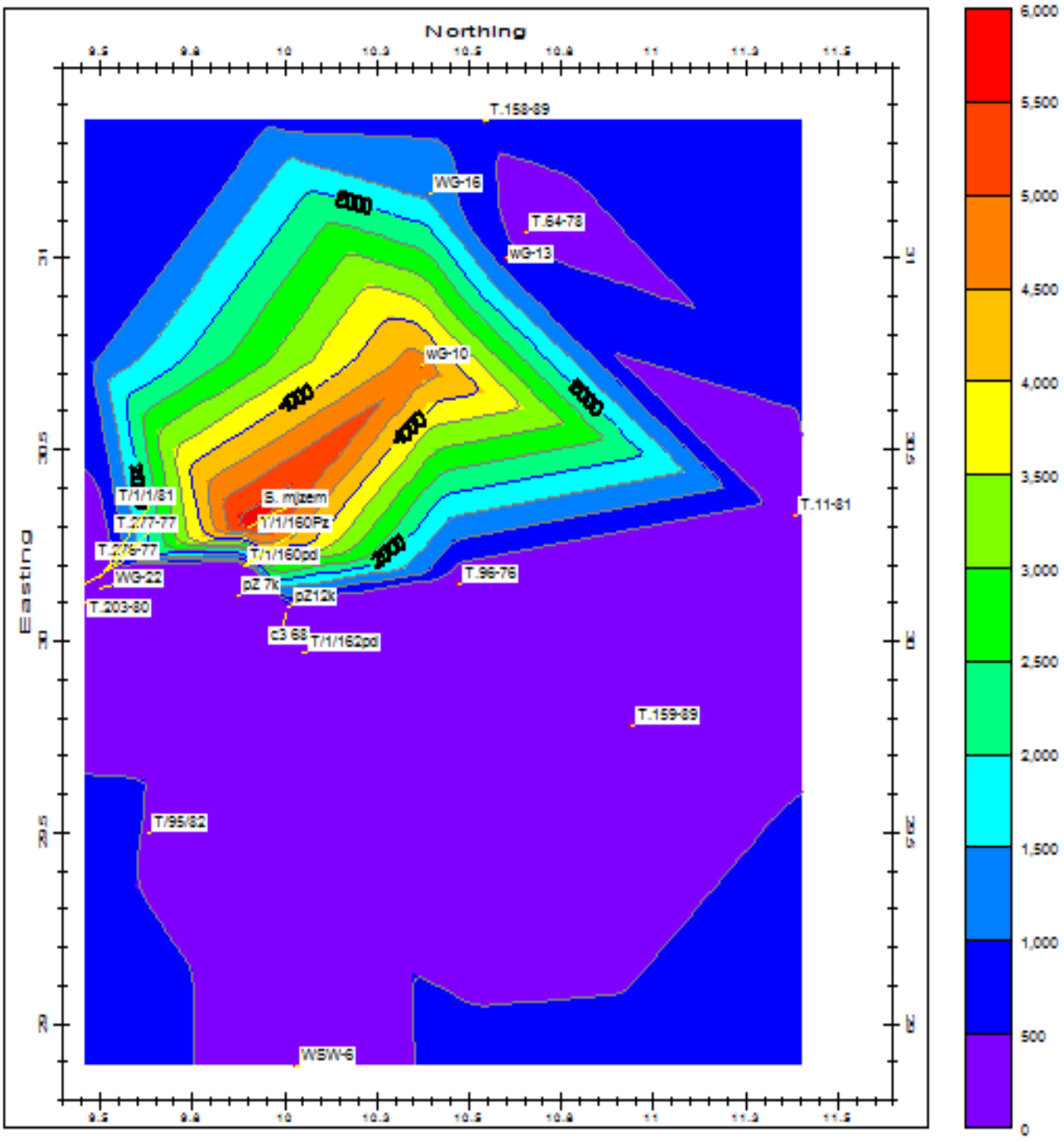
Source :- Researcher's work reliance on the consequences of chemical test of water specimens

Format (82):- Represented of findings chemical analysis of highly salinity wells on Piper Diagram



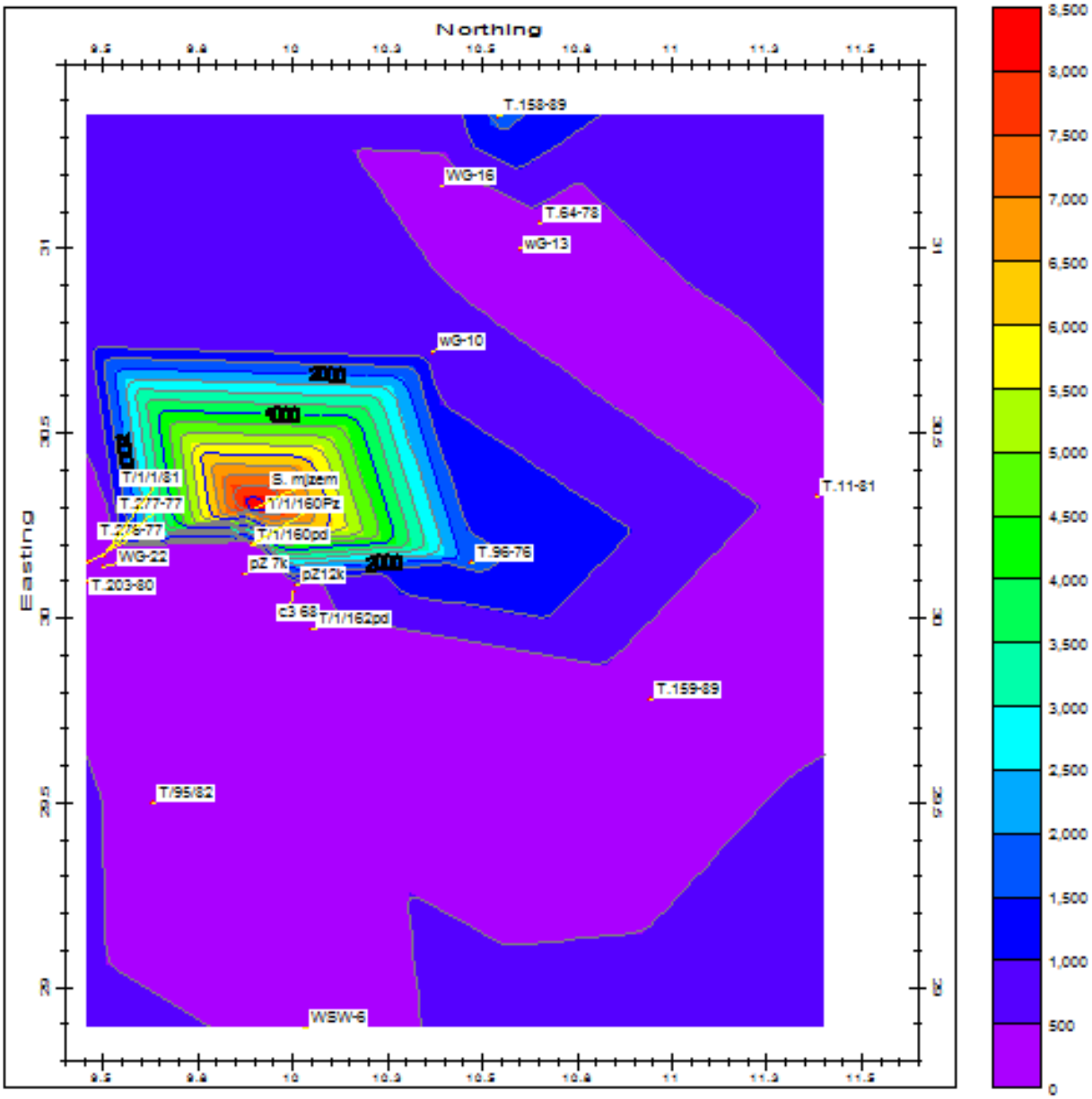
(Source:- Researcher's work depend on the findings of chemical analysis of highly saline water specimens)

Format (83):- Map of the geographical apportionment of sodium ion in mg/L in water samples from highly salinity wells in the region of study



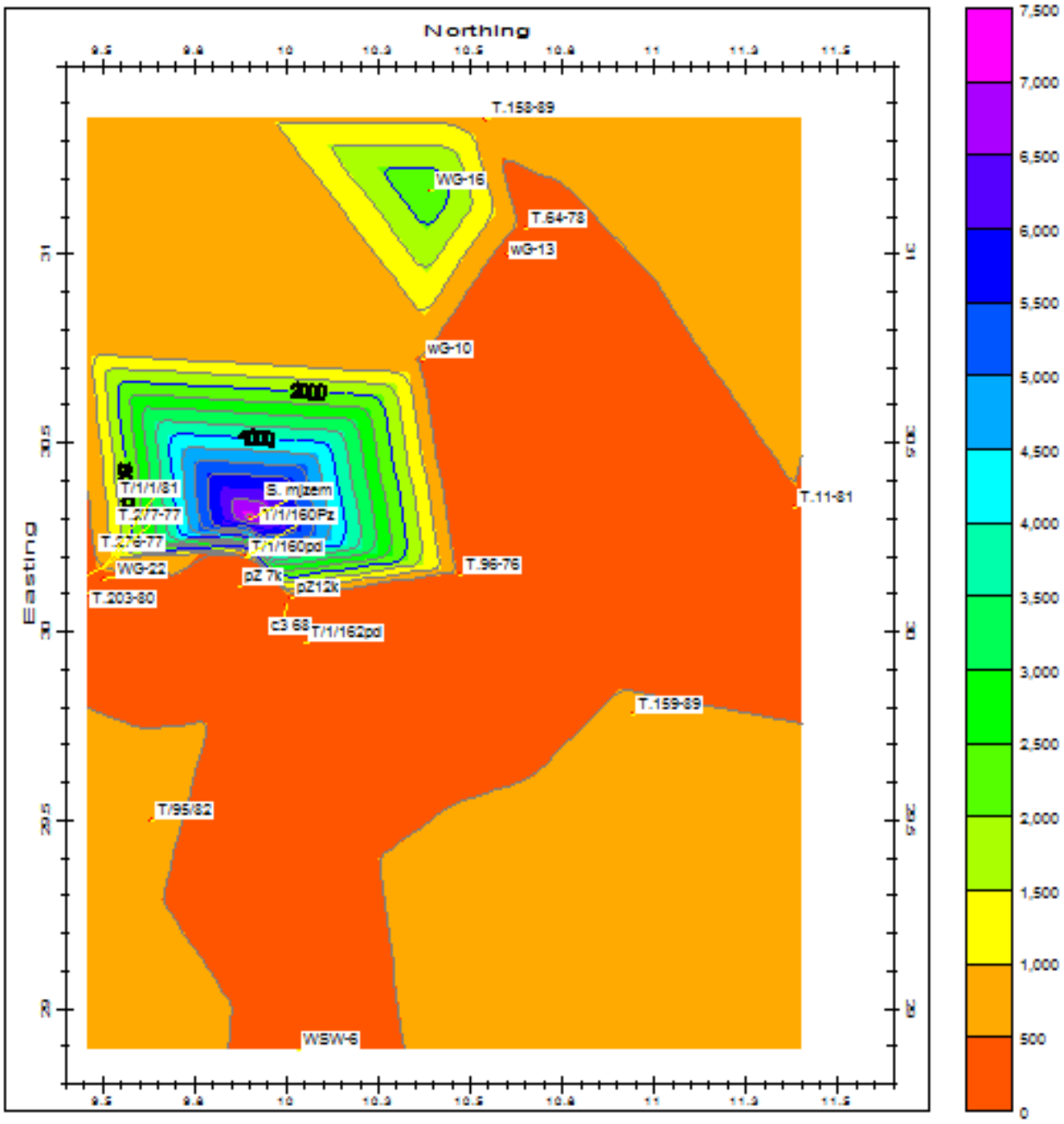
(Source:- Researcher's work depend on the outcomes of chemical breaking down of water specimens from highly saline wells)

Format (84):- Map of the geographical apportionment of chlorine ion in mg/L in water samples from highly salinity wells in the region of study



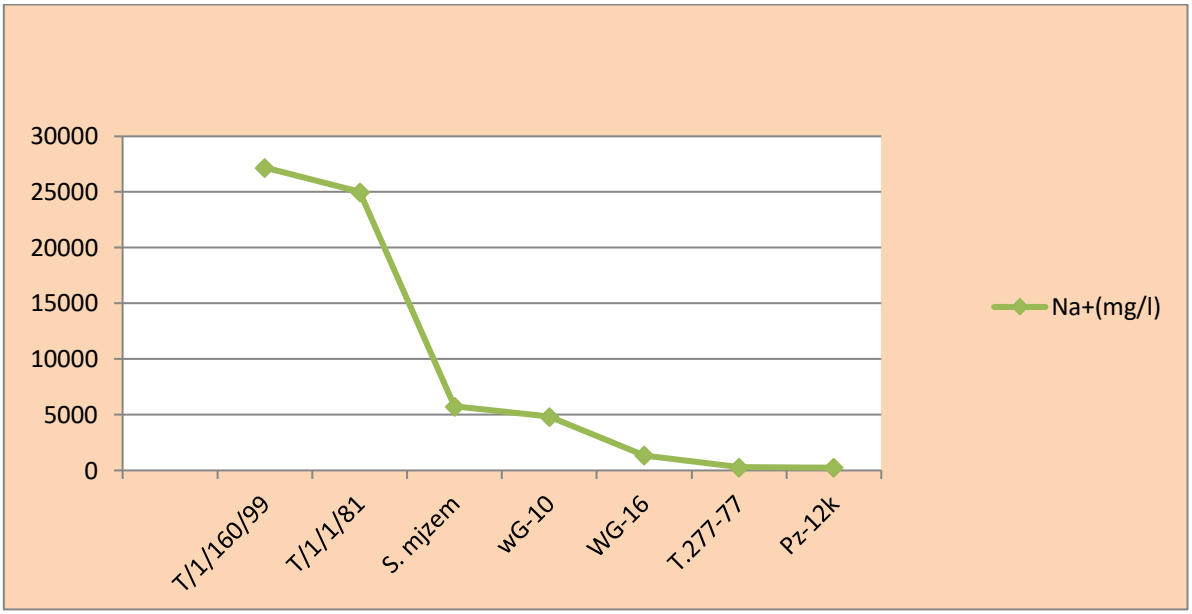
(Source:- Researcher's work depend on the findings of chemical analysis of water specimens from highly saline wells)

Format (85):- Map of the geographical apportionment of sulfate ion in mg/L in water samples from highly salinity wells in the region of study



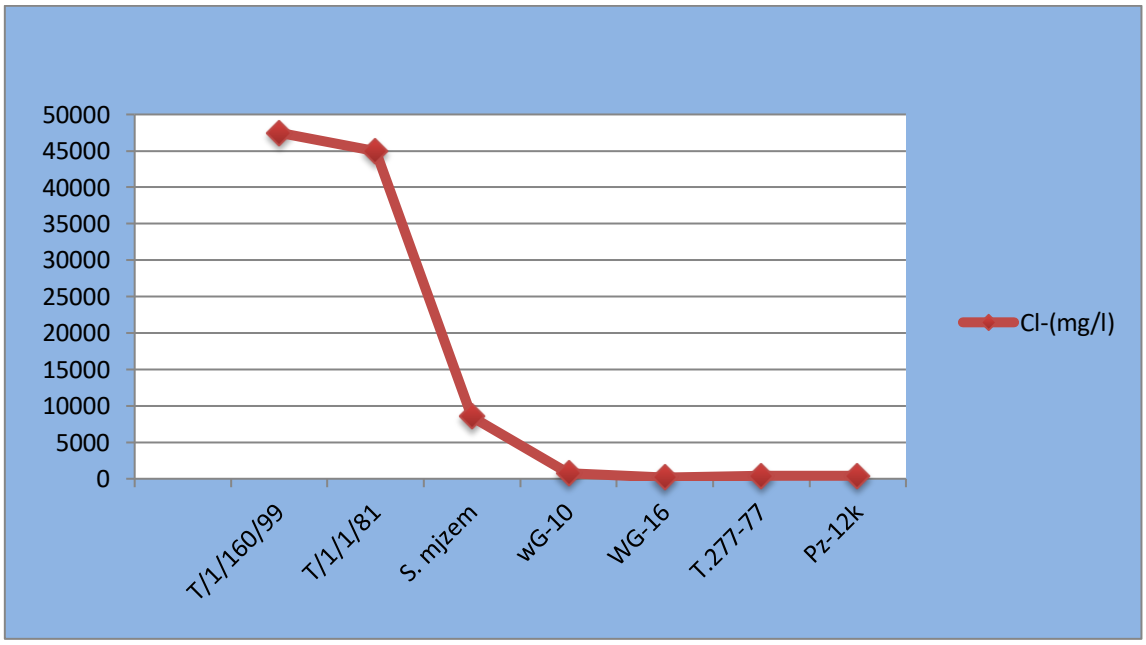
(Source:- Researcher's work depend on the outcomes of chemical breaking down of water specimens from highly saline wells)

Figure (86):- Change in sodium concentrations in highly salinity wells in the region of study



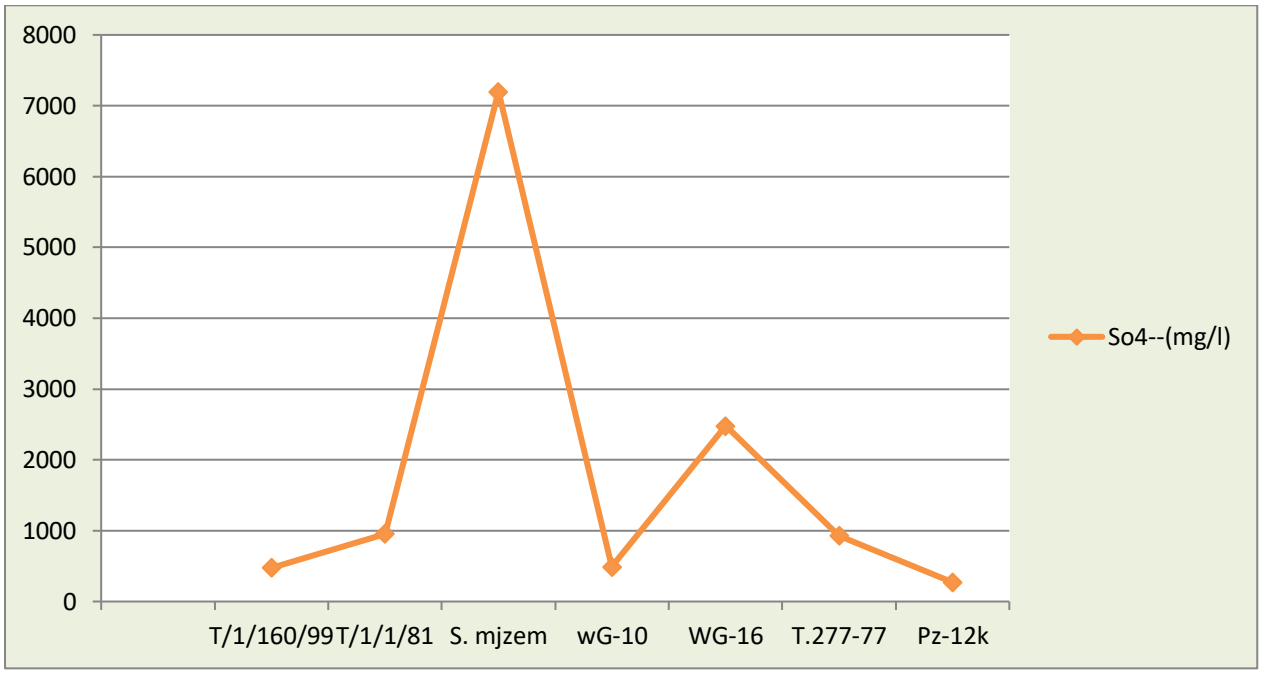
(Source:- Researcher's work depend on the outcomes of chemical breaking down of well water specimens and its graphical representation)

Figure (87):- Change in chlorine concentrations in highly salinity wells in the region of study



(Source:- researcher's work depend on the findings of chemical analysis of well water specimens and its graphical representation)

Figure (88):- Altered in the emphasis of sulfates in highly saline wells in the region of study



(Source:- Researcher's work depend on the findings of chemical analysis of well water specimens and its graphical representation)

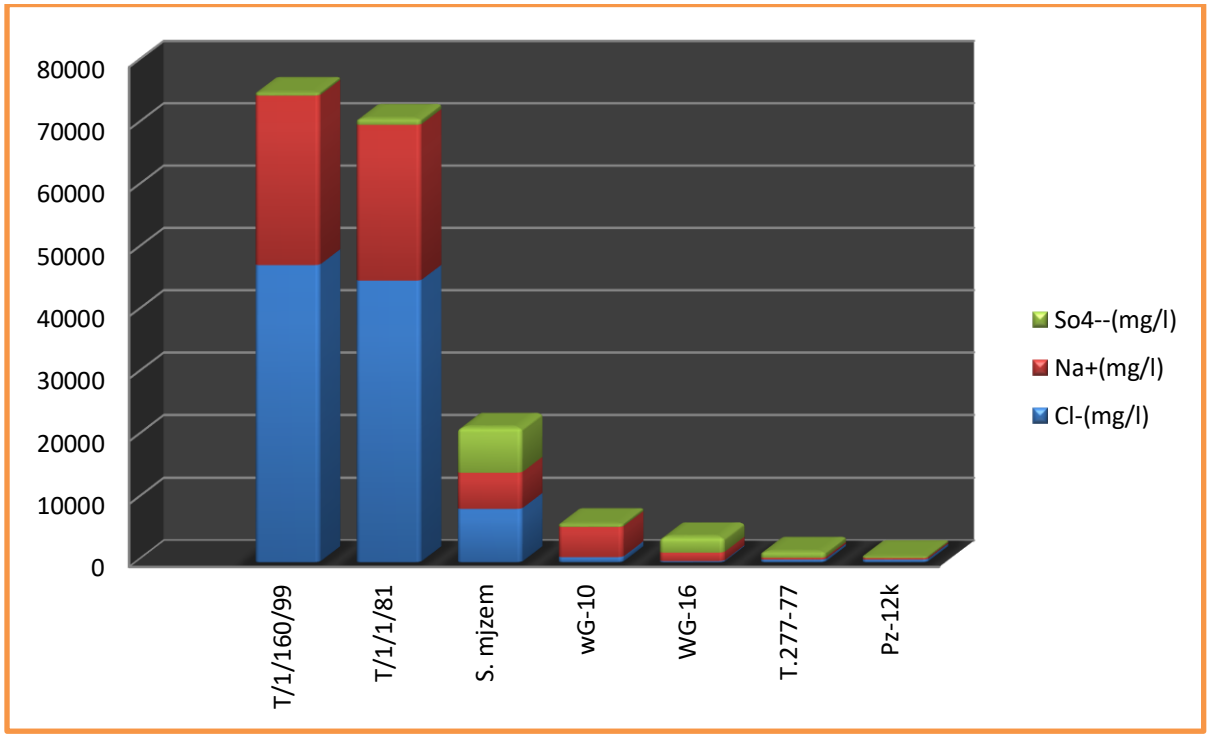
5.7.*Phenomena of Sudden Salinity, Pressure Drop and Lack O Influx in certain Wells of the region f of study*

5.7.1 Evolve of the phenomenology

1. Given that Ghadames Basin is one the biggest sedimentary tubs in Libya, which is by marked of aquifers represented by the formations of Mezda, Qasr Tigirinnah, Nalut and Kiklah. General Water Authority has studied this basin to determine the possibility of the basin as a source of groundwater, and most of these studies in the Ghadames area showed that there was a surprise raising in imphasis in total melt salts (T.D.S), arrive to 19000 mg/L with decline in productivity in the water of Kiklah composition as in wells WG-10, WG-9, in conformity with studies (1980), as shown by (BRL) in 1997, there was a change in some of the wells drilled in Kiklah Formation with a decline in productivity. This change was supported by (OSS) in the study in (2003) As to with regard Bea the system of water reservoirs of the Northwest Desert, which includes Tunisia, Algeria and Libya.

2. After digging the exploration wells and the supervised wells in the region , the borehole (T/160/99), that falls in the Wadi Awal and on the eastern sides of the Megzem Subkha, showed a sudden to the emergence of high salinity water. The emphasis of dissolved solids reached 79000 mg/L . The well (T/1/1/81), well (T/ 277/77) and well (T/203/80). The newly dug observation wells in Ghadames Basin did not show this phenomenon except the well (PZ-2K), which be situated in the north flank of the well field that feeds the Man-Made River system. These wells also showed a decrease in pressure and a decline in productivity and sheath problems .
3. Wells etched into the top part of Mezda and Nalut composition did not emerge an raising in the emphasis of total dissolved salts. It was not more than 1550 mg/L, while artesian wells newly drilled in the field of Ghadames in Ain Tobi Formation, showed total dissolved solids ranging from 5000 to 6000 mg/L.

Figure (89):- The relationship emphasis sodium and chlorine and sulfate in highly saline wells in the region of study .



(Source:- Researcher's work depend on the findings of chemical analysis of well water specimens and its graphical representation)

5.7.2. *Appearances of Phenomenal of Salinization*

In this current study, the appearances identified in the action field-based for the salinity phenomenon are summarized below :-

1. The surprising rise in the emphasis of total dissolved solids (79000 mg/L).
2. The rise occurred during a short period of time not exceeding (3) minutes and after about (10) minutes from the beginning of pumping.
3. Stopping the self-flow after locking (decline of productivity).
4. Flow occurs after the well is opened when injected with quantities of water and return to normal productivity and salinity after a short period of time.
5. The artesian pressure level in the well is reduced from several meters above the ground to a large level below the surface. This phenomenon, as in the well (T/160/99), was not observed in the nearby observation well, which is 35 meters away.

5.7.3. Aspects of Studying the Phenomenon of Salinity

Accordingly on the outcomes of study, the current study dealt with this phenomenon from the following aspects :-

1. Studying the stratigraphy and subsurface rock formations to determine the possibility of saline layers or rocks in the upper formations, and the limits of their spread, thickness and depth.
2. Take advantage hydro-chemical study of water samples from highly saline wells to monitor water quality and salinity concentration .
3. Correlation of the designs of old wells and modern wells that suffer from problems of high salinity water to assess the impact of design elements and completion on the emergence of this problem.
4. Geological study of the regime on the motion of water in underground layers , in especially Kiklah composition
5. Studying hydraulic determinants of Kiklah aquifer and its relation to the hydraulic constants of the upper formations and the underlying formations.

5.7.4. Field Tests Confirming The Phenomenon of Salinity

The researcher conducted several field tests for 2 boreholes in the district of study to ensure the presence of salinity phenomenon, and the most important of these tests are :-

1. Field Test of Well (T/160/99)

When testing experimental pumping well T/160/99, located in Wadi Awal, about 8 km east of Ain Tobi, Subkha Mejzem, and gauge the attributes of water samples in the field, the outcomes were as follows below :-

- The level of static water is 37+ m above ground.
- The productivity is (400) m^3/h with self-flowing.
- Water drawdown is (34) meters.
- Total dissolved solids reach (800) mg/L.
- Temperature is about (39) °C.
- The electrical conductivity (EC) around (1250) µm/cm.

a • The results of the multi-stage and long-term pumping experiment showed the appearance of high-salinity water in the well within a short period of time not exceeding (3) minutes, and after about 10 minutes from the beginning of pumping, where a water sample was taken and chemical measurements were made and the results were as follows:-

- The electrical conductivity (EC) is about (129800) µm/cm.

- Total dissolved salts (T.D.S) reached to (79544) mg/L.

b • It was observed that when the well was locked for more than (3) days and when it was opened again, there was no flow systematically of the well declined from (37+) top of the ground evenl to (60) beneath from surface of the earth . And it is worth mentioning that, where the phenomenon of high salinity accompanied by no self-flow was identified, there was no impact of it in the water specimen from the adjacent observation well, which was about 35 meters away .

2. ***Field Test of Well:- (T/1/81)***

a. The well was closed before operating for two days

b. The well was operated with a 55 hp pump.

c. The results of field measurements was as following lines :-

- The electricity conduction (EC) is around 1396 µm /cm .

- amounted melt salts (T.D.S) are around (860)mg/L

- Water temperature is about (34.8) °C.

d. After about (25) minutes of pumping, flowing water was so salty . The findings of the measurements were as shown below lines :- -

- Electrical conduction (EC) is roughly 121300 µm/cm .

- Amounted melt salts (T.D.S) reached (56000) mg/L.

- After another 15 minutes of pumping, water salinity began to decline from highly saline to medium saline to saline water and finally normal saline water over time.

5.7.5.Causes of Phenomenon of High Salinity in Some Selected Wells

It was observed in water wells, which showed the phenomenon of sudden high salinity, pressure drop and lack of flow, such as wells (T/1/1/81, T/160/99, WG-22, T/64/78, WG-16, and WG10), higher emphasis of sodium, chlorine, calcium and sulfate ions and decrease in water temperature compared to other wells in the area.

Also, the distance from these wells off the coast excludes the hypothesis of seawater intervention as a cause for the higher saline of water, and probably the cause for the existence of this phenomenon, from the researcher's point of view, is one or more of the following reasons :-

- Hydraulic contact between Kiklah aquifer and the deep groundwater aquifer (Ras Hamia) particular in the existence of defects and crackings in below the surface rock for the region of study.

● Leakage of marsh water in the region through faults, cracks, joints and caves that exist in many formations.

● There are also carbonate rocks, gypsum and higher concentrations of salinity in Sidi Assaid Formation (Yefirin Member and Ain Tobi Member).

- The possibility of a leakage of saline water behind the pipes wrapper at the top , due to of lack of cohesion of the cement plug around the pipes, confirms that this high salinity does not appear in the adjacent surveillance wells .
- Decline in water temperature supports the mixing hypothesis of upper aquifers, especially since studies have shown that the phenomenon of high salinity is usually near petroleum and gas fields and far from the seaboards of the sea, as a result of the meltwater interactions of salt minerals or gypsum or groundwater leak of sewerage sanitation water. This is sure by the cylindrical core samples obtained from Ain Tobi Formation, the highest point of Kiklah Formation, consisting of halite or rock salt (Na CL). It also confirms the direct impact of this cause of the phenomenon that the new wells drilled in the region, which relied the new layout of the borehole , and which relyed on the insulation of the layers above Kikla Formation (Yefirin and Ain Tobi members), which contains layers of salt rock. As the cylindrical core samples indicate, these wells did not show this phenomenon either at the start of operation and pumping or after a period of locking the well and then restarted .

5.6.7. .*Considerations for Avoiding Phenomenon of high Salinity*

In In order to avert the problem of surprise saline, decline of pressure and shortage of influx in the wells to be dug it up , there must be following conditions are :-

1. Adoption of the new design of the wells at the feat process, which was interested with cover and segregation the salt layers in the formations above Kiklah Formation.
2. Interest in conducting a photography (conductivity log) to determine and know the different salinity degrees.
3. Attention to the imaging measure of the degree of cohesion of cement behind casing (CBL), (VDL) after locking the well and thus know the part or depth from which saline water is leaked into Kiklah aquifer.

4. Follow-up of phenomenon of non-flow the region of study after locking wells for a certain period and stop pumping. When the well is operated, the flow is self-inflated only after the well is injected with water and saline water gets out of the pumper .The outpouring adopt on the denser of the saline water leaking into Kiklah aquifer from above.
5. A careful study of cylindrical core samples collected from the salt layers above Kiklah aquifer, which is often composed of cohesive salt rock. There is also a need to know the depths on which these layers exist and their relationship to cracks, cracks, faults, joints and caves in the rock layers. This is due to its direct relationship with the saline water leakage of the aquifer and its flow decline.

5.8 CONCLUSION

The study has drawn a number of conclusions that for condition of water , quo of the currently exploited wells, in addition to recognizing the phenomena of sudden rise in salinity, lack of pressure and low productivity in many wells that exploit Kiklah Formation in Ghadames Basin .

The study has also come out with a set of recommendations and proposals that should be take care when the well dug .

Study have a considerable bearing on the water status of a region, which located in the dry climate, characterized by low rainfall and lack of consistency and the absence of currents durable or temporary as deep ravines, also decreasing the quantum of water leaking to feed the aquifers on account to the nature of currents which pressurized , often be fragile , the presence of sabkha districts , the normal of the soil and its exposure to erosion with vulnerable permeable . On the one, as well as high evaporation rates due to high temperature, have a large impact on the plant cover , the motion of on roof the impediment for overflows in the case of happened . Furthermore , these factors cause decrease in water influx and water qualitative water and in underground reservoirs. The utilization of these reservoirs is highly dense with low feeding rates .This has had a passive effect on the water equilibrium of the region as score of the drop water level in these tubs and the regression of the productivity of wells tapped and salts of water over time with the intensity of exploitation.

Hydrogeological studies, results of exploration wells and geophysical well logs of the basin is a viable water source. Water-bearing layers in this basin represent water potentials that can be exploited .The most important reservoirs in the district are, Nalut, Killah and Rass Hamia reservoirs, particular in the borehole fields situated in the district of the Man-Made River that were their utilization in the Ghadames- zwara- Alzawia system .

Kiklah reservoir is the principal reservoir widespread use in the region of study. Its depth varies within the area (300-1200) meters below the surface. This variation in deep is because to the presence of many faults in the region.

The study of the geophysical well logs and the drilling products of the drilled wells that utilize this aquifer indicates that the top of this aquifer is overlapping with the Ain Tobi aquifer, as well as its lower part overlapping with Takbal Formation. Practically, there are obstacles that make it difficult to exploit the water supplies of this aquifer. Some of them are

geographical, such as mountainous areas, plateaus, swamps, while others are hydraulic, like deep of the wells, the move of water the regression in well productivity.

It is evident that there are many risks related to this aquifer and their effect on its water exploitation. Some of these risks are:-

▪ Periodic emergence of water salinity.

▪ Low water level and disappearance of artesian property in many wells of the region, which led to increased cost of drilling wells.

▪ Sudden increase in water salinity in conjunction with the lack of hydrostatic pressure and the gradual decrease in productivity after operating and locking wells.

▪ Returning of the well to self-flow after the injection of a quantity of water.

▪ Water discharge with very high salinity with the start of pumping again.

The study demonstrated a big variation in productive , the boreholes chosen , between (27-400) m3/ hour. In operationally , this divergence in the qualitative and productivity maybe caused to :-

▪ Divergence in the formation up geological and installation of basin

▪ Differed in the quantifiable of water in the tub and recharge ratios .

▪ Acreage and broadening of the tub and variations in thickness insider the confines of the region of study

▪ Structural changes under the surface

▪ Change in water velocity and direction of move in the aquifer

▪ Variation in the stockp factor and the loss modulus of water load-bearing layers

▪ The alteration in the valued of permeable level ,of water flow towards the refinery, or the closure of the drain holes due to some sediments or paucity water .

The study has revealed that the wells that do not suffer from any technical or design troubles or altered in the qualitative of their water, their qualitative production increase with the decline of people’s needs. This is evident of the efficiency and quality of the production of these wells. Wells with many problems have low quality production, low quality water and low efficiency.

The hydro-chemical studies of water specimens from the selected wells, which uses Kiklah Formation, found that these water samples are classified according to their specifications in most cases from fresh and water average brackish in the condition of wells that do not suffer from any problems. It was also possible to conclude that the chemical facies prevailing in water specimens are the facies of sodium, calcium and chlorine.

As of new resolve wells in the region, it was concluded that they were designed according to the following considerations :-

● Nature and properties of the natural sequence and rock formations.

- Composition Configuration and characterize of the lithological water-bearing layers and the identification of the salts layers and depths.

● The total thickness of water-bearing layers in Kiklah Formation exploited by the selected wells.

- Depth to the level of the satiated part of the carrier layer of water .
- The requested throughput of the well and its quality.

● Water quality.

● Subsurface areas were covered with cracks, faults, joints and caves.

● Separating the parts and formations above the aquifer and isolating them using cement so as not to be a source of salinity leakage.

● Accurate visual geophysical imaging (CCTU) for the treatment of any separations in casing pipes and screens.

The equipment used in the processing, accomplishment and carrying out of the wells with the new design was made using CRB pipes and screens instead of casing pipes and stainless galvanized iron screens used in the old design cement specially selected for its high resisting was used for the practical of cementing and lining of the wells, which is carried out in one phase of the portion user from the forming of the crust to the surface.

The sudden rise in salinity, the lack of hydrostatic pressure and the decrease in productivity observed in some wells that exploit the deep Kiklah aquifer were very common in the region of study. It was presumed that the sudden increase in salinity is due to an overlap or leakage of saline water from the aquifers above Kiklah Formation or from Sabkhat spread in some parts of the region. This conclusion is supported by the following points:-

a. ***Structural Design***:- studies show that the selected wells penetrated a number of formations before breaking through Kiklah Formation. These are the formations of Qasar Tigirinnah, Nalut and Sidi Assid (Yefirin Member and Ain Tobi Member). The study of exploratory drilling samples also show that salt rocks (gypsum-anhydrite-halite) represent thick overlays in Sidi Assid Formation, which is higher than Kiklah Formation, especially Ain Tobi Member.

b. ***Cylindrical core samples:-*** studied and described for formations above Kiklah Formation, especially Sidi Assid Formation (Yefirin Member and Ain Tobi Member), proved that the lithological structure and the rocky description of these samples indicate that these formations r constitute evaporation precipitates of gypsum, anhydrite and halite, which is a source of salinity expected to leak.

c. ***Studying structural characteristics***:- The presence of many cracks, faults, joints and caves was interpreted as outlets of water leakage from these formations to Kiklah aquifer, which is located below. It meant that there was a hydraulic connection between these formations and Kiklah aquifer.

5.9 RECOMMENDATIONS

These recommendations include a set of proposals presented by the current study to avoid the problems of wells exploited in the region and to address the phenomena of sudden rise of salinity, lack of hydrostatic pressure and productivity decline in many of these wells.

Are as follows the most important suggestions made by the researcher:-

1. It is necessary to work on separating the wells that have been affected by the salinity phenomenon and not exploiting them at the present time . The well design to be used should ensure the specifications of the processing, completion and isolation of the layers above Kiklah Formation and the prevention of hydraulic contact between them. This was suggested with the purpose of controlling these wells as a source of high salinity with their gypsum content and saline interference.
2. The design should take into account the changing geological and hydrogeological circumstances in the different portions of the region of study. Attention should also be paid to the selection of materials for the preparation and implementation of wells, especially the casing pipes and screens, which should be made of materials resistant to the effect of high salinity and corrosion processes.
3. The accurate geophysical imaging of wells (CCTV) during the completion and processing of these wells to determine the location of any breaks or separations it should be from the priorities between the casing pipes and the screens to avoid the occurrence of leaks or losses..
4. Establishing a wide network of control wells to monitor the water levels and change in quality periodically to predict any problems that may arise with productive wells and exploited for the aquifer or any defect in the exploitation system of these wells to determine the appropriate maintenance methods in a timely manner.
5. Governorate the water of the aquifer the water from contamination by stopping the random drilling by citizens and public bodies, while adhering to the technical specifications and construction designs approved in the processing and completion of wells by (General Water Authority).
6. Rationalization of consumption and reconsideration of water balance in the region through the expansion of quantitative and qualitative studies and raising the public the scarcity problem that faces the underground water resources in this region .

7. Coordination with the participating countries in the basin within the consultation mechanism of the Sahara and Sahel Observatory for all information, data and statistics regarding the exploiting of the pelvis and work continually and cyclic to determination the mathematical paradigm of the pelvis and follow the changes and manifestations that influence in it , in light of the enormous water potential of the huge water-bearing layers in Kiklah aquifer, which calls for study and analysis and continuous scrutiny of its large data to be optimally exploited.

5.10 REFERENCES

Abuloqma, M. (1995). *A study of the geography of Libya*. The Libyan House for Publishing, Distribution and Advertising. Tripoli, Libya.

Al-Futtaisi, R., Radhi, M. (2007). *Technical Report on Field Visits and Field Measurements of the Ghadames Basin Area*. Unpublished Report. General Water Authority. Tripoli, Libya.

Al-Futtaisi, R. (2007). *A Study of the Phenomenon of Sudden Increase in Water Salinity in Some Productive Water Wells in Ghadames Basin*. Unpublished Report. GWA. Tripoli, Libya.

Al-Salawi, M. (1986). *Groundwater between Theory and Practice*. Publications of Dar Al-Jamahiriya. Tripoli, Libya.

Al-Salawi, M. (1997). *Practical Applications in Groundwater*. Publications of Dar Al-Jamahiriya. Tripoli, Libya.

Al-Talhi, J. A. (2004). *So as Not to Die Thirst*. The Libyan House for Publication, Distribution and Advertising. Tripoli, Libya.

Arab Center for Studies of Arid Zones and Drylands (ACSAD). (1985). *Lectures on Water and its Applications*. Center Press. Damascus, Syria, pp.23-25.

Arab Center for Studies of Arid Zones and Drylands (ACSAD). (2002). *Study and Mapping of Natural Resources, Agricultural Use and Planning*. Publication Center. Damascus, Syria, pp. 12-23.

Banana, M. E. (1998). *Applied Geoengineering*. Arab Institute for Development. Institute Publications. Tripoli, Libya, pp. 63-71.

Bertello, F. (2003). *An Overview of the Evolution and Petroleum Systems of the Eastern Ghadames (Hamra) Basin, Libya.* AAPG Hedberg Conference, Palaeozoic and Petroleum systems in North Africa, Algiers, Algeria, AAPG.

Bogomulov, C. (1983). *Water Geology and Principles of Applied Geology*. Dar Mir of Press and Publication. 3rd ed. Susco, p. 88.

Bokhary, M. Salem,O. (1999). *Why The Great Man-Made River Project?* Conference of Regional Aquifer Systems in Arid Zones. Managing Non-Renewable Resources. Tripoli, Libya.

BRL Engineering Project (1997). *Water Resources in Ghadames Basin*. GWA, Tripoli, Libya.

Davis, S. N. and R. J. Dewiest (1999). *Hydrogeology*. New York. John Wiley & Sons.

Deutsch, W. J. (1997). *Groundwater Geochemistry:- Fundamentals and Applications*. Lewis Publishers. San Francisco.

Diebe, N. (2009). *Digitizing the Structural Map of Libya*. Unpublished Report. General Water Authority. Tripoli, Libya.

Diebe, N. (2018). *Geology and Geochemistry of Underground Water in the Eastern Parts of Ghadames Basin*. Publications of Technical Water Affairs Institute. Tripoli, Libya.

Durarkha, K. (1988). *Hydrogeology of Groundwater*. Dar Al Bashir for Printing and Publication. Amman, Jordan.

Elchikh, K. (1998). *Geology and Oil in Ghadames Basin, Northwest Libya.* Conference of Petroleum Geology in North Africa. London. UK.

Energo Project (1976). Preliminary Report on Regional Groundwater Hydrology in *Ghadames Basin, North Western Libya.* GWA. Tripoli, Libya.

Engineering Consultant Office (1997). *Water Transfer Project from Ghadames Basin to the Western Region of Jafara Plain and West Bay*. GWA Report. Tripoli, Libya.

General People's Committee of Agriculture (1984). Climate of Libya (Measures and Indicators). Tripoli, Libya.

General People's Committee of Education (1985). *Educational Atlas*. Map Serve Publication House, Stockholm, Sweden, p. 41.

General Water Authority (1983). *Report on Water and Soil:- Studying the Possibility of Reclamation And Cultivation Of The Area Located In The East And South-East of Derj Area*. GWA. Documentation Center. Tripoli, Libya.

General Water Authority (1982). *Classification of Three Land Areas of Ghadames Basin.* GWA. Documentation Center. Tripoli, Libya.

General Water Authority (1991). *Libya Rain Map*. GWA. Documentation Center. Tripoli, Libya.

General Water Authority (2002). *Final Technical Reports of Water Wells in Ghadames Basin*. GWA. Documentation Center. Tripoli, Libya.

General Water Authority (2003). *Summary of the Results of the Study of North-western Desert of Libya and the System of The Great Man-Made River Project*. GWA. Documentation Center. Tripoli, Libya.

General Water Authority (2006). *Water Situation in Libya*. GWA. Documentation Center. Tripoli, Libya.

General Water Authority (2019). *Final Technical Reports of Structural Designs of Water Wells in Ghadames Basin, North West Libya*. GWA. Documentation Center. Tripoli, Libya.

Goudarzi, G. (1980). *Structural Map of Libya*. Geology of Libya, Book III, pp. 879-892. Tripoli, Libya. Academic Press.

Hamid, W. F. (2006). *Assessment of the Quality of Groundwater of Kiklah Aquifer in the Western Part of Ghadames Basin, Northwest Libya*. Unpublished Report. GWA. Documentation Center. Tripoli, Libya.

Hamouda ,(1989). *The Earth:- Introduction to Natural Geology*. Publications of Al Fateh Complex of Universities. Tripoli, Libya.

IRC. (1979). *Geological Map of Libya:- Ghadames Basin*. Publication of Industrial Research Center. Tripoli, Libya.

Jacob, C. (1946). Engineering, Hydraulics and Groundwater. J. Wiley and Sons, New York.

Khalil, E. M. (2005). *Groundwater and Wells.* Dar Al-Kutub Al-A'almia for Publication and Distribution. 2nd ed. Cairo, Egypt.

OSS (2009). Water Basin in North western Desert of Libya. GWA. Documentation Center. Tripoli, Libya.

Pallas, p , (1980) water Resources in Jamahiriya Arab Libyan people′s Socialist , The Geology of Libya , Second Symposium Geology of Libya .

Pallas, P. Salem, O. (1999). *Utilization and Management of Water Resources in Libya*. GWA. Documentation Center. Tripoli, Libya.

Pizzi, G. (2001). Modelling of the Western Libya Aquifer System:- Technical Documents in Hydrology. UNESCO.

Radhi, M. A. (2003). *Report on Abnormal Phenomena in Water Test on Well № (T/160/99), Ghadames Area*. Unpublished Report. GWA. Documentation Center. Tripoli, Libya.

Radhi, M. A. (2006). *Report on the Decreasing of Productivity and Increasing of Salinity of Well № (T/160/99), Ghadames Area.* Unpublished Report. GWA. Documentation Center. Tripoli, Libya.

Radhi, M. A. and M. El-Aqeel (2006). *Geology and Hydrology of the Southwestern Ghadames Basin, Northwest Libya.* Unpublished Report. GWA. Documentation Center. Tripoli, Libya.

Radhi, M. A. (2007). *Detailed Studies on water Quality of Kiklah Aquifer, North western Libya*. GWA. Documentation Center. Tripoli, Libya.

Rashrash, S. Farag,H. (2016). *Evaluation of Water Resources in Ghadames Basin*. Libya Journal of Water Resources and Protection (8) 1191-1209.

Sakr, A. (1982). Water Wells. Dar El-Falah for Publication. 2nd ed. Kuwait.

Serafascaf, M. (1981). *Hydrogeological Studies of Ghadames, Derj and Senawen, Northwest Libya*. GWA. Documentation Center , public Authority for water . Tripoli, Libya.

Sinha, S. C. (1981). *On the Application of Geophysical Logging in the Assessment of Ground Water Potential in Al-Hamada Al-Hamra Region*. Academic Press.

Srivastava, M. L. (1977). *A Note on the Occurrence of Springs in Ghdamas-Derj-Sinawn Area*. GWA. Documentation Center. Tripoli, Libya.

(1980). *Groundwater Hydrology*. J. Wiley and Sons, New York.

Underdown, R. Redfern,J. (2008). Petroleum Generation and Migration in *Ghadames Basin, North Africa:- A two-dimensional* Basin Modelling study. AAPG Bulletin, 92(1), pp 53-76.

World Water Council (WWC) (2013). *Report on Water Resources Management and Basin Study*. The Hague, pp.8-11.

BIOGRAPHY

Mr Adel Ahmed Ewhaida was born on Dec 25, 1975, in Azzawia, northwest Libya, in 1975. He received his compulsory education and the secondary school in Azzawia. He holds a BA in Geography (1998) from Azzawia University. In 2009, Adel received his Master's Degree in Hydro-geography from Academy of Postgraduate Studies, Tripoli/Libya, with a dissertation titled "***Seawater Intrusion and its Impact on the Productivity of Agricultural Crops, and its Relation to the Development of Water Situation in the Quaternary Aquifer, Northwest of Libya***".

Mr. Adel's career background spans a diverse range of teaching experiences:- 6 years (2003-2008) as a school teacher in two different high schools in Azzawia, and 4 years (2011-2014) as a full-time university teacher (assistant lecturer) in the Dept. of Geography/Faculty of Arts/Alzzawia University, teaching postgraduate students a variety of subjects, including *Biogeography, Water Resources***,** *Climate Geography, Geomorphology, Physical Geography, and Population Geography*.

Mr Adel has published some refereed scientific papers in national and international scientific journals, which are related to Hydrogeology. One paper has been published by peer reviewed online journal "***Journal of Water Chemistry and Technology"***, under title of (***Hydro-chemical quality of well water in Ghadames area in northwestern Libya***).