The Unesco Regional Office for Science and Technology for the Arab States

Unesco - ROSTAS

The Arab Centre for the Studies of Arid Zones and Dry Lands

ACSAD

Translated from the original Arabic version
Paris, 1986

THE MAJOR REGIONAL PROJECT ON RATIONAL UTILIZATION AND CONSERVATION OF WATER RESOURCES IN THE RURAL AREAS OF THE ARAB STATES WITH EMPHASIS ON THE TRADITIONAL WATER SYSTEMS

UNESCO/ACSAD

Distribution: limited
ROSTAS/HYD/1/86

On the basis of country reports submitted by experts from the Arab countries, and results of a number of meetings and working groups, at the regional level, the original manuscript of this document was prepared in Arabic, in 1985, by the Unesco Regional Office for Science and Technology for the Arab States (Unesco/ROSTAS) and the Arab Centre for the studies of Arid Zones and Dry Lands (ACSAD). Due to the large number of experts who took part in this work (see acknowledgement) an apology is extended to those whose names were inadvertently dropped.

The present English version is the translation made, in 1986, by Dr. Muin Baasiri of the American University of Beirut, Lebanon.

ROSTAS/HYD/1/86
Paris, 1986

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SUMMARY AND CONCLUSIONS

This report represents the first two parts of the Regional Report on the Rational Utilization and Conservation of Water Resources in the Rural Areas of the Arab States with Emphasis on the Traditional Water Systems. It contains five chapters, three of which belong to the first part, and two to the second.

The first chapter starts with a general introduction to the report and its subject, then it deals with the concept of the project, its birth and purpose; later, it covers the project plan and the stages of evolution and execution until the time of preparing this report. The last part of this chapter contains an analysis of the natural and environmental aspects prevailing in the Arab World and their influence on the resemblance of the various traditional water systems.

The survey and description of the traditional water systems known to the Arab World are the subject of the second chapter. There are 25 systems classified under four groups:

1- Systems for harvesting and storage of surface water, there are six of them.
2- Systems for harvesting and spreading of surface water, there are six of them.
3- Groundwater systems, there are five of them.
4- Water lifting systems, there are eight of them.

For each one of these systems, the survey included a description , the geographic distribution, the method of operation and source of water, and the synonymous names. Also, photos and diagrams were presented.

The last chapter of the first part described the 19 Arab states participating in this report. General information on each state were given: geographic location, population count, area, topography, prevailing climate, and arable land area both potential and used. Then the chapter gives an assessment of the available resources both surface water and groundwater and the methods of their use. The final part of this chapter briefly surveys the available water systems in each state and, when possible, their geographic distribution.

The Second part of the report presents an evaluation of the traditional water systems along with the prospects for their improvement. The first chapter studies the 25 water systems from the standpoint of the importance of their water source, efficiency, water quality, and suitability of the local conditions to operate these systems. The scientific basis for each system was explained. The evaluation of the systems was based on the constructional, economic, social and environmental aspects. Systems improvement is studied with reference to the importance of the systems and the presence or absence of the State's attention in that regard. The result of this study was to identify the promising water systems that were the subject of this report. The promising systems are grouped as follows:

1- Cisterns, small dams, and hafirs were selected from the group of systems used for surface water harvesting and storage.
2- Terraces, diversion dams, and miskat were selected from the group of systems used for surface water harvesting and spreading.
3- Foggaras, shallow wells, and springs were selected from the group of groundwater systems.
4- Saquia, windmills, and solar energy pumps were selected from the group of water lifters.

The last chapter concentrates on the assessment and prospects of improvement of the promising water systems and presents suggestions for raising their efficiency as to cope with the modern age.

Given the prevailing social, economic and environmental changes in addition to the advent in technology, it is conceivable that the promising traditional water systems should benefit from the new technology whenever possible in order to help improve their efficiency.

The reasons for the adoption of traditional water systems in the past are progressively fading away. Now, there are new and different conditions which require the introduction of new water systems. However, this notion should not be considered universal, since under some conditions it may prove harmful. Therefore, every case should be considered individually and a solution should be worked out for it.

The traditional water systems are generally confined to the remote and less developed rural areas, which due to various economic and geographic limitations receive a smaller share in the national development plans than the richer and more productive areas. This fact give rise to a strong justification to pay more attention to the improvement of the traditional water systems, in order to help reduce the development gap among regions of the same country, also to discourage people from migrating from rural areas to the city.

The traditional water systems selected by the Arab working group require essentially considering the following points:

1- The protection of the available water resources from over draft and misuse, and the protection of water systems against neglect. This can be achieved by issueing the proper laws.

2- Improvement of water systems should tackle their basic elements as to enable their use in the proper locations.

3- Making a serious effort in training the beneficiaries of these water systems and creating the level of awareness neccessary for the proper operation and maintenance of these systems.

ACKNOWLEDGEMENT

This volume is considered the fruit of the constructive cooperation between the Arab Center for Studies of Arid Regions and Dry Lands (ACSAD) and the UNESCO Regional Office for the Arab States (ROSTAS). Due to the continuous efforts of the experts from ACSAD, ROSTAS and the Arab States in completing the first phase of the regional project for the maintenance and management of water resources with an emphasis on traditional water systems in the Arab World, it was possible to produce this work which is considered as a starting point in the process to revive some important water systems that have been proven to be viable.

The UNESCO Regional Office and the Arab Center express their appreciation for all the experts who contributed to the completion of the first phase of the project through either supervision and follow-up, preparation and submission of state's report, taking part in the work of the Arab action group and the technical committees, or the preparation of this volume in its final form. Due to the large number of experts who took part in this work, an apology is extended to those whose names were inadvertently dropped.

(a) Experts in Charge of Supervision and Follow-up: Kamal Farid Saad from the UNESCO Regional Office and John Khoury from the Arab Center took a leading role by supervising the project; following up on all the phases; coordinating among the Office, the Center and the Arab states; and contributing in all the committees and meetings, collecting the states reports, and finally reviewing the manuscript.

(b) Experts Who Prepared the Final Report: Shawki Ibrahim from the Arab Center took charge of the major work of organizing and prevailing the contents of the report in their final form. In reviewing the report, he was supported by Abdou Shata from Egypt and Mohamed Hassan Ettayib from Sudan. More help was extended by Mostafa Absi and Michel Zayoun.

(c) Experts Who Prepared the States Reports

- Algeria: the report was prepared by Attaher Alkalali (Rural Research Center), another report was prepared by A. Saidi (National Academy for Water Resources).
- Egypt: the report was prepared by the National Committee for Hydrology under the supervision of Ahamd Ali Kamal, another report was done by Ibrahim Hassan Hamida (Desert Research Academy).
- Iraq: Mohamed Saher Ayoub (National Research Council) and Abdel Ilah Hawa (Arab Center) prepared the report.
- Lebanon: the report was prepared by Muin Baasiri (American University of Beirut and Aref Abdel-Baki (National Research Council).
- Libya: the report was prepared by Alhadi Alhadari (Rural Research Center), another report was prepared by specialists from the Department of Water and Soil.
- Morocco: John Shis and Abdel Hafiz Ashshabi (Rural Research Center) prepared the first report, another one was done by Ismail Zaryouhi (Water Resources Research and Planning Committee).
- Oman: the report was prepared by Mohamed Samir Kotob (Arab Center).
- Qatar: the report was prepared by specialists in the Geology Division - Qatar University).
- Sudan: Mohamed Al-Hasan Attayib Al-Haj (Arab Center) has prepared the report.
- Syria: Salah Kadmani (Ministry of Irrigation and Arab Center) has prepared the report.
- Tunisia: the report was done by Salah Eddine Alamani, al-Hadi al-Hadari, Abdel Hafiz Ashabi, Omar Mutaymit, and Ahmed Mamou (Rural Research Center).
- United Arab Emirates: the report was prepared by Wathek Rasoul Agha (Arab Center).
- People's Democratic of Yemen: the report was prepared by Khalid Abdel Wahab (General Committee for Water).
- Moritania: the report was prepared by Said Zahra (Arab Center).

(d) The Arab Working Group: The UNESCO Regional Office organized in collaboration with the Arab Center a meeting for an Arab working group at the headquarters of UNESCO in Paris during the period between 13 and 24 June, 1983. The objective was to study and analyze the states reports, to set the framework for the regional report on the traditional water systems, also to put the general recommendations pertaining to the selection of the leading projects. The working group had as members Shafik Assafadi (Syria), Abdu Shatta (Egypt), Salah Eddine Alamami (Tunisia), Ismail Zaryouhi (Morocco), Mohamed al-Hassan Attayib (Arab Center), and Kamal Farid Saad (UNESCO/ROSTAS).

(e) The Regional Meeting of the Arab States: The regional meeting on water resources in the Arab States was held in the UNESCO headquarters in Paris in Nov. 21-28, 1983. The report of the Arab working group was discussed and recommendations were presented for future work on the selection and execution of the leading projects. Ahmad Ali Kamal (Egypt) headed the session on traditional water systems, it included experts from: Algeria, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Syria, Tunisia, United Arab Emirates, Arab Yemen, Democratic Yemen, in addition to experts from the Arab Center (ACSAD), the Arab League Education, Culture and Science Organization (ALECSO), and UNESCO (ROSTAS).

To all of these colleagues a word of thanks and appreciation is extended from the UNESCO Regional Office for Science and Technology for the Arab States and the Arab Center for the Studies of Arid Regions and Dry Lands for their contribution and efforts in the execution of the first phase of the leading regional project and in the completion of this volume, hoping it will be useful in exposing the important traditional water systems to the Arab specialists. These systems that were at one time prevailing, some still are, in order to help in their revival and development for promoting water management in the remote rural parts of the dry lands of the Arab World.

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Office for Science & Technology
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CHAPTER I

INTRODUCTION

1- Concept, Birth and Purpose of Project:

The concept of the project entitled "the Rational Use and Management of Water Resources in the Rural Regions of the Arab States with Emphasis on Traditional Water Systems" was initiated upon a recommendation by the Congress of Arab Ministers in charge of the implementation of Science and Technology (CASTEARAB) held in August, 1976. A similar recommendation was issued by the Congress of the Agriculture Ministers in the Arab Gulf States. Also, support for this recommendation came later from regional Arab organizations as the Arab Center for the Studies of Arid Regions and Dry Lands (ACSAD). Approval for the regional project came in the twenty first session of the general congress of the UNESCO held in Belgrad in 1980. The approval covered the general framework and the funding of the project.

The majority of the Arab states suffer from water shortage. This fact necessitates strict management in order to maximize benefits from the available water resources. One aspect of this management may be in promoting the use of traditional water systems that once thrived for a long period, but then received a set back by the introduction and increased use of modern water systems.

The revival of some of the traditional water systems, after being improved, seems to help promise in solving some of the social and economic development problems specially in the rural regions; this is the objective of this project. The project has a number of activities in the fields of social and natural sciences, education and extention. These activities should contribute to the improvement of the local technical potentials, enlighten and educate the population, and improve the local information network. These improvements would help the overall development and life conditions and services in the rural areas. These results are possible only if the following long-term objectives are met:

1-1 Paying attention to the problem of drinking water in order to increase the available quantities and improve its quality.

1-2 Developing the agricultural production as to allow rural regions reach self-sufficiency at a minimum cost.

1-3 Protecting the environment by proper water resources management and soil preservation.

1-4 Limiting people migration from rural regions to urban ones by creating more jobs in the rural regions.

1-5 Making the modern and traditional water systems complete one another while striving at improving water supply.

The short-term objectives are summarized as follows:

1-1 Preparing a list of the available traditional water works and systems and their method of operation.

1-2 Surveying and analyzing these systems in order to identify the potentials for their improvement and the ways for achieving it.

1-3 Specifying the promising traditional water systems.

1-4 Preparing detailed studies for the leading projects using some of the promising water systems in order to improve harvesting and storage of rain water used for drinking and irrigation, to increase soil moisture, to preserve soil, and to improve groundwater abstraction by various methods.

1-5 Training the technicians, involved in water systems and rural development, on the operation and maintenance of these systems.

1-6 Creating interest on the part of the rural people in order to get involved in the execution of the project.

1-7 Encouraging the Arab states to exchange information, knowledge and expertise in the field of traditional water systems.

2- Project Plan

The project plan was prepared during the period between 1981 and 1983, it contains the following activities:

(1) Preparation of survey on the traditional water systems at the state level during 1981-1983.

(2) Collection of states surveys and preparation and distribution of a regional survey document with the knowledge of UNESCO and ACSAD in 1983.

(3) Review of the regional document and preparation of studies for experimental projects during a meeting of the regional committees under the International Hydrologic Program.

To insure the success of the project, it was noted in the plan to ask each state to assign a special committee made out of the present committees or prepare a new one charged with the execution and follow-up of the project. This committee will be the legal party through which all cooperation and correspondance related to the project is done. The success of the project depends upon the active involvement of the concerned Arab state either during the preparation of the list of the traditional water systems, or the execution of the experimental projects as approved by the regional meeting through the support of the state offered to the nominated party. In addition to the technical assistance from the UNESCO Regional Office and its division of water sciences, the UNESCO has allocated from its regural general budget a sum of U.S. $ 220,000 to cover costs incurred by the experts travel, the necessary experimental studies, and the preparation and distribution of extension materials.

Also, the plan took note of the contribution of the Arab Center for Studies of Arid Regions and Dry Lands (ACSAD) in the execution of the project as one of the Arab organizations interested in the development and management of water resources. This contribution is part of the technical cooperation program that ACSAD has with the UNESCO.

A regional meeting was scheduled as part of the plan to take place toward the end of 1983, in order to study the then completed part and to prepare a working program for 1984-85. It is expected that the evaluation of the

project achievements will be done during the general meeting of the UNESCO and its general budget are considered. Based on this, efforts will be made to secure additional funds necessary to execute works of renovation and rehabilitation on the promising traditional water systems.

2-1 Stages of Project Execution:

Since the beginning of 1981 the UNESCO has called for a series of meetings which were held to prepare a plan for the execution of the project in collaboration with a group of Arab experts and the Arab Center (ACSAD). The plan was adopted in June, 1982. Under this plan the Arab center prepared 11 state reports dealing with the Arab traditional water systems, while UNESCO took charge of preparing six other state reports after direct consultation with the concerned Arab Countries.

A meeting organized by UNESCO was held in Paris during the period between 13 and 24 of June, 1983. The meeting was for a group of Arab experts charged with the study of state reports and the preparation of the regional survey of the traditional water systems common in the Arab world. The meeting resulted in setting the framework for the survey and its components, which were included in the report of the Arab group. The recommendations in this report were later discussed in another meeting held in Paris between November 21-28, 1983 under the chairmanship of UNESCO.

Also, the recommendations of the Arab working group presented a classification for the traditional water systems, which consisted of four principal groups:

- Harvesting and storage of surface water
- Harvesting and spreading of surface water
- Groundwater
- Water lifting

Under each group the relevant water systems were identified, also in order to help in the development of some of these systems, the principles for selecting the promising water systems were set.

The UNESCO Regional Office for Science and Technology in the Arab States (ROSTAS) charged the Arab Center (ACSAD) with the preparation of the document for this regional project. The assignment was done because of the Center's regional experience in the Arab World, its close cooperation in the preparation of the earlier phases of the project, its active contribution in the writing of one part of the project reports, and for its attending all the afore mentioned meetings. As indicated earlier, the report was prepared based on the states reports and the recommendations that resulted from the work of the action group and all the other meetings.

This report falls in two parts: the first contains the survey of the traditional water systems prevailing in the Arab states; it includes a general description of the important ones of these systems, their geographic distribution, and their present status. The second part, on the other hand, concentrates on the evaluation of each system with reference to some unified rules. It also covers an analysis of the systems potential for improvements as a final step toward their modernization and revival.

3- Overview of the Natural and Environmental Conditions Prevailing in the Arab World and Their Influence on the Resemblance of the Traditional Water Systems:

The surface area of the Arab World is 14,000,000 Km^2 with an estimated population of 150,000,000. The Arab states cover the south western part of Asia and the northern part of Africa. In the north they are bounded by the southern and eastern coasts of the Mediterranean Sea, the Atlantic Ocean is on the west, while in the south fall the Arabian Gulf, the Indian Ocean and Great African Desert. One may consider the Red Sea, which separates the two continents of Asia and Africa, an Arabian sea, Plate 1.

It is easy for an observer of traditional water systems of the Arab World to note the great resemblance in their types, ways of use and to a greater extent their common names. There are many reasons for this resemblance; they are addressed below:

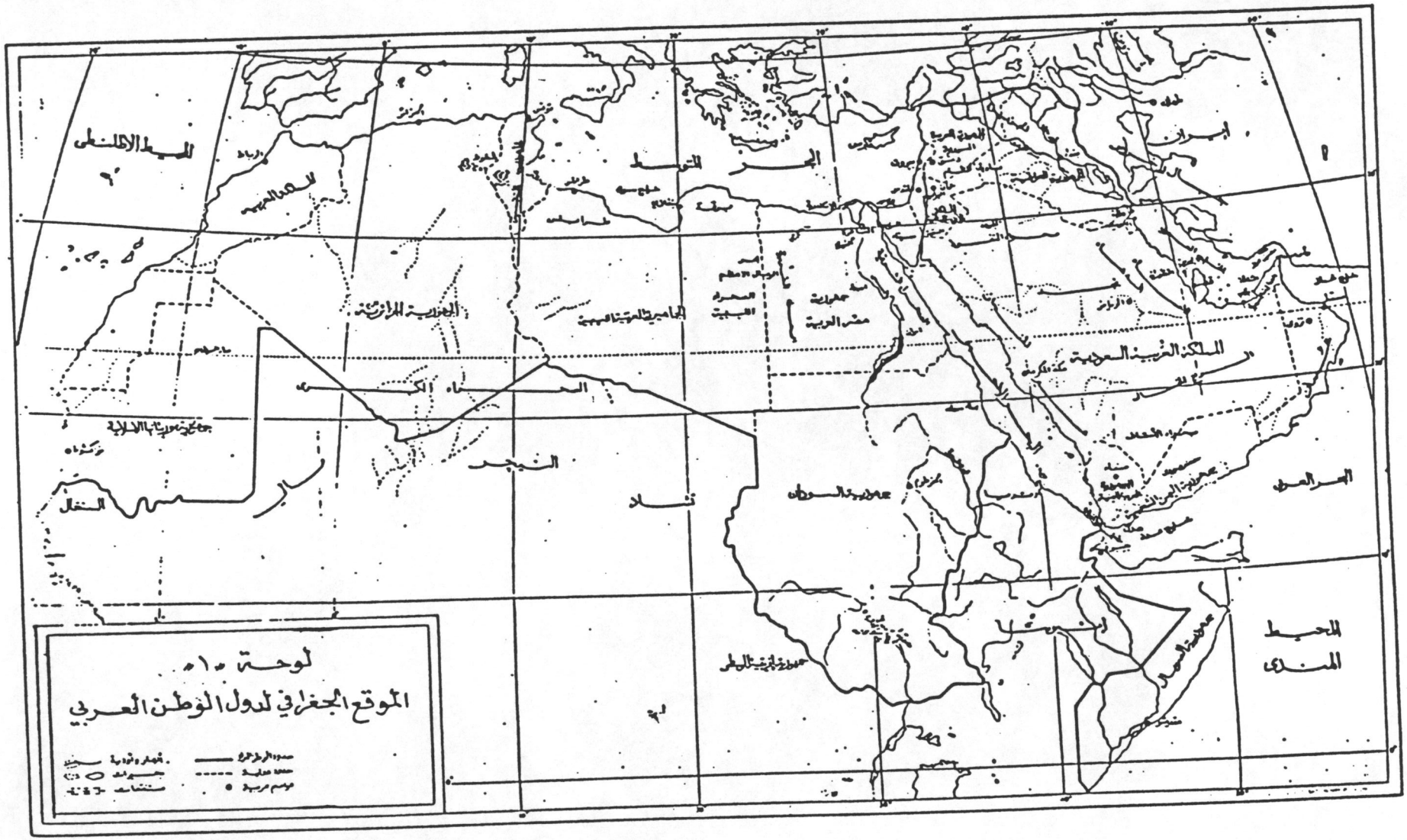

Plate 1. The Geographic Map of the Arab World.

3-1 Historical aspects:

Historians noticed that throughout the recorded history the Arabian land was always connected to each other in one way or another as an integrated unit.

Centuries before Christ during the times of the Romans and Greeks many parts of the northern and central regions of the Arab World were for several centuries controlled first by the Greeks and then by the Romans. The influence of these two civilizations was well pronounced in the colonized countries where a number of water systems became popular; examples of these systems are the Roman wells or the cisterns, the water conveyance systems, the surface wells and the tambour (Archimedes Screw).

With the arrival of Islam, the conquests of the new religion covered the whole Arab World and went even beyond that to include parts of the Persian Empire and reaching the Indian borders in the east and Europe in the north, i.e. Turkey and Spain up to south France. Through their successive states, the Arabs ruled from the Fourth Century till the beginning of the Sixteenth Centure, during this era the Arabs introduced a number of improvements and rennovations on the the prevailing water systems and made the use of these systems more common. The Arab civilization was characterized by significant achievements in the various fields of sciences and their applications as in irrigation, engineering, medecine, etc...

At the close of the Ayoubite State, the Ottoman firm rule began and covered most of the Arab Countries for a long period lasting till the start of World War I during the first quarter of the Twentieth Century. As before, the Ottomans influenced the design and operation of water systems. In fact, some items of the Ottoman Civil Code published in 1870 (The Magazin) by the Turkish administration are still in effect in the water legislation of some Arab states.

Under the western colonization, which lasted until the middle of the current century, the Arab states were subjected to the Italian, French and British mandates after which they succeeded in achieving national independence. Management of water projects was affected by the type of policies then imposed by the colinizing government.

3-2 Climatic Conditions:

The majority of the Arab states fall between latitudes 4° and 37° north of the equator. A region which is characterized by an arid climate. This climate varies between arid, semi-arid and is some parts very dry or dersertic, Plate 2. Therefore, there is resemblance in the climatic aspects, except for variations in the average annual rainfall, time of precipitation, geographic location of precipitation as affected by the arrival time of the saturated air masses coming from the Mediterranean Sea, the Atlantic Ocean or the Indian Ocean, and by the presence of the mountains like the Atlas and Rif Peninsula in the Arab Maghred, the Red Sea mountains, the Ethiopian Hill in Africa, the Arab Shield in Arabia and the mountains of Syria and Lebanon along the east coast of the Mediterranean Sea.Plate 3 shows the annual isoheyts for the Arab World.

3-3 Physiographic Properties:

There is also a resemblance in the physiographic features among the Arab states, Plate 4 presents some of these feasures:

1- The coastal plains are characterized by relatively flat lands; the seasonal streams and rivers flow to the sea where they form deltas, saline spots or sand dunes; the vegetative cover is limited to pasture and small forests, and some agricultural activities are exercised.

2- The internal plains are characterized by level lands and gravely or clayey soils or exposed calcareous rocks. These plains can also be made of vast sand areas as in Algeria's eastern and western regions, the Rabiana sand sea in Libya, the large sand sea extending between Libya and Egypt, and the Empty Quarter in the Kingdom of Saudi Arabia.

3- The Central hills located in the center of some Arab states, examples are the Black Huruj in Libya, the Atlas internal hills, the Al-Hamad hill common between Jordan, Saudi Arabia, Syria and Iraq, the middle hills of Yemen, and the Annufuz Hill in Saudi Arabia.

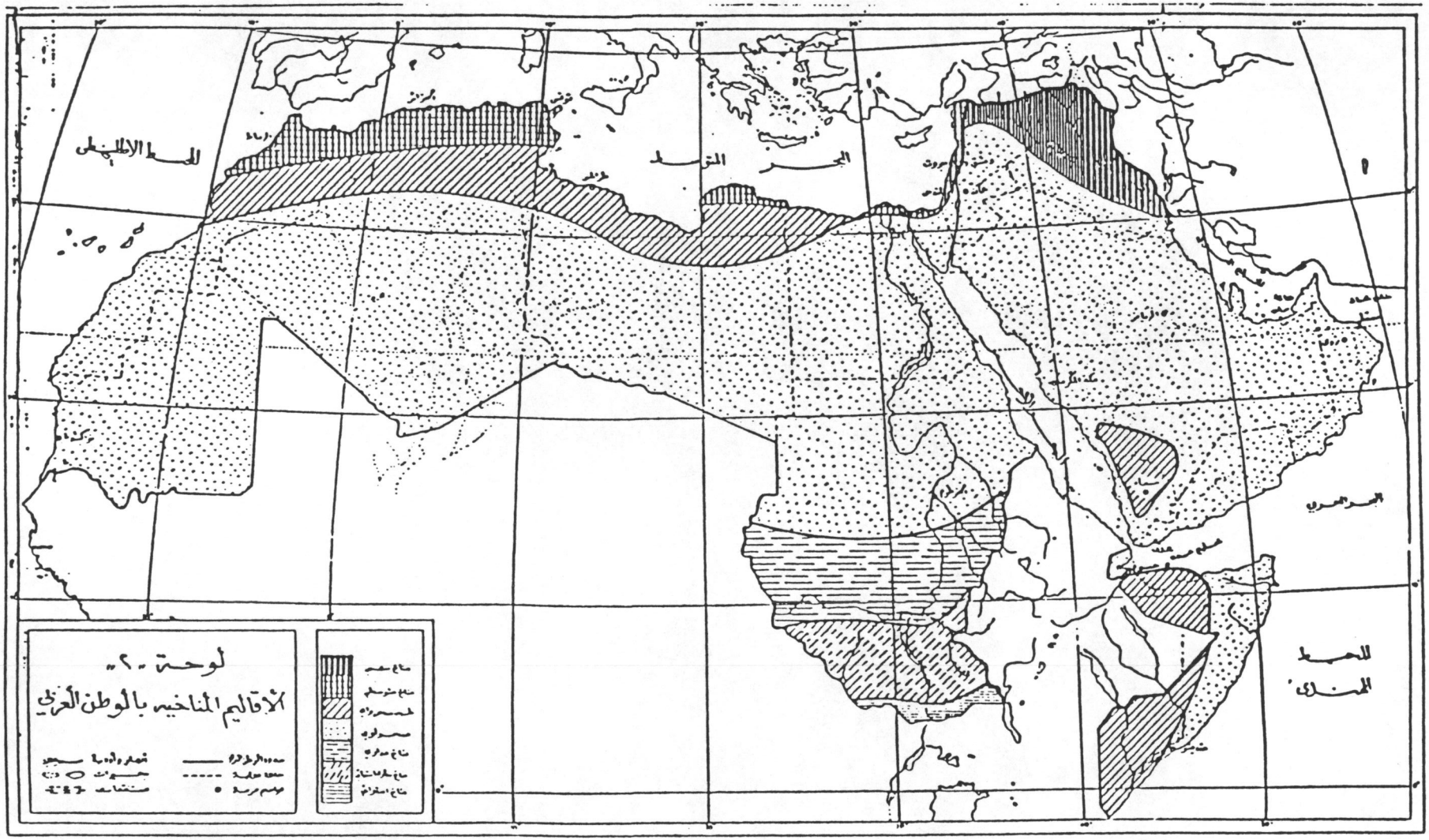

Plate 2. The Climatic Regions of the Arab World.

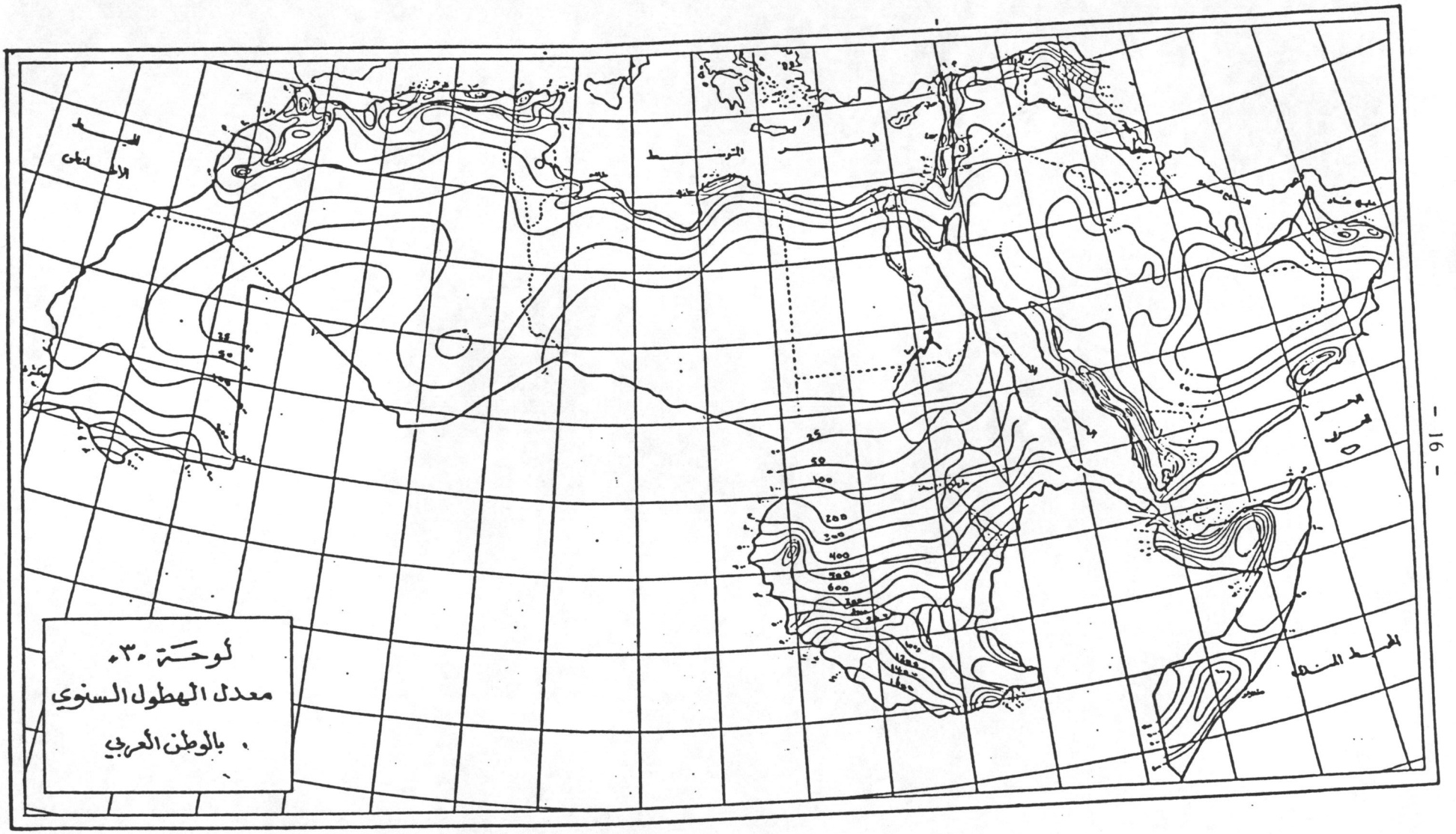

Plate 3. The Isohyetal Map of the Arab World.

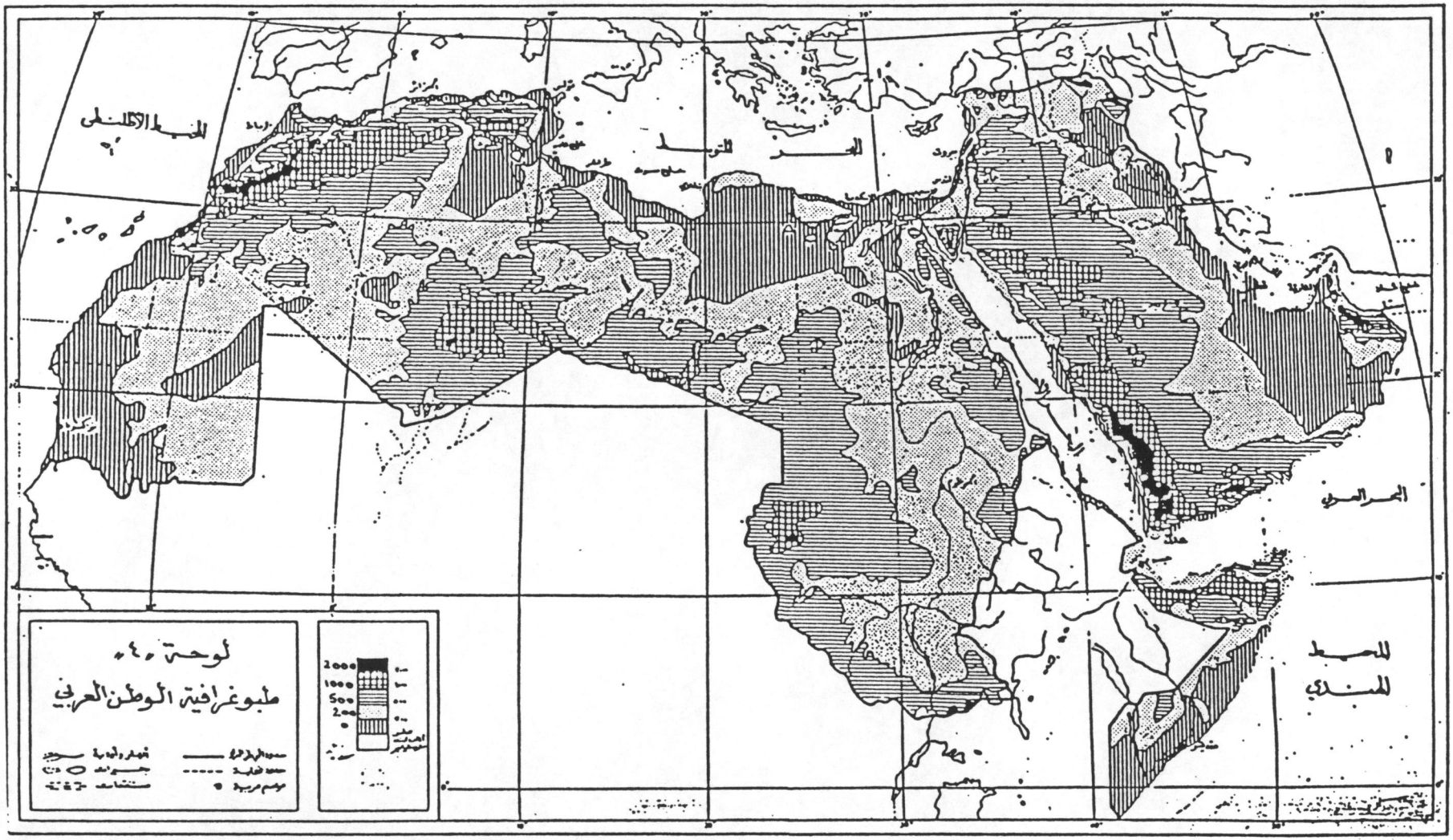

Plate 4. The Topographic Map of the Arab World.

4- The mountainous regions are present in most of the Arab states: the Arab Shield extends from Saudi Arabia and the two Yemens to the Mediterranean Sea in Syria, Jordan, Lebanon, Sinai Penisula, the Green Mountain, Nafoussa in Libya up to the Al-Rif and Atlas mountains in Tunisia, Morocco and Algeria. Also, there is the Murra mountains in Sudan, the Red Sea Peninsula in Egypt and Sudan, Zaghrus Peninsula in the north east of Iraq, and the mountains of Oman and Hadramout.

3-4 Geologic Properties:

The geologic features in the Arab states carry a number of similarities as seen in Plate 5. The thickness of the sedimentary deposits exceeds 10 kilometers and located directly over the volcanic crystalline rocks. The sequence of the features are as follows:

1- The lower group, which belongs to the first geologic age and the beginning of the second one with sand as the predominant element therefore it contains the major groundwater reservoirs known in the Arab states;
2- the middle group, which belongs to the second geologic age and most of the third, it consists of limestone rocks featuring karstification in some of their parts, these rocks prevail in regions east of the Mediterranean Sea and the mountains and the northern coasts of Africa as in the Green Mountain in Libya, Nafoussa Mountain, the Atlantic Rif mountains and the Red Alhamada;
3- the upper group, which belongs to the third and fourth geologic ages, it was formed by the evaporation of water from the sandstone and flood deposits, this group is generally found along the Red Sea coasts, the Arabian Gulf region and the northern part of Africa.

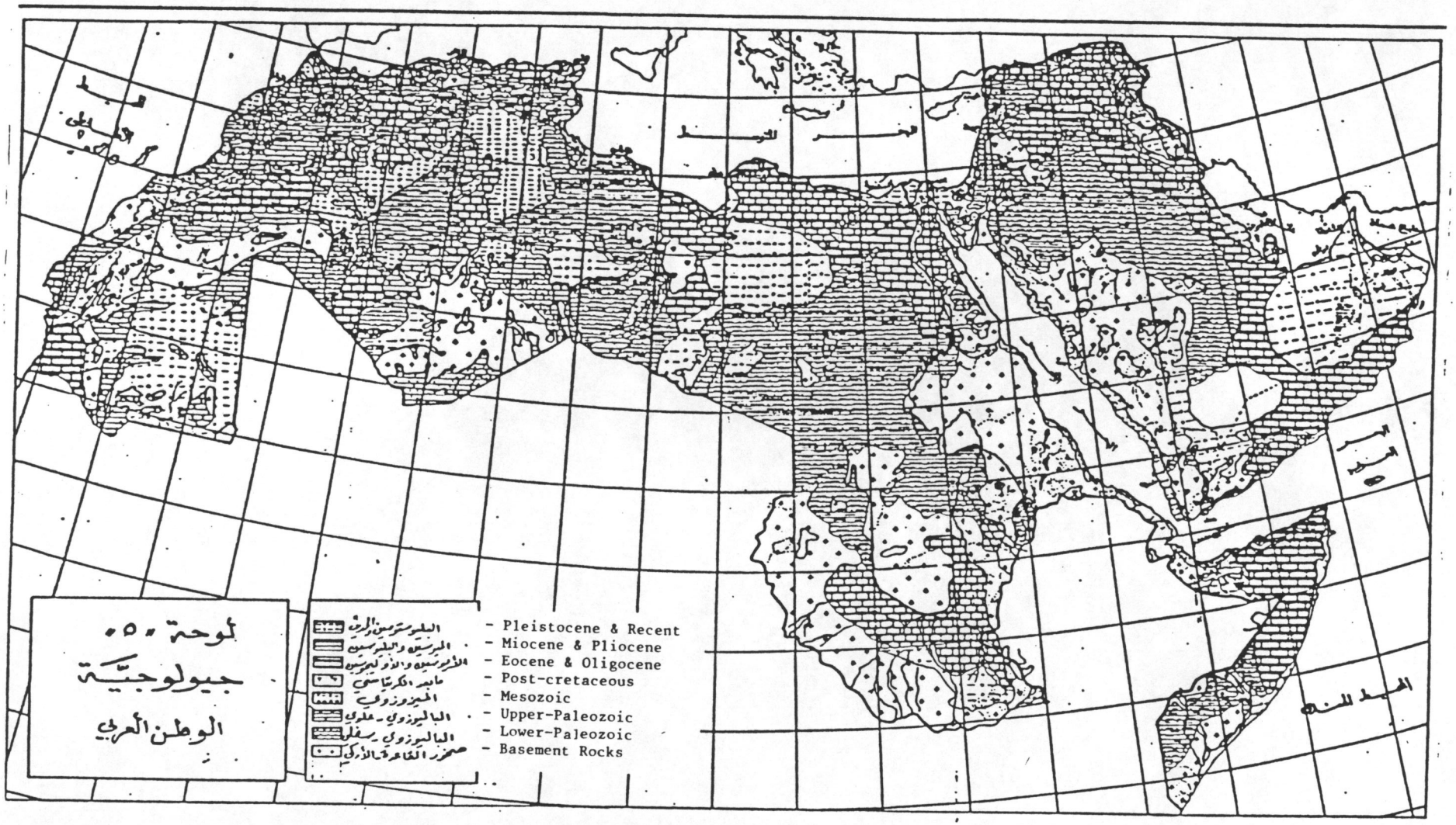

Plate 5. The Geologic Map of the Arab World.

3-5 Water Resources:

3-5-1 Surface Water Resources:

With the exception of the Nile River flowing from the tropical lakes, and the Tigris and Euphrates flowing from the semi-humid central Turkey, there are only several smaller rivers in Syria, Lebanon, Tunisia and Morocco. Other numerous seasonal rivers prevail in most of the Arab states which are characterized by sharp flow fluctuations and periods of drought exceeding sometimes eight months or up to several years in some regions.

3-5-2 Groundwater Resources:

There are groundwater reservoirs in several geologic formations, the most important are:

1- The sandstone formation occupies the lower part of the geologic profile, it is known as the Noubi sandstone or as the rocks of the continental Intercalari, these rocks are quite common in north Africa and Saudi Arabia, it is considered as the world largest groundwater reservoir;

2- the Karstic limestone formation from the second and third geologic age, it occupies the eastern coast of the Mediterranean Sea, the Arab Gulf and the northern coasts of Africa;

3- alluvial deposits and deltas;

4- saline deposits in the coastal regions and the internal plains.

3-6 Other Natural Resources:

There is a strong resemblance among the Arab states in the distribution of the other resources. Pastures and dry farming lands prevail in these countries and form the major part of the arable lands. While the permanent agricultural lands are distributed in the basins of the major rivers as in Egypt, Sudan, Syria and Iraq. This resemblance in resources has led to creating similar job opportunities, animal sheperds became

common and land farming prevailed and became the most popular profession. This fact has led to the introduction of some new plants as cotton, flax and sugar canes from India, Palms from Persia, and figs and olives from Syria and Greece. From the Arab east these plants were spread in the Arab west along with the accompanying traditional water systems like wells, naoura, shadouf and others.

Agricultural development and water resources improvement, seen in the Arab states during the last several decades, have lead to the improvement of some water systems. This was done at a rate similar to that of social and economic growth, technological development, and to the degree of adopting the new technology.

CHAPTER III

SURVEY OF THE TRADITIONAL WATER SYSTEMS AND THEIR DISTRIBUTION IN THE ARAB STATES.

1- The Hashemite Kingdom of Jordan:

1-1 Location:

The Hashemite Kingdom of Jordan falls between the longitudes 35°00' and 39°15' East and Latitudes 29°22' and 33°22' North. It is bounded on the east by Saudi Arabia, Syria on the North and Palestine on the West.

1-2 Surface Area: 96500 km^2

1-3 Population: It is estimated at about 2.6 million.

1-4 Physiography:

Jordan is divided into three basic physiographic units, they are:

(a) The mountains: They consist of two groups of high barren lands extending from the North to the South, and from the North-east to the South-west confined between them the Jordan River depression, the Dead Sea and the Araba Valley. The elevation of the Western mountains reaches 1000m above sea level, and that of the eastern mountains 1856m near Ma'an. The most important valleys crossing the eastern mountains are the Yarmouk, Azraq, Moujeb and Hasat. These valleys are all eastern tributaries for the Jordan River, while the eastern slopes of the western mountains are crossed by the main drains of the western bank of the Jordan River.

(b) The Low Lands: they include the Ghors of the Jordan River, the Dead Sea and Araba Valley, they consist of a large land slide 360km in length extending between Tiberias lake in the north and the Gulf of Aqaba on the Red sea. The average ground elevation ranges between 200 and 250 below sea level, reaching 400 m below sea level at the Dead Sea which has its bottom lying deeper by additional 400 m.

(c) The Eastern Desert Hill: It runs from the eastern slopes of the Jordan eastern mountains till the Jordan Saudi borders and the Jordanian syrian border. The elevation starts with 1000 m above sea level at the hill and gradually reaches 600m above sea level at the bottom of al-Sarhan valley. A large number of seasonal streams cross this hill and end with shallow depressions called Ka' or in al-Sarhan valley.

Most rocks in Jordan are the limestone type, while the sandstones appears in the south of the eastern mountains and the sedimentary rocks in the Jordan River depression. The metamorphic rocks appear in the south near Aqaba, while the volcanic rocks from al-Arab Mountain cover large parts of the Eastern Desert Hill.

1-5 Climate:

Jordan is characterized by having a number of climatic regions. A Mediterranean climate prevails in the eastern and western mountains, while the Ghors has a semi-arid climate and gradually changing to arid in the Easter Desert Hill. Most rainfall occurs during winter with the possibility for rain storms in the spring. There is a gradual reduction in rainfall from the North to the south and a sharp reduction from the west the East. The average annual precipitation is distributed as follows: 300 to 650 mm the Eastern and Western mountains, 200 to 400 mm the Ghor of Jordan, 50 to 150 mm the Eastern Desert Hill.

1-6 Agricultural Lands:

The area of the agricultural land is estimated at 13 percent of the total area of Jordan. Some 60,000 hectares are irrigated in the Ghor region while the rest is dry-farming supported partly by irrigation from the Jordan River and other streams and springs.

1-7 Water Resources:

Most of the surface water resources are confined to the Jordan River Depression. They are estimated at 880 million m^3 a year, of which 400 million m^3 came from the Yarmouk river and about 283 million m^3 from the flow of springs (100 springs), the rest is the flow of the eastern tributaries of the Jordan River. The annual surface runoff in the eastern region and southern desert is less than 50 million m^3. The portion of the water volume reaching the ground water aquifers is estimated at 580 million m^3. At present, 380 million m^3 is used from these aquifers.

1-8 Traditional Water Systems:

1-8-1 Surface Water Systems:

1-8-1-1 Cisterns: They are known since the time of the Romans in many regions of Jordan, until now they are constructed in many locations for the purpose of rainwater harvesting which is later utilized for drinking and domestic purposes and in limited cases for irrigation. Cisterns are employed in the moutain and remote rural regions. The storage capacity ranges between 50 to more than 1000 m^3.

1-8-1-2 Small Dams: They are constructed for the purpose of storing runoff water in the eastern desert region and on the slopes of al-Arab Mountain. The storage capacity does not exceed 0.5 million m^3. Water is utilized for drinking, irrigation and other limited agricultural purposes. Examples of these dams are: al-Soltani Dam, Boraqa' Dam, Um Al-Katin Dam and the Dams of Rowayshid.

1-8-1-3 Al-Mahafir: These are aritifical shallow holes mechanically constructed in the natural shallow depressions, they are locally called Ka'a. Al-Mahafir are used for storing rainwater and runoff water collected during a long period in al-Kaian. The water is utilized for drinking and animal watering in the Badia region they are quite common in the Eastern Desert Hill.

1-8-1-4 Al Masateb: They are also called terraces. They are common in the moutain regions. Terraces take different forms, some are constructed as horizontal strips and then

cultivated, or they have short gravel walls 1m high extending in a vertical direction to the slope and in form of parallel lines spaced at a distance selected to fit the ground slope. Land strips between the walls are usually planted with agronomic and leguminous crops or fruit trees. The Hashemite Kingdom of Jordan pays special attention to these terraces, for this purpose the division of foresty supervises the construction of terraces, educates the farmers about the importance of forests and the ways of their up-keep.

1-8-1-5 Water spreading Dykes: This type is confined to a small part of the flood plain in some potential seasonal streams like Rowayshid Valley. Although it is limited at present, there is a genuine interest in it as one of the techniques that can improve pasture lands in the semi-arid regions.

1-8-1-6 Check Dams: They are similar to the terraces. They are constructed as small check dams that serve in slowing water flow in the steep streams of the mountain regions. Also, check dams help reduce soil erosion by trapping suspended sediments in front of the dams. Dams are usually built with carefully compacted stones or cement is added to the stones, or stones broken and compacted in gabion boxes.

1-8-1-7 Artificial Recharge of Ground water : Only recently that recharge became known when a number of trials were conducted in one of the valleys in Zarqa basin. The process is achieved by injecting water withdrawn from the upstream side of an earch dam into wells in order to feed the water table and to combat the reduction in ground water levels due to excessive pumping for irrigation .

1-8-2 Ground Water Systems:

1-8-2-1 Surface Wells: They are common in the Hashemite Kingdom of Jordan. They secure water for drinking, irrigation and domestic purposes. In some cases it is used for limited agriculture. The depths of the wells vary depending on the location with respect to the valley or the depth to water from ground surfaces.

1-8-2-2 Springs: They are scattered on the slopes of the Jordan Eastern Mountains and in some other parts of the Kingdom. They are estimated at about 1000 springs with a total annual flow of 283 million m^3. They are used for drinking and sometimes for irrigation.

1-8-3 Water Lifting Systems: The system of bucket and pulleys is common in many of the surface wells. Some wells are equiped with pumps powered by electricity or diesel. The wind mill was employed in the past but now it is out of use. While other systems such as Shadouf, Saquia and Tambour were not used in the past and still are out of use.

7- The Democratic Republic of Sudan:

7-1 Location:

The Democratic Republic of Sudan falls in the heart of Africa. It is bounded by Egypt in the north. Libya and Tchad in the west; Rawandi, Borondi, Zair, Oganda, Kenia and Tanzania in the south; and Ethiopia is in the east. In the north east the coast line extends 780 km on the Red Sea. Sudan is located between longitudes 21°46' and 38°35' east and latitudes 3°38' and 23°8' north.

7-2 Surface Area: 2,505,813 km².

7-3 Population: about 20 million (an estimate).

7-4 Physiography:

Sudan consists of an internal flat plain having an average elevation of 325 m above sea level. It is a vast plain with a general mild slope running toward the north and crossed by the Nile River and its tributaries. It is surrounded or crossed by a number of variable hills as the Amatung mountain in the south, Murra mountains (3,071 m) in the west, al-Uwaynat mountain (1,892 m) on the north-west borders, al-Noba mountains (850 m) in Central Sudan, the Peninsula of the Red Sea rising to 2,260 m in the north east corner and confining in front of it the desert coastal plain on the Red Sea.

Two thirds of the land in Sudan is covered by sandy desert; sand dunes, both fixed and mobile, are found in the north-east part as an extension of the eastern boundary of the Great Desert.

The volcanic rocks of granite and the metamorphic rocks, are exposed over 45 percent of the area of Sudan. They are seen in the south, west, east and north-east and along the Peninsula of the Red Sea. Also, they appear in other locations in Central Sudan. They all date back to the Cretaceous and the earlier time. The sand stone occupies the north and the north-west of Sudan over about 25 percent of the land. Some volcanic rocks appear also in the north -west. The recent sedimentary rocks made of sand and clay cover most of the land of the Nile River basin.

7-5 Climate:

Generally, the climate in Sudan is continental tropical characterized by drought and excessive temperature except along the coast of the Red Sea. The precipitation falls in the summer as a result of the Mansoun winds blowing from the Atlantic Ocean in a south-west direction. Rainfall diminishes as less clouds are able to reach the north. It is distributed as follows:

Less than 20 mm in the desert region of the north.
50 - 300 mm in the semi-desert region.
300 - 800 mm in the savana vegetation region.
1800 - 800 mm in the extreme south in the tropical jungles.

7-6 Agricultural Lands:

The area of the arable land is estimated at 58.9 million hectares, only 7 million hectares are effectively exploited, of which 1.7 million is irrigated and the rest is rainfed. The area of the pasture land is 24 million hectares, while the tropical jungles are 50 million hectares.

7-7 Water Resources:

The Nile River represents the main surface water source. The average annual flow at Aswan is estimated to be 84 billion m^3 distributed on the tributaries as follows:

The Blue Nile 48 billion m^3
The White Nile 24 billion m^3
Atbara River 12 billion m^3

According to the 1959 Agreement between Egypt and Sudan regarding the Nile River water, the share of Sudan is estimated at 18.5 billion m^3 at Aswan after the construction of the High Dam, while Egypt receives 55.5 billion m^3.

The water losses in the swamps of the south (47,000 km^2 in area) are estimated at 26.5 billion m^3. There are many projects intended to reduce these losses. They began by digging the

Jonjali canal in 1979 that serves in reducing water lost to Bahr-al-Jabal and al-Zaraf. Later, other similar projects were planned as in Moshar swamps, al-Sabat Basin, Bahr-al-Ghazal Basin, and the project to deepen the white Nile stream in order to accomodate the increase in its flow resulting from the reduction in evaporation losses from the swamps.

There are many seasonal streams that attain a flow of several billions cubic meters but does not reach the main tributaries of the Nile. These streams fall in the peninsula of Mura, al-Noba Mountains, al-Kash river, and Baraka along the coast of the Red Sea (available information on these streams are not accurate). At present partial use is made of this water for drinking projects in the rural areas, or for irrigation of rainfed lands and limited basins. Groundwater is available in large quantities in the underground formations known as the Noubi stone which covers an area of 704,000 km² in the layers of Um-Rawaba and Nouh. In addition, other shallow groundwater formations are available, they are fed by the runoff water and the Nile tributaries. There are no sufficient records on this recharge, although it is generally believed that it is limited except along the strip near the Nile River between Dankala City and Wadi Halfa Town where recharge is expected to be high due to the presence of the lake al-Noba (6500 km²) which resulted from the construction of the High Dam. Groundwater resources are primarily used for drinking, animal watering and in limited amount in supplemental irrigation. The average annual abstraction is about 1.3 billion m³.

7-8 Traditional Water Systems:

7-8-1 Surface Water Systems:

7-8-1-1 Al-Hafir:

They are ground reservoirs mechanically dug in impervious clay soils for storing rain water of runoff water to be used for drinking and animal watering. They are very common in the dry savana belt in Sudan where, some 1000 hafirs are present with a total storage capacity of about 19 million m³ a year. The operation of these systems proved to be efficient specially

after the improvement which was introduced since the beginning of their use in the mid fourties. The capacity of a hafir ranges between 5000 m^3 and more than one million m^3 in case of water storage for small towns.

7-8-1-2 Small dams:

It is one of the systems that is receiving attention in Sudan. Small dams are constructed on the seasonal valleys and between hills which are far from the Nile and its major tributaries. Water from dams is basically dedicated for drinking and animal watering and in some cases for irrigation. Depending on the location and the available construction materials, dams are built from earth fill, stones or concrete with a height usually not exceeding 8 m. The storage capacity ranges between several thousands and a million m^3.

7-8-1-3 Al-Rohoud:

They are natural depressions in which rain water and runoff water are collected, or they are formed inside the branches of seasonal valleys which get isolated during the period of its formation, water reaches these depressions during a high flood wave. The collected water is used for animal watering and after treatment for drinking.

7-8-1-4 Tebeldi Trees:

They are one of the systems used for storing rainwater in some parts of Sudan to be used later during the drought season. The inside of the Tebeldi tree is carved and then filled with water using the rope and bucket system during the rainy season after collecting the water in a small basin near the tree. Trees are still used in Sudan but with a lower efficiency. Each tree may store about 100 m^3.

7-8-1-5 Diversion Dams:

There are two types of diversion dams: the first is meant for irrigation where they may be involved in medium or large irrigation projects therefore excluded from the classification of the traditional water system. The other type of dams is used for spreading water from seasonal streams, this type is common in

the dry regions by constructing earthfill check structures in the stream beds. This helps raise the water level as to overtop the banks of the stream thereby allowing the soil the chance to absorb more water. After the water recesses and the soil surface is dry the land is planted. Such dams are built in the eastern regions and, along the coast of the Red Sea, in the northern region and in some valleys of Darfour and Kardafan in the west of Sudan.

7-8-2 Groundwater Systems:

7-8-2-1 Surface Wells:

They take several local names such as al-Tamad, al-Ad, al-Mashish, al-Jamam, al-Matra, al-Saqia, in addition to new names like the open wells, the ordinary wells or the hand-dug wells. They are quite common in most parts of Sudan and vary in depth between 3 and 200 m. They can be dug by hand or mechanically or sometimes by explosive charges. The inside is lined with tree branches and weeds, by stones or can be left unlined depending on the geologic conditions. They are mostly found on the banks of valleys and rivers or in the depressions collecting rain water or in the regions with shallow water tables.

7-8-2-2 Springs:

They are limited in number and appear in the hills along the Red Sea and some internal hills in the Murra peninsula and al-Nouba Mountain. The flow from these wells is limited and water is used for drinking and very limited agriculture.

7-8-3 Water Lifting Systems:

Some traditional water lifting systems were used in Sudan and still are but on a limited scale, examples are al-Saqia, al-Shadouf, and the wind mill. Yet, their use is fading away as modern water lifters, like the pumps driven by electric motors or diesel engines, are introduced. While, the system of bucket and pulleys and bucket pulled by animals enjoy a limited use in the remote rural regions where introducing the new pumps is economically not justified as yet.

Pumps powered by solar energy were also tested in two locations south of Khartoum, this is a very recent technology with a high cost at present; in the coming few decades, it may have a future in Sudan.

8- The Syrian Arab Republic:

8-1 Location:

The Syrian Arab Republic falls on the east of the Mediterranean Sea, bounded by Turkey on the north, Iraq on the east, Jordan on the south and Lebanon and the Mediterranean Sea on the west. The boundaries fall between longitudes 35°38' and 42°20' east, and latitudes 32°20' and 37°19' north.

8-2 Surface Area: 185,000 km²

8-3 Population: 9,700,000 (1982)

8-4 Physiography:

Syria is divided into the following natural units:

(a) The coastal strip: It is a narrow strip crossed by many valleys sloping toward the Mediterranean Sea. It has a length of 250 km and extends between the Turkish borders and the end of the Great Northern River.

(b) The Coastal Heights: They run as two peninsula parallel to the Mediterranean Sea. The eastern one consists of al-Amanos Mountains, al-Akra'a, and the al-Alawiyyin Mountains. The internal peninsula consists of Akrad Mountain, Sama'an, Harem, al-Zawiya and Jabal Haramoun (al-Shaikh).

(c) The Tectonic Plains: The coastal hills include the plains of al-Omk, al-Rouj and al-Ghab. They are considered an extension of the African plain (Okhdoud) which extends to the Gulf of Aqaba.

(d) The Internal Heights till the Gulf of Aqaba: They are scattered and run in a direction from the north east to the south west. They include Jabal al-Arab, the Ghoulan Hill, the mountain chain of south Tedmor, and Jabal abdel-aziz.

(e) The Internal Plains and Hills: They include the region of al-Jazira and Badiat al-Sham.

Most soils in Syria are made of rocks of sedimentary origin with varying formations. They include the limestone ,marl, clay and sand stone. Also, volcanic rocks appear in Houran and Jabal al-Arab, in the Ghoulan Hill in south west Syria, and a hill west of middle Homs. Green rocks also appear in the far north along the coastal heights.

8-5 Climate:

Syria falls in the mild warm region within the climate of the Mediterranean sea having a mild rainy winter and a dry hot summer. The coastal heights have an influence on the rainfall regime as they form a natural barrier facing the saturated clouds coming from the Mediterranean sea; therefore, depriving the Eastern regions of the Country from most of the moisture . Rainfall is distributed as follows:

500 - 1000 mm in the coastal strip, the coastal heights and the low plains.

250 - 500 mm in the internal heights.

50 - 250 mm in the internal plains and hills.

There is also a noted variation in the rates of temperature and relative humidity along the regions in Syria. Therefore, it can be divided into four climatic regions, they are: The coastal plain, the region of coastal heights, the internal regions and the Badia desert.

8-6 Agricultural Lands:

The area of the arable land is about 58,640 km² or 31.7 percent of the total surface area of Syria, of which 90 percent is exploited at present. There are 5,280 km² of irrigated land and the rest is rainfed.

8-7 Water Resources:

The total annual surface water resources are estimated at 33.7 billion m³, of which 26 billion m³ are the flow of the Euphrates River and 4.1 billion m³ are the flow of springs that feed during the year a number of rivers. The most important rivers of Syria are: Barada, al-Awaj, al-Yarmouk, al-Assi, Afrin, al-Sin, al-Kabir al-Shamali, al-Kabir al-Janoubi, Kowayk, and the Euphrates and its tributaries al-Khabour, al-Ballik and al-Sajour. The rivers cross six basins out of the seven found in Syria. The Storage capacity of the present water projects of Syria is about 12.5 billion m³, the most important ones are: the Euphrates basin, al-Rasten, Mojarda, Taldou, Dara' and al-Shahba'. Also, there are some 68 small dams with a total capacity of 182 million m³, most of them is located in the regions of al-Badia and the coast serving to meet drinking needs, animal water or some supplemental

irrigation. Also, there are 16 dams under construction with a capacity of 148 million m^3.

Ground water is available in the main water bearing formations, their order in descending importance is: The carbonate rocks dating back to the Jurassic and Cretaceous time, the marine time stone rocks dating back to the Pleocene and Meocene time, and the basalt rocks. The annual replenishment is estimated at 1,625 million m^3 and found primarily in the coastal strip, the lower plains and the internal plains of the west and the north east. It is observed that water quality deteriorates when moving east. The picture about the potential of the ground water resources in Syria is still unclear although the pumping rate in some aquifers has reached the critical limit as in the basins of Damascus, Al-Assi, Aleppo and the Central Euphrates.

8-8 Traditional Water Systems:

Syria enjoys the use of many traditional water systems although some of them lost popularity and become outdated. Some other systems evolved with time and kept playing an important role. Below, is a summary of these systems:

8-8-1 Surface Water Systems:

8-8-1-1 Cisterns:

They are found in the high points of the mountains in al-Badia and the coastal region where water was for drinking, animal watering and other purposes. Attention is made at present to revive the use of cisterns and improve their efficiency in the remote regions where securing water from other sources is difficult.

8-8-1-2 Al-Hafir:

They are found in the Basalt southern region and in al-Badia region. They are used to supply villages with water for drinking and animal watering. The introduction of tube wells lead to a drop in their importance. There is a suggestion now to reuse the hafir but after improving their efficiency.

8-8-1-3 Small Dams:

Many dams were built in al-Badia region and the coastal strip. In the past and later they were rebuilt in order to solve the problem of water shortage. Water is used for drinking, animal watering and irrigation. There are 68 dams that store 182 million m^3 and 16 new dams are being constructed with a capacity of 148 million m^3.

8-8-1-4 Terraces:

They are found in particular on the coastal plains. They are still in use but need more support to work on improving their efficiency.

8-8-1-5 Irrigation Diversion Dams:

The irrigation network of Damascus Ghouta is considered a typical example of this type of dams where water is diverted from the dam via canals to the agricultural land. The Government is working on reviving the use of the old dams and constructing new ones based on modern considerations for the coastal region.

8-8-1-6 Water Spreading Diversion Dams:

In the past, these dams were built in different types: earth fill, rock fill or as a wall. The purpose was to increase the soil moisture and improve the fallow farming. Some of them were destroyed. At present, the government is providing maintenance of the old dams and constructing new ones based on modern techniques in al-Badia region and the southern region of the Yarmouk Basin.

8-8-2 Ground Water Systems:

8-8-2-1 Foggaras:

They are ancient systems that were and still are known in Syria on a limited scale; yet, their use is fading away because of lack of maintenance and increased abstraction from modern wells.

8-8-2-2 Surface Wells:

They are common in some parts of Syria and a number of wells are still in operation specially in al-Badia and coastal regions.

8-8-2-3 Springs:

They are one of the natural systems that are found in a large number of springs in Syria playing an important role in the economy. Examples of the springs are: Ain-Barada and Ain-Fija which supplies Damascus with the drinking water; and al-Sin spring, Tell-Ayoun, al-Arous, Zayzoun, Mzeirib, Banias, al-tanour and al-Bared. These springs are used to supply water for drinking, animal watering and sometimes for irrigation.

8-8-3 Water Lifting Systems:

8-8-3-1 Al-Shadouf:

It was used on the rivers of al-Khabour and the Euphrates, but now they run out of use.

8-8-3-2 Naoura:

It was commonly used on the banks of the rivers of al-Assi and al-Khabour, but now they are fading away. At present, they are considered as historic touristic ruins.

8-8-3-3 Tambour:

It is no longer in use.

8-8-3-4 Bucket and Pulley:

It is still in use, but on a limited scale, in wells of small flow.

8-8-3-5 Wind Mill:

It is still in use in the region of Kalamoun where suitable natural conditions of topography and water resources prevail.

9- The Republic of Iraq:

9-1 Location:

The Republic of Iraq falls in the North-East part of Arabia. It is bounded by Turkey in the North, Iran in the East, Kuwait and Saudi Arabia in the South, and Syria and Jordan in the West. The boundaries are confined between longitudes and 48°33' East, and latitudes 29°09' and 37°20' North.

9-2 Surface Area: 434,724 Km^2

9-3 Population: 12 million (census of 1976)

9-4 Physiography:

Iraq is divided into four natural units, these are:

(a) The Mountain Region: it includes the Peninsula of Zaghrous-Tourous which extends along the boundaries between Iraq and Turkey and Iraq and Iran in the North-Eastern part. The maximum elevation is 3,700m above sea level. It is a rugged mountainous region with steep valleys.

(b) The Mountain Slopes: they include the western slopes the mountain region with an elevation ranging between 2000 an 900m above sea level. They are suitable for fallow farming.

(c) Al-Jazira and the Plains: they represent 30 percent of Iraq's area, and include the lands below the mountain slopes and those lands extending between the rivers of Tigirs and Euphrates till the Syrian - Iraqi borders. It is a desert that slopes from Jabal Sinjar in a South-East direction toward the Arabian Gulf. The Southern part contains the Plains region located south of al-Tharthar Depression. This part is a low land with irrigated agriculture being practiced.

(d) The Desert Region: It covers 38 percent of Iraq's area, and extends from the West and South-West of Iraq to the borders of Iraq with Jordan, Saudi-Arabia and Syria. In its Northern part, the rocks are exposed, while in the Southern region there are many sand dunes. A number of seasonal streams cross this region and end with depressions. Water from these streams rarely reach the Euphrates River.

The soil of Iraq is made of sedimentary rocks in various formations of limestone, marl, sandstone and gypsum, also river and continental sand sedimentary material prevails in al-Jazira Plains.

9-5 Climate:

The climate in Iraq is semi arid and semi continental generally, characterized by a hot and dry summer and a cold winter with a distinct variation in temperature and humidity in the mountain region and the desert of al-Jariza. Annual rainfall is distributed as follows:

500 - 1,200 mm on the mountain region with snowfall
300 - 500 mm on the North and East mountain slopes.
100 - 300 mm on al-Jariza region and the plains.
50 - 100 mm on the desert region.

Rainfall occurs at the end of the Fall, during the winter and at the begining of the Spring. In the regions of al-Jariza, the Plains and the desert, rainfall has an irregular geographic distribution.

9-6 Agricultural Lands:

The area of arable lands is estimated at 19 percent of the total area of Iraq, of which 13 percent is irrigated and the rest is for fallow farming. Some 80 percent of the arable land suffers from salinity problems. Most of the irrigated land is included in the public irrigation networks which are served by diversion dams and large storage dams.

9-7 Water Resources:

Surface water (106 billion m^3) is considered the major water source for Iraq. The distribution of water resources on the rivers of Iraq is as follows:

50 percent comes from the Turkish and Syrian territories.
30 percent comes from the Iranian territories.
20 percent comes from the Iraqi territories.

The water from Tigris and Euphrates Rivers represents the main source. The average annual flow in the Tigris River and its tributaries is estimated at 49.7 billion m^3, while the Euphrates has 30.2 billion m^3 at the point of their entrance to Wadi al-Rafidain Delta near Baghdad. There is also about 26.0 billion m^3 other surface water resources in the South of Baghdad.

All studies on the potential flow of the rivers in Iraq indicate that the available surface water resources after excluding losses by evaporation from the reservoirs are as follows:

The maximum annual flow	67.5	billion m^3
The average annual flow	54.0	billion m^3
The minimum annual flow	43.2	billion m^3

Many projects were constructed for water storage and flood mitigation in Iraq of which: the dams of Doukhan, Darbandi Khan, Dibs Lake, al-Habania, al-Tharthar Depression. Other proposals were made to construct additional dams as al-Musel Dam and Najma Dam on the Tigris River, al-Haditha on the Euphrates River and Hamrin on Deyala River.

Groundwater is found in five water bearing formations, they re: the Quaternary deposits, Bekhtiari formation, Fares al-Ala formation, al-Damam and al-Rodouma formation, and the carbonate rocks in the Euphrates. Also, there are five geographic regions for groundwater, they are: the mountain region, the mountain slopes. The water quality is good and the quantity is sufficient. While the region falling between the two rivers and to the East of Tigris in central Iraq has a poor water quality (10,000 - 50,000 mg/1) preventing its exploitation. The fourth region includes the lands of al-Jazira, it also has a poor quality water (3,000 - 10,000 mg/1). The fifth is the desert region having an acceptable water quality (500 - 3,000 mg/1) but the quantity is limited.

The annual replenishment is estimated at about 1,200 million m^3, of which 40 percent is exploited at present. In general, groundwater resources need more extensive studies.

9-8 Traditional Water Systems:

9-8-1 Surface Water Systems:

9-8-1-1 Cisterns: They were commonly used in the past in the Northern regions. In general, they are large in volume and supply water to large communities. Most of them survived and the government is interested in rehabilatating them as they proved to be economical.

9-8-1-2 Hafirs: They are found in the Northern regions in special, where no other water resources are available. They are used for drinking purposes. At present, they receive no attention because of the presence of substitutes.

9-8-1-3 Small Dams: Although they were commonly used in the past in the Northern regions, they were not successful as little technical knowledge was available at that time causing their quick failure. Water is used for drinking and animal watering Currently, many small dams are being constructed with modern technical knowledge in the Northern regions and South-West Desert.

9-8-1-4 Irrigation Diversion Dams: This system ranks first among all the other water systems known in Iraq. Successive governments competed on spreading this system and on improving its technical, economic and social aspects. This fact has led one of the international experts to say at the begining of this century: "Iraq is in no need for a new plan for canal networks and river water lifting, the ruins that remained from the time of Abbasites are sufficient to plan agriculture and irrigation...". The efforts of the government are now concentrated on constructing new irrigation diversion dams on the rivers with modern concepts, and on rehabilitating and improving the existing old dams.

9-8-1-5 Water Spreading Dams: This system was known in the past on a limited scale in the Northern parts of the country but now it is extinct.

9-8-1-6 Terraces: They are found in the hills of Jabal Sinjar and the North-Eastern hills of Iraq.

9-8-2 Groundwater Systems:

9-8-2-1 Foggaras: Also called Kahariz, they were known in the past when many were constructed in the Northern regions. However, they are diminishing in number as more under ground wells are dug with increased pumping rates that caused foggaras to run dry. The remaining ones need a great deal of attention from the government.

9-8-2-2 Surface Wells: There is still a large number of surface wells specially in the South-Western Badia and the Northern region. They are gradually diminishing as more competition comes from the modern wells, equipped with diesel engines or electric motors, which deliver higher flows.

9-8-2-3 Springs: They are commonly found in the Northern regions of Iraq, the majority are sweet while others are not and of mineral nature.

9-8-3 Water Lifting and Conveyence:

Many methods were used in the past for water lifting as the Shadouf, Tambour, naoura and the bucket and pulleys which were constructed on the banks of the rivers. Now, they have run out of use because of their low efficiency and because they were replaced by modern lifting equipment (pumps).

13- The Republic of Lebanon:

13-1 Location:

Lebanon is located on the Eastern coast of the Mediterrranean Sea between longitudes 35°05' and 36°37' East and latitudes 33°03' and 34°41' North.

13-2 Surface Area: 10,400 km^2

13-3 Population: 3,200,000

13-4 Physiography:

Lebanon is a mountainous state consisting of the following natural units:

(a) The Coastal Plain: it has a width of 2-3 km and runs parallel to the coast of the Mediterranean Sea for a distance of 220 km.

(b) The Western Heights: they run parallel to the Mediterranean Sea in the North East direction. The peak elevation is 3088 m above sea level at the Kurnat al-Saouda in the North and only 600 m above sea level near Marjayoun. The most important mountains are Jabl al-Makmal, Jabal al-Munaitara, Jabal Sannine and Jabal al-Barouk.

(c) The Eastern Heights: they run parallel to the western heights and form the political boundaries between Syria and Lebanon. The peak is at 2,633 m above sea level near Tala't Musa. Also, there is Jabal Haramoun (al-Sheikh) at 2,804m above sea level near the Southern end of the peninsula.

(d) Beqaa Plain: it is a tectonic valley between the Eastern and Western Heights. While it narrows in the South to several Kilometers, it diverges in the North and reachs a width of 20 km near Lake Homs. The elevation of the plain ranges between 900 and 1,100 m above sea level.

The sedimentary rocks prevail in Lebanon, the majority of which are made of limestone, dolomite and marl with interceptions by the sandstone and marine sand rocks. The sedimentary deposits prevail in the Beqaa Plain, while the sandstone and the Quaternary deposits are found in the coastal region of the North.

13-5 Climate:

The climate in Lebanon is Mediterranean with a humid rainy winter and a dry summer. Rainfall is affected by the heights and reaches an average of 950 mm, it is distributed in the following manner:

- 800 to 1000 mm fall on the coastal strip and increases to 1500 along the slopes of the western heights;
- 400 mm fall on the Beqaa Plain and increases to 1000 mm in Mount Harmoun then it drops to 200 mm in the North of the Beqaa.

The peaks of the mountains are covered with snow till the end of March.

13-6 Agricultural Lands:

The area of the arable lands is estimated at about 47 percent of the total area, of which 66,900 hectares are irrigated.

13-7 Water Resources:

Surface water is available in all parts of the country; there are 15 perennial rivers most of which are fed by springs emanating from the western hills. These rivers are found in the coastal plain. Among the large rivers of the Beqaa Plain there are: al-Assi River, al-Litani River and al-Hasbini River. The annual flow of all the rivers is estimated at about 4,200 million m^3 (that includes the water common with Syria), of which 1,300 million m^3 flow in the Beqaa rivers, while the rest comprises the flow of the coastal rivers including al-Kabir River that emanates from Syria.

Groundwater resources are also found in all parts of Lebanon specially in the coastal plain and the Beqaa Valley. Although the groundwater resources are not quite determined, the first estimates of the annual replenishment to groundwater is set at about 600 million m^3.

13-8 Traditional Water Systems:

Lebanon is endowed with abundant surface and ground water resources considering the small area of the country. There

were many traditional water systems that flourished for a long period; however, the impressive modern development that took place in Lebanon after the independence necessitated replacing many of the traditional water systems and improving some others as to cope with the economic development and agricultural conditions. This fact required the use of the most modern systems needed to improve the production efficiency and the standard of living of people.

13-8-1 Surface Water Systems:

13-8-1-1 Cisterns: They were commonly used in the past in the mountain regions to secure water for drinking and animal watering. At present, this system is no longer used after drinking water distribution networks were made available in all the villages of the mountains. Yet, some of these cisterns is still being used for animal watering.

13-8-1-2 Small Dams and Lakes: They are considered medium to large projects and fall outside the group of traditional water systems; their construction needed some modern machinery. Their storage capacity reaches several million cubic meters. They are few in number, examples of which are al-Kawasra, Dahr al-Daraja, Kfar-Kouk, Ballout and Ain Douzine.

13-8-1-3 Pools: They are used for the storage of rainwater resulting from the slopes of the hills. This water is used in the irrigation of terraces. Pools take different forms; some are made of excavated soil or small embankments to store water before them, or made of lined reservoirs which are fewer in number. The capacity of the pools ranges between several hundred and several dozens of thousands of cubic meters.

13-8-1-4 Terraces: terraces are successfully used in the mountainous regions for several purposes such as rainwater harvesting and using it effectively in soil reclamation for agriculture by improving soil moisture, also to help combat soil erosion and soil protection against failure.

13-8-1-5 Irrigation Diversion Dams: This system was actively used since the ancient times and still are on the perennial rivers of the Western heights looking over the sea. There is at present a plan to construct 19 earthfill dams with a total storage capacity of about 613 million m^3.

13-8-2 Groundwater Systems:

13-8-2-1 Foggaras: This system was put out of use and seems to have no future.

13-8-2-2 Surface Wells: They represent one of the major systems employed in the exploitation of shallow groundwater for agricultural and domestic purposes. Their number does not exceed several hundreds, and their sites are carefully selected as to secure irrigation water supply for the entire year. The average flow is estimated at about 20 l/s.

13-8-2-3 Springs: They represent one of the major natural systems in Lebanon. There is about 700 springs in Lebanon with a flow ranging between 0.5 l/s and more than $4m^3/s$.

13-8-2-4 Aghwat: Almost out of use and have no significant role.

13-8-3 Water Lifting Systems:

The use of most of these systems has faded away as the case of Shadouf, while others like the bucket and pulleys are on the way to disappear as the new pumps run by diesel or electricity are increasingly used.

Windmills were also used during the last few decades on farms for drinking, animal watering and limited agriculture, and for lifting sea water to shallow ponds used to extract table salt, however this application is no longer practiced.

coastal strip, but now they are replaced by electically or diesel operated pumps.

15- The Arab Republic of Egypt:

15-1 Location:

The Arab Republic of Egypt occupies the north-eastern corner of Africa. It is bounded by the Mediterranean Sea in the north, the Red Sea in the east, Palestine and the Gulf of Aqaba in the north-east, Libya in the west and Sudan in the south. The boundaries are confined between longitudes 24°36' and 35°35' east, and latitudes 21°56' and 31°46' north.

15-2 Surface Area: 1,000,000 km²

15-3 Population: about 47,000,000

15-4 Physiography: the physiography consists of the following major units:

(a) The Coastal Plains: They run parallel to the Red Sea having a narrow width and of desert nature. While the plains along the Mediterranean Sea are wide and have more desert pastures and saline spots.

(b) The Nile Valley: It runs along the banks of the Nile River in a narrow strip extending from the waterfall till Cairo in the north, where the river diverges into the outset of the Delta which covers an area of 15,400 km².

(c) The Deserts: They include the Sinai Desert, its most important mountain is Jabal Saint Catherine with a peak at 2,637 m above sea level. Most parts of Sinai are mountainous with a slope toward the north where barren and undulated plains are found. While the Eastern Desert runs parallel to the Red Sea between Swez and Ras Benas. It consists of the Red Sea Peninsula that forms a barrier with variable height and reaches 2,187 m above sea level at Jabal al-Shayeb. This barrier has a steep slope toward the coast and a mild slope on the west side toward the Nile Valley.

The Western Desert covers the lands located on the west of the Nile River. The south-western part is level and has a slope in the north. There are several vast depressions in this desert as for example the Oases of al-Kharija, al-Dakhila, al-Farafera and al-Bahria.

There are also some deep depressions with their bottom falling below sea level as Wadi al-Natroun (-23 m) and Siwa Oasis, but the greatest depression is al-Kattara (-145 m) having an area of 18,000 km². The western desert is considered an extension of the Libyan desert, which is covered with sand and mobile sand dunes.

The rocks in the desert of Sinai and the heights of the Red Sea are made of the Granite base rocks and the metamorphic rocks dating back to before the Cretaceous age. The mountains were formed by severe tectonic movements that resulted in the formation of the Red Sea. While the sedimentary rocks of the Nile River are of marine origin and not of limestone. In the Western Desert, the limestone appears in the north-western parts in a set of interfused layers of limestone, clay, sandstone and silt.

15-5 Climate:

The climate of the coastal regions is affected by the presence of the Mediterranean Sea and Red Sea; the weather starts moderate in the north and quickly becomes dry and hot in summer and warm low rainfall in winter.The climate of the Delta is considered moderate as compared to that of the northern coast and Upper Egypt. Because of the low pressure atmosphere zones occurring over the coast, rainfall is limited and diminisher further in the south. Annual rainfall ranges between 200 mm on the coast and 20 mm at the outset of the Delta.

15-6 Agricultural Lands:

The area of the arable land is about 2.5 million hectares; they are intensely cultivated. Also, land reclamation projects in the north Delta region and the Western Desert in the New Valley are covering additional areas.

15-7 Water Resources:

The surface water resources are limited to the share of Egypt in the flow of the Nile River estimated, by the 1955 agreement,at

about 55.5 billion m^3 at Aswan after the construction of the High Dam. There are joint projects on the way to be executed; these projects aim at reducing losses to evaporation in the region of the swamps of South Sudan. The losses are about 27 billion m^3 a year. The first phase of these projects is the construction of Jonjali canal that commenced in 1979.

There is some surface water resulting from the runoff occurring in the Eastern Desert and in Sinai; however, it is very limited and uncertain, as such not counted on. Groundwater represents an important additional source that is needed to meet the increased water needs for agricultural, land reclamation and drinking purposes used in the regions far from the River. The present volume of water exploited is about 1.0 billion m^3. Reports indicate the presence of a large groundwater reserve in Nubi Sandstone. However, the costs of exploitation remain high and more studies are being carried out.

15-8 Traditional Water Systems:

15-8-1 Surface Water Systems:

15-8-1-1 Cisterns: They are called the Roman reservoirs, the ground reservoirs or al-Harrabat. They are dug in rocks or in the deposits of the coastal regions where rainfall is highest. Usually, the reservoirs have collection and diversion walls for rainwater, and a stilling basin to trap sediments. The number of cisterns is about 3,000, they are found in northern Sinai, Mariout region and the northern coast. The capacity of a single cistern ranges between 50 and 500 m^3. At present, they need maintenance as to improve their efficiency.

15-8-1-2 Small Dams:

They are very common in the northern coast. They are made of earthfill or rockfill with walls lined by a layer of gravel or by desert plants. The height of the reservoir does not exceed 3.0 m at most. They are used to store runoff water in the desert streams as to serve in the development of limited irrigation projects and for drinking.

15-8-1-3 Koroum:

They consist of shallow holes constructed in different shapes, where the excavated material is placed around the hole as an embankment in the form of a horse shoe. The embankment serves as a means to direct rain water into the hole for storage. This system is commonly used in the coastal region west of the Nile River Delta. The capacity of the system reaches several thousand cubic meters. Koroum suffer from high rates of evaporation, seepage and sometimes salination.

15-8-1-4 Terraces:

They are rare in Egypt; however, there are some ruins indicating that they were used in the past in some parts of the coastal region.

15-8-1-5 Diversion Dams:

These dams are made of earthfill embankments, often constructed in the coastal plain west of the Delta. They are intended to divert runoff water from the desert streams to the neighbouring agricultural lands. The use of these dams is limited.

15-8-1-6 Water Spreading Dams:

They are commonly used in the desert streams where a cascade of earthfill barriers are constructed in order to accomodate the excess flow from the streams. Each barrier has an overflow used to deliver the excess water to the next barrier. Also, their use is limited. This type of dams is sometimes used for recharging shallow water tables whenever sufficient volume of water is available.

15-8-2 Groundwater Systems:

15-8-2-1 Foggaras:

Locally, they are called water tunnels. They are quite common in the northern coast. The systems surveyed are about 23 tunnels, they can be either open or covered, they are excavated to 1.0 m depth below the water table. They have limited flows, yet they are suitable for the coastal and desert environments.

15-8-2-2 The Ordinary or Shalow Wells:

They are also called al-thamayel. Their depth does not exceed

5.0 m. This system covers in addition the deep wells having a depth of 60 m, they are called sawani or al-bayarat. In both cases, water is lifted by bucket and pulleys, with the help of animals, wind mills or reciprocating pumps. They may be lined from inside or left as they are in case of consolidated soil layers.

15-8-2-3 Al-Aghwat:

They are called al-mawasi. Their use is common in the region of north east Sinai and in the coastal sand dunes regions where the depressions are excavated almost to the water table level. Usually, they are planted with palm trees.

15-8-2-4 Springs:

They are commonly used in the western oases specially Siwa. Their number is 200. The water outlet is confined to a basin before it is distributed via canals, lined or earth, to the fields or to the drinking water reservoirs. Their daily flow is about 200,000 m^3.

15-8-3 Water Lifting and Conveyence Systems:

There are many water lifting systems used in Egypt, of which al-saqia, al-tambour, al-shadouf, wind mills, buckets and pulleys and pumps. The importance of these systems varies depending on the prevailing conditions. The saqia followed by the pumps are the most commonly used systems at present.