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Political Borders Effects on Sustainable Management of the Arab Shared Aquifers Resources

Osama Mohammed Sallam
The High Commission for the development
of Makkah AL-Mukrramah Province, Saudi Arabia

Abstract

At present time, the Arab region is suffering from water scarcity; which will become more severe in the near future. The prevailing arid to semi- arid climate is generally a common feature. Most rivers originate outside the borders and their water is almost fully utilized. Although extensive aquifer systems are encountered, groundwater contained in such systems is almost non- renewable. Renewable groundwater, on the other hand, is limited to specific regions where aquifers of limited extent are prevailing. Groundwater systems are often the only source of fresh water in most of Arab region particularly under arid and semi-arid climatic conditions where demand is rapidly increasing. Water resources may be contained in large shared regional aquifers that represent a substantial and secure supply for many beneficial socio-economic uses and are thus critical for national and regional water security. According to groundwater systems Arab regions can be distinguished in four main hydrological zones, the Mediterranean- Atlantic Ocean, the Sub- Sahara, the Saharan, and The Red Sea. -Indian Ocean zones.

The present problems related to shared aquifer management in the Arab Region can be summarized as Extensive drawdowns that are affecting the sustainability of the resource; Lack of proper management tools and related knowledge, Poor enforcement of legislation , and Frequently the circumstances of the aquifer system are such that the recharge zone might be remote, while the discharge zone may lie across a national boundary, also The utilization of groundwater is subject to socio-economic, institutional, legal, cultural, ethical and policy considerations. However, its beneficial use is often constrained by weak social and institutional capacity, and poor legal and policy frameworks. This difficulty may become significant in shared aquifers because of contrasting capacities and institutional frameworks on each side of the border. Moreover, the shortage of hydrogeological data as water level and quality at the border zones because of its aridity.

The main purpose of this paper is studying the Political borders Effects on Sustainable Management of the Arab Shared Aquifers, and this research is carried out by summarizing the current understanding of shared aquifers; demonstrate their significance in water resource management, Collection and Analyzing reliable information on shared aquifer systems in Arab region and its relationship to political borders, and evaluating and mapping all potential damaging impacts that occurred in shared aquifers. The main results and Recommendations of this paper are: Groundwater has received limited attention in international treaties or conventions. While, one of the more comprehensive agreements, notably, the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes, brokered by the United Nations, Encourage Arab states to work cooperatively toward mutually beneficial and sustainable shared aquifer development, and Integration of water resource management across Arab states borders can best be achieved within the context of some form of agreement or a treaty between parties sharing the aquifer system.

Introduction

The Arab Region extends between longitude 16.5̊ west passing through Nouakchott , Mauritania on the African coast of the Atlantic Ocean and Longitude 60˚ East near the city of Masqat, Oman the region also extends from the equator south crossing the southern Somalia border to latitude 37.5˚ North at the Iraq-Turkish border . it bound from the west by the Atlantic ocean , from the East by Arabian Gulf and Iran . Central Africa, the Great Lakes Plateau, the Ethiopian, Plateau, and the gulf of Eden constitute the southern boundaries while the Mediterranean Sea and Turkey constitute The Northern borders (figure 1)

Water is vital. Without water, life will simply cease to exist. Water may be everywhere, but its availability has always been limited in terms quantity and/or quality. In the past hundred years, the world population is tripled while the demand for water has increased seven-fold. Water is constantly in motion, flowing from one location to another, ignoring political boundaries. Hence, increasing competition over such a precious resource can eventually become a source of tension and even conflict between states. Groundwater represents the main water resource in most parts of the arid and semiarid regions of the Arab region in the Middle East and Northern Africa, at present time the Arab region is suffering from water scarcity; which will become more severe in the near future, and the prevailing arid to semi- arid climate is generally a common feature.

In the Arab Region most rivers originate outside the borders and their water is almost fully utilized. Although extensive aquifer systems are encountered, groundwater contained in such systems is almost non- renewable groundwater, on the other hand, is limited to specific regions where aquifers of limited extent are prevailing. Groundwater systems are often the only source of fresh water in most of Arab region particularly under arid and semi-arid climatic conditions where demand

is rapidly increasing. Water resources may be contained in large shared regional aquifers that represent a substantial and secure supply for many beneficial socio-economic uses and are thus critical for national and regional water security.

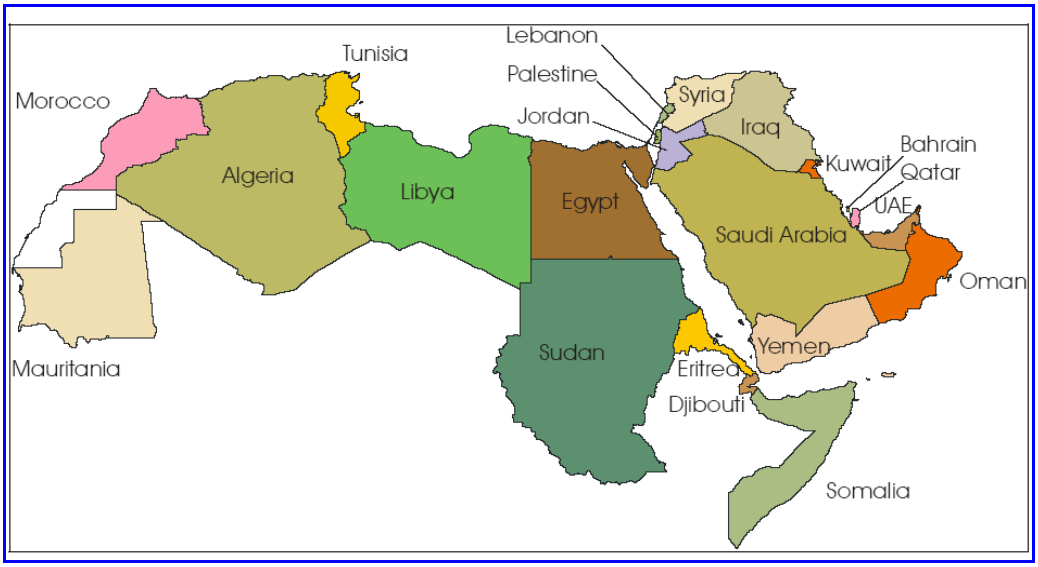

Figure 1 political borders in the Arab Region, *(ACSAD- BGR 2003)*

Problem Identification

The present problems related to shared groundwater aquifers management in the Arab Region can be summarized as Extensive drawdowns that are affecting the sustainability of the resource; Lack of proper management tools and related knowledge, Poor enforcement of legislation , and Frequently the circumstances of the aquifer system are such that the recharge zone might be remote, while the discharge zone may lie across a national boundary, also The utilization of groundwater is subject to socio-economic, institutional, legal, cultural, ethical and policy considerations. However, its beneficial use is often constrained by weak social and institutional capacity, and poor legal and policy frameworks. This difficulty may become significant in shared aquifers because of contrasting capacities and institutional frameworks on each side of the border. Moreover, the shortage of hydrogeological data as water level and quality at the border zones because of its aridity.

Objectives

The main purpose of this paper is studying the Political borders effects on Sustainable Management of the Arab Shared Groundwater aquifers systems.

Methodology

This paper is carried out by summarizing the current understanding of shared groundwater aquifers; demonstrate their significance in water resource management, Collection and Analyzing reliable information on shared groundwater aquifers systems in the Arab Region and its relationship to political borders, and evaluating and mapping all potential damaging impacts that occurred in shared aquifers.

Shared aquifers definition

The key features of shared or shared aquifers include a natural subsurface path of groundwater flow, intersected by political borders or international boundaries, such that water transfers from one side of the boundary to the other (Figure. 2). In many cases the aquifer might receive the majority of its recharge on one side, and the majority of its discharge would occur in another side. The subsurface flow system at the political borders itself can be visualized to include regional, as well as the local movement of water, *(UNESCO, 2001)*.

In hydrogeological terms, these crossing resources can only be estimated through good observations and measurements of selected hydraulic parameters, analogous to the estimation process of other shared resources such as fisheries and wildlife, each requiring statistically sound observations.

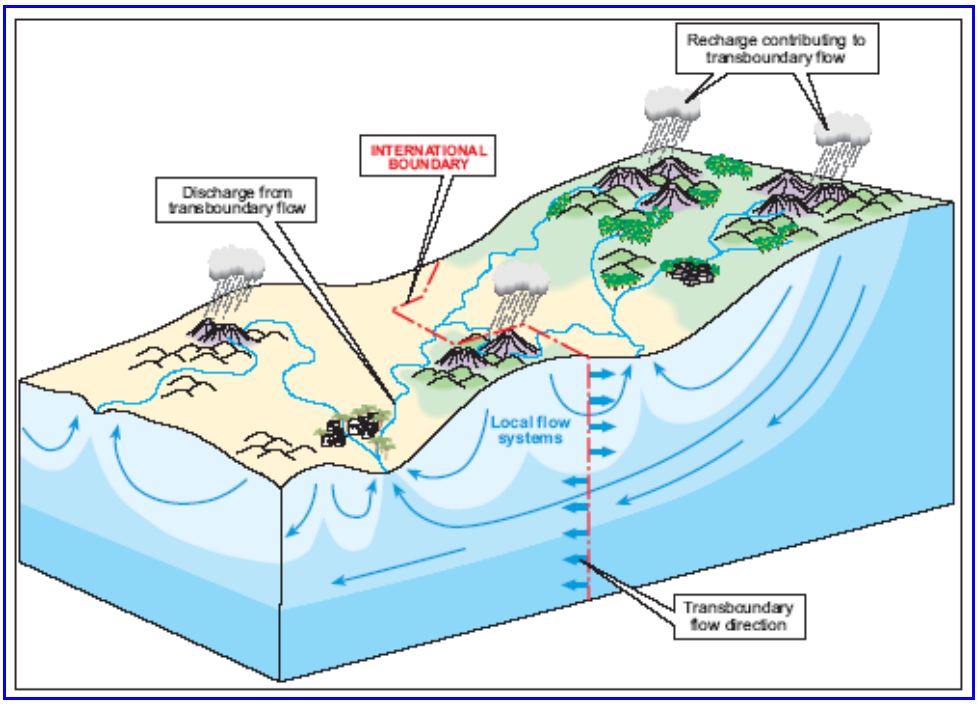

Figure 2 schematic illustrations of shared aquifer

Importance of the Arab shared aquifers

Groundwater, though not visible as surface water, is ubiquitous in the global landmass and is contained in the pore spaces of rock formations (aquifers). Its science, hydrogeology, has rapidly developed over the last 35 years, contributing to the well being and development of the human population in all parts of the Arab region (*Burke and Moench, 2000*).

In most the Arab countries, groundwater aquifer systems have been fully evaluated and extensively used for municipal and other demands. Such resources represent a substantial hidden global capital that still needs prudent management. Competition for visible transboundary surface waters, based on available international law and hydraulic engineering, is evident in all continents.However the hidden nature of shared groundwater and lack of legal frameworks invites misunderstandings by many policy makers. Not surprisingly therefore, shared or transboundary aquifer management in the Arab Region is still in its infancy, since its evaluation is difficult, suffering from a lack of institutional will and finance to collect the necessary information. Although there are fairly reliable estimates of the resources of rivers shared by two or more countries, no such estimates exist for transboundary aquifers *(Salman, 1999)*.

Groundwater resources in the Arab Region

Overall, the Arab Region renewable fresh water availability is estimated at about 388 km^3/ year, More than 55% of this amount is originating from outside the region.

The average amount of rain received by the Arab Region is estimated at 2148 km^3/year, out of which 378 km^3 /year occur in the countries of west Asia. About 50% of the rainfall occurs in Sudan. The average annual precipitation for the Arab nations varies considerably between 18 mm/year in Egypt and the Gulf countries and 827 mm/year in Lebanon and averages at 156 mm/year; More than 75% of the limited precipitation received by the region is evaporated indicating the highest aridity in the world. *(FAO, 1995, 1997)*.

Due to the scarcity of water resources in the Arab Region, non–conventional water supplies have been widely adopted in the form of desalination plants, agricultural drainage water. Fossil groundwater has been extensively tapped in the desert areas. A total of about 30 km^3 /year of non renewable and non conventional water supplies are being produced. The demand, on the other hand is exceeds 200 km^3/ year (about 60% of the renewable resources) and is highly escalating. On the average, irrigation consumes about 88% of the total scrotal abstraction. Industrial and domestic uses about 7% and 5% respectively.

In 1950, the average annual share per inhabitant of renewable water resources in the Arab Region was exceeding 4000m^3/cap/year.The later share decreased dramatically to 1312 m^3/cap/year. In 1995, 1233 m^3/cap/year in 1998 and is projected to drop to 547 m^3/cap/year by year 2050. A clear imbalance

between the available water resources and water demands is thus the expected to continue in the future. (*FAO, 1995, 1997*).

At present, groundwater resources in the Arab Region in general and in the Arabian Peninsula in particular are under critical condition. The current rate of groundwater extraction far exceeds the natural recharge resulting in a conditions decline in groundwater levels and quality deterioration in most of the countries due to seawater and connate waters encroachment.(figure 3)

Renewable Groundwater resources are in the shallow alluvial aquifers recharged from the main rivers in the region or directly from precipitation in limited coastal areas. Theses include the Nile valley (all through its course) and Nile delta ,tropical areas in Sudan , Jezira and wadi Batin aquifers in Iraq, Tehama alluvial of Yemen and Saudi Arabia , scattered strips along the southern and eastern Mediterranean coast (table1, Groundwater resources in the Arab countries)

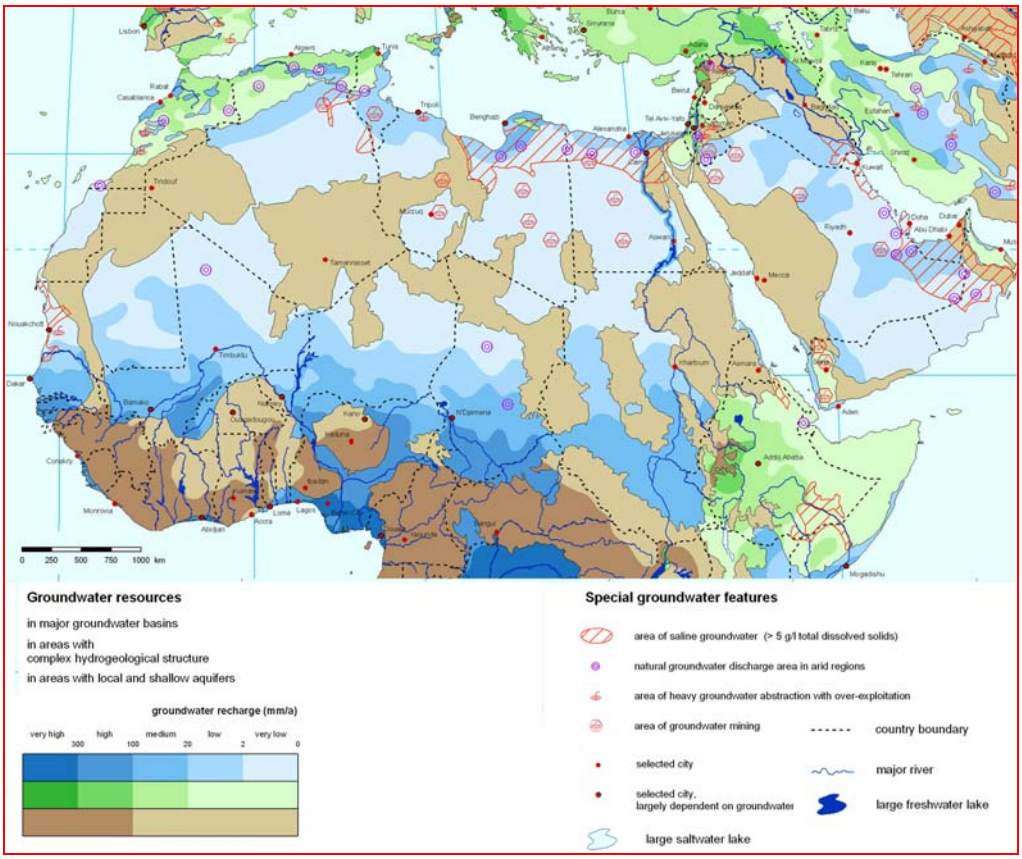

Figure 3 Groundwater resources in Arab countries (BGR-2008)
Source: GRDC, 2008, GPCC, 2008. www.whymap.org

Table 1 Groundwater resources in the Arab countries.

Country	Storage km^3	Available km^3 /year
Jordan	12000	275
U.A.E.	5,000	134
Bahrain	-	90
Tunisia	170000	1724
Algeria	150000	2800
Djibouti	-	-
Oman	-	1267
Palestine	-	950
Qatar	2500	55
Kuwait	-	160
Lebanon	1361	3000
Libya	400000	2500
Saudi	254050	2338
Syria	-	2935
Somalia	-	3300
Iraq	-	1000
Yemen	-	1400
Egypt	600000	4500
Sudan	39000	2300
Morocco	200000	10000
Mauritania	400000	1500
Total	7733900	42228

Arab shared aquifers systems

The Arab region can be distinguished in ffour main hydrological zones, as follows:

- The Mediterranean- Atlantic Ocean Zone Consists of coastal watersheds or low- Aquifers have specific characteristics that distinguish them from other water bodies: (i) they can help in removing suspended solids and disease-causing organisms; (ii) they can store water in quantities exceeding those which are or conceivably could be stored in all natural and artificial surface-water bodies; (iii) they can regulate the water temperature and its chemical quality; (iv) they transport water from areas of recharge to areas of need; and (v) they slow- down the natural discharge of water to the surface. As such, aquifers can be utilized as strategic storage reservoirs for water to make up the bulk of the dry- weather flow of streams.lands in the borders of mountains facing the Mediterranean Sea and Atlantic Ocean where large volumes of fresh water are captured regularly from continental rains. Countries falling in this category (Morocco and northern part of Algeria, Lebanon, and small portions of Syria and Iraq) have generally renewable water resources (rivers and shallow groundwater).
- The Sub- Saharan Zone consists mainly of arid to semi- arid low- lands traversed by international rivers originating in other countries having humid climates.Countries falling under this category (Egypt, Mauritania, northern Sudan, and most of Syria and Iraq) have renewable rivers supplemented mainly from deep groundwater. Non-renewable
- The Saharan Zone is a flat desert region where extremely arid conditions prevail and rare or no renewable water resources exist. Countries falling under this category (Libya, Tunisia, Jordan, and a large portion of the Arabian Peninsula) depend mainly on deep non- renewable groundwater existing in extensive sedimentary rocks.
- The Red Sea- Indian Ocean Zone Comprises a variety of formations and geomorphological features. Countries falling under this category (southern part and coastal areas of Sudan, western part and coastal plains of Yemen, southwestern part of Saudi Arabia, northern part and coastal plains of Oman, and northern Emirates) have either big rivers that provide recharge to wadi deposits (Sudan), or have intermittent short- duration flash floods resulting from heavy summer rains in the mountains as well as perennial flows along the upstream areas of some wadis. (*UNESCO, 2002*)

In the Sahara desert, the major water resources are the combined Nubian Sandstone and continental intercalaire non-renewable aquifers which extend from Egypt to Mauritania .The Nubian sandstone aquifer is a non rechargeable basin that was filled up during the humid periods of pluvial age 8000 years BC and beyond. The basin, which is shared by four nations (*Egypt- Libya, Sudan, and*

Chad) exhibits an a real extent of 2350 km^2 and posses a maximum reservoir capacity of 150000 km^3

As indicated by *ESCWA, UNEP*, and *IDB (1996)*, about 20 different aquifers system are prevailing throughout the Asian Arabian countries and comprising semi – confined / shallow aquifers, and deep confined aquifer systems of different geological formation. Eight of theses basins are consederd as shared aquifers. The Dammam aquifer, the Aruma aquifer, and Umm-er-Radhuma aquifer among groundwater basins in the sub- region.(figure 4)

Although recharge is better in the Mashreq sub region, deep aquifers at the Arabian Peninsula sub – region have by far greater reserves of fossil water. Groundwater reserves in the west Asian sub- region are roughly estimated 143.8 km^{3}in 1995 Saudi Arabia alone abstracted about 14.66 km^3 and 7.515 km^3 for the Arabian Peninsula and the Mashreqe Sub- region respectively.(table 2 , Arab shared basins information.).

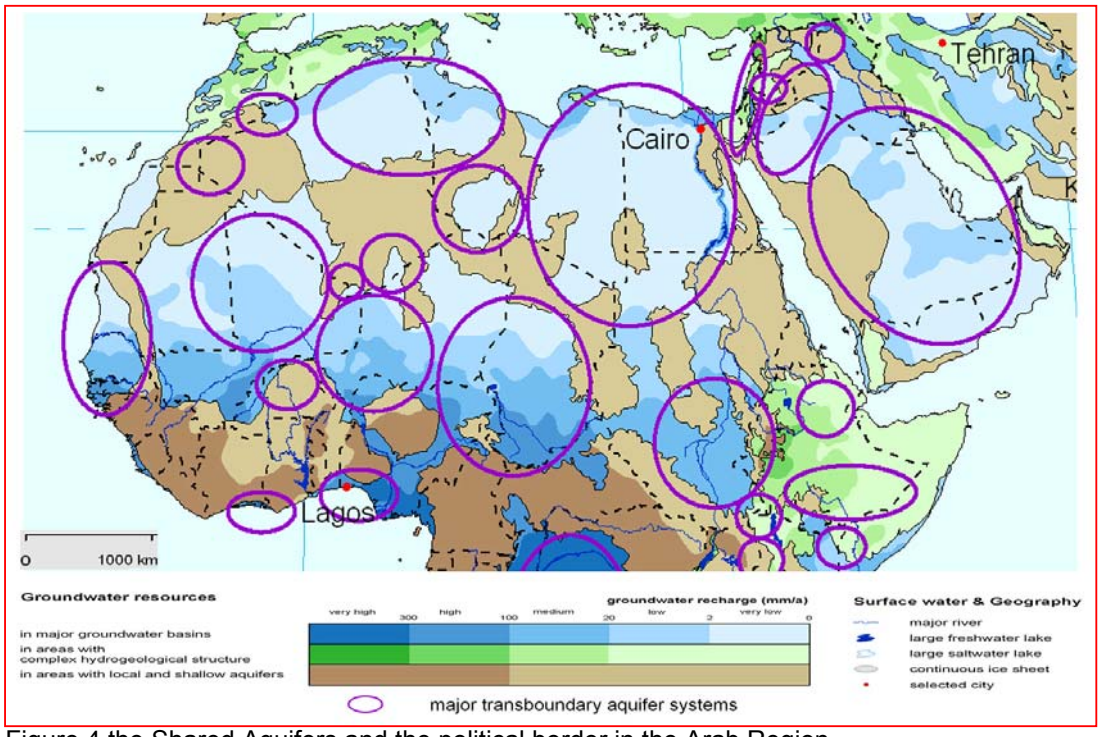

Figure 4 the Shared Aquifers and the political border in the Arab Region.
Source: GRDC, 2008, GPCC, 2008. www.whymap.org

Table 2 Arab shared basins information.

Basin	Countries	Basin area Km^2	Storage Km^3	Recharge MM^3/year	Abstraction MM^3/year
Nubian Sandstone Aquifer	Egypt, Libya, Sudan Chad	2000000	150000	1000	12000
Continental intercalaire (North Sahara basin)	Libya, Algeria Tunisia	780000	60000	580	1100
Mashreq Basin (Arabian peninsula)	Saudi Arabia. Kuwait, Qatar U.A. E., Bahrain	1400000	35000	1050	17000

(Jan Khori, 1999)

Political borders Effects

Because of the Political borders in the Arab Region, there are many factors requires attention for development of shared aquifer resources These include the scientific-hydrogeological, the legal, the socio-economic, the institutional and the environmental aspects. Moreover there area other specific conditions issues, e.g. aquifers in arid zones (Arab region) with limited recharge. The scope of scientific-hydrogeological issues, in considering the management of shared aquifer resources, is illustrated as follows:

1 Parameters distribution

Many factors may affect the behavior and the development potential of aquifers, including hydraulic parameters; rainfall and recharge zones; confined and unconfined areas; natural discharge zones; present and planned groundwater development zones; water quality, potential risks of its deterioration; and vulnerability to polluting agents. In shared or transboundary aquifers one or more of these factors may receive a different weighting on either side of a boundary.

There are several examples of shared aquifers where recharge is received on one side while the natural discharges (and sometime better yields) are across the border. Examples of this condition are found in the Mountain Aquifer extending over Palestine (W.R.A.P., 1994) (figure 5)

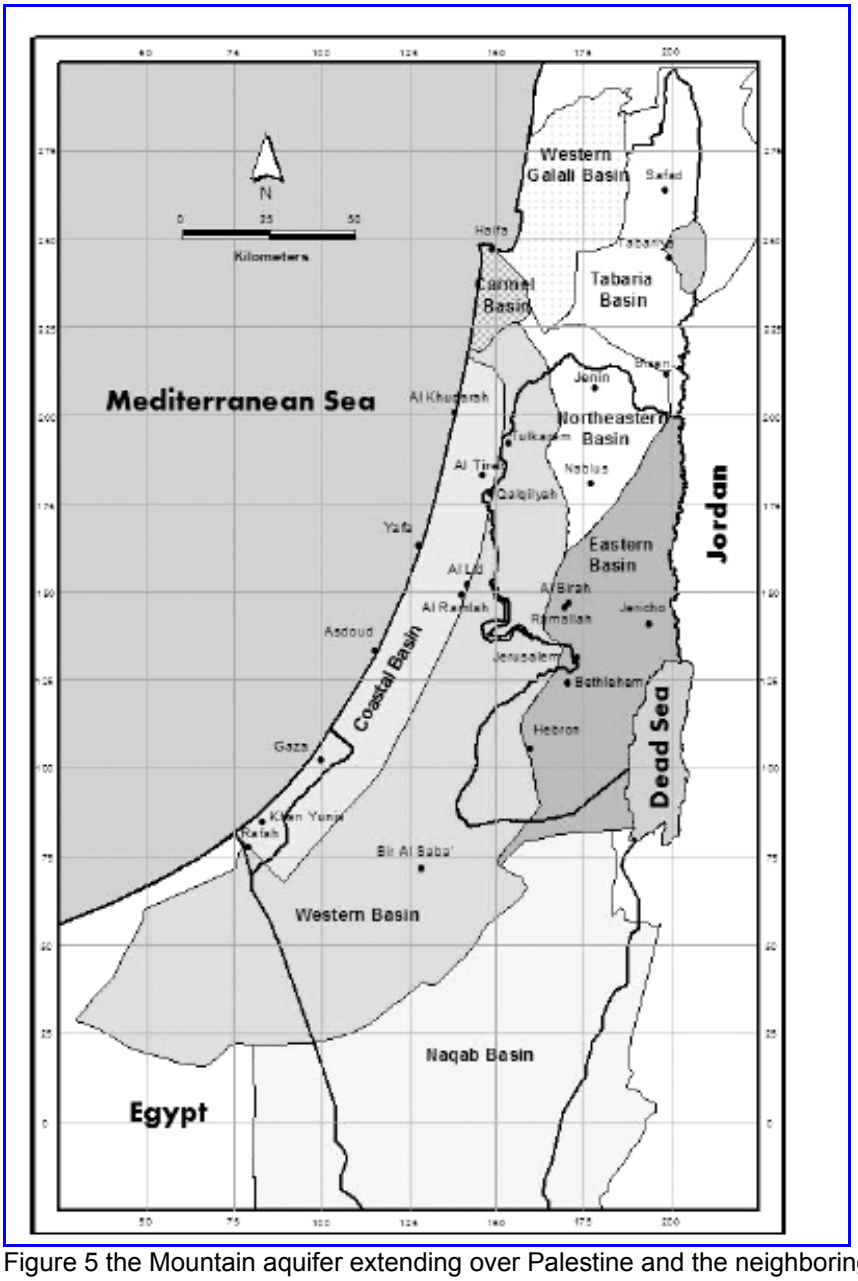

Figure 5 the Mountain aquifer extending over Palestine and the neighboring countries, (*UNESCO, 2001*).

2 Groundwater flow pattern

Groundwater flow passing a political border cannot be measured directly. It is estimated from parameters and calculated through mathematical models. Abstraction on one side of the border may alter the flow through the border. An example from Northern Sahara Aquifer System, (*UNDP/OPE, 1983*) illustrates this:

• The underground outflow of the deep aquifer (Continental Intercalaire) is a source of recharge for the coastal aquifer (Jifarah aquifer).
• Additional development from the deep aquifer in Algeria only would reduce the outflow to the coastal aquifer by 5%, (figure 6)
• The development scenario was selected to minimize the impact of Algerian development on the Tunisian coastal aquifer.

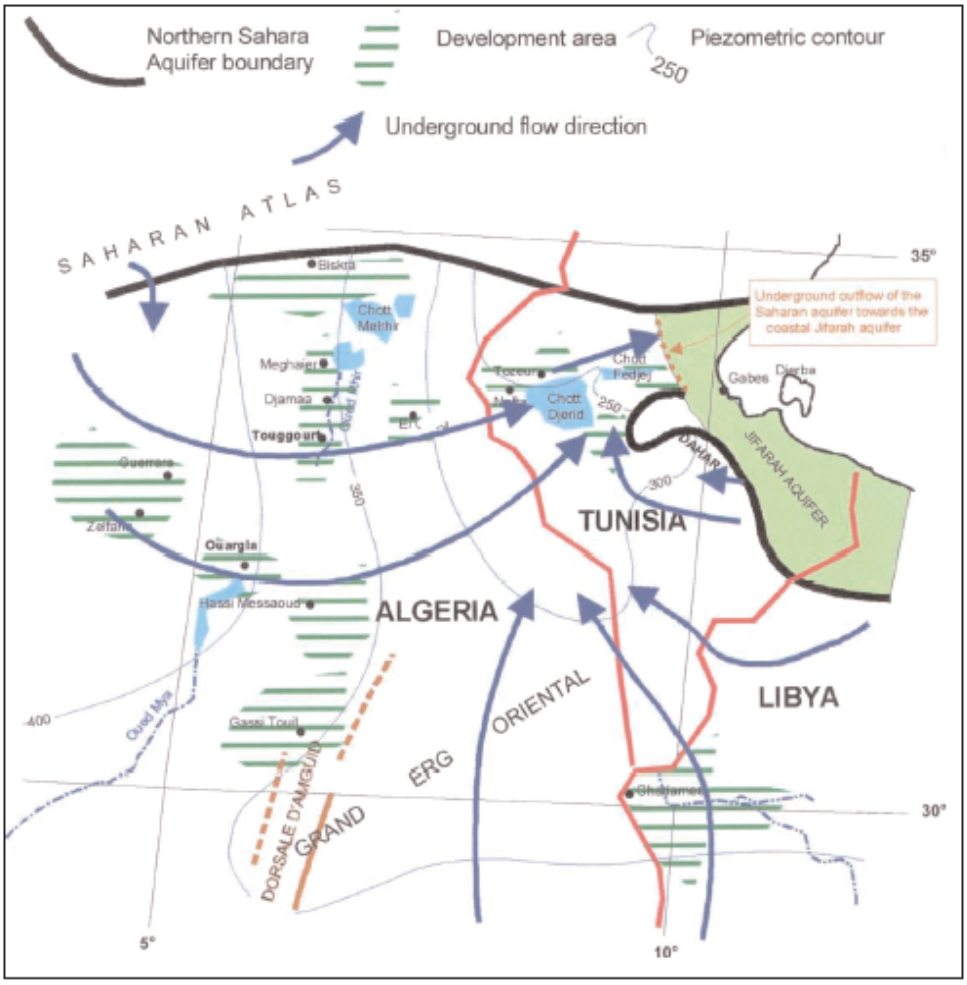

Figure 6 Northern shared aquifer at Algeria Tunisia borders (*UNESCO, 2001*)

Groundwater flow is passing a political border at Dammam aquifer; figure 7 , Cross section showing the Dammam Aquifer zonation in Bahrain.

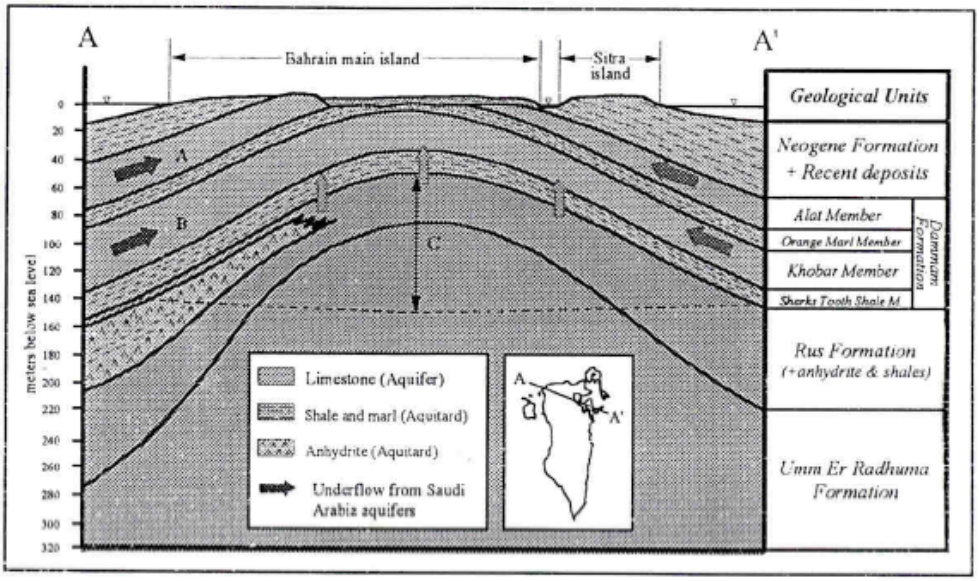

Figure 6 Cross section showing the Dammam Aquifer zonation in Bahrain (*UNESCO, 2001*)

3 Groundwater Levels

Groundwater abstraction from wells results in modifications of groundwater levels in the form of a concentric cone of depression. Cones of depression may spread beyond political borders. A model simulation (Figure 8) of the Nubian Sandstone Aquifer System illustrates the possible long term impact. Modeling foresees that in case of intensive use of the aquifer in the South Western part of Egypt, by the year 2060 the cone of depression might spread in all directions and particularly upstream towards Sudan.

4 Groundwater water quality

Water quality deterioration may take place as a result of development. Poorer quality water from the coastal area or inland saline water bodies can be mobilised, as a result of groundwater abstraction. The impacts could be transmitted from unilateral actions in one of the countries sharing the transboundary resource

Vulnerability of aquifer is higher when groundwater moves through formations where large interconnected fractures or cavities are present and encourage rapid flow as in the case of the karstic aquifers (*Margat, 1992*).

A model simulation, conducted under an IFAD funded project, can illustrate the possibility of mobilization of poorer quality water. Figure 9 shows a simulation of the possible impact that might be generated in case of additional extraction in Siwa (Egypt) and eventually new development in Jaghbub (Libya).

The saline water contained in the aquifer, currently some 20–25 km north of Siwa, would probably migrate towards the development areas, essentially towards Siwa.

Quality deterioration from vertical leakage can also occur. In arid regions some topographic depressions favour evaporation of groundwater due to high

piezometric levels and create sabkhas containing poor quality water. Production from deeper better quality aquifers will result in reversal of leakage and invasion by poor quality water.

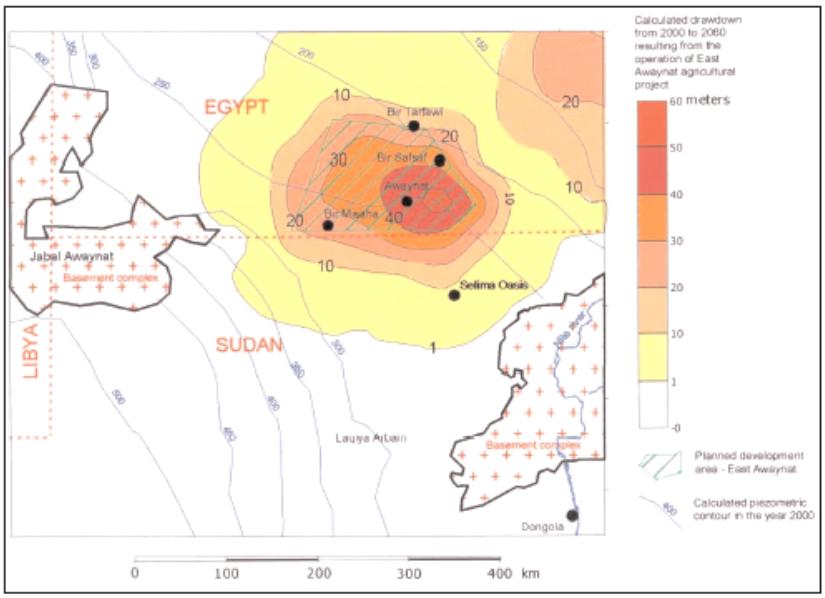

Figure 8 calculated groundwater levels at Egypt Sudan borders 2060 (*UNESCO, 2001*).

5 Shared aquifers recharge

Shared aquifers with minor contemporary recharge, but large volume in storage, can be drawn on for limited time periods (*UNESCO, 2001*). The amount and rate of extraction by each country should be subject to multilateral agreements, the purpose of these agreements would be to ensure that each sharing country accepts the mutual effect – even if slightly detrimental – on its own resource, and of groundwater development in the partner countries. Examples of shared aquifers (figure 10) with minor contemporary recharge are:

- Algeria, Tunisia and Libya sharing the Northern Sahara Aquifer System mostly developed in Algeria and Tunisia;
- • Libya, Egypt, Sudan and Chad sharing the Nubian Sandstone Aquifer System developed only in Libya and Egypt;
- • Saudi Arabia and Jordan sharing the Saq aquifer (*Puri et al., 1999*).

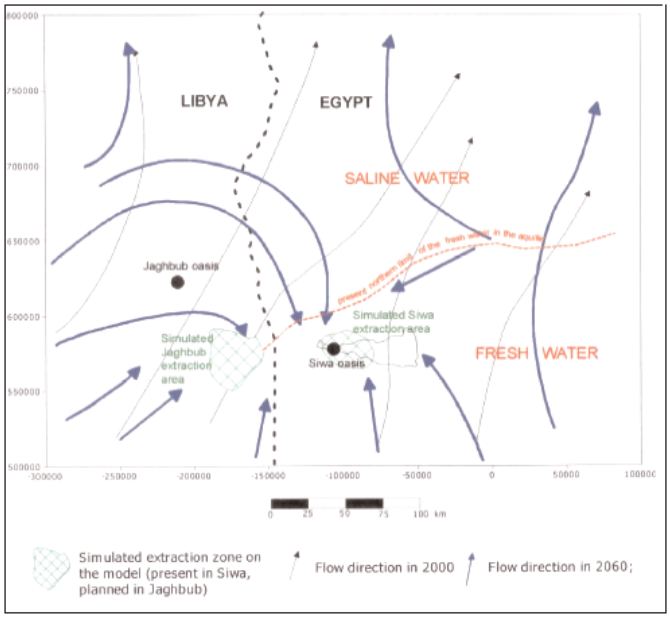

Figure 9 Simulated extraction zone on the model (present in Siwa, Planned in Jaghbub) (*UNESCO, 2001*).

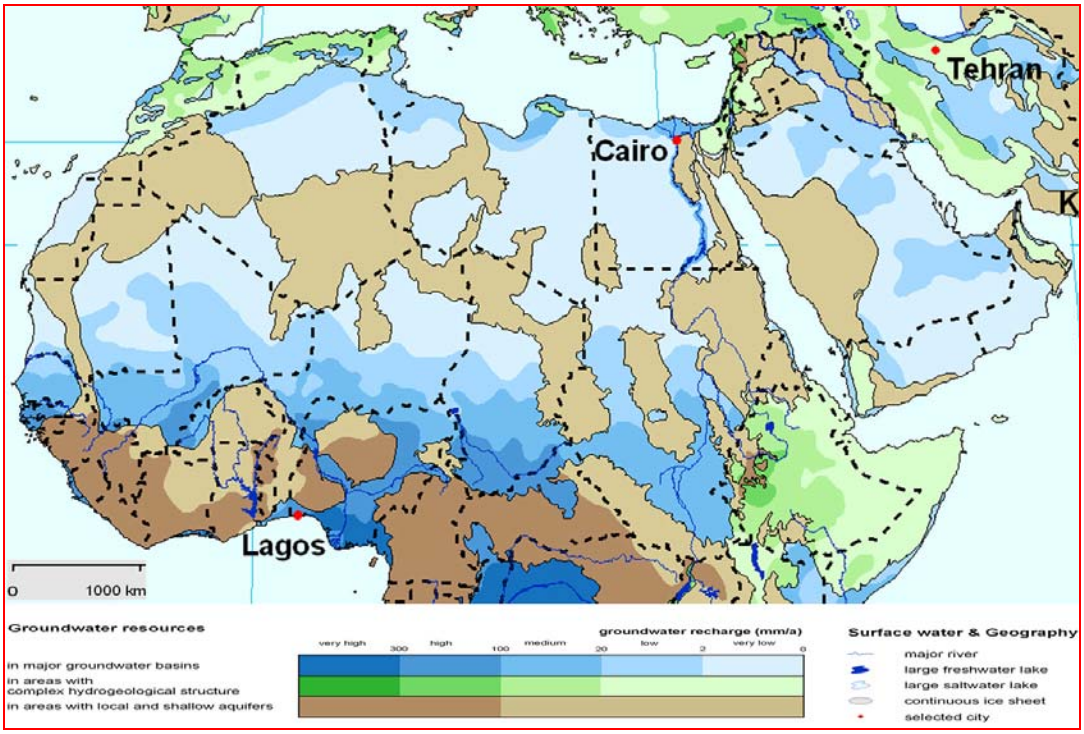

Figure 10 Groundwater recharge in the Arab Region *Source: GRDC, 2008, GPCC, 2008. www.whymap.org*

Figure Recharge

Sustainable management of the Arab Shared Aquifers

Many studies have confirmed the need for having a unified and consistent knowledge base as a prerequisite for the management of shared aquifers. Ideally this should be developed within a conceptual model of the whole shared aquifer, providing a firm foundation that supports sound development through risk based management. Determination that a particular rate of groundwater withdrawal or general management plan is sound depends on in-depth understanding of the groundwater system. This understanding begins with knowledge of basic hydrological processes. Relating this to specific situations requires understanding of the extent and nature of the aquifer, how it relates to other aquifers and hydrogeologic features, how the recharge and discharge of water takes place within the aquifer, and where potential sources of contamination are located.

Without such understanding the use of a shared aquifer cannot be confidently planned. This conceptual model should be augmented by a consistent program on both sides of a boundary to monitor basic hydrologic parameters, such as precipitation, groundwater levels, stream flow, evaporation, and water use. The monitoring program will provide the data essential to generate a quantitative perspective on the status of the groundwater system and to validate the conceptual understanding. The data must be consistent with the conceptual model. If not, the conceptual model may need to be revised. (*UNESCO , 2001*)

Most Shared aquifer systems in Arab Region have ecosystems, landscape elements, or pre-existing water users that are dependent on current discharge or recharge patterns. Further development may require trading off these dependencies in favor of new plans or policy. If dependencies are not well understood or considered, management changes may have major unanticipated impacts.

Recommendations

- The Arab Countries should work to evaluate and solve the present problems related to groundwater management in the Arab Region that can be summarized as follows: (i) extensive drawdown that are affecting the sustainability of the resource; (ii) sea water intrusion in coastal aquifers; (iii) pollution from various sources; (iv) vague or poor institutional set- up; (v) lack of proper management tools and related knowledge; (vi) poor enforcement of legislation; and (vii) lack of public participation and public awareness.(*UNESCO , 2002*).
- The Arab Countries should work to cooperate toward mutually beneficial and sustainable shared aquifer development, and Integration of water resource management across borders can best be achieved within the context of some form of agreement or a treaty between parties sharing the aquifer system.
- It is essential to view the entire aquifer system, including all aquifers that are hydraulically interconnected, directly by lateral or indirectly through vertical contact or through fractures because the shared groundwater resource

boundaries in the Arab Region, are often very poorly known and so many shared aquifers remain only partly recognized.

- Regional ethical concepts are critical for management of shared resources where In the Arab region water is a free natural resource that should be made available not only for basic needs but to farmers to meet the social and development demand for each country, to guarantee cultivation of agricultural products. All steps towards 'commercialization' of water resources are considered as unethical (*AOAD, 1997*).
- Institutional, cultural and ethical dimensions are likely to be as important as technical and macroeconomic dimensions in the evolution of approaches to address existing and emerging international groundwater problems. Sharing basic data and information on internationally shared aquifer systems and the projected demands are clearly important, but so too is the joint promotion of effective management. International water issues are too important to be left to local participation and the market.
- The impact of climate change on shared aquifers of the Arab Region must be fully evaluated in the same way as it has been for agriculture and land use. In some regions climate change will result in increasing recharge and in others reducing. The consequences of either of these impacts on abstraction, maintenance of wetlands, and discharge to water bodies could be very serious, especially where well developed infrastructure has been established. Global sea level changes, may impact marine saline intrusion, the hydraulic reference point change could mean that many aquifers may extend inland intrusions, thus affecting groundwater quality.
- The initial stage in any legal agreements for the equitable share of shared aquifers in the Arab Region must be the correct identification of flow and movement of water followed by its quantification.

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