2 Natural Water Resources of the MENA Region

In this chapter we will quantify the renewable and exploitable freshwater resources in MENA. Basically the natural resources of freshwater are rainfall, rivers, lakes and groundwater sheds. A very comprehensive definition of the different resources is given in /FAO 2003/. The following definitions are used for the different freshwater resources (Table 2-1):

Internal renewable water resources account for the average annual surface flow of rivers and the recharge of groundwater generated from endogenous precipitation.

External renewable water resources refer to surface water and to renewable groundwater that come from other countries plus part of shared lakes and border rivers as applicable, taking into account the net consumption of the country in question. Dependency on incoming water from external sources is quantified by the **dependency ratio**.

Renewable resources are the total of internal and external surface and groundwater resources. Double counting of surface water and groundwater is avoided as far as possible.

The **exploitable water** potential was estimated if available or was set equal to the renewable water value /FAO 2007/. Exploitable water may either be limited by technical and economical reasons (e.g. if the source is very far from the demand or in a region that is difficult to access), by international treaties regulating the allocation of water from rivers that cross international borders as e.g. in Syria and Egypt, or by reasons of environmental protection.

Non-renewable groundwater resources are naturally replenished only over a very long timeframe. Generally, they have a negligible rate of recharge on the human scale (<1 percent) and thus can be considered non-renewable. In practice, non-renewable groundwater refers to aquifers with large stocking capacity in relation to the average annual volume discharged. Figures included in this table are the best estimate of annual withdrawals.

2.1 Overview of Freshwater Resources

Considerable rainfall in the MENA region with an annual precipitation of more than 300 mm/y is mainly limited to the Mediterranean coastal areas of the Maghreb (Morocco, Algeria, Tunisia), the Northern Mashreq (Syria, Lebanon, Israel) and the western mountains of Yemen and Iran (Figure 2-1, Table 2-1). Only four countries – Iraq, Iran, Syria and Lebanon – can be considered well above the water poverty limit of 1000 m^3/cap/y, while all other countries in MENA must be considered as water poor (Figure 2-2). There are only a few major perennial rivers and lakes in the MENA region, namely Euphrates and Tigris in Syria and Iraq and the Nile and Lake Nasser in Egypt, and some smaller rivers in the Maghreb region (Figure 2-3). Some countries like Egypt depend almost exclusively on external freshwater resources entering the country from outside, in this case the Nile river, which accounts for 97 % of the available freshwater.

There are very large groundwater aquifers in the MENA region, that are re-charged by rainfall and by incoming rivers (Figure 2-4). Most of the water contained in those subterranean basins is however fossil water that is not renewed on an annual basis /BGR 2007/.

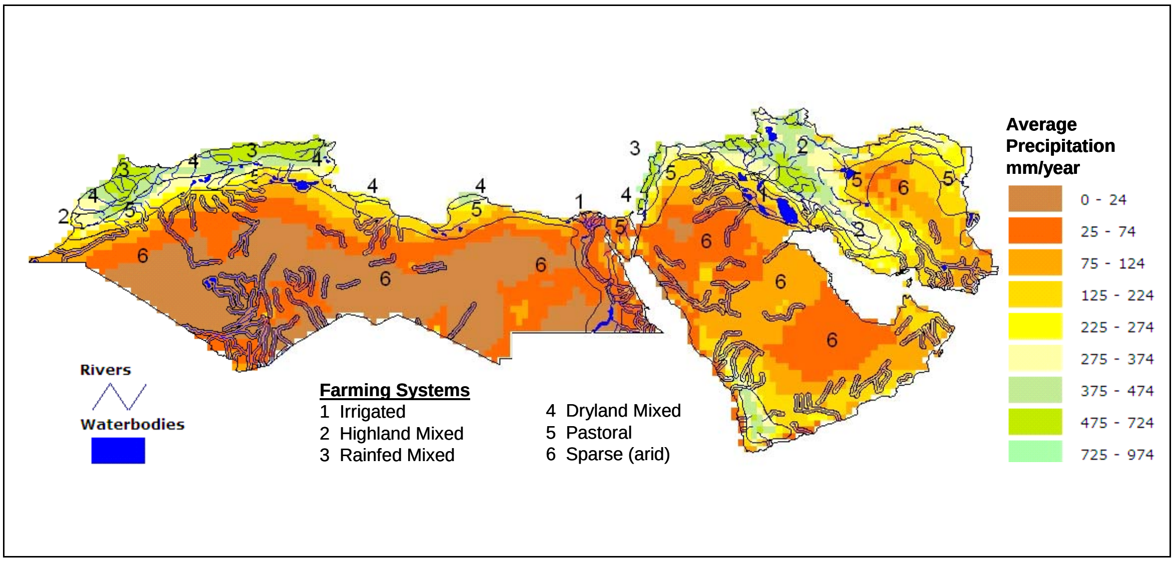

Figure 2-1: Annual Precipitation in the MENA Region /FAO 2007-2/

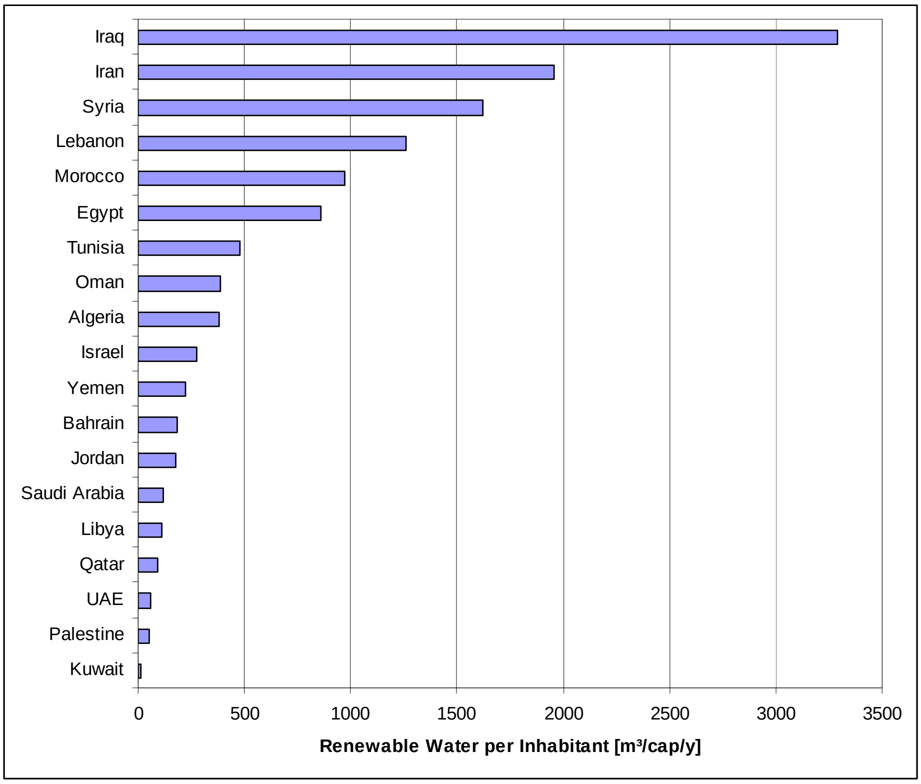

Figure 2-2: Total available natural renewable freshwater sources available per capita in the MENA region for the year 2000. Only four countries are beyond the water poverty threshold of 1000 m^3/cap/y.

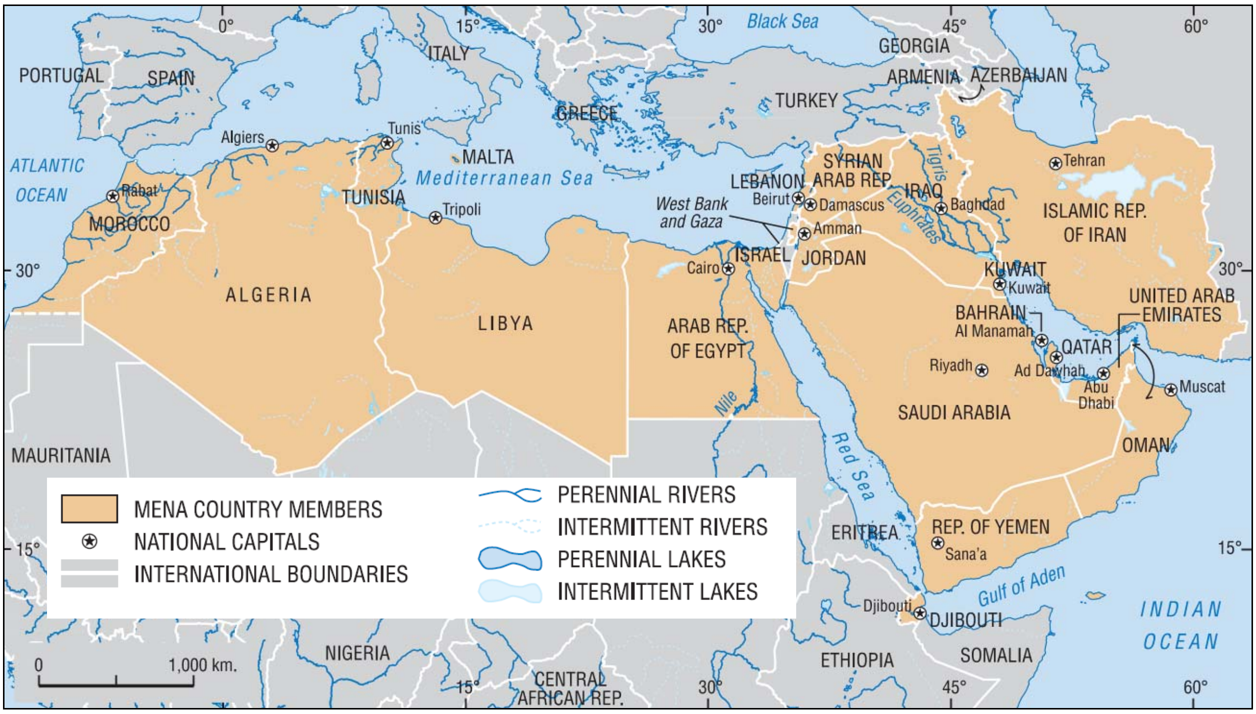

Figure 2-3: Major Rivers and Lakes in the MENA Region /World Bank 2007/

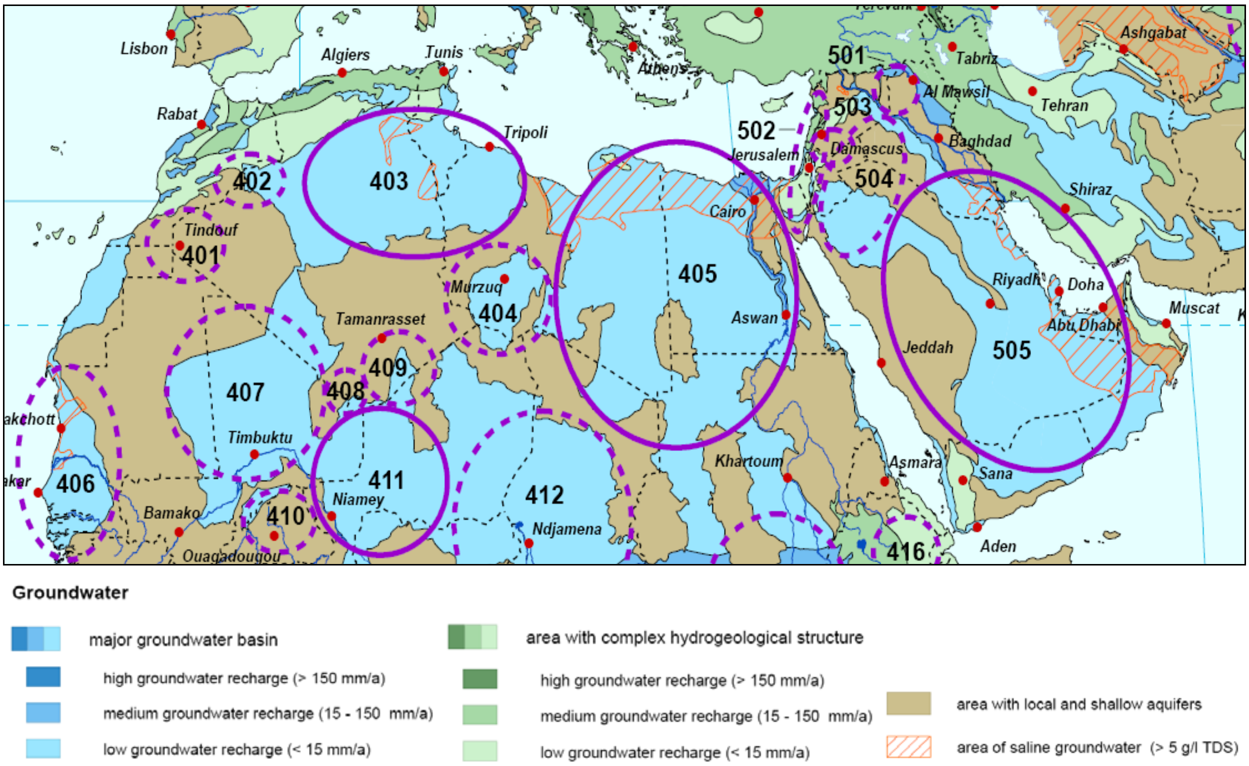

Figure 2-4: Groundwater Aquifers of the MENA Region /BGR 2006/

Renewable and Exploitable Water in MENA	Average Precipitation (mm/y)	Annual Rainfall (km³/y)	Internal Renewable Water (km³/y)	Internal Renewable Groundwater (km³/y)	Internal Renewable Surface Water (km³/y)	Overlap: Surface and Groundwater (km³/y)	Total Renewable Water (natural) (km³/y)	Total Renewable Water (actual) (km³/y)	Total Population in 2000 (million)	Total Renewable Water (actual) (m³/cap/y)	Dependency Ratio (%)	Exploitable Water (km³/y)
Morocco	346	154.7	29.0	10.0	22.0	3.0	29.0	29.0	29.2	993	0	20.0
Algeria	89	211.5	11.2	1.4	9.8	0.0	11.6	11.6	30.5	380	3	7.9
Tunisia	313	51.3	4.2	1.5	3.1	0.4	4.6	4.6	9.6	475	9	3.6
Libyan Arab Jamahirija	56	98.5	0.6	0.5	0.2	0.1	0.6	0.6	5.3	113	0	0.6
Egypt	51	51.4	1.8	1.3	0.5	0.0	86.8	58.3	67.3	866	97	49.7
North Africa	**--**	**567.3**	**46.8**	**14.7**	**35.6**	**3.5**	**132.6**	**104.1**	**141.9**	**733**	**--**	**81.8**
Israel	435	9.2	0.8	0.5	0.3	0.0	1.7	1.7	6.1	274	55	1.64
Palestine	316	0.1	0.1	0.1	0.0	0.0	0.1	0.1	3.2	19	18	0.06
Jordan	111	9.9	0.7	0.5	0.4	0.2	0.9	0.9	5.0	176	23	0.88
Lebanon	661	6.9	4.8	3.2	4.1	2.5	4.8	4.4	3.4	1297	1	2.19
Syrian Arab Republic	318	58.9	7.0	4.2	4.8	2.0	46.1	26.3	16.8	1563	80	20.6
Iran, Islamic Rep. of	228	375.8	128.5	49.3	97.3	18.1	137.5	137.5	66.4	2071	7	137.51
Iraq	216	94.7	35.2	1.2	34.0	0.0	96.4	75.4	25.1	3005	53	75.42
Western Asia	**--**	**555.5**	**177.0**	**59.0**	**140.9**	**22.8**	**287.5**	**246.2**	**126.0**	**1954**	**--**	**238.3**
Oman	125	38.7	1.0	1.0	0.9	0.9	1.0	1.0	2.4	413	0	0.99
Kuwait	121	2.2	0.0	0.0	0.0	0.0	0.0	0.0	2.2	9	100	0.02
Qatar	74	0.8	0.1	0.1	0.0	0.0	0.1	0.1	0.6	83	4	0.05
Saudi Arabia	59	126.8	2.4	2.2	2.2	2.0	2.4	2.4	21.5	112	0	2.4
United Arab Emirates	78	6.5	0.2	0.1	0.2	0.1	0.2	0.2	3.2	47	0	0.15
Yemen	167	88.3	4.1	1.5	4.0	1.4	4.1	4.1	17.9	229	0	4.1
Bahrain	83	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.7	171	97	0.12
Arabian Peninsula	**--**	**263.4**	**7.7**	**4.8**	**7.3**	**4.4**	**7.8**	**7.8**	**48.5**	**161**	**--**	**7.83**
Total MENA	**--**	**1386.2**	**231.4**	**78.4**	**183.7**	**30.7**	**427.9**	**358.1**	**316.4**	**1132**	**--**	**328.0**

Table 2-1: Renewable and exploitable freshwater resources in the MENA countries by AQUASTAT /FAO 2007/. Values of exploitable water shaded in blue were not available and have been assumed to be equal to the total actual renewable water.

2.2 Individual Country Information

(most of the following information is taken from AQUASTAT /FAO 2007/ if not stated otherwise)

Algeria

Algeria receives rain in an annual average of 89 mm/y, that allows a flow of 211 km³/y. But taking into account the aridity of the major part of the country, most of this water is evaporated, while only a small proportion constitutes the renewable water resources. The surface water resources are evaluated to net 9.8 Km³/y, distributed among 5 water sheds /UN 2005/, renewable groundwater resources are estimated at 1.4 km³/y. Internal renewable water resources are estimated at 11.2 km³/year. Incoming surface water has been estimated at 0.4 km³/year. of which 0.2 km³ from Morocco and 0.2 km³ from Tunisia. The water resources, that are potentially available for use in the northern part of the country and the high plateaux have been estimated at 7.9 km³/year, of which 6.4 km³/y is surface water to be regulated by dams and 1.5 km³/y is groundwater. In 2006, dams had been constructed or were under construction with a total dam capacity of 6 km³.

Bahrain

With only 83 mm/y of annual precipitation, the total annual rainfall in Bahrain amounts to roughly 0.1 km³/y of with only 0.004 km³/y can be considered as internal renewable source. The external renewable sources amount to 0.112 km³/y. The total renewable water has also been considered as exploitable, with a total of 0.116 km³/y.

Egypt

The Nile river is the main source of water for Egypt. Under the 1959 Nile Waters Agreement between Egypt and Sudan, Egypt's share is 55.5 km³/y. The 1959 Agreement was based on the average flow of the Nile during the 1900-1959 period, which was 84 km³/year at Aswan. The flow of the Nile at Aswan varies monthly in a proportion from 1 to 10: monthly flows are lower than 5,000 Mm³ during six months, from January to June, increase until reaching 20,000 Mm³ in July, then decrease until reaching 5,000 Mm³ in December. Average annual evaporation and other losses from the High Dam lake were estimated to be 10 km /year, leaving a net usable annual flow of 74 km³/year, of which 18.5 km³/y was allocated to Sudan and 55.5 km³/y to Egypt. Internal surface water resources are estimated at 0.5 km³/year. This brings the total (actual) surface water resources to 56.0 km³/y.

The volume of groundwater entering the country from Libya is estimated at 1 km³/year. Internal renewable groundwater resources are estimated at 1.3 km³/y. This brings the total renewable groundwater resources to 2.3 km³/y. The main source of internal recharge is percolation from irrigation water, and its quality depends mainly on the quality of the irrigation water. In the northern part of the Delta, groundwater becomes brackish to saline due to sea water intrusion. About half of the Delta contains brackish to saline groundwater. The Nubian Sandstone aquifer, located under the Western Desert and extending to Libya, Sudan and Chad, contains important non-renewable fresh groundwater resources, already developed in the oasis of the new valley. Large irrigation schemes pumping water from the Nubian aquifer are under development in the south-western part of the country (Al Aweinat).

In Egypt the Nubian ground water sheet would have a potential of 15,000 km^3, non-renewable, and not exploitable because the great depth of the piezometric level. In addition, the Nile alluvial ground water sheet would have a potential of 500 km^3, of which only 7.5 km^3 are exploitable.

Iran

Iran can be divided into the following major river basins: the Central Plateau in the middle, the Lake Orumieh basin in the north-west, the Persian Gulf and the Gulf of Oman in the west and south, the Lake Hamoun basin in the east, the Kara-Kum basin in the north-east and the Caspian Sea basin in the north. With an area of 424 240 km^2, the Caspian Sea is the largest landlocked water body in the world and its surface lies about 22 metres below sea level.

All these basins, except the Persian Gulf and Gulf of Oman, are interior basins. There are several large rivers, the only navigable one of which is Karun, the others being too steep and irregular. The Karun river, with a total length of 890 km, flows in the south-west of the country to the Shatt ElArab, which is formed by the Euphrates and the Tigris after their confluence. The few streams that empty into the Central Plateau dissipate into the saline marshes. All streams are seasonable and variable. Spring floods do enormous damage, while there is little water flow in summer when most streams disappear. Water is however stored naturally underground, finding its outlet in subterranean water canals (qanats) and springs. It can also be tapped by wells.

Internal renewable water resources are estimated at 128.5 km^3/year. Surface runoff represents a total of 97.3 km /year, of which 5.4 km^3/year comes from drainage of the aquifers, and groundwater recharge is estimated at about 49.3 km^3/year, of which 12.7 km^3/year is obtained from infiltration in the river bed. Iran receives 6.7 km^3/year of surface water from Pakistan and some water from Afghanistan through the Helmand river. The flow of the Arax river, at the border with Azerbaijan, is estimated at 4.63 km^3/year. The surface runoff to the sea and to other countries is estimated at 55.9 km^3/year. The total safe yield of groundwater (including non renewable water or unknown groundwater inflow from other countries) has been estimated at 49.3 km^3/year.

The actual total renewable water resources allocated to Iran are estimated to be 137.5 km^3/y which are considered as exploitable, because of lack of other information.

Iraq

There is only one river basin in Iraq, the Shatt Al-Arab basin. The Shatt Al-Arab is the river formed by the confluence downstream of the Euphrates and the Tigris and flows into the Persian Gulf after a course of only 190 km. Before their confluence, the Euphrates flows for about 1 000 km and the Tigris for about 1 300 km respectively within the Iraqi territory. Nevertheless, due to the importance of the Euphrates and the Tigris, the country is generally divided into three river basins: the Tigris, the Euphrates, and the Shatt Al-Arab (referring to the part downstream of the confluence of the two rivers).

Both the Tigris and the Euphrates are international rivers originating their source in Turkey. The Tigris river basin in Iraq has a total area of 253 000 km², or 54% of the total river basin area.

The average annual flow of the Euphrates as it enters Iraq is estimated at 30 km³/y, with a fluctuating annual value ranging from 10 to 40 km³/y. Unlike the Tigris, the Euphrates receives no tributaries during its passage in Iraq. About 10 km³ per year are drained into the Hawr al Harnmar (a marsh in the south of the country).

For the Tigris, average annual runoff as it enters Iraq is estimated at 21.2 km³. All the Tigris tributaries are on its left bank. From upstream to downstream:

- the Greater Zab, which originates in Turkey and is partly regulated by the Bakhma dam. It generates 13.18 km³ at its confluence with the Tigris; 62% of the 25 810 km² of river basin is in Iraq;
- the Lesser Zab, which originates in Iran and is equipped with the Dokan dam (6.8 km). The river basin of 21 475 km² (of which 74% is in Iraqi territory) generates about 7.17 km, of which 5.07 km³ of annual safe yield after the Dokan construction;
- the Al-Adhaim (or Nahr Al Uzaym), which drains about 13 000 km² entirely in Iraq. It generates about 0.79 km³ at its confluence with the Tigris. It is an intermittent stream subject to flash floods;
- the Diyala, which originates in Iran and drains about 31 896 km², of which 75% in Iraqi territory. It is equipped with the Darbandikhan dam and generates about 5.74 km³ at its confluence with the Tigris;
- the Nahr at Tib, Dewarege (Doveyrich) and Shehabi rivers, draining together more than 8 000 km². They originate in Iran, and bring together in the Tigris about 1 km³ of highly saline waters;
- the Al-Karkha, whose course is mainly in Iran and, from a drainage area of 46 000 km², brings about 6.3 km³ yearly into Iraq, namely into the Hawr Al Hawiza during the flood season, and into the Tigris river during the dry season.

The Karun river, originating in Iran flows with its mean annual flow of 24.7 km^3 into the Shatt Al-Arab. It brings a large amount of fresh water into the Shatt Al-Arab, just before it reaches the sea.

The Euphrates and the Tigris are subject to large and possibly disastrous floods. The level of water in the Tigris can rise at the rate of over 30 cm/hour. In the southern part of the country, immense areas are regularly inundated, levees often collapse, and villages and roads must be built on high embankments. The Tharthar reservoir was planned inter alia in the 1950s to protect Baghdad from the ravages of the periodic flooding of the Tigris by storing extra water discharge upstream of the Samarra barrage.

Average precipitation in Iraq is of 216 mm/y. The internal renewable water sources are estimated to an amount of 35.2 km^3/y of which 34 are surface water. Taking into account the external sources entering the country and their allocation to Iraq, about 75 km^3/y are considered as total actual renewable water resources. They have also been considered as exploitable, lacking better information.

Jordan

In Jordan, rainfall is limited to 111 mm/y, and surface water resources are unevenly distributed among 15 basins. The largest source of external surface water is the Yarmouk river, at the border with Syria. Originally, the annual flow of the Yarmouk river was estimated at about 400 million m^3 (of which about 100 million m^3 are withdrawn by Israel). Total flow is now much lower than 400 million m^3 as a result of the upstream Syrian development works which have been done in the 1980's. The Yarmouk river accounts for 40 % of the surface water resources of Jordan, including water contributed from the Syrian part of the Yarmouk basin. It is the main source of water for the King Abdullah canal and is thus considered to be the backbone of development in the Jordan valley. Other major basins include Zarqa, Jordan river side wadis, Mujib, the Dead Sea, Hasa and Wadi Araba. Internally generated surface water resources are estimated at 0.4 km^3/y.

Jordan's groundwater is distributed among 12 major basins. Total internally produced renewable groundwater resources have been estimated at 0.5 km^3/y, of which 0.22 km^3 constitute the base flow of the rivers. Groundwater resources are concentrated mainly in the Yarmouk, Amman-Zarqa and Dead Sea basins.

The safe yield of renewable groundwater resources is estimated at 0.275 km^3/year. Most of it is at present exploited at maximum capacity, in some cases beyond safe yield. Of the 12 groundwater basins, 6 are being over-extracted, 4 are balanced with respect to abstraction and 2 are under-exploited. Over-extraction of groundwater resources has seriously degraded water quality and reduced exploitable quantities, resulting in the abandonment of many municipal and irrigation water well fields, such as in the area of Dhuleil.

The main non-renewable aquifer presently exploited is the Disi aquifer (sandstone fossil), in southern Jordan with a safe yield estimated at 0.125 km³/year for 50 years. Other non-renewable water resources are found in the Jafer basin, for which the annual safe yield is 0.018 km³. In total it is estimated by the Water Authority of Jordan that the safe yield of fossil groundwater is 0.143 km³/year.

Total renewable water resources in Jordan are estimated at 0.88 km³/y which are also considered as exploitable, due to lack of other information.

Kuwait

There are no permanent surface water flows in Kuwait. Rainwater (121 mm/y) accumulates in the natural depressions where water remains for several weeks. Only a small part of this water percolates into the ground because of the high evaporation and the presence of an impervious layer in some regions.

There are two major aquifers: the Kuwait group (upper layer) and the Damman group (lower layer). Groundwater inflow has been estimated at about 20 million m³/year through lateral underflow from Saudi Arabia.

There are three classes of groundwater: fresh water with salinity below 1000 ppm which is used for drinking and domestic purposes, slightly saline water with salinity ranging between 1 000 and 10 000 ppm which is used for irrigation, and highly saline water with salinity exceeding 10 000 ppm which is used in special cases only. In general groundwater quality and quantity are deteriorating due to the continuous pumping of water. 90% of the wells pump water with a salinity level higher than 7 500 ppm in 2000.

Lebanon

In total, there are about 40 major streams in Lebanon and, based on the hydrographic system, the country can be divided into five regions:

- the El Assi (Orontes) river basin in the north. The El Assi flows into Syria in the north-east of the country;
- the Litani river basin in the east and south. The Litani reaches the sea in the south-west of the country;
- the Hasbani river basin in the south-east. The Hasbani, which flows into Israel in the south east of the country, is a tributary of the Jordan river;

- all the remaining major coastal river basins. The northern El Kebir river basin is shared with Syria, the river itself forming part of the border between the two countries before flowing into the sea;
- all the remaining small in-between scattered and isolated sub-catchments with no noticeable surface stream flow, like some isolated coastal pockets.

Lebanon has a relatively favourable position as far as its rainfall (661 mm/y) and water resources (1260 m^3/cap/y) are concerned, but constraints for development consist of the limited water availability during the seven dry summer months. Annual internal renewable water resources are estimated at about 4.8 km^3/y. Annual surface runoff is estimated at 4.1 km^3/y and groundwater recharge at 3.2 km^3/y, of which 2.5 km^3 constitutes the base flow of the rivers. About 1 km^3 of this flow comes from over 2 000 springs with about 10-15 l/s of average unit yield, sustaining a perennial flow for 17 of the total of 40 major streams in the country.

Lebanon being at a higher elevation than its neighbours has practically no incoming surface water flow. A contribution of 0.074 km^3/year to the El Kebir river, to the north, is estimated to be generated by the 707 km^2 bordering Syrian catchments areas. There might also be some groundwater inflow from these areas, but no figures on quantities are available. Surface water flow to Syria is estimated at 510 million m^3/year through the El-Assi (Orontes)) river and the bordering El Kebir river. An agreement between Lebanon and Syria on the Orontes river has led to a share of 0.080 km^3/year for Lebanon and the remainder for Syria. Surface water flow to Israel is estimated at 0.160 km^3/y, of which about 0.138 km^3 through the Hasbani river including a contribution of 0.03 km^3 from its tributary, the Wazzani spring. Annual groundwater outflow is estimated at 1.030 km^3/y, of which 0.130 km^3/y flow to Syria, 0.180 km^3 to Israel and 0.72 km^3 to the sea.

The relative importance of groundwater flow to the sea and the difficulties related to its control, added to the difficult geological conditions of most of the investigated sites for storage dams, make the manageable resources of Lebanon certainly much lower than the global figure of 4.8 km^3/year. The most realistic figure recognized does not exceed 2.2-2.5 km /year.

Libya

The total mean annual runoff calculated or measured at the entrance of the wadis in the plains is estimated at 0.2 km^3/year, but part of it either evaporates or contributes to the recharge of the aquifers. Sixteen dams, with a total storage capacity of 0.387 km^3 and with an expected average annual volume of water controlled in the order of 0.06 km^3/y, had been constructed by 2000. This difference between the average annual runoff and the storage capacity of the dams is so that the runoff water of exceptionally wet years can be stored.

Currently, aquifers are only recharged in the northern regions, namely in the northwestern zone, Jabal Nafusah and Jifarah Plain, and in the north-eastern zone, Jabal al Akhdar. Renewable groundwater resources are estimated at 800 to 1 000 million m³/year, but part (perhaps 50%) now flows out either to the sea or to evaporative areas (sabkhas). Not all the renewable groundwater can be abstracted without affecting the environment, because of the deterioration of water quality by saline water encroachment. For this reason, the safe yield has been estimated at 0.5 km³/year. South of the 29th parallel, an important development of Palaeozoic and Mesozoic continental sandstone enabled water to be stored safely during the long period of the late Quaternary, before the climate turned extremely arid. Most water used in Libya comes from these huge fossil reserves.

Through the Great Manmade River Project about 2 km³/year of fossil water is transported from the desert to the coastal areas, mainly for irrigation but part is used for the water supply of the major cities.

Morocco

Precipitation in Morocco amounts to 346 mm/y, mostly in the coastal regions and in the Atlas mountains. There are no external water resources available. The total internal renewable water resources of Morocco have been evaluated at 29 km³/year, (19 km³/y surface water, 10 km³/y groundwater) out of which 16 km³ of surface water and 4 km³ of groundwater are considered to represent an exploitable water development potential. The most important rivers are equipped with dams, allowing surface water to be stored for use during the dry seasons. In the year 2000, dams with a total capacity of 16 km³ were operational. Over 45 % of the surface water and over 50 % of the groundwater quality of Morocco is considered bad or very bad.

Oman

A great deal of uncertainty lies in the assessment of Oman's water resources. Internal renewable water resources have been evaluated at 0.985 km³/y. Surface water resources are scarce. In nearly all wadis, surface runoff occurs only for some hours or up to a few days after a storm, in the form of rapidly rising and falling flood flows. Since 1985, 15 major recharge dams have been constructed together with many smaller structures, in order to retain a portion of the peak flows, thus allowing more opportunity for groundwater recharge. In addition, several flood control dams produce significant recharge benefits. In 1996, the total dam capacity was 0.058 km³. Groundwater recharge is estimated at 0.955 km³/year.

Qatar

There is practically no permanent surface water - annual surface runoff has been estimated at 0.001 km³/y. Direct and indirect recharge of groundwater from rainwater forms the main natural internal water resources. Two-thirds of the land surface is made up of some 850 contiguous depressions of interior drainage with catchments varying from 0.25 km² to 45 km² and with a total aggregate area of 6 942 km². While direct recharge from rainfall might take place during very rare heavy storms, the major recharge mechanism is an indirect runoff from surrounding catchments and the pounding of water in the depression floor. Surface runoff typically represents between 16 and 20% of rainfall. Of the amount reaching the depressions, 70% infiltrates and 30% evaporates.

There are two separate and distinct groundwater regions: the northern half, where groundwater occurs as a freshwater 'floating lens' on brackish and saline water and the southern half where no such lens exists and where water quality is generally brackish with only a thin veneer of freshwater at the top of the water table. Annual groundwater recharge has been estimated at 0.050 km³/y.

The two main aquifers underlying Qatar are recharged in Saudi Arabia. Over most of Qatar the Damman formation does not contain water because of its altitude. It dips lower in southwest Qatar where it contains water, but is also overlain by impervious layers. The artesian aquifer which results from this structure is called the Alat unit of the Damman. Below this aquifer is the Umm er Radhuma, which is similarly artesian. In 1981, the Master Water Resources and Agricultural Development Plan (MWRADP) estimated that in the southern part of Qatar the safe yield of the Alat aquifer is 2 million m³/year and that of the Umm er Radhuma 10 million m³/year, based on an estimate of annual flow from Saudi Arabia. However, these safe yields would be substantially reduced if the aquifer were exploited more extensively on the Saudi Arabian side of the border. In the northern and central part the Rus aquifer overlies the Umm el Radhuma aquifer, which is partly an unconfined aquifer, recharged by percolating rainfall and return flows from irrigation but losing some water to the sea and some through abstractions. The safe yield of the aquifer system in the northern and central part of Qatar is estimated at 13 million m³/year from the upper layer and 20 million m³/year from the lower layer (the latter leading to a depletion in 50 years). In total, the estimated safe yield for the whole of Qatar is 45 million m³/year.

Another potential source of groundwater is beneath the capital Doha itself. According to the MWRADP, considerable volumes of water leak from pipelines and other sources throughout much of Doha. This leakage, estimated at about 15 million m³/year, has caused the water table to rise locally, flooding basements as well as shallow excavations.

Saudi Arabia

Although the annual precipitation only amounts to 59 mm/y, heavy rainfall sometimes results in flash floods of short duration. River beds are dry for the rest of the time. Part of the surface runoff percolates through the sedimentary layers in the valleys and recharges the groundwater, some is lost by evaporation. The largest quantity of runoff occurs in the western region, which represents 60% of the total runoff although it covers only 10% of the total area of the country. The remaining 40% of the total runoff occurs in the far south of the western coast (Tahama) which covers only 2% of the total area of the country. Total surface water resources have been estimated at 2.2 km³/year, most of it infiltrating to recharge the aquifers. About 1 km³ recharges the usable aquifers. The total (including fossil) groundwater reserves have been estimated at about 500 km³, of which 340 km³ are probably extractable at an acceptable cost in view of the economic conditions of the country.

Syria

There are 16 main rivers and tributaries in the country, of which 6 are international rivers:

- the Euphrates (Al Furat), which is Syria's the largest river. It comes from Turkey and flows to Iraq. Its total length is 2 330 km, of which 680 km are in Syria,
- the Afrin in the north-western part of the country, which comes from Turkey, crosses Syria and flows back to Turkey,
- the Orontes (El-Ass) in the western part of the country, which comes from Lebanon and flows into Turkey,
- the Yarmouk in the south-western part of the country with sources in Syria and Jordan and which forms the border between these two countries before flowing into the Jordan river,
- the El-Kebir with sources in Syria and Lebanon and which forms the border between them before flowing to the sea,
- the Tigris, which forms the border between Syria and Turkey in the extreme north-eastern part.

15.75 km³ of water are entering to Syria with the Euphrates, as proposed by Turkey, 0.43 km³ of water is entering with the Orontes, as agreed with Lebanon. With the tributaries of Euphrates and Afrin, this becomes a total 18.11 km³/year (Table 2-2). The Tigris, which is the second most important river in the country, borders the country to the east and has a mean annual flow of 18 km³/y, of which 50 % can be accounted for Syria, making a total of water entering Syria of 27.1 km³/y. The total natural average outflow from Syria is 31.98 km³/year, of which an agreement exists for 9.2 km³, resulting in a total of actual external surface water resources balance for Syria of 17.9 km³/year (27.1 km³/year - 9.2 km³/year).

Although figures for water resources are very difficult to obtain due to the lack of reliable data, it can be estimated that water resources generated from rain falling within the country amount to 7 km³/year. Groundwater recharge is about 4.2 km³/year, of which 2 km³/year discharges into rivers as spring water. Total groundwater inflow has been estimated at 1.35 km³/year, of which 1.2 km³ from Turkey and 0.15 km³ from Lebanon. Although not quantified, the amount of groundwater flowing into Jordan may be significant.

The total actual renewable water sources are estimated at 26.3 km³/y of which 20.6 are considered as exploitable.

Name of river	Inflow into Syria (km³/year)			Outflow from Syria (km³/year)		
	from	natural	actual	to	natural	agreement
Euphrates *	Turkey	26.29	15.75	Iraq	30	9
Tributaries of Euphrates	Turkey	1.74	1.74		-	
Afrin	Turkey	0.19	0.19	Turkey	0.25	
Orontes, El Kebir	Lebanon	0.51	0.43		1.2	
Yarmouk		-	-	Jordan	0.4	0.2
Baniyas		-	-	Israel	0.13	
Sub-total		28.73	18.11		31.98	9.2
Bordering Tigris	50% of total	9	9			
Total	Inflow	37.73	27.11	Outflow	31.98	9.2

Table 2-2: Major rivers entering, bordering and leaving Syria, * Turkey has unilaterally promised to secure a minimum flow of 15.75 km³/year at its border with Syria

Tunisia

The hydrographic system of Tunisia is rather dense in the north where the Medjerda wadi is the most important water course. This is also the zone where the principal irrigation development and flood protection works have been carried out.

Surface water resources have been estimated at 3.4 km^3/year, of which 3.1 km^3 are produced internally. About 2.1 km^3/year are exploitable through reservoirs, by means of large water conservation works and groundwater recharge systems. At present, there are dams with a total capacity of 2.5 km^3.

Internal renewable groundwater resources have been estimated at 1.5 km^3/year. At present, there are 83000 open wells and 1830 tube wells. Two categories of groundwater resources can be distinguished in function of the depth:

- when the water table is above 50 metres, groundwater can be used for private exploitation (with some restrictions). The potential has been estimated at 0.67 km^3/year;
- below 50 metres of depth, the groundwater has been reserved for public exploitation.

The potential of the deep ground water sheets in Tunisia is estimated at 1.4 km^3, of which 0.75 km^3 of renewable resources (53.7%), and 0.65 km^3 of non-renewable resources (46.3%). The potential of ground water is better distributed in the South of the country where primarily three large deep sheets of variable quality are located:

- The Complex Terminal (40 to 700 m)

- The Continental Intercalary (from 700 to 2000 m)

- Sheet of Djeffara (on the coastal plain)

- The deep sheet of the Continental Intercalary is considered fossil and without renewal.

The actual renewable water resources of Tunisia are approximately 4.6 km^3/y, of which 3.6 km^3/y are considered exploitable.

United Arab Emirates

Rain accounts for only 78 mm/y, the total annual surface runoff produced from rain is about 0.15 km^3, but there are no perennial streams. The average annual groundwater recharge is about 0.12 km^3, most of which comes from infiltration from the river beds. Over-extraction of groundwater resources has led to a lowering of the water table by more than one metre on average during the last two decades, while sea water intrusion is increasing in the coastal areas. About 0.15 km^3/y of freshwater are considered renewable and exploitable, lacking better knowledge.

Yemen

Yemen can be subdivided into four major drainage basins, regrouping numerous smaller wadis:

- the Red Sea basin
- the Gulf of Aden basin
- the Arabian Sea basin
- the Rub Al Khali interior basin

The floods of the wadis in Yemen are generally characterized by abruptly rising peaks that rapidly recede. In between the irregular floods the wadis are either dry or carry only minor base flows.

Surface water resources have been estimated at 4 km^3/year, including the runoff from major rivers and the runoff produced within the smaller catchments. Renewable groundwater resources have been estimated at l.5 km^3/year, a large part probably coming from infiltration in the river beds. A major groundwater aquifer was discovered in the eastern part of the country with an estimated storage of 10 km^3. This aquifer is still under study and it is not known whether the groundwater is rechargeable or whether it is all fossil water.

The surface runoff to the sea measured in some major wadis is estimated at 0.27 km^3/year, the groundwater outflow to the sea at 0.28 km^3/year. There might be some groundwater flowing into Saudi Arabia, but no data are available. The existence of surface drainage crossing into Saudi Arabia suggests that some sharing of surface flows could be possible, but details are not known.

The renewable and exploitable freshwater resource of Yemen is estimated at 4.1 km^3/y, due to the lack of better data.

The Chapter at hand has given a brief overview of the existing freshwater resources in the single MENA countries. More information on groundwater resources and a discussion about the socio-economic consequences of water scarcity is provided within Chapter 5.