Groundwater Resources in the Mediterranean Region: Importance, Uses and Sharing

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More than a quarter of the approximately 600 billion m³ of water received annually in the Mediterranean Basin takes subterranean routes in parts of its path. Aquifers also contain the major part of the Mediterranean Basin's water reserves, and these reserves account for the largest part, perhaps even the whole, of the summer flow of the Basin's rivers and other streams. A panoramic overview, focussing on the Mediterranean Basin, highlights both the general importance of groundwater as a vital resource for the Mediterranean people and for the natural environment, and also the diversity of the groundwater available and its utilisation. Transboundary groundwater resources are increasing in importance. As much as 80% of the water resources in the Mediterranean region is shared between two or more countries, and in North Africa and the Middle East shared aquifers are the most important source of fresh water. The main activities of UNESCO in 2007 are summarised against this background, paying special attention to the application of the UNESCO-ISARM (Internationally Shared Aquifer Resources Management) project in the Mediterranean. ISARM is an international multidisciplinary demonstration project coordinated by the UNESCO International Hydrological Programme (IHP) in Paris.

Aquifer Resources in the Mediterranean Region

The complex and very compartmentalised geological structure of the Mediterranean Basin has not allowed the formation of very extensive aquifer systems, with the exception of the South-East African Platform. These aquifers are not very varied in their extension, lithological nature or structure.
Map 5 shows the three most common types of aquifers. These are:

- *Karstic carbonated aquifers*, common almost everywhere in the Mediterranean Basin; they are particularly developed in the Dinaric Alps, as for example in Slovenia, where the region of Kras may be considered to have provided the origin of the term "karst". These karstic carbonated aquifers are underground reservoirs, which are of uneven volume and flow. Being fed predominantly by perpetual surface drainage, they often form abundant springs and important groundwater reserves whose water originates from the plains surrounding them. They also supply numerous coastal and submarine springs, which are often brackish or briny due to sea water intrusion. The water is often at very deep levels, and drilling access is undependable, impeding the direct exploitation of these aquifers. Their exploitation should, however, be considered.
- *Alluvial aquifers*, located in the valleys and deltas of the main rivers, are closely linked and often hydraulically connected with the streams. The most extensive ones are those of the Po River Plain in Italy, and of the Nile Delta in Egypt, which contain deep confined layers of water. Easily accessible, they are the most exploited type of aquifer and indeed are sometimes over-exploited.
- *Aquifers of sedimentary, often detritic formations* are either located in coastal plains where they

are in contact with the sea, or in large broad basins in the south-east (Libya, Egypt), and especially outside the Mediterranean Basin in the Saharan region. These deep aquifers contain large quantities of water but are mainly unrenewable ('fossil waters'). They are relatively independent from surface waters and largely endorheic; their slight underground drainage converges towards enclosed depressions near the Mediterranean which are below sea level (down to 90 m at Al Qattara in Egypt), and their waters are mostly saline in the Mediterranean Basin.

Renewable water resources in the Mediterranean Basin are unevenly distributed between the northern shores (Europe and Turkey, 93%), and the southern shores (7%) depending on the climate. The average annual recharge of aquifers amounts to about 155 km³/year, with recharge varying from a few mm/yr in the arid zone of the south to more than 500 mm/yr in the Dinaric Alps.

The majority of these underground flows contribute to the regular flow rate of the water streams, therefore constituting a constant resource in surface water. However, a significant part ends up in the near-shore submarine springs previously mentioned in relation to karstic aquifers, whose total flow might reach 30 to 50 km³/yr.

According to technico-economic criteria, these resources are unevenly accessible and exploitable, and commensurate with the constraints applied for the conservation of surface flow. They are also sometimes relevant to the preservation of tributary aquatic ecosystems of the emerging underground water.

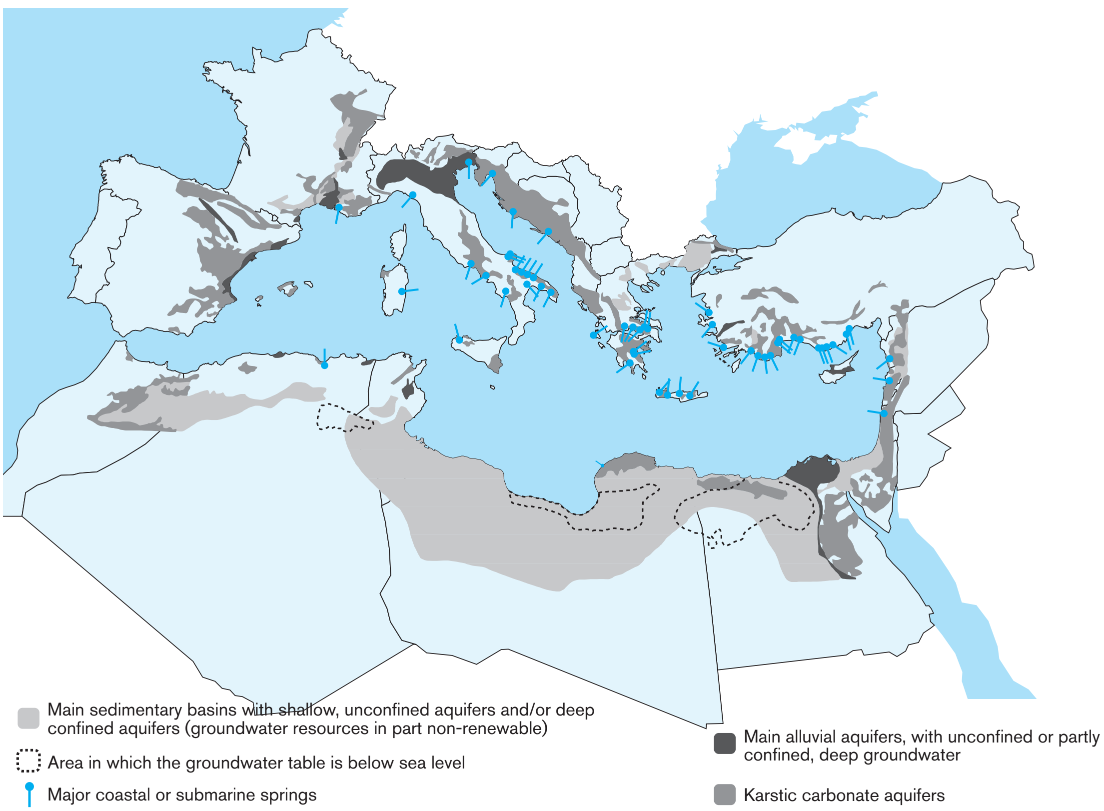
An Essential Source of Water Supply

For the inhabitants of the Mediterranean region, the exploitation of groundwater largely contributes to the current water supply, both for drinking and irrigation purposes.

Table 17 summarises the annual average groundwater recharge as well as the total groundwater abstractions in the Mediterranean countries.

Looking at the Mediterranean countries as a whole, at the end of the 20th century the abstraction of groundwater was assessed at approximately 66 km³/yr, of which about 40 km³/yr were in the area of

MAP 5 Aquifer Formations in the Mediterranean



Source: Margat, Blue Plan, 2004

TABLE 17 **Groundwater Resources in the Mediterranean Region**

Country	Renewable internal groundwater recharge Annual averages in km³/yr		Portion (%) of total internal renewable water resources		Total current groundwater abstractions (in 2000 or close year) in km³/yr	
	Entire country[1]	Part in the Mediterranean Basin[2]	Entire country[1]	Part in the Mediterranean Basin[2]	Entire country[1]	Part in the Mediterranean Basin[2]
Spain	29.9	10.44	27	37.3	6	3.27
France	100.0	32.0	53	50	6.4	1.97
Italy	43.0	43.0	24	23.6	10.4	10.4
Malta	0.033	0.033	87	~100	0.032	0.032
Slovenia	13.5	3.0	72	71.3	0.13	~0.01
Croatia	11.0	9.0	29	50	0.2	~0.1
Bosnia and Herzegovina	6.0	2.0	17	14.3	0.3	~0.1
Montenegro	~3.0	~1.5	~20	~20	0.02	~0.01
FYR of Macedonia	1.0	1.0	18	18.5	0.2	0.2
Albania	6.2	6.2	23	23	0.6	0.6
Greece	10.3	10.3	18	17.8	3.56	3.56
Cyprus	0.41	0.41	53	35.9	0.166	0.166
Turkey	69.0	20.0	30	30.3	63	5.0
Syria	6.04	2.38	58	47.6	8.27	~2.0
Lebanon	3.2	3.1	67	64.6	0.4	0.4
Israel	1.07[4]	0.83[4]	67	71.4	1.05	~0.8
Palestinian Territories	0.68 / 0.065	~0.50 / 0.055	86 / 100	87.7 / ~100	0.095 / 0.09	~0.06 / 0.09
Egypt	6.1[3]	~6.0[3]	72	62.5	7.01	6.1
Libya	0.5	0.5	83	85.7	4.08	1.8
Tunisia	1.45	1.15	35	~31.1	1.88	1.63
Algeria	1.6	1.33	14	11.1	2.6	1.6
Morocco	5.77	1.0	28	~20	3.71	0.2

Source: FAO/AQUASTAT2005. Notes: [1]National sources compiled by the Plan Bleu; [2]Including non-renewable source extractions; [3]Egypt: of which 4.8 are infiltrations from Nile irrigations (secondary resources); [4]Israel: of which 0.38 are external (from West Bank, mountain aquifer).

the Mediterranean Basin ($^2/_3$ in the north and $^1/_3$ in the south).

In almost all the countries, the greatest part of abstracted groundwater is used for irrigation: 80% to 90% in Spain, Cyprus, Syria, Israel, Libya, Tunisia and Morocco; more than 50% in Italy, Greece and Turkey. The second greatest part is generally used for the supply of drinking water, and in some places it is even the first (France, Egypt).

The groundwater abstracted largely covers the demand for drinking water in the majority of the Mediterranean countries; and also contributes to a more variable extent to the supply of irrigation water. In several countries in the south, Algeria, Libya, Tunisia, Israel, the Palestinian territories, Cyprus and Malta, extracted groundwater constitutes a major part of irrigation water supply.

Groundwater thus plays an important role in the regional and national water economies in the Mediterranean and is the predominant source of water supply in one country out of three.

Resources Are Exploited rather than Managed

When comparing water demand with total available water resources it can be seen that in many Mediterranean countries the capacity to satisfy water needs has become a serious problem. The pressures resulting from groundwater exploitation are varied, often heavy and even excessive in numerous cases. Over-exploitation is frequent and further increasing, notably in the coastal aquifers, where it has resulted in marine water intrusion. This process will be difficult to reverse, both in the north and the south. It has also caused streams to dry up and has weakened or destroyed aquatic ecosystems. The overexploitation of groundwater is already estimated at 5 km³/yr in the region. In the majority of the countries in the south, the exploitation of non-renewable groundwater resources of the large Saharan aquifers, all of which are transboundary, is intensive and growing. This currently amounts to 7 km³/yr, a situation which is not sustainable.

Taking into account both this level of overexploitation and the mining of 'fossil water', it can be said that nearly one fifth of the current extraction of groundwater in the Mediterranean countries is not sustainable.
An extensive seawater intrusion area has evolved from the northern part of Egypt to eastern Libya. This development has also caused a substantial deterioration of groundwater quality in the Djeffara coastal plain shared between Libya and Tunisia. Saltwater intrusion also occurs in Sicily, Italy.
These strong pressures on resources often provoke conflicts in usage, including conflicts between users of groundwater and surface water.

In numerous areas of the Mediterranean the quality of groundwater is under threat from pollution, which is especially linked to urbanisation and the impacts of intensive agriculture

Moreover, in numerous areas of the Mediterranean the quality of groundwater is under threat from pollution, which is especially linked to urbanisation and the impacts of intensive agriculture. This situation also constitutes an area of conflict between users of groundwater and land owners. Satisfying the need for high quality drinking water represents a particularly complex problem. The rational use of groundwater can play an important role in solving this problem.

An Unequal State of Knowledge

Hydrogeological inventories and research and the basic knowledge concerning groundwater in the Mediterranean Basin are generally quite advanced, since progress has followed the trend for exploitation. Regional monographs and national synthesis maps and studies are available in the majority of the Mediterranean countries.
However, follow-up studies of natural or influenced regimes of groundwater reserves, detailed cartography and the precise demarcations or boundaries of aquifer systems, which permit the establishment of appropriate management units, have not yet been developed on an even basis. A similar situation exists for hydrodynamic modelling, which could provide effective management tools. In addition, the organisation of user communities is needed for these purposes.
The uneven state of the progress in studying Mediterranean aquifer systems constitutes a handicap to their conservation and sustainable management and has a bearing on the sustainable management of the countries' overall resources.

Shared Aquifer Resources

Transboundary or shared aquifer systems are important sources of fresh water in many regions of the world, particularly under arid and semi-arid climatic conditions, which prevail in the South Mediterranean Region. Management of shared groundwater resources should be based on reliable scientific knowledge and information and avoid potential conflicts between neighbouring countries.
Developing cooperative databases for sharing information from different sources and mainly from regional monitoring networks is a prerequisite for formulating and implementing common strategies and management policies for shared groundwater resources. Collecting data at rates that can be sustained over long periods of time, such as water levels, water extraction and groundwater quality in an aquifer, is the foundation on which groundwater management is based. In parallel to reliable data collection, the organisation of databases for analysing information and data on groundwater resources, in terms of quantity and quality, are vital to efforts directed towards planning in order to meet present and future water demands. The groundwater monitoring data can be integrated into geographic information systems in order to facilitate analysis and the use of this information in the decision-making process.
To develop reliable cooperative databases, efforts should be made by all member states in order to harmonise groundwater monitoring networks design, standards, quality control and data storage and processing in the region. It is essential that monitoring and assessment of shared groundwater resources in the countries of the region be performed in a comparable way. This means, for example, that in order to assess trends in groundwater quality, the definition of trends, the sampling procedures and chemical and numerical analyses should be comparable on both sides of the border of a shared aquifer.
In order to facilitate an integrated approach to transboundary groundwater resources management, UNESCO started the ISARM initiative. This was launched

in June 2000 at the 14th Session of the Intergovernmental Council of UNESCO-IHP and is an intergovernmental project involving all national IHP Committees. The Council also invited the Food and Agriculture Organization of the United Nations (FAO), the International Association of Hydrogeologists (IAH) and the United Nations Economic Commission for Europe (UNECE) to cooperate in order to create the UNESCO-FAO-IAH-UNECE inter-agency ISARM initiative to promote studies concerning transboundary aquifer systems.

Following is an overview of the UNESCO-ISARM activities during 2007 in the Mediterranean Region, especially in South-East Europe (SEE or the Balkans) and also in the Euro-Mediterranean Partnership countries (Morocco, Algeria, Tunisia, Libya – an observer country –, Egypt, Israel, Palestine, Jordan, Lebanon, Syria and Turkey), known collectively as the MEDA region. In this region the UNESCO Chair and International Network of Water-Environment Centres for the Balkans (INWEB) in cooperation with UNESCO/IHP, the Economic Commission for Europe (ECE), the Economic and Social Commission of Western Asia (ESCWA) and the Economic Commission of Africa (ECA) investigated the shared aquifer resources by use of a two-step methodological approach: first, an inventory of the existing internationally shared groundwater aquifers located in these regions was developed and then a WEB-based interactive meta-database was made available on the Internet to all interested stakeholders, using Google Earth technology.

More specifically INWEB, in cooperation with ECE, ESCWA and UNESCO-IHP, has performed the following tasks:

- Solicited data on shared aquifers in the Mediterranean region from existing databases in relevant UN agencies and relevant non-UN organisations;
- Collected input from other Mediterranean water institutions and experts;
- Compiled data covering groundwater availability, use and demand;
- Integrated the results into an electronic database on shared aquifers in the region that will be accessible to all interested stakeholders.

Inventory of Shared Aquifers in SEE and MEDA Regions

Groundwater exploitation in the SEE and MEDA regions has increased dramatically during the last decades, mainly due to an increase in irrigated agriculture, tourism and industry. Thus, many groundwater resources are at risk of being exhausted by over-pumping. With abstraction exceeding the internally renewable water resources, the resulting groundwater scarcity is rapidly becoming a major concern in most SEE and MEDA countries. The pressures on natural groundwater resources are higher in the summer period, when natural supply is minimal while water demands are at a maximum (irrigation, tourism).

Groundwater scarcity is in many cases accompanied by poor groundwater quality, especially in coastal aquifers, where water is often highly saline, reducing its utility. A general groundwater quality deterioration has occurred in many parts of the Mediterranean region, due to contamination in recharge areas, mismanagement during irrigation practice, overexploitation of coastal aquifers and other reasons.

With growing groundwater scarcity and quality deterioration in many parts of the Mediterranean, the contribution and role of internationally shared aquifers in meeting the growing water demand is likely to increase. Cooperative arrangements to jointly develop, manage and protect shared aquifers will become a necessity, not only to avoid conflict but also to optimise utilisation and to achieve water security.

INWEB's regional assessment in SEE covers transboundary groundwaters shared by two or more of the following countries: Hungary, Slovenia, Croatia, Romania, Serbia, Bosnia and Herzegovina, Montenegro, the Former Yugoslav Republic of Macedonia, Albania, Bulgaria, Greece and Turkey. Some transboundary groundwaters in the region had previously been identified, and had already been noted in earlier UNECE and INWEB inventories. However, the region has seen major conflict and political change in the last fifteen years. Aquifers and groundwaters that for many years were located within a single country are now shared between new countries. While the previous UNECE inventory recorded 23 transboundary aquifers in the region and the draft INWEB report 47, this latest assessment identified 65 transboundary aquifers in the region.

The locations of these aquifers are shown in Map 6 and their names are given in Table 18 (see both in Annex). In some cases, these are not yet formally recognised as such, and it has been difficult to obtain information on them.

As a result of the data collected under this project, the database of transboundary aquifer resources in the MEDA region is available in draft form on INWEB's web site (www.inweb.gr). Two main types of aquifers are distinguished:

(1) Sedimentary basins with shallow unconfined aquifers and deep confined layered aquifers;
(2) Karstic carbonate aquifers.

Furthermore, the study aimed at briefly exploring transboundary karstic and porous aquifers in the region on a national level, and presenting data and information for comparative purposes.
Concerning the MEDA region, the geographic location of shared aquifers was identified and their corresponding names are shown in Maps 7 and 8 as well as in Tables 19 and 20 for North Africa (South Mediterranean area) and Middle East respectively (see Annex).

The Internet-Based Google Map Database

The interactive database is provisionally located on the UNESCO/INWEB's internet site (www.inweb.gr) under the menu Water Database.
The Water Database menu opens four sub-menus:

- Transboundary Aquifers (for the Balkans);
- Internationally Shared Surface Waters (for the Balkans);
- South MEDA Countries Aquifers, and
- East MEDA Countries Aquifers.

Basic hydro-geological characteristics and also information on groundwater use and assessment of the current situation are provided online in summary and in descriptive form. These meta-data and additional information on shared aquifers in SEE and the MEDA regions are available and accessible for use by all member states and other interested stakeholders.
The interactive map allows the web-user from any country involved to take a virtual tour in Google Earth of all shared aquifers in the region and zoom into selected aquifer locations.
By looking at satellite pictures of Google Earth, the local situation (e.g. the location of a river) and the land use (for example agricultural activities and the location of a city in the aquifer's area) can be clarified. Furthermore, by accessing basic information on hydrology, hydrogeology, water uses and policy, a general understanding of the situation of any particular aquifer or aquifer system can be developed.
Such information is useful to decision makers, water professionals, educators, students and all interested citizens for various purposes like monitoring, modelling and stakeholder participation in the decision-making process.

Conclusions

The importance of groundwater resources in the Mediterranean region and particularly that of shared aquifer resources becomes most apparent when there is increased pressure for economic development and water-related activities on either side of the border. Joint management of internationally shared aquifer resources is not only a scientific or technical problem. It should also involve joint institutions, common monitoring networks, information and data sharing and a common vision for sustainable development of the entire river catchment. The political linkages in transboundary aquifer management are important and involve wider regional concepts, such as "water for cooperation."
Regional partnerships and networks involving decision makers, different scientific disciplines, and stakeholders are important driving forces behind the promotion of innovative approaches and the development of effective action plans. In this respect UNESCO's ISARM Mediterranean and worldwide programme demonstrates methodological approaches, and shows how multidisciplinarity can contribute to sustainable transboundary groundwater management. UNESCO ISARM plans to produce a toolkit showing the best practices for achieving good results in the field.

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Annex

MAP 6 **Overview Map of Transboundary Aquifers in the SEE Region**

Source: UNESCO, Chair/INWEB, 2008

TABLE 18 **Names of Shared Aquifers in SEE and Countries Involved**

Number	Aquifer name	Countries	Type
1	Dragonja	Slovenia-Croatia	karstic
2	Mirna-Istra	Slovenia-Croatia	karstic
3	Opatija	Slovenia-Croatia	karstic
4	Rijeka	Slovenia-Croatia	karstic
5	Kupa	Slovenia-Croatia	karstic
6	Zumberak	Slovenia-Croatia	karstic
7	Sava	Slovenia-Croatia	alluvial
8	Sutla	Slovenia-Croatia	alluvial
9	zDrava	Slovenia-Croatia	alluvial
10	Mura	Croatia-Hungary	alluvial
11	Drava	Croatia-Hungary	alluvial
12	Baranja	Croatia-Hungary	alluvial
13	West Serbia	Croatia-Serbia	alluvial

14	Sava	Croatia-Bosnia Herzg.	alluvial
15	Kupa	Croatia-Bosnia Herzg.	karstic
16	Una	Croatia-Bosnia Herzg.	karstic
17	Krka	Croatia-Bosnia Herzg.	karstic
18	Cetina	Croatia-Bosnia Herzg.	karstic
19	Neretva	Croatia-Bosnia Herzg.	karstic
20	Dubrovnik	Croatia-Bosnia Herzg.	karstic
21	Karst-Montenegro	Bosnia Herzg-Montenegro	karstic
22	Dinaric karst West Coast	Montenegro- Croatia	karstic
23	Dinaric karst East Coast/Skadar Lake	Montenegro-Albania	karstic
24	Beli Drim	Albania-Serbia	karstic
25	Metohija	Montenegro-Serbia	alluvial
26	Lim	Montenegro-Serbia	karstic
27	Tara Massif	Serbia-Bosnia Herzg.	karstic
28	Macva-Semberija	Serbia-Bosnia Herzg.	alluvial
29	Backa	Serbia-Hungary	alluvial
30	Banat	Serbia-Romania	alluvial
31	Miroc & Golubac	Serbia-Romania	karstic
32	Dacian Basin	Serbia-Romania	alluvial
33	Timok Alluvium/Bregovo Novo	Serbia-Bulgaria	alluvial
34	Stara Planina/Salasha Montanaa	Serbia-Bulgaria	karstic
35	Nishava & Tran Karst	Serbia-Bulgaria	karstic
36	Zemen	Serbia-Bulgaria	karstic
37	FYROM-SW Serbia	Serbia-FYROM	karstic
38	FYROM-Central Serbia	Serbia-FYROM	alluvial
39	Tetovo-Gostivar	Serbia-FYROM	karstic
40	Bistra-Stogovo	Albania-FYROM	karstic
41	Jablanica	Albania-FYROM	karstic
42	Ohrid Lake	Albania-FYROM	karstic
43	Vjosa/Pogoni	Albania-Greece	karstic
44	Mourgana	Albania-Greece	karstic
45	Prespes Lakes	Albania, Greece & FYROM	karstic
46	Galicica	Greece-FYROM	karstic
47	Pelagonija/Florina	Greece-FYROM	alluvial
48	Gevgelija/Axios-Vardar	Greece-FYROM	alluvial
49	Dojran Lake	Greece-FYROM	alluvial
50	Sandansky-Petrich	Bulgaria, Greece & FYROM	alluvial
51	Gotze/Agistro	Greece-Bulgaria	karstic
52	Nastan-Trigrad	Greece-Bulgaria	karstic
53	Smolyan	Greece-Bulgaria	karstic
54	Rudozem	Greece-Bulgaria	karstic
55	Erma Reka	Greece-Bulgaria	karstic
56	Svilegrad/Orestiada	Bulgaria, Greece & Turkey	alluvial
57	Evros/Meric	Greece-Turkey	alluvial
58	Topolovgrad karst waterbearing massif	Bulgaria & Turkey	karstic
59	Malko Tarnovo kasrt waterbearing massif	Bulgaria & Turkey	karstic
60	Upper Pleistocenesomes alluvial fan	Romania-Hungary	alluvial
61	Lower Pleistocene Mures alluvial fan	Romania-Hungary	alluvial
62	Lower Pleistocene Somes alluvial fan	Romania-Hungary	alluvial
63	Middle Sarmatian Pontian	Romania-Moldova	alluvial
64	Sarmatian	Romania-Bulgaria	karstic
65	Upper Jurassic-Lower Cretaceous	Romania-Bulgaria	karstic

MAP 7 **Location of Major Transboundary Aquifers in the South Mediterranean Region**

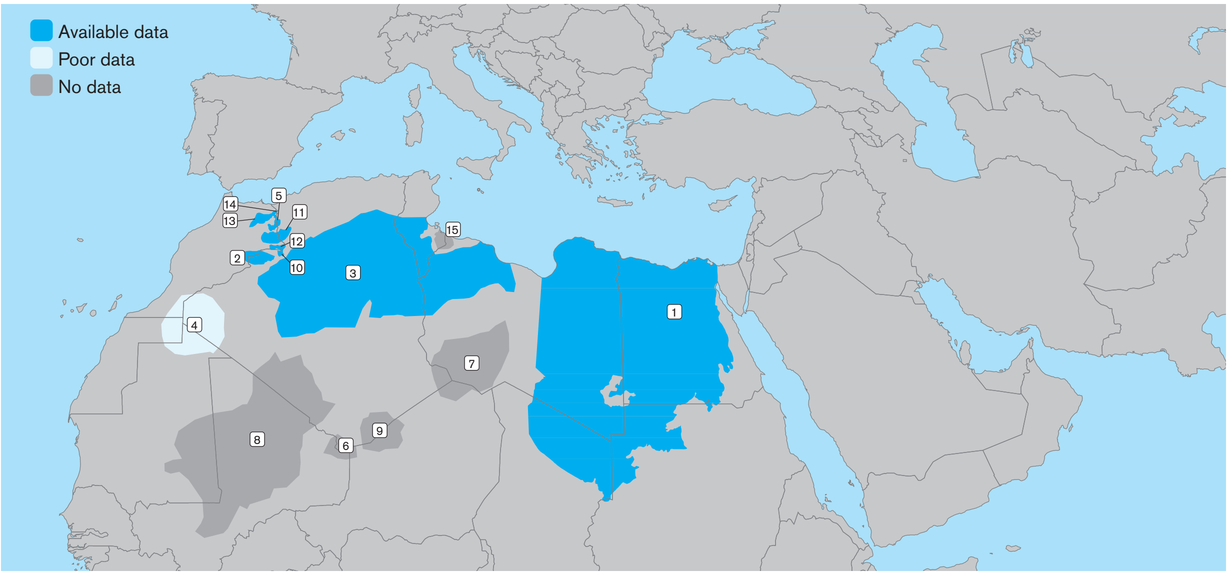

TABLE 19 **Names of Shared Aquifers in South Mediterranean Region and Countries Involved**

Number	Aquifer name	Countries	Type
1	Nubian Sandstone Aquifer System (NSAS)	Egypt, Libya, Sudan, Chad	Nubian
2	Errachidia	Algeria, Morocco	Sandstone, calcarous, dolomite
3	North Western Sahara Aquifer System (NWSAS)	Algeria, Libya, Tunisia	Sandstone, sandy clay, calcareous, dolomite
4	Tindouf Aquifer	Algeria, Morocco	Alternating series of calcareous rocks and sand
5	Angad Maghnia	Algeria, Morocco	N/A
6	Lullemeden	Algeria, Mauritania, Mali	N/A
7	Mourzouk Djado	Algeria, Libya, Nigeria	N/A
8	Taoudeni Tanezrouft	Algeria, Mali, Mauritania	N/A
9	Tin Seririne	Algeria, Nigeria	N/A
10	Fiquia	Algeria, Morocco	Porous, phreatic
11	Ain Beni Mathar	Algeria, Morocco	Karst, limestone and dolomite
12	Chott Tigri-Lahouita	Algeria, Morocco	Limestone and sandstone
13	Triffa	Algeria, Morocco	Porous, quartenary
14	Jbel El Hamra	Algeria, Morocco	Karstic
15	Djaffar Djeffara	Libya-Tunisia	N/A

MAP 8 **Overview Map of Transboundary Aquifers in the Middle East Region**

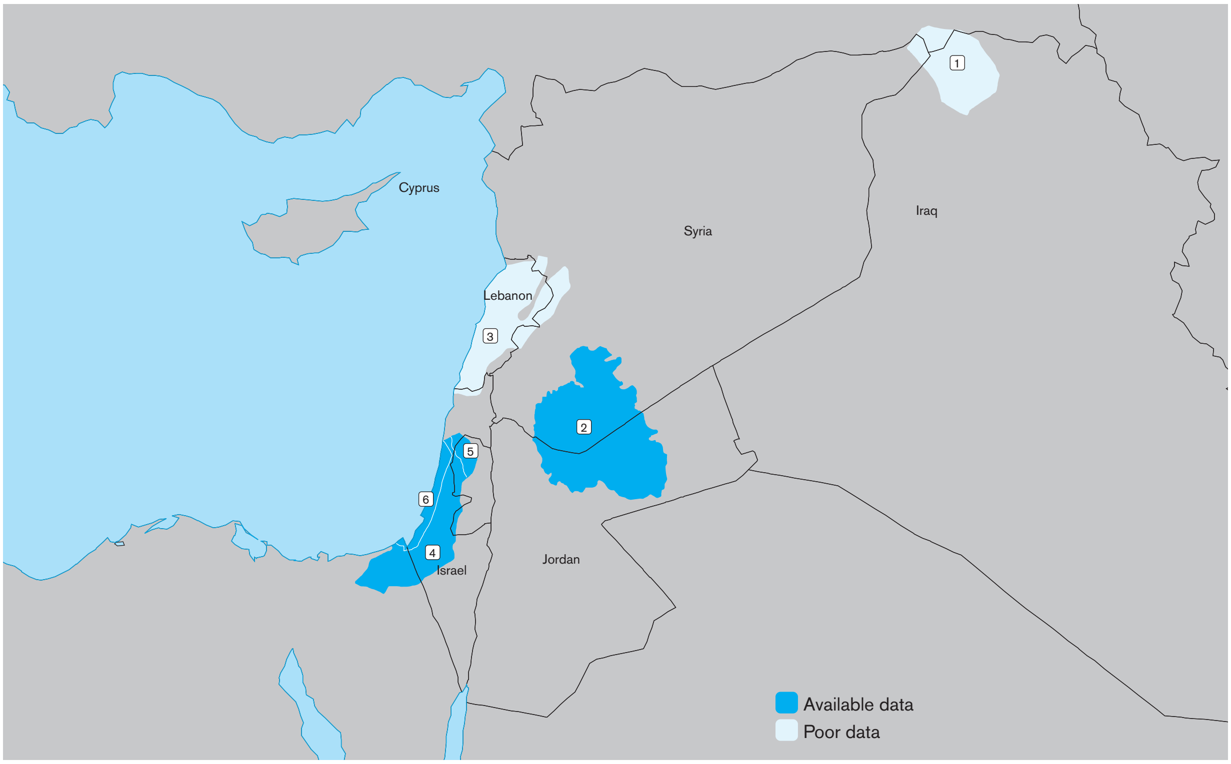

TABLE 20 **Names of Shared Aquifers in the Middle East Region**

Number	Aquifer name	Countries	Type
1	Eocene -Helvetian	Syria, Turkey	Limestone
2	Bazalt-Azraq	Syria, Jordan	Basalt
3	Nahr el Karib(Cenemonian - Turonian)	Lebanon, Syria, Israel	Limestone
4	Western Aquifer	Israel, Gaza Strip, Egypt	N/A
5	North-Eastern Aquifer	Israel, West Bank	N/A
6	Coastal Aquifer	Israel, Gaza Strip	N/A