# Trans-boundary Water Resources of Lebanon: Monitoring and Assessment

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**ABSTRACT**

Lebanon, the Middle Eastern country with an area of about 10,400 km$^2$, is known by a plenty water resources. It receives between 800 and 1500mm of precipitated water, snow covers around 2000km$^2$; hence this small land area encompasses 15 permanent watercourses (rivers) and more than 2,000 major springs, in addition, there is a number of aquiferous formations and karstic galleries, which are known to be filled with groundwater. However, there are parallel paths of increasing water stress stemming from both natural and human driving forces. Climate change, pollution, over-exploitation and the mismanagement of trans-boundary water resources are amongst the geo-environmental problems that affect these resources, the latter being the major water problem in Lebanon today. In the light of this issue, more than 74% of Lebanon's border is shared with neighboring countries, which makes the surface and subsurface water intermingle with neighboring regions, thus no volumetric measures are known. Two trans-boundary rivers between Lebanon and Syria in the north and one river with Israel to the South. Snow covers large areas of the mountain chains of Anti-Lebanon, which are shared with Syria, and Hermon chain with snow cover also shared with Israel. In addition, the three major aquifers of Lebanon extend to neighboring regions. To date, however, there is no creditable study to assess how to allocate these resources. Consequently, geo-political conflicts frequently exist due to the obscure nature of the hydrologic conditions. This study aims to introduce first hand information on the assessment and monitoring approaches to identify the principal hydrologic aspects of trans-boundary water resources of Lebanon, including quantitive measures and spatial delineations. This could be obtained through a systematic analysis of the shared hydrologic and hydrogeologic elements, thus conventional and recent tools and techniques.

**Key words:** shared rivers, trans-boundary, geo-political, Lebanon.

## 1. INTRODUCTION

Lebanon is located in the middle part of the eastern coast of the Mediterranean Sea. It is divided into three major physiographic units. These are the ranges of Mount Lebanon and Anti-Lebanon, which are separated by the Bekaa plain. The two mountain ranges are originally uplifted blocks. The three units are trending NNE-SSW (Fig. 1). The eastern Mediterranean constitutes a part of the unstable shelf of the Middle East region, which is affected by plate tectonic movements of the Dead Sea Rift system (Beydoun, 1988).

The exposed stratigraphic succession in Lebanon, starts from the Middle Jurassic age and exhibits sedimentation in a marine environment until the Middle Eocene, with carbonate rocks (mainly limestone) building up the largest part of the stratigraphic column, which is separated by continental sands and clastics at the base of the Cretaceous (Nubian facies) and some intercalated volcanic rocks up to the Pliocene. The exposed succession totals a thickness of about 5650 m (Beydoun, 1977).

The existence of elevated mountain chains, especially those facing the Mediterranean, created a climatic barrier that receives the cold air masses from west, thus resulting a high precipitation rate reaches up to 1500mm/yr. for this reason, Lebanon is known by tremendous water resources, and then described as the "*Water Tower*" of the Middle East. It is the unique region in the Middle East where thick accumulation of snow cover remains for more than four months on mountain crests and occupying coverage of about 2000km$^2$. As well as, there are more than 2000 major springs, with discharge exceeding 10*l*/sec, and also some 60 major submarine springs issuing off-shore (Shaban, 2003). Additionally, Lebanon is well known by the karstic cavities, which constitute a major source for groundwater.

Lebanon is considered as a country under water stress, notably in the view of climatic variability and population growth. Therefore, the available water resources are witnessing an obvious volumetric decrease since the last few decades that estimated as 40% in average (Shaban, 2009).

Even though, Lebanon has a small land area (~10,400 km$^2$), yet the large part of its water resources is shared with the neighboring countries. Hence, out of the 882km perimeter of Lebanon area, there are approximately 559 km (63%) is bounded with Syria in the north and utmost in the east, and 98km (11%) with Israel in the south and some parts to the east. While, the rest 225 km are facing the Mediterranean Sea (Fig. 1). Moreover, the geographic land marks (e.g., mountain tops, valleys, watercourses, etc) are often found to be coincided with the political borders between the three countries.

The lack of comprehensive hydrologic measures; however, resulted incomplete assessment to allocate shared water resources with the adjacent countries, thus geo-political conflicts frequently exist due to the obscure nature of the hydrologic conditions. This study aims to introduce first hand information on the assessment and monitoring approaches on Lebanese shared water resources. Thus, it highlights on: 1) the actual length of shared rivers and their tributaries, 2) surface water divides, i.e., catchment areas, 3) the percentage of snow cover extent in each region and 4) the extent of trans-boundary aquiferous rocks between them. This was achieved utilizing a variety of conventional and advanced tools and techniques to identify and measure the fundamental elements of shared water resources of Lebanon.

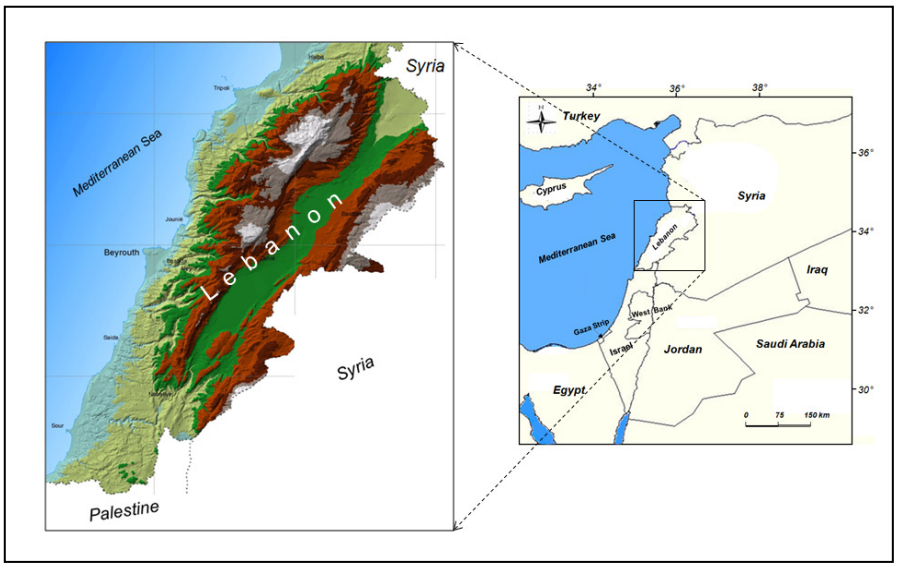


**Figure 1.** Regional location map of Lebanon.

## 2. ASPECTS OF SHARED WATER RESOURCES

There are about 215 international rivers and 300 groundwater basins that shared by two or more countries (ADB, 2008). However, trans-boundary water resources take a number of aspects either on surface or in subsurface. Some of them occur in a large-scale. Whilst, other aspects of trans-boundary water resources appear in a relatively small-scale extent.

Normally, aquifers and rivers are the only hydrologic components that considered as shared water resources. However, other components (streams, springs, etc) are also important; especially they are in direct relation with the hydrologic cycle.

Aspects of trans-boundary water must include perennial and temporary resources of different scales (Shaban and Douglas, 2008). They can be summarized as follows:

1. Groundwater reservoirs (aquifers): where groundwater is stored in rock formations that extend for large areal extent (e.g. several hundreds of kilometers) and owing considerable thickness of several hundreds of meters.

2. Rivers: as permanent watercourses usually run along slopping topography and then transect different countries.
3. Springs: which are usually considered as essential source of water. There are several springs located near political borders and issue water from one country and outlet in another.
4. Streams: which is similar to rivers, and are also transecting different topographic regions, but they usually run surface water for limited time duration after rainfall.

## 3. METHOD OF IDENTIFICATION

Usually, the ued tools to identify and assess shared water resources often include: topographic and cadastre maps. The combination of these two maps in conjunction with geological and hydrological data can help adjoining countries to diagnose their shared waters. However, erroneous delineation and readings of these maps usually create conflict between these countries.

In this study, the used method followed a number of approaches and a miscellany of tools was utilized (Fig.2). Also developed and recent techniques were utilized either in computerizing the available maps, or in their analysis through different software types. Thus, the applied steps can be summarized as follows:

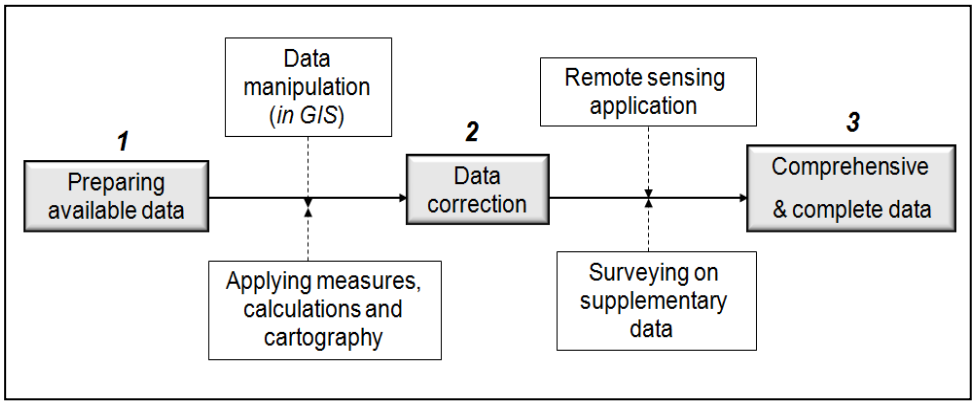


**Figure 2**. Schematic presentation of the followed method in this study.

1. Preparing the available maps (topography, geology and cadastre) in digital forms, including the adjacent regions between Lebanon and the neighboring countries.
2. Manipulating these maps and their supplementary data in attributed tables among the Geographic Information System (*GIS*) in order to be able to modify, measure, calculate and draw needed information.
3. Correcting the shared spatial data, including: rivers, streams, geological boundaries, location of springs, etc.
4. Using remotely sensed data; especially in monitoring the snow cover extent. For this purpose, MODIS-Terra satellite images were analyzed. In some cases, high resolution images were processed (e.g. IKONOS, Aster and Landsat).
5. Carrying out a filed survey (whenever applicable) to induce the names, ownership, and other related data on shared water resources at the border area.
6.

## 4. RESULTS

Following the previous mentioned approach for shred water identification by using the appropriate tools, thus surface and subsurface water resources of Lebanon shared with neighboring regions could be identified as follows.

### 4.1 Groundwater

Shared groundwater in aquiferous rock formations between Lebanon and the neighboring regions is composed largely of carbonates rocks and basalt with an approximate ration of 92%, where 87% shared with Syrian and the rest 13% with Israel. These rock formations are almost of carbonate rocks with high fracture and karstic systems.

Figure 3 represents a map showing the distribution of these rock formations. The major fractures systems (i.e. faults) in these rock formations were identified from satellite images. Therefore, 185 major faults were identified. These faults work as hydrologic channels and transporting groundwater from/ and to Lebanon.

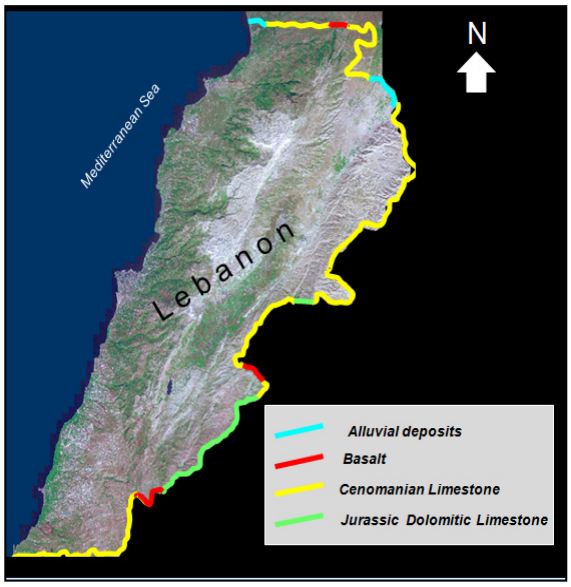


**Figure 3.** Shared aquiferous rock formations of Lebanon.

### 4.2 Rivers

There are three shared rivers between Lebanon the neighboring countries. Two with Syria and one with Israel. These are Al-Kabir River (150MCM) along the northern border of Lebanon with Syria, El-Assi (500) originated from Lebanon and extends to Syria to the north and then to Turkey, and El-Wazzani (220 MCM) from Lebanon southward to the occupied territories in Israel. Table 1 shows the fundamental characterizations of these rivers.

**Table 1.** Fundamental characterizations of Lebanese shared rivers.

| River | Length *(in Lebanon)* | Catchment area *(in Lebanon)* | Origin | To | Major exploitation |
|---|---|---|---|---|---|
| Al-Kabir | 60 km | 295 $km^2$ | Shared | Mediterranean | 65% Syria |
| El-Assi | 65 km | 1900 $km^2$ | Lebanon | Syria, Turkey | Syria, Turkey |
| El-Wazzani | 75 km | 625 $km^2$ | | Israel | Israel |

### 4.3 Springs

Yet, springs origin in Lebanon is identified, but their actual runoff routes are almost unidentified, notably when they run toward the neighboring regions. They constitute an essential source of water in Lebanon and receive their recharge mainly from snowmelt. There are 77 major shared springs in Lebanon as resulted from the obtained survey from the topographic maps (Table 2).

**Table 2.** Major shared springs in Lebanese.

| **Topographic sheet** *(1:20000)* | **Major springs*** | **Sharing regions** |
|---|---|---|
| Wadi El Qaren | 3 | With Syria |
| Deir El Ashayer | 2 | |
| Zemrani | 1 | |
| Hourete | 1 | |
| Assal El-Wared | 1 | |
| Anjar | 5 | |
| Tfail | 1 | |
| Amshiki | 5 | |
| Ait El Foukhar | 40 | |
| Hermon | 1 | |
| Kfer Kouk | 5 | |
| Raite | 5 | |
| El Khyam | 4 | With Israel |
| Kfer Shouba | 3 | |

**Unnamed springs with discharge exceeding 50l/sec.*

### *4.4 Streams*

Normally streams do not accounted during the assessment of shared water resources because they do not issue water permanently. However, they appear as a geo-political issue when dams are built along these streams and running water became restricted to the upstream country and not to the downstream one. In the study, major shared streams were identified among their catchment areas, as shown in Table 3.

**Table 3.** Major shared streams in Lebanese.

| **Catchment** | **Shared with** | **Orientation** | **Feeding river** | **Surface water flow** | |
|---|---|---|---|---|---|
| Al-Kabir | Syria | E-W | Al-Kabir | Lebanon & Syria | |
| Ouadi Khaled | | SW-NE | Int St*, Ouadi Al Atshan | Lebanon | Syria |
| El-Assi | | SW-NE | El-Assi | Lebanon | Syria |
| Asaal El Wared | | W-E,NE-SW | Ouadi El Ouazze, Emjer El Asaaal | Syria | Syria |
| Barada and El Aawja | | NW-SE | Barada and El Aawja | Syria | Syria |
| Hasbani | Israel | NE-SW | Hasbani-Wazzani | Lebanon | Israel |
| Marjayoun | | NW-SE | Ouadi Deir Mimess | Lebanon | Israel |
| Naquora | | NE-SW | Ouadi Naqouran- Alma Eshaab | Lebanon | Israel |

**Intermittent streams*

## 5. CONCLUSION

Likewise many regions worldwide, Lebanon has given recently a great concern to its water resources, which became threatened in the light of the changing climatic regime and the dramatic increase in population size. However, comprehensive studies on this respect are still rare enough to make a detailed assessment for Lebanese shared water resources. This study is extends a brief discussion on the major elements of the Lebanese water resources and the approach of assessment and monitoring.

It is obvious that the existing water resources in Lebanon are almost shared with the neighboring regions. This is attributed mainly to the geomorphic and geologic setting of Lebanon. In addition, it clearly appears that most shared water resources are originated from Lebanon, which indicates their availability. However, no specific hydrologic measures have been known yet to articulate the current

status of shared water resources in Lebanon. Thus, it is recommended to apply a detailed assessment to allocate the volumetric measures of shared water resources. This will help composing an integral part of the water budget for Lebanon. In addition, identifying the hydrologic characteristics of water resources will add a valuable contribution to the future agreements and protocols.

This study also shows the importance of using new techniques to identify spatial terrain signatures, and more certainly to recognize water resources and their routes and areal extent. They can be a helpful tool in applying in-depth regional studies on shared water resources.

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