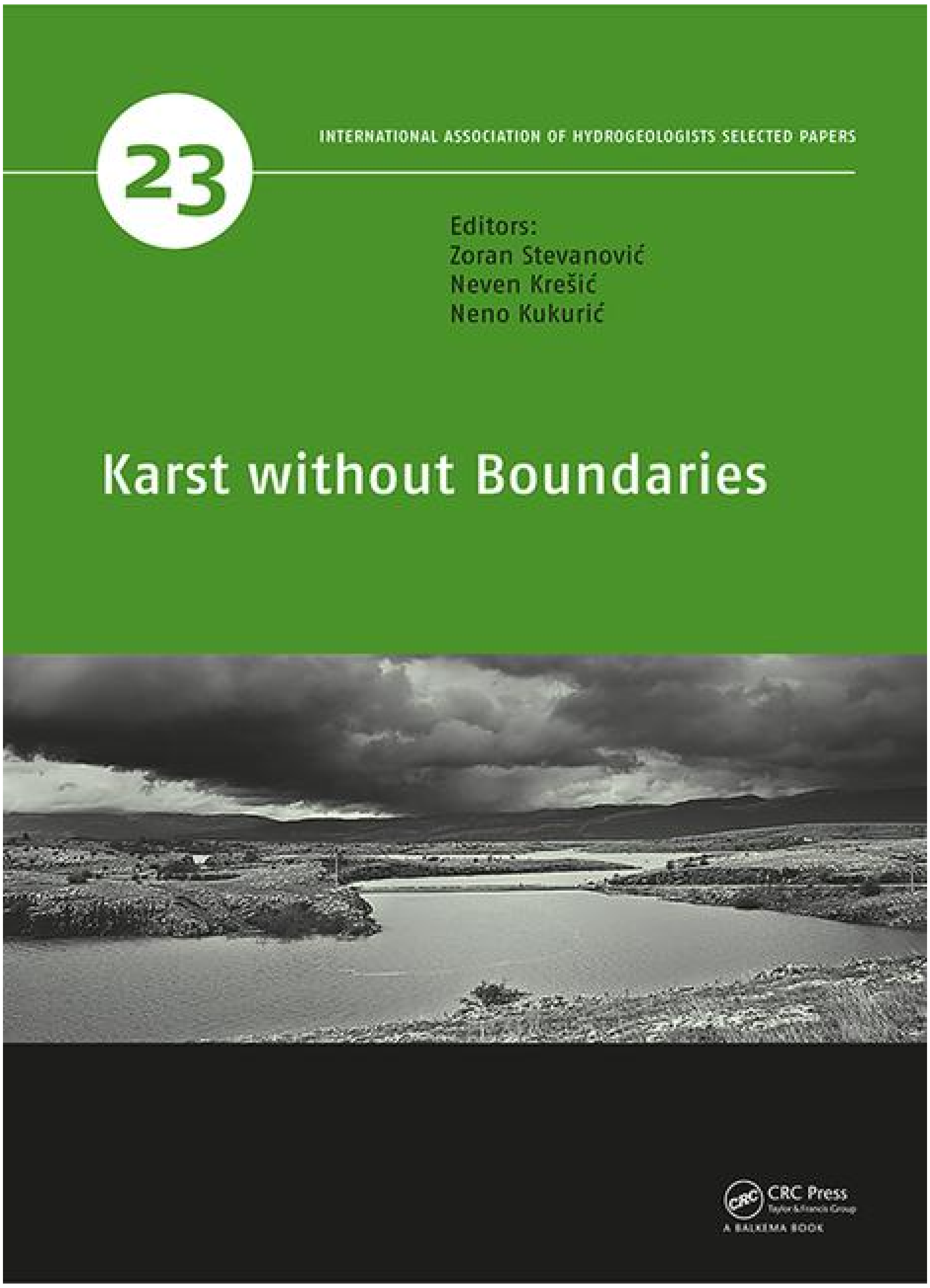
Chapter 4. Groundwater flow in the Orontes River basin and the Syria-Lebanon water sharing agreement

François Zwahlen, Michel Bakalowicz, Raoul Gonzalez, Ahmed Haj Asaad, Myriam Saadé-Sbeih, and Ronald Jaubert

Citation Information
Karst without Boundaries
Edited by Zoran Stevanović, Neven Krešić, and Neno Kukurić
CRC Press 2016
Pages 53–61
Print ISBN: 978-1-138-02968-2
eBook ISBN: 978-1-4987-8773-4
DOI: 10.1201/b21380-6



Groundwater flows in the Orontes River basin and groundwater in the Syria-Lebanon water sharing agreement

François Zwahlen[1], Michel Bakalowicz[2], Raoul Gonzalez[3], Ahmed Haj Asaad[3], Myriam Saadé-Sbeih[3], Ronald Jaubert[3]

[1]Chyn, Neuchâtel University, Switzerland
[2]HydroSciences, Montpellier University
[3]IHEID, Geneva University, Switzerland

ABSTRACT

The paper analyses groundwater flows in the Orontes River basin and the changes which occurred in the past forty years as a result of the massive expansion of irrigated lands using groundwater resources in the Orontes River basin. The region contains significant karstic water resources supplying springs in the upper and middle reach of the basin. Although variations in annual flows are difficult to access precisely, there was a significant decrease since the 1960s. The Syrian Lebanese agreement on the sharing of the Orontes water signed in 1992 focused almost exclusively on surface water resources. The drilling of wells in Lebanon was restricted only nearby the Orontes River bed. Amendments to the agreement, in 1997 and 2002, restricted the drilling of wells in the Lebanese section of the basin as a whole. However no restrictions were imposed on groundwater withdrawals in Syria. Because of the continuity of the main Jurassic-Cretaceous aquifer between the two countries the latter withdrawals are likely to affect groundwater resources in Lebanon.

INTRODUCTION

The extensive development of irrigation in the Orontes River basin, from the 1970s, has completely disorganized subsurface flows feeding water sources of this region, particularly within the Lebanese-Syrian border region.

The literature reviewed allowed to locate the approximate recharge areas of the main sources and to reconstitute the impact of the recent intensive exploitation of the Jurassic-Cretaceous aquifer on subsurface water flows.

From Lebanese territory, upstream portion of the watershed, surface water carried by the Orontes river flows toward Syria as well as significant amounts of groundwater from the Jurassic-Cretaceous aquifer complex extending at depth into to the Syrian territory.

This paper aims to analyze the effects of irrigation developments on the dynamics of groundwater resources and how this issue was taken into account in the 1994 water agreement and the 1997 and 2002 amendments. The study was conducted as part of a research program supported by the Global Program Water Initiatives of the Swiss Agency for Development and Cooperation.

ORONTES RIVER BASIN: GENERAL HYDROGEOLOGY AND AQUIFERS SUPPLYING MAIN SOURCES AND PRODUCTION WELLS

The Orontes basin contains significant karstic water resources, which largely fed the Orontes River before the extensive development of the irrigation in the past four decades. In the 1960s, the downstream discharge rate reached almost 100 m3/s at the Syrian- Turkish border, but in the 2000s, it fell to less than 15 m3/s.

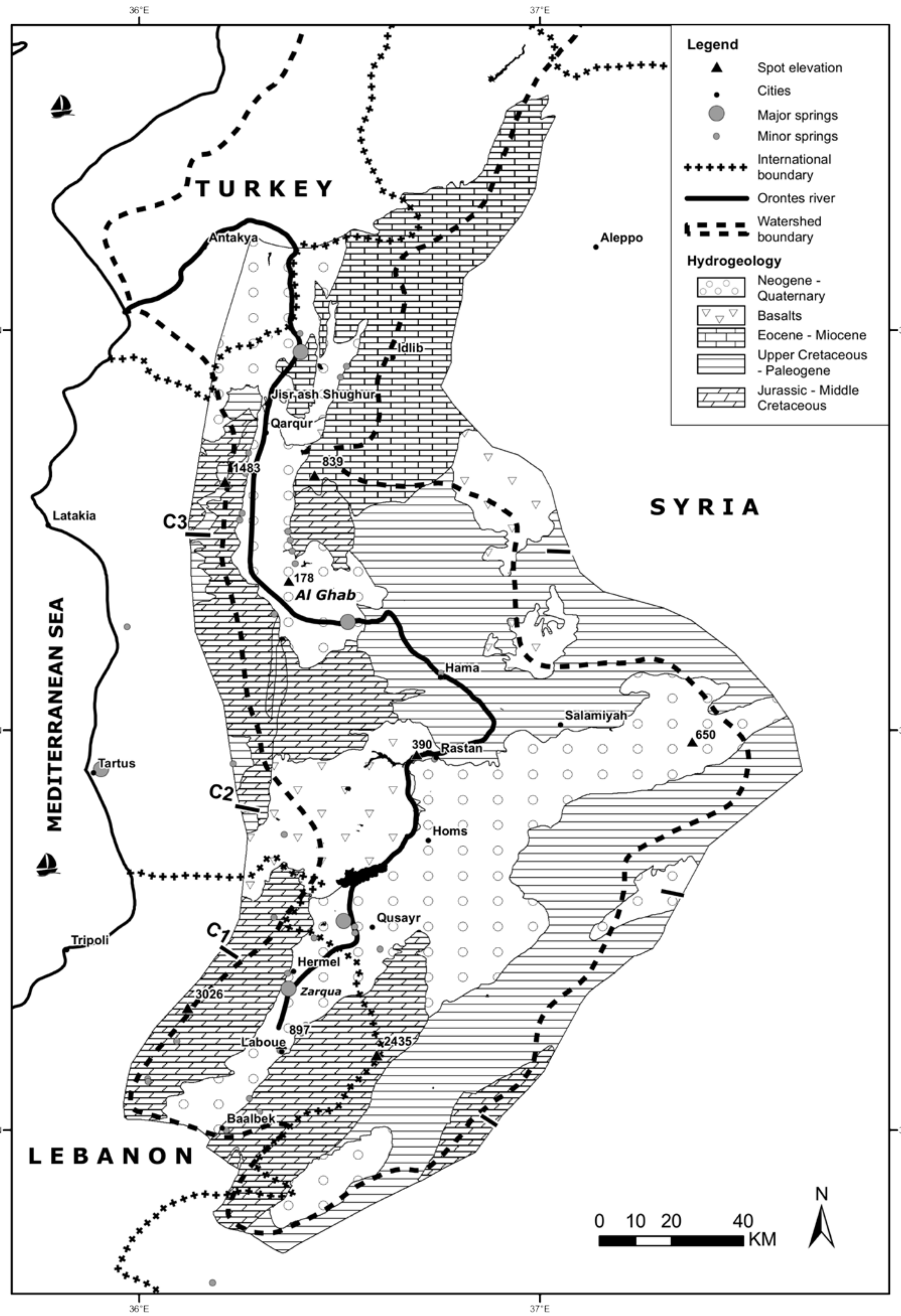


Figure 1 Simplified hydro-geological map of the Orontes River basin

The huge aquifers supplying the main springs located in the upstream reach of the basin are thick limestone formations from the Jurassic and Cretaceous, Figure 1. Even if these formations are certainly not equally fractured and karstified, they contain groundwater flowing through them and from one to the other, using tectonics faulting or fracturing, even if they are separate by lower Cretaceous quite impermeable formation. Regarding the scale of the basin, by simplifying, we can consider the Jurassic and Cretaceous formations as a unique complex aquifer, a very large reservoir in hydraulics continuity, Figure 2.

In the southern and central parts of the basin, this large karstified reservoir supplies many sources, Fig. 3. The annual flow of the main sources is of several m3/s. Their regime is more or less stable throughout the year because of the very large water reserves, the high hydraulic conductivity, the well-developed internal drainage and the extended confinement of this complex reservoir.

In the southern and central parts of the basin, this large karstified reservoir supplies many sources, Fig. 3. The annual flow of the main sources is of several m3/s. Their regime is more or less stable throughout the year because of the very large water reserves, the high hydraulic conductivity, the well-developed internal drainage and the extended confinement of this complex reservoir. Recharging of the Jurassic and Cretaceous reservoir, it is particularly important in the highest areas of the basin, specifically the Mount Lebanon and the AntiLebanon. Where limestone formations outcrop, the recharge could reach 60% of precipitations varying between 750 and 2000 mm per year on the mountain range (Droubi 2012). Taking place mainly during the winter season, local recharging lasts until spring due to the melting of the snow-coat.

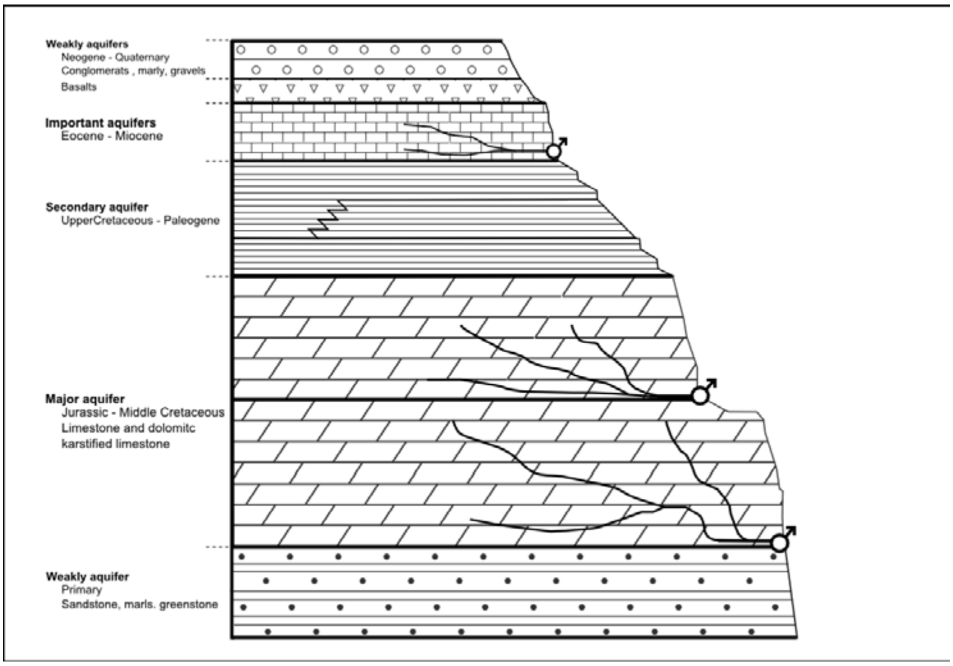


Figure 2 Hydro-litho-stratigraphical figure of the Orontes River basin formations

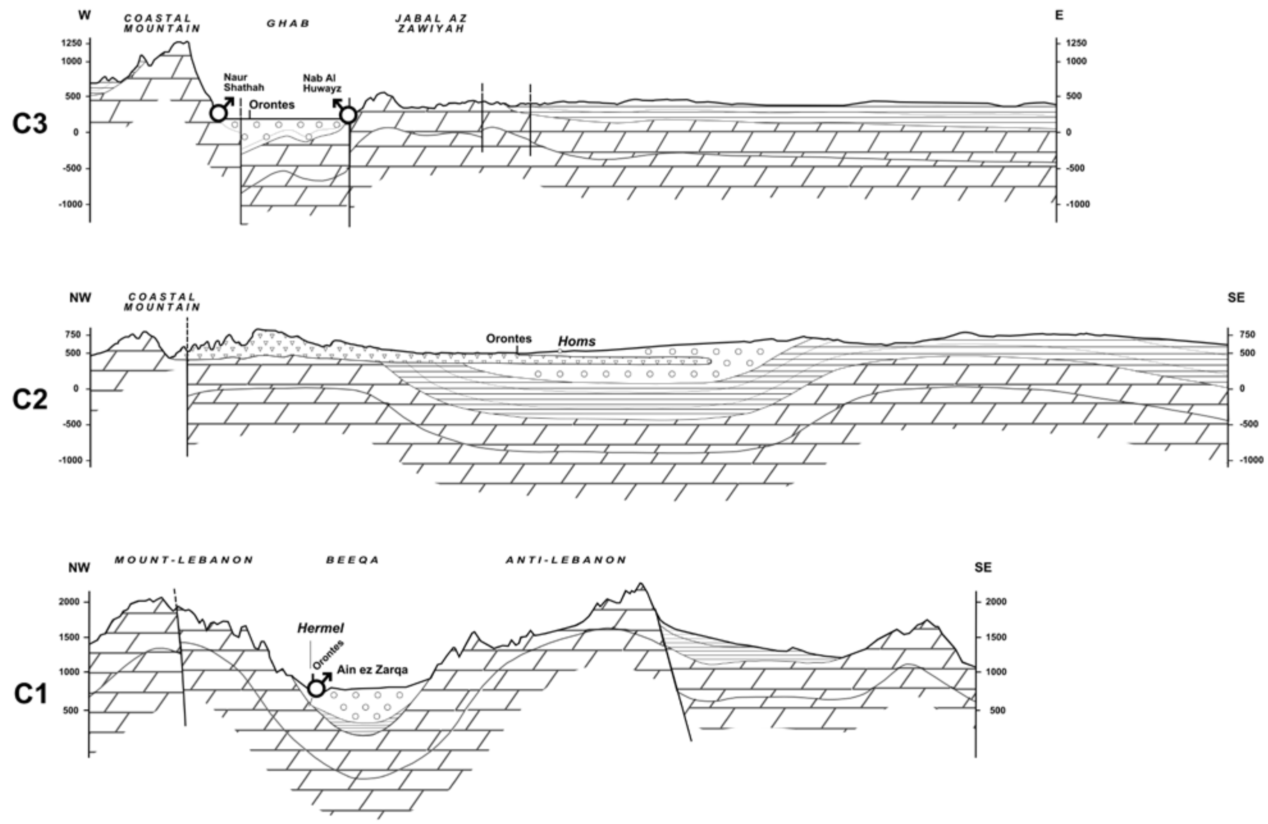


Figure 3 Hydrogeological cross-sections of the Orontes River basin (legend see Figure 1)

INVENTORY OF GROUNDWATER SOURCES, EVOLUTION OF THEIR FLOW AND OF THE ORGANIZATION OF THE SUBSURFACE FLOWS SUPPLYING THEM

Introduction

The inventory of groundwater sources and resurgences of major interest of the Orontes basin, Figure 1, counts around 30 springs, including several major located close to the Lebanon-Syrian border.

The evolution of their annual average flow between the 1960s and the 2000s is difficult to access precisely. We generally observe a significant decrease because of the intensive use of water, more specifically groundwater pumped from deep wells, due to recent and rapid extension of irrigated lands, mainly in Syria.

Supplied by groundwater coming from Jurassic and Cretaceous aquifer, the main sources in Lebanon are Ayn ez Zarqa (Orontes spring) and Ayn el Laboue just pre-frontier Syria and in Syria close to the border, Ayn at Tannur, Uyun as Samak and Ayn al Damamel (Kloostermann 2008).

Remote groundwater discharge of the same Jurassic and Cretaceous aquifer have been much more affected downstream, in particularly in the East of the Al Ghab plain. Some of them have even been dried up, as shown in Table 1, which provides references of the sources appearing on the map, Figure 1.

Main sources or groups of sources	**Flow l/s years 60**	**Flow l/s years 1990-2000**	**Sources**	**ID**	**Elevation**
Ayn ez Zarqa	**13 000**	**13 000**	Ayn ez Zarka	1.01	676
Ayn el Laboue	**1 400**	**700**	Ayn el Laboue	1.02	903
			Ayn at Tannur	2.01	510
Ayn at Tannur region	**2 300**	**1 500**	Uyun as Samak	2.02	512
			Ayn al Damamel	2.03	518
			Tall al Uyun	2.11	193
			Ayn Qalat al Madiq	2.12	172
Al Ghab east region	**13 000**	**virtually zero flow**	Ayn at Taqah, Ash Shariah	2.13	170
			Nab an Nasiriyah	2.14	172
			Nab al Huwayz	2.15	171

Table 1 Estimated flows of the main sources or group of sources, in the 1960s and in the late 1990s, south and central parts of the basin

Schematic diagram of the organization of the subsurface flow, in the 1960s

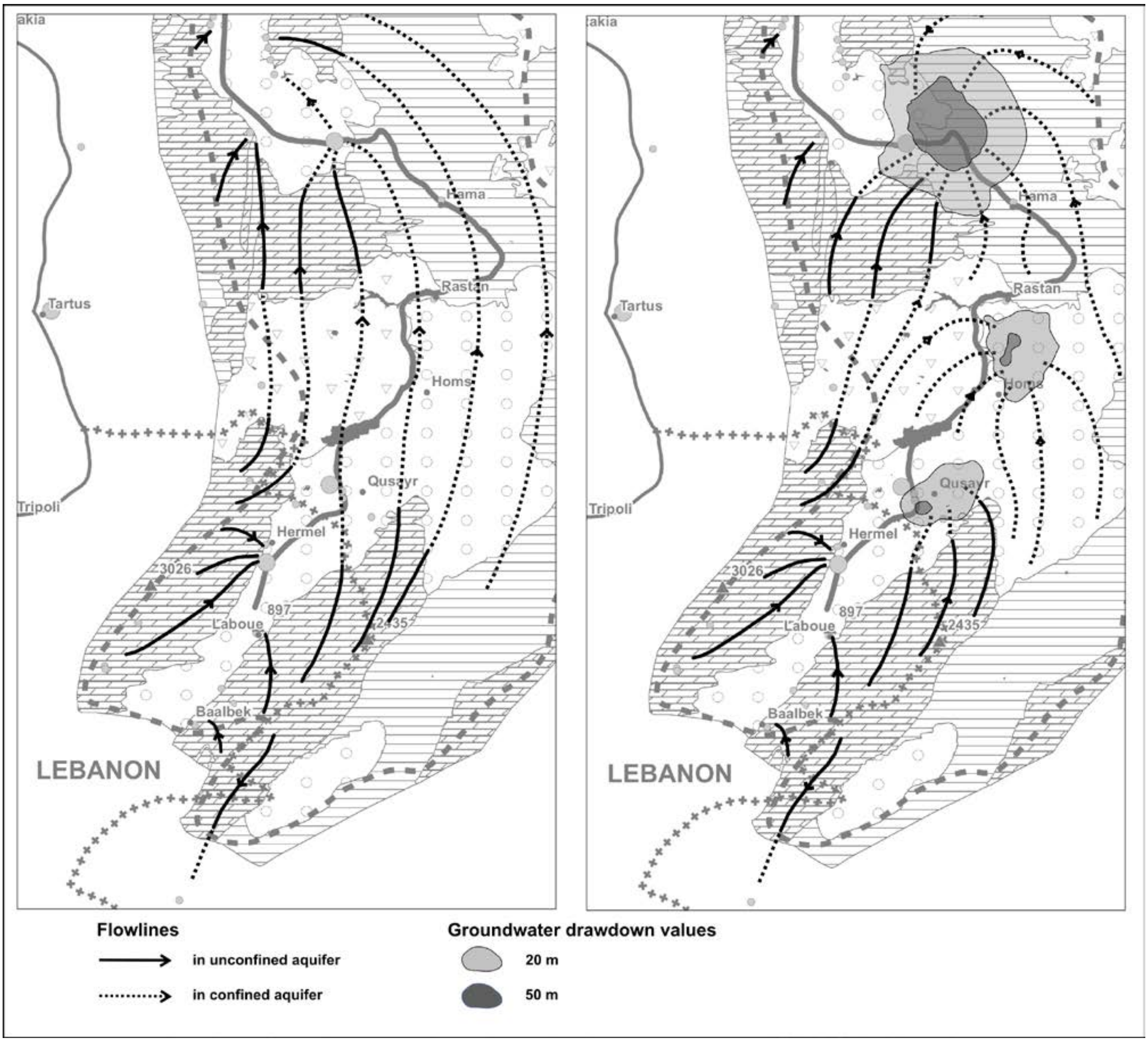
Various observations presented above allow us to propose a schematic diagram of the organization of the main subsurface flow lines in the Orontes basin, in the 1960s. Figure 4 shows the groundwater flow oriented northward, mainly affected by longitudinal hydro-geological structure of the basin. South of Anti-Lebanon however the flow is oriented in the opposite direction southward toward the Syrian source of Figueh.

Schematic diagram of the organization of the subsurface flow, years 1990-2000

In response to the intensive development of irrigation in the Syrian part of the basin, more particularly in areas with no surface water reservoirs, a dramatic proliferation of legal or illegal water wells toke place in the late 1990s.

Used without limits deep wells pumping of Jurassic and Cretaceous groundwater induces important drawdown of groundwater heads more specifically in artesian areas. The TNO numerical simulation, (Kloostermann & Vermooten 2008), which roughly simulates the extension of groundwater drawdown, clearly delineates three areas particularly hard hit: Qusayr, just downstream of the Lebanese-Syrian border, Homs in the middle of the basin and Asharneh ahead of the Al Ghab. Regarding the area of Qusayr, the drawdown dropped several dozen meters, Figure 5.

This large-scale drawdown caused a sharp reduction in water flow of numerous springs in the Orontes basin, more particularly in the central part of the basin where some of them dried up. In the vicinity of the Lebanese-Syrian border, the springs have also been seriously affected but not to the same degree.



Figures 4 and 5 Schematic diagram of the organization of the subsurface flow, on the left years 1960, on the right years 1990-2000

Moreover, the directions of the nearby groundwater flow lines have in some areas significantly changed, because they have been attracted to main drawdown areas, especially in the Asharneh plain area, Figure 5.

Regarding more particularly the border area, the intense water pumping in Qusayr area, because of local drawdown, may likely cause an intensification of the groundwater flow passing through the border. This could ultimately lead to lower groundwater resources of the Lebanese part of the Orontes basin.

THE SYRIA-LEBANON AGREEMENT AND GROUNDWATER FLOW INVOLVEMENT

History of the agreements

Discussions between the two countries, with the goal of establishing a water resources sharing agreement in the upstream part of the basin started in the 1940s. A first agreement was signed in 1994, modified by an addendum in 1997 and followed in 2002 by a new one, today still in force.

The 1994 Agreement

The 1994 “Agreement of the Distribution of the Orontes River Water Originating in Lebanese Territory “ defined “a fixed amount of 80 million cubic meters (MCM/year) *(scheduled10 MCM for each following period, Sept-Oct, Nov-Feb, Mar-Apr and 50 MCM for May-Aug period one)* allocated to the Lebanon if the river flow exceeds 400 MCM/year at the Hermel Bridge gauging station and 20 % of the annual flow if the discharge volume is less than 400 MCM/year” (Sarraf 2013).

Comair 2013 specified that « the 1994 Agreement addressed the issue of groundwater withdrawals with a provision of authorizing pumping from wells drilled before the signature of 1994 agreement, but prohibiting new wells. The wells allowed were the ones located within a radius of 1500 m from the center of the source and 500 m of either banks of the river ».

In fact, in absence of dams or diversion works (not mentioned in the agreement), a large part of the water allocated to Lebanon, in particularly during winter season, cannot be used. Moreover, because of groundwater withdrawals restriction, the Lebanese border village of Kaa and Hermel couldn’t promote any irrigation development.

The 1997 Addendum

Because of the weaknesses of the 1994 Agreement, considered as not equitable to Lebanon, an addendum was added mentioning two new points with regard to Lebanese population. The utilization of the waters of four small “closed” basins (Yammoune, Marjhine, Joubab el Homor and Ouyoun Orgosh) shall be equal to the quantity of renewable water of these basins. And the Lebanese party may benefit, for the region Baalbek-Hermel, from all the waters deriving from the Laboue sources during the irrigation season (end of April till October 15) as well as from the drinking water in use in the neighboring villages).

It means that the quantity of waters mentioned in the two points are no more included in the discharge volume of 400 MCM/year referred in the 1994 Agreement.

The 2002 Agreement

This new agreement comprises the 1994 Agreement, the 1997 Addendum and approved minutes of the Joint Lebanese –Syrian meetings held in the 2000s. These minutes include the construction of a derivation dam with a storage capacity of 27 MCM (located directly after the Ayn ez Zarqa sources that will serve two sides of the river supplying a network of 3000 ha) and a multipurpose dam with a storage capacity of 37 MCM upstream of the Hermel bridge (water stored used for drinking, new irrigation lands of 3800 ha and power production). Finally, the proposed irrigation schemes should comprise a total of 6800 ha in the Hermel and Al Qaa area.

This last Syrian-Lebanese Agreement is seen as equitable for the two parties and complying with international law, in particularly the 1997 “Convention on the Law on the Non-Navigational Uses of International Watercourses (UNWC)”. However, the non-involvement of Turkey in the negotiations remains an obvious negative aspect.

How groundwater is taken into account in the Agreements

General aspects

At present, the use of the water from the Orontes River is limited in Lebanon to small scale farming, fish farms and tourism. Total use of water is estimated, according Sarraf (2013), at only 21 MCM/year of which 23 % is for domestic purposes and the rest for irrigation (irrigated areas in the Lebanese part of the Orontes basin reach officially 1.703 ha).

As the fixed amount of water allocated to Lebanon is of 80 MCM/year, Lebanese withdrawals are far from the part attributed and the situation so far doesn't require any specific discussion between the two countries regarding the shared water part as established in the Agreement. On another hand, sharing the water according the Agreement should be quite complex, involving in dry years to calculate for each month the water deficit regarding the monthly flow of an average year which will be taken in account in the following months for reduce withdrawal.

Hydrogeological aspects

Water sharing between Syria and Lebanon, based to the flow of the Orontes river at the Hermel Bridge gauging station, is only apparently referring to the surface flow. Indeed, most landscape of Lebanese part of Orontes basin is karstified outcrops without any surface runoff. And the episodic runoff flowing when heavy rains occur in the middle of the Bekaa valley, on the Neogene formation, are almost negligible in comparison with the Orontes discharge flowing at Hermel.

The above considerations thus lead to the conclusions that the Syrian-Lebanon agreement exclusively covers groundwater issue.

Regarding deep wells pumping Jurassic and Cretaceous groundwater, the Agreement is very clear, prohibiting any new wells and allowing only the wells drilled before 1994 close to the sources or the Orontes River to be used.

This latter point means that the groundwater flow which doesn't supply directly or indirectly the Orontes rivers is in fact attributed to Syria, all over the Lebanese part of the basin except the four "closed" basin and partly the Laboue sources.

Moreover, no restriction is mentioned regarding the Syrian exploitation of groundwater in the vicinity of the border even if the hydrogeological situation clearly shows the continuity of the main Jurassic and Cretaceous aquifer between the two countries. In reality, the important quantity of groundwater pumped close to the border, as it does exist now south of Qusayr, will increasingly affect in the long-term the Lebanese groundwater head, and in that way likely indirectly impacting the 400 MCM annual river flow taken as reference in the Agreement.

It is interesting to evaluate the subsurface annual flow passing the border by the Jurassic - Cretaceous aquifer. A very rough analytic calculation using Darcy law can be applied and give an order of magnitude of annual groundwater volume entering Syria of 65 MCM, (about 2 m3/s with K 5.10-4 m/s, hydraulic gradient 10-3, width of the water flow 28 km, average thickness of hydraulic flow 150m). This volume can be compared to the annual volume of 30 MCM corresponding to the over exploitation of groundwater in the irrigated area of Qusayr, according to the "Annual Effective Storage use" calculated by TNO numerical simulation (Kloosterman 2008).

CONCLUSIONS

This paper provides an update of recent issues from the hydrogeology of the Orontes basin and seeks to show how existing huge groundwater resources have been taken into account in the Lebanese-Syrian Agreement.

Unlike with river flow rate, sharing groundwater resources cannot be directly based on fixed observation points. It requires taking in account the groundwater flow for large areas and long periods of time involving a great deal of uncertainty. In such a situation is especially difficult to reach a common approach between the negotiation partners.

Regarding this aspect, the history of the Lebanese-Syrian Agreement is a good example of how groundwater flow has been step by step taken in account. It also makes clear how far taking groundwater diversity into account continued to be partly absent particularly because of the difficulty of determining simple and effective rules based on subsurface environment.

The creation of new numerical procedures for water flow simulation delivers today a very useful aid for the negotiators. They nevertheless imply, in addition to robust data, to prior establish a coherent conceptual model, which is all the greater because of constituting the base for negotiations.

REFERENCES

Comair G.F., McKinney D.C., Scoullos M.J., Flinker R.H., Espinoza G.E. (2013) *Transboundary cooperation in internationanl basins : Clarification and experiences from the Orontes River Basin agreement : Part 1*. Environmental Science & Policy 31, 133-140.

Comair G.F., McKinney D.C., Scoullos M.J., Flinker R.H., Espinoza G.E. (2013) *Transboundary cooperation in internationanl basins : Clarification and experiences from the Orontes River Basin agreement : Part 2*. Environmental Science & Policy 31, 141-148.

Droubi A. (2012) Communication interne. Meeting du projet IHEID Orontes River basin Liban-Syrie. Novembre Bekaa, Lebanon.

ESCWA13 (2013) Inventory of Shared Water Resources in Western Asia. *Chapter 7, Orontes River Basin, UN, ESCWA/SDPD/2013/WG13/REPORT.*

FAO (2011) Aquastat database. *Syria Arab Republic.*
http :www.fao.org/nr/water/aquastat/countries/syria/index.stm; last visit 10.01.2012.

Hamade S., Tabet, Ch. (2013) *The impacts of Climate Change and Human Activities on Water Resources Availability in the Orontes Watershed : Case of the Ghab Region in Syria.* Journal of Water Sustainability 3(1), 45-49.

Kloosterman F.H., Vermooten, J.S.A. (2008) Final Report, Development of a Numerical Groundwater Flow Model for the Larger Orontes Basin. *Dutch-Syrian Water Cooperation, TNO report.*

Kloosterman F.H. (2009) Notes on the Origin of the Groundwater issuing from The Ain Altnour, Ain Asamak and Ain Alzzarka Springs. *Mission Report EVD Syria Bridging Phase. TNO/Deltares.*

Maalouf F. (1999) Approche du fonctionnement de l'aquifère de l'Oronte. DEA Univ. St Joseph, Beyrouth.

Sarraf S. (2013) *Connecting transboundary water resources management with national visions and plans in Lebanon*. Near East & North Africa Land and Water Days, Amman, 1-9.