Hydropolitical Baseline of the Yarmouk Tributary of the Jordan River

WATER SECURITY RESEARCH CENTRE
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Hydropolical Baseline Study of the Yarmouk Tributary of the Jordan River

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Cover photo: The al Wehdeh Dam Reservoir on the Yarmouk tributary viewed from Jordan, November 2015. *Source*: Heather Elaydi.

Abstract

This study lays the base of knowledge required for diplomacy that seeks more equitable and sustainable water-sharing arrangements in the Yarmouk and wider Jordan River Basins. The driving rationale is that informed diplomacy will better equip residents to face constant political change, massive demographic shifts, highly variable weather and projected long-term changes in climate. The study supplements all available hydrological and hydrogeological data with archival records, observation, satellite images, and interviews with key policymakers. Apart from documenting numerous biophysical and political features, it finds the transboundary water arrangements in 2017 to be inequitable and unsustainable. The study makes makes five broad recommendations: i) improvement of the knowledge base; ii) development of 'transboundary community' projects; iii) optimisation of the infrastructure; iv) use of International Water Law to guide diplomacy; and 5) revision of the existing water agreements. It further identifies a number of windows of opportunity for diplomacy, and sketches a long-term path to an equitable and sustainable arrangement.

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Abbreviations / Acronyms

ASL	Above Sea Level
BR	Bifurcation Ratio
BSL	Below Sea Level
CBS	Central Bureau of Statistics (Syria)
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
CWR	Crop Water Requirement
DEM	Digital Elevation Model
DMZ	Demilitarised Zone
DoS	Department of Statistics (Jordan)
EF	Evaporative Fraction
ET	Evapotranspiration
EGC	East Ghor Canal
GCWR	General Commission of Water Resources (Syria)
GoJ	Government of Jordan
GoS	Government of Syria
HSI	Hydrological Service of Israel
ILC	International Law Commission
IWL	International Water Law
JVA	Jordan Valley Authority (Jordan)
JVWA	Jordan Valley Water Association (Israel)
KAC	King Abdallah Canal

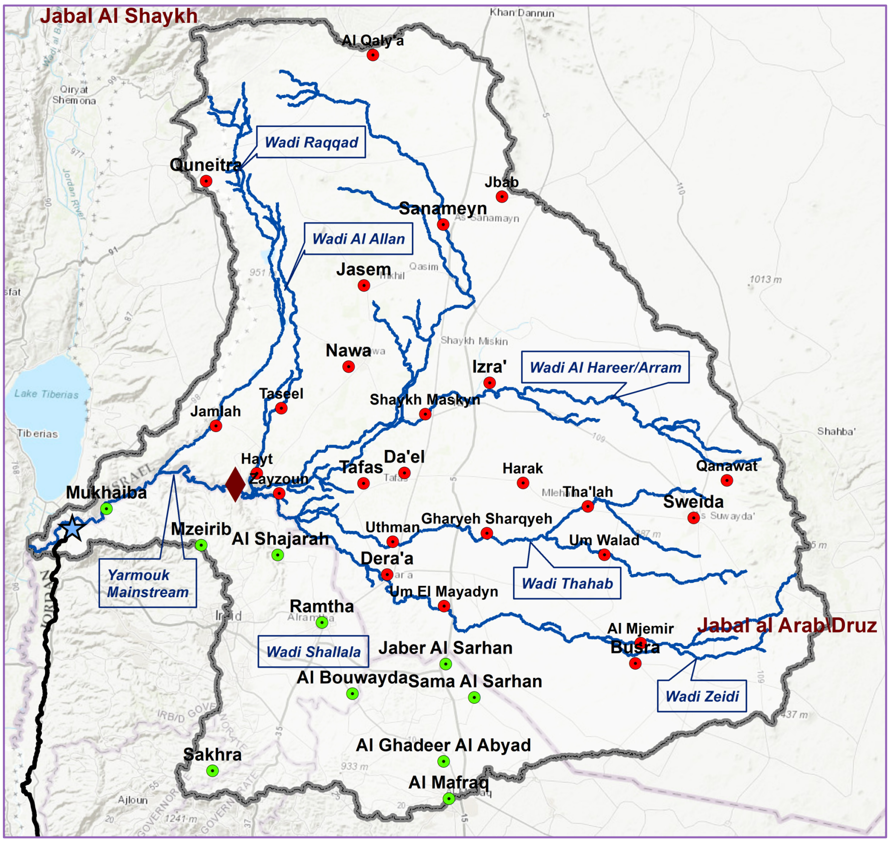
LST	Land Surface Temperature
LUC	Land Use and Cover
MoU	Memorandum of Understanding
MCM	million cubic metres
MCM/y	million cubic metres per year
MWI	Ministry of Water and Irrigation (Jordan)
MoWR	Ministry of Water Resources (Syria)
NDVI	Normalised Different Vegetation Index
NWC	National Water Carrier
OSoI	Occupying State of Israel (refers to the political entity in the figures)
PLO	Palestinian Liberation Organization
SPI	Standardised Precipitation Index
TC	Theoretical Capacity
TWINS	Transboundary Water Interaction NexuS
UNECE	United Nations Economic Commission for Europe
UNRWA	United Nations Relief and Works Agency for Palestine Refugees in the Near East
UNWC	United Nations Watercourses Convention
USGS	United States Geological Service
WAJ	Water Authority of Jordan

Executive Summary

Towards an equitable and sustainable arrangement on the Yarmouk tributary of the Jordan River.

This study provides the comprehensive biophysical and political analysis of the Yarmouk tributary of the Jordan River required by diplomacy that seeks a more equitable and sustainable arrangement. It was designed and implemented by researchers from Jordan, Syria, Lebanon, Switzerland, Germany and the United Kingdom, with funding from the Swiss Agency for Development and Cooperation, and the University of East Anglia.

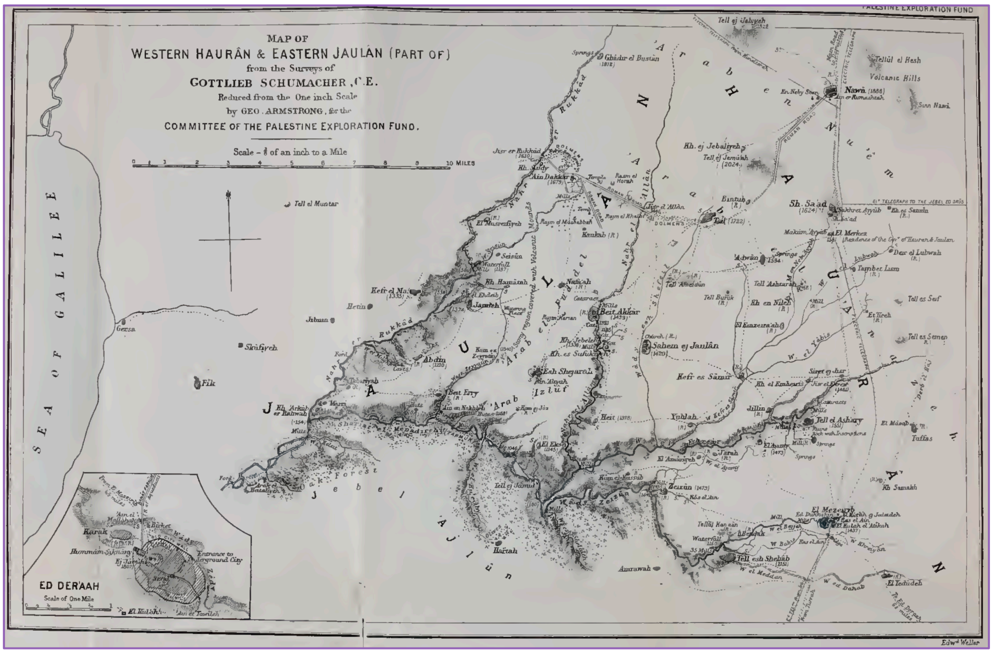
The Yarmouk tributary basin in relation to the Jordan River Basin.



An equitable and sustainable arrangement on the Yarmouk tributary is expected to greatly reduce social and political tensions for the roughly 1.6 million people living in the basin in Jordan and Syria. It could also enable more effective transboundary water management across the entire Jordan River Basin. However, reaching that point requires diplomacy that can cut through the patchy knowledge and misperceptions that characterise our common understanding of the Yarmouk.

Diplomacy that ignores the politics and hydrology of the area risks perpetuating the mistakes of the past into the future, resulting in evermore uncoordinated and inefficient infrastructure, skewed and ambiguous treaties, and confrontational narratives. Indeed, if the pattern of basin development that this study has identified persists for a few more decades, the basin will be riddled with unnecessary water swaps, out-of-basin transfers, and desalination projects through treaties and institutions that lost their relevance more than half a century earlier and no longer meet the needs of the people. Informed diplomacy, on the other hand, can help equip residents of the Yarmouk tributary basin to better face the challenges caused by political upheavals, massive demographic shifts and long-term changes in climate – not to mention the recurrent possibility of punctual or protracted war.

The *Sharia't el Menadireh* (Yarmouk), between the Jaulan (Golan) and Hauran Plain. Source: Schumacher 1889.

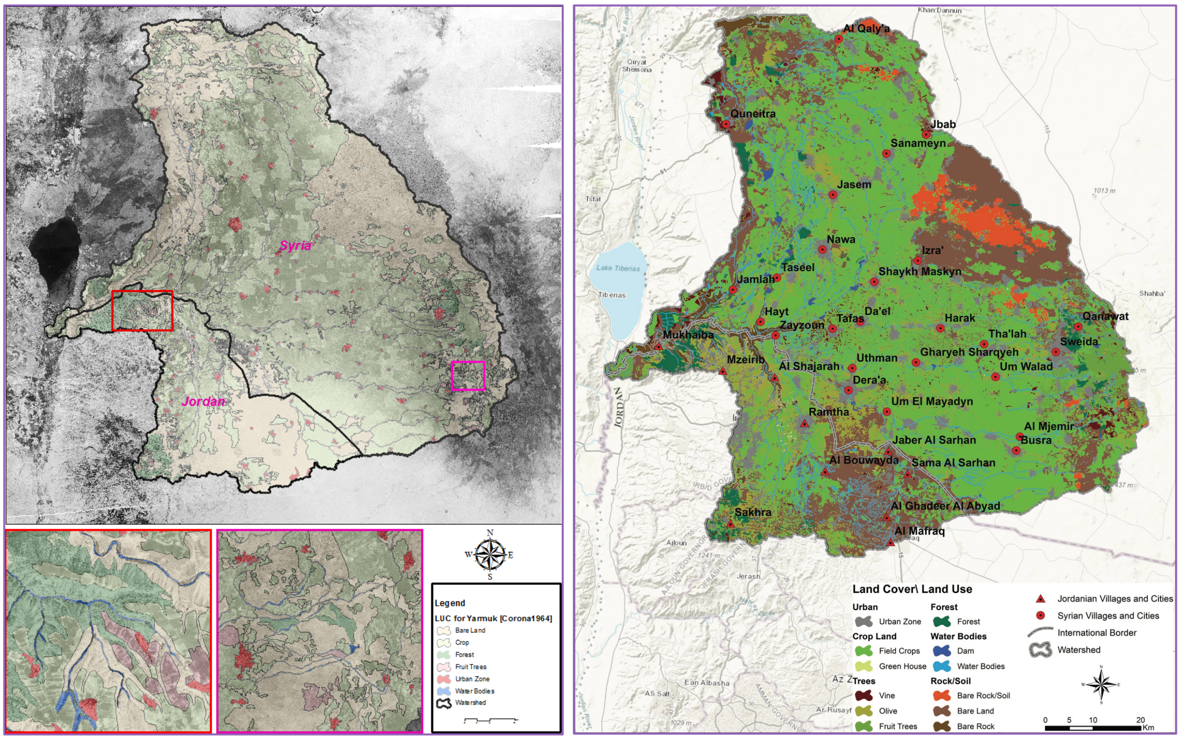


How the study examines the past to illuminate the present.

The report draws on several hundred sources and multiple lenses to scrutinise how water has been used throughout the tributary basin. Examination of archives in Jordan, Lebanon, Israel, France and the United Kingdom has revealed, for instance, the extent of the shift in importance of the Yarmouk Valley as a path for the Hejaz Railway (under Ottoman rule) to a source of water for state-building efforts (under British and French rule). The colonial authorities negotiated water-sharing arrangements from 1920 onwards, whether out of concern of rebellion amongst their new subjects (as the French authorities with the Druze communities around Jabal al Druze in Syria), or to respond to regional crises (as the British with Transjordan and Palestinians displaced by the *Nakba*/creation of the State of Israel in 1948). The archives also reveal the extent to which international law was used to guide American diplomacy in the Jordan Basin – but only until the late 1970s.

The Yarmouk tributary's more recent past is explored through extensive analysis of satellite images. The method proves very useful to track the considerable conversion of bare land in the 1960s to the current widespread level of cultivation, and to identify dams and patterns of agricultural water use. The result is the most accurate estimate to date of the area of the basin (7,387 km^2), length of the river (154 km, from the heights of Jabal al Arab / Druze to the confluence with the Jordan River), and elevation profiles of the main wadis that contribute to the Yarmouk mainstream. One particularly useful outcome is the highly detailed land use and cover map (1:20,000 scale) that will serve water resource managers in their respective States, and – eventually – across the borders.

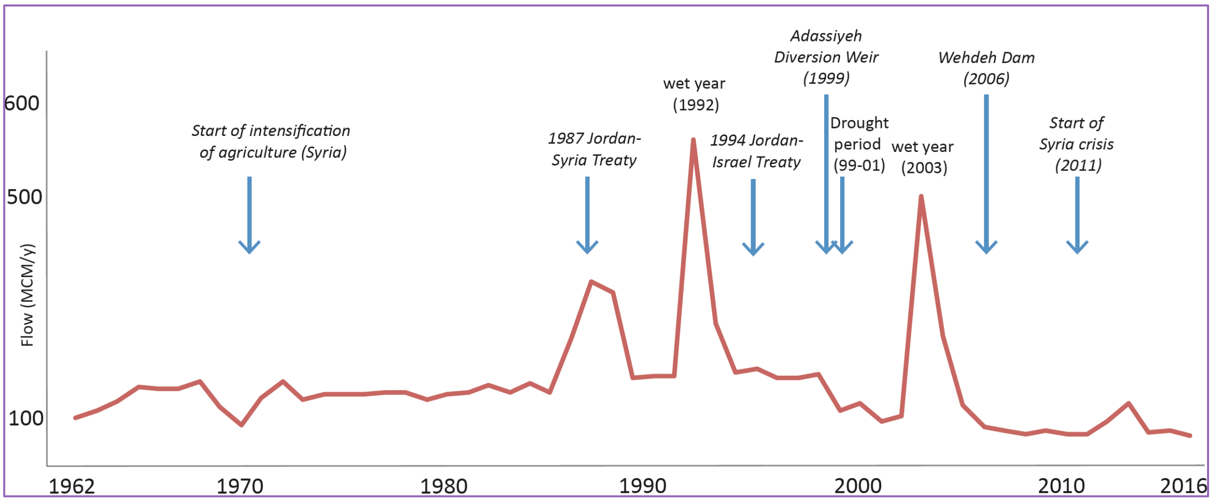
Changes in land use and cover between 1966 (left) and 2011 (right). Refer to main document for sources.



The study employs all available sources of information, including pumping and availability data publically available from or provided by the Jordanian Ministry of Water and Irrigation, the Jordan Valley Authority (in Jordan), the Jordan Valley Water Authority (in Israel), and the Hydrological Service of Israel. It draws upon the widest possible range of hydrological and hydrogeological studies, whether published in peer-reviewed scientific journals, donor reports, local media or PhD theses (and whether in Arabic, Hebrew, French or English). The quantitative data has been verified by field-level observation in Jordan and Israel (although not in Syria, because of the ongoing crisis), and supplemented by more than 30 interviews conducted with Syrian, Jordanian and Israeli scientists, water resource managers, farmers and policymakers.

The body of knowledge holds that the long-term average total 'availability' of water in the basin is very roughly 450 MCM/y measured at Adassiyeh, of which roughly 200 MCM/y is counted as surface water and 250 MCM/y as groundwater. The river flow is highly sensitive to changes in precipitation and abstraction, with the average annual flow varying within the same decade from 50 to 250 MCM/y, and flood flows that can exceed 500 MCM/y (in e.g. 1992).

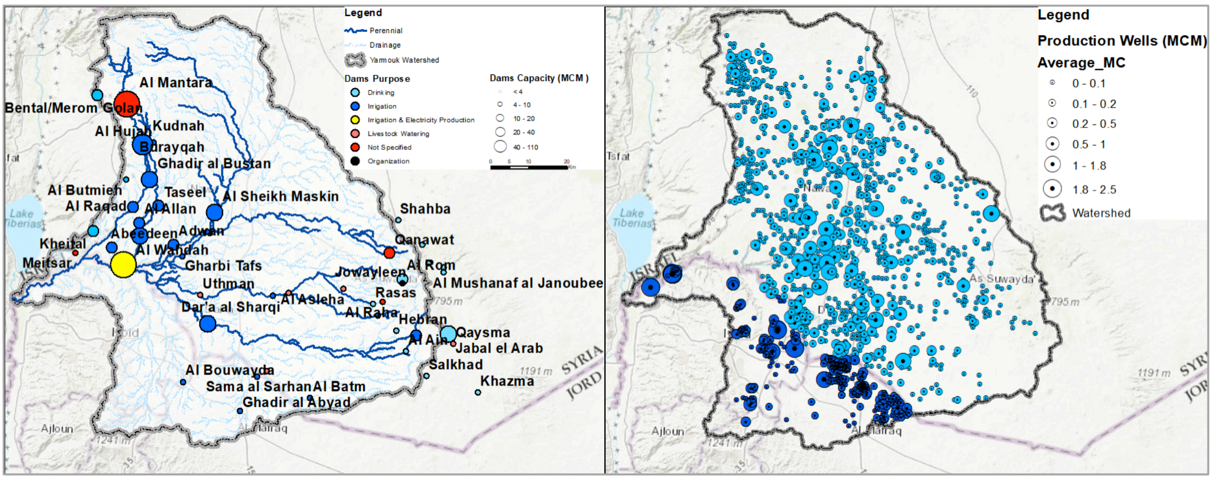
The flow of the Yarmouk measured at Adassiyeh (1962-2016). Source: Compiled based on yearly reporting by JVA.



The groundwater flowing through the three major aquifer systems is more stable than the surface flows, and more significant as a useable source – particularly for agricultural water use from the 1970s onwards. More recently, the Shallow Basalt Aquifer is exploited through thousands of licensed and unlicensed wells in Syria, providing approximately 170 MCM/y for drinking and irrigation water, while more than 32 MCM/y is pumped in Jordan from over 200 wells that exploit the A7/B2 – Cr_2cn cp/Cr_2m-d (Wadi as Sir/Amman-Al Hissa) Aquifer, primarily for irrigation in the Jordan River Valley and drinking water in Amman.

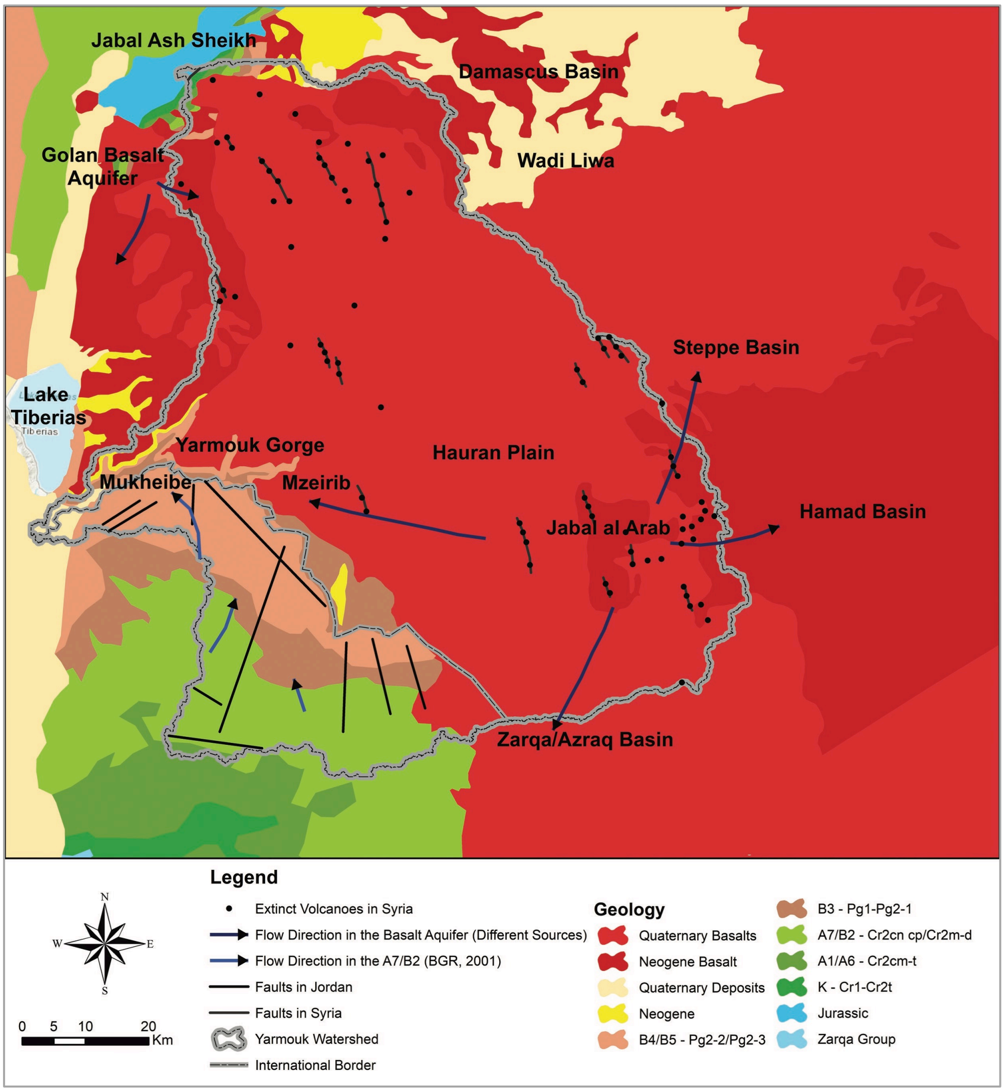
Diplomacy for the future. Diplomacy may best be served by the study's identification of patterns arising from the constant interplay of *interests*, *infrastructure*, *treaties* and *narratives*. The findings corroborate commonly held knowledge about the steady decline of flow in the Yarmouk mainstream (from 450 MCM/y measured at Adassiyeh prior to development in the basin to roughly 40 MCM/y gauged at the same location between 2008 and 2015). This is likely due to upstream surface water and groundwater abstractions, via the many wells or 40 dams on Yarmouk wadis. The 32 dams found in Syria are calculated to have a theoretical total storage capacity of approximately 205 MCM, though actual volumes stored are estimated at very roughly half that amount. The flow of the river is further affected by the variable precipitation, by the Adassiyeh Diversion Weir completed in 1999, and by the Wehdeh Dam completed in 2006, as discussed below.

Dams and wells in the Yarmouk tributary basin (2017). Refer to main document for sources.



Interestingly, the flow of the Yarmouk mainstream has been increasing since 2011, due at least in part to reduced agricultural activity in Syria following the start of the crisis there. Expecting that water use will eventually revert to pre-crisis patterns, the recent increase in mainstream flow should be seen less as encouraging news than as a clarion call for renewed efforts to improve the water-sharing arrangements. Experience with agricultural pumping suggests that the groundwater in the aquifers is being abstracted at rates beyond their sustainable limits, though accurate volumes of lateral flows from neighbouring hydraulically connected aquifers remain very difficult to estimate.

Geology of the Yarmouk tributary basin and general flow direction of groundwater in the main aquifers. Based on Hobler et al., 2001; Margane, 2015; Orient, 2011; Ponikarov and Mikhailov, 1964; UN-ESCWA/BGR, 2013).

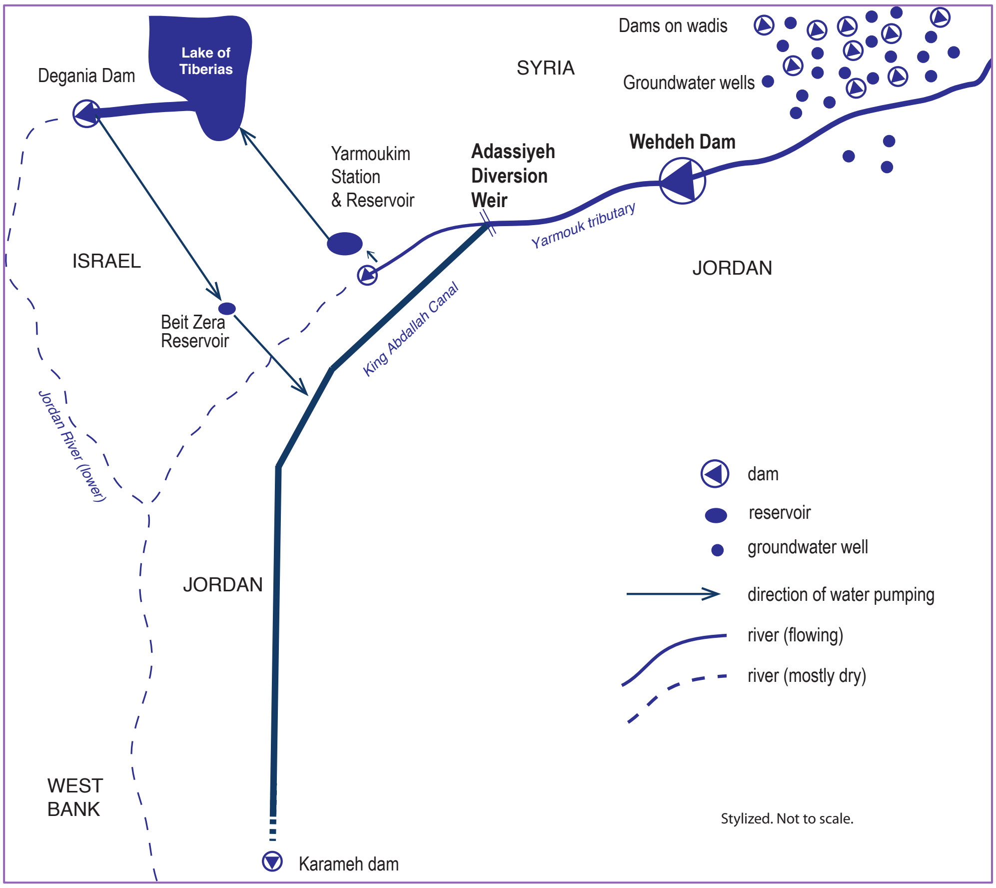


The diplomatic response can come through any admixture of three main conclusions that stem from the interplay of interests-infrastructure-treaties-narratives: i) an equitable and sustainable distribution is feasible; ii) the infrastructure should be much more efficient; and iii) revised treaties can be part of the solution.

i) An equitable and sustainable arrangement is feasible. The study's mapping of Jordanian-Syrian water relations tracks their dramatic variation over the decades, as they reflect changes at the broader political level (e.g. 1950s pan-Arabism, the 2003 US/UK Invasion of Iraq, current Syria crisis). Jordanian-

Israeli relations were most intense from the 1950s to the 1970s, with repeated Israeli attacks on the East Ghor Canal and kidnapping of soldiers protecting the temporary weir at Adassiyeh. Relations improved through the now well-known secret political dialogue (much of which was facilitated by talks related to Yarmouk flows), which culminated in the 1994 Peace Treaty.

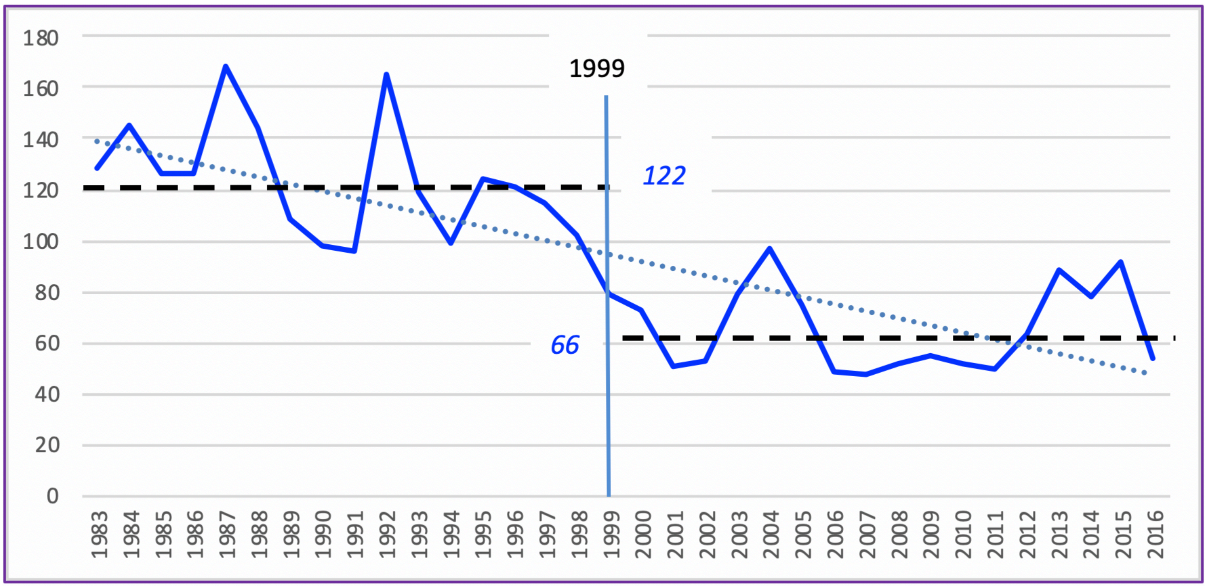
Sketch of infrastructure on the Yarmouk tributary and Lower Jordan River (2017).



The study further evaluates the current distribution of control and use of Yarmouk flows, vis-à-vis the principles of International Water Law applied to the wider Jordan River Basin (notably the 1997 UN Watercourses Convention, which the governments of Syria and Jordan have ratified). Secondary sources show that Syria uses on average roughly 335 MCM/y of Yarmouk flows; Jordan roughly 98 MCM/y (not including an average of 47 MCM/y of non-Yarmouk flows supplied by Israel from the Lake of Tiberias in partial accordance with the terms of the 1994 Jordan-Israel Peace Treaty); and Israel roughly 56 MCM/y (not counting the 47 MCM/y supplied to Jordan, but including water used in the Occupied Syrian Golan Heights and Meitsar settlement). Israel currently uses significantly more than the maximum range of its legal entitlement from the Jordan River Basin; both Syria and Jordan currently use less.

ii) The infrastructure could be much more efficient. The post-2011 increase in Yarmouk tributary flows is reflected in the flows entering into and released from the Wehdeh Dam. Though it remained nearly empty in the first years following its completion in 2006, the average flow into the dam from 2008 to October 2016 was 33 MCM/y (while the average release was 35 MCM/y). In 2015, the dam was filled to 75% of its 110 MCM/y capacity. Importantly, the flows into the King Abdallah Canal (KAC) have not increased accordingly, as explained below.

Drop in the diversion of Yarmouk flows to the King Abdallah Canal, from 1986-2016 (MCM/y). JVA 2016.



The analysis of Section 6 shows that the average annual flows diverted from the Yarmouk to the KAC for the 18 years prior to construction of the Adassiyeh Weir in 1999 was 122 MCM; the average since then has been 66 MCM. The average annual flow *bypassing* the KAC during the same period were 87 MCM and 50 MCM, respectively. In other words, Yarmouk flows to the KAC dropped by about half following the construction of the Adassiyeh Weir, while the flows bypassing the KAC dropped by considerably less, and (when flood flows are counted) are cu§rrently greater on average than the flows diverted into it. The Yarmouk flows that bypass (or overspill) the Adassiyeh Weir flow downstream until they are pumped entirely into the Yarmoukim Reservoir in Israel.

The relative increase in flows bypassing the KAC is explained in part by the Yarmouk-Tiberias 'water swap' arrangement detailed in the 1994 Jordan-Israel Peace Treaty. The flows are then pumped for use for drinking and agriculture of Israeli kibbutzim, and to the Lake of Tiberias. The transmission to the Lake of Tiberias is based on an idea originally proposed in the 1950s, prior to the intensification of agriculture in the Jordan River Valley and when it was logical to store the excess winter floodwater in the lake. While that arrangement is now cemented in the 1994 Peace Treaty, its logic has broken down given the rise in agricultural water demand in the Jordan River Valley.

iii) Revised agreements can be part of the solution. The temporary conclusion of negotiations (which resulted in the 1987 Jordan-Syria Water Agreement and the Water Annex of the 1994 Jordan-Israel Peace Treaty) may have led to cautious optimism that water use throughout the Jordan River Basin could be coordinated in a sustainable manner. More than a quarter of a century on, however, the agreements are proving to be part of the problem. When evaluated against the clauses of a model treaty, both fall well short of their potential.

The 1987 Jordan-Syria Treaty is considered unsustainable for a number of reasons, including: i) it does not account for the impact on downstream users; ii) it is no longer 'fit for purpose' (which was to build the Wehdeh Dam); iii) it fails to reflect the actual availability and use of water (particularly the connected surface water and groundwater flows, increased demand driven by population influxes, and projected effects of climate change); and iv) it is inequitable in its allocation of use and control over the flows when evaluated against the principles of International Water Law. The omissions, contradictions, specificity and ambiguity are found to work in Syria's favour, in the narrow sense of the term. Syrian violations of the treaty are debatable, even if the number of dams currently constructed (32) is greater than the number stipulated in the treaty (26).

Evaluation of the Yarmouk treaties against the clauses of a model treaty. Refer to main document for sources.

Features of a Model Transboundary Water Agreement	**1987 Jordan-Syria**	**1994 Jordan-Israel**	**1995 PLO-Israel**[27]
Allocative mechanisms			
Based on 'equitable and reasonable use'	**No**	**No**	**No**
Specific, rather than ambiguous	**Yes**	**No**	**Yes**
Flexible, rather than rigid	**No**	**No**	**No**
Technical mechanisms (related to e.g. conjunctive groundwater and surface water)			
Acknowledgement of surface water and groundwater as part of the same transboundary watercourse	**No**	**No**	**No**
Adequate accounting for use, amount and quality of groundwater in reserve, and rate of its replenishment	**No**	**No**	**No**
Common identification, delineation and characterisation of transboundary groundwater	**No**	**No**	**No**
Appropriate measures to prevent, control and reduce the pollution of transboundary groundwater	**No**	**No**	**No**
Comprehensive water accounting (including for use, amount and quality of soil water, and gains made through improvements in irrigation efficiency/in the 'paracommons')	**No**	**No**	**No**
Uncertainty Mechanisms (related to changes in needs, climate, etc.)			
Revisiting clauses	**No**	**No**	**No**
Escape clauses	**No**	**No**	**No**
Institutional mechanisms			
'prior notification'	**No**	**Yes**	**No**
'no significant harm'	**No**	**No**	**No**
Enforcement clauses	**No**	**No**	**No**
Monitoring provisions	**No**	**No**	**No**
Dispute resolution mechanisms	**No**	**No**	**No**
Self-enforcement mechanisms	**No**	**No**	**No**
Multilateral bodies for information exchange or management	**Yes**	**Yes**	**Yes**
Environmental and health concerns			
Water-quality provisions	**No**	**Yes**	**No**
Biodiversity, river base flows, etc.	**No**	**No**	**No**

The Water Annex of the 1994 Jordan-Israel Peace Treaty is likewise considered unsuitable for several reasons, including: i) it does not account for the impact on downstream users; ii) it fails to account for groundwater flows; iii) it does not account for Israeli water use in the Occupied Syrian Golan; and iv) it is inequitable, when the very ambiguous allocation mechanism is seen in the light of established water use, International Water Law, and significant asymmetries in power.

Both water agreements are also problematic in that they disregard environmental and water-quality concerns, are inflexible in a constantly changing context, and legitimise the water use that has been established. For instance, the Jordan-Syria Treaty sanctions uncontrolled and inefficient irrigated agriculture in Syria, at the expense of inflows into the Wehdeh Dam. The Jordan-Israel treaty locks in the use of floodwater solely for Israel, a 'water swap' that diverts flows *away* from the KAC for use in Israel (even if some of the flows are returned to the KAC), and continued Israeli water use in the Occupied Syrian Golan.

Recommendations for an equitable and sustainable future. The future can look bleak, or better. Any conception of the basin 50 years from now under a 'business-as-usual' scenario sees ever-more infrastructure pushing the basin's water resources beyond their sustainable limits, while obstructing state development (particularly in Jordan), and contributing to political tensions. A more equitable and sustainable arrangement is simple to envision, if challenging to implement: one where the flows are used efficiently within their sustainable limits, and shared equitably amongst all riparian States and residents.

Opportunities for diplomacy to improve the Yarmouk arrangements include fairly widespread recognition that the 1987 Water Agreement is no longer fit for purpose; a shared history of water users in the Hauran Plain; and a heightened importance of the flows for the rebuilding of a stable Syria. Opportunities for Jordan and Israel include the relative ease with which Jordan may exploit more of the Yarmouk flows through minor modifications to existing infrastructure; the game-changing current level of desalinated flows in Israel, which could relieve pressure on the competition for the freshwater flows; and the 2019 Al Baqura and al Ghamr negotiations.

Finally, the study recommends that parties interested in pursuing the path towards an equitable and sustainable arrangement:

i) **Develop a common and more complete knowledge base**. The first gaps to fill relate to surface water and groundwater quality, and groundwater availability in light of projected changes in use and climate. The improved understanding of the biophysical features of the basin – through a joint groundwater monitoring programme, for instance – should be extended to all users, to address current disagreements over data;

ii) **Support 'transboundary community' projects**, between the States and/or between communities on both sides of the border in the Hauran Plain. These include participatory mapping, twinning of water operators, water users associations, farming knowledge exchange and joint research into the benefits of coordinated transboundary water management;

iii) **Optimise the infrastructure**. Consider a more optimal infrastructural arrangement, by initiating a pre-feasibility study. This would investigate the benefits of greater use of gravity and in-basin use, and the accompanying great potential savings in energy costs and evaporation losses;

iv) **Be guided by International Water Law**, including identification of the opportunities that may arise from using the UN Watercourses Convention as a guide to negotiations or ratifying of the UNECE Water Convention; and

v) **Revisit the agreements**, to make them more effective, drawing on advances in the collective understanding of treaty resilience, environmental concerns and expected changes in climate and water demand.

The extensive Qualitative and Technical annexes detail one path to implement the recommendations, and provide substantial supporting documentation.

Part I – SET UP

1 Introduction

The objective of this study is to provide a hydrological and political baseline analysis of the Yarmouk tributary of the Jordan River in order to serve hydro-diplomacy programming. The main motive for the establishment of the baseline is the generally poor level of knowledge about water availability and use: the literature is rife with major discrepancies over such basic characteristics as basin size and river flow. Considering the scrutiny that is devoted to the Jordan River Basin, the collective lack of knowledge of the Yarmouk tributary is astounding. It may also lead to many misperceptions that hamper the effectiveness of hydro-diplomatic efforts.

A second good reason to study the river and aquifers in the basin is their cultural and economic importance. The flows of the Yarmouk tributary of the Jordan River are the main source of water for the residents of Dera'a, Irbid and dozens of villages. The flows also irrigate over 35,000 ha, and support the livelihoods of over 1 million people across the Hauran Plain and beyond.

Furthermore, the Yarmouk's water resources are being used unsustainably. The land in the basin has gone through dramatic changes, with evermore bare land brought into the production of field crops and olive trees. The flow of the river has been declining steadily for more than half a century. Groundwater levels are more stable, but both the Shallow Basalt and the A7/B2 – Cr_2cn cp/Cr_2m-d Aquifers have been exploited beyond their sustainable limits. Droughts like the devastating one in 2008-2011 seem likely to reoccur, with projections of up to 75% decrease in river flows by 2050 (Rajsekhar*, et al.* 2017). Coordinated action is required between the three main state actors if the Yarmouk tributary basin is to be managed sustainably.

The detailed examination of the Yarmouk tributary is also timely. Inequitable use of the flows remains a source of tension between Syria, Jordan and Israel, and the communities living there. The ongoing crisis in Syria both heightens the need for hydro-diplomacy and complicates it. While the crisis has at least exposed the links between agricultural water use and river flow, it brings into focus the importance of effective transboundary water resources management as the crisis develops or ends.

A final reason to establish this baseline is even more aspirational. Efforts to ensure more equitable use of the Yarmouk tributary are necessarily nested within Jordan River-wide negotiations, which brings upstream Lebanon and downstream Palestine back into the picture. The over-development and in-equitable sharing of the flows across the entire basin is straining the resource as much as it is social and political relations, increasing the urgency of refreshed diplomacy.

1.1 Over-development in the Jordan River Basin

The distribution of use and control of the Jordan River flows has over the decades attracted a great number of hydrological and hydropolitical analysts, not least because of the violence (especially in the 1950s and 1970s), the extreme asymmetry in use and power, and the numerous contradictions that still exist (see e.g. Naff*, et al.* 1984, Frey*, et al.* 1985, Lowi 1993, Amery 1998, Amery*, et al.* 2000, Amery 2002, Haddadin 2002a, Suleiman 2003, Courcier*, et al.* 2005, Sosland 2007).

However, in practice, these analyses have not led to rational or even coordinated water management. In 2018, the water of the Jordan River Basin is still used to grow crops for export outside of the region rather than to supply local demand centres (e.g. Amman), much less to support an industrial economic base. Lebanese water development in the basin is compromised by Israeli control. The livelihoods of farmers in northern Jordan and Palestinians in the southern West Bank are compromised by the water-sharing agreements that their political representatives consented to. Indeed, an unbridled quest to satisfy the demand for water has led each State to compete for every drop through the development of infrastructure, leading Smith (1966: 111) to compare the rivalry to a 'limb-from-limb rending of the infant by irreconcilable and importunate parents'.

With about 1.6 million people living in the Yarmouk tributary basin and climate-induced droughts looming, the inevitable pressure on water resources obliges long-term planning and effective cooperation if tensions are to be reduced. In a rational world, the shortcomings might be addressed through technological innovation, demand management, shifts in agricultural policy, or the renegotiation of transboundary water treaties. But such policies would oblige decisions that could be politically suicidal.

The scramble to satisfy water demand through ever-greater exploitation means that the Jordan River Basin in 2018 is not just 'closed' in the hydrological sense (see e.g. Swatuk 2008), but effectively sealed shut. Any notion of the basin in 2070 under a 'business-as-usual' scenario includes evermore redundant and overlapping infrastructure that will progressively exacerbate tensions in the basin and continue to push the resource beyond its sustainable limits. A preferable reality would result from serious engagement with the alternatives: wastewater reuse, demand management, shifts in agricultural policy and renegotiation of transboundary water treaties leading to more equitable and sustainable transboundary water arrangements.

1.2 Research questions and analytical framework

However, a solid baseline obliges answers to a more structured set of questions. The main research question is *to what extent does previous and current water availability, use, and sharing in the Yarmouk tributary shape future transboundary hydro-diplomatic and management efforts?* Sub-research questions may be broken down into four categories:

Water-resource availability

- What does existing data tell us about historical and more recent surface-water flows?
- What does existing data tell us about historical and more recent groundwater availability?
- What does existing data tell us about the quality of the flows?

Water use

- How much surface water has been used historically and more recently, by whom and for what purposes?
- How much groundwater has been used historically and more recently, by whom and for what purposes?
- What can satellite imagery reveal about changes in agricultural water use?
- How much soil water has been used historically and more recently for agricultural production?

Water sharing

- To what extent is the distribution of Yarmouk flows consistent with International Water Law?
- How have the current transboundary water arrangements been achieved and maintained?

Diplomacy

- What opportunities for diplomatic engagement exist in the near term?
- What would be the main features of a strategic hydro-diplomacy plan?

1.3 Methodology and limitations

As specified in the research methodology of Annex 1, data acquired comes from reviews of literature with remote sensing, satellite imagery analysis, hydrological and hydrogeological analysis, interviews, archives and media – with a rough cut-off date of 2017. The methods of analysis derive from multiple disciplines and are often interdisciplinary (and refer to Annex B for supporting documentation on the technical analysis).

The accuracy of many of the findings presented here is limited by the quality and format of the secondary data that the analysis relies upon. While the original data and analysis presents the 'state of the art' of existing knowledge, and is considered complete within these limitations, the study as a whole does not cover the data gaps identified in Section 9.3.

The main limitation is the incomplete data related to or from Syria. The ongoing crisis in Syria prevented the researchers from visiting the Syrian part of the basin, and also increased the reluctance of Syrian decision makers and water users to be interviewed. Furthermore, scientific water data is not available to the general public. The limitations have been circumvented to the extent possible by meeting relevant people outside of Syria,by extending the review of data to include what has been presented publicly (i.e. beyond grey or published literature), and through the extensive remote-sensing data-collection techniques that make up the bulk of Sections 3 and 4.

A second limitation relates to the first: the focus at the inter-state level. Because of the limited access to water users in Syria, relations between communities within the basin have been given less attention than they deserve.

A third limitation derives from the mismatching format of the several forms of hydrological and rainfall data. Though the preferred format is the hydrological year (e.g. November 2003-October 2004), the format retained throughout the study is the calendar year (e.g. January-December 2004). This format is retained a) to match with the very many forms of data on related topics (i.e. not hydrological), which all follow the annual year, and b) because even much of the hydrological data was presented according to the annual year. Thus a bias is introduced in the annual peak river flow and rainfall records, though the impact on multi-year trends identified is not considered to be significant.

The study furthermore under-explores the narratives and interests that are so determining of patterns of water development, and offers only circumscribed technical evaluations of the Wehdeh Dam and Syrian dams in the Hauran Plain.

Some base assumptions about water and conflict: The study appreciates that politics surrounding transboundary waters are generally subordinate to – and not determining of – the broader political context within which transboundary water arrangements are formed. The study also takes as a departure point the inseparability of physical and social processes related to water.

This means that water scarcity is understood to be determined by use and distribution of the flows as much as by the biophysical terms of quantity and quality. In both senses, then, the study rejects the 'environmental deterministic' approaches assuming 'water will lead to peace' (or to war), for one that accepts human responsibility for the conflicts and that human ingenuity is required to redress these.

2 Analysis for Diplomacy

This section lays out the theory that underpins the analysis of the report, while Annex A2 covers relevant theory on water conflict transformation and power.

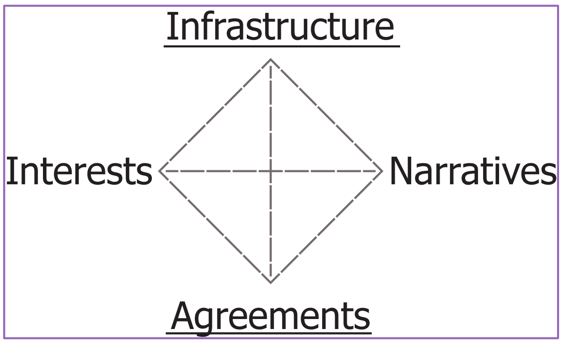
2.1 Interacting factors, destructive cooperation

Though the overdevelopment of the basin that has led to the current misuse and inequitable sharing may appear chaotic, there is actually an observable trend in the coordination of the States. As shown in Figure 2.1, the trend concerns four factors: **interests, infrastructure, narratives and treaties.**

This pattern is used to guide the topics of investigation and obliges analysis from multiple disciplines, including water-related sciences (hydrology, hydrogeology, agronomy, etc.), hydropolitics (hydro-hegemony, transboundary water interaction analysis, etc.), negotiations and discourse theory (securitisation, politicisation, etc.) and law (International Water Law). The primary focus is on infrastructure and treaties, with interests developed to a lesser degree. As discussed in Section 1.3, due to difficulties in securing interviews with water users and key decision makers (particularly from Syria), the analysis of narratives has been sacrificed for deeper questioning of the remaining factors. Readers interested in a partial account of the narratives are directed to Hussein (2017).

The essence behind the saying that there is 'no progress without conflict' is that conflict at least brings issues and tensions into a forum where they can be dealt with. Just as there is constructive conflict, however, there can also be destructive cooperation. Like the political prisoner ordered to 'cooperate' by the guard who is seeking to extract information from him, 'cooperation' can serve destructive ends.

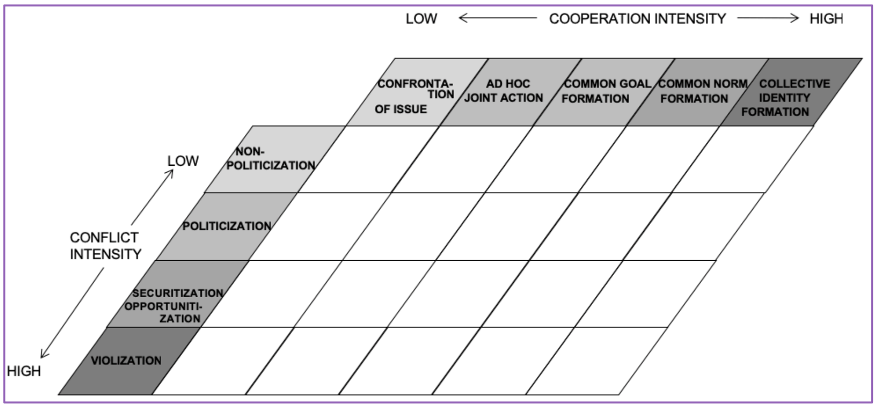
Figure 2.1 Four interacting factors leading to current transboundary water arrangements on the Jordan River and its Yarmouk tributary: interests-infrastructure-agreements-narratives. The report focuses on infrastructure and agreements. *Source*: Authors.



In this sense, the uncritical promotion of 'cooperation' over transboundary waters (e.g. SFG 2013, EcoPeace 2015, SFG 2016) is not helpful to those who seek to transform water conflicts. The uncritical approach is particularly problematic if (undefined) 'cooperation' becomes the end goal of activism or diplomacy. The uncritical perspective leads analysts to label the agreement of a transboundary water *treaty* as 'highly cooperative' (e.g. Wolf, *et al.* 2003), and the follow-on policy message is that a treaty is an end goal rather than a means to a more equitable and sustainable transboundary water arrangement. But beyond the generally friendly and well-ordered relations that exist in North America or Europe, if a water treaty is at all skewed, it is almost inevitably so in favour of the basin hegemon. As we will see in Sections 7.2 and 7.3, the three bilateral treaties that maintain the water conflicts in the Jordan River Basin are truly cases in point.

A more nuanced understanding of water conflict and cooperation is offered through Mirumachi's (2015) analytical tool known as *Transboundary Water Interaction NexuS* (TWINS), as shown in Figure 2.2. Use of the TWINS matrix implies acknowledgement that both conflict and cooperation coexist, and that either can be 'constructive' or 'destructive' in the sense of affecting relations over transboundary water arrangements.[1] It is in this sense that a skewed treaty – as the three that govern interaction over the Jordan River – are evidence of conflict, rather than of cooperation. Application of the TWINs matrix thus reveals patterns that hydro-diplomacy may want to encourage or discourage.

Figure 2.2 Mirumachi's (2015) Transboundary Water Interaction Nexu(S) (TWINS) matrix.



2.2 International Water Law

International Water Law is most thoroughly elaborated in the 1997 UN Watercourses Convention (UNWC) (UNGA 1997). Because the UNWC is a codification of customary state practice (i.e. how States have interacted over transboundary waters in the past), it applies to all States, whether or not they have ratified it (McCaffrey 2007). The main guidance of the UNWC is offered by elaboration of its three substantive principles: i) no significant harm; ii) prior notification; and – most importantly for the study at hand – iii) equitable and reasonable use. All three are important features of any model treaty, while the last is the most relevant to determining equitable allocations. The UNWC offers the following seven factors to be used when determining 'equitable and reasonable use':

(a) Geographic, hydrographic, hydrological, climatic, ecological and other factors of a natural character;

(b) The social and economic needs of the watercourse States concerned;

(c) The population dependent on the watercourse in each watercourse State;

(d) The effects of the use or uses of the watercourses in one watercourse State on other watercourse States;

(e) Existing and potential uses of the watercourse;

(f) Conservation, protection, development and economy of use of the water resources of the watercourse and the costs of measures taken to that effect;

(g) The availability of alternatives, of comparable value, to a particular planned or existing use.

[1] Transboundary water interaction is considered 'positive' if it improves political relations, and 'negative' if not (see Zeitoun, *et al.* 2008).

2.3 What a model agreement might look like

The renegotiation in 1987 of the 1953 Jordan-Syria Treaty testifies to an often-observed fact: treaties are modified, ripped up or renegotiated whenever there is sufficient political will and an adequate political climate to do so. Any chance to renegotiate a treaty should thus 'get it right'. A treaty can otherwise endure for decades, no matter how skewed or flawed in terms of omissions. Fortunately, a considerable body of legal and social science research into the effectiveness of transboundary water treaties provides considerable guidance here, in the form of a number of features or 'mechanisms' that sustainable treaties should include (Table 2.1).

The body of research tells us first that the **allocative mechanism** should be based on water use rather than availability. Actual water use is seen to more accurately reflect need for the water, rather than its availability, and should thus be more relevant to a water-sharing arrangement (and, therefore, more sustainable). The UNWC and United Nations Economic Commission for Europe (UNECE) Convention are the gold standards here, notably for their mention of the substantive principle of 'equitable and reasonable use'. This principle of allocation has developed since the 1950s and was drawn upon in the case of the Yarmouk tributary basin by American diplomat Eric Johnston as well as Sevette (1953), and ICJ judge Baxter in the 1970s (discussed further below). Different water uses water could be prioritised in a way agreed by the two sides. Water used for domestic purposes, for example, is often prioritised over water used for economic gain (i.e. for agriculture or industry).

Furthermore, allocative mechanisms are more effective if they specify the flows and uses, rather than leaving them ambiguously defined. As Fischhendler (2008) notes in his paper *When ambiguity in treaty design becomes destructive*, the potential different interpretations of ambiguous clauses allow the negotiating parties to present the agreement in a favourable light, but can lead to lowest-common-denominator outputs, thus compromising a better arrangement (even one that is not underpinned by a treaty). Allocative mechanisms should be flexible rather than rigid, moreover, notably to reflect annual changes in availability (see e.g. Zentner 2012, Dinar*, et al.* 2015). A treaty that specifies fractions of flows is much easier for all sides to comply with than one that allocates specific volumes, for example, particularly as rainfall and river flow often vary significantly from year to year.

Second, effective transboundary water treaties should incorporate **all sources of water** available for human use. Most notably, treaties should consider *groundwater* alongside surface water resources. This is especially relevant when groundwater pumping affects mainstream or tributary flows, though few treaties concerned with conjunctive flows exist. The related discussion about the extent to which groundwater deserves particular attention has led to the Bellagio Draft Treaty (Hayton*, et al.* 1989), the International Law Commission's (ILC) Draft Aquifer Articles (Eckstein*, et al.* 2014), and the UNECE's Transboundary Groundwater Provisions (UNECE 2012).

Soil water is a further 'resource' that could be considered, notably for the substantial amount of food it produces, particularly in humid or tropical climates. Soil water – or the water transpirated through rainfed agriculture – is qualitatively different than groundwater or surface water, since it is not 'shareable' (i.e. it cannot be pumped, abstracted and distributed). The UNWC is a useful guide again here, as it focuses the discussions on 'watercourse systems', as opposed to simply rivers. The general guidance is to count soil water as an 'alternative source' – one of the seven factors that make up equitable and reasonable use – and let soil water influence the negotiations accordingly.

The very different physical features of the three types of water (surface water, groundwater, soil water) emphasises the importance of adequate *accounting of the water* flowing into and out of the watercourse. Irrigation water that seeps into the soil or aquifers is often considered an indicator of inefficiency, for example, but the flows are often made available for use elsewhere. Tracking such flows accurately is important for water diplomacy. If irrigation in Syria were 100% 'efficient', for example, we would expect to see lower flows in the river, which would entail less water available for Jordanian use (Rajsekhar and Gorelick (2017). 'Efficiency gains' that are made as irrigation systems become more 'efficient' are part of what Lankford (2013) calls the 'paracommons', and can add considerable transparency to the negotiations through proper water accounting methods.[2]

[2] Water accounting methods are debated in the literature (see e.g. Simons*, et al.* 2015).

Table 2.1 Features of a model treaty. Source: Compiled by authors based on (Hayton*, et al.* 1989, UNECE 1992, Fischhendler 2008, Rieu-Clarke*, et al.* 2012, Zentner 2012, Lankford 2013, UNECE 2013, Dinar*, et al.* 2015, Simons*, et al.* 2015, Jafroudi 2018).

Features of a Model Transboundary Water Agreement
Allocative mechanisms
Based on 'equitable and reasonable use'
Specific, rather than ambiguous
Flexible, rather than rigid
Technical mechanisms (related to e.g. conjunctive groundwater and surface water)
Acknowledgement of surface water and groundwater as part of the same transboundary watercourse
Adequate accounting for use, amount and quality of groundwater in reserve, and rate of its replenishment
Common identification, delineation and characterisation of transboundary groundwater
Appropriate measures to prevent, control and reduce the pollution of transboundary groundwater
Comprehensive water accounting (including for use, amount and quality of soil water, and gains made through improvements in irrigation efficiency/in the 'paracommons')
Uncertainty Mechanisms (related to changes in needs, climate, etc.
Revisiting clauses
Escape clauses
Institutional mechanisms
'prior notification'
'no significant harm'
Enforcement clauses
Monitoring provisions
Dispute resolution mechanisms
Self-enforcement mechanisms
Creation of multilateral bodies for information exchange or joint management
Environmental and health concerns
Water-quality provisions
Biodiversity, river-base flows, etc.

Third, effective treaties must be able to **adapt to changes and uncertainty** brought on by changes in climate or water availability and use. Potential mechanisms include a) revisiting clauses, whereby a renegotiation of the treaty is periodically scheduled (as the clause in the Columbia River Treaty that triggered its successful renegotiation and decommissioning of hydropower dams in 2016, 40 years after its ratification) or upon major sudden changes (e.g. war, earthquakes), with several years advance notice; and b) 'escape clauses' to cover exceptional circumstances (e.g. acts of revolution, floods, etc.) (see Fischhendler 2004, De Stefano*, et al.* 2012, Dinar*, et al.* 2015).

The fourth feature of effective transboundary water treaties are functioning **institutional mechanisms** (Dinar*, et al.* 2015). These are intended to enable i) enforcement, through clauses that punish defectors; ii) monitoring through joint inspection or gauging stations (preferably in real time) in order to confirm or dispel perceptions of violations or freeriding; iii) conflict resolution (through e.g. dispute resolution clauses that can provide forums for discussing concerns not covered in the treaty (thus related to the revisiting clause discussed above); iv) self-enforcement mechanisms (e.g. side payments, benefit sharing, issue linkage); and v) joint bodies to monitor or implement any of the above.

Finally, any effective treaty written after 2017 should incorporate **environmental concerns** as well as social and economic concerns (UNWC, UNECE, etc.). These relate to minimum flows for rivers in order to sustain ecosystems, and are informed by extensive physical and social science on biodiversity (McIntyre 2007).

Part II – BASELINE

3 Audit of water resources

This section employs satellite imagery analysis to supplement all the published and unpublished knowledge of water resources in the Yarmouk tributary basin. The resultant 'audit' is thus considered comprehensive – within the limits of the significant gaps and limitations discussed herein (see also Annex A1).

3.1 Basic characteristics of the basin

The Yarmouk is the largest tributary of the Jordan River. It accounts for 40% of the surface-water resources of Jordan and is a primary source of water for the King Abdallah Canal (Al-Hmoud, 2012; Orient, 2011). Originating from different sources in Syria and Jordan (such as Al Muzeirib, Zayzoun, Ain Thakar, Naba' As Sakher in Syria (Youmans 2016) and Ghazzal, Al Rafeed, Al Sukkar in Jordan (Batayneh 2011), the Yarmouk extends over three countries. The bulk of the basin is in Syria (75.5%, not including the Occupied Syrian Golan), while 19.7% is in Jordan, 4.5% in the Occupied Syrian Golan and 0.3% in Israel. The river itself flows along the north-western part of the Jordanian border with Syria, between Jordan and the Occupied Syrian Golan, and then between Jordan and Israel, until it reaches its confluence with the Jordan River (Batayneh 2010). As Figure 3.1 shows, the Yarmouk forms the border between Syria and Jordan over approximately 31.2 km (of river run), then between Jordan and the Occupied Syrian Golan Heights over approximately 19.4 km and between Jordan and Israel over 11.1 km.

The river has a general east to west flow. It is surrounded by the peaks of Jabal al Druze (also known as Jabal al Arab) that reach an altitude of 1,700 m ASL in the east, and the peaks of Jabal al Sheikh that reach up to 2,000 m ASL in the north-west. The altitude of the riverbed decreases as it winds westwards through the Lejja and Hauran Plains (altitudes around 400-700 m ASL) towards the Jordan River Valley, and joins the Jordan River at more than 200 m BSL a few kilometres south of the Lake of Tiberias (Al-Rubeai 2004, Al Manaseer 2012, Al-Hmoud 2012, UN-ESCWA/BGR 2013, Etana 2015).

Figure 3.1 The Yarmouk tributary showing the length of borders between Jordan and Syria (31 km), between Jordan and the Occupied Syrian Golan (19 km) and between Jordan and Israel (11 km). *Source*: Authors.

3.1.1 Area of the basin

The literature reports a very wide range of basin sizes for the Yarmouk tributary basin, ranging from 6,700 km^2 (Al-Ghraibeh 2008) to 8,378 km^2 (Al Manaseer 2012) (Table B 9.1). The main reason for the discrepancies is that official Syrian sources use the administrative, rather than the hydrological boundaries of the basin. The administrative boundaries include part of the territory of Al Suweida Governorate, which is well beyond the hydrological divide at the east of the basin (see Annex B1). Automated drainage network extraction based on SRTM-DEM at 30-m resolution estimated the Yarmouk tributary basin area at 7,387 km^2 (Figure 3.2).

3.1.2 Length of the river

There is also considerable disagreement about the length of the Yarmouk tributary. As shown in Table B 9.2, lengths provided in the literature vary from a minimum of 40 km (Al Manaseer 2012) to a maximum of 143 km (UN-ESCWA/BGR, 2013). Most publications do not specify whether the length quoted is that of the mainstream Yarmouk only (i.e. after the confluence of most of the tributaries at Maqaren), or that of the longest path taken by the river. This study's derivation from the Digital Elevation Model finds that the length of the Yarmouk tributary, from the highest point of the Al Hareer main tributary (at 1,425 m ASL on Jabal al Druze/Arab) to the lowest point (247 m BSL at the confluence of the Jordan River) is 154 km; with an approximate gradient of 16 m/km.

3.1.3 Tributaries and sub-catchments

Spring discharge and surface runoff from southern Syria and northern Jordan join to form many tributaries, with six primary tributaries: Wadi Raqqad, Wadi Al 'Allan, Wadi Al Hareer/Arram, Wadi Thahab (all exclusively in Syria); Wadi Shallala, exclusively in Jordan; and Wadi Zeidi, shared between Syria and Jordan. Apart from Wadi Raqqad, all the wadis of the Yarmouk meet just upstream of Maqaren, the site of the Wehdeh Dam (Figures 3.2 and B 1.2).

The longitudinal profiles of the tributaries are summarised in Figure 3.3. One of the main tributaries, Wadi Raqqad, originates in the northern Golan Heights at the foot of Jabal al Sheikh, whose snowmelts affect the flow of the Yarmouk mainstream (Schumacher*, et al.* 1889, Al-Rubeai 2004). Wadi Al ‘Allan to the east of Wadi Raqqad shares the same geological depression (Al-Rubeai 2004) and floods during winter and spring when the snow melts in the Golan Heights. Wadi Al ‘Allan joins the Yarmouk to the south of Hayt, just upstream of the Wehdeh Dam (Schumacher*, et al.* 1889).

Wadi Al Hareer/Arram originates from the western slopes of Jabal al Arab/Druze and flows through the Hauran Plain. Its three primary streams meet to the south-west of Da’el and Al Sheikh Maskin, forming the main Al Hareer/Arram River that joins the Yarmouk mainstream just upstream of the Wehdeh Dam. To the south of Wadi Al Hareer is Wadi Thahab, which originates near Dera’a before joining Wadi Zeidi at Tell Shehab.

The Wadi Zeidi sub-basin is shared between Syria and Jordan. In Syria, it starts near Al Mjmeir and flows to the west and eventually through Dera’a. A separate tributary of the Zeidi in Jordan starts near Al Bouwayda and flows north by Ramtha to join the Yarmouk mainstream at Zayzoun. Wadi Shallala, the sole primary Jordanian tributary, is a wide wadi that forms the boundary between the Hauran Plain and Ajloun Mountains. In summer it turns into a small stream that is nearly dry at its mouth. Wadi Shallala joins the Yarmouk tributary mainstream just upstream of the Wehdeh Dam.

The slope in most parts of the sub-basins is rather gentle. The slope of each wadi becomes steeper at 400-500 m ASL (in the sub-basins of Wadi Al ‘Allan, Al Hareer/Arram, Raqqad, Thahab and Zeidi), as they reach Maqaren at just under 100 m ASL.

Figure 3.2 The Yarmouk tributary basin with its main tributaries shown in relation to the cities and villages. Source: See Figure B 1.2 for further detail on perennial and seasonal streams. *Source*: Authors, based on multiple sources listed in the text.

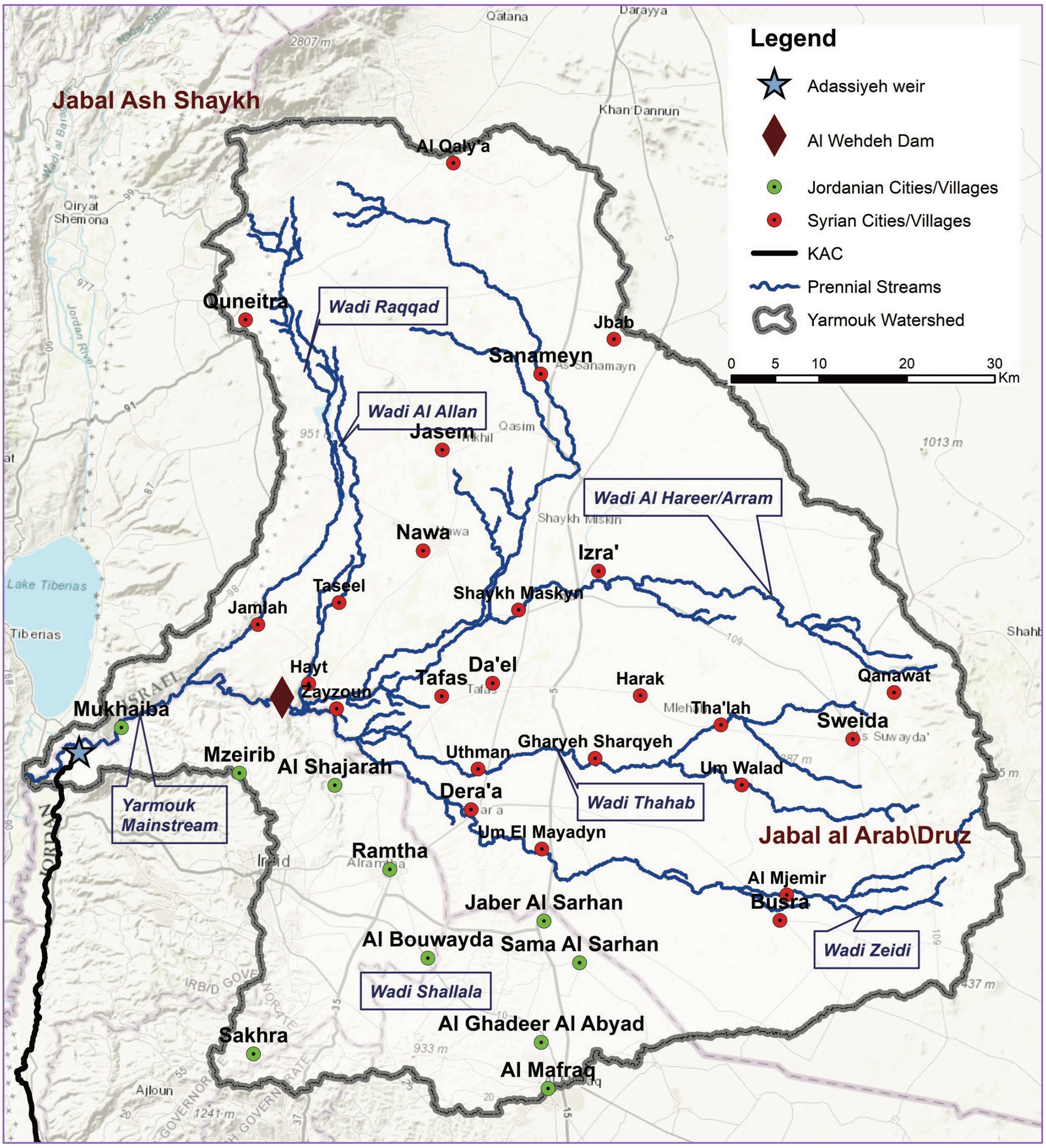
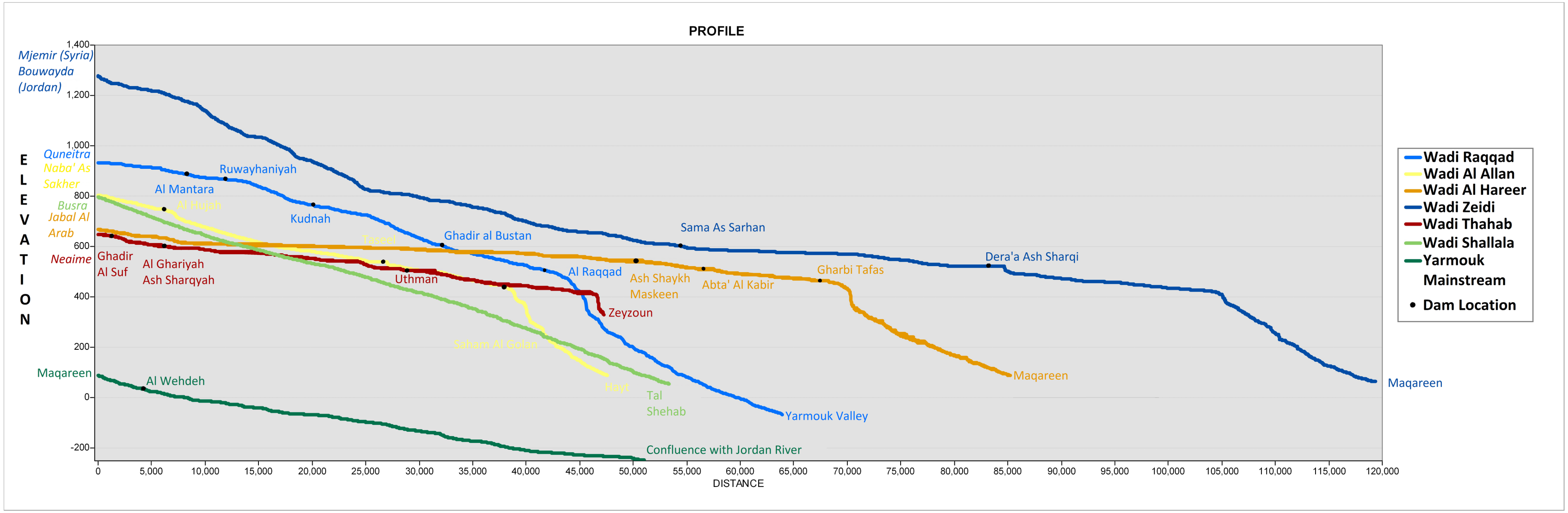


Figure 3.3 Longitudinal profiles of the tributaries of the Yarmouk, with locations of main dams, plotted against elevation in metres above sea level.

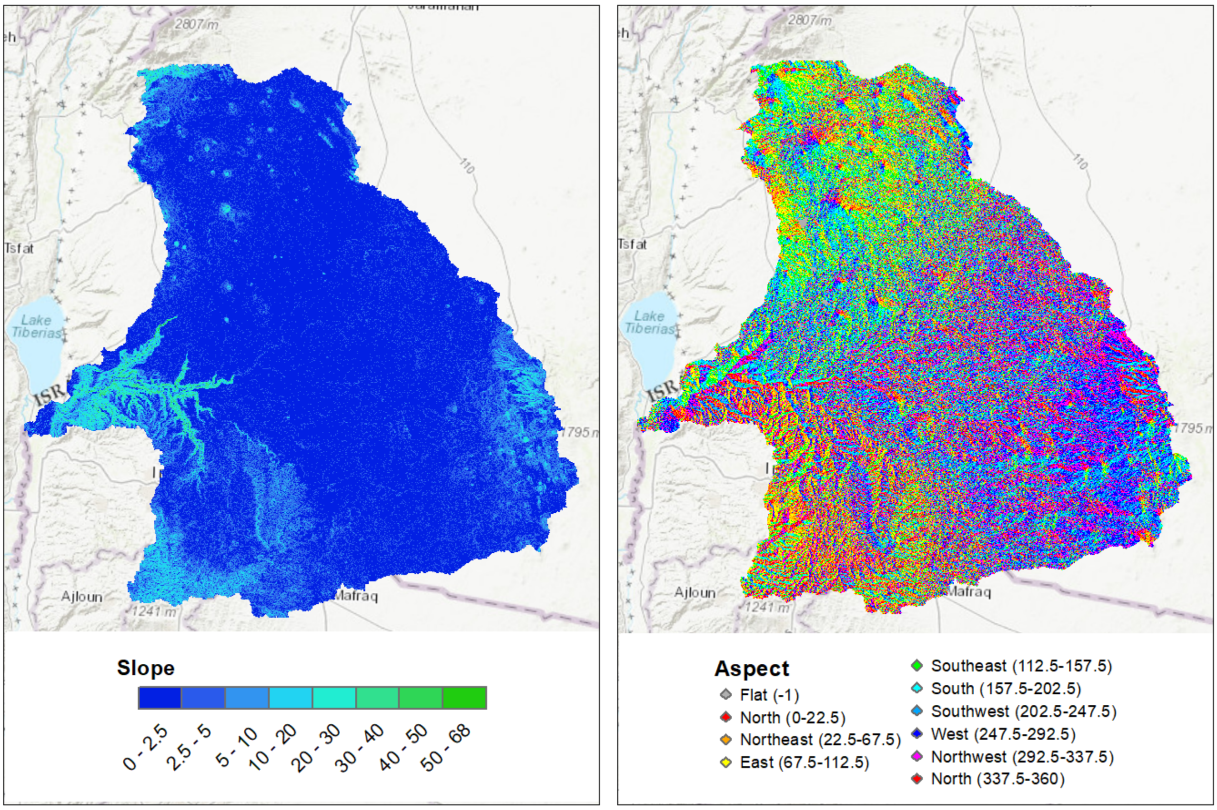


3.1.4 Physical and morphometric characteristics

Different morphometric characteristics of the Yarmouk tributary basin and its main sub-basins were extracted using Digital Elevation Models (DEM) established from the SRTM at 30 m resolution.

Overall, the slope of the Yarmouk tributary basin is rather gentle where large parts of the basalt outcrops form a plateau. Slopes become steeper in the mountainous areas near Al Quneitra in the north-west, Jabal al Arab in the south-east, the Jordanian mountains near Ajloun in the south, and in the Yarmouk Gorge near the confluence with the Jordan River, reaching up to 40% in the Yarmouk Gorge as a result of the Jordan Rift and the related Dead Sea Transform Fault. As shown in Figure 3.4, the basin is characterised by rolling hills. The slope aspect – which mainly affects snowmelt and evaporation rates – varies considerably throughout the basin. The land faces mainly south to south-east in the north-western part of the basin; west in the eastern part of the basin; and north-east in the south-western part of the basin. Flat areas are rare.

Figure 3.4 Slope (left) and slope aspect (right) of the Yarmouk tributary basin. Source: Authors, based on multiple sources listed in the text.



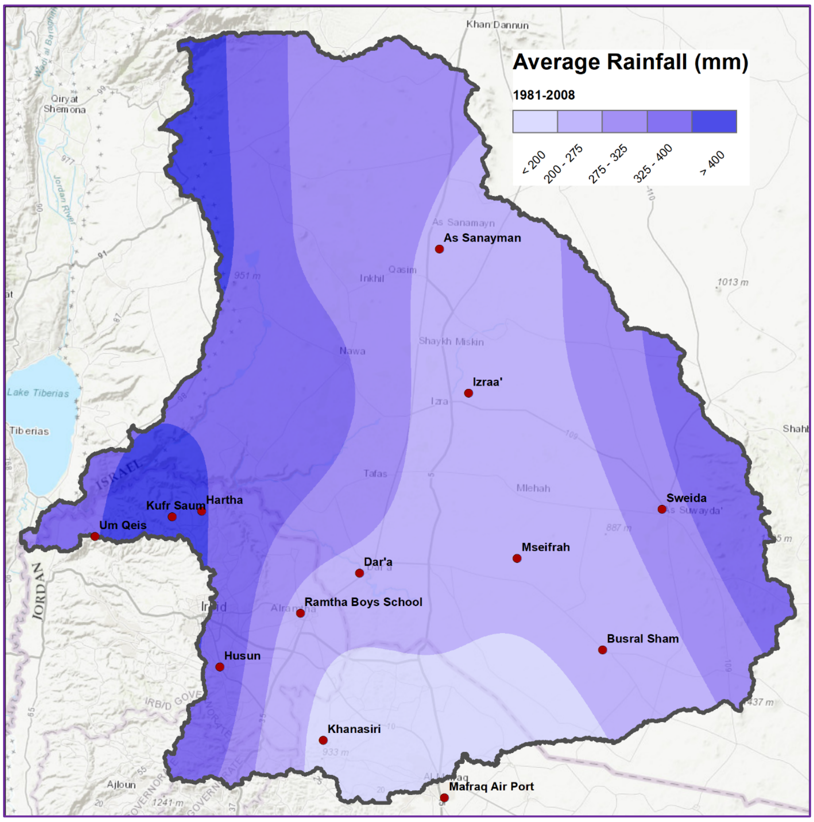
3.1.5 Climate (rainfall, drought, surface temperature)

The climate in the Yarmouk tributary basin is Mediterranean, with cold and relatively wet winters from November to April and dry and warm summers. As throughout much of the Middle East, precipitation in the Yarmouk tributary basin is characterised by a strong annual variability. More detail of different climatic characteristics such as albedo, Normalized Difference Vegetation Index (NDVI), Evaporative Fraction (EF), Evapotranspiration (ET), etc. are provided in Annex B9 (Figures B 9.1 to B 9.7).

3.1.5.1 Rainfall

The literature shows that the average precipitation in the Yarmouk tributary basin is around 350 mm/y (Ionides 1939, Burdon 1954, Baker*, et al.* 1955, Energoprojekt 1964, Mourad*, et al.* 2011, Orient 2011, Hoff n.d.). Precipitation ranges between 200 mm/y in the Hauran Plain to roughly 500 mm/y in Jabal al Arab/Druze and the Occupied Syrian Golan Heights (Makke-Traboulsi 2013, UN-ESCWA/BGR 2013), reaching its maximum in the area of Al Quneitra at approximately 775 mm/y (Husein 2012). However, understanding the effect of climate and precipitation on water availability requires extensive analysis. The long-term rainfall patterns presented in Figure 3.5 have been generated by coupling data available from remote sensing (CHIRPS) and ground-gauging stations between 1981 (the start of CHIRPS data) and 2008 (the latest available reliable ground station measurements) (see Annex B2). Based on this coarse analysis, the average rainfall between 1981 and 2008 was about 275 mm/y (2016.51 MCM/y), with a minimum of approximately 150 mm/y at Mafraq Airport and a maximum of approximately 430 mm/y in Kufr Saum in the Yarmouk Gorge.

Figure 3.5 Indication of average rainfall in the Yarmouk tributary basin (1981-2008). *Source*: Authors based on CHIRPS analysis and ground-gauging stations for which reliable data were found.



3.1.5.2 Temperature

The maximum Land Surface Temperature (LST) was derived from the thermal bands in Landsat 5 and 8 satellite images (Annex B 2.1). The analysis shows that *maximum* near-surface temperatures increased by 4.5°C across the Yarmouk tributary basin between the periods 1985-1987 and 2014-2016 (Table 3.1 and Figure 3.6).

Table 3.1 Average maximum Land Surface Temperature in the Yarmouk tributary basin (°C). *Source*: authors, based on images from Landsat 5 and 8.

Area	1985-1987	2014-2016	Difference (2010s-1980s)
Yarmouk tributary basin	28	33	5
Syrian portion	28	33	5
Jordanian portion	28	31	3

3.1.5.3 Droughts

The Yarmouk tributary basin has experienced several drought periods since records have been kept (Abou Zakhem*, et al.* 2010, Abou Zakhem*, et al.* 2015, Rajsekhar*, et al.* 2017). Global circulation simulations project that the Yarmouk is to experience a further decrease in precipitation, coupled with an increase in temperature (Quba'a 2017, Rajsekhar*, et al.* 2017, RICCAR 2017). Cyclical variations in precipitation in the last few decades are well represented in the literature (Margane*, et al.* 1995c, Orient 2011, De Châtel 2014).

Using the Standardized Precipitation Index (SPI), the short-term agricultural (three months) and long-term meteorological (12 months) droughts were studied for 21 stations in Syria, from 1958 to 2010 (Figures B 2.2 and B 2.3). As Figure 3.7 shows, major periods of drought were 1960/61, 1999/01, and 2007/08, while the years 1973, 1979, 1989, 2004 and 2010 are classified as dry. The year 1992 is the only one classified as wet, both on the short and long term. Most of these findings conform with the recorded droughts in literature. (See Annex B2 for methodology and results of the drought classification.)

Figure 3.6 Land Surface Temperature in the Yarmouk tributary basin for select years. *Source*: Authors, based on multiple sources listed in the text.

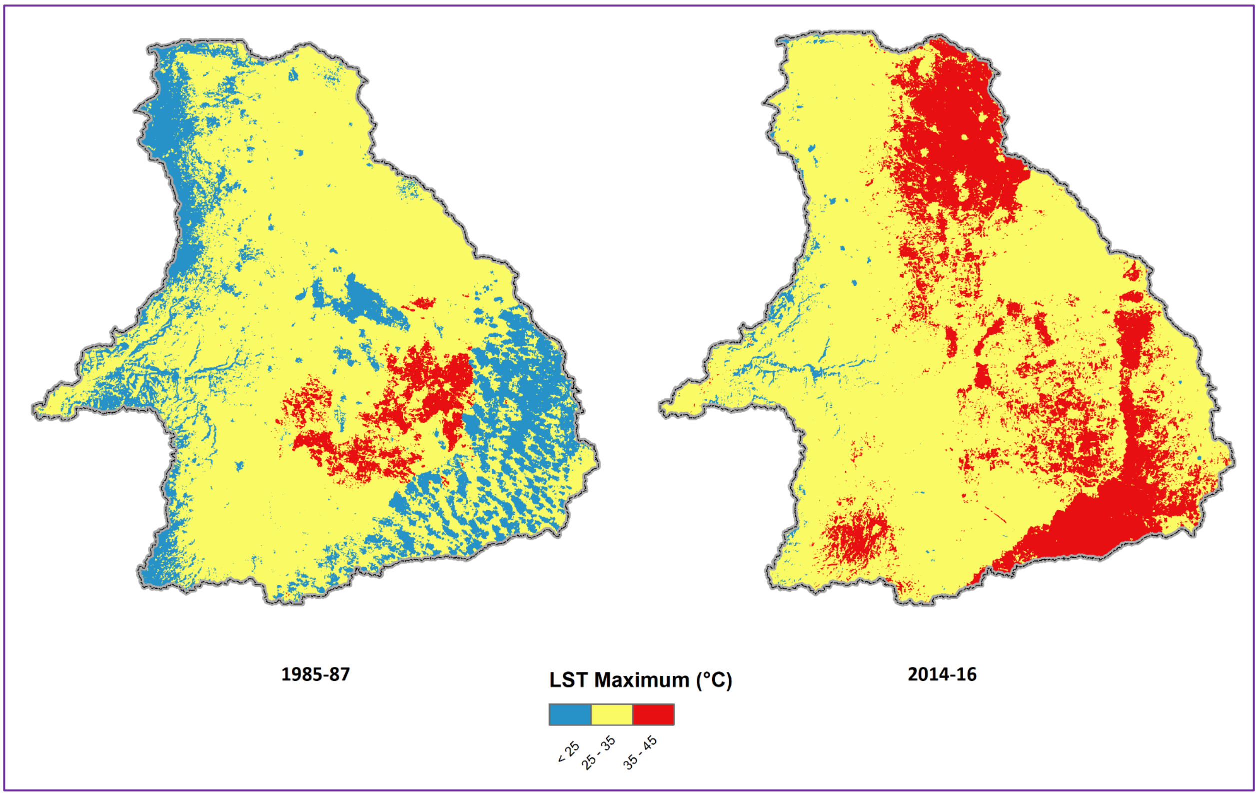
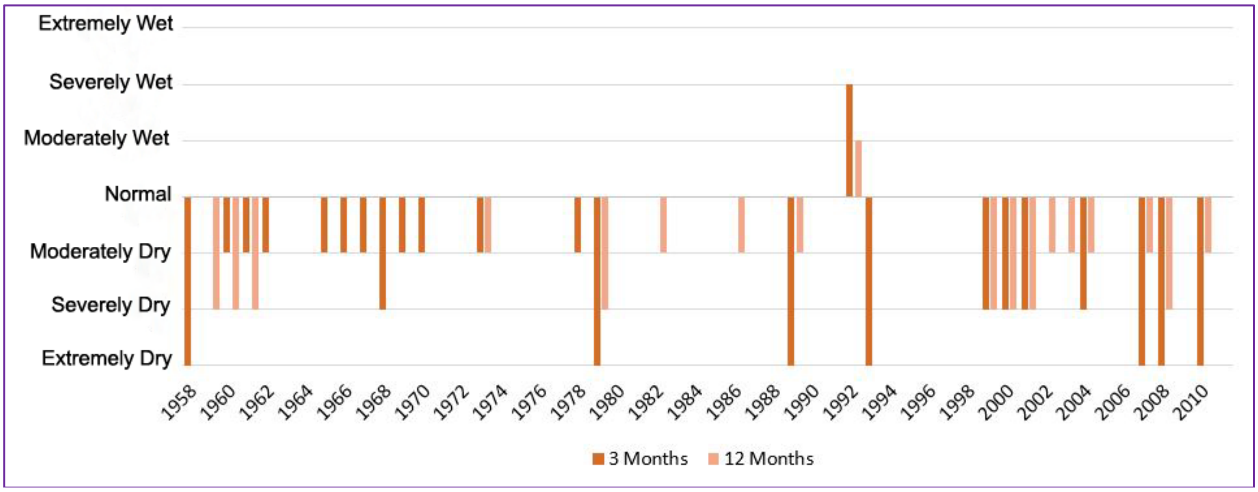


Figure 3.7 Drought periods in the Yarmouk tributary basin, based on Standardized Precipitation Index (1958-2010). Source: Authors, based on multiple sources listed in the text.



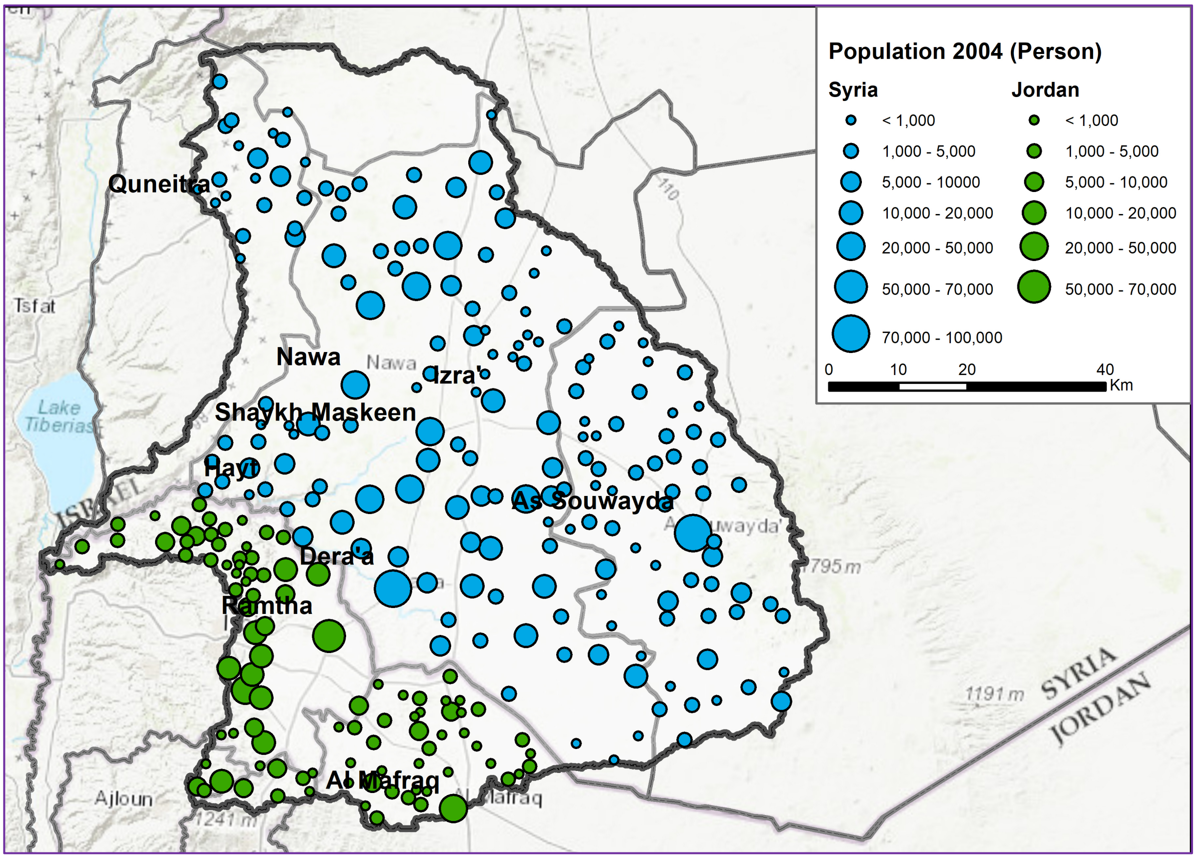
3.1.6 Population

According to UN-ESCWA/BGR (2013), the number of people living within the Yarmouk tributary basin prior to the Syrian crisis was around 1.6 million, distributed as shown in Figure 3.8. Prior to the 2011 Syrian crisis, approximately 850,000 people lived in Dera'a Governorate, 450,000 in Al Suweida Governorate, 300,000 in Al Queneitra Governorate and 'a small number' in the part of the basin that lies in Golan Governorate (Al Qusaym 2016). Roughly three quarters of the population lives in rural areas and one quarter in urban areas (Tawil (pers. comm.) 2017). The population in the Yarmouk Governorates has increased sharply over recent decades (Figure B 9.2), rising from 170,887 inhabitants in 1960 (according to a census in '*Atlas Syrie Gildas*') to 1,040,352 inhabitants in 2004 (CBS 2016). This growth is partly due to efforts by the

Government of Syria to develop agriculture in the Hauran Plain. The basin's population has shifted dramatically from the start of the crisis in 2011, driving approximately 370,000 people out of the Syrian part of the Yarmouk tributary basin (Muller*, et al.* 2016) and displacing millions across the country. Approximate figures from March 2014 estimate 401,400 people were displaced from Dera'a, 66,600 from Al Suweida and 51,300 from Al Quneitra (MOLA 2014a, MoLA 2014b).[3]

The population within the Jordanian part of the basin has also risen sharply, from 467,990 in 2004 (2004 Census) to roughly one million in 2015 (2015 Census) (Figure B 9.3). The rapid increase is to a large degree explained by the recent influx of people from Syria, many of whom are currently residing in the governorates of Mafraq (roughly 70,000 – Figure B 9.4) and Irbid (roughly 130,000 – Figure B 9.5) (UNHCR 2017).

Figure 3.8 Population in Yarmouk tributary basin (2004). *Source*: Authors based on Central Bureau of Statistics – Syria, Atlas of Jordan data and Atlas Syrie Gildas.



3.2 Surface water

3.2.1 A note on the poor quality of the data

Assessment of the availability of water resources in the Yarmouk tributary basin is made difficult by the very ambiguous and highly contradictory figures in the literature. An overview of the flow figures is provided in the following section, while a non-exhaustive list of the flows from available literature is found in Table B 3.1. Much of the discrepancy is explained by the fact that the figures relate to different locations along the river, whereas flows gauged upstream at Dera'a or Maqaren

[3] Not including the large-scale displacement that started in June 2018.

would be expected to be lower than flows gauged downstream, at Adassiyeh. The discrepancy is further explained by the unclear communication of the method used in different references to calculate, measure or estimate the flow.

Another source of the discrepancies in flow rates is related to the lack of separation between the *flood flow*, which is the part of the runoff originating from direct surface flow during the rainy season, and the *baseflow*, which is the contribution from the saturation zones, originating from groundwater and flowing throughout the year from springs (Hobler*, et al.* 2001, Orient 2011). The distinction between flood flow and baseflow was maintained in data provided by the Jordan Valley Authority (JVA); data published by the Hydrological Service of Israel (HSI) does not make this distinction.

3.2.2 Yarmouk flows found in the literature

Though the flows of the Yarmouk tributary are subject to significant inter- and intra-annual variability, early studies converged on an average flow (at Adassiyeh) of approximately 450 – 480 MCM/y (Ionides 1939, Burdon 1954, Burdon*, et al.* 1954, Baker*, et al.* 1955, Energoprojekt 1964), while flood flow alone was estimated at 226 MCM/y (Ionides 1939). Studies from the 1990s estimated the flow of the Yarmouk tributary basin to the Jordan at around 400 MCM/y (Ayeb 1993, Ayeb 1998). Recent studies estimate the surface water average at 90-180 MCM/y in Syria alone (Agha*, et al.* 2005, Kout 2008, Tawil (pers. comm.) 2017); and between 200-260 MCM/y when including both Syria and Jordan (Hadadin 2015, Alhusban 2016).

The mean annual flow at Adassiyeh gauging station was reported to be 264 MCM/y between 1971 and 1995 and 145 MCM/y between 1996 and 2008 (Orient 2011). The river flow has thus dropped between 45% and 70% from the 'pre-development' period (1928-1962) and the period during which water use was heavily developed (1971-2008) (Figure 3.12).

The literature asserts that the average annual flow is even lower from 2008 to 2015 following construction of the Wehdeh Dam: about 79 MCM. As discussed in greater detail in Section 6, the reduction can be attributed to both the intensification of agriculture irrigated from groundwater and surface water (particularly within Syria on the Hauran Plain, within Jordan in the Jordan River Valley, and (to a lesser extent) within Israel in the 'Yarmouk Triangle' area) and to the increase of drought attributed to climate change (Farber*, et al.* 2004, Rosenberg 2006, FAO 2008, Al-Hmoud 2012, UN-ESCWA/BGR 2013, Muller*, et al.* 2016).

3.2.3 Yarmouk flows based on gauging stations

The locations of river gauging stations are shown in Figure 3.9. Data for stations monitored by Jordan were acquired from the JVA; data for stations monitored by Israel were acquired from the HSI. Data for stations monitored by Syria are not publicly available, but the data here have been confirmed through confidential personal communication with knowledgeable experts.

The only available data on flow in sub-basins from Syrian gauging stations on wadis goes back to winter (February and March) 2002/03 and was found to be 330 MCM (Tawil (pers. comm.) 2017). The bulk of the flow came from Wadi Hareer (112 MCM) – due to its large collection area and rainfall over Jabal al Druze/Arab – and Wadi Raqqad (109 MCM) – due to rainfall over the Golan and the slopes of Jabal al Sheikh. Wadi Thahab contributed least to the flow (21 MCM), while Wadi Al 'Allan and the Syrian part of Wadi Zeidi had almost equal contributions (48 and 40 MCM, respectively).

The flow data and information about the gauging stations in the Jordanian part of the

Yarmouk are given in Table 3.2 and Figure B 3.1, while the long-term average of the flow at Adassiyeh station and intra-annual variations is presented in Figures 3.10 to 3.12. As detailed in Table B 3.1, the flow at Adassiyeh station decreased by 83%, from approximately 229 MCM/y (1979-1988) to 40 MCM/y (2008-2015), while the flow at Maqaren station decreased by 74% from 231 MCM/y (1979-1988) to 60 MCM/y (1999-2007).

Figure 3.9 River flow gauges of the Yarmouk tributary basin. *Source*: Authors, based on multiple sources listed in the text.

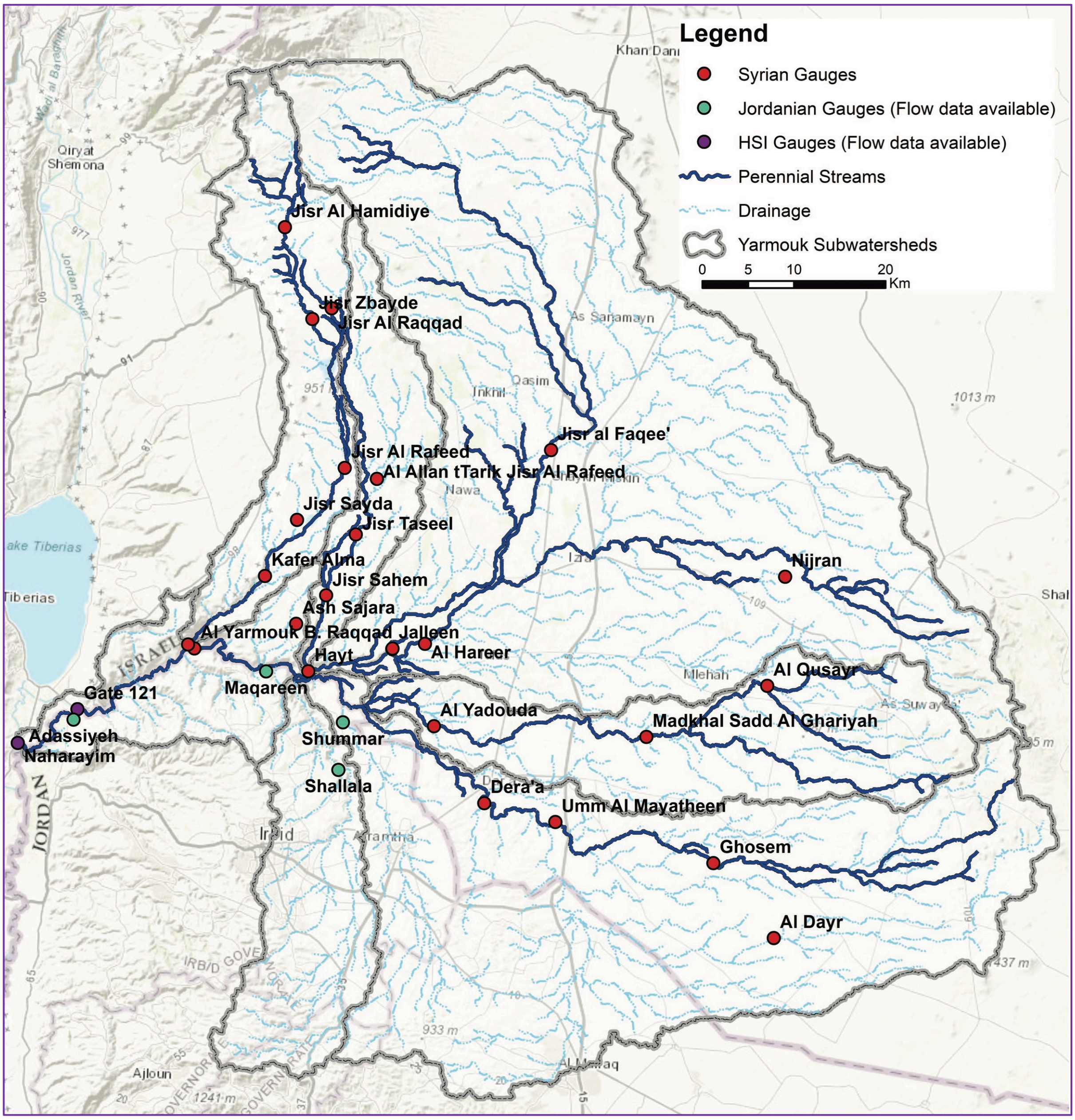


Table 3.2 Flow in stations monitored by JVA (Jordan) in MCM/y. The wet years 1992 and 2003 have been excluded from the long-term average.

Station Name	Period	Average (MCM/y)	Baseflow (MCM/y)	Flood flow (MCM/y)	Location	Catchment monitored
Maqaren	1979 – 2007	144	119	26	Before the Wehdeh Dam	From Syria to Jordan
Adassiyeh	1979 – 2015	136	86	50	At the Jordanian border	From Yarmouk (including Jordanian part)
Shallala	1999 – 2016	0.4	0.1	0.3	In Wadi Shallala, before its confluence with the Yarmouk main stream	From Wadi Shallala
Shummar	2001 – 2015	0.4	0	0.4	Before the confluence of the Jordanian part of Wadi Zeidi with the Yarmouk main stream	Jordanian part of Wadi Zeidi

Figure 3.10 Flood and baseflow trends of the Yarmouk gauged at Adassiyeh, according to *daily* reporting by JVA from 1979 to 2015. Detailed daily flow data are unavailable for years 2002-2004 and 2016. *Source*: as noted in text.

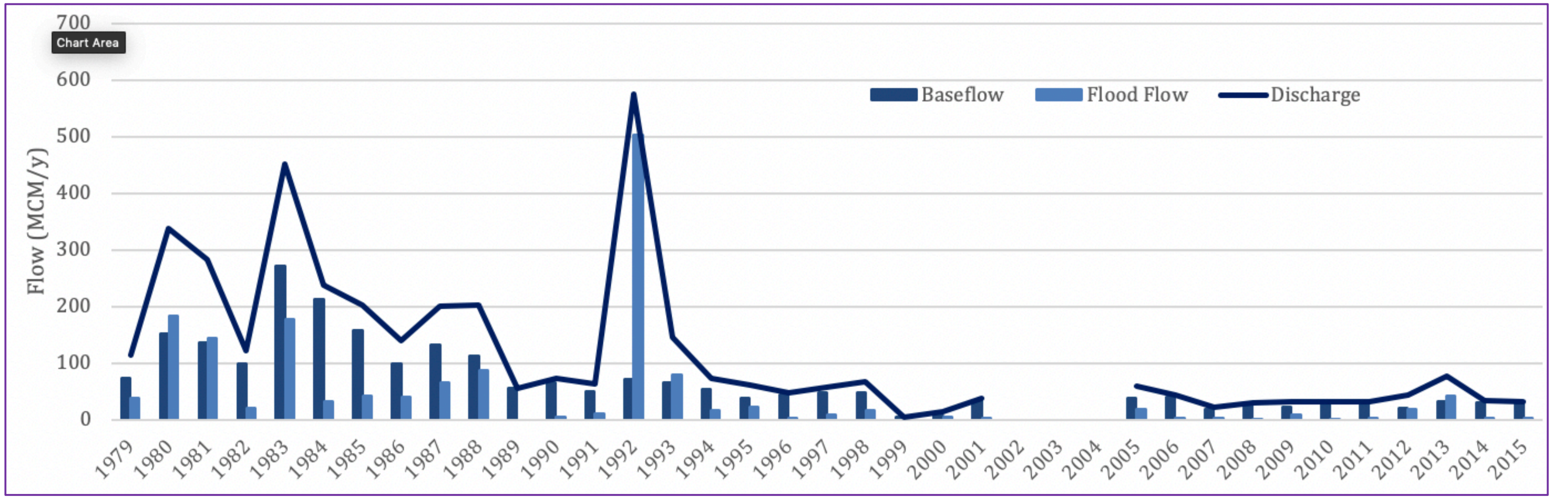


Figure 3.11 Intra-annual flow variation of the Yarmouk gauged at Adassiyeh, showing high *seasonal variability*, according to daily reporting by JVA from 1979 to 2015, including gaps. *Source*: as noted in text.

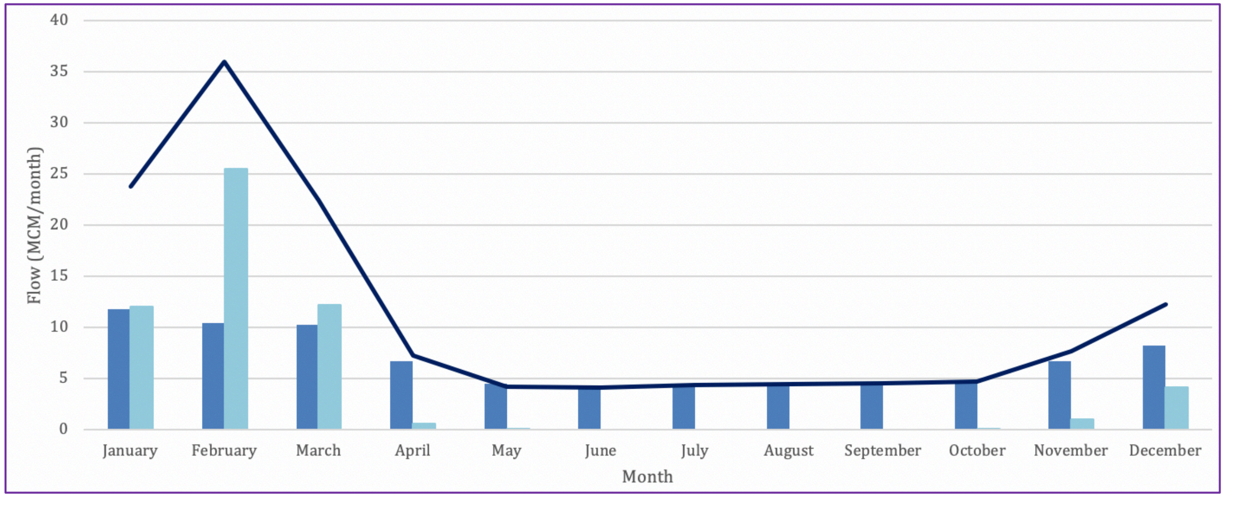
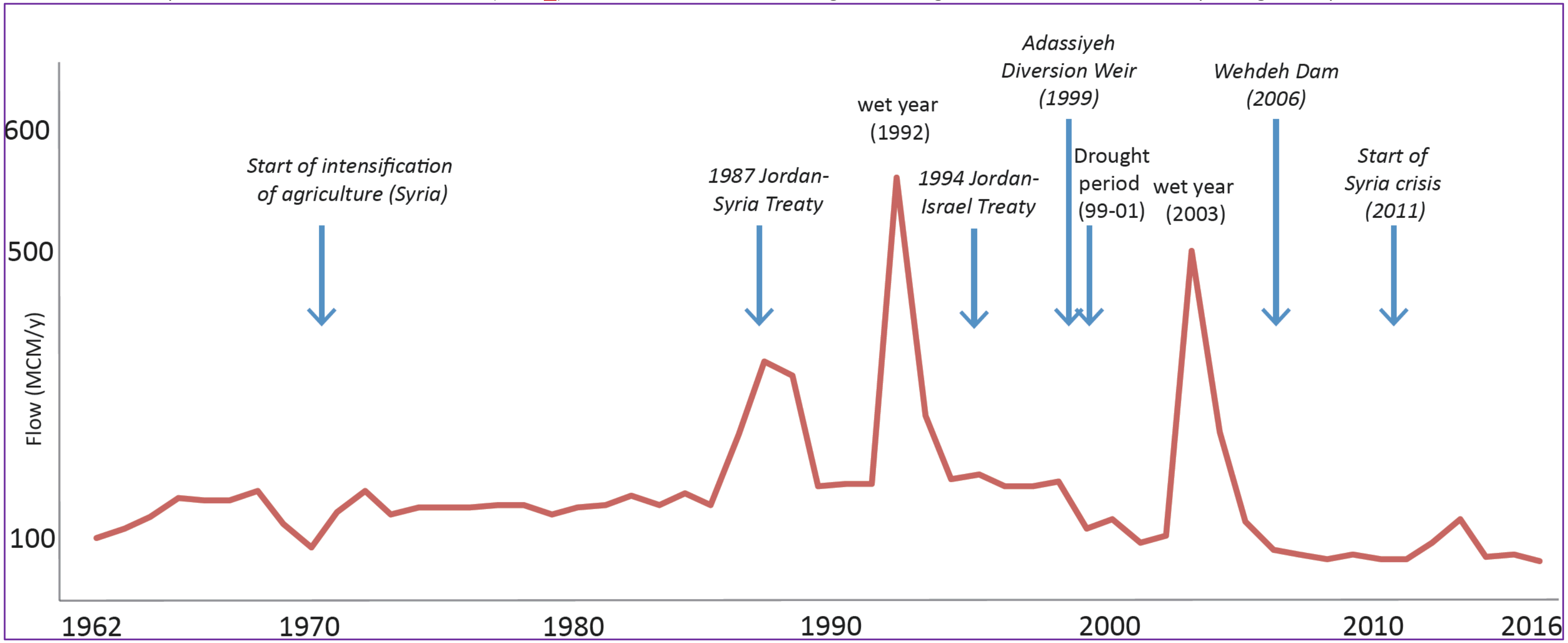


Figure 3.12 Total flow of the Yarmouk measured at Adassiyeh, according to yearly reporting by JVA from 1962 to 2016, indicating major climatic and political events. Includes what the dataset labels as 'Alpha' and 'Beta' flows. *Source*: JVA (2016b). Differences between this figure and Figure 3.9 are attributed to reporting discrepancies.



3.2.4 Flows into the Wehdeh Dam

The data provided by the JVA for the Maqaren gauging station are interrupted in 2007, though the inflow and outflow of the Wehdeh Dam (completed in 2006 near Maqaren) is provided as proxy. Releases from the Wehdeh Dam (by the Government of Jordan, to be diverted to the KAC or carried on downstream) have been steadily increasing (Figure 3.13), though the inflow continues to vary considerably. The mean inflow to the Wehdeh Dam from 2008 to October 2016 was 32.5 MCM/y, while the mean outflow was 35 MCM/y. Though variable, the inflow can be observed to be rising on average after 2011. Muller et al. (2016) attribute this to reduced agricultural activity in Syria. Data from the HSI for 'Gate 121' and at Naharayim/Al Baqura (Table 3.3) do not differentiate between baseflow and flood flow. The data show great variability and a steady downward trend at both stations, with an average of 147 MCM/y (from 1978 to 1999) at Naharayim/Al Baqura and 77 MCM/y (from 1990 to 2010) at Gate 121 (Figure B 3.2).

Figure 3.13 Inflow and outflow of the Wehdeh Dam between 2008 and 2016. Compare with flows stored in the Wehdeh Dam (Figure 4.8). *Source*: JVA (2016a).

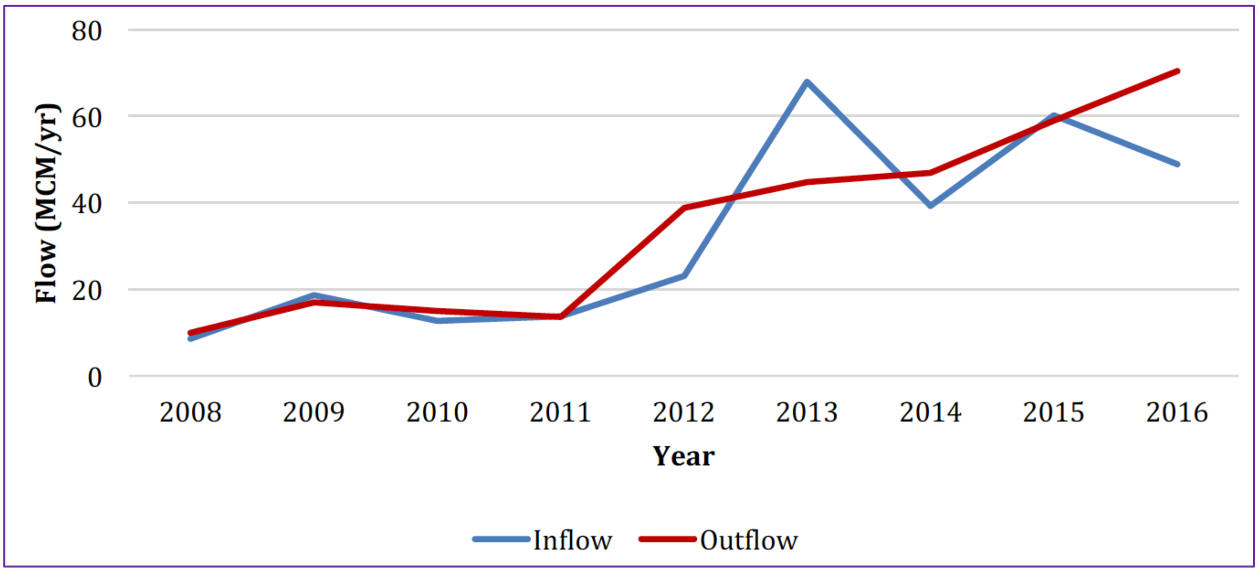


Table 3.3 Flow in stations monitored by HSI (Israel) (not including wet year of 1992).

Station Name	Source	Time	Long-term average (MCM/y)	Location	Catchment
Gate 121	HSI	1990 – 2010	77	Downstream of the confluence of the Raqqad with the Yarmouk mainstream	Monitors Wadi Raqqad flow, just before it enters the Yarmouk mainstream
Naharayim/Al Baqura	HSI	1978 – 1999	147	At the confluence with Jordan River	Monitors the input from the Yarmouk to Jordan River

3.3 Groundwater and aquifers

3.3.1 A note on geological names

There is a significant difference between Syrian and Jordanian research undertaken on the geology of the Yarmouk tributary basin. Syrian studies employ the divisions of the chronostratigraphic chart for the names, while Jordanian studies use the system of formations. Therefore, a lithostratigraphic correlation between the names was required (Table B 4.1). Figure 3.14 summarises the hydrogeological structures and interactions in the Yarmouk tributary basin. Figure 3.15 provides a rough approximation of the geology and general direction of groundwater flow (compiled from Ponikarov*, et al.* 1964, Hobler*, et al.* 2001, Orient 2011, UN-ESCWA/BGR 2013, Margane 2015).

3.3.2 Basic geological and groundwater characteristics, including springs

As shown in Figure 3.14, the Yarmouk tributary basin overlies three major aquifer systems which are sometimes formed by more than one aquifer and separated by aquitards. From top to bottom we can distinguish the Upper Aquifer System, the Middle Aquifer System, separated by an aquitard, and the Deep Aquifer System.

The groundwater and surface water are closely interlinked, as are the different aquifers (Orient 2011, UN-ESCWA/BGR 2013). The aquifers in the Yarmouk tributary basin recharge mainly from precipitation in the outcropped areas inside and outside the basin boundaries, but there is also indirect recharge from the flow of the wadis[4] and exchange of groundwater between aquifers. The groundwater in the Shallow Basalt Aquifer (that which is most commonly tapped into within Syria) is usually 'young' (less than 10,000 years old) (see Annex B 4.2), especially in outcropped parts of the aquifers, though the water in confined areas is older.

Groundwater flows in the Shallow Basalt Aquifer from the Jabal al Arab area towards the west and south-west to the main discharge area in Muzeirib and the Yarmouk tributary. In the A7/B2 – Cr_2cn cp/Cr_2m-d Limestone Aquifer, groundwater flows southwards from the recharge areas in Jabal al Sheikh in Syria under the basalt, and northwards in Jordan, towards its main discharge area at the Yarmouk Gorge and the Jordan-Syrian border. These flows form the baseflow of the Yarmouk tributary (Figure

[4] This occurs where the streams infiltrate the rocks to join the groundwater. The literature considers the magnitude of these flows as insignificant.

3.10) and are all considered ‘transboundary’ in the sense that they cross the international border.

Figure 3.14 Hydrogeological column of Yarmouk tributary basin with aquifers and aquitards. The partial aquitard between the Upper and Middle Aquifer Systems is shown in orange. Lateral inflows are not accounted for. *Source*: Authors, based on multiple sources listed in the text.

System	Formation	Code	Age	Lithology	Type
Upper Aquifer	Basalt		Neogene - Quaternary	basalt	Aquifer
Upper Aquifer	Um Rijam/Wadi Shallala	B4/B5 – Pg_2^2 /Pg_2^3	Eocene	limestone, marl	Aquifer
	Muwaqqar	B3 – Pg_1-Pg_2^1	Paleocene	marl, chalky limestone	Aquitard
Middle Aquifer	Wadi As Sir/ Amman - Al Hissa	A7/B2 – Cr_2cn cp/Cr_2m-d	Coniacian - Maastrichtian	chalky, dolomitic limestone	Aquifer
Middle Aquifer	Naur / Shueib	A1/A6 – Cr_2cm-t	Cenomanian – Coniacian	Marl, Chalky Limestone	Alternation
Deep Aquifer	Kurnub	K – Cr_1-Cr_2 t	Lower Cretaceous	Sandstone	Aquifer

Burdon (1954) identified a total number of 172 springs in the Yarmouk tributary basin. Gauged springs had an average discharge of 242 MCM/y, when taking into consideration the evaporation rate in the area, a figure that matches closely with the estimates of Ionides (1939), which was 254 MCM/y. After the start of intensive groundwater withdrawal for irrigation and domestic use in Syria (especially) and Jordan, the discharge of many springs decreased and some springs dried up completely (Margane, *et al.* 1996, Al-Husein 2007, Orient 2011, Etana 2015, Youmans 2016, Dar'a News 2017). Such overexploitation has probably affected the natural flow and discharge patterns of groundwater and may also have contributed to the hydrological decline of the Yarmouk mainstream (Margane 2015). The reliability of the data on spring discharge is quite low, however, due to the scarcity of measurements and the lack of accuracy in the surveying of the location/elevation of the springs (as noted by Margane et al. (1996).

3.3.2.1 Upper Aquifer System (The ‘Shallow Basalt Aquifer’ and B4/B5 - Pg22 /Pg23)

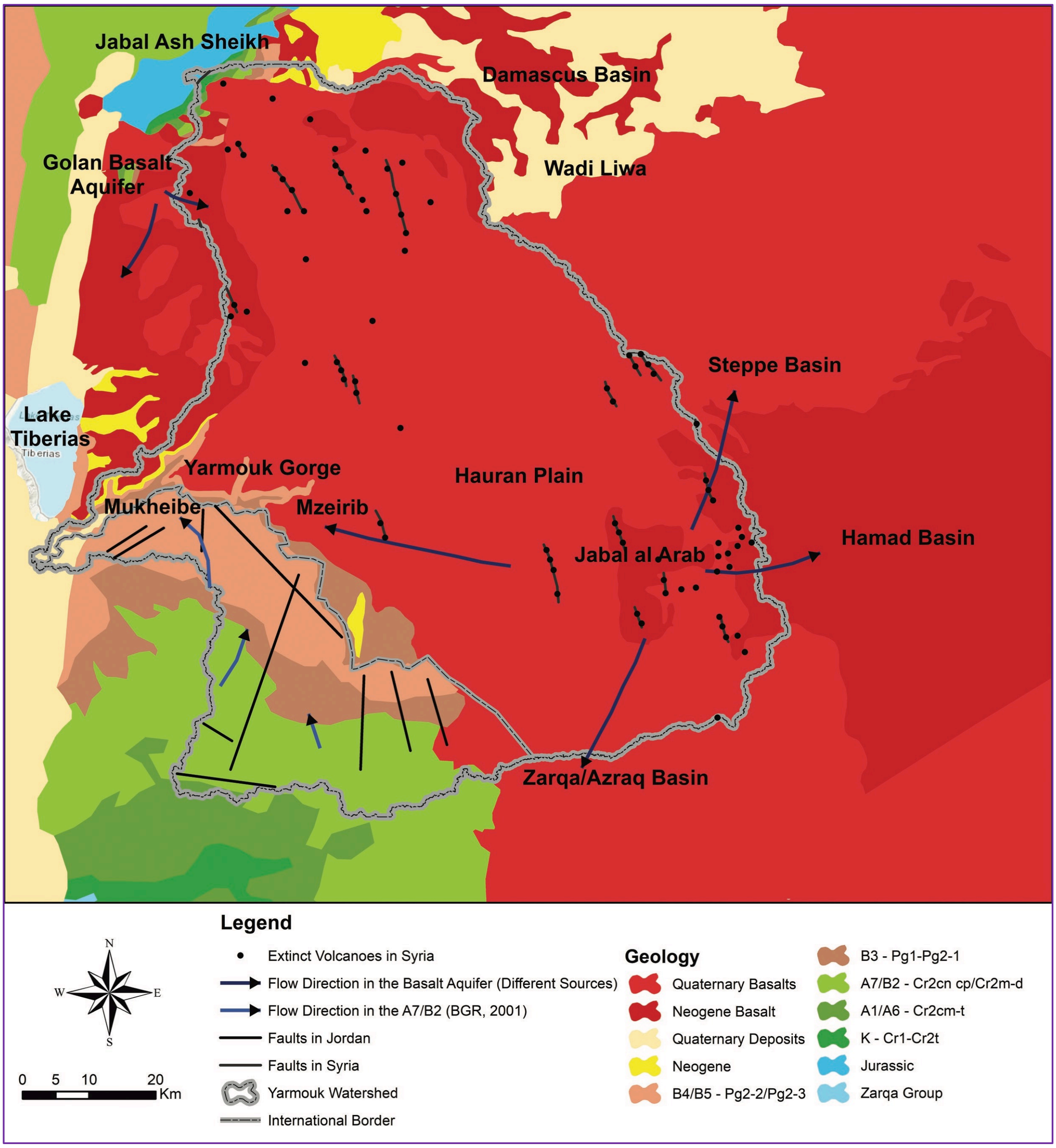
The Upper Aquifer System is formed by the Neogene-Quaternary Basalts and comprises two aquifers. The B4/B5 – Pg_2^2/Pg_2^3 Aquifer is composed of chalky limestones, while the Shallow Basalt Aquifer is exploited primarily in the Syrian part of the Yarmouk tributary basin. As shown in Figure 3.15, the basalts extend mainly over the Syrian part of the Yarmouk tributary basin and the Occupied Syrian Golan Heights, playing a major hydrogeological role in this region of Syria. They are aged from the Neogene (mainly Pliocene) to the Quaternary (Pleistocene). Their thickness varies from a minimum of around 50 m towards the Yarmouk Gorge to a maximum of 1,500 m in the Jabal al Arab area (Table B 9.14) (Bourgoin, *et al.* 1948, Burdon*, et al.* 1954, Wagner*, et al.* 1999, Hobler*, et al.* 2001, Dafny*, et al.* 2003, UN-ESCWA/BGR 2013).

The saturated thickness of the basalt ranges from less than 100 m on the fringes of the basalt field to 170-300 m in the region of Jabal al Arab (Figure B 9.9). The groundwater is located at shallow to intermediate depths above the water table of the main Basalt Aquifer in the western foothill zone of the Jabal al Arab Mountain range (groundwater level: 900-1,300 m ASL) and in the Hauran Plain (groundwater level: approx. 300 m ASL) (UN-ESCWA/BGR 2013, Tawil (pers. comm.) 2017).

The Basalt Aquifer System is generally unconfined, with a recharge rate estimated at 10% in Syria (Burdon 1954) and 12% for the basalts in the Golan (Dafny et al. (2003). The downward movement of groundwater from the Basalt Aquifer is absent in regions where the impermeable Paleogene marls exist. In other regions, however, the basalts form a combined aquifer with the underlying Upper Cretaceous Carbonate rocks, and leakage from the basalts to the underlying Cretaceous Aquifer is suspected (Burdon 1954, Burdon*, et al.* 1954, Wagner*, et al.* 1999, UN-ESCWA/BGR 2013).

As the cross-sections in Figure 3.16 show, recharge conditions can be found in the Jabal al Arab mountain range (east/north-east), the Wadi Liwa Basin and southern margins of the Damascus Plain (north), the Lejja Plain, the western part of the Hauran Plain, the foothills of Jabal al Sheikh, and the (north-west) Golan Heights. Indirect recharge from surface runoff occurs in different valleys from Jabal al Arab flows over the Hauran Plain to the main discharge zones at Muzeirib and the Yarmouk mainstream (south-western direction). Jabal al Arab also feeds Wadi Zarqa and the Azraq area in the south, and the Steppe Basin in the Hamad area in the east and north-east. The Yarmouk mainstream is further fed by groundwater from the Golan Basalt Aquifer that otherwise mainly feeds the Lake of Tiberias (Figure 3.15).

Figure 3.15 Geology of the Yarmouk tributary basin, with general flow direction of groundwater in the main aquifers. *Source*: Authors based on Hobler et al., 2001; Margane, 2015; Orient, 2011; Ponikarov and Mikhailov, 1964; UN-ESCWA/BGR, 2013.



Springs from the Basalt Aquifer have considerable discharge, estimated at 170-177 MCM/y before the start of intensive groundwater development. However, natural groundwater flow has been affected by agricultural development and the extensive drilling of wells in the Syrian part of the Yarmouk tributary basin. As a result, the discharge of many springs has dropped, or stopped completely (Burdon*, et al.* 1954, Wagner*, et al.* 1999, Dafny*, et al.* 2003, UN-ESCWA/BGR 2013, Youmans 2016). Intensive groundwater use has led to the deepening of wells in the Basalt Aquifer, for instance at Da'el where the depth of local wells has gone from 60-100 m to 100-160 m, in Tafas (from 60 m to 100 m), and in Muzeirib (from 40 m to 90 m) (Al Qusaym 2016).

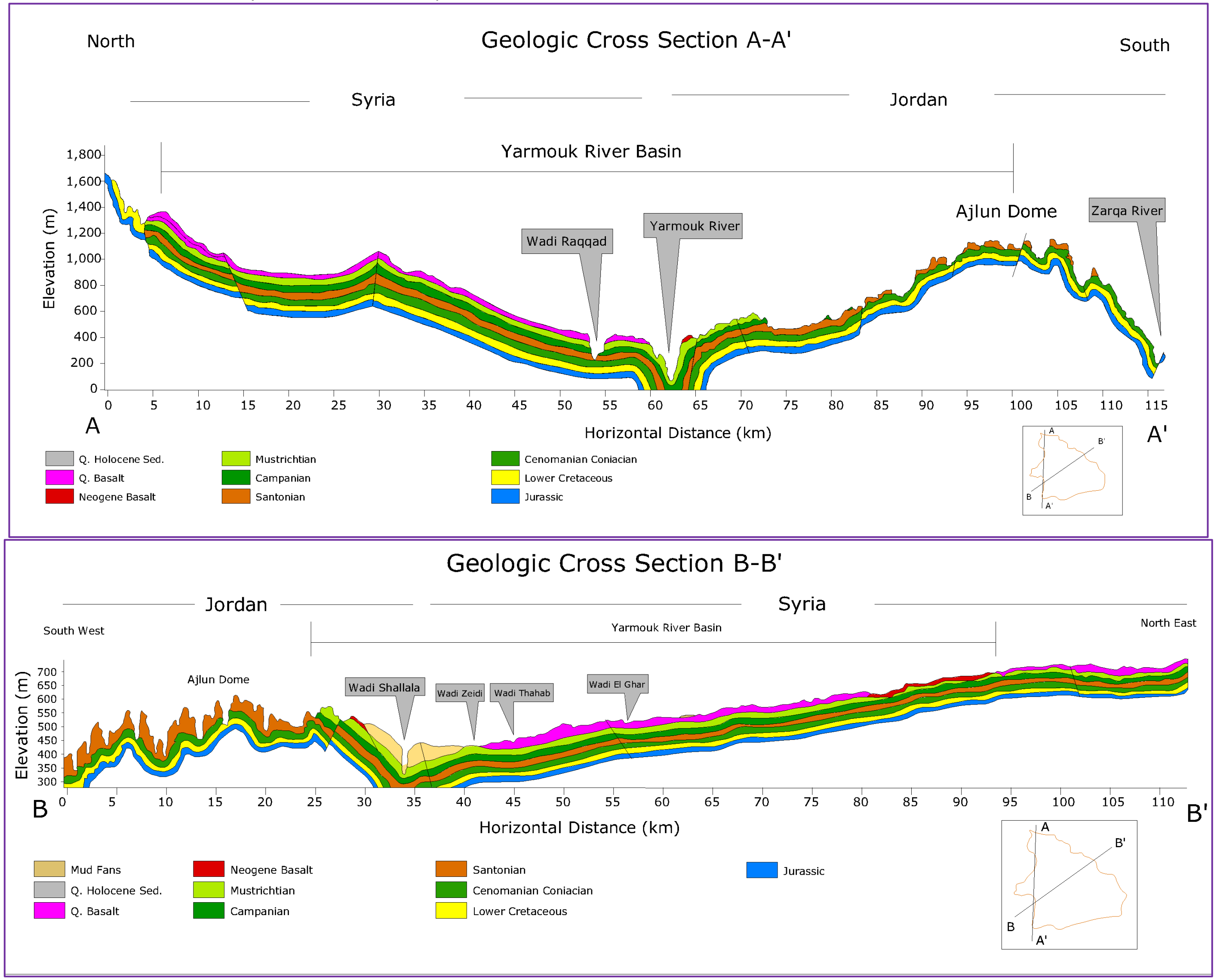
The B4/B5 - Pg_2^2/Pg_2^3 Aquifer (referred to as Umm Rijam/Wadi Shallala in Jordan – Nummulitic in Syria) is of Eocene age. It is formed mainly of Nummulitic Limestone, chalky limestone, marls, clays, with a lot of facies change. In Jordan, the transition from the B4 to the B5 layer is marked by the decrease in chert and appearance of marls (Burdon 1954, Burdon*, et al.* 1954, Bender 1968, Hobler*, et al.* 1994, Hobler*, et al.* 2001, Bandel*, et al.* 2013, Youmans 2017). The thickness of the B4/B5 - Pg_2^2/Pg_2^3 Aquifer is variable: 100-700 m in Syria, and around 200-300 m in Jordan (the thickness is reduced due to erosion where it is exposed in the north of Irbid) (Burdon*, et al.* 1962, Moh'd 2000, Smadi 2000, Youmans 2016) (Table B 9.14).

The B4/B5 - Pg_2^2 /Pg_2^3 Aquifer is recharged from rainfall in outcropped areas (Irbid, Ramtha and areas in southern Syria) and by infiltration from the Basalt Aquifer. The water is randomly distributed and its levels align closely with the levels of groundwater in the Basalt Aquifer. Discharging in the Muzeirib areas and in wadis dipping towards the Yarmouk mainstream area, the aquifer is mainly exploited in the north Irbid area for local water supply and irrigation (Margane*, et al.* 1997, Swarieh*, et al.* 1998, Wagner*, et al.* 1999, Hobler*, et al.* 2001, Youmans 2017).

3.3.2.2 The B3 Aquitard (B3 - Pg_1-Pg_2^1)

Known as the Muwaqqar Chalk Marl Formation in Jordan, the B3 - Pg_1-Pg_2^1 Formation separates the Upper Aquifer System from the Middle Aquifer System. Dominated by impermeable chalk-marl, clays, some chalk and chalky limestones, it is of uncertain age (Annex B 4.3). Exposed in Syria near Dera'a and in the north of Jordan in the area of Maqaren and Mukheibeh in the Yarmouk Valley, the thickness of the aquitard differs considerably from one area to another (Table B 9.14). It can reach up to 500 m in the Yarmouk Valley (while being totally absent in other areas), leaving the basalt in direct contact with the Upper Cretaceous limestones and dolomites and thus influencing the location of groundwater in the Basalt Aquifer (Hobler*, et al.* 1994, Abu-Jaber*, et al.* 2008, Orient 2011, Bandel*, et al.* 2013, UN-ESCWA/BGR 2013). Nonetheless, the research literature does not agree on the age of the B3 - Pg_1-Pg_2^1 Aquitard.

Figure 3.16 Cross-sections of the Yarmouk tributary basin. *Source*: Adapted from Orient 2011.



3.3.2.3 The Middle Aquifer System: (A7/B2 - Cr_2cn cp / Cr_2m-d and A1/A6 - Cr_2cm-t)

The Middle Aquifer System is formed by the Coniacian-Maastrichtian limestones, known as the A7/B2 – Cr_2cn cp / Cr_2m-d Aquifer, that is mainly exploited in Jordan; and the Cenomanian-Turonian complex (A1/A6 – Cr_2cm-t) formed by a succession of aquifers and aquitards.

The A7/B2 - Cr_2cn cp / Cr_2m-d (Wadi as Sir/Amman-Al Hissa Aquifer in Jordan, and Senonian in Syria) is a moderately karstified aquifer formed of highly permeable massive limestones, marls and chalks outcropping in the Yarmouk area and underlying the entire north of Jordan. Its thickness is variable and ranges between 300 and 500 m in the Yarmouk area, and more in other areas (Table B 9.14), while the depth to groundwater is between 300 and 350 m (Burdon 1954, Burdon*, et al.* 1954, Burdon*, et al.* 1962, Hobler*, et al.* 1994, Heinz*, et al.* 1997, Hobler*, et al.* 2001, Abu-Jaber*, et al.* 2008, Awawdeh 2010, Obeidat*, et al.* 2012).

The A7/B2 - Cr_2cn cp / Cr_2m-d Aquifer is recharged from precipitation in the outcropped areas outside the basin: the Ajloun Dome[5] and Jabal al Sheikh. In the areas where the B3 – Pg_1-Pg_2^1 Aquitard is missing, the aquifer is also recharged from the Basalt Aquifer. Finally, the aquifer is recharged from the K - Cr_1-Cr_2 t Aquifer in the Yarmouk Valley, while a downward leakage exists in the Yarmouk tributary basin part in Jordan (Swarieh*, et al.* 1998, Hobler*, et al.* 2001, Orient 2011)(Figures 3.11 and 3.13). Several springs discharge from the A7/B2 - Cr_2cn cp / Cr_2m-d and partly from underlying aquifers in the Yarmouk, with an average discharge of 17 MCM/y between 1983/84 and 1992/93 (Hobler*, et al.* 2001).

The A7/B2 - Cr_2cn cp / Cr_2m-d Aquifer is exploited primarily in Jordan. Abstraction has sharply increased since the 1980s when many agricultural wells were drilled. This has resulted in a decline in water levels (Figure B 9.14 and Table B 9.15) – up to 60 m in the Jaber area of the Yarmouk tributary basin between 1995 and 2013, as well as the loss of about 15% of the total saturated area, and a related change in groundwater regime (Margane 2015).

The A1/A6 - Cr2cm-t complex is formed by the alternation of aquitards and aquifers (Table B 9.14), which separates the A7/B2 - Cr_2cn cp / Cr_2m-d Aquifer from the deeper Lower Cretaceous-Kurnub Aquifer. In Jordan, the aquifer is aged as Cenomanian-Coniacian and consists of marly limestone and dolomitic limestone, and has a thickness of between 190 and 530 m (Hobler*, et al.* 1994, Hobler*, et al.* 2001, Abu-Jaber*, et al.* 2008, Bandel*, et al.* 2013). After the water-level decline in the A7/B2 - Cr_2cn cp / Cr_2m-d in Jordan, some irrigation wells were deepened to the A4 and A1/2 Aquifers (Margane, 2015). In Syria, the Cenomanian-Turonian forms an important limestone aquifer with a thickness of 900-1,000 m in the south-west of Syria. It extends from Jabal al Sheikh to the Yarmouk Valley, framing and underlying the Plateau Basalts. However, it is not exploited within the Yarmouk tributary basin (Burdon*, et al.* 1954, Burdon*, et al.* 1962, Youmans 2016).

3.3.2.4 Deep Aquifer System (K - Cr1-Cr2 t)

Known in Jordan as the Kurnub Aquifer, the K - Cr_1-Cr_2 t is of Lower Cretaceous age, formed

[5] Recharge estimated at 25-30% (Hobler et al. 2001), from rates of spring discharge gauged prior to the start of heavy well abstraction.

mainly of sandstone, and varies in thickness from 120 to 350 m. It has thus far not been officially exploited in northern Jordan, primarily due to its depth and relatively high salinity levels (Hobler*, et al.* 2001). However, as with the A1/A6 complex, some farmers have deepened their irrigation wells and tapped into the aquifer, thereby risking contamination of the overlying aquifers (Margane 2015). In Syria, it is known as the Nubian Sandstone, or *Grès de base*, formed of sandstones overlain by the Aptian-Albian sandy marls and varying in thickness between 300 and 400 m. It is not considered an important aquifer (Burdon*, et al.* 1954, Abed 1982).

4 Estimates of water use (1966-2016)

This section describes basic water management and governance in the basin, and provides an initial approximation of water use throughout the basin over roughly the last half century. It combines available published and unpublished reports, studies, personal communication and satellite imagery analysis. Readers are referred to Annex A3 for further background on the related water institutions.

4.1 Land use and cover

4.1.1 Methodology

To estimate changes in water use, two Land Use Cover (LUC) maps were established. The first was based on the CORONA panchromatic satellite images[6] of 1966-1967. Six strips of 2-m resolution were mosaicked, orthorectified (using 935 Ground Control Point (GCP)) and clipped to the extent of the basin boundaries. The established map shown in Figure 4.1 revealed six main land use classes at a scale of 1: 20,000 (Figure B 9.15): bare land, crop, fruit trees, urban zones and water bodies.

The second LUC map (Figure 4.2) was built from ESRI base maps [7] of GEOEYE 2011 (50-cm resolution) at a scale of 1: 20,000, with 13 different classes (Figure B 9.16). The different classes of the LUC were realised through intensive visual interpretation of the satellite images over a period of five months by a team of four engineers, and spot-checked through field observation in Jordan with approximately 97% accuracy.

A variety of sources provided the best-available images used to identify shifts in practices at the basin level. These include Landsat 5 satellite images (for the years 1984, 1985, 1986), Landsat 8 satellite images (2014, 2015, 2016) of 30-m resolution, and SPOT 5 satellite images of 10-m resolution (2009). As four-monthly Landsat images (of 185 x 185 km) were required to cover the entire basin, the analysis was carried out on a total of 288 images throughout the year. Nine SPOT images were employed to allocate the different cultivated areas and calculate the crop water requirements, and a supervised classification along with NDVI and EVI indices was run on both SPOT 5 and Landsat images.

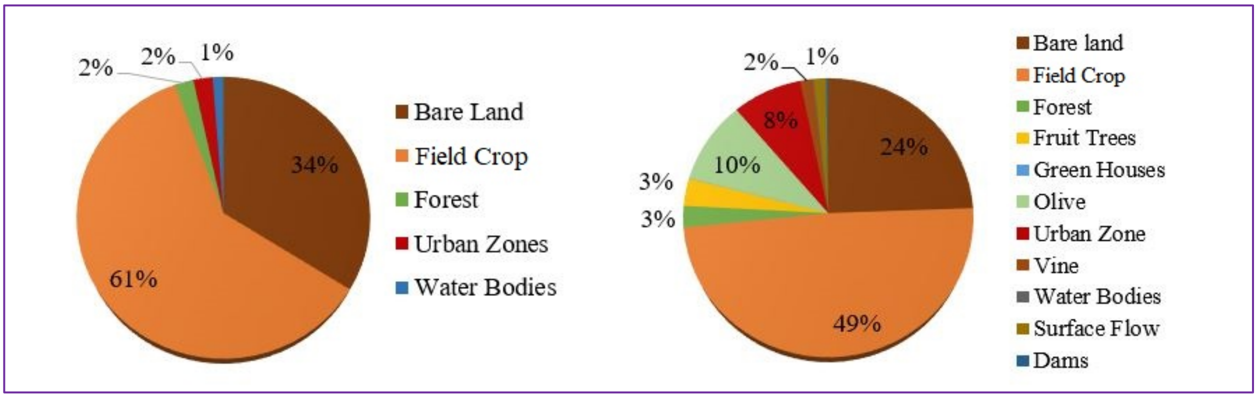
4.1.2 Changes in land use and cover

Within Syria, nearly three quarters of the land use in the basin is composed of field crop (54%) and bare land (22%) (Figure B 9.17-A). Land use is more distributed in Jordan (Figure B 9.17-B), with bare lands (35%) and crops (28%) still representing the biggest uses. The small portion (0.3%) of the basin that lies in Israel is primarily used for crops (33%) and fruit trees (28%) in the 'Yarmouk Triangle' (Figure B 9.17-C). Figures B9.18 and B9.19 show detailed LUC for each governorate in Syria and Jordan.

[6] The CORONA images were chosen because they had the earliest cloud-free images available. The CORONA was a US satellite originally used for spying, but for which all images are in the public domain.

[7] The ESRI 2011 base maps were chosen as they are the most recent high-resolution images in the public domain.

Figure 4.1 Land use in the Yarmouk tributary basin 1966 (*left*) and 2011 (*right*).



The study of the LUC maps for 1966 and 2011 shows the extent of the increase from bare lands and field crop to urban, forest and fruit trees. As Figure 4.1 shows, the Yarmouk tributary basin witnessed an urban expansion of almost 6% of the basin's total area between 1966 and 2011 (440 km^2), at the expense of field crops and bare lands. The major part of this increase occurred in the areas bordering existing urban zones. Field crops decreased by 10% (857 km^2) and bare lands by 9.5% (704 km^2) of the basin's total area. They were replaced by urban areas and permanent cultivation such as fruit trees, vines and olive-tree plantations. The increase in the number of water bodies in the basin is also notable, and is the result of the creation of small reservoirs to collect rain in the wet season and the building of dams of different sizes.

Figure 4.2 Land use and cover in the Yarmouk tributary basin (1966). *Source*: CORONA images.

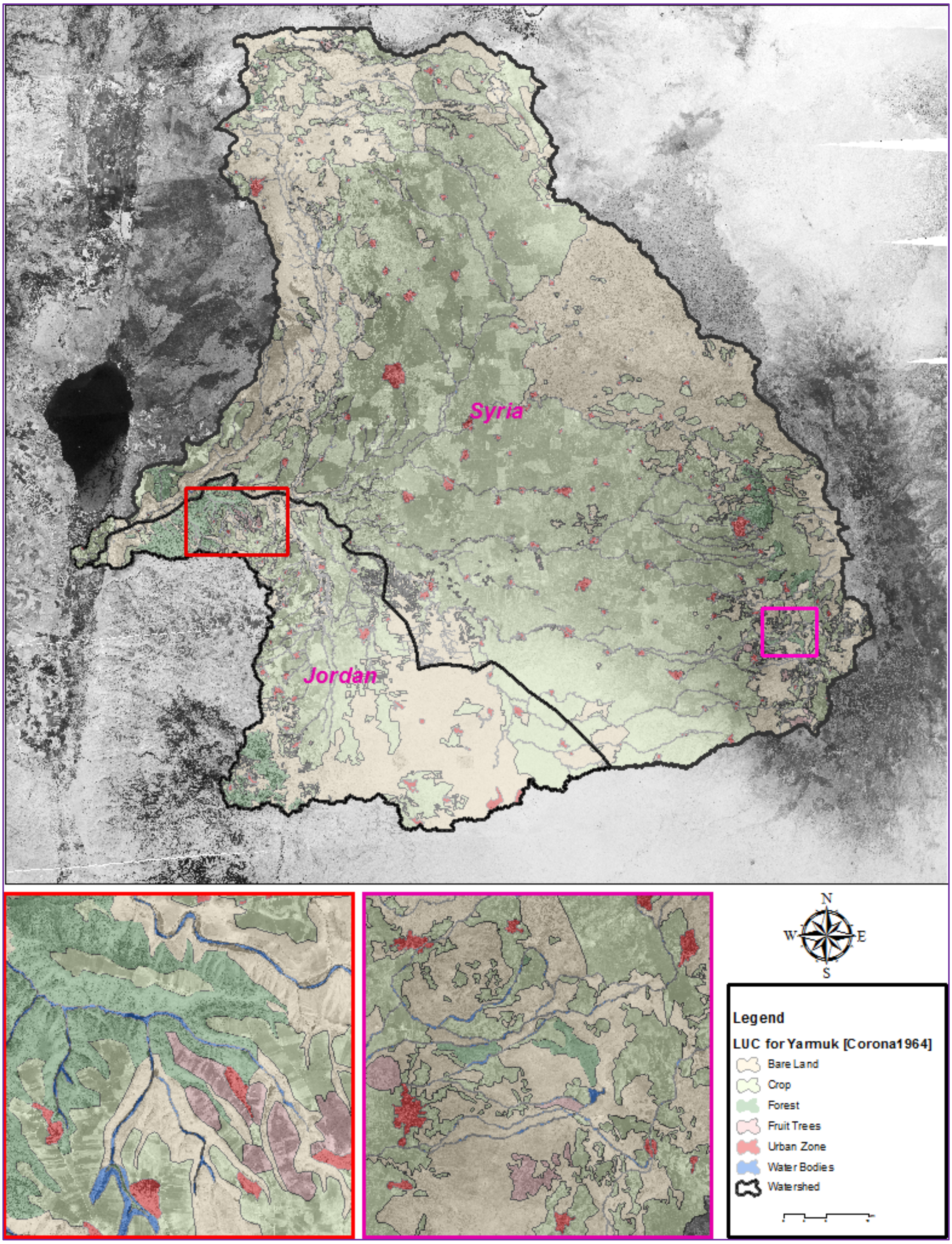
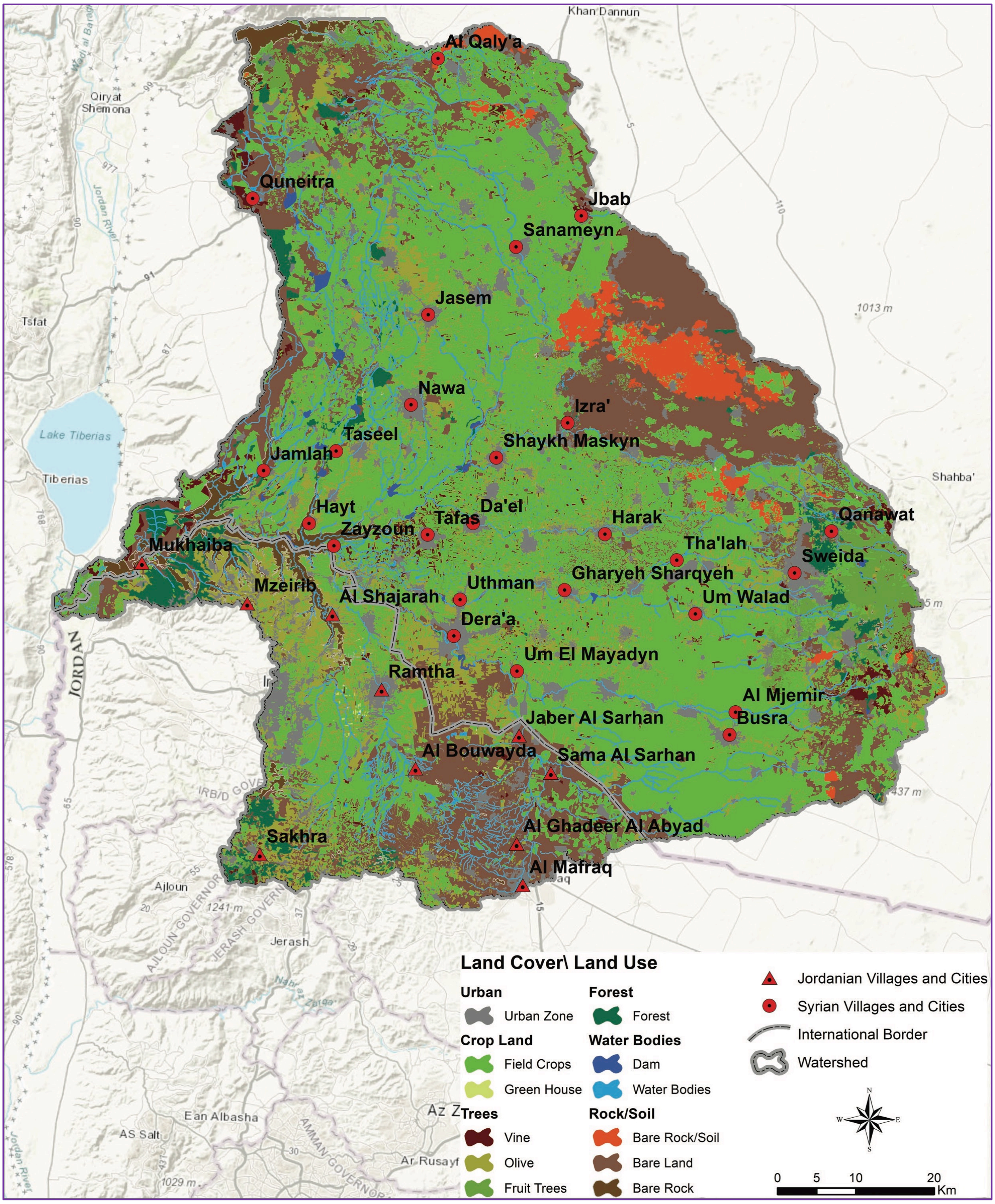


Figure 4.3 This study’s land use and cover map in 2011, based on 2011 ESRI Base Map. 1:20,000. High-resolution map and data are to be made available.



4.2 Agricultural water use

The changes in land use reflect the Government of Syria’s initiation of a countrywide policy of food self-sufficiency, which was supported by an agricultural intensification scheme (Al-Droubee 2000). For instance, wheat imports were stopped in 1994 and replaced by wheat grown in Syria, which eventually reached such a level of production that it was exported (Ali Deeb*, et al.* 2004). Bare lands were thus ‘reclaimed’ and planted, with an increase observable in three phases: at a rate of 12.7 ha/y from 1970 to 1986;

at about 27.2 ha/y between 1986 and 1991; and at the more rapid pace of 44.1 ha/y between 1991 and 1999. The nationwide increase was reflected by an increase in water demand from 6 to 9 BCM/y before 1991 to 12 BCM/y afterwards (Youmans 2016).

Irrigated areas in Syria form a small portion of the total cultivated area. In Dera'a, Al Suweida and Al Quneitra Governorates, the irrigated area increased from 370,344 ha in 1991 to 426,098 ha in 2014 (MoAAR 2014). According to Al-Husein (2007), the total irrigated area in the Syrian part of the Yarmouk tributary basin was 34,773 ha.[8] The water for irrigation was supplied almost equally from dams used for agricultural purposes (35%), springs and wadi runoff (33%) and groundwater from wells (32%). Syrian water experts stated that between 2005 and 2013, the average planted area in the Syrian part of the basin was 35,862 ha, with most of the water pumped from groundwater wells (app. 73%), and the rest from surface water (El Taneh (pers. comm.) 2017, Tawil (pers. comm.) 2017). Agricultural irrigation consumes an average of 253 MCM/y of water, of which roughly 82 MCM/y is from surface water and 171 MCM/y from groundwater (Mazen 2017). However, it should be noted that these figures relate to the administrative boundary of the Yarmouk tributary basin, not the hydraulic boundary (see Section 3.1.1).

In Jordan, a total of 14,010 greenhouses were built in the governorates of Irbid, Mafraq, Jarash and Ajloun, though not all are within the Yarmouk tributary basin (MoA 2014). Data provided by the Jordanian Ministry of Water and Irrigation (MWI) show that 36 MCM of groundwater is abstracted annually for irrigation. However, based on the assessments of crop water requirement (using remote sensing technology and evapotranspiration calculations), Al-Bakri (2015) estimates that the roughly 5,920 ha planted in 2014 in fact required 54 MCM of water, which is considerably higher than the MWI estimate.

The Government of Syria reconsidered its water consumption in light of declining groundwater levels in most of the country's aquifers, the decline in spring discharge, the decline in available water per capita and the deterioration of water quality. The government has sought to reduce the amount of water consumed for irrigation since the 1990s, first through personal efforts by farmers, and then by implementing projects to modernise the irrigation system (Box B1) (Al-Nahas 2011).

4.2.1 Agricultural water requirement

To calculate the water requirement for agriculture in the basin, Landsat images acquired from January to October were used to detect the vegetation in both winter (January to May) and summer (June to October) seasons. The NDVI was calculated and used to estimate the crop yields ($NDVI_{Green\ Vegetation} > 0.18$). As such, the areas classed as 'crop' areas in the LUC with a NDVI higher than 0.18 were studied (see Annex B 2.1). As shown in Table 4.1, the average annual crop water requirement (CWR) throughout the basin during the period 1985-1987 was 190 MCM (of which 13.37% was used for summer crops), increasing to 325 MCM in 2009 (70.67%) with 31% needed for summer crops. During the period 2014-16, CWR decreased to 281 MCM (-13.48%), with 23% used for summer crops.

[8] Year or range of years not specified.

Table 4.1. Crop Water Requirements in winter and summer in the Yarmouk tributary basin. *Source*: Authors, based on multiple sources listed in the text.

	Winter		Summer		Total CWR (MCM)
	Area (ha)	CWR (MCM)	Area (ha)	CWR (MCM)	
1985	83,849	182	7,967	28	210
1986	75,162	159	7,329	25	184
1987	70,983	153	7,960	24	177
2009	109,159	223	32,323	102	325
2014	102,702	180	14,480	58	238
2015	119,543	255	17,764	68	323
2016	106,595	213	17,763	69	282

An accurate estimate of the water required for the irrigation of orchards is difficult because trees are not consistently irrigated throughout the basin and irrigation levels depend on local rainfall levels. Based on several agro-economic variables, including annual rainfall depth and probability, but without taking into consideration soil quality or recent climatic changes, the Yarmouk tributary basin was divided into agro-climatic zones, as shown in Figure B 5.1 (Orient 2011). Trees in Zone I – receiving less than 200 mm/y of precipitation – are considered irrigated, and their total water requirement is estimated at 72 MCM/y (see Annex B5).

4.3 Dams, surface water use and storage

Dams are perhaps the most 'securitised' issue within the basin, considering the claims of violations of the 25 dams defined by the terms of the 1987 Jordan-Syria Treaty (see Section 7.3 and Figure 4.6). This section examines the evolution in the number of dams and amount of water stored in their reservoirs, by combining satellite images and personal communication with data from the Syrian Ministry of Water Resources, the Jordanian Jordan Valley Authority and the Israeli Mey Golan (Golan Heights Water Association).

The construction of dams in the Yarmouk tributary basin began in 1964, with the construction of the Rasas Dam in Syria. The bulk of existing dams were built in the 1980s as part of the Syrian scheme for intensive development in the Hauran Plain. Most of these were semi-permanent earthen dams (as opposed to much longer-life concrete dams) (Etana (pers.comm) 2017).

Official records (from the Jordanian MWI and JVA, and Israeli Mey Golan) show that there are 50 dams in the Yarmouk tributary basin: 42 Syrian, one Jordanian-Syrian (the Wehdeh Dam), four built by Israel in the Occupied Syrian Golan Heights and three Jordanian (with total storage capacities 247, 110, 10 and 3.1 MCM, respectively). Importantly, however, and as shown in Figure 4.4, not all these dams fall inside the hydrological borders of the Yarmouk tributary basin. Ten dams in Al Suweida Governorate listed as within the Yarmouk basin are actually outside the hydrological limits of the Yarmouk tributary basin (see Section 3.1.1 and Figure B 9.1).

The *'hydrological' basin* thus contains 40 dams. As detailed in Table B7.1, Thirty-two of these are in the Syrian part of the basin and have a combined storage capacity of 205 MCM; one is Jordanian-Syrian (the Wehdeh Dam, 110 MCM); three are Jordanian (3.1 MCM), and four are built by Israel in the Occupied Syrian Golan (very approximately 10 MCM). A more detailed explanation of the implications that the number and capacity of the dams has on the 1987 Jordan-Syria Agreement is provided in Section 7.3.2.

The literature shows that few if any of the dams ever reach their full storage capacity and that they are often threatened by untreated wastewater runoff. Some dams in Dera'a Governorate may have reached their full capacity only twice in 20 years, while their actual retention in other years ranged from 20 to 40% of their actual capacity (SANA 2015, 2016). Etana (2015) reported that 16 dams in the Syrian part of the Yarmouk tributary basin held 54.8 MCM in 2014 (or 28% of their total capacity). Of the dams proposed for irrigation in Syria, ten were reported polluted and six were out of service (Etana, 2015), which implies that roughly 2,300 ha of land is irrigated with polluted water and 3,140 ha has lost its source of surface irrigation water. Pollution also threatens water stored in Jordanian dams, due chiefly to wastewater runoff and agricultural practices (Hadadin 2015). For instance, sediment accumulation in the Jordanian Al Bouwayda Dam significantly reduces its storage capacity (Hadadin 2015).

Because of the lack of accurate field estimates and the inability to conduct field visits to the Syrian dams, the volume of water retained by dams was calculated from 34 Landsat Satellite images for the period between 1985 and 2016, and covering the spring and summer/fall seasons. The method employed was based on Liebe et al. (2005). Accordingly, 21 dams in Syria and Jordan were studied, representing 92% of the total dam storage capacity in the Yarmouk tributary basin (Table B7.1).

The calculations show that the dams in the Syrian part of the basin were never filled to their full capacity (Figures 4.5 and 4.6), though the maximum of 99% was reached in 1985. After the construction of the last dam in 2001 (Al Mantara), the actual retention of the dams increased to reach a maximum of 78% (141 MCM) in 2012, before declining in the following years, probably due to the effects of the Syrian crisis. The decline is attributed more specifically to changed agricultural practices due to the crisis, lack of maintenance of the dam reservoir walls, and electricity cuts (see e.g. Avisse*, et al.* 2017). The three minor dams in Jordan were built during the 1960s and were filled within a few of the studied years (Figure 4.7).

Figure 4.4 Location, purpose and storage capacity (MCM) of dams within the Yarmouk tributary basin and administrative units. Dams *outside* of the hydrological limits of the Yarmouk tributary basin are included here to highlight that these are counted by the Government of Syria (though not in the 1987 treaty or legal analysis (see Section 7.3.2). *Source*: Authors, based on multiple sources listed in the text.

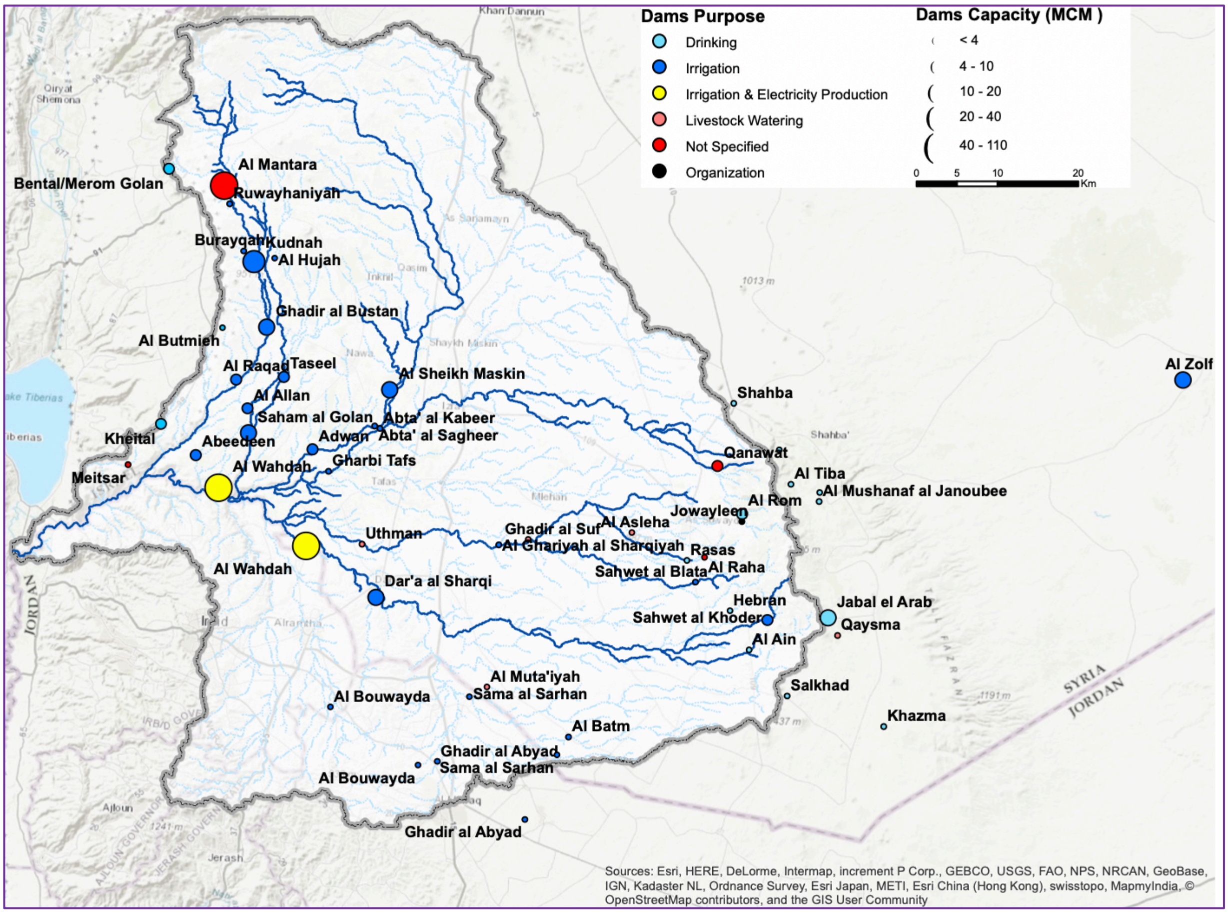


Figure 4.5 Volume retained by dams in Syria (spring season). Refer to Annex B7 for methodology. *Source*: Authors, based on multiple sources listed in the text.

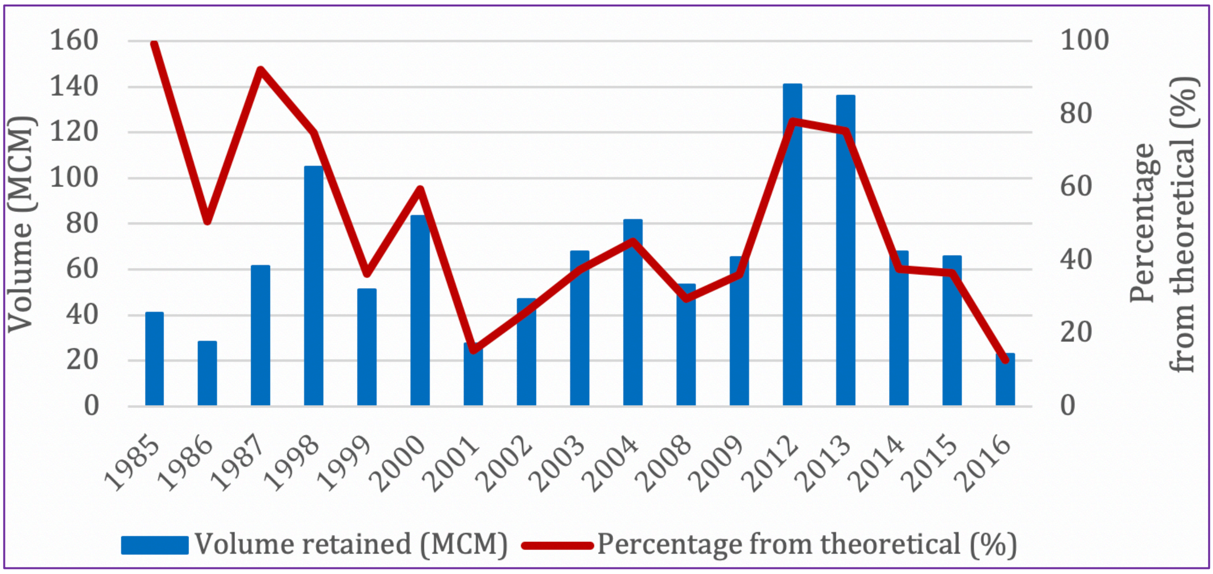


Figure 4.6 Number of dams (*left*) and theoretical storage capacity (*right*) of Syrian dams, over decades since 1960. *Source*: Authors, based on multiple sources listed in the text.

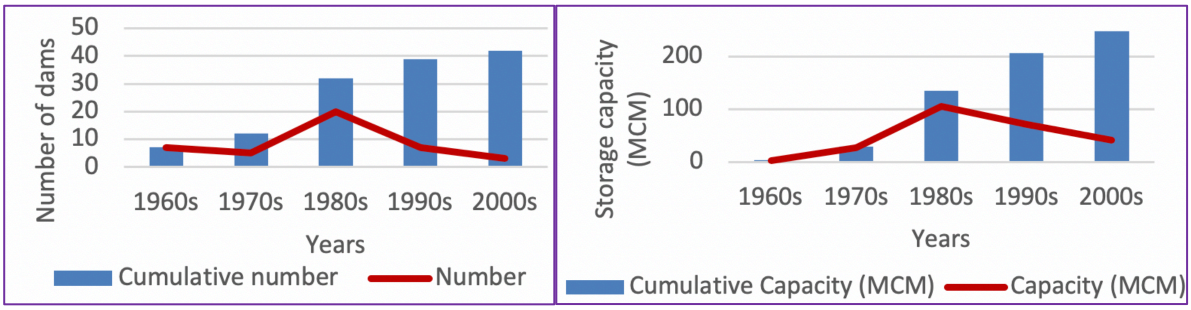
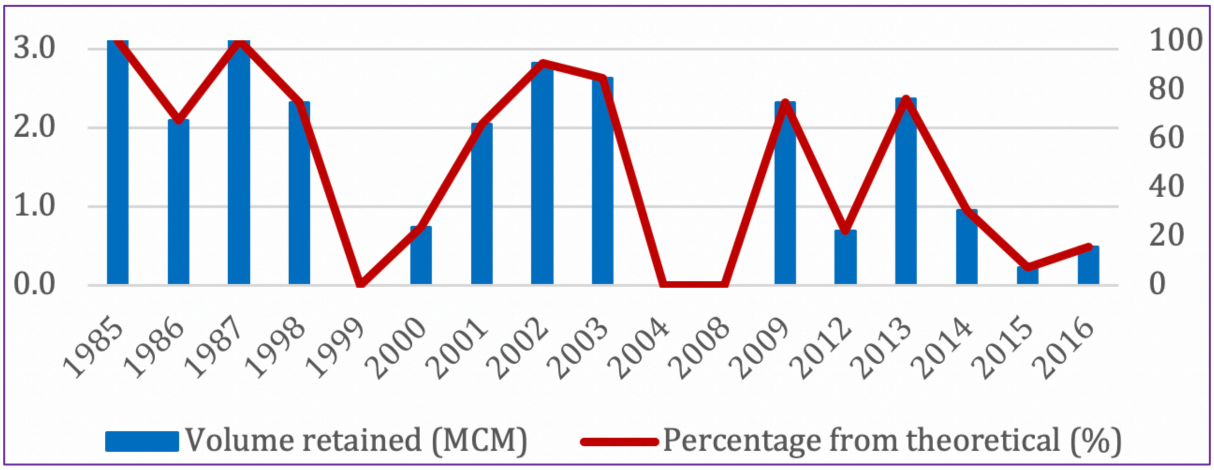
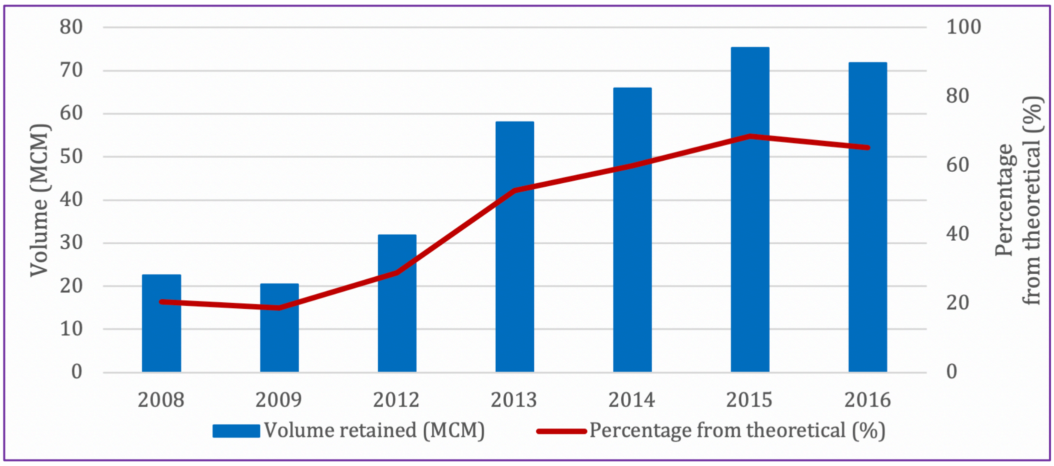


Figure 4.7 Volume retained by dams (not including the al Wehdeh Dam) in Jordan (spring season), including negligible amounts in dry periods (refer to Figure 3.7). Refer to Annex B7 for methodology. *Source*: Authors, based on multiple sources listed in the text.



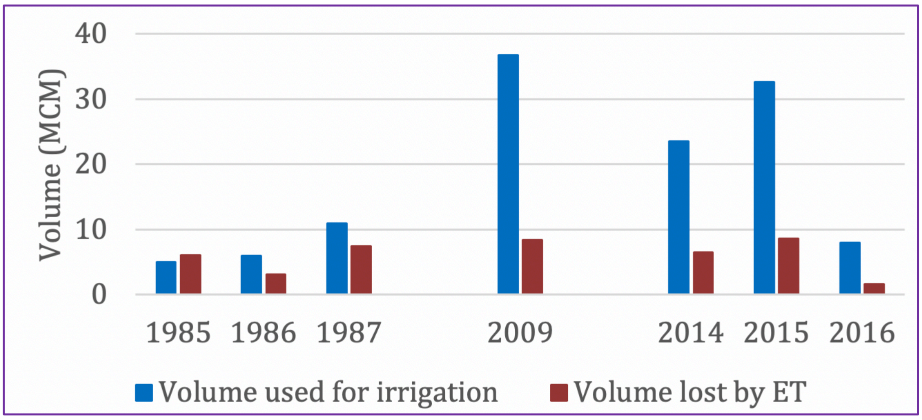
As discussed in Section 3.2.4 and shown in Figure 4.8, the reservoir behind the Wehdeh Dam has never been filled to its capacity. This study's analysis of the satellite imagery shows that the volume of water retained increased from 29% (32 MCM) in 2012 to 53% (58 MCM) in 2013 and reached a maximum of 68% (75 MCM) in 2015 (and 65% (72MCM) in 2016), values that are concurrent with Avisse et al. (2017). Note further that 2013 was a very wet year and therefore almost all dams in Syria and Jordan retained water.

Figure 4.8 Volume retained by the Wehdeh Dam (spring season). Note this is different to the gauged inflow into the dam presented in Figure 3.13. *Source*: Authors, based on multiple sources listed in the text.



The volume used from the dam reservoirs for selected years was estimated using the volumes calculated in spring and summer and the estimated evapotranspiration for the dams (Figure 4.9 and Table B 9.7). The volumes used from dams reached a peak in 2009 (before the Syrian crisis and after the intensification of irrigated agriculture in Syria), and then decreased afterwards (2014-16), probably due to changes in water use induced by the Syrian crisis.

Figure 4.9 Estimates of volumes used and lost from dam reservoirs throughout the Yarmouk tributary basin during selected years. *Source*: Authors, based on multiple sources listed in the text.

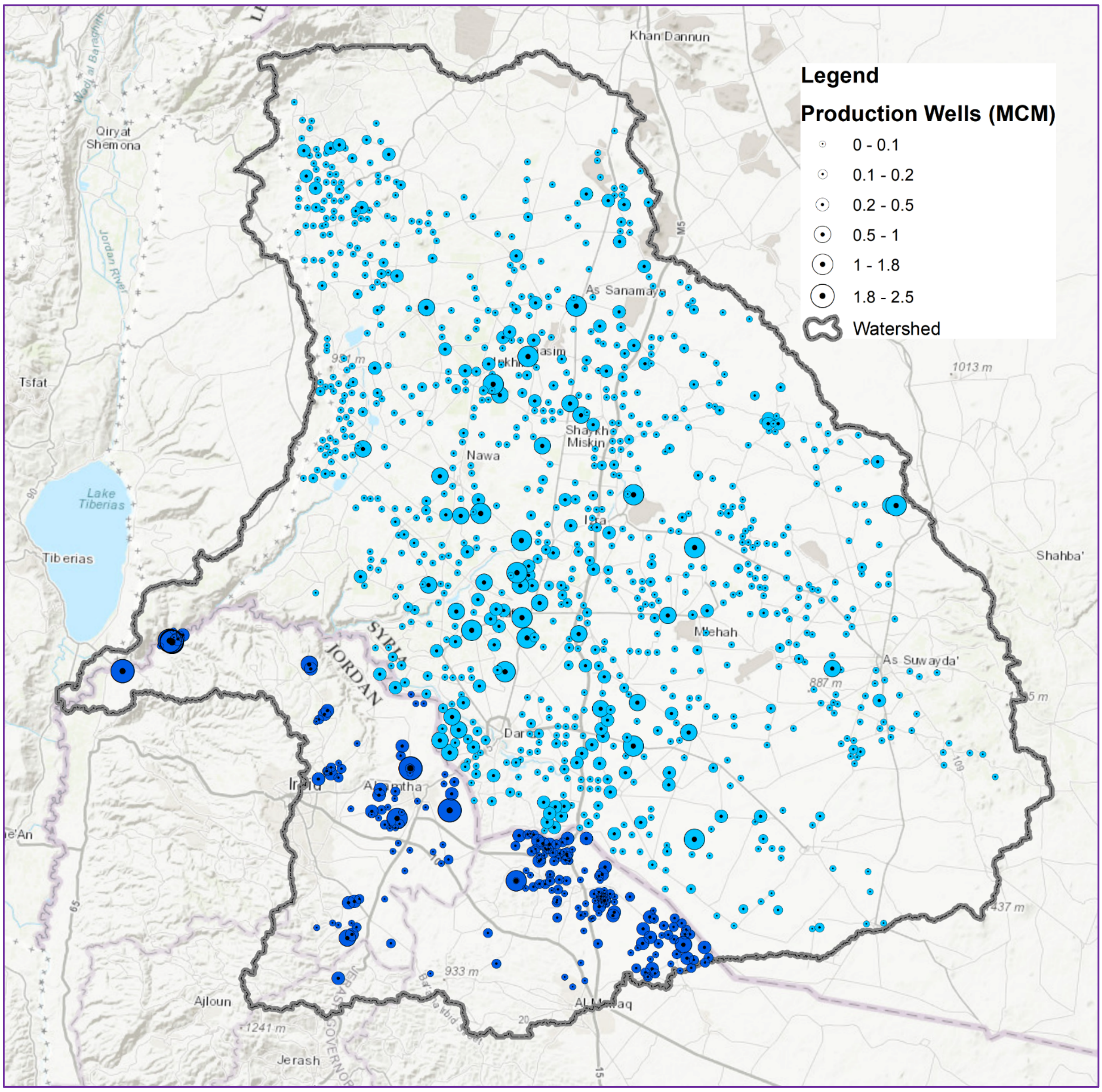


4.4 Groundwater abstraction

A rapid increase in the number of groundwater abstraction wells in the Yarmouk tributary basin accompanied the Government of Syria's agricultural intensification plan for the Hauran Plain in the mid- to late-1980s (Margane 2015). The majority of wells used for irrigation are found on the Plain and the western slopes of Jabal Al Arab (UN-ESCWA/BGR 2013). According to Al-Husein (2007), more than 5,000 reported wells in the basin (including 4,000 in Syria alone) are used to irrigate 11,241 ha and to provide domestic water[9] - see Figure 4.10.

[9] Throughout Syria, the average area irrigated from groundwater between 1999 and 2009 was 21,732 ha (60% of the total irrigated area) (UN-ESCWA/BGR, 2013).

Figure 4.10 Well fields in the Yarmouk tributary basin. *Source*: Authors, based on multiple sources listed in the text.



Annual figures on the amount of water extracted from wells in Syria was not available. However, MoAAR (2014) data shows that the number of wells and the area irrigated from them increased between 1997 and 2014 (Figure B 9.21). In 1997, 2,770 wells were used to irrigate 10,731 ha in the governorates included in the Yarmouk tributary basin, which extends beyond the basin's hydrological boundaries. However, 2,087 wells were located in Dera'a Governorate alone, which lies entirely within the basin. The data also shows that in 2003 there were approximately 4,400 wells irrigating roughly 20,000 ha (maximum estimated area). By 2009, 5,600 wells were used to irrigate around 17,500 ha. In 2014, the total number of wells had increased to 6,116, irrigating 14,338 ha (MoAAR 2014).

The average annual abstraction from wells in the Syrian part of the Yarmouk tributary basin was 189 MCM/y between 1999 and 2009, with the water being used mainly for irrigation purposes (UN-ESCWA/BGR 2013). Average abstraction from around 1,000 wells with known locations

(Figure 4.10) is around 152 MCM/y, with the smallest wells extracting less than 0.1 MCM/y and the largest wells around 1-1.8 MCM/y (Youmans 2016). Note that most of the high-capacity wells are in Dera'a Governorate in the centre of the Yarmouk tributary basin. However, the amount of water extracted from wells must be greater than the figures provided, since the groundwater demand for irrigation alone between 2005 and 2013 was approximately 170 MCM/y, according to water experts in Syria (Tawil (pers. comm.) 2017).

Many of these wells are not licensed, though the number of illegal wells decreased from 1997 to 2014 (Figure B 9.22) and the status of 1,536 wells was corrected between 2000 and 2005 (Agha*, et al.* 2005), especially in the area around the reservoir of the Wehdeh Dam (Abed (pers. comm.) 2017). Many wells have not been fully functioning since the start of the Syrian crisis, due to fuel and power shortages, theft of equipment (El Taneh (pers. comm.) 2017), or reduced irrigation needs.

The Government of Jordan also passed legislation to stop the drilling of unlicensed wells in 2002, and began its implementation in 2013 (Hussein 2016). The number of wells in Jordan is considerably lower than those in Syria, with the Jordanian Department of Statistics reporting 169 wells in the Yarmouk tributary basin in 2011. These are located within two main well fields (DOS 2014). The first is the Mukheibeh well field that contributes roughly 20 MCM/y to the King Abdallah Canal in the summer and whose wells are closed when not needed (Margane 2015). The second is the Somaya well field (around Sama al Sirhan and Samasdoud), which held 11 wells in 1995, and whose water is pumped to Za'atari pumping station, east of Mafraq (Margane*, et al.* 1995a, Margane*, et al.* 1995b).

In its analysis of groundwater in northern Jordan, Margane *et al*. (1995c) joined the groundwater abstraction wells from the Yarmouk tributary basin and Wadi Arab (to the south-west of the Yarmouk tributary basin). The analysis showed that between 1985 and 1993, total groundwater consumption increased in Jordan, with most of the water used for agricultural purposes. Abstraction from 112 governmental and private wells in the upper Yarmouk tributary basin in Jordan has been estimated at 22 MCM in 1987 and 62 MCM in 1993 (Margane*, et al.* 1995c). However, abstraction decreased between 1993 and 1998 (Hobler et al. (2001) (Figure B 9.23). In 1994, abstraction dropped to 57 MCM (Margane*, et al.* 1995b), a decrease attributed to pumping restrictions implemented by the MWI. Data from Margane et al. (1995a) from 1993 and 1994 show that most of governmental wells were being used for domestic and industrial purposes, while most private wells were used for agricultural purposes (Figure B 9.11 and see also Odeh*, et al.* 2019). JVA monitoring of groundwater shows that the number of wells exploited and the amount of water extracted increased between 2009 and 2015 (Figure B 9.12). On average, the total amount of groundwater abstracted from over 200 wells was 32 MCM/y, most of which (approx. 70%) was used for irrigation, while the rest was used for domestic purposes and less than 1% for industrial purposes. The average abstraction from wells ranged from less than 0.05 MCM/y to less than 2.5 MCM/y (Figure 4.10). However, a recent study by Al-Bakri (2015) showed that the amount of groundwater extracted is likely to be higher than the amounts registered.

4.5 Pollution and water quality

The limited research devoted to water *quality* issues is a source of concern, given how important the flows are to so many. While not nearly as contaminated as the lower reaches of the Jordan River (Margane*, et al.* 1999, UN-ESCWA/BGR 2013, Etana 2015), both surface and groundwater in the Yarmouk tributary basin show signs of pollution (Orient 2011, Abboud 2018).

Surface water pollution in Syria can be traced to several sources, including the discharge of untreated or partially treated wastewater (bacterial and nitrate contamination), the discharge from olive presses, and irrigation water contaminated by fertilisers, pesticides and herbicides (Al-Yazeji*, et al.* 2004, Al-Husein 2007). Existing wastewater treatment plants manage to treat water to a level acceptable for irrigation, but their capacity is limited, and many are not fully functional (Al-Zoghbi*, et al.* 2014). In some areas within the Yarmouk tributary basin (e.g. in Al Suweida Governorate), wastewater is used directly for irrigation (MoWR 2014).

In many cases, dams are the endpoint for water flows from valleys and they often become reservoirs for poor-quality water, some of which is even unsuitable for further use. Examples include Gharbi Tafas, Al Sheikh Maskin, Adwan, Ibta', Dera'a, Al Asleha, Hebran, and Jabal al Arab (Al-Husein 2007). Natural water bodies and lakes have also been affected by pollution at least since 2001, as is the case for Lake Muzeirib (near Dera'a), rendering its waters unsafe for irrigation of vegetables consumed raw and affecting the nearby fisheries (Al-Yazeji*, et al.* 2004, Al Qusaym 2016).

The groundwater in the Basalt Aquifer in Syria is generally of good quality. Historical Total Dissolved Solids (TDS) values are less than 250 mg/l in the high springs, and range between 250 and 500 mg/l in the area of Jabal al Arab and in the Occupied Syrian Golan Heights (Burdon 1954). More recent data shows that the salinity in most of the Yarmouk tributary[10] basin is low (between 100 and 500 mg/l), rising to 500-900 mg/l in the north of the basin and around the city of Dera'a and reaching up to 1,300 mg/l in places, which is close to the recommended limit for drinking water (Al-Yazeji*, et al.* 2004, UN-ESCWA/BGR 2013, Tawil (pers. comm.) 2017) (Figure B 9.8). Some springs, such as the Zayzoun Spring in the west of Dera'a Governorate, show organic pollution from wastewater beyond the safe drinking-water standards, while some wells, such as Da'el well to the north of Dera'a, are contaminated seasonally with bacteria (Al-Yazeji*, et al.* 2004, Nizam*, et al.* 2014). The groundwater in the B4/B5 – Pg_2^2 / Pg_2^3 Aquifer also has low salinity in Syria, fluctuating between 300-500 mg/l with a maximum of 600-800 mg/l in the discharge area of the Yarmouk tributary (Youmans 2017).

Though two treatment plants exist in Mafraq and Ramtha in Jordan, surface water shows clear signs of varied pollution. Monthly measurements of surface-water quality by the JVA at two monitoring stations (JV0 at Wehdeh Dam and JV1 at the Yarmouk Tunnel) between 2008 and 2016 show contamination by E. coli (suggesting pollution from wastewater), as well as high levels of chloride, bicarbonates, magnesium, Total Nitrogen and high salinity (see Annex B8). Analysis done by Orient (2011) on the water stored in the Wehdeh Dam showed also relatively high salinity, biological pollution and nitrate concentrations, attributed to agricultural runoff, wastewater discharge and infiltration of domestic or wild animal faecal matter. Finally, the sediments of the Yarmouk tributary were found to be contaminated by heavy metals of anthropogenic sources such as lead, cadmium, nickel, cobalt and zinc (Abu-Rukah*, et al.* 2001).

[10] Year or range of years not specified.

The groundwater of the A7/B2 – Cr_2cn cp/Cr_2m-d and B4/B5 Aquifers is generally considerd to be of good quality, if somewhat brackish in isolated areas (Orient, 2011) and vulnerable to pollution (Margane*, et al.* 1997). However, water from the B4/B5 Aquifer's springs and wells shows bacteriological and chemical contamination. The latter is reflected in high salinity (ranging from 270 to 1,200 mg/l), though lower Total Dissolved Solids values are found in areas where rainfall is high and groundwater shallow. High nitrate concentration (ranging between 7 and 200 mg/l) prohibits the use of many springs for public water supply. Most of this water is found in the middle part of the Yarmouk tributary basin, where groundwater is used in agriculture (Margane*, et al.* 1997, Awawdeh 2010, Orient 2011). More recent studies in Jordan show that 28% of samples taken were above acceptable limits in nitrates, magnesium, and Sodium (Abboud 2018).

Within the Yarmouk tributary basin, groundwater salinity in the A7/B2 – Cr_2cn cp/Cr_2m-d Aquifer increases with the general direction of groundwater flow, i.e. towards the west (Figure B 9.8) and elevated salinity values occur where the groundwater is confined by the B3 Aquitard. The nitrate concentration increases in the north, where the bulk of agricultural activities occur (Margane*, et al.* 1997, Orient 2011). As previously discussed, however, overabstraction from A7/B2 – Cr_2cn cp/Cr_2m-d Aquifer has led to a change in water regime, as part of which certain wells have been deepened following the abstraction of more saline water (Margane 2015).

5 Development in the basin

This section reviews the dynamics that have led to the Yarmouk tributary basin's current level of overdevelopment. Readers interested in earlier development plans and other infrastructure are referred to Annex A4, while a much more detailed reading of the negotiations is available in Annex A5.

5.1 Frame and timeline of interests, infrastructure, treaties and narratives

As noted in Section 2, transboundary water arrangements in the Jordan River Basin have developed through an observable interaction of four factors: interests, infrastructure, treaties and narratives, as shown in Figure 5.1.

Along with the baseline of Sections 3 and 4, examination of the interaction of the four factors in Figure 5.1 reveals that:

a) Water (or water-related political) *interests* are the impetus to develop the flows;

b) formal and informal negotiations eventually lead to the *treaties* that are required to establish the legal or administrative framework for the infrastructure or distribution of flows;

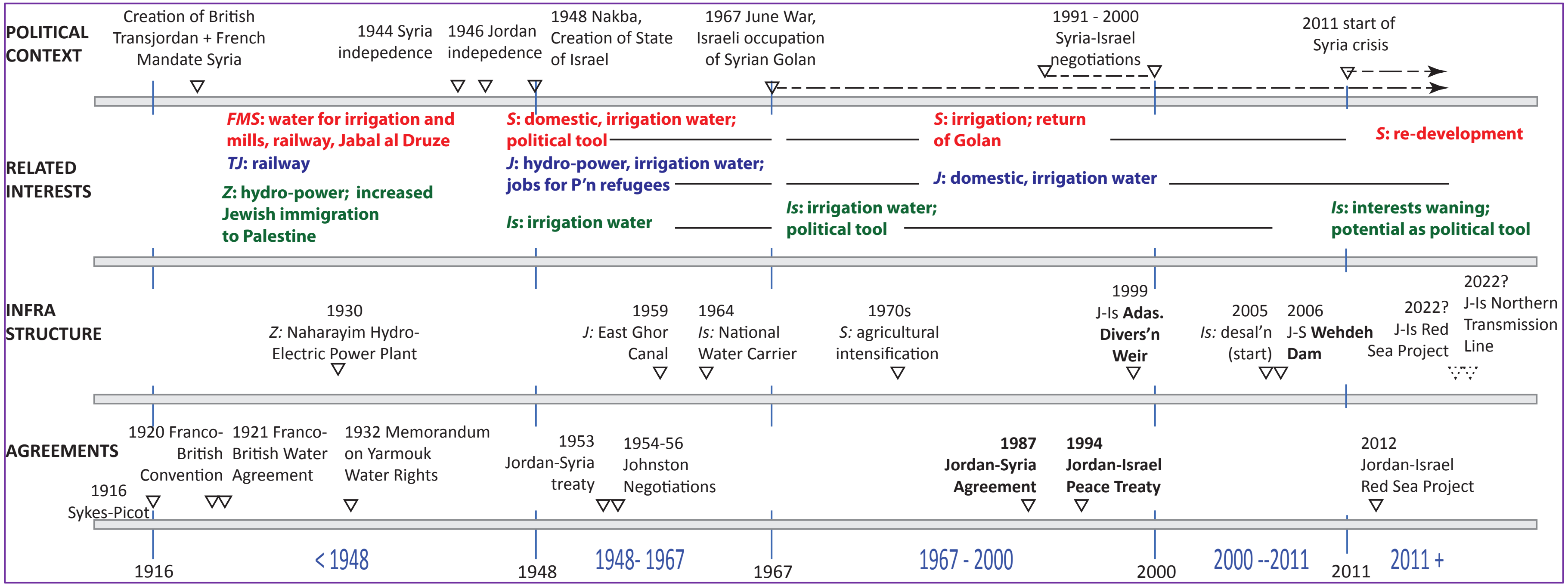
c) *infrastructure* establishes water use and distribution physically;

d) *narratives* serve the negotiations and to maintain or challenge the arrangements that have been made (though these are insufficiently explored); and

e) *all four* are in constant interaction with each other, and develop with changes in the broader context.

In short, **interests drive, infrastructure concretises, treaties lock in and narratives (probably) serve to either contest or consent to** the transboundary water arrangements on the Yarmouk. In many ways, each factor contributes to the other. What is also clear is that water agreements cannot be separated either from discussion over other issues (e.g. rail, territory), or from the geopolitical interests of the larger players in the region (e.g. the colonial powers prior to independence, and the United States from the 1950s until today).

Figure 5.1 Hydropolitical timeline of interests-infrastructure-treaties-narratives related to the Yarmouk tributary basin. FMS = French Mandate Syria; TJ = Transjordan; Z = Zionist; S = Republic of Syria; J= Hashemite Kingdom of Jordan; Is = State of Israel.



5.2 Early conceptions

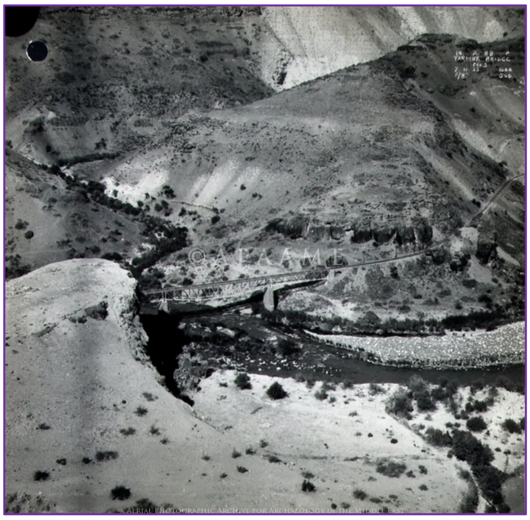
'The rival Jordan diversion schemes now being carried out by Israel and the Arab states can be likened to a limb-from-limb rending of the infant by irreconcilable and importunate parents' – C.G. Smith (1966: 111).

5.2.1 Etymology: the Shari'at el Menadireh

Though overshadowed by the Jordan mainstream that it joins, the Yarmouk tributary basin has played a central a role in the political history of the Levant.[11] The river is referred to as *Hieromax* or *Jarmoch* in the Talmud, reflecting the Roman Empire and Hebraic settlement along its banks. The presence in AD 300 of the Arab Christian kingdom of the Lakhmids or Muntherites in the Yarmouk's Hauran Plain was part of their plans to create a unified Arab kingdom (Nicolle 1994). Khalid Ibn al Waleed and his Arab Muslim forces effectively terminated Byzantine Christian rule in the area during the Battle of the Yarmouk in 636 AD. With both armies confined by the Yarmouk to the south and its main tributary, Wadi Raqqad, to the north, the victory for the Rashidi Caliphate (under Caliph Omar Ibn al Khattab) paved the way for the establishment of the Umayyad dynasty (Nicolle 1994).

More recent empires also placed the Yarmouk central to their political strategies. The Hejaz Railway was built during the Ottoman era to connect Medina to the Mediterranean, with the branch from Dera'a to Haifa that ran along the river valley completed in 1908. Though the railway was extensively bombed by the Allies during the First World War, several of the train bridges that connected the different stations on either side of the river remain, as shown in Figure 5.2.

Figure 5.2 Two of the Yarmouk mainstream bridges forming part of the Hejaz Railway branch from Dera'a to Haifa. *Left*: 1934, location unknown. Source: British Royal Air Force (Aerial Photographic Archive for Archaeology in the Middle East, Flickr); *Right*: Jisr al Majami' (the connecting bridge of the two rivers)[12] crossing the Yarmouk mainstream just before it enters the Jordan River. Jisr Binat al Yacoub (Jacob's Daughters' Bridge) is in background. *Source*: Palestine remembered.



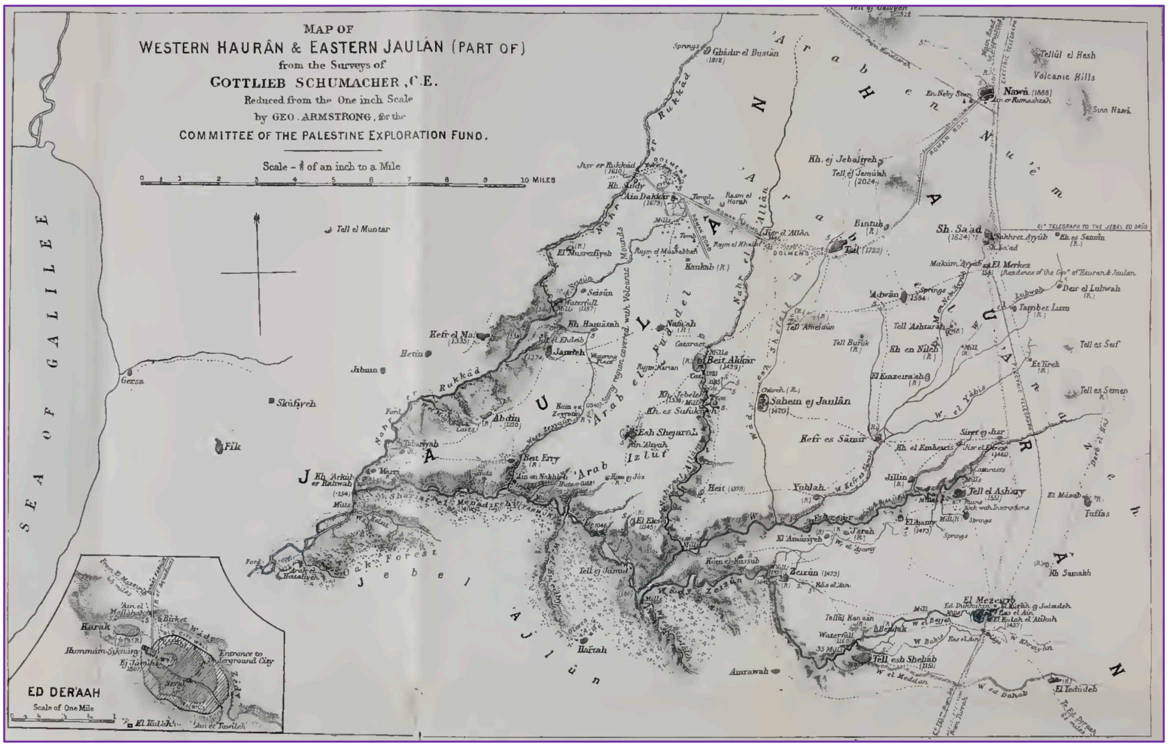
[11] This brief history does not claim to capture the extent of the diversity of human settlement in the area, which includes the important history of the Druze, among several other communities.

[12] Jisr al Majami' was also the name of a Palestinian village whose native population was expelled in 1945. Today, it is the site of the Kibbutz Gesher.

Figure 5.3 The Himmeh Bridge, bombed by the (Zionist military organisation) Haganah on 17 June 1946 as part of a plan to destroy 11 bridges linking Palestine to neighbouring Arab States. *Source*: Benjamin, 2004, Flickr.

As explained in greater detail in Section 3.2, the Yarmouk mainstream is fed by a number of tributaries in the Hauran Plain extending from *Jabal al Druze* (a.k.a. *Jabal el Arab*) to the highlands of the Golan. As Schumacher explains in his detailed 323-page 1889 *Across the Jordan: Being an Exploration and Survey of Part of Hauran and Jaulan*, the area was then part of the Ottoman sanjaks *Liwah* and *Hauruân* (Schumacher 1889). He describes the influence of rivers over the political units, invoking the river basin as the border for political units: 'The natural boundary, as also the political division recognised by the present government, between Hauran and Jaulan is the *Nahr el 'Allân*; the boundary between Jaulân and 'Ajlûn is formed by the *Shari'at el Menâdireh* (the ancient Hieromax or Yarmouk); while that between the Hauran and 'Ajlun is the *Wadi esh Shelâleh'* (Wadi al Shallala) (Schumacher 1889: 2).

Figure 5.4 Map of the *Sharia't el Menadireh* between the Jaulan (Golan) and Hauran Plain. *Source*: Schumacher 1889.



The downstream end of the Yarmouk was commonly referred to in the 1880s as *Sharia't el Menadireh* (شريعة المناذرة), meaning the watering/irrigation place. [13] Schumacher captures just how important the river was for the local inhabitants, mostly to power their mills: '*Shari'at el Menadireh* is the most remarkable stream of the country east of the Jordan, and it brings to that river about the same amount of water as the Jordan itself carries at the point of junction' (Schumacher, 1889: 8).

The name *Al Shari'ah* is still in common use amongst Jordanians, Palestinians and Syrians living in the transboundary communities. Apart from the previously mentioned *Hieromax* and *Jarmoch*, different parts of the river have also been referred to as *Ehreir* and *'Irak*.[14]

5.2.2 Colonial, Zionist and national construction of 'The River as Border'

Ottoman interest in the area between the Yarmouk mainstream and the Zarqa River increased by the mid-19th century, making Irbid its centre and attaching it to the Hauran *Mutasarifyeh* region. However, the area remained part of *Al Sham* (Damascus) as a united geographical entity until the fall of the Ottoman Empire. French and British correspondence regarding *Jabal al Druze* during this period reveals French interest in maintaining Druze unity, while French authorities strongly believed that the Zionists were pressuring Britain about this area (see FNA 1921a, FNA 1921e).

[13] Shari'at el Menadireh, Schumacher (1889: 10) explains 'is applied to the river from the points of junction of the Wadi Ehreir, Zeizun and Shelâleh land, and is retained by it to its junction with the Jordan'.

[14] 'Irak, meaning cliff, was another local name given to the river.

While the tributaries defined much of the Ottoman *sanjaks*/provinces, the mainstream Yarmouk became a political border only during European colonial rule, with the Sykes-Picot Agreement employing the talweg of the river to demarcate the borders of the territories that the British and French were to rule (Amadoni 1997: 542). The well-documented Zionist lobbying of British authorities to expand the borders of British Mandate Palestine to include the Litani River in Lebanon (see Zeitoun*, et al.* 2012) extended to the Yarmouk as well (Wolf*, et al.* 2007). Well before he became Israel's first president, Chaim Weizmann raised the issue in his letter to the British Foreign Secretary, Lord Curzon, following the San Remo accord in 1920:

> '[T]he accord draft France proposed not only separates Palestine from the Litani River, but also deprives Palestine from the Jordan River sources, the east coast of the Sea of Galilee and all the Yarmouk Valley north of the Sykes-Picot line. I am quite sure you are aware of the expected bad future the Jewish national home would face when that proposal is carried out. You also know the great importance of the Litani River, the Jordan River with its tributaries, and the Yarmouk River for Palestine' (Dolatyar 1995).

The Yarmouk thus served as the border between French Syria, British Transjordan, and (at least for the six to eight miles at the 'Yarmouk Triangle' near the confluence of the Jordan and the Yarmouk) British Mandate Palestine. Following Syrian and Jordanian independence from France and Britain and the *Nakba*, the Yarmouk by 1948 marked the border of Syria, Jordan, and, to a lesser extent, Israel. Israel's occupation of the Golan in 1967 expanded its territorial control a further two miles, to the confluence of the Raqqad with the Yarmouk mainstream – the site of the Battle of the Yarmouk over 1,300 years earlier, and near today's colony of Kibbutz Meitsar on the Occupied Syrian Golan Heights.

Box 1*:* The British 'piecemeal' approach in support of regional plans to accommodate an agreement with Israel

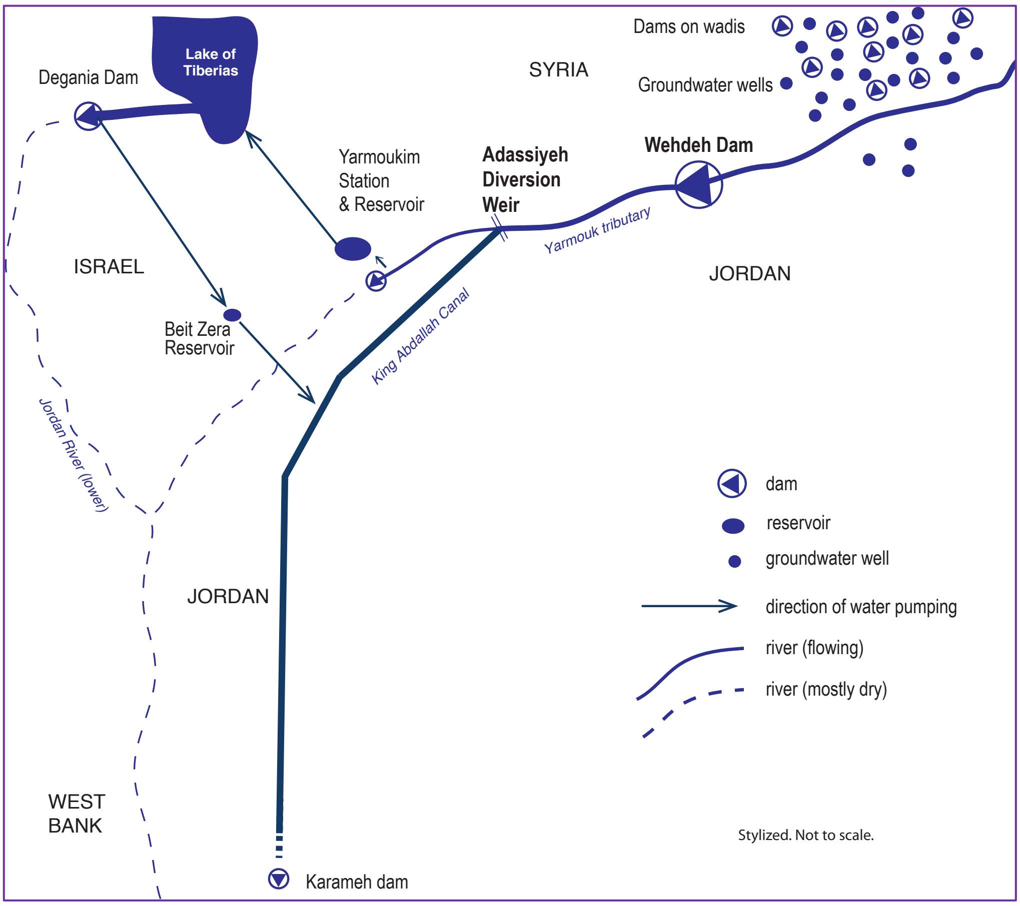
Investigation of the 1950s correspondence between Ionides, Murdoch and Walpole clearly shows how the British position had shifted to a focus on scaling down the Jordan Valley development projects. Britain's main contention and preference at that time was to stick to a small-scale project that was an offshoot of the Murdoch and Partners study. It was seen to be less time consuming, with the potential of offering a quick response to the refugee problem (i.e. putting refugees to work) and boosting of the Jordanian economy. The smaller-scale project was also expected to attract more donors and, after successful implementation, encourage further investments in larger extension phases of the Yarmouk project (FO 1951). However, the scaling-down approach on the Yarmouk did not alter the British plan for a regional scheme which included Israel. With the regional plan as strategy, the tactics included the development of unilateral infrastructure in each country that was to be linked once the political atmosphere permitted. One example is Ionides' identification of the differences between the Simansky and Murdoch plans regarding the water level at the start of the main canal. The water level in Simansky's canal was 10 m higher than in the Murdoch plan, under the assumption that no accommodation with Israel would be reached. Ionides argued that the lower level should be chosen, in order to take into account an eventual agreement between Israel and Jordan (FO 1951).

5.3 Infrastructure

There are numerous accounts of the flurry of development plans and projects on the Jordan River (see e.g. Schmida (1984) and summary in Attili (2004)), the majority of which concerned the Yarmouk tributary directly. Particularly well-detailed accounts include Haddadin (2000, 2002a) and Shamir (2003b) (for Israeli-Jordanian negotiations); Chapter 6 of Sosland (2007) and Jägerskog (2003) (for Israeli-Jordanian Yarmouk negotiations); Alatout (2011) (for political/constructivist interpretation of the Johnston Mission); Phillips et al. (2007a) (for critical assessment of the Johnston Allocations); and Suleiman (2003) and Courcier (2005) (for tracking water use and infrastructure over the decades).

The net result of the infrastructure is a heavily developed basin, as sketched in Figure 5.5. Rather than tell the story of the flurry of activity, this section synthesises the plans and draws attention to their main drivers within the interests-infrastructure-negotiations-narratives frame.

Figure 5.5 Sketch of infrastructure on the Yarmouk tributary and Lower Jordan River in 2017. *Source:* Authors.



5.3.1 The East Ghor/King Abdallah Canal

The Government of Jordan began construction of the first phase of the East Ghor Canal in 1959, as part of an ambitious state-building effort to irrigate the lands on the Jordanian side of the Jordan River Valley with Yarmouk flows. The East Ghor Canal had been hailed as 'signifying the Hashemites' modernity and resistance to Israel' following Egyptian President Nasser's accusation of King Hussein's acquiescence to Israel and western powers (Kingston 1996, Citino 2017: 165). Citino also asserts that the

East Ghor project concealed the Jordanian-Israeli relationship and support the king provided to the Johnston Plan, arguing that King framed it as a post-Ottoman development, while his strategy was 'to contain Nasser and promote Jordan as Israel's leading Arab rival when it came to "making the desert bloom"'.

Later renamed the King Abdallah Canal, the infrastructure also required the construction of a storage dam at Mukheibeh (referred to as the Khalid ibn al Waleed Dam – See A4.3), which was conditional on Jordan's contribution to the Arab Diversion Plan (Citino 2017). The Government of Jordan was at the same time obliged to abide by the Johnston allocation, according to an agreement signed with the US financier of the East Ghor Canal,[15] as well as guarantee it would not deprive Israel of what was considered its share (25 MCM/y, agreed to for use by Israeli farmers in the Yarmouk Triangle – see below). Between 1968 and 1970, Israel attacked the East Ghor Canal at least eight times, in what the United States considered an attack on the 'most important and visible American-sponsored and -financed project in the country (Sosland 2007: 98). There was further violence in the 1970s when the Israeli farmers in the Yarmouk Triangle[16] suffered the effect of the diverted flows to the canal after sandbags had been placed in the river, leading to armed conflict, kidnapping of Jordanian soldiers and intense negotiations (Haddadin 2002a).

5.3.2 The Maqaren/Wehdeh Dam (Jordan-Syria)

The Bunger Plan of 1952 details the master plan for water infrastructure within the majority-Arab States. Its keystone was the Maqaren Dam, which was to be built at the confluence of most of the Yarmouk's tributaries to a height of 160 m, making it the highest dam in the world at that time. With a storage capacity of 500 MCM, the dam was designed to produce electricity and regulate the flow into the East Ghor/King Abdallah Canal.

As examined in detail in Section 8.2.1, although the governments of Syria and Jordan agreed to build the dam in both the 1953 and 1987 Syria-Jordan agreements, its construction was delayed by Israeli military and diplomatic activity and Syrian stalling. Ruling out the Maqaren Dam at the start of negotiations, the Johnston Plan settled for a 85-m dam with a capacity of 73 MCM, with a possibility of extending the height to 95 m. Following decades of Israeli obstruction to build the dam, Jordan pursued it aggressively in the 1970s (Haddadin 2007: 102), including it in the Jordan Valley Commission Seven-Year Plan (1975-1982) and the amendment of the 1953 Yarmouk water treaty.

[15] The Kuwait Fund for Arab Development also contributed to the construction of 8 km of the EGC from 70 to 78 km between 1967-1970.

[16] The farmers later organised into the Jordan Valley Water Association – see Annex A3.3. One of its leaders was Noah Kinnarty, later a water negotiator for Israel in its negotiations with Jordan and the Palestinians.

Figure 5.6 The Wehdeh Dam lying nearly empty in October 2018. *Source*: Zeitoun.

Increased Syrian use of the tributary flows (see below) and the increasing pressure on the Government of Jordan to secure more water for its citizens led it to expand the purpose of the dam in 1978 from hydroelectricity and irrigation to include provision of municipal and industrial water for northern Jordan (Haddadin 2002a: 227). The Government of Jordan also reduced the proposed height of the dam to 110 m in order to allay Israeli concerns about its 25 MCM/y water allocation for the farmers in the Yarmouk Triangle.[17] The opportunity to build the dam finally came about after Israeli concerns were allayed by the 1994 Jordan-Israel Peace Treaty and during a period of good relations between Jordan and Syria. Construction began in 2003, and the dam was completed as the Wehdeh (Unity) Dam in November 2006.

The Wehdeh Dam did not store significant volumes of water in its first years of operation, ostensibly because of Syrian groundwater abstractions and surface-water use upstream (Comair*, et al.* 2012, UN-ESCWA/BGR 2013, Etana 2015, Rajsekhar*, et al.* 2017), but also because of low rainfall levels. As discussed in Section 3.2.4, inflows into the dam increased from 2008 to 2016, ostensibly because the Syrian crisis has reduced pumping and storage, mostly in the Hauran Plain.

5.3.3 The Adassiyeh Diversion Weir (Jordan-Israel)

The 1952 Bunger Plan also proposed a smaller dam (8 MCM storage capacity) at Himmeh and a diversion weir near Adassiyeh to work in conjunction with the Maqaren Dam in order to deliver a reliable supply of water to the eastern side of the Jordan River Valley. As detailed in Sections A5.2 and 8.2.2, and as with the case of the Maqaren Dam, Jordanian efforts to build the

[17] Israeli officials had advocated for assuring 25 MCM/y of the flow during the 1950 Johnston Negotiations, and this was secured in the Johnston allocations. Interestingly, the Memorandum of Understanding (MoU) between Israel and the US Government stated that Israel's share is 40 MCM/y, while the MoU with the Arab countries stated 25 MCM/y. The issue was raised again in 1976 by then-Deputy Water Commissioner Shaul Arlosoroff (US NESAA 1976) and in 1978 by the acting US Deptuty Chief of Mission Samuel Hart in a letter to Israeli Deputy Director General of the Ministry of Foreign Affairs Moshe Alon. The letter states: '[I]mportant factors to be kept in mind are the 25 mcm to be made available of the Yarmouk Triangle and the provision of certain amounts of water to the West Bank; it would be useful if Israel and Jordan could agree on the construction of the weir separate from the above issue' (Hart 1978). Section 6.2 reviews how Israel has in fact secured this and considerably more, and how the issue of a secure supply for Yarmouk Triangle farmers remains a negotiations issue to be resolved (see also Annex A5.2.1).

weir were consistently thwarted by successive Israeli governments, themselves under pressure from the Israeli farmers in the Yarmouk Triangle just downstream of Adassiyeh. The Government of Israel insisted on negotiating with the Government of Jordan regarding the weir as part of the Yarmouk Scheme project in the 1950s and 1970s, thus jeopardising Syria's cooperation and the whole scheme. The United States was meanwhile pushing Israel to keep the construction of the weir separate from the Maqaren project in 1978, to avoid the issue disrupting the secret Jordan-Israel negotiations.

Israel and Jordan eventually agreed to build the Adassiyeh Weir in the 1994 Peace Treaty, though the associated dam at Himmeh, which would have acted as a regulating reservoir, was dropped. This meant a particular allocation scheme to deal with the highly variable river flows had to be developed, which has considerable hydropolitical implications, as explained in detail in Section 6.1. As explained in Boxes 2 and 3, Himmeh lies at a crucial hydropolitical point on the Yarmouk tributary, and is contested by Syria, Palestine, Israel and Jordan.

In any event, the weir was designed, funded and executed by the Government of Jordan in 1999. As discussed in Section 6.1 and Section 7.2, the weir in effect compromises Jordanian use of Yarmouk flows to the present day. A related point is that the idea of 'swapping' Yarmouk flows via a pipeline at the location of the Adassiyeh Weir to the Lake of Tiberias was replaced with the construction of a pumping and storage scheme further downstream. This arrangement was set out in the 1994 Jordan-Israel Peace Treaty, and is referred to here as the 'Yarmouk-Tiberias water swap'. Because of the central role it plays in Yarmouk hydropolitics, this water swap is discussed in detail in Section 6.1.

Figure 5.7 Jordanian Water Minister Hani al Mulqi with Israeli Foreign Minister Ariel Sharon at the temporary Adassiyeh Weir, 26 October 1998. *Source*: Alamy 1998.

Box 2: Hydropolitical history of al Himmeh, and siting the Adassiyeh Diversion Weir

The Yarmouk riverside village of Himmeh has attracted settlement from the days of the Roman Empire, primarily because of its five hot springs. Because of its favourable location just upstream of the KAC (see photo), it was once considered the best location to build the 8-MCM storage dam associated with the Adassiyeh Diversion Weir. Claimed as Palestinian by the British during their post-WW1 negotiations with the French, British authorities granted a concession to develop the Himmeh area to Lebanese businessman Suleiman Nassif in 1936. The official Palestinian position held that the area was part of the Ka'wash triangle, or Palestinian Himmeh, which had a population of just 245 in 1948 (Ishtayyeh 2011). The Government of Syria did not recognise the Europeans' agreement and the area was 'returned' to Syria at the April 1949 Lausanne Conference (Al Majdoub 1998). Syria developed Himmeh as a touristic area from 1948 to 1967.

Himmeh was nonetheless located in the demilitarised zone (DMZ) established between Israel and Syria after the 1967 war (Matsushima*, et al.* , Neff 1994). Seven Israeli soldiers were killed in Himmeh in 1951, when a force entered to displace the villagers and establish an Israeli settlement in what became known as the 'Himmeh Incident' (Kipnis 2007). Israel occupied Himmeh along with the rest of the Golan in 1967, but its ownership remains contested and is bound to resurface as an issue in any future negotiations between Syria and Israel.

The village of Himmeh in relation to the Adassiyeh Diversion Weir. Also visible are the fish ponds (right) and irrigated agriculture (top right) by Israeli settlers. Source: Adapted from Google Earth.

Additional water storage capacity at Himmeh would indeed have helped regulate the flows diverted into the KAC, possibly ensuring a steady year-round supply. The Jordanian authorities refused the flooding of the site because they did not recognise Israeli control over Himmeh (Haddadin 2007), while Israeli authorities rejected the idea due to concern over the site's archaeological importance (Haddadin 2007, Abed (pers. comm.) 2017). The Jordanian and Israeli authorities agreed to a site just a few hundred metres downstream (known in Israel as 'Gate 121', in reference to the border crossing between Israel and the Occupied Syrian Golan) though this was a) too narrow to allow a storage structure to be built (Haddadin 2007), and b) still within the DMZ, and therefore contentious to the Syrian authorities. The idea of a dual-purpose structure (i.e. dam and weir) was dropped, the weir alone was built (albeit still partly on contested territory) and Jordan remains committed to its design intake capacity and agreed operations (Section 6.1).

5.3.4 The Israeli National Water Carrier

Israel completed the National Water Carrier in 1964, with the aim of transferring water from the Lake of Tiberias to drinking and agricultural water demand centres on the coast and in the Naqab (Negev) Desert. With the intake structure originally proposed at the higher altitude on the upper tributaries of the Jordan River, the NWC has withdrawn 286 MCM/y from the lake on average between 1963 and 2014 (HSI 2016b: 449). The NWC is also the sole (and very significant) source of water transfer outside of the Jordan River Basin.

Box 3*: Adassiyeh, the Bahá'í village*

Three Bahá'í settlements were established on the eastern and southern shores of the Lake of Tiberias in the 1880s: Umm-Jūna, Es-Samrā and Nuqeib. A fourth settlement, Adassiyeh, was established in the early 1900s next to the Yarmouk tributary (Rozen 2012). As with the other three settlements, the Bahá'í farmers of Adassiyeh enjoyed success growing citrus (Shawni (pers. comm.) 2016), which were irrigated with the flows of the Yarmouk, by building stone dams and diverting water through canals to their plots (Pootschi 2010). The community was obliged to hand over its land to the Jordan Valley Authority when the East Ghor Canal was being prepared in the 1960s. As ownership of land is forbidden in the Baha'í religion, some decided to remain on their land, while others accepted other forms of compensation.

5.3.5 Syrian agriculture intensification through dams and wells

As discussed in greater detail in Section 4.4, the Government of Syria initiated an agricultural intensification scheme in the Hauran Plain in the 1970s, with roughly 426,000 ha irrigated in the governorates of Dera'a, Al Suweida and Al Quneitra by 2014 (MoAAR 2014). This was supported primarily from groundwater wells (about 73%) and surface water captured by dams. The plan was intended to increase agricultural production in and around those parts of the Occupied Syrian Golan Heights that were still controlled by Syria following the 1967 Six-Day War (Libiszewski 1995). The scheme was part of the national policy for food self-sufficiency, along with the political goal to use all available water in the basin so as to deny it to Israel (Dana (pers. comm.) 2016). Collectively, the agricultural dams and wells use about 253 MCM/y (roughly 82 MCM/y of surface water and 171 MCM/y of groundwater – see Section 4.2). The bulk of this infrastructure is above the 250 m ASL elevation set out in the 1953 and 1987 treaties between Jordan and Syria, and remains a point of contention (see further Section 7.3).

Box 4: The discovery of groundwater in Mukheibeh and the plan of a parallel canal in 1982

The JVA began exploitation of the groundwater in Mukheibeh in 1982, as part of its quest to satisfy growing demand for agricultural and domestic water (primarily for the residents of Amman). The artesian well field developed in Al Sharq al Bared was productive to the point that an irrigation canal was added to support local farms. A local farmer testifies that the development of the scheme served several farmers well, until the 1994 Peace Treaty prohibited further abstractions: 'Since the water was suddenly available and accessible, I began considering growing citrus crops and 370 guava trees. I used to plant crop fields: okra in the summer and such field crops. My land was 38 dunums (geographically dispersed). For six years, I continued growing these crops and the water was flowing at a very good pressure. I even constructed a reservoir to store that water, pumping from the canal and then schedule the irrigation to my land (2,800 m^3). After the [1994] Peace Treaty, the water was diverted to flow in the Yarmouk River and it stopped being channelled through this canal' (Sharif (pers. comm.) 2016). An official from the JVA confirmed that the canal was put out of use following the ratification of the Peace Treaty, as the flows were to 'be added to the discharge of the river and then diverted at Adassiyeh to secure [the] Israeli share' (Sultan (pers. comm.) 2016). As the geological and hydrogeoligical maps (Figures 3.15 and 3.16) reveal, groundwater from the Mukheibeh wells is indeed not used locally, but flows into the Yarmouk riverbed, to be diverted to the KAC or carry on downstream to Israel (refer also to Annex A4.3 and A5.1).

5.3.6 The (ill-fated) Jordanian Karameh Dam

Aware that the Maqaren Dam would not be able to capture all of the floodwater of the Yarmouk, then-Water Minister Haddadin proposed either the Khalid Ibn al Waleed Dam at Mukheibeh (see Section 4.4 and A4.3) or the Karameh Dam at the downstream end of the Jordan River Valley near the Dead Sea (Adelphi 1992, Suleiman 2003). With the negotiations over construction of the Maqaren Dam stalling during the 1980s, Jordanian authorities turned to the idea of building the Karameh Dam – a much easier project, given that it was solely within Jordanian territory. Construction of the dam began in 1992 and was completed in 1997 with a capacity of 53 MCM (JVA 2006). With the Yarmouk and the Zarqa Rivers both fully used by that time, however, the dam has largely remained empty ever since. As Jordanian academic Salameh (2004: 251) states: '[T]hinking of storing the floodwater of the Yarmouk River in the Karameh Dam will certainly deprive the planned Unity [Wehdeh] Dam on the Yarmouk River of its justification, because the discharge of the Yarmouk River will not be enough to fill both dams.' As we will see further in Sections 6.2 and 9, the interplay of Yarmouk flows between the Wehdeh Dam (completed in 1999), the Lake of Tiberias, the King Abdallah Canal and the Karameh Dam is a very political interplay.

Box 5*:* Contrasting British and American hydro-diplomatic efforts

The development of the Yarmouk-Jordan scheme according to the 1952 Bunger Plan effectively supplanted the British role in hydro-diplomacy (which had largely been a 'piecemeal approach', as in the 1939 Ionides Plan – see Box 2). The Bunger Plan also exemplified the increasingly divergent scale and objective of the British and American water experts' plans for the development of the Jordan Valley. For Kingston (1996: 140), it resulted in a 'technical controversy' between the two, documented by criticism of the Bunger Plan by Ionides himself. While the Bunger Plan referred to a 'unified development concept', Ionides dismissed it as 'dogmatic abstraction'. Ionides critiqued the American approach, asserting that it 'could provide a lot of employment for… planners and experts with big desks to work at and more committee tables to sit around. If the refugees could eat paper and drink ink, they would be very well off'. British and American diplomatic approaches harmonised during the US-led Johnston mission, when the British position was to support initiatives on the condition that they were not opposed by the Israelis (FO 1962).

Part III – ANALYSIS

6 The infrastructure

This section evaluates two key components of Yarmouk infrastructure: the Adassiyeh Diversion Weir and the Yarmouk-Tiberias 'water swap'.

6.1 Evaluation of the Adassiyeh Weir

This section investigates the design and functioning of the Adassiyeh Weir. As discussed in Section 5.3.3, the weir's construction in 1999 ended decades of Jordanian reliance on sandbags to partially block and divert the flow into the King Abdallah Canal. It was the result of Paragraph 1 of Article II of the Jordan-Israel Water Annex (which we return to in Section 7.2):

> *Israel and Jordan shall cooperate to build a diversion/storage dam on the Yarmouk River directly downstream of the point 121/Adassiyeh Diversion. The purpose is to improve the diversion efficiency into the King Abdullah Canal of the water allocation of the Hashemite Kingdom of Jordan, and possibly for the diversion of Israel's allocation of the river water* (emphasis added).

Construction of the weir also put an end to the lengthy delays caused by Jordanian-Israeli disagreements over both the sovereignty of Himmeh (Box 2) and the relative share of Yarmouk flos (Annex A5.2). However, the extent to which the infrastructure and institutions that have been developed have actually improved the efficiency of the weir (as Paragraph 1 calls for) warrants further investigation.

6.1.1 The bypass flows

The Jordan Valley Authority has been gauging the river flow at Adassiyeh since at least 1962, and distributing and recording it in different manners as the Adassiyeh Weir and Wehdeh Dam have been brought on-line – as summarised in Table 6.1. The primary dataset employed is JVA (2016b), though this has been checked against JVA (2006) and JVA (2018) – with minor irregularities.

The JVA data in the second-to-left-hand column of Table 6.1 shows a highly variable average of about 120 MCM/y diverted into the KAC by the sandbag and rock weir from the 1960s to the 1990s, though given the measurement devices of the day, the data cannot be considered robust. There is a marked drop from 1994 onwards (the year of the Jordan-Israel Peace Treaty) which continues from 1999 (the year of construction of the Adassiyeh Diversion Weir and of the 'water swap' arrangement detailed in the Water Annex of the 1994 Peace Treaty).

The drop can be explained in part by the apparent reduction in baseflow gauged at Adassiyeh from about 1989 (and especially from 1999) (Figure 3.10), likely reflecting increased Syrian abstractions in the basin upstream. The drop is even more significant when the shift in the way that the JVA managed the river and recorded data from 1999 onwards is factored in. From 1999, flows gauged as entering the KAC included the flow of the artesian Mukheibeh wells (column c), which the JVA had diverted away from the use of local farmers and into the river – see Box 4 and Section A 4.3.). From 2006 – the year of construction of the Wehdeh Dam – the flows gauged by the JVA at the entrance to the KAC further include the flows released from the al Wehdeh Dam. The 'Total flows' going into the KAC from 2006 onwards (in column e) are thus counted based on their three sources (river flow, Wehdeh releases, and Mukheibeh wells), even if they flow physically together.

Table 6.1 Distribution of Yarmouk flows at Adassiyeh (MCM/y). *Source*: JVA (2016).* As discussed in the text, discrepancies are due to measurement error, and poor reliability of the reported data.

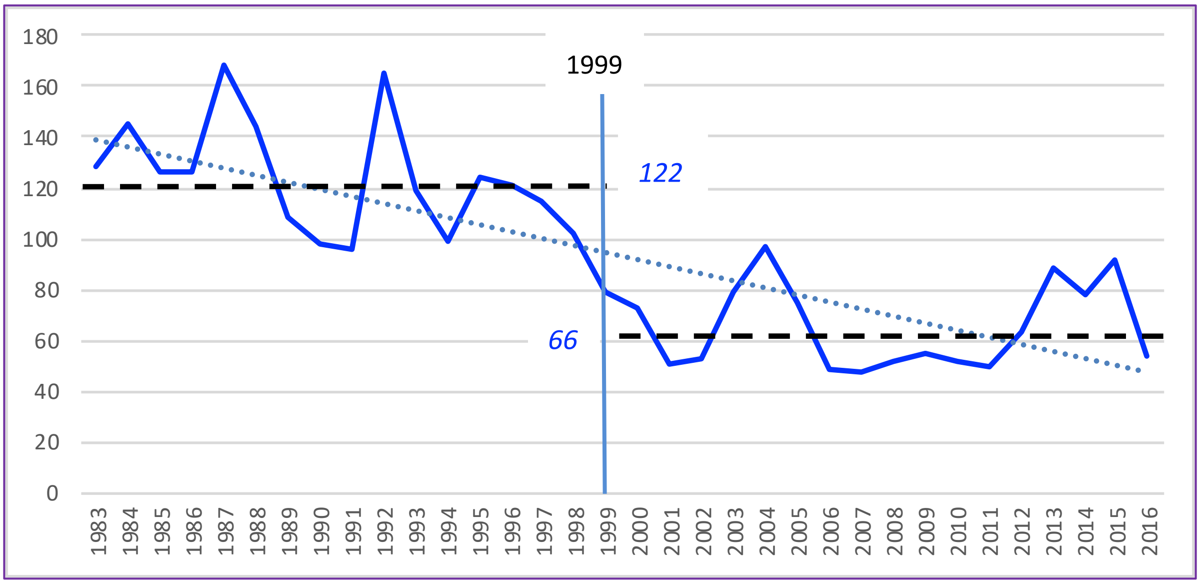
a	b	c	d	e	f	g
Year	Yarmouk flows recorded as diverted into the KAC at Adassiyeh, by sandbar or the AW	Discharge from Mukehibeh Wells used locally (<1995) or diverted into the KAC	Wehdeh releases diverted into the KAC by the Adassiyeh Weir	^ ***Total*** flows *diverted into the KAC*, via sandbar/rock weir/ AW (including Mukheibeh Wells discharge and Wehdeh releases) ('alpha' flows) (JVA 2016)*	^^ Flows *not diverted into the KAC*, because they i) (< 1999) *overspill* the sandbar or rock weir; or ii) (> 1999) overspill or *bypass* the AW, ('beta' flows) (JVA 2016)*	Flows over spilling the AW ('uncontroll ed water') (JVA 2016)*
1962	77.50	nd	nd	nd	nd	nd
1963	93.44	nd	nd	93.44	nd	nd
1964	109.08	nd	nd	109.08	nd	nd
1965	138.94	nd	nd	138.94	nd	nd
1966	133.93	nd	nd	133.93	nd	nd
1967	136.15	nd	nd	136.15	nd	nd
1968	150.54	nd	nd	150.54	nd	nd
1969	97.73	nd	nd	97.73	nd	nd
1970	63.22	nd	nd	63.22	nd	nd
1971	115.86	nd	nd	115.86	nd	nd
1972	149.64	nd	nd	149.64	nd	nd
1973	112.01	nd	nd	112.01	nd	nd
1974	124.57	nd	nd	124.57	nd	nd
1975	125.60	nd	nd	125.60	nd	nd
1976	126.10	nd	nd	126.10	nd	nd
1977	126.78	nd	nd	126.78	nd	nd
1978	128.64	nd	nd	128.64	nd	nd
1979	113.75	nd	nd	113.75	nd	nd
1980	124.23	nd	nd	124.23	nd	nd
1981	128.26	nd	nd	128.26	nd	nd
1982	144.02	nd	nd	144.02	nd	nd
1983	128.56	nd	nd	128.56	nd	nd
1984	145.12	nd	nd	145.12	nd	nd
1985	126.39	nd	nd	126.39	nd	nd
1986	125.92	nd	nd	125.92	109.42	nd
1987	167.90	nd	nd	167.90	179.92	nd
1988	144.35	nd	nd	144.35	184.67	nd
1989	108.12	22.1	nd	108.12	50.84	nd

1990	98.4	23.6	nd	98.4	58.18	nd
1991	95.5	16.9	nd	95.5	66.42	nd
1992	164.9	9.2	nd	164.9	613.34	nd
1993	118.5	16.2	nd	118.5	146.95	nd
1994	99.2	20.6	nd	99.2	67.73	nd
1995	108.0	16.6	nd	**124.6**	68.70	nd
1996	100.8	20.6	nd	**121.4**	55.58	nd
1997	99.7	15.0	nd	**114.7**	57.02	nd
1998	87.3	15.0	nd	**102.3**	62.98	nd
1999	**62.9**	16.3	nd	**79.2**	**28.11**	nd
2000	**54.6**	17.9	nd	**72.5**	**51.27**	nd
2001	**30.4**	19.9	nd	**50.3**	**38.36**	nd
2002	**23.0**	30.1	nd	**53.1**	**58.65**	nd
2003	**54.7**	24.4	nd	**79.1**	**465.42**	418.5
2004	**68.6**	28.8	nd	**97.4**	**172.84**	136.2
2005	**42.6**	32.1	nd	**74.7**	**59.06**	18.1
2006	**14.25**	34.8	nd	**49.1**	**45.05**	2.3
2007	**15.99**	31.8	nd	**47.8**	**35.13**	1.6
2008	**14.90**	30.2	6.9	**52.0**	**30.78**	2.5
2009	**10.59**	29.1	15.3	**55.0**	**40.58**	6.6
2010	**12.67**	27.7	11.5	**51.9**	**33.00**	0.2
2011	**13.65**	25.8	10.1	**49.6**	**32.72**	0.6
2012	**18.52**	27.9	16.8	**63.2**	**51.59**	10.2
2013	**28.32**	25.9	34.3	**88.5**	**76.86**	31.7
2014	**16.04**	23.8	38.7	**78.5**	**33.94**	0.0
2015	**19.00**	23.3	48.9	**91.2**	**32.51**	0.1
2016	**7.52**	23.2	23.2	**53.9**	**34.38**	0.2
Avg. for series	90	28	23	104	99	45
Avg 1986 - 1999				**119 / 107** (if 1987,1988 and 1992 removed)	**125 / 70** (if 1987,1988 and 1992 removed)	
Avg. from:	*1999-2018:* **28**	n/a	n/a	*1986-1999:* **119 / 107** (1987,1988 and 1992 removed) *1999-2016:* **66 / 65** (if 2003, 2004 removed)	*1986-1999:* **125 / 70** (if 1987,1988 and 1992 removed) *1999-2016:* **73** / **50** (if 2003, 2004 removed)	n/a

*Checked against JVA (2006) and JVA (2018), with minor irregularities due to different labels and periods. ^ Column e calculated as: from 1962 to 1995 equal to Column b; from 1995 to 2006 sum of columns b and c; from 2006 to 2016: sum of columns b, c, and d. ^^ Column f includes 'uncontrolled water' (Column g) from 2003. AW= Adassiyeh Weir; *nd*: no data.

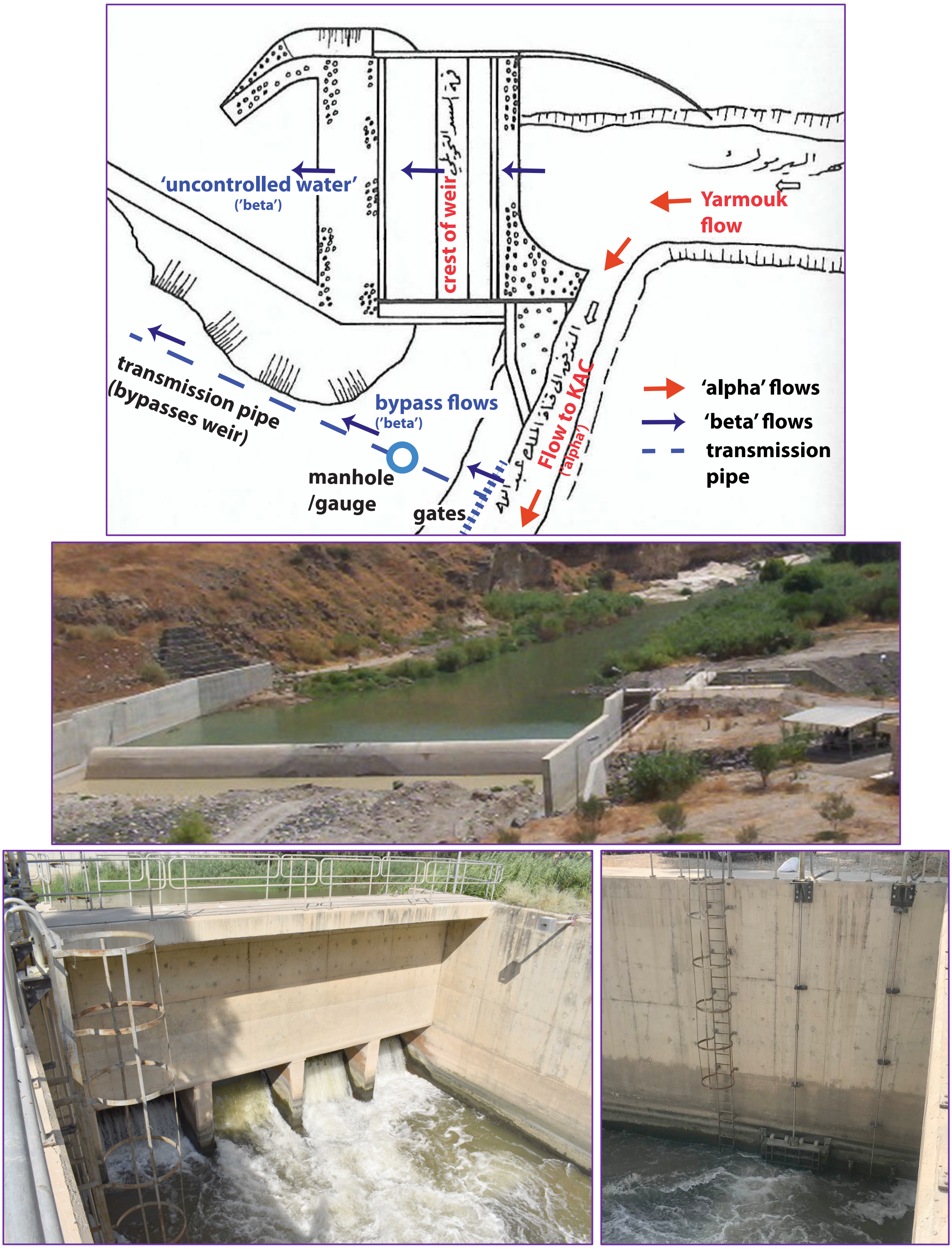
The drop in the flows diverted into the KAC can also be explained in part by the Adassiyeh Weir itself. As seen from Table 6.1 and shown in Figure 6.1, the average flow diverted into the KAC by the Adassiyeh Weir from 1999 to 2016 is 65.9 MCM/y, while the average flow diverted by the rock and sandbag weir in the equal number of years before construction of the Adassiyeh Weir (i.e. from 1983 to 1999) was nearly double, at 121.5 MCM/y.

Figure 6.1 Total Yarmouk flows to the King Abdallah Canal in MCM/y (1983 to 2016), within data limitations discussed in the text. Trendline shows steady decline, though the steady drop around 1994-2001 is more telling. The dashed bars show the average flow before and after construction of the Adassiyeh Weir in 1999 (including flood years). Source: JVA 2016.



As shown in Figure 6.2, the weir blocks the entire flow of the Yarmouk mainstream in order to send the bulk of the flows south into the KAC channel – what the JVA refers to as the 'alpha' flows. Two gates along the channel can be opened to allow some of the flows to byass the weir via a gauged transmission pipe and return to the river bed several dozen metres downstream – referred to as the 'beta' flows by the JVA. During heavy floods (e.g. years 1992 and 2003), the mainstream can spill over the crest of the weir and continue into the river channel – referred to as 'uncontrolled water'.

Figure 6.2 The Adassiyeh Diversion Weir. Top: sketch adapted from Haddadin 2007: 289, with labels referenced to JVA (2016b). Middle: looking Northeast – showing the crest on the left, the channel towards the KAC on the right, and the flushing channel in between (*Source*: unknown, Feb 2002). Bottom left: looking north - 'Alpha' flows diverted to the KAC through the channel, with remote gauge shown on top right (*Source*: Zeitoun, September 2018). Bottom right: looking west - two gates (one open) for 'beta' flows to bypass the weir (*Source*: Quba'a, September 2018).



The limit of flow diverted to the KAC was established by the Water Authority of Jordan at 10-14 m^3/s (441 MCM/y),[18] out of concern for excess turbidity that it would have to treat to provide drinking water. This limit is controlled by an additional set of gates about 50 metres downstream of the KAC offtake (not shown in Figure 6.2) (Joubran (pers. comm.) 2017) (Ghureir (pers. comm.) 2018). The physical limit that the Adassiyeh Weir can divert into the KAC is 3m3/s (94 MCM/y), and, as with most weirs, the volume of the flow diverted varies with changes in the depth and velocity of the streamflow (Joubran (pers. comm.) 2017). As Table 6.1 shows, the the flows spilling over the crest are frequently substantial.

In accordance with the Water Annex of the 1994 Jordan-Israel Peace Treaty that laid the institutional foundation for the construction of the weir five years later (and as will be examined in detail in Section 7.1), the operators of the weir ensure that a minimum of 1m3/s flows through the two gates for use by Israel (Ghureir (pers. comm.) 2018). This is roughly 32 MCM/y, or the equivalent of the 25 MCM/y agreed in the Water Annex, plus an additional amount (about 28%) to make up for evaporation or seepage losses in order to ensure that 25 MCM/y is delivered at the Israeli border) (Ghantous, pers. Comm. 2018). As the JVA data in the right-hand column of Figure 6.1 shows, roughly 75 MCM/y bypasses or overspills the weir (and is counted by the JVA as 'beta' flows, but presumably includes the 'uncontrolled water') though the gates. This is more than double what the Jordanian side has committed to, and is generally expected to carry on downstream, but requires yet further investigation.[19]

6.1.2 Analysis

A deeper look of the design and operation of the Adassiyeh Weir reveals three points of note. First, the size of the offtake to the KAC has decreased in scope over the decades. In the 1952 draft of the Syrian-Jordanian Yarmouk Treaty, it was conceived to accommodate 505 MCM/y (16 m^3/s) (FO 1952). This dropped to 277 MCM/y in the 1953 Baker-Harza Plans[20] (Baker-Harza 1953: 24), and increased to 631 MCM/y in the 1979 Harza Plan[21] (Harza 1979: 4). The current design limit of the weir is 441 MCM/y (14 m^3/s) to prevent excess turbidity for the flows destined for drinking water.

Second, the decreased flow into the KAC (Figure 6.1) is a real concern to all the users of these flows, whether these are households in Amman or farmers in the Jordan River Valley. Of particular relevance here here is that the

[18] In contrast, the 1979 Harza Jordan River Stage II project had suggested controlled releases and a maximum diversion of 20m^3/s (630 MCM/y) (Harza 1979: 11, Haddadin (pers. comm.) 2017).

[19] The estimate of flows going downstream from 1982-89 is 96 MCM/y, based on declassified US State Department records for this period. Sosland (2007: Table 4-6) states that Israel was able to pump about 45 MCM/y, though Abed (2017) states Israeli capacity to pump 142 MCM/y (4.5 m^3/s)). The JVA spreadsheet JVA *2006* shows average 'Beta' discharge 1990-2003 = 105 MCM/y (or 63 MCM/y if the very wet year 1992 is removed) – see Tab 'F90to2003' in the dataset. 'Beta' is indicated as 'To Tiberias' on Tab '90'. Note that 'Beta (over crest)' values are not included in the analysis and are considered equivalent to 'uncontrolled water' of JVA (2016b), as shown in Table 6.1. The flow gauged at Adassiyeh station decreased by 83% from roughly 229 MCM/y for the period of 1979-1988 to roughly 40 MCM/y for 2008-2015 (Section 3.2.3 and Table B 3.1). JVA data gauged at the Adassiyeh Weir show that 58.3 MCM/y on average entered the KAC while 52.3 MCM/y was released through the bypass gates (Table 6.1). The different rates are attributed to the different periods considered as well as the accuracy in gauging and reporting (generally considered to be more reliable at the Adassiyeh Weir).

[20] The report does not specify the intake structure for the EGC, but states that 'The entire 277,000,000 cubic metres of required annual storage release for the East Ghor can be obtained from the Yarmouk itself' (Baker-Harza 1953: 24).

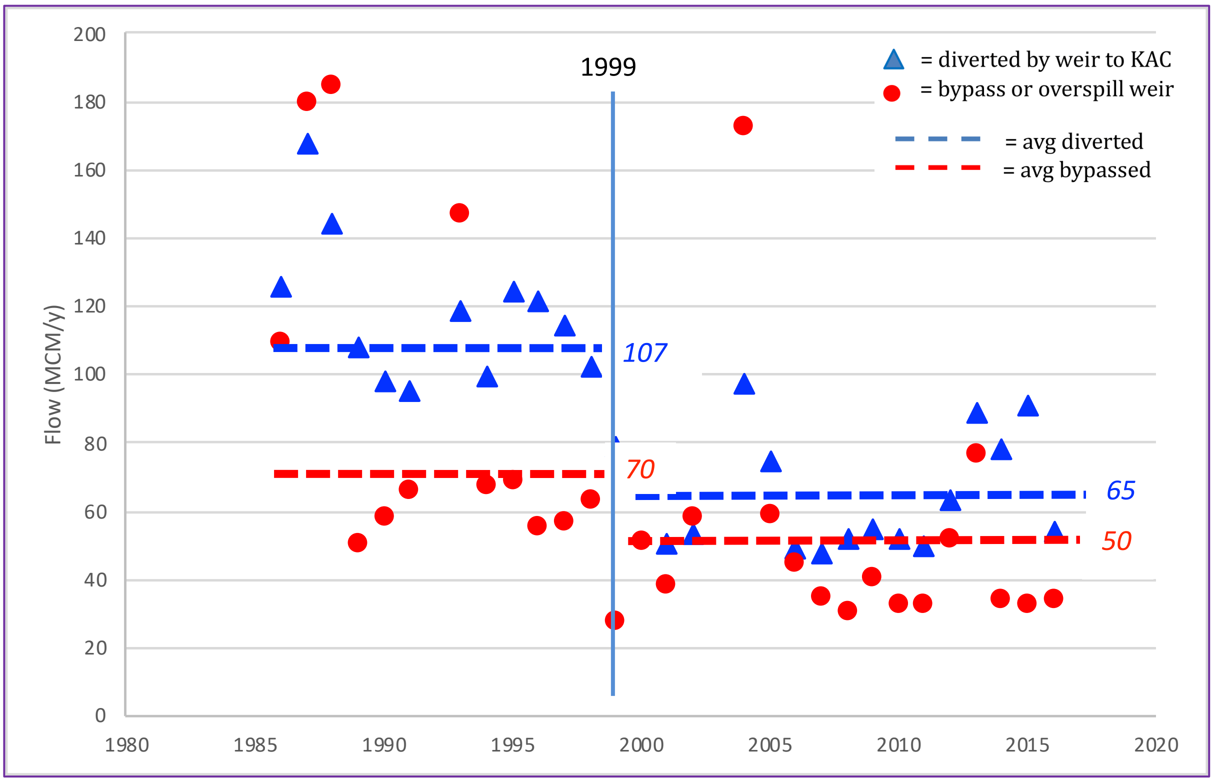
[21] To meet what Harza thought would be the design capacity of the East Ghor Canal (i.e. 20 m^3/s).

increased flow into and released from the al Wehdeh Dam (see Figure 3.13) that followed the start of the Syria crisis in 2011 was not reflected by a corresponding increase into the KAC.

Third, the drop in flows into the KAC before and after the construction of the Adassiyeh Weir does not affect the bypass flows in a relatively equal amount. As discussed, the KAC had about 65 MCM/y on average diverted into it in the 18 years period from the year that the weir was built (1999) until 2016 (when the flood years are excluded form the analysis), which is considerably lower than the 107 MCM/y diverted into it from 1986 to 1999 (1986 being the first year for which data on the bypass flows is available).

The flows that *bypass* or overspill the weir have during the same periods dropped from 70 MCM/y to (only) 50 MCM/y (when flood years are excculded), or from 125 MCM/y to 73 MCM/y when flood years are included. The dynamic is attributed in part to the agreement on the exchange of flows between Jordan and Israel, as explored in the following section.

Figure 6.3 Flows diverted to and bypassing the KAC (1986-2016), shown on either side of 1999 – the year of completion of the Adassiyeh Diversion Weir (flood years excluded), within data limitations discussed in the text. When flood years are included, the average flows bypassing the weir before 1999 is 125 MCM/y, and 73 MCM/y after it. (The range from 1986 – 2016 is different than the range of Figure 6.1 (1983 – 2016) and was chosen because 1986 is the first date for which data on flows bypassing the weir are available). *Source*: JVA (2016b).



6.2 Evaluation of the Yarmouk-Tiberias 'water swap'

A key feature of the Water Annex of the 1994 Jordan-Israel Peace Treaty is the 'water swap' that was to use the Lake of Tiberias to store 25 MCM/y from the Yarmouk and return 20 MCM/y to Jordan into the King Abdallah Canal (see Section 7.2). The formula is laid out in Article I, Paragraph 1:

1. Water from the Yarmouk River

a. Summer period - 15th May to 15th October of each year. Israel pumps (12) MCM and Jordan gets the rest of the flow.

b. Winter period - 16th October to 14th May of each year. Israel pumps (13) MCM and Jordan is entitled to the rest of the flow subject to provisions outlined herein below: Jordan concedes to Israel pumping an additional (20) MCM from the Yarmouk in winter in return for Israel conceding to transferring to Jordan during the summer period the quantity specified in paragraphs (2.a) below from the Jordan River.

c. In order that waste of water will be minimized, Israel and Jordan may use, downstream of point 121/Adassiya Diversion, ***excess flood water*** *that is not usable and will evidently go to waste unused.* (emphasis added).

This section examines the water-swapping arrangement, nesting it within the flows possibly diverted as Israeli allocation (of Article II, Para 1 seen in Section 6.1), and paying particular attention to the 'excess flood water' detailed in the first article.

6.2.1 How the Yarmouk-Tiberias water swap works

Adapted from an information board outside of the Beit Zera Reservoir, Figure 6.4 explains one part of the 'water swap' arrangement: the flows that are 'returned' to Jordan (into the KAC) from the Lake of Tiberias.

What the public information board does not show is the first half of the arrangement, or the flows pumped from the Yarmouk river via the Yarmoukim reservoir and onto to the Lake of Tiberias (see Figure 6.5) Operational since 01 October 1993, the Yarmoukim Reservoir and Pumping Station is run by the Jordan Valley Water Association (JVWA), which was established as a result of the Yarmouk Triangle farmers lobbying for a consistent supply of Yarmouk flows, and which remains semi-independent from Israel's main water provider, Mekorot (see Annex A3.3).

The Yarmoukim Reservoir has a storage capacity of 750,000 m^3 and four pumps each with a capacity of 6,500 m^3/h, or 56.9 MCM/y. The combined total maximum design pumping capacity is 16,000 m^3/h (as the design restricts all pumps from operating in parallel) (Nathan (pers. comm.) 2017a)). Equivalent to 140 MCM/y, the maximum pumping capacity is well beyond the average of flood flows bypassing or overspilling the Adassiyeh Weir (74.7 MCM/y including flood years, from Table 6.1).

The Yarmoukim Reservoir pumping configuration explains the abrupt end of the flow of the Yarmouk tributary, as shown in Figure 6.5. A JVWA staff member at the Yarmoukim Reservoir confirms: 'Today, the Yarmouk has been diverted into that big pond. *For all intents and purposes, that is the end of the Yarmouk*' (Nathan (pers. comm.) 2017b).

Figure 6.4 Information board at the Beit Zera pumping station showing water supplied by Israel to Jordan, or half of the Yarmouk-Tiberias 'water swap'. The English part of the sign states: 'Water Supply to the Hashemite Kingdom of Jordan according to the Peace Treaty from 1994. Operation Year: 1995; Source of the Water: Upstream Deganya Dam; Daily Quantity: 200,000m^3; Annual Quantity: 55 million m^3.' The figure does not show the rest of the Yarmouk-Tiberias water swap, whereby Israel receives water from the Yarmouk for pumping to the Lake of Tiberias and for local use. *Source*: Muna Dajani.

Figure 6.5 Top: The Yarmoukim Reservoir and the termination of the Yarmouk riverbed (red circle): the 'end of the Yarmouk'. *Source*: Adapted from Google Earth. Bottom: The reservoir, and motors of the four pumps that abstract from the Yarmouk. *Source*: Authors.

6.2.2 Yarmouk flows used in and returned by Israel

The Israeli JVWA records shown in Table 6.2 are used to complement the Jordanian JVA data of Table 6.1. Table 6.2 shows that an average of 18.6 MCM/y has been pumped from the Yarmoukim Reservoir into the Lake of Tiberias from the start of its operation in 1985 until 2015 (and 19.3 MCM/y from 1999-2015).[22] The table also shows that JVWA pumps an average of 16.1 MCM/y (1985-2015) (and 15.6 MCM/y from 1999-2015) out of the Yarmoukim Reservoir for use by local kibbutzim (including Sha'ar Golan, Masada, Ashdot Ya'akof Meuhad and Ashdot Ya'akov Ihud, and Naharayim (Baqura)).[23] JVA data shows that an average of 46.6 MCM/y is received at the KAC (from 1999-2016) via Beit Zera, mostly during the summer months. In summary, roughly 71 MCM/y are used in Israel and 47 MCM/y received by Jordan, for a difference of 27 MCM/y (the significance of which is put into context following).

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[22] The volume is consistent with Article 1 of the Water Annex, and corresponds roughly with the HSI records for receiving flows (20.8 MCM/y for the period 1995-2015), apart from the shift in record-keeping around 1995, from hydrological (winter-summer) to calendar years (HSI 2016b, HSI 2016a).

[23] According to the JVWA data, flows for these kibbutzim came from various sources until 1993, after which point they are indicated to originate from the Yarmoukim Station.

Table 6.2 Distribution of Yarmouk flows after Adassiyeh, showing balance of the Yarmouk-Tiberias 'water swap' (MCM/y) within data limitations. *Sources*: as noted; *nd*: no data. As discussed in the text, discrepancies are due to measurement error, poor reliability of the reported data, and non-calibration of different datasets.

Year	^***Total*** flows *diverted into the KAC*, via sandbar/rock weir/ AW (including Mukheibeh Wells discharge and Wehdeh releases) ('alpha' flows) (JVA 2016)*	Flows *not diverted into the KAC*, because they i) (< 1999) *overspill* the sandbar or rock weir; or ii) (> 1999) overspill or *bypass* the AW, ('beta' flows) (JVA 2016)*	Pumped from Yarmouk to Tiberias (HSI 2016b)	Total JVWA pumping from Yarmoukim Reservoir^ (JVWA 2016)	JVWA pumping from Yarmoukim Reservoir to Tiberias (JVWA 2016)	JVWA pumping from Yarmoukim Reservoir to nearby kibbutzim (JVWA 2016)	Flows received into KAC downstream of Adassiyeh via Beit Zera Reservoir (JVA 2016)*
1962	77.50	nd	nd	nd	nd	nd	nd
1963	93.44	nd	nd	nd	nd	nd	nd
1964	109.08	nd	nd	nd	nd	nd	nd
1965	138.94	nd	nd	nd	nd	nd	nd
1966	133.93	nd	nd	nd	nd	nd	nd
1967	136.15	nd	nd	nd	nd	nd	nd
1968	150.54	nd	nd	nd	nd	nd	nd
1969	97.73	nd	nd	nd	nd	nd	nd
1970	63.22	nd	nd	nd	nd	nd	nd
1971	115.86	nd	nd	nd	nd	nd	nd
1972	149.64	nd	nd	nd	nd	nd	nd
1973	112.01	nd	nd	nd	nd	nd	nd
1974	124.57	nd	nd	nd	nd	nd	nd
1975	125.60	nd	nd	nd	nd	nd	nd
1976	126.10	nd	4.3	nd	nd	nd	nd
1977	126.78	nd	6.8	nd	nd	nd	nd
1978	128.64	nd	13.1	nd	nd	nd	nd
1979	113.75	nd	29.8	nd	nd	nd	nd
1980	124.23	nd	4.5	nd	nd	nd	nd
1981	128.26	nd	4.7	nd	nd	nd	nd
1982	144.02	nd	17	nd	nd	nd	nd
1983	128.56	nd	31.1	nd	nd	nd	nd
1984	145.12	nd	30	nd	nd	nd	nd
1985	126.39	nd	25.8	nd	25.4	21.1	nd
1986	125.92	109.42	54.4	nd	24.4	16.4	nd
1987	167.90	179.92	18.2	nd	13.4	19.1	nd

1988	144.35	184.67	20.2	nd	3.2	18.5	nd
1989	108.12	50.84	28.3	nd	18.3	22.6	nd
1990	98.4	58.18	32.5	nd	26.0	22.0	nd
1991	95.5	66.42	33.7	nd	32.2	13.9	nd
1992	164.9	613.34	6.8	nd	11.1	11.3	nd
1993	118.5	146.95	17.8	6.9	4.3	16.3	nd
1994	99.2	67.73	8.9	30.8	18.9	12.0	nd
1995	108.0	68.70	21.8	25.0	9.5	15.6	21.8
1996	100.8	55.58	26.9	40.8	26.5	14.3	30.8
1997	99.7	57.02	26.2	47.3	28.3	19.1	47.4
1998	87.3	62.98	10.6	38.3	20.5	17.8	55.9
1999	62.9	28.11	20.8	22.9	10.4	12.6	41.9
2000	54.6	51.27	20.7	40.9	24.9	16.0	54.5
2001	30.4	38.36	34.3	36.5	23.3	13.1	45.4
2002	23.0	58.65	43.8	48.3	35.4	12.9	51.1
2003	54.7	465.42	22.0	59.4	48.0	11.4	53.4
2004	68.6	172.84	31.1	33.4	18.9	14.5	50.2
2005	42.6	59.06	25.0	42.0	26.9	15.1	47.0
2006	14.25	45.05	17.1	39.6	24.2	15.4	53.1
2007	15.99	35.13	8.7	30.3	14.7	15.6	43.4
2008	14.90	30.78	15.3	25.9	10.2	15.6	42.1
2009	10.59	40.58	14.2	29.6	16.5	13.1	42.2
2010	12.67	33.00	10.9	27.2	10.5	16.7	45.5
2011	13.65	32.72	16.1	26.8	11.6	15.2	43.6
2012	18.52	51.59	20.2	34.1	17.8	16.3	48.4
2013	28.32	76.86	4.5	37.1	17.2	19.9	52.9
2014	16.04	33.94	nd	27.2	8.8	18.4	55.1
2015	19.00	32.51	nd	27.8	9.0	18.7	48.3
2016	7.52	34.38	nd	nd	nd	Nd	51.9
Avg. for series	90	99	21	34	19	16	46
Avg. from:	*1999-2016:* **28.2**	*1999-2016:* **74.7** / **52.3** (if 2003 removed)	*1995-2016:* **20.5**	*1995-2016:* **35.7**	*1995-2016:* **19.3**	**15.6**	*1995-2016:* **46.6**

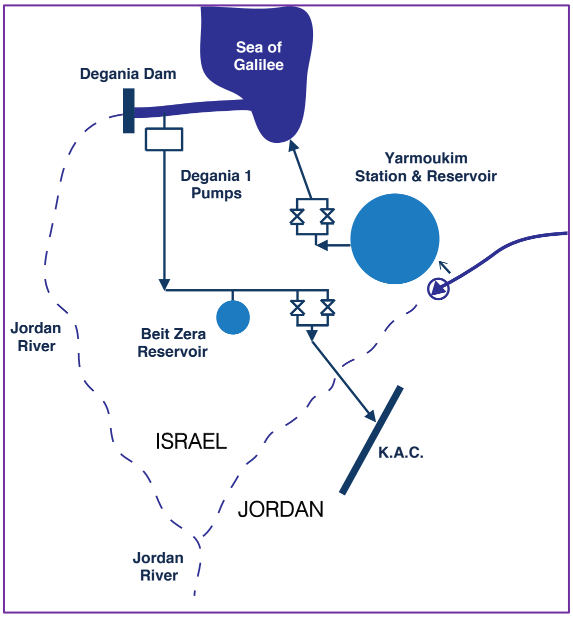
*Checked against JVA (2006) and JVA (2018), with minor irregularities due to different labels and periods. ^ Total pumping from the Yarmoukim Reservoir is not identical to sum of pumping to Tiberias plus pumping for local kibbutzim, because of minor changes in JVWA pumping regime.

6.2.3 Analysis of the Yarmouk-Tiberias water swap

There are several features to note from the intricate function of the infrastructure and institutions that make up the Yarmouk-Tiberias water swap. The first two relate to the accuracy and completeness of the public information board (Figure 6.4). The board mis-represents the flow of the Jordan River by the width of its line, for instance. From well before the signing the treaty (and until today), the flow of the Jordan River from Tiberias downstream of the Degania Dam is effectively nil. As Israeli HSI data confirms, the first release of flows was 7.7 MCM/y in 2013/14 (HSI 2016b), the result of a national water surplus generated by large-scale desalination on the coast. Apart from these recent releases, the only flow in the Jordan River after the Degania Dam comes from diverted saline springs and wastewater from the city of Tiberias.

The public information board also shows that the flow of the Yarmouk reaches the confluence with the Jordan. Yet satellite imagery (figure 6.5) confirms what field observation and the operators of the Yarmoukim Reservoir know: *all* of the flow that has found its way past the Adassiyeh Weir is pumped by the Israeli JVWA into the reservoir, apart from exceptionally large flood years (as in 1992 but not 2003). Part of the reason for the volume of pumping may be the desire not to 'waste' any of the flows, as stated in the Water Annex of the Peace Treaty. A JVWA staff member at Yarmoukim Station confirms the logic behind the political agreement: '[Letting the river flow past] is an absolute taboo, I can't let this happen' (Nathan (pers. comm.) 2017a). In fact, and as shown in Figure 6.5, the Yarmoukim pool truly has become 'the end of the Yarmouk' river. With this data in mind, a broadened and more accurate diagram of water use in this area is proposed for the public information board in Figure 6.6.

Figure 6.6 A more complete sketch of the Yarmouk-Tiberias 'water swap', based on the Beit Zera public information board. The sketch emphasises the pumping from the Yarmouk into the Lake of Tiberias, as well as the effective ends of both the Lower Jordan River and Yarmouk tributaries. *Source*: Authors.



Considered alongside Yarmouk use in Israel, the investigation of the Yarmouk-Tiberias water swap first of all confirms that there is little to no flow in the Yarmouk downstream of the Yarmoukim reservoir.

A second point to note relates to the floodwater that is reserved solely for Israeli use, as summarised in Figure 6.7 and discussed below. The Jordanian JVA data of Tables 6.1 and 6.2 show that from 1999-2015, roughly 75 MCM/y bypassed the Weir and KAC (or 52 MCM/y if the flood years 1992 and 2003 are discounted). The Israeli JVWA data shows that the local water authority uses on average 35.7 MCM/y during the same period (including flood flows). The discrepancy between the two sets of data – 39.3 MCM/y – is not readily accounted for, and may most likely be attributed to differences in the datasets stemming from the gauging data, or difficulties in accurately gauging the heavy floods that overspill the weir.[24] As discussed in the following section, the sole Israeli use of such flows appears to contradict the terms of Annex II of the 1994 Jordan-Israel Peace Treaty, which states that the 'excess floodwater' should be available to both parties (and see concurrence in Haddadin (2002: 289).

There is further discrepancy with the agreement signed. The Water Annex stipulates that Israel is to receive 45 MCM/y from the Yarmouk (25 as stated above from Article 1, Para 1, plus an additional 20 per Article 1, Para 2), and to send 20 MCM/y back. Yet Israeli JVWA data shows that Israel uses 35 MCM/y on average (10 MCM/y less) and sends 47 MCM/y (27 MCM/y extra) back. While the discrepancy with the first figure (of 27 MCM/y) is attributed to the sources previously discussed, the discrepancy with the second figure may be explained by the JVA method of accounting.

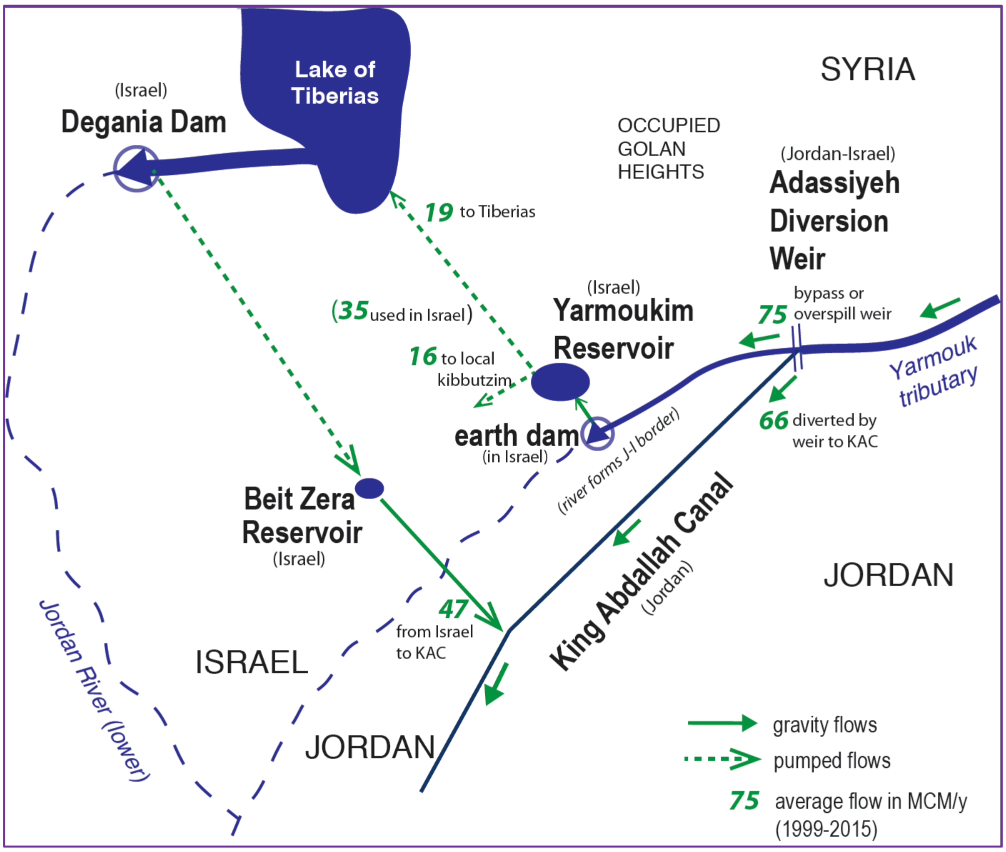
Data from the Jordanian Jordan Valley Authority and interviews provide the context. The records and interviews (JVA, 2006; Abed (pers. comm.), 2017; JVA, 2017; Ghureir (pers. comm.), 2018) demonstrate that the flows are accounted for from four different 'sources'. This includes a steady 25 MCM/y promised by then Israeli PM Ariel Sharon to King Hussein in 1997 (labelled by the JVA as "Additional"[25]; a steady 10 MCM/y labelled "Desalination", even if it is freshwater from Tiberias; additional flows that Jordan allows to bypass the Adassiyeh Weir (labelled "Concession", and *not* counting the flood or overspill flows that make up the rest of the 'Beta flows', in practice varying from 2 to maximum 20 MCM/y); and water that Jordan purchases from Israel (labelled "Sold water", theoretically up to 20 MCM/y and in practice varying from 0-16 MCM/y). The additional 27 MCM/y may also be composed of part of the additional 40 MCM/y that Israel agreed to provide in the March 1998 addendum (see footer of Table 3 and Haddadin (2002: 438)).

Israel also uses a grossly estimated 5 MCM/y from the four dams in the Occupied Syrian Golan Heights (Section 4.3, retention capacity 10 MCM/y), roughly 2 MCM/y from the wells at Meitsar (HSI 2016a: 352), and 14 MCM/y (1987-2010) of spring discharge at Hamat Gader (HSI 2016a: 353). Alongside the 35 MCM/y that the JVWA data shows is pumped from the Yarmoukim Reservoir, the total Israeli use of Yarmouk flows is 56 MCM/y. Israel has thus secured nearly double the 25 MCM/y that its Yarmouk Triangle farmers had long been lobbying for (see Section 5.3.2), in large part by virtue of the design of the Adassiyeh Weir and the infrastructure and institutions of the Yarmouk-Tiberias water swap.

[24] The JVA data of the right-hand column in Table 6.1 is consistently much greater than the agreed volume that the operators of the Adassiyeh Weir assert (i.e. 1m3/s (32 MCM/y). The JVWA data is consistent with what the operator of the Yarmoukim Station asserts (i.e. roughly 36 MCM/y total pumping), a volume that is well within the pumping capacity of one of the four pumps at the station. The difference of 39 MCM/y (75-36) may thus be explained by difficulty in accurately measuring the flood flows that overspill the weir, or inconsistent and uncalibrated gauging records.

[25] Sharon's promise of 25 MCM/y may be in partial fulfillment of the "additional 50 MCM/y of Artice II, Para 3 – see Shamir (2003a: 12).

Figure 6.7 Flows related to the Yarmouk-Tiberias 'water swap' (average in MCM/y, from 1999 – 2015). Related to Table 6.2. Includes heavy flood year of 2003. The difference between the flows bypassing the Adassiyeh Weir and the flows pumped from the Yarmoukim Reservoir reflects differences in the datasets. *Source*: Prepared by the authors from JVA and JVWA data.



The sole use of the overflow is reminiscent of Johnston's 'double accounting' of return flows when allocating the basin based on irrigable land. Phillips et al. (2007a: 30) note how it was understood, if not explicitly stated, that such return flows would flow to Israel for its use.[26] Both findings are relevant to any sort of diplomatic intervention, and lead to questioning of the sustainability of current arrangements.

Furthermore, it would seem that the intent of the original 1920 Franco-British Convention is fulfilled, in a way. As shown in Annex A6.1, that convention called for the government of France to 'give its representatives the most liberal instructions for the employment of the surplus of these waters for the benefit of Palestine' (Baxter 1977: 77), with the benefit being (now) for Israel.

A final point to question about the Yarmouk-Tiberias water exchange is its logic. The rationale of storing winter floods in the Lake of Tiberias and releasing them during the dry summer months was hydrologically sound when it was originally developed in the 1950s. Such over-winter storage is less necessary, however, with the great intensification of agriculture along the KAC and the construction of the Wehdeh Dam upstream, and the Karameh Dam downstream. Without the benefit of a feasibility study, it would appear more efficient that the excess floodwater (or an agreed portion of it)

[26] Meaning an effective Johnston allocation of 616 MCM/y, rather than the 394 or 400 MCM/y that Phillips et. al. (2007b) show most authors cite.

were pumped back into the KAC directly from the Yarmoukim Reservoir for use in Jordan, rather than be pumped the distance to the Lake of Tiberias and back again via the Beit Zera Reservoir.

It would be yet more efficient to change the design or operational arrangement of the Adassiyeh Weir, so that more of the flood flows would be diverted into the KAC. The extent of agricultural development along the KAC may ensure a demand for 'all' of the flows, while the Karameh Dam (or an improved version of it) would be ready to capture any flows that might be considered to be in excess (see Section 5.3.6). Such an arrangement could i) save energy and pumping costs by relying on gravity; ii) reduce evaporation losses from storage in the Lake of Tiberias (for which the total (for Yarmouk and other flows) is estimated at 235 MCM/year (HSI 2016b: 448)); and iii) ensure that Jordan also benefits from the years of good or even heavy rains. The arrangement is also similar to the argument first advanced by the Transjordan authorities to use the excess flows not used by the Palestine Electrical Corporation hydroelectric dam in 1939 (a small Yarmouk development scheme related to Wadi Yabis, as part of the Ionides Plan), as well as of the current plans for Israel to provide an additional 50 MCM/y to Jordan for transmission to Irbid Governorate (in exchange for 60 MCM/y of desalinated flows that Jordan will provide to Aqaba as part of the Jordan Red Sea Project (Hussein*, et al.* 2017)).

7 The agreements

7.1 The Yarmouk agreements compared to the model

Table 7.1 compares the two bilateral treaties on the Yarmouk to the provisions of the Model Treaty shown in Table 2.1, and the PLO-Israel Oslo II water agreement.

Table 7.1 The three bilateral agreements related to water sharing in the Jordan River Basin, compared with the clauses of a model treaty. *Sources*: Based on (Hayton*, et al.* 1989, UNECE 1992, Fischhendler 2008, Rieu-Clarke*, et al.* 2012, Zentner 2012, UNECE 2013, Dinar*, et al.* 2015).

Features of a Model Transboundary Water Agreement	**1987 Jordan-Syria**	**1994 Jordan-Israel**	**1995 PLO-Israel**[27]
Allocative mechanisms			
Based on 'equitable and reasonable use'	**No**	**No**	**No**
Specific, rather than ambiguous	**Yes**	**No**	**Yes**
Flexible, rather than rigid	**No**	**No**	**No**
Technical mechanisms (related to e.g. conjunctive groundwater and surface water)			
Acknowledgement of surface water and groundwater as part of the same transboundary watercourse	**No**	**No**	**No**
Adequate accounting for use, amount and quality of groundwater in reserve, and rate of its replenishment	**No**	**No**	**No**
Common identification, delineation and characterisation of transboundary groundwater	**No**	**No**	**No**
Appropriate measures to prevent, control and reduce the pollution of transboundary groundwater	**No**	**No**	**No**
Comprehensive water accounting (including for use, amount and quality of soil water, and gains made through improvements in irrigation efficiency/in the 'paracommons')	**No**	**No**	**No**
Uncertainty Mechanisms (related to changes in needs, climate, etc.)			
Revisiting clauses	**No**	**No**	**No**
Escape clauses	**No**	**No**	**No**
Institutional mechanisms			
'prior notification'	**No**	**Yes**	**No**
'no significant harm'	**No**	**No**	**No**
Enforcement clauses	**No**	**No**	**No**
Monitoring provisions	**No**	**No**	**No**
Dispute resolution mechanisms	**No**	**No**	**No**
Self-enforcement mechanisms	**No**	**No**	**No**
Multilateral bodies for information exchange or management	**Yes**	**Yes**	**Yes**
Environmental and health concerns			
Water-quality provisions	**No**	**Yes**	**No**
Biodiversity, river base flows, etc.	**No**	**No**	**No**

[27] A detailed analysis of the water clauses signed by the PLO and Israel in 1995 lies beyond the scope of this project.

7.2 Evaluation of Annex II of the 1994 Jordan-Israel Peace Treaty

Annex II of the 1994 Jordan-Israel Peace Treaty features the water clauses that proscribe the water-sharing arrangement between Jordan and Israel. The Annex has been heralded as a significant achievement, in particular for securing Israeli recognition of Jordanian 'rightful allocations',[28] after decades of contestation and violence (see e.g. Al-Kloub*, et al.* 1998, Shamir 1998, Haddadin 2002b, Shamir 2003b, Wiczyk 2004, Meisen*, et al.* 2011, Choudhury 2017, Yasuda*, et al.* 2017). Critics of the treaty approach it from political and economic angles (e.g. Baim 1997, Kubursi*, et al.* 2011, Talozi*, et al.* submitted 2018), with one suggesting the large number of 'creative compromises' made by Jordan ensured that it ended up well short of the Johnston allocation that the state had long been lobbying for (Sosland 2007: 175). Beaumont (1997) asserts that the water given up by Jordan was for gains in other spheres, or that Jordan exchanged water for peace, in other words.

One virtue of the Water Annex is its consideration of water quality (Article III), both for calling for the protection of the resource against pollution and for proposed desalination of the saline flows diverted from the Lake of Tiberias. It is also relatively strong on institutional mechanisms, specifying a six-month warning period of any projects that might affect the other signatories (Article V),[29] establishing a Joint Water Committee, and proposing the committee as the forum for discussion on prevention of harm and mitigation of adverse effects of any project. It is also forward looking, in the sense that it holds for Jordan a clause that both sides develop an additional 50 MCM/y.

The water clauses are wanting in many other ways, however. As shown in Table 7.1, few of the clauses one would expect to see in a model water agreement can be found. For instance, groundwater is mentioned in relation to Israel securing its pumping in Wadi Araba, but not considered for its hydraulic connections or conjunctive management with surface water within the Jordan River Basin. There is also no scope for dealing with changed circumstances, be they related to conflict, climate change or increase in 'new water' such as wastewater reuse and desalination (particularly pertinent for Israel, due to the high production levels). And despite the fact that the water treaty with Israel was doubly important for the Government of Jordan (because of the constricting agreement it had signed with Syria six years earlier, and the lack of progress on construction of the Maqaren Dam), it appears to remain some distance from securing for Jordan an 'equitable and reasonable' share of the Jordan River waters, or even of the Yarmouk tributary flows. This is in large part due to the ambiguous allocation mechanism.

7.2.1 An overly specific and yet ambiguous allocation mechanism

The allocation clauses in Article I of Annex II of the 1994 Jordan-Israel Peace Treaty are very complex and not equal in measure, at least on paper. Varying from very specific to very ambiguous, the clauses detail how Jordan is:

[28] As stated in the text of the main treaty, not in the water Annex II.

[29] As Beaumont (1997: 416) points out, however, the fact that Israel had no more projects to develop effectively means that the clause applies only to Jordan.

i) to receive 20 MCM/y from Israel in the summer from the Lake of Tiberias (Art. I.2a);

ii) entitled to 10 MCM/y of desalinated salt springs diverted by Israel away from Tiberias (or freshwater until the desalination project is complete) (Art. I.2d);

iii) entitled to use an average of 20 MCM/y of 'floods' downstream of the confluence of the Yarmouk with the Jordan (i.e. from the Jordan mainstream, not the Yarmouk) (Art. I.2b);

iv) entitled to a quantity equivalent to Israeli use of the Jordan River downstream from the Yarmouk to the edge of the West Bank (Art 1.2c);

v) to receive 'an additional quantity of (50) MCM/year' from an unspecified source ('Israel and Jordan shall cooperate in finding sources for the supply to Jordan of an additional quantity of (50) MCM/year of water of drinkable standards' Art. I.3); and

iv) entitled to use (with Israel, as previously noted) the 'excess flood water' from the Yarmouk downstream of the Adassiyeh diversion, after Israel takes 25 MCM/y ('*In order that waste of water will be minimized, Israel and Jordan may use, downstream of point 121/Adassiyeh Diversion, excess flood water that is not usable and will evidently go to waste unused*' - Art. I.1c).

Annex II also stipulates that Israel:

i) will continue to withdraw 25 MCM/y (12 MCM from 15 May to 15 October, and 13 MCM from 16 Oct to 14 May) (Art. I.1.a,b);

ii) can pump an additional 20 MCM/y from the Yarmouk (Art. I.1b);

iii) is entitled to maintain its current uses of the Jordan River waters from the Yarmouk confluence to the northern border of the West Bank (Art. I.2c);

iv) is to retain (and increase pumping from) its wells inside Jordan in the Wadi Araba (Art. IV.1,3); and

v) is entitled to use (with Jordan) the '*excess flood water*' downstream of the Adassiyeh diversion, after Israel takes the above-mentioned 25 MCM/y (Art. I.1c). The latter point is discussed further below.

As previously discussed, the two sides further agreed '*to cooperate to build a diversion/storage dam on the Yarmouk River directly downstream of the point 121/Adassiyeh Diversion. The purpose is to improve the diversion efficiency into the King Abdallah Canal of the water allocation of the Hashemite Kingdom of Jordan, and possibly for the diversion of Israel's allocation of the river water. Other purposes can be mutually agreed*' (Art. II.1).

From the Yarmouk flows alone, then, the treaty reserves 45 MCM/y for Israel, 20 MCM/y for Jordan, with both sides to benefit from the diversion weir and any excess flows.

7.2.2 Current water use, and contradictions and violations of the clauses

The arrangement of water use that has been established appears more asymmetric than the treaty itself. The Water Annex does not make explicit reference to the water used by Israeli farmers in the Yarmouk Triangle, for example. This was estimated in the late 1970s to be roughly 70 MCM/y, and the subject of fierce debate at the Jordan-Israel Yarmouk Forum/'picnic table talks' (Haddadin 2002a, Sosland 2007: 108). As discussed in Section 6.2, the '*excess flood water*' granted in Article I.1c to both parties can and is in fact used only by Israel, as only Israel has built the infrastructure to store and pump it (from the Yarmoukim Reservoir).

Thus while the treaty dictates that Israel is supposed to receive 45 MCM/y from the Yarmouk and send 20 MCM/y back, JVWA data shows that Israel uses 35 MCM/y on average (10 MCM/y less) and sends 47 MCM/y (27 MCM/y extra) back (Figure 6.7) – though there is discrepancy between Israeli and Jordanian data. The former flows are used locally and agreed as the '*excess flood water*' in the treaty, while the latter are non-committal, in the sense that they are not covered by the terms of the treaty, as discussed following

As discussed in Section 6.2.3, the 47 MCM/y 'returned' is counted by the JVA (and, so, presumably, by their Israeli counterparts) as the flows from former PM Ariel Sharon to former King Hussein, desalinated flows (Article 2d), 'concession' flows that vary annually, and flows purchased by Jordan from Israel. The accounting is problematic from a perspective of fulfilment of the clauses of the 1994 Water Annex, because the 20 MCM/y due from Israel (Article I, Para 2a) is *not* counted; ii) the 10 MCM/y counted as 'desalinated' (Article 2, Para 2d) are actually freshwater from Tiberias (the volume is the same but the cost is much cheaper, and the flows are contested with other Jordan River Basin states); iii) the 0-16 MMC/y of water purchased by Jordan is an economic arrangement, not part of a treaty; and iv) the 25 MCM/y water promised by former PM Sharon is not guaranteed. Apart from the desalinated flows, which are covered in Article 2d, none of the rest of the flows are mentioned in the Water Annex. Even counting the desalinated flows in this way lacks rationale, for the flows provided are freshwater flows from Tiberias.

Beyond the treaty, Israel uses 35 MCM/y of surface water for local use, a grossly estimated 5 MCM/y from the four dams in the Occupied Syrian Golan Heights (of retention capacity 10 MCM/y), roughly 2 MCM/y from the wells at Meitsar (HSI 2016a: 352), and 14 MCM/y (1987-2010) of spring discharge at Hamat Gader (HSI 2016a: 353), resulting in a total of 56 MCM/y. Of course, Israel also 'returns' 47 MCM/y to Jordan, but these are flows from the Lake of Tiberias (and, indeed, heavily contested with Lebanon, Syria, and Palestine).

For its part, Jordan uses approximately 98 MCM/y directly from the Yarmouk, roughly 32 MCM/y of which is groundwater, and approx. 66 MCM/y is surface water diverted by the Adassiyeh Weir into the King Abdallah Canal. In the sense that Jordan receives 47 MCM/y on average from the Lake of Tiberias, it can be considered that Jordan receives approximately 145 MCM/y from the arrangement. Only about 10 MCM/y of this is secured by Annex II of the Jordan-Israel Peace Treaty, when considering current JVA accounting methods and the Annex' lack of discussion of groundwater.

Furthermore, the '*additional quantity of (50) MCM/year*' of Article I.3 has never materialised. The planned arrangement through which Israel is to deliver 50 MCM/y to Jordan for use in Irbid by the Yarmouk Water Company is sometimes considered part of the 'additional 50'. Yet this remains an economic arrangement, in exchange for the 60 MCM/y of deslinated flows that Jordan is to provide to Israel at Aqaba/Eilat. The treaty further locks Jordan into an operational context that legitimises the Israeli occupation of the Golan, by virtue of implicitly acknowledging both Israeli irrigated farming and the construction of the Adassiyeh Weir there.

In sum, Jordan i) may still be due the 20 MCM/y according to the Treaty; ii) receives the 25 MCM/y promised by Sharon, but this is not guaranteed; iii) purchases up to 16 MCM/y through an economic arrangement; iv) is still due 60 MCM/y, including the 10 MCM/y of desalinated flows and the 50 MCM/y that has never materialised. Israel, meanwhile, uses roughly 22 MCM/y that is not accounted for in the Treaty (or by Jordanian authorities).

7.2.3 Analysis: ambiguity allowing an asymmetric outcome

Beyond the fact that they lack the great majority of the model treaty clauses, the Water Annex of the 1994 Jordan-Israel Peace Treaty is considered sub-optimal for a number of reasons. The clauses of the Annex a) do not account for the impact on downstream users; b) fail to account for groundwater flows; c) do not account for Israeli water use in the Occupied Syrian Golan Heights; and d) are moderately to highly inequitable, when the allocation mechanism is seen in the light of established water use and significant asymmetries in power.

The extent of the asymmetry may go unnoticed by many because of the considerable ambiguity underwriting the allocation mechanisms. Fischhendler (2008) demonstrates just how the ambiguity in the annex allowed the negotiators of each side to present the treaty in a good light, in order to diffuse domestic opposition to it. He demonstrates that the most extreme Israeli accounting would see Israel conceding (only) 35 MCM/y to Jordan, while the most extreme Jordanian accounting would see a concession of 245 MCM/y (not only from Yarmouk flows). Al Kloub and Abu-Taleb (1998: 165) claim, for instance, that the treaty 'guarantees to Jordan about 215 MCM/y', a figure repeated in Al Majdoub (1998).

The ambiguity means that the current arrangement and levels of use may be argued to not be violations of the treaty – even if it is about two-thirds the volume that has been claimed that Jordan receives. Furthermore, the fact that only Israel (and not Jordan) can actually make use of the 'excess flood water' mentioned in Article I.1c does not mean Jordan cannot do so, in theory. Likewise, the fact that the '*additional quantity of (50) MCM/year*' of Article I.3 and the 'storage' part of the '*diversion/storage dam*' of Article II.1 have not *yet* materialised does not mean that Israel and Jordan have not stopped 'cooperating', as the treaty obliges. At the same time, this quality of 'cooperation' does not result in significant tangible gains, and begs the question whether it may be improved (for instance, to be guided by the principles of International Water Law).

7.3 Evaluation of the 1987 Jordan-Syria Water Agreement

Like its predecessor in 1953,[30] the main purpose of the 1987 Jordan-Syria Water Agreement was to establish the basis for the construction of a dam at Maqaren to both regulate water flows to produce hydroelectricity (for irrigation and for 'other Jordanian schemes' (Article II)). Subject to the considerable ebb and flow of Jordanian-Syrian relations (see Section 8.2.2 and A5.1), as well as to Israeli efforts to prevent its materialisation (see Section 8.2.3 and A5.2), construction of the dam began only in 2004 (under the name of the Wehdeh Dam) and has yet to fill consistently to or near its capacity .

As Table 7.1 shows, the 1987 Jordan-Syria Water Agreement falls well short of the model in several ways. While it does acknowledge the hydraulic connection between groundwater and surface water in the discussion of springs, the agreement does not refer to geology, groundwater pumping rates, or well-drilling in any meaningful way. This is a particularly important omission, considering that roughly half of water use in the basin is groundwater (Table 4.2), just as roughly half of the flow of the Yarmouk tributary measured at Adassiyeh originates from groundwater in the form of springs (Section 3.3).

[30] Of interest is the American draft Jordan-Syrian water agreement of 1952, which appears to be the basis of the 1953 treaty originally signed (FO 1952: 42), although the 1952 draft is much more specific (quantifying flows, for example) and avoids the 250 m ASL benchmark altogether.

The Syria-Jordan Joint Commission created under the agreement has indeed served as a forum for discussing water-related issues in a less politicised (or securitised) setting than a purely political forum would have, though it does not benefit from all the other desired institutional mechanisms (e.g. provisions for monitoring, prior notification, etc.). Furthermore, apart from the clause specifying potential heightening of the dam 'where such measures are technically and economically justified and agreed on by the two States' (Art. VI), there is little scope for dealing with changing circumstances, whether rapid-onset changes in water use (driven e.g. by war), or long-term issues like climate change. Indeed, the agreement expresses no concern for the environment in any way.

While the 1987 agreement has a number of ambiguous clauses, it is in other ways very specific. Apart from the clear elevations specified in the allocation mechanism (see below), it also specifies each party's share of generated hydroelectricity (75% for Syria, 25% for Jordan), which party would bear all the costs (Jordan), and the number and storage capacity of Syrian dams (see below).

7.3.1 An ineffective allocation mechanism

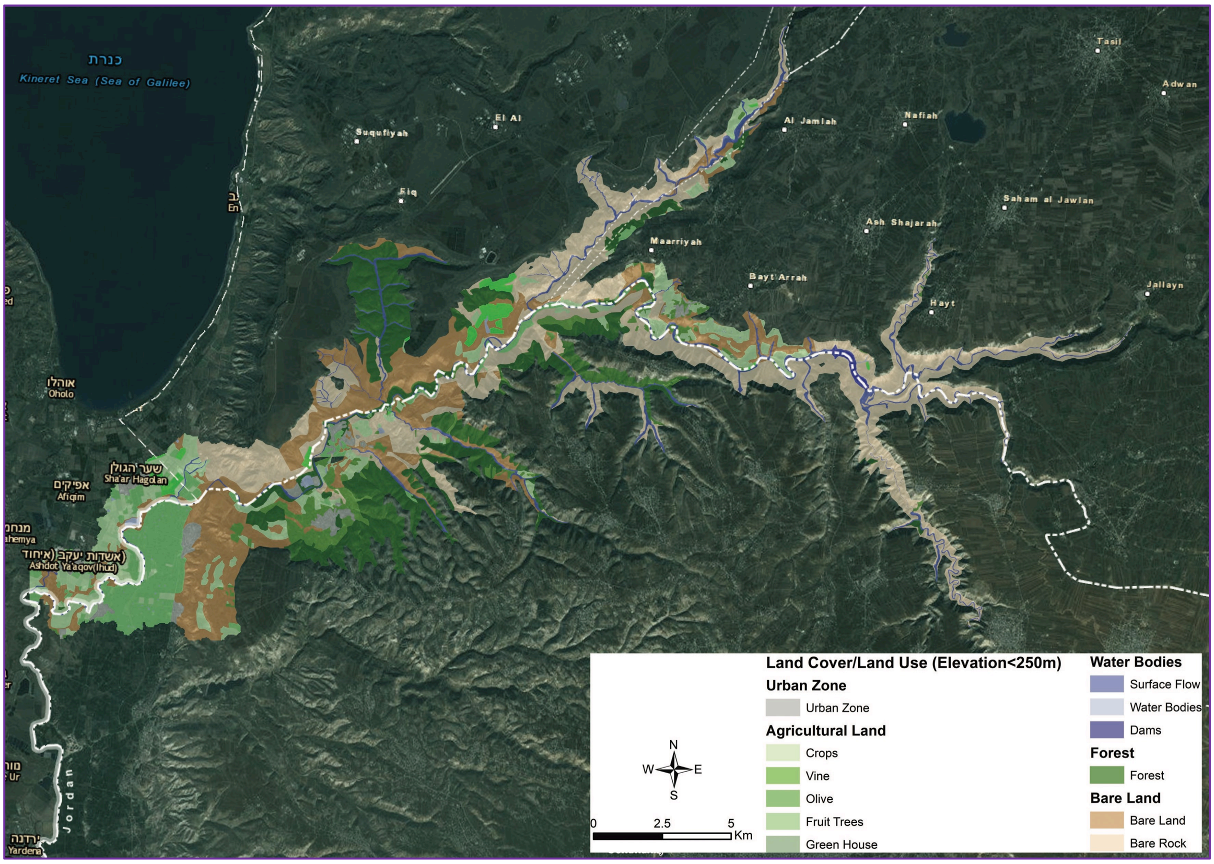
It is less the omissions than the *content* of the agreement that suggest a more sustainable transboundary water arrangement along this tributary would be beneficial, as revealed by consideration of the allocation clauses. Article VII states that Jordan is given '*the right to use the overflow from the Wehdeh Dam Reservoir*'.[31] Because the dam was originally intended to generate electricity, the 'overflow' referred to was probably referring indirectly to the planned releases from the dam after the generation of electricity, and following the withdrawal of a certain (unspecified) amount for irrigation or drinking water. By way of the agreement, then, Jordan is entitled only to the flows released from the Wehdeh Dam in the Yarmouk mainstream. The Agreement constricts the filling of the Wehdeh Dam to those flows that are in excess of whatever (unspecified) amount Syria can hold back through 26 dams that are specified in annex, with a storage capacity of 134 MCM in total.

On the other hand, Article VII specifies that Syria '*retains the right to use of the water of all springs welling up within its territory in the basin of the Yarmuk [sic] and its tributaries, with the exception of the waters welling up above the dam below the 250-metre level*'. With the Wehdeh Dam situated at 45 m ASL and the height of its peak at 110 m ASL in the first instance, the Agreement provides Syria with the entitlement to use all the spring water in the basin (presumably within its territory) either below 45 m ASL or above 250 m ASL. Article VII also appears to contradict the text of Article II(a), which stipulates the construction of the dam be used for the collection of river flow, with '*such water being utilized for the generation of electrical power, for the irrigation of land in Jordan and for other Jordanian schemes, for the irrigation of land in Syria situated below the site of the dam and along the course of the river to an altitude of 200 metres above sea level*'.

The agreement can thus be interpreted to limit Jordanian use of surface water in the Yarmouk tributary basin to the flows released from the dam, and (arguably) the surface water within its own territory (effectively) below 250 m ASL. As shown in Figure 7.1, this means the water in most of the wadis, but not in the highlands.

[31] The arrangement is similar to the 1922 Franco-British agreement that specified, among other things, that the 'runoff not used by Syria' would flow to Palestine (see Annex A6.1).

Figure 7.1 Land cover map showing use of land below the elevation 250 m ASL. According to Article VII of the 1987 Jordan-Syrian Agreement, all springs above this elevation are reserved for Syrian use. *Source*: Authors, based on multiple sources listed in the text.

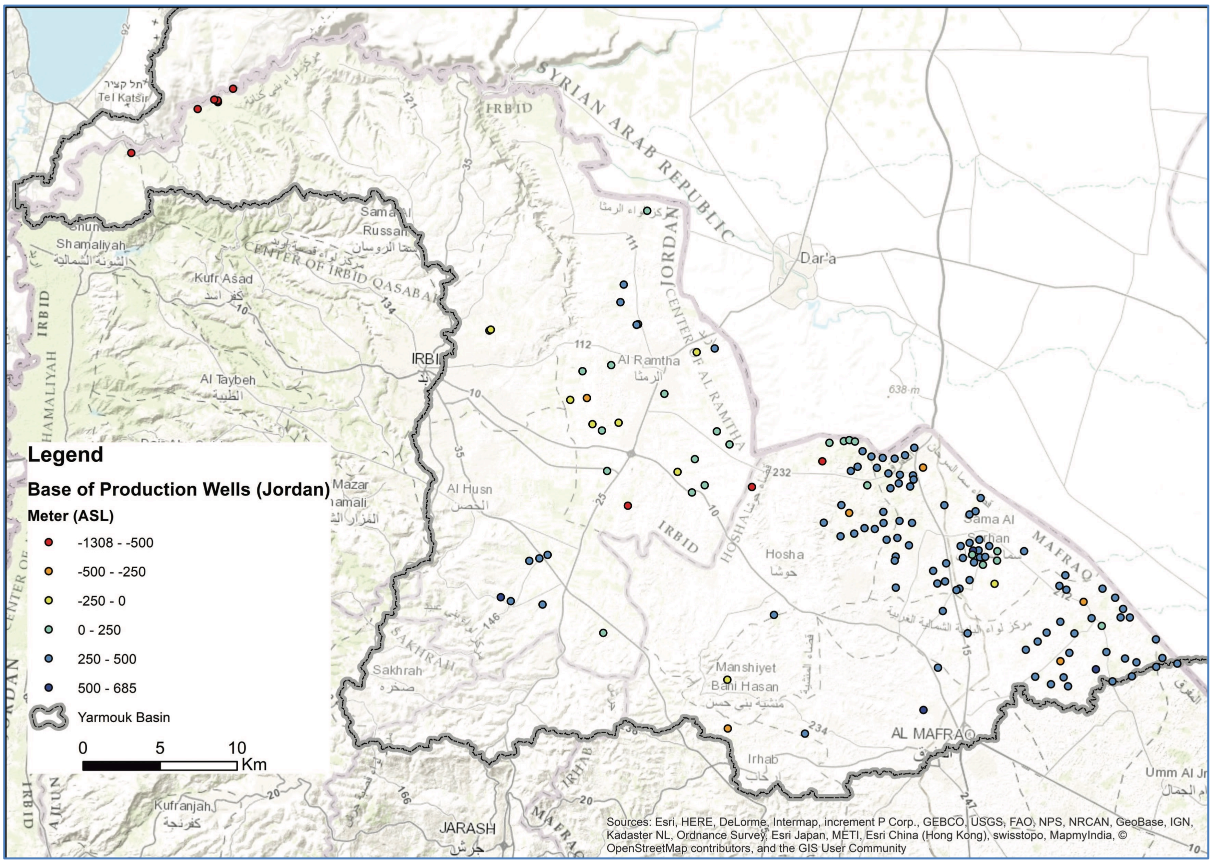


Crucially, the agreement places no limits on groundwater abstraction for either side. This is problematic for two reasons. The first is the direct connection between the shallow Basalt Aquifer and the surface water flow or spring discharge, meaning that pumping from wells can diminish surface water flows. In other words, the terms of the agreement do not reflect the hydraulic connections between surface water and groundwater.

The second problem with the agreement's poor treatment of groundwater is political. Strict interpretations of the text (notably the text on 'springs', which is the point at which groundwater is counted as surface water) could argue that Syria would have to limit the depth of the withdrawal levels of its wells to above 250 m ASL. It could be argued in turn that Jordan would have to extend the limit of its wells *below* 250 m ASL. In this strictest interpretation of the terms (but not the spirit) of the Agreement, this would mean that the Jordanian production wells around Sama al Serhan, for example, are not covered by the agreement (see Figure 7.2).

Of course, the guiding principle for the limits of groundwater pumping should be governed by common knowledge or positions in the debates about the 'safe yield' of an aquifer (see Bredehoeft 1997, Jarvis 2014). As we have seen in Section 3.3 and Figure 3.16, furthermore, the hydraulic conductivity of groundwater is precluded by the fault that runs parallel to the middle reaches of the Yarmouk mainstream across the Jordan-Syria border, but not across the easternmost parts (e.g. the Hauran Plain). Figure 7.2 *does not suggest that such wells are in violation of the 1987 Agreement*, but it does draw attention to the benefits of considering groundwater and its conjunctive use with surface water in any future Jordanian-Syrian water arrangement.

Figure 7.2 Map showing the location and elevation of the base of Jordanian production wells. Under a very strict interpretation of the text (but not the spirit) of the 1987 Agreement, wells whose base is above 250 m ASL could be considered to be in violation. *The point of the map is* ***not*** *to suggest that such wells are in violation of the Agreement*, but to draw attention to the benefits of considering groundwater and its conjunctive use with surface water in any future Jordanian-Syrian water arrangement. *Source*: Authors, based on multiple sources listed in the text.



7.3.2 Dams and violations of the Agreement

The ambiguity and omissions in the agreement's allocative mechanism create a number of contradictions, including: i) which state has the right to use the surface flows below the dam; ii) limits on groundwater pumping; and iii) the number and storage capacity of Syrian dams.

On the first two points, the most recent estimates of actual water use (not including soil water) are instructive. Syria uses approximately 335 MCM/y from within the basin, of which approximately 170 MCM/y is groundwater pumped from thousands of wells (average from 2005 to 2013 – see Section 4.4), and roughly 165 MCM/y[32] is surface water from behind 32 dams.

[32] MWI 2014 cited in UN-ESCWA/BGR (2013: 197) states that Syrian use in the Yarmouk tributary basin is 453 MCM/y, but this figure applies to the administrative boundary of the Yarmouk (i.e. including all of Al Suweida Governorate, beyond the hydrological boundary of the Yarmouk tributary basin). The source states that 327 MCM/y of this figure is used for agriculture (of which 60% groundwater), 92 MCM/y is for domestic use (assumed all from groundwater), and 34 MCM/y is for industry (assumed all from surface water). The figure 165 MCM/y is derived from these figures and accurate only within the margin of errors deriving from the above assumptions. The figure also matches closely with the

Jordan uses approximately 98 MCM/y, of which roughly 32 MCM/y is pumped from over 200 wells, and 66 MCM/y is surface water diverted by the Adassiyeh Weir into the King Abdallah Canal (not including the 47 MCM/y on average that are 'returned' by Israel according to the Water Annex of the 1994 Jordan-Israel Treaty).

Article VI states that

> '*Jordan shall undertake to design and build the Wahdah [sic] dam to a total height of 100 metres including floodgates, in order to store the waters flowing into the Yarmouk river after the filling of the reservoirs of the Syrian dams which are specified with their storage capacity in the annexed table*.'

The table in question names 26 dams, with a total storage capacity of 134 MCM (including Ibta' 1 and Ibta' 2 separately – but not counting al Rumi and al Butm). As shown in Table B7.1, the 32 dams built in Syria within the Yarmouk tributary basin (but outside of the Occupied Syrian Golan) include the 26 listed in the 1987 Agreement, and al Rumi and al Butm, plus the Jowayleen (0.5 MCM, built in 1988), the Qanawat (6.2 MCM, 1991), the Al Raha (0.45 MCM, 2000), and the Al Asleha (0.04 MCM, 1968. Given that the *actual* storage capacity of the 26 named dams is 190 MCM (rather than 134, as stated in the Agreement), plus the capacity of the additional four dams not named on the Agreement (7.2 MCM), the total storage capacity of Syrian dams within the Yarmouk tributary basin is roughly 197 MCM.

There are thus currently four more dams built than the 26 specified by the annex of the 1987 Agreement, and a capacity to store 63 MCM more than the 134 MCM specified. As discussed in Section 4.3, however, the actual retention of the dams is considerably less [33] than the theoretical capacity, because of siltation, pollution, redundancies and rainfall variability. It is unlikely that the 26 Syrian dams specified in the annex have ever been consistently filled to their capacity. Because the filling of these dams is a pre-condition for the design of the Wehdeh Dam, it could be argued that the capacity (if not strictly the number) of dams is in compliance with the terms of the agreement.

The findings thus challenge the allegations of violations expressed in water policy and academic communities in Jordan (see Hussein 2017). Furthermore, the contradictions in the terms of the agreement leave much open for debate. For example, the Jordanian side may argue that it is well within its agreed entitlement to pump groundwater within its territory, while the Syrian side could retort that Jordan is limited to accessing the 205-m deep 'slice' of the water table between 45 m ASL and 250 m ASL (even if this was by all interpretations *not the intent* of the text).[34]

7.3.3 Analysis: a skewed and now redundant Agreement

Like the water clauses of the 1994 Jordan-Israel Peace Treaty, the 1987 Jordan-Syrian Agreement does not include the great majority of the model treaty clauses. It is considered unsustainable because it: a) does not account for the impact on downstream users; b) is no

180 MCM/y given in Al Qusaym (2016) and Hoff (n.d.). See also Table B 9.8.

[33] As detailed in Section 4.3, estimates of the volumes stored in the dams in Dera'a range from 20% to 40%, while many others store water too polluted for use.

[34] The reasoning can be extended to the damming of the Yarmouk tributaries within Jordan, in light of the fact that the hydroelectric component of the Wehdeh Dam was never built. In the extreme, Syria may argue that Jordan has no agreed right to use the water currently released from the dam, as this would not be classified as 'overflow'.

longer 'fit for purpose' (which was to build the Wehdeh Dam); c) fails to reflect the actual availability and use of water (particularly the conjunctive use of surface and groundwater); and d) is highly inequitable in its allocation of use and control over the flows, when compared with the principles of International Water Law. With Syria the much stronger party, the omissions, contradictions, specificity and ambiguity all work in Syria's favour (in the narrow sense of the term).

Syrian violations of the Agreement are debatable within its own terms, however, as is some of the Jordanian use. In this sense, the elevation-based rule for use of spring water and the omission of groundwater (and its hydraulic connections with surface water) are particularly problematic. Syria can in fact claim to have exceeded its commitments, through the water releases between 1999 and 2003 (see Section 4).

The weaknesses of the agreements are not generally acknowledged by those who criticise the water arrangement with Syria, which is most often expressed in terms of Syrian violations of the Agreement (although a full study of narratives has not been undertaken). A former Jordanian MWI official implies that the Agreement was about more than just water, asserting that it is viewed 'not as a water agreement, but as an investment agreement' (Zahra (pers. comm.) 2016). The Agreement itself is also blamed: 'there were flow meters on the Yarmouk, I installed five meters downstream and upstream of the dam... but even if this data was presented, the Joint Committee will promise to raise recommendations for the higher decision-making levels in Syria and nothing will happen. The problem is in the implementation of an agreement that has no common understanding or technical logic' (Dalit (pers. comm.) 2017).

As is the case with the Water Annex of the 1994 Jordan-Israel Peace Treaty, then, *the problem with the 1987 Water Agreement is not with its violations, but with the agreement itself*. As a result, a key part of the path towards more equitable and sustainable arrangements on the Yarmouk (Annex A7) revolves around revisiting the insitutions.

8 Distribution and interaction

This section first evaluates the current distribution of Yarmouk flows against the principles of the UN Watercourses Convention. It then interprets interstate interaction through a TWINS analysis, and investigates the role that power plays. Background on the interaction is provided in Annex A5.

8.1 Distribution of the flows

8.1.1 Current distribution and use of the Jordan River

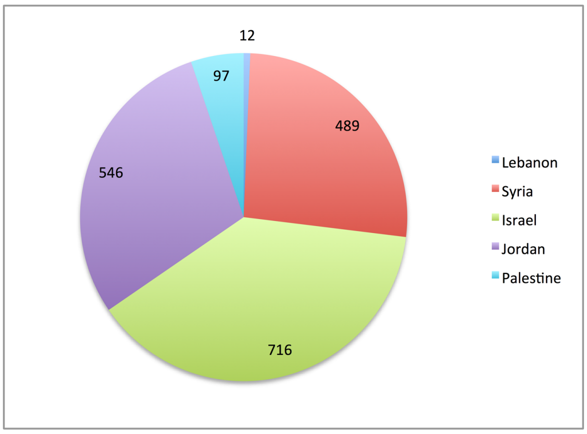
Sharing of the Yarmouk and Jordan flows is in many ways the outcome of the interplay of interests-infrastructure-negotiations-narratives described in Section 3. It is most significantly shaped by the diplomatic activity and water engineering plans of the 1950s-1970s, the violent reprisals, and the Israeli takeover of the Golan Heights and the West Bank in 1967.

The current use and allocation of Jordan River Basin flows was locked in by the 1987 Jordan-Syria Treaty, the 1994 Jordan-Israel Peace Treaty, and the 1995 PLO-Israel Oslo II Agreement. Furthermore, Israel has deterred upstream Lebanon from developing the river (see Zeitoun*, et al.* 2013). Table 8.1 and Figure 8.1 show current estimates of Jordan River Basin-wide use.

Table 8.1. Estimate of Jordan River Basin (including Yarmouk) surface water and groundwater use by country, around 2012 (MCM/y). Source: Based on secondary sources as summarised in Quba'a (2017b: Table 2.2). The figures for Syrian use are significantly different from this study's findings, possibly due to confusion in accounting for use in the Occupied Syrian Golan Heights. The *relative* shares of use have not changed significantly since the 1990s.

	Lebanon	Syria	Israel	Jordan	Palestinians	*Total*
Surface water use	6	204	657	249	5	*1121*
Groundwater use	6	285	59	297	92	*738*
Total water use	*12*	*489*	*716*	*546*	*97*	*1850*

Figure 8.1 Estimate of Jordan River (including Yarmouk) Basin total water use by country around 2012 (MCM/y). Source: Based on secondary sources as summarised in Quba'a (2017b: Table 2.2). The figures for Syrian use are significantly different from this study's findings, possibly due to confusion in accounting for use in the Occupied Syrian Golan Heights. The *relative* shares of use have not changed significantly since the 1990s.



8.1.2 Current use of the Yarmouk

Of the Yarmouk tributary only, Syria is estimated to use approximately 335 MCM/y, of which approximately 170 MCM/y is groundwater pumped from thousands of wells (Section 4.4), and roughly 165 MCM/y [35] is surface water from behind 32 dams (Section 4.3).

As discussed in Section 7.2.2, Jordan currently uses about 98 MCM/y directly from the Yarmouk, roughly 32 MCM/y of which is groundwater pumped from over 200 wells (Section 4.4), and 66 MCM/y of which is surface water diverted by the Adassiyeh Weir into the King Abdallah Canal (Figure 6.7). Jordan also benefits from 47 MCM/y on average of non-Yarmouk flows supplied by Israel from the Lake of Tiberias since 1995, according to the terms of the 1994 Jordan-Israel Peace Treaty. Jordan's effective use of the Yarmouk, then, is roughly 145 MCM/y.

Sections 7.2.2 and 6.2.3 also shows how Israel currently uses approximately 56 MCM/y of Yarmouk flows, counting the 35 MCM/y used directly from the Yarmouk tributary via the Yarmoukim Reservoir (Figure 6.7), a grossly estimated 5 MCM/y from the four dams (with 10 MCM/y retention capacity) in the Occupied Syrian Golan Heights (Section 4.4), roughly 2 MCM/y from the wells at Meitsar (HSI 2016a: 352), and 14 MCM/y (1987-2010) of spring discharge at Hamat Gader (HSI 2016a: 353).

Box 6: The Johnston Plan

The history of the US-led hydro-diplomatic initiative headed by Eric Johnston has been told at great length and in considerable detail (Lowi 1993, Wolf 1995, el Musa 1998, Sosland 2007, Alatout 2011), with particularly relevant emerging findings related to Israeli benefit of unspecified return flows (Phillips, *et al.* 2007a). The story is not retold here, except to note that from the Yarmouk tributary alone, the Johnston Plan proposed an allocation of 377 MCM/y to Jordan, 90 MCM/y to Syria, and 25 MCM/y to Israel. Notable shortcomings of the plan include its lack of consideration for drinking water needs, lack of quantification of groundwater availability, and allowance of out-of-basin transfers for Israel only (Phillips, *et al.* 2007a). Though the Johnston Plan was never implemented, and despite its shortcomings, the 'Johnston allocations' remains a (problematic) reference point among some water policymakers and analysts until the present.

[35] MWI 2014 cited in UN-ESCWA/BGR (2013: 197) states that Syrian use in the Yarmouk tributary basin is 453 MCM/y, but this figure applies to the administrative boundary of the Yarmouk (i.e. including all of Al Suweida Governorate). 327 MCM/y of this is used for agriculture (of which 60% groundwater), 92 MCM/y is for domestic use (assumed all from groundwater), and 34 MCM/y is for industry (assumed all from surface water). The figure 165 MCM/y is derived from these figures and accurate within the margin of errors deriving from the above assumptions. The figure also matches closely with the 180 MCM/y given in Al Qusaym (2016) and Hoff (n.d.). See also Table II-22.

8.1.3 Use of International Water Law in diplomacy

As discussed in Section 5.2, the early inhabitants of the Yarmouk tributary basin competed over or shared local water, rather than the flows along the entire river or across the basin. Use of the 'basin' as a sharing unit started with the Palestinian *Nakba*, and the creation of the State of Israel. Each of the diplomatic efforts that followed were subsequently obliged to consider the consequences for the rival riparian States (which had been created only recently – see Section 5.2.2). The earlier diplomats reached for the only guide available at the time (and the only one available today) – international law.

Commissioned by the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) to assess of the international public legal implications of the Bunger and TVA/Main Plan, the head of the Electric Power Section of the Economic Commission of Europe found law an obstruction to development. He recommended that neither project be built because of the 'legal difficulties' related to diversion of flows away from a State, expressing particular concern for the consequences for or possible retribution from the Palestine Electric Company (Sevette 1953: 15). With the projects still under consideration in 1977, USAID commissioned Harvard Law School professor Richard Baxter to investigate the legal ramifications that construction of the Maqaren Dam would have for Israel – what became known as the 'Baxter Report'[36] (Baxter 1977). In direct contradiction with Sevette's analysis, the Baxter Report concluded that violations of the principle of equitable use/apportionment were unlikely because 'construction of the dam does not necessarily involve any change in present allocations of the basin waters' (Baxter 1977: 131). As discussed in Section 6.1, the eventual construction of the dam (renamed as Wehdeh) did indeed have little or no effect on the allocations between Syria and Jordan. From that point onwards, furthermore, a shift away from the use of law to guide diplomacy is apparent. Neither International Water Law nor international law more generally have been used to guide the negotiations, the infrastructure, the treaties that were signed, or the narratives developed.

Box 7: The Arab Diversion Plan

The first Arab Summit of 1967 was intended to develop a joint strategy on water, in response to Israel's decision to start pumping from the Lake of Tiberias in 1964. One part of the strategy was to divert approx. 125 MCM/y from the headwaters of the Jordan River to the Yarmouk, in what has become known as the Arab Diversion Plan (Arab Plan 1954). The Syrian portion of the project was attacked by Israel, in March, May and August 1965, and ultimately halted by a July 1966 attack (Lebanon had already halted related construction on the Hasbani in July 1965 out of fear of attack (Kirschbaum 1997)).

8.1.4 Legal entitlements

Though the array of bilateral treaties that cement the current distribution of the flows supersede International Water Law (IWL), the principles of the UN Water Convention apply nonetheless, because the legal instrument is customary law; that is, it builds on state *practice* (McCaffrey 2007). Recall from Section 2.3, that the 'equitable and reasonable use' allocation principle is composed of seven factors (geographic, social needs, dependent population, effects of use, existing use, conservation and availability of alternatives).

[36] Baxter later became a judge at the International Court of Justice and served to pioneer International Water Law (McCaffrey 2007).

The principle of 'equitable and reasonable use' has also been applied to the Jordan River Basin by several authors, notably Mimi and Sawalhi (2003) and Phillips et al. (Phillips*, et al.* 2007b, 2009) (see Table 7.2)

Table 8.2 Various estimates of the legal entitlements of each of the Jordan River States, in comparison with the Johnston allocations. Estimates do not include groundwater availability or use. *Source*: as indicated.

	Lebanon	**Syria**	**Israel**	**Jordan**	**Palestinians**	*Total*
Mimi and Sawalhi (2003)	147	429	281	295	188	*1340*
Phillips et al. (2007b)	60	401	56	601	281	*1399*
Johnston	35	132	616	480	240	*1503*

The very large discrepancy between the two authors may be attributed not only to the use of different data (for e.g. population or access to other water sources), but to the different weights attributed to the factors that make up 'equitable and reasonable use'. In any case, both estimates are considered quite off the mark, as they neglect the groundwater that we have seen makes up approximately half of the Yarmouk tributary flows, and the bulk of water contested between Palestinians and Israel.

The first estimate of legal entitlements across the Jordan River Basin that incorporates groundwater into the analysis is Quba'a et al. (2017b). The work also provides a number of different scenarios reflecting different weightings of the factors, as shown in Table 8.3 and Figure 8.2.

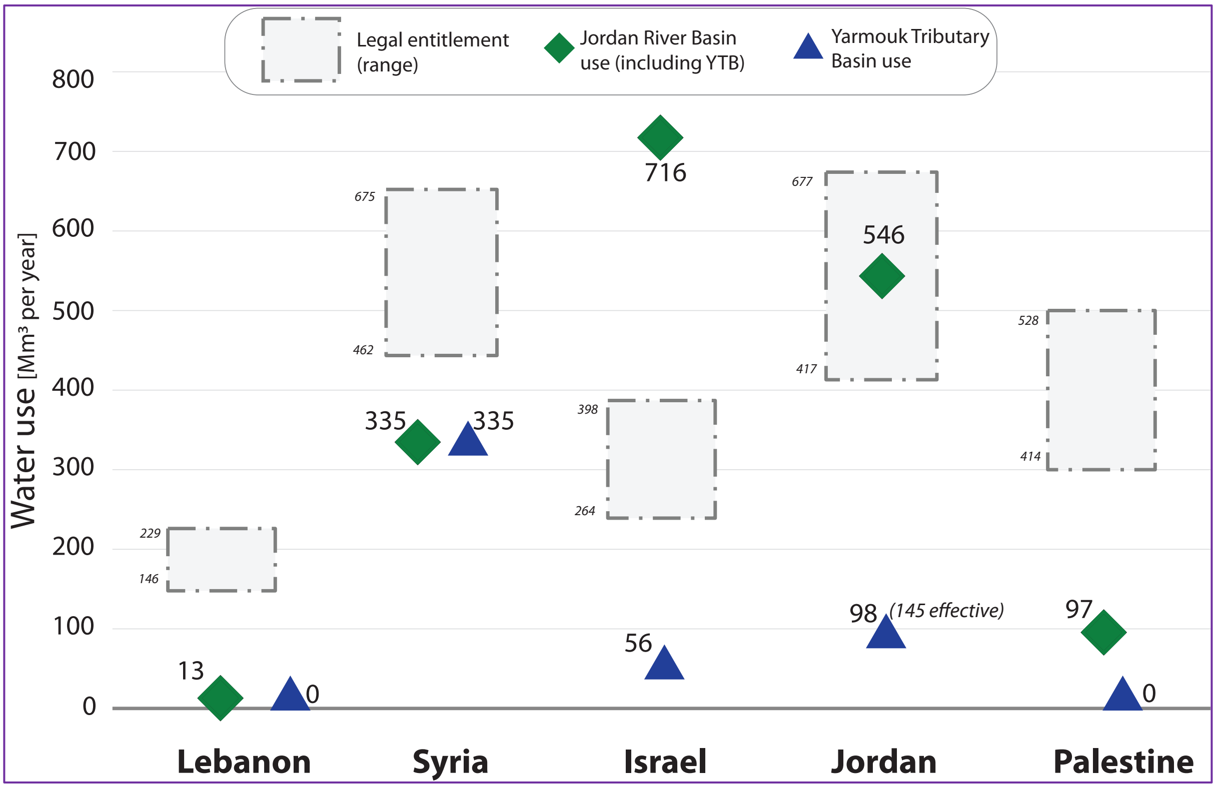
Figure 8.2 raises a number of issues that either confirm or challenge conventional thought on allocation of the Jordan River flows. The first is the well-known asymmetry in distribution of the flows. Palestine and Lebanon stand to gain the most from a basin-wide arrangement based on IWL. The second is that Syria and Jordan are currently using flows within the range of their legal entitlement, suggesting each could stand to gain from IWL-based diplomacy – including additional flows and the security of an internationally backed arrangement. The third is that possibilities for resolution lie primarily with reallocation of current Israeli allocations/use, an idea that has been considered in Phillips (2009), Quba'a *et al.* (2017a), van Veen et al. (2017), (to a lesser degree) Yasuda et al. (2017: 107), and the positive-sum solution of RPSO (2009).

Table 8.3 The range of the legal entitlements of each riparian state, presented as a range reflecting different weighting on each of the seven factors that make up 'equitable and reasonable use'. Includes groundwater and surface water. *Source*: Quba'a et al. (2017b).

	Lebanon	**Syria**	**Israel**	**Jordan**	**Palestinians**	***Total****
Min. equitable share	148	443	242	414	300	*1547*
Max. equitable share	227	654	386	675	499	*2441*

*Total shares differ from the total available flows, reflecting the range of weighting of the factors defining the equitable shares.

Figure 8.2 Estimated use of Jordan River Basin and Yarmouk tributary basin flows by country, in relation to estimated legal entitlements of each State for the entire Jordan River Basin, around 2012. The legal entitlement of each is presented as a range,[37] reflecting different weightings given to 10 factors that compose the calculation of 'equitable and reasonable use'. The Occupied Syrian Golan Heights is counted towards the *legal entitlement for Syria* and towards *use for Israel*. *Source*: Based on analysis in Sections 6 and 7, and Quba'a et al. (2017b: Tables 2 and 6). The numbers are *indicative only*, due to limitations induced by reliability and compatibility of the data.



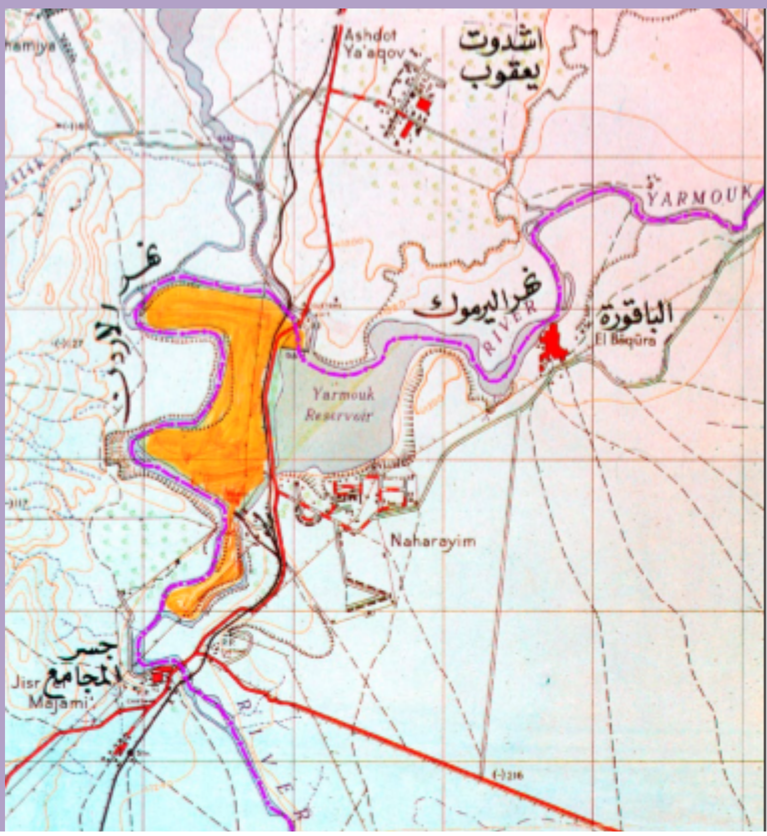
[37] Ranges shown are for 30% weighted favouring (based on total availability of 1891 MCM/y): Israel: 242 (Factor 6) - 386 (F4); Jordan: 414 (F6) - 675 (F7); Lebanon: 148 (F4) - 227 (F10); PA: 301 (F4) - 499 (F9); Syria: 443 (F9) - 654 (F5).

Box 8: Al Baqura – an opportunity for hydro-diplomacy

The contest over the lands of al Baqura – known as Naharayim in Hebrew – developed directly from the concession of 6,000 dunums that the British authorities granted to Pinhas Rutenberg and the Palestine Electric Company for the construction of the Naharayim Electrical Power Plant (see Section A 4). Not requiring all of the land, and in apparent contradiction to contemporary Jordanian law and agreements, Rutenberg sold some of the land to the Jewish Agency (Jarrar 2018). Following Iraqi bombing of the plant in 1948, the Plant stopped production, and in 1950 the Israeli army occupied approximately 830 dunums of the land (claiming that it was part of the Israeli side of the Armistice Line (Abu Sitta 2011)). The lands were subsequently cultivated by Israeli farmers, and irrigated by multiple sources of water (though not the Yarmouk (Nathan (pers. comm.) 2017b)).

The 1994 Jordan-Israel Peace Treaty stipulates (in Annex I (b)) that a "special regime" applies to al Baqura because of 'Israeli private ownership rights and property interests'. It also allows Israeli access to and use of the land whilst recognising Jordanian sovereignty for 25 years (until 23 October 2019). The water in al Baqura area is managed by the Jordan Valley Water Authority, which is semi-independent from the Israeli water supplier Mekoroth (see Section A 3.3). The decision by King Abdullah on 21 October 2018 notifying his intent to enter into consultations over the status of the regime offers an opportunity to improve the transboundary arrangements over the Yarmouk tributary and Jordan, possibly through the application of International Water Law.

The Al Baqura lands (in orange) comprise 850 dunums (85 ha) near the confluence of the two rivers. The map also shows the site of the Naharayim power plant and Yarmouk Reservoir. *Source*: (Abu Sitta 2011).



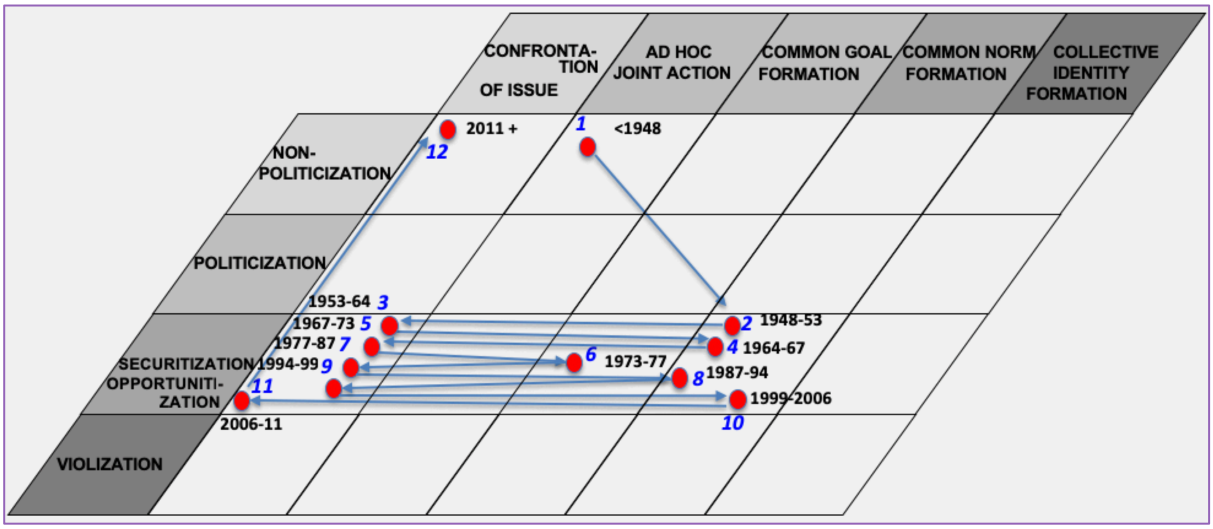
8.2 Inter-state interaction

This section examines bilateral interaction over the Yarmouk tributary basin through the use of Mirumachi's TWINS matrix, with a view to evaluating the sustainability of the transboundary water arrangements. All assertions are based on the review of transboundary water interaction presented in Annex A5.1 and A5.2.

8.2.1 Analysis of Jordan-Syria state interaction (1953-2017)

Figure 8.3 gives a visual representation of the dramatic interaction between the governments of Syria and Jordan over the Yarmouk. The ad-hoc water collaboration of the States soon after their independence (and the Palestinian *Nakba* a few years later) evolved within a few years to be part of the rallying call for the liberation of Palestine, as well as the signature of the 1953 Treaty. The 1953 Treaty was meant to have led to the construction of the Maqaren Dam, Jordan's cornerstone development project. There was official cooperation during the period of the Johnston Negotiations, though the tensions over the lack of progress in building the dam were palpable, and both sides cooperated more closely on the Arab Diversion Plan. The June 1967 war (which resulted in the Israeli occupation of the Syrian Golan Heights and the West Bank from Jordan) temporarily halted the plans and Jordanian-Syrian cooperation. Under the government of President Hafez Al Assad and with continuously shifting regional politics, relations cycled between warm (leading e.g. to the amendment of the 1953 Treaty, but not the construction of the Maqaren Dam) and cold (with ever-increasing Syrian groundwater development and construction of dams on the tributaries of the Yarmouk for example); warm (with the signature of the 1987 Treaty, but still no dam); and cold again with Jordanian signing of the Peace Treaty with Israel. Relations improved from 1999 onwards to the point that the Maqaren (renamed Wehdeh) Dam was actually completed in 2006. The fact that the Wehdeh lay nearly empty for years after its construction may have raised the general feeling that the Syrian side is violating the treaty (a narrative the researchers of this study often heard voiced (see Hussein 2017), and the general poor water relations did not change before the start of the crisis in Syria in 2011. The crisis also saw the end of the joint projects and meetings of the Joint Technical Committee until the present day.

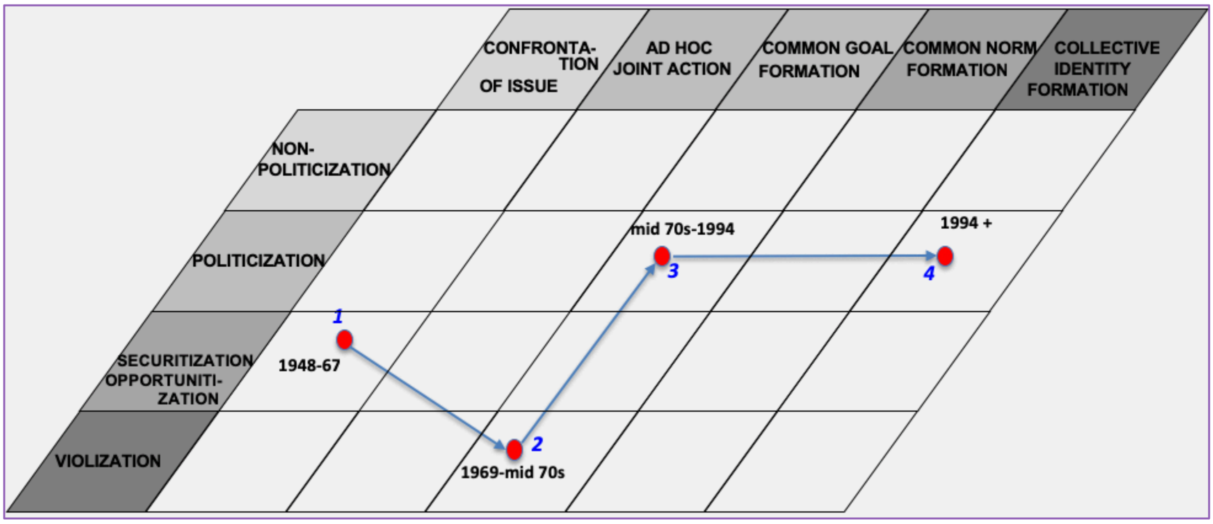
Figure 8.3 Interaction over the Yarmouk tributary basin flows between the governments of **Jordan** and **Syria**, plotted on Mirumachi's (2015) Transboundary Water Interaction Nexus frame. *Source*: Authors, based on multiple sources listed in the text.



8.2.2 Analysis of Jordan-Israel interaction (1960-2017)

In comparison with the interaction over the Yarmouk between the governments of Jordan and Syria, Jordanian-Israeli transboundary water interaction appears much more straightforward (Figure 8.4). On the public level, Jordan sided with the other majority Arab states throughout the tumultuous years of the Johnston Negotiations and Arab Diversion Plan up to 1967. The Israeli occupation of the Syrian Golan Heights brought Jordan in direct contact with Israel over the diversions at Adassiyeh for the East Ghor Canal, the first phase of which it completed in 1969, and the period of violence (Israeli bombing of the East Ghor Canal, kidnapping of soldiers at Adassiyeh) was in full swing. Out of the public eye, Jordanian-Israeli negotiations were taking place concurrently, and evolving to the point that Jordanian negotiators had now to consider Israeli interests in their discussions with Syria. The talks were maintained as the violence diminished, and emerged as the Water Annex of the 1994 Peace Treaty. Jordan and Israel have continued to take risks together ever since. Even through periods of tensions (as the 1998 algal bloom scandal (see Abbt-Braun*, et al.* 2010, Barinova*, et al.* 2010)). The interaction has led to the construction of the Adassiyeh Diversion Weir (which was realised even before the Jordan-Syria Maqaren Dam), negotiated the Red Sea-Dead Sea Canal, and are currently in the middle of the Jordan Red Sea Project, which sees 60 MCM/y of desalinated water that Jordan pays for swapped with 50 MCM/y of Tiberias flows for the north of Jordan.

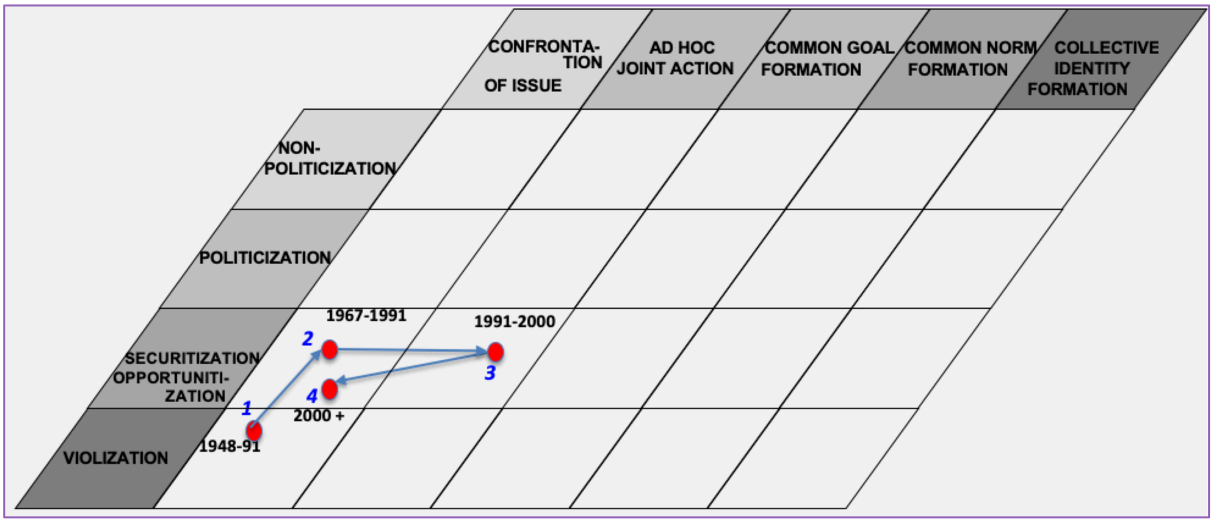
Figure 8.4 Interaction over the Yarmouk tributary basin flows between the governments of **Jordan** and **Israel**, plotted on Mirumachi's (2015) Transboundary Water Interaction Nexus frame. *Source*: Authors, based on multiple sources listed in the text.



8.2.3 Analysis of Syria-Israel interaction (1948-2017)

The Syrian-Israeli interaction over the Yarmouk flows shown in Figure 8.5 appears even more straightforward than the Jordan-Israeli interaction. In the sense that very little developed in private, the interaction really *is* quite uncomplicated. The early periods of violence that started with the creation of the State of Israel continued through the Johnston Negotiations, attacks by Syria on initial Israeli attempts to build the intake of the National Water Carrier, and Israeli bombing of the Arab Diversion Project. Unlike the case of Jordan, there was no official interaction over the flows following the Israeli occupation of the Golan, and the flows remained heavily 'securitised' (that is, presented by the Government of Syria in terms of national security) until the Syrian-Israeli negotiations began in 1991. Water featured heavily in those negotiations, and would have certainly formed part of any treaty signed (Daoudy 2008). With the breakdown of talks, interaction between the two States has reverted to nil, and seems likely to remain that way for the immediate future.

Figure 8.5 Interaction over the Yarmouk tributary basin flows between the governments of **Syria** and **Israel**, plotted on Mirumachi's (2015) Transboundary Water Interaction Nexus frame. *Source*: Authors, based on multiple sources listed in the text.



8.3 The influence of power

Considering the asymmetry in water allocations and use, Israel is clearly the 'hydro-hegemon' in the Jordan River Basin (see A2.2). Understanding whether or not there is a different hydro-hegemon on the Yarmouk tributary to the Jordan (or whether that is even possible) obliges an examination of power, as the assertion by a Jordanian academic reveals: 'Turkey exerted its hegemony and forced Syria to accept its Atatürk Dam and other dams and has the power now to cut off water to Syria. Syria is exerting the same power and tactics against Jordan. Jordan is downstream, and will not start a war against Syria. Israel, on the other hand, is willing to go to war for water, and they did it before during the 1960s, when they bombed Khalid Dam' (Sultan (pers. comm.) 2016).

In fact, power runs through each of the interests, infrastructure, treaties and narratives that make up the current interstate arrangements over the Yarmouk. Each State has its measure of structural, bargaining and ideational power – the components of the main pillar in the analytical framework of hydro-hegemony (Zeitoun*, et al.* 2006). While a detailed examination of the structural power of each riparian State is beyond the scope of this study, it suffices to say that the current relative economic and military power of Israel dwarfs that of the others, while the relative advantage of Syria over Jordan is significant in and of itself, even if (currently) diminishing.

8.3.1 Bargaining power

As the review of archives in A5.1 shows, Syria's position during the European Mandate Period may be considered that of the 'lone wolf', particularly in face of coordinated British and Zionist intentions for Palestine and Jordan and in negotiations with the French Mandate authorities. The French drew upon their own bargaining skills in negotiations with British authorities, through talks of exchanging land around the Euphrates or Banias Rivers for a greater share of land around Jabal al Druze (to ensure Druze unity). Following the *Nakba* in 1948, Israel had relatively much less bargaining power than Jordan and Syria, though tacit US support during the Johnston Negotiations helped considerably at that time.

Through its decades of stalling with the construction of the Maqaren Dam, Syria employed bargaining tactics, reminding British authorities, for instance, that they had sufficient water, and no need for electricity (see FO 1959, FCO 1980). These were also on display in discussions about water and the Occupied Syrian Golan Heights during the Syria-Israel talks in the 1990s (Daoudy 2008). Israel relied considerably on its bargaining power during its negotiations with Jordan, particularly for ensuring the ambiguity in the 1994 Water Annex of the Peace Treaty (Fischhendler 2008).

The bargaining power of Jordan vis-à-vis Syria has varied throughout the hydropolitical history of the Yarmouk. It was in very limited supply over the decades passed before the agreed Maqaren/Wehdeh Dam was built, but used effectively when Jordanian-Syrian relations warmed. As a cable from the US embassy entitled ‘107 MCM of Air’ put it: ‘The Unity Dam will not have a major impact on Jordan's water supply in the near term. In order to maximize the potential of the structure, both Jordan and Syria will have to limit groundwater extraction and make more surface flows available. Jordan has not yet exercised sufficient political leverage to get Damascus to make available significant new quantities of water for the Unity Dam’ (US Embassy in Jordan 2007). Jordanian bargaining power vis-à-vis Israel stems from the political leverage that the country had while it was normalising relations with Israel.

Israel has deployed considerable bargaining power over the decades, perhaps most noticeably in relation to the lobbying for a secure supply for the farmers of the Yarmouk Triangle. As we saw in Section 5.3.2, a secure flow of 25 MCM/y had been advocated for by Israeli officials during the 1950 Johnston Negotiations, and secured under the Johnston allocations. Israel has in fact secured a far greater amount, and the issue of a secure supply for Yarmouk Triangle farmers remains a negotiations issue to be resolved.

8.3.2 Ideational power

The Government of Israel appears to have focused from early on upon shifting the mindset of the international community. In response to the resistance to its planned construction of the National Water Carrier (which was centred on the refusal of out-of-basin transfers), for example, the Israeli envoy to Washington was instructed by the Ministry of Foreign Affairs: ‘We cannot miss the opportunity that Jordan was the one to start pumping water out of the Jordan-Yarmouk network. It is necessary for us – ahead of the expected struggle with the Arabs in a year and a half – to instil in the public consciousness and regular political circles, that the first step was taken by the Arabs, accompanied with consequences such as the increase of salt levels in the lower Jordan, and harming Israel's water rights in the Yarmouk’ (ISA 1962).

8.3.3 Hydro-hegemony

The distribution of Yarmouk flows between Syria-Jordan-Israel (roughly 80-10-10) suggests that Syria is in a hydro-hegemonic position – if the tributary could be separated from its mainstream. Even with the current crisis in Syria and the resultant great loss in relative power and ability to exploit the water, Syria has lost little of its control over the bulk of Yarmouk flows. This is due primarily to its upstream position on both the surface water (95% of the Yarmouk tributary basin) and the aquifers, which will remain unchanged (barring any further territorial conquests).

Hegemony within the Yarmouk arrangements is less clear in the Gramscian sense of hegemony; that is, in the sense of maintenance of an arrangement through force and (more crucially) consent. Syrian efforts to maintain the arrangement vis-à-vis Jordan appear to have stemmed mostly from force, apart from the earlier appeals to Arab brotherhood and the framing of the water releases around the turn of the century. However, the strong disagreement over the arrangement gathered during interviews (though not evidenced in this study) suggests that few in Jordan, authorities or otherwise, are satisfied with the current arrangement. There is thus no 'veiled consent' to the arrangement, as has been claimed the Government of Lebanon has in relation to Israeli hydro-hegemony (Zeitoun*, et al.* 2016). On the other hand, there certainly is veiled consent from Syria towards Jordan's arrangement with Israel, which is based in part on continued Israeli occupation of the Golan.

The resentment in Jordan against the Syrian transboundary water arrangement does not appear to extend to its arrangement with Israel. The water clauses of Annex II were clearly very welcome in Jordan in 1994, and the fruit that the Peace Treaty bore – including Israeli consent for Jordan to build the Adassiyeh Weir, and an average of double the flow released from Israel than it is committed to – are by any standard greatly preferred over the bombing and kidnapping Jordan endured in the late 1960s and early 1970s. Over one quarter of a century onwards, however, and as this study has explored, the treaty and the Adassiyeh Weir maintain Jordan's use of the Yarmouk at about 90 MCM/y (or 145 MCM/y, considering the 'water swap' arrangement). Israeli use of the flows bypassing or overspilling the weir appears to happen without Jordanian awareness, furthermore. Although this study has not investigated the issue adequately, continued official Jordanian consent to the transboundary water arrangement suggests that there is a fair amount of ideational power active.

The international community also seems to take an uncritical and poorly-informed view o fthe Jordanian-Israeli transboundary water arrangement. Considerable financial support remains for infrastructure (e.g. the Jordan Red Sea Project), scientific studies, or cooperation initiatives on the *lower* Jordan (e.g. EcoPeace 2015), but none whatsoever for the sources in the uppoer reaches or the Yarmouk tributary. There are also very few voices that question if the arrangement is fair, equitable, or even efficient, suggesting that Israeli ideational power continues to have considerable sway over the public or diplomatic 'consciousness'.

Part IV – CONCLUSION

9 Conclusions

If the pattern of past basin development that this study identifies persists for another few decades, the basin will be riddled with outdated institutions governing unnecessary water swaps, out-of-basin transfers and desalination projects through treaties that lost their relevance to the needs of the people more than a half century ago. Without informed diplomacy to transform the arrangements, residents of the Yarmouk tributary basin will be ill-equipped to continue to face constant political change, massive demographic shifts, highly variable weather and probably long-term changes in climate, and a recurrent possibility of punctual or drawn-out war. On the other hand, informed diplomacy can lead to an equitable and sustainable arrangement that itself creates a virtuous cycle of reduced social and political tensions amongst the roughly 1.6 million people living in the basin.

Two very different futures are contrasted in Annex A7: a stifled and inefficient 'business-as-usual' scenario, and a scenario where the arrangement is equitable and sustainable. This section summarises the opportunities that serve diplomatic efforts towards the latter arrangement, then recaps the main findings, and makes a number of recommendations for interested parties.

9.1 Windows of opportunity and arguments for improving the water arrangements

Given the political climate and relations between States in the Yarmouk tributary basin in 2018, any programme will clearly have more chance of success if it endures over a sustained period. Rather than to seek to force changes when the time is not opportune, a successful diplomatic programme would capitalise on 'windows of opportunity' that open with time to allow advancement in otherwise closed situations. The study has revealed a number of such windows towards an equitable and sustainable arrangement.

9.1.1 Opportunities for diplomacy between Jordan and Syria

Perhaps the first window that exists for improving the Yarmouk arrangement between Jordan and Syria is the *general dissatisfaction with the 1987 Jordan-Syria Treaty*, and/or perceived violations of it. Considered alongside the fact that the treaty has evidently outlived its purpose (which was to build a hydroelectric dam at Maqaren), the idea of its renegotiation may be more welcome than is generally expected.

A second potential opportunity is, paradoxically, *protracted conflict or rebuilding in Syria.* The outcome and timing of the end of the Syria crisis is entirely unclear. On the other hand, it is perfectly clear that i) the importance of the Yarmouk to Syrian people has been maintained throughout the crisis, and will probably continue to increase as transfers of food and goods even within Syria (not to mention across international borders) becomes more difficult; ii) the Yarmouk will be a key resource for renewed state-building development activities (such as food production) that are likely to follow the end of the crisis (or that will occur as it drags on); and iii) the first two points hold, whoever is making the decisions as the crisis continues in different forms, or after it is finished. If the crisis is seen to end, there will be a rush of donors and agencies keen to do work in the water sector, and this can both encourage and crowd out any diplomatic activities. Engagement with the water authorities at the present time – regardless of the level of difficulty – would lead to greater ability to move with diplomacy at the right moment. Furthermore, and as the TWINS analysis has shown, cooperation and conflict over water issues are tied to the quality of broader political relations. With this in mind, any progression towards resolution of the Syrian crisis will be a timely opportunity to advance progression on the Yarmouk arrangement.

A rational argument for more sustainable transboundary water management are *concerns about changes in water use and quality*. The increasing salinity of the groundwater resources suggests a further rational reason that both States should be willing to improve Yarmouk arrangements. It is not improbable that a vicious cycle may take over and make things worse/increase the need for diplomacy: overabstraction has caused a change of the groundwater regime, leading to the deepening of some wells, and the abstraction of water with higher salinity (Margane 2015).

This study's archive search confirmed what is apparent to anyone who talks to farmers on both sides of the border in the Hauran Plain: there are at least as many *commonalities between Syrian and Jordanian farmers* as there are differences. This is due in large part to common culture and history, and possibly not tribes and political allegiances. The exchange of goods and ideas (and the movement of people) across the border has persisted long after the Syrian-Jordanian Joint Technical Committee has stopped meeting. Effective and sustainable water management is a clear and pressing issue for people on all sides of the Yarmouk tributary. It follows that work with these 'transboundary communities' has the potential to progress in spite of the broader political context (projects with such communities are identified in Section 9.3).

Jordanian irrigation and renewable energy expertise can cross borders. Jordan has relatively greater experience with irrigation technology and renewable energy related to agriculture. The experience is buttressed with a certain command of novel technology (such as GIS analysis, use of social media for data collection, etc.) which could lead to cooperation with Syrian counterparts.

9.1.2 Opportunities for diplomacy between Jordan and Israel

The planned negotiation over Al Baqura and al Ghamr in 2019 may be the first window to open on the Jordanian-Israeli water arrangement. As discussed in *Box 8*, the direct ties with water use in the Yarmouk could be the leverage required to reach a preferred arrangement.

Unlike the dissatisfaction voiced over the Jordan-Syria Treaty, the majority of Jordanian and Israeli water officials consulted for the study did not express discontent over the *Water Annex of the 1994 Jordan-Israel Peace Treaty*. On the other hand, several non-officials in Jordan voiced concerns about the transboundary arrangement their government has with Israel, and vocal and published criticism is mounting as well. The opportunity for *an improved water agreement with Israel may thus stem from a desire to both pre-empt ever-greater tensions, and secure a greater volume of water sources at reduced cost*. In order to avoid sparking the tensions that led to the kidnappings and violence of the 1970s over the same subject, any such discussions would be most effective if linked with wider Israeli strategies for national water security, which includes desalination and wastewater reuse (see below).

The Northern Transmission Line is set to be received by the Jordanian Yarmouk Water Company by 2020. Though a Memorandum of Understanding has been signed and construction has started, the two sides must yet agree a legal framework for the initiative. This is an opportunity to initiate discussions on improvements to the infrastructure of the

Yarmouk-Tiberias 'water swap', or renegotiation of the treaty.

Desalination and future plans for Israeli national water security provide possibly the most rational argument for renegotiation of the transboundary water arrangements. The past few years have already demonstrated how the manufacture of water through desalination processes (mainly reverse osmosis) helps the State to deal with the uncertainty of poor winter rains and in-country upstream abstactions (Wine 2018). Increasing steadily since the construction of the Ashqelon plant in 2005, up to 600 MCM/y are currently produced (Katz 2016). Considered alongside wastewater reuse and water-savings programmes, the desalination means that Israel now has a 'surplus' of water (Marin, *et al.* 2017), and is seeking buyers of its manufactured water within Israel and in Palestine (see NRC 2015). As noted in the 'positive-sum outcome' for resolution of the Jordan River conflict (RPSO 2009, see also Aviram, *et al.* 2014), the ability to produce water should ease national concerns about freshwater use – and so open the doors to consideration of International Water Law as the future basis for allocation of flows. Such discussions would have to consider the cost and reliability of different sources, of course, alongside the seven features that make up the 'equitable and reasonable' share of each State's legal entitlement.

9.1.3 Opportunities to improve arrangements across the Jordan Basin

Related to the previous point, the Israeli *National Water Carrier* (NWC) is already over half a century old, and requires routine replacement of the pumping and transmission infrastructure every 10-20 years. The NWC transfers 286 MCM/y on average (from 1963 to 2014) out of the basin (HSI 2016b), consuming great amounts of energy to lift water from 200 metres below sea level, at the Lake of Tiberias. There will come a moment at which decision makers decide not to invest in renewal of the NWC, in light of technological advancements and reductions in the cost of desalinated flows and wastewater reuse.

Furthermore, four of the Jordan River Basin's five riparian States have ratified the UN Watercourse Convention, and several of them are in discussions to ratify the UNECE Water Convention. The various instruments that make up *International Water Law* also provide the only legitimate method to reconcile upstream water-development entitlements with established water use downstream.

9.2 Main findings

This section summarises the study's main findings and contributions, in effect answering all of the research questions posed in Section 1.2.

9.2.1 Basin biophysical characteristics findings

1. This study estimates the area of the Yarmouk tributary basin at 7,387 km^2. The length of the river from the top of Jabal al Druze to the confluence of the Jordan River is calculated at 154 km. Prior to the start of the Syrian crisis in 2011, there were approximately 1.6 million people living in the basin, and roughly 35,000 and 6,000 ha devoted to irrigated agriculture in Syria and Jordan, respectively.

2. The water resources estimated in the Yarmouk mainstream at Adassiyeh is made up surface water runoff and groundwater in roughly equal measures.

3. The long-term average total availability of water resources in the basin is very roughly 450 MCM/y, of which roughly 200 MCM/y is counted as surface water and 250 MCM/y as groundwater.

4. Extensive development throughout the basin

has dramatically affected the flow of the Yarmouk tributary mainstream, such that the average flow at Adassiyeh between 2008 and 2011 is estimated at 32 MCM/y, and 47 MCM/y between 2011 and 2015. The flow of the river at Adassiyeh has been further tempered by the Wehdeh Dam ever since its completion in 2006. Flows into and released from the Wehdeh Dam in 2016 were in the range of 30+ MCM/y (Figure 3.13).

5. The bulk of the groundwater exploited comes from two of the three main aquifers: the Shallow Basalt Aquifer (which is exploited primarily in Syria) and the A7/B2 – Cr_2cn cp/Cr_2m-d Aquifer (which is exploited mainly in Jordan – see Section 3.3).

9.2.2 Water use and sharing findings

6. Development on the Yarmouk (and broader Jordan) has been uncoordinated since the time of European colonisation. The first French and British attempts to reach a water agreement (in 1921) were neither realistic nor successful (see Annex A 6.1).

7. Currently 40 dams have been built within the basin, 32 of which are Syrian, one Jordanian-Syrian (the Wehdeh Dam), four built by Israel in the Occupied Syrian Golan Heights, and three Jordanian (with total storage capacities of 205, 110, 10 and 3.1 MCM, respectively). Landsat image analysis suggests that the actual amount of water stored behind Syrian dams matched the theoretical capacity only once (in 1985), and is on average about 40%.

8. Thousands of wells tap into the aquifers, with over 4,000 exploiting the Shallow Basalt Aquifer in Syria (irrigating over 11,000 ha with 150-170 MCM/y), and approximately 200 in Jordan exploiting the Deep Limestone A7/B2 – Cr_2cn cp/Cr_2m-d Aquifer (using 32 MCM/y or more on average, mostly for irrigation).

9. The infrastructure and institutions that govern water use in the basin are sub-optimal. Some of the infrastructure may form part of an improved arrangement, however, as detailed in Annex A7.

10. The flow in the Yarmouk mainstream (measured at Adassiyeh) has been increasing since 2011 (32 MCM/y from 2008-2011 and 47 MCM/y from 2012-2015). This is probably due to decreased surface water and groundwater use associated with the Syrian crisis, which began in 2011.

11. Flows into the Wehdeh Dam have increased temporarily. Though it lay near-empty (at about 20 MCM) for the first years following its completion in 2006, the mean inflow to the Wehdeh Dam from 2008 to October 2016 was 33 MCM/y while the mean outflow released was 35 MCM/y.

12. Flows into the King Abdallah Canal (KAC) have not always increased with the increased flow in the Yarmouk mainstream, nor with increased Jordanian releases from the Wehdeh Dam. Figure 6.3 shows how the average annual flows into the KAC dropped from approximately 116 MCM before construction of the Adassiyeh Weir to about 66 MCM after it. Meanwhile, roughly 50 MCM/y bypasses the weir (75 MCM/y when flood years are included). There is certainly scope for more effective and coordinated operation between the Wehdeh Dam and the Adassiyeh Weir. There is also potential for greater diversions to the KAC, with minimal infrastructure effort.

13. The Yarmouk-Tiberias 'water swap' infrastructure (see Section 6.2) is also sub-optimal, as it pumps flood flows to Tiberias for later (pumped) return to the KAC. Diverting more water into the KAC at Adassiyeh would both reduce energy costs (for pumping to the Lake of Tiberias) and evaporation losses (from the lake), though a pre-feasibility study is required to determine the extent of potential gains.

14. Each riparian State's use of the Yarmouk flows must be considered as part of its use of flows within the broader Jordan River Basin. Of Yarmouk flows, this study estimates that Syria uses on average roughly 335 MCM/y, Jordan roughly 98 MCM/y, and Israel roughly 56 MCM/y. Of Jordan River flows, Syria uses 489 MCM/y, Jordan 545 MCM/y, and Israel 720 MCM/y. Both Syria and Jordan currently use less than the provided estimates of legal entitlements, while Israel uses significantly more.

9.2.3 Findings relevant to theory and knowledge

15.The international Yarmouk arrangements may be understood through the observable interaction of four factors: interests, infrastructure, treaties and narratives. The study has shown the extent to which *interests drive* the Yarmouk arrangements, while infrastructure *concretises*, treaties *lock in*, and narratives serve to either contest or consent to them.

16. The interplay of the four factors is a result of the clear link between the quality of interaction over water issues between Jordan, Syria and Israel, and the state of political (i.e. non-water) relations (Section 8.2.1). Interaction over the Yarmouk between the States is clearly subordinate to the political relationships between them, in other words. The dynamics may be best interpreted in greater detail through the concept of 'river-border complexes' (see e.g. Thomas 2016).

17. The skew in the treaties and in distribution of control and use of the flows also very clearly reflects the asymmetry in power between the different actors. The use of ideational power is found to be most relevant to the international diplomatic community, for the framing of conflict and cooperation (Section 8.3). The most relevant forms of influence amongst the riparian States to shape the Yarmouk arrangements are found to be bargaining power and structural/coercive power. The state of 'hydro-hegemony' solely over the Yarmouk flows, in this sense, does not reflect the same state of hegemony that Israel has over the Jordan River flows (particularly vis-à-vis Palestine and Lebanon).

18. Water data remains very heavily 'securitised' in Syria and (to a lesser extent) Jordan. Even basic water availability and use data is kept tightly within these governmental ministries. Data from the Hydrological Service of Israel and other agencies in Israel is more readily available to the general public.

19. Water data remains nonetheless accessible (within limits) through remote sensing and analysis of satellite imagery. As shown in Section 3, full land-use maps can be recreated for decades running, and, when combined with weather data, DEM and pumping records, can serve to give useful approximates of agricultural water use.

9.2.4 Contributions to diplomacy

20. This study's examination of the archives has revealed how international law once guided US hydro-diplomacy, to an extent (Sections 5.2 and 8.1). However, from the 1970s there has been a discernible shift away from the use of law in diplomacy in the Yarmouk tributary and Jordan River Basins. All subsequent water arrangements appear to be the result of diplomacy guided by the vagaries of power more than by the principles of law.

21. The inefficient Yarmouk arrangements are cemented by problematic bilateral treaties. Both the 1987 Jordan-Syria Treaty (Section 7.3) and the water clauses of the 1994 Jordan-Israel Peace Treaty (Section 7.2) are evaluated as unsustainable, for being ambiguous, rigid and inequitable, and for neglecting groundwater and current needs, amongst many other considerations.

22. The 1987 Jordan-Syria Water Agreement is considered further unsustainable not least of all because it: a) does not account for the impact on downstream users; b) is no longer 'fit for purpose' (which was to build the Maqaren Dam); c) fails to reflect the actual availability and use of water (particularly the conjunctive surface water and groundwater); and d) is highly inequitable. With Syria the much stronger party, the omissions, contradictions, specificity and ambiguity all work in Syria's favour (in the narrow sense of the term).

23. The Water Annex of the 1994 Jordan-Israel Peace Treaty are considered unsuitable for a number of reasons beyond the fact that it lacks the great majority of the model treaty clauses. The clauses a) do not account for the impact on downstream users; b) fail to account for groundwater flows; c) do not account for Israeli water use in the Occupied Syrian Golan Heights; and d) are moderately to highly inequitable, when the allocation mechanism is seen in the light of established water use and significant asymmetries in power. JVA accounting of flows 'returned' to the KAC are particularly circumspect, in terms of treaty compliance.

24. The future can look bleak, or better. Any conception of the basin 50 years from now under a 'business-as-usual' scenario (Annex A7) inevitably includes a basin that is 'developed' with evermore infrastructure that pushes the basin's water resources beyond their sustainable limits, while obstructing state development and contributing to political tensions.

25. A more equitable and sustainable arrangement is simple to envision, if challenging to implement: one where the flows are used within their sustainable limits and are shared equitably amongst the five riparian States and water use is more efficient (see Annex A7.5).

26. There are a number of opportunities and arguments for improving the Yarmouk arrangements. As specified in Section 9.1, these include for Jordan and Syria: fairly widely held recognition that the 1987 treaty is not fit for purpose, a shared history of water users in the Hauran Plain, and a heightened importance of the flows for the rebuilding of a stable Syria. For Jordan and Israel, opportunities and arguments include: the relative ease with which Jordan may exploit more of the Yarmouk flows (through minor modifications to existing infrastructure), as well as the Al Baqura negotiations scheduled for 2019 (and of which water will be one component), as well as the game-changing volume of desalinated flows in Israel, which could relieve pressure over competition for the freshwater flows.

9.3 Recommendations for States and third-party actors

If 'interests drive, infrastructure concretises, treaties lock in, and narratives can serve to securitise' (Section 5.1), it follows that each must also form part of any plan for improvement. States and third-party actors interested in fostering an equitable and sustainable arrangement on the Yarmouk/Jordan are thus recommended to develop a long-term strategy based on the avenues described below. The list is relevant to ministries, NGOs and donors in all countries. Existing national initiatives – such as the MWI's 2015 Yarmouk Action Plan (MWI 2015) – are not included here, though they are of course strongly encouraged.

9.3.1 Develop a common and more complete knowledge base

The comprehensive review of archives, grey literature and publicly available literature has revealed that the great majority of publicly available data is disaggregated at the national level. *There is very little research of any sort done across the Yarmouk tributary basin*, in other words. Furthermore, the research or policy work that has been done across the Yarmouk tributary basin does not situate it within the wider Jordan River Basin.

The country-level focus is particularly true for technical studies. The accuracy of the water balance calculation provided here (Section 4.6) is limited by the lack of reliable data from rainfall stations or river gauges and groundwater piezometric measurements. As such, cross-border water-availability and monitoring studies such as 'the Orient study' (2011) should be updated and validated.

The focus should clearly be first on *water quality*, whether groundwater or surface water – followed by the identification of vulnerable areas (which may lead ultimately to the establishment of protection zones). A greater understanding of *groundwater availability* is also crucial (building on the good work of the JVA and GIZ – e.g. Margane et al. (2015) , and might necessitate a long-term cross-border monitoring programme, or at least the harmonisation of monitoring conducted in each country.

This would be possible through the establishment of a Joint Monitoring Programme (JMP). Surface water monitoring stations would gauge stream-flow volumes throughout the years, as well as critical water-quality parameters (e.g. Total Dissolved Solids, Biological Oxygen Demand, Total-Nitrogen, Phosphates, etc.). Groundwater monitoring wells would gauge water levels, infiltration rates, drawdown rates, and critical water quality parameters (e.g. Total Dissolved Solids, Biological Oxygen Demand, Total-Nitrogen, Phosphates, etc.). Weather monitoring stations would gauge precipitation, humidity and windspeed. All gauging would be telemetric, thereby allowing monitoring from both Amman and Damascus; The Yarmouk gauging stations would be calibrated with existing stations, notably those of the JVA, MWI and MoWR; An appropriately sophisticated app would permit real-time analysis of all the monitoring stations in concert – thereby allowing the development of the 'bigger picture'; And the JMProgramme would also include training sessions, accompaniment for three years and operational costs for 10 years.

In terms of qualitative data, the literature also reveals an *almost complete lack of presentation of the Syrian perspective* on transboundary water interaction. The Jordanian and Israeli perspectives dominate the research literature, particularly contributions written in English.[38] In other words, there is no Syrian equivalent to the foundational texts of Haddadin (2002a) and Shamir (2003b). This sizeable gap in the Syrian perspective has consequences on the narratives heard by diplomats. Important historical features – e.g. the concern of the French authorities in 1921 about a rebellion by the Druze of the Hauran Plain (FNA 1921d) – thus remain as footnotes, rather than opportunities to understand the roots of tensions in the basin.

Syrian water use in the Yarmouk tributary basin is also considerably understudied. This is due in no small part to the fact that basic water-use data that is collected by various government bodies is not shared openly with the public, even before the crisis began in 2011. While much of it is available through public presentations, data on the volumes of water impounded behind dams in Syria or withdrawn from the aquifers remains generally inaccessible. Given the great amount of research attention directed at Israeli water use, there has been *remarkably little research of Israeli water use* in the Occupied Syrian Golan Heights, along Wadi Raqqad, in the

[38] A collection of Arabic literature is provided in the database associated with the project.

Yarmouk Triangle, or in the demilitarised zone in the foothills of the Occupied Syrian Golan Heights up to Himmeh.

There is also *no Yarmouk equivalent of the extremely useful cultural and historical insight into water use provided by the anthropological perspectives* of traditional water use in Syria (e.g. de Châtel*, et al.* 2014, de Châtel 2015) and Jordan (e.g. Darmane*, et al.* 2010). Such studies in the Yarmouk tributary basin would serve to highlight the cultural relations for example between Druze on the Occupied Syrian Golan Heights and on Jabal al Druze, or commonalities of communities on the Jordanian and Syrian side of the Hauran Plain.

While the links between the Syrian crisis and water resources has attracted considerable attention (e.g. Gleick 2014, Muller*, et al.* 2016, Avisse*, et al.* 2017, Rajsekhar*, et al.* 2017, Selby*, et al.* 2017), there remains a *basic lack of understanding of how water resources management will continue to be affected or shaped whether or not the crisis ends* anytime soon. Efforts led by the Overseas Development Institute (e.g. Jobbins*, et al.* 2017) appear to be steps in the right direction.

One further type of gap in the collective knowledge in the basin is to *quantify and qualify the benefits of a more equitable and sustainable arrangement*. Such a study could employ Phillips' (2008) Transboundary Water Opportunity methodology to evaluate the potential benefits related to water – e.g. food, energy, climate, urbanisation – through a 'whole hydro-cycle' water-accounting approach, which includes soil water, virtual water, wastewater-reuse and other water 'savings'. The rationale is that if riparian states are able to identify new opportunities arising from water, then the sum of the benefits gained from such cooperation would far outweigh benefits acquired by acting unilaterally. Similar studies have led to shifts in policy and practice along the Nile, Kagera, Incomati, Orange and several other rivers.

9.3.2 Support transboundary projects

Transboundary water projects between States and/or communities in Jordan and Syria can serve to begin to shift the narratives that lock the current arrangements in place. The medium-term strategic goal of such desecuritisation is to offer the rationale for avoiding risks and sharing benefits. The rationale is based on a recognition that the development of institutions and infrastructure in the Yarmouk tributary basin has not only been largely uncoordinated, but also very much 'top-down', centralised and guided primarily by technical and supply-side paradigms, thereby missing out on contributions that can come from society, institutions and other policy thinking.

9.3.2.1 Participatory Mapping / 'citizen science'

A 'participatory mapping' project would provide an opportunity to better understand the use and availability of surface water and groundwater in the Yarmouk tributary basin, as well as the social value of water. The programme could leverage this study's extensive technical analysis by engaging various users to map water use and availability in the basin and aquifer. Activities like 3-D interactive modelling of the hydrology and hydrogeology of the Yarmouk tributary can result in local communities sharing social and traditional knowledge of the basin, and to begin to better understand the basin dynamics. The modelling can be further used to reveal the complexity of the basin by adding multiple political and socio-economic factors such as borders, conflict, overabstraction, commercial agriculture, population growth, etc. – turning it into a powerful training and teaching tool. The programme would probably be best hosted in an academic setting (e.g. JUST, University of Damascus) and would target local authorities, water-user associations (see below), farming communities, students, etc.

9.3.2.2 'Haurani' Farming and Water Associations

This project would strengthen the existing interaction between different communities. Building on existing institutions such as the Highlands Water Forum, the project will encourage transactions amongst the very communities that know water management the best: the farmers on both sides of the border in the Hauran Plain. Sharing a common cultural heritage, the Haurani communities have historically traded as much with each other as they have with Damascus or Amman. The crisis in Syria has furthermore led to the emergence and strengthening of local councils and committees to address water-supply shortages. Informal farming and/or water-user associations could facilitate the exchange of farming practice and institutional structures, thus establishing the base upon which future diplomacy may build. The project would also take advantage of the many Syrian farming families currently hosted in Jordan. Potential activities of these associations include:

- Sharing lessons learned through water-energy types of projects (e.g. in Azraq);
- Dissemination and learning from the findings of the RICCAR and other food security-climate change projects;
- Exchange of best irrigation techniques, cropping patterns, water use efficiency, water resources management (e.g. conjunctive use of surface water and groundwater). This would build on recent experience especially in Jordan;
- Exchange of technological and practice innovations in pumping, cropping, irrigation etc.;
- Sharing of experience with the regulation of the competition between domestic and agricultural users; and
- (eventually) joint monitoring projects (of e.g. groundwater levels, well quality, etc.).

9.3.2.3 Water Operators Twinning

This project would strengthen the capacity of drinking water operators in Syria and Jordan. Regular exchange between the municipal authorities would serve to build the technical capacity, as well as to build an epistemic community that may be drawn on by future diplomatic initiatives. Likely candidates include the General Establishment for Potable Water and Sewage of Dera'a, and the Yarmouk Water Company in Jordan, though the programme could eventually be expanded to operators in Al Suweida or Al Quneitra. The twinning programme could be greatly assisted by the support of the Global Water Operators Partnership Alliance, which supports exactly this type of south-south cooperation. The Water Operators Twinning programme would share lessons about:

- Performance improvement (e.g. leak reduction);
- Dialogue between water operators and local authorities, and WUAs;
- New forms of governance (e.g. the merits and limitations of privatisation or mixed models);
- Effective ways to conform to national water management policy, and transboundary water management best practice;
- Effective financial and institutional arrangements;
- Pumping and other technology (e.g. sharing experiences of which motors, pumps and pumping procedures work best under which conditions)

9.3.2.4 Joint farming and virtual water research project

This research project would establish and then serve to break down perceptions about water use on both sides of the border. Best hosted as collaboration between universities (e.g. JUST and University of Damascus) and select transboundary communities, the project would gain a deep understanding of who the water users are (e.g. local, small-scale, industrial scale), forms of agricultural practice, and where the produce is sent (e.g. out of basin, or out of country), as well as the water resources and infrastructure required to sustain it all. By capturing perceptions of water use on across the border, the project would also identify ways to break down the deeply held beliefs (about e.g. treaty violations in Syria) that this study has found.

9.3.2.5 Regional Water Roundtable Discussions

This project would establish better contacts and eventual coordination between ministry-level decision makers. Such meetings would discuss regional – not domestic or simply cross-border – water challenges and technical solutions. These include climate change, drought, project financing, international basin management, brackish water desalination, regional environmental regulation (e.g. International Water Law, Ramsar), etc. A wide range of people nominated by their water ministries would be invited to attend. The meetings would best be chaired by an independent third party, take place in confidence, and not be reported upon.

9.3.3 Make the treaties more effective

The analysis has shown how the treaties that govern relations over Yarmouk/Jordan flows are skewed, ambiguous, or have lost their relevance. Furthermore, each fails to take advantage of more recent thinking on resilient and effective 'model' treaties. If the existing treaties are understood as part of the problem, then renewed or renegotiated treaties can be part of the solution. The study has revealed how improving transboundary water relations is possible over decades, at a timescale that passes over the numerous and predictable swings in political alliances. States and interested parties are thus recommended to develop a long-term plan to lay the political groundwork required for treaties that underlie an equitable and sustainable arrangement, and seize opportunities to advance the agenda when they present themselves.

9.3.4 Optimise the infrastructure

The study has revealed the potential efficiency savings to be gained by an infrastructure system that supports the equitable and sustainable scenario of transboundary water arrangements. The Jordan River Basin could benefit from the river restoration and dam decommissioning type of water works that is currently taking place on other overbuilt rivers and aquifers, primarily in North America and Europe. The States and interested third parties are thus recommended to undertake a pre-feasibility study in the first instance to examine the functioning of the infrastructure in detail. The pre-feasibility study would scrutinise the extent of redundancies that exist between the dozens of Syrian surface water dams, the Wehdeh Dam, Adassiyeh Weir, Yarmoukim Reservoir, Beit Zera Reservoir, East Ghor Canal and Karameh Dam. It would thus investigate the merits of a replacement weir at Adassiyeh to allow (an agreed) greater offtake into the King Abdallah Canal, which might imply resizing the offtake structure, if not the canal itself. Considerable energy and water could be saved for all, if the need for the entire Yarmouk-Tiberias 'water swap' pumping infrastructure were replaced by one that relies on gravity. Aside from the technical aspects, the pre-feasibility study could also consult on the preferred legal and institutional frameworks.

9.3.5 Be guided by international law

While international law guided the diplomatic efforts of the US and others until the 1970s, it has been virtually absent since, and did not contribute to the drafting of the 1987 or 1994 water treaties. A number of instruments, most of which have developed after the signing of the Yarmouk treaties, may serve a future equitable and sustainable transboundary water arrangement.

Perhaps the most relevant instrument is the ILC's 1997 UN Watercourses Convention (UNWC), which was ratified by Syria in 1998 and by Jordan in 1999. Both States are recommended to clarify their positions in relation to the UNWC, and to anchor any future negotiations, policy or infrastructure within its principles, notably the principles of 'no significant harm', 'prior notification' and 'equitable and reasonable use'.

Both States are encouraged, too, to accede to the UNECE's Water Convention, which has been extended for ratification and support to States beyond the European Community. The Convention's Secretariat can provide platforms for support, such as legal analysis, review of best practice, and further scientific investigations. Alignment with the principles of international law may be the most relevant to the Government of Syria in a post-war context where it is seeking to rebuild both the country and political relations.

The ultimate goal is far beyond simple ratification of the different instruments, however. Reaching the equitable and sustainable arrangement laid out in Annex A7 can be achieved by *use* of the tried and tested principles to guide negotiations. Considering the importance of groundwater in the Yarmouk tributary basin, diplomats may thus also be guided by the growing body of work on groundwater being developed by the ILC, UNECE and UNESCO. Diplomacy that relies on international law will both be aligning with international norms and legal frameworks, and also making the best use of the extensive body of knowledge that has been generated over the last few decades.

REFERENCES

Abbt-Braun, Gudrun, William Alkhoury, Markus Ziegmann, Fritz H. Frimmel and Elias Salameh (2010). "Water quality of the King Abdullah Canal / Jordan - impact on eutrophication and water disinfection." *Toxicological & Environmental Chemistry* 92(5): 855-877.

Abboud, I.A. 2018. Geochemistry and quality of groundwater of the Yarmouk basin aquifer, north Jordan. *Environ Geochem Health* 40(4): 1405-1435

Abdelhamid, G. (1993). Geological map of Jarash [map]. National Mapping Project, Map Sheet No 3154 - I, 1:50,000. Amman, Ministry of Energy and Mineral Resources - Natural Resources Authority (Geology Directorate).

Abdelhamid, G. (1995). The Geology of Jarash Area - Map sheet No. 3154-I. Bulletin 30. Amman, Ministry of Energy and Mineral Resources - Natural Resources Authority (Geology Directorate).

Abed (pers. comm.), Mohammad (2017). "Personal communication, Amman, 6 April 2017. Anonymised.".

Abed, Abdulkader M. (1982). "Depositional Environments of the Early Cretaceous Kurnub (Hathira) Sandstones, North Jordan." *Sedimentary Geology* 31: 267-279.

Abou Zakhem, B. and R. Hafez (2010). "Climatic Factors Controlling Chemical and Isotopic Characteristics of Precipitation in Syria." *Hydrological Processes*.

Abou Zakhem, Boulos and Bassam Kattaa (2015). "Cumulative drought effect on Figeh karstic spring discharge (Damascus basin, Syria)." *Environmental Earth Sciences* 75.

Abu Qudaira, M (2005). Geological Map of Dayr Abu Sa'id [map]. National Mapping Project. Map Sheet No. 3154 - IV, 1:50,000. Amman, Ministry of Energy and Mineral Resources - Natural Resources Authority (Geology Directorate).

Abu Sitta, Salman (2011). An Atlas of Palestine. London, Palestine Lands Society.

Abu-Jaber, N. and A. Kharabsheh (2008). "Ground water origin and movement in the upper Yarmouk Basin, Northern Jordan." *Environ Geol* 54: 1355-1365.

Abu-Rukah, Y. and H. A. Ghrefat (2001). "Assessment of the anthropogenic influx of metallic pollutants in Yarmouk River, Jordan." *Environmental Geology* 40: 683-692.

Action Aid (1976). Jordanian/Syrian Agreement re Yarmouk River Waters. Declassified document released by US Department of State EO Systematic Review 22 May 2009, ID No. 1977AMMAN04057_c, Cable from Action Aid - Agency for International Development. https://wikileaks.org/plusd/cables/1976TELAV08483_b.html

Adelphi (1992). The Jordan basin and the Litani. The Adelphi Papers. 32:273, 8-26,.

Agha, W. R. and A. Deeb (2005). حالة الموارد المائية في سوريا. Syria, Ministry of local administration and environment.

Agri-News (2011). "الحزام الاخضر في محافظة درعا أحد أهم مشاريع التشجير المثمر يستفيد منه 6500 فلاح من أبناء المحافظة."

Akdim, Nadia, Silvia Maria Alfieri, Adnane Habib, Abdeloihab Choukri, Elijah Cheruiyot, Kamal Labbassi and Massimo Menenti (2014). "Monitoring of Irrigation Schemes by Remote Sensing: Phenology versus Retrieval of Biophysical Variables." *Remote Sens.* 6: 5815-5851.

al Farawati, Oula (2001). Wihdeh Dam construction to start next March. Jordan Times, see Independent Media Review Analysis http://www.imra.org.il/story.php3?id=7358

Al Majdoub, Tareq (1998). La Ahada Yashrab: Mashare' Al Miya fi Istratijiyat Israel [Not a Drop to Drink: Israeli water strategy. Beirut, Riad El-Rayyas Books.

Al Manaseer, Ata Fahed Abdel Rahman (2012). Jordan's Water Security: Challenges and Risks. Middle East University, Political Sciences.

Al Qusaym, M. (2016). "تقرير أولي عن واقع المياه في المنطقة الجنوبية)حوض اليرموك(."

Al-Bakri, J. T. (2015). Mapping Irrigated Crops and Their Water Consumption in Yarmouk Basin. A Report for Regional Coordination on Improved Water Resources Management and Capacity Building. Amman, Jordan, Ministry of Water and Irrigation.

Al-Droubee, Rania (2000). "المسألة الزراعية في سورية بين عامي 1970 - 1995 واقعها وآثار تطورها." *Journal of the university of Damascus* 16.

Al-Fares, W. (2016). "Using Vertical Electrical Soundings for Characterizing Hydrogeological and Tectonic Settings in Deir El-Adas Area, Yarmouk Basin, Syria." *Acta Geophysica* 64: 610-632.

Al-Ghraibeh, Rasha Adil (2008). Yarmouk river basin management, an attempt to an integrated approach. Jordan university of science and technology, Faculty of Graduate Studies.

Al-Hmoud, Nisreen (2012). "Transboundary water management in western part of Jordan, challenges and solutions."

Al-Husein, A. B. (2007). "التلوث في حوض اليرموك." *Syrian Cosmological Society*.

Al-Kloub, B. and Maher F. Abu-Taleb (1998). "Application of multicriteria decision aid to rand the Jordan-Yamrouk basin co-riparians according to the Helsinki and ILC rules." *Water International* 23(3): 164 - 173.

Al-Nahas, A. (2011). "الري الحديث في القطر العربي السوري." مجلة جامعة دمشق للعلوم الهندسية 27 :23-42.

Al-Rubeai, Sahib (2004). The Syrian Water Conflict in Al-Yermouk and Orontes (Al-Asi) Basins. Al-diwan Printing Press - Bagdad-Batawen.

Al-Sa'ed, Rashed and Ahmad Al-Hindi (2013). Challenges of transboundary wastewater management for Palestinian communities along the Green Line - The Israeli-Palestinian border. Shared Borders, Shared Waters: Israeli-Palestinian and Colorado River Basin Water Challenges. Megdal, S. B., R. G. Varady and S. Eden. CRC Press - Balkema, Taylor and Francis Group. 203 - 220.

Al-Yazeji, W., A. M. Al-Belkhi and M. Al-Belkhi (2004). "رصد التلوث الكيماوي والجرثومي في مياه المنطقة الجنوبية الغربية من حوض اليرموك." *Journal of the university of Damascus* 20: 175-200.

Al-Zoghbi, M., A. Majar, H Darwish, O. Jozdan, N. Hboub and M. Hkoun (2014). استعمال مياه الصرف الصحي المعالجة في الزراعة, الهيئة العامة للبحوث العلمية الزراعية.

Alatout, Samer (2006). "Towards a bio-territorial conception of power: Territory, population, and environmental narratives in Palestine and Israel." *Political Geography* 25: 601 - 621.

Alatout, Samer (2009). "Bringing abundance into environmental politics: Constructing a Zionist network of water abudance, immigration, and colonization." *Social Studies of Science* 39(3): 363 - 394.

Alatout, Samer (2011). "Hydro-Imaginaries and the Construction of the Political Geography of the Jordan River: The Johnshton Mission, 1953-56."

Alhusban, Y. (2016). "Automated analysis of the Watershed of Yarmouk Basin using ASTER (DEM) data and GIS."

Ali Deeb, Tarek and Faten Soussy (2004). "دراسة تطور استهلاك القمح في الجمهورية العربية السورية." *Journal of the university of Damascus for agricultural sciences* 20: 191 - 213.

Allan, J.A. (2001). The Middle East Water Question: Hydropolitics and the Global Economy. London, UK, I.B. Tauris.

Allen, R. G. , L. S. Pereira, D. Raes and M. Smith (1998). Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. Rome, Food and Agriculture Organization.

Amadoni, V.M. (1997). "The Formation of the Transjordan-Syria Boundary, 1915-32." *Middle Eastern Studies* 31(3): 533 - 549.

Amery, Hussein (1998). "The role of water resources in the evolution of the Israeli-Lebanese border." *GeoJournal* 44(1): 19-33.

Amery, Hussein (2002). "Water Wars in the Middle East: A Looming Threat." *The Geographical Journal* 168(4): 313 - 323.

Amery, Hussein and Aaron Wolf, Ed. (2000). Water in the Middle East: A Geography of Peace. Austin, USA, University of Texas Press.

Arab Plan (1954). "The Arab's Plan for Development of Water Resources in the Jordan Valley, March 1954."

Attili, Shaddad (2004). Graphic of Historical Development Plans of the Jordan River Basin. Ramallah, West Bank, Negotiation Support Unit, Negotiations Affairs Department, Palestine Liberation Organisation.

Aviram, Ram, David Katz and Deborah Shmueli (2014). "Desalination as a game-changer in transboundary hydro-politics." *Water Policy* 16: 609-624.

Avisse, Nicolas, Amaury Tilmant, Marc F. Müller and Hua Zhang (in preparation). "Monitoring small reservoirs storage from satellite remote sensing in inaccessible or remote areas." *(part of the Jordan Water Project)*.

Avisse, Nicolas, Amaury Tilmant, Marc François Müller and Hua Zhang (2017). "Monitoring small reservoirs storage from satellite remote sensing in inaccessible areas." *Hydrology and Earth System Sciences Discussions*: 1-23.

Avitzur, Shmuel (2003). The Power Plant on Two Rivers. Tel Aviv, The Israel Review of Arts and Letters. website hosted by Ministry of Foreign Affairs (Israel) http://mfa.gov.il/MFA/MFA-Archive/2003/Pages/The%20Power%20Plant%20on%20Two%20Rivers.aspx

Awawdeh, M. M., Jaradat, R. A. (2010). "Evaluation of Aquifers Vulnerability to Contamination in the Yarmouk River Basin, Jordan, Based on DRASTIC Method." *Arabian Journal of Geosciences* 3: 273-282.

Ayeb, Habib (1993). Le bassin du Jourdain dans le conflit Israelo-Arabe. Beyrouth, Presses de l'Ifpo.

Ayeb, Habib (1998). L'eau au Proche-Orient, La guerre n'aura pas lieu. Paris, France, Karthala-CEDEJ.

Baim, Karen A. (1997). "Come Hell or High Water: a Water Regime for the Jordan River Basin." *Washington University Law Review* 75(2): 919 - 952.

Baker, M. and Harza (1955). The Hashemite Kingdom of Jordan - Yarmouk-Jordan Valley Project - Master Plan Report.

Baker-Harza (1953). Yarmouk-Jordan Valley Project Appraisal Report, prepared by Michael Baker Jr., Inc., Rochester Pennsylvania and Harza Engineering Company, Chicago, Illinois, USA. Jordan, Cooperative Department, Water Resources Development, Ministry of Finance, Government of the Hashemite Kingdom of Jordan.

Bandel, Klaus and Elias Salameh (2013). Geologic development of Jordan: Evolution of its rocks and life. Jordan, SMART.

Bar-Gal, Yoram (1991). The Good and the Bad: A hundred years of Zionist images in geography textbooks. Research Paper number four. London, UK, Department of Geography, Queen Mary and Westfield College, University of London.

Barach, Yoram (2016). "personal communication with farmer, Yarmouk Triangle, July 2016. Anonymised.".

Barinova, Sophia S. and Eviatar Nevo (2010). "The Upper Jordan River Algal Communities are Evidence of Long-Term Climatic and Anthropogenic Impacts." *Journal of Water Resource and Protection*: 507 - 526.

Barnes, Jessica (2009). "Managing the Waters fo Ba'ath Country: The Politics of Water Scarcity in Syria." *Geopolitics* 14(3): 510 - 530.

Batayneh, Awni T. (2010). "Heavy Metals in Water Springs of the Yarmouk Basin, North Jordan and their Potentiality in Health Risk Assessment." *International Journal of the Physical Sciences* 5: 997-1003.

Batayneh, Awni T. (2011). "Hydrochemical characteristics of the major water springs in the Yarmouk basin, north Jordan." *Natural Science* 31: 28-35.

Baxter, Richard R. (1977). Legal Questions Arising out of the Construction of a Dam at Maqarin on the Yarmuk River. Washington, D.C., Report of a Working Group Established by the American Society of

International Law under Contract AID/NE-C-1256 with the Agency for International Development. AKA 'the Baxter Report'.

Beaumont, Peter (1997). "Dividing the Waters of the River Jordan: An Analysis of the 1994 Israel-Jordan Peace Treaty." *Water Resources Development* 13(3): 415 - 424.

Belkin, Shimson and Shoshana Gabbay (2000). The Quest for Water Efficiency - Restructuring of Water Use in the Middle East. The Netherlands, Kluwer Academic Publishers.

Bender, Friedrich (1968). "Geologie von Jordanien: Beitr." *regionalen Geologie Erde* 7: 230.

Bourgoin, MM. A., H. de Cizancourt and W. B. Fish (1948). Etudes géologiques et géographiques sur le Liban, la Syrie et le Moyen-Orient.

Bredehoeft, John (1997). "Safe Yield and the Water Budget Myth." *Ground Water* 45(6): 929.

Burdon, D. (1954). "Infiltration Rates in the Yarmouk Basin of Syria-Jordan."

Burdon, D. J., S. Mazloum and C. Safadi (1954). "Ground water in Syria." *Assemblé générale Ass. Int. d'Hydrologie*.

Burdon, D. J. and C. Safadi (1962). The karst ground waters of syria. Damascus, Ministry of Public Works.

Cafiero, Carlo (2016). Supply and Demand Prospects for the Major Syrian Agricultural Products, FAO.

CBS (2016). Central Bureau of Statistics data, Government of Syria.

Choudhury, Enamul (2017). The Nature of Enabling Conditions of Transboundary Water Management: Learning from the Negotiation of the Indus and Jordan Basin Treaties. Water Diplomacy in Action: Contingent Approaches to Managing Complex Water Problems. Islam, S. and K. Madani. London, Anthem.

Citino, N. (2017). Envisioning the Arab Future: Mondernization in the U.S. - Arab Relations, 1945 - 1967. Cambridge, Cambridge University Press.

CO (1926). Agreement as to Water Concession at Jerusalem, between the Crown Agents for the Colonies and Euripides Mavrommatis. Westminister, London, UK National Archives Commonwealth Office record CAOG 14/124.

CO (1927a). Case concerning the Re-Adaptation of the Mavrommatis Concessions - Opinion of the Attorney General and Mr. Fachiri, UK National Archives Commonwealth Office record CO 733/131/1-3.

CO (1927b). Draft Agreement 13th October 1927 Between Field Marshall the Right Honourable Herbert Charles Onslow and the Jaffa Electric Company Limited, UK National Archives Commonwealth Office record CO 733/134/6.

Comair, G.F., C. McKinney and D. Siegel (2012). "Hydrology of the Jordan River Basin: Watershed Delineation, Precipitation and Evapotranspiration." *Water Resources Management* (DOI 10.1007/s11269-012-0144-8).

Courcier, R. and J-P. Venot (2004). "Bilan des ressources en eau au sein du Bassin versant du Jourdain en Jordanie. Evolution et prospectives sur la periode 1950-2025."

Courcier, Remy, Jean Philippe Venot and Francois Molle (2005). Historical Transformations of the Lower Jordan River Basin (in Jordan): Changes in Water Use and Projections. Comprehensive Assessment of water management in agriculture, Research Report 9. Colombo, Sri Lanka, International Water Management Institute.

Curtis, R. (2006). "The Odd Couple: Ending the Jordanian-Syrian 'Cold War'." *The Middle East Journal* 60(1): 33 - 56.

Da'Na, Seif (2013). "Israel's Settler-Colonial Water Regime: The Second Contradiction of Zionism." *Holy Land Studies* 12(1): 43 - 70.

Dafny, E., H. Gvirtzman, A. Burg and L. Fleischer (2003). "The Hydrogeology of the Golan Basalt Aquifer, Israel." *Isr. J. Earth Sci.* 52: 139-153.

Dalit (pers. comm.), Marwan (2017). "Pesonal communication by Skype with former MWI employee, 10 January 2017. Anonymised.".

Dana (pers. comm.), Odai (2016). "Personal communication with Syrian academic, via Skype 25 November 2016. Anonymised.".

Daoud, Maan Daniel (2014). Water and Agriculture Sector in the Arab Syrian Republic in light of the multi-scale socie-economic structural crisis, Syrian Economic Sciences Society.

Daoudy, Marwa (2008). "A Missed Chance for Peace: Israel and Syria's Negotiations Over the Golan Heights." *Journal of International Affairs* 61(2): 215 - 234.

Dar'a News (2017). Springs in Dar'a.

Darmane, Khadija, Stephen Nortcliff and Robert B. Potter (2010). The role of water and land management policies in contemporary socio-economic development in Wadi Faynan. Water, Life and Civilisation: Climate, Environment and Society in the Jordan Valley. Mithen, S. and E. Black. Cambridge, Cambridge University Press.

Dash, P., F-M. Göttsche, F-S. Olesen and H. Fischer (2002). "Land surface temperature and emissivity estimation from passive sensor data: Theory and practice-current trends." *International Journal of remote sensing* 23: 2563-2594.

De Châtel, Francesca (2014). "The Role of Drought and Climate Change in the Syrian Uprising: Untangling the Triggers of the Revolution." *Middle Eastern Studies* 50(4): 521-535.

de Châtel, Francesca (2015). Leaving the Land: The Impact of Long-term Water Mismanagement in Syria. Water Scarcity, Security and Democracy: a Mediterranean Mosaic. de Châtel, F., G. Holst-Warhaft and T. Steenhuis. GWP-Med and Cornell University.

de Châtel, Francesca and Mohammad Raba'a (2014). "Water Wadi Barada: Manufacturing Scarcity in a Syrian River." *Middle East Report* 271(Summer 2014).

De Stefano, Lucia, James Duncan, Shlomi Dinar, Kerstin Stahl, Kenneth M Strzepek and Aaron T. Wolf (2012). "Climate change and the institutional resilience of international river basins." *Journal of Peace Research* 49(1): 193 - 209.

Dearden, A. (1958). The Struggle for Water: Jordan. London, Robert Hale Limited.

Delli-Priscoli, Jerome and Aaron Wolf (2008). Managing and Transforming Water Conflicts. Cambridge, Cambridge University Press.

Dinar, Shlomi, David Katz, Lucia De Stefano and Brian Blankespoor (2015). "Climate change, conflict, and cooperation: Global analysis of the effectiveness of international river treaties in addressing water variability." *Political Geography* 45: 55-66.

Dolatyar, M. (1995). "Water diplomacy in the Middle East." *Iranian Journal of International Affairs* 7: 599 - 615.

Dorigo, M., W. Wagner, C. Albergel, F. Albrecht, G. Balsamo, L. Brocca, D. Chung, M. Ertl, M. Forkel, A. Gruber, E. Haas, P. Hamer, M. Hirschi, J. Ikonen, R.d. Jeu, R. Kidd, W. Lahoz, Y.Y. Liu, D. Miralles, T. Mistelbauer, N. Nicolai-Shaw, R. Parinussa, C. Pratola, C. Reimer, R.v.d. Schalie, S.I. Seneviratne, T. Smolander and P. Lecomte "ESA CCI Soil Moisture for improved Earth system understanding: state-of-the art and future directions." *Remote Sensing of Environment* in review.

DOS (2014). Environment statistics 2011. Jordan, Department of Statistics.

Eckstein, Gabriel and Francesco Sindico (2014). "The Law of Transboundary Aquifers: Many Ways of Going Forward, but Only One Way of Standing Still." *Review of European Community and International Environmental Law* 23(1): 32 - 42.

EcoPeace (2015). Regional NGO Master Plan for Sustainable Development in the Jordan Valley: Final Report - June 2015. TelAviv, EcoPeace Middle East.

el Musa, Sharif (1998). "Towards a Unified Management Regime in the Jordan Basin: The Johnston Plan Revisited." *Yale F&ES Bulletin* Bulletin 103.

El Taneh (pers. comm.), Ahmad (2017). "Personal communication with expert from Etana, Amman, 26 March 2017. Anonymised.".

Energoprojekt (1964). The Yarmouk Project - Preliminary Study.

Etana (2015). The Yarmouk Basin: Between Conflict and Development. Etana Files, ETANA Syria Publishing and Documentation.

Etana ((pers.comm) 2017). "Interview with the authors of The Yarmouk Basin: Between Conflict and Development, July 2017, Amman."

FAO (2008). Jordan river basin. Irrigation in the Middle East region in figures, Rome, Food and Agriculture Organization

FAO (2009). Irrigation in the Middle East region in figures. FAO Water Reports No. 34. Franken, K. Rome, Food and Agriculture Organization.

FAO (2016). Aquastat Database - Dams, Food and Agriculture Organization. www.fao.org/nr/water/aquastat/dams/index.stm

Faour, G., M. Mhawej and S. Abou Najem (2015). "Regional Landsat-Based drought monitoring from 1982 to 2014." *Climate* 3: 563-577.

Farber, Efrat, Avner Vengosh, Itai Gavrielli, Amer Marie, Thomas D. Bullen, Bernhard Mayer, Ran Holtzman, Michal Segal and Uri Shavit (2004). "The origin and mechanisms of salinization of the Lower Jordan River." *Geochimica et Cosmochimica* 68(9): 1989-2006.

FCO (1979). Jordan Waters. Correspondence between Foreign and Commonwealth Office and Embassy in Amman, UK National Archives Commonwealth Office record FCO93-1988, RRM040/1.

FCO (1980). The Maqarin Dam Project and the Status of International Frontiers. Report by M J Fuller, Research Department, and maps of demiltarized zones, UK Foreign and Commonwealth Office record FCO93/2756.

Fischhendler, Itay (2004). "Legal and Institutional adaptation to climate uncertainty: a study of international rivers." *Water Policy* 6(4): 281-302.

Fischhendler, Itay (2008). "Ambiguity in Transboundary Environmental Dispute Resolution: The Israel-Jordanian Water Agreement." *Journal of Peace Research* 45(1): 91 - 110.

FNA (1921a). Communication issued by Etat-Commissariat de la Republique Francaise en Syrie et au Liban, 19 Novembre 1921. Signed by "British Experts" General Grant and Rotenberg, and by "French Experts" E. Achaud and A. Younes. French National Archives in Nantes, Archives des postes diplomatiques, consulaires, culturels et de cooperation: Caisse 450; Fonds - "Beyrouth"/2e versement; Serie - Service Techniques "Hydraulique"; Sujet - Utilisation de la rivière Yarmouk et du bassin supérieur du Jourdain Station de jaugeage de Wadi-Khaled, 1921 - 1942.

FNA (1921b). ETUDE GENERALE DE LA FRONTIERE PROBABLE vers METELLI et du pays au N. et au SUD, immédiatement des deux côtés de (la) frontière. De l'Inspecteur des Travaux Publics de l'Etate du Grand Liban. French National Archives in Nantes, Archives des postes diplomatiques, consulaires, culturels et de cooperation: Caisse 450; Fonds - "Beyrouth"/2e versement; Serie - Service Techniques "Hydraulique"; Sujet - Utilisation de la rivière Yarmouk et du bassin supérieur du Jourdain Station de jaugeage de Wadi-Khaled, 1921 - 1942.

FNA (1921c). La Convention Franco - Anglaise du 23 Decembre 1920 sur les Mandats et ses Conséquences pour la Syrie, by M Achard, 27 October 1921. French National Archives in Nantes, Archives des postes diplomatiques, consulaires, culturels et de cooperation: Caisse 1373 (document 21); Fonds - Syrie-Liban/1er versement; Serie - Bureau Diplomatique, Dossiers de principe/Inventaires no 12 et 15, t.1, 1926 - 1941; Sujet - Conventions, Relations franco-britanniques dans leurs mandats respectifs.

FNA (1921d). Rapport sur le territoire du Sandjak de Saida, de Monsieur S. Florimond, chargé de mission par le Haut-Commissariat de la République Francaise à Monsieur le Lieutenant Colonel NIEGER, Administrateur en chef p.i. des T.E.O (Zône Ouest). French National Archives in Nantes, Archives des postes diplomatiques, consulaires, culturels et de cooperation: Caisse 1373; Fonds - Syrie-Liban/1er versement; Serie - Bureau Diplomatique, Dossiers de principe/Inventaires no 12 et 15, t.1, 1926 - 1941; Sujet - Conventions, Relations franco-britanniques dans leurs mandats respectifs.

FNA (1921e). Répartition des eaux fluviales entre la Syrie et la Palestine. Report of the Commission de répartition des eaux fluviales entre la Syrie et la Palestine. Issued as an annex in correspondence by E. Achard (Chef du Service de l'Agriculture du Haut-Commissariat) and Général Gouraud (Haut-Commissaire de la République Française en Syrie et au Liban. . French National Archives in Nantes, Archives des postes diplomatiques, consulaires, culturels et de cooperation: Caisse 656.

FO (1947). Use of the waters of the rivers Jordan and Yarmouk. Communication by Transjordan Prime Minister and Minister of Foreign Affairs (Samir Rifai) on the use of the waters of the rivers Jordan and Yarmouk, forwarded by British authorities to UK Secretary of State for Foreign Affairs (Ernest Bevin), UK Foreign Office record FO 816/96.

FO (1951). Ionides' Irrigation plan. Correspondence between British Foreign Office, Amman Legation, and merchants in relation to the Ionides' plan for irrigation of the Jordan valley with Yarmouk flows, UK Foreign Office record FO 371-91832.

FO (1952). American Draft Agreement. Copy of the draft agreement proposed between Syria and Jordan, and correspondence between British Embassy staff, UK Foreign Office record FO 371-9882.

FO (1953). On Jordanian Plans to Develop the Yarmouk Plans. Correspondence between Palestine Electric Corporation and UK Government, and between Jordanian Government and UK Government, UK Foreign Office record FO 371/104953 - 1532/15-19.

FO (1959). Jordanian Drainage of River Yarmuk: Effect on Israel's economy. Correspondence between Jewish Telegraphic Agency, Ltd. and Foreign Office, UK Foreign Office record FO 371-142383.

FO (1962). Gauging the extent of British involvement in the "Jordan Waters problem". Correspondence between British Embassy in Amman and British Embassy in Washington, January 1962, UK Foreign Office record FO 371/164137.

FO (1963). Yarmouk Project. Correspondence between British Embassy in Amman to Foreign Office, UK Foreign Office record FO 371-170331.

FO (1968). Lake Tiberias - River Yarmuk Proposed Israeli Canal Project. Correspondence between Foreign Office and British Embassy in Washington, UK Foreign Office record FO 17-611.

Frey, Frederick W. and Thomas Naff (1985). "Water: An Emerging Issue in the Middle East?" *Annals of the American Academy of Political and Social Science* 482(November 1985): 65 - 84.

Galili (pers. comm.), Arwa (2016). "Personal communication via Skype, 5 December 2016. Anonymised.".

Ghantous, (pers. comm. 2018). "Personal communication, Beirut, 17 July 2018. Anonymised.".

Ghureir (pers. comm.), Mohammad (2018). "Personal communication at Adassiyeh, Sept 2018. Anonymised.".

Gilmont, Michael, Steve Rayner, Erica Harper, Lara Nassar, Nadav Tal, Mike Simpson and Hilmi Salem (2017). Decoupling National Water Needs for National Water Supplies: Insights and Potential for Countries in the Jordan Basin. Amman, West Asia - North Africa Institute.

Gleick, Peter H. (2014). "Water, Drought, Climate Change, and Conflict in Syria." *Weather, Climate, and Society* 6(3): 331-340.

GoP (1946). The French-British Convention of 1920: contemplated nomination of experts to examine the possibilities of using waters of the Upper Jordan and Yarmuk for irrigation and power, Government of Palestine Chief Sectretary's Office, document V-5-46, No 480/.

GoP (1947). Memorandum on the Water Resources of Palestine. Presented by the Government of Palestine to the United Nations' Special Committee on Palestine in July, 1947. Jerusalem, Government Printer, Government of Palestine.

Greco, Francesca (2005). The Securitization of the Disi Aquifer: A Silent Conflict between Jordan and Saudi Arabia. Presentation given at First Workshop on Hydro-Hegemony, 21/22 May 2005, King's College London, London, UK, London Water Research Group.

Hadadin, Nidal (2015). "Dams in Jordan Current and Future Perspective." *Canadian Journal of Pure and Applied Sciences* 9: 3279-3290.

Haddadin (pers. comm.), Munther (2017). "Personal communication, Amman, 9 June 2017."

Haddadin, Munther (2000). "Negotiated resolution of the Jordan-Israel water conflict." *International Negotiation* 5(2): 263 - 288.

Haddadin, Munther (2002a). Diplomacy on the Jordan: International Conflict and Negotiated Resolution. New York, Springer Science and Business Media, LLC.

Haddadin, Munther (2002b). "Water in the Middle East peace process." *The Geographical Journal* 168(4): 324 - 340.

Haddadin, Munther (2006). Water Resources in Jordan: Evolving Policies for Development, the Environment, and Conflict Resolution. Washington, Resources for the Future.

Haddadin, Munther (2007). Salaam ala al Yarmouk Al Muwajahat w al Mufawadat (1967-2000) [Peace on the Yarmouk: Confrontation and Negotiation (1967-2000)]. Amman.

Hamdan, I. (2016). Characterization of groundwater flow and vulnerability assessment of karstic aquifers - Development of a time-based approach and application to the Tanour and Rasoun spring catchment (Ajloun, NW Jordan). Georg-August University School of Science (GAUSS), Germany.

Hammouri, N. A. (2009). "Assessment of Climate Change Impacts of Water Resources in Jordan."

Hart, Samuel F. (1978). Correspondence to Mr Moshe Alon, Deputy Director General of the Ministry of Foreign Affairs. Tel Aviv, October 4, 1978, Embassy of the United States of America, Tel Aviv.

Harza (1979). Jordan Valley Irrigation Project Stage II: Project Overview, Harza Overseas Engineering Company.

Hayton, Robert D. and Albert E. Utton (1989). "Transboundary Groundwaters: The Bellagio Draft Treagy." *Natural Resources Journal* 677.

Hays, James B. (1948). T.V.A. on the Jordan - Proposals for Irrigation and Hydro-Electric Development in Palestine. Washington, DC, USA, A Report Prepared Under the Auspices of the Commission on Palestine Surveys, Public Affairs Press, assisted by A.E. Barrekette, with an introduction by Walter C. Lowdermilk.

Heinz, Peter Brunke and GeoNumerix (1997). Volume 5 - Groundwater Modelling - Part 1 - Three Dimensional Groundwater Model of the Northern Jordan. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Hinnesbusch, R. (2011). The Ba'ath's Agrarian Revolution (1963 - 2000). Agriculture and Reform in Syria. Hinnesbushch, R. St Andrews, University of St Andrews Centre for Syrian Studies.

Hobler, Manfred, Armin Margane, Mohammad Almomany, Ali Subah, Mazen Rayyan, Nidal Khalifeh, J. Al Mahamid, Hani Hijazi, Zakaria Zuhdy, Saleh Ouran and Ali Hammoudeh (2001). Volume 4 - Contributions to the Hydrogeology of Northern Jordan. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Hobler, Manfred, Armin Margane, Izdehar Saffarini, Mohammad Almomany, Ali Hammoudeh, Saleh Ouran, Mazen Rayyan, Abbas Kalbouneh and Ali Subah (1994). Volume 3 - Structural Features of the Main Hydrological Units in Northern Jordan. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Hof, Frederic C. (1995). "The Yarmouk and Jordan River in the Israel-Jordan Peace Treaty." *Middle East Policy* 3(4): 47 - 56.

Hoff, H. (n.d.). "Climate change, impacts and adaptation in the MENA region, with focus on Syria."

Hoff, Holger, Christopher Bonzi, Brian Joyce and Katja Tielbörger (2011). "A Water Resources Planning Tool for the Jordan River Basin." *Water* 3(4): 718-736.

HSI (2016a). Development and Utilization of Water Resources in Israel until Autumn 2014 [in Hebrew]. Jerusalem, Hydrological Service of Israel.

HSI (2016b). State of water sources in Israel 2016 (Hebrew). Jerusalem, Hydrological Service of Israel. http://water.gov.il/Hebrew/ProfessionalInfoAndData/Data-Hidrologeime/Pages/water-resources-2014.aspx

Husein, Kifah Mohammad (2012). "تقييم الوضع المائي في سورية من خلال تطبيق مبدأ المياه الافتراضية في القطاع الزراعي." *Journal of the university of Damascus* 28: 69-84.

Hussein, Hussam (2016). An analysis of the discourse of water scarcity and hydropolitical dynamics in the case of Jordan. School of International Development. University of East Anglia, Norwich.

Hussein, Hussam (2017). "Whose 'reality'? Discourses and hydropolitics along the Yarmouk River." *Contemporary Levant*.

Hussein, Hussam and Mattia Grandi (2017). "Dynamic political contexts and power asymmetries: the cases fo the Blue Nile and the Yarmouk Rivers." *International Environmental Agreements*.

Ibrahim, H. (2013). The Red Minaret - Memoirs of Ibrahim Ghusheh: Ex-spokesman of Hamas. Al-Zaytouna Centre.

Ionides, M. G. (1939). Report on the the Water Resources of Transjordan and their Development.

ISA (1939). Zoltan Kluger Photos, dated 11/06/1939, Israel State Archives.

ISA (1962). Letter from Israeli Ministry of Foreign Affairs (Chet Tzad) to Israel envoy to Washington (Mr Gazit), 29 August 1962, Israel State Archives.

Ishtayyeh, Mohammad (2011). The Encycloaedia of Palestinian Terminology and Concepts. Amman, Dar al Jaleel.

Issa, M. (2013). "الموازنة المائية في سوريا وآفاقها المستقبلية من عام 1992-1993-2008-2009 لغاية 2024-2025 م." *Journal of the University of Damascus* 29: 551-585.

IWA (2012). Master Plan for the National Water Sector: Main Points of the Policy Paper (slide presentation), Israel Water Authority.

IWA (2015). The Wastewater and Treated Effluents Infrastructure Development in Israel, Israel Water Authority.

Jafroudi, Maryam (2018). "Climate change and accommodation of water availability in transboundary rivers: lessons learned from the Guadiana basin." *Water Policy* 20: 203 - 217.

Jägerskog, Anders (2003). Why States Cooperate Over Shared Water: The Water Negotiations in the Jordan River Basin. Linköping, Sweden, Linköping University.

Jarrar, Shaker (2018). "Will Jordan reclaim its territory from "Israel" in the next year?" *7iber* (18 January 2018). www.7iber.com

Jarvis, W. Todd (2014). Contesting Hidden Waters: Conflict resolution for groundwater and aquifers. Routledge.

JICA and Syrian Arab Republic (2012). Project on Development of Efficient Irrigation Techniques and Extension Phase II in Syria.

Jobbins, Guy, Miriam Dennis Le Seve and Abdullah Droubi (2017). Water security for peacebuilding: a scoping paper for future options in Syria. London, Overseas Development Institute.

Joubran (pers. comm.), Sami (2017). "Personal communication by Skype, 14 June 2017.".

JVA (1988). Jordan Valley Irrigation Project Stage II: Al Wehdah Dam Project - Final Report on System Operation, Harza Engineering Company, April 1988, and Jordan Valley Authority.

JVA (2006). Index for Surface Water, Dams, and King Abdallah Canal, 1990 - 2006. Amman, Spreadsheet of the Jordan Valley Authority (Jordan).

JVA (2016a). Water level at Al Wehdah Dam 2007 - 2016. Amman: Spreadsheet of the Jordan Valley Authority (Jordan), provided December 2016. Shows daily gauging records of 'In Flow Data' and 'Out Flow Data', in m3.

JVA (2016b). JVA Historical Data, Yarmouk River Discharge from 1962 to 2016, showing monthly totals. Amman, Spreadsheet of the Jordan Valley Authority (Jordan).

JVA (2017). Yarmouk Dams in Jordan, Jordan Valley Authority (Jordan).

JVA (2018). Inflows to KACn & Con & Alloc & JR 2008 - 2017. Amman. Spreadsheet of the Jordan Valley Authority (Jordan), provided September 2017. Shows sources of flows to northern parts of King Abdallah Canal, plus Concessions to Israel.

JVWA (2016). Yarmouk River pumping from April 1982 until May 2015. Tel Aviv, Spreadsheet of the Jordan Valley Water Authority (Israel).

Katz, David (2016). "Undermining Demand Management with Supply Management: Moral Hazard in Israeli Water Policies." *Water* 8.

Kelley, C. P., S. Mohtadi, M. A. Cane, R. Seager and Y. Kushnir (2015). "Climate change in the Fertile Crescent and implications of the recent Syrian drought." *Proc Natl Acad Sci U S A* 112(11): 3241-6. http://www.ncbi.nlm.nih.gov/pubmed/25733898

Kingston, P. (1996). Britain and the Politics of Modernization in the Middle East, 1945 - 1958. Cambridge, Cambridge University Press.

Kipnis, Yigal (2007). The Golan Heights: Political history, settlement, and geography since 1949. USA and Canada, Routledge.

Kirschbaum, M.E. (1997). Water resources: security impacts in the Jordan River basin (No. AU/ACSC/0028/97-03), Air Command and Staff Coll Maxwell AFB AL.

Klinger, Jochen, David Riepl, Heinz-Peter Wolff, Ingo Heinz, Tino Rödiger, Joseph Guttman, Subhi Samhan, Abdelrahman Tamimi, Ali Subah, Martin Sauter, Roland Müller, Stefan Geyer, Wassim Ali, Manfred van Afferden, Mi-Yong Lee, Tanja Liesch, Heinz Hötzl and Nico Goldscheider (2016). Challenges of Implementing IWRM in the Lower Jordan Valley. Integrated Water Resources Management: Concept, Research, and Implementation. Borchardt, D., J. J. Bogardi and R. B. Ibisch. London, Springer.

Kout, W. (2008). Integrated water resources management in Syria.

Kriesberg, Louis (2009). The Evolution of Conflict Resolution. The Sage Handbook of Conflict Resolution. Bercovitch, J., V. Kremenyuk and W. I. Zartman. Thousand Oaks, CA, Sage.

Kubursi, Atif, Velma Grover, Abdel Raouf Darwish and Eliza Deutsch (2011). Water Scarcity in Jordan: Economic Instruments, Issues and Options. Working Paper No. 599. Giza, The Economic Research Forum.

KUNA (1999). Syria Pumps the first amount of water to Jordan, 14 May 1999, Kuwait News Agency. http://www.kuna.net.kw/ArticlePrintPage.aspx?id=999853&language=ar

Lankford, Bruce (2013). Resource Efficiency Complexity and the Commons: The Paracommons and Paradoxes of Natural Resource Losses, Wastes and Wastages. London, Routledge.

Layne, Linda (1994). Home and Homeland: The Dialogics of Tribal and National Identities in Jordan. New Jersey, Princeton University Press.

Lederach, John Paul (2005). The Moral Imagination: The Art and Soul of Building Peace. Oxford, Oxford University Press.

Libiszewski, Stephan (1995). Water Disputes in the Jordan River Basin Region and their Role in the Resolution of the Arab-Israeli Conflict. Environment and Conflicts Project Occasional Paper No. 13. Berne, Switzerland, ETH Zurich / Swiss Peace Foundation.

Liebe, J., N. van de Giesen and M. Andreini (2005). "Estimation of small reservoir storage capacities in a semi-arid environment A case study in the Upper East Region of Ghana." *Physics and Chemistry of the Earth* 30: 448-454.

Liu, Y.Y., W.A. Dorigo, R.M. Parinussa, R.A.M. De Jeu, W. Wagner, M.F. McCabe, J.P. Evans and A.I.J.M. Van Dijk (2012). "Trend-preserving blending of passive and active microwave soil moisture retrievals." *Remote Sensing of Environment* 123: 280-297.

Liu, Y.Y., R.M. Parinussa, W.A. Dorigo, R.A.M. De Jeu, W. Wagner, A.I.J.M. Van Dijk, M.F. McCabe and J.P. Evans (2011). "Developing an improved soil moisture dataset by blending passive and active microwave satellite-based retrievals." *Hydrology and Earth System Sciences* 15: 425-436.

Lowi, Miriam (1993). Water and Power - The Politics of a Scarce Resource in the Jordan River Basin. Cambridge, USA, Cambridge University Press.

MacDonald & Partners (1951). Report on the Proposed Extension of Irrigation in the Jordan Valley. London, UK, Sir M. MacDonald & Partners, Chartered Civil Engineers, prepared for the Hashemite Kingdom of Jordan.

Makke-Traboulsi, M. (2013). "Les precipitations dans les marges arides du Proche Orient: l'exemple du bassin versant du Yarmouk." *Hannon, revue de geographie libanaise* 26: 53-76.

Margane, A. (2015). Updating the A7/B2 Groundwater Contour Map in North Jordan.

Margane, A., M. Hobler and A. Subah (1999). "Mapping of Groundwater Vulnerability and Hazards to Groundwater in the Irbid Area, N Jordan." *Z. angew. Geol.* 45.

Margane, Armin, Mohammad Almomany, Manfred Hobler, Izdehar Saffarini, Ali Subah, Nidal Khalifeh, Zakaria Zuhdy, Jihad Al-Mahamid and Kheir Al-Hadidi (1995a). Volume 2 - Groundwater abstraction and groundwater monitoring - Part 1 - Groundwater abstraction in Northern Jordan. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Margane, Armin, Manfred Hobler, Ali Subah, Mohammad Almomany, Saleh Ouran and Zakaria Zuhdy (1997). Special Report 3 - Mapping of Groundwater Vulnerability and Hazards to Groundwater in the Irbid Area. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Margane, Armin, Izdehar Saffarini, Manfred Hobler, Abbas Kalbouneh and Ali Subah (1995b). Volume 2 - Groundwater abstraction and groundwater monitoring - Part 2 - Monitoring of groundwater levels in Jordan. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Margane, Armin and Zakaria Zuhdy (1995c). Volume 1 - Part 1 - Rainfall in Jordan. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Margane, Armin, Zakaria Zuhdy and Izdehar Saffarini (1996). Volume 1 - Part 2 - Spring Discharge in Northern Jordan. Groundwater resources of Northern Jordan. Amman, Jordan, Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan.

Marin, Philippe, Shimon Tal, Joshua Yeres and Klas Ringskog (2017). Water Management in Israel: Key Innovations and Lessons Learned for Water-Scarce Countries. Water Global Practice Technical Paper, World Bank Group.

Matsushima, S., A. Arslan and B. Al-Hussein "Challenges of Converting to Efficient Water Saving Irrigation in Syria."

Mazen, N. (2017). Technical data shown to Yarmouk Hydropolitical Baseline team, May 2017. Anonymised.

McCaffrey, Stephen (2007). The Law of International Watercourses. Oxford, Oxford University Press.

McIntyre, Owen (2007). Environmental Protection of International Watercourses under International Law. Hampshire, Ashgate.

Meisen, Peter and Jenna Tatum (2011). The Water-Energy Nexus in the Jordan River Basin: The Potential for Building Peace through Sustainability, Global Energy Network Insitute.

Melton, F. (2016). "Electrifying Jaffa: Boundary-Work and the Origins of the Arab-Israeli Conflict." *Past&Present* 231(1): 201 - 236.

Meselmanee, Y. (2008). تقييم حساسية قطاع المياه للتغيرات المناخية في سوريا (سياسات المياه), UNDP, GEF, INC-Syria, Ministry of Environment, Ministry of local development.

Mhawej, M., G. Faour, A. Fayad and A. Shaban (2014). "Towards an enhanced method to map snow cover areas and derive snow-water equivalent in Lebanon." *Journal of Hydrology* 513: 274-282.

Mimi, Ziad and Bassam Sawalhi (2003). "A Decision Tool for Allocating the Waters of the Jordan River Basin Between all Riparian Parties." *Water Resources Management* EWRA 17(6): 447-461.

Mirumachi, Naho (2015). Transboundary Water Politics in the Developing World. London, Routledge.

MoAAR (2014). "Yearly statistics of the MoAAR."

Moh'd, Basem K. (2000). The Geology of Irbid and Ash Shuna Ash Shemaliyya (Waqqas) Map Sheets No. 3154-II and 3154-III. Jordan, The Hashemite Kingdom of Jordan, Ministry of Energy and Mineral Resources, Natural Resources Authority.

MOLA (2014a). Response plan for humanitarian assistances in emergencies cooperation between the Ministry of Local Administration and United Nations System working in Syria.

MoLA (2014b). إدارة النفايات الصلبة في سوريا، المخطط التوجيهي وواقع النظافة.

Molle, Francois, Jean Philippe Venot and Youssef Hassan (2008). "Irrigation in the Jordan Valley: Are water pricing policies overly optimistic?" *Agricultural Water Management* 95: 427 - 438.

Mourad, A. K. and R. Berndtsson (2011). "Syrian Water Resources between the Present and the Future." *Air, Soil and Water Research* 4: 92-100.

MoWR (2014). General company for sewage in Sweida, current situation and needs.

Muller, Marc François, Jim Yoon, Steven M. Gorelick, Nicholas Avisse and Amaury Tilmant (2016). "Impact of the Syrian refugee crisis on land use and transboundary freshwater resources." *Proceedings of the National Academy of Sciences* 113(52): 14932-14937. https://www.ncbi.nlm.nih.gov/pubmed/27930317

Musy, Andre (2001). e-drologie: cours d'hydrologie generale. Lausanne: EPFL.

MWI (2015). Action Plan for the Yarmouk River Basin. Amman, Ministry of Water and Irrigation Yarmouk River Basin Committee.

MWI (2016a). "Dams of Yarmouk in Syria."

MWI (2016b). National water strategy - Jordan 2016-2025.

Naff, Thomas and Ruth Matson (1984). Middle East Water: The Potential for Conflict or Cooperation. Water in the Middle East - Conflict or Cooperation? Naff, T. and R. Matson. (Westview Replica Edition) Boulder, USA, Westview Press.

Nathan (pers. comm.), Joel (2017a). "Personal communication by Skype with JVWA employee, 26 April 2017. Anonymised.".

Nathan (pers. comm.), Joel (2017b). "Personal communication with JVWA employee, Yarmoukim Reservoir, 28 Sept 2017. Anonymised.".

Neff, Donald (1994). "Israel-Syria: Conflict at the Jordan River, 1949 0 1967." *Journal of Palestine Studies* 23(4): 26 - 40.

Nicolle, David (1994). Yarmuk 636 A.D.: The Muslim Conquest of Syria. Osprey Publishing.

Nizam, A. A. and S. Mohamad (2014). "تقييم نوعية المياه في بحيرة المزيرب." *Journal of the university of Damascus* 30: 187-214.

NRC (2015). 'Doubling of the Mekorot Water Supply to Gaza Strip': Putting the Statement into Perspective. Version 4 - 24 June 2015, Norwegian Refugee Council - Palestine.

NSU (2005). The West Ghor Canal - Concept Paper. Confidential. Ramallah, Palestine, Negotiation Support Unit, Negotiation Affairs Department, Palestine Liberation Organisation.

Obeidat, M. M., M. Awawdeh and F. Abu Al-Rub (2012). "Multivariate Statistical Analysis and Environmental Isotopes of Amman/Wadi Sir (B2/A7) Groundwater, Yarmouk River Basin, Jordan." *Hydrological Processes*.

Odeh, Taleb, Alsharifa Hind Mohammad, Hussam Hussein, Mamoon Ismail and Thair Almomani (2019). "Over-pumping of groundwater in Irbid governorate, northern Jordan: a conceptual model to analyze the effects of urbanization and agricultural activities on groundwater levels and salinity." Envi*ronmental Earth Sciences* 78(40).

Orient (2011). Yarmouk River Basin Water Resources Assessment and Use - Final report, The Hashemite Kingdom of Jordan, Ministry of water and irrigation, Jordan Valley Authority.

Phillips, David, J. Anthony Allan, Marius Claassen, Jakob Granit, Anders Jägerskog, Elizabeth Kistin, Marian Patrick and Anthony Turton (2008). The TWO Analysis: Introducing a Methodology for the Transboundary Water Opportunity Analysis. Report Nr. 23. Stockholm, Stockholm International Water Institute.

Phillips, David, Shaddad Attili, Stephen McCaffrey and John Murray (2005). Water and the Jordan River Co-riparians: From a Zero-sum to a Positive-sum Game. Presentation given at the First Workshop on Hydro-Hegemony, 21/22 May 2005, London, UK, London Water Research Group.

Phillips, David, Shaddad Attili, Stephen McCaffrey and John Murray (2007a). "The Jordan River Basin: 1. Clarification of the Allocations in the Johnston Plan." *Water International* 31(5): 16 - 38.

Phillips, David, Shaddad Attili, Stephen McCaffrey and John Murray (2007b). "The Jordan River Basin: 2. Potential Future Allocations to the Co-riparians." *Water International* 31(5): 39 - 62.

Phillips, David, Anders Jagerskog and Anthony Turton (2009). "The Jordan River basin: 3. Options for satisfying the current and future water demand of the five riparians." *Water International* 34(2): 170 - 188.

Ponikarov, V and I. Mikhailov (1964). Geological Map of Syria.

Pootschi, I. (2010). "Adasiyyah: A study in agricultural and rural development." *Baha'i Studies Revew* 16(1): 66 - 105.

Quba'a, Rola (2017). A Positive Apportionment Framework for Water Allocation in Contested Transboundary River Basins: Energy as a Welfare Catalyst. PhD thesis submitted to the Department of Civil and Environmental Engineering. American University of Beirut, Beirut.

Quba'a, Rola, M. El-Fadel, I. Alameddine and M. Abou Najm (2017a). A Positive Apportionment Framework Towards Enhancing Cooperation in the Jordan River Basin. 9th International Conference on River Basin Management, 19-21 July 2017, Prague, WIT Transactions on Ecology and The Environment, Vol 221.

Quba'a, Rola, M. El-Fadel, I. Alameddine and M. Abou Najm (2017b). The role of groundwater in water allocation along the Jordan River Basin. 9th International Conference on River Basin Management, 19-21 July 2017, Prague, WIT Transactions on Ecology and The Environment, Vol 221.

Rajsekhar, Deepthi and Steven M. Gorelick (2017). "Increasing drought in Jordan: Climate change and cascading Syrian land-use impacts on reducing transboundary flow." *Science Advances* 3(e1700581 30 August 2017).

Reguer, Sara (1995). "Rutenberg and the Jordan river: a revolution in hydro-electricity." *Middle Eastern Studies* 31(4): 691 - 729.

RICCAR (2017). Climate Change and Adaptation Solutions for the Green Sectors in the Arab Region. Technical Report, The Arab Center for the Study of Arid Zones and Dry Lands (League of Arab States), Food and Agricultural Organization, and Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ).

Rieu-Clarke, Alistair, Ruby Moynihan and Bjørn-Oliver Magsig (2012). UN Watercourses Convention: User's Guide, IHP-HELP Centre for Water Law, University of Dundee.

Rodríguez, Iokiñe and Hernán Darío Correa (2006). Lessons, Approaches, and Challenges to Tranforming Socio-Environmental Conflicts in Latin America: The "C&C" Program Experience. Environmental Crossroads in Latin America: Between managing and transforming natural resource conflicts. Darío Correa, H. and I. Rodríguez. San José, Costa Rica, University for Peace.

Rook, Robert E. (2000). "An American in Palestine: Elwood Mead and Zionist Water Resource Planning 1923-1936." *Arab Studies Quarterly* 22(1): 71-90.

Rosenberg, David E. (2006). "The Yarmouk River Agreements: Jordan-Syrian Transboundary Water Management, 1953 - 2004." *The Arab World Geographer / Le Géographe du monde arabe* 9(1): 23 - 39.

Rozen, S. (2012). The rise and fall of the Baha'i settlemnets in the Jordan Valley, 1880s-1950s. presented at Irfan Colloquia Session No. 111. Centre of Baha'i Studies, Italy.

RPSO (2009). Trans-boundary Cooperation on the Jordan River Basin: A Regional Positive-Sum Outcome, Pamphlet not attributed to any source.

Rutenberg Concession (1921). Agreement for the Granting of a Concession for the Utilization of the Waters of the Riers Jordan and Yarmuk and their Affluents for Generating and Supplying Electrical Energy. Agreement between the Crown Agents for the Colonies and Mr. Pinhas Rutenberg, 21 September 1921, Israel Archives Doc 757/13-n 'Jordan Concession'.

Salameh, Elias (2004). "The Tragedy of the Karam Dam Project / Jordan." *Acta hydrochem. hydrobiol* 32(3): 249 - 258.

Salman, M. and W. Mualla "Water Demand Management in Syria: Centralized and Decentralized Views."

SANA 2015 "The total storage is around 1 MCM in Deraa dams" Syrian Arab News Agency 02 December 2015. Deraa. Accessed online http://sana.sy/?p=306513

SANA 2016 "more than 6 MCM is the total storage in Deraa dams" Syrian Arab News Agency 11 February 2016. Deraa. Accessed online http://sana.sy/?p=335240

Schmida, Leslie (1984). "Israel's Drive For Water." *The Link* 17(4): 1-14.

Schumacher, Gottlieb (1889). Across the Jordan, Being an Exploration and Survey of Part of Hauran and Jaulan. London, Alexander P. Watt.

Schumacher, Gottlieb, Laurence Opliphant and Guy Le Strange (1889). Across Jordan, an exploration and survey of part of Hauran and Jaulan. London, Alexander P. Watt.

Selby, Jan, Omar S. Dahi, Christiane Frölich and Mike Hulme (2017). "Climate change and the Syrian civil war revisited." *Political Geography* 60: 232 - 244.

Sevette, P. (1953). Legal Aspects of the Jordan Valley Development. Geneva, 8 October 1953, Memorandum by P. Sevette, Head of the Electric Power Section, Idustry Division, Economic Commission for Europe. Prepared at the request of the United Nations Relief and Works Agency for Palestine Refugees.

SFG (2013). Water Cooperation for a Secure World: Focus on the Middle East. Mumbai, Strategic Foresight Group.

SFG (2016). Cost of Non-Cooperation on Water: Crisis of Survival in the Middle East. Mumbai, Strategic Foresight Group.

Shamir, Uri (1998). Water Agreements Between Israel and its Neighbours. Transformations of Middle Eastern Natural Environments: Legacies and Lessons. Bernhardson, A. M. and R. Keena. Yale. 274 - 296.

Shamir, Uri (2003a). The Jordan River Basin, Part II: The Negotiations and the Water Agreement Between the Hashemite Kingdom of Jordan and the State of Israel. Technical Documents in Hydrology PC-CP Series No.15. Paris, UNESCO /IHP / WWAP.

Shamir, Uri (2003b). The Negotiations and Water Agreement between the Hashemite Kingdom of Jordan and the State of Israel, UNESCO.

Sharif (pers. comm.), Abed (2016). "Personal communication with farmer, al Himmeh, 4 August 2016. Anonymised.".

Shawni (pers. comm.), Ahmad (2016). "Personal communication with farmer, Adassiyeh, 4 August 2016. Anonymised.".

Siebert, C., P. Moller, S. Geyer, S. Kraushaar, P. Dulski, J. Guttman, A. Subah and T. Rodiger (2014). "Thermal waters in the Lower Yarmouk Gorge and their relation to surrounding aquifers." *Chemie der Erde* 74: 425-441.

Simons, G. W. H., W. G. M. Bastiaanssen and W. W. Immerzeel (2015). "Water reuse in river basins with multiple users: A literature review." *Journal of Hydrology* 522: 558-571.

Smadi, Ahmad Abdelkader (2000). The Geology of Mafraq area Map sheet No. 3254-IV. Jordan, The Hashemite Kingdom of Jordan, Ministry of Energy and Mineral Resources, Natural Resources Authority.

Smith, C.G. (1966). "The Disputed Waters of the Jordan." *Transactions of the Institute of British Geographers* 40: 111 - 128.

Sosland, Jeffrey K. (2007). Cooperating Rivals: The Riparian Politics of the Jordan River Basin. New York, USA, State University of New York Press.

Springborg, R. (1982). "Ba'athism in practice: agriculture, politics, and political culture in Syria and Iraq." *Middle Eastern Studies* 17(2): 191 - 209.

Suleiman, Rebhieh (2003). The Historical Evolution of the Water Resources Development in the Jordan River Basin in Jordan. Stockholm, Sweden, International Water Management Institute.

Sultan (pers. comm.), Ahmed (2016). "Personal communication, Amman, 6 September 2016. Anonymised.".

Swarieh, A. and J. Sahawneh (1998). Geology and Hydrogeology of Yarmouk River Basin. Jordan, The Hashemite Kingdom of Jordan, Natural Resources Authority, Geology Directorate, Subsurface Geology Division.

Swatuk, Larry A. (2008). "A Political Economy of Water in Southern Africa." *Water Alternatives* 1(1): 24 - 47.

Talozi, Samer, Yasmeen Al Sakaji, Hussam Hussein and Peter Reich (submitted 2018). "What constitutes an equitable share? A reassessment of the Jordan-Israel water agreement 20 years later." *Submitted for publication to Water International*.

Tawil (pers. comm.), Mazen (2017). "Personal communication with Syrian water expert, April 2017. Anonymised.".

The Financial Times (1962). Syrian-Jordan talks on £50m scheme for Yarmouk River.

Thomas, Kimberley Anh (2016). "The river-border complex: an broder-integrated approach to transboundary river governance illustrated by the Ganges River and Indo-Bangladeshi border." *Water International*.

UN-ESCWA/BGR (2013). Inventory of Shared Water Resources in Western Asia. Beirut, UN Economic and Social Commission for Western Asia (ESCWA), and the German Federal Institute for Geosciences and Natural Resources (BGR).

UNECE (1992). Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Helsinki, 17 March 1992, UN Economic Commission for Europe.

UNECE (2012). Model Provisions on Transboundary Groundwaters. ECE/MP.WAT/40, United Nations Economic Commission for Europe.

UNECE (2013). Guide to Implementing the Water Convention. ECE/MP.WAT/39, United Nations Economic Commission for Europe - Convention on the Protection and Use of Transboundary Watercourses and International Lakes.

UNGA (1997). Convention on the law of the non-navigational uses of international watercourses. New York, Resolution Adopted by the United Nations General Assembly, Fifty-first session, Agenda Item 144. http://www.un.org/documents/ga/res/51/ares51-229.htm

UNHCR (2017). Syria Regional Refugee Response (Inter-agency information sharing portal).

US CFA (1979). Economic Support Fund Programs in the Middle East: Report of a Staff Study Mission to Egype, Syria, Jordan, the West Bank, and Gaza, November 24 to December 15, 1978, to the Committee on Foreign Affairs, U.S. House of Representatives, U.S. Government Printing Office.

US DoS (1979). Maqarin Dam. Declassified document released by US Department of State EO Systematic Review 20 Mar 2014, ID No. 1979STATE283695_e, Cable from Executive Secretariat, Department of State to US Embassy in Tel Aviv. https://search.wikileaks.org/plusd/cables/1979STATE283695_e.html

US Embassy in Jordan (2007). UNITY DAM ON SYRIA-JORDAN BORDER STORING 3 MCM OF WATER, 107 MCM OF AIR. E.O. 12958. Amman, Cable from US Embassy in Amman (author: Hale) to US Department of Interior and Middle Eastern offices. https://wikileaks.org/plusd/cables/07AMMAN668_a.html

US NESAA (1976). Israeli Use of Yarmuk River Water. Declassified document released by US Department of State EO Systematic Review 04 May 2006, ID No. 1976TELAV08483_b, Cable from US Bureau of Near Eastern and South Asian Affairs in Tel Aviv to Secretary of State in Amman. https://wikileaks.org/plusd/cables/1976TELAV08483_b.html

van Aken, M. (n.d.). "Agricultural modernization and the reinvention of water in the Jordan."

Varela-Ortega, C. and J. A. Sagardoy (2001). Agricultural Water Use. Syria, FAO, Ministry of Agriculture and Agrarian reform (Syria), Italian Cooperation.

Veen, W. van, L. van Wesenbeck, M. Merbis and B. Sonneveld (2017). Towards concerted sharing: Development of a regional water economy model in the Jordan River Basin. Final Report, Centre for World Food Studies of the VU University Amsterdam.

Wagner, W., W.A. Dorigo, R.A.M. De Jeu, D. Fernandez-Prieto, J. Benveniste, E. Haas and M. Ertl (2012). Fusion of active and passive microwave observations to create an Essential Climate Variable data record on soil moisture. XXII ISPRS Congress.

Wagner, W. and M. A. Geyh (1999). Application of environmental isotope methods for groundwater studies in the ESCWA region. New York, United Nations - Economic and Social Commission for Western Asia (UN - ESCWA).

Wiczyk, Omer (2004). "An Analysis of the Treaty of Peace between Israel and Jordan in the Context of International Water Law." *Yearbook of International Environmental Law* 14(1): 139 - 160.

Wine, Michael L. (2018). "Under non-stationarity securitization contributes to uncertainty and Tragedy of the Commons." *Journal of Hydrology*.

Wolf, Aaron T. (1995). Hydropolitics along the Jordan River: Scarce Water and its Impact on the Arab-Israeli Conflict. New York, United Nations University [website edition - http://archive.unu.edu/unupress/unupbooks/80859e/80859E00.htm#Contents].

Wolf, Aaron T. and Masahiro Murakami (1995). "Techno-political Decision Making for Water Resources Development: The Jordan River Watershed." *Water Resources Development* 11(2): 147-162.

Wolf, Aaron T. and Joshua T. Newton (2007). The Jordan River - Johnston Negotiations 1953 - 1955; Yarmuk Mediations 1980s - Case Study, Program in Water Conflict Management and Transformation, Oregon State University.

Wolf, Aaron T., Shira Yoffe and Mark Giordano (2003). "International Waters: Identifying Basins at Risk." *Water Policy* 2003: 29-60.

World Bank (2001). Jordan - Valley Development Project. Washington, D.C., World Bank.

Yasuda, Y., J. Schillinger, P. Huntjens, C. Alofs and R. De Man (2017). Transboundary Water Cooperation over the lower part of the Jordan River Basin: Legal Political Economy Analysis of Current and Future Potential Cooperation. The Hague, The Hague Institute for Global Justice.

Ynet (2005). 1943: and you pumped water from the Yarmouk, Ynet vacation section, 28 October 2005, last accessed September 2017. http://www.ynet.co.il/articles/0,7340,L-3159537,00.html

Youmans, Sharif (2016). "Yarmouk basin in Syria - verification of facts. February 2016."

Youmans, Sharif (2017). "Water in the Paleogene - verification of facts. March 2017."

Zahra (pers. comm.), Mazen (2016). "Personal communication with former MWI employee, Amman, 7 September 2017. Anonymised.".

Zeitoun, Mark, Ana Cascão, Jeroen Warner, Naho Mirumachi, Nathanial Matthews, Rebecca Farnum and Filippo Menga (2016). "Transboundary water interaction III: Contesting hegemonic arrangements." *International Environmental Agreements*.

Zeitoun, Mark, Karim Eid-Sabbagh, Muna Dajani and Michael Talhami (2012). Hydro-political Baseline of the Upper Jordan River. Beirut, Association of the Friends of Ibrahim Abd el Al.

Zeitoun, Mark, Karim Eid-Sabbagh, Michael Talhami and Muna Dajani (2013). "Hydro-hegemony in the Upper Jordan Waterscape: Control and use of the flows." *Water Alternatives* 6(1): 86 - 106.

Zeitoun, Mark and Naho Mirumachi (2008). "Transboundary water interaction I: Reconsidering conflict and cooperation." *International Environmental Agreements* 8(4): 297 - 316.

Zeitoun, Mark, Naho Mirumachi and Jeroen Warner (2011). "Transboundary water interaction II: Soft power underlying conflict and cooperation." *International Environmental Agreements* 11(2): 159 - 178.

Zeitoun, Mark and Jeroen Warner (2006). "Hydro-Hegemony: A Framework for Analysis of Transboundary Water Conflicts." *Water Policy* 8(2006): 435-460.

Zeng, Y., Z. Feng and N. Nanping (2004). "Assessment of soil moisture using Landsat ETM+ temperature/vegetation index in semiarid environment." *IEEE International* 6: 4306-4309.

Zentner, Matthew (2012). Design and Impact of Water Treaties: Managing Climate Change. Berlin, Springer-Verlag.

Zoubi, M. (2008). Jordan's National Water Strategy 2008 - 2022.

Zrike, Jamal (2006). The Yarmouk River Catchment as a Pollution Potential for the Lake Kinneret. Master's thesis [in Hebrew]. Faculty of Social Sciences. University of Haifa.