water

Article

Basin Management under Conditions of Scarcity: The Transformation of the Jordan River Basin from Regional Water Supplier to Regional Water Importer

David Katz

Department of Geography and Environmental Studies, University of Haifa, Haifa 3498838, Israel; katzd@geo.haifa.ac.il

Abstract: The Jordan River system is one of the most iconic and most contested river systems in the world. The once "mighty Jordan", which has served as the primary source of water for populations in several countries, is currently a severely denuded river system, with only a fraction of its historic flow. Several initiatives, however, aim to restore some of the basin's flows. This paper will provide a historical overview and analysis of the trajectory of the Jordan River system from being a primary supplier of water to a desiccated shadow of its former glory. It highlights the critical role international borders played in dividing control over the basin, resulting in different types and levels of water scarcity experienced by each of the basin's riparians, each of whom has implemented different strategies to cope with such scarcity. The paper then presents several plans for large-scale interbasin transfers involving desalinated water initiated by basin riparians in attempts to deal with water scarcity and highlights how these planned initiatives are set to transform the basin from a regional supplier of water to a net importer.

Keywords: basin management; desalination; Jordan River; scarcity; transboundary

check for updates

Citation: Katz, D. Basin Management under Conditions of Scarcity: The Transformation of the Jordan River Basin from Regional Water Supplier to Regional Water Importer. *Water* **2022**, *14*, 1605. https://doi.org/10.3390/w14101605

Academic Editor: Brian Richter

Received: 2 March 2022
Accepted: 16 May 2022
Published: 17 May 2022

1. Introduction

"And Lot lifted up his eyes and saw that the Jordan Valley was well watered everywhere like the garden of the LORD . . . " Genesis 13:1.

For millennia the Jordan River has been the main artery supporting countless civilizations throughout an otherwise arid region. The Jordan River Basin has played a central role in humanity's development, as part of the Fertile Crescent, and has figured prominently in the religious traditions of Jews, Christians, and Muslims. It also serves a crucial ecological role, not just within the region, but being the primary source of water along the bottleneck of the Great Rift Valley Flyway, it is one of the world's most important bird migration routes connecting Africa and Europe. Yet, despite its historical, cultural, and ecological significance, the current state of the Jordan River Basin bears little resemblance to the lush biblical description in the quote above. Rather, modern development has resulted in the desiccation of the once-revered Jordan River.

The river's waters have been diverted to supply the growing populations of the countries sharing the basin. Flow through the lower reach of the river is now less than 5% of historical levels [1]. The level of the Dead Sea, a terminal lake fed by the Jordan, is declining at a rate of over one meter per year, continually breaking its own record as the lowest place on the earth's surface. In a response to the Jordan River system's dire situation, however, the governments of the region have committed to several projects that involve interbasin transfers importing water into the basin. This study offers a historical overview and analysis of the transformation of the Jordan River system from a primary source of water both within and outside of the basin, to what will likely soon be a net importer of water.

The study uses different measures of scarcity as a guiding framework to help understand the policies adopted by different actors over time. It identifies various factors that have contributed to the Jordan River Basin's management trajectory. These include both the rapid population growth experienced by the region over the past century, which continues to this day, as well as the fractured and contentious politics of the region, in which rival parties competed for and degraded the shared resource. However, the advent of large-scale seawater desalination in the region, together with political agreements within the region over the past decades, has opened opportunities for the import of water from outside the basin, in an attempt to address scarcity in a manner that could stem and even reverse the degradation of the Jordan River system.

The study continues as follows: Section 2 provides a brief overview of different measures of scarcity common in the water management literature. Section 3 presents an overview of the geography of the Jordan River Basin. Section 4 offers a review of the history of the role of water resources of the Jordan River Basin and an analysis of the factors leading to the degradation of the Jordan River, while Section 5 presents a look at how those factors changed and led to the proposal and initiation of projects intended to import water to the basin. Section 6 offers some conclusions and insights into the potential role of desalination in addressing scarcity in general and in basin management in particular.

2. Water Scarcity and Water Management

Many different measures for water scarcity exist. All such indicators are relative to some demand or consumption in a specified location [2]. In terms of national-level measures of freshwater scarcity for human consumption, the Food and Agricultural Organization of the United Nations (FAO), for instance, provides a measure of "water stress", which they define as the "ratio between total freshwater withdrawn by all major sectors and total renewable freshwater resources, after taking into account environmental flow requirements" [3]. This measure indicates how much water is used relative to available supplies. Brauman et al. [4] provide a more sophisticated measure of scarcity which they dub a "water depletion" metric, which accounts for seasonal variation and measures consumptive use rather than withdrawals. Such measures are useful in terms of highlighting the availability or sustainability of water use in a given region, but they do not relate to human water needs.

A measure of scarcity developed by Falkenmark [5] has been widely adopted by water professionals, academia, and international organizations such as the United Nations (e.g., [6]. This benchmark was originally based on assessments of the amount of water needed for countries to be largely self-sufficient in terms of food production, but since has become widely adopted as a rule of thumb for assessing national water scarcity in general. According to this index, countries with average renewable water resources of less than 1700 cubic meters per capita per year ($m^3/c/y$) suffer from water stress, while those with less than 1000 $m^3/c/y$ suffer from water scarcity, and those with less than 500 $m^3/c/y$ suffer from acute or "absolute" water scarcity. Scarcity in this context is defined as the level at which water availability threatens economic development and human health and well-being [7].

Though widely cited, the Falkenmark index has been criticized for being too static and for not taking into consideration countries' water use patterns [8] or adaptive capacity (e.g., [9,10]). Countries deemed water-scarce according to the Falkenmark index may be able to adapt by investing in a myriad of water conservation techniques, importing water-intensive food (virtual water), creative reuse of water, or undertaking many other measures. Other critiques of the Falkenmark index include that it does not address transboundary aspects of water resources, even though 80% of the world's fresh water originates in basins that go through more than one country [11], nor does it factor in the water needed for environmental or ecological purposes.

Given these shortcomings, several alternative scarcity indicators have been developed. Some scholars (e.g., [7,12]) developed what they called "water poverty" indices, which take into consideration countries' levels of economic development, as that bears directly on its ability to pay for water, water infrastructure, and/or alternative means of supplying food. These indicators can better reflect, for instance, the reality that countries with relatively limited water supplies may have a high level of water security due to their ability to invest in infrastructure and import virtual water, while others with relatively abundant supplies of water may have difficulty accessing and exploiting these resources due to limited economic and/or institutional capacity.

Lawrence et al. [13] highlighted several aspects of water scarcity in addition to the quantity of resources within a country (henceforth "quantitative scarcity"). These included access, capacity, use, and environment. Young et al. [14] provided an alternative, more subjective approach to evaluating household water security that stresses the perceptions of the users themselves and includes aspects such as accessibility, adequacy, reliability, and safety. A number of studies provide reviews and critiques of several commonly used water scarcity indicators, including ones that focus on economic capacity, environmental needs, and others (e.g., [15–17]). Such reviews demonstrate that no single measure of water scarcity is capable of capturing the complex reality of the sufficiency of national water supplies to meet a myriad of different uses. Rather, different measures of scarcity are needed to reflect the multidimensional nature of the concept.

This study presents indicators of water stress and scarcity for the countries of the Jordan River basin in order to demonstrate quantitative aspects of national water security over time and presents qualitative assessments of other aspects of water scarcity, such as affordability and access. It shows how the levels and types of scarcity resulted in various policies that eventually severely degraded the Jordan system, and how these dynamics are changing with the adoption of large-scale desalination in the region.

3. The Jordan River Basin—The Geographical Setting

The Jordan River system is currently shared by Israel, Jordan, the West Bank, Syria, and Lebanon. It is the primary surface water source for the first three. The headwaters of the river form in northern Israel, the Golan Heights, and southern Lebanon, with the major tributaries combining to form the Jordan River in Israel. From there the river southward to the Sea of Galilee, the region's largest freshwater lake. It exits from the southern portion of the lake and flows southward roughly 5 kilometers (km), where it is joined by the waters of the Yarmuk River. From the confluence of the two, the river continues until it reaches the Dead Sea, roughly 100 km to the south (Figure 1). The stretch of the Jordan leading into the Sea of Galilee is commonly referred to as the Upper Jordan River, while the stretch between the Sea of Galilee and the Dead Sea is often called the Lower Jordan. Salinity levels in the Dead Sea are approximately ten times those of the ocean, and the freshwater of the Jordan becomes increasingly saline as it reaches its natural outlet.

As can be seen in Figure 1, the Jordan catchment includes a large swath of territory south of the Dead Sea, covering much of the deserts of Jordan and Israel, and extending into the Sinai in Egypt. However, the areas surrounding the Dead Sea and south of it (indicated by a brown line in Figure 1) contribute almost nothing to the water balance of the river system. As such, in terms of basin management, the functional area extends only from the river's headwaters to the Dead Sea.

The natural inflow of the Upper Jordan to the Sea of Galilee has been estimated at between 500 and 550 million cubic meters (Mm^3) annually [18]. On average the lake receives another roughly 100 Mm^3 annually each from direct precipitation, direct runoff within the immediate catchment, and saline springs. This additional 300 Mm^3 is also roughly the amount lost to evaporation, and thus roughly 500–550 Mm^3 flows out of the lake into the Lower Jordan. The average annual natural flow of the Yarmuk has been estimated at between 450–500 Mm^3. In addition, flows from other smaller tributaries and wadis along the Lower Jordan contribute another 300–350 Mm^3, such that the average annual natural flow of the Jordan River into the Dead Sea has been estimated at 1200–1350 Mm^3 [1,18].

Figure 1. Jordan River Basin. Adapted from: UNEP, 2001. https://unepgrid.ch/en/resource/137 (accessed on 16 August 2021).

Much of the region of Jordan's riparians is arid or semi-arid. The Jordan River Basin constitutes over half of Jordan's natural renewable freshwater and roughly a third of Israel's. It represents a much smaller share of Lebanon and Syria's renewable water supplies, but it is an important source for local communities, especially the waters of the Yarmuk in southern Syria.

Due primarily to upstream abstractions, of the Lower Jordan's 1200–1350 Mm^3 of historical flow, for the past several decades the river's flow has been reduced to less than 100 Mm^3, much of this is poor quality agricultural runoff and floodwaters. As such, it is not a functional river, and its waters are not widely utilized. Palestinians are riparians to the Lower Jordan, but the flow is already severely diminished and polluted by the time it reaches the West Bank. Moreover, they do not have direct access to the river's waters, as will be explained in the case study.

As a result of the upstream abstractions, the level of the Dead Sea has declined nearly 40 m over the past half-century and continues to drop precipitously (Figure 2). This has already resulted in the disappearance of a third of the sea's surface area (Figure 3), as well as in the formation of hundreds of sinkholes along the sea's shores. The following section presents the case study detailing how the Jordan River system became so exploited and degraded.

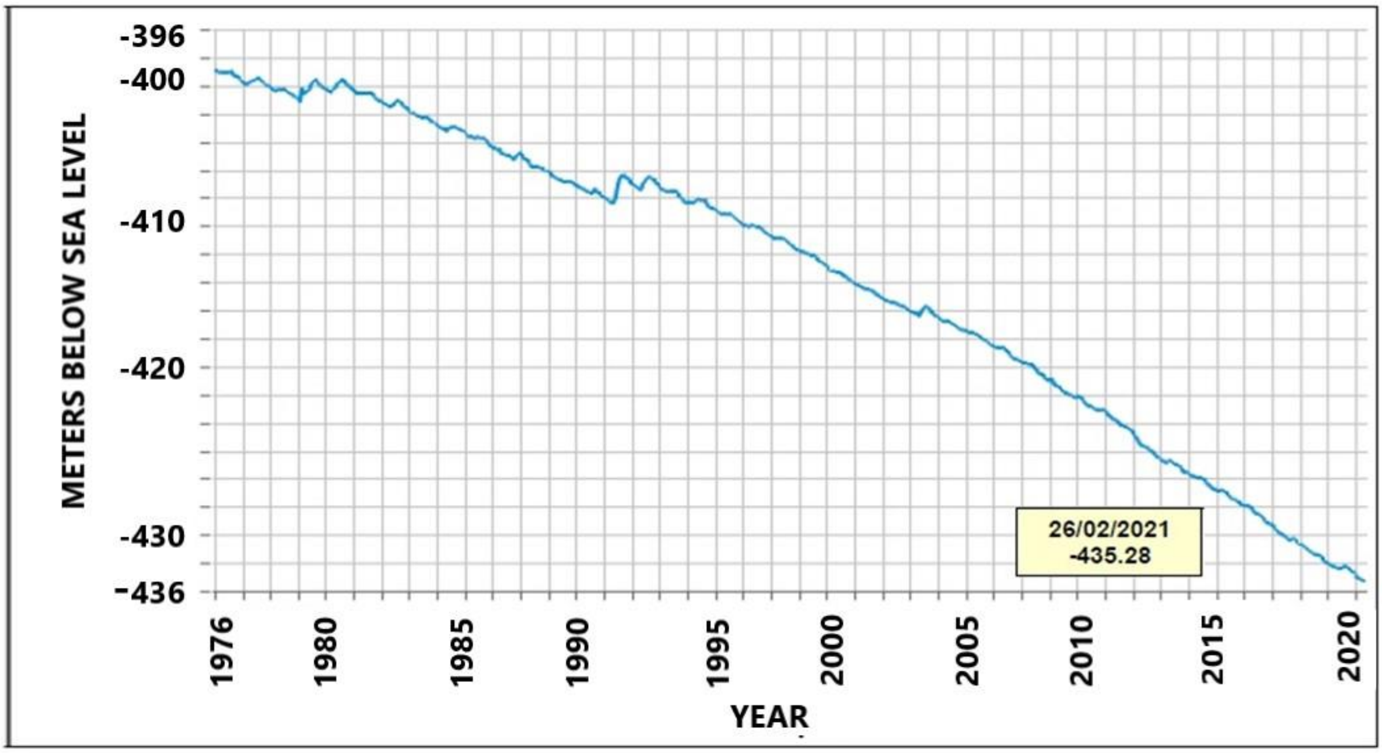


Figure 2. Change in Dead Sea level 1976–2021. Source: adapted from IWA, 2022. https://www.gov.il/he/Departments/General/dead-sea-stats (accessed on 14 January 2022).

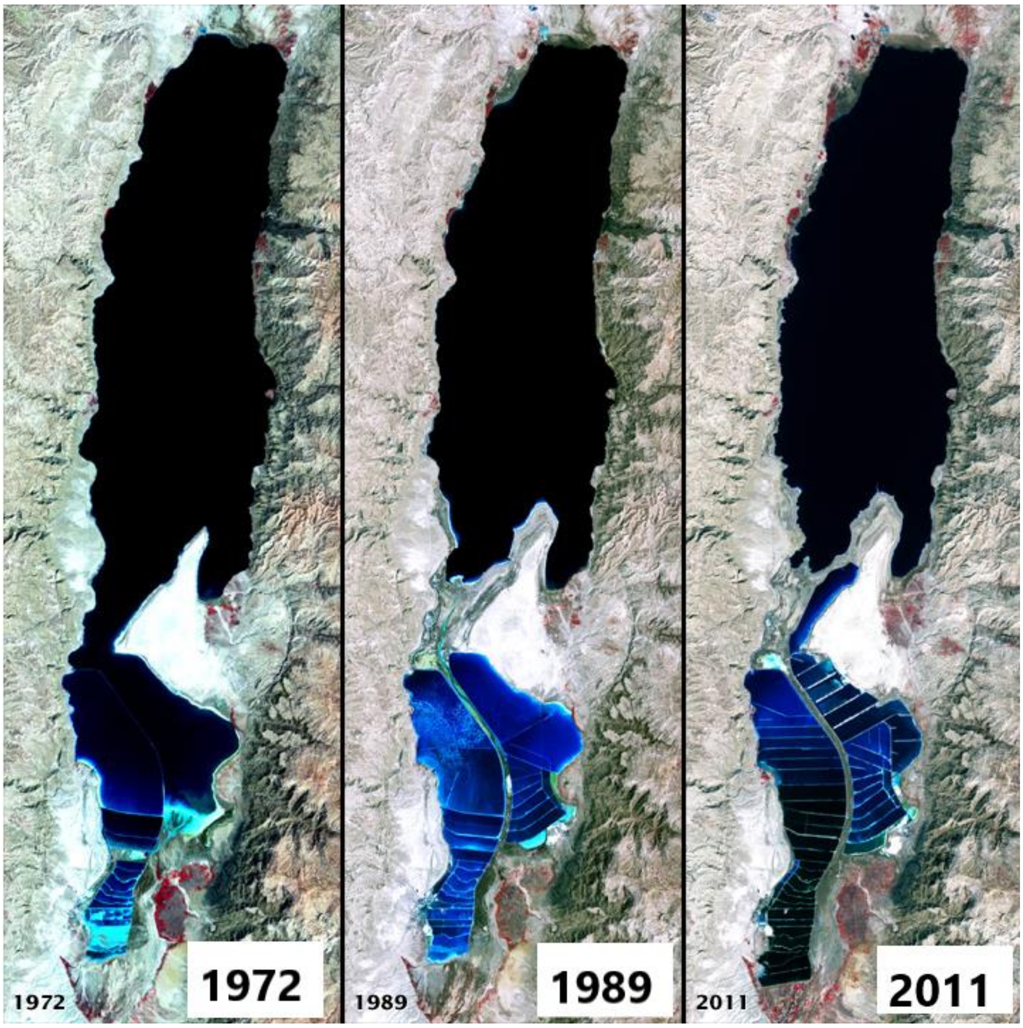


Figure 3. Change in Dead Sea surface area 1972–2011. Source Adapted from (NASA, 2012) https://earthobservatory.nasa.gov/images/77592/the-dead-sea (accessed on 20 April 2021). Note: the distinct color of the southern portion of the basin reflects its transformation from the natural sea to a series of managed evaporation ponds serving mineral extraction industries in Israel and Jordan.

4. Historical Overview of Factors Affecting Use of Jordan River Basin Waters

4.1. Pre-1949—Establishment of a Fractured Political Reality

Water of the Jordan River basin was critical in forming the borders of the modern Middle East. The Sykes–Picot agreement of 1916 divided the region into British and French spheres of control in anticipation of the fall of the Ottoman Empire in World War I. This agreement, made by British and French diplomats residing outside of the region, originally had the headwaters and the northern half of the Sea of Galilee under French control, with the southern half of the lake and the lower stretch of the Jordan River (from the Sea of Galilee to its terminus in the Dead Sea) under British control. In part due to realization of the difficulties in effectively managing water resources across jurisdictions, and in part due to lobbying on the part of Zionist residents of the region who were eager to have control over as much of the Jordan as possible in a future state, the eventual borders were altered to include almost all of the headwaters of the Upper Jordan, including the confluence of the primary tributaries into the main stem of the river, and the whole of the Sea of Galilee, under the British mandate [19]. Some of the upper basin tributaries, as well as a portion of the Yarmuk River, were still under French control, however.

Within the territory of the British Mandate, the Emirate of Transjordan was established in 1921 with the Lower Jordan as its western boundary, ensuring that the Lower Jordan too would entail shared governance. In 1948, upon the withdrawal of British forces from Palestine, Israel declared independence on a portion of the land, pursuant to a U.N. sanctioned partition plan. The unilateral declaration of independence (as well as the U.N. plan) was rejected by the Arab countries, which immediately launched a war to prevent the nascent state from achieving independence. When a cease-fire was finally signed between the sides a year later, Israel controlled more than the share allotted to it according to the U.N. plan, Egypt controlled the Gaza Strip, and Transjordan controlled both its original territory east of the Lower Jordan as well as territory west of the river, which would become known simply as the West Bank. As it controlled territory on both sides of the Jordan River, Transjordan changed its name to just Jordan (officially, the Hashemite Kingdom of Jordan). The borders between Israel and Lebanon and Syria were left close to those indicated by the U.N. partition plan.

In terms of the Jordan River Basin, the result was a very fractured system in which several countries, with very antagonistic relationships, shared both the main tributaries to the Jordan as well as the main stem of the Lower Jordan and the Dead Sea. Furthermore, both Jordan and Israel, which controlled most of the length of the Jordan, were both upstream and downstream of one another on different segments of the river and its tributaries. Tributaries making up the headwaters of the Upper Jordan were controlled by Lebanon, Syria, and Israel, respectively, with their confluence occurring within Israel. Syria and Jordan shared control of most of the Yarmuk River before its eventual merger with the Lower Jordan River, which then forms the border between Jordan and Israel. Israel controlled all of the Sea of Galilee, but Syrian territory and the Syrian military were only a few hundred meters from the lake's eastern shore. Upon its exit from the Sea of Galilee, the Lower Jordan flowed as the border between Israel and Jordan before flowing between the East and the West Bank of the river, both controlled by Jordan, and finally into the Dead Sea, which was shared by Jordan (both east and west banks) and Israel.

4.2. 1949–1964 Early Attempts at Basin-Wide Management

The region was relatively sparsely populated during this period. Table 1 shows the population and the associated Falkenmark Index values for each riparian for the period 1950–2020. As of 1950, none of the parties were below the benchmark of 1000 m^3/c/y that designates scarcity, and only Israel was below the threshold of 1700 m^3/c/y designating water stress.

Table 1. Population, Total Natural Renewable Freshwater Resources & Falkenmark Index Values.

Total Annual Renewable Freshwater (Mm^3)		Population (Thousands)							
		1950	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**	**2020**
	Israel	1258	2060	2814	3701	4448	5946	7346	8656
	Jordan	481	933	1721	2378	3566	5122	7262	10,203
	Lebanon	1335	1805	2297	2589	2803	3843	4953	6825
	Palestine					2101	3224	4056	5101
	Syria	3413	4574	6351	8931	12,446	16,411	21,363	17,501
		Per Capita Water Availability (m^3/Capita/Year)							
1300	Israel	1033	**631**	**462**	**351**	**292**	**219**	**177**	**150**
900	Jordan	1871	**965**	**523**	**378**	**252**	**176**	**124**	**88**
4500	Lebanon	3371	2493	1959	1738	1605	1171	**909**	**659**
290	Palestine					**138**	**90**	**71**	**57**
16,800	Syria	4922	3673	2645	1881	1350	1024	**786**	**960**

Sources: [3,20–22] Note: Figures in **blue** indicate quantities below the Falkenmark Index cut-off of 1000 m^3/c/y indicating water scarcity. Those in **red** indicate quantities below the cut-off of 500 m^3/c/y indicating acute water scarcity.

Given the relatively small populations in this period, water security for all parties was primarily an issue of access and affordability. All had developing economies, with little in the way of developed water and sanitation infrastructure. As such, all saw the Jordan River Basin's waters as critical for the development of the region. However, a lack of diplomatic relations between the parties prevented any formal international coordination.

In lieu of direct negotiations, the United States government sent an envoy named Eric Johnston to the region in 1953 in an attempt to help the Arab and Israeli sides reach an agreement for allocation of the Jordan's waters. Even prior to statehood, Israeli leaders had commissioned various plans for the use of the Jordan's waters. One such plan, devised in the 1940s by American Clay Lowdermilk, one of the primary architects of the Tennessee Valley Authority, called for the establishment of a regional Jordan Valley Authority for the whole region's waters and included elements of soil management, agricultural development, and the development of electrification. As such, it could be seen as an early attempt at integrated water basin management. However, one key element of the Lowdermilk plan was the diversion of waters of the Litani River for use in Palestine, an agenda for which Jewish residents of Mandate Palestine had been advocating for decades [23]. The Litani is a separate basin from the Jordan and flows entirely within Lebanon, but close to the headwaters of the Upper Jordan in what would become the State of Israel. Thus, Lowdermilk's plan was one in which interbasin transfers figured prominently.

Israel based its position in the Johnston negotiations on a modified version of the Lowdermilk plan, including diversion of the Litani, and the construction of a National Water Carrier (NWC), a massive pipeline diverting water from the Jordan River Basin to the central plains of Israel and even to the northern Negev desert in the south of the country. The NWC was seen by the Israelis as critical both to the country's economic development and its ability to absorb Jewish immigrants [24].

The coordinated Arab position vis-à-vis the Johnston negotiations was to limit discussions to the management of the Jordan River Basin only. In the words of a former Jordanian Minister of Water and Irrigation, the Arab position "emphasized the irrigation of lands inside the River basin, and opposed the transfer of water outside it" [25]. It also fully rejected the inclusion of the Litani in any negotiations, as it was not a shared basin. The motivations for the Arab plan were two-fold: both maximizing the potential benefits of the Jordan's waters to Arab countries [25] and preventing Israel's development and capacity to absorb new immigrants. In sum, the Arab position restricted water to within basin uses, while the Israeli position was one in which interbasin transfers both into and out of the Jordan River Basin figured prominently.

Eventually, both sides compromised on core demands: the Israelis agreed to drop the inclusion of the Litani, and the Arabs agreed to drop their insistence on restricting water to in-basin uses only. In 1955, technical committees on both sides approved what became known as the Johnston Plan. However, the plan was rejected by the Arab governments, primarily because acceptance could have been viewed as a tacit recognition of Israel itself, a move that was counter to Arab positions at the time [25]. Thus, an early opportunity for coordinated basin management was missed, though the unsigned agreement did serve as a general guideline for parties in the region.

4.3. 1964–1970: Military Conflict over Shared Waters and a New Hydro-Political Reality

With no official basin-wide agreement in place, Israel proceeded to develop its national water carrier project, while Jordan developed its own national water pipeline, today known as the King Abdullah Canal, which takes water from the Yarmuk, its major source of surface water, southward along the east bank of the Jordan through the Jordan Valley and to the country's most populated regions (see Figure 1). Israel originally planned for the intake to its NWC to be along the Upper Jordan River, which would have allowed much of the transfer of water out of the basin to be powered by gravity. The planned location, in a demilitarized zone between Israel and Syria, was objected to by the Syrians, who fired on Israeli construction workers and filed an official complaint with the U.N. [26]. After international intervention, the Israelis agreed to move the intake to the NWC to the Sea of Galilee, even though, at over 200 m below sea level, this would substantially increase the costs of pumping and transfer [24].

Israel completed the NWC, a central element in its national development plans, in 1964. The project was not only a major source of water to much of the country, but it enabled the connection of surface and groundwater supplies into an integrated national system. In early 1965, in its first official act as an organization, the newly formed Palestinian Liberation Organization (PLO), attempted to bomb the NWC. The attack, however, was unsuccessful. Soon thereafter, Syria and Lebanon began work on a plan to divert two of the three primary tributaries of the Upper Jordan: the Hasbani in Lebanon to the Litani, and the Banias in the Golan Heights, then controlled by Syria, to the Yarmuk. If successfully implemented, these diversions would have reduced by 35 percent the installed capacity of the Israeli Carrier and increased the salinity in the Sea of Galilee [26]. Israel warned that if implemented, it would consider the diversions an act of war and respond accordingly. Despite such warnings, in 1965 the Syrians began work on the diversions. The Israelis soon thereafter responded by bombing the diversion works, effectively putting an end to the plan.

Military conflict over shared waters of the Jordan was a prelude to, and according to some (e.g., [27]) a contributing factor, to the 1967 Arab–Israeli war. The result of the war was Israel gaining control over the Golan Heights from Syria, the West Bank from Jordan, and the Gaza Strip and Sinai Peninsula from Egypt. In so doing, Israel not only substantially increased the amount of land under its control, but also fundamentally altered the control over the region's water resources. In gaining control over the Golan Heights, it effectively replaced Syria as an upstream riparian on the Upper Jordan, giving it nearly complete control over the river's headwaters and the Sea of Galilee. It also increased its presence along the Yarmuk. By taking control over the West Bank, Israel extended its presence along the Lower Jordan all the way from the Sea of Galilee to the Dead Sea and gained full control over the Mountain aquifer, a major source of shared groundwater. This new power dynamic established Israel as what some have referred to as a regional hydro-hegemon, able to dictate water policy to other riparians [28].

4.4. Post-1967: Diverging Paths, Addressing Different Scarcities

4.4.1. From Lack of Access to Quantitative Scarcity

By the late 1960s and early 1970s, Israel and Jordan had built major components of their national water infrastructure tapping the bulk of the waters of the Jordan River system. Syria also was utilizing much of the headwaters of the Yarmuk. In fact, much to Jordan's disappointment, Syria was withdrawing much more than the share allocated to it under the Johnston Agreement. Lack of access or capacity to exploit major natural freshwater sources was no longer a limiting issue for Israel, which was already fully exploiting available renewable resources, though it still was for other riparians (Table 2). Due primarily to rapidly growing populations, quantitative scarcity became a concern for some of the region's populations. By the early 1970s, both Israel and Jordan had dropped below the Falkenmark benchmark of 500 $m^3/c/y$ indicating acute scarcity (Table 1).

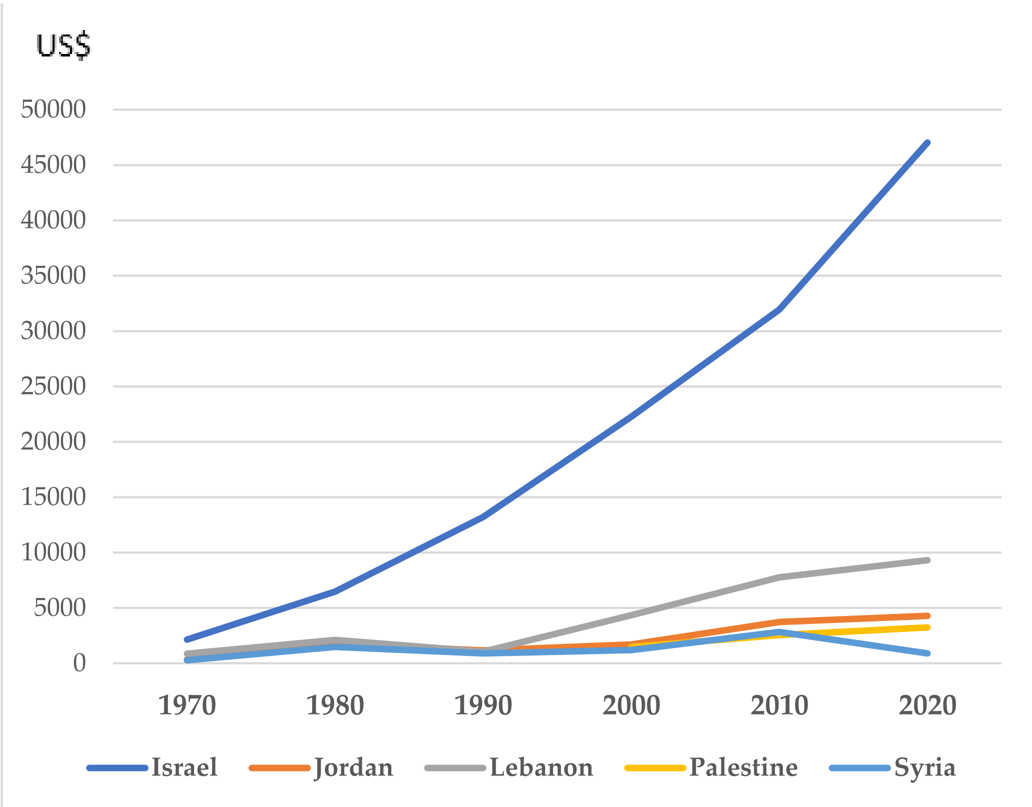
Table 2. FAO Water Stress Index (% of withdrawals relative to supply).

	1977	1982	1987	1992	1997	2002	2007	2012	2017
Israel	139.7	147.5	146.3	133.9	135.0	133.2	119.0	108.9	103.6
Jordan	53.7	63.0	80.2	103.7	91.4	81.8	103.2	94.0	100.1
Lebanon	26.2	30.8	35.5	40.0	44.2	39.5	40.2	51.8	58.8
Palestine						46.2	53.9	41.7	41.1
Syria	39.1	62.4	85.7	109.0	128.5	145.7	126.0	124.4	124.4

Source: [3].

The countries of the region undertook various strategies to attempt to deal with this scarcity. Some were common across countries. Israel and Jordan (and by virtue of Israel's occupation, also the West Bank and Gaza), for instance, basically gave up on any hopes for domestically produced food security and became dependent on large-scale food imports. This increasing reliance on "virtual water" imports was a significant aspect of the countries' national water management strategies [29].

Other strategies, however, were specific to each country's socio-economic and/or political circumstances, as detailed below. Socio-economic disparities between countries, especially between Israel and its neighbors, were already apparent prior but became more prominent, as can be seen in the differences in their gross domestic product (GDP) per capita over time (Figure 4). These differences in economic capacity translated into differences in finance, building, and maintenance of water infrastructure, policies, and innovation.



	1970	1980	1990	2000	2010	2020
Israel	2140	6475	13,219	22,276	31,941	47,034
Jordan	355	1740	1163	1703	3737	4283
Lebanon	866	2104	1052	4340	7762	9310
Palestine				1476	2557	3240
Syria	276	1472	897	1198	2830	890

Figure 4. Gross Domestic Product (GDP) per capita at current prices—US dollars. Sources: [30,31].

4.4.2. Israel

Despite its control over new water-rich areas and its new position as a hydro-hegemon, the quantity of water available to Israel did not change dramatically after 1967 [32,33]. Israel had already been fully exploiting its share of the Jordan River since the inauguration of the NWC. The Lower Jordan had already been reduced to a shadow of its former glory as a result of upstream diversions by Israel, Syria, and Jordan, with flow limited almost exclusively to agricultural runoff and winter floods. Israel had already been exploiting the bulk of waters of the Mountain Aquifer (shared with the West Bank) prior to 1967, since the major springs and many of the most accessible access points to the aquifer were located within Israel's pre-1967 borders. Thus, what Israel gained in 1967 was primarily a sense of security in terms of freedom from threats of upstream abstractions that would limit flows that it was already exploiting. Israel did increase groundwater withdrawals somewhat from the West Bank to supply both Palestinian and Israeli settler populations. While the latter has been a continued source of political tension as a fundamental rights issue, in practice, it did not affect the general water balance in the region.

In conquering the West Bank, Gaza Strip, Golan Heights, and the Sinai Peninsula, in 1967, Israel also became responsible for ensuring water supplies to residents of these territories. Israel eventually withdrew from Sinai following its peace treaty with Egypt in 1979. It also recognized the existing water rights of the relatively small Arab population of the Golan Heights. The Palestinian populations of the West Bank and Gaza Strip, however, were a different story. These areas were relatively densely populated, experiencing rapid population growth, and almost completely lacking in water infrastructure.

Prior to the inauguration of the NWC, Israel was dealing with both quantitative scarcity, as measured by the Falkenmark index, as well as scarcity in terms of accessibility and capacity. By 1967, due to economic growth and development of water infrastructure, accessibility and capacity ceased to be major issues for Israel (though environmental scarcity developed as withdrawals desiccated the country's streams and springs [34]). Having fully exploited its available water resources, Israel's water policy strategy switched from a largely supply-side focus to a demand management one [35].

By law, all water in Israel belongs to the public trust, and no private water rights are recognized; rather, the government is responsible for managing water for the public good (Water Law 1959). Israel's national water management structure is highly centralized, and its water grid is highly integrated. This allows it, for instance, to increase groundwater pumping when lake levels are low and vice versa. All water withdrawals are required to be by government-issued permit only. All water for agriculture is by government-determined allocations. This was the case for industry as well until 2015. This system allows the government to curtail such allocations during drought years, for instance.

As it faced increasing scarcity, Israel began implementing a wide array of other demand management policies (for a review, see [36]). It invested heavily in agricultural research and development including innovations such as lower water consuming crop varieties, saline tolerant crops, and drip irrigation systems. These measures, however, largely failed to reduce agricultural water consumption. Rather, they simply allowed crop yields to increase [37]. Reduction in agricultural freshwater consumption was accomplished in Israel only by a combination of allocation cuts and price increases implemented in the late 1990s after an intense and extended drought [36]. Since then, Israeli farmers pay significantly higher prices for water than do most farmers in the rest of the world, including those in other developed economies.

Another major adaptation to scarcity in Israel has been the adoption of wastewater reuse. Israel developed into the world leader in terms of the recycling and reuse of wastewater. By the early 21st century, Israel was treating and reusing over 85–90% of its wastewater, primarily in agriculture [38,39]. As a result, since the 1990s, freshwater consumption in agriculture has declined by nearly half, while overall water consumption has declined only minimally [40]. While recycled wastewater is highly demanded for irrigation, it has also led to increased salinization of soil and groundwater [39,41]. The shift from freshwater to recycled wastewater in the agricultural sector has allowed Israel to meet the ever-increasing demand for freshwater in the municipal sector. In 2000 the municipal sector in Israel surpassed agriculture to become the nation's largest consuming sector of freshwater. As of 2020, it was consuming almost twice as much freshwater as the agricultural sector [40].

Israel's highly centralized and integrated national management, its significant technological advances, and its array of supply and demand management practices, however, were insufficient to keep up with the country's growing population and with recurring droughts.

4.4.3. Jordan

Jordan, with more limited freshwater resources than its neighbors, has almost from its beginning experienced scarcity in terms of access, affordability, capacity, and environmental flow needs. Jordan's share of the Jordan River system waters is severely impacted by the actions of its neighbors. Jordan is downstream of Syria on the Yarmuk and has little leverage over its upstream neighbor. Cooperation between the two has been uneven and challenging. A so-called "Unity Dam" to be jointly built by the two on the Yarmuk, for instance, had been discussed since at least the Johnston negotiations, but was completed only a half-century later. The slow progress in the construction of the dam is symbolic of the rocky relations between the two riparians. Sharing of the Yarmuk River is governed by a 1987 treaty [42]; however, Jordan routinely accuses Syria of withdrawing more than its agreed share of basin waters [43].

Supply-side efforts to address scarcity in Jordan include the utilization of groundwater, including non-renewable fossil water from aquifers far from the basin in the south of the country. Jordan has long since tapped all of its available renewable resources and is continually withdrawing groundwater at unsustainable rates [44]. Jordan, like Israel, began implementing the reuse of wastewater in order to increase supplies to agriculture. Recent estimates put the percent of sewage reused in Jordan at 40% [38]. Increasing this amount is complicated by the large percentage of households and areas still not connected to piped sewage collection [38]. Some observers have also noted water quality issues with Jordanian recycling wastewater, including the degradation of freshwater sources when the two are mixed [45].

The lack of infrastructure in the case of sewage connections is an example of how scarcity in terms of capacity (economic and infrastructural) is contributing to water insecurity in Jordan. Another example is the high leakage rates in the Jordanian water delivery system. Non-revenue water (which includes both water lost to leakage and stolen and unbilled water use) was estimated to be as high as 52% in 2000 and 2014 [44]. In addition to the loss of water, non-revenue water is estimated to cost the Jordanian economy hundreds of millions of dollars per year [46], depriving the water sector of much-needed funds for infrastructure maintenance and investments. While addressing such issues has been a national priority for years [44,47], economic constraints have meant that progress has been slow and limited.

In terms of demand management practices, perhaps Jordan's biggest challenge is reducing use in the agricultural sector, which accounts for between 65–75% of national water consumption. A major obstacle is that water is supplied to farmers extremely cheaply (on average at US$0.01–0.03) [38], providing little incentive to conserve. Increasing prices for irrigation water, though a long-time official policy goal [44,47], is politically sensitive, especially as many farmers are both relatively poor and represent a relatively strong base of political support for the ruling monarchy. As such, prices, and therefore efficiency levels, in the sector have remained low.

4.4.4. Palestine (West Bank & Gaza)

Under the Johnston Plan and subsequent national water plans, Jordan was to develop water infrastructure throughout the West Bank. Priority was placed, however, first on developing water infrastructure on the east bank of the Jordan River. When Israel conquered the West Bank in 1967, relatively little water infrastructure was in place there. For instance, only 4 out of 708 Palestinian towns and villages were connected to modern water supply systems with running water [48]. This number increased dramatically in the years that followed, According to Gvirtzman [48], 309 villages and towns were connected to piped water systems by 1994 and 641 by 2010) and Palestinian water consumption in the West Bank doubled between 1967 and 1994.

Despite the above improvement, the water situation in Palestine has remained one of both quantitative scarcity and scarcity in terms of access and capacity. Palestinians have relatively little control over water resources. Israeli military presence since 1967 has essentially cut them off from the Jordan River system itself. Even if they had access, by the time the river reaches the West Bank, flows are minimal and water quality is severely degraded due to the upstream abstractions by Israel, Syria, and Jordan. This means that Palestinians are almost completely reliant on groundwater. However, Israel also restricts their access to groundwater. Israel claims that this is necessary to prevent over-utilization, but according to critics, it is to ensure that water is available primarily for consumers within Israel (e.g., [33,49], or even to intentionally drive Palestinians off their land [50]. Given their limited control over natural water resources, especially in the period prior to the establishment of the Palestinian Authority in the 1990s, Palestinians had relatively few opportunities for either supply or demand management policies. Wastewater reuse among Palestinians has been advocated by water professionals and international agencies but has been adopted only on a limited scale. Obstacles to widespread use include a lack of sufficiently treated wastewater, concerns over treated water quality and its environmental and health impacts, and cultural resistance to the usage of sewage [51].

In the case of the Palestinians, an additional aspect of scarcity—relative scarcity—is also important in explaining positions and policies regarding water in the region. As mentioned in Section 2 above, such subjective measures of scarcity also have welfare and policy significance. While the situation of Palestinians in the West Bank has improved significantly in comparison to levels of access to water resources in 1967, it has not matched that of its Israeli neighbors, who still use significantly more water, both in absolute and per capita terms, than the Palestinians [33]. The combination of a lack of control over resources and what is widely perceived as inequitable allocation of shared waters, is at the core of the difference between Palestinian and Israeli approaches to dealing with water scarcity, with the Palestinians primarily concerned with distribution and reallocation of existing waters, and Israel focused more on finding additional sources of water and using water more efficiently [52].

4.4.5. Syria and Lebanon

Syria and Lebanon both suffer much less from scarcity than their southern neighbors and are much less dependent on the Jordan River system. Until the 21st century, neither was below the Falkenmark standard for water scarcity of less than 1000 $m^3/c/y$ (Table 1). Since then, because of population growth, both natural, and in the case of Lebanon, also due to an influx of people fleeing the civil war in Syria, both countries currently fall into the category of water scarce, but not acute or absolute water scarcity (i.e., less than 500 $m^3/c/y$).

In the case of Lebanon, only a tiny fraction of the country is within the Jordan River Basin, and a single tributary—the Hasbani stream—connects it to the Jordan River system. Despite this minimal connection, attempts by Lebanese farmers to increase withdrawals from the Hasbani have occasionally been a source of tension, with Israel even threatening military action [53]. Transboundary pollution from the Hasbani into the basin has also been an issue of concern between Lebanon and Israel at times, however not one that has achieved the profile and attention as upstream abstractions.

The Jordan River Basin contributes a relatively small share to Syria's national water budget, as the country has access to much greater water sources than does Jordan. However, the Yarmuk is a significant source of water for the local population in Syria's extreme south, and, following the loss of the Golan Heights in 1967, Syria's primary activities with regard to the Jordan River Basin's rivers focused largely on simply securing shares of the Yarmuk, primarily to supply farmers in the region [54].

4.5. The 1990s: Peace Agreements and Regional Water Management: New Hopes and Dashed Hopes

The Oslo peace accords between Israel and the PLO and the peace agreement between Israel and Jordan, both signed in the mid-1990s, brought about some optimism in terms of the potential for coordinated management of the region's water resources. Water figured prominently both in the peace negotiations and in the agreements themselves. Both called for cooperation in the sustainable management of shared water resources, including maintaining water quality, sharing of data to enable coordinated planning, and cooperation in the development of new water resources. Beyond calls for coordinated action, the treaties also established actual elements of integrated basin management. For instance, under the terms of the Israeli–Jordanian agreement, Jordan allows winter flood flows in the Yarmuk to flow into Israel for storage in the Sea of Galilee, and Israel supplies Jordan with additional flows in summer when demand is high. Both the Israeli–Palestinian and Israeli–Jordanian agreements also established joint water committees that would be responsible for implementing policies to achieve these shared objectives.

Progress in integrated basin management since the signing of the agreements has been limited, especially in the case of Israeli–Palestinian water relations. While water experts have generally regarded the Israeli–Jordanian water agreement and its implementation as successful in improving basin management (e.g., [55], the Israeli–Palestinian agreement has been criticized sharply for entrenching Israeli domination under the guise of joint management (e.g., [56,57]. As evidence for such claims, critics note that the Joint Water Committee established by the treaty demands approval by both sides for all projects in the West Bank likely to affect the shared Mountain Aquifer. Such an arrangement demanding consensus is a commonly applied mechanism in common pool resource management. However, in this case, because the Palestinians in the West Bank are completely dependent on the Mountain Aquifer for their water supplies, the arrangement essentially gives Israel veto power over all Palestinian water development initiatives, but not vice-versa, as Israel has access to additional sources of water including the Jordan River system, additional aquifers, and more recently, desalination.

The biggest difference between the Israeli–Jordan and Israeli–Palestinian agreements is that the former was a final status peace treaty, while the latter was only meant to be an interim agreement in place for a period of five years, during which a final status agreement was to be negotiated. Thus, many issues of critical importance were left unresolved. Moreover, a final status agreement was never agreed on, and thus, the specifications set out in the interim agreement, including allocations and institutional arrangements, are still in place a quarter of a century after the agreement was supposed to have expired. As a result, Israeli–Jordanian relations over water have been far more cooperative than Israeli–Palestinian ones.

4.6. 2005-Present: Desalination: A Help but Not a Cure for Scarcity

Growing populations in the region have meant increasingly acute quantitative scarcity. In addition, the region has experienced a downward trend in overall precipitation, and increases in evaporation due to changes in both temperature and air pressure, especially in the Jordan River Basin [58–60]. The region is also witnessing more extended droughts and extreme weather events [60]. These trends are expected to continue and worsen as a result of global climate change [61,62], further exacerbating scarcity.

While the peace treaties called for cooperation in coordinated management and cooperation in developing new water resources, in practice the countries of the region pursued unilateral agendas [63]. For the past two decades, the central pillar of Israel's strategy to address acute water scarcity has been the development of large-scale seawater desalination. It opened its first plant in 2005, and by 2015 it had five such plants and was producing 600 Mm^3 of desalinated water annually, a quantity representing nearly a third of its total freshwater consumption and nearly double the average amount pumped annually from the Sea of Galilee into the NWC. As of 2022, another two large plants were being built, and

Israel's long-term water strategy calls for even more, with desalination actually scheduled to supply more than all of the country's renewable natural freshwater sources combined by 2050 [21].

The additional supplies of desalinated water alleviate scarcity in Israel to a great extent, allowing it, for instance, to keep water flowing even in situations of extended droughts. Desalination also allowed Israel to increase supplies to Jordan and the Palestinians beyond those mandated in the peace agreements. However, despite some depictions of desalination as a technical fix to the region's water scarcity (e.g., [64], it has not been a silver bullet. Firstly, even with its added capacity from desalination and wastewater reuse, per capita, water supplies are at under 300 Mm^3, still far below the Falkenmark index standard for absolute water scarcity. Secondly, the country's aquifers are still very depleted after decades of unsustainable pumping, and the streams and aquatic ecosystems are still desiccated, with most hosting only a small fraction of their historical natural flows [65]. Thirdly, the perception of desalination as having "solved" the country's water scarcity issues actually had the effect of decreasing the effectiveness of conservation campaigns, which led to an increase in per capita consumption [66]. Finally, not all regions of the country are connected to pipe systems capable of transporting desalinated water. Being relatively distant from the coast, the Jordan River Basin is one of these regions.

For these reasons, the waters of the Jordan River system continue to be exploited at unsustainable rates. For instance, the level of the Sea of Galilee often used as an indicator of basin scarcity, has repeatedly dropped below an administratively set red line below which there is a high risk of compromised lake water quality and permanent ecological damage. This trend has actually increased in recent years, rather than diminished with the addition of produced sources such as desalinated water and reclaimed wastewater (Figure 5).

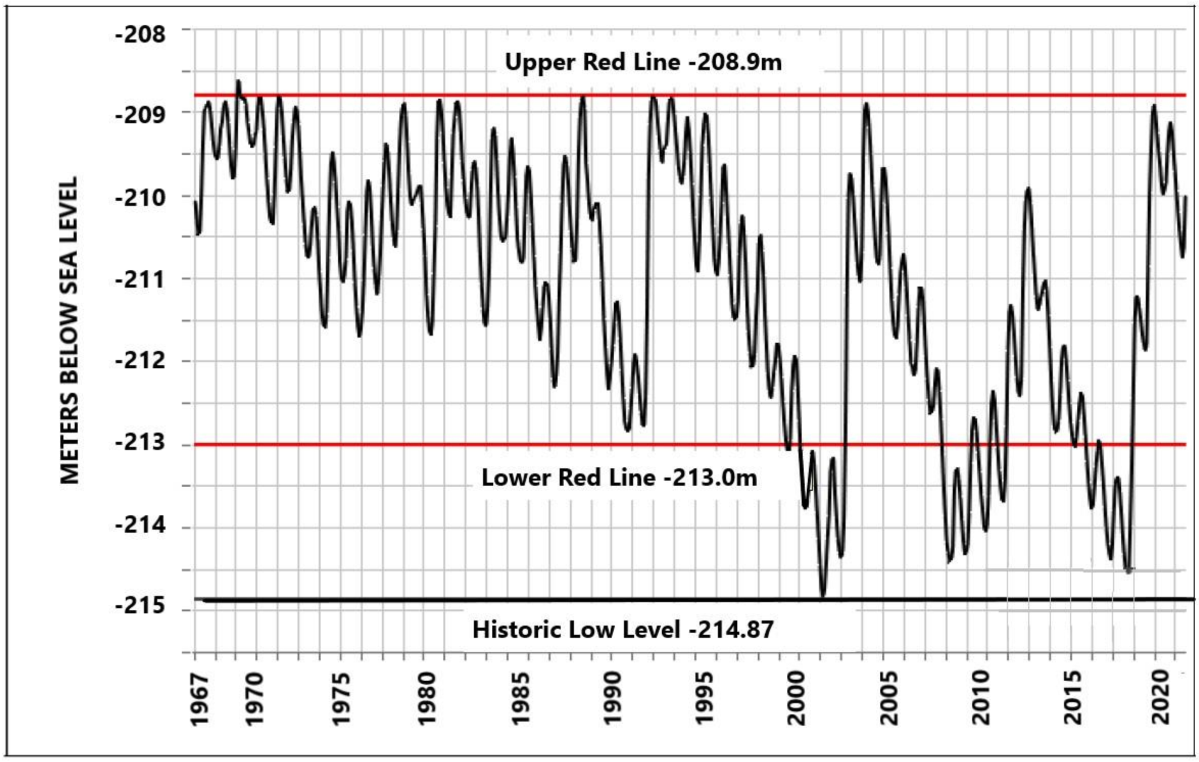


Figure 5. Change in Sea of Galilee level 1967–2022. (Note: Upper red line is the level at which a dam at the southern outlet is to be opened to allow flow into the Lower Jordan River to prevent flooding around the shores of the Sea of Galilee. The Lower red line is an administrative goal below which water levels are not supposed to drop in order not to cause high salinity and risk permanent ecological damage.) Source: adapted from (IWA, 2022). https://www.gov.il/he/Departments/news/news-kinneret (accessed on 14 January 2022).

The Palestinian Authority was at first hesitant to pursue desalination, fearing that doing so would undermine its claims to increased shares of natural transboundary waters [67]. Eventually, though, given both the severity of water scarcity, especially in the Gaza Strip and the lack of progress in negotiations with Israel, it decided to pursue large-scale desalination in Gaza. While detailed plans have been developed and international funding secured for the construction of a large desalination facility there, it has not moved forward due to security concerns [68]. Israel has objected to the transfer of building materials like cement, steel, and electronic equipment into the Hamas-controlled Gaza Strip, fearing that they could be used for hostile military purposes. It has instead offered to supply Gaza with desalinated water directly, a position rejected by the Palestinians who do not wish to increase dependency on Israel for water supplies.

Jordan has limited access to the sea, with its only port along the Red Sea in the city of Aqaba, far from the country's population centers. As such, desalination and transport of the water to where there is demand was long seen as prohibitively expensive for the country's developing economy. However, given the severity of its water scarcity, the Jordanian government has actively pushed for a large-scale desalination plant along the Red Sea as part of an international project that will be detailed in the following section.

Given these realities, the region, including all of the Jordan River Basin, is considered to still face extreme scarcity. According to the World Resources Institute's (WRI) Aqueduct database, the entire basin, as well as much of the rest of the region, is considered to face "extremely high" water stress, defined as having withdrawals at over 80% of available supplies (Figure 6), and "high" to "extremely high" water depletion [69].

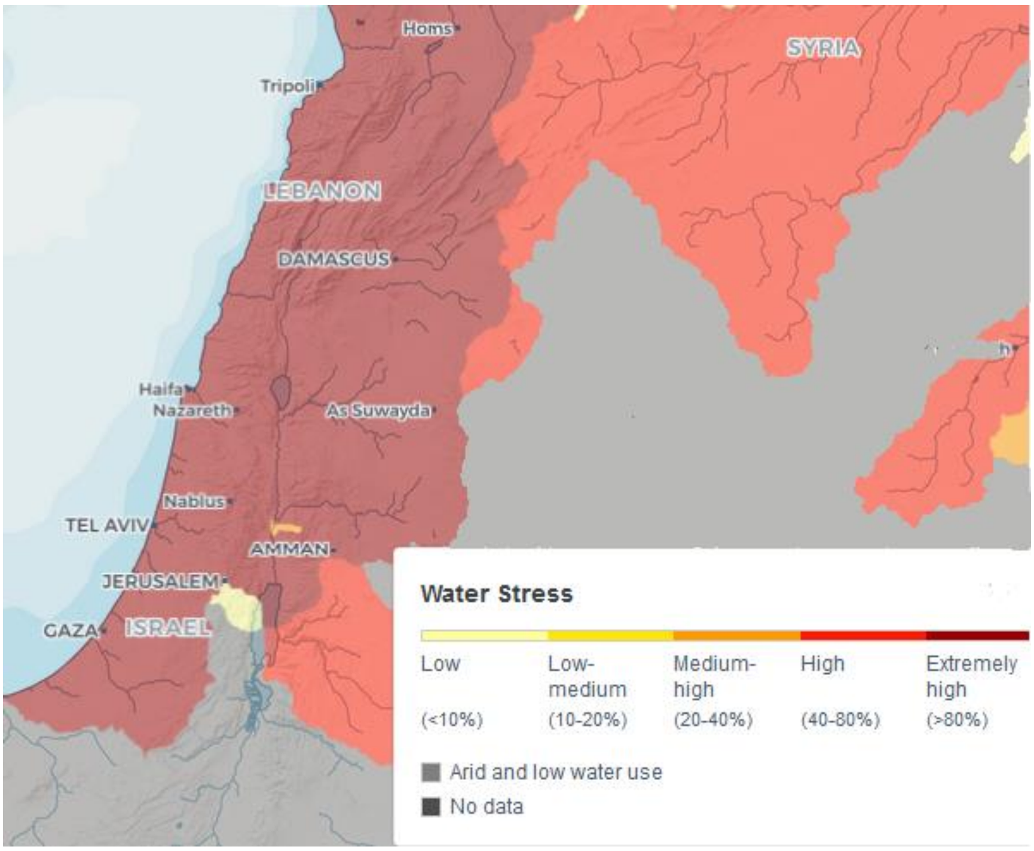


Figure 6. Water Stress (withdrawals relative to available supplies). Source: WRI Aqueduct (2022). https://www.wri.org/applications/aqueduct/water-risk-atlas/ (accessed on 14 February 2022).

5. The Fall and Potential Rise of Jordan River Basin—From Water Exporter to Water Importer

Given both the limited and over-tapped resources of the Jordan system and the vast potential for production of freshwater via desalination, a number of plans have been developed to transfer water from desalination into the Jordan River Basin, transforming the basin from a regional supplier into a net importer. This section briefly presents three of the major projects.

5.1. Med-Dead and Red-Dead Canals

Plans to connect the Mediterranean Sea or the Red Sea to the Dead Sea have existed for well over a century. In the mid-19th century, British officials proposed connecting all three seas for navigational purposes, as an alternative to the Suez Canal [70]. In a 1902 manifesto, Zionist leader Theodore Herzl presented a proposal for the construction of a canal from the Mediterranean to the Dead Sea to exploit the change in elevation in order to generate hydroelectricity [71]. Actual plans for a hydropower-producing 'Med–Dead' canal, as it became known, were included in the Lowdermilk Plan from the 1940s, and Israel began work on such a canal in the 1980s [72], but eventually abandoned the project due to economic and technical concerns.

Following both the peace agreements of the 1990s and improvements in desalination technologies, a different project began to be promoted: large-scale desalination of sea water from the Red Sea, with the brine being transported for dispersal into the Dead Sea instead of back into the source waters as is usually done. This would have the dual benefits of producing potable water for the region and stemming or even reversing the decline in the level of the Dead Sea, and energy production from the fall in elevation could partially cover the project's energy needs. Though the Mediterranean is closer to the Dead Sea than the Red Sea, and closer to population centers, Jordan was eager for this project to be a Red–Dead canal, rather than a Med–Dead one, in order for it to have control over the desalinated water. It was also interested in the project being regional, and not solely Jordanian, in order to benefit from cost-sharing with Israel and potentially from international donor assistance that might be invested in a large Arab–Israeli joint infrastructure project.

At the request of the Israeli, Jordanian, and Palestinian governments, the World Bank sponsored a feasibility study of the Red–Dead project, including alternatives such as sourcing the desalination from the Mediterranean and restoring natural flows to the Lower Jordan [73,74]. Following initial findings that the project was feasible, in 2013 governmental ministers from Israel, Jordan and the Palestinian Authority signed a Memorandum of Understanding agreeing to advance an initial stage of the project [75]. The project would involve water swaps, with Jordan supplying communities in the south of Israel with desalinated water and Israeli increasing supplies to Jordan from the Sea of Galilee. Such an arrangement would save both countries in terms of pumping costs for delivery.

The Red–Dead project has been criticized by some for being too costly and having potentially significant deleterious environmental impacts (e.g., [76]. For these reasons, and because of a deterioration in overall Israeli–Jordanian relations over the last decade, little progress has been made on the project, since the signing of the MOU. Construction had begun as of 2022, the year specified in Jordan's national water plan as the expected completion date for the project (Ministry of Water and Irrigation, 2015). As of the writing of this article, the future of the project is in doubt. It remains, however, officially endorsed by all sides and may resurface as overall relations in the region shift.

5.2. A Reverse National Water Carrier

The NWC, the backbone of the Israeli water delivery system, was designed to take water from the relatively water-rich north of Israel to the population centers along the coast and eventually to the desert in the south. However, the adoption of desalination along the coasts largely obviated the need to pump the waters of the Jordan River system all that distance. Moreover, changes in weather patterns in the region over the past decades have produced less rainfall in the north and more in the central coastal region. They have also resulted in longer and more pronounced droughts than experienced in the past [77]. As a result, the populations along the coast have a much greater degree of water security than do those living in the Jordan River Basin region, which is not served by the desalination facilities.

Israel's response to the regional scarcity in the Jordan River Basin has been to limit intake into the NWC to a trickle over the last decade, essentially using basin waters almost exclusively for use within the basin. Thus, it is essentially fulfilling demands made by Arab nations during the Johnston negotiations decades earlier for restricting the use of the Jordan River system's waters to in-basin purposes. Water planners in Israel have determined, though, that even this measure is insufficient to ensure adequate water supplies in the region, including both within Israel and to fulfill requests for additional supplies to Jordan [78]. Therefore, Mekorot, the company that built and operates the NWC, has initiated an effort to build a "reverse National Water Carrier"—a pipeline built alongside the NWC—that will take desalinated water from the coast to the Sea of Galilee. It finished implementing the first of three stages of this multi-billion-dollar mega-project in 2019 [79]. The project is expected to supply up to 50 Mm^3 annually to the basin, but this could be doubled to up to 100 Mm^3 (almost a third of the historical average of water pumped annually in the NWC) if needed [78].

Desalinated water quality differs from that of the Sea of Galilee, in terms of pH and other parameters. Out of concerns over water quality in the Sea of Galilee were desalinated water to be deposited directly into the lake, officials decided that desalinated water will be released into a wadi and flow several hundred meters by gravity to the Sea of Galilee, collecting minerals and changing in chemical composition along the way [78]. Thus, in essence, the project involves not only the import of large amounts of water into the basin but also the dramatic alteration of what is naturally a relatively dry channel that essentially only funnels floodwaters during rain events, into a major new tributary to the Sea of Galilee.

5.3. Desalination as Part of Water-Energy Exchanges

Work done by a regional environmental organization, Ecopeace, investigated the possibility of Israel and/or Palestine providing Jordan with desalinated water and in exchange, Jordan providing the two with solar energy [80]. The central premise of the idea was that Israel and Palestine have access to the Mediterranean, but are limited in terms of available open space, while Jordan has ample open space suitable for large solar fields but has limited options for desalination. Earlier studies, including the World Bank sponsored feasibility study of alternatives to the Red–Dead project had already shown that the Med–Dead option of providing freshwater to Jordan was economically more efficient than the Red–Dead [74]. However, Jordan still preferred the Red–Dead, given that the facilities and pipelines could be wholly within its territory, and was willing to pay a premium for this water independence.

In contrast to the original Med–Dead alternative, under which Jordan would simply increase its water dependence on Israel, in the project proposed by Ecopeace, relations would involve a mutual dependency and thus be more reciprocal and less asymmetric [81]. While the idea won international praise (e.g., [82,83]), it was not immediately endorsed by any government in the region.

Several circumstances came together since that changed this. First was the signing of a peace agreement between Israel and the United Arab Emirates (UAE) in 2020, after which, the Emiratis were eager to support regional cooperation projects, especially in the field of water and environment. The second was new ambitious commitments of the countries of the region to reduce greenhouse gas emissions. The third was the lack of progress on the Red–Dead project as a potential solution to Jordan's dire need for freshwater. Lastly, and perhaps most importantly, was a change in government in Israel in 2021 to one that was eager to work on improving the country's relationship with Jordan. This constellation of factors led Israel and Jordan to sign a UAE brokered agreement (officially a "Declaration of

Intent") in November of 2021 to adopt the water-energy exchange idea [84]. It is likely to involve the transfer of roughly 200 Mm^3 of water annually to the Jordan River Basin for consumption in Jordan. While details of the project have yet to be finalized, among the different options under consideration are delivery of water directly to the Jordan water system (e.g., the King Abdullah Canal) or, alternatively, delivering desalinated water to the Lower Jordan River to augment instream flows and have Jordan withdraw the water further downstream before the confluence with the Dead Sea.

6. Conclusions

Like many waterbodies, especially in arid regions, the Jordan River Basin has undergone substantial change in the modern period, as its waters have been utilized for offstream development. Given the limited resources of the region, the waters of the Jordan were a primary source of water for several populations both within and outside the basin's boundaries and were central to the development plans of the various riparians. They have proved insufficient however to supply the demand of populations that have experienced rapid growth. As the countries of the region faced increasing scarcity, they tapped the resources of the Jordan system at beyond renewable rates, leading to the severe degradation of the river and surrounding environment.

The history of conflict among riparians in the Jordan River basin has contributed to the uncoordinated management of the basin's waters. The change in the political climate among the primary basin partners, with agreements signed since the 1990s, however, opened the door for more cooperative management. This, together with the adoption of large-scale desalination in the region, will potentially change the trajectory of the basin. It is well known that desalination has the potential to reduce overall scarcity and, in so doing, also reduce pressures on existing natural resources. While previous studies have noted the import of desalination as a potential "gamechanger" in water management, including in transboundary settings (e.g., [85,86]), this study shows the potential it has to alter river basin management more generally. In the case of the Jordan, desalination is going beyond that to actually augment the natural sources in a basin facing increasing demands for its limited resources, transforming the basin from an overtapped exporter of water to a net importer. The example of the Jordan may be indicative of other future attempts at basin management in water-scarce areas, as desalination provides the potential for coastal areas to become the new "upstream" water suppliers.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: There are no conflict of interest for this paper.

References

1. Safier, G. *Roadmap for the Rehabilitation of the Lower Jordan River*; EcoPeace/Friends of the Earth Middle East: Tel Aviv, Israel, 2011.
2. Schulte, P.; Morrison, J. *Driving Harmonization of Water-Related Terminology Discussion Paper*; The CEO Water Mandate: New York, NY, USA, 2014.
3. FAO (Food and Agricultural Organization of the United Nations). SDG 6.4.2. Water Stress. 2022. Available online: https://www.fao.org/aquastat/statistics/popups/itemDefn.html?id=4550 (accessed on 14 January 2022).
4. Brauman, K.A.; Richter, B.D.; Postel, S.; Malsy, M.; Flörke, M. Water depletion: An improved metric for incorporating seasonal and dry-year water scarcity into water risk assessments. *Elem. Sci. Anthr.* **2016**, *4*, 000083. [CrossRef]
5. Falkenmark, M. Fresh water—Time for a modified approach. *Ambio* **1986**, *15*, 192–200.
6. World Water Assessment Programme. *The 4th United Nations World Water Development Report: Managing Water under Uncertainty and Risk*; UNESCO: Paris, France, 2012; Volume 1.
7. Feitelson, E.; Chenoweth, J. Water poverty: Towards a meaningful indicator. *Water Policy* **2002**, *4*, 263–281. [CrossRef]
8. Raskin, P.; Gleick, P.; Kirshen, P.; Pontius, G.; Strzepek, K. *Water Futures: Assessment of Long-Range Patterns and Problems*; Swedish Environment Institute/United Nations: Stockholm, Sweden, 1997.

9. Ohlsson, L. Environment, scarcity and conflict: A study of Malthusian concerns. Ph.D. Thesis, Department of Peace and Development Research, Goteborg University,, Gothenburg, Sweden, 1999.
10. Turton, A.R. *Water Scarcity and Social Adaptive Capacity: Towards an Understanding of the Social Dynamics of Water Demand Management in Developing Countries*; Water Issues Study Group, School of Oriental and African Studies (SOAS) Occasional Paper No. 9; University of London: London, UK, 1999.
11. UN Water. The United Nations Global Water Conventions: Fostering Sustainable Development and Peace. 5 February 2021. Available online: https://www.unwater.org/the-united-nations-global-water-conventions-fostering-sustainable-development-and-peace/ (accessed on 4 July 2021).
12. Sullivan, C. The Potential for Calculating a Meaningful Water Poverty Index. *Water Int.* **2001**, *26*, 471–480. [CrossRef]
13. Lawrence, P.R.; Meigh, J.; Sullivan, C. *The Water Poverty Index: An International Comparison*; Department of Economics, Keele University: Keele Straffordshire, UK, 2002.
14. Young, S.L.; Boateng, G.O.; Jamaluddine, Z.; Miller, J.D.; Frongillo, E.A.; Neilands, T.B.; Collins, S.M.; Wutich, A.; Jepson, W.E.; Stoler, J. The Household Water InSecurity Experiences (HWISE) Scale: Development and validation of a household water insecurity measure for low-income and middle-income countries. *BMJ Glob. Health* **2019**, *4*, e001750. [CrossRef]
15. WSM. Indicators and Indices for Decision Making in Water Resources Management. Water Strategy Man Newsletter. 4 (January–March). 2004. Available online: http://environ.chemeng.ntua.gr/WSM/Newsletters/Issue4/Indicators.htm (accessed on 23 June 2016).
16. Rijsberman, F.R. Water scarcity: Fact or fiction? *Agric. Water Manag.* **2006**, *80*, 5–22. [CrossRef]
17. Liu, J.; Yang, H.; Gosling, S.N.; Kummu, M.; Flörke, M.; Pfister, S.; Hanasaki, N.; Wada, Y.; Zhang, X.; Zheng, C.; et al. Water scarcity assessments in the past, present, and future. *Earth's Future* **2017**, *5*, 545–559. [CrossRef] [PubMed]
18. Naff, T. Chapter 5—Water Balance of the Jordan River System. Associates for Middle East Research. 1987. Available online: https://oregondigital.org/sets/middle-east-water/oregondigital:df70qw54b#page/1/mode/1up (accessed on 14 May 2018).
19. Gil-Har, Y. Boundaries delimitation: Palestine and Trans-Jordan. *Middle East. Stud.* **2000**, *36*, 68–81. [CrossRef]
20. United Nations (UN) Population Division. World Population Prospects 2019. 2022. Available online: https://population.un.org/wpp/DataQuery/ (accessed on 14 January 2022).
21. Israel Water Authority (IWA). Long-Term Master Plan for the National Water Sector Part A—Policy Document Version 4. 2014. Available online: http://www.water.gov.il/Hebrew/Planning-and-Development/Planning/MasterPlan/DocLib4/MasterPlan-en-v.4.pdf (accessed on 19 April 2015).
22. Palestinian Water Authority (PWA). *Annual Available Water Quantity in Palestine by Region and Source, 2015*; PWA Water Information System: Ramallah, Palestine, 2016.
23. Miller, R. Bible and Soil: Walter Clay Lowdermilk, the Jordan Valley Project and the Palestine Debate. *Middle East. Stud.* **2003**, *39*, 55–81. [CrossRef]
24. Herzog, D. Contested Waterscapes: Constructing Israel's National Water Carrier. Ph.D. Thesis, New York University, New York, NY, USA, 2019.
25. Haddadin, M.J. Negotiated resolution of the Jordan-Israel water conflict. *Int. Negot.* **2000**, *5*, 263–288. [CrossRef]
26. Wolf, A. *Hydropolitics along the Jordan River: The Impact of Scarce Water Resources on the Arab-Israeli Conflict*; United Nations University Press: Tokyo, Japan; United Nations University Press: New York, NY, USA, 1995.
27. Cooley, J. The War Over Water. *Foreign Policy* **1984**, *54*, 3–26. [CrossRef]
28. Zeitoun, M.; Warner, J. Hydro-hegemony—A framework for analysis of trans-boundary water conflicts. *Water Policy* **2006**, *8*, 435–460. [CrossRef]
29. Allan, T. *The Middle East Water Question: Hydropolitics and the Global Economy*; I.B. Tauris Publishing: London, UK, 2012; ISBN 9780857733658.
30. United Nations (UN) Statistics Division. Per Capita GDP at Current Prices—US Dollars. 2022. Available online: https://data.un.org/Data.aspx (accessed on 30 December 2020).
31. World Bank. WDI (World Development Indicators). 2021. Available online: https://databank.worldbank.org/source/world-development-indicators# (accessed on 29 December 2020).
32. Gvirtzman, H. *The Water Resources of Israel*; Yad Tzvi Publishing: Jerusalem, Israel, 2018. (In Hebrew)
33. Zeitoun, M.; Messerschmid, C.; Attili, S. Asymmetric Abstraction and Allocation: The Israeli-Palestinian Water Pumping Record. *Ground Water* **2009**, *47*, 146–160. [CrossRef]
34. Tal, A.; Katz, D. Rehabilitating Israel's Streams and Rivers. *Int. J. River Basin Manag.* **2012**, *10*, 317–330. [CrossRef]
35. Feitelson, E. The Four Eras of Israeli Water Policies. In *Water Policy in Israel: Context, Issues and Options*; Becker, N., Ed.; Springer Press: Dordrecht, The Netherlands, 2013; pp. 15–32.
36. Katz, D. Policies for water demand management in Israel. In *Water Policy in Israel: Context, Issues and Options*; Becker, N., Ed.; Springer Press: Dordrecht, The Netherlands, 2013; pp. 147–164.
37. Kislev, Y. *The Water Economy of Israel*; Taub Center for Social Policy Studies in Israel: Jerusalem, Israel, 2012; p. 137.
38. Jeuland, M. Challenges to wastewater reuse in the Middle East and North Africa. *Middle East Dev. J.* **2015**, *7*, 1–25. [CrossRef]
39. Tal, A. Rethinking the sustainability of Israel's irrigation practices in the Drylands. *Water Res.* **2016**, *90*, 387–394. [CrossRef] [PubMed]

40. Israeli Water Authority (IWA). Water Consumption by Sector. Various Reports 1996–2020. Available online: https://www.gov.il/he/departments/publications/reports/consumer-survey (accessed on 26 March 2021).
41. Brenner, A. Limitations and Challenges of Wastewater Reuse in Israel. In *Clean Soil and Safe Water*; Quercia, F., Vidojevic, D., Eds.; NATO Science for Peace and Security Series C: Environmental Security; Springer: Dordrecht, The Netherlands, 2012.
42. Rosenberg, D. The Yarmouk river agreements: Jordan–Syrian transboundary water management, 1953–2004. *Arab. World Geogr.* **2006**, *9*, 23–39.
43. Namrouqa, H. Yarmouk Water Sharing Violations Require Political Solution. Jordan Times, 28 April 2012. Available online: https://web.archive.org/web/20120504222805/http://jordantimes.com/yarmouk-water-sharing-violations-require-political-solution (accessed on 29 April 2012).
44. Ministry of Water and Irrigation (Hashemite Kingdom of Jordan). *National Water Strategy 2016–2025*; Ministry of Water and Irrigation (Hashemite Kingdom of Jordan): Amman, Jordan, 2015.
45. Mohammad, A.H.; Hazimeh, W.; Shatanawi, K.; Abualhaija, M. Quantity not quality: Promoting sustainable wastewater practices in Jordan. *Water Policy* **2020**, *22*, 435–448. [CrossRef]
46. USAID. Strengthening Water Security. 2021. Available online: https://www.usaid.gov/jordan/fact-sheets/strengthening-water-security (accessed on 25 December 2021).
47. Ministry of Water and Irrigation (Hashemite Kingdom of Jordan). *Water for Life: National Water Strategy 2008–2022*; Ministry of Water and Irrigation (Hashemite Kingdom of Jordan): Amman, Jordan, 2009.
48. Gvirtzman, H. The Israeli-Palestinian Water Conflict: An Israeli Perspective. Begin-Sadat Center for Strategic Studies. Jerusalem, Israel. 2012. Available online: http://www.biu.ac.il/SOC/besa/MSPS94.pdf (accessed on 26 September 2013).
49. Attili, S. Palestine's water de facto annexed since 1967. In *Palestine Liberation Organization Negotiations Affairs Department "Looming Annexation: Israel's Denial of Palestine's Right to Exist"*; State of Palestine: Ramallah, Palestine, 2020; pp. 60–67.
50. Dajani, M. Drying Palestine: Israel's Systematic Water War. Al-Shabaka Policy Brief. Al-Shabaka the Palestinian Policy Network. 2014. Available online: https://al-shabaka.org/summaries/drying-palestine-israels-systemic-water-war/ (accessed on 14 January 2015).
51. Khateeb, N. Sociocultural acceptability of wastewater reuse in Palestine. In *Water Management in Islam*; Faruqui, N., Biswas, A., Bino, M., Eds.; United Nations University Press: New York, NY, USA, 2001; pp. 79–84.
52. Weinthal, E.; Marei, A. One Resource Two Visions. *Water Int.* **2002**, *27*, 460–467. [CrossRef]
53. Amery, H.A. Water wars in the Middle East: A looming threat. *Geogr. J.* **2002**, *168*, 313–323. [CrossRef]
54. Zeitoun, M.; Abdallah, C.; Dajani, M.; Khresat, S.E.; Elaydi, H.; Alfarra, A. The Yarmouk tributary to the Jordan River I: Agreements impeding equitable transboundary water arrangements. *Water Altern.* **2019**, *12*, 1064–1094.
55. Hussein, H. Lifting the veil: Unpacking the discourse of water scarcity in Jordan. *Environ. Sci. Policy* **2018**, *89*, 385–392. [CrossRef]
56. Selby, J. Dressing up domination as 'cooperation': The case of Israeli-Palestinian water relations. *Rev. Int. Stud.* **2003**, *29*, 121–138. [CrossRef]
57. Zeitoun, M. The Conflict vs. *Cooperation Paradox: Fighting Over or Sharing of Palestinian-Israeli Groundwater? Water Int.* **2007**, *32*, 105–120. [CrossRef]
58. Kishcha, P.; Starobinets, B.; Lechinsky, Y.; Alpert, P. Absence of Surface Water Temperature Trends in Lake Kinneret despite Present Atmospheric Warming: Comparisons with Dead Sea Trends. *Remote Sens.* **2021**, *13*, 3461. [CrossRef]
59. Lelieveld, J.; Hadjinicolaou, P.; Kostopoulou, E.; Chenoweth, J.; El Maayar, M.; Giannakopoulos, C.; Hannides, C.; Lange, M.A.; Tanarhte, M.; Tyrlis, E.; et al. Climate change and impacts in the Eastern Mediterranean and the Middle East. *Clim. Chang.* **2012**, *114*, 667–687. [CrossRef]
60. Yosef, Y.; Halfon, N.; Porat, A.; Osinski-Tzadaki, E.; Porashpan, A. *Trends in Extreme Weather Events in Israel*; Report No. 21921416; Israel Meteorological Service: Beit Dagan, Israel, 2016. (In Hebrew)
61. International Panel on Climate Change (IPCC). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerland, 2014; p. 151.
62. Giordano, G.; Rüttinger, L. *Climate-Fragility Risk Brief: Jordan, Palestine and Israel*; Adephi: Berlin, Germany, 2021; p. 42.
63. Fischhendler, I.; Dinar, S.; Katz, D. Spatial and temporal politics of unilateral environmentalism: Cooperation and conflict over water management along the Israeli-Palestinian border. *Glob. Environ. Politics* **2011**, *11*, 36–61. [CrossRef]
64. Siegel, S.M. *Let There Be Water: Israel's Solution for A Water-Starved World*; St. Martin's Press: New York, NY, USA, 2015.
65. Society for the Preservation of Nature in Israel (SPNI). *Longing for the Stream*; SPNI: Tel Aviv, Israel, 2012. (In Hebrew)
66. Katz, D. Undermining Demand Management with Supply Management: Moral Hazard in Israeli Water Policies. *Water* **2016**, *8*, 159. [CrossRef]
67. Bateh, F. Personnel Communication with Fuad Bateh of the Negotiations Support Unit of the Palestinian Authority. 2010.
68. Office of the Quartet. Report on the Activities of the Office, January 2016–June 2017. 2017. Available online: https://www.un.org/unispal/document/report-on-the-activities-of-the-office-of-the-quartet-jan-2016-june-2017/ (accessed on 31 December 2018).
69. World Resources Institute (WRI). *Aqueduct Water Risk Atlas*; WRI: Washington, DC, USA, 2013; Available online: https://www.wri.org/applications/aqueduct/water-risk-atlas/ (accessed on 14 February 2022).
70. Allen, W. *The Dead Sea, a New Route to India: With Other Fragments and Gleanings in the East*; Longman, Brown, Green, and Longmans: London, UK, 1855.

71. Herzl, T. *Altneuland: The Old-New-Land*; Reprint; Wildside Press: Cabin John, MD, USA, 2018.
72. Stern, E.; Gradus, Y. The Med-Dead sea project—A vision or reality? *Geoforum* **1981**, *12*, 265–272. [CrossRef]
73. et Bellier, C. *Red Sea–Dead Sea Water Conveyance Study Program*; Final Feasibility Study Report—Summary; Report No. 12 147 RP 05; World Bank: Washington, DC, USA, 2012.
74. Allan, T.; Malkawi, A.I.H.; Tsur, Y. *Red Sea–Dead Sea Water Conveyance Study Program Study of Alternatives Final Report*; The World Bank: Washington, DC, USA, 2014.
75. World Bank. Senior Israeli, Jordanian and Palestinian Representatives Sign Milestone Water Sharing Agreement. Press Release. 2013. Available online: http://www.worldbank.org/en/news/press-release/2013/12/09/senior-israel-jordanian-palestinian-representatives-water-sharing-agreement (accessed on 22 April 2015).
76. Hussein, H. Politics of the Dead Sea Canal: A historical review of the evolving discourses, interests, and plans. *Water Int.* **2017**, *42*, 527–542. [CrossRef]
77. Venger, D.; Halfon, N.; Yosef, Y. *Historical Trends and Future Forecasts for Precipitation Patterns in Israel until the End of the Century*; Meteorological Service, Israeli Water Authority: Tel Aviv, Israel, 2021. (In Hebrew)
78. Rinat, T. The National Water Project Is Changing Its Face: A Look into Efforts to Fill the Kinneret. Haaretz. Available online: https://www.haaretz.co.il/nature/.premium-MAGAZINE-1.8566587 (accessed on 24 February 2020). (In Hebrew).
79. Kanfo, S. The National Water Carrier Is Changing Direction: Bringing Water to the Kinneret. YNet News. Available online: https://www.ynet.co.il/articles/0,7340,L-5764851,00.html (accessed on 19 July 2020). (In Hebrew).
80. Katz, D.; Shafran, A. *Water Energy Nexus: A Pre-Feasibility Study for Mid-East Water-Renewable Energy Exchanges*; Ecopeace Middle East & Konrad Adenauer Stiftung: Amman, Jordan, 2017.
81. Katz, D.; Shafran, A. Energizing Mid-East Water Diplomacy: The potential for regional water-energy exchanges. *Water Int.* **2020**, *45*, 292–310. [CrossRef]
82. Euro Solar. European Solar Prize 2017 Awarded to Ten Laureates in Vienna. Press Release. Available online: https://www.eurosolar.de/en/2017/11/15/european-solar-prize-2017-awarded-to-ten-laureates-in-vienna-2/ (accessed on 15 November 2017).
83. Friedman, T. Mother Nature Scoffs at Trump's Peace Plan. *New York Times*, 4 February 2020.
84. TOI (Times of Israel). Israel, Jordan Sign Huge UAE-Brokered Deal to Swap Solar Energy and Water. Available online: https://www.timesofisrael.com/israel-jordan-sign-uae-brokered-deal-to-swap-solar-energy-and-water/ (accessed on 22 November 2021).
85. Aviram, R.; Katz, D.; Shmueli, D. Desalination as a game-changer in transboundary hydro-politics. *Water Policy* **2014**, *16*, 609–624. [CrossRef]
86. Katz, D. Desalination and hydrodiplomacy: Refreshening transboundary water negotiations or adding salt to the wounds? *Environ. Sci. Policy* **2021**, *116*, 171–180. [CrossRef]