Chapter 1

Euphrates River Basin

INVENTORY OF
SHARED WATER RESOURCES IN WESTERN ASIA (ONLINE VERSION)

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Euphrates River Basin

The Euphrates at the Syrian-Turkish border, Syria, 2009. Source: Adel Samara.

EXECUTIVE SUMMARY

The Euphrates River is the longest river in Western Asia. The river has three riparian countries, Iraq, Syria and Turkey, and its basin is distributed among five countries with a total estimated population of 23 million.

Most of the Euphrates stream-flow originates from precipitation in the Armenian Highlands; contributions by the remaining riparian countries are generally small. In addition to some intermittent streams, the Sajur, Balikh and Khabour are the main contributors to Euphrates flow in Syria.

Historically, the natural annual flow of the Euphrates at the Syrian-Turkish border was around 30 BCM. However, data records over the last 70 years show a negative trend, indicating a decrease in mean annual flow to about 25 BCM.

The regulation of the Euphrates River is an extreme example of how human intervention can impact a river regime. With the construction of large water engineering structures in upstream Turkey and Syria, the Euphrates flow regime has shifted towards less pronounced seasonal variation.

Water use in the Euphrates Basin in Iraq, Syria and Turkey focuses on irrigation, hydropower and drinking water supply, with agriculture consuming the largest share of water (more than 70%).

As a result, water quality has become a serious issue on the Euphrates River: return flows from agricultural drainage cause salinity problems that are exacerbated along the river course. In addition, dumping of untreated sewage into the Euphrates and its tributaries contributes to other forms of water pollution.

The Euphrates is subject to two bilateral accords: an agreement between Syria and Turkey specifies the minimum average flow at the Syrian-Turkish border; and an agreement between Iraq and Syria determines the allocation of Euphrates water between those two countries. Riparian countries hold conflicting positions on international water law and terminology that have prevented a basin-wide agreement, with the exception of a Protocol for Technical and Economic Cooperation that was signed in 1980.

This resulted in the creation of the Joint Technical Committee, which is no longer functional.

BASIN FACTS

RIPARIAN COUNTRIES	Iraq, Syria, Turkey
BASIN AREA SHARES	Iraq 47%, Jordan 0.03%, Saudi Arabia 2.97%, Syria 22%, Turkey 28%
BASIN AREA	440,000 km^2
RIVER LENGTH	2,786 km
MEAN ANNUAL FLOW VOLUME	Before damming (1930-1973): ~30 BCM After damming (1974-2010): ~25 BCM
MAIN DAMS	>60 (max. storage capacity 144 BCM)
PROJECTED IRRIGATED AREA	~2.3 million ha
BASIN POPULATION	23 million

MAIN AGREEMENTS

SYRIA - TURKEY	1987 – The Protocol on Economic Cooperation is an interim agreement on water quantity which states that an annual 16 BCM (500 m^3/s) is to be released at the Syrian-Turkish border. 2009 – The Turkish-Syrian Strategic Cooperation Council Agreement addresses joint activities in the field of water such as the improvement of water quality, the construction of water pumping stations and joint dams as well as the development of joint water policies.
IRAQ - SYRIA	1990 – The Syrian-Iraqi Water Accord allocates the water of the Euphrates River according to a fixed ratio of 42% to Syria and 58% to Iraq.
IRAQ - TURKEY	2009 – The Memorandum of Understanding (MoU) on Water is one of 48 MoUs signed between the two countries. Both sides agreed to share hydrological and meteorological information and exchange expertise in these areas.

KEY CONCERNS

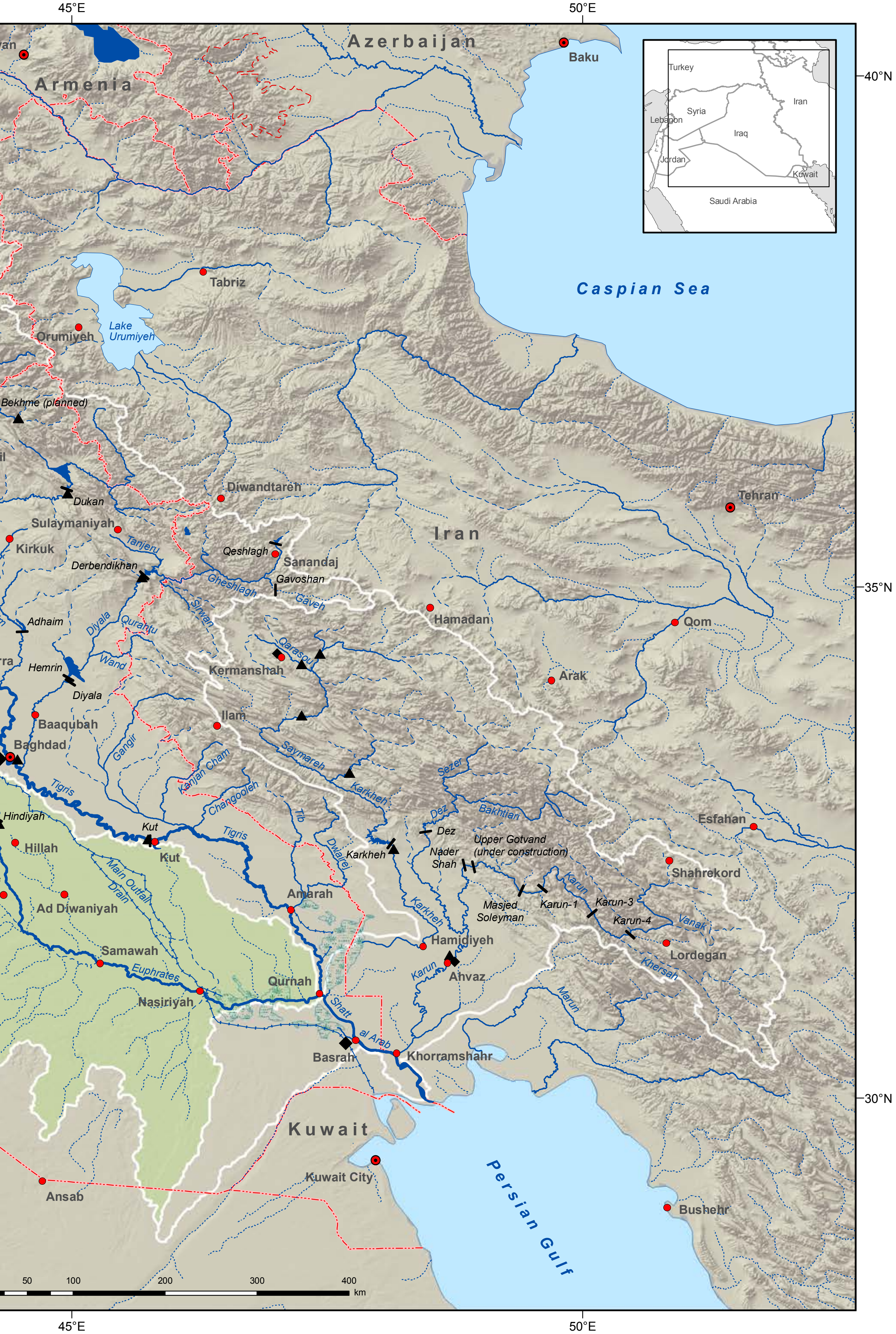
WATER QUANTITY

There is no basin-wide agreement and no common approach or consensus on how to regard the Euphrates and Tigris Rivers (i.e whether the two rivers should be considered part of a single watercourse system or as separate basins). In the past, the three riparians have disagreed on the division of water quantities and embarked upon individual water sector projects. Water use for human purposes (mainly irrigation and hydropower) increased sharply in the second half of the 20th century, resulting in a significant reduction in stream-flows and changes to the natural hydrological regime of the river.
The highly variable climate results in variable water availability. Under the current water management regime, droughts form a major natural hazard that affect water supplies in the basin, as witnessed in recent decades in Syria and Iraq.

WATER QUALITY

Pollution from agricultural and domestic sources seriously affects water quality. In Iraq, the Euphrates suffers from severe salinity that increases along the course of the river.

OVERVIEW MAP



45°E
50°E
40°N
35°N
30°N
Azerbaijan
Armenia
Iran
Kuwait
Caspian Sea
Persian Gulf
Baku
Tabriz
Orumiyeh
Lake Urumiyeh
Bekhme (planned)
Dukan
Diwandtareh
Sulaymaniyah
Kirkuk
Tanjero
Qeshlagh
Sanandaj
Derbendikhan
Gavoshan
Gheshlagh
Gaveh
Sirwan
Adhaim
Diyala
Quranjiu
Qarasou
Hamadan
Tehran
Qom
Arak
Hemrin
Wand
Diyala
Kermanshah
Ilam
Baaqubah
Baghdad
Gangir
Kanjan Cham
Saymareh
Karkheh
Sezer
Tigris
Changooleh
Tib
Dez
Bakhtiari
Hindiyah
Kut
Kut
Hillah
Dwarej
Karkheh
Nader Shah
Upper Gotvand (under construction)
Esfahan
Shahrekord
Main Outfall Drain
Amarah
Karun
Masjed Soleyman
Karun-1
Karun-3
Karun-4
Vanak
Ad Diwaniyah
Karkheh
Hamidiyeh
Lordegan
Samawah
Euphrates
Karun
Ahvaz
Khersan
Qurnah
Marun
Nasiriyah
Shatt al Arab
Basrah
Khorramshahr
Kuwait City
Ansab
Bushehr
Turkey
Syria
Lebanon
Iraq
Iran
Jordan
Kuwait
Saudi Arabia
50
100
200
300
400
km

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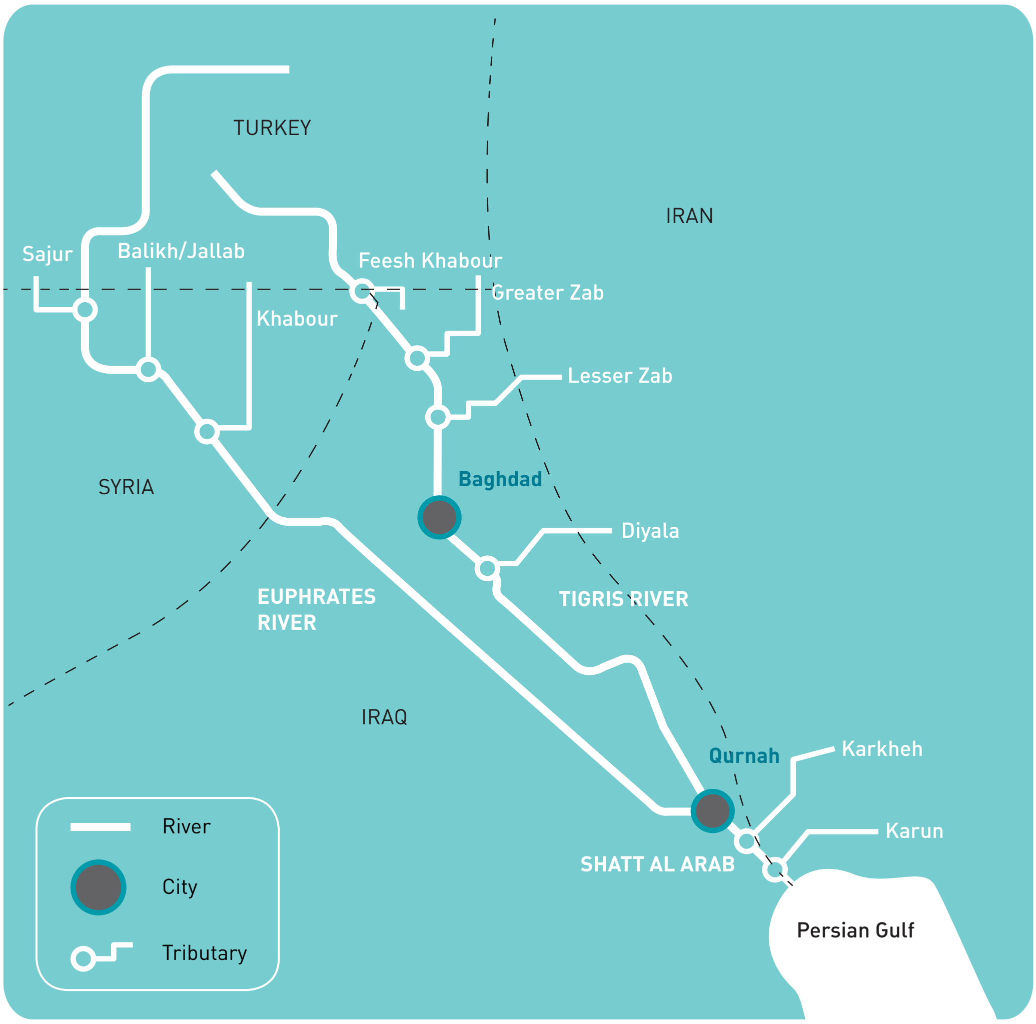
Defining the Euphrates-Tigris-Shatt al Arab Basins

The Euphrates-Tigris-Shatt Al Arab river system constitutes by far the largest surface water resource in the study area. Its combined topographic catchment covers more than 900,000 km^2 from the headwaters in the Taurus-Zagros Mountain Range to the Mesopotamian lowlands and the only outlet to the Persian Gulf, the Shatt Al Arab (Fig. 1). The overall basin is also home to around 54 million people in Iran, Iraq, Syria and Turkey. Given its importance and in order to adequately reflect the specific conditions as well as its complex hydrology, the Inventory dedicates five chapters to this river system.

The Euphrates River Basin (Chap. 1) and Tigris River Basin (Chap. 3) each have a different dynamic and set of characteristics, particularly with regard to their riparian countries, tributaries and contribution to discharge, as well as water use patterns and water quality. The shared tributaries of the Euphrates River (Chap.2) and the major shared tributaries of the Tigris River (Chap. 4) are covered in more detail in two separate chapters in order to highlight the role of these rivers and draw attention to local water issues and transboundary impacts. Chapter 4 also provides information on water use in Iran, which does not share the watercourse of the Tigris River itself but hosts important tributaries within the Tigris Basin. Finally, the Shatt al Arab River is discussed together with two additional major tributaries, the Karkheh and the Karun Rivers, which discharge directly into the Mesopotamian Marshes or the Shatt al Arab itself, and are hence neither part of the Euphrates or Tigris River basins (Chap. 5).

Figure 1. Sketch of the Mesopotamian river system

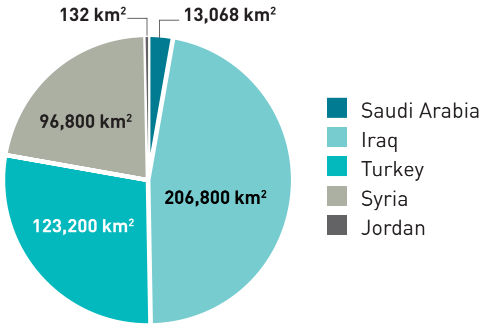


Source: Compiled by ESCWA-BGR.

Geography

The Euphrates River originates in Turkey, flows through Syria and joins the Tigris in Iraq to form the Shatt al Arab, which discharges into the Persian Gulf (see Overview Map and Fig. 1). The river has three riparians, but its basin is distributed among five countries: Iraq, Jordan, Saudi Arabia, Syria and Turkey. The Euphrates Basin covers about 440,000 km^2 of which 47% is located in Iraq; 22% in Syria, and 28% in Turkey (Figure 2).[1] Jordan (0.03%) and Saudi Arabia (2.97%) are considered basin riparians, but they contribute surface water only under very rare and extreme climatic conditions (see 'Overview and Methodology: Surface Water' for further information).

Figure 2. **Distribution of the Euphrates Basin area**



Source: Compiled by ESCWA-BGR.

RIVER COURSE

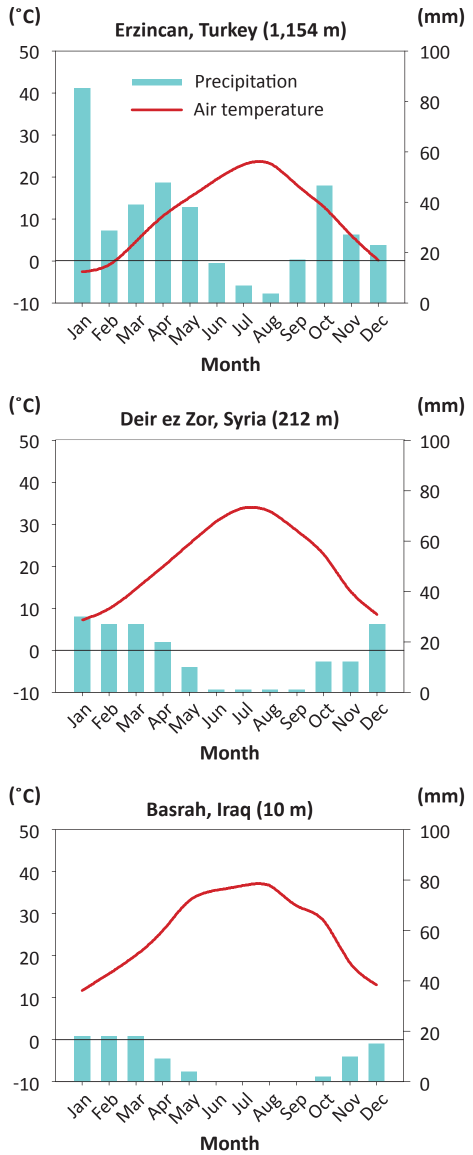
The Euphrates is the longest river in Western Asia with a total length of 2,786 km.[2] It originates in the mountains of eastern Turkey, not far from the city of Erzurum in the Armenian Highlands. Its headwaters, the eastern and western tributaries Karasu[3] and Murat,[4] originate at an altitude of nearly 3,000 m asl and join to form the Euphrates at the city of Keban. The Keban Dam is located 10 km downstream in a narrow gorge. From here the Euphrates flows south, and is fed by small tributaries and wadis before it crosses into Syria at the towns of Karkamis, Turkey, and Jarablus, Syria. The river covers 455 km from the confluence of the Karasu and the Murat to the Syrian-Turkish border.

Three tributaries flow into the Euphrates in Syria. The Sajur, the Balikh and the Khabour Rivers are all fed by tributaries or groundwater from Turkey.[5] These three sub-basins are therefore shared between Syria and Turkey.

South of the Khabour, the Euphrates has no other tributaries in Syria or Iraq. However, a number of dry riverbeds suggest that seasonal tributaries in the Syrian Desert flow into the Euphrates.[6] The river leaves Syria at Al Bukamal and enters Iraq at an elevation of 165 m asl. The Syrian stretch of the Euphrates covers 661 km.

Lake Assad, Syria, 2010. Source: Andreas Renck.

Figure 3. Climate diagrams for Erzincan in Turkey, Deir ez Zor in Syria, and Basrah in Iraq



Source: Compiled by ESCWA-BGR based on data provided by WorldClim, 2011; Climate Diagrams, 2009; Phytosociological Research Center, 2009.

Along its course to the Mesopotamian Plains in Iraq, the Euphrates continues in south-easterly direction, crossing desert uplands and narrow wadis until Ramadi. Near Hit, the river enters the alluvial lowlands of Mesopotamia, where it briefly splits into various channels. Further downstream, the river loses water to a number of desert depressions and canals, some natural and others man-made. Near the town of Fallujah, the river course veers to the north-east towards the Tigris, but then turns southward again. Here, parts of the river are diverted into canals, some of which drain into the shallow Lake Hammar, while others discharge into the Tigris. The Tigris joins the Euphrates from the east close to the city of Qurnah to form the Shatt al Arab River, which discharges into the Persian Gulf.

CLIMATE

From its origin in Turkey until its confluence with the Tigris, the Euphrates crosses several climatic zones. Mean annual precipitation in the Euphrates Basin ranges from approximately 1,000 mm in the Turkish headwaters in the north to 150 mm in Syria and just 75 mm in southern Iraq. The climate diagrams (Figure 3) for selected stations (see Overview Map for location) clearly illustrate this shift from a cooler Mediterranean climate to an increasingly hot and dry (arid) climate as the river progresses to the sea.

The Euphrates originates in a mountainous Mediterranean climatic zone, which is characterized by hot, dry summers and cold, wet winters. In the mountainous headwater areas, precipitation predominates in autumn, winter and spring with a mixture of rain- and snowfall in winter.[7]

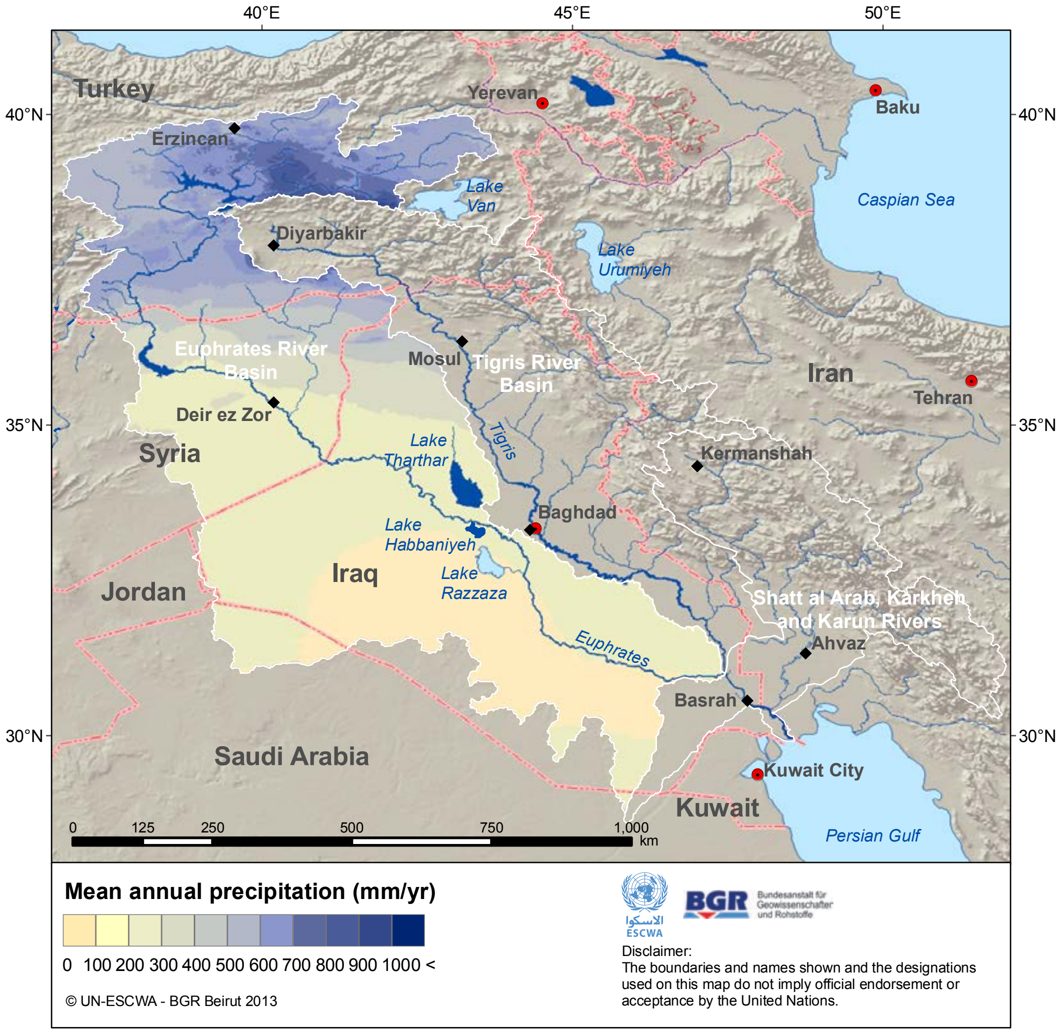
Figure 4 illustrates that mean annual precipitation gradually decreases to the south-west to about 300 mm near the Syrian-Turkish border. The mild influence of the Mediterranean Sea further decreases inland and to the south. Rainfall is sparse in the arid climate of the Iraqi Lowlands (Mesopotamian Plain), with an annual average of 150-200 mm falling mainly in the winter months. Summers are dry and hot with daytime temperatures of up to 50°C.

POPULATION

The Euphrates Basin has an estimated population of about 23 million, of which 44% lives in Iraq, 25% in Syria and 31% in Turkey (Table 1).

The Euphrates at the Syrian-Turkish border, Syria, 2009. Source: Andreas Renck.

Figure 4. Mean annual precipitation in the Euphrates Basin



Source: Compiled by ESCWA-BGR based on data provided by WorldClim, 2011.

Table 1. Estimated basin population

RIPARIAN COUNTRY	COUNTRY POPULATION (MILLIONS)	ESTIMATED POPULATION IN THE BASIN		SOURCE
		MILLIONS	AS PERCENTAGE OF TOTAL BASIN POPULATION	
Turkey	73.7	7.15	31	Turkstat, 2010.[a]
Syria	20.9	5.69	25	Central Bureau of Statistics in the Syrian Arab Republic, 2005.[b]
Iraq	32	10.2	44	Central Organization for Statistics in Iraq, 2010.[c]
Total		23.04		

Source: Compiled by ESCWA-BGR.
(a) The population estimate for the area of the basin situated in Turkey is based on a 2010 census and includes populations living in the Turkish provinces of Adiyaman, Agri, Bingol, Elazig, Erzincan, Erzurum, Gaziantep, Malatya, Mardin, Mus, Sanliurfa, Sivas and Tunceli.
(b) The population estimate for the area of the basin located in Syria is based on a 2010 assessment and includes populations living in the Syrian governorates of Aleppo, Deir ez Zor, Hama, Hasakah, Homs and Raqqah.
(c) The population estimate for the area of the basin situated in Iraq is based on a 2009 assessment and includes populations living in the Iraqi provinces of Anbar, Babil, Karbala, Najaf, Ninewa, Qadisiyah and Muthanna.

Hydrological Characteristics

Turkey provides about 89% of the total Euphrates flow generated from 28% of the basin area. By contrast, Syria contributes only 11% of total river flow generated from 22% of the drainage area due to comparatively less rainfall.[8] Contributions by the remaining riparians are generally very small.[9]

Most of the Euphrates stream-flow originates from precipitation in the Armenian Highlands, and in particular the Keban Hills (Figure 4).[10] In Syria, the Sajur, Balikh and Khabour Rivers and some intermittent streams contribute water to the Euphrates. Their contributions depend on the intensity and volume of precipitation and, increasingly, on water use and drainage in upstream irrigation areas. In Iraq, there are no major surface water contributions to the Euphrates except for rare runoff events generated by heavy storms.[11]

ANNUAL DISCHARGE VARIABILITY

The discharge of the Euphrates varies annually corresponding to climate variability. The stations at Jarablus in Syria (1938-2010), Hussaybah (1981-2011), Hit (1932-1998) and Hindiyah (1930-1999) in Iraq (see Overview Map for location) have the longest available data records, covering the period from 1930 to 2011. They were therefore used to illustrate the discharge dynamics and trends of the Euphrates (Figure 5). In order to allow for comparison of the flow along the main stream of the Euphrates, common periods have been selected (Table 2) for all stations. The period 1938-1974 was selected because it represents the near-natural flow of the river. Measured flow characteristics changed with the filling of the Keban Dam reservoir in Turkey and Lake Assad in Syria in the winter of 1973-74. This is reflected in the downstream discharge.[12] Hence the period between 1974 and 1998 was selected as it covers the first phase of infrastructure development in the basin.[13] In early 1990, construction on the Atatürk Dam in Turkey began. Hence, the last matching period covers the years between 1990 and 2010.

The mean annual flow for the entire period of record is 26.6 BCM at Jarablus and 27.1 BCM at Hit (Table 2). Maximum flow levels were recorded in 1969 with 40 BCM at Hindiyah, 56.8 BCM at Jarablus, and 63 BCM at Hit. This contrasts with the lowest annual flow of 3.1 BCM at Hindiyah in 1974, 12.7 BCM at Jarablus in 1976, and 9 BCM at Hit in 1990.

Table 2. Summary of annual flow volume statistics for the Euphrates River (1930-2011)

STATION (DRAINAGE AREA, km²)	PERIOD	MEAN (BCM)	MINIMUM (BCM)	MAXIMUM (BCM)	CV[a] (-)
Jarablus, Syria (120,000)	1938-2010	26.6	12.7	56.8	0.33
	1938-1973	**30.0**	**15.0**	**56.8**	**0.29**
	1974-1987	24.9	12.7	34.1	0.27
	1988-1998	25.5	14.4	50.1	0.42
	1974-1998	**25.1**	**12.7**	**50.1**	**0.34**
	1990-2010	**22.8**	**14.4**	**32.6**	**0.34**
Hussaybah, Iraq (221,000)	1981-2011	20.0	8.9	47.6	0.44
	1988-1998	22.8	8.9	47.6	0.54
	1999-2010	15.5	9.3	20.7	0.27
	1990-2010	**16.8**	**8.9**	**30.7**	**0.39**
Hit, Iraq (264,000)	1932-1998	27.1	9.0	63.0	0.36
	1938-1973	**30.6**	**15.1**	**63.0**	**0.30**
	1974-1987	23.1	9.3	31.2	0.32
	1988-1998	22.4	9.0	46.6	0.51
	1974-1998	**22.8**	**9.0**	**46.6**	**0.40**
Hindiyah, Iraq (274,100)	1930-1999	17.6	3.1	40.0	0.4
	1938-1973	**19.8**	**6.6**	**40.0**	**0.35**
	1974-1987	15.3	3.1	24.1	0.45
	1988-1998	13.8	7.7	27.9	0.48
	1974-1998	**14.7**	**3.1**	**27.9**	**0.46**

Source: Compiled by ESCWA-BGR based on Ministry of Irrigation in the Syrian Arab Republic in ACSAD and UNEP-ROWA, 2001; USGS, 2012; Ministry of Irrigation in the Syrian Arab Republic, 2012.
(a) Coefficient of Variation. For information on the definition and calculation of the CV see 'Overview & Methodology: Surface Water' chapter.

Negative trend

Figure 5 shows a statistically significant negative trend for the period of record (1937-2010) on the Euphrates at Jarablus indicating a decrease in mean annual discharge. Before 1973, the mean annual flow of the Euphrates at the Syrian-Turkish border (Jarablus) was around 30 BCM, but this figure dropped to 25.1 BCM after 1974 and fell to 22.8 BCM after 1990 (Table 2). This is most likely due to climate variability and more frequent drought periods, and the construction of large dams in Turkey as part of the Southeastern Anatolia Project (GAP).

The construction of a series of dams in Syria and downstream Iraq since the 1960s has further impacted flow volumes due to regulation and increased evaporation losses.[14] Even though a significant long-term trend could only be detected at Jarablus, all stations show lower mean annual flow volumes after 1973, most likely due to stream regulation through water abstractions and storage (Table 2).

Recent data on mean annual flow volumes of the Euphrates in Syria, as well as Euphrates annual inflow rates into Iraq measured at Hussaybah for the years 1990-2010 indicate a decline in flow volume compared to previous decades (Table 2).[15] According to the Iraqi Ministry of Water Resources, the inflow of water at the Iraqi-Syrian border is constantly decreasing. In March 2009, Iraq registered a record low discharge of 250 m³/s on the Euphrates.[16]

Figure 5b illustrates the mean annual specific discharge time series for the period from 1937 to 2010 at Jarablus, Hussaybah, Hit and Hindiyah. Since all time series are normalized by their respective drainage area, a lower discharge yield can be observed further downstream at Hit compared to the upstream station Jarablus. This is a typical hydrological feature of arid regions where no or few tributary rivers discharge within the area.

Droughts

Figure 5c shows the mean annual discharge anomaly in terms of water surplus (positive) and deficit (negative) compared to the long-term mean discharge over the period of record from 1937 to 2010. It shows wet and dry periods and reflects the impacts of stream regulation. The period of record exhibits four prolonged drought cycles (1958-1962; 1972-1976; 1983-1995; 1999-2011). The 1983-1995 drought was interrupted by a very wet year in 1989. Since 1999, the Euphrates shows below-average discharge at Jarablus and Hussaybah, possibly reflecting a combination of drier weather conditions and the effects of extensive dam building.

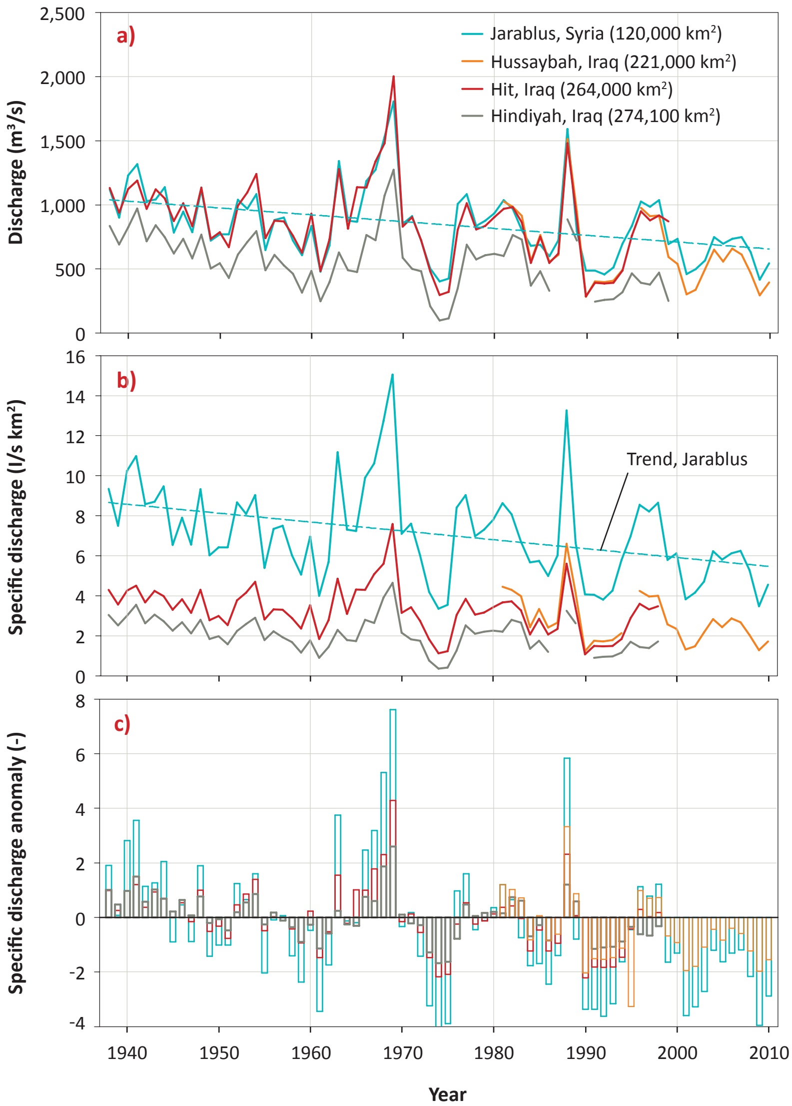
Comparison

For the common period 1938-1973 (Table 2), the comparison of the flow along the main stream of the Euphrates for the stations Jarablus and Hit shows no differences in mean annual flow volume. This period is often referred to as representing the near-natural flow of the river.[17] However, for the same period, differences in mean annual flow volume can be observed between the stations Hit and Hindiyah. This is most likely due to the fact that water is being diverted to a secondary branch that begins at the Ramadi Barrage (Table 3) from where it goes to Lake Habbaniyeh and Lake Razzaza in flood seasons. In addition, river water is used for various purposes.[18]

For the common period 1974-1998, the comparison between the stations shows an obvious reduction in the mean annual flow volume from 25.1 BCM at Jarablus to 22.8 BCM at Hit and 14.7 BCM at Hindiyah. Droughts and the construction of dams account for the diminishing flow volumes along the main stream.

For the period 1990-2010 mean annual flow volume at Hussaybah is lower than at Jarablus, which suggests a water consumption of about 6 BCM between the two stations. The flow is also reduced between Hussaybah and Hindiyah but a complete data record was not available for the most downstream station Hindiyah.

Figure 5. a) Mean annual discharge, b) specific mean annual discharge and c) discharge anomaly time series of the Euphrates (1937-2010)



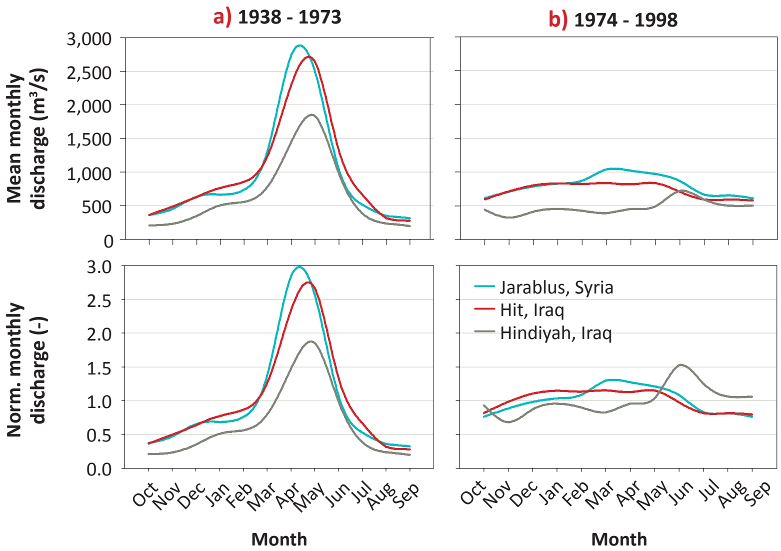
Source: Compiled by ESCWA-BGR based on data provided by the Ministry of Irrigation in the Syrian Arab Republic in ACSAD and UNEP-ROWA, 2001; USGS, 2012; Ministry of Irrigation in the Syrian Arab Republic, 2012.

FLOW REGIME

The Euphrates river flow regime before 1973 can be considered near natural as there was limited water regulation in the runoff-generating area in Turkey. This natural flow regime is shown in Figure 6a, with a high-flow season from March to July and a low-flow season from August to February. The increased discharge during the high-flow period was generated by snow-melt from the Highlands. Such a snow-melt regime was typical for the period of record from 1937 until the 1970s.

The construction and operation of the Keban Dam in Turkey in 1974 and the Tabqa Dam in Syria in 1975 led to a shift in the Euphrates flow regime. Figure 6b shows that increased regulation of the naturally snow-melt-driven flow regime of the Euphrates resulted in less pronounced seasonal flow variation (1973 to 1998). The water discharged during the high-flow period from March to July was mainly stored to fill the reservoirs and released later

Figure 6. **Mean monthly flow regime of the Euphrates River at different gauging stations for different time periods**



Source: Compiled by ESCWA-BGR based on data provided by the Ministry of Irrigation in the Syrian Arab Republic in ACSAD and UNEP-ROWA, 2001; USGS, 2012; Ministry of Irrigation in the Syrian Arab Republic, 2012.

The Tabqa Dam, Syria, 1992. Source: Ed Kashi/VII.

BOX 1

Regulating Seasonal Variability

The seasonal variability of the Euphrates is not suitable to meet crop needs. Water for winter crops is most needed during the low-flow season in September and October. The flood season with frequent inundations in spring puts the harvest at risk. Engineering works have therefore prioritized Euphrates stream-flow regulation in order to provide irrigation water in the low-flow season.

in the year for irrigation purposes (Box 1), thus artificially increasing the discharge during the low-flow season. The river was further regulated with the operation of the Atatürk Dam in Turkey in 1992 and the development of related irrigation projects.

GROUNDWATER

Along its course in Syria, the Euphrates River receives groundwater from aquifers in the western part of the river catchment. These include Eocene chalky limestones east of Aleppo and a multi-aquifer system of Cretaceous to Neogene Aquifers in the eastern steppe in Syria. The discharge quantities are, however, insignificant in comparison to the total river flow.

In the eastern part of the catchment in Syria, the Euphrates River receives important inflows from spring discharges, which feed the tributaries Balikh and Khabour. Syria and Turkey share the Jezira Tertiary Limestone Aquifer System, a productive limestone and dolomite aquifer of Middle Eocene to Oligocene age, which lies in the area between these tributaries on the northern edge of the Syrian Jezira (see Chap. 24). The aquifer system's annual recharge is estimated at 1,600 MCM; the recharge areas are located mainly on Turkish territory, while discharge occurs via two major springs in Syria.[19]

Small-scale irrigation from river water in Iraq may produce minor quantities of recharge from irrigation return flow in shallow aquifers. In the west and south-west of the Iraqi Jezira, groundwater movement in the Miocene Fatha Formation is directed toward the Euphrates. In most parts of the Iraqi Jezira and the adjoining south-eastern Jezira in Syria, groundwater moves to internal drainage discharge zones such as Wadi Tharthar, Lake Tharthar and the Tawila Salt Flat.[20]

Groundwater flow in Paleogene to Neogene carbonate aquifers in the western and southern deserts of Iraq (Umm er Radhuma-Dammam [North]) is directed toward the Euphrates river plain. The groundwater from these aquifers discharges mainly in mudflats, sabkhas and through a series of springs that run parallel to the river course over a length of about 450 km[21] on the edge of the Mesopotamian Plain.[22] The main recharge areas of the aquifers are located in Iraq; minor subsurface inflows occur from outcrop areas of the Paleogene aquifers in Saudi Arabia.

Alluvial deposits in the marshlands in the lower Mesopotamian Plain in Iraq create a shallow aquifer. Recharge mainly occurs during winter and through infiltration of Euphrates and Tigris river water. Generally, water flows into the groundwater during high flows when the water level of the rivers exceeds the groundwater table. Conversely, groundwater is discharged into the river during low-flow periods in summer. In the past, several springs discharged south of the Euphrates River and along the base of the western plateau in the marshlands. Groundwater from these springs most likely emanated from the Neogene Aquifer System (North-West) (see Chap. 25).

Water Resources Management

Water management in the Euphrates Basin dates back 6,000 years when the Mesopotamian landscape was transformed by the introduction of irrigation networks to improve agricultural yield. More recently in the 20th century, the basin witnessed the implementation of extensive water resources development schemes, with the construction of dams, reservoirs and hydro-electric power plants (Table 3). Today, water management in Iraq, Syria and Turkey focuses on hydropower, irrigation and drinking water supply. More than 70% of water in the Euphrates Basin is used for agricultural production.[23] The Southeastern Anatolia Project (GAP)[24] in the upper Euphrates Basin in Turkey has drastically impacted the natural flow regime of the river in recent decades (Box 2). The maximum storage capacity of the major dams and reservoirs (>144 BCM) on the Euphrates exceeds the natural annual flow volume of the river (30 BCM) by four to five times.

DEVELOPMENT & USE: TURKEY

Since the 1970s, the upstream riparian Turkey has become a strategic protagonist in water resources management in the Euphrates Basin. Its water infrastructure projects and programmes, particularly GAP, have greatly impacted water resources throughout the basin, modifying the natural flow regime of the Euphrates and affecting other riparians' water use patterns.

The first large project on the Euphrates in Turkey was the Keban Dam, which was built in the 1960s and completed in 1974. It is the farthest upstream of a series of Turkish dams on the Euphrates, serving the dual purpose of hydropower generation and flow regulation.[25] The Karakaya Dam, which was completed in 1987, was the first dam built as part of GAP. It was followed five years later by the project's centrepiece, the Atatürk Dam.

An aerial view of farmlands near the Atatürk Dam, Turkey, 1992. Source: Ed Kashi/VII.

Since then, the State Hydraulics Works (DSI) in Turkey constructed two more dams on the Euphrates River: the Birecik and Karakamis. Ultimately, a total of 14 dams and 11 hydroelectric power plants are to be built on the Euphrates and its tributaries, making the upper Euphrates the largest component of GAP.[26]

Besides hydropower generation, Turkey plans to expand irrigated agriculture as part of its long-term development strategy, particularly in south-eastern Anatolia. Ultimately, GAP aims to use water from both the Euphrates and Tigris to irrigate a total area of about 1.8 million ha, of which 270,000 ha is currently operational. Most of this land (230,000 ha) lies in the Euphrates Basin.[27] The Atatürk Dam provides water to two major irrigation projects through the Urfa tunnels. These projects have an impact on the Balikh catchment (see Chap. 2).[28]

Table 3. **Main dams and barrages on the Euphrates River in chronological order of construction**

COUNTRY	NAME	COMPLETION YEAR	CAPACITY (MCM)	PURPOSE[a]	BACKGROUND INFORMATION
Iraq	Hindiyah	1914	—	I, HP	This regulator was the first modern water diversion structure in the Euphrates Basin and was built when Iraq was still part of the Ottoman Empire. In the 1980s the old structure was replaced by a new barrage. This project also included the production of hydroelectricity.
Iraq	Ramadi	1948	3,300 (Lake Habbaniyeh)	FC, I	The Ramadi Barrage regulates the Euphrates flow regime by discharging excess flood water into Lake Habbaniyeh through the Warrar Regulator. After temporary storage in the lake, the water is either released back into the Euphrates or diverted to Lake Razzaza (2,000 km^2) through the Mujarra Regulator which was built in 1957.
Turkey	Keban	1974	31,000	HP, FC	Reservoir area: 675 km^2
Syria	Tabqa	1975	14,000	HP, I	Also called the Euphrates Dam or the Revolution Dam, it is considered the largest earth-fill dam in the world. The dam was built with the aim of producing hydropower and providing irrigation water.
Iraq	Fallujah	1985	..	FD, I	The Fallujah Dam was constructed next to the riverbed. The Euphrates River was rerouted to the dam after construction was completed.
Iraq	Haditha (Al Qadisiyah)	1987	8,280	FC, I, HP	The Haditha Dam was jointly constructed with the former Soviet Union. The nearly 10 km-long earth-fill dam created Lake Qadisiyah, which covers an area of 500 km^2.
Syria	Baath	1987	90	HP, FC	The Baath Dam generates electricity and regulates water flow from the Tabqa Dam.
Turkey	Karakaya	1987	9,580	HP	The dam is part of GAP and has a reservoir surface area of about 268 km^2.
Turkey	Atatürk (originally Karababa)	1992	48,700	HP, I	The Atatürk Dam is the centrepiece of GAP and one of the largest dams in the world. It is located about 80 km from the Syrian border. The dam's reservoir, Lake Atatürk, is the third-largest lake in Turkey. Turkey began filling the reservoir in 1990, and guaranteed a 500 m^3/s flow from the dam. With a maximum capacity of 48,700 MCM, the dam's reservoir is large enough to store the entire annual discharge of the Euphrates.
Syria	Tishreen	1999	1,900	HP	-
Turkey	Karkamis	1999	160	HP, FC	The dam is part of GAP and is located 4.5 km from the Syrian-Turkish border.
Turkey	Birecik	2000	1,220	HP, I	The dam's hydroelectric power plant has an annual average capacity of 2,500 GWh.

Source: Compiled by ESCWA-BGR based on Jones et al., 2008, p. 62; FAO, 2009; Beaumont, 1998; General Directorate of State Hydraulic Works in Turkey, 2009; Altinbilek, 2004, p. 21; Kaya, 1998; ACSAD and UNEP-ROWA, 2001; Ministry of Environment in Iraq et al., 2006; Ministry of Irrigation in the Syrian Arab Republic, 2012; Ministry of Water Resources in Iraq, 2012.
(a) Irrigation (I), Hydropower (HP), Flood Control (FC) and Flow Diversion (FD).

BOX 2

The Southeastern Anatolia Project

Launched in 1977, the Southeastern Anatolia Project (GAP) is an ambitious Turkish project to harness the water of the Tigris and the Euphrates for energy and agricultural production, and provide an economic stimulus to south-eastern Anatolia, the majority Kurdish region in Turkey. The project covers an area of 74,000 km^2 between the lower reaches of the Turkish part of the Euphrates, the tributaries of the Euphrates and the Tigris River. The area is home to approximately 7 million people.[a] Once completed, the project will comprise 22 dams and 19 hydroelectric power plants on the Euphrates and Tigris Rivers. In addition, numerous smaller dams and canal systems will channel reservoir water to newly irrigated land.[b]

The overall objective of the mega-development project is to produce 27,367 GWh of hydroelectric energy annually and to double irrigable farmland in Turkey to 1.8 million ha.[c] The project is currently still in its first phase, in which 1 million ha of irrigable land is to be created. To date, 27% of the project's first phase has been made operational (270,000 ha), 10% (100,000 ha) is under construction and 63% (630,000 ha) is in planning.[d]

The project originally started as a 'hydraulic mission'-type scheme.[e] In 1989, it was transformed into an integrated, multisectoral development programme that focuses on economic prosperity and sociocultural improvement in south-eastern Anatolia, with greater emphasis on agricultural development and energy production.[f] The project forms an integral part of the Turkish national development strategy and aims to create four million new jobs in impoverished south-eastern Anatolia.

Project completion was scheduled for 2010, but has been delayed until 2047 due to financial constraints.[g] Today almost half of GAP has been implemented with an estimated USD 21 billion of investment, which means a further USD 15 billion is needed to complete the project.[h]

The downstream riparians Iraq and Syria have objections to the project as they fear a decrease in water quantity and quality in the basin.[i] International experts share their concerns and expect GAP, once completed, to consume more than 50% of the Euphrates and about 14% of the Tigris.[j] The natural flow regime of the Euphrates has changed entirely over the last 40 years, mostly due to human interventions, as exemplified by the water development programmes along the upper Euphrates. However, not all changes are negative as regulation of the Euphrates can protect downstream countries from destructive floods and droughts, provided that reservoir water is released.

In addition to sparking regional tensions among riparians, GAP has also caused national discord and protests from NGOs and activists worldwide due to its potential harm to the region's natural environment[k] and social fabric; the flooding of archaeological sites; and the involuntary displacement of local populations.[l] Projects and programmes implemented as part of GAP have led to increased salinity of irrigated soils and changes to the ecosystem and river flow regimes. The current construction of the Ilisu Dam and Hydraulic Power Plant on the Tigris River has elicited strong worldwide condemnation (see Chap. 3, Box 1).

(a) This represents almost 10% of the total population of Turkey.
(b) For more information and discussion of GAP, see Kolars and Mitchell, 1991; Kibaroglu, 2002a; Unver, 1997.
(c) Ministry of Environment and Forestry in Turkey, 2009, p. 60; Unver, 1997, p. 466. The 1.8 million ha correspond to nearly 10% of the total surface area of Turkey.
(d) Daoudy, 2009, p. 369 states that a total of 272,972 ha are under irrigation in the entire project, of which roughly 240,000 ha lie in the Euphrates Basin and 32,000 ha in the Tigris Basin. A further 111,500 ha are under preparation.
(e) Warner, 2008, p. 279 also notes that GAP was based on the Tennessee Valley Authority (TVA) model.
(f) General Directorate of State Hydraulic Works in Turkey, 2009.
(g) Daoudy, 2009, p. 369.
(h) General Directorate of State Hydraulic Works in Turkey, 2009, p. 60.
(i) In particular, huge hydraulic infrastructure projects like the Atatürk Dam created severe tensions between the riparians.
(j) With reference to Kolars and Mitchell, 1991 and Kliot, 1994, Daoudy, 2009, p. 370 states that GAP will withdraw up to 70% of the natural flow of the Euphrates, 40-50% of the observed flow and 50% of the natural flow of the Tigris River. For further estimates see Tomanbay, 2000.
(k) For instance, Jones et al. underline that "upon completion of the GAP project (with projected reductions in AFV [annual flow volume] exceeding 5.3x109 m^3/yr, the sustainable marshes in Central and Al-Hammar area will be reduced by at least an additional 550 km^2" (Jones et al., 2008).
(l) For information see Sahan et al., 2001, p. 7.

DEVELOPMENT & USE: SYRIA

Like Turkey, Syria did not start exploiting the Euphrates until the 1960s. Upon completion of the Tabqa Dam in the 1970s, the country developed ambitious plans for major irrigation projects along the Euphrates River.[29] The Tabqa Dam, also known as the Euphrates Dam, was designed to meet Syria's primary irrigation and energy needs. Its construction led to the creation of Lake Assad, the country's largest water reservoir[30] with a projected capacity to irrigate 640,000 ha of land.[31] The third-largest dam on the Euphrates in Syria, the Baath Dam, was built in 1987, mainly to regulate flow from the upstream Tabqa Dam. The Tishreen Dam, located upstream of Lake Assad, was built in 1999 to generate hydropower.

Water resources in the basin are mainly used for a series of large irrigation projects.[32] Syria has vastly expanded its irrigated area in recent decades: total irrigated area has increased from 652,000 ha in 1985 to 1.4 million ha in 2005, remaining constant since then. Overall, the Euphrates Basin comprises the largest share of cultivated area in the country.[33]

One of the main water development projects in the Syrian part of the Euphrates Basin is the Great Khabour Irrigation Project, as part of which three dams were built on the Khabour River to produce hydropower and store water for irrigation. In 2010, about 59,550 ha of land were

The Euphrates at Jarablus, Syria, 2009. Source: Adel Samara.

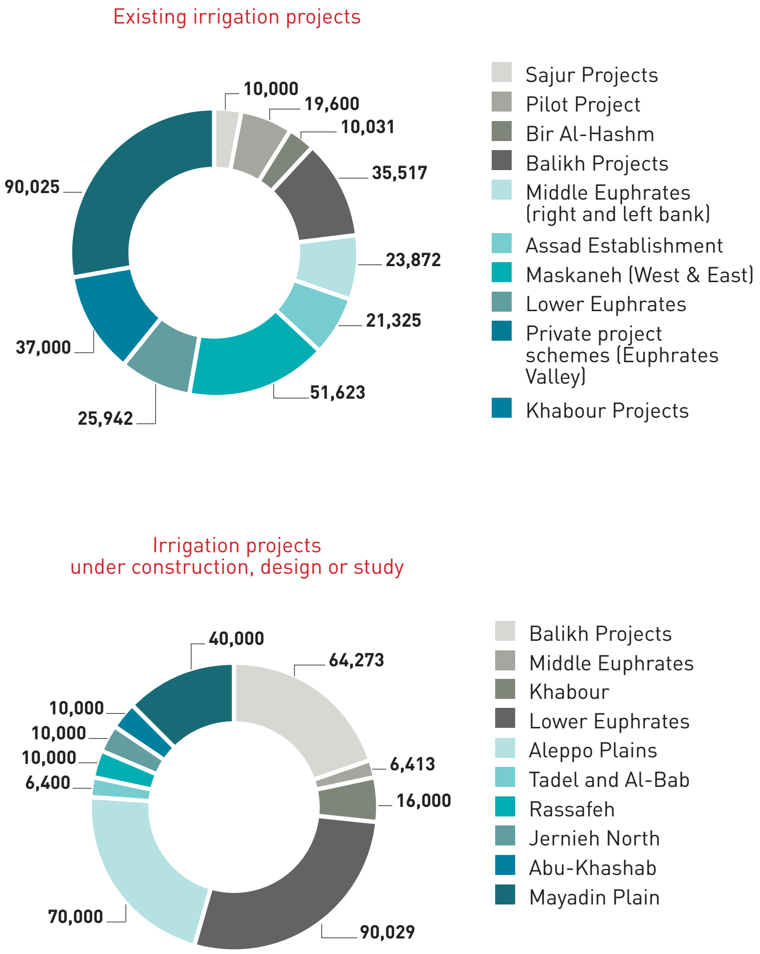
irrigated by the Khabour and Jagh Jagh Rivers[34] (see Chap. 2). In addition, two development projects in the Balikh/Jallab sub-basins use water imported from Lake Assad, while water from the Sajur River is also used for irrigation.

In the Syrian part of the Euphrates Basin, an estimated total of 325,000 ha of land were irrigated in 2000, with a further 325,000 ha of land earmarked for future irrigation projects (Figure 7).[35] The annual volume of water required for the proposed projects is assumed to be about 5,180 MCM. This volume should be added to the 3,586 MCM used in operational irrigation projects.[36] Official data states that 206,987 ha were irrigated by the Euphrates River in 2010 (Figure 8) in addition to 59,550 ha from the Khabour and Jagh Jagh Rivers, amounting to almost 270,000 ha.[37] Applying a commonly accepted rate for irrigation requirements,[38] this suggests an irrigation water use of about 2,700 MCM from the Euphrates, Khabour and Jagh Jagh Rivers.

Lack of information on the current state of irrigated land in the Euphrates Basin in Syria makes it difficult to explain the difference between the 2000 and 2010 figures. However, it is likely that irrigated agriculture has declined in some areas. The disparity could also be the result of different methods of assessing and defining irrigated land.

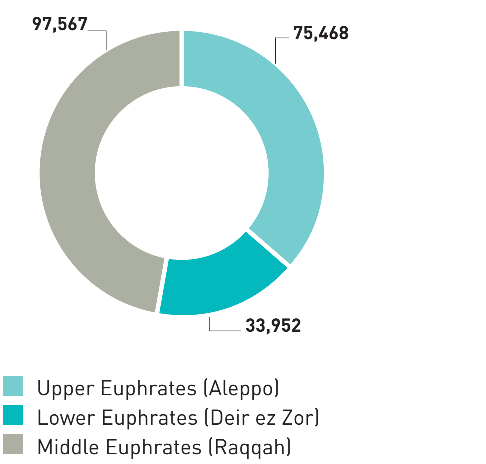
Either way, the figures show that the scale of Syrian irrigation projects is comparable to that of GAP in the Euphrates Basin in Turkey in terms of irrigated area. However, it must be noted that in Turkey as well as in northern Syria (unlike arid south-eastern Syria or Iraq), agriculture is partly rain-fed with seasonal supplementary irrigation. Nevertheless, Syria depends largely on the Euphrates as more than 50% of the blue water used in the country is abstracted from the basin.[39] While most of this is used for irrigation, the Euphrates also supplies drinking water to the cities of Deir ez Zor and Raqqah. Since 2006, Aleppo also draws its water from the Euphrates, with a pipeline running west from Lake Assad and supplying cities and villages along its route.

Figure 7. **Irrigation projects in the Euphrates Basin in Syria in 2000 (ha)**



Source: Compiled by ESCWA-BGR based on data provided by Ministry of Irrigation in the Syrian Arab Republic, 2000 in ACSAD and UNEP-ROWA, 2001; Varelo-Ortega and Sagardoy, 2003.

Figure 8. **Total area irrigated by the Euphrates River in Syria in 2010 (ha)**



Source: Compiled by ESCWA-BGR based on data provided by Ministry of Irrigation in the Syrian Arab Republic, 2012.

BOX 3

The Euphrates Valley Project

The Tabqa Dam was Syria's main development focus in the Euphrates Basin. Initiated in the 1960s, the project had multiple objectives including the expansion of the region's irrigated area to 640,000 ha, the generation of energy, and the prevention of seasonal flooding. The project comprised six irrigation districts which were all centrally supervised by the General Authority for the Development of the Euphrates Basin. However, after the initial plan failed, the government reduced the irrigated area objectives to 370,000 ha. The problems encountered included high gypsum levels in the soil and salinization caused by intensive irrigation.

DEVELOPMENT & USE: IRAQ

Before Turkey and Syria developed an interest in the Euphrates, Iraq was the main user of river water.[40] It was the first riparian to develop engineering projects along the river, irrigating more than five times as much land as Syria and nearly 10 times as much as Turkey in the Euphrates Basin.[41] However, by the late 1960s Syrian and Turkish irrigation projects had outgrown Iraqi projects.

Built in the first half of the 20th century, the Hindiyah Dam and the Ramadi-Razzaza Regulator were constructed to prevent flooding and ensure year-round irrigation of crops via canal systems.[42] The Haditha Dam is the largest dam along the Iraqi stretch of the Euphrates River with a maximum capacity of 8.2 BCM. It is located about 120 km from the Syrian border and regulates flow in addition to generating electricity.[43] Iraq also constructed a complex network of canals on the Euphrates, diverting Euphrates water to reservoirs such as Lake Habbaniyeh and Lake Tharthar which store excess flood water.

Iraq irrigates a greater surface area along its part of the Euphrates River than Syria and Turkey. In the 1960s, Iraq extracted about 16 BCM between Hit and Hindiyah to irrigate around 1.2 million ha.[44] While no recent statistics on irrigated area in Iraq are available, figures from 2000 suggest irrigated areas along the Euphrates River in Iraq added up to about 1.5 million ha.[45] Other sources suggest that an area of 1 to 1.3 million ha were irrigated by Euphrates water.[46] These estimates do not support the assumption that irrigated agriculture in Iraq had declined since the 1980s as a result of the Iraq-Iran war, economic sanctions and the two Gulf wars.

Total potential irrigable land in Iraq within the Euphrates Basin is estimated at 1.8 million ha.[47] Another study states that 4 million ha of land are suitable for agriculture in the Euphrates Basin in Iraq.[48]

BOX 4 The Third River or Main Outfall Drain

Also known as the Saddam River, the Third River flows from Baghdad to the Persian Gulf via the Khor Zubair Canal. Construction on the 565 km canal system was completed in 1992 after 30 years of work. As a main outfall, it collects drainage water from more than 1.5 million ha of land between the Euphrates and Tigris Rivers. The canals discharge into the extensive southern Hammar Marshes that are fed by the Euphrates and Tigris. The project was also set up to resolve the chronic salinity problem affecting farmland between the two rivers, by collecting saline drainage water and preventing it from flowing into the Euphrates. In 1995, around 17 million tons of salt reportedly flowed into the Gulf through the Third River.

The Haditha Dam on the Euphrates in Iraq, 2008. Source: Tyler W. Hill.

WATER QUALITY & ENVIRONMENTAL ISSUES

Irrigated agriculture is prevalent throughout the Euphrates Basin, resulting in a considerable return flow of drainage water, which in turn causes water pollution.[49] Salts are the main pollutants in drainage waters: as they are not naturally removed from the water, they tend to accumulate along the course of the river. The Euphrates is particularly prone to salinization as almost all of its discharge is generated in its headwaters in Turkey. The river then flows through semi-arid to arid areas for over 1,500 km, with high evaporation rates and no further dilution. In Syria, the Euphrates flows through areas with gypsiferous soils,[50] which have a high potential for salt mobilization and thus contribute to further salinization.[51] These characteristics, in addition to issues such as direct sewage disposal into the river, have resulted in a rapid decline in water quality along the Euphrates.[52] This increasingly affects potential downstream users of Euphrates river water.

The area south of the Tigris and Euphrates confluence has also been severely affected by upstream developments and the Mesopotamian Marshes have been largely destroyed as a result of large damming and drainage projects pursued in the second half of the 20th century. It has also led to the salinization of the Shatt al Arab River (see Chap. 5). The regulation of the Euphrates in particular led to heavy losses in river runoff.[53]

Spatial variation

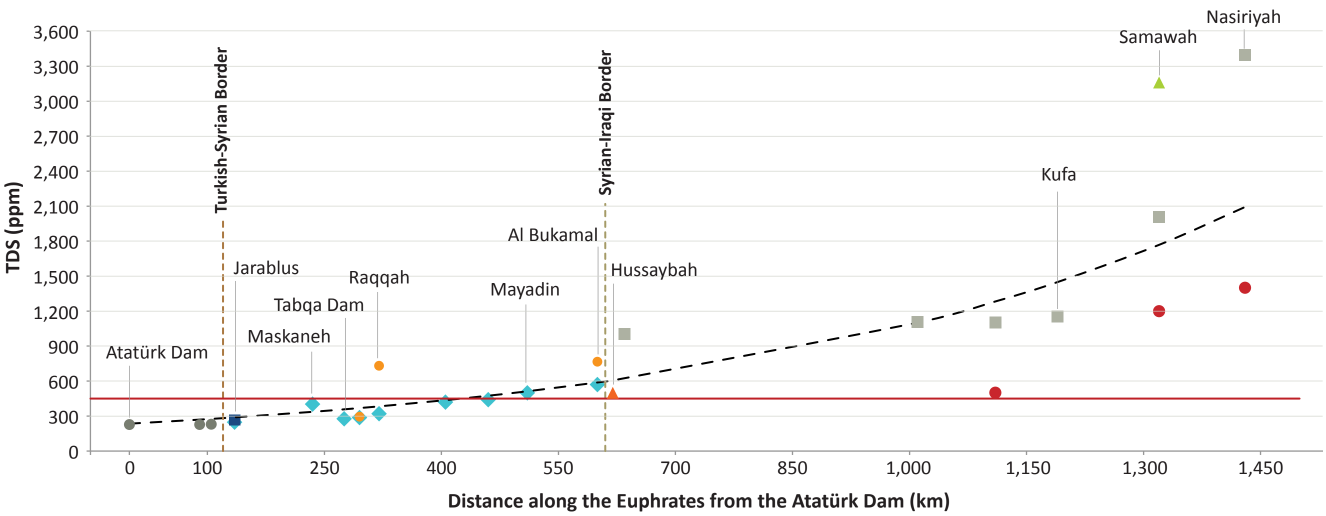
Figure 9 shows available data on Total Dissolved Solids (TDS) at different stations on the Euphrates from 1996 (after most of the dams were constructed). The spatial variations in salinity levels generally indicate an increasing trend of dissolved solids downstream.

In Turkey, analysis of water quality along the river for the years 2002-2003 showed an average salinity of around 237 ppm, a value that does not constitute a salinity hazard for crop productivity.[54] The Euphrates waters at Jarablus near the Syrian-Turkish border are of similar quality with a TDS value of 248 ppm.[55]

Further downstream, however, a progressive increase in salinity can be observed. This is probably the result of upstream pollution from Turkish irrigation projects, and Syrian agricultural activities in the floodplains of the Euphrates River as well as in the Balikh and Khabour sub-basins.[56] These sub-basins drain saline irrigation return waters into the Euphrates River itself (Box 5).[57]

This is reflected in the salinity values registered at Maskaneh (the site of the Maskaneh irrigation scheme located near the southern part of Lake Assad),[58] the city of Raqqah (at the confluence with the Balikh) and the city of Mayadin (after the confluence with the Khabour). Overall, the salinity level of the river at least doubles between the Syrian-Turkish border and the point where the Euphrates enters Iraq.[59]

Figure 9. Salinity variations along the Euphrates River since 1996



Source: Compiled by ESCWA-BGR based on the sources mentioned above.

Notes:

- This graph aims only to provide a general overview of salinity variations along the Euphrates River and should not be considered fully accurate: data was extracted from a number of literature sources and official data provided by riparian countries; for some stations only individual measurements were available. The margin of error may be significant as readings could differ depending on the methodology used, location and date of measurement, rounding of means, etc. Interpretation of the salinity data is further hampered by the fact that values cannot be compared with river flow data due to information gaps.
- The years in brackets refer to the sampling years. TDS values in Syria were converted from initial EC values. Cities/stations locations and distances along the river were estimated using Google Earth.

Intensive irrigation along the course of the Euphrates, Syria, 2009. Source: Adel Samara.

The same pattern is observed in Iraq, where salinity increases downstream as a consequence of a decrease in flow, which can in turn be ascribed to the presence of several dams, the inflow of saline water from Lake Tharthar,[60] and drainage originating from upstream and local irrigation projects.[61] In particular, the Euphrates absorbs irrigation return flows from at least four agricultural drains in the stretch extending from Kufa to Samawah.[62] In the lower reaches of the river, water quality deteriorates to a point where it is no longer safe for domestic or agricultural use. Current levels may lie well above the relatively conservative trend line in Figure 9.[63]

Temporal variation

Temporal variations of TDS concentrations also reflect the various water-related developments in the basin over the years.

In Turkey, a study using data from 1971 to 2002 concluded that there was no apparent change in salinity over this time period, except for some tributaries where an increase was observed (Murat and Tacik Rivers).[64] No information is available on water quality downstream of the Urfa-Harran agricultural area, where most of the Turkish use of Euphrates water takes place (see Box 5 and Chap. 2). Limited historic information was available for the quality of the Euphrates River in Syria (Table 4), and statistical trend analysis could not be performed. However, the most recent data for the Raqqah and Al Bukamal[65] stations suggests that salinity levels have increased over the last decade or so (Table 4 and Figure 9).

Table 4. **Mean Total Dissolved Solids (TDS) values of the Euphrates at different stations in Syria for different periods**

PERIOD	STATIONS				SOURCE
	TABQA DAM	RAQQAH	DEIR EZ ZOR	AL BUKAMAL	
pre-1971	333	..	413	..	Raslan and Fardawi, 1971 in Kolars and Mitchell, 1991.
2004-2005	..	320	..	571	Kattan, 2008.
2009-2010	277	732	441	766	Ministry of Irrigation in the Syrian Arab Republic, 2012.

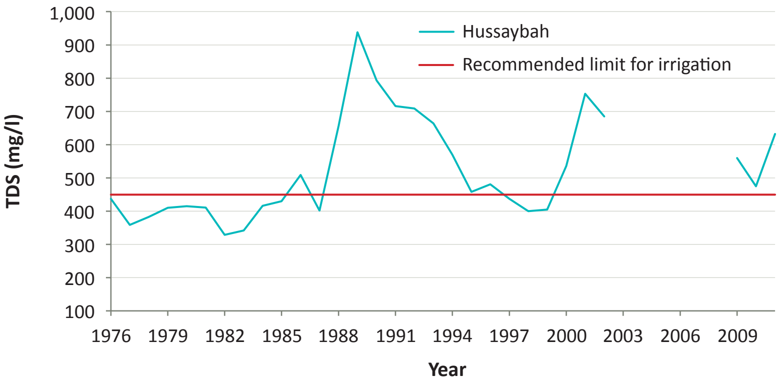
Source: Compiled by ESCWA-BGR.

In Iraq, the salinity time series for the stations of Hussaybah (Iraqi-Syrian border) and Samawah (Figure 10 and 11) show variability over the data period. However, the data period included gaps or was too short to perform a solid trend analysis. While changes in salinity often result directly from agricultural activities, the levels of discharge and hence dilution are also important factors in determining salt concentrations over time. The large peak in TDS values observed at Hussaybah in the period 1989-1993 coincides with reduced flow of the Euphrates entering Iraq, possibly due to the filling of upstream reservoirs, such as the Baath Dam (1987) and the much larger Atatürk Dam (1990).[66] Further increase in salinity can be observed after 2000, as additional reservoirs in Turkey and Syria were filled around this time.[67] This also applies to the station at Samawah, where salinity peaks also correspond to periods of dam filling in Iraq.[68] Data for Samawah over the years 1984-2003 might suggest an increasing trend, and the literature also indicates that salinity values were much lower before this period, with an average TDS value of 525 ppm in 1955.[69] This is also the case at the southernmost station Nasiriyah, where the mean annual TDS value has increased from 1,080 mg/L in 1979 to 5,000 mg/L in 2002.[70]

Overall, one can conclude that current salinity levels are in the range of 300 ppm at the Syrian-Turkish border, 600-800 ppm at the Iraqi-Syrian border, and 2,000-3,500 ppm in southern Iraq near the confluence with the Tigris River.

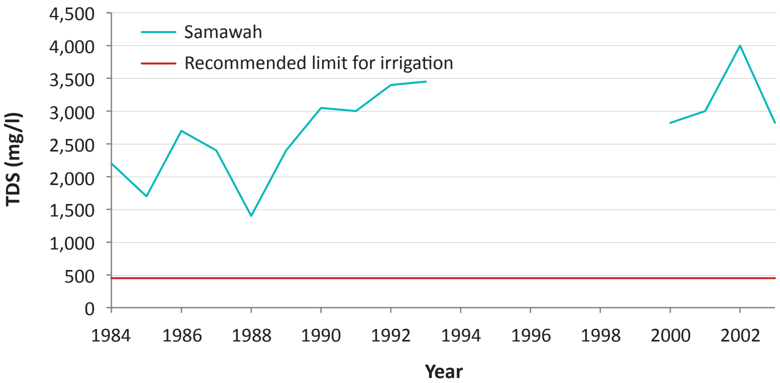
In addition to increasing salinity, intense agricultural activities and the dumping of untreated sewage in the Euphrates and its tributaries have contributed to other forms of pollution in all three riparian countries. These include increasing nutrient levels and coliform bacteria counts in the river.[71] Euphrates characteristics such as the high rate of evaporation, sharp climatic variations, the accumulation of salts and sediments, poor drainage and low soil quality in the lower reaches of the river[72] exacerbate the damaging effects of pollution from human activities.

Figure 10. **Mean Total Dissolved Solids (TDS) values of the Euphrates at Hussaybah in Iraq (1976-2011)**



Source: Compiled by ESCWA-BGR based on ACSAD and UNEP-ROWA, 2001; Ministry of Water Resources in Iraq, 2012.

Figure 11. **Mean Total Dissolved Solids (TDS) values of the Euphrates at Samawah in Iraq (1984-2003)**



Source: Compiled by ESCWA-BGR based on Al-Dulaimi, 2007.

BOX 5

Water Diversion in the Euphrates Basin Affects Water Quality

Agricultural development has a significant effect on water quality in the Euphrates Basin and is by far the largest source of pollution. It is worth noting, however, that these impacts are not necessarily felt at or near the point of abstraction of river water for irrigation. In Turkey, large quantities of good-quality water are diverted from the main course of the Euphrates at Lake Atatürk and taken through the Urfa tunnel and canal system to the extensive Urfa-Harran agricultural area in the upper Jallab/Balikh sub-basins (see Chap. 2). Return flows from this irrigation development are significant, entering Syria through the Jallab River and other streams near the town of Tell Abyad, around 90 km east of the point of inflow of the Euphrates River. These waters carry a considerable salt load and other pollution, which is ultimately discharged into the Euphrates River through the Balikh River near Raqqah, around 200 km from the Syrian-Turkish border. Water is also carried from Lake Atatürk through the Urfa tunnels to the Urfa-Harran project in the upper Khabour basin. This may be one of the reasons why Euphrates water quality at the Syrian-Turkish border has remained relatively unaffected by upstream Turkish development. Either way, assessing the dynamics of the various tributaries along the Syrian-Turkish border is of paramount importance when trying to understand the overall hydrological status of the upper part of the basin, and especially the downstream impacts of Turkish agricultural development. Water quality would therefore be an important topic to address in future discussions between Euphrates Basin riparians.

Agreements, Cooperation & Outlook

While no basin-wide agreement exists, some bilateral accords on water issues are in place, and there have been a number of attempts to find common ground.[73] In 1920, the first treaty entirely focused on the Euphrates and Tigris Rivers was put in place between France, as the mandatory power for Syria, and Great Britain, the mandatory power for Iraq. Protocols and treaties on basic water use rights for the Euphrates River followed, together with commitments for coordinated use (Table 5). In the wake of a protocol annexed to the 1946 Treaty of Friendship and Good Neighbourly Relations between Turkey and Iraq, both countries agreed to share related data and launch consultations.[74]

AGREEMENTS

Two bilateral agreements concluded since the 1980s play a vital role in the allocation of water quantities in the Euphrates Basin. In 1987, Syria and Turkey signed the Protocol on Economic Cooperation, in which Turkey agreed to release a minimum average flow of 500 m³/s across the Syrian border.[75] In the second agreement in 1990, Syria and Iraq agreed to allocate 42% of the Euphrates water measured at the Syrian-Turkish border to Syria and the remaining 58% to Iraq.

COOPERATION

After all attempts at joint projects in the Euphrates Basin failed in the 1960s,[77] the riparians embarked on unilateral development plans and dam projects, which sparked disputes in the 1970s.[78] In particular, the filling of the Keban and Tabqa Dams, and later the Atatürk Dam caused tension as downstream riparians feared a long-term decrease in flow.[79] However the tensions over planned or implemented water infrastructure projects also promoted cooperation and exchange between the riparians, such as the establishment of joint technical committees and even bilateral agreements on water allocation.

The idea of forming a Joint Technical Committee (JTC) between the three major riparians dates back to 1964 when Iraqi and Turkish experts met to discuss flow guarantees on the Euphrates.

BOX 6

Positions on International Water Law

Turkey regards the term "sharing waters" as inadequate and argues it is not possible to share a commodity that constantly changes in quantity and quality, and in time and space due to the variable conditions of the hydrological cycle. For Turkey, the Euphrates is a transboundary river that falls under Turkish sovereignty as long as it is within its territory. Iraq and Syria, on the other hand, view the Euphrates as an "international river" that should be treated as a shared entity by all riparians.[a]

Another point of contention revolves around whether the Euphrates and Tigris form a single water basin, as favoured by Turkey, or whether they should be regarded as two separate basins as favoured by Iraq and Syria.[b] Furthermore, Turkey claims that in order to reach an efficient allocation among the riparians, negotiations should include the total available water resources of each riparian. However, Syria does not want to include the Orontes River in the negotiations, while Iraq wants to exclude the waters flowing from Iran to Iraq.

Source: Aydin and Ereker, 2009; Ünal et al., 2009, p. 48; Akanda et al., 2007.
(a) Turkey is the only Euphrates Basin country that voted against the 1997 UN Convention on the Law of Non-navigational Use of International Watercourses. If Turkey signed the law, it could give lower riparians a veto right over development plans in Turkey, such as GAP.
(b) For Turkey, the Euphrates and Tigris Rivers form one river system because they merge into the Shatt al Arab water course. This view is reinforced by the existence of the Iraqi-built Tharthar Canal, which diverts water from the Tigris to the Euphrates. Syria and Iraq do not share this view.

The first trilateral meeting took place in 1965 in Baghdad, where riparians exchanged information on dam projects and negotiated a draft agreement for the establishment of a permanent JTC. However, Turkey refused the Iraqi proposition that JTC should have supervisory power over a water-sharing agreement. Although no agreement was reached, riparians continued to hold technical meetings.[80]

A decade later, JTC was formally established at the first meeting of the Joint Economic Commission between Turkey and Iraq in 1980. Syria joined the committee three years later, whereupon the three riparian countries participated in 16 meetings until 1993.

The committee worked under a mandate to "determine the methods and procedures which would lead to a definition of the reasonable and appropriate amount of water that each country would need from both rivers".[81] The agenda of JTC mainly focused on the exchange of hydrological data, sharing information on dam construction, irrigation schemes and plans for the filling of large dams.[82] After 1993, deadlock led to the group's dissolution.[83]

Riparian rapprochement

Although the riparians have not had a trilateral meeting that focuses exclusively on the Euphrates waters, their relationship has changed distinctly over the past 10 years.

While riparian relations were tense during the Cold War, with countries either following a strategy of unilateral water resources management (Turkey) and/or veto strategies to prevent a riparian from achieving its development plans (Syria, Iraq),[84] political relations between the riparian countries started to improve in the early 2000s. In 2001, the Turkish GAP and Syrian General Organization for Land Development agreed to hold joint trainings. Bilateral visits and a free-trade agreement between Turkey and Syria followed. In 2005, a group of scholars and professionals created the Track II Euphrates-Tigris Initiative for Cooperation (ETIC)[85] which seeks to promote cooperation on the technical level among the three riparian countries. In 2007 the three countries agreed to revitalize periodic JTC meetings.[86]

Table 5. Water agreements on the Euphrates River

YEAR	NAME	SIGNIFICANCE	SIGNATORIES
1920	Franco-British Convention	Mandatory powers agreed to establish a committee to examine and coordinate use of the Euphrates and Tigris Rivers.	France (Syria), Great Britain (Iraq)
1920	On Koveik River[a]	Includes mention of possible use of the Euphrates River.	France (Syria), Turkey
1921	Ankara Treaty	Reference is made to the obligation of riparian states to share the waters of a transboundary river and to satisfy the two parties. Article 12 states that the city of Aleppo should be able to use Euphrates water from Turkey to satisfy water demand in the city.	France (Syria), Turkey
1923	Lausanne Treaty	Article 109 confirms that issues related to transboundary water should be dealt with separately and with mutual respect. It also includes a provision that Turkey must consult Iraq before undertaking any hydraulic works.	Allied powers, Turkey
1926	Convention of Friendship and Good Neighbourly Relations	Commitment by both parties to coordinate their plans for use of the Euphrates River.	France (Syria), Turkey
1946	Treaty of Friendship and Good Neighbourly Relations	This was the first legal instrument of cooperation. Both parties agreed that Turkey shall install and operate permanent flow measurement facilities and inform Iraq periodically about recorded data (article 3) and water infrastructure projects.[b]	Iraq, Turkey
1980	Protocol for Technical and Economic Cooperation	The protocol mandates establishment of a joint technical committee to study the issue of regional waters – particularly the Euphrates and Tigris Rivers.	Iraq, Turkey (Syria signed in 1983)
1987	Protocol on Economic Cooperation	First bilateral agreement dealing with water sharing since World War II. It guarantees a yearly average release of 16 BCM (at a minimum annual average of 500 m^3/s) from the Euphrates at the Syrian-Turkish border.[c]	Syria, Turkey
1990	Water-Sharing Agreement	Agreement on water allocation between Iraq and Syria, which divides the flow of the Euphrates at the Syrian-Turkish border according to a 42% to 58% ratio.	Iraq, Syria
2001	Joint Communiqué	Under this agreement, the Regional Development Administration of the Southeastern Anatolia Project (GAP RDA) in Turkey and the General Organization for Land Development at the Syrian Ministry of Irrigation are to conduct joint projects and programmes.[76]	Syria, Turkey
2008	Declaration on the Establishment of the High-Level Strategic Cooperation Council	The mechanism of joint meetings between the Iraqi and Turkish cabinets also includes communication over the issue of shared water.	Iraq, Turkey
2009	Syrian-Turkish Strategic Cooperation Council Agreement	The agreement states that water is a focus point for cooperation between the two countries with specific emphasis on improvements to water quality, the construction of water pumping stations and joint dams, as well as the development of joint water policies.	Syria, Turkey
2009	Protocol on Water	The Memorandum of Understanding (MoU) on Water is one of a total of 48 MoUs signed between the two countries. The parties agreed to share hydrological and meteorological information, and exchange expertise in these areas.	Iraq, Syria

Source: Compiled by ESCWA-BGR based on data provided by Aydin and Ereker, 2009; Scheumann, 1998a; Scheumann, 1998b; Oregon State University's International Freshwater Treaties Database, ORSAM, 2009; Kibaroglu et al., 2008; Kibaroglu et al., 2011.
(a) More commonly spelled Qweik River.
(b) Hager states that while the treaty has demonstrated the two countries' best intentions, it has not been applied by either Turkey or Iraq (Hager in Elhance, 1999, p. 141).
(c) Article 7 states Syria and Turkey should work with Iraq to allocate Euphrates (and Tigris) water within the shortest possible time. Article 9 asserts the intention of the two states to construct and jointly operate irrigation and hydropower projects (Syrian Arab Republic and Turkey, 1993).

In 2009, Turkey and Syria signed 52 agreements in a Strategic Cooperation Council meeting on energy cooperation, transportation, trade and security. The two countries planned to jointly develop shared water resources under the umbrella of the Syrian-Turkish Strategic Cooperation Council.[87]

The regime change in Iraq created new opportunities for cooperation in the field of shared water. Negotiating mechanisms between Iraq and Turkey were created or revived and in 2009 a new water protocol was signed along with many other protocols on trade and security. Economic and strategic interests drive political cooperation between Iraq and Turkey. However, the question of shared water resources, water security and energy could become an obstacle in continuing good relations.[88] The dispute over the construction of the Ilisu Dam and the consecutive years of drought strained relations between the two countries.

OUTLOOK

With the Syrian crisis erupting in March 2011, relations between Turkey and Syria has severely deteriorated, with Turkey imposing a series of sanctions on Syria. However, Turkey explicitly stated in November 2011 that the sanctions would not target or restrict Turkish water supply to Syria, guaranteeing the 500 m^3/s flow at the Syrian-Turkish border.[89] The Syrian Ministry of Irrigation has also reaffirmed that the water agreements between the riparian countries of the Euphrates and Tigris river basins are not affected by the recent conflicts.[90]

It is however likely that the current situation in the region and the Syrian crisis have hampered the continuation of periodic trilateral meetings on shared water in general, and negotiations over the Euphrates River flow in particular in the near future.

Consecutive years of drought have affected all riparian countries and may also have contributed to the rural unrest and exodus of rural polulations, especially in northern Syria. The current situation suggests that water withdrawals will continue to rise in the foreseeable future, while water quality will further deteriorate, particularly given pressures from growing demand for food, rising energy needs and socioeconomic developments. Cooperative mechanisms to address these issues are not well established and progress is therefore likely to remain slow in the near future, unless more concerted efforts are made towards basin-wide management of water resources. This could include a comprehensive reservoir operation strategy and the development of a pollution control plan for the basin.

The Euphrates valley at the Syrian-Turkish border, Syria, 2009. Source: Andreas Renck.

Notes

1. Basin area was estimated from a digital elevation model (HydroSHEDS) similar to Lehner et al., 2008. In contrast to Lehner, neither the ACSAD and UNEP-ROWA, 2001 report, nor other basin descriptions consider Jordan to be part of the Euphrates River basin. Yet in terms of basin distribution, their numbers match Lehner et al., 2008. By contrast, Kibaroglu, 2002b, p. 162 speaks of 33% of the river being located in Turkey, 19% in Syria and 46% in Iraq, while Kolars and Mitchell, 1991 claim 40% lies in Turkey, 25% in Syria and 35% in Iraq. Isaev and Mikhailova, 2009, p. 384 estimate the percentage of the drainage basin lying in Turkey at 33%, 20% in Syria and in 47% in Iraq. Generally, such discrepancies between basin area estimates arise due to problems in delineating the not necessarily similar topographical and hydrogeological boundaries. In addition, large parts of the Euphrates Basin topography are flat, making the watershed less distinct.
2. The length of the Euphrates River was calculated tracing the Karasu from its source to the confluence with the Tigris.
3. The Karasu (Kara-su or Euphrates su), or Western Euphrates, originates in the Kargapazari Mountains, north of the city of Erzurum. It flows westwards over the Erzurum Plateau for more than 300 km before abruptly veering south, where it merges with the Murat.
4. The Murat or Murat-su River, also called Eastern Euphrates, is formed by the convergence of many springs in the Ala-dag area. The Urat Spring, west of Mount Ararat to the north of Lake Van, is one of the Murat's main sources. From here the river flows westwards through the Armenian Highlands over a distance of almost 500 km (other sources speak of 650 km: Medzini and Wolf, 2005, p. 111). A few kilometres north of the city of Keban and near the city of Ekbazari, the river encounters the Karasu.
5. See Chap. 2.
6. Medzini and Wolf, 2005, p. 112.
7. Kibaroglu, 2002b, p. 161.
8. Ünal et al., 2009, p. 48; Naff and Matson, 1984; FAO, 2009, p. 65. Other sources estimate that 93% of the Euphrates sources are located in Turkey (ACSAD and UNEP-ROWA, 2001), while some sources even suggest that 98% of the Euphrates flow originates in Turkey (Kolars and Mitchell, 1991).
9. Some sources assume Iraq does not contribute to the Euphrates at all (Ünal et al., 2009, p. 48).
10. It is estimated that about 72% of the total water resources of the Euphrates come from this area (ACSAD and UNEP-ROWA, 2001, p. 20). Beaumont, 1998, p. 70 goes further and estimates that precipitation in Turkey accounts for at least 95% of the total flow.
11. ACSAD and UNEP-ROWA, 2001.
12. Kolars and Mitchell, 1991 note that the observed "diminution of discharge during that time in Syria cannot be explained through reservoir filling alone and is undoubtedly climatic in origin. Had this information been known at the time, near confrontation between Syria and Iraq over the diminished river flow might have been avoided."
13. A similar grouping is found at ACSAD and UNEP-ROWA, 2001.
14. These large dams not only divert a large quantity of water for irrigation, but also have high levels of evaporation from their reservoirs. For instance, it is estimated that around 1,500 MCM/yr are lost due to evaporation from Lake Assad, the largest surface water reservoir in Syria built on the Euphrates near Tabqa in 1974 (Wakil, 1993).
15. Ministry of Irrigation in the Syrian Arab Republic, 2012; Ministry of Water Resources in Iraq, 2012.
16. Ministry of Water Resources in Iraq, 2010.
17. ACSAD and UNEP-ROWA, 2001; Kolars and Mitchell, 1991.
18. See also ACSAD and UNEP-ROWA, 2001.
19. The two springs are Ras al Ain at 40 m^3/s and Ain al Arous at 6 m^3/s. For more information on groundwater in Syria, see Burdon, 1954 and Chap. 2.
20. Jassim and Goff, 2006, p. 264. See also Chap. 25.
21. Sabkha is the Arabic word for salt pan or clay flat. See 'Overview: Shared Water Resources in Western Asia', Box 3 for further information.
22. Jassim and Goff, 2006.
23. FAO, 2009.
24. Turkey launched the ambitious Southeastern Anatolia Project (Güneydoğu Anadolu Projesi or GAP) in 1977 as a national initiative to harness the water of the Euphrates and Tigris Rivers for hydropower and agricultural production and thus provide economic stimulus to the south-east Anatolia region.
25. Kolars and Mitchell, 1991; Altinbilek, 2004, p. 24; Aydin and Ereker, 2009, p. 608.
26. ACSAD and UNEP-ROWA, 2001.
27. Numbers are based on the General Directorate of State Hydraulic Works in Turkey, 2009, p. 61. In order to place these figures in a national context it is interesting to note that arable land in Turkey is estimated at around 28 million ha of which 8.5 million ha have been identified as economically irrigable. In 2008, 5.28 million ha were under irrigation (see General Directorate of State Hydraulic Works in Turkey, 2009, p. 51).
28. The Urfa-Harran project (in the Sanliurfa-Harran region in Turkey) on the Balikh was one of the first projects implemented as part of GAP. It is currently the largest irrigation project in operation, with an irrigated area of about 140,000 ha. The Mardin-Ceylanpinar project in the Khabour Basin aims to increase the irrigated area to 388,000 ha, of which 60,000 ha will be irrigated by groundwater.
29. Beaumont, 1998.
30. Lake Assad has a maximum storage capacity of 11.7 km^2. During the filling of the reservoir in 1975, the flow of the Euphrates below the Tabqa Dam was reduced. This sparked tensions between Syria and Iraq which were resolved through intervention from Saudi Arabia and the Soviet Union.
31. Kolars & Mitchell state that the Soviet proposal claimed that 850,000 ha of land could be irrigated by Lake Assad, but German experts reduced this figure to 650,000 ha and Syria further revised it to 640,000 ha. Kolars and Mitchell, 1991, p. 145 estimate that only 208,000 ha were irrigated by the mid-1980s.
32. Several irrigation projects exist on the Balikh River (see Chap. 2). However, it should be noted that Syrian agriculture was and still is predominantly rain-fed.
33. Salman, 2004, p. 63.
34. Ministry of Irrigation in the Syrian Arab Republic, 2012.

35. Ministry of Irrigation in the Syrian Arab Republic, 2000 in ACSAD and UNEP-ROWA, 2001. However it is important to note that these numbers most likely do not refer to irrigated land exclusively and therefore also include large areas of supplementary irrigation.
36. The estimations for annual water requirements are published by the Ministry of Irrigation in Syria, 2000 in ACSAD and UNEP-ROWA, 2001.
37. Ministry of Irrigation in the Syrian Arab Republic, 2012.
38. See Beaumont, 1996.
39. Salman, 2004, p. 3. However, Barnes, 2009, p. 519 states that 70-80% of the country's water comes from the Euphrates.
40. Turkey focused on western Anatolia up until this time. See Kolars, 1986, p. 62 for more information.
41. Kienle, 1990, p. 93.
42. Kliot, 1994.
43. ACSAD and UNEP-ROWA, 2001.
44. Ubell in Beaumont, 1998, p. 178.
45. ACSAD and UNEP-ROWA, 2001.
46. Altinbilek, 2004, p. 20 refers to estimates made by the US Army Corps of Engineers revealing that 1-1.3 million ha are irrigated. Kolars and Mitchell state that over 1 million ha of land is irrigated by Euphrates water in Iraq (Kolars and Mitchell, 1991, p. 3) and FAO, 2009 estimates 1 million ha of land is irrigated by surface water from the Euphrates.
47. Kliot, 1994.
48. ACSAD and UNEP-ROWA, 2001.
49. FAO, 2009. The river water is mainly polluted by irrigation return waters, which often have a higher salt content and are contaminated by fertilizers and/or pesticides.
50. Florea and Al-Joumaa, 1998.
51. ACSAD and UNEP-ROWA, 2001 and Zaitchik et al., 2002.
52. Yesilnacar and Uyanik, 2005 and Al-Dulaimi, 2007.
53. For further information, see Chap. 3 and 5.
54. Alp et al., 2010; Odemis et al., 2010. The TDS recommended guideline for irrigation water is set at <450 ppm by FAO, 1994.
55. Kattan, 2008.
56. For more information, see Chap. 2.
57. ACSAD and UNEP-ROWA, 2001; Beaumont, 1996; Kattan, 2008.
58. ICARDA and IWMI, 2008; Almohamed and Doppler, 2008.
59. Kattan, 2008, Ministry of Water Resources in Iraq, 2012; Ministry of Irrigation in the Syrian Arab Republic, 2012.
60. For more information see Chap. 3.
61. ACSAD and UNEP-ROWA, 2001; Fattah and Abdul-Baki, 1980.
62. Rahi and Halihan, 2010; Al-Dulaimi, 2007. The salinity of these drains range between 2,065 and 4,262 ppm.
63. Rahi and Halihan, 2010.
64. Odemis et al., 2010.
65. Al Bukamal is located in Syria near the Iraqi-Syrian border.
66. ACSAD and UNEP-ROWA, 2001, p. 123.
67. These are the Atatürk Dam in 1990 as well as the Karkamis, Birecik and Tishreen Dams completed in 1999-2000. However increased salinity could also be due to a drought in 1998-2000. FAO, 2003 in Rahi and Halihan, 2010.
68. Such as the filling of the Fallujah Dam in the mid-1980s, the Atatürk Dam in 1990 as well as the Karkamis, Birecik and Tishreen Dams completed in 1999-2000 (Table 3).
69. The Iraqi Foundation, 2003 in Rahi and Halihan, 2010.
70. Ministry of Irrigation in Iraq in Rahi and Halihan, 2010, p. 27.
71. In Turkey, the high levels of coliform bacteria observed in Lake Atatürk are a result of the direct discharge of untreated wastewater into the dam lake. In addition, an increase in total nitrogen and phosphorus levels recorded since 1996 may cause eutrophication in the long term (Yazgan, 2001 in Yesilnacar and Uyanik, 2005). This is also a problem in the Keban Dam reservoir, where the high level of nutrients can be ascribed to the inflow of rivers such as the Murat which supports extensive agricultural activities. The pollution poses a threat to aquatic organisms (Akbay et al., 1999; Ural and Özdemir, 2011).
72. Erdem, 2003.
73. Nevertheless, water issues in the basin have to be seen in the context of overall relations between the three main riparians, and in particular take into account the following factors: historical animosity between Syria and Turkey (and general East-West tension until the 1990s); the Kurdish question; the rivalry between the Iraqi and Syrian Ba'ath parties, as well as the 1990 and 2003 Gulf wars.
74. The 1946 treaty even included a mandate for a committee to implement the agreements. Such an entity was however never created due to disputes between the riparians (Kaya, 1998).
75. Signatory parties regard this as an interim agreement until allocation of the Euphrates waters among the three riparian countries is finalized (Scheumann, 1998a). "The Arab states argue that since three states are sharing the river's flow, each is entitled to one-thirds, giving the two Arab states a total of around 667 m^3/s" (Gruen in Warner, 2008).
76. Kibaroglu et al., 2008.
77. Scheumann, 1998b, p. 110 stresses that integrated development of the Euphrates Basin was hindered by the conflicting interests of the Eastern and Western blocs.
78. Aydin and Ereker, 2009; Scheumann, 1998b; Kaya, 1998.
79. After Syria completed the Tabqa Dam in 1973, the filling of the reservoir reduced the flow of the Euphrates entering Iraq by 25%, causing serious tension between the two riparians. To prevent military escalation, Saudi Arabia and the former Soviet Union mediated the conflict. The tension eased when Syria increased water flow to 450 m^3/s (Scheumann, 1998a, p. 121; Schulz, 1995, p. 105). "Although the terms of the agreement were never made public, Iraqi officials have privately stated that Syria agreed to take only 40% of the water of the river, leaving the remainder for Iraq" (Naff & Matson, 1984 in Kaya, 1998, p. 3). Similar tension arose between Turkey, Syria and Iraq when Turkey filled the Atatürk Reservoir. Even though Turkey notified the two downstream countries, it could not prevent a pan-Arab outcry (Aydin and Ereker, 2009, p. 611).
80. Aydin and Ereker, 2009, p. 608.
81. Kibaroglu, 2002b, p. 227.
82. Ibid.
83. As the riparians positioned themselves differently with regard to terminologies and descriptions of the rivers, JTC's objective to achieve a trilateral agreement on the "sharing" of common watercourses was abandoned. See Box 6 for further information.

84. Kibaroglu et al., 2011 in Chapter 21.
85. The initiative comprises a group of scholars and professionals from Iraq, Syria and Turkey who promote cooperation for technical, social and economic development. In line with its overall objective, ETIC has organized joint trainings, capacity building programmes and research projects in recent years. See ETIC, 2012 for more information.
86. A series of meetings were conducted between 2007 and 2009. See Kibaroglu et al., 2011 for more information.
87. Syria Today, 2010.
88. Turunc, 2011.
89. Bloomberg Businessweek, 2011.
90. Ministry of Irrigation in the Syrian Arab Republic, 2012.

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