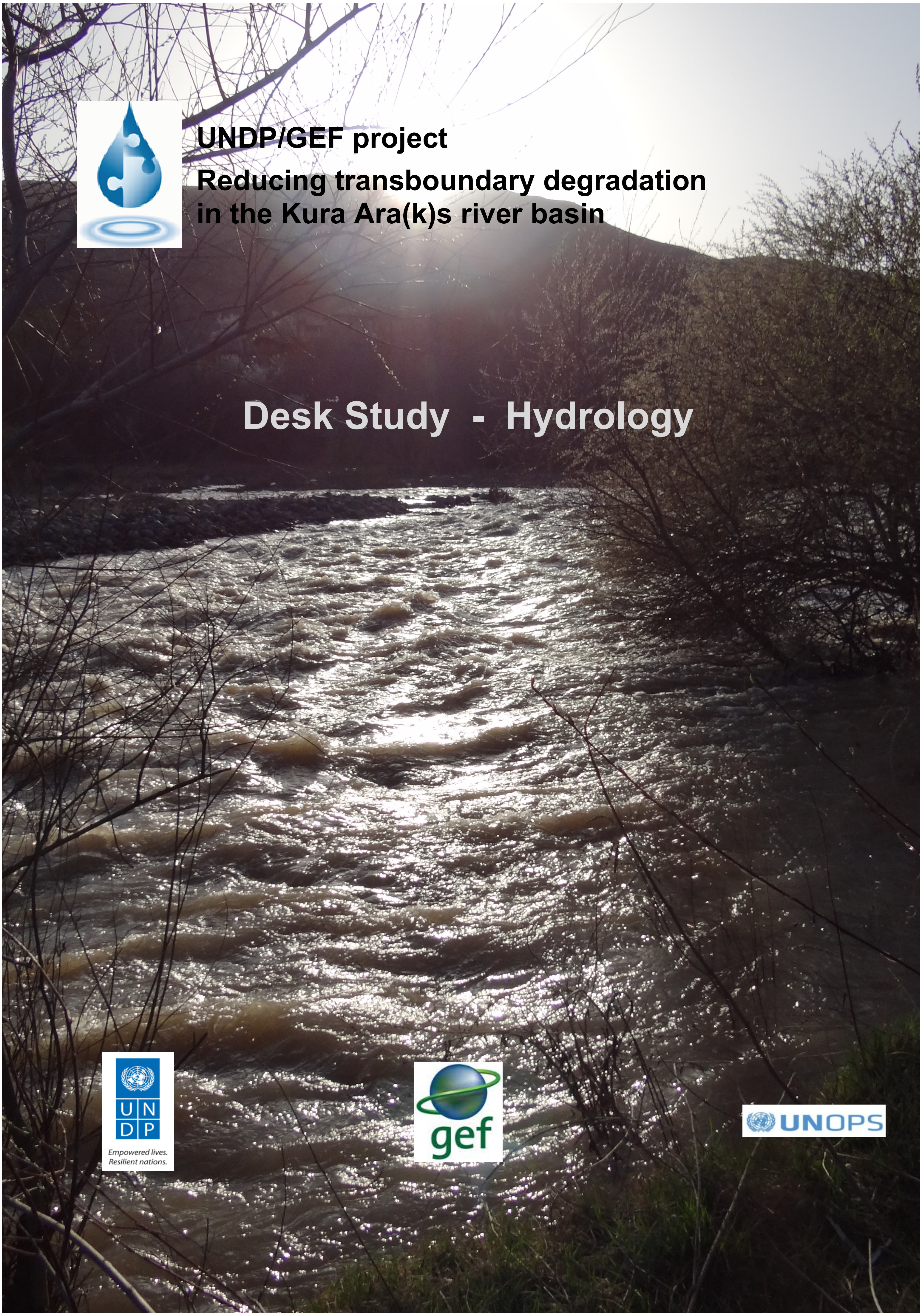

UNDP/GEF project

Reducing transboundary degradation in the Kura Ara(k)s river basin

Desk Study - Hydrology

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REDUCING TRANSBOUNDARY DEGRADATION IN THE KURA ARA(K)S RIVER BASIN

Desk Study - Hydrology

Tbilisi, Georgia – Baku, Azerbaijan – Yerevan, Armenia

September 2013

DESK STUDY 1 HYDROLOGY

The Hydrology Desk Study for the Kura Ara(k)s[1] river basin, executed in the framework of the UNDP/GEF project “Reducing transboundary degradation in the Kura Ara(k)s river basin” focuses on providing an update overview of available information on water resources in the Kura Ara(k)s basin, specifically river hydrology and groundwater issues.

The information presented in the Hydrology Desk Study largely was obtained from publicly available sources as collected by the UNDP/GEF project team in close cooperation with National Experts in the project countries Armenia, Azerbaijan and Georgia. Additional supportive information was obtained from the relevant national monitoring agencies responsible for water resources monitoring

The Hydrology Desk Study provides the background baseline information towards analysing priority environmental issues related to hydrology that are transboundary in nature. The assessment of the impacts (both environmental and socio-economic) of transboundary hydrology issues, and the identification of institutional, legal and policy issues that need to be addressed, is integrated in the Updated Transboundary Diagnostic Analysis (TDA). The Updated TDA as comprehensive analysis of transboundary issues provides a factual basis for the formulation of recommended options in the Strategic Action Program (SAP) towards improving the environmental situation and ensuring the sustainable development of the Kura Ara(k)s River Basin.

Colophon

Project title	Reducing transboundary degradation in the Kura Ara(k)s river basin
Financing	Global Environment Facility
Implementing Agency	UNDP United Nations Development Programme
Executing Agency	UNOPS United Nations Office for Project Services
Chief Technical Advisor / Project Coordinator	Dr Mary M. Matthews
Report Editors	Harald J.L. Leummens & Mary M. Matthews
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Suggested citation	Hannan T., Leummens H.J.L. & Matthews M.M., 2013. Desk study – Hydrology. UNDP/GEF project “Reducing transboundary degradation in the Kura Ara(k)s river basin”, Tbilisi-Baku-Yerevan, 2013, 29 pp.

[1] *[1] Other frequently used names for the Kura river include Mtkvari, Kurachay, Cyrus. Other names for the Ara(k)s river include Ara, Aras, Araz, Arax. The standardized use of the names “Kura” and “Aras” does not reflect any preference or opinion of the authors or contributors on the correct names of these rivers, other than of harmonization.*

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LIST OF ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AM	Armenia
AM-MNP	Ministry of Nature Protection of Armenia
AZ	Azerbaijan
AZ-MA	Ministry of Agriculture of Azerbaijan
AZ-MENR	Ministry of Ecology and Natural Resources of Azerbaijan
AZ-NWS	Azerbaijan National Water Strategy
BCM	Billion cubic meters
FAO	United Nations Food & Agricultural Organization
GE	Georgia
GEF	Global Environment Facility
GE-MEPNR	Ministry of Environment Protection and Natural Resources of Georgia
GE-MEP	Ministry of Environment Protection of Georgia
GW/h	GigaWatt hours
GSL	Global Sea Level
IRSWR	Internal Renewable Surface Water Resources
IWRM	Integrated Water Resources Management
JSC	Joint Stock Company
Masl	meters above sea level
MCM	Million cubic meters
Mln	Million
MW	MegaWatt
NEA	National Environment Agency of Georgia
SAP	Strategic Action program
Sida	Swedish International Development Cooperation Agency
SNC	Second National Communication
TB	Transboundary
TDA	Transboundary Diagnostic Analysis
UNDP	United Nations Development Program
UNECE	United Nations Economic Commission for Europe
UNFCCC	United National Framework Convention on Climate Change
WB	World Bank

1 INTRODUCTION

This document is the Hydrology Desk Study prepared as part of the Transboundary Diagnostic Analysis (TDA) for the UNDP/GEF project Reducing Transboundary Degradation in the Kura Ara(k)s River Basin.

The present report serves to elaborate on the update analysis of the hydrological features – water resources, water use and river discharge – of the Kura Ara(k)s river basin. The report presents a review of overall river discharge, and touches upon the changes that have taken place during the course of almost a century.

The analysis is based on long time series of average monthly flow data provided by the country hydro-meteorological departments of Armenia, Azerbaijan and Georgia, for selected stations along the course of both the Kura and Ara(k)s rivers.

2 GEOGRAPHICAL SITUATION

2.1 Basin Description

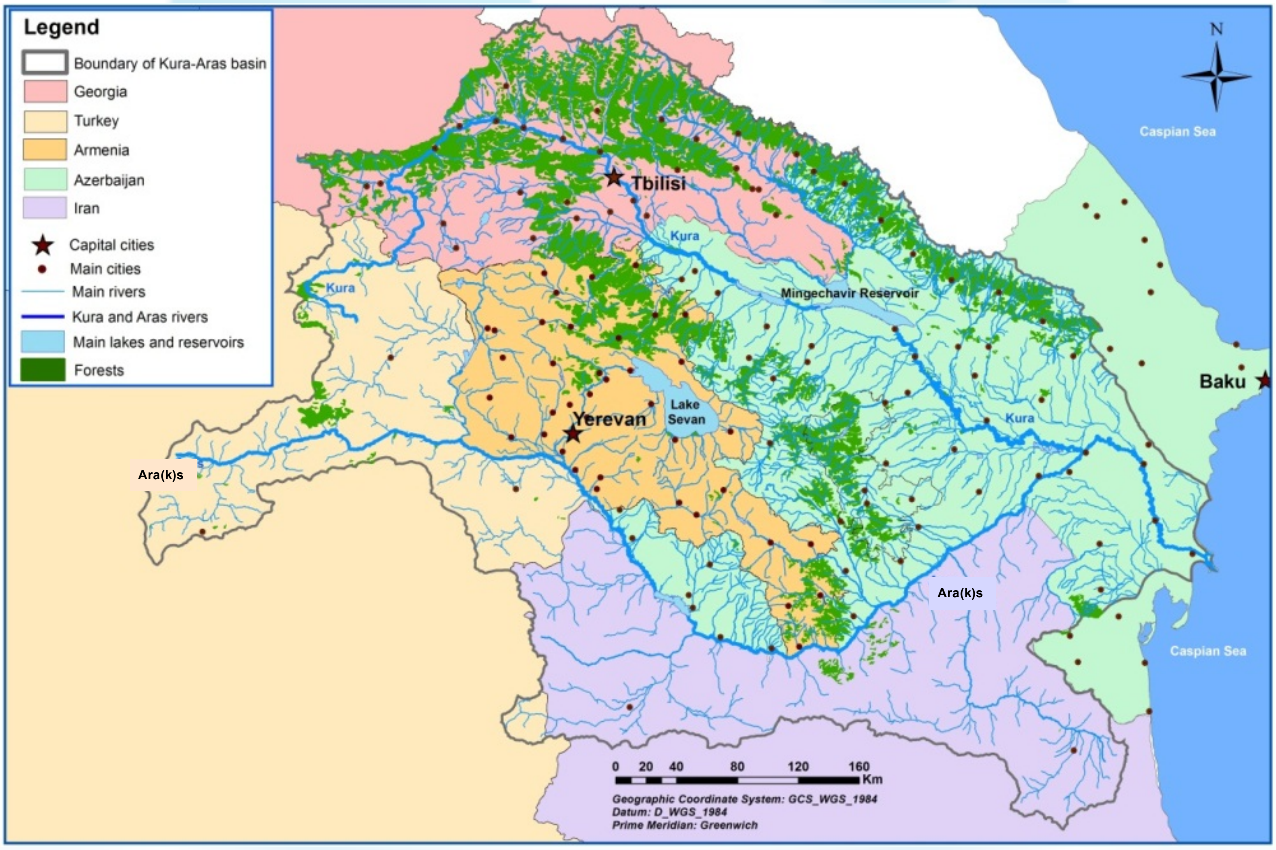
The Kura Ara(k)s River Basin covers 190,190 km^2 and is shared by 5 countries, as indicated in Table 2.1. The basin share of the UNDP/GEF Kura Ara(k)s project countries Armenia, Azerbaijan and Georgia is 65.4%. Figure 2.1 shows a map of the Kura Ara(k)s river basin with its key features - countries, cities, rivers and forest areas indicated.

Table 2.1 Country shares of the Kura Ara(k)s Basin.

Country	Total country surface in 2010 (km^2)*	Country surface area in basin (km^2) **	% of country	% of basin
Armenia	29,740	29,740	100.0	15.6
Azerbaijan	86,600	60,020	69.3	31.6
Georgia	69,700	34,560	49.6	18.2
Turkey	783,560	28,790	3.7	15.1
Iran	1,745,150	37,080	2.1	19.5
Total	**2,714,750**	**190,190**	**7.0**	**100.0**

*Notes: * Source: World Bank (2012).*
*** Source: FAO (2009)*

Figure 2.1 Map of the South Caucasus outlining the Kura Ara(k)s river basin.



Note: Prepared by the UNDP/GEF Kura Ara(k)s project (2012).

The Kura basin is the main river basin in the South Caucasus, with the length of the main channel being 1,515 km. The Kura begins in Turkey and flows through Georgia and Azerbaijan to enter the Caspian Sea near Neftchala (Azerbaijan). Numerous large, medium and small tributaries enter the Kura river in Georgia and Azerbaijan, including transboundary (TB) ones, including:

- In Georgia: Paravani, Potskhovistskali (TB: Turkey), Liakhvi, Aragvi, Debed-Khrami (TB Armenia).
- In Azerbaijan: Debed/Khrami (TB: from Armenia through Georgia), Aghstev/Agstafachay (TB: Armenia), Alazani/Ghanik (TB: Georgia), Iori/Qabirri (TB: Georgia), Ara(k)s (TB: Turkey, Armenia, Iran).

The Ara(k)s River is the main tributary to the Kura river, it has a length of 1,070 km, and also starts in Turkey. Flowing downstream, the river forms the border between Turkey and Armenia, Armenia and Iran and Azerbaijan and Iran before meeting the Kura river near Sabirabad (Azerbaijan). Transboundary tributaries of the Ara(k)s river include:

- In Armenia: Akhuryan (TB: Turkey), Hrazdan, Arpa (TB: Azerbaijan), Vorotan/Bazarchay (TB: Azerbaijan), Voghji/Okhchu (TB: Azerbaijan).

2.2 Climate

The topography of the South Caucasus Region, including the Kura Ara(k)s Basin, is characterized by the Greater Caucasus mountain range in the north, the western and eastern Transcaucasian Depressions characterized by upland and lowland plains, the southern Lesser Caucasus range, the Black Sea coast to the west and the Caspian Sea coast to the east. Topography varies from high mountain peaks up to 5,600 GSL in the Greater Caucasus to lowlands at about -27 GSL on the Caspian Sea coast. Most of the region is above 1,000 GSL.

The climate - temperatures and precipitation - varies considerably across the South Caucasus region, affected by elevation as well as by the moderating effects of the Black and Caspian Seas. The Greater Caucasus range protects the region from colder air descending from the north.

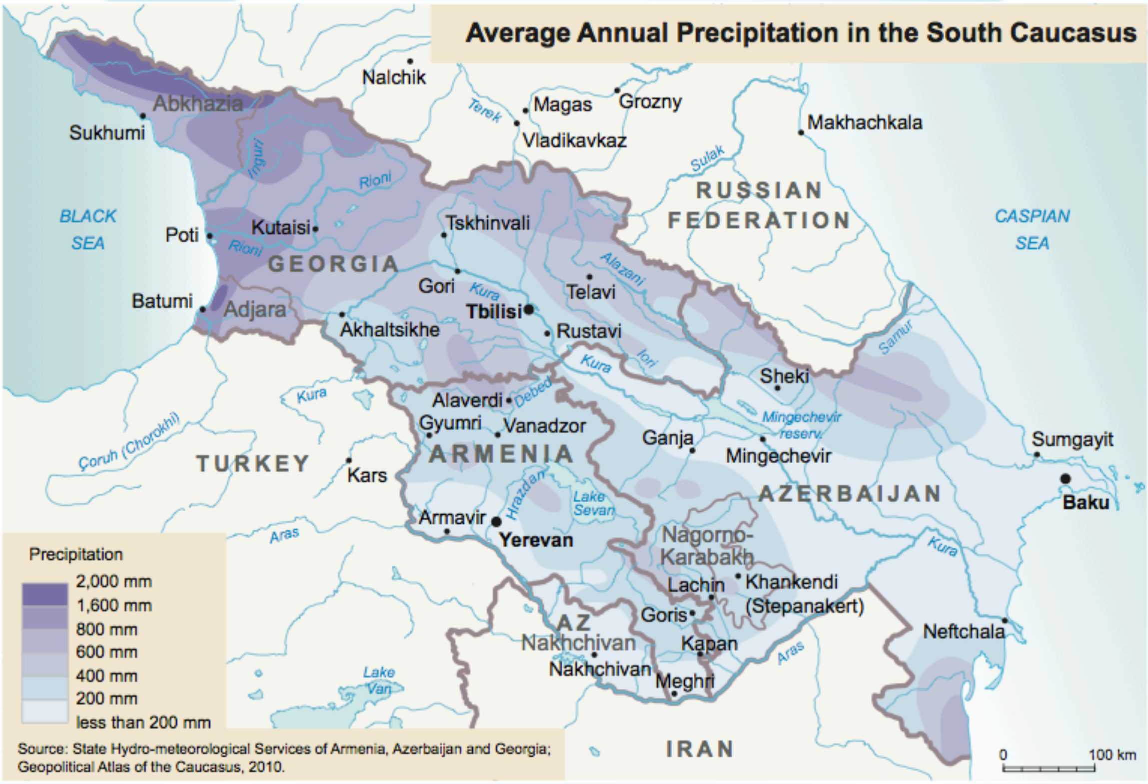
Figure 2.2 shows the variation in mean annual temperature across the region. Elevation has the greatest influence on temperature, with cooler areas at higher elevations and warmer ones in the lower areas and near the sea coasts. In elevated areas of the northwestern Kura Ara(k)s basin in Georgia and Azerbaijan, as well as the mountains of the Lesser Caucasus, the climate is typical temperate mountainous, with mean annual temperatures ranging from 2°C to 4°C, and absolute minima and maxima reaching -42°C and +42°C, respectively. At altitudes above 2,500 m the annual average mean temperature typically falls below 0°C. The upland plains of eastern Georgia, western Azerbaijan and central Armenia are dry continental, showing mean annual temperatures of 11°C-13°C. Summers are warm, with mean July temperatures varying between 15°-20°C, and winters are cold, with mean January temperatures between -4° to -7°C. Further east, in the lowland plains of Azerbaijan between the confluence of the Kura and Ara(k)s rivers and the Caspian Sea, the mean annual temperature reaches 15°C-16°C. Winters are generally warm, with January temperatures around 0°C, and summers hot, with average temperatures near 22°C.

Figure 2.3 shows the variation in mean annual precipitation for the region. Precipitation is also influenced by elevation, overlain by a trend of decreasing wetness from the northwest, the Black Sea coast, towards the southeast approaching the Caspian Sea coast. Precipitation in the Greater Caucasus range varies between 1,200-2,000 mm, with the observed absolute maximum annual rainfall being 4,100 mm in southwestern Georgia (Adjara Province). In the Lesser Caucasus precipitation varies between 800-1,200 mm, reducing further to an annual 300-800 mm on the upland plains of southern Georgia, Armenia and western Azerbaijan, to a low of 200-250 mm in the Ararat valley in western Armenia. Low amounts of precipitation are also observed in the eastern Kura Ara(k)s lowland plains in Azerbaijan, varying between 200-350 mm.

Figure 2.2 ***Spatial variation in mean annual temperature in the Kura Ara(k)s basin countries Armenia, Azerbaijan and Georgia.***

Source: ZOI (2011).

Figure 2.3 ***Spatial variation in mean annual precipitation in the Kura Ara(k)s basin countries Armenia, Azerbaijan and Georgia.***



Source: ZOI (2011).

3 WATER RESOURCES OF THE KURA ARA(K)S BASIN

3.1 Surface Water

3.1.1 The Kura in Georgia

Georgia has an abundance of fresh water resources - rivers, lakes and springs, due to the country's mountainous territory and the abundance of precipitation. The mean annual precipitation value within Georgia is 1,338 mm, and the mean annual precipitation volume is 93.3 km^3, equal to an annual amount of renewable fresh water per capita of 14,000 m^3 (GE-MEPNR, 2009).

There are over 26,000 rivers with total channel length of some 60,000 km, 99.5% of which are rivers with a length less than 25 km. Of these, most are short mountain rivers with an average length of 2.3 km. Due to Georgia's mountainous features, there are very few rivers with a long channel length or large basin size - only 273 rivers are more than 25 km long (GE-MEPNR, 2009).

Georgia can be divided into two hydrological basins: the Black Sea Basin in the west and the Caspian Sea Basin in the east of the country. About 8,000 rivers drain the Georgian part of the Caspian basin, either via Russia – the Terek and the Andiyskoye, or via the Kura through Azerbaijan into the Caspian Sea (GE-MEP, 2012). The Black Sea Basin is significantly richer in water resources, with about 75% of the total Internal Renewable Surface Water Resources (IRSWR) of Georgia generated there, 42.5 km^3/year vs. 14.4 km^3/year in the Caspian Sea basin (FAO, 2009).

Rivers in Georgia have good potential for all types of water uses, especially hydropower development and fisheries because of high channel slopes and high flow velocity. In terms of transboundary waters, Georgia is both an upstream and a downstream riparian, as water flows into Georgia from Turkey and Armenia, and flows out of Georgia – directly into the Black Sea, or indirectly into the Caspian Sea via Russia or Azerbaijan.

The mean annual total flow of rivers in Georgia is about 61 km^3, generated in upstream Turkey and Armenia (8.3 km^3) as well as within the country (52.7 km^3) (GE-MEPNR, 2009). The two rivers of the Kura basin in Georgia which find their origin in Turkey are the Kura (Mtkvari in Georgian), and the Potskhovitskali, while the Debed River enters from Armenia, joining the Khrami river before crossing the border into Azerbaijan. Within Georgia, the three main rivers of the Kura Basin are the Kura itself, the Alazani (named Ganikh in Azerbaijan) and the Iori (named Qabirri in Azerbaijan). The Kura, Iori and Alazani, as well as the Debed-Khrami flow across the border into Azerbaijan, to enter the Mingechevir Reservoir. Combining different sources, key features of transboundary rivers in Georgia are presented in table 3.1, including an estimate of average annual transboundary water flows. Based on the inflow from Turkey and Armenia, and the outflow to Azerbaijan, the annual IRSWR for the Georgian section of the Kura basin is estimated at 9.37 km^3. It is noted that data presented are as observed during the last 50 years, the period of active human water abstraction. As such the actual total flow to Azerbaijan is probably lower than during the pre-industrialized period.

Table 3.1 Surface water components of the Kura Ara(k)s basin – Georgia.

River basin	Georgia km^2 (%)	Transboundary countries [a] Armenia km^2 (%)	Azerbaijan km^2 (%)	Turkey km^2 (%)	TB inflow (BCM)	TB outflow (BCM)
Kura					0.91 [b]	6.22 [c]
Potskhovitskali	1,331 (72.3)			509 (27.7)	0.25 [b]	n/a
Debed/Khrami	4,470 (53.5)	3,790 [a] (45.4)	80 (1.1)		0.92 [b]	1.63 [b]
Alazani/Ganikh	6,700 (58.5)		4,755 (41.5)		n/a	3.50 [d]
Iori/Qabirri	4,645 (83.4)		610 (11.6)		n/a	0.10 [d]
				Total	**2.08**	**11.45**
				IRSWR	**9.37**	

Sources: [a] UNECE (2007); [b] FAO (2009); [c] Data provided by the GE-NEA for the station Tbilisi, period 1970-2010; [d] GE-MEPNR (2009).

In Georgia 734 glaciers occur, with an assessed surface area of 511 km^2. Glaciers store 30 km^3 of ice, of which on average 5% participates in the annual water circulation, or 1.5 km^3 (GE-MEPNR, 2009).

There are 860 predominantly small lakes (<1 km^2) in Georgia, covering a total surface area of 175 km^2 and containing a total volume of 400 mln m^3. Large lakes in Georgia's Kura basin include Lake Paravani, having the biggest surface area, 37.5 km^2, and Lake Tabatskuri, containing the largest volume of water – 0.22 km^3 (GE-MEPNR, 2009). Some lakes in the Kura basin of Georgia are transboundary – Lake Kartsakhi (26.3 km^2) with Turkey, Lake Jandara/Jandargol (12.5 km^2; 54,280 MCM) with Azerbaijan.

3.1.2 The Araks in Armenia

Rivers in Armenia are tributaries of the main rivers of the South Caucasus - the Araks and the Kura, with about 74% of Armenia being part of the Araks basin and 24% of the Kura basin (FAO, 2009). Tributaries discharging to the Araks river are Akhuryan, Metsamor, Hrazdan, Azat, Vedi, Arpa, Vorotan, Vokhchi, Meghri. Tributaries to the Kura river are Debed, Aghstev, Hakhum, Tavush, Khndzorut (UNDP/SIDA, 2005).

Like Georgia, Armenia is also both an upstream and a downstream riparian state. The Araks is the main river in Armenia, entering Armenia from Turkey. The Araks initially forms the border between Turkey and Armenia and, further downstream, between the I.R. of Iran and Armenia, before flowing into Azerbaijan. In Armenia some 9,500 mainly small- and medium-sized rivers occur, with a total length of 23,000 km. Out of that number 379 rivers are around 10–100 km long, and seven, namely the Akhuryan (186 km), Debed (176 km), Vorotan (178 km), Hrazdan (146 km), Aghstev (121 km), Arpa (128 km) and Metsamor-Kasakh, are longer than 100 km (FAO, 2009).The river network density varies from 0 to 2.5 km/km^2.

The inflow from Turkey from the Akhuryan and Araks combined is estimated at 2.51 BCM/year, based on average monthly observations at the Surmalu hydrological station, near the inflow of the Araks and Akhuryan for the period 1964-2010. Total outflow from tributaries to the Kura – via Georgia or Azerbaijan - is estimated at 1.33 BCM annually, and to the Araks at 6.60 BCM/year (FAO, 2009) for a total outflow from Armenia of 7.93 BCM. Combining different sources, some key features of the transboundary rivers in Armenia are presented in table 3.2, including an estimate of average annual transboundary water flows as well as IRSWR.

Table 3.2 Surface water components of the Kura Araks basin – Armenia.

River basin	Armenia km^2 (%)	Transboundary countries [a] Georgia km^2 (%)	Azerbaijan km^2 (%)	Turkey km^2 (%)	Iran km^2 (%)	TB inflow (BCM)	TB outflow (BCM)
Aras	22,560 (22)	0	18,140 (18)	19,500 (19)	41,800 (41)	2.51 [c, d]	5.01 [a]
Akhuryan	2,784 (28.7)			6,916 (71.3)			n/a
Aghstev	770 (30.8)		1,730 (69.2)			n/a	0.29 [c]
Debed	3,790 (92.4)	310 (7.6)				n/a	1.04 [c]
Arpa	2,080 (79)		550 (21)			n/a	0.53 [c]
Vorotan	2,030 (36)		3,620 (64)			n/a	0.69 [b]
Voghji	788 (67)		387 (33)			n/a	0.37 [b]
					Total	**2.51**	**7.93**
					IRSWR	**5.42** [e]	

Sources: [a] UNECE (2007); [b] FAO (2009); [c] Data provided by the AM-MNP, period 1955-2010; [d] includes water from the Akhuryan basin inside Armenia (0.39 km^3/year – FAO, 2009); [e] to be corrected for internal generated water in Akhuryan basin (0.39 km^3) and flow to Lake Sevan (0.265 km^3, FAO, 2009), thus real IRSWR is 6.08 km^3.

The largest lake in Armenia is Lake Sevan, which is one of the highest freshwater lakes in the world. In 2012 the water level of the lake is around 1,900 GSL, its surface area 1,276.6 km^2 and volume 37.95 BCM. Additionally about 100 small lakes occur, storing a total water volume of 0.8 BCM.

3.1.3 The Kura Ara(k)s in Azerbaijan

In Azerbaijan the two main rivers of the South Caucasus - the Ara(k)s and the Kura – come together to continue towards the Caspian Sea. As Armenia and Georgia, Azerbaijan is also both an upstream and a downstream riparian state of the Kura Ara(k)s basin, with the downstream component being the Caspian Sea. Most of Azerbaijan's surface water resources enter the country from the upstream Georgia, Armenia and Iran, as well as, indirectly, Turkey.

Azerbaijan counts 8,350 rivers, distributed over 3 main river basins - the Kura basin, Ara(k)s basin and rivers directly flowing to the Caspian Sea (AZ-MENR, 2012), creating an average river network density of 0.36 km/km^2 (ADB, 2008) Of all rivers, 21 are transboundary, flowing into Azerbaijan from Armenia, Georgia, Russia or Iran. River length is variable - 2 rivers extend over more than 500 km, 22 rivers are between 101-500 km, 324 rivers between 11 and 100 km, while all others are shorter than 10 km (AZ-MENR, 2012).

The estimated incoming surface flow from Georgia is 11.45 km^3 (see section 3.1.1 above), mainly through the Kura, Ghanik/Alazani, Qabirri/Iori and the Debed/Khrami rivers. Additionally a number of smaller rivers flow into Azerbaijan to the Kura from Armenia, including the Agstafachay/Aghstev, Tovuz/Tavush rivers. The Ara(k)s basin from Armenia and indirectly Turkey provides an average annual surface water volume of 6.60 km^3 to Azerbaijan (table 3.2), while from Iran an additional 0.81 km^3 enters (UNECE, 2007). As such, the overall estimated average annual surface water volume entering Azerbaijan's Kura Ara(k)s basin area from upstream countries amounts to 19.15 km^3 (table 3.3).

In addition to transboundary rivers, numerous rivers providing surface water originate inside Azerbaijan, in the Greater as well as Lesser Caucasus, accounting for a total annual IRSWR for Azerbaijan of 10.3 km^3 (Rustamov & Kashkay, 1989). As the Samur and Astara and a number of smaller rivers are not part of the Kura Ara(k)s basin, the corrected IRSWR for the Kura Ara(k)s basin in Azerbaijan is 7.2 km^3 (Rustamov & Kashkay, 1989), to a total of 26.35 km^3 of total surface water resources in the Azerbaijan section of the Kura Ara(k)s basin. Accordingly, 72.7% of all surface water resources in Azerbaijan are generated outside the country. The average annual outflow to the Caspian Sea as measured at Salyan is 14.26 km^3 for the period 1955-2010 (Data provided by AZ Hydro-meteorological department, 2012).

Table 3.3 Transboundary inflow and outflow of the Kura Ara(k)s basin – Azerbaijan.

	TB inflow(BCM)	TB outflow(BCM)
Kura	6.22 [c]	
Ghanik/Alazani	3.50 [d]	
Qabirri/Iori	0.10 [d]	
Debed/ Khrami	1.63 [b]	
Armenia - Aras	6.60 [e]	
Armenia - Kura	0.29 [c]	
Iran	0.81 [a]	
Salyan		14.26 [c]
Total	**19.15**	
IRSWR	**7.20** [f]	

Sources: [a] UNECE (2007); [b] FAO (2009); [c] Data provided by the AZ-MENR - Hydrology Survey, period 1955-2010; [d] GE-MENR (2009); [e] see table 3.2; [f] Rustamov & Kashkay (1989).

The glacier areas in Azerbaijan's Greater Caucasus area have decreased from 4.9 km^2 to 2.4 km^2 over the last 110 years (AZ-MENR, 2010).

There are nearly 450 lakes – fresh and saline - in Azerbaijan, covering a total surface area of 394 km^2, of which only 10 have a surface area exceeding 5 km^2. The largest lake is Lake Sarisu, located in the Kura Ara(k)s lowlands, with a surface area of 65.7 km^2 and a storage capacity of 59.1 MCM. Lake Jandargol/Jandara (12.5 km^2; 54,280 MCM) is a transboundary lake with Georgia (AZ-NWS, 2011).

3.1.4 Total Surface Water Resources of the Kura Ara(k)s Basin

Hydrological records of the Kura river downstream of the confluence of the Kura and Ara(k)s rivers in Azerbaijan, at the Surra Hydrological Station, show a mean annual flow of 15.44 BCM over the period 1950 to 2010. As this station is the one of the last in the Kura Ara(k)s Basin, it represents the totality of the basin discharge to the Caspian Sea. However, this average represents only the period of regulated discharge and extensive expansion of human activities, characterized by significant abstractions for irrigation, urban water supply, evaporative losses from artificial reservoirs, and other uses, in Azerbaijan as well as in the upstream countries.

As presented above, the inflow to Azerbaijan from Georgia is estimated at 11.45 BCM, and from Armenia at 6.89 BCM, while from Iran an additional 0.81 BCM enters the country. Adding these to the IRSWR generated in the Azerbaijan section of the Kura Ara(k)s basin – 7.20 BCM, the total surface water resource of the Kura Ara(k)s Basin is estimated at 26.35 BCM.

The unit water yield for the areas of the Kura Ara(k)s Basin in the three countries is shown in table 3.4, indicating the relative 'wetness' of each of the countries and their total contribution to the water resource of the basin. Georgia has by far the largest unit water yield, exceeding that of Armenia by almost 50%, and that of Azerbaijan by more than 100%. These figures confirm that Azerbaijan is a much drier country than Armenia, which is in turn drier than Georgia, which also corresponds with the differences in precipitation pattern evident on the map in Figure 2.2 above.

Table 3.4 Unit Water Yield by Country section in the Kura Ara(k)s basin.

Kura Ara(k)s basin		IRSWR (BCM)	Water Yield (m^3/km^2)
Country	**Surface area (km^2)**		
Georgia	34,560	9.37	271,120
Armenia	29,740	5,42	182,250
Azerbaijan	60,020	7.20	119,960

3.2 Groundwater

Information on groundwater resources in the Kura Ara(k)s basin countries Armenia, Azerbaijan and Georgia is sparse, due to very limited ongoing hydrogeological monitoring. In the three countries groundwater monitoring essentially stopped in the early 1990s, therefore estimates on groundwater reserves largely date back to the 1970-1980s. Meanwhile the ongoing changes in water and land use have certainly impacted actual groundwater reserves, their availability as well as basin recharging (Alakbarov, 2012). At present in all three basin countries initiatives are or have been launched to restart groundwater monitoring.

In Armenia, the available fresh groundwater resources are assessed at about 11 MCM/day (127 m^3/s), equal to about 4 BCM/year. The annual strategic subsurface water resource is estimated as 1.1 BCM. Secured usable resources of groundwater from 34 deposits in Armenia total 102.27 m^3/s (3.2 BCM/year), used for drinking, irrigation and other economic purposes (UNDP/GEF, 2007). Other estimates range from 1.0 BCM (AM-MNP, 2006) to 4.3 BCM, of which 1.4 BCM enters the rivers as subsurface drainage (FAO, 2009) and 1.6 BCM through springs (Harutyunyan, 2012). The transboundary groundwater inflow to Armenia is assessed at 1.2 BCM, the transboundary groundwater outflow at 1.1 BCM (Harutyunyan, 2012).

In Azerbaijan estimates of groundwater resources vary widely. Groundwater recharge is estimated at 6.51 BCM annually, but as 4.35 BCM constitutes the base flow of the main rivers, an actual groundwater resource of 2.16 BCM is suggested (FAO, 2009). Other estimates put the total groundwater reserves of fresh and low-mineralized groundwater at 8 to 9 BCM (Alakbarov & Imanov, 2010; AZ-NWS, 2011), with 4.4 BCM confirmed by the Groundwater Reserves Commission (AZ-NWS, 2011).

In Georgia, groundwater resources within the Kura catchment area total about 22 MCM/day (255 m^3/sec), or 8 BCM/year, of which about 50% originates in the Greater Caucasus, 25% in the Lesser Caucasus, and 25% in the Kura depression. Over 70% of the resources are concentrated exclusively in high mountain areas and are difficult to use technically and financially (UNDP/GEF, 2007). Other sources state that it is assumed that only about one third of the "known" groundwater resources have been surveyed in detail, and that total groundwater resources are estimated to be 18 BCM (GE-MEPNR, 2010), with 67% in Western Georgia and 33% in Eastern Georgia. Meanwhile FAO (2009) states that the renewable groundwater resources are estimated at 17.23 BCM/year, of which 16 BCM/year are drained by the surface water network, leaving only 1.23 BCM available for sustainable exploitation. Over one hundred fresh groundwater aquifers have been mapped in Georgia. They are distributed unevenly within the hydrogeological regions of the country, with more than half associated with the southern slopes of the main Greater Caucasus range.

As such, an overall assessment of total groundwater resources in the Kura Ara(k)s river basin varies significantly, between 5 and 31 BCM annually, showing the specific need for actualizing outdated information. This is especially important considering that groundwater will become more important to meet increasing demands for water from economic development and population growth, to augment declining surface water resources resulting from climate change.

3.3 Main Water Resources Structures

In Georgia, 44 artificial water reservoirs were constructed to support hydro-energy generation, irrigation and municipal water supply, covering a total surface area of 163 km^2 and storing a total water volume of 3.3 BCM, of which 2.2 BCM is useable (Tvalchrelidze *et al.*, 2011). Of all reservoirs, 35 are located in Georgia's part of the Caspian Sea basin, storing a total volume of 1.70 BCM, the remaining 8 reservoirs are located in the Black sea basin, storing 1,47 BCM (GE-MEPNR, 2010). Characteristics of the largest reservoirs in eastern Georgia are presented in table 3.5.

Water reservoirs in the Eastern Georgia are mainly used for irrigation. Exceptions are Zahesi and Tsalka reservoirs, used for energy generation. Four reservoirs – Zhinvali, Samgori Reservoir (Tbilisi Sea), Sioni and Tazvatsyaro are multifunctional. Zhinvali is used for energy generation, Tbilisi water supply and irrigation. Tbilisi Sea is used for recreation, Tbilisi water supply and melioration. Sioni reservoir is used for energy generation and irrigation (Tvalchrelidze *et al.*, 2011).

Located in Armenia, Lake Sevan is the largest lake in the Kura Ara(k)s basin, also being the most important water resources 'structure'. In its natural state it covered 1,416 km^2, storing 58.5 BCM. The average annual runoff from rivers in the catchment is 720 MCM, while on average an additional 50 MCM enters the lake as subsurface inflow. However, the development of human activities in its basin, mostly in the 1950s, led to a water level decrease of 19 meters, as well as a loss of stored water of 25.5 BCM. Despite attempts to restore the lake by means of inter-basin water transfers from the Arpa river, amounts do not constitute a real resource in itself other than to balance the seasonality of the natural inflows. There are many other reservoirs in Armenia, the largest are presented in table 3.6 below. The total reservoir volume in Armenia is 1.35 BCM.

Throughout Azerbaijan more than 140 reservoirs were constructed, mostly to serve irrigation purposes. Dual or multi-purpose reservoirs in the Kura Ara(k)s basin include the Mingechevir, Shamkir, Yenikend, and Varvara reservoir on the Kura, the Ara(k)s and Khudafarin reservoirs on the Ara(k)s river. The storage capacity of reservoirs in Azerbaijan is about 20.6 km^3, mainly exceeding 100 mln m^3 each (table 3.7) Of the stored volume, 12.4 km^3 is useable, the largest storage capacity in the Kura Ara(k)s basin. Reservoirs cover 877 km^2. The total capacity of hydroelectric power generation installed exceeds 1,000 MW (AZ-NWS, 2011).

Table 3.5 Main reservoirs in the Kura Ara(k)s basin – Georgia.

Reservoir	River	Volume (MCM)		Surface area (km^2)	Purpose
		Total	Usable		
Zahesi	Kura	12.0	3.0	2.0	Energy
Jandari	Kura	52.0	23.0	12.5	Irrigation
Zresi	Murjaheti	2.2	1.3	1.8	Irrigation
Tskisi	Kvabiani	1.5	1.5	0.3	Irrigation
Nadarbazevi	Liakhvi	8.2	7.2	2.0	Irrigation
Zonkari	Patara Liakhvi	40.0	39.0	1.4	Irrigation
Zhinvali	Aragvi	520.0	370.0	11.5	Multifunctional
Narekvavi	Narekvavi	6.8	5.6	0.6	Irrigation
Algeti	Algeti	65.0	60.0	2.3	Irrigation
Marabda	Algeti	1.2	1.2	0.2	Irrigation
Tsalka	Ktsia	312.0	292.0	34.0	Energy
Mtisdziri	Mashavera	3.3	3.0	0.9	Irrigation
Pantiani	Mashavera	5.4	5.3	0.6	Irrigation
Lakublo	Mashavera	11.0	11.0	2.0	Irrigation
Kumisi	Mtkvari	11.0	4.0	5.4	Irrigation
Sioni	Iori	325.0	300.0	14.4	Multifunctional
Tbilisi See	Iori, Zmaiti	308.0	115.0	11.8	Multifunctional
Tchala	Chugurgula	1.7	1.4	0.4	Irrigation
Kudigora	Duruji	3.5	3.5	3.0	Irrigation
Oktomberi	Avaniskhevi	1.8	1.5	0.2	Irrigation
Telatskali	Telatskali	1.6	1.2	0.1	Irrigation
Kushiskhevi	Kushiskhevi	4.0	2.3	0.6	Irrigation
Kratchiskhevi	Kratchiskhevi	1.3	0.9	0.3	Irrigation
Tazvatskaro	Aragvi	1.3	1.0	0.3	Multifunctional
11 small reservoirs		4.2	3.6	1.9	
Total		**1,704.0**	**1,257.5**	**110.5**	

Source: Tvalchrelidze et al. (2011).

Table 3.6 Main reservoirs in the Kura Ara(k)s basin – Armenia.

Reservoir	Purpose	Dam height (m)	Storage Volume (MCM)
Akhuryan	Irrigation	59.0	510.0
Spandaryan	Energy	83.0	257.0
Arpilich	Irrigation/Energy	16.0	105.0
Tolors	Energy	69.0	96.8
Aparan	Irrigation	50.6	91.0
Azat	Irrigation	77.0	70.0
Joghaz	Irrigation	60.0	43.8
Her-Her	Energy	71.5	26.0
Kechout	Irrigation	48.0	23.0
Karnout	Irrigation	34.5	22.6
Shamb	Energy	41.0	13.6
Hakhoum	Irrigation	46.0	12.0

Table 3.7 Main reservoirs in the Kura Ara(k)s basin – Azerbaijan.

Reservoir	Year	Total storage capacity (mln. m^3)	Useable storage capacity (mln m^3)	Dam height (m)	Capacity (MW)
Mingechevir	1953	16,000	7,400	80	371
Shamkir	1983	2,400	1,425	70	380
Araz	1971	1,350	1,150	34	22
Serseng	1976	560	500	125	50
Yenikend	2000	158	136	24	150
Jeyranbatan	1958	186	150		
Agstafachay	1969	120	109	52	
Vaykhir	2005	100		71	5
Varvara	1952	62	10	12	17
Khanbulanchay	1976	52	45	64	
Total		**20,718**	**10,925**		**995**

Source: Mammadov (2012); AZ-MENR (2012).

In total for the 3 countries together, the total usable storage capacity in reservoirs of the Kura Ara(k)s Basin (excluding Turkey and Iran) is estimated to be 14 - 15 BCM, which represents approximately 55% of the annual renewable water resources of the basin.

3.4 Water Use

Total water abstraction in Georgia in 2011 reached 2,012.3 MCM, of which 381.1 MCM from groundwater sources (GE-MENRP, 2013). Direct water consumption in the country totaled 1,044.7 MCM, divided over the sectors agriculture, fisheries & forestry – 247.7 MCM (23.7%), industry – 357.9 MCM (34.3%) and municipal & drinking purposes – 439.2 MCM (42.0%). An additional volume of 20,557.9 MCM was non-consumptively used by the hydropower sector (GE-MENRP, 2013).

Direct consumption in the Kura Ara(k)s basin part in 2011 reached 884.2 MCM, divided over the sectors agriculture, fisheries & forestry – 216.3 MCM (24.5%), industry – 303.0 MCM (34.3%) and municipal & drinking purposes – 364.9 MCM (41.3%). An additional 5,381.8 MCM is non-consumptively used by the hydropower sector (GE-MENRP, 2013). Comparing the country and basin data, it is also clear that irrigation exclusively takes place inside the Kura Ara(k)s section in Georgia, while the non-consumptive use for hydropower generation is by far higher in the Black Sea basin.

Water intake in Azerbaijan in 2011 totaled to 11,779.2 MCM, of which 10,208.4 MCM (86.7%) were collected inside the Kura Ara(k)s basin. Meanwhile, total water use in the country in 2011 amounted to 8,001.8 MCM, divided over the sectors irrigation & agriculture – 5,746.1 MCM (71.8%), industry & manufacturing – 1,760.3 MCM (22.0%) and municipal & drinking purposes – 396.7 MCM (4.9%) (AzerStat, 2012).

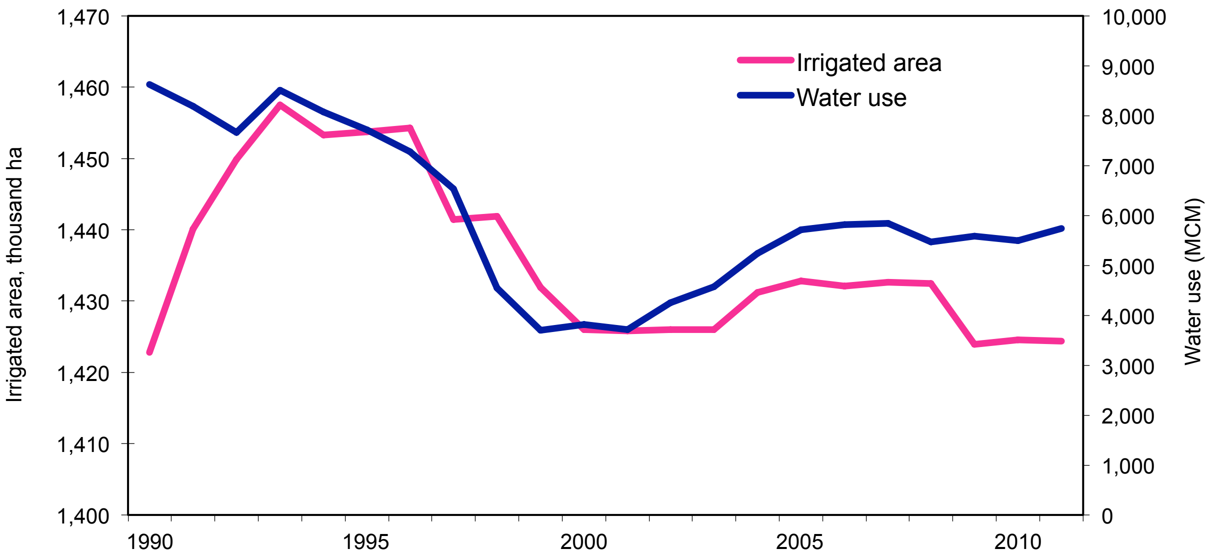
As not all of Azerbaijan is located in the Kura Ara(k)s basin, the corresponding water use inside the basin in 2011 was: irrigation & agriculture – 4,966.8 MCM (86.4% of all irrigation water), industry & manufacturing – 1,295.4 MCM (73.6% of all manufacturing water) and municipal & drinking purposes – 174.2 MCM (43.9% of all municipal water), to a total of 6,460.9 MCM, or 80.7% of all water use in Azerbaijan (AzerStat, 2012).

The data show that part of the water collected in the Kura Ara(k)s basin is “exported” to parts of the country outside the basin, being 6% of all intake, or 706.8 MCM. The statistics per administrative district distinguish between net water providers and net users, identifying the major water intake locations Mingechevir, Imishly and Yevlakh. Accordingly, the water losses in the country and the Kura Ara(k)s basin amount to 3,767.4 MCM (32.0%) and 3,308.8 MCM (32.4%) respectively (AzerStat, 2012).

The large amount of water used for irrigation confirms the need for water in agriculture, conditioned by the arid climate conditions in Azerbaijan. Irrigation development grew steadily from the 1950s until the early 1990s, by which time some 1.45 million ha were brought under irrigation. Although the overall irrigation infrastructure is still in place, especially secondary and tertiary irrigation channels have degraded due to the lack of maintenance. Due to the overuse of water and ineffective drainage systems, more than 600,000 ha of irrigated lands are assessed as degraded, mostly affected by salinization (FAO, 2009) – 9% severely saline, 14.9% moderately saline, and 35% slightly saline (AZ-MA, 2012).

The Amelioration & Water Management Joint Stock Company of Azerbaijan is responsible for managing and monitoring irrigation. Their figures of the change in irrigation area and in water use are shown in Figure 3.1.

Figure 3.1 Area under irrigation and irrigation water use in Azerbaijan, 1990 to 2011.



Source: Amelioration & Water Management JSC (2012).

From figure 3.1 the decline in water use is evident - from a high of 8.6 BCM in 1990 to a low of 3.7 BCM in the 1999-2001. Since 2002 irrigation water use has risen to a current high (2011) of 5.7 BCM (AzerStat, 2012), despite the decline in irrigation area to a low of 1.42 million ha, hinting at increasing inefficiency.

In Armenia there has also been a decrease in the total water withdrawal since the mid-1980s, mainly due to a decrease in agricultural and industrial water use. The total abstraction from water resources in 2011 amounted to 2,438.3 MCM, of which 1,002.8 MCM (41.1%) obtained from underground sources. Total consumption reached 1,738.1 MCM, divided over the sectors agriculture, fish breeding & forestry – 1,444.5 MCM (83.1%), industrial & communal use – 218.8 MCM (12.6%) and drinking – 74.8 MCM (4.3%) (ArmStat, 2012). As such, estimated losses amount to 700.2 MCM, or 28.7% of total abstraction.

Summarizing the water use figures from the three countries suggests that the total water consumption in the Kura Ara(k)s Basin countries Armenia, Azerbaijan and Georgia amounts to about 10.5 BCM in 2011. Features of water abstraction and water use are summarized in table 3.8.

Each of the countries has good potential for increasing water use in all sectors. The biggest impact would be from irrigation as currently unused irrigation areas could re-enter into production and expansion potential is exploited. This is a very likely situation over the next few decades as economic development, population growth and climate change all drive food needs upward with consequently greater demands for irrigated agriculture.

Table 3.8 Water abstraction and consumption in Armenia, Azerbaijan and Georgia in 2011.

	Armenia (MCM)	(%)	Azerbaijan (MCM)	(%)	Georgia (MCM)	(%)
Total abstraction	**2,438.3**	**100.0**	**11,779.2 (10,208.4)**	**100.0**	**2,012.3**	**100.0**
- of which groundwater	1,002.8	41.1	n/a		381.1	18.9
Total consumption, of which:	**1,738.1**	**100.0**	**8,001.8 (6,460.9)**	**100.0**	**1,044.7 (884.2)** [a]	**100.0**
- agriculture, fishery, forest	1,444.5	83.1	5,746.1 (4,966.8)	72.7	247.7 (216.3)	23.7
- Industry	218.8	12.6	1,760.3 (1,295.4)	22.3	357.9 (303.0)	34.3
- Drinking water	74.8	4.3	396.7 (174.2)	5.0	439.2 (364.9)	42.0
Estimate losses	**700.2**	**28.7**	**3,777.4**	**32.1**	**967.6**	**48.1**
Water consumption per capita (m^3/year)	**530.8**		**866.5 (1,237.1)**		**232.3 (323.9)**	

Notes: [a] - in brackets water use in the Kura Ara(k)s basin section of the country. Sources: ArmStat (2012); AzerStat (2012); GE-MEP (2012).

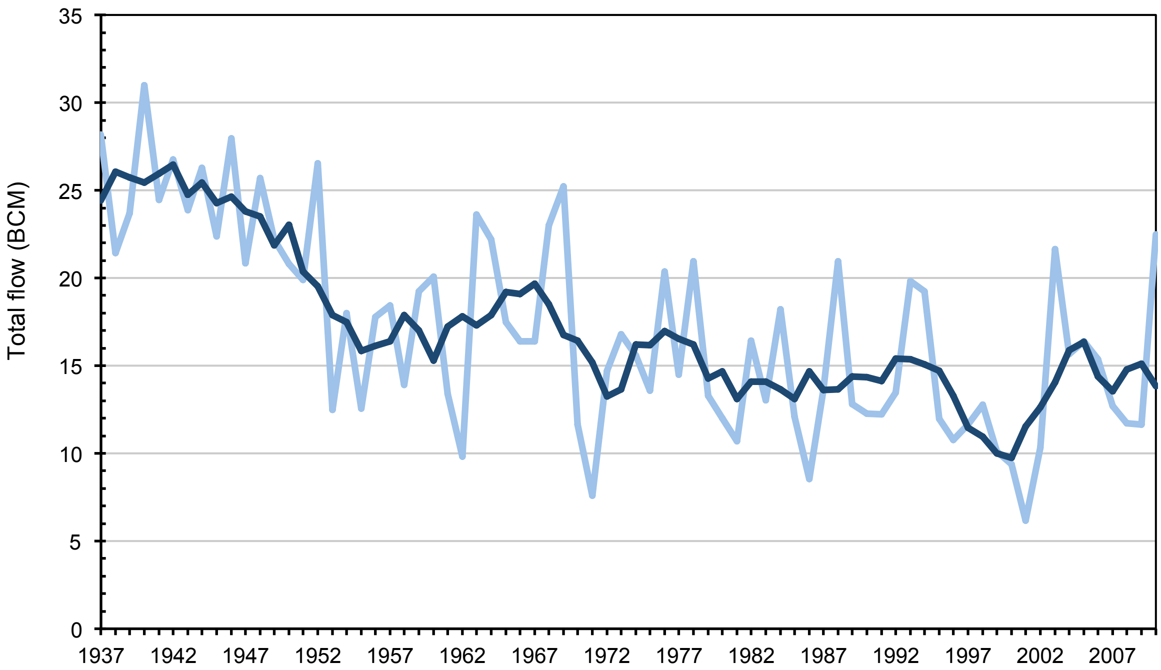
4 CHANGES IN RIVER FLOWS

Rivers in the South Caucasus riparian countries show significant inter-annual and seasonal variations in flow, typically depending on variations in climatic conditions from year to year and season to season. Additionally, also the expansion of human activities since the mid-20th century have impacted on water use and river discharge in the South Caucasus. The different trends and changes will be discussed in the sections below.

4.1 Inter-annual variation

Under natural conditions – before flow regulation and the expansion of water consumption - the average yearly river water discharge into the Caspian Sea is assessed to have varied between 25-30 km^3, of which the major portion of about 20 km^3 originated from the riparian states located upstream Azerbaijan, while about 10 km^3 of river flow was generated within the Azerbaijan Republic (Imanov *et al.*, 2009). Figure 4.1 presents the long-term record of discharge as measured at the hydrological station Surra (Azerbaijan), downstream of the confluence of Kura and Ara(k)s rivers. Figure 4.1 hints at the impact of human economic expansion in the mid-20th century – a reduction of annual river discharge in the downstream Kura Ara(k)s river, following reservoir construction (with related increased evaporation) and increased water intake, largely for irrigation.

Figure 4.1 Long term times series of combined Kura Ara(k)s annual discharge measured at Surra, Azerbaijan.



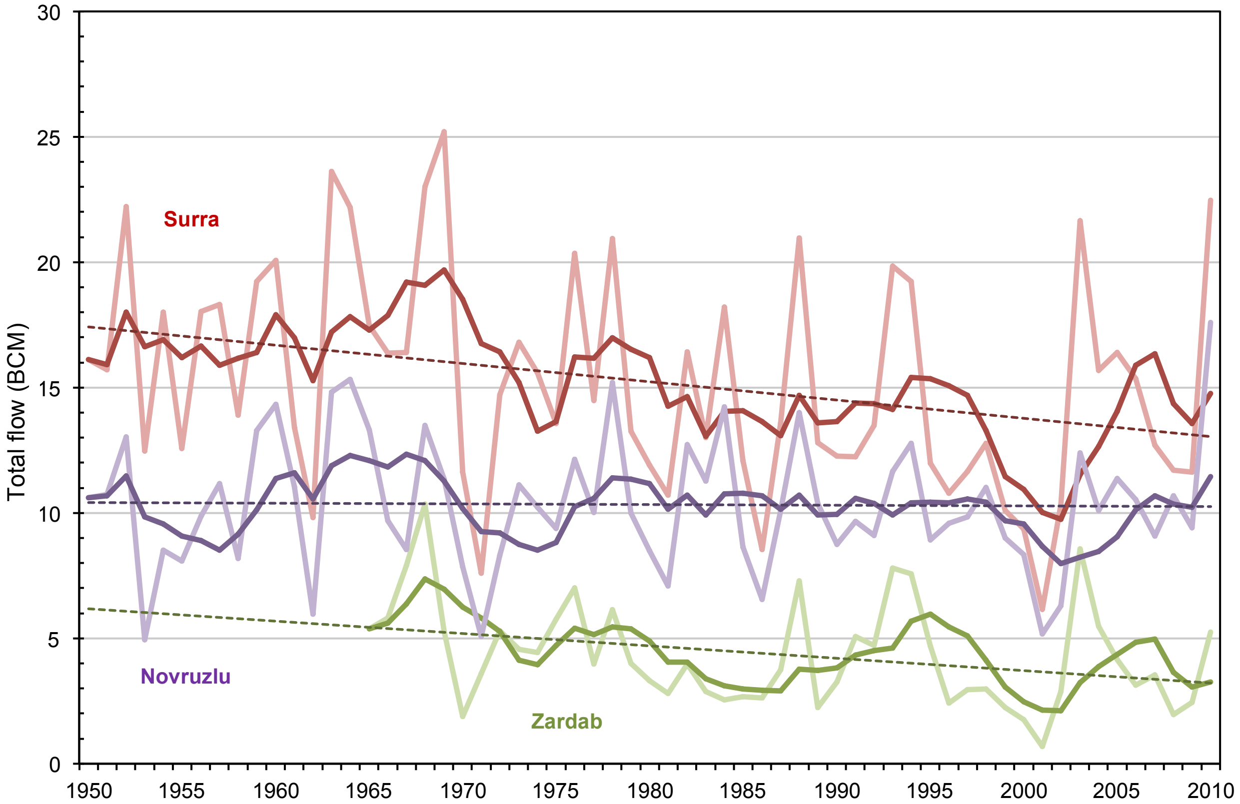
Source: Azerbaijan Hydro-meteorological Service (2012).

Based on average monthly flow data, the average yearly discharge for the Kura Ara(k)s river at Surra for the human-altered discharge period 1950-2010 was calculated as 15.2 km^3 (Azerbaijan Hydro-meteorological Service, 2011; Figure 4.1). For the Kura and Ara(k)s upstream of the confluence separately, the observed average yearly discharge is 10.3 km^3 (hydro-post Zardab, Azerbaijan, 1950-2010) and 4.3 km^3 (hydro-post Novruzlu, Azerbaijan, 1965-2010) respectively (Figure 4.2). The annual discharge in figure 4.2 is not corrected for annual water intake - consumption, irrigation etc., the total volumes of which are significant – 12 km^3 for Azerbaijan in 2011, but represent the period of regulated flow and consumptive use (AzerStat, 2012).

For the period of regulated discharge, the three Azerbaijan stations – Zardab on the Kura, Novruzlu on the Ara(k)s, and Surra, downstream of the confluence – all show a downward trend in annual discharge over the last 60 years, evident in both the annual series as well as the five-year running mean.

Although Azerbaijan did not analyze recent changes in river flows specifically, temperature and precipitation changes were assessed by comparing the periods 1961-1990 with 1991-2000 in the framework of the country's National Communications to the UNFCCC. Analyses show that temperatures across the country increased by an average of 0.52°C, while precipitation decreased on average by 9.8% (AZ-MENR, 2010). The related increased losses to evapotranspiration due to increased temperatures, combined with a significant decrease in precipitation may provide an explanation for the consequent decrease in river flows, as seen in figure 4.2. However, as discussed in section 3.1.3, the IRSWR for the Kura Ara(k)s basin in Azerbaijan constitutes 7.2 km^3, and accordingly the water losses due to increased temperatures and reduced precipitation seem insufficient to explain completely the decreasing trend in river discharge. However, more detailed data are needed, specifically also on irrigation water intake, evapotranspiration losses, surface and subsurface water flows, etc., to draw better founded conclusions.

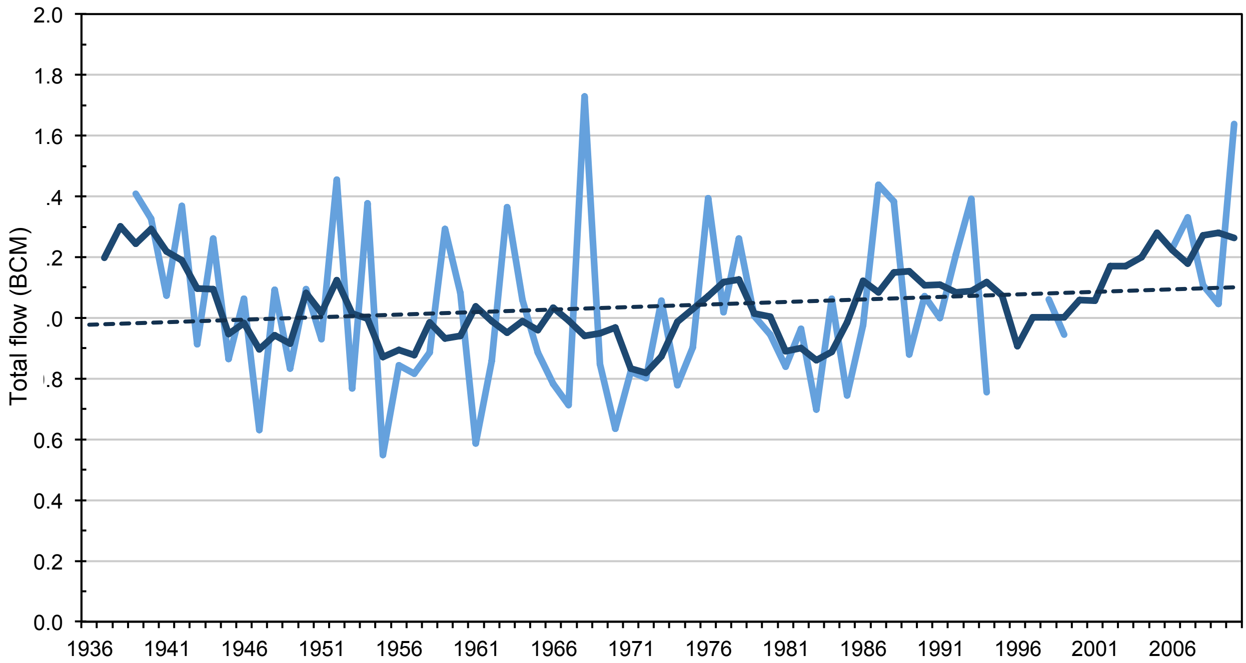
Figure 4.2 Variation in total yearly discharge at Zardab, Novruzlu and Surra (Azerbaijan).



Notes: Zardab – green lines, Kura River; Novruzlu – purple lines, Ara(k)s River; and Surra – red lines, Kura Ara(k)s river. Bold lines – 5 years running mean; light-colored lines – yearly total discharge; dashed lines – trend. Source: Azerbaijan Hydro-meteorological Service (2012).

Meanwhile the long-term variation in annual river discharge in the upstream Kura river – at Khertvisi, Georgia, presented in figure 4.3, shows a trend of slowly increasing discharge volumes, albeit with large inter-annual variation. Also in the time series for the Tbilisi station (Figure 4.4), representing the semi-mountainous Kura river in Georgia, the declining trend in river discharge is absent, in the data series and in the five year running mean calculated for it.

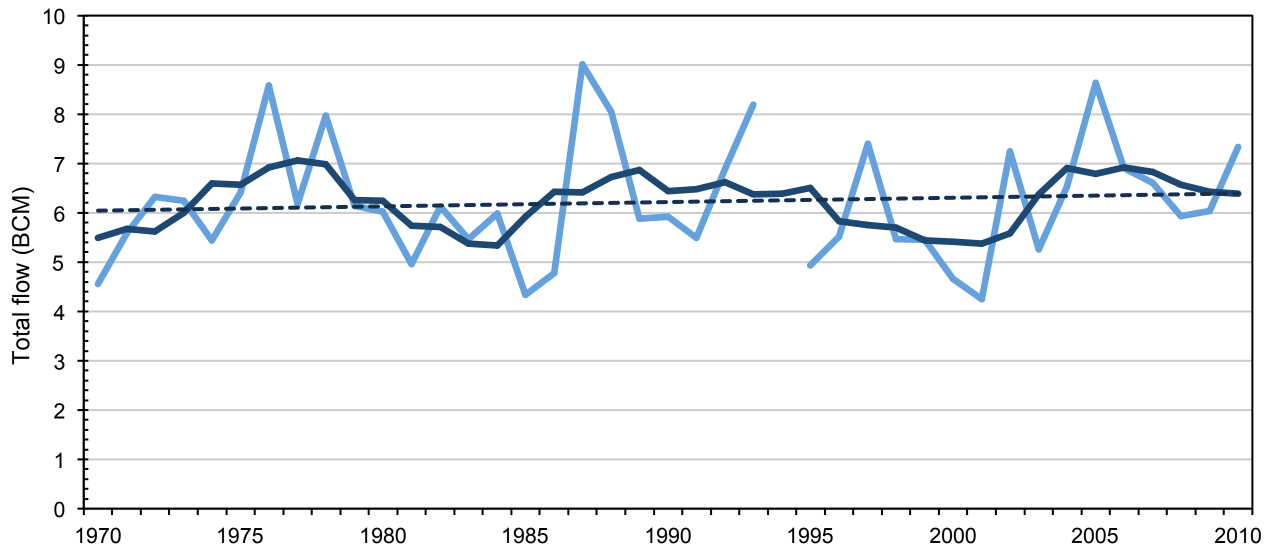
Figure 4.3 **Annual discharge time series for the upstream Kura river at Kertvisi, Georgia.**



Source: GE-MEP-NEA (2012).

The absence of a decline in Kura river flow in Georgia is supported by the climate changes analysis as reported in Georgia's 2nd National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC). While the document does not analyze river flow changes specifically, it does analyze recent changes in rainfall. For the whole of Georgia average annual temperatures have risen, especially in Eastern Georgia, part of the Kura Ara(k)s basin - by 0.6°C for the period 1990-2005 compared to the baseline period 1955 to 1970. Meanwhile precipitation has increased as well, by 6% in eastern Georgia. The increase in temperatures will have consequently increased evaporation and transpiration rates, leading to lower runoff into the rivers. At the same time the increase in precipitation could offset these increased temperatures, resulting in a balancing of runoff and negligible change in river flows.

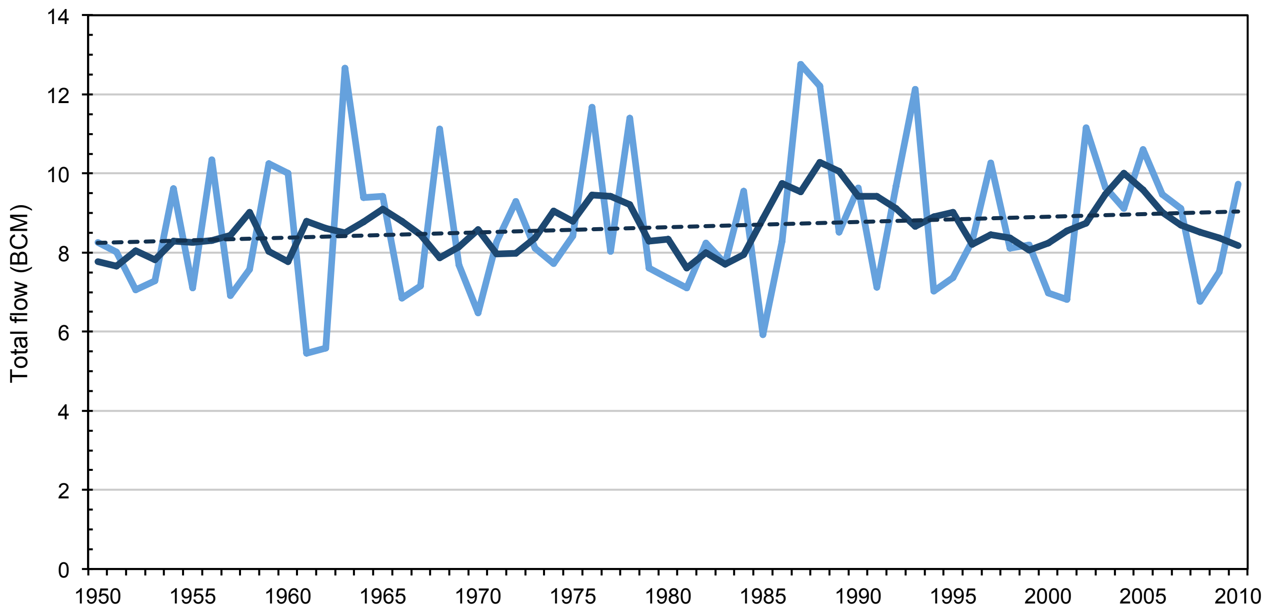
Figure 4.4 **Annual discharge time series for the Kura River at Tbilisi, 1970 to 2010.**



Source: GE-MEP-NEA (2012).

The absence of a declining trend in the upper Kura basin is confirmed by times series of calculated annual discharge at the Azerbaijan station Giraqkesemen, downstream of the border with Georgia (Figure 4.5).

Figure 4.5 River Flow Time Series for the Kura River at Giraqkesemen, 1950 to 2010.

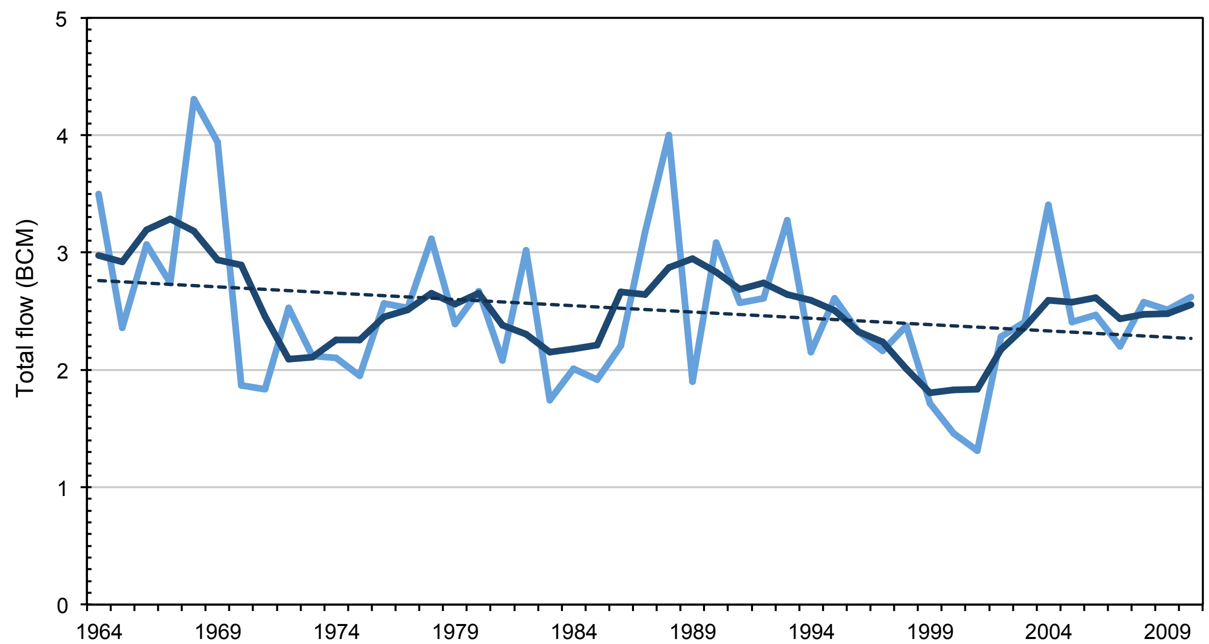


Source: Hydro-meteorological Service Azerbaijan (2012).

Additionally the decrease in water intake since the 1990s in Georgia may have attributed to increased river flows in the upper Kura basin, but too little information is available to draw conclusions on the matter.

Meanwhile, in contrast to the upper Kura, a downward trend in river flow is clearly visible in the hydrological series for the Armenian station of Surmalu on the semi-mountainous Ara(k)s River, as shown in Figure 4.6.

Figure 4.6 Annual river discharge time series for the Ara(k)s River at Surmalu, 1964 to 2005.



Source: Hydro-meteorological Survey Armenia (2012).

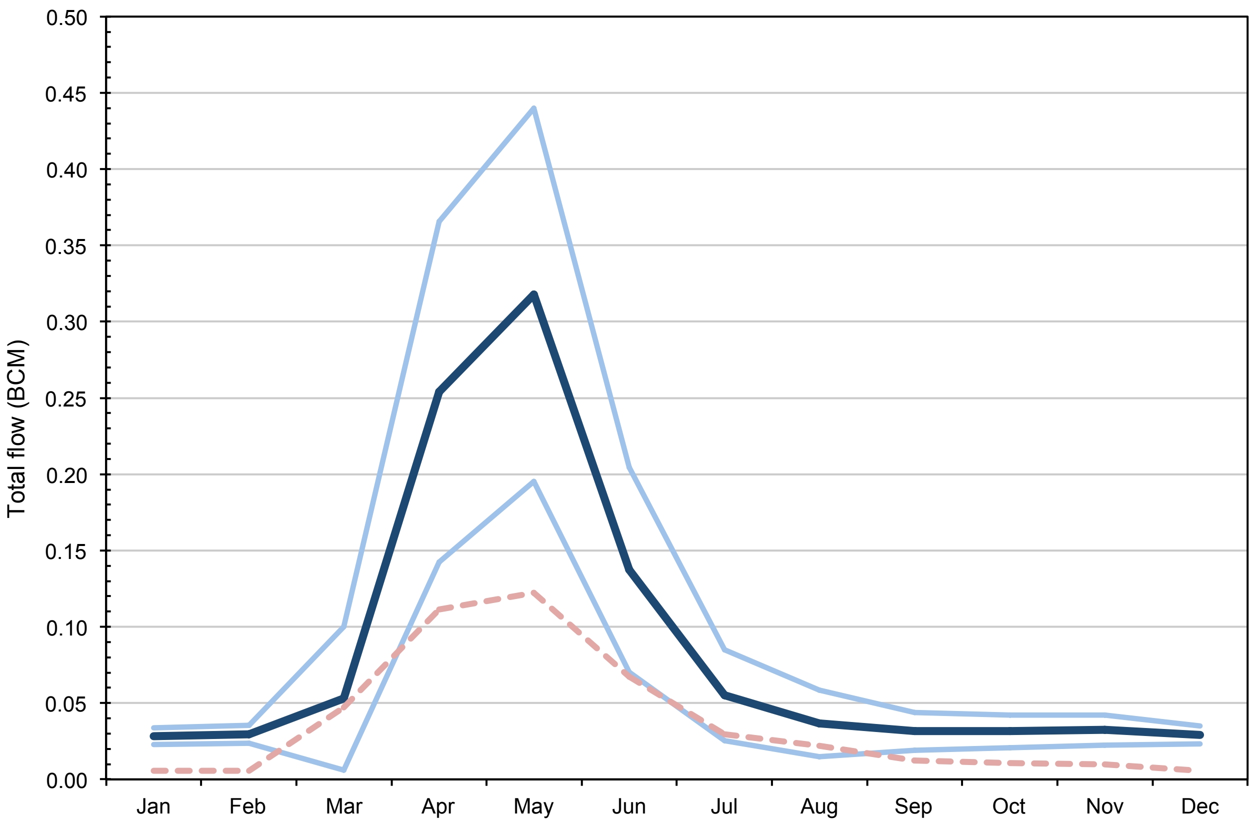
In their SNC to the UNFCCC Armenia analyzed river flows by comparing the average flow for 1961-1990 with the period 1991-2006 for 33 observation points on 28 rivers. The results show an increase in annual discharge for some rivers, and a decrease for others. Increases are relatively small (less than 3%), largely observed in the eastern part of the country, where precipitation has also shown to have increased. For other rivers declining trends in flow volumes in the order of magnitude of 3-5% have been observed. However, insufficient detailed information is available on water intake for industry, consumption and especially irrigation to assess whether changes in time may have contributed to the downward trend in Ara(k)s river discharge.

It should be noted that all three countries forecast significant increases in temperature over this century, while Georgia and Armenia both also forecast significant decreases in precipitation. Azerbaijan has reported increases in precipitation but has also casted doubt on the validity of the models used and does forecast a reduction in river flows of 23% in the 2021 to 2050 period and 29% in the 2070 to 2100 period. As such, it may be expected that in future decreasing river discharges may be observed throughout the Kura Ara(k)s basin, as increased evapotranspiration and decreased precipitation will reduce water availability, while the needs for human consumption will increase with warmer climate conditions.

4.2 Seasonal variation in river flow

The total amount of water being seasonally discharged through the region's rivers depends on the amount of snow in winter and rain in other seasons. Typically, the largest portion of the total annual discharge volume passes the rivers in spring, during the snow melting months of March through June/July, as evidenced by the hydrograph (figure 4.7) for the period 1939-2010 for the hydrological station Khertvisi in the upstream Kura basin, not affected by dam regulation and minimally by water intake.

Figure 4.7 Annual hydrograph for the Kura river at Khertvisi (Georgia) for the period 1939-2010.



Source: GE-NEA (2012). Legend: bold blue line – average monthly discharge; light blue lines – standard deviation interval; red line – monthly standard deviation value; y-axis – km^3.

Figure 4.7 also shows that the variation in monthly discharge is the highest during the spring months, depending on both the variation in winter precipitation as snow, and the character of snow melt in spring.

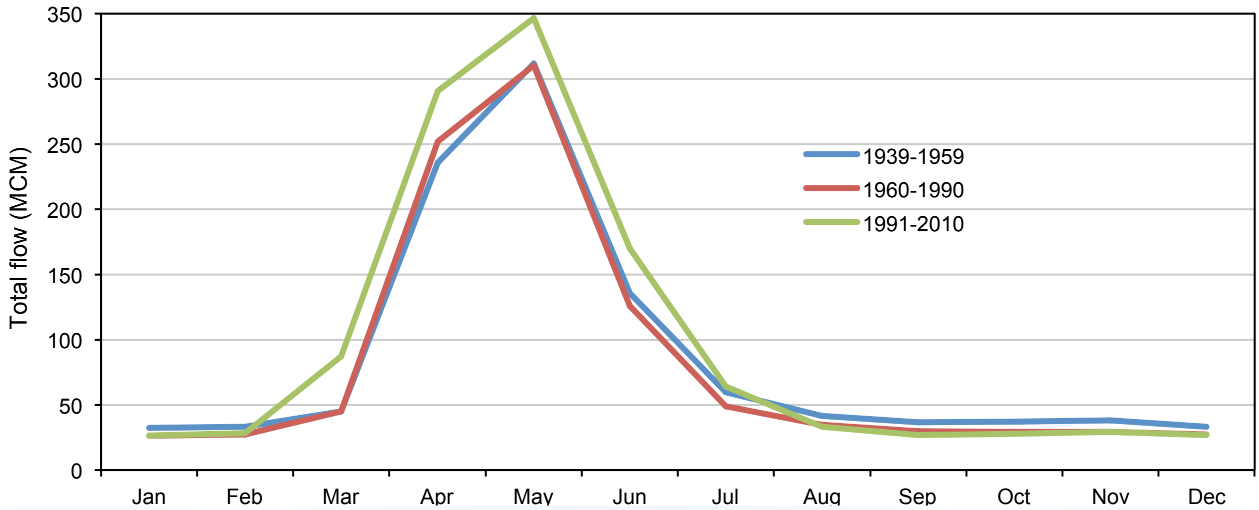
The observed impact of climate change has been discussed in the Climate Change Desk Study to the Updated TDA. With envisioned climate change, an increase in seasonal variation of river flow is expected, related to an increase/decrease of overall precipitation or an increase in the frequency and intensity of large storms, which may be associated with specific seasons. For the un-impacted hydrological station Khertvisi, the seasonal distribution of discharge was compared for the established period of “climatic norm” 1960-1990 and the period before (1939-1959) and after (1991-2010), presented in table 4.1 and figure 4.8.

Table 4.1 Monthly discharge statistics for different periods at Khertvisi, Georgia.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average discharge (mln m³/month)													
1939-1959	32.3	33.3	44.9	235.9	311.9	135.8	59.5	41.5	36.8	37.1	38.1	33.4	1040.4
1960-1990	26.2	27.5	45.2	252.1	310.5	125.9	48.7	34.9	29.7	29.2	29.5	27.2	986.7
1991-2010	26.5	28.2	87.2	290.8	346.7	169.9	64.1	33.1	26.7	27.8	29.2	26.7	1157.0
Standard Deviation (mln m³/month)													
1939-1959	6.2	5.8	15.7	123.6	112.3	61.9	33.5	32.1	19.5	15.5	12.5	6.7	260.8
1960-1989	3.8	4.1	24.0	105.7	121.7	62.0	23.2	15.0	5.7	5.4	6.2	4.3	258.1
1990-2010	3.7	6.5	91.7	93.6	135.7	77.5	33.2	11.0	2.8	4.5	6.4	2.8	220.0
Absolute change in discharge (mln m³/month) compared to 1960-1990													
1939-1959	6.1	5.7	-0.3	-16.2	1.3	10.0	10.8	6.6	7.0	7.9	8.6	6.1	53.7
1991-2010	0.3	0.7	42.1	38.7	36.2	44.0	15.3	-1.8	-3.0	-1.4	-0.3	-0.5	170.2
Absolute change Standard Deviation (mln m³/month)													
1939-1959	2.3	1.8	-8.3	17.9	-9.4	-0.1	10.3	17.1	13.8	10.1	6.3	2.4	2.7
1991-2010	-0.1	2.4	67.7	-12.1	14.0	15.5	10.1	-4.0	-2.8	-0.9	0.2	-1.5	-38.1
Relative change in discharge (%) compared to 1960-1990													
1939-1959	23.3	20.9	-0.6	-6.4	0.4	7.9	22.1	18.8	23.7	27.0	29.1	22.5	5.4
1991-2010	1.1	2.5	93.2	15.3	11.7	35.0	31.5	-5.2	-10.1	-4.8	-0.9	-1.9	17.3
Relative change Standard Deviation (%)													
1939-1959	60.9	43.0	-34.4	16.9	-7.8	-0.1	44.5	114.0	243.8	186.8	101.6	55.5	1.0
1991-2010	-3.3	58.5	282.2	-11.4	11.5	25.0	43.4	-26.8	-50.1	-16.8	2.5	-34.4	-14.8

Source: GE-NEA (2012).

Figure 4.8 Average total monthly discharge for different periods at Khertvisi, Georgia.



Source: GE-NEA (2012).

The analysis shows that in the mid-20th century spring discharge volumes were comparable in volume but had some slightly larger inter-annual variation, as shown by the standard deviation. However, summer, autumn and winter discharge volumes were larger than for the period 1969-1990. In comparison, the most recent time frame 1991-2010 shows a significantly larger spring discharge volume, but about equal discharge volumes for the other seasons.

For the hydrological station Surra (Azerbaijan), downstream of the confluence of the Kura and Ara(k)s rivers, an identical time period analysis was executed, presented in table 4.2 and figure 4.9. However, different time periods were used, 1939-1952 representing the pre-human expansion period, 1953-1990 the Soviet expansion period, and 1991-2010 the post-Soviet independence period.

Analysis shows that discharge regulation and expansion of water intake in the downstream Kura Ara(k)s basin, largely for irrigation, have significantly altered river discharge, both the annual total discharge (36% and 44% for the periods 1953-1990 and 1990-2010 respectively) as well as the seasonal distribution of river discharge, all compared to discharge characteristics for the period 1939-1952. Winter discharge – December-February - has increased, while the spring flooding peak has almost completely been eliminated. Meanwhile overall changes in standard deviation – indicator of the inter-annual variation – appear to be minimal.

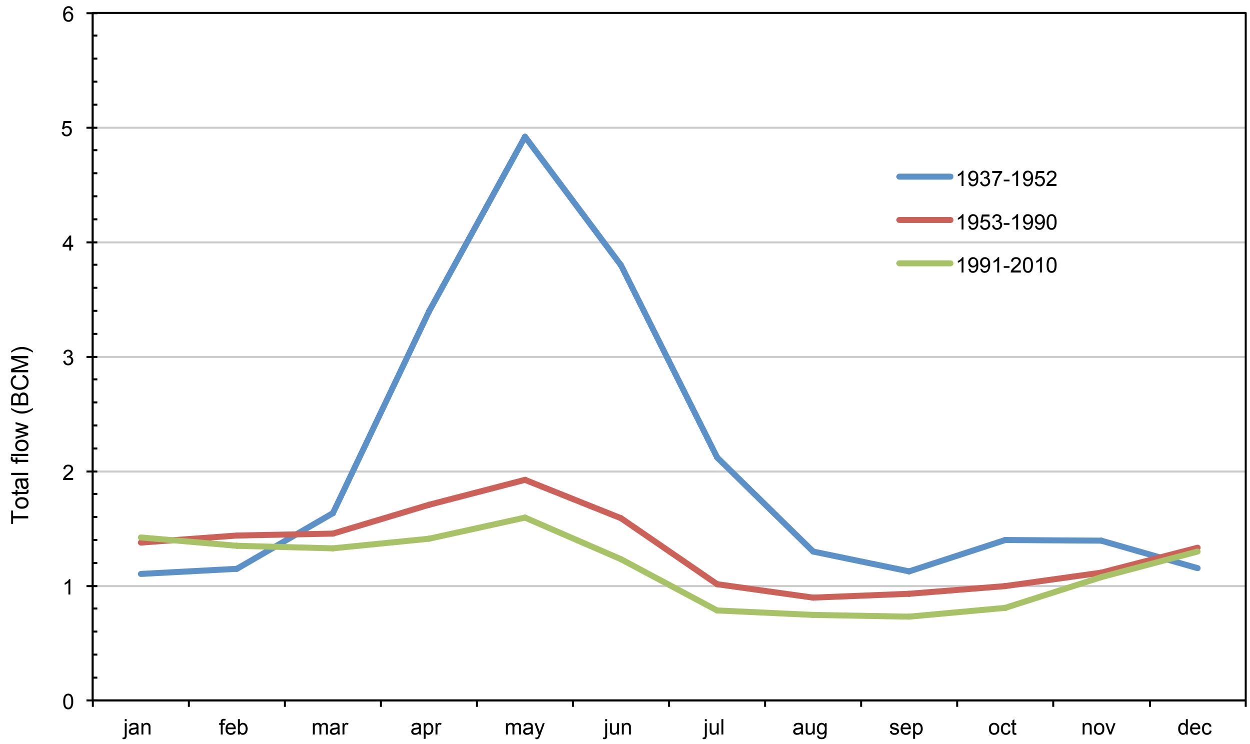
Table 4.2 Monthly discharge statistics for different periods at Surra, Azerbaijan.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average discharge (mln m³/month)													
1939-1952	1.10	1.15	1.63	3.39	4.92	3.80	2.12	1.30	1.13	1.40	1.39	1.16	24.49
1953-1990	1.38	1.44	1.45	1.71	1.92	1.59	1.01	0.89	0.93	1.00	1.12	1.33	15.78
1991-2010	1.42	1.35	1.33	1.41	1.60	1.23	0.78	0.75	0.73	0.81	1.08	1.30	13.78
Standard Deviation (mln m³/month)													
1939-1952	0.15	0.19	0.32	0.77	1.06	0.96	0.59	0.28	0.26	0.38	0.36	0.18	3.06
1953-1990	0.41	0.44	0.47	0.71	0.96	0.89	0.47	0.31	0.28	0.26	0.31	0.33	4.23
1990-2010	0.42	0.51	0.54	0.74	1.05	0.82	0.33	0.20	0.19	0.26	0.35	0.41	4.18
Absolute change in discharge (mln m³/month) compared to 1939-1952													
1953-1990	0.28	0.29	-0.18	-1.68	-3.00	-2.21	-1.11	-0.40	-0.20	-0.40	-0.28	0.18	-8.72
1990-2010	0.32	0.20	-0.31	-1.98	-3.32	-2.57	-1.34	-0.55	-0.40	-0.59	-0.32	0.14	-10.72
Absolute change Standard Deviation (mln m³/month)													
1953-1990	0.26	0.24	0.15	-0.07	-0.10	-0.07	-0.12	0.02	0.02	-0.12	-0.06	0.15	1.16
1990-2010	0.27	0.32	0.22	-0.03	0.00	-0.14	-0.26	-0.08	-0.07	-0.13	-0.01	0.23	1.12
Relative change in discharge (%) compared to 1939-1952													
1953-1990	25.2	25.0	-11.0	-49.6	-60.9	-58.2	-52.3	-31.1	-17.6	-28.7	-19.8	15.4	-35.6
1990-2010	29.2	17.3	-18.8	-58.4	-67.5	-67.6	-63.1	-42.5	-35.2	-42.5	-22.7	12.1	-43.8
Relative change Standard Deviation (%)													
1953-1990	172.7	128.0	47.4	-8.5	-9.0	-7.5	-21.1	8.5	6.3	-31.8	-15.3	86.1	37.9
1990-2010	179.4	166.5	67.7	-4.0	-0.2	-14.9	-43.9	-29.6	-27.5	-32.9	-2.6	129.6	36.5

Source: AZ-MENR (2012).

Discharge regulation along the Kura and Ara(k)s rivers resulted in the differences between annual maximum and minimum flow being significantly reduced since 1953, as evidenced by table 4.3 and figure 4.10. It shows that both minimum and maximum monthly discharges decreased. The absolute decrease in peak discharge is larger than the decrease in minimum flows, resulting in an overall decrease in variation in discharge volume resulting from human interventions.

Figure 4.9 ***Average total monthly discharge for the combined Kura and Ara(k)s river as observed at Surra (Azerbaijan) in different time periods.***



Legend: 1939-1953 – flow regime close to natural; 1953-1990 – period of Soviet agricultural expansion; 1990-2010 – post Soviet independence period. Source: AZ-MENR (2012).

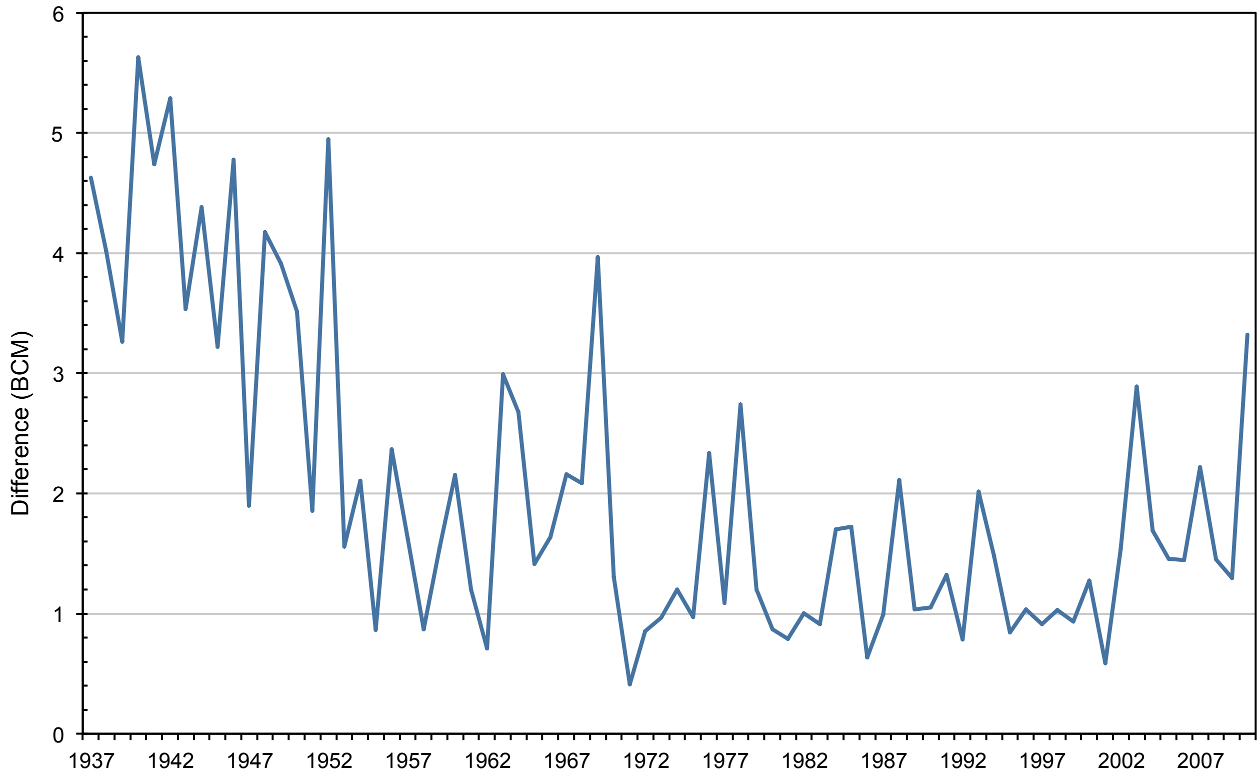
Table 4.3 ***Changes in average total annual and monthly maximum and minimum discharge in defined impact periods as observed at Surra (Azerbaijan).***

Period	Average total yearly discharge (km^3)	Averaged monthly minimum discharge (km^3)	Averaged monthly maximum discharge (km^3)	Difference between monthly minimum and maximum (km^3)
1937-1952	24.49	0.97	4.96	3.99
1953-1970	17.31	0.74	2.59	1.85
1971-1990	14.40	0.74	1.97	1.23
1991-2000	13.14	0.65	1.82	1.17
2001-2010	14.41	0.60	2.39	1.79

Source: AZ-MENR (2012).

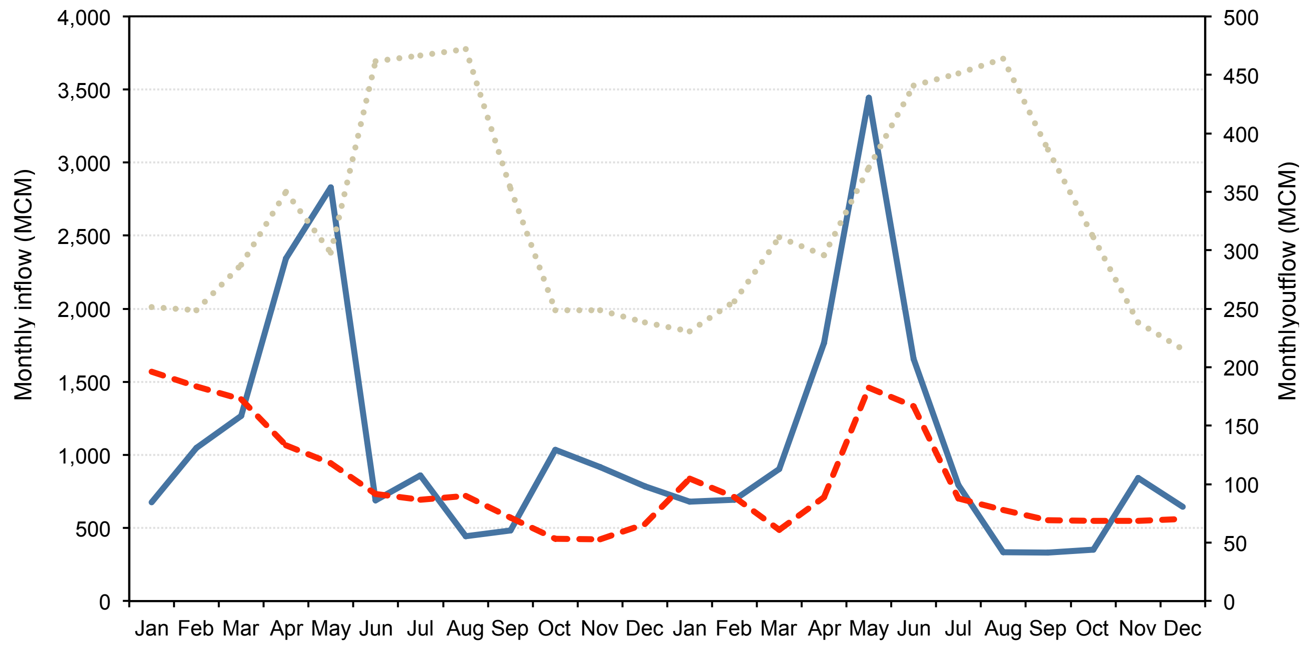
Figure 4.11 further elaborates on the impact of discharge regulation and water abstraction affecting the seasonal distribution of river discharge in the downstream Kura river, on the example of the Mingechevir Reservoir. The water balance of the reservoir shows the total inflow from the Kura and the Alazani/Ganikh rivers (blue line), characterized by a distinctive flood peak in spring. Outflow from the reservoir enters the downstream Kura river (red line) as well as two major irrigation channels – the Garabakh Channel and the Shirvan Channel (grey line, 2nd y-axis). Additionally, evaporation from the open water surface of the Mingechevir is estimated at 0.7 km^3 (FAO, 2012). As such, Figure 4.11 shows the significant intra-annual water redistribution from the flooding season (March-June) towards both the summer (June/July-September/October) and winter (December-March) seasons, with natural flow peaks almost to completely removed. The figure also shows the seasonality in water intake into the irrigation channels.

__Figure 4.10 Difference between absolute monthly maximum and minimum discharge as observed at Surra (Azerbaijan).__



Source: AZ-MENR (2012).

__Figure 4.11 Temporal monthly flow characteristics of the Mingechevir Reservoir water balance in 2006 and 2007.__



Source AZ-NWS (2011). Legend: blue line – Summed inflow from the Kura and Alazani/Ganikh rivers (left y-axis, MCM); red line – Outflow from the reservoir to the downstream Kura river (left y-axis, MCM); grey line – outflow from the reservoir into main irrigation distribution channels (right y-axis, MCM).

5 CONCLUSIONS & RECOMMENDATIONS

The present report presents the features of hydrology – water resources, water use and river discharge – of the Kura Ara(k)s river basin. The report also touched upon the changes that have taken place during the course of almost a century. The analysis is based on long time series of average monthly flow data provided by the governmental hydro-meteorological departments of Armenia, Azerbaijan and Georgia, for selected stations along the course of both the main Kura and Ara(k)s rivers.

Due to economic and financial problems in all three countries of the region over the last two decades, the number of hydrological stations has declined in Armenia and Georgia, while Azerbaijan managed to largely maintain its monitoring network. The reduced number of monitoring locations in Armenia and Georgia has caused problems associated with availability as well as reliability. As a consequence, the analysis carried out in earlier sections was based on rather limited data, and as such would benefit from analyzing a greater set of data.

At the regional level there are only two likely causes of the variation and reduction in river flows: increased water use, and climate change. It is not possible to determine how much of the overall impact each of these causes accounts for, because reliable data on actual water abstractions are largely absent. Would these data become available, river flow impacts specifically from abstractions and the growth of those abstractions over time could be quantified. Additionally, with such information remedial actions against inefficient water use could also be more easily identified.

There may be a more local aspect to the issue of a reduction in river flows and reduced variation of those flows. For example, given one of the main causes of the reduction, mainly increased abstractions, it is likely that some of the major tributaries experience far greater reductions and other variation patterns than does the main Kura or Ara(k)s channel. Analyses of these tributaries are not currently possible because of lack of data.

A related issue is the need to ensure environmental flows in the rivers, including for tributaries. Currently, environmental flows are calculated based on outdated methods which are not appropriate for modern thinking on ecosystem management. These methods need further reviewing.

Accordingly, the following recommendations are formulated towards improved information collection and management in line with international objectives and best practices:

- Redesign and expand the ambient river and atmospheric monitoring network: following an evaluation of the river network – main streams and tributaries, the location of former hydrological and meteorological stations, basin-wide climatic variations as well as the distribution of water intake locations over the basin, the monitoring network needs to be redesigned to comply with information needs useful for decision making. Existing and new stations need to be equipped with durable automatic loggers of water level, discharge and other basic features. An appropriate servicing program and standard operational procedures need to be formulated and implemented, supplied with sufficient financing.
- Specific attention needs to be paid to establishing a targeted monitoring program of groundwater resources in all three countries. Based on an inventory and analysis of existing information from past programs, country-wide networks of monitoring stations need to be designed, bore holes drilled and refurbished with state-of-the-art equipment.
- The modeling capacity – on actual sustainable use volumes as well as forecasting – in the basin countries needs to be evaluated, and an appropriate capacity building program be formulated, including the supply of appropriate equipment and software.
- The collection of monitoring data on water intake and consumption requires significantly improvement. Guidelines for water consumers on reporting actual water use need to be developed, while in parallel an appropriate control & enforcement mechanism needs to be designed, including appropriate pricing, billing and payment control, and field checks on accuracy of water consumers' reporting.

6 REFERENCES

ADB Asian Development Bank, 2008. Republic of Azerbaijan: supporting river basin and flood management planning project. Technical Assistance Consultant's report, project number 3508102 (TA 4301), January 2008, 184 pp.

Alakbarov A., 2012. UNDP/GEF Kura Ara(k)s Project National Expert on Groundwater for Azerbaijan –expert opinion.

Alakbarov A. & F. Imanov, 2010. Transboundary aquifers of Azerbaijan: current conditions, challenges and mitigation possibilities. In: UNESCO-IHP-ISARM & PCCP Programs 2010. Proceedings of the ISARM 2010 International Conference *"Transboundary Aquifers: Challenges and New Directions"*. Paris.

AM-MNP Ministry of Nature Protection of the Republic of Armenia, 2010. Second National Communication on Climate Change – a report under the United Nations Framework Convention on Climate Change, Republic of Armenia, Ministry of Nature Protection, Yerevan, Armenia, 2010, 134 pp.

ArmStat, 2012. Statistical Yearbook of Armenia - 2011. National Statistical Service of the Republic of Armenia, Yerevan 2012, 624 pp.

AzerStat, 2012. Statistical Yearbook of Azerbaijan 2012. State Statistical Committee of the Republic of Azerbaijan, Baku, 2012.

AZ-NWS, 2011. Azerbaijan Republic National Water Strategy Draft 2011. Baku, 119 pp.

AZ-MA Ministry of Agriculture of Azerbaijan, 2012. www.agro.gov.az

AZ-MENR Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, 2010. Second National Communication to the United Nations Framework Convention on Climate Change, Ministry of Ecology and Natural Resources of Azerbaijan, Baku, 2010, 85 pp.

AZ-MENR Ministry of Environment and Natural Resources of Azerbaijan, 2012. www.eco.gov.az

FAO, 2009. Irrigation in the Middle East region in figures – Aquastat survey 2008. FAO Water Reports No. 34, 2009, 423 pp.

FAO, 2012. Climate conditions database - CIMWAT 2.0. Accessed on 7 December 2012 at http://www.fao.org/nr/water/infores_databases_climwat.html.

GE-MEPNR Ministry of Environment Protection and Natural Resources of Georgia, 2009. Second National Communication to the UNFCCC, Ministry of Environment Protection and Natural Resources of Georgia Tbilisi, Georgia, 2009, 240 pp.

GE-MEPNR Ministry of Environment & Natural Resources of Georgia, 2010. National Report on the State of the Environment of Georgia 2007-2009.Tbilisi, December 2010, 207 pp.

GE-MEP Ministry of Environment Protection of Georgia, 2010. Water use in Georgia in 2010. Available in Georgian at http://aarhus.ge/index.php?page=118&lang=eng

GE-MEP Ministry of Environment Protection of Georgia, 2012. www.moe.gov.ge

Harutyunyan L., 2012. UNDP/GEF Kura Ara(k)s Project National Expert on IWRM for Armenia – expert opinion.

Imanov F., Hasanova N., Humbatova Sh., Ismayilov V., 2009. Hydrological aspects of flood control in Azerbaijan. International Symposium on Floods and Modern Methods of Control Measures. 23-28 September, Tbilisi, Georgia, p.195-201.

Mammadov A., 2012. UNDP/GEF Kura Ara(k)s Project National Expert on Hydropower for Azerbaijan – expert opinion.

Rustamov S.G. & R.M. Kashkay, 1989. Water resources of the Azerbaijan SSR. Baku, 1989.

Tvalchrelidze A., V. Papava & A. Silagadze, 2011. Georgia's social and economic development program. International Foundation for Sustainable Development, Open Society Georgia Foundation, Tbilisi, 2011, 242 pp.

UNDP/Sida, 2005. Preliminary background analysis of the Kura Aras river basin in Armenia. Technical Report, UNDP/Sida project "Reducing trans-boundary degradation of the Kura Araks river basin", Yerevan, Armenia, 136 pp.

UNDP/GEF, 2007. TDA Thematic Report - Groundwater resources of the Kura Aras River Basin. UNDP/GEF RER/03/G41/A/1G/31: Reducing Trans-boundary Degradation of the Kura-Aras River Basin, pp. 58.

UNECE Economic Commission for Europe, 2007. Our waters: joining hands across borders. First assessment of transboundary rivers, lakes and groundwaters. United Nations New York & Geneva, 2007, 388 pp.

World Bank, 2012. World development indicators (http://databank.worldbank.org/data/home.aspx.

ZOI Environment Network, 2011. Climate change in the South Caucasus – a visual synthesis. Geneva, Switzerland, 60 pp.