CHAPTER 2

Integrated Water Resources Management Diagnostic

Assessment of the Water Resources Baseline

On average, Armenia has sufficient water resources. Taking into account all available water resources in the country, Armenia has sufficient resources to supply approximately 3,100 cubic meters per capita per year,[1] well above the typically cited Falkenmark water stress indicator of 1,700 cubic meters per capita per year (Falkenmark 1989). All the rivers in Armenia are tributaries of the Araks and Kura Rivers. Most rivers are small, rapid, and fed by melting snow, springs, and groundwater. The overall river flow (originating within the country) has been estimated at 6.8 billion cubic meters (table 2.1) (USAID 2008b). This is in part driven by the estimated 16.7 billion cubic meters of precipitation, with less than 10.8 billion cubic meters lost by evaporation (USAID 2008b). An available 1.19 billion cubic meters originates from outside the country via the transboundary Araks and Akhuryan Rivers. Groundwater contributes an estimated 4 billion cubic meters. Note that there are discrepancies with regard to this baseline water balance (see appendix B) across various reported sources. Map 2.1 shows basin management organizations (BMOs) and river basins in Armenia.

These water resources are not evenly divided in space and time. Water resources are stressed, particularly in the densely populated Hrazdan River basin in the central part of the country (figure 2.1) (Ministry of Nature Protection 2010).

There is also significant seasonal and annual variability in river runoff, including frequent droughts and risk of flooding in the spring, when about 55 percent of total annual runoff occurs during the peak snow melting period (figure 2.2). The ratio of maximum to minimum flow can reach 10:1 (Ministry of Nature Protection 2010). For instance, the long-term (1953–2012) inflows into the Akhuryan reservoir are shown in figure 2.3. The coefficient of variation on the annual flows is 24 percent.

In order to address temporal variations in river runoff, the country has built 87 dams with a total capacity of 1.4 billion cubic meters. Most of these dams are

Table 2.1 Basin Management Organizations (BMOs) and River Basins in Armenia

BMO	*River basin*	*Area (km^2)*	*River flow (MCM/yr)*
Northern BMO	Debed	3,895	1,203
	Aghstev	2,480	445
	Kura tributaries	810	199
Hrazdan BMO	Kasakh	1,480	329
	Hrazdan	2,565	733
Sevan BMO	Lake Sevan	4,750	265
Ararat BMO	Azat	952	232
	Vedi	998	110
	Arpa	2,301	764
Akhuryan BMO	Akhuryan	2,784	391
	Metsamor (Sevjur)	2,240	711
Southern BMO	Vorotan	2,476	725
	Voghji	1,341	502
	Meghriget	664	166
Total			**6,775**

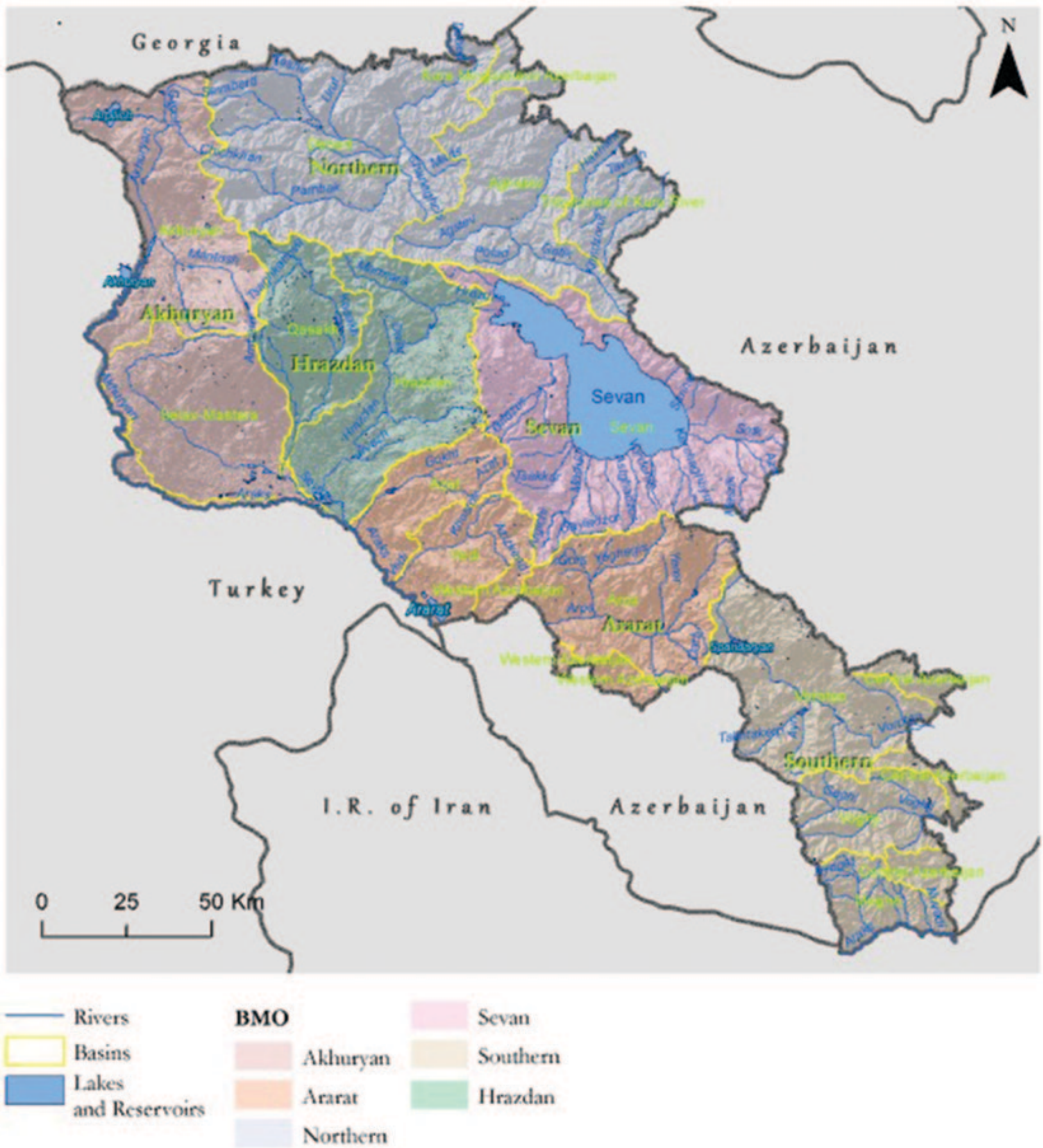
Source: USAID 2008b.
Note: MCM = million cubic meters.

single purpose, mainly for irrigation. Thirty-five reservoirs have capacities greater than 1 million cubic meters (MCM), and three have capacities greater than 100 MCM.[2] There are 9 incomplete dams, 28 dams at the design stage, and a further 67 dams for which feasibility studies have been undertaken that were planned or prepared during the Soviet era (Ueda 2012). For the government of Armenia, the highest-priority dams for irrigation expansion and conversion from pump to gravity schemes are the Kaps, Vedi, Yeghvard, and Selav-Mastara. These are currently being financed (for prefeasibility studies and designs) or considered by several international donors. Lake Sevan, the largest freshwater body in Armenia, is another important multipurpose water reservoir for irrigation, hydropower, and recreational uses.

Armenia also has considerable groundwater resources, which play an important role in the overall water balance. About 96 percent of the water used for drinking purposes and about 40 percent of water abstracted in the country comes from groundwater (figure 2.4) (ADB 2011).

At present, the knowledge on availability and quality of groundwater resources in the country is limited due to the lack of monitoring. After the collapse of the Soviet Union, groundwater monitoring stopped for over 20 years and has only restarted in the last 4–5 years. In the last nationwide assessment of groundwater resources in the 1980s, total groundwater resources were estimated to be 4.0 billion cubic meters per year, which included 1.6 billion cubic meters of spring flow, 1.4 billion cubic meters of drainage flow, and 1.0 billion cubic meters of deep flow (table 2.2) (USAID 2008b). In the critical Ararat valley, deep groundwater resources are estimated to be about 1.8 billion cubic meters

Map 2.1 Basin Management Organizations and River Basins in Armenia

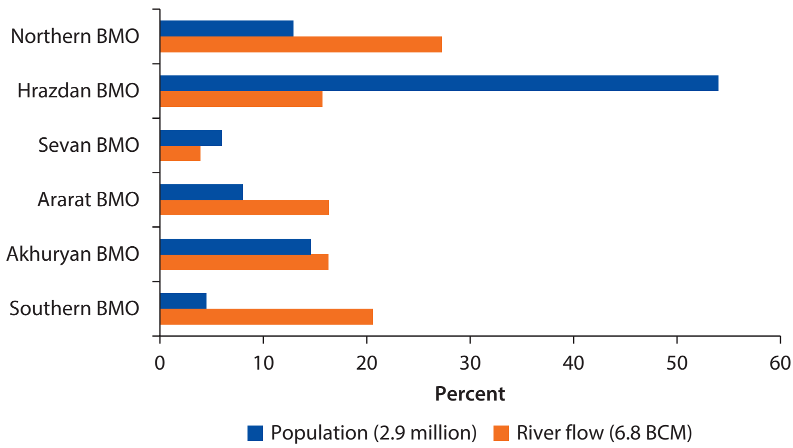


Source: USAID 2008b.
Note: A full-color version of this map may be viewed at http://www.issuu.com/world.bank.publications/docs/9781464803352.

per year (USAID 2014). This supports drinking water supply, irrigation, fish farming, and other economic activities in the area.

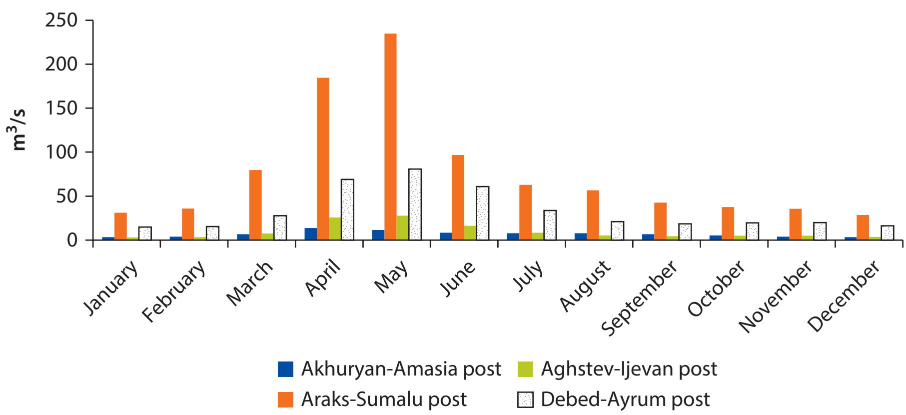
Figure 2.5 shows consumption by different water-using sectors, excluding consumption of recycled water or reuse of waste and sewage water. Water consumption has fluctuated over time. Irrigation remains the largest consumptive user.

Figure 2.1 Spatial Distribution of Population and River Flow



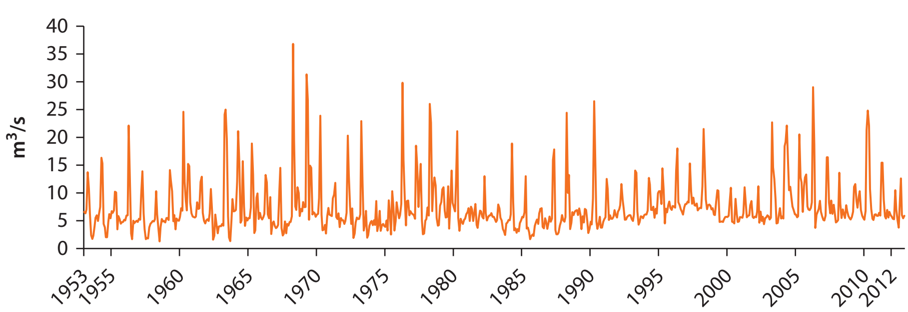
Source: USAID 2008b.
Note: BCM = billion cubic meters.

Figure 2.2 Long-Term Average Monthly Discharge



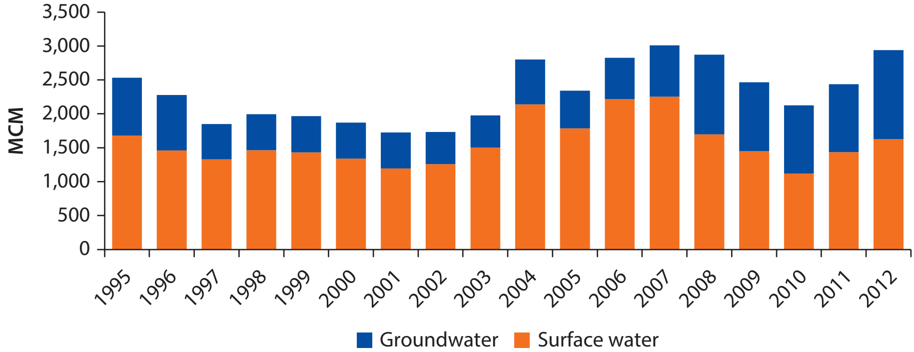
Source: Armenian State Hydrometeorological and Monitoring Service (ASHMS).

Figure 2.3 Time Series Monthly Discharge (Akhuryan-Akhurik station)



Source: ASHMS.

Figure 2.4 Water Abstraction by Source, 1995–2012



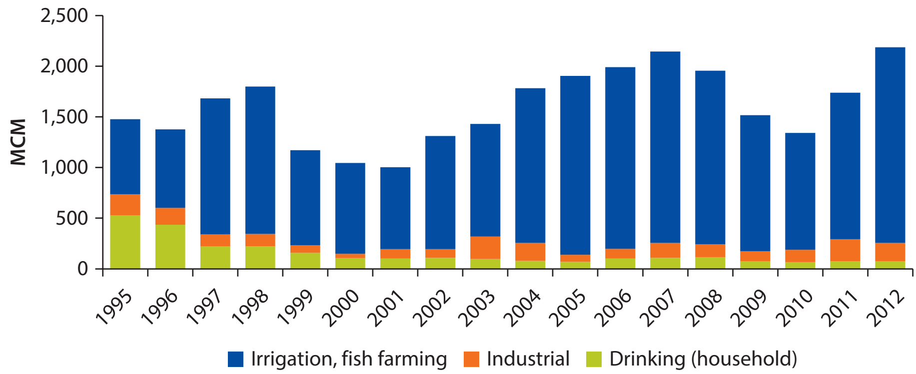
Source: National Statistical Service of Armenia.
Note: MCM = million cubic meters.

Table 2.2 Groundwater Resources of Armenia

	Area	Total groundwater resources	Of which:					
			Spring flow[a]		*Drainage flow*[b]		*Deep flow*[c]	
Basin	*km²*	*MCM/yr*	*MCM/yr*	*Total (%)*	*MCM/yr*	*Total (%)*	*MCM/yr*	*Total (%)*
Debed	3,790	506.4	113.3	22.4	356.2	70.4	36.9	7.3
Aghstev	1,730	192.8	44.0	22.8	85.9	44.5	62.9	32.6
Kura tributaries	477	54.0	19.7	36.5	29.2	54.1	5.1	9.4
Kasakh	1,480	426.5	129.1	30.3	68.2	16.0	229.2	53.8
Hrazdan	2,560	465.5	267.4	57.5	132.1	28.4	66.0	14.2
Lake Sevan	4,745	658.9	288.6	43.8	125.2	19.0	245.1	37.2
Azat	572	200.0	135.2	67.6	58.8	29.4	6.0	3.0
Vedi	633	39.1	15.0	38.4	14.7	37.6	9.4	24.0
Arpa	2,080	353.9	169.2	47.8	132.0	37.3	52.7	14.9
Akhuryan	2,784	367.1	142.8	38.9	85.9	23.4	138.4	37.7
Vorotan	2,030	544.0	171.9	31.6	251.9	46.3	120.2	22.1
Voghji	788	158.0	79.0	50.0	68.9	43.6	10.1	6.4
Meghriget	366	51.0	18.9	37.0	25.2	49.4	6.9	13.6
Total		**4,017.0**	**1,594.1**		**1,434.2**		**988.9**	

Source: Ministry of Nature Protection 2013, based on USAID 2008b; data are from the 1980s.
Note: MCM = million cubic meters.
a. *Spring flow* is artesian groundwater discharge. These values are based on field hydrogeological studies.
b. *Drainage flow* is base flow from shallow groundwater aquifers and is based on measurements in different river sections when there has been no precipitation.
c. *Deep flow* is calculated from the water balance.

Figure 2.5 Water Consumption by Sector

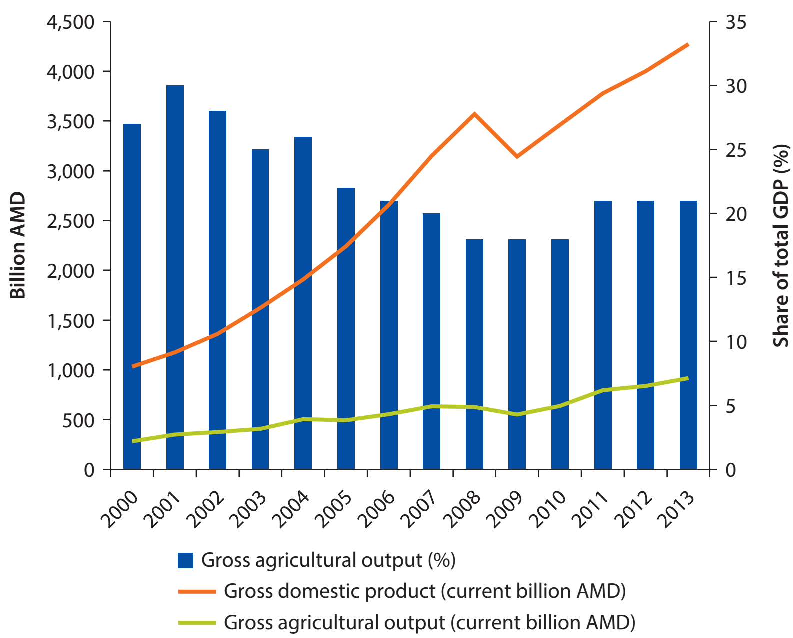


Source: National Statistical Service of Armenia.
Note: MCM = million cubic meters.

Irrigation and Drainage

Over recent decades, though the agriculture sector has added more value in absolute terms to the economy, its overall share of gross domestic product (GDP) has steadily decreased (around 18 percent in 2012) (figure 2.6). Yet, Armenia is still an agrarian society with the agriculture sector providing around 40 percent

Figure 2.6 Agriculture Value Added



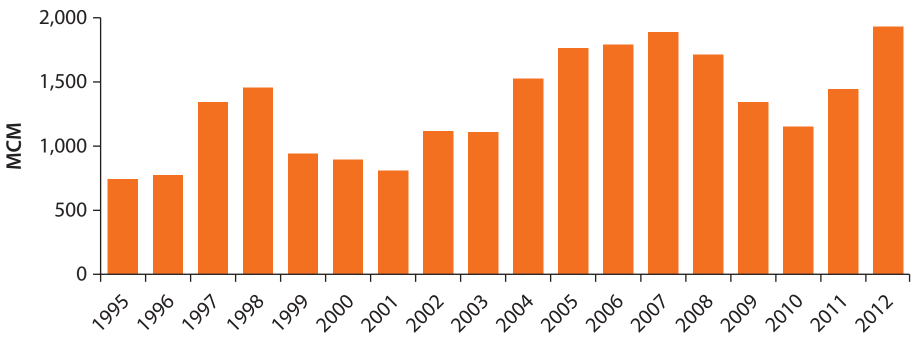
Source: National Statistical Service of Armenia.

of total employment. Moreover, with important links to the growing food processing industry, agriculture will continue to play an important role in the Armenian economy.

Agriculture in Armenia is heavily dependent on irrigation. More than 80 percent of the gross crop output is produced on irrigated lands. Wheat, potatoes, and vegetables claim two-thirds of the total irrigated arable land. The consumption of irrigation water has fluctuated significantly over time, mainly due to fluctuations in overall water availability, and reached almost 2 billion cubic meters in 2012 (figure 2.7). Total irrigable area in Armenia is around 208,000 hectares. In 2005, the net income per hectare for wheat was 65,000 Armenian drams (US$156), twice as much as on rain-fed lands in the mountainous areas. Due to agroclimatic conditions, the most fertile regions are also the greatest consumers of irrigation water. At the same time, they show the lowest water productivity: while taking 80 percent of the country's irrigation water, they generate 53 percent of the Armenian gross crop output (figure 2.8) (World Bank 2013a).

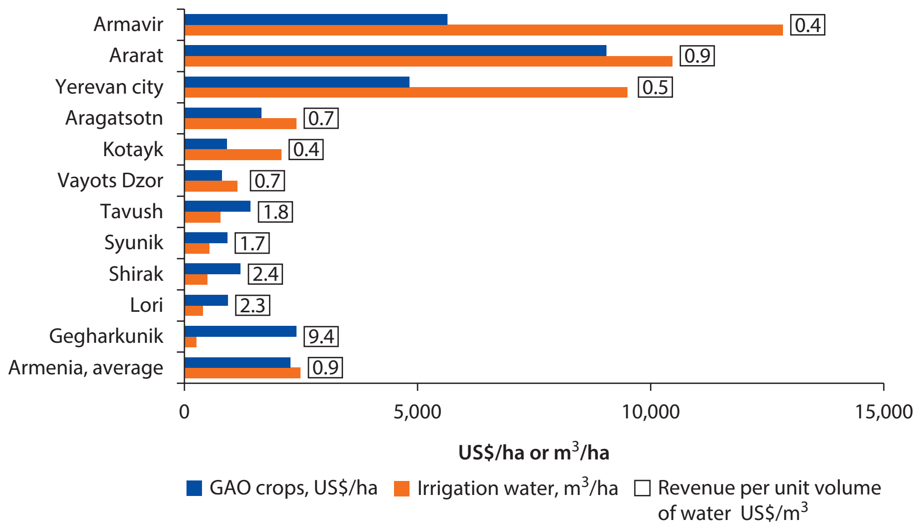
Water user associations play an important role in agricultural water management. Currently, there are 42 water user associations (WUAs) responsible for about 195,000 hectares (out of a total of 208,000 hectares of irrigable lands in Armenia). In 2013, 130,524 hectares were actually irrigated under WUAs. This difference is primarily due to rain-fed areas, areas with poor intercommunity or intracommunity networks, and lack of cultivation. The operation of secondary and tertiary systems and small pumping stations and reservoirs has been transferred to WUAs. Two State water supply agencies (WSAs) operate the main large reservoirs, big pumping stations, and main canals,[3] and deliver bulk supplies to these WUAs. Since WUAs became operational, water supply has improved, the collection of water fees has increased, and there is an increasing conversion from low-value crops (e.g., wheat) to higher-value crops (e.g., fruits and vegetables). Table 2.3 summarizes the improvements over time, and map 2.2 and figure 2.9 show the areas irrigated by WUAs by location and by crop.

Figure 2.7 Water Consumption for Irrigation



Source: National Statistical Service of Armenia.
Note: MCM = million cubic meters.

Figure 2.8 Irrigation Water Consumption and Agricultural Productivity by Province in 2010



Source: Based on World Bank 2013a.
Note: GAO = gross agricultural output.

Table 2.3 Improvements after the Operationalization of Water User Associations, 2004–2013

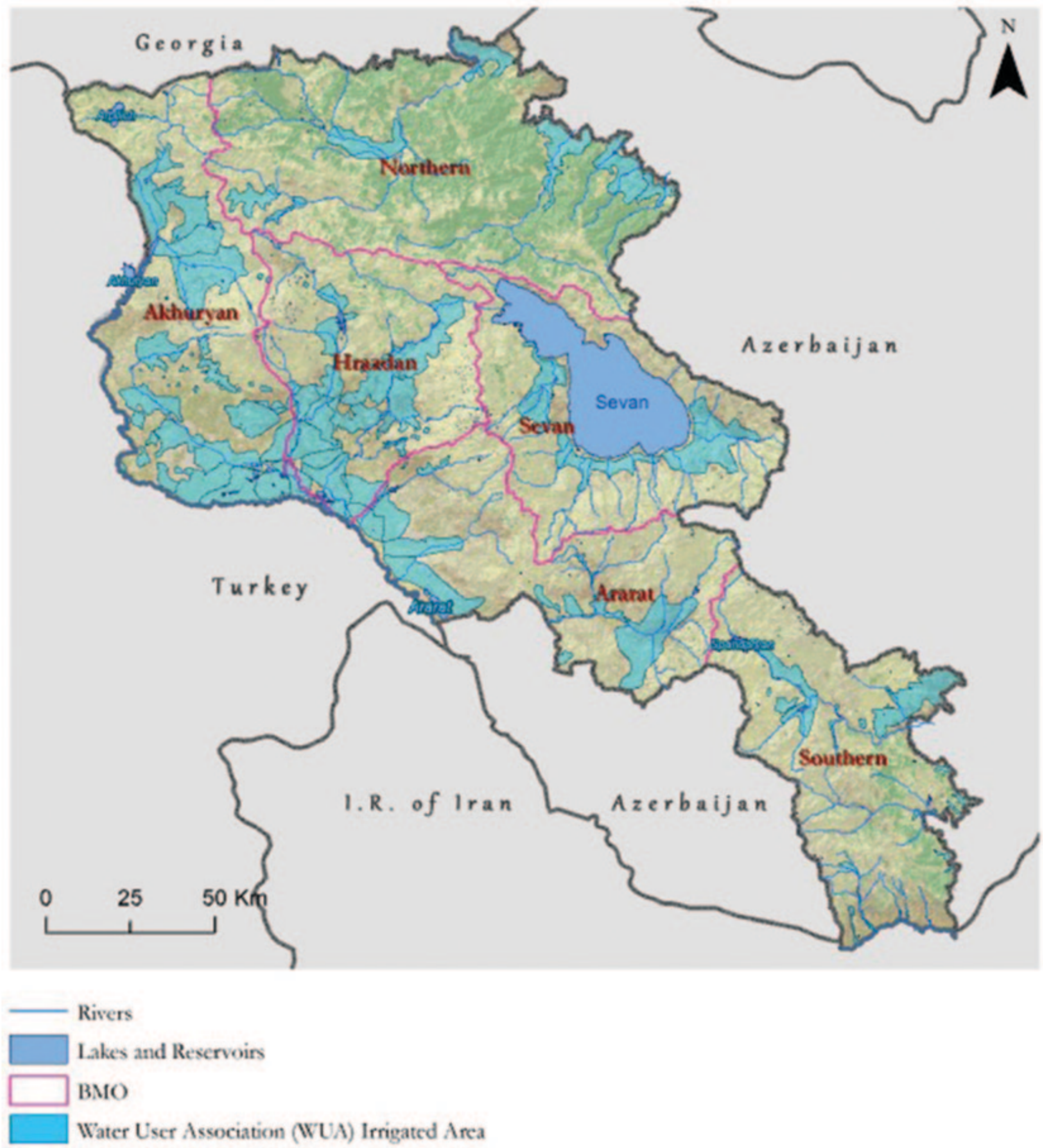
	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Irrigated area (ha)	113,366	125,648	123,298	125,632	128,860	128,076	129,194	129,406	130,180	130,524
Collection (billion AMD)	2.51	2.89	2.95	3.10	3.44	3.22	3.56	3.77	4.03	4.44
Collection rate (%)	56	66	69	73	68	87	82	83	78	86
High-value crops (%)	65	71	74	78	79	79	80	84	87	88

Source: Project implementation unit data.
Note: AMD = Armenian drams.

Water user associations are not yet financially sustainable and continue to depend on State subsidies. The irrigation service fee of WUAs is subject to a government-imposed ceiling. The current ceiling level is 11 Armenian drams per cubic meter of water, while the actual average cost is estimated at 17 drams.[4] The gap between the regulated fee and the actual cost is covered from the State budget. While the collection rate by WUAs averages 80 percent, actual cost recovery is estimated to be around 45 percent.[5] Current tariffs and subsidies do not encourage farmers to adopt more water- and energy-efficient practices or technologies. The water pricing system needs to be updated. Further financial strengthening of WUAs is a priority.

Agricultural water management is still subject to various inefficiencies. Most of the irrigation and drainage infrastructure built during Soviet times has not been adequately maintained. The budgets for rehabilitation and further infrastructure development decreased significantly from about 50 billion Armenian

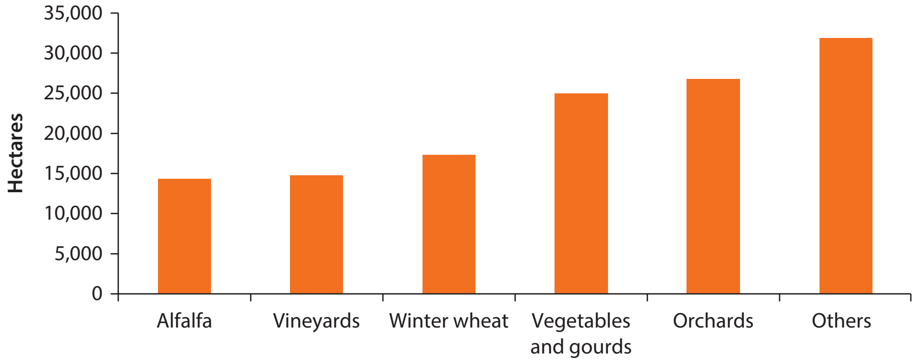
Map 2.2 Irrigated Areas under Water User Associations, 2008



Source: USAID 2008b.
Note: A full-color version of this map may be viewed at http://www.issuu.com/world.bank.publications/docs/9781464803352.

drams (US$120 million) per year during the Soviet era to 4 billion Armenian drams (US$10 million) per year on average in the period 1994–2011, including donor assistance. Operation and maintenance costs have been reduced from 25 billion Armenian drams (US$60 million) per year in the Soviet era to 8–10 billion Armenian drams (US$20–25 million) per year now (World Bank 2013a). As a consequence, water conveyance losses have gradually increased, to around

Figure 2.9 Water User Associations: Irrigated Area by Crop, 2012



Source: Project implementation unit data.

59 percent in 2012.[6] Rehabilitation of irrigation canals is needed, and water-saving technologies, such as drip irrigation, need to be adopted where economically and technically justified.

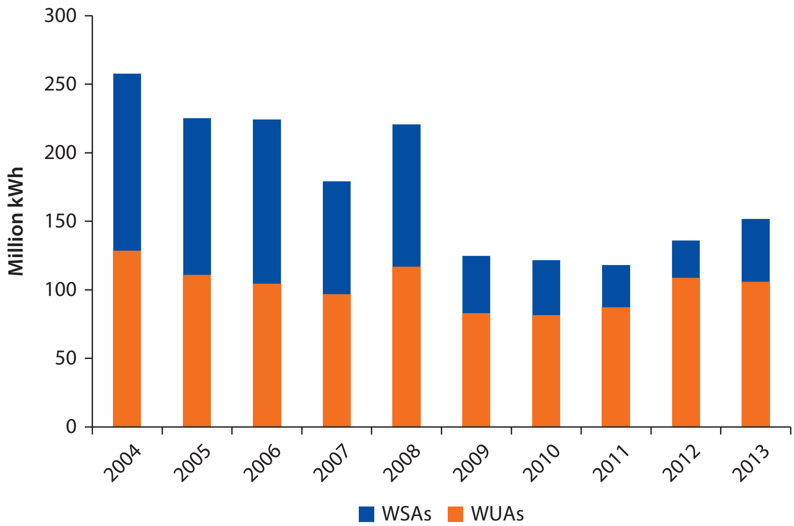
The deterioration of the drainage system has also caused an increase in groundwater levels, salinization, and waterlogging, particularly in the Ararat valley. From 2005 to 2010, the Ararat valley drainage system was rehabilitated with support from the Millennium Challenge Corporation. In addition, the rapidly expanding fish farming industry in Ararat valley has contributed to lower groundwater levels. However, unfortunately in some places, excessive withdrawals from fish farms are now being observed. In 2006, the area salinized by irrigation was 20,400 hectares and the area waterlogged by irrigation was 18,700 hectares.[7]

Widespread high-lift pump irrigation systems built during Soviet times are now uneconomical due to high energy costs. Electricity, which was heavily subsidized during Soviet times, is now supplied at market price to agricultural water users. Pump irrigation systems are now being substituted with more energy-efficient gravity schemes. As a result, electricity spending by WSAs has decreased from 129 million kilowatt-hours to 25 million kilowatt-hours (84 percent reduction) (figure 2.10).[8]

Urban and Rural Water Supply

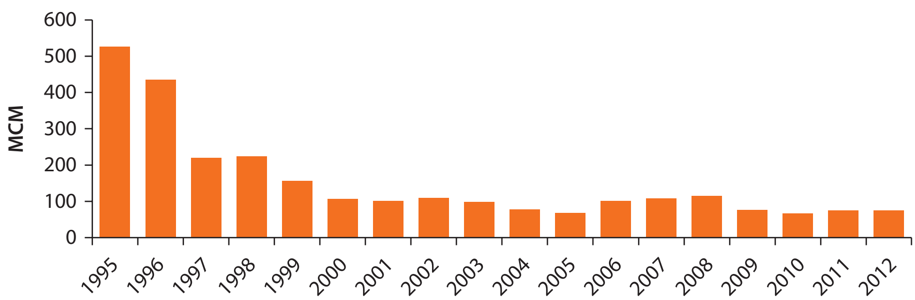
Domestic water consumption, which used to be the second-largest water user after irrigation, sharply decreased in the 1990s (figure 2.11). This dramatic drop is attributed to the introduction of water metering and a volumetric billing system. During Soviet times, domestic water bills were based on water pipe diameter and the number of household members. This practice was discontinued in 2000 when water meters were installed. The domestic water consumption data after 2000 better represent actual household water use. In 2012, domestic water consumption was 75.3 MCM per year,[9] or 25 cubic meters per capita per year.

Figure 2.10 Electricity Consumption for Irrigation



Source: Project implementation unit data.
Note: WSAs = water supply agencies; WUAs = water user associations; kWh = kilowatt-hours.

Figure 2.11 Water Consumption for Domestic Sector



Source: National Statistical Service of Armenia.
Note: MCM = million cubic meters.

For many years after the collapse of the former Soviet Union, water supply and sanitation systems in Armenia were in a serious state of disrepair. The water supply system provided water only for a few hours a day. In the early 2000s, the government set rehabilitation of water supply infrastructure and achieving 24-hour water service as top priorities. Over the past decade, water supply in Armenia has greatly improved with the increased use of public-private partnerships. Currently, the majority of the population of Armenia is served by three water and wastewater utilities under public-private partnership arrangements (table 2.4). Outside those arrangements, 560 villages (about 500,000 people) have their own arrangements.

Table 2.4 Water Supply Utilities under Public-Private Partnership

	Water and sewerage company				
	Yerevan	*Armenia*	*Shirak*	*Lori*	*Nor Akung*
Ownership	Private company	State company	51% State shareholding and 49% municipal shareholding		
Management model	Centralized	Centralized	Decentralized (community involvement)		
Operator	Veolia, France	Saur, France	MVV consortium		
Contract mode	Management, lease	Management	Management		
Contract period	Until 2016	Until mid-2016	Until mid-2016		
Population served	1.17 million	0.91 million	0.36 million		
Loan	World Bank	World Bank	KfW		

Source: World Bank 2011b.
Note: KfW = KfW Development Bank.

Table 2.5 Performance Measures for Water Supply Utilities, before PPP versus 2009

Water and sewerage company	Water supply duration (hours)		Compliance with water quality requirements		Energy consumption (million kWh)		Collection efficiency (%)		Installed water meter (% of customers)		Unaccounted for water (%)	
	Before PPP	*2009*	*Before PPP*	*2009*	*Before PPP*	*2009*	*Before PPP*	*2009*	*Before PPP*	*2009*	*Before PPP*	*2009*
Yerevan	4–6	20.4	94.5	97.8	240.3	109.6	21	97.6	0.8	96	72	81.1
Armenia	4–6	12.8	93.8	98.4	64.4	46.6	48	84.1	40	72.3	74	83.6
Shirak	4.7	10.2	98.1	99.6	0.9	1.2	49	78	12	50	85	83
Lori	4	9.5	88	92	0.96	0.92	58	80	67	85	77	71
Nor Akung	4	22.3	100	100	7.2	4.0	47	97	20	93	87	70

Source: World Bank 2011b.
Note: PPP = public-private partnership; kWh = kilowatt-hours.

The public-private partnership approach has shown success, particularly with improving water supply duration, water meter installment, and collection efficiency. Compliance with water quality requirements has also improved and energy consumption has, in most cases, been reduced (table 2.5). However, levels of nonrevenue water have remained high (70–85 percent), of which approximately 45 percent is estimated to be technical losses, such as leakages due to the age and very poor state of the physical pipework and assets, and 40 percent comprises commercial losses, including nonpayment, underpayment, and theft (World Bank 2011b). Levels of nonrevenue water have not been taken as a main performance measure under the present public-private partnership contracts.

There remain some challenges that public-private partnerships alone cannot resolve. Although the collection rate is high, the tariff is still currently too low to provide sufficient funding to cover even the routine operation and maintenance costs and investment costs. The current tariff is 200 Armenian drams per cubic meter of water, which is considered low compared to regional and international norms of around 400 drams per cubic meter.[10] The deficit is covered by government subsidies: for instance, the Armenia Water and Sewerage Company received a subsidy of 8 million drams (US$19,000) per year from 2009 to 2011 for cost recovery (OECD 2012).

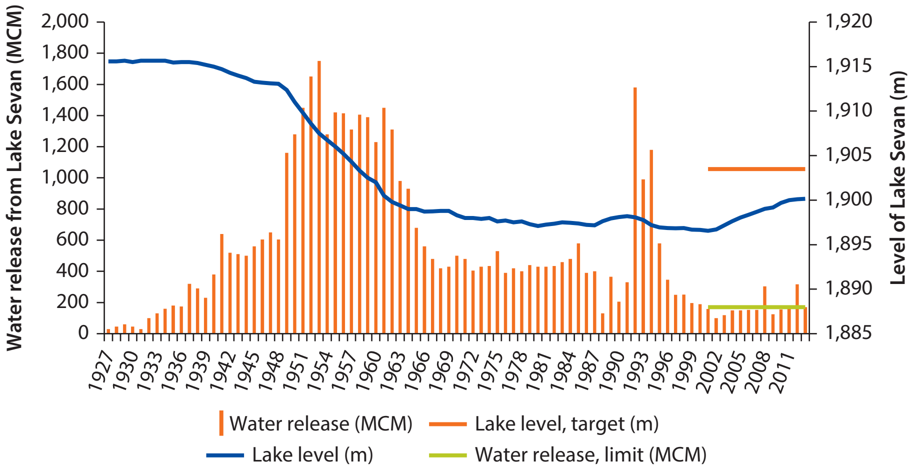
Moreover, while water supply has greatly progressed, sanitation has fallen behind. Wastewater collection and treatment systems are not sufficiently provided and operational, and wastewater is often discharged directly to water bodies or land, causing unhygienic conditions and water quality issues. Currently, 68 percent of the population (2 million, mostly urban) is connected to the sewerage network. There are 20 wastewater treatment plants, all built before the 1990s and inadequately maintained—either not operational or partially operational with mechanical treatment only. There is a need for major investment to rehabilitate and modernize wastewater treatment facilities and expand their coverage to rural areas (ADB 2011; World Bank 2011b).

Environment

Lake Sevan has environmental, economic, and social significance and is an important multipurpose water reservoir for irrigation, hydropower, and recreational uses. Lake Sevan, located in the central part of Armenia, is the largest lake in Armenia (almost 35 billion cubic meters) and one of the largest high-altitude lakes in the world. The lake is fed by 28 rivers and streams and is drained by the Hrazdan River. The lake outflow has been artificially regulated for irrigation and the Sevan-Hrazdan hydropower cascade since the 1930s. The level of Lake Sevan fell dramatically due to excessive use during the period from 1930 to the 1980s, resulting in serious environmental and ecological problems, including deterioration of water quality, destruction of natural habitats, and loss of biodiversity. A comparison between 2001 (the minimum level) and natural conditions in the 1930s shows a decrease in level by over 19 meters (from 1,915.65 meters to 1,896.55 meters above the level of the Baltic Sea), a decrease in volume from 58.5 billion to 32.9 billion cubic meters (44 percent), and a reduction of the surface area from 1,416 to 1,236 square kilometers (13 percent) (UNECE 2003, chapter 2: Lake Sevan).

Starting in the 1980s, programs to stabilize and raise the lake level were initiated, including the use of the Arpa-Sevan tunnel to transfer up to 250 MCM per year from the Arpa River. In the period 2001–13, on average 152 MCM per year were transferred to Lake Sevan through the Arpa-Sevan tunnel. The government adopted two laws[11] in 2001 that recognized the importance of Lake Sevan and aimed to raise the level by 6 meters[12] by 2030. This would add an additional 8.8 billion cubic meters to the lake. In addition to the Arpa-Sevan tunnel, the Vorotan-Arpa tunnel was built to increase the inflow to the lake. The tunnel was commissioned in 2004, and has the capacity to transfer up to 165 MCM per year from the Vorotan River.[13] Moreover, the lake outflow has been limited to 170 MCM per year for irrigation purposes (figure 2.12).[14] The Sevan-Hrazdan hydropower plants operate on a seasonal basis only during the release of Lake Sevan water for irrigation purposes.

Figure 2.12 Water Releases from Lake Sevan and Lake Level



Source: State Committee on Water Economy.
Note: MCM = million cubic meters.

As a result of these measures, the level of Lake Sevan has been steadily rising since 2001 (figure 2.12). Between 2001 and 2013, the lake level rose by 3.9 meters and its volume increased by 5.5 billion cubic meters. Various environmental indicators have also improved. In 2008, the Presidential Commission on Lake Sevan Issues was formed. However, due to continued overfishing, the lake's whitefish population has continued to decrease to near-extinction level. It was estimated at 30,000 tonnes in the early 1980s, 3,500 tonnes in early the 2000s, and only 8 tonnes in 2011 (box 2.1).

There are growing concerns with respect to the declining quality of water in the country. One main driver for this is the discharge of untreated or insufficiently treated wastewater into surface water bodies. From 2008 to 2012, the total wastewater volume doubled (from 375 million to 813 MCM per year), and untreated discharge increased seven times (from 42 million to 307 MCM per year) (figure 2.13).[16] Some of this increase can be attributed to improved measurement and the increase in discharge from fish farming. All wastewater treatment plants were built during Soviet times and are now outdated, in need of rehabilitation, and are energy intensive and expensive to operate. Most plants have stopped operating and a few are applying mechanical treatment only. The growth of the mining industry has resulted in another potential source of pollution (for example, heavy metals) to water bodies.

Water–Energy Nexus

Water resources play a critical role in the energy sector. Armenia depends on power generation from thermal, hydro, and nuclear sources (figure 2.14). The total installed capacity is 3,603 megawatts, including 1,756 megawatts of

Box 2.1 Fisheries in Lake Sevan

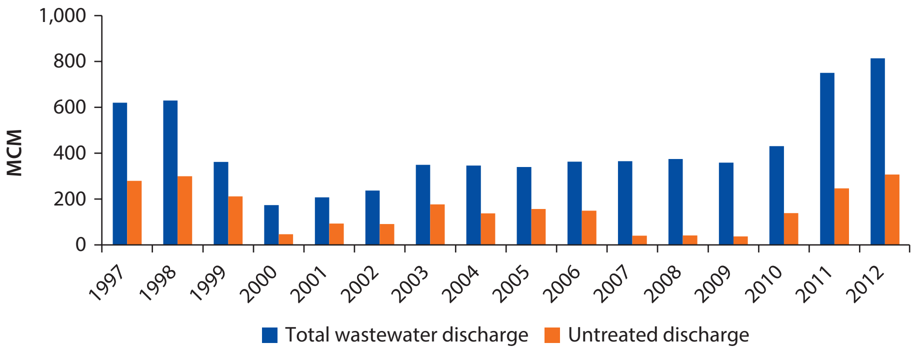
The fish species endemic to Lake Sevan are Sevan trout (*Salmo ichchan*), Sevan khramulya (*Varicorhinus capoeta sevangi*), and Sevan barbel (*Barbus lacerta goktchaicus*). During the Soviet period, common whitefish (*Coregonus lavaretu*), crucian carp, and crayfish were introduced to the lake in order to increase fish catches. However, due to years of unrestrained fishing, the fish stock has drastically decreased. According to an assessment by the Institute of Hydroecology and Ichthyology, the fish reserves in Lake Sevan decreased from 30,000 tonnes in the early 1990s to 7–8 tonnes in 2012 (EcoLur 2012). Different types of trout have dramatically reduced. All three endemic species are listed in the Red Book of Armenia (FAO 2011). In addition to the decreasing stock, the size of captured fish has also decreased. The average weight of whitefish in 1997 was 222 grams, compared to 904 grams in the 1970s (FAO 2011).

There have been different measures taken to reverse these trends in Lake Sevan. The Sevan National Park was established in 1978 and the area was designated a Ramsar site in 1993.[15] A ban on fishing (starting in 2002), particularly for trout and whitefish, is routinely applied for the winter months or for a year-long period. A plan to construct a fish hatchery for Sevan trout production is being discussed. Finally, though fishing is prohibited, enforcement is weak and economic alternatives for local fishers are not available (photo B2.1.1).

Photo B2.1.1 Fish Selling Stall, Lake Sevan

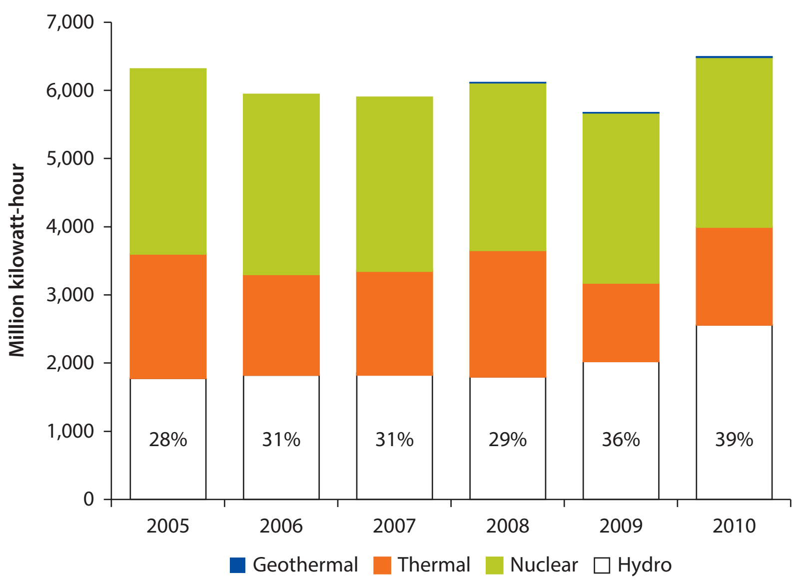
Source: ©World Bank/Ju Young Lee. Used with Permission; further permission required for reuse.

Figure 2.13 Wastewater Discharge



Source: National Statistical Service of Armenia.
Note: MCM = million cubic meters.

Figure 2.14 Electricity Production by Type

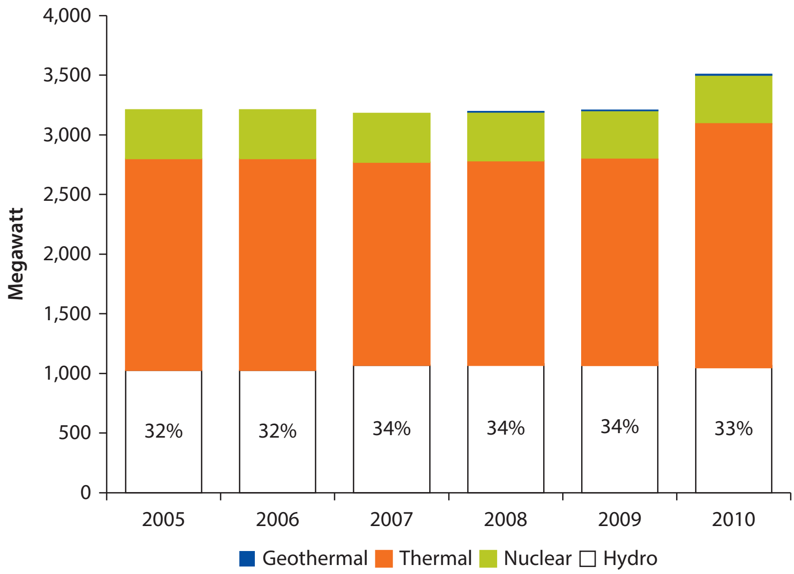


Source: United Nations 2010.

thermal power, 1,032 megawatts of hydropower, and 815 megawatts of nuclear power (figure 2.15) (World Bank 2011a). Armenia has great potential for hydropower from its mountains and fast-flowing rivers. Recent analysis finds that an additional 250–300 megawatts of generation is possible from small hydropower plants (Danish Energy Management 2011).

There are two large cascades and a number of small hydropower plants (table 2.6). Since the adoption of the Law on Privatization of State Property in 1997, all hydropower systems have been gradually privatized (especially small

Figure 2.15 Net Installed Capacity



Source: United Nations 2010.

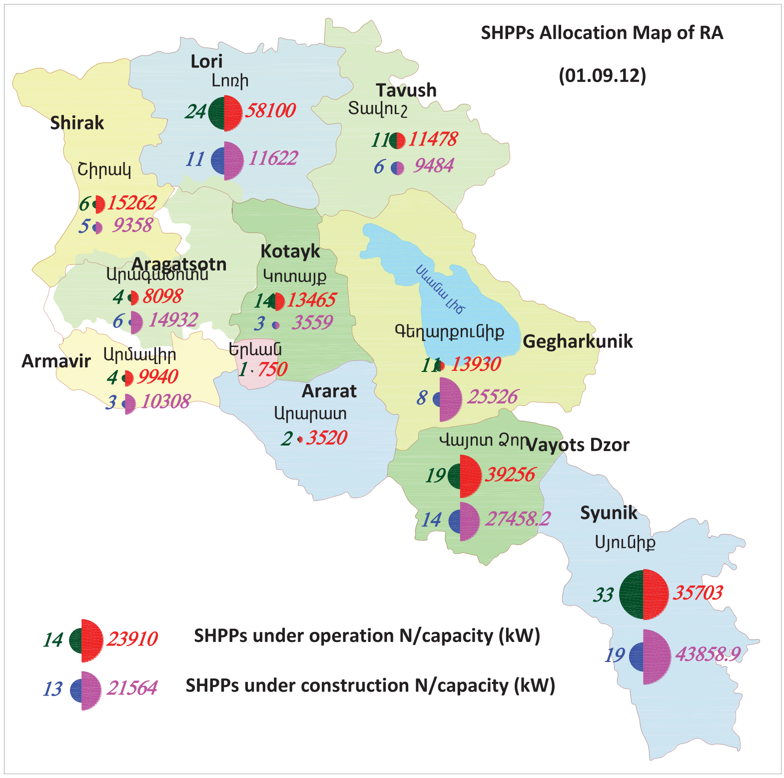
Table 2.6 Hydropower in Armenia

	Installed capacity (MW)[*]	*Actual power generation (GWh) 2012*[†]	*Commissioning date*[*]	*Ownership*[*]
Sevan-Hrazdan cascade	561	632.3	1940–62	RAO Nordic
Vorotan cascade	400	1,118.8	1970–89	Contour Global Hydro Cascade
Small hydropower plants	263.26[‡]	574.7[a]	–	Private owners
Total	**1,224.26**	**2325.8**	**–**	**–**

Sources: World Bank 2011a (*); Arthur Kochnakyan, World Bank (†); Public Services Regulatory Commission of Armenia (www.psrc.am) (‡).
Note: MW = megawatts; GWh = gigawatt-hours.
a. includes 62.1 GWh from Drozaget hydropower plant.

hydropower plants). The amendment to the Energy Law in 2001 provided for guaranteed 15-year power purchase agreements. In 2004, the Public Services Regulatory Commission adopted a feed-in tariff to drive forward investment in small hydropower plants, especially for run-of-the-river types. The Water Code was also amended to extend the water permit period to 5–10 years for small hydropower plants. As a result, the last decade has witnessed a major growth in the numbers of private small hydropower plants, spread throughout the country (map 2.3). As of 2012, there are 129 existing small hydropower plants with a capacity of 210 megawatts, and 75 more under construction with a capacity of 156 megawatts (for a total of 366 megawatts).[17] Currently, small hydropower plants provide about 6 percent of the total electricity in Armenia.

Map 2.3 Distribution of Small Hydropower Plants



Source: Hydroenergetica.
Note: kW = kilowatts. A full-color version of this map may be viewed at http://www.issuu.com/world.bank.publications/docs/9781464803352.

Some have raised concerns regarding the impact of existing and future small hydropower plants on water resources and environmental sustainability. The current permit system for small hydropower plants requires an environmental impact assessment and a study of streamflow limitations to satisfy minimum environmental flow requirements and other existing water demands. However, the environmental impact assessment is only partial and does not consider the basinwide cumulative impact. The procedures for the calculation of minimum environmental flow[18] may not be adequate, as they do not take into account seasonality and the site-specific ecosystem requirements. Moreover, small hydropower plants are not well monitored in relation to the water use permit system. Further analysis is needed on this issue.

Other power plants—thermal and nuclear—also use water resources for cooling purposes. In 2012, cooling water withdrawal and consumption were estimated to be 4–7 MCM and 3.3–6.4 MCM per year, respectively, for thermal power plants, and to be to be 23 MCM and 13 MCM per year, respectively, for nuclear power plants (table 2.7).

Table 2.7 Cooling Water Withdrawal and Consumption Estimates

	Cooling water requirement per unit power generation for recirculating system			*Cooling water estimate for Armenia*	
	Withdrawal (gallon/MWh)	*Consumption (gallon/MWh)*	*Power generation 2012 (MWh)*	*Withdrawal (MCM)*	*Consumption (MCM)*
Thermal power plant (natural gas steam turbine)	950–1,460[a]	662–1,170[a]	797,200	3–4	2.0–3.5
Thermal power plant (natural gas combined cycle)	150–283[a]	130–300[a]	2,577,028	1–3	1.3–2.9
Nuclear power plant	2,659[b]	1,481[b]	2,310,900	23	13
Total				**27–30**	**16.3–19.4**

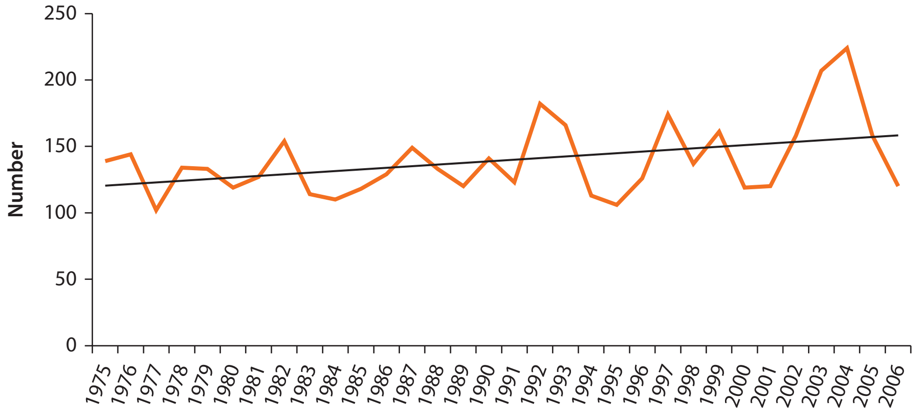
Note: MWh = megawatt-hours; MCM = million cubic meters.
Sources:
a. Union of Concerned Scientists 2013.
b. USAID 2008a (calculated from 2007 data).

Climate Change

Compared to other countries in the region, Armenia is highly vulnerable to climate change. According to the World Bank (2013b), Armenia shows high exposure, high sensitivity, and limited adaptive capacity to climate change. Studies show that climate change is already occurring in Armenia. The Ministry of Nature Protection (2009) finds that temperatures have increased by 0.85°C and precipitation has decreased by 6 percent in Armenia over the past 80 years. These changes in temperature and precipitation vary by region and season. Summer temperatures increased by 1°C during the period 1935–2007, whereas winter temperatures increased by 0.04°C. The Ararat valley region has become more arid, while the southern and northwestern areas and the Lake Sevan basin have had a significant increase in precipitation during the last 70 years. The frequency of severe hydrometeorological phenomena (here defined as frosts, hailstorms, heavy rainfall events, and strong winds) also increased by 1.2 cases per year (statistically significant) over the period 1975–2005 (figure 2.16) (Ministry of Nature Protection 2009).

Future climate projections indicate continued increases in temperature and decreases in precipitation (table 2.8). The Ministry of Nature Protection (2010) projects a 4°C increase in temperature and 9 percent reduction in precipitation by 2100. The Ararat valley region is projected to experience higher warming than the rest of the country for all seasons. Temperature increases are predicted to be highest in the summer, and precipitation decline to be the greatest in the summer, the key agricultural season. The largest changes in precipitation are expected at altitudes higher than 1,700 meters, which are the main areas of river flow formation (Ministry of Nature Protection 2010). On average (across different models; see appendix C for projected precipitation and temperature changes by 2050 across the range of global circulation models), overall water resources availability is expected to reduce (ENVSEC and UNDP 2011). Increased air

Figure 2.16 Extreme Hydrometeorological Events in Armenia, 1975–2006



Source: Ministry of Nature Protection 2010.

Table 2.8 Climate Change Scenarios by 2100

Category	*2030*	*2070*	*2100*
Temperature[a]	+1°C	+2°C	+4°C
Precipitation[a] (%)	−3	−6	−9
Evaporation (%) (compared to 1991–2006)	+1.6	+2.5	+3.7
Snow cover (%) (compared to 1961–1990)	−7~11	−16~20	−20~40
River flow (%) (compared to 1961–1990)	−6.7 (or 0.3 BCM)	−14.5 (or 0.7 BCM)	−24.4 (or 1.2 BCM)

Source: Ministry of Nature Protection 2010.
Note: BCM = billion cubic meters.
a. 1935–2007 data were compared with respect to the base period 1961–90.

temperature and lower precipitation will increase evaporation rates and reduce winter snowpack and spring runoff, resulting in less river flow. Snow cover is expected to decrease as much as 20–40 percent by the end of the 21st century and river flow by almost a quarter. However, there are some regional differences; in some basins, such as the Vorotan and Voghji, river flow may increase (Ministry of Nature Protection 2009).

The impacts of climate change will be particularly severe for Lake Sevan. The 28 rivers and streams that flow into the lake are expected to decrease by 41 percent or 310 MCM by 2100 (table 2.9). The tunnels that divert water to Lake Sevan may also face reduced flows at the source (for example, Arpa River flow is projected to decrease by 66 percent by 2100). Furthermore, due to the reduction in volume and increase in air temperatures, water quality may deteriorate (Ministry of Nature Protection 2010).

In the agriculture sector, the most climate-sensitive sector, crop yields are predicted to decline and irrigation demands to increase with climate change. The

Table 2.9 Predicted Changes in the Main Elements of Lake Sevan Water Balance

	Precipitation			*Evaporation*			*River flow*		
Date	*MCM*	*MCM change from the baseline*	*Change (%)*	*MCM*	*MCM change from the baseline*	*Change (%)*	*MCM*	*MCM change from the baseline*	*Change (%)*
1961–1990 (baseline)	457	n.a.	n.a.	1,076	n.a.	n.a.	758	n.a.	n.a.
2030	449	−8.0	−1.8	1,158	82.0	7.6	665	−93.0	−12.3
2070	445	−12.0	−2.6	1,192	116.0	10.8	559	−199.0	−26.3
2100	436	−21.0	−4.6	1,268	192.0	17.8	449	−309.0	−40.8

Source: Ministry of Nature Protection 2010.
Note: MCM = million cubic meters. n.a. = not applicable.

Ministry of Nature Protection (2010) estimates that by 2030, yields of the main agricultural crops will decrease by 8–14 percent without adaptation (9–13 percent for cereals, 7–14 percent for vegetables, 8–10 percent for potatoes, and 5–8 percent for fruits). In order to maintain crop yields, substantially more irrigation will be needed. For example, in the Ararat valley region, irrigation water requirements for vegetables are predicted to increase by 38–42 percent by 2100 (UNDP 2011). However, with overall water resources availability expected to decline, these demands may be difficult to fully meet in the future. According to the Ministry of Nature Protection (2009), a 25 percent reduction in river flow is projected to result in a 15–34 percent reduction in the productivity of irrigated cropland (average 24 percent). The total future losses to the agricultural sector are estimated at around 75 billion to 170 billion Armenian drams (US$180 million to US$405 million). This is equivalent to a loss of 2–5 percent of GDP (in 2009), or more if indirect losses (for example, food processing industry, input markets) are also included.

The energy sector will also be affected, as Armenia uses its rivers for hydropower generation and cooling water for nuclear and thermal power plants. In particular, the country's energy program to further develop hydropower and increase the energy dependency on hydropower could be at risk. Reduced river flows both in time and space coupled with an increased demand for irrigation water should be taken into account in future hydropower planning.

Climate change is also likely to decrease water supply in transboundary basins. Future streamflow is assessed to decrease by 45–65 percent in the Khrami-Debed basin (Armenia/Georgia) and by 59–72 percent in the Aghstev basin (Armenia/Azerbaijan) by the end of the century (UNDP 2011).

Notes

1. Usable water resources of 9 billion cubic meters per year (USAID 2008b) divided by 2012 population of 2.9 million.
2. FAO AQUASTAT database: http://www.fao.org/nr/water/aquastat/main/index.stm.

3. The current inventory of irrigation infrastructure includes 3,000 kilometers of primary and secondary canals, 18,000 kilometers of on-farm or tertiary canals, 400 pumping stations, and 2,200 deep and shallow wells (World Bank 2013a).
4. The actual cost of water varies significantly from one scheme to another, subject to climatic, agronomic, and topographic conditions. In some cases, it may go up to 30 drams per cubic meter when more pumping is needed (World Bank 2013a).
5. It is important to differentiate between the cost recovery of the whole irrigation system, which currently is estimated at the level of 45 percent (in 2011 the overall operation and maintenance expenses of the system, including water supply agencies, were 8.5 billion drams or US$ 20.5 million, and the amount collected by water user associations was 3.85 billion drams or US$ 9.3 million), and the collection rate, which on average is 80 percent. This means that if the ceiling is removed or increased the cost recovery may improve significantly, as in general water users pay for the received services (World Bank 2013a).
6. Project implementation unit data.
7. FAO AQUASTAT database: http://www.fao.org/nr/water/aquastat/main/index.stm.
8. Project Implementation Unit/Tigran Ishkhanyan.
9. National Statistical Service of Armenia.
10. The current tariff level needs to increase by 33 percent in 2014 to achieve full cost recovery for operation and maintenance, debt service, and depreciation by 2022 (World Bank 2011b).
11. On Lake Sevan (May 15, 2001) and on Adoption of the Annual and Complex Programs of Activities for the Use, Protection, Reconstruction, and Reproduction of the Lake Sevan Ecosystem (December 14, 2001).
12. To 1,903.5 meters above the level of the Baltic Sea, the minimum level required to improve lake conditions, according to the calculation of local scientists.
13. The Vorotan-Arpa tunnel transfers water from the Vorotan River to the Kechut reservoir, which then releases water to Lake Sevan through the Arpa-Sevan tunnel.
14. An exception can be made at the request of the Ministry of Agriculture and with parliamentary approval, for example in a drought year. In 2014, it is approved to abstract up to 240 million cubic meters.
15. Wetland of international importance as designated by the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention).
16. National Statistical Service of Armenia.
17. Personal communication with Inessa Gabayan, director at Hydroenergetica.
18. A new method of estimating minimum environmental flow (consecutive 10-day minimum flow from historical data) was introduced in 2011 to replace the old method (75 percent of the 95th percentile of previously recorded monthly water flow levels).

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