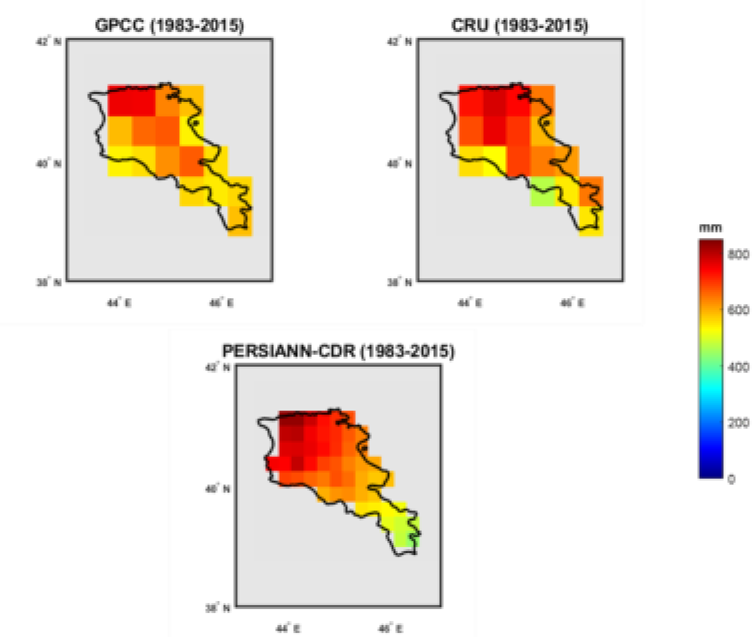
UNDP/GCF National Adaptation Plan to Advance Medium and Long-Term Adaptation Planning in Armenia Project

# Stocktaking exercise to identify legal, institutional, vulnerability assessment and adaptation gaps and barriers in water resources management under climate change conditions

**(First Draft version)**

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## List of Abbreviations

| | |
|---|---|
| AHS | Armenian Hydrometeorological Service |
| ASPIRED | Advanced Science & Partnerships for Integrated Resource Development |
| BMA | Basin Management Area |
| BMO | Basin Management Organisation |
| BOD | Biological Oxygen Demand |
| CC | Climate Change |
| CCSM | Community Climate System Model |
| CDR | Climate Data Record |
| CEPA | Comprehensive and Enhanced Partnership Agreement |
| CHRS | Center for Hydrometeorology and Remote Sensing |
| COD | Chemical Oxygen Demand |
| CRU | Climatic Research Unit |
| DO | Dissolved Oxygen |
| DSS | Decision Support System |
| EMIC | Environmental Monitoring and Information Center |
| ESM | Earth System Model |
| EU | European Union |
| EUWI+ | European Union Water Initiative Plus |
| FAO | Food and Agriculture Organization |
| GCF | Global Climate Fund |
| GCM | Global Circulation Model |
| GEF | Global Environmental Fund |
| GIS | Geographic Information System |
| GPCC | Global Precipitation Climatology Centre |
| GPCP | Global Precipitation Climatology Project |
| HPP | Hydro power plant |
| IPCC | Intergovernmental Panel on Climate Change |
| MAGICC | Model for the Assessment of Greenhouse-gas Induced Climate Change |
| ME | Ministry of Environment |
| OECD | Organisation for Economic Co-operation and Development |
| PBC | Public Basin Councils |
| PERSIANN-CDR | Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks - Climate Data Record |

| | |
|---|---|
| PRECIS | Providing Regional Climates for Impacts Studies |
| RA | Republic of Armenia |
| RBD | River Basin District |
| RBMP | River Basin Management Plan |
| RCM | Regional Climate Model |
| RCP | Representative Concentration Pathways |
| SCENGEN | Regional Climate Scenario Generator |
| SNCO | State Non Commercial Organization |
| SRES | Special Report on Emissions Scenarios |
| SWC | State Water Cadaster |
| UNDP | United Nations Development Program |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USAID | United States Agency for International Development |
| WEAP | Water Evaluation and Planning |
| WFD | Water Framework Directive |
| WMO | World Meteorological Organization |
| WRMA | Water Resources Management Agency |
| WUA | Water Use Association |

## Executive Summary

This "Stocktaking exercise to identify legal, institutional, vulnerability assessment and adaptation gaps and barriers in water resources management under climate change condition" was prepared within the "National Adaptation Plan to advance medium and long-term adaptation planning in Armenia" GCF-UNDP project, which supports the Government of Armenia to advance its medium and long-term adaption planning, including for water sector.

Armenia is considered as a country with high baseline water stress by the World Resource Institute, and is ranked as the 34th most water stressed country among the 164 UN member countries. According to the Organisation for Economic Co-operation and Development (OECD), Armenia is a country with low water availability, and subject to water stress with 45% Water Exploitation Index[1].

The proper management of water resources plays a key role in the socio-economic development of Armenia. Taking into account all available water resources in the country, Armenia has sufficient resources to supply approximately 3,100 $m^3$ per capita per year[2]. These water resources, however, are not evenly distributed in space and time, with significant seasonal and annual variability in river runoff.

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 single purpose, mainly for irrigation. On average, the per capita storage capacity of Armenia is about 465 $m^3$, which is considered low for a semi-arid country, and represents less than 20% of the per capita storage capacity of neighbouring countries of Azerbaijan and Turkey.

Groundwater resources play an important role in the overall water balance of Armenia. About 96% of the water used for drinking purposes and about 40% of water abstracted in the country comes from groundwater. Irrigation remains the largest consumptive water user in the country.

Compared with other countries in the region, Armenia is highly vulnerable to climate change. Armenia shows high exposure, high sensitivity, and limited adaptive capacity to climate change. Future climate projections indicate continued increases in temperature, and in the agriculture sector, the most climate-sensitive sector, crop yields are predicted to decline and irrigation demands to increase with climate change. In order to maintain crop yields with a growing population, substantially more irrigation will be needed unless new water saving technologies is massively introduced. Overall water resources availability, however, expected to decline, and meeting these demands is likely to be difficult in the future. Thus, the overall objective of this study is to assess the vulnerability of water resources due to climate change and propose a roadmap for climate change adaptation planning for water resources in Armenia, including recommendations related to climate

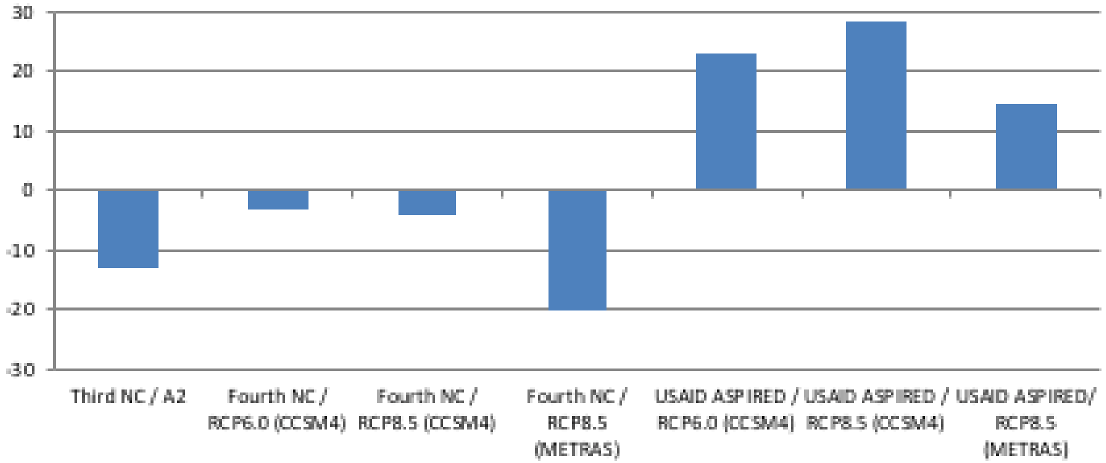
[1]) According to OECD, if the Water Exploitation Index is higher than 40%, than the country is considered under water stress.
[2]) According to the Republic of Armenia Law "On National Water Program of the Republic of Armenia" (2006) the total annual quantity of usable surface water resources composes about 8.1 billion $m^3$, and the quantity of usable groundwater resources composes 1 billion $m^3$.

change consideration in water resource management through overcoming legal, institutional and data gaps and barriers.

**Chapter 1** of the report provides an analysis of policy, legal and institutional framework of water sector and identified gaps and barriers in the context of climate change. Particularly, in this chapter stocktaking of water sector policy, legal and institutional framework is performed, and the recent developments since 2015 are analysed. The main emphasis is on how the policy, legal and institutional framework enable coping with the impact of climate change on water resources of the country.

The analysis of recent developments in the legislative, policy and institutional frameworks of the water sector in Armenia shows certain progress and improvements to cope with the impact of climate change on water resources. This includes continued improvements in water legislation and policy, development and adoption of river basin management plans, improvements in surface and groundwater quantity and quality monitoring, and introduction of tools and mechanisms to promote more efficient water use by different sectors, and strengthen compliance assurance. The analysis, however, also identifies policy, legal and institutional deficiencies and barriers to cope with climate change impact and factor in climate change adaptation in water management of the country. This includes deficiencies in the legislation (Water Code, National Water Policy, National Water Program, Tax Code), the need to strengthen the institutional framework (Basin Management Organizations, Public Basin Councils) and streamline certain functions (water resources monitoring, functions and roles of the former National Water Council), as well as the need to include the climate change factor in the process of issuing (or extender) water use permits.

**Chapter 2** reviews, identify and systematize available information on climate change impacts on water resources, and vulnerability assessments of water resources due to climate change, and performs an in-depth assessment and identification of inconsistencies between different assessments and uncertainties in the assessments, with focus on key vulnerability components and analysis of information gaps for assessing the vulnerability of water resources and management due to climate change.



***Projected river flow changes at Vedi-Urtsadzor post by 2100, %***

The review of the national communications of Armenia to the UNFCCC, river basin management plans that are adopted or in the process of development, and other relevant studies, revealed several inconsistencies in terms of assessment of vulnerability of water resources within the climate change context, as shown in the diagram above. Such inconsistencies are due to data gaps (and particularly insufficient hydro-meteorological in flow formation zones), deficiencies in applied methodologies (very large ambiguity in calculation of natural flow data, using “standard” coefficients for return waters), large gaps of actual water use data and deficiencies in water balance calculations, as well as uncertainty of the global and regional models for the precipitation forecast. Insufficient hydro-meteorological monitoring makes it particularly difficult to assess the “share of the impact of climate change” on the reduction of river flow.

**Chapter 3** is dedicated to review climate change adaptation measures in water sector implemented since 2015, including water sector adaptation plans and international adaptation projects. Compilation of existing water use sub-sector strategies, and identification of existing adaptation programs/ projects, identifies synergies between development and adaptation objectives, policies, plans and programs, including the 2017 Comprehensive and Enhanced Partnership Agreement between the Republic of Armenia and the European Union, and other strategic documents. Gender inclusiveness is also analysed in this chapter, in the context of gender mainstreaming in climate change adaptation planning in water sector.

The analysis shows that while several internationally funded projects, implemented in the water sector of Armenia promote adaptation to climate change (through reduction of water losses, regulation of river flow, improvement water quality and increasing water availability, improvement of water management at national and river basin levels, etc.), there is insufficient level of integration of climate change adaptation into the development planning process of Armenia, and particularly in the existing water use sub-sector strategies. Thus, in irrigation, which is the largest water use sector in Armenia, the irrigation norms are based on historical data and do not encounter the significant increase in irrigation water demand due to increased air temperature and subsequently increased evaporation due to climate change. The “Concept Note on Dam Construction”, which was adopted in 2019 and which is designed to ensure safe and reliable irrigation water supply in the country, does not factor in the climate change impact, as a result of which river flow was reduced in the country. In the hydropower sector, which in recent years is abstracting over 5 billion $m^3$ of water annually, the “Strategic Development Program of the RA Hydropower Sector”, adopted in 2011 also does not take into consideration the forecasted river flow decrease due to climate change. Thus, integration of climate change adaptation into development planning process of Armenia becomes prerogative.

Finally, **Chapter 4** of the study compiles the list of identified gaps and barriers related to climate change consideration in water resources management based on the analysis undertaken in the previous chapters of the study, and develops recommendations to overcome the gaps and barriers including on legal/regulatory and institutional issues, as well as data for evidence-based decision making. The recommendations are presented in a form of a road map on how to fill in the identified legal, institutional, capacity and gaps in water sector within the context of climate change adaptation. The proposed recommendations to fill in deficiencies, gaps and barriers are summarized in the table below.

*Proposed recommendations to fill in deficiencies, gaps and barriers in water sector within the context of climate change adaptation*

| Area/sector | Policy, legal, institutional deficiencies and data gaps | Recommendation to fill in deficiencies, gaps and barriers |
|---|---|---|
| Improvement of water management legislation for full consideration of water resources vulnerability and adaptation to climate change | Water Code | Introduce the justified urgency for water resources management under climate change;<br>Provide provisions containing legal basis for the effective implementation of water reuse, as well as establish privileges and incentives for water re-use;<br>Set provisions for rejecting an application for a water use permit should also include cases where activities carried out under water-use permit may increase the vulnerability of water resources to climate change;<br>Add in the list of the documents subject to mandatory public notification the forms of public participation in water resource vulnerability reduction and adaptation measures |
| | Law on Fundamental Provisions of the National Water Policy | Introduce the ideology of water resources management under climate change |
| | Law on National Water Program[3] | |
| | Law on Lake Sevan | Introduce legal regulation mechanisms in place to take into account and to assess Lake Sevan ecosystem vulnerability to climate change changes (reduction of river inflow, increase in evaporation, decrease in precipitation, changes in water balance components) |
| | Tax Code | Provide provisions containing legal basis for the effective implementation of water reuse, as well as establish privileges and incentives for water re-use;<br>Revise the water use rates, which are unjustifiably low |
| Improvement of institutional framework for water management in terms of water resources vulnerability assessment and | Basin Management Organizations (BMOs) | Strengthen the role of BMOs as the authorities in the basins in charge of implementation and control of adaptation measures and climate change data sharing at the local level, as prescribed by the law |
| | Public Basin Councils (PBCs) | Establish sustainable foundations for formation and operation of PBCs as a mechanism of cooperation between different competent authorities and public in the basin, and playing an active role in water resources management, including water resources adaptation to climate change |
| | Functions and roles of the dissolved National Water | Established a Center of Excellence for Water Resources and Climate Studies in order to strengthen the institutional framework of water sector |

[3] Amendment to the RA Law on the National Water Program (2006) are currently under development, which includes a number of provisions for approaching the EU Floods Directive, in particular the requirements for water hazards and risk management plans.

| Area/sector | Policy, legal, institutional deficiencies and data gaps | Recommendation to fill in deficiencies, gaps and barriers |
|---|---|---|
| adaptation to climate change | Council | |
| | Water resources monitoring | The functions of the Ministry of Environment related to monitoring should be clearly defined, including the approved list of water objects, indicators and schedule for providing qualitative and quantitative monitoring demand of water resources and summarizing monitoring data, the preliminary assessment of water resources quality and quantity |
| Improvement of the assessment and forecast of vulnerability of water resources in the context of climate change in Armenia | Evaporation data from Lake Sevan and large reservoirs | Installation of the mobile observation gauges at the Lake Sevan and the reservoirs with 20 million $m^3$ water capacity and larger in order to measure the evaporation from the surface of water |
| | State Water Cadaster and data sharing system | Establish a mechanism and tools for linking the hydrological, water quality, meteorological and irrigation water accounting databases with the State water cadaster system |
| | Mechanisms and tools to collect and share actual water use data | Establish a mechanism to make the actual water use data collected through SCADA system available for state agencies and organizations dealing with water |
| | Methodologies for assessment of vulnerability of water resources under climate change | Improve the methodology on calculation of natural flow, based on the actual river flow and water use data, including verification of the developed methodology in pilot basin;<br>Introduce modern hydrological models to assess the vulnerability of water resources in the river basin level and to analyze the existing hydrological information;<br>Develop a new method for assessing the vulnerability of water quality in a river basin under climate change |
| | Methodology for assessment of vulnerability of groundwater resources under climate change | Introduce modern hydrogeological models to assess the vulnerability of groundwater under climate change, based on the good international practice, and including separation of the impact of anthropogenic pressures from the impact of climate change |
| Filling in the gaps in planning of climate change adaptation programs in water sector | Drinking water supply and sanitation | Incorporation of the forecasted changes in quantity and quality of drinking water resources due to climate change in the "Water Supply and Sanitation Strategy and Financing Plan for 2018-2030 of the Republic of Armenia" |
| | Irrigation water supply | Update the existing irrigation norms in Armenia (2007) through introduction of crop water requirement model based on FAO Irrigation and Drainage Paper No 56 ("Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements"), and taking into consideration increased irrigation water demand due to climate change impact;<br>Update the "Concept Note on Dam Construction" (2014) designed to support the process of shifting from mechanical to gravity fed irrigation in the country, through performing hydrological analysis in terms of water availability due to new e-flow requirements and climate change impact; |

| Area/sector | Policy, legal, institutional deficiencies and data gaps | Recommendation to fill in deficiencies, gaps and barriers |
|---|---|---|
| | | Renovate primary and secondary irrigation canals to reduce high percentage of water losses in the irrigation water supply systems |
| | Hydropower development | Introduce requirement to consider climate change scenarios and projected river flow changes in the process of issuance of water use permits or extending the permit for hydropower generation purposes;<br>Revise the "Strategic Development Program of the RA Hydropower Sector" (2011) to take into consideration the water resources vulnerability in the context of climate change |
| | Mainstream and enhance gender sensitivity, inclusiveness and gender-balanced participation in climate change adaptation policies and plans in water sector | Consider sex-disaggregated data and analysis of gender implications and risks in subject related policies, programs and strategies, and establish M&E system;<br>Strengthen the participation of women in decision-making and management of climate change adaptation in water sector, through capacity building, awareness raising campaigns for gender balanced participation in design and implementation of policies, programs and strategies on climate change adaptation in water management |
| | Long-term strategic development plans and Marz development programs | Incorporation of forecasted impact of climate change on water resources and climate change adaptation planning given that these strategies underline the improvement of water supply and sanitation, as well as agricultural development as high priority |
| Modernization of the hydro-meteorological observation system and services | Hydrological monitoring network | Renovate the following hydrological monitoring posts with modern equipment: (1) Hrazdan-Hovtashen (Masis); (2) Metsamor-Ranchpar; (3) Arpa-Areni; (4) Vorotan-Tatev HPP;<br>Establish 14 new hydrological posts at flow formation zones of the river basins for conducting regular measurement of water level, river flow, water and air temperature in order to conduct more accurate assessment and forecast of river flow changes in the country under climate change: (1) Shoghvak-Dzoragyugh; (2) Ashotzq-Hartashen; (3) Halavar-Meliqgyugh; (4) Gegharot-Aragats village; (5) Mili-Mets Gilanlar; (6) Vedi-Khosrov; (7) Azat-Lanjazat; (8) Yeghegis-Getikvanq; (9) Geghi-Ajabaj; (10) Masrik-Nerqin Shorzhja; (11) Chichkhan- Bashgyugh; (12) Aghstev-Krivoymost; (13) Sisian-Arevis; (14) Loradzor-Shenatagh |
| | Meteorological monitoring | Renovate the following high-altitude meteorological posts with modern equipment: (1) Semyonovka; (2) Vardenyatz (Yanikh);<br>Establish 5 new meteorological stations for more accurate assessment and forecast of climate change impact on high-altitude zones: (1) Yeghnajur; (2) Jajur mountain pass; (3) Sotq; (4) Tashtuni-maintain pass; (5) Sevaberd |

| Area/sector | Policy, legal, institutional deficiencies and data gaps | Recommendation to fill in deficiencies, gaps and barriers |
|---|---|---|
| Study, mapping, and introduction of an early warning system for flood hazards | Flood and mudslide monitoring and early warning systems | Carry out mapping and inventory of flood and mudslide areas, based on GIS technologies.<br>Create an early warning system in flood zones based on the best international experience.<br>Strengthen the institutional capacity for monitoring and managing floods and mudslides. |

# CHAPTER 1. ANALYSIS OF POLICY, LEGAL AND INSTITUTIONAL FRAMEWORK OF WATER SECTOR AND IDENTIFICATION OF GAPS AND BARRIERS IN THE CONTEXT OF CLIMATE CHANGE

## Summary of Chapter 1

The reducing of water vulnerability and implementation of adaptation measures to climate change is an essential step in ensuring provision of efficient water resources management system and clear and complete legal regulations on water resources, their adaptation to climate change. Effective management of water resources is the most important precondition for adaptation to climate change, which at the same time requires the state to protect human rights in relation to water accessibility and other essential human rights related to water resources. The right of access to clean water and sanitation presupposes a number of the state obligations in relation to the provision of this right. The legislation on water resources management must be flexible enough to ensure that adaptation measures are implemented.

This chapter dedicated to the discussion and analyses of the water legal and institutional framework for implementation of adaptation measures, in particular, effective management of water resources, improvement of decision-making process in the field of water resources, improvement of legal regulations related to this issue and their conforming to the conditions of flexibility and adaptability to climate change, as well as clear definition of the functions of authorized bodies in this field, their clear differentiation, as well as the introduction of the tools needed to implement these functions and carry out effective control and monitoring.

The main emphasis is on how the policy, legal and institutional framework enable coping with the impact of climate change on water resources of the country. In this context, all possible barriers in the legal and institutional systems were identified and discussed.

Implementation of relevant international obligations, adoption and implementation of relevant national legal acts, implementation of required measures, and international cooperation in this field were also analyzed.

## 1.1 The concept and criteria of water resources adaptation to climate change

Through the study of the international best practices and the theoretical sources related to the field, it becomes clear that the steps to ensure the adaptation of water resources to climate change should not be an end in themselves, and that legal regulations aimed at them should meet the following requirements:

1. Ensuring a reasonable balance between legal certainty and legal flexibility, by defining legal regulations that can be valid also in climate change conditions, without becoming controversial or unclear;

2. Legal regulations shall provide for the possibility of interpretation and application in accordance with the changed situation and the improvement of the system;
3. Ensuring public access to the governance system and public participation in the decision-making process, as well as guaranteeing the right to judicial protection in order to ensure the realization of goals in a legitimate way.
4. Management of natural resources at all levels, i.e., state, territorial and local levels.
5. Effectiveness of the legal bases for achieving the goals, which implies the existence of legal regulations that are sufficient to achieve the set goal [4]. This principle includes the availability of measures and tools for practical application and implementation of legal regulations, as well as the absence of legal barriers during their application and implementation [5], which is a real guarantee for achieving the set goals.

Measures for water resources vulnerability reduction and adaptation to climate change also imply balancing the interests of all water users and clearly defining their rights and responsibilities when establishing appropriate legal regulations.[6]
The analysis of the laws and legal acts of the Republic of Armenia on water resources management, protection and other issues related to water resources indicates that the above-mentioned criteria, despite the shortcomings and gaps, are also reflected in the legislation of the Republic of Armenia. In the framework of this legal study, the legal regulations related to water resources were assessed and analyzed in terms of adaptation to climate change, emphasizing mainly some problems in the RA water legislation, water resources management bodies and the adequacy of powers in this context granted to them according to the RA legislation, availability of the mechanisms required for their realization, water resources monitoring, availability of the mechanisms taking into account the factors related to climate change when issuing water use permits, mechanisms for providing public participation in the field of water resources management.

With regard to the relationship with the European Union in this field, it is to be noted that within the framework of the EU WFD Common Implementation Strategy, an activity on Climate Change and Water was initiated in 2007 aimed at incorporating consideration of climate variability and change into the implementation of EU water policy. The developed Guidance Document 24 on “River Basin Management under Climate Change," focuses on the following issues:

1. EU water legislation and its ability to allow and support adaptation to climate change.
2. The importance of integration with other policies.
3. WFD and objective-setting under a changing climate.
4. How adaptation is addressed in the first RBMPs.
5. The role of adaptation in the second and third river basin management cycles.

Related to the aspects of adaptation measures relevant to the WFD, the Guidance Document mentions:

[4] A.M. Keessen et al., ‘Transnational River Basin Management in Europe’, 2008 Utrecht Law Review 4, no. 3, pp 35-56.
[5] A.W.G.J. Buijze, ‘Effectiviteit in het bestuursrecht’, 2009 Nederlands Tijdschrift voor Bestuursrecht 8, pp 228-237.
[6] H.F.M.W. Van Rijswick, Moving Water and the Law, 2008; Van Rijswick & Havekes 2012, supra note 15.

- Take account of likely or possible future changes in climate when planning measures today, especially when these measures have a long lifetime and are cost-intensive, and assess whether these measures are still effective under the likely or possible future climate changes.
- Favour measures that are robust and flexible to the uncertainty and cater for the range of potential variation related to future climate conditions. Design measures based on the results of water pressures assessment carried out previously including climate projections.
- Choose sustainable adaptation measures, especially those with cross-sectoral benefits, and which have the least environmental impact, including GHG emissions.
- Avoid measures that are counterproductive for the water environment or that decreases the resilience of water ecosystems.

At present, the above is very important for Armenia in the process of development of river basin management plans. With the decrease in precipitation and the anticipated increase in average temperature, it is forecasted that evaporation will increase, and snow precipitation and snow melting in spring will reduce. As a result, the reserves of water resources will reduce, and the forecasts on the reserves can greatly assist river basin managers when incorporating climate change in their respective river basin management plans.[7]

[7] Assessing the Vulnerability of Water Resources in the Republic of Armenia under Climate Change, Yerevan 2018. pp 15-16:

## 1.2. The need to reflect the reduction of water resource vulnerability and adaptation in the context of climate change and its enshrining in the RA legislation

### 1.2.1 The legislation of the Republic of Armenia on the reduction of water resource vulnerability and adaptability in the context of climate change

Climate change and the resulting various problems are directly or indirectly related to the life, health and living conditions of each individual, the proper activity of individual states, as well as the policies and actions of organizations formed in different dimensions of the international community and cooperation. Therefore, such a comprehensive topic has been gradually but steadily incorporated into both the domestic legislation of individual countries and the international legislation of the central institutions of international law.

The history of the formation and development of water legislation in the Republic of Armenia, which began in the 1998s, evidences that legal and institutional measure to address the vulnerability and adaptability of water resources to climate change have been taken mainly in recent years. Proof of this is the changes in this direction in a number of legal acts of the Republic of Armenia, as well as the adoption of new legal acts, of which, in particular:

1. The Government Protocol Decision N 3-16 of the Republic of Armenia "On Approving the State Environmental Monitoring Concept" dated 25.01.2018, the provisions of which provide a basis for consistently solving monitoring problems, developing national capacities for the management of information on the state environmental monitoring, ensuring a comprehensive assessment of the condition of the environment and natural resources by providing implementation of more effective environmental policy.
2. The Decision “On approving the procedure for Running the State Water Cadaster and Invalidating the Decision №1060-N of the RA Government dated July 23, 2003” (02.02.2017 №68-N), which approved the new procedure for running the Water Cadaster,
3. The content of the water basin management model plan approved by protocol decision №45 on 26.10.2017.
4. The RA Law "On Making Amendments and Addenda to the Water Code” adopted on 21.12.2015, on the basis of which the repeated or secondary use of water resources is encouraged and promoted.
5. The RA Government Decision №1187-N adopted on 08.09.2017 "On approval of the Annual Plan for 2018 for Recovery, Conservation, Reproduction, Natural Development and Utilization Measures for Lake Sevan Ecosystems”.
6. The RA Government Decision №947-N adopted on 04.09.2014 “On Approval of the Procedure for the Establishment of a Unified Electronic Database for Lake Sevan and its Catchment Basin Monitoring, Collection, Registration, Summarizing and Providing of Information“.

7. The RA Law on “Environmental Impact Assessment and Expertise” adopted in 2014, and the currently circulated draft law on making amendments and addenda to the law, as well as a number of other legal acts.

To better understand the current legal framework of the field, to assess the existing legal regulations more comprehensively, to outline the shortcomings and gaps more clearly, we present below the approaches and provisions on the issue under discussion envisaged under the RA Water Code, international treaties ratified by the RA, relevant EU Directives, other normative legal acts, certain policies and concept papers.

In particular, in spite of the fact that almost all concepts and definitions, basic principles of water resources and system management, use and protection, as well as a number of other basic provisions and regulations provided for in Article 1 of the RA Water Code [8] are indirectly but clearly related to the assessment of the vulnerability of water resources under climate change. None of the provisions related to those concepts, however, directly provide for definitions and legal arrangements for *climate change, water resources vulnerability or adaptation to it.* Moreover, defining the purpose of the Code, Article 6 of the RA Water Code stipulates: " The main purpose of this Code is the conservation of the national water reserve, the satisfaction of water needs of citizens and economy through effective management of useable water resources, securing ecological sustainability of the environment, as well as the provision of a legal basis to achieve the objectives of this Code." We believe that in order to implement each component of this provision, the process of assessing the vulnerability of water resources to climate change and adaptation planning must be taken into account along with a number of other factors.

◊ Therefore, we consider it necessary and justified to clearly reflect the ideology of water resources management under climate change, and perhaps the processes aimed at that goal in the Water Code. We are sure that it should run as a golden thread through this normative legal act defining the policy of the country's water resources and envisaging all the processes, starting from the Article setting out its purpose to all the legal arrangements of various institutions.

It should be noted that the same gap also applies to the RA Law “On the Fundamental Provisions of the National Water Policy”, since in spite of the purpose of this law being ensuring access to water resources of required quantity, regime and quality for improvement of the present and future welfare of population, the development of the socio-economic system of the Republic, and meeting the ecological needs, the Law does not provide for any legal arrangements related to the regulation of the issue under discussion.

In addition to the above, the RA Law “On National Water Program” is also of central importance for the water resources management. Article 1 of this Law provides for the relations related to the establishment and implementation of the National Water Program of the Republic of Armenia, involving assessments of national water reserve, strategic water reserve, usable water resources, supply of and demand for water, main issues of water conservation and development and its prospects, implementation of measures of the National Water Program based on the preconditions

[8] RA Official Bulletin 2002.07.10/24 (199), adopted 04.06.2002, has come into force 10.10.2002.

of water resources being limited, constituting one of the main means for protection of human life and health, fauna and flora, and ensuring their accessibility. We strongly believe that also the climate change is a fundamental factor that must be a basis for defining the subject of regulation and content of this Law. The Law, however, mentions "climate change" only in the Annex to the Law on Water Resources Management, noting that the impact of climate change and anthropogenic effects on flow must also be assessed during the assessment of water resources components. There is no mention of implementation of measures for adaptation to climate change in the Law or in its Annex.

◊ Given the cornerstone importance of the issue, however, we believe that it will be more fundamental if the idea of adaptation to climate change and certain measures for this purpose, which are among the baselines for water resources management, are more adequately reflected in these laws.

Drawing attention to the legislative reforms mentioned at the beginning of this paragraph, it should be noted that Article 25.1, adopted as a result of the amendment to the current Water Code, which came into force in 2016, stipulates: “In order to economically promote the repeated (secondary) use of water generated as a result of drainage from fish farming and crayfish farming for other purposes, norms for the calculation of nature use charges promoting the repeated (secondary) use of water resources are established in accordance with the “Law on Environmental and Nature Use Charges. Repeated (secondary) water use may be carried out by other persons for agricultural or industrial purposes.”

It should be noted that with the adoption of the RA Tax Code, the RA Law “On Environmental and Nature Use Charges” was repealed and Article 25.1 of the Water Code was amended in 2018. The latter will come into force in 2020 and has the following wording.

“1. The Tax Code of the Republic of Armenia shall provide privileges for calculation of nature use charges for establishing appropriate infrastructure for repeated (secondary) use of water resources removed after water use and for the persons implementing water withdrawal from the water resource for repeated (secondary) water use.
For repeated (secondary) water users, the nature use charge for water resources supplied for repeated (secondary) use is not calculated.
2. Repeated (secondary) water use may be carried out in accordance with the meaning defined by the Law “On the National Water Program of the Republic of Armenia”, in compliance with the requirements for water used according to the water use purpose”.

At present, taking into account the conditions stipulated by the Code for saving water resources in the Republic of Armenia, for entrepreneurs in the field of fisheries and crayfish farms and secondary water users, as well as based on the processes of the implementation of the Sustainable Development Goals[9], this provision has a very important role and significance in environmental and ecological terms. However, it should be borne in mind that this provision, which has been in force

[9] https://www.un.am/hy/p/sustainabledevelopmentgoals

since 2016, and formulating its improved definition in the near future, will not be sufficient for several reasons.

◊ First of all, it is not clear from the wording of the discussed norm whether the repeated and secondary water uses are identified or not, the limits for secondary water use are not envisaged, the relations between the 1st and 2nd water users, the institution of risk control remain unregulated, there are no conditions to ensure the interest of the repeated or secondary water user in this process. Moreover, the mechanisms for the calculation of nature use fees that promote the repeated (secondary) use of water resources under the tax legislation are not clearly defined so far.

In particular, the Articles 214 and 215 of the Tax Code of Armenia establishes the procedure for calculating the natural resources utilization fee subject to payment to the State Budget for entrepreneurs carrying out fishery and crayfish breeding activities according to surface water use and extracted groundwater quantities.

◊ The procedure for implementing this process in both the Water Code and the Tax Code, the mechanisms for implementing "promotional norms" are not yet fully available for the implementation of the relevant subjects by the addressees, which is why Article 25.1 of the Water Code cannot be interpreted as a necessary and sufficient legal basis. Although in some communities of the Republic of Armenia the use of wastewater from fish farms is already being carried out, but only after the full implementation of the necessary tools, we consider it possible to have a wide application of the legal regulation by a large number of relevant entities. In particular, there is a need to clarify whether double and secondary water use is the same or not. Moreover, Article 25.1 of the Water Code does not clearly regulate the issues of water use permits, secondary water use limits and a number of issues in the relations between primary and secondary water users.

◊ We believe that the reformulation of Article 25.1 of the Water Code should be a legislative reform on the measures for reduction of water resources vulnerability and adaptation to climate change, which should be implemented by eliminating the current obstacles and solving the involved problems.

In this context, we consider it important to address also the very low water use rates, which not only do not promote rational and efficient use of water, but also represent a contributing factor for not reducing high leaks in water distribution and water use systems (up to 80% in the field of drinking water supply and around 50% in the field of irrigation water supply). Although Article 78 of the RA Water Code provides for the application of water management economic mechanisms for promoting rational use of water resources, the water intake rates established under the RA Law No. 864 “On the Rates of Natural Resources Charges” adopted in 1998, and the ones defined by the RA Tax Code of 2018 do not contribute to this policy in any way. Thus, in the current system, in case of surface water intake (except for water intake from Lake Sevan), it is AMD 0 for the use of each cubic meter for irrigation, AMD 0.5 for use with drinking and household purposes. Hydropower does not pay for water at all, although it does have an impact on the environment, which is why in many European countries a partial fee for water is used for hydropower.

◊ We believe that the revision of the rates of nature use fees will be a major step in the policy of this sector, especially for the reduction of large leaks in water distribution and water use systems, for the rational and efficient water use.

As a basis, we can accept the comprehensive study on "Promotion of Economic Mechanism Reforms in Water Management in Armenia" implemented by Organization of Economic Cooperation and Development (OECD) in 2014. The study presents changes to water intake fee rates that will promote the efficient water use on the one hand, and will not create payment problems for water users on the other. Among the proposals is the establishment of a payment of 0.1 AMD / $m^3$ water intake for HPPs, which will not have a significant impact on the tariff of electricity supplied to customers and can provide an additional income of more than AMD 500 million per year for strengthening the water sector management and monitoring network.

From this point of view, it should be noted that in May 2020 the draft law on making amendments and additions to the RA Code on Administrative Offenses was drafted and into under circulation. The draft document related to doubling the administrative fines for violating water use rules, water resources protection rules, voluntary works affecting waters, water intake and water supply.[10]

Climate, climate changes and their consequences are related to the impact not within certain countries and not only on certain activities in that country, but to the whole planet. It would be impossible to point out a single state that has been excluded from the effects of climate change in general and from the scope of assessments of climate change impact on water resources, water ecosystems, and water reserves in particular. The Republic of Armenia is actively involved in the international processes of reducing the vulnerability of water resources and developing an effective policy of adaptation to climate change.

In this context, it is important to emphasize that the international treaties ratified by the Republic of Armenia are an integral part of the RA legislation. As provided by the Constitution of the Republic of Armenia, in case of conflict between the norms of international treaties ratified by the Republic of Armenia and those of laws, the norms of international treaties shall apply. This means that all international documents, including those related to climate change and other related documents have a great place and role in the RA legislation. In particular, Armenia is involved in various international climate change processes, has ratified the UN Framework Convention on Climate Change[11], the Kyoto Protocol to the Convention[12], the Paris Agreement[13], the Convention on Biological Diversity[14] and a number of other documents that are key cornerstones for Armenia on the way to consolidating efforts for solution of numerous problems. It should be noted that the geographical location of Armenia, as a mountainous country with no access to the sea and with vulnerable systems and the provision of national security of the country, require giving preference to the direction of adaptation to climate change.

[10] https://www.e-draft.am/en/projects/2517
[11] RA MFA Official Bulletin 2004.12.20/4(12), adopted 09.05.1992, has come into force 21.03.1994
[12] http://kyotoprotocol.org/
[13] RA MFA Official Bulletin 2017 1 (38), 26.07.17 ՔՄՊ, art. 7, adopted 12.12.2015, has come into forc 20.04.2017
[14] https://www.cbd.int/doc/legal/cbd-ru.pdf

The "Paris Agreement on the UN Framework Convention on Climate Change" was adopted at the 21st Conference of the Parties to the UN Framework Convention on Climate Change held in Paris from November 30 to December 12, 2015, according to which, all countries of the world assumed commitments aimed at curbing climate change. According to the Agreement, the reduction or limiting of greenhouse gas emissions by developing countries shall start in 2020. All parties must formulate and regularly update the actions / contributions envisaged by them at the national level, defining the goals of mitigating the climate change. The Armenian parliament ratified the Paris Agreement on 8 February 2017. It establishes an expanded transparency framework that envisages providing accountability and analysis by countries on emissions, mitigation measures, and assistance provided or received.
In international context, it is also very important that by signing the Comprehensive and Enhanced Partnership Agreement, Armenia has agreed to harmonize its national legislation with the European Union legislation. One of the first steps in harmonization is the analysis of national water legislation in the context of the five EU directives related to the sector, which are:

Water Framework Directive,
Floods Directive,
Urban Waste Water Directive,
Drinking Water Directive and
Nitrates directive.

Climate change has a serious impact on the conditions of and pressures on the aquatic environment, which are managed by the Water Framework Directive[15]. It is indisputable that climate change impacts cannot be immediately apparent, and in the first stage they cannot be easily distinguished from normal climate fluctuations; however, it must be borne in mind that a policy containing long-term and comprehensive solution will be needed for a longer period, which will perform an umbrella function and cover many areas of improvement and prevent serious problems. In other words, if climate changes are not taken into account at present, it may lead to a reduction in the results and effectiveness of the contributions needed or measures planned to achieve the goals of the Water Framework Directive. In view of the climate change effects, the European Commission has identified water resources management as a priority.

The Water Framework Directive is based on the integrated principles of water resources management, including a step-by-step approach related to characterization of risks, monitoring and action plans in the basis of river basin management planning[16].

It should be noted that one of the important steps taken in Armenia in recent years is the implementation of the policy of the RA Government on the approval of river basin management model plan and the water basin management model plan, which were implemented based on a number of decisions. It is worth mentioning that the RA Government decisions on approval of Ararat

[15] https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF

[16] Water vulnerability under climate change, Yerevan 2012:Third National Communication of Armenia to the UNFCCC (TNC) UNDP/GEF/00060737

(2016-2021) [17], Southern (2016-2021)[18], and Akhuryan (2017-2022) [19] water basin management plans and priority actions for effective management have been formally adopted. In addition, the development of Sevan and Hrazdan water basin management plans started in March 2018, and is planned to be presented at the stakeholders' discussion in May-June 2020.

Nevertheless, there are some concerns about the water basin management plans. According to the Comprehensive and Enhanced Partnership Agreement (CEPA) signed on 24 November 2012 between the Republic of Armenia on the one hand and the EU and European Atomic Energy Community and their member states on the other hand, Armenia has assumed the obligation of developing river basin management plans in line with the principles of the EU Water Framework Directive (WFD), including conducting consultations with the public, and publishing these plans based on WFD Articles 13 and 14.

According to the EU WFD, as well as advanced international experience in water resources management, the river basin management plan guides us on how to achieve a "good ecological status" in a given river basin, or the same as a "healthy river basin" while trying to meet the needs of water users. It is of technical nature.

The main purpose of river basin management plans is to develop measures to help meet the requirements for flora and fauna to achieve "good" status. These activities are called action plans. The basis for the development of the action plan is the situation of the river basin, as well as the analysis of the man-made impact on the rivers.

One of the main steps in the development of river basin management plans is the interconnection of man-made activity with its impact on the aquatic ecosystem, i.e., pressure and impact analysis. The pressure and impact analysis must be specific to the site, and as a result of the analysis, the problem and the reasons for that, the water bodies at risk must be clearly identified. An action plan must be developed for each water body at risk, which means that the action plan is specific to the location and pressure.

There is a misconception in Armenia that a river basin management plan is a tool for organizing daily water use, particularly for distribution/supply of water, while it is **not an operational management document**, but a policy document that highlights the main issues for each 6-year planning cycle and provides appropriate measures for their solution. In spite of the above, many in Armenia consider the river basin management plans as operational management document for everyday use, on the basis of which water use permits must be issued. Accordingly, river basin management plans are considered as water distribution plans, and despite the requirements of Article 2 of the RA Water Code[20], are still interpreted as an operational management document, which is not in line with the WFD and the advanced international experience of water resources management.

[17] 31.03.2016, 338 – N
[18] 26.05.2016, 539-N
[19] 09.03.2017, 240-N
[20] According to Article 2 of the RA Water Code, if the international treaty of the Republic of Armenia stipulates other norms for the regulation of water relations than those envisaged in the Water Code, then the norms of international treaties are applied.

This is the main reason that the measures / actions included in the South, Ararat and Akhuryan water basin management plans (adopted by the RA Government in 2016-2017) have not been implemented in practice, even for those plans that do not require significant funding. The above-mentioned water basin management plans are used only, when issuing water use permits as necessary (reference is made to the sections on water balance and water economy balance, which are not included in the river basin management plans according to the WFD).

Taking into account that Armenia has made a clear commitment under the CEPA to develop river basin management plans in line with the WFD principles within 5 years of the Agreement's entry into force, **there is a need to reach a consensus on the development of the plan's goal, key steps, action plan and clear implementation mechanisms as soon as possible**.

In this regard, we consider it necessary to refer to the RA Prime Minister’s 1 June 2019 decision on approving the roadmap for the implementation of the Comprehensive and Extended Partnership Agreement with the European Union and the European Atomic Energy Community and their member states[21]. The measures in the roadmap provided in the Annex to this decision include the development of the concept of adaptation to climate change and national action plan before the first quarter of 2021, aimed at mitigating, reducing and preventing climate changes in agricultural, economic and other sectors that have possible impact on climate, and planning and implementing activities in line with the measures.

According to the Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, the roadmap provides for revision and full approximation of water legislation, including revision and approval of basin management plans for six territorial basin management bodies, aimed at their approximation with the requirements of Directive 2000/60 / EC.

However, there are concerns related to the **roadmap** provided in Annex 666-L to the RA Prime Minister’s 1 June 2019 decision on approving the roadmap for the implementation of the Comprehensive and Extended Partnership Agreement, in the following two aspects:

1) The provisions on the Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (EU Water Framework Directive) are very general and do not significantly promote fulfillment of Armenia's commitments assumed under the CEPA.

For instance, in the context of the Water Framework Directive, in terms of the adoption of domestic legislation and the definition of a competent body, the roadmap proposes to approve the list of rivers prohibited for the construction of HPPs, which is not directly related to Armenia's commitments under the CEPA. Regarding other provisions too (analysis of river basin area characteristics (Article 5), preparation of water quality monitoring plans (Article 8) and preparation of river basin management plans, consultations with the public and publication of those plans (Articles 13 and 14) the roadmap lists general measures, the implementation of which is not sufficient to fulfill Armenia's commitments.

[21] N 666-L, adopted on 01.06.2019, has come into force on 08.06.2019

For example, in order to prepare water quality monitoring plans in line with the principles of the WFD, it is necessary to start implementation of a number of fundamental measures as soon as possible. Thus, according to the WFD, the basic information required for the classification of water bodies ("excellent", "good", "moderate" and "bad" status) is provided through biological monitoring (which is not carried out in Armenia), while chemical and hydro morphological monitoring provides supporting information. Biological monitoring allows having a clear picture of the impact of pollution on the ecosystem and its activities, for which it is necessary to observe the populations of rivers, streams and lakes at monitoring points. One of the advantages of biological monitoring is that it responds to the impact over time. It is unlikely that chemical monitoring will provide information on the sudden and short-term polluting emissions/discharges, which, however, will have a long-term impact on biodiversity (depending on the duration of the life cycle of affected organisms). Introducing biological monitoring is quite a time-consuming and labor-intensive process, while the roadmap does not mention anything about it. Moreover, monitoring in line with the principles of the EU WFD includes different types (control, operational, research, reference, and shift) depending on the status of the water body, the pressures on it, which differs significantly from the current logic and approaches of monitoring in Armenia.

2) The Roadmap also contains certain inaccuracies regarding the Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on assessment and management of flood risks (EU Floods Directive). In particular, the roadmap in Annex 666-L to the RA Prime Minister's decision mentions that there is no need for further approximation, since the following commitments have already been carried out: (a) Implementation of initial flood risk assessment (Articles 4 and 5 of the EU Floods Directive); (b) Preparation of flood hazard and risk maps (Article 6); and c) Preparation of flood risk management plans (Article 7).

Despite numerous discussions with the representatives of the "Service of the Hydrometeorology and Active Influence on Atmospheric Phenomena" SNCO under the RA Ministry of Emergency Situations responsible for the floods, the Water Committee of the RA Ministry of Territorial Administration and Infrastructure, as well as the representatives of other agencies, the evidence indicates that none of the above-mentioned measures mentioned in the roadmap have been implemented in accordance with the requirements of Articles 4-7 of the EU Floods Directive. Moreover, there are no developed plans for flood risk management in Armenia, as stated in the road map.

In order to promote compliance and harmonization of Armenia's water resources management field with the principles of the EU Water Framework Directive, the European Union, in turn, provides significant assistance to Armenia through various initiatives and programs. In particular, within the framework of the Eastern Europe, Caucasus and Central Asia component, a National policy dialogue on comprehensive management of water resources has been held in Armenia since 2007. Within the framework of this process, basic assistance has been rendered through providing support to water quality monitoring laboratories, equipment to other departments and implementing regional projects, where Armenia has been actively involved[22]. One of the best summaries of the cooperation

[22] Assessing the Vulnerability of Water Resources in the Republic of Armenia under Climate Change, Yerevan 2018, pp 11-12

in question is the opening of the renovated and re-equipped laboratory of the Environmental Monitoring and Information Center SNCO in January 2020, which allows for recording significant progress, especially in terms of water monitoring.

Like in many other countries, in the Republic of Armenia too there are certain areas of nature, which are designated by the state as areas or objects of special significance due to their aesthetic, historical-cultural, environmental, health and a number of other features. In the field of water resources, Lake Sevan is endowed with such a status and has been declared a national treasure[23], a strategic reservoir of fresh water. It has been given the status of a specially protected natural area via the National Park and the legal regulation of public relationship related to Lake Sevan is implemented in accordance with the RA Law "On Lake Sevan"[24] and a number of other normative legal acts. The law defines the legal and economic bases of the state policy for proper development, restoration, reproduction, of natural resources (hereinafter referred to as reproduction), maintenance and use of Lake Sevan as an ecosystem of environmental, economic, social, scientific, historical, aesthetic, health, climatic, recreational (rehabilitation) and cultural value of strategic importance.

◊ Having a highly important role for the state and society, and representing one of the primary subjects of climate change impacts in the field of water resources in the Republic, an ecosystem approach should be applied; and a number of environmental, legal and economic measures for improvement of Lake Sevan ecosystem and mitigation of climate change impacts on it, undertaken. These should include improvement of the legal and institutional frameworks for Lake Sevan ecosystem conservation, strengthening of criminal, administrative responsibility for relevant offenses, raising the level of public awareness on lake ecosystem conservation, stronger control of fishing, fisheries and poaching in the lake, providing mutual relationship and information exchange between the state agencies in the field of management, monitoring, and conservation of the lake ecosystem and the research sector, introduction of innovative technologies for the lake protection, use, and monitoring, minimization of pollution of Lake Sevan with municipal and coastal wastewater, etc.

This will be an important guarantee for the protection of the lake, as well as for the reduction of the vulnerability of this water resource to climate change and achieving greater results in the implementation of adaptation measures.

To get a deeper understanding and a more complete picture of the issue under discussion, let us look at the gap that prevails in the policies of different sectors of the Republic of Armenia on the issue of water resource vulnerability in the context of climate change. In particular, in important areas for our country, such as hydropower or natural resource management, the "Strategic Development Program of the RA Hydropower Sector" and the "Natural Resources Management Strategy" were adopted in 2011 and 2018 respectively. Although the first program rightly assesses the role of using hydropower resources in the frame of energy security and independence in the Republic of Armenia, unfortunately, this document does not address the issue of water resource

[23] Sevan RBMP-Part 1, March 2019, p. 4
[24] RA Official Bulletin 2001.07.04/19(151), adopted on 15.05.2001, has come into force on 04.07.2001

vulnerability in the context of climate change. As for the RA Natural Resources Management Strategy, it envisages elimination and mitigation of adverse impact of climate change, anthropogenic factors on the sustainability of forest ecosystems only among the principles of forest protection. We strongly believe that strategies and concepts that are fundamental to the policy of all sectors important in terms of water resources vulnerability, from now on must take into account water resources vulnerability and adaptation issues and steps to address them in the context of climate change.

### 1.2.2 The system of authorized bodies in the field of implementation of measures for water resources adaptation to climate change and reflecting the vulnerability of water resources to climate change in the legal arrangements for issuing water use permits

It is not a secret that for any state, every idea and institution is implemented only as a result of designing a clear system of relevant authorities, distributing the powers of the field among them, and implementing them.

The main and supporting structures in the sphere of water management in the Republic of Armenia are the Water Resources Management Agency of the staff of the RA Ministry of Environment, the Water Committee of the RA Ministry of Energy Infrastructure and Natural Resources, the Public Services Regulatory Commission, the RA Ministry of Health, the Bioresources Management Agency of the Ministry of Environment, the Environmental Monitoring and Information Center of the Ministry of Environment, the Hydrometeorological Service of the Ministry of Emergency Situations, etc.

The RA Ministry of Environment is currently the authorized body of water resources management and protection in the Republic of Armenia based on the RA Government Decision of 30 January 2003 N 75-N "On Designation of the Authorized Water Management and Protection Body". Armenia has adopted the principle of decentralization of water resources management, which has been included in the legislation since the 2000s. It should be noted, however, that according to the main players in the field, including specialists and water users, many problems still remain unresolved. According to Article 10 of the Water Code, to promote more effective, purposeful and decentralized management of water resources, Water Basin Management Authorities shall be established in the composition of the Water Resources Management and Protection Body according to the procedures, established by the legislation of the Republic of Armenia. To avoid various misunderstandings, it should be noted that there is a certain terminological inconsistency between the different names of the basin management body in different legal acts. The Water Code uses the term "water basin management authority", while some by-laws use the term “territorial basin management division ". In both cases, there is unequivocal reference to the same entity, the territorial management sub-division of the Water Resources Management Agency (hereinafter referred to as the WRMA), or in other words, the territorial water basin management division.

Moreover, the RA Water Code, the RA Law “On the Fundamental Provisions of the National Water Program”, the RA Law “On the National Water Program”, as well as a number of legal acts use the concept of "water basin management plan" instead of the internationally accepted "river basin management plan". In terms of hydrology, there is no such thing as a "water basin", and it would be better to use the term "river basin", as well as "river basin management plan" instead of "water basin management plan". It should be added that in all the above-mentioned legal documents, there is a clear confusion between the concepts of "river basin management plan" and "integrated water resources management plan". The terminological diversity can cause misunderstandings and misconceptions.

The purpose of establishing basin management bodies was to give them the role of providing a link between the WRMA and the communities, in particular to accept water use permit applications, to register them by sector, to submit them to the WRMA for further processing, as well as to register the issued water use permits, to classify them by sector and use and to control the compliance with the conditions in water use permits and non-breach of standards. Current regulations, however, for the development and implementation of river basin management plans by basin management organizations (BMOs) are contradictory. Further, the territorial divisions of the WRMA (BMOs) currently do not exercise their full powers in practice in the manner prescribed by law. Thus, institutional improvements should be carried out.

◊ We believe that the legal framework is to be structured in a way to eliminate the above mentioned inconsistencies in terminology, the split in the appointment of heads of basin management bodies, as well as to clarify the subjects for the development, approval and implementation of basin management plans and to provide them with higher professional and technical capacity.

This will provide sound bases for implementing the principle of decentralized water management in a more serious and sustainable way.

It should be noted that on 13 November 2019 the RA National Assembly adopted on the second reading the draft laws "On Making Amendments to the Water Code of the Republic of Armenia" and "On Making Amendments to the RA Law on the National Water Program of the Republic of Armenia". Based on this, the National Water Council was dissolved, and the latter's powers were delegated to the RA Ministry of Environment. Despite the reasons provided in the justification of the draft law and the actual dissolution of the National Water Council, we would like to draw your attention to the problematic aspects related to water resources in terms of possible adverse impacts on their adaptability to climate change.

The National Water Council was the highest advisory body in the field of water resources management, and through interdisciplinary participation, was discussing and recommending on the National Water Policy, National Water Program and other legal acts, and providing conclusions. As a justification for dissolving the National Water Council, the document refers to the following circumstances. The RA Government Decisions N 338-N of 31 March 2016, N 539-N of 26 May 2016 and N 240-N of 9 March 2017 approved the basin management plans of Ararat, Southern and Akhuryan basins (it is to be noted that despite the approval of the above-mentioned plans, the

overwhelming majority of the measures included in the action plans have not been implemented so far and the plans have largely remained on paper. This is true also for the measures that do not require major investments). The Sevan and Hrazdan Basin Management Plans are currently under development, and the Northern Basin Management Plan is expected to be developed by 2023. Based on the above, as well as taking into account that the RA Government Decision No. 218-N of 7 March 2003 “On Approving the Model Water Use Form and Water Use Permit Forms, procedures for issuance and extension of duration of the water use permit, the water source and well datasheets, forms of geological-technical design sections of hydrogeological borehole” has already approved regulations for agreement with some entities interested in water use permit applications, the activity of the National Water Council has lost its former significance.
With the dissolution of the National Water Council, changes are projected as this body's activities was not limited to its role in the preparation of several approved basin management plans, since the Water Code considers the main mission of the National Water Council submitting recommendations on National Water Policy, National Water Program and other legal acts related to the field, through inter-sectoral participation. Therefore, in addition to providing conclusions on management plans, the Council had a number of other functions, and the draft does not justify in any way the absence of the need and advisability of their further implementation. Even if the only function of the National Water Council were to provide a conclusion on management plans, it is clear that even for that part the latter's activities cannot be considered exhausted, since a number of basin management plans of essential importance for Armenia have not yet been approved.

The transfer of the functions of the National Water Council to the RA Ministry of Environment, in its turn, raises a number of problematic issues. Is it possible and legitimate to authorize the same body to implement issuance of a water use permit and to issue a conclusion on it? Is it correct to expect from the Ministry of Environment that it will provide an impartial conclusion on its own draft legal acts? Instead of uncertain answers to these questions, we think it would be more appropriate to take steps to create mechanisms to improve the efficiency of the National Water Council and more favorable conditions for the implementation of its functions.

Moreover, the National Water Council had a Dispute Resolution Commission, which was essentially called upon to act as an independent mediator, and, if effective, it could be a serious legal guarantee for the examination of disputes over water use in short periods of time, thus preventing lengthy judicial processes related to the subject of the dispute. Meanwhile, with the dissolution of the National Water Council, the issue of further implementation of the functions of the Dispute Resolution Commission is not clear, which in turn can create difficulties.

The advantage of the National Water Council was its being an advisory body, and the existence of such bodies is an internationally recognized means in terms of implementing measures for adaptation to climate change, as such bodies provide an opportunity to ensure public participation, balancing the interests through conclusions of an independent body, and through interdepartmental cooperation in the preparation of basic documents in the field of water resources management and protection.

◊ Summing up the above-mentioned, it should be noted that we do not consider positive the concentrating of the functions into one state body, related to providing water use permits, conclusions, as well as resolving the disputes. Creating an overload and subjective grounds, it can reduce both the efficiency of the activity and the expected results.

We do not deny that structural changes in this area, likewise everywhere, are mainly aimed at improving water resources management and increasing the efficiency of activities. It should not be, however, neglected that frequent changes also have negative consequences, since they may weaken the functioning of the entire water resources management system for some time, hinder the cooperation especially between interdepartmental bodies, often be accompanied with budgetary revisions and, in some cases, reductions.

◊ We consider the formation and operation of public councils as an advisory body in this area important. The public council institution is functioning in an inconsistent and incomplete way in Armenia. For example, the Akhuryan Basin Management Plan envisages the establishment of a River Basin Public Council, which has not been implemented so far; though the role of such entities as a type of instrument of cooperation between different competent authorities is another possibility to engage public and sector scientists and to play an active role in water resources management.

Among the above-mentioned bodies, we consider it important to refer to the Armenian Hydro meteorological Service. Article 1 of the RA Law on Hydrometeorological Activities envisages the following goals of the law[25]:

a) establishment of the legal basis of hydro meteorological activities;

b) creation of appropriate conditions for forming market relations in the field of production, storage and use of information on the hydro meteorological phenomena and processes;

c) legal support of coordination and effective activities of national hydro meteorological system as a part of the international hydro meteorological network.

It should be noted that prior to the structural changes on 30 January 2020, the Service of the Hydrometeorology and Active Influence on Atmospheric Phenomena SNCO[26] was a structural division of the RA Ministry of Emergency Situations, which monitors the weather, climate, hydrological and geophysical conditions and situation in Armenia, provides warning on disasters. Its activities also include supporting the implementation of international commitments undertaken by Armenia in this area. It is currently merged with the Environmental Monitoring and Information Center and the Forest Monitoring Center to reorganize as the Hydrometeorological and Monitoring Center SNCO.

Agriculture, as one of the leading branches of Armenia's economy, is considered one of the most vulnerable sectors from hydro meteorological point of view. Other sectors at risk include communication, transport, construction, energy and water resources management[27]. More reliable weather and hydrological services and information can improve daily activities and planning in these

[25] RA Official Bulletin 2001.0.20/9 141, adopted on 07.02.2001, has come into force 20.03.2001

[26] https://www.e-gov.am/gov-decrees/item/33360/

[27] Modernization of weather, climate and hydrological services. Road map for the Republic of Armenia. 2018 September, p. 9

areas[28]. To emphasize the importance of the topic discussed in the above-mentioned law, we consider it advisable to refer to Article 15 of the law, according to which: "The activities of the hydrometeorological service in the field of hydrology are carried out in order to collect data on rivers, lakes, reservoirs, canals, swamps, underground sources, other water bodies and water reserves necessary for:

a) meeting the needs of the population and the economy through information on changes in the hydrological regime of water bodies (freshets, floods, etc.);

b) studying the spatio-temporal patterns of the hydrological regime, conducting state water accounting, running water cadaster, calculating water resources and water balances of water basins and districts, assessing the impact of economic activity on the regime of water bodies and water resources”.

Thus, the activities of this Service play an important role in obtaining and disseminating relevant data and information, and in this sense, it is necessary to constantly take strategic steps to modernize the hydrometeorological service in Armenia, to adapt it to the extent possible to the needs of the economy and society.

Similar to many other countries, the main legal tool for the rational use of water resources in Armenia is water use permits. It is this authoritative document that addresses the requirements of the law to a specific water user, creating a clear framework for his rights and responsibilities. We can consider the best substantiation of the above-mentioned to be Article 21 of the RA Water Code, according to which everyone shall obtain a water use permit for water use, except for the cases provided by law. In order to have a deeper understanding of these legal relations, we consider it necessary to present the structural subdivision of the RA Ministry of Environment, one of the main functions of which is issuing water use permits. Thus, the Water Resources Management Agency was established in 2002 to regulate water resources management issues. Among the functions of the Agency are:

1. Issuing water use permits;
2. Exercising transfer of the right of water use permit to other persons;
3. Granting the water user an exemption from the requirement of obtaining a water use permit, as specified under the legislation of the Republic of Armenia;
4. Providing information to the State Water Cadaster on water use permits;
5. Formulating the documents on suspension, change or cancellation of the water use permit.
6. Organizing public notice on documents developed by WRMA, as specified under the legislation of the Republic of Armenia and a number of other functions defined under its Charter.

It should be noted that by the Prime Minister's decision 1785-L of 2 December 2019, the RA Ministry of Environment's Water Resources Management Agency, the Bioresources Management Agency and the Waste and Atmosphere Emissions Management Agency merged to form the Department of

[28] See the same place.

Licenses, Permits and Agreements - the main professional structural subdivision of the Ministry. It turns out that as a result of the merger of the three agencies, from now on, not the Water Resources Management Agency, but the Department of Licenses, Permits and Agreements will act as a party in the relations relevant to water use permits.

According to Article 29 of the Water Code, a water use permit shall be issued based on the applicant's request. The request may be refused, if the water use requested does not comply with the Code, the "National Water Policy", "National Water Program", relevant "Water Basin Management Plans" and relevant other legal acts, protection requirements of the national water reserve, water standards.

In fact, the RA Water Code stipulates that any person wishing to obtain a water use permit must submit an application to the Water Resources Management and Protection Authority or the Basin Management Authority. Within 30 days of receiving a water use permit application, the Water Resources Management and Protection Body shall make an initial recommendation of acceptance or rejection and provide the initial findings to the permit applicant either directly or through the delegated authority. The initial assessment by the Water Resources Management and Protection Body shall include an identification of any special use conditions required by the Code, statement of any additional information required, and determination of need for Environmental Impact Assessment.

Within 30 days of concluding the initial assessment, the Water Resources Management and Protection Body shall provide adequate public notice of the pending water use permit application.

Article 30.1 of the RA Water Code defines the grounds in case of which the application for water use is rejected by the competent body. Such grounds include non-compliance with water use permits with the Code or the National Water Policy or the National Water Program or basin management plans or other related legal acts, insufficient water resources for issuing water use permits, and possible damages to other water users' rights. We believe that the norm incompletely defines the grounds for refusing issuance of water use permit. In particular.

◊ Although the Water Code stipulates that in certain cases, it is necessary to require an environmental impact assessment expertise in order to issue a water use permit, the legislator have not considered the negative conclusion of the expertise as a basis for rejecting the water use application. Under such conditions, the competent authority may theoretically grant a water use permit in the presence of a negative expertise opinion. We believe that the grounds of rejection miss the circumstance that the activities carried out on the basis of the mentioned water use permit can have a negative impact on the environment, significantly increasing the level of water resources vulnerability to climate change.

In fact, these grounds are not included in the list of grounds in the Code for refusal of permission; the first one of them is mentioned as a ground for suspending the water use permit, which causes a violation of legal certainty and an ungrounded differentiated approach.

◊ We propose to add items 7 and 8 to the first paragraph of Article 30.1 of the Water Code ,with the following content:

1. There is a negative conclusion of environmental impact assessment if the law stipulates that the planned activity is subject to environmental impact assessment expertise.

2. An activity implemented based on water use permit can have a negative impact on the environment, substantially increasing the vulnerability of water resources to climate change.

As mentioned above, the preliminary assessment of application includes also the environmental impact assessment of the water use. Article 30 of the Code stipulates that if required by law, the applicants for a water use permit shall submit an environmental impact assessment. If necessary, time allowed for application review shall be adjusted to comply with environmental impact assessment review requirements.

◊ The assessment of water use impact on the environment must also include an assessment of the potential impact of climate change on the water resource and an assessment of the potential hazards arising from that water use in terms of effective water resource management under climate change.

For example, a water use permit is issued for the operation of HPPs where the climate change factor is not taken into account, or, a reservoir construction plan is developed based on Soviet-era calculations where the climate change factor is not taken into account.

Thus, within 30 days of completing the preliminary reviews, the Water Resources Management and Protection Body shall complete a final review of the permit application. It shall include a consideration of all relevant issues, including public comment received in response to notification, and a determination of water use specific conditions required to protect water resource quantity and quality.

◊The next gap in water use permits is that although paragraph 4 of Article 3 of the RA Government Decision 218-N adopted in 2003 provides for the possibility of submitting an electronic application for a water use permit, the electronic tool is still in testing stage (http://wrma.am/wateruser). The implementation of this mechanism is very important both in terms of socio-economic problems of the society, as well as of employment and time savings.

Based on the above, we can conclude that the legal regulations and enforcement practice on issuing water use permits must be developed in a way that both issuing of water use permits and the control over activities carried out by water users exclude the negative impact on water resources and the environment, including the increase of water resources vulnerability to climate change as a result of water use.

## 1.3. Reflecting water resources vulnerability to climate change in legal regulations on water resources monitoring

Reliable, timely and updated data on water quality and quantity are among the most important foundations for effective management of water resources and proper planning under climate change. They are also important for future investments, since the risks increase with the lack of sufficient knowledge about the existing water reserves. Moreover, the day-to-day operation of various water systems, both for production (e.g., irrigation, urban water supply) and risk prevention (for example, flood warning), cannot be optimized without an effective, real-time monitoring network. After all, management of the overall water reserve stability and mitigation of various stresses is possible only with regular data monitoring and resource evaluation[29].

The water quality monitoring system in Armenia, which was established in 1977, and the hydrological or meteorological observations that were started earlier, has passed a rather complicated and partially changed nowadays.

According to Article 19.1 of the RA Water Code, monitoring of water resources is a function mandatorily performed by the state through specialized organizations, which aims to implement consistent and publicly available assessment of the condition of water resources in the Republic's water basins, as well as to ensure reliable data on quality and quantity of water resources.

The analysis of the essence and goals of the monitoring indicate that the monitoring of water resources and the effective implementation of this process are preconditions, without which it is impossible to speak about the implementation of measures for water resources adaptation. The legal regulations on monitoring and their enforcement practice must, therefore, be the subject of a analysis and assessment when addressing the reduction of the vulnerability of water resources to climate change.

According to Article 16 of the RA Law on the National Water Program, water resources monitoring is one of the priorities of the water supply and sanitation sector.

According to the Water Code, the objectives of water resources monitoring are:

1) Identification of the conditions of water resources formation, changes in them due to natural and man-made factors.

2) Assessment of the course of development of the identified changes and application of appropriate measures.

3) Identification of interactions of environment and water ecosystems, forecasting their possible changes (short-term and long-term, based on the results of at least 10 years of observations) and application of protection measures.

4) Promoting water resources protection, efficient use and management.

[29] Assessment of the vulnerability of water resources in the Republic of Armenia under climate change. Yerevan, 2018, p. 28

5) Promoting the development of basin management plans.

The water resource monitoring is aimed not only at providing the necessary data to assist solving the problems mentioned in the Code; it should also become a subject of assessment and serve a baseline for the authorized body while permiting a water use and implementing control over the business entity after issuing the water use permit.

On the way to the establishment of the monitoring institute in the Republic of Armenia, we consider it important to point out the legal and institutional change made in 2016, which was implemented by the RA Government Decision “On reorganization of a number of state non-commercial organizations in the system of the RA Ministry of Environment through merger and on invalidation of a number of RA Government decisions” (15.12.2016 №1277-N), according to which “Waste Research Center”, “Hydro-Geological Monitoring Center”, “Environmental Impact Monitoring Center" and "Information and Analytical Center" state non-commercial organizations were reorganized through merger to establish the "Environmental Monitoring and Information Center " SNCO. It should be noted that the European Union has a significant contribution to the improvement of this sphere. Taking into account the recommendations of the EU Water Initiative + Program’s Laboratory Assessment Team, the RA Government Decision No. 1584-A of 7 December 2017 was adopted on the allocation of new space to the Laboratory of "Environmental Monitoring and Information Center " SNCO in the Institute of Chemical Physics of the RA National Academy of Sciences. Significant work is being done to bring the laboratory to international accreditation with co-financing from the EUWI+ program.

Paragraph 3 of the Annex to the RA Government Decision No. 639-N of 22 May 2003 “On approving the order of implementation of water resource monitoring and registration of their reports” states that the task of water resource monitoring includes also:
… c) forecasts on:
water resources stability,
water system safety,
atmospheric temperature regime,
disaster probability and risk areas in the field of water.

The monitoring task also includes other requirements related to the **restoration**, **management of water resources**, **protection of aquatic ecosystems**.

The study of the requirements for the implementation of the monitoring task shows that one of the priority goals for water resource monitoring is to forecast possible changes in water resources (including in the context of climate change). Based on the above, we can state that the existing legal regulations on monitoring seem to be sufficient to prove the responsibility of the competent body in assessment of water resources, their vulnerability to climate change, the available resources and adaptability of the legal regulations during preparation of the water resource monitoring task, and then during its implementation.

There are, however, also gaps and shortcomings in the legal regulations and practice, which may negatively affect the implementation of measures for adaptation to climate change and reduction of vulnerability. First of all, there is a close connection and interrelation between the components of the environment, such as atmospheric air, water resources, flora and fauna (including specially protected nature areas and forests, land, subsoil protection) and natural resources. Due to this circumstance, monitoring of each of these components, including the monitoring of water resources, and the data obtained, cannot be considered complete if during the preparation of the monitoring task and during its implementation the interrelation with the other environmental components and their possible impact is not taken into account. The diversity of the bodies authorized for monitoring of environmental components, and the lack of mechanisms for sufficient cooperation between them were also obstacles to achieving this goal.

Taking into account this circumstance, the Environmental Monitoring and Information Center, the Forest Monitoring Center and the Service of the Hydrometeorology and Active Influence on Atmospheric Phenomena SNCOs were merged to reorganize as the Hydrometeorological and Monitoring Center SNCO according to the RA Government Decision 81-N of 30 January 2020[30].
The goal was to establish a single body for monitoring of natural resources in Armenia to ensure the effectiveness of monitoring, introduce a unified approach to environmental monitoring, and improve the versatility and interconnectedness of monitoring data.

It should be noted that a clear monitoring program has already been proposed in the basin management plans developed with the EU support (the Akhuryan basin, the Debed River Basin, the Aghstev River Basin), however they have not been implemented to date.

The fact that the function of monitoring is assigned to the Ministry of Environment, and the function of implementing the actual monitoring procedure is assigned to a specialized organization directly derives from the RA Government Decision No. 639-N of 22 May 2003 "On approving the order of implementation of water resources monitoring and registration of their reports". It is not, however, clear on what basis the authorized body shall separate the water resources subject to monitoring, the function of ensuring the formation of quality and quantity monitoring requirements is not stipulated among the functions of the authorized body. Although the need for preliminary assessment of the quality and quantity of water resources before the implementation of the monitoring is mentioned, the authorized body is not required to perform such an assessment function by the legislation of the Republic of Armenia.

◊ Based on the above, we recommend to clearly define the functions of the Ministry of Environment related to monitoring, including the functions of providing qualitative and quantitative monitoring demand of water resources and summarizing monitoring data, the preliminary assessment of water resources quality and quantity.

[30] https://www.e-gov.am/gov-decrees/item/33360/

◊ It should be noted that the state program of surface water quality monitoring in Armenia includes only studies of physico-chemical indicators. The lack of monitoring of hydro biological indicators does not allow assessing the ecological status of water resources, as well as introduce ecosystem assessment approach for Sevan Lake. Surface water monitoring strategy and normative-methodological approaches to implementation must be revised and adapted to the requirements of the European Union Water Framework Directive.[31] There are also obstacles to the implementation of surface and underground water monitoring in line with the requirements of the EU Water Framework Directive, such as data inadequacy, lack of funding, incomplete quantitative and qualitative water observations, lack of modern technology and equipment, etc. Biological monitoring of water resources is not carried out in the Republic, despite the fact that there are cases of damage to river ecosystems and biodiversity loss[32].

## 1.4 Ensuring public participation as a key factor in water resources adaptation to climate change

As already mentioned at the beginning of this analysis, ensuring public participation in implementation of water use, water resources management and conservation holds a special place among the legal measures for adaptation of water resources to climate change. Therefore, during the analysis of domestic regulations on water resources vulnerability to climate change, it is important to clarify the issue of the availability of legal mechanisms required to ensure public participation.

The most important guarantee for public participation is its interest and awareness in this field. In terms of awareness, the institute for access to information in this area also has a significant role to play and it is properly enshrined in both international and domestic legislation. Regulations on the formation, provision, dissemination of ecological information and a number of other issues are implemented in Armenia, based on “Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters”[33], the RA Law on Freedom of Information[34], the RA water legislation and a number of other legal acts.

In particular, Part 1 of Article 5 of the Water Code defines the recognition of importance of public participation and awareness in the processes of management and protection of water resources, as one of the main principles of management, use and protection of water resources and water systems. Article 17, Part 1, Item 17 of the RA Law on National Water Policy also stipulates the principle of ensuring access to information in the sphere of national water policy in the manner prescribed by law.

[31] Assessment of the vulnerability of water resources in the Republic of Armenia under climate change. Yerevan 2018, p. 30
[32] Draft Fourth National Communication of Armenia to the UNFCCC (TNC)
[33] https://www.unece.org/fileadmin/DAM/env/pp/documents/ACtext/Aarhus_Convention_Armenian.pdf
[34] RA Official Bulletin 2003.11.05/55(290), adopted on 23.09.2003, has come into force on 15.11.2003

The list of documents and information that the public must be informed about is exhaustively defined.

According to Article 20 of the RA Water Code, the following items are subject to public notice by the state authorized bodies: 1.draft national water policy general concepts 2.draft national water program 3.draft water basin management plans 4.pending water use permits 5.pending water system use permits 6.draft water standards 7.draft water tariff strategy.

◊ It would be more effective to include the forms of public participation in measures for reducing the vulnerability of water resources and adaptation in the list of documents subject to notification in the Water Code. It would be an important guarantee for raising the level of public awareness in such a multi-layered process and ensuring the participation of the interested public.

The RA Government Decision No. 217-N "On approving the procedure of public notification and publicity of documents developed by the Water Resources Management and Protection Body", dated 07.03.2003, establishes the main provisions of the public notification, the obligations of the authorized body for summarizing the comments and suggestions received during the notification and including them in the summary sheet on comments and recommendations of the stakeholder ministries, the procedure of realizing the right to get acquainted with the development of documents and with the draft documents. It should be noted that the obligation to organize public discussions is enshrined in Part 4 of Article 15 of the RA Law on National Water Policy, according to which public participation in the process of preparation of basin management plans is ensured through organizing public hearings and discussions and by providing information about them through the media.

Although today the main legal acts of the sector provide for the possibility of public participation in the process of adopting almost all documents in the water sector, however, effective structures have not been developed to make the participation process really effective.

◊ In particular, there are many technical and legal obstacles that prevent the interested public from receiving timely information about the relevant processes, getting acquainted with the documents under discussion, and presenting their comments and suggestions. Possibilities for feedback are often not provided. In this context, the issue of involving the local self-government, as a structure representing the interests of the community in the process of providing water use permits remains unresolved. The local government's opportunity to provide information on water use permits to the community and to organize participatory processes is not properly assessed. Despite the fact that the RA Law on Local Self-Government, as a matter of principle, envisages the participation of community residents in local self-government, this structure has entirely failed in water sector issues. The sole competent authority for all components of participation in the process of issuing water use permits is the Water Resources Management and Protection Body. Implementation of notification only by that body alone when issuing water use permits is not effective enough, since in practice the residents of the community or communities where the water use is to be carried out are often unaware of the draft water use permit under discussion. It is posted either on the website of the Water Resources Management Agency or in a periodical with a press run of at least 1000 copies, which is not enough to provide information.

◊ In addition, the notice on the water use permit application states that all interested persons who wish to get acquainted with the development of the document and the initial version of the draft document can apply to the Water Resources Management and Protection Body on weekdays at a concrete time (17:00 to 18:00). This regulation provides a very limited opportunity for the interested public to get acquainted with the relevant draft, to form an opinion and to voice it.

An important guarantee is paragraph 7 of the Annex to the Decision, which stipulates the right of the persons potentially affected by the document enforcement to appeal the document in the manner prescribed by law, in case the final version of the documents developed by the authorized body does not satisfy the public. However, this norm causes certain legal uncertainty. In particular, the norm does not provide the definition of concept of "potentially affected person", while any person may be potentially affected in case the document in question is of fundamental importance and involves a danger of increased water vulnerability to climate change.

◊ Moreover, the RA legislation does not stipulate any procedural provision on the appeal of such documents, which makes exercising this right practically impossible. Evidence of this can be seen, for example, the appeal of the administrative act on the issuance of a water use permit by those persons who consider the water use permit to be promotive of the increase of the vulnerability of water resources. Article 53 of the RA Law "On Fundamentals of Administration and Administrative Proceedings" considers the water use permit a favorable administrative act, while the RA Code of Administrative Procedure does not provide for a legal possibility to appeal a favorable administrative act. Therefore, it becomes clear that realization of such a fundamental right and of an advanced regulation is virtually impossible due to the lack of appropriate legal mechanisms.

◊ Therefore, in the context of full realization of the right of public participation, it is necessary to define the procedure for exercising the right of the interested public to appeal the documents on water resources management, making appropriate changes in the RA Code of Administrative Procedure.

According to Article 106 of the Water Code, which is included in Chapter 15 on Protection and State Supervision of Water Resources, non-governmental organizations and citizens may participate in the discussion of issues related to water resources and water systems conservation and submit proposals. In the conduct of activities aimed at the protection of water resources and water systems, the state authorized management bodies have a right to take into consideration the recommendations of public organizations and citizens. It follows from Article 106 that both entities of this legal relationship have rights under state supervision of the protection of water resources – the representatives of the society have the right for participating in the discussion of issues related to water resources and water systems conservation and submitting proposals, and the state authorized management bodies – for the discussion of those proposals.

◊ It would be more constructive if within the same legal relationship, one entity's right imposed the obligation of the other entity, in this case, to discuss the proposals of public organizations and citizens.

This approach is also consistent with Part 2, Article 3 of the UNECE Convention on “Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters”, according to which .each party shall endeavor to ensure that officials and authorities assist and provide guidance to the public in seeking access to information, in facilitating participation in decision-making and in seeking access to justice in environmental matters.

A significant part of the information capital of the sector accrues to the Armenian Water Cadaster, which includes huge amounts of data that mainly must be available to the public. The State Cadaster of Water Resources (hereinafter referred to as the State Water Cadaster) is an information system that runs the processes of establishing a database of qualitative and quantitative characteristics of water resources, natural and man-made impacts on water resources, protection, use and rehabilitation of water resources and aquatic ecosystems. The main goal of the State Water Cadaster is to create an information base for the implementation of a unified state strategy in the field of management and protection of water resources, hydraulic structures, which contribute to their efficient use within the framework of the National Water Policy[35].

It should be noted that the RA Government Decision N 68-N of 2 February 2017 approved the new procedure for running the Water Cadaster, according to which it is planned to develop a GIS- based online platform for providing access to information on water and for informing public and relevant interdepartmental bodies. The data of the State Water Cadaster, except for information containing official, commercial and other confidential information protected by law, will be posted on the relevant website, which can be used free of charge by all interested legal entities and individuals. Moreover, according to the above-mentioned Government decision, the Water Resources Management Agency is authorized to consolidate and store all the information on water resources and water systems in the official database. Thus, all the departments involved in the information system of the State Water Cadaster shall annually submit data to the WRMA in electronic form, which in turn shall be entered into the centralized database. It should be noted that the information system of the State Water Cadaster is a new approach to data management and exchange in Armenia, which should be gradually implemented in the culture and working style of various institutions. Although the data on water resources are currently available through the database under the management of the RA ME, the data exchange between all institutions and the public is still relatively weak.

Nevertheless, the RA Government Decision 68-N of 2 February 2017 has a number of shortcomings, including the following:

- Inconsistency of the title with the content: the State Water Cadaster plans to collect data on water systems.
- Unreasonably long interval for data update: for most of data, updating once a year cannot does not help manage water resources properly and efficiently.
- Administrative-command approach to data provision: it is necessary to emphasize the idea of data exchange between all interested institutions.

[35] Identification of Major Legal Issues to Improve Comprehensive Management of Water Resources in the Republic of Armenia and Legislative Reform Proposals. USAID «Clean Energy and Water» project, Yerevan 2015, p. 22

- Lack of need for data accountability: in contrast to the current decision, the decision of 2003 contained data-based annual report formats.
- Lack of emphasis on the need to use modern technology: there is no provision for data collection and exchange with application of Internet technologies.
- Lack of geospatial component: the State Water Cadaster should combine both tabular and geospatial data and ensure the interconnection of these two components.
- Lack of emphasis on the need for data accessibility: at present, the water use permits registered in the State Water Cadaster are available only in part.

In addition to the above, it should be emphasized that even if all the data is provided, the State Water Cadaster will not fulfill its main function, which is to provide the decision-makers and the public with reliable and up-to-date water data. The reasons are as follows:

- **Lack of analyses** based on the collected data,
- **Lack of the Internet portal of the water sector** for ensuring availability and access to data and analyses.

Summing up the above, it should be noted that despite the availability of a number of legal regulations in the RA legislation aimed at ensuring public participation, they are not yet complete, moreover, they must be constantly improved and reflected in all components of public life along with life and scientific and technical development.[36] The actual description of these processes in the Republic of Armenia remains the fact that public awareness and participation in decision-making processes is very weak. The availability and accessibility of information are not well-established institutions (in some cases, due to their complexity) on the one hand, and the public is not yet completely prepared to fully express its views in a literate and well-grounded manner, make serious contributions into cooperation, correctly assess its role and voice on the other hand. The above applies to both the availability of data on water resources and the real publicity of information on the issuance of water use permits or on the permits already issued.

## Conclusion of Chapter 1

Since 2015, there are a huge number of activities were undertaken aimed to improve the policy, legal, and institutional framework of the water sector, including the development and adoption of basin management plans in Armenia.

Although, the review and depth analyses of recent developments in water legislation in the context of climate change in the country shows certain progress and improvements, a number of remaining deficiencies and barriers in policy, legal and institutional framework are identified that serve as barriers to coping with climate change impact and adaptation in water management of the country.

This includes deficiencies in the legislation (Water Code, National Water Policy, National Water Program, Tax Code), the need to strengthen the institutional framework (Basin Management Organizations, Public Basin Councils) and streamline certain functions (water resources monitoring,

[36] Development of the draft Hrazdan RBMP-Part 1, March, 2019, p 7.

functions and roles of the former National Water Council), as well as the need to include the climate change factor in the process of issuing (or extender) water use permits. Provisions on the water resources management under climate change and the process aimed to it in the RA Water Code and other basic legal documents on water resources protection and management (in particular the Law on National Water Program) are insufficient or missing at all. In addition, there is not a satisfactory ecosystem approach to improve the ecosystem of Lake Sevan and to mitigate the climate change effects. A number of environmental, legal and economic measures and solutions needed to achieve this goal have not yet been implemented.

The practical recommendations and activities to overcome the revealed gaps and barriers in policy, legal, and institutional frameworks of the water sector in the context of climate change are provided and discussed in Chapter 4.1 of this report.

# CHAPTER 2. REVIEW OF VULNERABILITY ASSESSMENT OF WATER RESOURCES DUE TO CLIMATE CHANGE

## Summary of Chapter 2

Since 1998, when the First National Communication of Armenia on the Climate Change was adopted, a number of studies were conducted in order to analyze the climate change trends, develop climate change projections and assess possible climate change impacts on different sectors. One of the key elements of climate change impact studies in Armenia is the assessment of vulnerability of water resources and development of adaptation measures. Major works on water resources vulnerability assessment have commenced since 2008.

These studies are summarized in the form of three National Communications to UNFCCC and a fourth that is currently in the process of development, and are also presented in the reports of donor-funded projects, as well as included in the river basin management plans (RBMP) for Akhuryan, Ararat, Southern, Hrazdan, and Sevan River Basin Districts (RBDs), research papers, relevant reports prepared during the implementation of the similar projects of international donor organizations.

The following studies have been reviewed in scope of this report:

| Category | Title | Year | Short description |
|---|---|---|---|
| National Communications of Armenia to the UNFCCC | First National Communication of Armenia to the UNFCCC (FNC) | 1998 | The First National Communication on Climate Change was submitted by Armenia in 1998, and it covered the period of 1990-1996. Changes in the annual river flow for the entire territory of Armenia, as well as the water balance of Lake Sevan were discussed. Future climate change projections for temperature and precipitation were developed and provided for the period up to 2100. |
| | Second National Communication of Armenia to the UNFCCC (SNC) | 2010 | The Second National Communication on Climate Change was submitted in 2010, and it covered the period of 1996-2006. Changes in the annual river flow for separate river basins, as well as the entire territory of Armenia were |

| Category | Title | Year | Short description |
| --- | --- | --- | --- |
| | | | discussed. The results of water balance of Lake Sevan were also provided. In the SNC, changes in the average regional temperature and precipitation in Armenia were assessed using the simulation outputs from a number of General Circulation Models (GCMs) reported in the Special Report on Emissions Scenarios (SRES) A2 and B2 Greenhouse Gases (GHG) of Intergovernmental Panel on Climate Change (IPCC). Subsequently, based on the signal/noise ratio and dispersion of models, seven were selected as the "best" models for the current climate of the country. The results of the combination of models - changes in precipitation and temperature - were assessed for three time periods - 2030, 2070, and 2100. |
| | Third National Communication of Armenia to the UNFCCC (TNC) | 2015 | The Third National Communication on Climate Change was submitted in 2015, and it covered the period of 2007-2012. It has extended the studies on and assessments of climate change-related issues. Recent developments in the country, as well as under the Convention, that took place after SNC submission were also considered in TNC. In addition, vulnerability assessment and prediction for water quality were presented for the first time for the Arpa River. |
| | Current Report: The Vulnerability Assessment of Water Resources of the Republic of Armenia under the Climate Change | 2018 | This report has been prepared within the scope of the "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" UNDP/GEF project. It provides a detailed assessment of vulnerability of water resources (quantity and quality) for all major river basins and important water bodies in Armenia due to the climate change.<br>In the Third and Fourth National Communications of Armenia to the UNFCCC, climate change in Armenia is assessed using following IPCC recommended Representative Concentration Pathways (RCPs) scenarios for emissions: RCP8.5 (corresponding to SRES A2 scenario) and RCP6.0 (corresponding to SRES B2 scenario). In these communications, future climate change projections for temperature and precipitation have been developed for three time periods – 2040, 2070, and 2100.<br>The vulnerability of water resources from climate change in the National Communications were assessed based on these scenarios and time periods, accordingly. |
| Reports on the Basin Management Plans | Ararat Basin Management Plan | 2016 | Ararat Basin Management Plan was developed for the period from 2016 to 2021. Along with other elements of basin management planning, climate change impacts on the water resources in the Azat, Vedi, and Arpa River Basins were also assessed and reported. |
| | Southern Basin Management Plan | 2016 | Draft Southern Basin Management Plan was developed in the scope of USAID Clean Energy and Water project. The climate change impacts on the water resources (quantity and quality) in Vorotan, Voghji, and Meghriget River Basins were assessed and reported. |
| | Akhuryan Basin Management Plan | 2016 | This draft pilot River Basin Management Plan for the Akhuryan River Basin District (RBD) of the Republic of Armenia (RA) was developed and reported according to the requirements of the European Union Water Framework Directive (EU WFD) in scope of the Environmental |

| Category | Title | Year | Short description |
|---|---|---|---|
| | | | Protection of International River Basins" EU funded project ". |
| | Draft Sevan Basin Management Plan. Part 1 – Characterization | 2019 | Sevan Basin Management Plan is currently being developed within the framework of European Union Water Initiative Plus (EUWI+) Programme. First part of the Plan that includes basin characterization, pressure-impact assessment, water body delineation and identification of water bodies at risk, was completed in 2019. Second part of the plan (setting the environmental objectives, economic analysis of water use, development of program of measures) will be finalized in May, 2020. |
| | Draft Hrazdan Basin Management Plan. Part 1 – Characterization | 2019 | Hrazdan Basin Management Plan is also being developed within the framework of European Union Water Initiative Plus (EUWI+) Programme. First part of the Plan that includes basin characterization, pressure-impact assessment, water body delineation and identification of water bodies at risk, was completed in 2019. Second part of the plan (setting the environmental objectives, economic analysis of water use, development of program of measures) will be finalized in May, 2020. |
| Other relevant studies | Complex Assessment of Climate Change Impacts on Water Resources of Marmarik River Basin of Armenia[37] | 2009 | This report was prepared in the scope of "Enabling Activities for the Preparation of Armenia's Second National Communication to the UNFCCC" UNDP/GEF/00035196 Project, UNDP, 2009. |
| | Regional Climate Change Impacts Study for South Caucasus Region | 2011 | UNDP/ENVSEC study on the impacts of climate change and adaptation in the South Caucasus involving all three countries in the region - Armenia, Azerbaijan and Georgia. The study has considered four areas for investigation: (1) recent historical and projected climate change, (2) impacts of climate change on transboundary river basins, (3) impacts of climate change on crop water and irrigation requirements in critical agricultural areas, and (4) the effect of climate change on urban heat stress in selected cities in the region.[38] |
| | Vulnerability of Water Sector due to the Climate Change[39] | 2012 | This report was prepared in the scope of "Enabling Activities for the Preparation of Armenia "Enabling Activities for the Preparation of Armenia's Third National Communication to the UNFCCC's Third National Communication to the UNFCCC" UNDP/GEF/00060737 Project. |
| | Toward Integrated Water Resources | 2015 | This publication of the World Bank identifies the challenges in the different water subsectors, reviews the current institutional framework and implementation of relevant |

[37] http://www.nature-ic.am/hy/publication/COMPLEX-ASSESSMENT-OF-CLIMATE-CHANGE-IMPACT-ON-WATER-RESOURCES-IN-MARMARIK-RIVER-BASIN--REPUBLIC-OF-ARMENIA--2009-/7320

[38] http://www.nature-ic.am/hy/publication/REGIONAL-CLIMATE-CHANGE-IMPACTS-STUDY-FOR-THE-SOUTH-CAUCASUS-REGION/7308

[39] http://nature-ic.am/hy/publication/VULNERABILITY-OF-WATER-RESOURCES-IN-THE-REPUBLIC-OF-ARMENIA-UNDER-CLIMATE-CHANGE--2009-/7319

| Category | Title | Year | Short description |
|---|---|---|---|
| | Management in Armenia[40] | | water-sector policies, and makes recommendations for the next steps to strengthen water resources management in the country. The book's overall goal is to provide guidance to the government and to donors to help enhance Armenia's future water security. |
| | Climate Change Analysis for the Ararat Valley | 2019 | In scope of this study of the USAID ASPIRED Project, vulnerability of water resources due to the climate change for Ararat Valley was analyzed using the Climate Change Model of Decision Support System (DSS) ArcGIS extension. |

[40] http://documents.worldbank.org/curated/en/433731468218409267/pdf/Toward-integrated-water-resources-management-in-Armenia.pdf

## 2.1 THE ANALYSIS OF DATA AND OBSERVATIONS

This section analyzes the official communications, documents on assessment of water resource vulnerability to climate change, with the aim of identifying the gaps in water resource data, discrepancies in the communications, and consequently, the causes of the gaps and discrepancies.

The present state of the hydrometeorological monitoring observation network of the Republic, the problems in the monitoring system, the reliability of the observation data were also analyzed. This evaluation was deemed necessary because the monitoring network provided the basis for the data on which the studies for assessment of water resources vulnerability to climate change were carried out.

### 2.1.1 Assessment of the vulnerability of river flow to climate change provided in the National communications

A number of documents have been developed so far on the analysis, assessment and forecasting of water resources in Armenia in terms of climate change, the results of which have been summarized in national communications and other official publications which were summarized above.

Water resources investigations in Armenia in terms of climate change have been conducted since 1998. The activities of assessment of the vulnerability of water resources of Armenia to climate change started in 2008.

The following is an analysis of the data and the gaps related to river flow during baseline and selected periods in national communications and documents/papers on the assessment of water resource vulnerability to climate change.

#### 2.1.1.1 Assessment of the vulnerability of river flow to climate change in the report on "Armenia: Climate Change Issues", 1999

To assess the vulnerability of river flow to climate change in this document, the actual observation data of 13 hydrological observation stations were selected for the period from the beginning of the observations until 1996 (Table 1).

As can be seen from the table, there is no special approach (no consistent start date) for the selection of observation data series of the observation stations; simply the observation stations with long series were selected. The correlation method was used to fill the gaps in the observation data using only river flow data.

Regression equations between river flow and meteorological elements (precipitation, temperature) were obtained by physical-statistical method to assess the vulnerability of the river flow. Afterwards, the river flow change was evaluated for three possible scenarios of air temperature rise.

The document also assesses the impact of climate change on river flow among the components of Lake Sevan balance. The actual data on the river inflow for the period of 1927-1990 were used for assessment; physical-statistical graphs were compiled, the analysis of which yielded the following results: during the period of 1927-1990 the river inflow increased by 80 million m$^3$. From these, selected scenarios of increased air temperature and reduced precipitation (temperature increase by 2°C and precipitation decrease by 10%) were reviewed, and the possible change in river inflow estimated at -8.4%.

**Table 1. List of hydrological observation stations for which river flow vulnerability was assessed**

| № | Hydrological observation station | Observation period |
|---|---|---|
| 1 | Akhuryan-Haykadzor | 1946 up to now |
| 2 | Vorotan-Borisovka | 1962 up to now |
| 3 | Marmarik-Aghavnadzor | 1936 up to now |
| 4 | Argichi-Getashen | 1926 up to now |
| 5 | Azat-Garni | 1936-1942 and 1945 up to now |
| 6 | Vedi-Urcadzor | 1945 up to now |
| 7 | Arpa-Jermuk | 1957 up to now |
| 8 | Voghji-Kapan | 1929 up to now |
| 9 | Pambak-Meghrut | 1936 up to now |
| 10 | Dzoraget-Gargar downstream | 1940 up to now |
| 11 | Aghstev-Ijevan | 1929 up to now |
| 12 | Kasakh-Vardenis | 1966 up to now |
| 13 | Gavaraget-Noradus | 1926 up to now |

This document also discusses the change in total evapotranspiration and evaporation capacity due to climate change. The analysis of the data on evaporation from soil for the period of 1930-1990 revealed that there was a decrease in total evaporation in the range of 3.6-7.5% in Talin, Paghakn, Spitak communities, and in the range of 2.0-6.3% in Sisian, Stepanavan communities.

Since 1990, no evaporation observations have been carried out at the meteorological stations of MES Hydromet Service. This is, of course, a problem for assessing the change in evaporation due to climate change and hence the change in water resources.

### 2.1.1.2 Assessment of the vulnerability of river flow to climate change in the Second National Communication to UNFCCC of Armenia

The information contained in the Second National Communication on water resources vulnerability assessment in Armenia is presented below by reports:

***Report on "Assessment of the Vulnerability of Water Resources in the Republic of Armenia under Climate Change", 2008***

The major river basins of the Republic were selected in this report to assess the change in river flow. Changes in the flow of 28 rivers were analyzed based on multi-year observation data from 33 observation stations (Annex 3). The document provides a comparative analysis of the actual multi-year average river flow values for the baseline period of 1961-1990 and the entire observation period up to 2007.

In order to fill in the data gaps, the physical-statistical or regression method was used, as well as the Geographic Information System (GIS).

The river flow values for long-term and baseline (1961–1990) periods in the document are based on actual observation data from hydrological observation stations. That is to say, the natural river flow was not restored; the bases for selection of the above 33 hydrological observation stations were not interpreted. In the river basins with several observation stations, either the station near the river source, or the one in the middle stream was selected. The main approach was that hydrological observation stations with long series of observational data were mainly selected to assess the change in river flow.

The GIS package was used to assess the vulnerability of Armenia's water resources. The baseline data for the analysis were the annual average, extreme (maximum, winter minimum) flows, as well as the snow cover data available in the Hydromet Service.

In the Second National Communication the period from 1996-2006 was discussed for the assessment of the climate change impact on various sectors, however, for the river flow vulnerability assessment the data for the period of 1991-2006 was analyzed and estimated with respect to the baseline period of 1961-1990.

***Adjustment of up-to-date characteristics of the components of the RA water resources and water reserves, 2009***

This document studies the impact of climate change on the quantity and quality of the actual river flow in the Republic of Armenia and elaborates on possible positive and negative scenarios.

To assess the change in the river flow in Armenia, the physical-statistical or regression method was used, in addition to the model compiled in GIS.

The actual observation data from 33 hydrological observation stations were used to assess the change in the flow; Table demonstrates the observation data showing significant deviations (Table 2).

The river flow values or the baseline period (1961-1990) shown in the document are identical to the values given in the document "Assessment of the Vulnerability of Water Resources in the Republic of Armenia under Climate Change" (2008).

Table 2. The RA river flow variation for the period of 1991-2006 against to 1961-1990 baseline period.

| № | Hydrological observation stations | Average river flow, mln $m^3$ | | |
|---|---|---|---|---|
| | | 1961-1990 | 1991-2008 | Deviation |
| 1 | Pambak-Meghrut | 251.2 | 283.0 | 31.8 |
| 2 | Pambak-Tumanyan | 336.1 | 385.2 | 49.1 |
| 3 | Dzoraget-Gargar downstream | 480.4 | 471.7 | -8.7 |
| 4 | Debed-Ayrum | 1063.4 | 1045.4 | -18.0 |
| 5 | Aghstev-Dilijan | 107.1 | 99.7 | -7.4 |
| 6 | Paghjur-Getahovit | 63.1 | 49.0 | -14.1 |
| 7 | Akhuryan-Akhurik | 225.8 | 255.2 | 29.4 |
| 8 | Hrazdan-Hrazdan | 243.4 | 254.6 | 11.2 |
| 9 | Argichi-Verin Getashen | 192.3 | 180.8 | -11.5 |
| 10 | Gavaraget-Noradus | 105.8 | 110.4 | 4.6 |
| 11 | Arpa-Jermuk | 168.3 | 163.0 | -5.3 |
| 12 | Meghriget-Meghri | 93.8 | 80.9 | -12.9 |

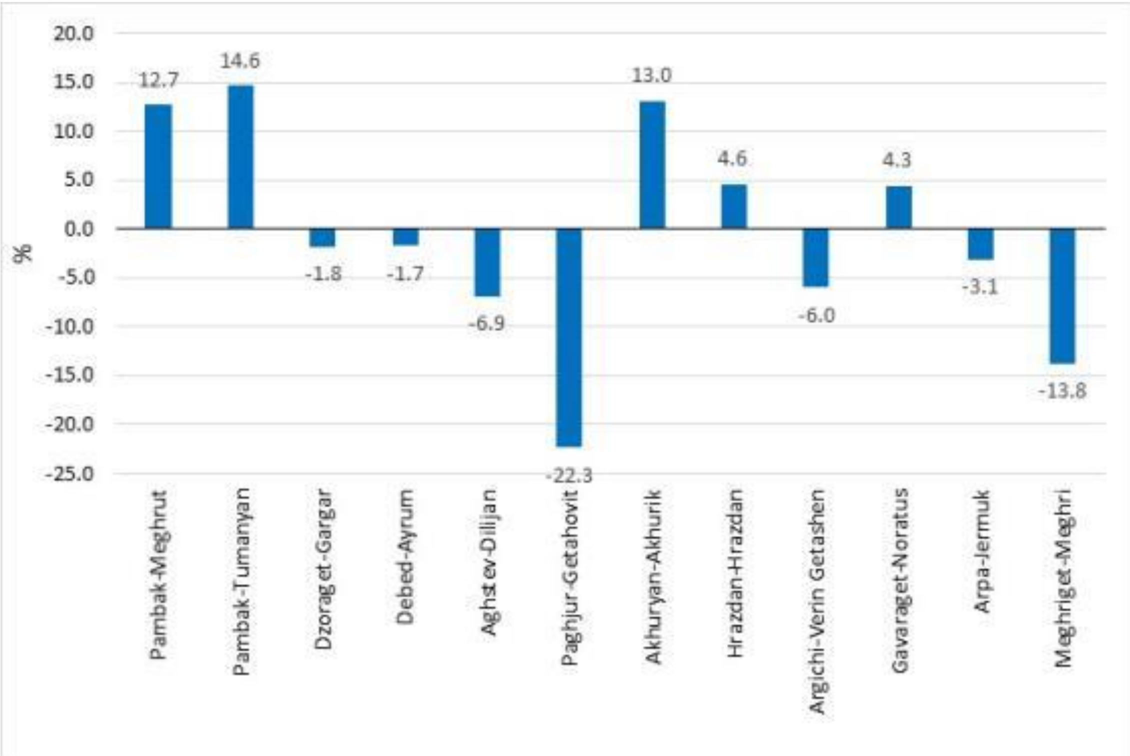



Figure 1. Annual river flow change for the period of 1991-2006 against to baseline period of 1961-1990.

The document also examines the maximum, minimum flows of the rivers of Armenia and assesses their tendencies. The highest flows in the river basins had a tendency to decrease by 2-5%, with the exception of Aghstev-Ijevan, Hrazdan-Hrazdan, Marmarik-Aghavnadzor and Dzknaget-Tsovagyugh observation stations, where the maximum flows of the rivers have a tendency to increase to some extent.

In this report too, the change in the river flow was estimated based on actual observation data of hydrological observation stations, i.e. the natural river flow was not restored, and in this case, the change in water use amounts would have a significant impact on the river flow.

***Assessment of climate change impact on water resources in Marmarik River basin, Armenia, 2008***

The results of this study are included in the Second National Communication on Climate Change.

The document analyzes and assesses the change in water resources of the Marmarik River Basin due to climate change up to 2007 and provides a flow forecast. The observation data from three hydrological observation stations in the Marmarik River basin, namely, Masrik-Hankavan, Masrik-Aghavnadzor and Gomur-Meghradzor were selected for river flow analysis (from the beginning of observations until 2007). The actual values of the observation data were used to assess the river flow change. The actual average annual flow of the mentioned three observation stations over the period of 1991-2007 was compared to the average annual flow of the baseline period of 1961-1990.

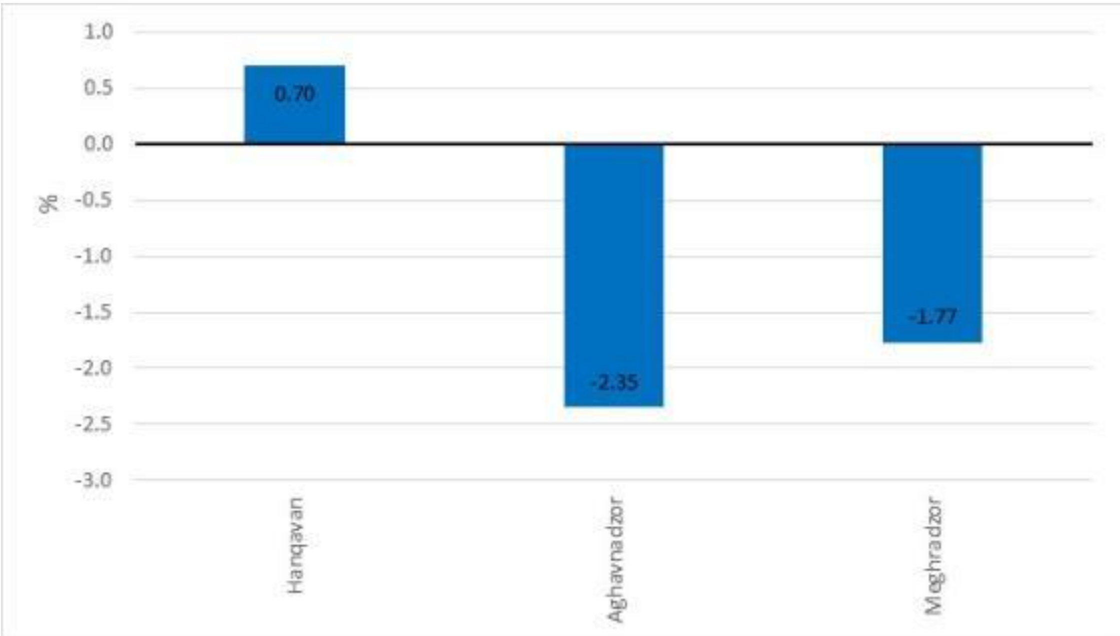



**Figure 2. Change in actual river flow in the Marmarik River Basin in 1991-2007 against to baseline period of 1961-1990.**

In order to assess the change in the river flow in Armenia, the physical-statistical or regression model was used, in addition to the geospatial model.

The analysis of the data shows that the actual river flow in the Marmarik River basin has shown an increasing trend at the Marmarik-Hankavan observation station, while showing decreasing trends at the Marmarik-Aghavnadzor and Gomur-Meghradzor observation stations (Figure 2).

Such a picture is a result of the fact that the two periods (basline and assessment) compared together using the actual data of river flow. In other words, the change of water intake from the river for different purposes was not taken into account for the basline period.

### 2.1.1.3 Assessment of the vulnerability of river flow to climate change in the report on Armenia's Third National Communication

The information contained in the third national communication on water resources vulnerability assessment in Armenia is presented below by reports.

***Regional Climate Change Impacts Study for the South Caucasus Region, Tbilisi, Georgia, 2011***

The report assesses the impacts of climate elements' changes on river flow in three river basins in the South Caucasus (Alazani, Khrami-Debed and Aghstev). To study the climate change impact on river flow in these river basins, the flow data of hydrological observation stations of Aghstev-Ijevan (1961-2006), Voskepar-Kirants (1961-2006), Debed-Ayrum (1954-2006), Pambak-Tumanyan (1950-2006) and Dzoraget-Gargar (1950-2006) in Armenia were collected. The river flow was assessed by the actual flow values. In order to assess the change in the river flow in Armenia, the physical-statistical or regression method was used, in addition to the geospatial model.

A comparative analysis of the river flow data between the period of 1991-2011 and the baseline period of 1961-1990 was not performed in this report; only the baseline data of the hydrological observation stations and a forecast for 2100 were provided.

***Water sector vulnerability to climate change, 2012***

The results of the document are included in the Third National Communication on Climate Change.

Using the Water Evaluation and Planning Model (WEAP), the river flow of the Arpa River Basin was evaluated for 2006-2010 and based on it; the river flow for 2030, 2070, 2100 was simulated according to climate change scenarios A2 and B2. It should be noted that the flow change projections were given as compared to the 1961-1990 baseline period.

The natural flow of the Arpa River was calculated in the report based on the actual average annual flow data of the Arpa-Areni hydrological observation station (the Yelpin River flow was also taken into account). The Arpa River's average natural flow for the period of 2006-2010 estimated through the model was 696.59 mln. $m^3$.

The vulnerability of maximum water levels as a result of global climate change in the Akhuryan, Aparan and Azat reservoirs extremely important for Ararat Valley and its premountainous zone, as well as the vulnerability of Lake Sevan to climate change were assessed by using the physical-statistical or regression method.

To assess the vulnerability of Lake Sevan, the data of Lake Sevan water balance for 1933-2011 were analyzed and forecasts were made for 2030, 2070 and 2100 based on these data.

The document also presents the results of the river flows of the Debed and Aghstev River Basins in the "Regional Climate Change Impacts Study for the South Caucasus Region", Tbilisi, Georgia, 2011.

***Vulnerability of Ararat Valley Water Resources to Global Climate Change, 2014***

The report was developed within the framework of the UNDP / GEF / 00059937 project on "Creating Favorable Conditions for the Preparation of Armenia's Third National Communication on Climate Change under the United Nations Framework Convention on Climate Change".

To assess the change in river flow for the period of 1991-2013, the multi-year flow observation data of 11 hydrological observation stations on 8 rivers were selected and the deviations of annual values of the flow were calculated compared to the mean values of the baseline period of 1961-1990 proposed by IPCC (Table 3). The actual river flow data were used to assess the change in water resources.

**Table 3. Changes in actual rivers flow in Ararat valley during 1991-2013 as compared to the baseline flow.**

| Hydrological observation stations | Average River Flow, mln $m^3$ | | |
|---|---|---|---|
| | 1961-1990 | 1991-2013 | Deviation, mln $m^3$ |
| Araks-Surmalu | 2656 | 2408 | -248 |
| Hrazdan-Hrazdan | 241.9 | 257.7 | 15.8 |
| Azat-Garni | 138.3 | 131.7 | -6.5 |
| Akhuryan-Akhurik | 225.7 | 251.8 | 26.1 |
| Akhuryan-Haykadzor | 950.1 | 923.4 | -26.7 |
| Metsamor (Sevdjur)-Taronik | 498.1 | 307.0 | -191.1 |
| Metsamor-Echmiadzin | 686.8 | 434.2 | -252.6 |
| Qasakh-Vardenis | 48.7 | 28.8 | -19.9 |
| Qasakh-Ashtarak | 111.8 | 98.4 | -13.4 |
| Hrazdan-Lusakert | 135.9 | 140.7 | 4.75 |
| Vedi-Urcadzor | 58.6 | 54.4 | -4.18 |

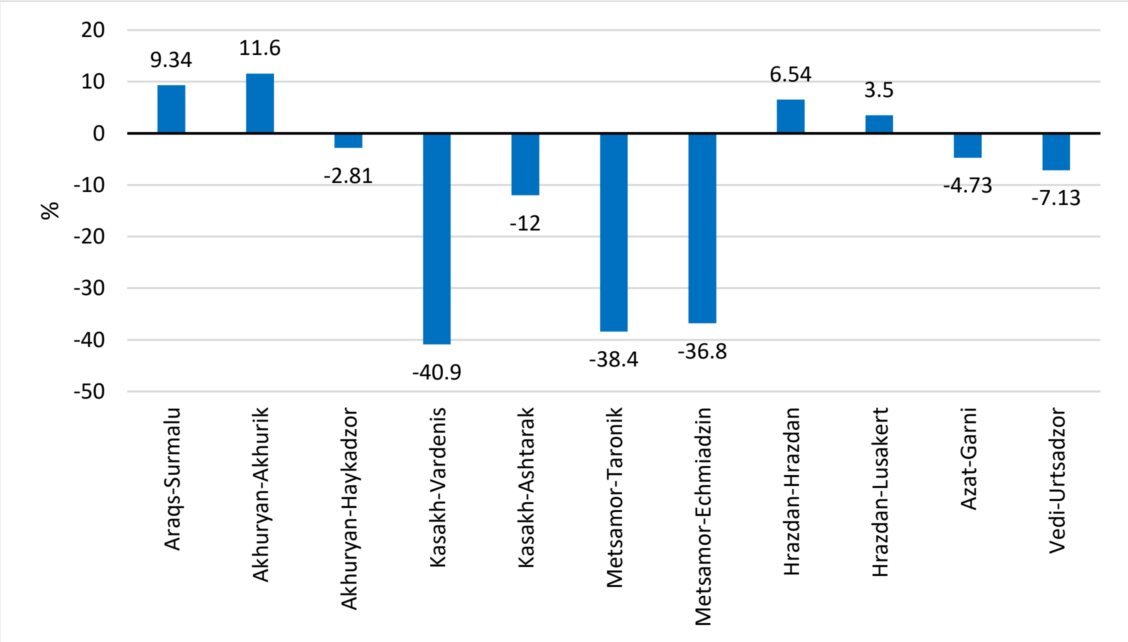



**Figure 3. The change in river flow of the Ararat Valley during 1991-2013 against to baseline period of 1961-1990 (%)**

The document also assessed the possible change in the Araks River flow as a result of construction of major reservoirs on the territory of the Republic of Turkey.

Assessment of change in spring floods and snow cover over the period by 2013, as well as analysis of extreme hydrological phenomena were provided.

#### 2.1.1.4 Assessment of the vulnerability of river flow to climate change in the report on "Armenia's Fourth National Communication"

The information contained in the second national communication on water resources vulnerability assessment in Armenia is presented below by reports:

***Assessment of the Vulnerability of Water Resources in the Republic of Armenia under Climate Change, 2018***

The document estimates the change in the river flow during the period of 1991-2017. For that purpose, the multi-year observation data from 32 observation stations with long data series were selected, which provided sufficient reliability in terms of accuracy. The deviations of annual values of those flows were estimated as compared to the average values of the baseline period of 1967-1990 proposed by IPCC (Annex 4).

The actual river flow data were used to assess the change in water resources, since the current methods for natural flow restoration do not provide sufficient accuracy.

To assess the vulnerability of river flow due to climate change, the physical-statistical or regression model was selected that provides sufficient accuracy of vulnerability assessment in the mountainous conditions of our country.

To assess the vulnerability of river inflow as a result of global climate change into the Akhuryan, Aparan and Marmarik reservoirs of strategic importance to the RA during spring snowmelt (April-June), again the physical-statistical or regression model was selected. Multi-factor correlations were established between hydrometeorological elements and equations were obtained. The vulnerability of maximum water levels as a result of global climate change in the Akhuryan, Aparan and Azat reservoirs was also assessed by using the physical-statistical or regression method.

The largest reduction in river flow occurred in the basins of the Voghji, Kasagh and Metsamor river basins. As a result of abrupt reduction of the discharges of Metsamor-Aknalich springs group (conditioned by increase in water use volumes of groundwater resources) the Metsamor River flow decreased by 38.4% at Taronik observation station as compared to the 1961-1990 baseline flow, and by 36.8% at Echmiadzin observation station.

At Voghji-Kapan, Kasagh-Vardenis hydrological observation station too, the water flows in rivers have undergone major changes as a result of human economic activity and climate change, reducing by 43.4% and 40.9% respectively compared to the baseline flow (Figure 4).

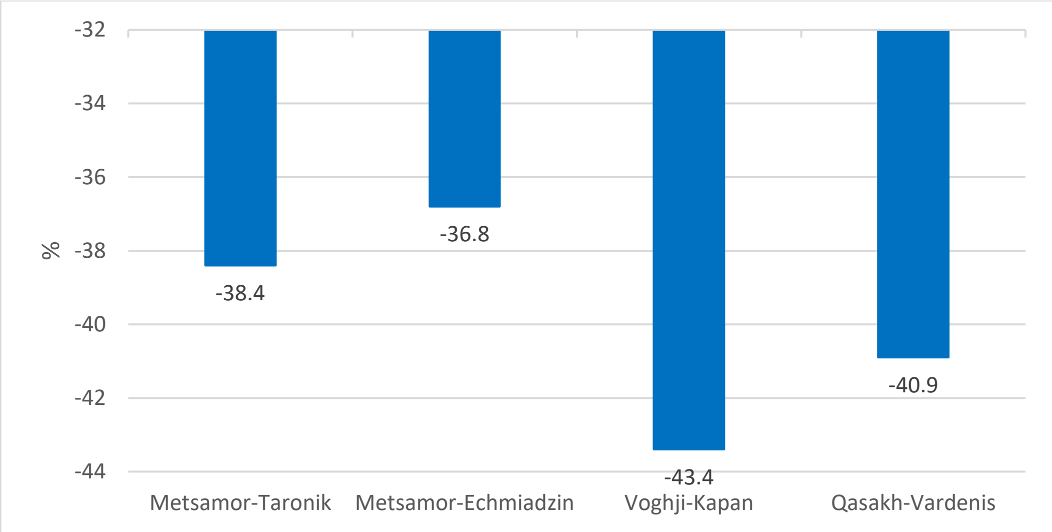


**Figure 4. Rivers flow changes during 1991-2017 against the baseline period of 1961-1990.**

A tendency of increasing trend in actual river flow was observed especially in the Pambak, Aghstev, Gargar, Tavush, Akhourik and Tsghuk rivers 10-28% (Figure 5).

The increasing tendency is lower (up to 5%) in the Debed and Hrazdan river basins.

The document also considered the possible change in the Araks River flow by Turkey, assessment of the tendencies of extreme hydrological phenomena, as well as assessment of change in spring floods and snow cover by 2017.

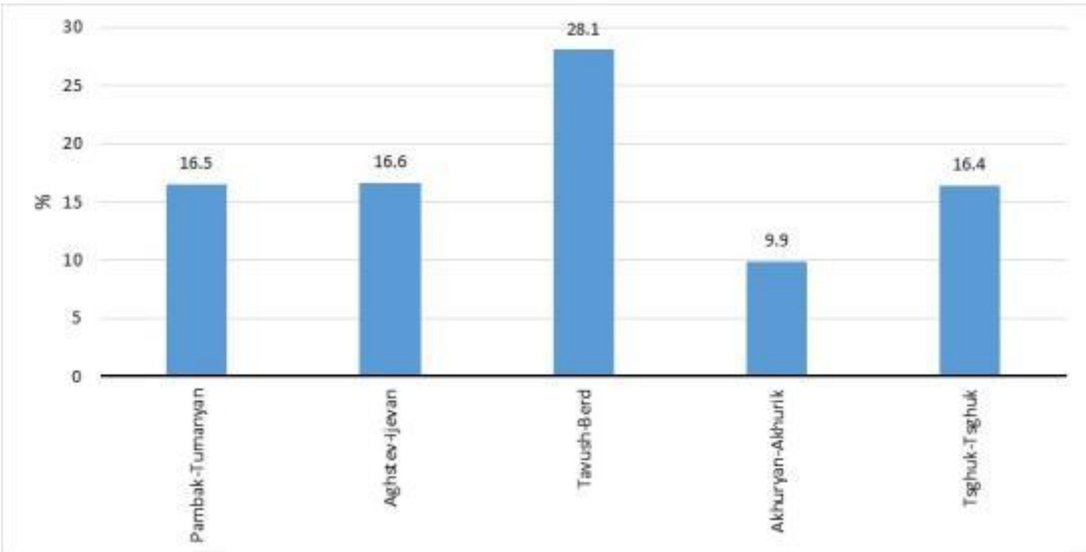


**Figure 5. Rivers flow changes during 1991-2017 against the baseline period of 1961-1990.**

***Toward Integrated Water Resources Management in Armenia, World Bank Group, 2015***

The document provides the data on water resources of the water basin management areas from the hydrological atlas for 2008. These data are substantially different from those provided in the water basin management plans (Table 4).

Table 4. Comparison of data on water resources

| Basin Management District | Based on Report of Toward Integrated Water Resources Management in Armenia, World Bank Group, 2015 | | | Based on River Basin Management Plans | | |
|---|---|---|---|---|---|---|
| | Usable water resources, mln $m^3$ | Strategic water reserve, mln $m^3$ | National water reserve, mln $m^3$ | Usable water resources, mln $m^3$ | Strategic water reserve, mln $m^3$ | National water reserve, mln $m^3$ |
| Akhuryan | 1602 | 564.0 | 608.2 | 3188.3 | 41.83 | 522.57 |
| Araratyan | 1306 | 229 | 245 | 1292.1 | 233.74 | 137.47 |
| Southern | 1443 | 90.5 | 101.1 | 1150.1 | 203.6 | 356.0 |

The value of natural river flow in the Akhuryan RBD (the amount of water available for Armenia downstream the confluence of the Araks and Akhuryan rivers is 1114.9 million $m^3$) is 1478 million $m^3$, while according to the document "Toward Integrated Water Resources Management in Armenia, World Bank Group, 2015", the Akhuryan RBD's river flow is 1102 million $m^3$.

***Climate Change Analysis for the Ararat Valley, USAID ASPIRED Project, 2019***

The document analyzes the actual data on annual flow volume and flow layer height at Vedi-Urtsadzor, Azat-Garni, Hrazdan-Yerevan, Qasagh-Ashtarak and Sevjur-Taronik hydrological observation stations for the period of 1991-2016 and their deviation as compared to the baseline period of 1961-1990.

The annual river flow over the period of 1991-2016 decreased in all of the studied observation stations as compared to 1961-1990. The sharpest decrease was observed at Sevjur-Taronik observation station (-16.6%) (Table 5).

Table 5. Changes in annual river flow and runoff depth

| Hydrological observation stations | 1961-1990 | | 1991-2016 | | Difference | | |
|---|---|---|---|---|---|---|---|
| | mln $m^3$ | mm | mln $m^3$ | mm | mln $m^3$ | mm | mln $m^3$ |
| Vedi-Urcadzor | 61. 8 | 171. 8 | 49. 9 | 138. 5 | -11. 9 | -33. 3 | -19. 4 |
| Azat-Garni | 146. 7 | 450. 1 | 139 | 426. 3 | -7. 7 | -23. 8 | -5. 3 |
| Hrazdan-Yerevan | 596. 7 | 297. 1 | 595. 3 | 296. 4 | -1. 4 | -0. 7 | -0. 2 |
| Kasakh-Ashtarak | 222. 9 | 218. 6 | 202. 8 | 198. 8 | -20. 1 | -19. 8 | -9. 1 |
| Sevdjur-Taronik | 631. 7 | 404. 9 | 526. 5 | 337. 5 | -105. 1 | -67. 4 | -16. 6 |

### 2.1.2 Assessment of the vulnerability of river flow to climate change provided in the River Basin Management Plans

In 2015-2018, Southern, Ararat, Akhuryan river basin management plans (RBMPs), as well as draft Sevan and Hrazdan RBMPs were developed by various organizations and expert teams in Armenia. During the development of the RBMPs the physical-statistical or regression model was applied to assess the changes in river flow within the river basin districts (RBD). Also, for calculation of the water balance and water economic balance, experts commonly used GIS-based DSS model created within the framework of the USAID "Clean Emergy and Water" Project. To assess the vulnerability of the water resources of Armenia to climate change, the actual data on the river flow during the baseline period of 1961-1990 and during the period following the baseline period were adjusted to natural flow in the RBMPs.

#### 2.1.2.1 Ararat RBMP (2015)

The tendency in the river flow is assessed in the Ararat RBMP. To assess the climate change impact on the river flow in Ararat RBD the natural flow in the hydrological observation stations was restored by channel balance method and assessment of tendency of changes in the natural flow in the selected observation stations was done for the period of 1991-2013 as compared to the mean value of the baseline period (1961-1990) (Table 6). The document provides also the annual distribution of the natural flow by 7 observation stations.

**Table 6. Deviations of annual average natural flow of Ararat RBD rivers during 1991-2013 against to basline period of 1961-1990.**

| Hydrological observation stations | Average of 1961-1990, $m^3$/sec / mln $m^3$ | Average of 1991-2013, $m^3$/sec / mln $m^3$ | Deviation, $m^3$/sec |
|---|---|---|---|
| Azat-Garni | 4.64/146.3 | 4.71/148.6 | 0.07 |
| Vedi-Urcadzor | 2.05/64.7 | 1.53/48.3 | -0.52 |
| Arpa-Jermuk | 5.33/168.1 | 5.24/165.3 | -0,09 |
| Arpa-Yeghegnadzor | 13.89/438.1 | 13.23/417.3 | -0.66 |
| Arpa-Areni | 21.87/689.8 | 20.31/640.6 | -1.56 |
| Yeghegis-Hermon | 5.12/161.5 | 5.35/168.6 | 0.23 |
| Yeghegis-Shatin | 7.88/248.5 | 8.00/252.3 | 0.12 |

The analysis shows that during the period of 1991-2013, an increase in the river natural flow by 1.5% was observed at Azat-Garni observation station. The river flow in the Vedi River basin was reduced by 25.4%. In the Arpa river basin, there was a decrease of the river flow by 1.7-7.1%. In the Yeghegis river basin, an increase of the river flow by 1.5-4.5% was observed (Figure 6).

According to the Ararat RBD management plan, the natural renewable groundwater resources entering the Ararat Valley were estimated at 1822.8 million $m^3$. This value is obtained by the water balance method, and, of course, the climate change impact on it cannot be directly estimated. The artesian basin useful reserves of 34.7 $m^3$/s approved by the State Reserves Commission in 1984 is given in the management plan.

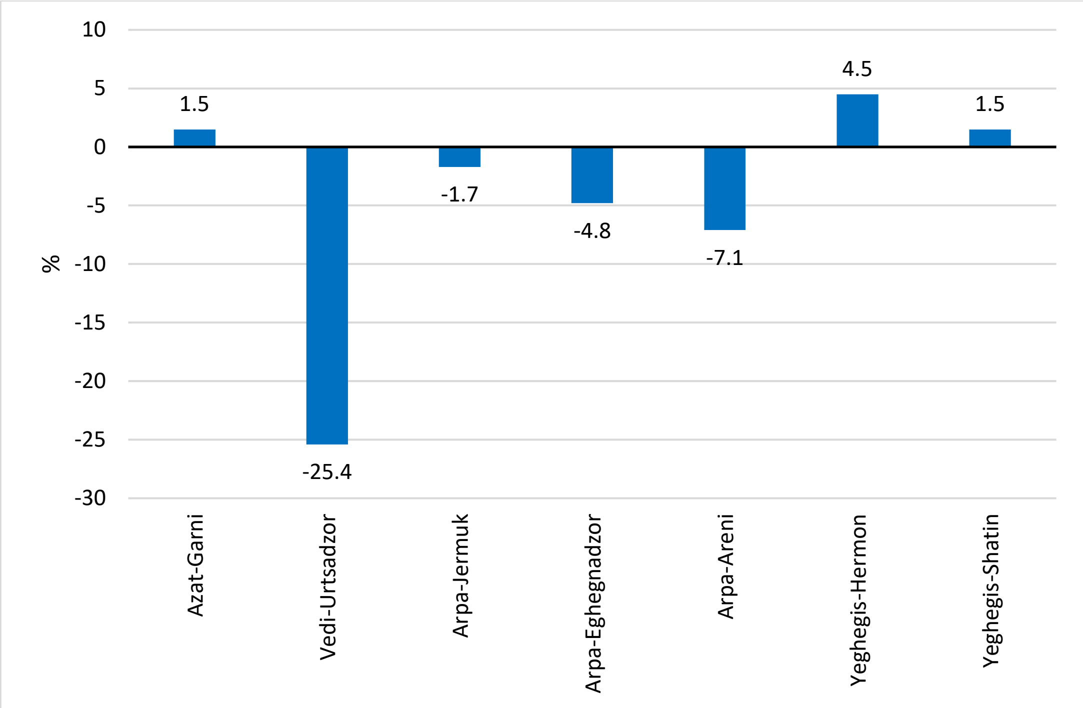



**Figure 6. Deviation of the annual natural flow in the Ararat RBD against to the baseline period of 1961-1990.**

That is, the data on the basic characteristics of water resources of the Ararat Valley artesian basin are provided according to 1984 data, thus, studies are needed to assess the present condition, which will allow assessing the significance of the vulnerability of the groundwater resources to climate change (presently reassessment of the reserves of basin in the Ararat valley is being carried out within the framework of USAID ASPIRED project).

The management plan provides data on the natural flow of underground water by river basin (Table 7).

**Table 7. Natural groundwater flow formed in the river basins of Ararat RBD**

| Name of watershed | Natural flow of groundwater resources, m³/sec | | | |
|---|---|---|---|---|
| | Total | Spring flow | Drainage flow | Deep flow |
| Azat | 6.33 | 3.28 | 2.86 | 0.19 |
| Vedi | 1.66 | 0.25 | 0.27 | 1.14 |
| Arpa | 11.22 | 5.36 | 3.20 | 2.66 |
| Overall | 19.21 | 8.89 | 6.33 | 3.99 |

### 2.1.2.2 Southern RBMP (2015)

To assess the climate change impact on the flow of the rivers in the Southern RBD, observation data from 14 hydrological observation stations (including 9 operational and 5 closed stations) were used, with an observational data series over 25 years and more. The actual observation data of the observation stations were brought to natural flow. An assessment of tendency of changes in the natural flow was done for the period of 1991-2011 as compared to the mean value of the baseline period (1961-1990) (Table 8).

**Table 8. Multi-year average values of the natural river flow of Southern RBD and their deviations against the baseline period of 1961-1990.**

| № | Hydrological observation stations | 1961-1990, mln $m^3$ | 1991-2011, mln $m^3$ | Deviation, mln $m^3$ |
|---|---|---|---|---|
| 1 | Vorotan-Gorhayk | 492 | 499 | 7 |
| 2 | Vorotan-Vorotan | 378 | 367 | -11 |
| 3 | Vorotan-Tatev HPP | 336 | 321 | -15 |
| 4 | Tsghuk-Tsghuk | 614 | 602 | -12 |
| 5 | Gorisget-Goris | 310 | 311 | 2 |
| 6 | Sisian-Arevis | 208 | 227 | 18 |
| 7 | Loradzor-Ltsen | 110 | 124 | 13 |
| 8 | Voghji-Qajaran | 114 | 94 | -20 |
| 9 | Geghi-Geghi | 154 | 141 | -13 |
| 10 | Geghanush-Geghanush | 20 | 14 | -6 |
| 11 | Vachagan-Kapan | 16 | 12 | -4 |
| 12 | Voghji-Kapan | 388 | 269 | -119 |
| 13 | Meghtiget-Meghri | 103 | 96 | -7 |
| 14 | Meghriget-Lichq | 20 | 19 | -1 |

Based on the data analysis provided in the RBMP, during the period of 1991-2011, a decrease in the annual natural flow by 6%-31% was observed in the Voghji and Meghriget river basins, mainly conditioned by 8-18% decrease of annual precipitation in the mentioned river basins.

In the Vorotan River basin source and middle streams there is a 1% -3% decrease in the natural flow, while in the lower stream there is an increase of natural flow up to 1-12% (Figure 7).

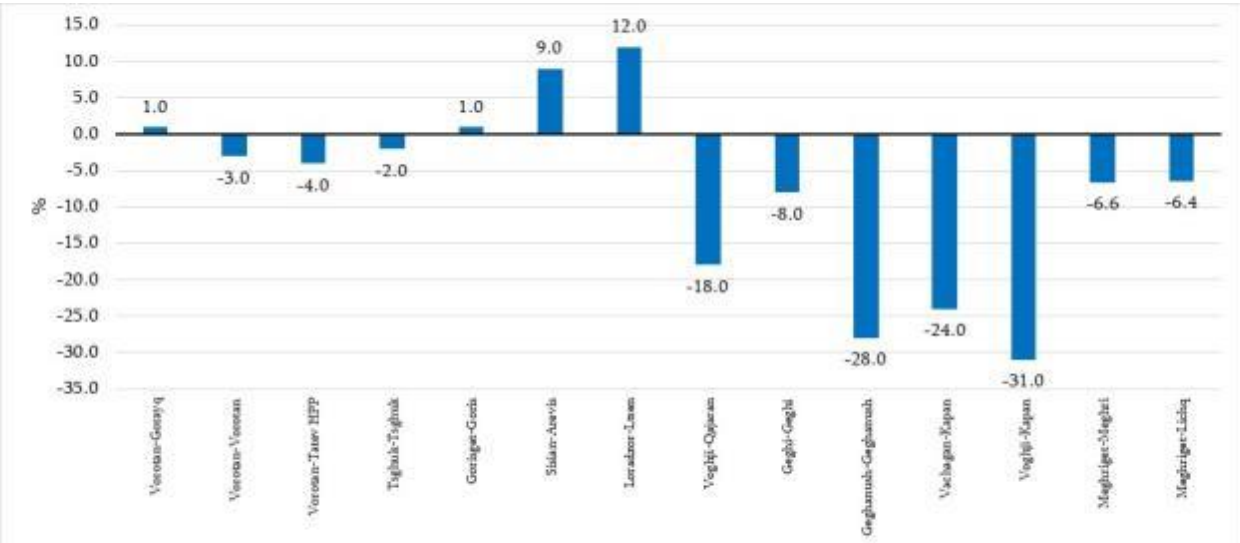



**Figure 7. Deviation of annual natural flow in the Southern RBD compared to the natural flow in the baseline period of 1961-1990.**

### 2.1.2.3 Akhuryan RBMP (2015)

The assessment of climate change impact on water resources in the Akhuryan RBD was based on data from 11 hydrological observation stations (Table 9). The document does not analyze the change in the river flow during 1991-2014 compared to the baseline period of 1961-1990.

**Table 9. Average annual river flow in the Akhuryan RBD during the baseline period (1961-1990).**

| № | Hydrological observation stations | 1961-1990, mln $m^3$ |
|---|---|---|
| 1 | Akhuryan-Akhurik | 232 |
| 2 | Akhuryan-Haykadzor | 951 |
| 3 | Karkachun-Gharibjanyan | 33 |
| 4 | Metsamor-Ejmiatsin | 338 |
| 5 | Metsamor-Ranchpar | 442 |

### 2.1.2.4 Sevan RBMP (2018)

In the draft Sevan RBMP, the assessment and prediction of climate change impact on surface flow were based on the river flow data for 12 hydrological observation stations for the period of 1961-1990 (Table 10). However, the analysis of the changes in the river flow during 1991-2017 against the baseline period of 1961-1990 were not conducted in the RBMP.

**Table 10. Average annual river flow in the Sevan RBD during the baseline period (1961-1990).**

| № | Hydrological observation stations | 1961-1990, mln $m^3$ |
|---|---|---|
| 1 | Pambak-Pambak | 6.9 |
| 2 | Dzknaget-Tsovagyugh | 34.7 |
| 3 | Drakhtik-Drakhtik | 7.6 |
| 4 | Masrik-Tsovak | 119.9 |
| 5 | Karchaghbyur-Karchaghbyur | 38.5 |
| 6 | Vardenis-Vardenik | 61.8 |
| 7 | Martuni-Geghhovit | 60.2 |
| 8 | Argichi-Verin Getashen | 200.0 |
| 9 | Tsakhashen-Vaghashen | 44.5 |
| 10 | Lichkh-Lichkh | 64.7 |
| 11 | Bakhtak-Tsakqar | 28.9 |
| 12 | Gavaraget-Noradus | 117.3 |

### 2.1.2.5 Hrazdan RBMP (2018)

The assessment of climate change impact on the Hrazdan RBD's water resources was given for 11 hydrological observation stations (Table 11).

The river flow data for the baseline period from the Hrazdan RBD hydrological observation stations were adjusted to natural, however, analysis of the change in the flow over the baseline period was not provided.

Table 11. Average annual river flow in the Hrazdan RBD during the baseline period (1961-1990).

| № | Hydrological observation stations | 1961-1990, mln $m^3$ |
|---|---|---|
| 1 | Kasakh-Vardenis | 72.33 |
| 2 | Kasakh-Ashtarak | 222.94 |
| 3 | Gegharot-Aragac | 36.68 |
| 4 | Hakhverd-Parpi | 27.58 |
| 5 | Hrazdan-Hrazdan | 250.26 |
| 6 | Hrazdan-Lusakert | 365.55 |
| 7 | Hrazdan-Yerevan | 596.72 |
| 8 | Hrazdan-Masis | 705.5 |
| 9 | Marmarik-Hankhavan | 54.8 |
| 10 | Marmarik-Aghavnadzor | 150.53 |
| 11 | Gomur-Meghradzor | 45.36 |

### 2.1.3 Identification of the gaps and barriers in reports on the assessment of the RA water resources vulnerability to climate changes officially published in 2008-2018

The analysis of the documents developed so far for assessment of the RA water resources related to climate change shows that river flow values from the same observation stations for the baseline period (1961-1990) are different (Table 12).

In most of the documents, the river flow was analyzed based on the actual data from hydrological observation stations, and in other documents the river flow data were adjusted to represent natural flow. The baseline values for river flow under climate change represented in the management plans do not correspond to the values reported in other documents, since the natural flow has been restored in the management plans with the purpose of analyzing the river flow.

**Error! Reference source not found.** shows the hydrological observation stations, in case of which the comparison of the data on the flow over the baseline period revealed significant differences.

The baseline values (1961-1990) of 13 hydrological observation stations in the report on "Assessment of the Vulnerability of Water Resources in the Republic of Armenia under Climate Change" (2008) do not correspond to the ones provided in the report on "Assessment of the Vulnerability of Water Resources in the Republic of Armenia under Climate Change" (2018). The baseline value of Debed-Ayrum observation station is 1063.4 mln $m^3$ in the 2008 report and 1054.5 mln $m^3$ in the 2018 report (the difference is 8.9 mln $m^3$). The difference in Azat-Garni observation station is 19.26 mln $m^3$.

**Table 12. Comparison of the data of the hydrological observation stations for the baseline period in the reviewed documents (1961-1990).**

| № | Hydrological observation stations | Water resources vulnerability assessment under climate change in Armenia, 2008 | Regional Climate Change Impacts Study for the South Caucasus Region, Tbilisi, 2011 | Water vulnerability assessment under climate change, 2012 | Vulnerability of Ararat Valley water Resources due to global climate change, 2014 | Water resources vulnerability assessment Under climate change in Armenia, 2018 | Southern RBMP | Araratyan RBMP | Draft Hrazdan RBMP | Draft Sevan RBMP | Akhuryan RBMP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Debed-Ayrum | 1063.4 | 1054 | 1054 | | 1054.5 | | | | | |
| 2 | Aghstev-Ijevan | 243.8 | 286 | 286 | | 296.4 | | | | | |
| 3 | Kasakh-Vardenis | 48.7 | | | 48.7 | 48.7 | | | 72.33 | | |
| 4 | Kasakh-Ashtarak | 124.1 | | | 111.8 | 111.8 | | | 222.94 | | |
| 5 | Hrazdan-Lusakert | | | | 135.9 | 135.9 | | | 365.55 | | |
| 6 | MAsrik-Torph | 102.2 | | | | 99.6 | | | | 119.9 | |
| 7 | Karchaghbyur-Karchaghbyur | 32.7 | | | | | | | | 38.5 | |
| 8 | Vardenis-Vardenik | 56.1 | | | | 56.1 | | | | 61.8 | |
| 9 | Argichi-Verin Getashen | 192.3 | | | | 194.7 | | | | 200.0 | |
| 10 | Bakhtak-Tsakhqar | 21.7 | | | | 21.7 | | | | 28.9 | |
| 11 | Azat-Garni | 119.04 | | | 138.3 | 138.3 | | 146.3 | | | |
| 12 | Arpa-Areni | | 728.8 | | | | | 689.8 | | | |
| 13 | Vorotan-Vorotan | 440.5 | | | | | 378 | | | | |

The following are among the main reasons of the differences between the baseline values of the river flow in the analyzed documents:

- **Relocation of hydrological observation stations**: In some cases, as a result of relocation of the observation stations, the river flow data naturally changes, and the observation data series becomes inconsistent and heterogeneous. In such a case, the flow analysis will yield incorrect results. In these cases, analysis should be made on the basis of homogeneous data series. Such observation stations in the surface water resources quantitative monitoring network include Voghji-Kapan, Vorotan-Gorayk, Vorotan-Vorotan, Vedi-Urtsadzor and Gegharot-Aragats hydrological observation stations.
- **Recovery of missing years in the observation data series**: deviations can make up to 5-15% during the restoration of the years experiencing missing river flow data. The main causes of these deviations may be incorrect selection of hydrological observation stations having physical-geographical conditions of similar flow. Weak graphical relationship between the

data of the observation stations selected for the river flow data restoration and consequently, the resulting deviations during the recovery of the missing river flow data.

- **As a result of water diversions and abstraction**: during the last decade, the construction of small hydropower plants (SHPPs) has been developing rapidly in the Republic. During the construction of a small HPP, as a result of abstraction, hydrological observation station that has been operating for many years is often bypassed, thereby effecting the homogeneity of observation data, while information on the actual abstraction carried out by the SHPP, which would allow to restore the river flow, is not available. In addition, there is no available and reliable data on other actual water uses to restore the natural flow in the river basins, based on which it would be possible to assess the change in flow under the climate change.
- **other**:
  - lack of professional experience;
  - use of inadequate data recovery method, absence of practical verification of recovered or evaluated data;
  - application of different hydrological models without localization;
  - technical shortcomings.

### 2.1.4 Identification of the issues in the assessment of the RA water resources vulnerability

One of the problems of the RA water resources vulnerability assessment is the current technical condition of the hydro-meteorological monitoring network, as well as the structure of the network deployment.

Quantitative monitoring of surface water resources in Armenia is carried out at 93 hydrological observation stations (see maps on the locations of the hydrological and meteorological stations in Armenia in Annex 2), including 82 river observation stations, 5 reservoir observation stations (Arpilich, Akhuryan , Aparan, Marmarik, Azat), 4 lake observation stations (Lake Sevan), 2 on canals (Hrazdan HPP canal - Geghamavan observation station and Arpa-Sevan water main - Tsovinar observation station).

We classified the 82 river hydrological observation stations by elevation in the following ranges: up to 1800 meters, 1800-2000 meters and above 2000 meters. This classification approach was applied, taking into account that the flow formation zone in the country is above 1800 meters.

According to this classification, there are 60 hydrological observation stations at elevations up to 1800 meters, 18 ones at elevations of 1800-2000 meters, and 6 ones in the zones above 2000 meters.

It should also be noted that 11 out of 18 observation stations located at 1800-2000 m elevation zone are located in Lake Sevan catchment. The basin is located in zones above 1900 m, but the 11 hydrological observation stations in Lake Sevan basin are located in the mid or near-to-estuary reaches of the rivers, which does not allow for estimating the climatic flow formed in Lake Sevan basin accurately.

For more accurate estimation of climatic flow, it is necessary to have data on the river flow regime for zones above 1800 meters; however, 24 of the operating observation stations are located in zones above 1800 meters.

There are a small number of hydrological observation stations operating in the lower reaches - estuaries of the river basins. This gap does not allow to completely estimating the river flow formed in a given river basin, thus it does not allow for a more accurate assessment of the vulnerability of the flow to climate change.

Unaccounted water use and diversions have a significant impact on the restoration of the natural river flow, in particular the transfer of the flow from one river basin to another through canals. Reliable data on the river flow transfer from one river basin to another are available on the flow transferred from the Arpa basin to Sevan basin and on water releases from Sevan basin. In order to obtain reliable data on flow transfer between river basins, hydrological observations stations need to be established on hydro technical structures for flow transfer in order to estimate the transferred flow volumes, and consequently, to assess the water resources of each river basin more accurately.

Reliable open and accessible data on annual water fill level and annual change in volume are available only for 5 major reservoirs in the Republic (Arpilich, Akhuryan, Aparan, Marmarik, Azat). It is also necessary to collect data on the water resources of other major reservoirs in the country.

The hydrometeorological observation network of the Republic comprises 47 meteorological stations (including 6 high-mountain stations). Because of the long-term absence of tools and equipment at the meteorological stations, no monitoring of evaporation and evapotranspiration has been carried out, instead of 6 stations at which the evaporation from the water surface is conducted. For restoration of observations and in order to obtain more reliable data on the observed meteorological elements, the Republic's meteorological network needs to be upgraded, with installation of automatic meteorological stations[41]. A problem for more reliable estimation of the change in the hydro meteorological elements under climate change is the structure of the current meteorological network deployment. High-mountain automatic meteorological stations should be established in high-mountainous zones of large river basins.

The underground freshwater monitoring network includes 100 underground water sources in 6 water basin management areas (Northern, Akhuryan, Hrazdan, Sevan, Ararat, Southern), including 24 flowing wells, 32 non-flowing wells and 43 natural springs. Water flow, level (pressure) and temperature observations are carried out at the water sources, 6 times a month[42].
Data on groundwater resources in the Republic's river basins indicate that only useful underground water resources are estimated; however, water resources and reserves in underground water basins are not estimated in inter-mountain depressions. The changes in underground water resources due to climate change are also not estimated.

[41] Modernizing Weather, Climate and Hydrological Services: A Road Map for Armenia
[42] Environmental and Information Center SNCO Bulletin for 2019

It is quite difficult to assess the dynamics of water resources change in underground water basins due to climate change, conditioned by the characteristics of underground water flow formation. Changes in underground water resources under climate change can only be estimated using the water balance method, separating the flow into river natural and deep flows.

Currently, USAID's ASPIRED project is assessing the water resources of the Ararat Valley underground water basin. Once the underground water re-assessment is completed, it is necessary to re-assess the resources at five-year intervals. With the availability of this data, it will be possible to assess the vulnerability of water resources to climate change in the Ararat Valley.

The lack of accurate data on diversions and abstraction from river basins for different purposes affects the accurate estimation of natural river flow and the results of assessment of flow changes under climate change. Since there is no reliable data on water abstraction for socio-economic purposes, it is very difficult to assess the dynamics of water resource changes in the river basins, therefore it is not possible to accurately assess the change in water resources under climate change. Reliable assessment of water resources in river basins and reliable assessment of changes in water resources under climate change are very important for managing the problems related to water demand.

The basin management plans provide the water supply and demand volumes for the water basin management area. These calculations, however, were based on the data in water use permit applications. This is an essential issue: there is no reliable information on the extent to which each water user actually performs abstraction, and no reliable data on the water returned after use.

To solve this problem, it is necessary to create a unified system for collecting, processing and maintaining data on actual abstraction from river basins and on drainage.

Hydrological models are rarely used to analyze water resources and to assess their vulnerability. This gap is conditioned by a number of circumstances:

- From the existing hydrological models, it is necessary to select the models created for the mountainous regions, and then localize and apply them.
- Verification and localization of hydrological models require hydrological and meteorological data series of long years of observations.

## 2.2 VULNERABILITY ASSESSMENT OF ARMENIA’S WATER RESOURCES IN TERMS OF QUANTITY DUE TO PROJECTED CLIMATE CHANGE

In this section, the results of reviewing the reports on quantitative vulnerability assessment of water resources due to the climate change listed in the summary of Chapter 2 are presented and analysed.

With the accumulation of data and knowledge on climatic parameters and their trends, enhancement of General Circulation Models (GCMs), including Earth System Models (ESMs) that also simulate the carbon cycle, as well as regional climate models such as MAGICC/SCENGEN regional climate scenario generator, PRECIS, CCSM4 and METRAS, the climate change projections for specific territories of the world seem to become more reliable.

Scenarios of climate change have been also revised. The first group of 40 scenarios developed by International Panel on Climate Change (IPCC) in 2000 is presented in **Special Report on Emissions Scenarios (SRES)**. Each scenario is divided into one of four "families" (A1, A2, B1, B2), each with common themes (e.g: Population changes, energy sources, economic development, etc.). In the case of the A1 model, there are 4 scenario "groups" based on the possibility of a certain energy source becoming more dominant (e.g: A1C scenarios are based on a coal-driven society). SRES use a sequential approach to determine their scenarios. Political or legislative actions have no effect on the development of these scenarios. The scenarios are based on socio-economic futures; this setup requires each individual scenario (emission scenario, radiative forcing scenario, climate model scenario) to be formed in sequence with the previous scenario. If there is a change in any previous scenario, the whole sequence must be restarted. This makes the sequential approach time-consuming.

**Representative Concentration Pathways (RCPs)** are the group of 4 individual scenarios (RCP8.5, RCP6, RCP4.5, RCP2.6) developed by the IPCC in 2014 to supersede SRES. Each scenario consists of a specific radiative forcing projection and makes assumptions about future population, GDP, energy use, etc. based on the radiative forcing. RCPs use a parallel approach in the development of its scenarios. The parallel approach allows for policy changes to be implemented since the socio-economic scenarios are not the starting station for the RCPs. Scenarios are based off of radiative forcing projections; this allows for socio-economic, emissions and climate scenarios to be developed in parallel with each other. This way, changes can be made to one individual scenario without having to restart the whole sequence [http://www.glisaclimate.org/node/2416].

The RCPs cover a wider range than the scenarios from the Special Report on Emissions Scenarios (SRES) used in previous assessments, as they also represent scenarios with climate policy. In terms of overall forcing, RCP8.5 is broadly comparable to the SRES A2/A1FI scenario, RCP6.0 to B2 and RCP4.5 to B1. For RCP2.6, there is no equivalent scenario in SRES. As a result, the differences in the magnitude of AR4 and AR5 climate projections are largely due to the inclusion of the wider range of emissions assessed [Fifth Assessment Report, 2014].

### 2.2.1 Vulnerability Assessment of Water Resources within National Communications of Armenia to UNFCCC

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are required to periodically submit a National Communication (NC) to the UNFCCC. The National Communication reports represent the most standardized and comparable documents on the climate policies of different countries. The NCs provide information on country’s national circumstances, greenhouse gas inventory, mitigation measures, vulnerability and adaptation measures, etc. In the table below, the climatic and hydrologic models, emission scenarios, and assessment periods applied in the National Communications of Armenia to UNFCCC are presented.

**Table 13. Vulnerability Assessment of Water Resources due to the Climate Change for River Basins in Armenia presented within the National Communications to UNFCCC**

| National Communication (NC) to UNFCCC | Territory, River Basin | Climate Model Applied | Hydrologic Model(s) Applied | IPCC Emission Scenario(s) Applied | Projection Periods |
|---|---|---|---|---|---|
| First National Communication | Armenia, Lake Sevan | | Empiric: snowmelt-runoff, rainfall-runoff | Temperature rise for 2°C, Precipitation decrease for 10% | 2100 |
| Second National Communication | Main river basins of Armenia, Lake Sevan | PRECIS | Linear regression model | SRES A2 | 2030, 2070, 2100 |
| Third National Communication | Arpa, Debed, Aghstev, Vorotan, Araks-Akhuryan, Hrazdan, Azat, Vedi River Basins, Arpi Lake Reservoir, Lake Sevan | CCSM4, ECHAM5, GFDL CM2.X, GISS-ER and HadCM3 | WEAP, linear regression models | A2, B1, B2, RCP6.0, RCP8.5 | 2030, 2040, 2070, 2100 |
| Forth National Communication | Main River Basins of Armenia, Main Reservoirs, Lake Sevan | CCSM4, METRAS | | RCP6.0, RCP8.5 | 2040, 2070, 2100 |

**In the First National Communication (1998),** the changes in the annual river flow for the entire territory of Armenia and changes in the water balance of Lake Sevan were assessed. The observed and expected changes of the climatic characteristics of Armenia are estimated with the use of empirical-statistical methods, recommended by IPCC for that period and ArmStateHydromet hydrometeorological database, including the observations of 56 meteo stations for the period of 1885-1996. Climatic anomalies, i.e. the deviations of mean monthly, seasonal average meteorological parameters from their norms (mean values for 30-year period) are determined relative to WMO standard period of 1961-1990. Based on that, the increase of the air temperature by 2100 was estimated for 1.5 -2°C and reduction of atmospheric precipitation by 2100 was estimated for 10-15%. Based on the information presented in the FNC, snowmelt-runoff and rainfall-runoff modelling was applied to assess the climatic parameters change impact on the river flow of the 75% of the rivers in Armenia. According to the calculations of authors, the river flow will decrease for 15-20% by 2100. The values were accepted for the whole country.

According to the authors, the increase of the air temperature by 2°C the average annual evaporation in comparison with its basis (1961-1987) will increase for about 13-14%. Assessment of the changes in the lake water balance for several scenarios of climate change was performed due to the level of incertitude of the projected values of climatic parameters, especially precipitation.

Table 14. Change of Lake Sevan water balance by 2100 for three different climate change scenarios (First National Communication, 1998)

| Scenario of climate change | | Change in water balance of the lake, mln. $m^3$/year |
|---|---|---|
| Change of temperature, °C | Change of precipitation, % | |
| +2 | 0 | -150 |
| +2 | -10 | -250 |
| +3 | -15 | -360 |

For the scenario considered in the First Communication (rise of temperature for 2°C and decrease of precipitation for 10%) decrease of water volume in the lake will be about 250 mln. $m^3$. In case of such scenario, the water level in Lake Sevan will decrease for 20 meters, according to the authors.

In the **Second National Communication (2010),** vulnerability of river flow due to the climate change was assessed using the values of climatic parameters for 2030, 2070, and 2100 projected using PRECIS model and IPCC SRES A2 scenario and trends in river flow and snow cover changes for 1991-2006.

In the majority of the rivers in Armenia, the maximum flow has shown a 3-5% declining trend, except for Aghstev, Hrazdan, Marmarik and Dzknaget Rivers, where a very small increase in the maximum flow is observed.

Declining trends in minimum flow were observed in Voghji-Kapan, Vorotan-Vorotan, Azat-Garni observation stations - up to 3% per year. In Dzoraget, Tavush, Karjakhbyur, Vardenis, Gavaraget, Bakhtak, Argichi and Meghri Rivers the decline is very small. Relatively small rising trends of the minimum flow are noted in Pambak, Aghstev, Marmarik, Masrik, Martuni and Arpa Rivers.

The regression model was used for evaluating the forecasts of changes in the river flow. The model ensures an adequate accuracy of vulnerability assessment in Armenia's mountainous conditions. Using the multiyear observation data on the annual river flow and atmospheric precipitation and air temperature from meteorological stations in river basins, multi-correlational links were identified between the mentioned elements.

The vulnerability of the annual river flow of individual river basins in Armenia was assessed for the years 2030, 2070 and 2100.

According to the modelling performed in scope of the SNC, the river flow in Armenia will reduce by 6.7% by 2030, 14.5% - by 2070, and 24.4% - by 2100.

Table 15. Forecasted changes in the total river flow compared to the average for 1961-1990

| Year | Flow, million $m^3$ | Changes in flow | |
|---|---|---|---|
| | | million $m^3$ | % |
| 1961-1990 | 4994.4 | 0.0 | 0.0 |
| 2030 | 4660.9 | -333.5 | -6.7 |
| 2070 | 4269.6 | -724.5 | -14.5 |
| 2100 | 3777.6 | -1216.8 | -24.4 |

The assessment of Lake Sevan water balance in scope of SNC indicated a decreasing trend in surface flow starting from the last decade. Evaporation shows an increasing trend in recent years, which will continue also in the future and is mainly caused by changes in the temperature regime. The active water yield of Lake Sevan, which is 252 million $m^3$/year, will decrease up to 220-225 million $m^3$/year by 2030, according to the authors.

**Table 16. Vulnerability assessment of the annual actual river flow in Lake Sevan basin compared to the average for 1961-1990, according to various climate change scenarios, Second National Communication, 2010**

| Scenarios | Flow, million $m^3$ | Changes of flow | | Year |
|---|---|---|---|---|
| | | million $m^3$ | % | |
| Baseline | 758 | - | - | 1961-1990 |
| T+1.5, 0.983Q | 665 | -93 | -12 | 2030 |
| T+3.3, 0.973Q | 559 | -199 | -26 | 2070 |
| T+5.1, 0.954Q | 449 | -309 | -41 | 2100 |

*Q is the average annual precipitation in the corresponding basin. The value of Q coefficient smaller than 1 means reduction in precipitation (for example 0.75Q means 25% decrease in precipitation), while coefficients higher than 1 indicate an increasing precipitation (for example 1.25Q indicates a 25% increase in precipitation).*

**Table 17. Vulnerability assessment of the annual actual river flow in Lake Sevan basin compared to the average for 1961-1990, according to various climate change scenarios, Second National Communication, 2010**

| Year | Precipitation | | Evaporation | | Surface flow | |
|---|---|---|---|---|---|---|
| | million $m^3$ | Deviation | million $m^3$ | Deviation | million $m^3$ | Deviation |
| 1961-1990 | 457 | - | 1076 | - | 758 | - |
| 2030 | 449 | -1.7% | 1158 | +7.6% | 665 | -12.2% |
| 2070 | 445 | -2.6% | 1192 | +9.7% | 559 | -26.3% |
| 2100 | 436 | -4.6% | 1268 | +17.8% | 449 | -40.7% |

In summary, the forecast of the water balance elements changes for the entire country in the SNC shows that the river flow in Armenia, compared to the average for 1961-1990, will decrease by 0.48 billion $m^3$ by 2030, 1.03, billion $m^3$ - by 2070 and 1.73 billion $m^3$ - by 2100.

**In the Third National Communication (2015),** the vulnerability assessment of the water resources of model water objects - Arpa, Debed, Voratan, Voghji, Meghriget river basins, Arpi and Aparan reservoirs – was conducted using the WEAP model. The vulnerability of Lake Sevan water resources, for which no assessment was made during the preparation of SNC, was also analyzed.

**Table 18. Projected changes in aggregate river flows in Armenia Third National Communication, 2015**

| Year | Flow, million $m^3$ | Flow change | |
|---|---|---|---|
| | | million $m^3$ | % |
| 1961-1990 | 5,797.0 | 0 | 0 |
| 2030 | 5,141.6 | -655.3 | -11.6 |
| 2070 | 4,405.6 | -1,391.5 | -24.9 |
| 2100 | 3,602.2 | -2,195.0 | -39.8 |

Under the A2 scenario, the projected change in the aggregate volume of studied river flows in the territory of Armenia will decrease approximately by 11.9% by 2030, 24% by 2070, and 37.8% by 2100.

Vulnerability assessment of water resources in different river basins, reservoirs, and lakes in Armenia were conducted using different methodologies, and models. Also, the scenarios and time periods used are not the same for all observed water bodies.

The monthly, seasonal, and annual value of the **Arpa** river flow was modelled using the SRES A2 and B2 scenarios for 2030, 2070, and 2100 using WEAP software. Due to this assessment, the annual average flow of the Arpa will significantly decrease compared to the baseline (1961-1990).

Table 19. Projected Change in the Arpa River Flow. Third National Communication, 2015

| River – Monitoring Station | Scenario | Flow change | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1961-1990 | | 2030 | | 2070 | | 2100 | |
| | | million $m^3$ | % | million $m^3$ | % | million $m^3$ | % | million $m^3$ | % |
| Arpa – Areni | A2 | 728.8 | 0 | 578.9 | -21 | 532.8 | -27 | 489.1 | -33 |
| | B2 | 728.7 | 0 | 604.0 | -17 | 573.5 | -21 | 513.7 | -30 |

In the Third National Communication, the results of the UNDP "Climate change in the South Caucasus" project (2009-2011) are also included. In scope of that project, project the vulnerability of the river flows of the **Debed and Aghstev** transboundary river basins were analyzed and assessed according to the ECHAM5, GFDL CM2.X, GISS-ER and HadCM3 regional atmospheric-circulation models. By testing historical data, these models have been adopted by South Caucasus countries to generate the most reliable results in a result of historical data testing. Thus, the results for average values derived by the aforementioned.

four models show that, in the A2 scenario, the flow of the Debed river will fall by 10-11% by 2040; by 29-37% in 2041-2070; by 55-62% in 2100. By 2040 the Aghstev river flow will decrease by 11-14%; by 2070 – 31-37%; by 2100 – 62-72%.

The vulnerability of water resources as a result of climate change in the **Vorotan** River Basin was assessed within the framework of the USAID "Clean Energy and Water" programme during the development of the Vorotan River Basin management plan and also included to the Third National Communication. According to that assessment, according to the A2 scenario, snowfall will also increase by 2100 in parallel with the projected increase in the total annual average precipitation amount in the river basin: in Voratan mountain pass by about 24 mm (16%); in Goris by about 15 mm (16%); in Sisian by about 8 mm (17%).

At the observation stations of Vorotan-Vorotan, Voratan-Tatev HPP, Gorisget-Goris and Loradzor-Lchen river basins, the projected decrease in natural river flow by 2100 is 4%, 9%, 8% and 25% respectively. At the observation stations in Tsghuk-Tsghuk, Sisian-Arevis and Vorotan-Gorhayk, the projected flow will grow by 11-15%. This means that the mid- and upstream river flow will increase, while it will decrease downstream. This is due to intensive evaporation driven by the projected high temperature in the downstream part of the Vorotan river.

**Table 20. Projected Change in Flow of the Aghstev and Debed Rivers, A2 Scenario. Third National Communication, 2015**

| River – Monitoring Station | Flow change | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1961-1990 | | 2030 | | 2070 | | 2100 | |
| | million $m^3$ | % | million $m^3$ | % | million $m^3$ | % | million $m^3$ | % |
| Debed – Ayrum | 1054 | 0 | 937 | -11 | 669 | -37 | 402 | -62 |
| Dzoraget – Gargar | 480 | 0 | 427 | -10 | 343 | -29 | 215 | -55 |
| Pambak – Tumanyan | 336 | 0 | 300 | -11 | 240 | -29 | 160 | -53 |
| Aghtev – Ijevan | 286 | 0 | 255 | -11 | 196 | -31 | 108 | -62 |
| Voskepar (with its tributary Kirants) – Voskepar | 67 | 0 | 58 | -14 | 42 | -37 | 19 | -72 |

**Table 21. Projected Changes in Vorotan River Flow. Third National Communication, 2015**

| River – Monitoring Station | Scenario | Flow change | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1961-1990 | | 2040 | | 2070 | | 2100 | |
| | | million $m^3$ | % | million $m^3$ | % | million $m^3$ | % | million $m^3$ | % |
| Vorotan - Gorhayk | A2 | 131.9 | 0 | 137.9 | 5 | 145.0 | 10 | 152.8 | 16 |
| | B1 | 131.9 | 0 | 136.7 | 4 | 141.4 | 7 | 148.3 | 12 |

According to natural flow projections in various observation stations of the Vorotan river basin, it is expected that the annual natural river flow will increase by about 3%. For Vorotan-Gorhayk station, it is projected that the river flow will increase by approximately 21.4 million $m^3$ (16%) (A2 scenario); 16.8 $m^3$ (13%) (B1 scenario) by 2100.

In the Third National Communication, the vulnerability of the **Araks and Akhurian** river annual flows for 2040, 2070, and 2100 has been projected using CCSM4 model data emissions scenarios (RCP8.5 (A2) and RCP6.0 (B2)). According to the assessments, there will be no significant change in flows for both river basins by 2040. In 2071-2100 it is expected that the flow in the Haykadzor sector of the Akhurian river will fall by 2.1% (A2)/4.4% (B2); in 2071-2100 the flows will reduce by 10.5% (A2)/5.7% (B2). For both scenarios there will be some increase in the Araks river flow: 3-4% in 2041-2070, and 1-2% in 2071-2100.

The climate change impacts on river flows were also assessed for **Hrazdan, Azat, and Vedi** River Basins. The results are varying from one basin to another. It is projected that, by 2040, there will be a 2-3% increase in annual river flow in the Azat and Vedi River basins, while in upper streams of the

Hrazdan river there will be a reduction of 2-3% (A2). In 2041-2070 there is a projected decrease in river flows for all three river basins: 3-4% in 2070 in the Azat and Vedi river basins, and 6-7% in the Hrazdan river basin; in 2100 the projected decrease will reach to 12-14% and 15-20% respectively.

**The vulnerability of maximum water levels** as a result of climate change in the **Akhurian, Aparan and Azat reservoirs** was also assessed within the Third National Communication by using the physical-statistical (regressive) method. By using maximum annual water levels for these reservoirs and many years' observation data for precipitation and air temperature in these reservoir watersheds collected by hydro-meteorological stations, multifactorial correlative links have been established between these elements, by which (based on the RCP8.5 (A2) and RCP6.0 (B2) emission scenarios) the vulnerability of maximum water levels in these reservoirs is projected for 2040, 2070 and 2100. The results show that Aparan reservoir is expected to be the most vulnerable: reduction of 11 m by 2100 (A2). In terms of volume, it means that, in 2100 the maximum quantity of water in the Aparan reservoir will be 25-36 million $m^3$ (the capacity of the reservoir is 90 million $m^3$). This indicator for the Akhurian reservoir will be 405 million $m^3$ (the capacity of the reservoir is 525 million $m^3$), and for the Azat reservoir it will be 45 million $m^3$ (the capacity of the reservoir is 70 million $m^3$).

The climate change impacts on the water resources of Lake Arpi reservoir and Lake Sevan were also assessed.

**Lake Arpi** reservoir is located in the upstream area of the Akhurian river. Initially, the natural water volume in the lake was about 5 million $m_3$. After the construction of a 10-metre high dam in 1951 it was turned into a lake-reservoir. At present, the reservoir depth is approximately 8.0 m, its volume is 105 million $m_3$, and the surface area is 22.5 $km_2$. According to the results presented in Third National Communication, under the A2 scenario, the water temperature in the reservoir will increase by $6.6^0$ C against the baseline ($12.4^0$C) by 2100; for B2 – by $6^0$C. The maximum reservoir inflow will fall by about 4 million $m^3$ against the 2030 baseline (60.15 million $m^3$); in 2070 by about 9 million $m^3$; in 2100 by about 15 million $m^3$ (see table below).

For the **Lake Sevan**, within the Third National Communication water temperature changes were projected under the A2 and B2 scenarios for 2030, 2070 and 2100 using ambient air and water temperatures interconnection formulae. The results indicate that Lake Sevan's water temperature, according to the A2 scenario, will increase by $4^0$C against the baseline ($9.4^0$C) by 2100; for B2 – by $3.6^0$C. Therefore, it is projected that, in 2030, Lake Sevan inflow will decrease by more than 50 million $m^3$ against the baseline (787 million $m^3$); in 2070 – by about 110 million $m^3$; in 2100 – by about 190 million $m^3$. This means that the water level will start going down by about 16 cm per year (Table 22).

**Table 22. Projection of inflows in Arpi reservoir and Lake Sevan, A2 scenario, million $m^3$**

| Lake/Reservoir | 1961-1990 | 2030 | 2070 | 2100 |
|---|---|---|---|---|
| Lake Arpi Reservoir | 60.15 | 56.12 | 51.43 | 45.47 |
| Lake Sevan | 787 | 734 | 673 | 595 |

**Fourth National Communication** of Armenia to the UNFCCC is planned to finalize in 2020. The report on "The Vulnerability Assessment of Water Resources of the Republic of Armenia under the Climate

Change” (2018) have been prepared within the scope of the project within the framework of the “Development of Armenia’s Fourth National Communication to the UNFCCC and Second Biennial Update Report” UNDP/GEF project. In that report, the assessments of climate change impacts conducted within the framework of the Third National Communication were reviewed and the correlations between climatic parameters and surface flow for each of the main river basins of Armenia were analyzed. After that, vulnerability assessment of the water resources of main river basins, reservoirs, and Lake Sevan were conducted using the physico-statistical or regression model based on the climate change projections obtained from CCSM4 and METRAS climate models for the periods of 2011-2040, 2041-2070, and 2071-2100.

Water balance elements of Armenia were also projected using the climate change scenarios.

**Table 23. Vulnerability Assessment of Annual River Flow in Armenia due to the Climate Change. Vulnerability Assessment of Water Resources of the Republic of Armenia under the Climate Change, 2018**

| Scenario | | Annual River Flow | Flow Change | | Period |
|---|---|---|---|---|---|
| | | million m³ | million m³ | % | |
| RCP6.0 (CCSM4) | Basis | 6279.9 | 0 | 0 | 1961-1990 |
| | T+1.7, 1.03Q | 5760.4 | -519.5 | -8.27 | 2011-2040 |
| | T+2.3, 1,02Q | 5450.5 | -829.4 | -13.2 | 2041-2070 |
| | T+3.1, 1.04Q | 5037.9 | -1242.0 | -19.8 | 2071-2100 |
| RCP8.5 (CCSM4) | Basis | 6279.9 | 0 | 0 | 1961-1990 |
| | T+1.8, 1.01Q | 5513.5 | -766.4 | -12.2 | 2011-2040 |
| | T+3.2, 1,05Q | 5148.2 | -1131.7 | -18.0 | 2041-2070 |
| | T+4.7, 1.02Q | 4165.1 | -2114.8 | -33.7 | 2071-2100 |
| RCP8.5 (METRAS) | Basis | 6279.9 | 0 | 0 | 1961-1990 |
| | T+1.4, 0.97Q | 5433.4 | -846.5 | -13.5 | 2011-2040 |
| | T+3.1, 0,95Q | 4547.9 | -1732.0 | -27.6 | 2041-2070 |
| | T+4.5, 0.92Q | 3832.0 | -2447.9 | -39.0 | 2071-2100 |

**Table 24. Projection of the Elements of the Annual Water Balance of Armenia. Vulnerability Assessment of Water Resources of the Republic of Armenia under the Climate Change, 2018**

| Scenario | Projection | Precipitation | | Evaporation | | River Flow | | Period |
|---|---|---|---|---|---|---|---|---|
| | | billion m³ | mm | billion m³ | mm | billion m³ | mm | |
| | T,Q basis | 17.6 | 592 | 10.5 | 352 | 7.1 | 238 | 1961-1990 |
| RCP6.0 (CCSM4) | T+1.7, 1.03Q | 18.1 | 611 | 11.6 | 393 | 6.5 | 218 | 2011-2040 |
| | T+2.3, 1,02Q | 18.0 | 605 | 11.9 | 398 | 6.1 | 207 | 2041-2070 |
| | T+3.1, 1.04Q | 18.2 | 614 | 12.5 | 423 | 5.7 | 191 | 2071-2100 |
| RCP8.5 (CCSM4) | T+1.8, 1.01Q | 17.8 | 599 | 11.6 | 390 | 6.2 | 209 | 2011-2040 |
| | T+3.2, 1,05Q | 18.5 | 623 | 12.7 | 428 | 5.8 | 195 | 2041-2070 |
| | T+4.7, 1.02Q | 17.7 | 596 | 13.0 | 438 | 4.7 | 158 | 2071-2100 |
| RCP8.5 (METRAS) | T+1.4, 0.97Q | 17.1 | 576 | 11.0 | 370 | 6.1 | 206 | 2011-2040 |
| | T+3.1, 0,95Q | 16.6 | 560 | 11.5 | 388 | 5.1 | 172 | 2041-2070 |
| | T+4.5, 0.92Q | 16.1 | 543 | 11.8 | 398 | 4.3 | 145 | 2071-2100 |

Using the correlation between the values of annual inflow to the Lake Sevan and the air temperature and precipitation in the meteo stations within the lake's basin, the vulnerability of the annual inflow to the lake to the climate change were assessed.

**Table 25. Vulnerability Assessment of the Annual Inflow to the Sevan Lake for the 2040, 2070, and 2100. Vulnerability Assessment of Water Resources of the Republic of Armenia under the Climate Change, 2018**

| Scenario | Projection | Annual River Flow, million m³ | Flow Change | | Period |
|---|---|---|---|---|---|
| | | | million m³ | % | |
| | Basis | 783.8 | 0 | 0 | |
| RCP6.0 (CCSM4) | T+1.7, 1.03Q | 712.6 | -71.2 | -9.09 | 2011-2040 |
| | T+2.3, 1,02Q | 681.6 | -102.3 | -13.0 | 2041-2070 |
| | T+3.1, 1.04Q | 646.4 | -137.4 | -17.5 | 2071-2100 |
| RCP8.5 (CCSM4) | **Basis** | **783.8** | **0** | **0** | |
| | T+1.8, 1.01Q | 693.7 | -90.1 | -11.5 | 2011-2040 |
| | T+3.2, 1,05Q | 648.0 | -135.8 | -17.3 | 2041-2070 |
| | T+4.7, 1.02Q | 552.8 | -231.0 | -29.5 | 2071-2100 |
| RCP8.5 (METRAS) | **Basis** | **783.8** | **0** | **0** | |
| | T+1.4, 0.97Q | 687.5 | -96.3 | -12.3 | 2011-2040 |
| | T+3.1, 0,95Q | 597.0 | -186.8 | -23.8 | 2041-2070 |
| | T+4.5, 0.92Q | 519.0 | -264.9 | -33.8 | 2071-2100 |

Changes in the water balance elements were also assessed.

**Table 26. Changes in the Water Balance Elements of Lake Sevan due to the Climate Change**

| Scenario | Projection | Precipitation | | Evaporation | | River Flow | | Period |
|---|---|---|---|---|---|---|---|---|
| | | million m³ | mm | million m³ | mm | million m³ | mm | |
| | T,Q basis | 503.9 | 401.0 | 1074.5 | 856.0 | 783.8 | 624.2 | 1961-1990 |
| RCP6.0 (CCSM4) | T+1.7, 1.03Q | 519.0 | 413.0 | 1194.9 | 952.0 | 712.6 | 567.4 | 2011-2040 |
| | T+2.3, 1,02Q | 513.9 | 409.0 | 1246.2 | 992.9 | 681.6 | 542.7 | 2041-2070 |
| | T+3.1, 1.04Q | 524.0 | 417.0 | 1316.9 | 1049.3 | 646.4 | 514.6 | 2071-2100 |
| RCP8.5 (CCSM4) | T+1.8, 1.01Q | 508.9 | 405.0 | 1203.3 | 958.7 | 693.7 | 552.3 | 2011-2040 |
| | T+3.2, 1,05Q | 529.1 | 421.0 | 1326.0 | 1056.5 | 648.0 | 515.9 | 2041-2070 |
| | T+4.7, 1.02Q | 513.9 | 409.0 | 1467.1 | 1169.0 | 552.8 | 440.0 | 2071-2100 |
| RCP8.5 (METRAS) | T+1.4, 0.97Q | 488.7 | 388.9 | 1186.1 | 945.0 | 687.5 | 547.4 | 2011-2040 |
| | T+3.1, 0,95Q | 478.7 | 380.9 | 1335.4 | 1064.0 | 597.0 | 475.2 | 2041-2070 |
| | T+4.5, 0.92Q | 463.6 | 368.9 | 1467.1 | 1169.0 | 519.0 | 413.0 | 2071-2100 |

Another important assessment performed within this study is the estimation of the vulnerability of river inflow to the main reservoirs of Armenia in the spring high water period.

Table 27. Vulnerability Assessment of the River Inflow to the Reservoirs during the High Water Period

| Reservoir Name | Scenario | Projection | River Flow Change | | Period |
|---|---|---|---|---|---|
| | | | million $m^3$ | % | |
| Akhuryan | | **T,Q basis** | **495.8** | **0** | **1961-1990** |
| | **RCP6.0 (CCSM4)** | T+1.7, 1.03Q | 452.0 | -8.85 | 2011-2040 |
| | | T+2.3, 1,02Q | 423.2 | -14.7 | 2041-2070 |
| | | T+3.1, 1.04Q | 392.3 | -20.9 | 2071-2100 |
| | **RCP8.5 (CCSM4)** | T+1.8, 1.01Q | 427.2 | -13.8 | 2011-2040 |
| | | T+3.2, 1,05Q | 408.3 | -17.7 | 2041-2070 |
| | | T+4.7, 1.02Q | 309.1 | -37.7 | 2071-2100 |
| | **RCP8.5 (METRAS)** | T+1.4, 0.97Q | 392.5 | -20.8 | 2011-2040 |
| | | T+3.1, 0,95Q | 286.5 | -42.2 | 2041-2070 |
| | | T+4.5, 0.92Q | 192.9 | -61.1 | 2071-2100 |
| Aparan | | **T,Q basis** | **61.8** | **0** | **1961-1990** |
| | **RCP6.0 (CCSM4)** | T+1.7, 1.03Q | 59,2 | -4,25 | 2011-2040 |
| | | T+2.3, 1,02Q | 56,0 | -9,47 | 2041-2070 |
| | | T+3.1, 1.04Q | 52,9 | -14,4 | 2071-2100 |
| | **RCP8.5 (CCSM4)** | T+1.8, 1.01Q | 56,3 | -8,86 | 2011-2040 |
| | | T+3.2, 1,05Q | 54,6 | -11,7 | 2041-2070 |
| | | T+4.7, 1.02Q | 43,4 | -29,8 | 2071-2100 |
| | **RCP8.5 (METRAS)** | T+1.4, 0.97Q | 50,2 | -18,7 | 2011-2040 |
| | | T+3.1, 0,95Q | 36,9 | -40,3 | 2041-2070 |
| | | T+4.5, 0.92Q | 25,1 | -59,5 | 2071-2100 |
| Marmarik | | **T,Q basis** | **85.7** | **0** | **1961-1990** |
| | **RCP6.0 (CCSM4)** | T+1.7, 1.03Q | 76.5 | -10.7 | 2011-2040 |
| | | T+2.3, 1,02Q | 70.4 | -17.9 | 2041-2070 |
| | | T+3.1, 1.04Q | 63.0 | -26.4 | 2071-2100 |
| | **RCP8.5 (CCSM4)** | T+1.8, 1.01Q | 72.4 | -15.5 | 2011-2040 |
| | | T+3.2, 1,05Q | 64.5 | -24.7 | 2041-2070 |
| | | T+4.7, 1.02Q | 47.1 | -45.0 | 2071-2100 |
| | **RCP8.5 (METRAS)** | T+1.4, 0.97Q | 68.9 | -19.6 | 2011-2040 |
| | | T+3.1, 0,95Q | 49.8 | -41.9 | 2041-2070 |
| | | T+4.5, 0.92Q | 33.4 | -61.1 | 2071-2100 |
| Azat | | **T,Q basis** | **120.1** | **0** | **1961-1990** |
| | **RCP6.0 (CCSM4)** | T+1.7, 1.03Q | 125.4 | 4.43 | 2011-2040 |
| | | T+2.3, 1,02Q | 122.9 | 2.39 | 2041-2070 |
| | | T+3.1, 1.04Q | 121.3 | 1.06 | 2071-2100 |
| | **RCP8.5 (CCSM4)** | T+1.8, 1.01Q | 123.6 | 2.95 | 2011-2040 |
| | | T+3.2, 1,05Q | 121.4 | 1.13 | 2041-2070 |
| | | T+4.7, 1.02Q | 109.2 | -9.07 | 2071-2100 |
| | **RCP8.5 (METRAS)** | T+1.4, 0.97Q | 118.5 | -1.30 | 2011-2040 |
| | | T+3.1, 0,95Q | 112.1 | -6.64 | 2041-2070 |
| | | T+4.5, 0.92Q | 105.9 | -11.8 | 2071-2100 |

## 2.2.2 Vulnerability Assessment of Water Resources within Basin Management Area Plans

The assessment of vulnerability of water resources for separate river basins and Basin Management Areas in Armenia have been done in different years, using various approaches, methodologies, models, and scenarios. In the scope of the current project, all these studies are reviewed, compared and summarized, gaps and shortcomings are identified. Based on that, the most actual and reliable approach and methodology will be revealed and recommended for use in assessing the water resources vulnerability in all six Basin Management Areas of Armenia.

**Table 28. Vulnerability Assessment of Water Resources due to the Climate Change for Basin Management Areas of Armenia: Results presented in BMA (RBMP) Plans**

| Basin Management Area | BMA Plan, Year of Adoption | Vulnerability Assessment of Water Resources due to the Climate Change | Climate Model (s) Applied | Hydrologic Model(s) Applied | IPCC Emission Scenario(s) Applied | Projection Periods |
|---|---|---|---|---|---|---|
| Akhuryan | 2017 | Yes | CCSM4 | Linear regression equations | RCP6.0; RSP8.5 | 2011-2040; 2041-2070; 2071-2100 |
| Northern | Draft RBMPs for Aghstev and Debed Rivers, 2010 | No | - | - | - | - |
| Hrazdan | 2020 (in the process of development) | Yes | CCSM4, METRAS | DSS (USAID ASPIRED) | RCP6.0; RSP8.5 | 2011-2040; 2041-2070; 2071-2100 |
| Sevan | 2020 (in the process of development) | Yes | CCSM4, METRAS | DSS (USAID ASPIRED) | RCP6.0; RSP8.5 | 2011-2040; 2041-2070; 2071-2100 |
| Ararat | 2016 | Yes | PRECIS | Linear regression equations | A2 | 2011-2030; 2041-2070; 2071-2100 |
| Southern | 2016 | Yes | PRECIS | DSS (USAID ASPIRED) | A2 | 2011-2040; 2041-2070; 2071-2100 |

In the **Ararat Basin Management Plan (2016),** climate change impacts on the water resources in the Azat, Vedi, and Arpa River Basins were assessed. PRECIS regional climate model and IPCC SRES A2 scenario were used for the projection of the air temperature and precipitation in Ararat BMA. The changes in the surface flow in Azat, Vedi, and Arpa basins were modeled using the linear regression equations and projections of climatic elements. The changes were assessed for the periods of 2011-2040, 2041-2070, and 2071-2100. The results are presented in Table 29.

**Table 29. Changes in the Annual River Flow in the Azat, Vedi, and Arpa River Basins**

| River – Monitoring Station | 2011-2040 | 2041-2070 | 2071-2100 |
|---|---|---|---|
| | % | % | % |
| Azat - Garni | + 2,5 | - 3,5 | - 13 |
| Vedi - Urtsadzor | + 2,5 | - 3,5 | - 13 |
| Arpa - Areni | - 17 | - 21 | - 30 |

In the **Southern Basin Management Plan (2016),** the climate change impacts on the water resources in Vorotan, Voghji, and Meghriget River Basins were assessed. PRECIS regional climate model and IPCC SRES A2 and B1 scenarios were used for the projection of the air temperature and precipitation in Southern BMA. The vulnerability of water resources to climate change was assessed by application of the physical-statistical regression modeling approach. Based on this, correlations between multi-annual observation data for precipitation and temperature recorded at hydro-meteorological stations and the natural river flow at Southern BMA rivers were established, and the projected changes in the natural flow against the baseline average values were assessed under A2 climate change scenario (Table 30).

**Table 30. Modeled annual natural river flow values at hydrological stations of the Southern BMA for short- and long-term horizons, under IPCC A2 scenario**

| River-Hydrological observation station | Baseline period | Modeled natural low, million $m^3$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Short-term(for the next 6 years, according to the BMP cycles) | | | | | | Long-term | | |
| | 1961-1990 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2040 | 2070 | 2100 |
| **Vorotan River Basin** | | | | | | | | | | |
| Vorotan-Gorhayk | **132.0** | 135.1 | 135.2 | 135.3 | 135.4 | 135.6 | 135.7 | 137.9 | 145.0 | 152.8 |
| Tsghuk -Tsghuk | **83.5** | 84.9 | 84.9 | 85.0 | 85.0 | 85.1 | 85.1 | 86.1 | 89.0 | 92.2 |
| Sisian-Arevis | **24.6** | 24.9 | 24.9 | 24.9 | 24.9 | 25.0 | 25.0 | 25.2 | 26.1 | 27.2 |
| Loradzor-Ltsen | **13.0** | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 | 12.8 | 12.7 | 12.3 | 11.9 |
| Vorotan-Vorotan | **585.3** | 582.9 | 582.8 | 582.7 | 582.6 | 582.5 | 582.4 | 580.6 | 571.6 | 559.7 |
| Vorotan-Tatev HPP | **672.8** | 666.0 | 665.8 | 665.5 | 665.3 | 665.0 | 664.7 | 659.8 | 638.7 | 612.1 |
| Gorisget-Goris | **20.1** | 20.0 | 20.0 | 19.9 | 19.9 | 19.9 | 19.9 | 19.8 | 19.3 | 18.6 |
| **Voghji River Basin** | | | | | | | | | | |
| Voghji–Kajaran | **113.9** | 109.0 | 108.8 | 108.6 | 108.4 | 108.2 | 108.0 | 104.5 | 96.5 | 84.8 |
| Geghi–Geghi | **159.5** | 155.1 | 155.0 | 154.8 | 154.6 | 154.5 | 154.3 | 151.1 | 143.4 | 130.7 |
| Vachagan–Kapan | **15.7** | 15.1 | 15.0 | 15.0 | 15.0 | 15.0 | 14.9 | 14.5 | 13.5 | 12.1 |
| Geghanush-Geghanush | **19.6** | 19.0 | 18.9 | 18.9 | 18.9 | 18.9 | 18.9 | 18.4 | 17.3 | 15.5 |
| Voghji–Kapan | **388.4** | 374.0 | 373.5 | 372.9 | 372.4 | 371.8 | 371.3 | 360.8 | 337.9 | 306.5 |
| **Meghriget River Basin** | | | | | | | | | | |
| Meghriget–Meghri | **102.9** | 98.4 | 98.2 | 98.0 | 97.9 | 97.7 | 97.5 | 94.2 | 86.7 | 75.2 |
| Meghriget–Lichk | **20.4** | 19.4 | 19.4 | 19.4 | 19.3 | 19.3 | 19.3 | 18.6 | 17.1 | 15.1 |

In the **Akhuryan Basin Management Plan (2017)**, projections for air temperature and precipitation quantity up until 2100 have been developed based on RCP8.5 and RCP6.0 emission scenarios of CCSM4 model. Simple linear regression equations were used between average annual temperature, annual cumulative precipitation and elevation above sea level (a.s.l.) values of meteorological stations throughout the territory of Armenia for rescaling the results. Spatial estimates of the climatic parameters including temperature and precipitation variables were obtained with the help of dependence equations, which were also mapped within the GIS.

The vulnerability of water resources of Akhuryan RBD has been assessed using the projected values of temperature and precipitation for 2011-2040, 2041-2070 and 2071-2100 against the average baseline of 1961-1990 according to the RCP6.0 and RCP8.5 scenarios, as well as annual flow projection equations of Akhurik-Haykadzor, Akhuryan-Akhurik and Karkachun-Gharibjanyan hydrological observation stations and interpolated values of flow change at Metsamor-Etchmiadzin and Metsamor-Ranchpar hydrological observation stations.

**Table 31. Average annual river flow values for 1961-1990 and their changes in relation to baseline values at Akhuryan RBD**

| River – Monitoring Station | Scenario | Baseline 1961-1990 | Flow Alteration | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2011-2040 | | 2041-2070 | | 2071-2100 | |
| | | million $m^3$ | million $m^3$ | % | million $m^3$ | % | million $m^3$ | % |
| Akhuryan-Akhurik | RCP6.0 | 232 | 237.3 | 2.5 | 237.7 | 2.7 | 242.0 | 4.5 |
| | RCP8.5 | | 240.7 | 4.0 | 249.1 | 7.6 | 252.5 | 9.1 |
| Akhuryan-Haykadzor | RCP6.0 | 951 | 993.1 | 4.4 | 1013.8 | 6.6 | 1041.5 | 9.5 |
| | RCP8.5 | | 1008.8 | 6.1 | 1066. | 12.1 | 1088.6 | 14.5 |
| Karkachun-Gharibjanyan | RCP6.0 | 33 | 29.8 | -8.7 | 27.4 | -16.1 | 26.8 | -18.0 |
| | RCP8.5 | | 30.1 | -7.9 | 28.4 | -13.1 | 27.8 | -15.0 |
| Metsamor-Ejmiatsin | RCP6.0 | 338 | 330 | -2 | 320 | -5 | 300 | -11 |
| | RCP8.5 | | 327 | -3 | 315 | -6 | 295 | -13 |
| Metsamor-Ranchpar | RCP6.0 | 442 | 435 | -1 | 425 | -4 | 400 | -9 |
| | RCP8.5 | | 426 | -4 | 420 | -5 | 390 | -12 |

In **Sevan Basin Management Plan**, which is currently being developed within the framework of EUWI+ Programme, projections for air temperature and precipitation quantity up until 2100 have been developed based on RCP8.5 and RCP6.0 emission scenarios of CCSM4 regional climate model and RCP8.5 emission scenario of METRAS model. Using the the Climate Change Model of the Decision Support System (DSS) developed in the scope of USAID ASPIRED project, the surface natural flow changes for the periods of 2011-2040, 2041-2070, and 2071-2100 were assessed for the sub-basins of the rivers which flow to the Lake Sevan. The DSS is a GIS based toolbox that uses the physical-statistical equations, hydro-meteorological observation data and geospatial data including digital elevation model to perform water and water-economic balance and climate change analysis. The results of the DSS Climate Change Model application for Sevan BMA are presented in Table 32 and Table 33.

**Table 32. Projected Changes in Annual Surface Natural Flow, % (CCSM4)**

| Hydrostation Code | River-Station | RCP6.0 | | | RCP8.5 | | |
|---|---|---|---|---|---|---|---|
| | | 2040 | 2070 | 2100 | 2040 | 2070 | 2100 |
| 85339 | Pambak-Pambak | 1 | 1.3 | 1.7 | 1 | 1.8 | 2.6 |
| 85352 | Dzknaget-Tsovagyugh | -12.8 | -21 | -27 | -17.3 | -25.5 | -49.4 |
| 85353 | Drakhtik-Drakhtik | -18.4 | -26.9 | -35.6 | -21.6 | -35.4 | -58.7 |
| 85363 | Masrik-Tsovak | 8.3 | 9.8 | 13.7 | 7.3 | 15 | 17.6 |

| Hydrostation Code | River-Station | RCP6.0 | | | RCP8.5 | | |
|---|---|---|---|---|---|---|---|
| | | 2040 | 2070 | 2100 | 2040 | 2070 | 2100 |
| 85366 | Karchaghbyur-Karchaghbyur | -14.7 | -20 | -26.9 | -15.6 | -27.7 | -41 |
| 85371 | Vardenis-Vardenik | 9.8 | 11.4 | 16 | 8.5 | 17.7 | 20.2 |
| 85376 | Martuni-Geghhovit | 6.2 | 6.5 | 9.4 | 4.6 | 11 | 9.7 |
| 85378 | Argichi-Verin Getashen | -17.7 | -25.1 | -33.5 | -19.9 | -33.8 | -53.4 |
| 85379 | Tsaghkashen-Vaghashen | -9.2 | -14.8 | -19.1 | -12.1 | -18.3 | -34.3 |
| 85380 | Lichk-Lichk | 13.8 | 18.3 | 24.8 | 14.2 | 25.9 | 36.6 |
| 85381 | Bakhtak-Tsakkar | -2 | -3 | -3.9 | -2.4 | -3.9 | -6.5 |
| 85384 | Gavaraget-Noratus | 0.5 | 0.8 | 1 | 0.7 | 1 | 1.8 |

Table 33. Projected Changes in Annual Surface Natural Flow, % (METRAS)

| Hydrostation Code | River-Station | RCP8.5 | | |
|---|---|---|---|---|
| | | 2040 | 2070 | 2100 |
| 85339 | Pambak-Pambak | 0.8 | 1.7 | 2.5 |
| 85352 | Dzknaget-Tsovagyugh | -19.7 | -42.7 | -62.8 |
| 85353 | Drakhtik-Drakhtik | -20.3 | -44.4 | -64.8 |
| 85363 | Masrik-Tsovak | 3.4 | 7.9 | 11.1 |
| 85366 | Karchaghbyur-Karchaghbyur | -12.3 | -27.3 | -39.6 |
| 85371 | Vardenis-Vardenik | 3.5 | 8.3 | 11.7 |
| 85376 | Martuni-Geghhovit | 0.2 | 1 | 1.1 |
| 85378 | Argichi-Verin Getashen | -17.5 | -38.4 | -56 |
| 85379 | Tsaghkashen-Vaghashen | -13.3 | -28.9 | -42.5 |
| 85380 | Lichk-Lichk | 10.3 | 22.9 | 33.1 |
| 85381 | Bakhtak-Tsakkar | -2.2 | -4.9 | -7.2 |
| 85384 | Gavaraget-Noratus | 0.7 | 1.5 | 2.3 |

In **Hrazdan River Basin Management Plan**, which is also currently being developed within the framework of European Union Water Initiative Plus (EUWI+) Programme, the same scenarios and approach were applied for the vulnerability assessment of water resources as in Sevan Basin Management Plan. The results are presented in Table 34 and Table 35.

Table 34. Projected Changes in Annual Surface Natural Flow, % (CCSM4)

| Hydrostation Code | River-Station | RCP6.0 | | | RCP8.5 | | |
|---|---|---|---|---|---|---|---|
| | | 2040 | 2070 | 2100 | 2040 | 2070 | 2100 |
| 85308 | Kasakh-Vardenis | -11,8 | -16,7 | -22,3 | -13,3 | -22,5 | -35,5 |
| 85313 | Kasakh-Ashtarak | -11 | -15,3 | -20,4 | -12 | -20,8 | -31,9 |
| 85318 | Gegharot-Aragats | -10,7 | -13,7 | -18,8 | -10,6 | -19,8 | -26,9 |
| 85319 | Hakhverd-Parpi | -7,5 | -10,6 | -14,2 | -8,4 | -14,3 | -22,6 |
| 85323 | Hrazdan-Hrazdan | -1 | -2,7 | -3,1 | -2,4 | -2,4 | -7,7 |
| 85331 | Hrazdan-Lusakert | -2,8 | -4,6 | -5,9 | -3,8 | -5,6 | -10,8 |
| 85335 | Hrazdan-Yerevan | -2,7 | -4,1 | -5,4 | -3,3 | -5,3 | -9,2 |
| 85336 | Hrazdan-Masis | -6 | -8,6 | -11,5 | -6,8 | -11,5 | -18,4 |
| 85338 | Marmarik-Hankhavan | -2,2 | -4,4 | -5,5 | -3,8 | -4,7 | -11,7 |
| 85340 | Marmarik-Aghavnadzor | +1,6 | +0,4 | +1,1 | -0,1 | 2,3 | -2,2 |
| 85342 | Gomur-Meghradzor | +3,2 | +2,7 | +4,2 | 1,7 | 5,3 | 2,7 |

Table 35. Projected Changes in Annual Surface Natural Flow, % (METRAS)

| Hydrostation Code | River-Station | RCP8.5 | | |
|---|---|---|---|---|
| | | 2040 | 2070 | 2100 |
| 85308 | Kasakh-Vardenis | -11,6 | -25,4 | -37,1 |
| 85313 | Kasakh-Ashtarak | -10,1 | -22,2 | -32,3 |
| 85318 | Gegharot-Aragats | -7 | -15,8 | -22,8 |
| 85319 | Hakhverd-Parpi | -7,4 | -16,2 | -23,7 |
| 85323 | Hrazdan-Hrazdan | -4,1 | -8,7 | -12,8 |
| 85331 | Hrazdan-Lusakert | -4,3 | -9,3 | -13,7 |
| 85335 | Hrazdan-Yerevan | -3,4 | -7,3 | -10,7 |
| 85336 | Hrazdan-Masis | -6,1 | -13,3 | -19,4 |
| 85338 | Marmarik-Hankhavan | -5,5 | -11,8 | -17,4 |
| 85340 | Marmarik-Aghavnadzor | -3 | -6,2 | -9,3 |
| 85342 | Gomur-Meghradzor | -1,3 | -2,5 | -3,9 |

## 2.2.3 Vulnerability Assessment of Water Resources due to the Climate Change within Other Studies

During last years, a number of studies and projects within those questions related to the vulnerability of water resources from climate change were addressed in some extent.

Below the most significant assessments were presented.

**Complex Assessment of Climate Change Impacts on Water Resources of Marmarik River Basin of Armenia, Geoinfo, 2009**

PRECIS climate model and IPCC SRES A2 emissions scenario were used for the projections of air temperature and precipitation.

Table 36. Assessment of Annual RIver Flow Vulnerability in Marmarik River Basin for 2030, 2070 and 2100

| River – Monitoring Station | Scenarios | River Flow, million m$^3$ | Change in Flow | | Timelines |
|---|---|---|---|---|---|
| | | | million m$^3$ | % | |
| Marmarik-Aghavnadzor | Baseline* | 152.05 | | | |
| | T+1.4, 0.91Q | 117.87 | -34.18 | -22.5 | 2030 |
| | T+3.2, 0.82Q | 77.65 | -74.40 | -48.95 | 2070 |
| | T+5.0, 0.75Q | 40.35 | -113.70 | -73.5 | 2100 |
| Marmarik-Hankavan | Baseline* | 53.43 | | | |
| | T+1.4, 0.91Q | 44.94 | -8.49 | -15.9 | 2030 |
| | T+3.2, 0.82Q | 34.88 | -18.54 | -34.7 | 2070 |
| | T+5.0, 0.75Q | 25.51 | -27.92 | -52.3 | 2100 |
| Gomur-Meghradzor | Baseline* | 49.12 | | | |
| | T+1.4, 0.91Q | 39.64 | -9.48 | -19.3 | 2030 |
| | T+3.2, 0.82Q | 28.94 | -20.18 | -41.1 | 2070 |
| | T+5.0, 0.75Q | 19.39 | -29.73 | -60.5 | 2100 |

**1961-1990*

Vulnerability of water resources of the basin was assessed and mapped using statistical or regression model, and model created with ArcGIS software application for 2030, 2070 and 2100 (Table 36).

For Marmarik-Aghavnadzor observation station, river flow vulnerability level for 2030, 2070 and 2100 was defined by seasons (Table 37).

Table 37. Amount of Seasonal Decrease in River Flow for Marmarik-Aghavnadzor Monitoring Station, mln $m^3$

| Timeframe | Winter | Spring | Summer | Fall | Annual |
|---|---|---|---|---|---|
| Baseline | 9.6 | 91.5 | 39.7 | 11.2 | 152 |
| 2030 | 2.0 | 21.0 | 9.0 | 2.0 | 34.0 |
| 2070 | 4.0 | 44.8 | 19.8 | 5.4 | 74.0 |
| 2100 | 6.9 | 67.7 | 29.8 | 8.6 | 113 |

**Regional Climate Change Impacts Study for South Caucasus Region, ENVSEC-UNDP, 2011**

In this study, the climate change projections presented in the Second National Communication of Armenia to UNFCCC were used. The PRECIS climate model and MAGICC/SCENGEN regional climate scenario generator were used for projection of air temperature and precipitation changes according to IPCC SRES A2 and B2 scenarios.

In scope of this study, the vulnerability of the water resources of Aghstev and Debed transboundary river basins were assessed for the periods of 2011-2040, 2041-2070, and 2071-2100 according to the A2 scenario (Table 38).

Table 38. Projected Mean Annual Streamflow and Change Relative to 1961- 1990 for Hydrological stations in the Aghstev and Debed RIver Basins

| River -Hydrological Station | Baseline Period (1961-1990), mln $m^3$ | 2011-2040, mln $m^3$ / % | 2041-2070, mln $m^3$ / % | 2071-2100, mln $m^3$ / % |
|---|---|---|---|---|
| Agshtev-Ijevan | 286 | 255 / -11 | 196 / -31 | 108 / -62 |
| Kirants- Voskepar | 67 | 58 / -14 | 42 / -37 | 19 / -72 |
| Debed-Ayrum | 1054 | 937 / 11 | 669 / -37 | 402 / -62 |
| Dzoraget-Gargar | 480 | 427 / -10 | 343 / -29 | 215 / -55 |
| Pambak-Tumanyan | 336 | 300 / -11 | 240 / -29 | 160 / -53 |

**Vulnerability of Water Sector due to the Climate Change, UNDP-GEF, 2012**

Vulnerability assessment of water resources of Arpa River Basin using WEAP model was performed in the scope of this study Enabling Activities for the Preparation of Armenia "Enabling Activities for the Preparation of Armenia's Third National Communication to the UNFCCC's Third National Communication to the UNFCCC". The results are included to the Third National Communication of Armenia to the UNFCCC  and presented in the Chapter 2.1 of this report.

**Toward Integrated Water Resources Management in Armenia, World Bank Group, 2015**

In this study, authors mainly refer to the water resources vulnerability assessments presented within the Second National Communication of Armenia to the UNFCCC (2010) and Regional Climate Change Impacts Study for South Caucasus Region (ENVSEC-UNDP, 2011).

**Climate Change Analysis for the Ararat Valley, USAID ASPIRED Project, 2019**

The Climate Change Model of Decision Support System (DSS) ArcGIS extension was applied for the assessment of the vulnerability of surface water resources in Ararat Valley due to the climate change. The input data for the analysis were hydro-meteorological observations data collected and analyzed in scope of this study, GIS layers of meteorological stations, hydrostations locations and sub-catchment areas within the studied territory.
Latest assessments of climate change impacts in Armenia using the CCSM4 and METRAS models in accordance with the IPCC recommended RCP8.5 and RCP6.0 scenarios for $CO_2$ emissions were accepted in this study. Future change forecasts for ambient air temperature and rainfall have been developed for the periods of 2011-2040, 2041-2070 and 2071-2100 ["Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" UNDP/GEF project].

Table below presenting the projected values of the surface natural flow (inflow to the Ararat Valley) obtained through the Climate Change Model of DSS for the periods of 2011-2040, 2041-2070 and 2071-2100 (Table 39).

Table 39. Projected Values of the Surface Natural Flow (inflow to the Ararat Valley)

| River-Station | Surface Flow Volume, million $m^3$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline Period | Analysis Period | RCP6.0 (CCSM4) | | | RCP8.5 (CCSM4) | | | RCP8.5 (METRAS) | | |
| | 1961-1990 | 1991-2016 | 2011-2040 | 2041-2070 | 2071-2100 | 2011-2040 | 2041-2070 | 2071-2100 | 2011-2040 | 2041-2070 | 2071-2100 |
| Vedi-Urtsadzor | 61.8 | 49.9 | 70.6 | 72.0 | 76.0 | 69.1 | 77.8 | 79.2 | 64.4 | 68.0 | 70.9 |
| Azat-Garni | 146.7 | 139.0 | 159.1 | 162.7 | 168.5 | 158.8 | 169.8 | 177.3 | 154.2 | 164.0 | 171.5 |
| Hrazdan-Yerevan | 596.7 | 595.4 | 586.6 | 580.6 | 574.6 | 582.6 | 576.6 | 558.5 | 580.6 | 564.5 | 550.5 |
| Kasakh-Ashtarak | 222.9 | 202.8 | 214.2 | 209.1 | 205.0 | 211.1 | 206.0 | 188.7 | 209.1 | 192.8 | 178.5 |
| Sevjur-Taronik | 631.7 | 526.5 | 619.3 | 614.6 | 608.4 | 617.8 | 608.4 | 595.9 | 619.3 | 605.3 | 592.8 |
| *Total Surface Inflow* | *1659.9* | *1513.5* | *1649.8* | *1639.0* | *1632.5* | *1639.4* | *1638.6* | *1599.7* | *1627.7* | *1594.6* | *1564.2* |

## 2.2.4 Comparison of Vulnerability Assessment Results

As we can see from the sectors 2.2.1, 2.2.2, and 2.2.3 above, the vulnerability assessment of water resources has been implemented in the scope of various studies for different river basins and water bodies in Armenia, using different climate and hydrologic models, emission scenarios, and assessment periods. Below the comparison of the results obtained in different studies is presented for the entire Armenia, Lake Sevan Basin, and main river basins.

### 2.2.4.1 Vulnerability Assessments of the Annual River Flow for Entire Armenia

Vulnerability assessments of annual river flow for the entire country were performed only within the framework of the National Communications.

According to the calculations of authors of the First National Communication, the river flow will decrease somewhere in the range of  15-20% by 2100.

According to the results presented in the Second National Communication, under the SRES A2 scenario, the river flow in Armenia will reduce by 6.7% by 2030, 14.5% - by 2070, and 24.4% - by 2100.

The same A2 scenario was used in the Third National Communication. According to the aggregate volume of studied river flows in the territory of Armenia will decrease approximately by 11.9% by 2030, 24% by 2070, and 37.8% by 2100.

In the “Development of Armenia’s Fourth National Communication to the UNFCCC and Second Biennial Update Report” (UNDP/GEF, 2018), climate change projections obtained from CCSM4 and METRAS climate models for the periods of 2011-2040, 2041-2070, and 2071-2100 according RCP6.0 and RCP8.5 scenarios were used to assess the climate change impact on water resources of Armenia. According to the RCP6.0 scenario (CCSM4 model), the aggregate river flow in the territory of Armenia will decrease by 8.27% by 2040, 13.2% by 2070, and 19.8% by 2100. According to the RCP8.5 scenario (CCSM4 model), the aggregate river flow in the territory of Armenia will decrease by 12.2% by 2040, 18.0% by 2070, and 33.7% by 2100. According to the RCP8.5 scenario (METRAS model), the aggregate river flow in the territory of Armenia will decrease by 13.5% by 2040, 27.6% by 2070, and 39.0% by 2100.

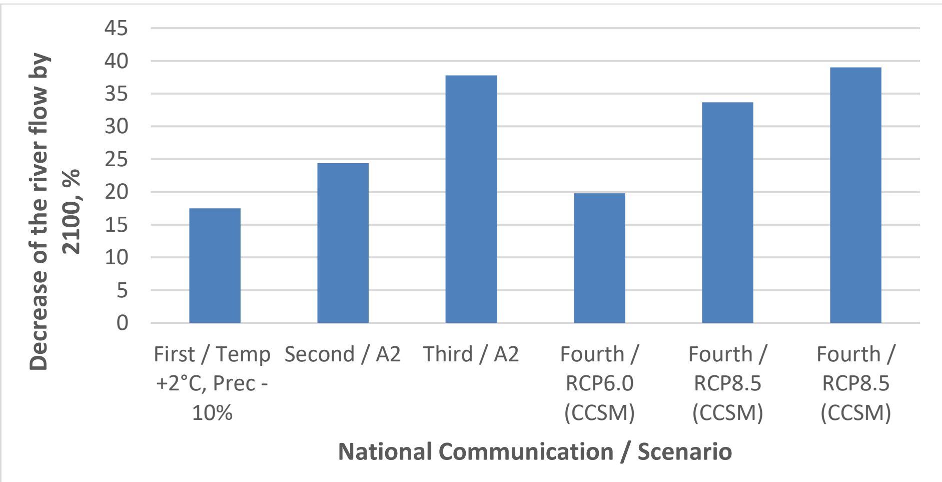



**Figure 8. Changes in the River Flow in Armenia by 2100 against the Baseline Period Average according to the National Communications of Armenia to the UNFCCC**

The smallest decrease in annual total river flow by 2100 for Armenia was calculated within the First National Communication (15-20%), the biggest decrease – in the latest study (Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report) – 39% according to the RCP8.5 scenario using METRAS model.

In the Second and Third National Communications the same scenario (A2) was used, but the modelled values of total river flow decrease differ one from another significantly, 24.4 and 37.8%, accordingly.

### 2.2.4.2 Water Resources Vulnerability Assessments for the Lake Sevan Basin

For the scenario considered in the First Communication (rise of temperature for 2°C and decrease of precipitation for 10%) decrease of water volume in the lake will be about 250 mln. $m^3$ by 2100. In case of such scenario, the water level in lake Sevan will decrease for 20 meters, according to the authors [First National Communication of Armenia to UNFCCC, 1998].

According to the assessments presented in the Second National Communication, the annual river inflow to the Lake will decrease by 309 million $m^3$. In the Third National Communication, the decrease in inflow to the lake for the same period is assessed for 190 million $m^3$, according to the same scenario.

Changes in annual inflow to the Lake Sevan are also assessed in the "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" (UNDP/GEF, 2018). According to the RCP6.0 scenario (CCSM4 model), the annual inflow to the Lake Sevan will decrease by 137.4 million $m^3$ or 17.5% by 2100. According to the RCP8.5 scenario (CCSM4 model), decrease for this period will be 231 million $m^3$ or 29.5%, and according to the RCP8.5 scenario (METRAS model) – 264.9 million $m^3$ or 33.8%. These assessments are also included to the Draft Sevan Basin Management Plan, where the changes in river flow for the main 28 river basins are also presented.

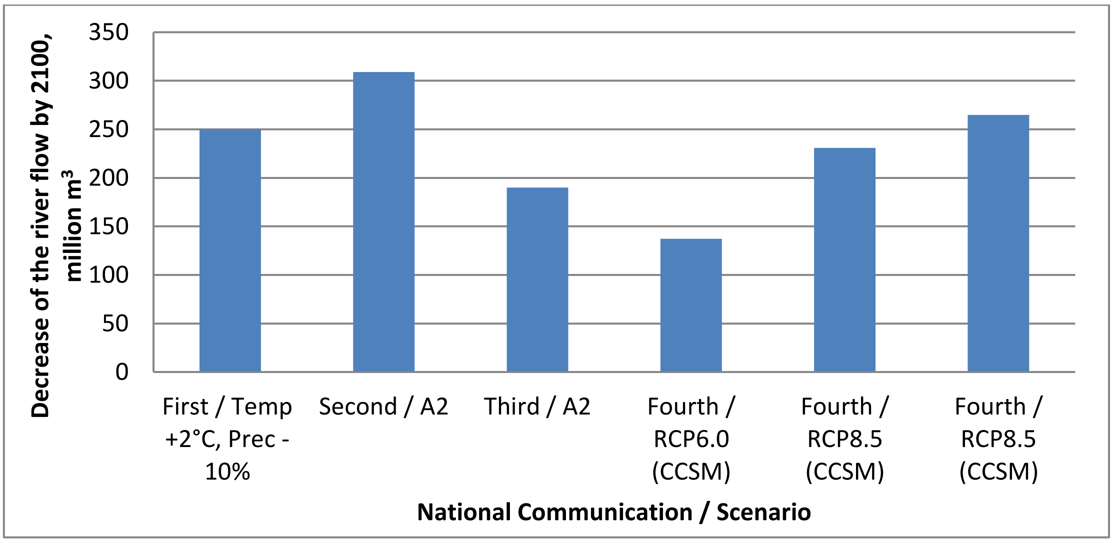



**Figure 9. Changes in the River Inflow to the Lake Sevan by 2100 against the Baseline Period Average according to the National Communications of Armenia to the UNFCCC**

### 2.2.4.3 Water Resources Vulnerability Assessments for Some of the Main River Basins in Armenia

**Debed River Basin**

Vulnerability assessment of water resources in Debed River Basin was performed in Third National Communication (2015), as well as in the the "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" (2018).

According to the A2 scenario applied in the Third National Communication, the annual river flow 2100 at Debed-Ayrum hydrological monitoring station will decrease against the baseline (1961-1990) by 11% by 2030, 37% - by 2070, 62% - by 2100. This values are also presented in the "Regional Climate Change Impacts Study for South Caucasus Region" (2011).

In the "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" (UNDP/GEF, 2018), according to the RCP6.0 scenario (CCSM4 model), the aggregate river flow at the Debed-Ayrum hydrological station will decrease against the baseline (1961-1990) by 5.75% by 2040, 8.85% by 2070, and 12.2% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected decrease will be 9.2% by 2040, 11.4% by 2070, and 26% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Debed-Ayrum station will decrease by 11.8% by 2040, 24.5% by 2070, and 35.9% by 2100.

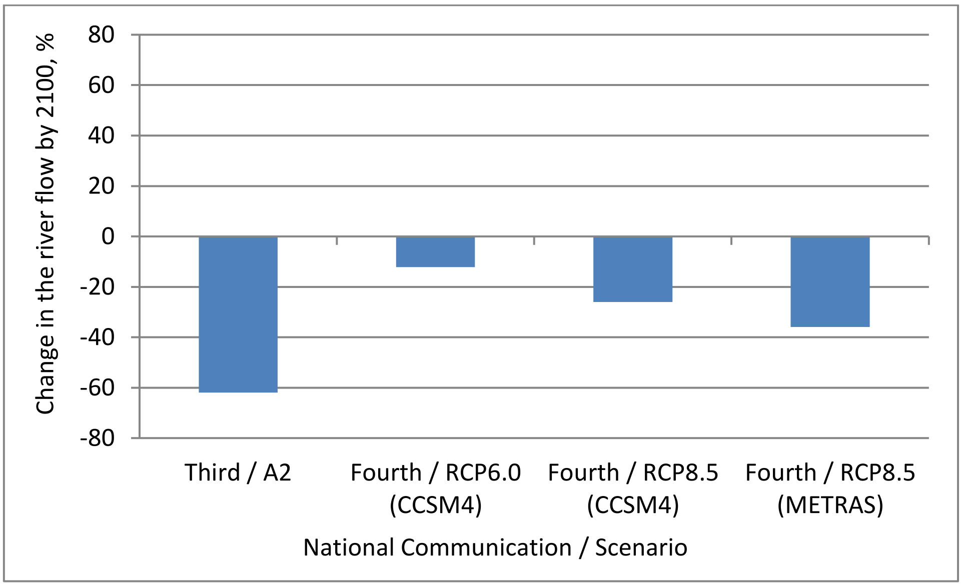



**Figure 10. Changes in the River Flow at Debed-Ayrum Hydrostation by 2100 according to the National Communications of Armenia to the UNFCCC**

**Aghstev River Basin**

Vulnerability assessment of water resources in Aghstev River Basin was performed within the same studies as the assessments for Debed River Basin.

According to the A2 scenario applied in the Third National Communication, the annual river flow 2100 at Aghtev-Ijevan hydrological monitoring station will decrease against the baseline (1961-1990) by 11% by 2030, 31% - by 2070, 62% - by 2100. These values are also presented in the "Regional Climate Change Impacts Study for South Caucasus Region" (2011).

In the "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" (UNDP/GEF, 2018), according to the RCP6.0 scenario (CCSM4 model), the aggregate river flow at the Aghstev-Ijevan hydrological station will increase against the baseline (1961-1990)  by 7.56% by 2040, 8.68% by 2070, and 9.92% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected increase will be 5.44% by 2040, 12.9% by 2070, and 7.91% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Aghstev-Ijevan station will decrease by 2.38% by 2040, 5.08% by 2070, and 8.35% by 2100.

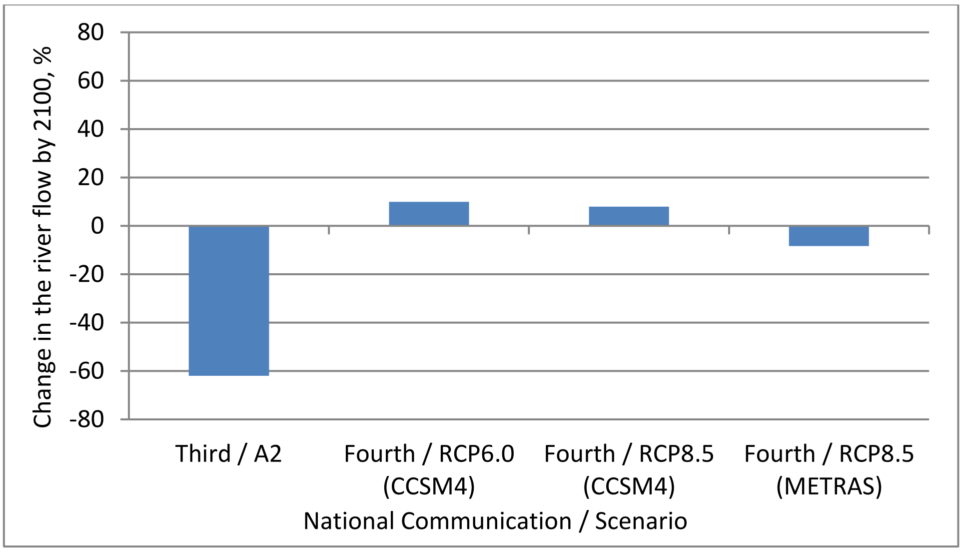



**Figure 11. Changes in the River Flow at Aghstev-Ijevan Hydrostation by 2100 according to the National Communications of Armenia to the UNFCCC**

**Table 40. Changes in the Annual River Flow in the Azat, Vedi, and Arpa River Basins**

| River – Monitoring Station | 2011-2040 | 2041-2070 | 2071-2100 |
|---|---|---|---|
| | % | % | % |
| Azat - Garni | + 2,5 | - 3,5 | - 13 |
| Vedi - Urtsadzor | + 2,5 | - 3,5 | - 13 |
| Arpa - Areni | - 17 | - 21 | - 30 |

The climate change impacts on river flows were also assessed for **Hrazdan, Azat, and Vedi** River Basins. The results are varying from one basin to another.  It is projected that, by 2040, there will be a 2-3% increase in annual river flow in the Azat and Vedi River basins, while in upper streams of the Hrazdan river there will be a reduction of 2-3% (A2). In 2041-2070 there is a projected decrease in river flows for all three river basins: 3-4% in 2070 in the Azat and Vedi river basins, and 6-7% in the Hrazdan river basin; in 2100 the projected decrease will reach to 12-14% and 15-20% respectively.

**Azat River Basin**

As it is presented In the Third National Communication, as well as in the Ararat Basin Management Plan, according to the SRES A2 scenario, the annual river flow at Azat-Garni hydrostation will increase against the baseline (1961-1990) by 2.5% by 2040, after that will decrease against the by 3.5% by 2070 and 13% by 2100.

In the "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" (UNDP/GEF, 2018), according to the RCP6.0 scenario (CCSM4 model), the aggregate river flow at the Azat-Garni hydrological station will increase against the baseline (1961-1990) by 4.97% by 2040, 4.73% by 2070, and 4.60% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected increase at Azat-Garni will be 4.37% by 2040, and 3.94% by 2070, after that the decrease is projected (-0.09% by 2100 against the baseline). According to the RCP8.5 scenario (METRAS model), the annual river flow at the Azat-Garni station will decrease by 1.81% by 2040, 4.49% by 2070, and 7.02% by 2100.

According to the climate change analysis for the Ararat Valley conducted within USAID ASPIRED Project (2019), the river flow in Azat Basin will continuously increase. Thus, according to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Azat-Garni hydrological station will increase against the baseline (1961-1990) by 8.5% by 2040, 10.9% by 2070, and 14.9% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected increase at Azat-Garni will be 8.2% by 2040, 15.7% by 2070, and 20.9% by 2100 against the baseline. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Azat-Garni station will increase by 5.1% by 2040, 11.8% by 2070, and 16.9% by 2100.

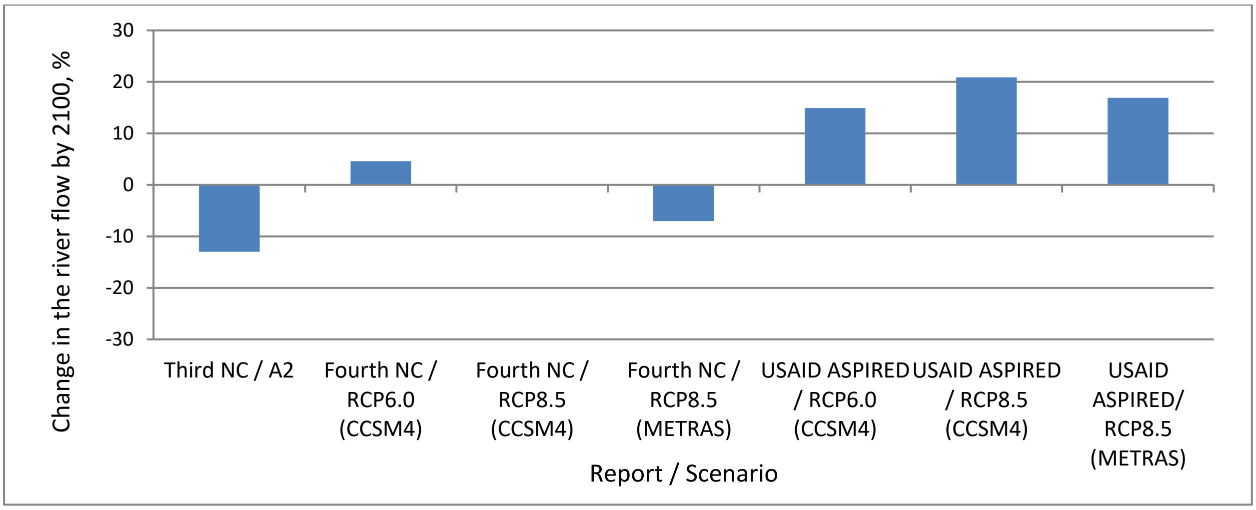



**Figure 12. Changes in the River Flow at Azat-Garni Hydrostation by 2100 according to the Studies Conducted in Armenia**

**Vedi River Basin**

As it is presented in the Third National Communication, as well as in the Ararat Basin Management Plan, according to the SRES A2 scenario, the annual river flow at Vedi-Urtsadzor hydrostation will increase against the baseline (1961-1990) by 2.5% by 2040, after that will decrease against the baseline by 3.5% by 2070 and 13% by 2100.

In the “Development of Armenia’s Fourth National Communication to the UNFCCC and Second Biennial Update Report” (UNDP/GEF, 2018), according to the RCP6.0 scenario (CCSM4 model), the aggregate river flow at the Vedi-Urtsadzor hydrological station will decrease against the baseline (1961-1990) by 2.25% by 2040, 3.15% by 2070, and 3.20% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected decrease at Vedi-Urtsadzor will be 2.41% by 2040, 3.34% by 2070, and 4.17% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Vedi-Urtsadzor station will decrease by 7.36% by 2040, 14.3% by 2070, and 20.2% by 2100.

According to the climate change analysis for the Ararat Valley conducted within USAID ASPIRED Project (2019), the river flow in Vedi Basin will continuously increase. Thus, according to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Vedi-Urtsadzor hydrological station will increase against the baseline (1961-1990) by 14.2% by 2040, 16.5% by 2070, and 23% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected increase at Vedi-Urtsadzor will be 11.8% by 2040, 25.9% by 2070, and 28.2% by 2100 against the baseline. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Vedi-Urtsadzor station will increase by 4.2% by 2040, 10% by 2070, and 14.7% by 2100.

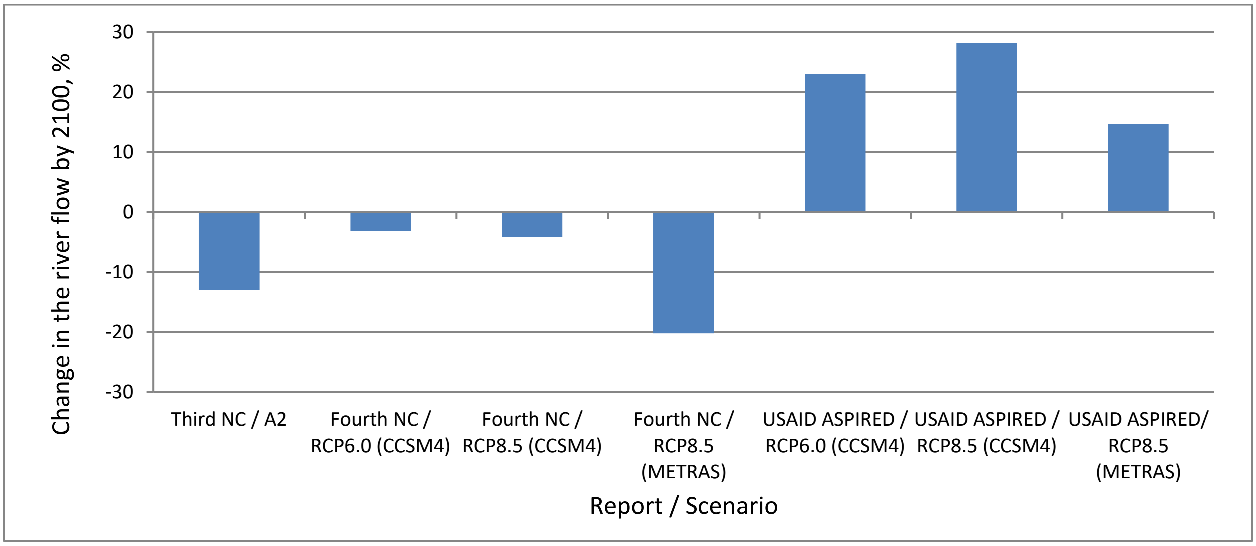



**Figure 13. Changes in the River Flow at Vedi-Urtsadzor Hydrostation by 2100 according to the Studies Conducted in Armenia**

**Arpa River Basin**

As it is presented In the Third National Communication, as well as in the Ararat Basin Management Plan, according to the SRES B2 scenario, the annual river flow at Arpa-Areni hydrostation will decrease against the baseline (1961-1990) by 17% by 2040, 21% by 2070, and 30% by 2100. According to the SRES A2 scenario, the annual river flow at Arpa-Areni hydrostation will decrease against the baseline (1961-1990) by 21% by 2040, 27% by 2070, and 33% by 2100 (Third National Communication, 2015).

In the “Development of Armenia’s Fourth National Communication to the UNFCCC and Second Biennial Update Report” (UNDP/GEF, 2018), the vulnerability analysis of water resources in Arpa River Basin is conducted based on the observation data of Arpa-Jermuk hydrostation. According to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Arpa-Jermuk hydrological station will decrease against the baseline (1961-1990) by 5.48% by 2040, 8.72% by 2070, and 12.2% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected decrease at Arpa-Jermuk will be 7.8% by 2040, 10.9% by 2070, and 21.3% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Arpa-Jermuk station will decrease by 9.34% by 2040, 20.2% by 2070, and 29.7% by 2100.

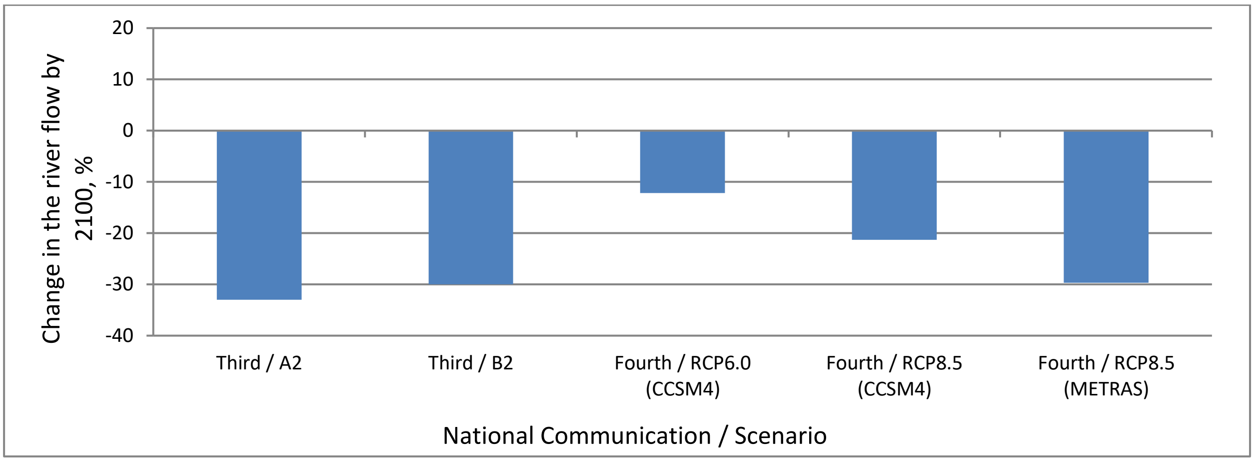



**Figure 14. Changes in the River Flow in Arpa River Basin by 2100 according to the Studies Conducted in Armenia**

**Hrazdan River Basin**

As it is presented in Draft Hrazdan River Basin Management Plan, according to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Hrazdan-Yerevan hydrostation will decrease against the baseline (1961-1990) by 2.7% by 2040, 4.1% by 2070, and 5.4% by 2100. According to the RCP8.5 scenario (CCSM4 model), the annual river flow will decrease by 3.3% by 2040, 5.3% by 2070, and 9.2% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow will decrease by 3.4% by 2040, 7.3% by 2070, and 10.7% by 2100.

In the “Development of Armenia’s Fourth National Communication to the UNFCCC and Second Biennial Update Report” (UNDP/GEF, 2018), the vulnerability analysis of water resources in Hrazdan River Basin is conducted based on the observation data of Hrazdan-Hrazdan hydrostation. According to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Hrazdan-Hrazdan hydrological station will decrease against the baseline (1961-1990) by 17.5% by 2040, 28.2% by 2070, and 40.4% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected decrease at Hrazdan will be 22.9 by 2040, 395% by 2070, and 68.1% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Hrazdan-Hrazdan station will decrease by 23.3% by 2040, 51.7% by 2070, and 76.0% by 2100.

According to the climate change analysis for the Ararat Valley conducted within USAID ASPIRED Project (2019), the river flow in Hrazdan Basin will continuously increase. Thus, according to the

RCP6.0 scenario (CCSM4 model), the annual river flow at the Vedi-Urtsadzor hydrological station will decrease against the baseline (1961-1990) by 1.7% by 2040, 2.7% by 2070, and 3.7% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected increase at Vedi-Urtsadzor will be 2.4% by 2040, 3.4% by 2070, and 6.4% by 2100 against the baseline. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Vedi-Urtsadzor station will increase by 2.7% by 2040, 5.4% by 2070, and 7.7% by 2100.

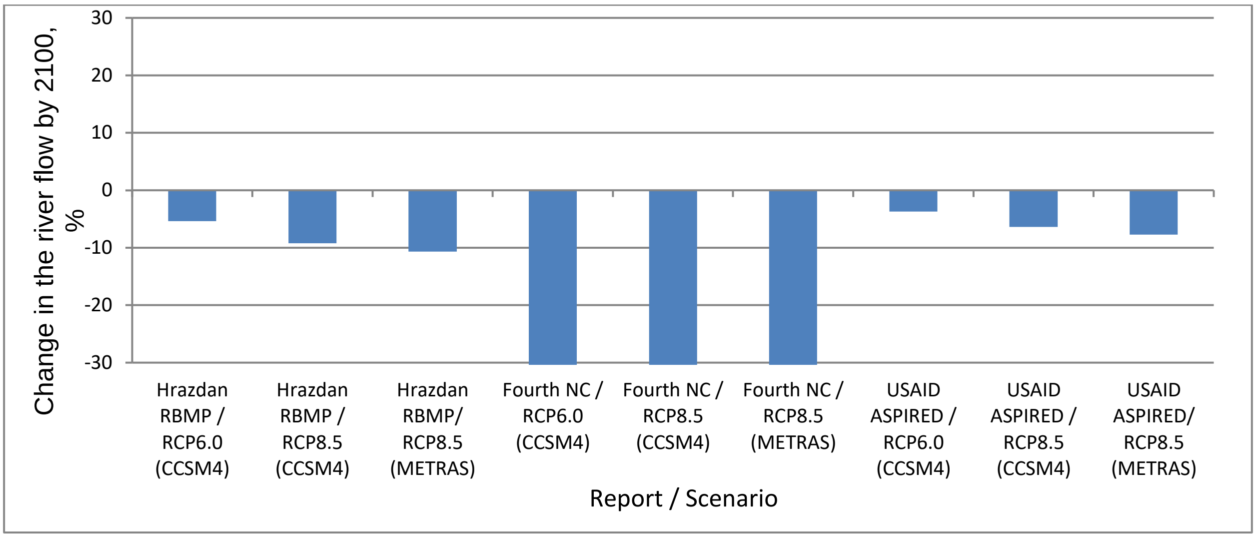



**Figure 15. Changes in the River Flow in Hrazdan River Basin by 2100 according to the Studies Conducted in Armenia**

Vulnerability assessments of water resources for the Marmarik River Basin, the basin of the biggest tributary of Hrazdan River, are conducted within the studies “Complex Assessment of Climate Change Impacts on Water Resources of Marmarik River Basin of Armenia”, (Geoinfo, 2009), Draft Hrazdan River Basin Management Plan, and “Development of Armenia’s Fourth National Communication to the UNFCCC and Second Biennial Update Report” (UNDP/GEF, 2018).

In the “Complex Assessment of Climate Change Impacts on Water Resources of Marmarik River Basin of Armenia”, it is presented that according to the SRES A2 scenario, the annual river flow at Marmarik-Hankavan hydrostation will decrease against the baseline (1961-1990) by 15.9% by 2040, 34.7% by 2070, and 52.3% by 2100.

As it is presented in Draft Hrazdan River Basin Management Plan, according to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Marmarik-Hankavan hydrostation will decrease against the baseline (1961-1990) by 2.2% by 2040, 4.4% by 2070, and 5.5% by 2100. According to the RCP8.5 scenario (CCSM4 model), the annual river flow will decrease by 3.8% by 2040, 4.7% by 2070, and 11.7% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow will decrease by 5.5% by 2040, 11.8% by 2070, and 17.4% by 2100.

In the “Development of Armenia’s Fourth National Communication to the UNFCCC and Second Biennial Update Report” (UNDP/GEF, 2018), according to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Marmarik-Hankavan hydrological station will decrease against the baseline (1961-1990) by 3.03% by 2040, 6.08% by 2070, and 11.2% by 2100. According to the RCP8.5

scenario (CCSM4 model), the projected decrease at Marmarik-Hankavan will be 6.69% by 2040, 8.91% by 2070, and 22.2% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Vedi-Urtsadzor station will decrease by 9.27% by 2040, 19.7% by 2070, and 29.0% by 2100.

**Vorotan River Basin**

As it is presented in the Third National Communication, as well as in the Southern Basin Management Plan, according to the SRES A2 scenario, the annual river flow at Vorotan-Gorhayk hydrostation will increase against the baseline (1961-1990) by 5% by 2040, 10% by 2070, and 16% by 2100. Same values are presented in the Southern Basin Management Plan (2016) as well.

According to the assessments based on the B1 scenario presented in the Third National Communication, the increase will be by 4% by 2040, 7% by 2070, and 12% by 2100.

In the "Development of Armenia's Fourth National Communication to the UNFCCC and Second Biennial Update Report" (UNDP/GEF, 2018), according to the RCP6.0 scenario (CCSM4 model), the annual river flow at the Vorotan-Gorhayk hydrological station will decrease against the baseline (1961-1990) by 2.63% by 2040, 5.07% by 2070, and 7.83% by 2100. According to the RCP8.5 scenario (CCSM4 model), the projected decrease at Vorotan-Gorhayk will be 4.79% by 2040, 6.58% by 2070, and 15.5% by 2100. According to the RCP8.5 scenario (METRAS model), the annual river flow at the Vorotan-Gorhayk station will decrease by 7.06% by 2040, 16.4% by 2070, and 24.6% by 2100.

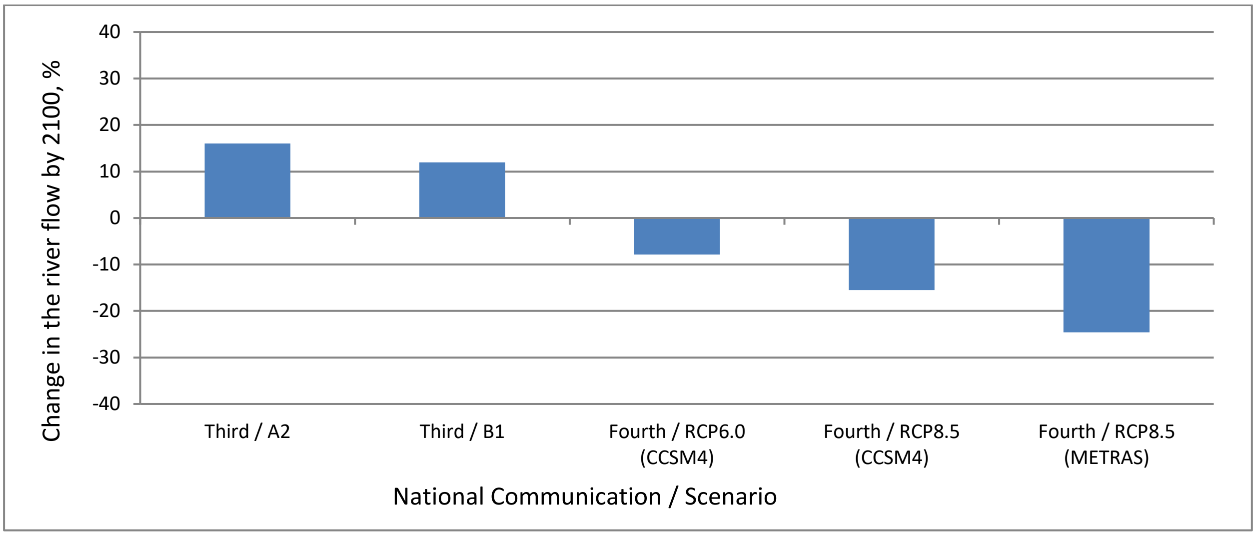



**Figure 16. Changes in the River Flow in Vorotan River Basin by 2100 according to the Studies Conducted in Armenia**

## 2.3. ASSESSMENT OF CLIMATE CHANGE IMPACT ON WATER QUALITY OF WATER RESOURCES IN ARMENIA

In this section, the results of reviewing the reports on water quality vulnerability assessment of water resources due to the climate change listed in the summary of Chapter 2 are presented and analysed.
There are a few studies about water resource quality changes, caused by climate change, due to the lack of hydrochemical data and methodology. However, the hydrochemical quality changes will occur in rivers, for sure, in the case of alteration of the hydrological regime caused by climate change.

### 2.3.1 Assessment of climate change impact on water quality of the RA water resources provided in the National Communications

No any assessment of water quality vulnerability was provided in the First and Second National Communication reports.

The Third National Communication report. The assessment of vulnerability of water quality in rivers in Armenia was first conducted as part of the development of the Third National Communication report. The study results have been presented in the Report on the vulnerability assessment of water resources due to the climate change prepared by V. Sargsyan and A. Arakelyan in 2012. In the report, the Chapter 3, the Methodology of Qualitative Assessment of Water Resources Vulnerable due to Climate Change on the Example of Arpa River Basin" has been dedicated to the assessment of changes in the oxygen regime depending on air and water temperature. Based on the climate change assessment WEAP model, the authors used data on $BOD_5$ and dissolved oxygen in the water of the Arpa River for 2006-2010 to find the correlation between air and water temperature. For this purpose, the total sum for concentrations of dissolved oxygen (DO) and $BOD_5$ was determined, and the further calculations have been conducted for those concentrations. Based on the revealed correlation ratio between the total concentration of $BOD_5$ and DO and air/water temperature the forecast of water quality of the Arpa River has been provided for 2030, 2070 and 2100.

The Forth National Communication report. More comprehensive assessment of the water quality vulnerability of water resources due to the climate change was provided in the draft reports for the Fourth National Communication to UNFCCC. The report on Assessment of the vulnerability of water quality of water resources under climate change in Armenia prepared by L. Margaryan, was presented the changed in the oxygen and mineralization regimes for 8 rivers (Hrazdan, Marmarik, Voghji, Geghi, Sisian, Meghriget, Gegharot) during 2007-2018 against to 1980-1990, and slightly provided the connection between changes in air, water temperature, precipitation and natural flow of rivers. The data is presented in Table 2.3.1.

During the study 9 water quality monitoring points were selected, 7 of which (Marmarik-Hankavan, Voghji-Kajaran, Geghi-Geghi, Sisian-Arevis, Meghriget-Lichkh, Gegharot-Aragats) were located at far from anthropogenic pressure points, near heads of the rivers. Thus, any hydrochemical changes in the rivers' water were considered as a result of the changes in natural conditions: climate change impact.

In the other two observation points (Hrazdan-Hrazdan and Voghji-Kapan) the rivers' water quality is also conditioned by anthropogenic activity, such as untreated domestic and industrial wastewater discharge into the rivers. However, during the assessment and prediction of water quality for the Voghji-Kapan observation point, the anthropogenic and natural pressures were determined and separated in the calculations.

**Table 41. Deviation of average values of parameters for the period of 2007-2018 observed in several rivers in Armenia against the baseline average values for 1980-1990, %.**

| *Parameters* | *Hrazdan-Hrazdan* | *Marmarik-Hankavan* | *Voghji-Kajaran* | *Geghi-Geghi* | *Vorotan-Gorhayk* | *Sisian-Arevis* | *Meghriget-Lichk* | *Gegharot-Aragats* |
|---|---|---|---|---|---|---|---|---|
| ***Oxygen regime*** | | | | | | | | |
| Dissolved oxygen | +2.5 | no | +2. 7 | no | +2.7 | no | no | no |
| $BOD_5$ | +2.6 | +7.1 | no | no | +4.5 | no | +9.6 | +4.3 |
| ***Mineralization regime*** | | | | | | | | |
| Total hardness | -3.4 | no* | no | no | -20.4 | no | +11.0 | no |
| Main Ions | +1.2 | -7.8 | -9. 0 | -5. 1 | -19.8 | no | +7.4 | no |
| Sulfate ion | -8.4 | -9.8 | -8. 7 | -11. 3 | -23.3 | no | +2.9 | +5.1 |
| Hydrocarbonate ion | no | -6.6 | -10. 1 | -3. 1 | -17.6 | -1.5 | +9.5 | -6.5 |
| Chloride ion | no | -8.2 | -13. 6 | -14. 0 | -21.8 | -9.8 | -6.1 | no |
| Calcium ion | no | +4.1 | no | +9. 2 | -19.8 | +1.7 | +12.5 | no |
| Magnesium ion | +5.6 | -13.9 | -4. 7 | -12. 8 | -21.2 | -1.5 | +7.3 | -4.8 |
| Sum of sodium and potassium | -10.3 | -15.7 | -13. 5 | -16. 7 | -21.5 | -5.6 | -8.5 | -2.5 |
| River natural flow | no | -25.0 | -18.0 | -18.0 | no | +9.0 | -8.9 | - |
| Precipitation | +5.4 | -** | -18.0 | -18.0 | -23 | +6.7 | -8.9 | - |

* no changes were observed

** no data

Based on the example of the Hrazdan river, the first time it was presented the seasonal correlation among water quality of river, air temperature, precipitation and river flow. It was shown, that compared to the baseline period, the deviations from the values of the hydrochemical parameters are particularly high for October, when the same air temperature is observed like in April-May, however, lower river flow and less precipitation were recorded. Although the deviations in the annual values of the hydrochemical parameters of the river are small, the seasonal observations show the opposite picture: seasonal hydrochemical deviations refer only to sulfate, sodium, and potassium ions, as well as precipitation by 5.4%, and air temperature increase by 14.4%.

Figure 17 presented the direct dependence of the changes in concentrations of main ions among precipitation and river flow for 7 observation points.

However, there was no assessment of the water quality due to the climate change conducted for other rivers, such as Debed, Akhuryan, Khasak, Metsamor, etc, which have a significant value for the formation of the water balance and water use demand in the country.

In addition, there are no, if any, assessments of water quality changes in drinking water springs due to the climate change. The above mentioned report on drinking water quality mineralization changes were presented only for Kapan, Meghri, Hankavan, Meghradzor, Aghavnadzor, Tsakhadzor, Aragats, Ara, Vardenut and Tsakhashen communities. No any predictions for water quality changes due to the climate change impact have been developed.

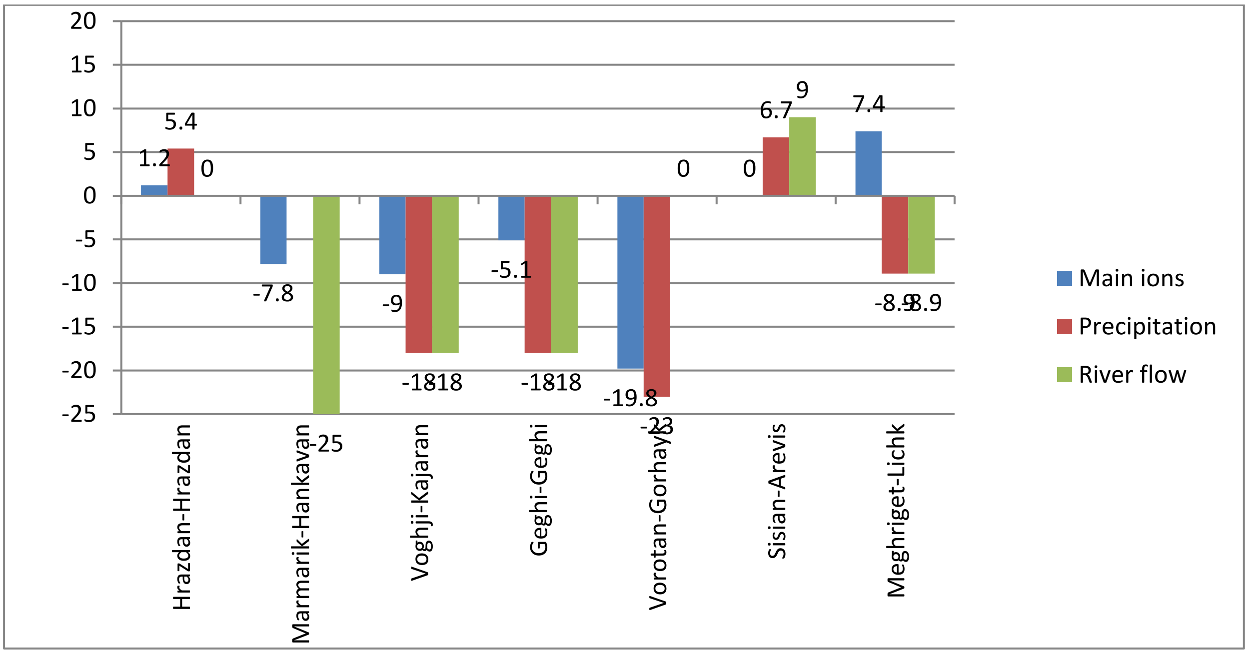



**Figure 17. Deviation (%) of the sum concentration of main ions in the rivers comparing to the deviation of the precipitation and river flow for the period of 2007-2018 against to baseline period of 1980-1990.**

**Table 42. Vulnerability Assessment of Water Quality due to the Climate Change for Rivers in Armenia presented within the National Communications to UNFCCC**

| Observation point | Baseline period | Analysis period | Parameters | Water quality prediction | Used model for prediction | Anthropogenic pressure |
|---|---|---|---|---|---|---|
| Arpa-Areni | Not used | 2006-2010 | DO, BOD5, water temperature | Long-term prediction (2030, 2070, 2100) | WEAP model | Untreated domestic wastewater discharge |
| Voghji-Kapan | 1980 | 2008-2015 | Nitrate and ammonium nitrogen, copper, zinc | Short-term prediction (2018, 2019, 2020, 2025) | Substance Transfer Index by Nikanorov | Untreated domestic and industrial (mining) wastewater discharge |
| Voghji-Kajaran | 1980-1990 | 2007-2018 | $DO$, $BOD_5$, Total Hardness, mineralization, | - | - | Absence |
| Harzdan- | 1980-1990 | 2007-2018 | | - | - | Untreated |

| | | | | | | |
|---|---|---|---|---|---|---|
| Hrazdan | | | Ca, Mg, Na+K, $SO_4^{-2}$, $Cl^-$, $HCO_3^-$ | | | domestic wastewater discharge |
| Marmarik-Hankhavan | 1980-1990 | 2007-2018 | | - | - | Absence |
| Geghi-Geghi | 1980-1990 | 2007-2018 | | - | - | Absence |
| Vorotan-Gorhayk | 1980-1990 | 2007-2018 | | - | - | Absence |
| Sisian-Arevis | 1980-1990 | 2007-2018 | | - | - | Absence |
| Meghriget-Lichk | 1980-1990 | 2007-2018 | | - | - | Absence |
| Gegharot-Aragats | 1980-1990 | 2007-2018 | | - | - | Absence |

### 2.3.2 Assessment of climate change impact on water quality of the RA water resources provided in the River basin management plans

Only in the Southern RBMP unlike the other five RBMP the climate change impact assessment on water quality of the rivers was presented. The assessment is based on the data of annual reports of the EMIC of the RA Ministry of Environment, covering the periods of 1982-1990 and 2007-2013.

The assessment was conducted for the observations points located in the river heads, where anthropogenic impact on the water quality is absent or minimum. These observation points include: Vorotan-Gorhayk for the Vorotan River, the observation point located upstream the Arevis village for the Sisian River, the observation point located upstream the Kajaran town for the Voghji River, Geghi-Geghi observation point for the Geghi River, and the observation point near the Lichk village for the Meghriget River (**Table 43**). The assessment has not been possible to be conducted for other rivers in the Southern BMD due to insufficient data.

The assessment results were updated for the period of 2007-2018 and used in the Fourth National Communication. The same assessment methodology was used. It should be noted, that the baseline period of 1980-1990 was selected in the water quality vulnerability assessment in the Draft Fourth National Communication, meanwhile, in the Southern RBMP 1982-1990 period was mentioned.

Comparing the assessment results of water quality vulnerability, presented in the Draft Fourth National Communication (2007-2018) with the results presented in the Southern RBMP (2007-2013), it was revealed a number of differences on a deviation of water quality parameters, especially for the Vorotan-Gorhayk and Sisian-Arevis observation points.

Based on the Southern RBMP the highest deviation during 2007-2013 against to baseline average values (1982-1990) was observed in calcium concentrations for the Geghi-Geghi observation point, by up to -43.6%, meanwhile, according to the 4th National Communication in the Southern BMA the highest deviation for the period of 2007-2018 against to the baseline period (1980-1990) was observed for sulphate ion for the Vorotan-Gorhayk, by up to -23.3% and calcium deviation in the Geghi-Geghi pooint was +9. 2).

**Table 43. Deviation of average values of concentration of hydrochemical parameters for the period of 2007-2013 observed in the Southern BMA rivers against the baseline average values for 1982-1990, %**

| Hydrochemical parameters | Vorotan-Gorhayk | Sisian-Arevis | Voghji-Kajaran | Geghi-Geghi | Meghriget-Lichk |
|---|---|---|---|---|---|
| ***Oxygen regime*** | | | | | |
| Dissolved oxygen (mg/l) | No* | No | No | No | No |
| Biochemical oxygen demand($BOD_5$) (mg O/l) | No | No | No | No | +7.3% |
| ***Mineralization*** | | | | | |
| Hardness (mg eq/l) | No | -42.7% | No | No | No |
| The sum of main ions (mg/l) | -7.1% | -3.5% | +9.0 | No | +6.7% |
| Sulphate ion (mg/l) | +13.0% | -15.2% | +6.7 | +9.2 | No |
| Hydrocarbonate ion (mg/l) | -4.7% | -25.6% | +17.7 | No | No |
| Chloride ion (mg/l) | -42.0% | -35.4% | +11.2 | +30.2 | No |
| Calcium ion (mg/l) | +24.4% | -42.2% | No | -43.6 | No |
| Magnesium ion (mg/l) | -28.0% | No | No | +18.9 | No |
| The sum of Sodium and Potassium ions (mg/l) | -29.0% | -34.1% | +10.5 | +14.3 | +6.8% |

* no changes were observed

The above-mentioned differences may be the results of the selection of different baseline periods and high changes in the concentrations of observed parameters. It should be also taken into account, that there are no sufficient seasonal data of observed hydrochemical parameters during 1980-1982, which might be a result of an unclear image of the baseline period.

The identification and selection of the baseline period data have the high priority during the assessment of water quality vulnerability under climate change.

## 2.4. DISCUSSION OF SHORTCOMINGS IN TERMS OF THE LIMITATIONS OF THE METHODOLOGIES AND DATA GAPS

### 2.4.1 Methodology and Shortcomings in Assessment of Water Resources Vulnerability under Climate Change

In this section, the results of reviewing the methodologies and data used for assessment of vulnerability of water resources due to the climate change were presented and discussed. The gaps and barriers in methodologies were revealed and analyzed.

### 2.4.1.1 Discussion of Methodologies on Water Resources Vulnerability Assessment due to Observed Climatic Changes

- ***Methodology of assessment of meteorlogical elements and water resources vulnerability***

For the study, assessment and forecasting of water resources vulnerability to climate change, the IPCC (Intergovernmental Panel on Climate Change) has provided some guidelines. They recommend using physical-statistical or process genetic theoretical models that allow assessing the vulnerability of water resources to climate change through the existing relationships between individual elements of water resources and the climatic factors conditioning them.

The process genetic models are based on established physical laws and theories, expressing the dynamics of interactions between climate and its impact object. The impact of climate and other factors on the formation of water resources is different in different river basins in mountainous countries; therefore, theoretical or process-based models are not currently applicable in practice.

The physical - statistical models are based on statistical interconnections between climate and its impact object. Besides, they establish correlations between individual elements of water resources and the main factors that underlie them. There is a wide range of uses of physical - statistical models, from one-dimensional regression model to multidimensional models, with the help of which a number of estimates and forecasts are made.

The assessment of the change and vulnerability of the RA water resources due to climate change have been carried out using physical-statistical or regression models in all papers, which provide sufficient accuracy of vulnerability assessment in the mountainous conditions of our country. It allows the establishment of correlations between the river flow and climate elements, such as precipitation and air temperature. The physical-statistical or regression model has the following standard form:

$$\mathbf{W = K_1X + K_2T + B}$$

where:

*W- is the river flow, $m^3/sec$,*
*X- is total precipitation, mm,*
*T- is air temperature, $^oC$,*
*B- is a constant of the equation,*
*$K_1$ and $K_2$ - are coefficients.*

Along with the physical-statistical or regression models, the GIS-based DSS models created in frame of USAID project have also been used and reported in the literature.

Due to the complexity of separating atmospheric precipitation (snow, rain and sleety shower) and implementing snow-measuring works in the river basins, as well as the availability of air temperature data in the territory of the Republic, depending on the forecasted climate changes, the possible changes in the river flow characteristics of Armenia were evaluated in the following order:

- Data missing in the series of multi-year observations at hydrological observation stations and meteorological stations in river basins were restored: the series observed for up to 20 years is considered short and it is inappropriate to establish correlations between hydrometeorological elements. Therefore, the series were extended to 40-50 years. The data of missing months in the year series were also restored.
- With the help of graphical relationships between the absolute elevations of hydrological observation stations and meteorological stations and their data the average weighted values for precipitation, evapotranspiration and river flow in the river basins were determined;
- Graphical relationships were established between the data of the hydrological observation stations and the meteorological stations of the river basins.

➢ ***Methodology of Assessment of Lakes' and Reservoirs' Vulnerability***

For assessment of the changes and vulnerability of water resources in lakes and reservoirs due to climate change in the Republic, observed air temperature, precipitation, river flow and evapotranspiration data were used.

To determine the value of evaporation from the surface of the water mirror of lakes and reservoirs the empirical formulas used for mountainous areas, the evapotranspiration maps compiled in the past for the Republic were used, or new graphical relationships were compiled between the total evapotranspiration and absolute elevations of meteorological stations located nearby lakes and reservoirs.

The average annual flows of the rivers that flow into and out of the reservoir or lake were determined, taking into account the values of abstractions and water releases, according to water use permits. The average annual atmospheric precipitation on the surface of the reservoir or lake mirror was determined, according to the data of meteorological stations located nearby the water body.

➢ ***Methodology of calculation of river basin water balance***

The purpose of water balance calculation is the quantitative assessment, accounting, management and planning of the water resources of river basin in its natural state.

The water balance of the river basins of Armenia was prepared based on the method proposed by M.I. Lvovich. The river basin water balance was determined by the following equation, expressed quantitatively between precipitation, evaporation and flow:

$$\mathbf{X = E + Y_{nf.}},$$

where:

*X – is precipitation,mm,*

*E – is total evapotranspiration, mm,*

*$Y_{nf}$–is the natural flow (which is equal to $Y_{nf.} = Y_{rf.} \pm Y_{df.}$, $Y_{rf.}$), mm,and $Y_{df.}$ – is the deep flow, mm.*

- ***Determination of precipitation -*** Graphical relationships were established between the precipitation values measured in the meteorological stations of the river basin and the absolute elevation of the stations. From the average weighted elevation of the river basin from the graphical relationship, the average value of precipitation (X) was determined.

- ***Determination of total evapotranspiration –*** The values of total evapotranspiration (E) were mainly calculated by the following equation by A. Valesyan:

$$\mathbf{E = E_g[(1+0.07\,(V_i - V_{ave})]H_{ave}/ H_i,}$$

where:

*E – is the average monthly total evapotranspiration, mm,*

*$E_g$ – is monthly evapotranspiration (determined by graphical relationship between precipitation and air temperature), mm,*

*$V_i$ – is the average monthly wind velocity at the meteorological station, m/sec,*

*$V_{ave}$ – is the average monthly wind velocity in the Republic, established at 3.3 m/sec,*

*$H_{ave}$ – is the average value of atmospheric pressure in the Republic, established at 605 mm,*

*$H_i$ –is the average value of atmospheric pressure for the given month in the meteorological station.*

The total evapotranspiration of river basin was estimated by compiling graphical relationship between the total evapotranspiration values estimated in the meteorological stations and the values of their absolute elevations. From the average weighted elevation of the river basin from the graphical relationship, the average value of precipitation (X) was determined.

- ***Determination of natural river flow –*** The difference between the precipitation and total evapotranspiration from water balance is used to determine the total (climatic) flow - $Y_{nf.} = X - E$.

The natural flow is divided into natural and deep river flows: $Y_{nf} = Y_{rf.} + Y_{df.}$.

In order to determine the natural river flow ($Y_{rf.}$), first, the actual river flow at the river basin hydrological observation stations is brought to natural.

The actual river flow is brought to natural by using the equation of channel and water balances.

The formula has the following standard form:

$$\mathbf{Y_{rf.}} = Y_i + Y_a - Y_b - V_c + E \pm \Delta S_{res},$$

where:

*$Y_i$ – is the actual flow in the hydrological observation station,*
*$Y_a$ – is the water abstraction,*
*$Y_b$ –is the return water from water abstraction,*
*$V_c$- is the transfer of water from one river basin to another,*
*$\Delta S_{res}$ - is the change (use or storage) of water reserve in reservoirs,*
*E - is the amount of evaporation from the water surface of the reservoir.*

The data on the amount of abstraction and the return water from abstraction are taken from the Water Use Permits issued by the WRMA of the RA Ministry of Environment. In case the water use permits do not include the amount of return water from the abstraction, it is calculated based on the results of the investigations carried out at the Water Problems and Hydraulic Engineering Institute. According to these results, the average volume of return water from irrigation in the territory of the Republic is about 20% of the abstracted water and 70% of water abstracted for industry and household purposes.

Thereafter, a graphical relationship is drawn between the values of the river flow brought to natural in hydrological observation stations and the absolute elevations of the hydrological observation stations. Placing the weighted elevation of the river basin from the graphical relationship on the graph, we determine the average natural river flow of the river basin.

- **Determination of deep flow –** The deep flow is determined by the difference of the natural flow and the natural river flow: $Y_{df.} = Y_{nf.} - Y_{rf.}$.

Water balance estimation for mountainous regions is usually associated with a number of difficulties resulting not only from climatic and hydrological data for high mountainous regions, but also from harsh climatic conditions in mountainous regions. These regions have complex geological and hydrogeological structure, which makes the flow redistribution accounting into surface and deep flows difficult. The surface watershed line of the river basin usually does not correspond to the deep flow formation area.

#### 2.4.1.2 Identification of shortcomings in terms of the limitations of the methodology and data gaps

- **Shortcomings in determination of precipitation**

Not all river basins in the Republic of Armenia have sufficient number of meteorological stations to determine the average value of precipitation in the river basin, such as in the Azat, Vedi, Tavush, Hakhum, Khndzorut river basins.

Most of the meteorological stations of the Republic are located mainly in the middle reaches of the river basins.

The watersheds of the Republic's river basins reach elevations of 3000-3500 meters. At elevations above 2500 meters, there is only one meteorological station, the Aragats high mountainous station. This means that we do not have complete precipitation data above 2500 meters, which affects obtaining accurate values for precipitation estimates in the river basin. Meteorological stations at river headwaters are also few.

For obtaining accurate precipitation values, it is necessary to install precipitation gauges in the upper reaches of the river basins, in the river headwaters, as well as in the river estuaries.

- **Shortcomings in determination of total evapotranspiration**

Until now, the value of the total evapotranspiration of river basins has been determined by the method of the 1960s. The methodology sets the average value of atmospheric pressure in the Republic at 605 mm, and the average monthly wind velocity - at 3.3 m/s calculated with the same values for about 50-60 years. To accurately calculate total evapotranspiration, first the wind velocity and pressure values shall be recalculated.

New modern methods are to be used. Various methods, such as energy, radiation, balance, combined, etc., are used worldwide to determine the value of total evapotranspiration. Penman-Monteith and Pristley-Taylor equations are the most commonly used equations of these methods.

The total evapotranspiration consists of the sum of the values of evaporation from the soil, water surface and transpiration from plants. To calculate it, observations must be carried out at meteorological stations of the Republic to determine evaporation from the soil, water surface and transpiration from plants. Only at six meteorological stations throughout the country, observations of evaporation from the water surface are made. No observation is carried out for calculation of transpiration from plants. Also, the measurements of evaporation from the soil were not performed.

As noted in the case of precipitation, where observations must be made in the upper reaches and estuaries of the river basins, here too observations of soil, water and plants should be carried out to determine the evapotranspiration value.

There is no factual observation data on evapotranspiration related to the components of Lake Sevan water balance. Evaporation from Lake Sevan surface is calculated based on measurements of meteorological stations in the coastal areas of the lake (until the 1960s measurements were made on the surface of the lake). In order to correctly determine the evaporation of water from Lake Sevan, it is necessary to carry out measurements on the surface of the lake in several places; and based on these data calculate the exact evaporation from the surface of the lake. As a result, the amount of evaporation from the surface of Lake Sevan under climate change can be estimated.

Observations of evaporation in the Republic's reservoirs is almost not carried out, while the evaporation rate from the reservoirs is estimated to be around 7-10% of the reservoir volume.

As a result of climate change, evapotranspiration from the river basins, lakes and reservoirs of the Republic is increasing yearly and water resources are becoming more vulnerable. Therefore, more attention should be paid to evapotranspiration.

The official communications on assessment of water resource vulnerability due to climate change, as well as water basin management plans did not include total evapotranspiration analysis, vulnerability assessment and forecasting.

- **Shortcomings in determination of natural river flow**

The following types of economic activity have the greatest impact on the water regime of river basins: construction of reservoirs, arid land irrigation, domestic-household water supply, water transfer to other river basins, urbanization (creation of cities and major industrial-domestic complexes), and mining industry. Most, if not all of the above-mentioned activities affecting water resources and water regime in the river basins effect simultaneously, therewith, a part of the factors are major, and others are secondary factors.

The anthropogenic impact on water resources and the dependence of available water supply on climate characteristics are increasing substantially. This is especially true in areas with scarce water resources. Therefore, it is necessary to accurately calculate the values of the elements for bringing the actual river flow to natural flow.

In order to effectively use water resources, it is important to have a clear understanding of the changes in hydrological regime that have already taken place under the influence of economic activity, as well as of the consequences that the planned measures in the river basin may have on changing the conditions for the formation and flow of river water.

There are methodological shortcomings in the calculations for bringing the river flow to the natural flow at the hydrological observation stations.

- There are no actual water use data in the country. In the former USSR, water use data, such as the abstraction and disposal, were mandatorily recorded in water use logs, based on which the actual river flow restored to the natural flow had near-to-natural accuracy. As for the actual flow brought to the natural at present, it has deviations, resulting in an inaccurately estimated natural flow that cannot be used to have an accurate picture for assessment and forecast of climate change.
- While bringing the river flow to natural flow for the rivers, on which relatively large reservoirs were built, the amount of evaporation from the surface of the reservoir mirror was not taken into account.

## 2.4.2 Methodological Shortcomings, Data Gaps, and Conclusions on Vulnerability Assessment of Armenia's Water Resources in terms of Quantity due to Projected Climate Change

### 2.4.2.1 Climate Models

Climate models are based on well-documented physical processes to simulate the transfer of energy and materials through the climate system. Climate models, also known as general circulation models or GCMs, use mathematical equations to characterize how energy and matter interact in different parts of the ocean, atmosphere, land. Building and running a climate model is complex process of identifying and quantifying Earth system processes, representing them with mathematical equations, setting variables to represent initial conditions and subsequent changes in climate forcing, and repeatedly solving the equations using powerful supercomputers.

General Circulation Models (GCMs), including Earth System Models (ESMs) that also simulate the carbon cycle are systematically upgrading, and the resolutions of regional climate model seem to become more reliable.

The PRECIS climate model (stands for "Providing Regional Climates for Impacts Studies"), used in the Second National Communication, is an atmospheric and land surface model of limited area and high resolution which is locatable over any part of the globe. Dynamical flow, the atmospheric sulphur cycle, clouds and precipitation, radiative processes, the land surface and the deep soil are all described. Boundary conditions are required at the limits of the model's domain to provide the meteorological forcing for the RCM.

In the recent studies on climate change in Armenia, CCSM4 and METRAS regional climate models were used.

Community Climate System Model 4.0 (CCSM4) developed by National Center for Atmospheric Researh of America (NCAR) is the advanced model with four components: atmosphere, ocean, earth surface and glaciers, and has a 0.94° x 1.25° horizontal resolution (approximately 110 km) and 26 levels of elevation (up to 40 km).

The METRAS regional climate model has originally been developed at Meteorological Institute, University of Hamburg (Schlünzen, 1988, 1990). t is based on the results of ACCES, CNRM, MPIM, GFDL GCMs, Spatial resolution of the model is 12 km.

### 2.4.2.2 Emission Scenarios

The RCPs represent the range of GHG emissions in the wider literature well 1); they include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one scenario with very high GHG emissions (RCP8.5). Scenarios without additional efforts to constrain emissions ('baseline scenarios') lead to pathways ranging between RCP6.0 and RCP8.5. RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures.

The RCPs cover a wider range than the scenarios from the Special Report on Emissions Scenarios (SRES) used in previous assessments, as they also represent scenarios with climate policy. In terms of overall forcing, RCP8.5 is broadly comparable to the SRES A2/A1FI scenario, RCP6.0 to B2 and RCP4.5 to B1. For RCP2.6, there is no equivalent scenario in SRES.

As RCPs are developed by IPCC in 2014, first results of their application for Armenia are presented in the Third National Communication (2015). In that Communication, the vulnerability assessment of water resources due to climate change for some basins was based on the SRES scenarios.

RCP6.0 intermediate scenario and RCP8.5 pessimistic scenario is applied in Armenia only. It would be also useful to have climate change projections based on the RCP2.6 optimistic scenario.

#### 2.4.2.3 Assessment Periods

In earlier studies (First and Second National Communications), the projection periods of 2011-2030 (early phase), 2031-2070 (middle phase), and 2071-2100 (latter phase) were used in combination with SRES scenarios. Starting from the Third National Communication, the early phase projection period changed from the 2011-2030 to 2011-2040. However, there are some basins for which the vulnerability assessment was conducted for the period of 2011-2030. Assessment periods need to be standardized to be used in the further studies.

In the river basin management plans, vulnerability assessment is also implemented for the RBMP's six-year implementation period. This is very important for water supply assessment and water use planning in the specific implementation period.

#### 2.4.3.4 Hydrologic Models

In the early studies, for assessment of the vulnerability of water resources from the climate change linear regression equations were mostly used that included the air temperature, precipitation, and river flow.

Started from the 2009, in several studies GIS-based models were used for vulnerability assessment which allows incorporating more factors (especially, Digital Elevation Model (DEM) and its derivatives) in calculations. GIS-based Decision Support System developed within USAID Clean Energy and Water Project has a Climate Change module that can analyze historical trends in climatic parameters and project the surface natural flow for the selected river basin using user-defined emission scenarios and projection periods. The system uses not only linear, but also power, logarithmic, and exponential equations. The output of the projection is the raster model of surface natural flow where for each raster cell has a projected value of surface flow. This model is used for the vulnerability assessment in frames of the projects on Southern, Sevan, and Hrazdan River Basin Management Plan development.

For the vulnerability assessment in Arpa River Basin, Water Evaluation and Planning Tool (WEAP) developed by the Stockholm Environment Institute was tested within the study "Vulnerability of Water Sector due to the Climate Change" (2012) conducted in the scope of "Enabling Activities for the Preparation of Armenia's Third National Communication to the UNFCCC's Third National Communication to the UNFCCC" UNDP/GEF/00060737 Project. The results are presented in the Third National Communication. WEAP operates on the basic principle of a water balance and can be applied to municipal and agricultural systems, a single watershed or complex transboundary river basin systems.

The main difficulty in using the complex hydrologic models like WEAP is their high requirements to input parameters. We can expect a representative output from models only in the case if we have the accurate and reliable data on hydro-meteorological parameters, hydrogeology (infiltration coefficient, porosity, deep flow, etc.), soil composition, vegetation, as well as water use. It is, therefore, necessary to conduct studies aimed to the identification of available data sources for hydrological modeling. Based on the results of these studies, the priorities in hydro-meteorological and hydrogeological monitoring network upgrade, hydrogeological, soil, vegetation and other research for the data obtaining for hydrological modeling will be identified.

## 2.4.3 Methodology and Data Gaps for assessment and projection of the water quality of water resource in Armenia

### 2.4.3.1 Baseline Periods

In Armenia the water quality observations were started since 1978 with a limited number of monitoring observation points. During the 1978-1982 period, the water quality monitoring network was developed for only 22 hydrochemical parameters, as well as no all observation points have data for all 4 seasons. Generally, a few, if any hydrochemical data is available in wintertime and spring due to the high location of observation points, which are far from the anthropogenic pressure.

In the Southern river basin management plan, the baseline period was selected for 1982-1990, meanwhile in the draft 4$^{th}$ National Communication it was 1980-1990. During the water quality vulnerability assessment the wrong datasets (annual and seasonal data) for the baseline period caused unclear pictures of the deviations of water quality parameters under the climate change, such as an example for Geghi, Sisian and Vorotan rivers presented in the reports.

### 2.4.3.2 List of hydrochemical parameters

The second important factor during the assessment of water quality vulnerability under climate change projections is the identification of the parameters that will show the climate change impact on the water resources. Taking into account that water quality database includes interrupted data sets, a misconception of the mean annual value may be expressed for some hydrochemical parameters due to the absence of data for some seasons. Thus, the vulnerability assessment should be based on the hydrochemical parameters that do not depend or slightly depend on seasonal variety.

These parameters are DO, $BOD_5$, mineralization, main ions, total hardness, metals. The high seasonally dependent parameters include nutrients: nitrate, nitrite nitrogen, ammonium nitrogen, phosphorus.

In the Southern river basin management plan and the draft 4th National Communication, the vulnerability assessment was conducted only for the oxygen and mineralization regime parameters, the metals (copper, zinc, iron) were not included in the assessment.

It is also important to assess and identified water temperature changes of the rivers under the climate change, which discussed only for Hrazdan-Hrazdan observation point in the draft 4$^{th}$ National Communication. Water temperature is one of the water quality parameters that are highly related to the changes in climatic conditions.

#### 2.4.3.3 Water quality data reliability

It should be noted that over the years, methods of analytical determination of the hydrochemical parameters have also changed, and are often incompatible with the water tests methods from 1980-1990. For example, in the case of determination of the sum of sodium and potassium the rude calculation methods has been used, while since 2005 a mass spectrometric method has been implemented to determine these parameters.

To avoid calculation errors, differences in the water test methods used to determine each hydrochemical parameter in 1980–1990 and in 2007–2018 were taken into account (up to 10–15% of determination method error).

However, the deviation of the parameters from 2007-2018 against to 1980-1990 can also depend on the sensitivity of the chemical analytical methods. For example, in the case of several parameters, such as calcium, copper, zinc and iron, the up to $10^{-3}$ accuracy of data was available for the 1980-1990 and for 2005-2018 – up to $10^{-9}$ accuracy (mass-spectrometry method). It means the low concentration ($<10^{-3}$) of these parameters for the baseline period may be referred to as zero value. This was not considered during the assessments.

#### 2.4.3.4 Location of the observation points

In assessing water quality vulnerability it is highly important to differentiate the anthropogenic and climate impacts on water resources.

In the reviewed studies the assessment was done for those water quality monitoring observation points, which are located far from the anthropogenic pressures and near to the head of rivers. Water quality predictions, however, were done for 2 observation points with anthropogenic impact: Arpa-Areni and Voghji-Kapan in the Third and Fourth National Communications, accordingly.

In case of the water quality assessment at Vaghji-Kapan site, the Substance transfer Index by Nikanorov was implemented to calculate and differentiate the anthropogenic impact u climate change.

#### 2.4.3.5 Water quality prediction methods

In the reviewed studies, two different methods were offered for water quality prediction under the climate change.

*In the Third National Communication*, the water quality prediction was conducted by WEAP model (Arpa-Areni observation point). WEAP model is requested the array of data and information for the tested water body (soil moisture, uninterrupted database for water quality parameters, river flow, air and water temperature, etc), which makes difficulty for calculations.

From the point of view of hydrochemistry, the implemented method for assessing and predicting water quality under climate change impact has several drawbacks.

First of all, the $BOD_5$ and DO are the reverse comparative hydrochemical parameters. If DO has a low concentration, it means the water polluted by the organic compounds, thus the $BOD_5$ and COD expected to have a high value. However, there is no line correlation among these three parameters; it depends on many other factors and characteristics of the water body. Therefore, total concentration may vary or remain in the same values in the water body regardless of air or water temperature change. For example, decrease in DO due to the low air and water temperature and no changes in $BOD_5$ in winter (total sum will decrease), or decrease in DO due to the organic pollution or active grow of biodiversity and increase in $BOD_5$ (perhaps no any changes in the total amount will be detected).

The second drawback in the method is the selected observation point. For the assessment and prediction of water quality changes in Arpa River it was selected the sapling point located 0.5km downstream Areni village. Taking into consideration the fact that no wastewater treatment plant is existed and operated in the village, this part of the river is polluted by the organic compounds from the domestic wastewater discharge. It means the variation in the concentrations of DO and $BOD_5$ is highly depends on anthropogenic factors, such as population number, wastewater content and volume, etc. In this case, the climate change impact on the river water quality may not be significant or very low comparing to the anthropogenic factors impact. So, the predicted changes in the concentrations of DO or $BOD_5$ might not be accurate and dedicated to the result of the climate change impact.

*In the Draft Fourth National Communication*, the water quality prediction was conducted using Substance transferring index by Nikanorov method. Amount of transferring substance by river flow is calculated, which is consist of natural and anthropogenic amounts. Then the anthropogenic amount of the substance (hydrochemical parameter) was calculated based on the baseline period for 1980. The background period, in this case, is the period, when anthropogenic impact on river's hydrochemical regime was absent or unsignificant. Mostly, that time period is considered up to 1980, because of the human impact on natural water resources was extremely increased in the coming years.

Using the predicted value of the natural flow, based on climate change appropriate two scenarios (RCP8.5 (A2) and RCP4.5 (B1)), the recalculation of the natural amount, then sum of the transferring substance was calculated.

$$C_{p/A2pred} = \frac{\sum_{i=1}^{3} \bar{G}_a + \frac{W_{a/A2pred}}{W_{BP}} \cdot G_f}{31.536 \cdot W_{a/A2pred}}$$

This is the privilege of the model to separate the anthropogenic amount of the transferring substance (for example, total nitrogen), and determine how it will be changed depends on changes in river natural flow according to climate scenarios.

However, only for one observation station, Voghji-Kapan, the method was implemented. No other rivers or reference sites were assessed to predict water quality changes under climate change impact.

## 2.5 INTRODUCTION OF INTERNATIONAL PRACTICE ON THE ASSESSMENT OF WATER RESOURCES VULNERABILITY TO CLIMATE CHANGE IN ARMENIA

### 2.5.1 International practice on assessment of vulnerability of water resources

The IPCC (2018) defines vulnerability as “the degree to which a system is able or unable to cope with the adverse effects of climate change, including climate variability and extreme effects”. Vulnerability is a function of the character, magnitude and rate of climate change to which a system is exposed, its sensitivity and its adaptive capacity. In the area of water resource vulnerabilities, researchers define the term in relation to the physical, biological, socio-economic and ecological conditions of the environment, the policy decisions and the regulatory framework for water protection [Allier et al., 2008; Sinan et al., 2003; Wang et al., 2012].
In all water resource vulnerability research, the vulnerability of water resources is defined in relation to internal and/or external factors. The conceptualization in water resources vulnerability assessment is based on the choice of factors considered relevant [Kanga et al., 2019].

Several authors conceptualize vulnerability in different ways, but this difference lies in the fact that the factors that influence the risk of vulnerability of water resources are numerous and require a relevant choice by scientists in conceptualizing vulnerability. IPCC (2018) points out that many specialists in different fields have conceptualized vulnerability according to their areas of intervention, based on the objectives to be achieved and the methodologies applied.

In the water resources vulnerability assessment, the choice of factors is one of the most important steps. There are a number of methods for selecting the right factors [Organization for Economic Cooperation and Development, OECD, 2008; Hinkel et al., 2011, Adger, 2006, and other] and their relative weights [Statistical methods: principal component analysis; Participatory methods (GIZ, 2014; OECD, 2008); “Budget Allocation Process (BAP)”; Public opinion]. This is an opinion poll addressed to the public, focusing on the notion of concern. Methods such as expert opinion or Delphi technique, deductive approach, LR, empiric approach and analytic hierarchy process (AHP) are also used to weight factors [Kanga et al., 2019].

Based on the review of international practice, the most frequently used methods for water resources vulnerability assessment due climate change are:

- Parametric methods or overlay and index methods;
- Process-based models or methods by physical modeling;
- Statistical methods.

SWAT (Soil and Water Assessment Tool), WEAP (Water Evaluation and Planning) and similar small watershed to river basin-scale hydrological models are being widely used in different countries to evaluate the observed and projected climate change impacts on the quantitative and qualitative characteristics of water resources. Retrospective analysis using the hydro-meteorological observational data usually conducted for testing and calibration of those models for the local conditions of studied basins and returns reliable results in case of sufficient and accurate actual input data. Thus, most uncertain and sensitive factors in the assessment of the vulnerability of water resources to climate change are the projected values of the temperature and precipitation according to the various scenarios of IPCC. This means that the greatest effort should be made to improve GCMs and methods for statistical downscaling of GCM simulations.

There are several initiatives aimed at the development of the reliable, long term, consistent global precipitation datasets that can be used for more accurate projecting of future precipitation and imoproving the GCMs and RCMs. Three datasets of this type are described below.

**Climatic Research Unit (CRU) Global Land Precipitation Data**

The Climate Research Unit (CRU) dataset has been constructed at the University of East Anglia. This dataset provides monthly global precipitation at 0.5° * 0.5° spatial resolution from 1900 to the present. The data is available for public via the Centre of Environmental Data Archival (https://crudata.uea.ac.uk/cru/data/hrg/)

**Global Precipitation Climatology Centre Monthly Product**

The GPCC V2018 Full Data Monthly Product provides precipitation estimation at 0.5° * 0.5° spatial resolution for the period from 1891 to the present. This dataset uses the data of rain gauges from 75,000 stations over the globe and includes extensive quality control and further weather dependent corrections. This data can be obtained through https://www.esrl.noaa.gov/psd/data/gridded/data.gpcc.html website.

**PERSIANN-CDR**

PERSIANN-CDR (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks - Climate Data Record) developed by the Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine (UCI) provides daily rainfall estimates at 0.25 deg for the latitude band 60N-60S over the period of 01/01/1983 to 12/31/2019 (and updated every quarter). PERSIANN-CDR is aimed at addressing the need for a consistent, long-term, high-resolution and global precipitation dataset for studying the changes and trends in daily precipitation, especially extreme precipitation events, due to climate change and natural variability. PERSIANN-CDR is generated from the PERSIANN algorithm using GridSat-B1 infrared data and adjusted using the Global Precipitation Climatology Project (GPCP) monthly product to maintain consistency of the two datasets at 2.5 deg monthly scale throughout the entire record. The PERSIANN-CDR product is available to the public as an operational climate data record via the NOAA NCDC CDR Program website under the Atmospheric CDRs category.
http://rainsphere.eng.uci.edu/
www.ncdc.noaa.gov/cdr/operationalcdrs.html

### 2.5.2 Analysis of the precipitation datasets for Armenia based on international practices performed by Center for Hydrometeorology and Remote Sensing (CHRIS) at University of California Irvine

#### Analysis of two commonly used gridded Long-term (1900-2015) Datasets (GPCC V8 and CRU).

These two rainfall datasets have been processed and prepared to provide global coverage and both date back to the start date of 1900. Description for both of them is provided at the 2.5.1 section above.

1. Figure 18 shows the spatial patterns of mean annual precipitation at 50km grid resolution, over Armenia for both GPCC V8 and CRU for the period of 1900-2015. Relatively speaking, both data sets show similar patterns for the Northern and upper parts of Western Armenia.
2. Figure 19 which is more relevant to this discussion shows the result of trend analysis for these two datasets. As can be seen, the long term data shows **No detectable trend in precipitation over Armenia over the 115 years (1900-2015) analyzed by either dataset, suggesting that on the average over 115 years, there is no indication of any statistically detectable positive or negative trends in precipitation.**

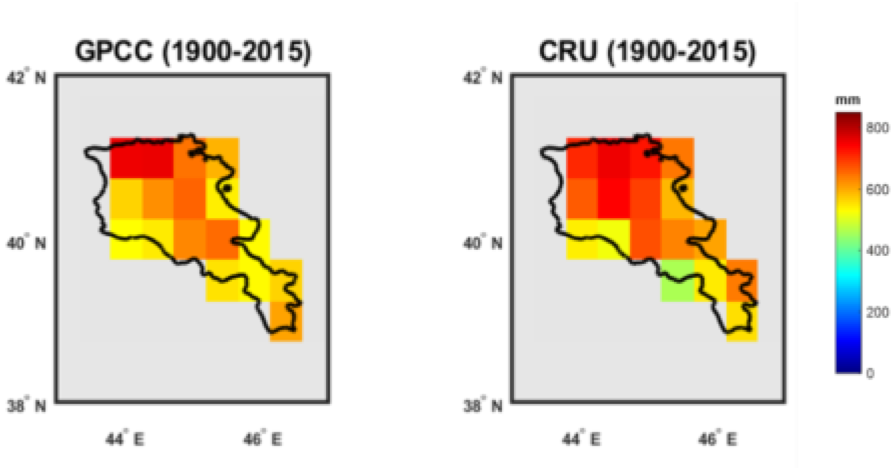



**Figure 18. Spatial patterns of annual precipitation over Armenia for GPCC-V8 and CRU datasets.**

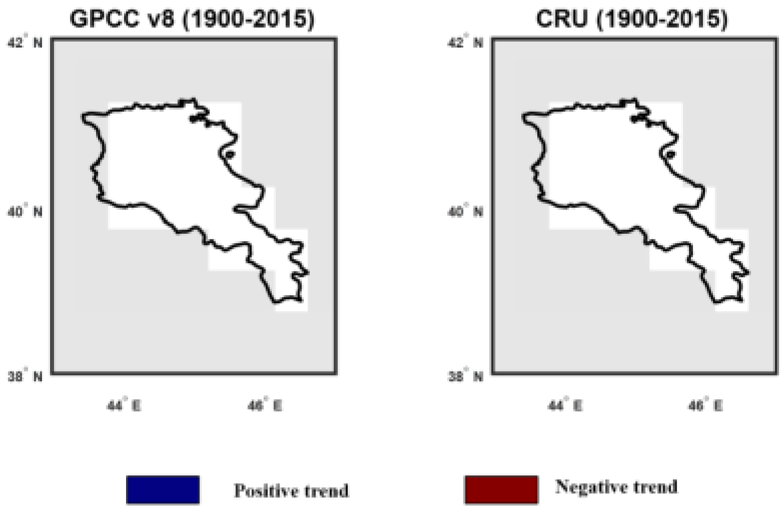



**Figure 19. Long-term trends in precipitation over Armenia for GPCC-V8 and CRU datasets.**

### Analysis of 3 datasets (GPCC-V8, CRU and PERSIANN-CDR) over the period of 1983-2015.

We next focused on the past three and half decade and from the time (1983) an additional high resolution satellite-based dataset, the PERSIANN-CDR is available.

1. Figure 20 shows the spatial patterns of mean annual precipitation for the three datasets over the period of (1983-2015). As can be seen, in general the three datasets agree with each other about the spatial patterns indicating that, on the average, the northern half of Armenia receiving more precipitation. Please note that PERSIANN-CDR has a finer resolution (25km) when compared to the other 2 (50km), providing more detailed observation with respect to spatial heterogeneity.
2. Figure 21 shows the result of trend analysis for the three datasets (GPCC-V8, CRU and PERSIANN-CDR). As can be seen, the over 3 decades of data show that:
    1. Both GPCC-V8 and PERSIANN-CDR show either no trend over some areas of Armenia and positive trend over some regions, especially the southern half of the country.

Again, the PERSIANN-CDR because of its higher resolution provides much finer details.

2. In this case CRU did not show any trend.

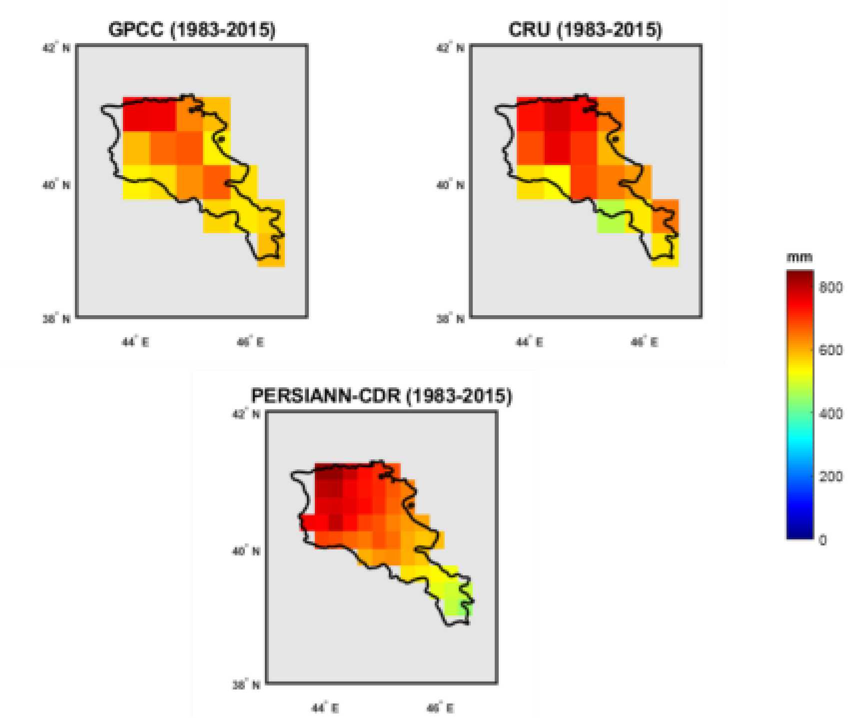



Figure 20. Spatial patterns of annual precipitation over Armenia for GPCC-V8 (50km), CRU (50km) and PERSIANN-CDR (25km) datasets over the period (1983-2015).

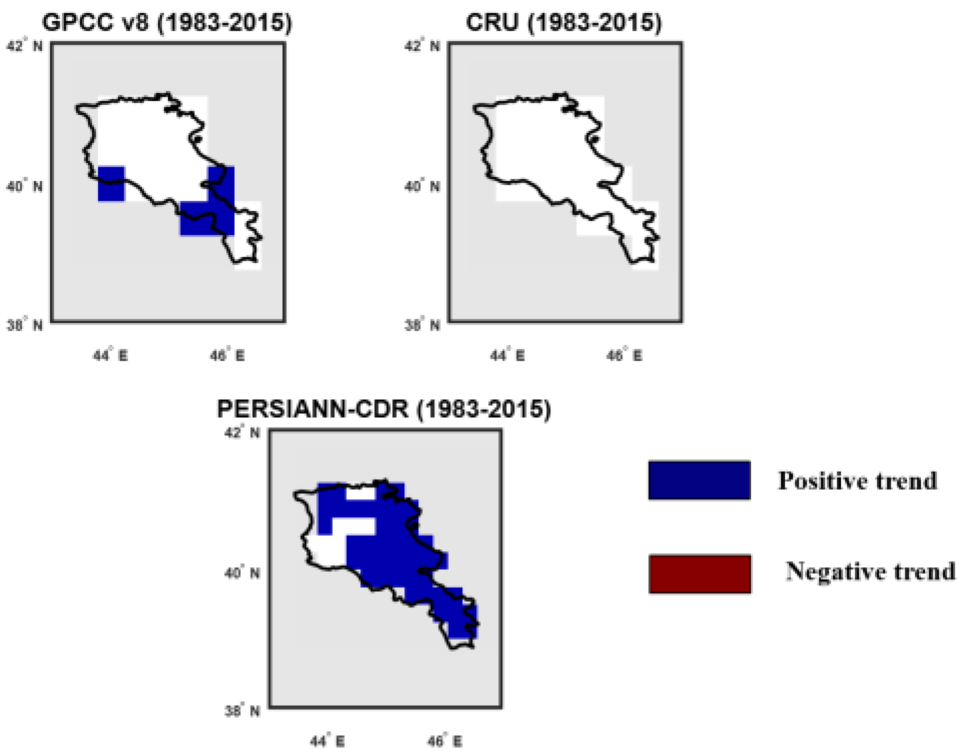



Figure 21. Precipitation trends over the three decades of study for the three datasets (GPCC-V8, CRU and PERSIANN-CDR) over Armenia for GPCC-V8 and CRU datasets.

### Overall Conclusion

Hydroclimatologically speaking, there is no evidence that Armenia has experienced any decrease in the amount of precipitation. On the contrary, the data shows that on the average, a modest positive long-term annual trend in precipitation has been occurring over the 3 decades studied.

## Conclusion of Chapter 2

Studies on assessing the impact of climate change on water resources have been carried out in Armenia since 1998. Since 2008, climate change prediction and vulnerability assessments of water resources have been also started using various methods and models.

The review of the national communications of Armenia to the UNFCCC, river basin management plans that are adopted or in the process of development, and other relevant studies of climate change impact on water resources published in 1998 up to date, revealed several inconsistencies in terms of assessment of vulnerability of water resources within the climate change context.

It was shown that the main inconsistencies are due to the gaps and barriers in datasets and applied methodologies using during the assessment and prediction of water vulnerability to climate change. Particularly, insufficient hydro-meteorological data in flow formation zones, deficiencies in applied methodologies (very large ambiguity in calculation of natural flow data, using “standard” coefficients for return waters), large gaps of actual water use data and deficiencies in water balance calculations. Insufficient hydro-meteorological monitoring makes it particularly difficult to assess the “share of the impact of climate change” on the reduction of river flow.

The comparative analysis of water vulnerability assessments has shown that the projections of future water resources are wide ranging, therefore, none of them can be considered as convincing. The reasons for this variance are lying in the differences of applied climate and hydrologic models, emission scenarios, baseline data and assessment periods and discussed in the Chapter 2.4 of this report: “Discussion of shortcomings in terms of the limitations of the methodologies and data gaps”.

The practical recommendations and activities to overcome the revealed gaps and barriers, which are identified during the review of the officially published number of studies and reports on the assessment of water vulnerability in Armenia, are provided and discussed in Chapter 4.2 and 4.4 of this report.

# CHAPTER 3. REVIEW OF IMPLEMENTED AND ON-GOING CLIMATE CHANGE ADAPTATION MEASURES IN WATER SECTOR IN ARMENIA

## Summary of Chapter 3

This chapter is dedicated to review climate change adaptation measures conducted or on-going in water sector (including drinking water supply, irrigation, fishery, HPPs, industry, and wastewater treatment) since 2015, in the frame of several projects funded by donor organisations, as well as a number of state programs and sectorial strategies related to improvement of irrigation, drinking water supply infrastructures, water reservoirs building, introduction of innovation technologies for agriculture, etc.

A review was made of existing climate change adaptation and mitigation initiatives, including the activities conducted by the local and international organizations related to climate change risks and vulnerability and adaptation. Deep look was made on water use sub-sector strategies (improvement of water infrastructures, introduction of innovation systems for irrigation, etc.) and their synergies between development and adaptation objectives, strategy, plans and programs, including increased intensity of extreme precipitation events, terrestrial flooding, and temperature extremes risks in the water sector adaptation plans, water use sub-sector strategies, and international adaptation projects. The analysis also focused on the actions quantified the impact of climate change on factors governing regional and structural responses to extremes including water supplies and demands.

In addition, analysis and assessment of gender inclusiveness in the country and identification of the main challenges and needs for gender mainstreaming in climate change adaptation planning in the water sector is performed.

The technical analyses were based on the reviewing the following reports and studies:

- The 1$^{st}$, 2$^{nd}$, 3$^{rd}$ and draft 4$^{th}$ National Communications of Armenia to UNFCCC;
- National strategies and international obligations for developing water use by different sectors (irrigation, water supply, hydropower generation, construction of reservoirs, industry and fish farming);
- Regional programs for 11 marzes of Armenia;
- National and international adaptation measures implemented or on-going in Armenia.

## 3.1 REVIEW OF ADAPTATION MEASURES BY SECTORS OF WATER USE

Proper water resource management plays a key role in Armenia's socio-economic development.

In the country the annual water abstraction from water sources for the period of 2013-2017 amounted to 3 027 million m$^3$, of which about 1 211 million m$^3$ or 40% abstraction annually was from underground sources. About 61% of the country's water resources is used for irrigation purposes, and the remaining 39% is used for utilities, industrial water supply, fish farming sectors. The breakdown of actual water use by sector is shown in Figure 22.

All water resources in Armenia are sufficient to supply about 3,100 $m^3$ of water per person per year. However, the temporal distribution of water resources is highly disproportionate due to seasonal and annual fluctuations in river flow.

Based on the draft 4th National communication report the efficiency factor of irrigation water use varies in a range of 0.47 to 0.62.

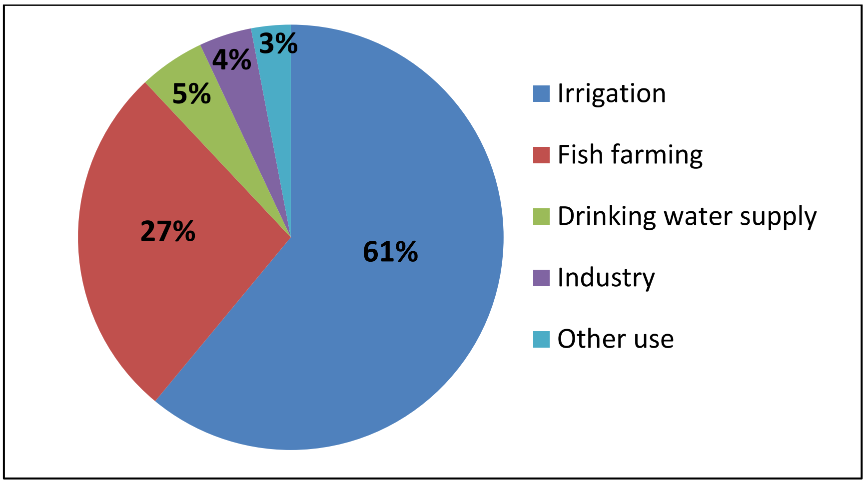



**Figure 22. Actual water use by sectors in Armenia.**

According to the World Resource Institute the Armenia is considered as a country with high baseline water stress and is ranked as the 34th most water stressed country among the 164 UN member countries. According to the Organisation for Economic Co-operation and Development (OECD), Armenia is a country with low water availability, and subject to water stress with 45% Water Exploitation[43].

Compared to other countries in the region, Armenia is extremely vulnerable to climate change. The climate change prediction scenarios indicate a continuing increase in temperature and decrease in precipitation in the region. It is anticipated that in the more sensitive agricultural sector climate change will lead to an increase in crop yields and demand for irrigation, as well as it will need to be significantly increase irrigation to maintain crop yields. However, with the expected decrease in the availability of expected total water resources, it will be difficult to fully meet this demand in the future.

Although, several adaptation measures have been taken in the country, in some cases, the implemented adaptation measures are repetitive, or not effective in the context of climate change adaptation. For example, the main issue in water sector remains the household and industrial wastewater treatment, which has not been addressed in the measures impelemnetd to date.

[43] According to the Organization for Economic Co-operation and Development (OECD), a country is considered to be under water stress if the water exploitation index exceeds 40%.

In this section the indepth view and analysis of the strategy and effectiveness of implemented or ongoing adaptation measures for the sectors of agriculture, drinking water supply and sanitation, hydropower generation and construction of reservoirs were conducted and discussed.

## 3.1.1 Agriculture

Agriculture is one of the key sectors of the Republic's economy and is of strategic importance for formation of the country's gross domestic product, provision of macroeconomic stability, improvement of the balance of external commodity turnover, provision of the food security of the country, as well as income generation for the entrepreneurs in agriculture and stability and development of rural settlements. Crop cultivation and fish farming are the key branches of agricultural development in the Republic.

According to the RA Statistical Committee, as of 2018 about 1064.6 million $m^3$ of water annually abstracted for irrigation purpose and 489.2 million $m^3$ for fish farming.

This section analyzes the state policy in the field of agriculture (irrigation, fisheries), the government programs, the marz development strategies, the investment projects implemented by international organizations. The purpose of the analysis was to identify the issues of water resources vulnerability to climate change in current and ongoing agricultural projects and the proposed water resources adaptation measures.

### 3.1.1.1 Potential impact of climate change on irrigation

Agriculture in Armenia heavily relies on irrigation. More than 80% of gross crop production is obtained in irrigated areas. Irrigation water consumption varies considerably at different times, mainly due to the variability of available total volumes of water.

According to the RA Law “On water user associations and federations of Water User Associations (WUA)" adopted in 2002 for the purpose of implementing reforms of the RA irrigation system, about 50 water user companies were established in the Republic, based on the idea of one hydraulic unit. As a result of institutional reforms in the field of irrigation, the companies have been reorganized in several phases, resulting in the operation of 15 WUAs at present.

The WUAs were formed on the basis of the indivisibility of one general hydraulic unit, and today these companies operate 1700 km of secondary and approximately 16,000 km of tertiary canals, over 55 small and medium reservoirs, pumping stations and about 650 deep wells, of which 90 are self-flowing wells for the provision of irrigation water supply services to around 180,000 water users in over 600 communities.

According to the data of the Land Cadastre of the Republic of Armenia, irrigated land in the Republic comprises about 210 thousand hectares, of which 190,000 hectares of irrigated land is in the service area of WUAs. In recent years, WUAs have actually irrigated 90,000 hectares of land (Figure 23).

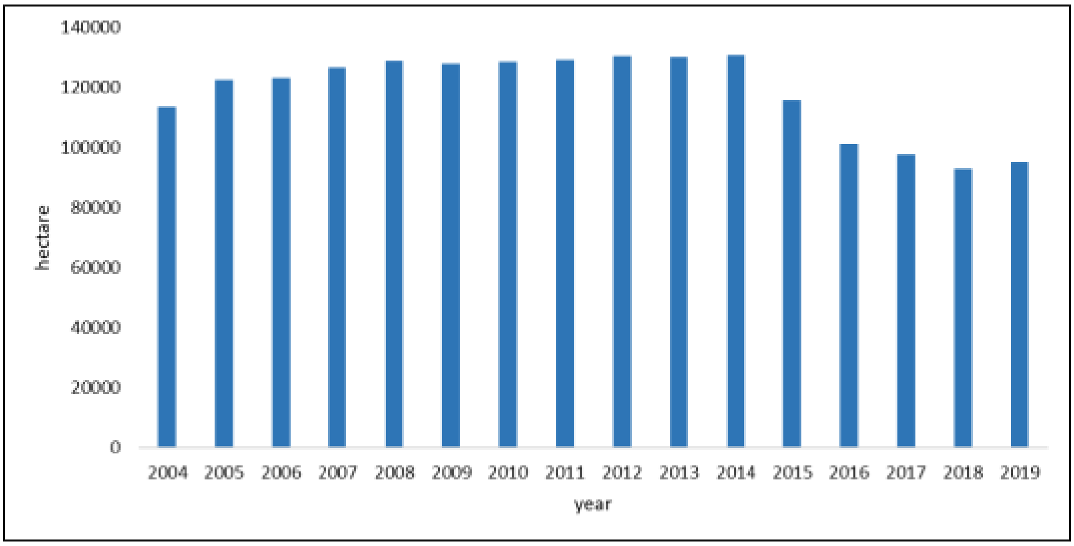



**Figure 23. Dynamics of actually irrigated land area**

Irrigation water management in the Republic is characterized by certain inefficiency. Most of the irrigation water lines in Armenia were built in Soviet times and have a high degree of wear and tear. The issue of ensuring the efficiency of irrigation water supply in Armenia largely depends on the availability of irrigation water, infrastructures and the technical state of existing systems. The existing systems were designed for large tracts of land. Currently, most land is in small plots, and these large irrigation systems are no longer suitable, and in some cases no longer operational (operated with high water losses and require high operating and maintenance costs). In addition, in many communities irrigation water is supplied by earthern channels. Due to problems with irrigation systems, the average leakage rate is estimated to be around 40-50%.

The replacement of pressure pipelines at the Mkhchyan (operated since 1967) and Ranchpar (operated since 1986) pumping stations with new ones is more urgent than the modernization of operating systems. They are currently worn out, with wall thicknesses of 5-6 mm in some parts, which often causes water damage during irrigation though these pumping stations pump approximately 50 million $m^3$ of water annually to the intensive irrigated land of the Ararat Valley. These pressure pipelines have large diameters (over 1,800 mm), and dismantling and replacing them will be costly and time consuming. Taking this into account, the sector specialists also consider the possibility of modernizing the pipes, in particular covering the inside with a suitable coating.

In addition to the above issues, in order to ensure the efficiency of irrigation water supply and in order to reduce the vulnerability of irrigated agriculture as much as possible, from the potential risks of climate change, from dry weather the most frequently observed in recent years, (scarcity, incomplete filling of the large reservoirs) the most efficient use of water resources by *engaging new water sources and creating opportunities for the accumulation of additional water resources,* have became new challenges in the water sector management.

To address this issue, the Armenian Government has considered water reservoir construction as a strategic development path. Currently, taking into account the diversification need for surface water flow management risks (surface flow regulation, flood prevention), water supply demand and water system management risks (due to irrigation land fragmentation), the nature of surface flows (dominating small rivers with spring flood outflows), as well as the volume of required investments, the implementation of small and medium-sized reservoirs construction projects has been considered as a priority.

Taking into consideration the vulnerability of water resources to climate change, it is necessary to renovate irrigation canals and introduce modern water-saving technologies, in particular make a transition to drip irrigation, which is economically and technically justified.

At the same time, the Government of Armenia, considering the importance of these projects and the financial problems of their implementation, plans to offer potential investors public-private partnership options.

### 3.1.1.2 Issues of the fish farming sector and climate change

In recent years, industrial fisheries have also become increasingly popular in the field of agriculture. The climatic conditions of the country are quite favorable for breeding and growing salmon and sturgeons, and as a result of targeted use of groundwater it is possible to organize fish production at all seasons. This field has great prospects in agriculture: attempts are being made to establish fish farms in foothills and even in mountainous areas of the republic where there are no favorable conditions for agriculture and the opportunities for livestock development are quite limited.

The geographic distribution of fish-breeding field in RA is not proportionate: the prevailing part of fish-breeding economies (76%) is allocated in Ararat and Armavir Marzes that generate more than 80% of annual products share. Only the 24% of fish farms are operating in the other 8 Marzes of RA, and provide approximately one fifth of the volumes of fish production.

Currently there are about 166 fish farms registered in the republic, of which 82% operate in Armavir and Ararat marzes. High quality, artesian groundwater resources of Ararat Valley are the main source of water supply for these fisheries.

The second important water resource for fish farming is the Lake of Sevan. As of January 2018, there were 10 fish farms in the Sevan RBD. The total annual permitted water use for fish farms composed 12,634 thousand $m^3$ permitted water use**.** These farms occupy 29,464 $m^2$ of land and abstract water from 5 natural springs, 13 groundwater wells and two rivers (Argichi). The fish farms mainly located in the Gavaraget, Karchaghbyur, Argichi and Martuni River Basins.

In the Minor Sevan, two cage farms are operated. One of them is located near the Shorzha village. From 2012, 4 cages have been installed with the area of 6,400 $m^2$ and capacity 50t. The second fish cage farm is located near the Hayrivank village and operating since 2017. It occupies 82,425 $m^2$ and produces about 60.86 t fish.

The fish farms can have an influence on the water quality and the bottom quality of the rivers and Lake Sevan. The eutrophic impact of fish farming has not been intensively studied yet and phosphorus balance has not estimated. However, fish farms are a source of phosphorus, which can cause of eutrophication of Lake Sevan.

There is no, if any, study relevant to investigate the impact of climat change in fish farming sector of Armenia, however, there are few assessments of climate change impact on water ecosystems, particularly for Sevan Lake, provided in the draft 4th National Communication.

According to those projections, it is expected that the water temperature will rise by 2°C in 2070 and by 4°C in 2100. Based on these data, projections on changes in primary products (phytoplankton and phytobenthos or macrophyte products) and secondary products (zooplankton and zoobenthic symbiont products, fish products) were made at different functional levels in the chain similar to Lake Sevan ecosystem.

It is estimated that the increase in temperature will have a negative impact on Salmonidae fish species. At temperatures above 18°C, the Salmonidae species lose their motility and stop feeding. They are very sensitive to dissolved oxygen in water, which means that during the summer their habitat is limited from above by a water layer with temperatures above 18°C and from the bottom – by a water layer with low content of dissolved oxygen. This zone is getting narrower and narrower and may eventually disappear. Changes in nutrition regime also lead to worsening of oxygen conditions. While the Cyprinidae species, on the contrary, prefer higher water temperatures and are less sensitive to dissolved oxygen in water. It is very likely that Lake Sevan will be transformed from a trout reservoir into a carp reservoir characterized by a higher fish production but lower water quality.

#### 3.1.1.3 Review of the agriculture sector development strategy and adaptation plans in the context of climate change

The RA Government's Protocol Resolution N 22 dated 25 May 2017 approved the "Management concept considering the actual water use in irrigation water supply", and the RA Government's Protocol Resolution N54-36 dated 28 December 2017 approved "The action plan of the management concept considering the actual water use in irrigation water supply".

In 2017, the RA Parliament approved the amendment on Article 25.1 in Water Code, in accordance with the RA Government encourage the secondary or re-use of water resources. The water resources can be secondary used only for the purposes of agricultural or industrial production. The following legislative changes should help established new water-saving technologies or other innovative irrigation systems and improve water use in the fish-farming sector. In this context, it should be noted, that in January 17 of 2019 the RA Government adobted 39-L decisition on "The concept of implementing water-saving technologies and the approval of the program of measures arising from the concept". In the concept dedicated to the basic principles and necessity of protecting and effective use of water resources in the country using the latest technologies, which which will make it possible to minimize the volume of water use, reduce water losses, as well as will support the conservation of water resources, restoration of degraded ecosystems, continuous and efficient use of water resources, provision of sustainable management, revision of the state policy on the economical use of water resources and definition of technological solutions.

The RA Ministry of Economy (former the Ministry of Agriculture) developed a project, approved by the RA Government in December 2017, subsidizing interest rate of loans for the introduction of drip irrigation systems and to make the interest rate of such loans less than 2%. The project envisages stimulating the introduction of effective irrigation methods in perennial plants - fruit and vineyards, high-value crops fields.

During 2018-2022, there are plans to install drip irrigation systems in annually 1,600-1,700 ha of land in the country, which requires around 2.0 billion drams per year to subsidize interest rates - 2.275 billion drams in total.

The RA Goverment anticipates both quantitative and qualitative results from the project - increased and improved crop yields, more efficient use of the country's water, energy and land resources, expanding cultivated lands, modernizing the irrigation system, improving efficiency of irrigation accounting and management, and so on.

To increase water supply and irrigate new lands, there's a loan project for modernizing irrigation systems, financed by the Eurasian Development Bank, the cost of which is around 50 mln USD, 40 mln of which is a loan.

The Program of Activities for 2018-2022 of the RA Government envisages installation of online flowmeter equipment in the selected fish farms, introduction and operation of a computerized SCADA software package, as well as introduction of the current system of water cadastre maintenance and inspection of actual water volume in the Ararat Valley fish farms.

Currently, there are two RA Government draft decisions in circulation: "On approving the concept of the development of the irrigation system of the Republic of Armenia" (https://www.e-draft.am/projects/2045/about) and "On approving the concept of development and introducing of legal, economic, and administrative incentives for reducion of leakage in water systems and the action plan resulting from the concept" (https://www.e-draft.am/ru/projects/2168/about).

The first concept outlines the mid-term measures of the concept of developing the irrigation system in the RA and the mechanisms for their provision.

Observing water resources in terms of their vulnerability to climate change, the concept addresses the following:

- Introducing mechanisms for detection, standardization, real assessment and reduction of water losses in the irrigation system, implementation of works for proper maintenance, repair and restoration of hydraulic structures;
- Creation of prerequisites for water resources accumulation and storage through construction of new reservoirs, improvement of the technical condition of the existing reservoirs, modernization of pumping units and associated equipment used in the irrigation system;

- Water management and metering in the field of irrigation, mechanisms of energy cost accounting and modernization of mechanical water production systems;
- Development of a map of the organization of agricultural activities (taking into account the peculiarities, zonation and natural-climatic conditions of the marzes);
- Promoting saving and efficient use of irrigation water through introducing modern irrigation technologies (drip, sprinkler, subsoil irrigation);
- Use of fisheries' return waters for irrigation purpose, introduction of closed water supply systems;
- Mechanisms for redistribution and enlargement of irrigated lands according to water system availability;
- Institutional strengthening and management improvement of WUAs;
- Legislative reforms to improve the sector.

However, the measures listed above are aimed at developing the sector and in the context of climate change can be considered as measures for mitigation of climate change impact on water resources, rather than adaptation measures.

Besides, the measures presented are planned for stable climatic conditions and do not take into account the climatic features of the site and the expected changes in climate conditions. For example, the measures do not take into account the projected water balance changes in the country, the change in water yield of sources by regions, the effectiveness of the use of drip irrigation systems depending on site characteristics and the type of water resources (the use of highly mineralized artesian water in Armavir Marz is ineffective for drip irrigation and may contribute to secondary salinization of the land).

Appendix 2 to the second concept outlines the action plan resulting from the concept of development and introducing of legal, economic and administrative incentives to reduce leakage in the water system, where the following measures are relevant in view of water resources vulnerability to climate change:

- Analysis of condition, accounting, assessment, inventory of the water systems;
- Introdcuing remote control and remote sensing data collection equipment in irrigation systems;
- Implementation of water system renovation and modernization projects;
- Implementation of cleaning, repairing, restoring, upgrading of irrigation systems, construction of gravity irrigation systems;
- Secondary use (reuse) of water resources, implementation of incentive mechanisms to address it.

The proposed measures are mainly aimed at the efficient use and conservation of water resources. Here, secondary use (reuse) of water resources should be mentioned as a climate change adaptation measure for water resources.

There are a number of past and ongoing state and donor-funded programs and projects aimed to development agricultural sector in Armenia in order to decrease water losses and introduce water reuse systems. The list and a brief discussion of the conducted or on-going measures to climate change adaptation in agricultural sector are provided in Annex 9.

### 3.1.2 Drinking water supply and sanitation

The water supply and sanitation sector development issues are included in the RA Government's program and the list of priority issues. A lease contract was concluded with "Veolia Djur" CJSC on 21 November 2016. The responsibilities of operating and providing drinking water supply and sanitation systems in Armenia in around 410 settlements according to the Leasing Contract are handed to a joint Lessee «Veolia Djur» CJSC. Modernization of the drinking water supply and sanitation systems is being implemented by projects financed by KfW, EBRD banks and other investment organizations. These programs are mainly implemented in the above mentioned 410 settlements. At the same time, drinking water supply services in approximately 560 settlements are provided by local self-government authorities. Within the framework of the projects under implementation, the water supply and sewerage networks of Yerevan are being improved, emergency sections of water supply and sewerage systems of 6 cities and 37 rural areas of the Republic are being rehabilitated, the project for rehabilitation of water supply and sewerage systems of 560 self-serviced rural settlements is being developed.

According to the RA Statistical Committee, as of 2018 about 124.4 million $m^3$ of water annually abstracted for drinking purpose.

According to the long-term strategic development plan of the Republic of Armenia for 2014-2025 approved by RA Government's Decision N 442-N dated 27.03.2014, It is envisaged to continue the improvement of the drinking water system with the aim of increasing the reliability and efficiency of the operation of the systems and improving the quality of water supply and sanitation services, with a focus on mitigating territorial disparities.

This section analyzes the policy for improvement of drinking water supply and sanitation in the Republic, the Government's plans, the strategic plans for development of marzes, investment projects implemented by international organizations.

#### 3.1.2.1 Potential impact of climate change on drinking water supply/sanitation

**Drinking water supply.** The existing drinking water networks in the Republic were built in Soviet times and have a high level of wear and tear. Water losses before reaching the end user and using the old technology to achieve the same result require greater financial and electricity costs. At the same time, constant accidents also affect the quality of drinking water.

According to the annual reports of Veolia Djur CJSC, on average, drinking water losses in Armenia reached 85% in 2007, decreased to 82% in 2011, and to 79.2% in 2018.[44]

According to the Lease Contract for the Water and Wastewater Systems and Other Property Currently Used and Maintained by "Yerevan Djur", "Hayjrmughkoyughi", "Lori-jrmughkoyughi", "Shirakjrmughkoyughi" and "Nor Akunq" closed joint-stock companies, the Lessee (Veolia Djur CJSC) shall implement mandatory capital works for water systems each year to maintain property condition and to improve it. According to the report on the main works carried out in 2018 by the RA MTAI Water Committee, pipelines for drinking water supply, wastewater and irrigation, canals and water mains were constructed, restored and repaired during the reporting year. Around 555.0 km of new water lines and 36.5 km of sewerage lines were reconstructed under water and sanitation systems reconstruction project in the water supply and sanitation systems of 11 cities and 41 villages within the framework of the works envisaged for the solution of the problems of disproportionate distribution and accessibility of drinking water resources in the regions of Armenia. As a result of technical upgrading works of distribution networks in a number of administrative districts of Yerevan, construction of 73.0 km of new water lines and 58.0 km of inlet lines, installation of 8558 water metering chambers were implemented in administrative districts of Yerevan.

Overall, the constructed and upgraded pumping stations, reservoirs, chambers, gravity and water pipeline systems allow not only to reduce water losses, but also to achieve significant electricity savings (e.g., thanks to improved water supply systems, about 360 million kWh of electricity was saved in the Republic in 2007 and 260 million kWh in 2011)[45].

Thus, modernizing drinking water supply systems not only contributes to water loss reduction and more efficient use of water resources, thereby mitigating some climate change impacts on water resources, while contributing to reduced energy consumption and reduction of carbon dioxide emissions.

**Sanitation.** Before 1990, all cities and about 150 villages in Armenia were connected to sewage systems, serving 60-80% of urban population and up to 50% of rural population. 97% of Yerevan's population was connected to the sewage system. Only part of the wastewater removed from the sewered settlements, however, was treated in the wastewater treatment plants. Wastewater removed from other residential areas was immediately discharged into surface water basins.

About 80-90% of wastewater in the country is not treated and reused. There are few, if any, projects are conducted to improve the wastewater treatment and to introducte cheaper, more innovative and flexible wastewater treatment systems, such as constructed wetlands, closed-cycle water use systems, rainwater treatment and use, etc.

[44] https://www.dropbox.com/sh/4iyfgvjzv4l2y6g/AAAHOn_vlpaikQvdzGUG_am3a?dl=0&fbclid=IwAR0Ehb9y-_Kn_6qr6PAul2M_erKeFD5zuo3TyQguRLP7ugH_wU9sQfeWSW0
[45] http://report.gov.am/?id=6

Currently, 89 settlements are sewered and serviced, of which 69 are being serviced by Veolia Djur CJSC and the remaining 20 by local governments. The length of the existing sewer collectors and collecting pipelines is 2,500 km, more than 50% of which needs replacement.

Instead of the 20 WWTPs existing in the past, only five ones are currently operating, servicing the cities of Yerevan, Gavar, Martuni, Vardenis (also Parakar community in 2015-2016). Four operating plants provide only mechanical treatment.

**Sector problems.** Although many problems have been resolved over the past years in the water sector, the following problems must be addressed in the coming years:

- In more than 560 rural communities the drinking water supply and wastewater services are carried out by local self-government, who do not have technical and financial capacity, as well as competent human resources to provide appropriate services.
- The wastewater removal and treatment sectors were not considered as priority in the past. According to expert assessment, 70-80% of household wastewater is not collected and treated in Armenia.
- Despite numerous implemented projects, water losses remain high (79%) in water supply systems due to poor technical condition and water theft; a significant part of water loss is also due to poor technical condition or incorrect design of water intakes.
- Sector regulations do not assess and observe water shortages and projected changes in water balance, change in temperature conditions, projected increase in hydro-meteorological hazardous phenomena, etc. due to climate change.
- The year-on-year trends of decline in water yield of drinking water sources due to climate change impacts are not studied and assessed in water supply sector. Possible changes in the water-chemical composition of water sources that may lead to inadequacy of sources for drinking purpose are not studied and projected.

#### 3.1.2.2 Review of the drinking wtare supply/sanitation sector development strategy and adaptation plans in the context of climate change

**Investment policy.** According to the Long-term Development Strategic Plan of the Republic of Armenia for 2014-2025 approved by the RA Government's Decision N442-N dated 27.03.2014, the drinking water system remains among the state investment priorities. For the entire program period, the level of annual investments in the system would make up 0.4% of GDP.

The target of investment policy is to improve the quality and duration of services rendered and to mitigate the existing territorial disparities. The investment policy is also aimed at increasing the efficiency of drinking water systems, with a particular focus on reducing water losses. In the field of sanitation, it is also important to reconstruct the sewage system of cities and large settlements and to construct wastewater treatment plants. The investment policy provides a separate approach to around 560 rural communities where water supply and sanitation services are not currently implemented by specialized entities holding licenses for rendering water supply services.

According to the investment policy, the main target indicator of the drinking water supply sector is to ensure the continuity of water supply (hours / days) by providing residents with 24-hour water supply.

Taking into account the works carried out in 2015-2017 and the current problems, the RA MTAI Water Committee has developed the water supply and sanitation sector strategy and financing plan for 2018-2030, which summarizes the works carried out in the sector over the last 3 years, sets out the objectives, priorities and necessary actions for further development of the sector. This strategy was approved by the Protocol Resolution No. 10 of the Government of Armenia's sitting of 15.03.2018 (update of the strategy that approved by protocol N38-17, dated 13.08.2015).

The priority actions of the Government of Armenia within the framework of the Strategy are as follows:

- Effective management, operation and maintenance of assets under the Lease Contract.
- Require providing of effective rendering of services by the single Lessee and building public confidence that a justified tariff change is acceptable to the public.
- Develop and implement reliable and affordable plans for sustainable, uninterrupted and safe water supply and sanitation in the 'serviced' and 'not serviced' areas.

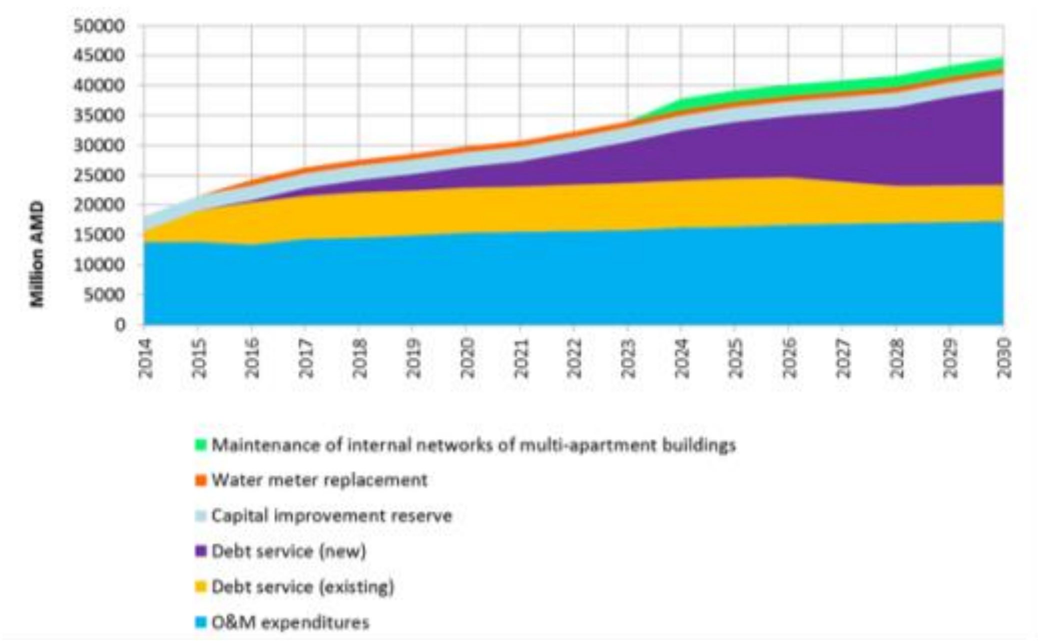



**Figure 24. Single operator: summary of all costs (= revenue requirements)**

The strategy estimates that the revenue requirements for full cost recovery of water supply and sanitation services in the RA settlements for the period of 2014 to 2030 may grow significantly (under the conditions of stable prices). This is due to the fact that debt service costs will increase several times during that period. This will create problems with access to water services and put pressure on public funding for water services (Figure 24).

However, the strategy did not assess and consider the expected changes in the RA water balance by 2030 due to climate change, the water supply and demand by regions dependent on that, the change in the water balance of the Republic, as well as the decreasing trend of water yield of water sources due to climate changes.

It should be noted that for the elaboration of the Water Supply and Sanitation Strategy and Financing Plan for 2018-2030 the studies carried out in 2014 served a basis, which are presented in Table 44. The Basin Management Plans (Ararat, South and Akhuryan RBDs) appoved in 2016 and national communications developed until 2018 have not been included in the strategy development.

The below-mentioned steps should be outlined among the steps taken in the strategy as climate change adaptation measures:

- Apply less costly and advanced technologies, pilot project testing (e.g., non-energy consuming technologies, safe reuse of treated wastewater and sludge generated at WWTP, etc.).
- Implement works to reduce supplied drinking water losses, including setting and providing water loss reduction indicators.

**Table 44. List of studies that served a basis for the development of water supply and sanitation strategy and financing plans.**

| Reference | Title |
|---|---|
| **KfW funded studies/** Joint study by the Consortium of Dorsch International Consultants, "Hydrophil IC", VGM Partners and "Hydroenergy" companies | |
| Dorsch (2014) | Water Sector Study Armenia: Final Report on the Present State of the Water Sector |
| Dorsch (2014) | Water Sector Study Armenia: Final Report on Financial and Human Resource Impact |
| Dorsch (2014) | Water Sector Study Armenia: Sector Review and Strategy. |
| **KfW funded study/ CES study – a joint study with "Jrtuk" LLC** | |
| CES (2014) | Feasibility Study on Improvement and Development of Water Supply and Wastewater Systems in Rural Areas of Armenia, Main Report, October 2014, and Annexes (March 2015). |
| **Joint study by Trémolet Consulting and JINJ LTD** | |
| OECD (2014) | Towards a National Strategy for Sustainable Sanitation in Armenia: Stage 2: Report on Principles of providing sanitation conditions in Armenia |
| OECD (2014) | Towards a National Strategy for Sustainable Sanitation in Armenia: Integrated report: Final report. |
| **ADB funded studies** | |
| ADB (2013) | Policy and Advisory Technical Assistance (PATA). Armenia: Infrastructure Sustainability Support. Water sector. Final Report. |
| ADB (2014) | Non-Revenue Water reduction action plan. |
| **WB** | Armenia - Water sector tariff study. |

The measures presented, however, are viewed not as a measure of vulnerability reduction and adaptation of water resources to climate change, but as a measure of conservation and efficient use of water resources under unchanging climate conditions.

It should be noted that in 2019 the draft Decision of the RA Government "On approving the concept of development of the field of wastewater discharge" was developed (https://www.e-draft.am/projects/2047/about). The aim of the draft concept is to improve and modernize the sector, to increase the quality of services provided, to provide access, to support the solution of relevant health and environmental problems. The concept was developed based on a study and proposal by the OECD entitled "Developing a National Strategy for Sustainable Drainage and Wastewater Treatment in Armenia", which also includes international experience in the sector. In terms of climate adaptation, the proposed concept contains following key provisions:

- Improving the legal framework for the purpose of regulating the processes of wastewater discharge and treatment, sludge treatment, reuse of treated wastewater and sludge.
- Ensure the installation and operation of local treatment plants and equipment at the expense of own funds in areas without a centralized sewage network.
- If possible, review the current tariffs for wastewater discharge and treatment services using the principle of self-sufficiency.

Despite its importance, the concept has not been adopted yet.

There are a number of past and ongoing state and donor-funded programs and projects aimed to development drinking water supply and sanitation sector in Armenia in order to decrease water losses and improve water sanitation in the country. The list and a brief discussion of the conducted or on-going measures to climate change adaptation in this sector are provided in Annex 9.

## 3.1.3 Hydropower generation

Hydropower, considered as a non-consuming water user, plays an essential role in the country's energy sector. In recent years the annual water abstraction for hydropower in Armenia has exceeded 5 billion $m^3$. The country's hydroelectric power is 21.8 billion kWh, which can be realized using the complexes of the two major hydroelectric plants- Sevan-Hrazdan (designed capacity is 2.32 billion kWh per year) and Vorotan (designed capacity is 1.16 billion kWh per year), and 3 new large HPPs and exploiting SHPPs’ capacity.

Currently 187 small HPPs generate about 1 billion kWh of electricity annually, and another 28 small HPPs are in the design or construction phase with annual production of 203 million kWh.

However, in a number of basins, small hydropower plants are experiencing environmental disruption, which is a significant pressure on water resources.

### 3.1.3.1 Potential impact of climate change on hydropower generation

Renewable energy technologies, such as hydropower, contribute significantly to the reduction of GHG emissions and to the security of the energy supply. In comparison with conventional coal power plants, hydropower prevents the emission of about 3 GT $CO_2$ per year, or about 9% of global annual $CO_2$ emissions. In general, hydropower is a source of energy that produces few GHG emissions. According to the World Energy Council (WEC), the $CO_2$ emissions per GWh are 3–4 t for hydropower run-of the river, and 10–33 t for hydropower with a reservoir; these values are about 100 times less than the emissions from traditional thermal power [World Energy Council, 2004]. In addition, the SRREN (2011), which is a special report of the International Panel on Climate Change (IPCC) titled “Renewable Energy Sources and Climate Change Mitigation,” shows that the majority of lifecycle GHG emission estimates for hydropower cluster are between 4 and 14 g $CO_2$ eq·$(kWh)^{-1}$, as shown in Figure 25 [Edenhofer et al., 2011].

Under certain scenarios, however, the potential exists for much larger quantities of GHG emissions from hydropower, as shown by some outliers–although these quantities are always much lower than those from thermal power [Edenhofer et al., 2011]. There are practically no fossil fuels available in Armenia and water energy resources are of high importance for the country.

There are more than 200 rivers and streams in Armenia with the length of 10 and more km. The Hrazdan River flowing out lake Sevan, the rivers Araks, Vorotan and Debed have the most energy potential.

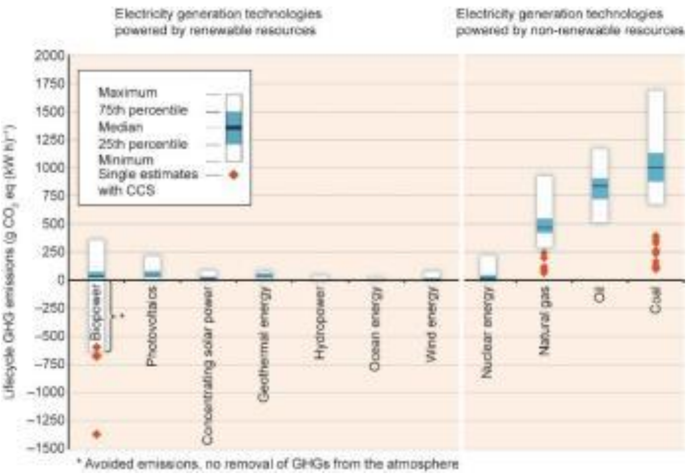



**Figure 25. Lifecycle greenhouse gas (GHG) emissions of electricity generation technologies powered by renewable and non-renewable resources [Edenhofer et al., 2011]**

The potential water energy resources of Armenia are 21,8 bln.kWh (large and medium size rivers - 18,6 bln.kWh, and small rivers- 3,2 bln.kWh).

Till the First World War, 9 small hydropower plants (SHPPs) operated in Armenia with total capacity of 2155 kW. In 1913, the production of energy was 5.1 mln. kWh.

### 3.1.3.2 Review of the hydropower generation sector development strategy and adaptation plans in the context of climate change

As mentioned in the Chapter above, hydropower is a green source of energy and it contributes to the reduction of $CO_2$ emissions. But HPPs have also negative impacts on the river aquatic ecosystem: in a certain section of the river after HPP the environmental flow is not maintained that lead to the deterioration of aquatic ecosystem and biodiversity. Other negative environmental impacts are complication of fish passage, waste, dust and noise, visual pollution, illegal hunting [Baskaya, et al., 2011].

The projected decrease in water availability will also affect hydropower potential in the country.Thus, climate change scenarios and projected river flow values should be considered during provision or extension of the water use permit for hydropower purpose.Currently, water use permits for HPP exploitation are given for up to 25 years.

River flow reduction due to the projected climate change may increase the probability of violation of environmental flow in the rivers with SHPPs and the aquatic ecosystems will become more vulnerable.

In last years, there are several Government resolutions approved and programs started related to the hydropower generation in Armenia.

The position of the Republic of Armenia under the Paris Agreement is enshrined in the document on "Intended Nationally Determined Contributions" (now "Nationally Determined Contributions "), which was approved by the Government of Armenia's Protocol Resolution N 41 as of 10 September 2015 and submitted to the UNFCCC Secretariat on 22 September 2015.

This document is based on the principle of "green economy" and the ecosystem approach to mitigation and adaptation actions. According to the document, the total emissions of the country for the period of 2015-2050 should not exceed 633 million tonnes of carbon dioxide equivalent (tonnes of $CO_2$ eq.).

*Protocol Resolution of the Government of Armenia № 53-36 as of 29.12.2016 "On Approving the Hydropower Development Concept of the Republic of Armenia*". Hydropower is ecologically clean and environmentally friendly, ensures reduction in $CO_2$ greenhouse emissions to the atmosphere and the Government of Armenia views the development of hydropower in the context of minimal adverse environmental impact.

The concept paper sets forth the vision of the Government of Armenia for the development of the hydropower sector, the need to apply the "public-private" partnership options to make the investment framework more attractive, and to provide certain guarantees from legal point of view.
*Protocol Resolution № 8 as of 01.03.2018 "On Approval of Environmental Impact Assessment Criteria for the Construction and Operation of Small Hydro Power Plants":* adoption of this Resolution was conditioned by the fact that operation of SHPPs has adverse impacts on ecosystems (particularly on aquatic ecosystems) because of the reduced river flow caused by active water use as well as climate change in recent years. Therefore, there was a need to set criteria for the construction and operation of small HPPs that should prevent or reduce the harmful effects of small HPPs on the environment.

As it is stated in the Resolution, “Though hydropower is considered to be environmentally friendly and aims to reduce the emission of $CO_2$ greenhouse gases into the environment, the operation of SHPPs has a negative influence on the ecosystems (particularly water ecosystems) because of the reduction in river flows due to climate change.

Criteria for the construction and operation of SHPPs should be established to solve the emerged environmental problems, to ensure the preservation of water ecosystem during water use and to ensure balance, which will prevent or reduce the harmful impacts of SHPPs on the environment”.

These required criteria are as follows:

- Availability of red-listed and/or area-specific endemic fish species and water plants,
- Availability of spawning spots of area-specific endemic fish species,
- Availability of overload by 40% and more by derivation pipelines,
- Preservation of factual water course in the river section not exceeding the magnitude of the environmental flow set in the water usage permit,
- Availability of sanitary zones of water ecosystems, the criteria of which are laid down in Clause 3 of the appendix to the governmental resolution N 64-N dated on 20 January 2005.
- Availability of monuments of nature in a diameter of 150 meters,
- Availability of landslide areas,
- Availability of roads running to the construction area of SHPPs or the need to construct roads,
- The distance of constructed SHPP from the nearest residential area, Impact of noise on the environment and human health.”

*Action Plan of the Ministry of Energy and Natural Resources of the RA Stipulated by the Provisions of the National Security Strategies of Armenia, adopted in 2007,* envisages the construction of generating facilities and measures to be taken by 2025, including:

Construction of new 540 MW HPPs (including 260 MW small HPPs); construction of 200 MW wind turbines; upgrading of the currently operational two TPPs using gas-turbine installations with a total capacity of 648 MW; construction of a new 1,000 MW power unit in ANPP; modernization of electricity transmission and distribution networks to reduce losses; construction of Iran-Armenia gas pipeline; restoration of 150 million $m^3$ capacity of underground gas storage; restoration of heat supplies with the maximum use of geothermal, biogas, solar and other Resources; organization of large-scale introduction of sustainable measures to ensuring energy saving. The work plan includes timeframes and financing sources for the implementation of measures.

In 2010, the *Small Hydropower Plants Development Scheme* was designed to promote the construction of small HPPs and includes hydro energy indicators for more than 100 HPPs.

On the regional level, Development Strategies for 2017-2025 have been composed for each of 10 Marzes of Armenia.

In these strategy documents, capacity of existing HPPs and HPPs under construction is presented. It is mentioned that future climate change may affect the hydropower potential, thus, vulnerability assessment of water resources and implementation of necessary adaptation measures is of vital importance.

Development Strategy for Lori Marz stated, that development of hydro energetic potential is priority for the Marz. According to the Government of Armenia's Protocol Resolution No. 35 "On Approving the Strategic Development Program of the RA Hydro Energy Sector" approved by point 12 of the sitting of 22 September 2011, it is encouraged to develop hydropower sector in the Marz through the construction of new SHPPs on Debed River and its tributaries.In the Development Strategy for Shirak, it is mentioned that the Marz has favorable natural conditions for hydropower sector development. Syunik, Vayots Dzor, and Tavush Marzeshave a great hydropower potential and developed HPP infrastructure.

In the VayotsDzor Development Strategy, it is briefly mentioned that the HPPs have also negative impact: they changed the flow regime of the rivers and deteriorated river fauna (spawning problems, loss of small fish).

In general, in the Development Strategies for Marzes the double relationship of hydropower and climate change is indicated. It is briefly stated, that HPPs are sources for "green" energy with low carbon emissions, and the reduction of river flow due to the climate change will also reduce the hydropower potential of the rivers.

*Proposed Investments Projects*

**On the website of the Ministry of Energy Infrastructures and Natural Resources of the Republic of Armenia, there are two potential investment projects for HPP construction (Shnogh and Meghri HPPs)[46]. Pre-feasibility studies were conducted for that projects, however, climate change adaptation issues have not been discussed in that studies.**

There are a number of past and ongoing state and donor-funded programs and projects aimed to promote renewable energy (including hydropower generation) development in Armenia in order to decrease GHG emissions from energy sector.

The list and a brief discussion of the conducted or on-going measures to climate change adaptation in this sector are provided in Annex 9.

### 3.1.4 Construction of water reservoirs

Totally 87 reservoirs with 1.4 billion $m^3$ water capacity have been constructed in Armenia to regulate seasonal fluctuations in the river flow. Most of these reservoirs mainly serve for one purpose

[46] http://www.minenergy.am/en/page/464

irrigation. In Armenia the volume of water storage per capita is about 465 $m^3$ on average, which is considered a low indicator for the semi-arid climate of the country.

This section analyzes the development policy for construction of reservoirs in the Republic, government programs, strategic plans for development of marzes, investment programs implemented by international organizations.

#### 3.1.4.1 Potential impact of climate change on the construction of water reservoirs

Reservoir construction projects are of vital importance in the Republic of Armenia. The reservoirs currently operating in Armenia were built during the Soviet era.

The impacts of climate change and the consequences of future forecasts have not been taken into account when designing the reservoirs. It is true that hydrological calculations have provided minimum flow provision calculations, but this is not sufficient and these minimum flows can also be altered by climate change impacts.

Reservoirs are usually operated for 70 years or more, depending on the time that the reservoir's dead volume is filled with fluvial alluvium (solid substances). However, there are no studies of the solids through the surface flows of the reservoirs in Armenia. It should be taken into account that as a result of climate change, the amount of solid substances in the fluvial alluvium also changes.

Long-term operation of the reservoirs in Armenia has already led to a number of problems. After the collapse of the USSR, during the independence of the Republic of Armenia, there were very few repairs of the reservoirs, as a result of which:

- the water losses from the reservoirs have increased, because of failing to implement measures against water infiltration in the bottom of the reservoir, in the lateral parts of the reservoir basin;
- the stability of the reservoir dams needs to be re-examined and measures to be taken;
- changes in evaporation from the reservoir water surface also need to be studied, assessed and measures to be taken.

In addition, a growing number of scientific studies indicate that reservoirs, especially in the tropics, are a significant source of global greenhouse gas pollution. Greenhouse gases, primarily methane ($CH_4$) and carbon dioxide ($CO_2$), are emitted from all of the dozens of reservoirs where measurements have been made. Gases are emitted from the surface of the reservoir, at turbines and spillways, and for tens of kilometers downstream (Figure 26). Emissions are highest in hot climates. Hydro plants in the tropics with large reservoirs relative to their generating capacity can have a much greater impact on global warming than fossil fuel plants generating equivalent amounts of electricity.

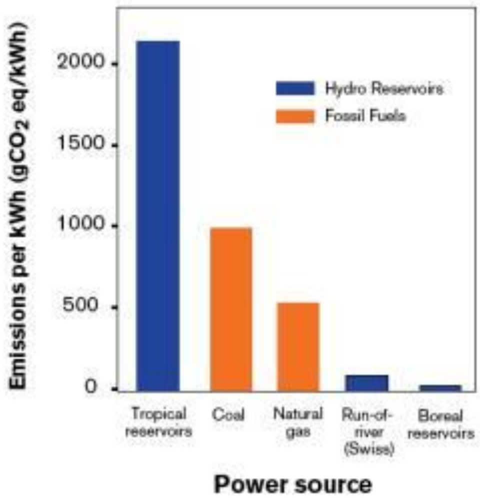



**Figure 26. Comparison of Reservoir Emissions with Fossil Fuels**[47]

The "fuel" for these emissions is the rotting of organic matter from the vegetation and soils flooded when the reservoir is first filled. The carbon in the plankton and plants that live and die in the reservoir, the detritus washed down from the watershed above, and the seasonal flooding of plants along the reservoir fringes, ensure that emissions continue for the lifetime of the reservoir. Emission levels vary widely between different reservoirs depending upon the area and type of ecosystems flooded, reservoir depth and shape, the local climate, and the way in which the dam is operated.

There is no, if any, studies to investigate the emissions from reservoirs in Armenia, as well as there isn't a methodology to conduct this type of analysis in the country.

#### 3.1.4.2 Review of the construction of water reservoir sector development strategy and adaptation plans in the context of climate change

The 2014-2025 long-term development strategic plan of the Republic of Armenia considers the reservoir construction as a component of community development and irrigation improvement, however, it does not assess the trends in climate change, hydrological conditions of the reservoirs (fullness of reservoir) conditioned by climate change.

For the reservoir construction development strategy in the context of climate change and for assessment of adaptation measures, the development strategy plans for the RA marzes for 2017-2025 have been analyzed (Annex 6).

The strategic plans for the development of Armavir, Aragatsotn, Lori, Kotayk, Gegharkunik, Syunik, Vayots Dzor and Tavush marzes for 2017-2025 do not provide for any activity for reservoir construction in terms of the implementation of climate change and adaptation measures.

The strategic plans for the development of Ararat and Shirak marzes for 2017-2025 only mention that construction of reservoirs is planned: the Vedi reservoir in Ararat marz and the Kaps reservoir

[47] https://www.internationalrivers.org/campaigns/reservoir-emissions?fbclid=IwAR1ixBV3nuDoxc9VmxZKTUOETEg4iYsY_HOGfXoDWma06I04pyNqYTZdsCE

in Shirak marz. However, the issue of potential vulnerability of water resources to climate change is not addressed in the preliminary assessment package of the reservoirs construction.

In the Government of Armenia's 10.07.2019 Decision N 900-N on Approval of 2020-2022 Medium-Term State Expenditure Program, irrigation is mentioned as one of the main targets of the sector policy. In the field of irrigation it is envisaged to carry out structural reforms that will reduce water losses, improve collection rates for irrigation water, and continuously implement the policy of replacing mechanical irrigation systems with gravity irrigation systems.

According to the Medium-Term Expenditure Program, during 2020-2022. works will be carried out for construction of Vedi, Kaps reservoirs and irrigation system To address the issues of strategic importance for water use and water management, the development of a regulatory and legal framework is necessary for the construction and operation of water reservoirs of local and national importance by private, public-private partnership  and ensuring their accessibility and publicity to potential investors (with regulations  for the possible locations of the reservoirs, their technical and economic description, conditions of construction and operation, their inclusion in the existing irrigation system, private (at approved tariffs) operation).

In 2018-2019, the RA Water Committee also initiated the construction of small reservoirs. A project for construction of 22 small-volume reservoirs has been developed. The total capacity of the reservoirs will be 127 million $m^3$ and the initial cost of the project – USD 220 million. The reservoirs will be located in different marzes: Gegharkunik, Shirak, Vayots Dzor, Aragatsotn, Armavir, Kotayk. The State Water Committee has set priorities for the construction of reservoirs, according to which the reservoirs will first of all be constructed in Martuni, Khndzoresk, Koghb, Vernashen and Hartavan.

The state expects private sector participation in the form of investments for the implementation of the mentioned reservoir construction project. By construction of a reservoir with investments, the private sector will also be allowed  to use it for commercial purposes, such as construction of a hydropower plant, fish farming, etc. As a result, many communities will have small water reservoirs through cooperation with private sector and the irrigation problems will be solved.

The draft government decision on approving the RA Reservoir Construction and Resource Management Concept and the Action Plan for the development of the RA Reservoir Construction and Resource Management is currently in circulation https://www.e-draft.am/projects/2042/about).

The component of water resource vulnerability and adaptation measures under climate change is indirectly included in this plan. The concept addresses the capacity and operating characteristics of the existing reservoirs, and the solution of the problem of reducing the deficit of water resources and their efficient use. It includes actions that imply vulnerability adaptation measures to climate change.

Those are:

- assessment of supply and demand of water for agricultural use;

- ways of solving the long-term problems of meeting the water demand of the Republic in the conditions of a possible water supply deficit, and assessing the water supply and demand;
- measures to prevent and mitigate harmful effects on water;
- creation of prerequisites for accumulation and storage of water reserves through construction of new reservoirs, improvement of the technical condition of existing reservoirs;
- measures for protection and increase of water resources, strategic water resources, usable water resources, classification of water systems, definition of criteria for determination of state-owned water systems and the list of those systems.

The above-mentioned climate change adaptation measures in the reservoir construction sector miss the actions of the assessment of microclimate change in the given region as a result of the construction of reservoirs, the prediction of its impact on environmental components and ecosystems.

Another draft government decision (https://www.e-draft.am/projects/2045/about) on approving the Concept of the development of the irrigation system of Armenia is also in circulation, which addresses the following measure:

- Creation of prerequisites for accumulation and storage of water reserves through construction of new reservoirs, improvement of the technical condition of existing reservoirs.

The concept mainly focuses on water saving, introduction of water circulation systems, efficient water use measures, as well as surface water management through the construction of reservoirs, including the construction of small and medium reservoirs. However, there are no actions in the solutions proposed in the Concept for the development of the reservoir construction sector, the assessment of the sector under climate change (for example the assessment of trends in changes in reservoir fullness).

Construction of new reservoirs is planned to improve water resource storage in the country. The 2017-2025 strategic programme envisages the investigation and construction of four new artificial reservoirs in Armenia.

There are a number of past and ongoing state and donor-funded programs and projects aimed to development agricultural sector in Armenia in order to decrease water losses and introduce water reuse systems. The list and a brief discussion of the conducted or on-going measures to climate change adaptation in this sector are provided in Annex 9.

## 3.2 ANALYSIS OF GENDER MAINSTREAMING

There are a number of climate change adaptation measures in water sector of Armenia, however few of them take an in-depth view on gender issues, inclusiveness and mainstreaming in the relevant sector. Although men and women both have water-related responsibilities, women are the major users of water in households, because they undertake the domestic activities that are linked with female gender roles. They are, therefore, severely affected by water restrictions (ADB, 2015). When there is no centralized water supply, women are also responsible for fetching water (ADB, 2015), which adds an extra burden to their workload. Moreover, women have greater responsibilities for domestic tasks and an increasing role in agriculture labor that disasters and water shortages make more difficult and time-consuming. Thus, women are acutely affected by limitations on household water, and projects to improve access to safe water have the potential to bring about time savings and reduced workloads for women.

Taking into consideration the above, it becomes apparent that gender integration across national policy processes is critical to ensure effective implementation of climate change adaptation measures. Human rights emphasize participation of concerned communities, non-discrimination and accountability as the backbone of guaranteeing human rights. These elements are useful in considering planning decisions at the national or local levels on adaptation measures. Applying the principle of non-discrimination in measures to address climate change requires specific attention to the groups who are normally the most affected, yet still neglected - the excluded and the marginalized.

In this section, a review and assessment of gender inclusiveness in country climate change adaptation planning in water sector is presented as well as the identification of the main challenges and needs for gender is done.

### 3.2.1 Gender inclusiveness and mainstreaming in climate change adaptation in water sector

As per UN definition "gender refers to the different roles, rights, and responsibilities of men and women and the relations between them. Gender does not simply refer to women or men, but to the way their qualities, behaviors, and identities are determined through the process of socialization".

The differences and inequalities between women and men influence how individuals respond to changes in water resources management. Understanding gender roles, relations, and inequalities can help explain the choices people make and their different options. Involving both women and men in integrated water resources initiatives can increase project/program effectiveness and efficiency[48].

For decades there has been growing awareness of the need to include all parts of a community in water resources adaptation and management, as well as sectorial water use (including water, sanitation, and hygiene programmes and initiatives), because if segments of the population are excluded, interventions are likely to fail.

[48] https://www.un.org/waterforlifedecade/gender.shtml

Gender mainstreaming is a comprehensive strategy aimed at achieving greater gender equality. This is possible through integrating a gender perspective into existing institutions, programs, activities or sectors.

*The objectives of mainstreaming gender issues are to:*

- Reduce gender inequities that may exist in a given area or sector.
- Encourage both men and women to jointly participate in finding solutions to their problems, ensure that their specific needs are satisfied and that they benefit from joint participation for positive impacts on their lives.
- Create conditions for men and women to have equal access to resources and benefits.
- Create conditions for equal participation in planning, implementation and decision making of identified joint endeavors and actions.

Ensuring that adaptation interventions take gender into consideration usually requires a deliberate strategy of gender mainstreaming. This strategy aims to embed the interests, needs and issues of men and women in the design, analysis, implementation, monitoring and evaluation of water projects[49].

**Criteria for gender assessment and mainstreaming in water management.** Based on the literature, it seems that there is an agreement that gender equality is a key factor to face climate change (Eakin, 2005; UNPD, 2016; Wong, 2016). From this perspective, UNFCC (2018) argues that "Successful action on climate change depends on the engagement of women as stakeholders and planners in ensuring that everyone has access to the resources they need to adapt to and mitigate climate change" (UNFCC,2018).

Desk review of international documents and other relevant sources shows that there are certain criteria for gender inclusiveness in water management.

Summing up those it can be concluded that that gender inclusive water management should indicate the following:

- Include both male and female perspectives and sex disaggregated data in situation analysis,
- Develop and apply gender-sensitive criteria and indicators,
- Include statistics on women as well as on men when collecting and presenting data,
- Capitalize on skills of both women and men,
- Set targets for women's involvement in activities,
- Prioritize women's equality, access to info, economic resources and education,
- Focus on gender differences in capabilities to cope with climate change adaptation and mitigation,
- Undertake a gender analysis of all budget lines and financial instruments.

[49] https://www.shareweb.ch/site/Water/resources/Documents/GenderWaterBrief_Draft.pdf

### 3.2.2 Assessment of gender inclusiveness and mainstreaming in water sector of Armenia

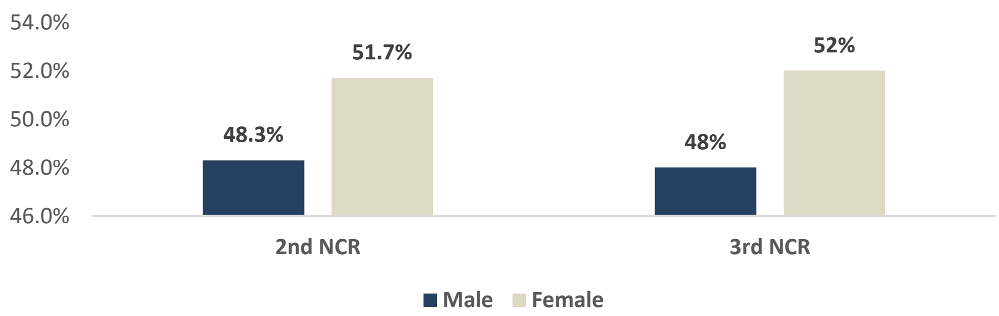
Desk review of relevant laws, legislative documents, national and international reports in Armenia has shown that gender inclusiveness is of little consideration in the relevant documentation, although gender issues are a crosscutting theme in climate change adaptation and water resources management sector in the country.

Of note, relevant laws and legislations of the RA do not include any gender related regulations and/or requirements for water management and climate change adaptation, except for RA Law on "National Water Policy Provisions" adopted in May 3, 2006[50], where in Chapter 1 article 7 "Principles of water resource management" it is stipulated that ***"transparent and participatory management of water resources and systems, as well as implementation of gender policy principles should be ensured".*** It, however, neither specifies the exact principles nor provides any reference on approaches and procedures in ensuring those.

The desk review of regional development strategies of RA marzes of 2017-2025 didn't show any strategic priorities in terms of gender inclusiveness in water management either, except for Tavush marz[51]. In the relevant strategy it is said that gender equality and mainstreaming in all priority sectors should be ensured.

The review of country's First, Second and Third national communication reports to UNFCCC revealed that these include vulnerability assessments along with preliminary adaptation priorities, nevertheless, the only gender related information is the disaggregation of RA population per sex.
**The First National Communication (1998)** doesn't include any gender related data, not even population's disaggregation per sex.

**The Second National Communication (2010)** presented gender disaggregation among the population and average life expectancy per sex as of 2006. In the report, gender needs and issues are not discussed with regards to climate change. Similar data is presented in **Third national communication report (2015)** as of 2012**.**




[50] https://www.arlis.am/DocumentView.aspx?DocID=1784
[51] http://www.mtad.am/files/docs/1780.pdf

Hence, the NC three reports lack gender analysis per water consumption and water management, as well as specific needs of women and men are not considered as a part of climate change adaptation.

***Araratyan, Southern, Akhuryan and Hrazdan river basin management*** plans (RBMP) (2016-2019) have been reviewed. As per desk review, the RBMPs contain only sex disaggregation of the population living in relevant areas.Gender needs and importance of gender inclusiveness are not considered in the plans and they don't reflect any gender specific information and data other than demographic data.

It is noteworthy that in relevant reports and assessments done by international organizations the importance of gender inclusiveness in climate change adaptation in water management is taken into account and emphasizes. In Gender Equality Strategy 2016-2020 of UNDP Armenia Country Office, Outcome 5 focuses on UNDP activities to help countries to rapidly and effectively recover from conflict-induced crises in cases where prevention has fallen short, and to deal with consequences of natural disasters. One of strategic point states that ***"UNDP finds important to support mainstreaming of gender equality in disaster and climate risk reduction policies and plans, as well as in the budgetary frameworks of key sectors (e.g., water, agriculture, energy, education). This includes supporting national capacities to collect, analyze and use sex and age-disaggregated data and analyze gender implications and risks".***

Another document, which is Adaptation Planning support for Armenia through UNDP Readiness proposal approved on 2 July 2018, emphasizes gender sensitive adaptation plans and mainstreaming, in particular gender-responsive CCA indicators and development of gender sensitive action plan, evaluation and monitoring system, etc. in water management sector as well[52]. This means that essential steps are being taken by the Government and international organizations towards elaborating measures to mainstream gender equality through integrating gender inclusiveness and mainstreaming in further CCA Plans for Armenia.

The review of Armenia Country gender assessment conducted by Asian Development Bank in December 2019[53] revealed that in rural areas, men are more likely to assume tasks using machinery and technology, leaving more time-consuming manual labor such as fetching water to women. In the same assessment it is mentioned that due to the increasing migration of male family members, women are assuming a greater workload for agriculture production as the sector becomes more prone to disaster risks, putting women at the forefront of dealing with disaster impacts on agriculture production. For example, lack of irrigation water can significantly add to women's chores in collecting and storing water and manually watering vegetable gardens and other crops. These findings once more emphasize the importance of gender mainstreaming in climate change adaptation in water management.

As women are key users of water for fields and domestic use, so they should be involved in designing improvements in water management. However as seen in several reports, they don't have enough engagement in water management. Desk review of a **Household Study on Water Utilization**

[52] https://www.greenclimate.fund/document/adaptation-planning-support-armenia-through-undp

[53] https://www.adb.org/sites/default/files/institutional-document/546716/armenia-country-gender-assessment-2019.pdf

**in the Ararat Valley**[54] conducted in 2017 revealed that most of local residents in Ararat Valley (96% and more) are not actively involved in water resource management processes, nor they have received information/trainings. However, the level of participation in trainings is slightly higher among men (**5.6%** vs. **3.1%** among women)

To the question whether respondents will participate in discussions in their community related to drinking or irrigation water if such discussions are held by the bodies responsible for water sector, men showed higher interest **(80%)** than women **(61%).** As explained in the report this can be conditioned with cultural norms.

**Summarizing the findings of desk review,** we can conclude that there are some gaps with regards to gender analysis and inclusiveness in climate change adaptation in water sector. Noteworthy, in majority of reviewed documents only sex disaggregation per locations was provided, however there was no focus on specific needs of men and women and water usage requirements. Despite the fact that women are the main consumers of water, they have quite a low level of participation and involvement in water management processes. Moreover, relevant programs/projects/intervention do not have gender sensitive monitoring and evaluation systems. Hence we find it extremely important to consider their needs while elaborating climate change adaptation plans and increase the level of their participation in relevant processes.

## 3.3 NATIONAL ADAPTATION PLANNING ACCORDING TO IMPLEMENTATION OF INTERNATIONAL OBLIGATIONS

In this section, a review of international obligations by country address to climate change adaptation planning in water sector is presented as well as the identification of the main challenges and needs is done.

### 3.3.1 EU-Armenia Comprehensive and Enhanced Partnership Agreement (CEPA)

On November 24, 2017 the European Union and Armenia signed an agreement aimed at significantly deepening their relations at a ceremony in Brussels on Friday held on the sidelines of the Eastern Partnership Summit.

[54] Participatory Utilization and Resource Efficiency of Water activity (PURE-Water Activity) funded by the United States Agency for International Development (USAID), the Urban Foundation for Sustainable Development (UFSD)

Signatures to the document entitled the Comprehensive and Enhanced Partnership Agreement (CEPA) were put by High Representative of the European Union for Foreign Affairs and Security Policy Federica Mogherini and Armenia's Foreign Minister Edward Nalbandian.

With new agreement, among other things, Armenia will take obligations to approximate its legislation to the EU acts and international instruments. In the field of water quality and resources management, this approximation will include 5 Directives: Water Framework Directive, Floods Directive, Urban Wastewater Directive, Drinking Water Directive and Nitrates Directive; in addition, Armenia will take obligations to implement measures resulting from multilateral environmental agreements, including UNFCCC and Paris agreement. This cooperation will promote climate change mitigation and adaptation measures at local, regional and international levels, guide the involvement of climate issues in general and sector policies and create market and non-market mechanisms for facing climate change.

Implementation of the agreement will be a new impetus for the development of clean energy sources. It will also raise the supply security level and reduce the dependence on energy import.

EU-Armenia CEPA road map (2018). The document is a joint action plan for CEPA signed between the EU and the RA. It is aimed at environment quality assurance, protection, improvement and rehabilitation, human health protection, sustainable use of natural resources and promotion of measures for solution of regional and global environmental problems at international level.

EU Water Initiative Plus (EUWI+) Project is being implemented within the frames of CEPA agreement. The main aims of that project are:

- Support to further reforms of water policies, establishment of an adequate governance framework, and development of institutional capacities in support of policy implementation.
- Support the transition from pilot basin to country scale timely implementation of EU Water Framework Directive (WFD) principles for integrated water resources management and River Basin Management Plan harmonisation in transboundary basins.
- Strengthening of the monitoring of the water bodies status and upgrade needed infrastructure and quality management.
- Institutional capacity building to insure sustainable results.

As we can see from the ambitions of the EUWI+ project, there is a strong link to the climate change adaptation questions in the water sector.

### 3.3.2 Treaty on on the Accession of the Republic of Armenia to the Treaty on the Eurasian Economic Union of May 29, 2014 (2015)

With this treaty, Armenia joined the 29 May 2017 Treaty on the Eurasian Economic Union, as well as other international treaties concluded within the framework of the legal-contractual basis of the Customs Union and the Common Economic Area and forming part of the law of the Eurasian

Economic Union and has become a member of Eurasian Economic Union since the date of entry into force of this Treaty.

In 2017 the regional project on “Regulatory Framework to Promote Energy Efficiency in Countries of the Eurasian Economic Union” was launched. The goal of the project is promoting application of energy efficiency technologies through developing and introducing ES requirements, aimed at reduction of enegy consumption and greenhouse gas emissions in the countries of the Eurasian Economic Union.

In 2017, “Regulatory Framework to Promote EE in EAEU Countries” regional project has started The overarching goal of this project is to reduce emissions of greenhouse gases (GHG) by promoting energy efficiency (EE) in the countries of the Eurasian Economic Union (EEU), namely Armenia, Kyrgyzstan, Kazakhstan and Belarus, via strengthening the national systems for appliances EE standards. The project also will facilitate harmonization of test procedures, standards and labels among EEU countries, when appropriate. The project is expected to cost-effectively deliver an average reduction of 78 billion kWh energy consumption in the residential and commercial energy use in partner countries, resulting in average of 43 million ton of $CO_2$ equivalent GHG emissions reduction in total at the time of peak impact by the year 2030 compared to a baseline scenario. As it is stated in the project document, the introduction of energy efficiency standards will contribute to the common market development, attraction of investment and achievement of the ultimate goal – reduction of greenhouse gas emissions. The project thereby will contribute also to more environmentally sustainable and economically efficient development. The project will focus largely on capacity building and assisting governments, standardization institutions, manufacturing, distributing, retail, consumer and environmental stakeholders throughout the EEU region to implement the most cost-effective energy efficiency measure available.

Social and environmental risk screening were conducted in the preparational stage of the project, the results are presented in the project document. Especially, following possible climate change and water-related risks were discussed:

| Question | Answer |
|---|---|
| Does the Project involve significant extraction, diversion or containment of surface or ground water (f*or example, construction of dams, reservoirs, river basin developments, groundwater extraction)*? | No |
| Does the Project include activities that require significant consumption of raw materials, energy, and/or water? | No |
| Would the Project potentially cause adverse impacts to habitats (e.g. modified, natural, and critical habitats) and/or ecosystems and ecosystem services (*for example, through habitat loss, conversion or degradation, fragmentation, hydrological changes)*? | No |
| Will the proposed Project result in significantgreenhouse gas emissions or may exacerbate climate change? | No |
| Would the potential outcomes of the Project be sensitive or vulnerable to potential impacts of climate change? | No |
| Is the proposed Project likely to directly or indirectly increase social and environmental vulnerability to climate change now or in the future (also known as maladaptive practices (for example, changes to land use planning may encourage further development of | No |

| Question | Answer |
|---|---|
| floodplains, potentially increasing the population's vulnerability to climate change, specifically flooding))? | |

### 3.3.3 Priveleges and Immunities Agreement between Green Climate Fund (GCF) and Government of the Reublic of Armenia (2016)

Armenia's acting minister of nature protection Erik Grigoryan and Executive Director ad interim of the Green Climate Fund Javier Manzanares signed the bilateral Main agreement between the Republic of Armenia and the GCF in the Polish city of Katowice on December 11, during the 24th Conference of the Parties to the Framework Convention on Climate Change. The agreement will ensure the actions being carried out in Armenia under the Fund.

The Green Climate Fund (GCF) is the world's largest dedicated fund helping developing countries reduce their greenhouse gas emissions and enhance their ability to respond to climate change. It was set up by the United Nations Framework Convention on Climate Change (UNFCCC) in 2010. GCF has a crucial role in serving the Paris Agreement, supporting the goal of keeping average global temperature rise well below 2 degrees C. It does this by channelling climate finance to developing countries, which have joined other nations in committing to climate action.

Responding to the climate challenge requires collective action from all countries, including by both public and private sectors. Among these concerted efforts, advanced economies have agreed to jointly mobilize significant financial resources.

GCF launched its initial resource mobilisation in 2014, and rapidly gathered pledges worth USD 10.3 billion. These funds come mainly from developed countries, but also from some developing countries, regions, and one city. Coming from a variety of sources, these resources address the pressing mitigation and adaptation needs of developing countries.

Currently, three projects or programmes are being implemented by the Green Climate Fund financing in Armenia.However, none of them is focused on the climate change adaptation in the water sector.

***De-Risking and Scaling-up Investment in Energy Efficient Building Retrofits***

This project (started in 2017) will build the market for EE building retrofits in Armenia, leading to sizeable energy savings and GHG emission reductions (up to 5.8 million tCO2 of direct and indirect emission savings over the 20-year equipment lifetimes), green job creation and energy poverty reduction. It will directly benefit over 200,000 people and will catalyse private and public sector investment of approximately USD 100 million.

GCF will invest a USD 14M loan to make EE loans for building retrofits more affordable. The Municipality of Yerevan will add USD 8M in co-financing. In addition, GCF will provide USD 6M in technical assistance to remove market and policy barriers to building retrofits, with UNDP providing

USD 1.4M and the Ministry of Nature Protection USD 0.4M co-funding. The technical assistance will seek to overcome lack of information and awareness about the benefits of retrofitting through the establishment of measurement, reporting and verification measures, the development of policy frameworks. The cost-effective combination of policy and financial de-risking instruments and targeted financial incentives will address market barriers and achieve a risk-return profile for EE building retrofits that can attract private investments.

The project has an estimated lifespan of 20 years.

***GCF-EBRD Sustainable Energy Financing Facilities (SEFF) Co-financing Programme***

EBRD and GCF co-financed programme to deliver climate finance to the private sector at scale through Partner Financial Institutions across 10 countries.

This programme will deliver climate finance at scale via Partner Financial Institutions (PFIs) in developing countries, which will fund over 20,000 scalable and replicable projects across industrial, commercial, residential, transport and agricultural sectors.

Sustainable Energy Financing Facilities is an on-lending programme that will provide credit lines to PFIs with the aim to create self-sustaining markets in the areas of energy efficiency, renewable energy and climate resilience.

The PFIs in the Programme will on-lend the funds to the borrowers such as MSMEs, special purpose companies and households for energy efficiency, renewable energy and climate resilience projects. Financing activities will be complemented by the provision of technical assistance (TA), both to the local PFIs and to the borrowers. This component will include capacity building of local PFIs and micro-, small- and medium-sized enterprises, project assessment and monitoring, and gender mainstreaming activities.

The programme has an estimated lifespan of 15 years.

***Green Cities Facility***

The goal of this project is enabling the transition of cities to low-carbon, climate-resilient urban development.

Green Cities minimise environmental impact and maximise opportunities to improve and support the natural environment. Green Cities are energy efficient and reduce reliance on non-renewable energy sources, actively encourage waste reduction and management, include green and resilient infrastructure, low carbon transport, water cycle management and deliver improved quality of life outcomes for residents.

Under this project, 10 cities which have higher than average energy and carbon density, and are facing a range of environmental and social issues, will have access to a Green Cities Facility. The Facility will help address the cities' climate change challenges while building the market case for private sector investments in sustainable infrastructure. It will provide concessional financial instruments that will allow ambitious investments in climate-resilient urban infrastructure such as district heating/cooling, low-carbon buildings, and solid waste management.

The project has an estimated lifespan of 23 years.

### 3.3.4 Nationally Determined Contributions (NDC) Partnership (2018)

Armenia joins partnership in August, 2018. The purpose of the Partnership is to support the development and effective implementation of national-level investments approved by the RA. Armenia's NDC is based upon the principles of equity (taking into account the rights of present and future generations to use resources) as well as the Green Economy (planning its NDC in line with social and economic development goals). Armenia seeks to apply an ecosystem-based approach to mitigation and adaptation actions, with a preference to balanced and combined actions. With the support of the NDC Partnership, Armenia is developing a Partnership Plan to update and achieve its NDC.

Armenia has stated that its total aggregate emissions between 2015 and 2050 will be "equal to 633 million tons carbon dioxide equivalent", and that the country will strive to "achieve ecosystem neutral GHG emissions in 2050 (equivalent to 2.07 tons/per capita per annum) with the support of adequate (necessary and sufficient) international financial, technological and capacity building assistance."

Identified sectors for mitigation action are: Energy (including renewable energy and energy efficiency); Transport (including development of electrical transport); Urban development (including buildings and construction); Industrial processes (construction materials and chemical production); Waste management (solid waste, waste water, agricultural waste); and Land use and Forestry (afforestation, forest protection, carbon storage in soil). Sectors for adaptation action are not yet identified[55].

### 3.3.5 Sustainable Development Goals (SDGs) in Armenia

On 1 January, 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development—adopted by world leaders in September 2015 at an historic UN Summit - officially came into force. Over the next fifteen years, with these new Goals that universally apply to all, countries will mobilize efforts to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind.

The SDGs build on the success of the Millennium Development Goals (MDGs) and aim to go further to end all forms of poverty. The new Goals are unique in that they call for action by all countries, poor, rich and middle-income to promote prosperity while protecting the planet. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and addresses

[55] https://ndcpartnership.org/countries-map/country?iso=ARM

a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection.

While the SDGs are not legally binding, governments are expected to take ownership and establish national frameworks for the achievement of the 17 Goals. Countries have the primary responsibility for follow-up and review of the progress made in implementing the Goals, which will require quality, accessible and timely data collection. Regional follow-up and review will be based on national-level analyses and contribute to follow-up and review at the global level.

At the global level, the 17 SDGs with 169 targets will be monitored using a set of 230 global indicators.

On November 2017, the Government of Armenia and the United Nations have set up the world’s first National SDG Innovation Lab to accelerate the achievement of the Sustainable Development Goals (SDGs) in Armenia. For the first time, the state, in cooperation with the United Nations, is creating an innovation platform to support the UN SDGs implementation at country level. To do so, the Lab will draw upon innovative methodologies and expertise available from across the world, including the UN’s own innovation facilities and tools.

In July of 2018, UN in Armenia prepared voluntary national review (VNR) on SDG implementation that has been presented at High-level Political Forum 2018 in New York. The VNR is important both as a participatoryprocess itself and as a measurement of the progresstowards achieving SDGs. The aim of VNR was to assess work done in the scope of theSDGs and shape opportunities for future innovative and impactful solutions.

The main SDGs related to the climate change adaptation in the water sector are SDG 6 – Clean Water and Sanitation, and SDG 13 –Urgent Action to Combat Climate Change and its Impacts.

In the section related to the **SDG 6**, the information about the progress, challenges, and opportunities and priority actions in drinking water and sanitation in Armenia are presented.

***Progress***

In 2017, to improve the water management in the country, Armenia prepared and published its first SatelliteWater Account System which provides a comprehensive data and picture of water resources and the use of the existing resources. It is an important instrument that will contribute to enhancing the effectiveness of water monitoring and planning.

*Drinking water and sanitation (SDG targets 6.1 and 6.2)*

Armenia has improved its drinking water supply significantly in both urban and rural areas. In effect, almost all urban (100%) and majority (94%)[56] of rural communities have access to safe drinking

[56] Social Snapshot and Poverty in Armenia, SCA 2017

water. There has been good progress also in ensuring access to improved sanitation in urban areas, with over 96 percent of urban population having access to safely managed sanitation services.

*Water quality improvement and wastewater treatment (SDG target 6.3)*

Since 2012, Armenia considerably enhanced its wastewater treatment capacities by building three new sewer treatment plants in regions and rehabilitating two existing plants[57]. The country-wide proportion of safely treated wastewater increased to more than 85%. This level is higher in the capital where 97% of wastewater is safely treated.

*Water use efficiency (SDG target 6.4)*

There has been notable improvement in terms of the water-use efficiency across all sectors, though overall it still remains high. The freshwater withdrawal as a proportion of available freshwater resources reduced from 50.8% in 2015 to 44.9% in 2016.

*Integrated water resources management (SDG 6.5)*

Proportion of transboundary basin area with an operational arrangement for water cooperation was around 90%, which was constantly maintained during the 2015 and 2016.

***Challenges***

*Sanitation (SDG target 6.2)*

Overall, 23.4% of population has no access to improved sanitation services. This is a challenge to be addressed in rural areas of Armenia. There is unequal access to sanitation between urban and rural population. The gap between urban and rural population with access to safely managed sanitation services was 47.5%.

*Water use efficiency (SDG target 6.4)*

Despite the reduction of water withdrawal, Armenia still remains a water-stressed country[58]. The largest share of water withdrawal is attributed to agriculture. Agricultural water withdrawal comprises more than 90% of total water withdrawal in the country[59].

Due to various inefficiencies in the irrigation infrastructure as well as in the management of the irrigation water, water losses in the irrigation system were significant. More than half of irrigation water is lost and does not reach the farmer and the field (irrigation water loss was 59% in 2012). The challenge of water use efficiency is related also to aquaculture - one of the dynamically developing

[57] Source: http://www.armwater.am/am/main-activities.html
[58] Countries could be defined as water-stressed if they withdraw more than 25 percent of their renewable freshwater resources, as approaching physical water scarcity when more than 60 percent is withdrawn, and as facing severe physical water scarcity when more than 75 percent is withdrawn. http://www.fao.org/nr/water/aquastat/didyouknow/index2.stm
[59] Source: FAO AQUASTAT: http://www.fao.org/nr/water/aquastat/data/query/results.html

and export-oriented sectors in Armenia – which, however, exploits significant amounts of underground water resources. Most of the fish farms in the country (which are located in Ararat valley) still use precious underground water with a single-pass system, where water is not recycled and is used only once. Aquaculture facilities consume precious clean water, and often there is competition and even conflict for water between aquaculture, agriculture and rural communities.

There are 579 communities (of which two communities are urban, and the rest are villages) with 680,000 population, where water supply is provided by the municipality, not by a water operator(s). In these communities, data for water consumption does not exist, as there is no metering of water use.

***Opportunities and Priority Actions***

Efficient water technologies and innovation: Armenia has made significant investments to improve the irrigation system, including a number of large-scale projects with the support of international financial institutions, such as the World Bank, and the donor community. Certainly, the improvement of physical infrastructures should be continued to reduce water losses in the system itself. To further address and effectively tackling this challenge, however, it is vital to raise awareness about and promote wider use of efficient water technologies and practices such as drip irrigation in crop production, and water recycling technologies in aquaculture. The promotion of such technologies requires and also provides opportunities for multi-stakeholder cooperation and public-private partnership. Innovative approaches should be encouraged through policy incentives.

The Government's leasing program in agriculture to promote the investment by farmers in advanced and sustainable technologies and machinery has been successful so far and could be continued with higher emphasis on sustainable practices.

Water monitoring: Proper water management require improving the water monitoring system with the use of advanced technologies such as K-Water's Smart Water Management Initiative which is an integrated management model covering the entire water cycle. Global initiatives such as the UN-Water Integrated Monitoring Initiative for SDG 6 can effectively support the efforts to enhance the water monitoring. The UN-Water SDG 6 Synthesis report 2018 on Water Sanitation, which will be launched during the High-level Political Forum on Sustainable Development, would be very helpful in identifying priorities for action and possible solutions.

Water knowledge and skills: Education, training and awareness raising about water efficiency, freshwater ecosystems and ambient water quality among all participants and stakeholders play an important role in aching SDG 6.

Integration approach: Water is a vital factor for many aspects of economy and human life, and, thus, SDG 6 is inter-linked with many other SDGs such as agricultural production, a major source of human livelihood (SDG 2), energy production (SDG 7), sustainable cities and communities (SDG 11), sustainable production and consumption (SDG 12), life on earth (SDG 15), and life below water (SDG 14). Thus, an integrated approach is necessary to achieve effective synergies and avoid conflict between SDGs and various stakeholders such as agriculture, industry, cities, human consumption, aquaculture. In this context multi-stakeholder participatory approach and partnerships is a must for building.

In the section related to the **SDG 13**, current and projected climate conditions, as well as hydrometeorological hazards intensity and frequency are analyzed.

It is mentioned, that climate change is expected to amplify the frequency and intensity of meteorological hazards in Armenia. Two scenarios for future climate change projections for temperature have been developed up until 2100. Average annual temperature increase projections in the territory of Armenia related to the 1961-1990 average show that, in a first scenario, the temperature will increase by 1.7°C in 2040, by 3.2°C in 2070, and by 4.7°C in 2100. In a second scenario, the temperature will increase by 1.3°C, 2.6°C, and 3.3°C respectively. The precipitation is predicted to decrease by 10% by 2100. Due attention shall be given to protecting children from possible negative effects of climate change, environmental degradation threaten children's wellbeing and ensuring access to clean, affordable energy (CEE). Many children in Armenia are exposed to CEE conditions that impact their basic rights to safe, nutritious and sufficient food, a clean and healthy living environment, care and protection, and quality education, all of which undermine Armenia's progress towards meeting national development ambitions and the SDG's.

Armenia has undertaken significant comprehensive measures to establish legal and institutional frameworks necessary for adaptation to climate change as well as to reduction of natural disaster risks. Armenia ratified the UN Framework Convention on Climate Change (UNFCCC) as a non-Annex I country in 1993, UNFCCC Kyoto Protocol - in 2002, Doha Amendment of Kyoto Protocol and Paris Agreement in 2017. The current national program for Intended Nationally Determined Contributions (INDC) under the UNFCCC was adopted in 2015. It is an integrated strategy aimed at ensuring effective adaptation to the adverse impacts of climate change and fostering climate resilience and low greenhouse gas emissions in a manner that does not threaten food production. Armenia issued three National Communications on Climate Change (in 1998, 2010, and 2015), and Biennial Update Reports on UNFCCC in 2016 and 2018.

To coordinate climate change activities, the Intergovernmental Council on Climate Change was established in 2012. The Council, with its working groups establishes a consistent process for coordination of climate change policy, enhances cooperation at the international and regional levels, as well as professional training and education on climate change-related issues. Armenia adopted national disaster risk management strategy in line with the Sendai Framework for Disaster Risk Reduction 2015-2030. The strategy sets seven broad objectives, including: (i) reduction of deaths from disasters; (ii) reduction of the number of people suffered from disasters; (iii) reduction of economic damages from disasters; (iv) reduction of the effects of disasters on essential infrastructures and services including health and educational institutions; (v) development of local disaster risk management strategies; (vi) international cooperation; (vii) enhancement of early warning systems. The number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population affected by natural disasters in 2015 and 2016 was 43.5 and 77, respectively.

As part of the localization of the SDGs, the NAP process will contribute to the formulation of corresponding national climate-responsive indicators and targets[60].

For the several SDG there is an aligned climate target, action, policy measure or need in the Nationally Determined Contributions (NDC). This alignment was identified based only on the information communicated in the NDC, not the domestic policy context. It is therefore only an entry point for considering the degree of potential alignment between the country's climate and sustainable development objectives.

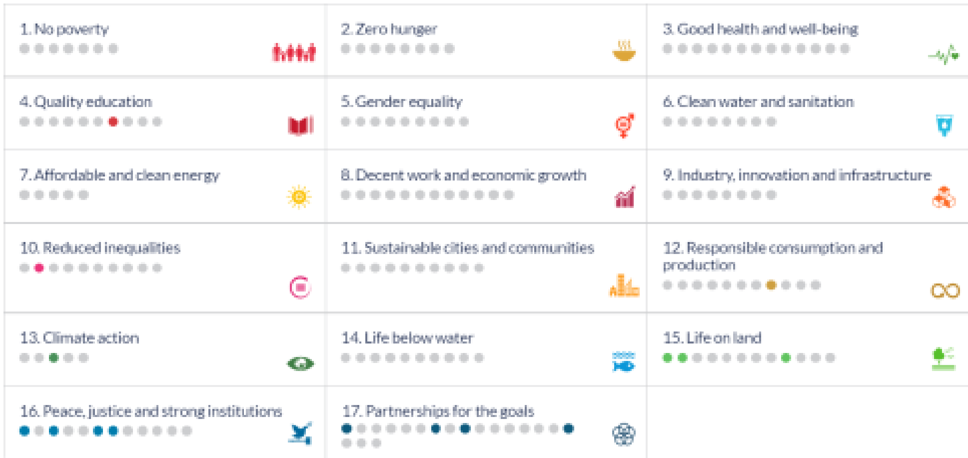



**Figure 27. NDC-SDG Linkages**

As can be seen from the figure above, there no aligned climate target, action, policy measure or in the NDC for SDG 6 – Clean Water and Sanitation.

There is a linkage between SDG 13 (Climate Action), Target 13.3 (climate change mitigation, adaptation, impact reduction, and early warning) and Protocol Decision No 41, 10 September, 2015 of Government of the Republic of Armenia – "Intended Nationally Determined Contribution of the Republic of Armenia under the UN Climate Change Framework Convention" (Annex 4).

## 3.4. DISCUSSION OF DEFICIENCIES IN PLANNING AND ACHIEVEMENTS IN CLIMATE CHANGE ADAPTATION PROGRAMS

This section is dedicated to the gaps and barriers revealed during the technical analysis of existing water use sub-sector strategies, water sector development plans and climate change adaptation measures. The water use sub-sector national and international strategies were detailed discussed in the previous sections 3.1, 3.2 and 3.3.

### 3.4.1 Agriculture

Although, as mentioned in section 3.1.1, various water-saving measures, such as the installation of drip irrigation systems and secondary use of water, are supported by the newly developed concepts

[60] https://www.adaptation-undp.org/projects/NAP-armenia

and a national strategy for agriculture sector development, however the climate change impact on water resources still does not in the course.

In addition, the national strategy for the development of the agricultural sector practically does not take into account the impact of climate change on water resources in planning long-term activities.

Based on the in-depth analyses of the agricultural sector development strategy provided in section 3.1, a number of gaps and deficiencies in planning and achievements in climate change adaptation programs were revealed.

The main gaps in this sector under climate change are as follows:

- The measures listed in the sector development strategy and concepts are dedicated to mitigating the water stress in the country, rather than adaptation measures. Thus they do not consider the water availability changes due to the climate change impact in the long-term period.
- The national strategy and concepts for the development of the sector implies improving water supply systems and reducing the volume of water losses, however, in the measures and planning activities the potential changes in the irrigation lands and irrigation water norms do not consider in order to be able to reliably estimate the irrigation water demand and its possible change in the nearby future.
- In the Development Strategies for Marzes, it is slightly mentioned that the reduction of precipitation and river flow and increase in natural disasters due to climate change will be lead huge impact on the agricultural sector. However, in-depth assessments on potential changes in hydrometeorological phenomena, water balance, water supply and demand due to climate change impacts should be conducted and considered during the development of adaptation programs on Marz level.
- A strategic plan and concept on fish breeding sector development in the republic have not been developed yet. The only project is the "Lake Sevan Trout Reserve Development and Fish breeding Development Program". However, the program does not address the vulnerability of Lake Sevan to climate change and no adaptation measures are foreseen.
- The vulnerability of groundwater resources to climate change has not been assessed in the Republic. Based on this gap, it is not possible to predict trends in the volumes of water use from groundwater sources in fish farming and irrigation due to climate change.
- During the permitting of the long-term use of surface water resources for fish farming and irrigation, the potential vulnerability of river flow due to climate change does not consider which will create risks for the effective development of the agricultural sector.

At the same time, it should be noted that the vulnerability of river flow to climate change in the short term is not immediately apparent (hydrological cycles can be expressed over a couple of years, that is, the hydrological state of the river with respect to the long-term average value and, possibly, the maximum or minimum annual flow), so it is difficult to take into account the impact of climate change when granting short-term water use permits for irrigation and fish farming.

### 3.4.2 Drinking water supply and sanitation

Drinking water supply and sanitation is one of the most vulnerable and important sectors in the Republic. Although a lot of investments and structural changes were conducted to improve this sector, nowadays, a number of gaps and deficiencies in sector development strategies and planning of the measures revealed in the context of climate change.

The key of them are listed below:

- The "Water Supply and Sanitation Strategy and Financing Plan for 2018-2030" of the Republic are based on the studies carried out in 2014 and does not include the farther assessments of water resources changes provided in the National Communications and river basin management plans. In addition, this main strategy document does not consider the expected changes in the RA water balance by 2030 due to climate change, the water supply and demand by regions dependent on that, the change in the water balance of the Republic, as well as the decreasing trend of water yield of water sources due to climate changes.
- While in all regional programs and Marzes development strategies mentioned that the improvement of the water supply and sanitation sector is a priority, nevertheless there are a few if any, measures conducted or developed to treat the household wastewater and re-use the treated one in other sectors. The sector development strategies and concepts do not set the privileges and mechanisms for the self-supply communities to promote the establishment a local wastewater treatment plant and secondary use of treated household wastewater.
- Even in several Development Strategies for Marzes it is mentioned that the changes in climatic conditions made impact on drinking water sources; however, there is no assessment to understand the water capability of the water sources and the trend of changes during a short-term and long-term period. In-depth assessments on potential changes in hydrometeorological phenomena, water balance, water supply and demand due to climate change impacts should be conducted and considered during the development of adaptation programs on Marz level.

### 3.4.3 Hydropower generation

As mentioned in the section 3.1.3, although hydropower, being renewable and green source of energy, contributes to the reduction of $CO_2$ emissions, HPPs also have negative impacts on the river aquatic ecosystem. The main negative impact is the disturbance of environmental flow in the certain part of the river that lead to the deterioration of aquatic ecosystem and biodiversity. Obviously, with the projected reduction of the river flow due to the climate change, this problem becomes more complicated.

However, currently, water use permits for HPP exploitation are given for up to 25 years.

The issues related to the hydroenergy sector vulnerability, also the negative impacts of the HPPs on river ecosystems that may become more severe with the projected reduction of the river flow are generally discussed in some of strategic documents analysed in the section 3.1.3.2. The importance of hydropower potential vulnerability assessments and adaptation measures development, however, are not well formulated or not presented at all. In particular:

- The Protocol Resolution № 8 as of 01.03.2018 "On Approval of Environmental Impact Assessment Criteria for the Construction and Operation of Small Hydro Power Plants" highlights the necessity of establishment of criteria for the construction and operation of SHPPs in order to ensure the sustainability of river ecosystems. However, the importance of the vulnerability assessment of the river flow due to the climate change in short-term, mid-term, and long-term perspectives is not listed among those criteria.
- In the Small Hydropower Plants Development Scheme (2010), hydroenergy indicators for more than 100 HPPs have been analysed, however, issues related to the projected river flow reduction also not covered. For two of those 100 HPPs – Shnogh and Meghri, there are also investment pre-feasibility studies were conducted. In those studies, climate change adaptation issues have also not been discussed.
- In the Development Strategies for Marzes it is briefly discussed that the reduction of river flow due to the climate change will also reduce the hydropower potential of the rivers. However, more specific assessments should be conducted and adaptation programs on Marz level should be developed.

### 3.4.4 Constrtuction of water reservoirs

From the point of view of accumulation and utilization of water, the reservoirs, as artificial water bodies, are complex hydrotechnical structures, and climate change needs to be taken into account for the management of these accumulated water volumes.

Below are identified gaps in the sector development strategies and concept for construction of reservoirs that need to be addressed:

- As in the design of previously constructed reservoirs, nowadays, only the hydrological elements of the river flow, including the fluvial alluvium (hard flow) are calculated in the technical and economic documents to design and construction of the reservoir. The adopted sector development strategy does not take into account short and long-term trends in river flow and accumulation of the fluvial alluvium (determine the dead volume of the reservoir) due to climate change.
- The national development strategy and concepts for construction of water reservoirs in the country do not address the evaporation range at the water surface and its further trend under climate change, thus, the future economic benefits of reservoirs are not considered, as well.
- Although the regional programs and Marzes development strategies mention the high importance of the construction of the reservoir to develop the agriculture sector, nevertheless, they do not assess and forecast the potential changes in microclimate and its impact on the environment and biodiversity in the area of reservoir construction.
- The 2014-2025 long-term development strategic plan of the Republic of Armenia considers the reservoir construction as a component of community development and irrigation improvement, however, the document does not consider the amount of greenhouse gases

emissions and alluvium from reservoirs. The strategic plan does not regulate the development of methodology and principles to calculate the emissions of greenhouse gases during the operation of the reservoirs.

## Conclusion of Chapter 3

Since 2015, a number of strategies, regulations, concepts have been drafted to improve and developed water use sub-sectors, as well as several measures, funded by the Government or international donors, have been undertaken aimed to adapted water resources to climate change.

Based on the review of existing water use sub-sector strategies and climate change adaptation measures in water sector implemented since 2015, as well as identification of synergies between development and adaptation objectives, gender exclusiveness, policies, plans, programs, including international obligations, it was revealed several gaps, deficiencies and barriers in terms of implementation of the adaptation measures in Armenia.

The analysis shows that while several internationally funded projects, implemented in the water sector of Armenia promote adaptation to climate change (through reduction of water losses, regulation of river flow, improvement water quality and increasing water availability, improvement of water management at national and river basin levels, etc.), there is insufficient level of integration of climate change adaptation into the development planning process of Armenia, and particularly in the existing water use sub-sector strategies. It has been shown that only a few relevant documents (water use sector development strategies and concepts) slightly examine the impact of climate change on water resources, however, they do not take into account the increase in water demand and vulnerability to water resources in terms of predicted climate change.

The practical recommendations and activities are provided and discussed in Chapter 4.3 of this report, in order to overcome the revealed deficiencies and barriers in the planning and implementation of adaptation measures for each water use sector (agriculture, drinking water supply and sanitation, hydropower generation, construction of water reservoirs).

# CHAPTER 4. RECOMMENDATIONS TO OVERCOME THE BARRIERS IN CONSIDERATION OF CLIMATE CHANGE COMPONENT IN WATER RESOURCES MANAGEMENT

## Summary of Chapter 4

This chapter is prepared based on identified gaps and barriers in water legislation and institutional framework, data and methodologies used for water resources vulnerability assessment and prediction, as well as observed deficiencies in strategies of water use sector development and planning of adaptation measures in the context of climate change.

This section provides practical recommendations and proposed activities to overcome the identified gaps and barriers in the water resources vulnerability assessment within the climate change and integration of climate change adaptation into development planning process of water sector, in particular, related to:

- Recommendations to improve the legal and institutional framework of water resources management in the context of climate change.
- Recommendations to overcome the gaps and barriers to an assessment of water vulnerability under climate change.
- Recommendations to overcome the deficiencies in planning and gender mainstreaming in climate change adaptation programs.
- Recommendations on the modernization of the hydrometeorological observation system and services.

The practical recommendations are developed following the best international practice applied for similar socio-economic and geographical areas as Armenia. The good practices of the Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine have been applied to analyse and provide practical recommendations for improving the hydrometeorological service in Armenia in the context of use/sharing of data on assessing the vulnerability of water resources to climate change.

The section also includes detailed information on proposed strategic approaches in adaptation planning and goals, brief description of proposed activities and responsible water state organizations, basic needs for implementation of each activitiy, as well as expected outcomes and results of the activity.

## 4.1. RECOMMENDATIONS TO IMPROVE THE LEGAL AND INSTITUTIONAL FRAMEWORK OF WATER RESOURCES MANAGEMENT IN THE CONTEXT OF CLIMATE CHANGE

As a result of legal and institutional analysis of water resources vulnerability and adaptation to climate change carried out within the project on "Assessment of Water Sector Vulnerability to Climate Change and Climate Change Adaptation Planning in Armenia" it was identified that the legal framework for water resources management and protection does not consider the water resources vulnerability to climate change.

The impact of climate change must be taken into account in the dynamics of development of Armenia's water resources management as a potential tool for overcoming the challenge of climate change. It is necessary to improve both the legal and institutional dimensions of the Republic of Armenia for the most efficient organization of this huge-scale process. In particular, the impact of climate change on water quality and quantity is currently insufficiently studied in terms of the impact of particularly extreme phenomena (floods, mudflows, landslides, etc.) [61]. Though, in addition to the actual aspects of water quality and quantity management, extreme phenomena are also included in EU policy for this field. EU Floods Directive requires the EU Member States to implement flood risk assessment and management to reduce the adverse impacts on population health, environment, cultural heritage and economy.

New studies of the impacts of climate change on Armenia's water ecosystems need to be carried out, taking into account the water balance, hydrological and hydrochemical regiems of rivers, reservoirs and lakes, and the concept of reservoir construction is to be revised. There is also a need for new studies on the impacts of socio-economic aspects on water resources, where the impact of climate change on water demand for different purposes must be taken into account.

In scope of the future studies related to the water resources management in Armenia, it should be mandatory to include a section on the vulnerability assessment of water resources due to climate change in order to take into account the projected water availability in the processes of water use permits application evaluation, as well as in the development of sectoral strategies.

The tables below present the legal and institutional gaps, shortcomings in water resources management and protection, as well as the recommendations for their solution.

[61] Vulnerability of water sector to climate change. Creating favorable conditions for the preparation of Armenia's Third National Communication under the UN Framework Convention on Climate Change. Yerevan, 2012.

**Table 45. Recommendations for Improving the Legislation of the Republic of Armenia in the Field of Water Resources Vulnerability and Adaptation to Climate Change**

| | Name and active reference to legal act | Legislative gaps and shortcomings | Recommendations | Justification | Expected outcomes |
|---|---|---|---|---|---|
| 1. | The RA Water Code, as well as the Law on the Fundamental Provisions of the National Water Policy and the Law on National Water Program | The Water Code of the Republic of Armenia, as well as the Law on the Fundamental Provisions of the National Water Policy and the Law on National Water Program lack the concepts and legal regulations for *climate change, water resources vulnerability and adaptation to it*. | Set out the ideology of water resources management under climate change, and the processes aimed at achieving this goal in the regulations of the Water Code, the Law on the Fundamental Provisions of the National Water Policy and the Law on National Water Program | The Water Code of the Republic of Armenia is a fundamental document on water resources management, the subject of regulation of which mandatorily implicates also the stipulation of provisions on water resources adaptation and reduction of their vulnerability to climate change. Legal regulations for reduction of water resources vulnerability to possible adverse effects of climate change and increasing their adaptation to it shall be compulsorily set out in the Law on the Fundamental Provisions of the National Water Policy and the Law on National Water Program, which are among the most important legal acts in the field of water resources protection. | Improved water legislation aline with climate change impact on water resources in Armenia. |
| 2. | The RA Water Code | The formulations of the water reuse (secondary use) provision in the RA Water Code are not clear and complete for the effective implementation of this institute, which is one of the most important measures of adaptation to climate change. In particular,<br>1. it is unclear whether water reuse | Provide regulations containing legal bases for the effective implementation of water reuse in the RA Water Code and the RA Tax Code, as well as establish privileges and incentives for water re-use/ secondary use cases.[62] | The legal relationships related to water reuse, as one of the most important institutes aimed at increasing adaptation of water resources to climate change, need to be more completely regulated by the RA legislation, which derives from the interests of water resource saving, entrepreneurs in fish production and astaciculture fields, water re-users, based on the process of | A mechanism for encouraging the installation of water-saving technologies as an adaptation of water resources to climate change. |

[62] Since January 2020, privileges and incentive mechanisms for water re-use/secondary use, as well as changes in water use tariffs, were drafted by the RA Ministry of Environment and, currently, are in internal circulation.

| | Name and active reference to legal act | Legislative gaps and shortcomings | Recommendations | Justification | Expected outcomes |
|---|---|---|---|---|---|
| | | and secondary use cases are identified in the RA legislation;<br>2. the following are not regulated:<br>a. the relationship between 1st and 2nd level water users,<br>b. risk control institution,<br>3. no conditions are provided to ensure the interest of the secondary or double water user in this process;<br>4. no limits on the water amount to be reused are provided. | | implementation of Sustainable Development Goals. This provision has a vital role and significance in both environmental and ecological terms. | |
| 3. | The RA Tax Code | Water use rates set out by the RA legislation are unjustifiably low, which results in inadequate use of water resources and does not encourage water reuse. | It is recommended to revise the water use rates established by the RA Tax Code.[63] | Although Article 78 of the RA Water Code provides for the application of economic mechanisms of water management to promote the rational use of water resources, the extremely low water use rates do not promote rational and efficient use of water; moreover, they represent a promoting factor not to reduce major leakage in water distribution and water use systems (up to 80% in drinking water supply systems, and up to 50% in irrigation water supply systems). In addition, from the point of view of assessing the vulnerability of water resources under climate change, these rates require a revision that will promote rational water use on the one hand and will not create affordability | A mechanism for encouraging the installation of water-saving technologies as an adaptation of water resources to climate change. |

[63] The same note as above (62).

| | Name and active reference to legal act | Legislative gaps and shortcomings | Recommendations | Justification | Expected outcomes |
|---|---|---|---|---|---|
| | | | | problems for water users on the other hand. | |
| 4. | The RA Water Code, Protocol decision on the Content of the basin management model plan approved by item 6 of Protocol No. 45 of the RA Government sitting of 26.10.2017 | In spite of the fact that three water basin management plans (South, Ararat, Akhuryan) have been adopted and two ones are in the development phase (Sevan, Hrazdan) in accordance with the requirements of the RA Water Code and the Water Framework Directive, the assessment of the water resources vulnerability to climate change is **partially** presented in the management plans. Moreover, the practical implementation of the adopted RBMPs seriously lags. In the context of climate change, the existing data and information on water vulnerability presented in the RBMP is insufficient to understand the real picture of the impact of climate change on water resources and the effective adaptation measures taken.<br>Water basin management plans are considered as an operational management document, however, water use permit issuance processes (water use limit, WP validity period) do not stipulate any projection for the given water resource under climate | Revision of the RA water legislation and its full approximation with the requirements of Directive 2000/60 / EC, including review and approval of water basin territorial management plans for the six water basin territorial management units.<br>Given that under the CEPA Armenia has made a clear commitment to develop river basin management plans in line with WFD principles within 5 years of the entry into force of the Agreement, a clear consensus on the purpose, key steps and action plan needs to be achieved as soon as possible. | Failure to consider climate change at present may result in a reduction in the anticipated results and efficiency of investments or the envisaged measures required to meet the objectives of the Water Framework Directive.<br>There are certain concerns regarding the Roadmap for the implementation of the CEPA, issued in the Appendix to the RA Prime-Minister's Decision 666-L of June 1, 2012 "On the approval of the Roadmap for the Comprehensive and Extended Partnership Agreement between the European Community and their Member States". The provisions defining the scope of Community action in the field of water policy are very general and do not substantially contribute to the fulfillment of Armenia's commitments under the CEPA.<br>The Roadmap also contains inaccuracies regarding the Floods Directive, as it states that there is no need for further approximation, since the following commitments have already been carried out: (a) Implementation of initial flood risk assessment (Articles 4 and 5 of the EU Floods Directive); (b) Preparation of flood hazard and risk maps (Article 6); and c) Preparation | Improved water legislation aline with climate change impact on water resources in Armenia.<br>Improved water basin management planning system aline with climate change impact. |

| | Name and active reference to legal act | Legislative gaps and shortcomings | Recommendations | Justification | Expected outcomes |
|---|---|---|---|---|---|
| | | change. | | of flood risk management plans (Article 7). However, in reality none of the measures mentioned in the Roadmap have been implemented in accordance with the requirements of Articles 4-7 of the EU Flood Directive. Moreover, there are no developed flood risk management plans in Armenia, as stated in the Roadmap. | |
| 5. | The RA Law "On Lake Sevan", RA Government Decision 517-N as of 28.04.2011 on "Establishment of a Foundation for the Resto-ration, Preser-vation and Development of Lake Sevan", RA Govern-ment Decision 1187-N as of 28.09.2017 "On Approval of the Annual Plan for 2018 for Recovery, | The legal framework for Lake Sevan protection is inadequate; there are no legal regulation mechanisms in place to take into account or to assess Lake Sevan ecosystem vulnerability to climate change.<br>The legal framework on management of the Lake Sevan, as water resources, should always take into account the projected impact of CC on the ecosystem of the lake (changes on water balance, increase in evaporation, decrease in precipitation, etc), aimed to the protection of the lake under the CC. | To improve Lake Sevan ecosystem and mitigate the impacts of climate change, it is necessary to apply an ecosystem approach and to undertake a number of environmental, legal and economic measures and solutions to this end. These should include improvement of the legal and institutional frameworks for Lake Sevan ecosystem conservation, strengthening of criminal, administrative responsibility for relevant offenses, raising the level of public awareness on lake ecosystem conser-vation, stronger control of water use and poaching in the | Being highly important for the state and society, and representing one of the primary climate change impacts in the field of water resources in the Republic in the relations regarding Lake Sevan, the state should be guided by policies based on the priorities of environmental protection, health, climate, natural development of ecosystems, natural resources reproduction. Otherwise, damage to the ecosystem, economic and cultural losses will be unavoidable. | Improved legal framework to protect the Lake Sevan under climate change impact. |

| | Name and active reference to legal act | Legislative gaps and shortcomings | Recommendations | Justification | Expected outcomes |
|---|---|---|---|---|---|
| | Conservation, Reproduction, Natural Development and Utilization Measures for Lake Sevan Ecosystems " a number of other legal acts. | | lake, providing mutual relationship and information exchange between the state agencies in the field of management, monitoring, and conservation of the lake ecosystem and the research sector, introduction of innovative technologies for the lake protection, use, and monitoring, minimization of pollution of Lake Sevan with municipal and coastal wastewater, etc. | | |

| | Name and active reference to legal act | Legislative gaps and shortcomings | Recommendations | Justification | Expected outcomes |
|---|---|---|---|---|---|
| 6. | RA Government Decision N 218-N as of 7 March 2003 | Bases for refusal to issue a water use permit in the RA Water Code are incomplete, since they do not reflect the problem of water resources vulnerability to climate change related to certain planned activities. | It is proposed to add items 7 and 8 to the first paragraph of Article 30.1 of the Water Code, with the following content:<br>1. There is a negative conclusion of environmental impact assessment if the law stipulates that the planned activity is subject to environmental impact assessment expertise.<br>2. An activity implemented based on water use permit can have a negative impact on the environment, substantially increasing the vulnerability of water resources to climate change. | The main legal instrument ensuring the rational use of water resources in the Republic of Armenia is water use permit. It is this statutory document that addresses the requirements of the law to a specific water user, creating a clear framework for the latter's rights and responsibilities. Therefore, the grounds for refusal of application for a water use permit should also include cases where the activities implemented on the basis of water use permit can have a negative impact on the environment, substantially increasing the vulnerability of water resources to climate change and the negative conclusion of the expertise.<br>Moreover, the environmental impact assessment of water use must also include an assessment of the potential impact of climate change on the water resource and an assessment of the potential hazards arising from that water use in terms of effective water resource management under climate change. | Improved water legislation aline with climate change impact on water resources in Armenia.<br>Effective water use in the country aline with climate change impact. |
| 7. | The RA Water Code and the RA Government Decision of 07.03.2003 No. | The RA Water Code lacks provisions for mandatory notification and provision of public participation in water resource vulnerability reduction and adaptation measures. | The list of the documents subject to mandatory public notification by the state governance authorities as per the Water Code shall specify | Ensuring public participation in implementation of water use, water resource management and conservation is a key priority among the legal measures for water resources adaptation to climate change. This | Participatory water management and use aline with climate |

| | Name and active reference to legal act | Legislative gaps and shortcomings | Recommendations | Justification | Expected outcomes |
|---|---|---|---|---|---|
| | 217-N "On Approval of the Procedure for Public Notification and Publication of Documents Developed by the Water Resources Management and Protection Body". | | also the forms of public participation in water resource vulnerability reduction and adaptation measures (Article 20 of the RA Water Code). | is an important guarantee for raising the level of public awareness in such a multi-layer process and ensuring the interested public participation. | change impact on water resources in Armenia. |

**Table 46. Recommendations for Improving Institutional Sector in terms of Water Resources Vulnerability Assessment and Adaptation to Climate Change**

| | Gaps and shortcomings | Recommendations | Justification | Expected Outcomes |
|---|---|---|---|---|
| 1. | Current legal regulations in the area of development and implementation of water basin management plans by the water basin management organisations (BMOs), the appointment of their authorized bodies, are contradictory. At present, the Regional Divisions of the WRMA do not exercise their full powers in the manner prescribed by law. BMOs role is very passive in implementation and control of adaptation measures and climate change data sharing at the local level. | Legal and institutional changes are needed to eliminate the split in the appointment of heads of water basin management bodies, as well as to clarify the subjects for the development, approval and implementation of water basin management plans and to provide them with higher professional and technical capacity. | Armenia has adopted the principle of decentralization of water resources management, which has been incorporated into the legislation since the 2000s; however, a number of issues remain unresolved. For example, the purpose of the establishment of the basin management bodies was to give them the role of providing a link between the WRMA and the communities, in particular to accept water use permit applications, to register them by sector, to submit them to the WRMA for further processing, as well as to register the issued water use permits, to classify them by sector and use and to control the compliance with the conditions in water use permits and non-breach of standards. The procedure for appointing authorized representatives of the water basin management bodies, as central players in the sector, must also be clarified. | Strengthened water resources management, implementation of adaptation measures and climate change data sharing at the local level. |
| 2. | The Institute of Public Councils in the Republic of Armenia is non-sustainable and incomplete. Public councils were formed by the goodwill of certain governance entities, with no continuous activity. | Sustainable foundations and conditions need to be established for the formation and operation of public councils as a type of instrument of cooperation between different competent authorities, to engage public and sector scientists and to play an active role in water | From the point of view of international practice, the role of public councils is also important from the perspective of implementation of climate change adaptation measures, since the presence of such bodies allows providing public participation, balancing the interests through conclusions of independent body, inter-ministerial cooperation during the development of baseline documents in the field of water resources management and protection.<br>It should be added that the Akhuryan River Basin Management Plan envisages the establishment of a River Basin Public Council, which has not been implemented so far. | Strengthened institutional framework for water resources management and protection under climate change impact. |

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| | | resources management, including water resources adaptation to climate change. | | |
| 3. | Uncertainties and gaps caused by the dissolution of the National Water Council. | Established a Center of excellence for water resources and climate studies in order to improve institutional framework of water sector.<br>In order to fill the revealed gaps as a result of the dissolution of the National water council, it is recommended to established a Center of excellence for water resources and climate studies.<br>The role and responsibilities of the proposed Center are described in section 4.2 (Table 4.2.1) of this report. | The dissolution of the National Water Council and the transfer of its functions to the RA Ministry of Environment is considered a negative rather than a positive reform, which brings a number of difficulties with it. Dissolution of the National Water Council at this stage is problematic in view of the potential adverse impacts of water resources adaptation to climate change. In particular, the National Water Council has a major role in the development of the basin management plans, while the Sevan and Hrazdan basin management plans are currently under development and the North Basin Management Plan is planned to be developed by 2023. With the dissolution of the National Water Council, changes are projected also by the fact that the purpose of this body's activities was not limited to its role in the preparation of several approved basin management plans. All the more that the Water Code considers the main mission of the National Water Council submitting recommendations on national water policy, national water program and other legal acts related to water resources management and climate change adaptation measures. | Strengthened institutional framework for obtaining, analyze and archive of climate change data to assess and predict the vulnerability of water resources. |
| 4. | The functions of the authorized body and the relevant professional organization in the field of water resource monitoring organization and | The functions of the Ministry of Environment related to monitoring should be clearly defined, including the functions of | It follows from the analysis of the nature and objectives of environmental monitoring that water resource monitoring and the effective implementation of this process are preconditions, without which it is impossible to speak of water resource adaptation measures. That is why the | Strengthened institutional framework for obtaining and monitoring of climate change data to assess |

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| | implementation are not coordinated and clearly defined. | providing qualitative and quantitative monitoring demand of water resources and summarizing monitoring data, the preliminary assessment of water resources quality and quantity. | functions of the relevant authorities in the process of organizing and implementation of monitoring should be clearly differentiated, fully and smoothly implemented in addressing reduction of water resources vulnerability to climate change.<br>The existing monitoring regulations should be sufficient to substantiate the responsibility of assessment of water resources and their vulnerability to climate change, the available resources and adaptation of legal regulations during preparation and following implementation of the assignment of water resources monitoring. | and predict the vulnerability of water resources. |

## 4.2. RECOMMENDATIONS TO OVERCOME THE GAPS AND BARRIERS ON ASSESSMENT OF WATER VULNERABILITY UNDER CLIMATE CHANGE IN ARMENIA

This section is provided recommendations to overcome the identified gaps in water resource data and methodologies applied for assessment and prediction of the vulnerability of water resources to climate change in Armenia.

In the table below the list of proposed recommendation and activities are provided to improve the water resources managmenet, assessment and prediction of vulnerability of water resources in the context of climate change in Armenia.

The main state authority responsible for the implementation of proposed activities is the RA Ministry of Environment with its subdivisions.

**Table 47. Recommendation and activities for improving the assessment and prediction of vulnerability of water resources in the context of climate change in Armenia**

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| 1. | Strengthening of the existing hydrometeorological monitoring network is of a high priority. With the future in mind, the ability to conduct a comprehensive and systematic evaluation of hydroclimatic conditions and water resources vulnerability assessment must be based on hydrometeorological observations over the entire country which are in par with international standards. Accordingly, plans for the installation of a state-of-the-art observation network to fill the existing gaps should be considered. In particular: - Extension of the hydrometeorological network through the establishment of the new up-to-date observation stations (measuring flow velocity, water level, precipitation, water and air temperature, snow depth and density) at the rivers' flow formation zones (at the altitudes of 2200-3000m) in 14 major river basins in the country defined by the RA National Water Program, 2006. | Data from these stations will help 1) fill existing gaps in the meteorological and hydrological monitoring system, 2) monitoring and archiving changes in precipitation patterns and trends over the entire country; 3) assess the changes and variability in rivers flows, both natural and human controlled extractions and diversions. | Additional research and mapping of the flow formation zones in major river basins are required to identify the optimal sites for establishing and maintaining the observation stations. The international-based practice should be followed as a guiding principal for selection and installation of automatic stations with data recording, storage, transmission, that are resistant to harsh winter conditions. Fore more details see section 4.4 of this report. | Improved hydrometeorological network to assess the water resources vulnerability under climate change. Reliable basin-level projections on water resources vulnerability under climate change. |
| 2. | Installation of the mobile observation gauges at the Lake Sevan and the reservoirs with 20 million $m^3$ water capacity and | The Lake Sevan, as a largest freshwater reserve in Armenia and the Caucasus region, has high strategic importance for the whole region. In terms of the | The feasibility study should be conducted to define the locations, numbers of | Reliable meteorological data for current and future water balance |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
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| | larger in order to measure the evaporation from the surface of water. | calculation and observation of the changes in the water balance of the lake under the climate change impact, the determination of the water, air temperature, precipitation and evaporation from the water surface is an important activity. Currently, evaporation at the water surface of the lake is calculated on the basis of observations conducted in the USSR period. This data should be updated and clarified. Moreover, there is no reliable data for precipitation, air and water temperature for the lake.<br>Also, there is no data about the precipitation, air and water temperature, evaporation for the large reservoirs in Armenia. Appropriate measurements should be carried out also for that reservoirs. | observation gauges, costs, as well as the type of devices that should be installed at the Sevan Lake and the large reservoirs in Armenia for measuring the air, water temperature, precipitation and evaporation at the water surface. According to preliminary analyses conducted by the Geoinfo team, minimum 4 observations gauges should be installed for the Lake Sevan to determine the evaporation from the water surface. | assessment of Lake Sevan and large reservoirs in Armenia.<br><br>Obtaining data on evapotranspiration at surface of the reservoirs and lakes to assess and predict changes in evaporation rate at reservoirs, as well as to evaluate the economic benefit of water-storage in the country. |
| 3. | Improving the existing State Water Cadaster and data sharing system to have accurate, reliable and open access data on the hydrological and meteorological parameters to be used in water resources vulnerability assessments in the country. | The State Water Cadaster (SWC) was initiated in the 2003 by the RA ME Water Resources Management Agency according to Water Code demands in order to store complete data on surface water and groundwater resources, water users, water quality and water quantity. In 2017, the new regulations of maintaining Water State Cadaster were approved by the RA Government (the RA Gov. 02.02.2017 N68-N decision). According to the new regulations, it is anticipated to develop a GIS-based online platform to enable access to the water data and information for public and relevant agencies.<br>However, there are high degree of uncertainties in the exiting national information and when the data is shared with international organizations such as | Establish a mechanism and tools for importing a newly developed hydrological and meteorological database of the ArmHydromet service into the State water cadaster system, as well as develop criteria for evaluating the database to adjust archived water data.<br>Set the Armhydromet service as the responsible state water body for maintaining hydrological and meteorological data and exchanging information at the national and international levels. | Upgraded State Water Cadaster system that should be well administrated and regularly updated in order to provide a reliable and actual data for water resources vulnerability assessments and management. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
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| | | World Meteorological Organization (WMO), the same uncertainties are transmitted to the global datasets.<br>According to the results of the review of the previously published assessment reports on water resources vulnerability in Armenia, significant differences in the results related to precipitation changes are identified and in most cases, it exhibits decreases in precipitation for many regions of the country. To understand the reason for the different results, a brief study was carried out by the international consultant of the Geoinfo team and his student at the Center for Hydrometeorology and Remote Sensing (CHRS), the University of California, Irvine, US. In scope of that study the various available data sources created by the international organizations, such as WMO, including the CHRS's PERSIANN-CDR data were analyzed to understand from a hydroclimatological perspective how has precipitation (on long term basis) changed over Armenia in terms of annual amounts and trends.<br>The results of the study also indicated that there are a number of contradictions in the meteorological data produced in Armenia, which may be caused by an inadequate monitoring system, data measurements or data management system.<br>It should also be noted that within the framework of the EUWI+ project, a new operating database on hydrological and water quality data is being created, which will be provided to the state body at the end of 2020. This database should be maintained by the | | |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | | Hydro-meteorological and Environmental Monitoring Centre and will be linked to the state Water Cadaster system. | | |
| 4. | Establishing mechanisms and tools to collect actual and reliable water use data which should be shared between the Inspectorate for Nature Protection and Mineral Reousrces undert the Governmetn of Armenia, Ministry of Environment, Water Committee, and other relevant agencies and organizations and stored in the State Water Cadastre system. | Since 2016, the Water Committee started installing and operating radar and ultrasonic measuring stations for water level measurement at primary irrigation canals, including remote data transmission and Supervisory control and data acquisition (SCADA) software. This system proved to be efficient for controlling the irrigation water distribution and collecting the actual water use data. However, the system needs to be broadened by water use sectors throughout the whole country. Furthermore, the data should be made available for use by other state water agencies, and the public and private sector.<br>This will allow specialists to identify data gaps and accuracy issues and propose measures aimed at improving the water use data accounting and management. The more accurate the data on water use will be, the more reliable will be the estimates of natural flow, water economic balance and assessment of the water scarcity under the climate change, as well. | Establish a mechanism to make the water use data collected through SCADA system available for other state water agencies and organizations, such as Ministry of Environment and its relevant departments. The proposed mechanisms will also include the tools for sharing the data on actual water use with the State Water Cadaster system. Develop criteria and tools for evaluating accuracy of data on actual water use obtained through SCADA system. | Reliable and complete data on actual water use that will:<br>- improve water resources management and use, including water permitting processes in context of climate change impact on water resources;<br>- enable more accurate restoration of natural flow;<br>- enable effective adaptation measures in water use sub-sectors. |
| 5. | Develop several methodologies for appropriate assessment of the vulnerability of water resources under climate change. In particular:<br>➢ Develop the method on natural flow restoration to carry out river flow | Our review of the past assessment reports show that different climate models have been used to study the impact of climate change with respect to projections of future precipitation over Armenia and the conclusions particularly in the context regional assessments have varied. It is our recommendation | In order to have more reliable methodologies on vulnerability assessment that will be discussed and accepted by the group of specialists, it is recommended to establish the center of excellence | • Verified methodology for flow restoration.<br>• Verified methodology for assessing the vulnerability of water quality in a river basin |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | restoration using the same principls and datasets for different river basins in the country. The methods developed should be verified and then applied in activities for water resources assessment and analysis.<br>➢ Introduce modern hydrological models to assess the vulnerability of water resources in the river basin level and to analyze the existing hydrological information.<br>➢ Develop a new method for assessing the vulnerability of water quality in a river basin under climate change. The new method in parallel with a list of hydrochemical parameters should consider also changes in the indicators for determining river feeding sources, such as snow depth and snow density, as well as the changes in the main hydrological parameters (air and water temperature, precipitation and river flow).<br>➢ Introduce modern hydrological models to assess the vulnerability of groundwater under climate change. | that a future evaluation of climate models using available observations performed in a retrospective simulation will be of great value. Such simulation study will provide an objective mechanism to see which of the available IPCC climate models perform better in the historical context. The models that pass the test are most likely to provide more reliable projections of precipitation patterns and trends over Armenia in the future. We recommend the use of publically available global datasets, particularly the popular high resolution daily 25km PERSIANN-CDR dataset which covers the period of 1983-present(https://rainsphere.eng.uci.edu/ ; https://www.ncdc.noaa.gov/cdr/atmospheric/precipitation-persiann-cdr). Such dataset can provide the observational coverage and serve as a comparative evaluation (in a retrospective mode) of the IPCC climate models whose historical simulation runs of the 20th century has already been archived for CMIP5 and for CMIP6 will soon become available with IPCC AR6 release at the end of 2020. | for water resources and climate studies under the Ministry of Environment. The responsibilities of this center can include 1) the evaluation and recommendation of the climate and hydrologic models for future studies; 2) evaluation and approval of the National Communications of Armenia to UNFCCC; 3) Determine and analyze data gaps and define necessary data for hydrological modeling (hydrometeorological data, water use data, hydrogeology, topography, soil composition, vegetation, land use). The center should also be responsible for finding the ways to cooperate with IPCC and other international organizations such as UNESCO and WCRP for transferring the best practices in climate models downscaling and water resources vulnerability assessment for the regions with conditions similar to Armenia. | under climate change.<br>• Selected climate and hydrological models that will provide most reliable result for the territory of Armenia taking into account the physico-geographical, socio-economic conditions and model input data availability.<br>• Center of excellence for water and climate studies that will supervise the researches on vulnerability assessment of water resources due to the climate change. |
| 6. | Conducting studies to assess vulnerability of groundwater resources under climate change in Armenia. | In Armenia, the studies of climate change impact on groundwater resources are not conducted. It should be noted that groundwater resources are directly | A field surveys should be conducted to obtained groundwater data for conducting | Reliable assessment and projections on groundwater resources |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
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| | | linked to precipitation and evaporation amounts, as well as related to the formation of river flow.<br>It is obvious that along with a decrease in precipitation and river flow and an increase in temperature the groundwater table will also be changed. Therefore, the vulnerability of groundwater resources has to be also assessed in the country. | the assessment of water vunlarability to climate change. The method should be develop to separate the anthropogenic pressures to climate change imact of water resources.<br>The good international practice should be studied during the assessment of groundwater vulnerability to climate change. | vulnerability under climate change. |

## 4.3. RECOMMENDATIONS TO OVERCOME THE DEFICIENCIES IN PLANNING AND GENDER MAINSTREAMING IN CLIMATE CHANGE ADAPTATION PROGRAMS IN ARMENIA

This section provides recommendations to overcome the identified deficiencies in water use sub-sectors strategies and their synergies between development and adaptation objectives, strategy, plans and programs. The recommendations are developed based on the review of existing climate change adaptation and mitigation initiatives, including the activities conducted by the local and international organizations related to climate change risks, impacts, adaptation, and mitigation.

The table below provides a list of proposed recommendations and activities to improve water use in sub-sectors and sector development strategies for implementing effecitive adaptation measures in the context of climate change in Armenia.

**The state authorities responsible for the implementation of proposed activities are:**

- RA Minitsry of Environment with its subdivisions, RA Ministry of Territorial Administration and Infrastructure, including Water Committee and Marz administrations (Marzpetarans)
- RA Ministry of Economy

Recommendations are aimed to improve strategy and concepts for the development of water use sub-sectors aline with climate change impact on water resources. The proposed improvements should be considered during the preparation of the following strategic documents:

- Long-term strategic development plan of the the Government of the Republic of Armenia
- Action Plan of the Government of the Republic of Armenia
- Marz development programs
- Water use sub-sectors development strategies and concepts
- Basin management plans

Table 48. Recommendation to overcome the gaps in planning of climate change adaptation programs in water sector

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| 1. | Strategies and concepts that are fundamental to the policy of all sectors important in terms of water resource vulnerability, must take into account water resources vulnerability and adaptation issues and+ steps to address them in the context of climate change. These documents are: long-term strategic development plans of the the RA Government, as well as Marz development programs, water use sub-sectors development strategies and concepts. | The problems of water resources' vulnerability reduction and adaptation to climate change are lacking or not fully addressed in the strategic plans for the development of different water use sectors, such as HPPs, irrigation, water supply/sanitation, construction of reservoirs, of serious importance for the Republic of Armenia. Particularly, in the long-term strategic development plans of the RA Government and Marz development programs it is mentioned about the high priority of improved water supply and sanitation sector, as well as develop agriculture in the country, however, the existing strategies do not address to climate change impact on water resources.<br>In the key sectors of the country, such as hydropower or natural resource management, the "Strategic Development Program of the RA Hydropower Sector" and the "Natural Resources Management Strategy" were adopted in 2011 and 2018 respectively. Although the first program rightly assesses the role of using hydropower resources in the frame of energy security and independence in the Republic of Armenia, unfortunately, this document does not address the issue of water resource vulnerability in the context of climate change. As for the RA Natural Resources Management Strategy, it envisages elimination and mitigation of adverse impact of climate change, anthropogenic factors on the sustainability of forest ecosystems only among the principles of forest protection. | In order to improve climate change adaptation planning in Armenia, it is recommended to include and take into consideration the results of the assessment of water vulnerability to climate change in the water use sub-sectors development strategies and concepts.<br>It should be noted, that the provided recommenddation should be considered in the new drafting strategies on water use sub-sector development, as it is practically unrealistic to add changes to already adopted strategies. | New water use sab-sectors development strategies aline with climate change impact on water resources. |
| 2. | Improve drinking and irrigation water supply in conditions of water resource vulnerability aimed at water use adaptation to climate change. In particular:<br>• The potential changes in the irrigated | Due to an increase in temperature based on climate projections in the agriculture sector, the most climate-sensitive sector, crop yields are predicted to decline and irrigation demands to increase with climate change. In order to maintain crop yields, substantially more irrigation will be needed unless new water-saving technologies are massively introduced. However, with overall | In order to improve climate change adaptation planning for agricultural sector, it is recommended to | Improved national strategy for irrigation water in order to adapt water use to climate change. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | lands (degradation due to changes in climate conditions) and water norms to irrigate the lands should be considered in the agricultural sector development strategy and concepts in order to be able to reliably estimate the irrigation water demand and its possible change in the nearby future.<br>• Long-term use of surface water resources for fish farming and irrigation due to changes in river flow will create risks for the effective development of the agricultural sector. Therefore, when considering long-term water use permitting, the amount of water provided must take into account the potential vulnerability of river flow to climate change. | water resources availability expected to decline, these demands may be difficult to fully meet in the future.<br>There is an insufficient level of integration of climate change adaptation into the development planning process of Armenia. Thus, in irrigation, which is the largest water use sector in the country, the irrigation norms are based on historical data and do not encounter a significant increase in irrigation water demand due to increased air temperature and subsequently increased evaporation due to climate change.<br>It should be also noted the poor conditions and high losses of irrigation water in canals, which lead to inappropriate water use in the agriculture sector. Thus, to this end, the Ministry of Environment has proposed a draft on approving the RA Government's Protocol Resolution "On approving the concept of development and introducing of legal, economic, and administrative incentives for reducion of leakage in water systems", which is currently in the stage of revision (https://www.e-draft.am/projects/575/about). However, the concept discusses the impact of climate change on water resources only superficially and does not suggest mechanisms to observe climate change impacts on water resources (reduction of water yields of springs, reduction of precipitation, increase of droughts and mudflows, changes in water supply and demand, etc.). | include and take into consideration the results of the assess-ment of water vulnera-bility to climate change in development strate-gies and concepts of this sector. The main attention should be paid to the predicted changes in water demand, establishe-ment of irrigation norms aline with climate change, intro-duction of innovation water saving and energy efficiency technologies in agricultural sector. | |
| 3. | Improve drinking water supply in conditions of water resource vulnerability aimed at water use adaptation to climate change. In particular:<br>• The potential changes in quality and quantity of drinking water sources due to the climate change should be assessed and considered in the "Water Supply and Sanitation Strategy and Financing Plan for | Although the "Water Supply and Sanitation Strategy and Financing Plan for 2018-2030" of the Republic and development strategies for all Marzes mentioned of high priorities of improving drinking water supply and sanitation services in communities, the strategic documents do not encounter a significant increase in drinking water demand and water stress due to increased air temperature and decrease in precipitation, as well as subsequent qualitative and quantitative changes in freshwater sources due to climate change. | In order to improve climate change adapta-tion planning for drinking water supply and sanitation sector, it is recommended to include and take into consideration the results of the assess- | Improved national strategy for drinking water supply and sanitation in order to adapt water use to climate change. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | 2018-2030" of the Republic.<br>• In-depth assessments on potential changes in hydrometeorological phenomena, water balance, water supply and demand due to climate change impacts should be conducted and considered during the development of adaptation programs for drinking water supply and sanitation on Marz level. | Taking into account the vulnerability of water resources to climate change and the high percentage of water losses (up to 75%) in drinking water supply systems, it is necessary to modify the drinking water supply and sanitation strategies based on climate projections in the sector. In addition, the key focusing should be made on the renovation of the drinking water supply networks (first of all secondary and tertiary networks), minimize leakages, and organizing the water supply through using energy efficiency technologies. | ment of freshwater vulnerability to climate change in development strategies and concepts of this sector. The main attention should be paid to predicted changes in water demand, the improvement of sanitation and drinking water supply using energy efficiency technologies, etc. | |
| 4. | Introduce the modern technologies on wastewater local treatment to communities for encouraging the wastewater re-use aimed at water resources adaptation to climate change. Include the treated wastewater re-use schemes in the development strategies and concepts for 2030 in the water supply and sanitation sector. | An important component of climate change mitigation and adaptation measures is the reuse of wastewater. From this point of view, it is important to consider the wastewater discharged from the settlements of the Republic as a possible source of water, introduce modern sewage and municipal wastewater treatment systems, develop the licensing mechanisms for the reuse of treated wastewater. | In order to improve climate change adaptation planning for water use sectors, it is recommended to introduce natural-based solutions for domestic wastewater and other innovation water-saving, energy efficiency technologies for industrial wastewater treatment aimed to re-use water and minimize predicted increase in water | Improved national strategy for wastewater treatment in order to adapt water use to climate change. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | | | demand and stress under climate change in the country. | |
| 5. | Climate change scenarios and projected river flow changes must be considered in the process of provision or extension of the water use permit for hydropower purpose. | The main negative impact of HPPs on the river aquatic ecosystem is that in a certain section of the river after HPP the environmental flow is not maintained that leads to the deterioration of aquatic ecosystem and biodiversity. As we can see from the results of vulnerability assessment of water resources due to the climate change presented in the Deliverable 3, the river flow in the territory of Armenia has mainly decline trends. River flow reduction due to the projected climate change will increase the probability of environmental flow violation in the rivers with SHPPs and the aquatic ecosystems will become more vulnerable. Despite this, currently, water use permits for HPP exploitation are given for up to 25 years. Therefore, it is strongly recommended to revise all active HPP water use permits to reveal the problems which may arise with reduction of the river flow, as well as consider the projected river flow values in the process of provision or extension of the water use permits for HPPs. | In order to improve climate change adaptation planning for hydropower sector, it is recommended to include and take into consideration the results of the assessment of water vulnerability to climate change in development strategies and concepts of this sector. The main attention should be paid to:<br>• Add in the basis for refusal to issue a water use permit the vulnerability of water resources to climate change;<br>• Introduce requirement to consider climate change scenarios and projected river flow changes in the process of issuance of water use permits or extending the permit for | Improved national strategy for hydropower generation in Armenia aimed at adaptation of water resources to climate change. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | | | hydropower generation purposes. | |
| 6. | In the climate change adaptation strategy of Armenia, Sustainable Development Goals and National Determined Contributions agendas must be aligned in order to reduce redundancies and increase efficiency - maximize resources, technical capacity, information, and expertise sharing. For instance, climate targets, actions, and policy measures must be established for the SDG 6 (Clean Water and Sanitation). | The 2030 Agenda and the Paris Agreement put forth an innovative and complementary framework for accelerating action and achieving ambitious sustainable development objectives. Under the 2030 Agenda, a series of 17 global Sustainable Development Goals (SDG) have been agreed that are to be universally achieved. Under the Paris Agreement countries are expected to submit a Nationally Determined Contribution (NDC) which outlines their commitments to reduce greenhouse gas emissions and strengthen resilience to climate change. Although SDGs are not legally binding, governments are expected to establish national frameworks to achieve the goals. The SDGs are integrated and indivisible, balancing economic, social, and environmental dimensions of sustainable development, whilst the Paris Agreement aligns with the 2030 Agenda and demands urgent climate action. As we move forward with implementation of these two agreements, we must transform them into concrete action and tangible results [UNDP, 2017].<br>The alignment of these SDG and NDC agendas is imperative to reduce duplication and increase efficiency - maximizing resources, technical capacity, information, and expertise sharing. As presented in the recent working paper by the World Resources Institute [2016], many of the climate actions highlighted in the NDCs also have the potential to generate mutual benefits across the 17 SDGs. Similarly, actions defined to meet SDG targets have the potential to contribute towards achieving NDC commitments. The two agendas are interlinked and aligning their implementation provides a great opportunity to accelerate progress across both agreements.<br>UNDP has unique experience supporting countries to develop Intended NDCs (INDCs), leading global public consultations to define SDGs, and most recently to support governments in designing and implementing NDC and SDG roadmaps to meet these commitments [UNDP, 2017]. | In order to improve climate change adaptation planning in accordance with international obligations, it is recommended to:<br>• Analyze the current state of NDC-SDG interlinkages for Armenia;<br>• Identify where the benefits from aligning the SDGs and NDCs are likely to be greatest in order to facilitate more coordinated and coherent planning and policymaking for linking these two agendas;<br>• Consider the climate change commitments (NDCs) in the planning of SDGs implementation. | Improved climate change adaptation strategy of Armenia based on national obligations. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| 7. | In the National and Marz development strategies, as well as in the process of designing and constructing water reservoirs the following points should be undertaken in the context of climate change:<br>- assess the economic feasibility (benefit / cost ratio) and water evaporation volumes from the reservoirs for different periods (up to 2040, 2041-2070, 2071-2100) due to climate change impacts;<br>- consider and assess the potential changes in microclimate and its impact on the environment and biodiversity in the area of reservoir construction;<br>- Adopt the best international practices on calculation of the greenhouse gases emissions in a result of the operation of the reservoirs. | Although reservoir construction is one of the climate change adaptation measures, the design and construction of the reservoirs is meanly based on the principles and assessments applied in the Soviet time. For example, the most of the large and medium-sized reservoirs are built in the lower reaches of the river basins or near the border of the Republic, which causes serious problems or unsafety for managing; the design of the new reservoirs is based only on river flow data and does not consider the flow change trendsdue to climate change; the efficiency (economic benefits) of the reservoirs has not been assessed in Armenia so far and the annually evaporated water volumes of at least large reservoirs due to climate change have not been evaluated and predicted.<br>When designing and constructing reservoirs, it is necessary to study and evaluate potential microclimate changes due to their impact, based on the analysis of changes in climate conditions in an analogous reservoir area after the construction of the reservoir, using long-term hydro-meteorological monitoring data. | In order to improve climate change adaptation planning during the construction of water reservoirs, it is recommended to include and take into consideration the results of the assessment of water vulnerability to climate change in development strategies and concepts of this sector. The main attention should be paid to:<br>• Assessment of the location and volume of during construction of a reservoir in an upper river, as well as the study of hydrological and hydrogeological changes under the predicted climate change.<br>• Evaluation of the efficiency/economic benefits of a reservoir.<br>• Investigation and | Improved national strategy for water reservoirs construction in Armenia aimed at adaptation of water resources to climate change. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | | | evaluation of the microclimate of reservoirs and their possible changes.<br>• Evaluation of water inflows to the reservoir as a result of climate change.<br>• Include the potential vulnerability of water reservoirs to climate change in the preliminary assessment package for the design and construction of a reservoir. | |
| 8. | Study of flood and mudslide areas, as well as introduction of an early warning system about the danger of flooding | One of the consequences of climate change is an increase in the intensity and frequency of hydrometeorological events-floods and mudslides, due to rising temperatures and changing precipitation patterns. Floods and mudslides cause great damage to agriculture and infrastructure, and can endanger human health and lives.<br>Currently, monitoring and large-scale research on floods and mudslides are not carried out in the Republic of Armenia. The need to introduce early warning systems is also highlighted by the EU flood Directive, the principles of which Armenia has committed to adopting within the framework of the CEPA. | • Carry out inventory, mapping and assessment of the danger, risk and vulnerability, using the capabilities of modern technologies of GIS and using data obtained from ground monitoring, remote sensing and drone.<br>• The collection, processing and archiving of observations and data on floods and mudslides should be | Installed flood early warning systems, including its hardware and software, as well as legal and institutional regulations in order to adapted water resources to climate change. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | | | legally assigned to a specific government Agency.<br>• After completion of mapping and modeling of flood zones, based on the best international experience, establish early warning systems in the most dangerous/ risk zones, including hardware and software for data collection, transmission and analysis, and establish responsible authorities for the operation of these systems. | |
| 9. | Mainstream and enhance gender sensitivity, inclusiveness and gender balanced participation in climate change adaptation policies/strategies/plans in water resource management sector and relevant interventions. | In many countries gender inclusiveness and particularly gender mainsteaming in climate change adaptation measures in water management have quite a strong focus. The desk review of relevant state laws and regulations, regional development strategies of RA marzes of 2017-2025, 1stm 2nd and 3rd national communications and other relevant documents showed a very slight focus on gender issues and didn't contain any gender sensitive analysis and/or indicators and also lack sex-disaggregated data. This data is of great importance as women are the main water daily consumers in Armenia and their needs should be considered while elaborating relevant policies/strategies/programs/plans. This will enable the relevant stakeholders to track how climate changes affect women and men and develop a gender- | Consider sex-disaggregated data and analysis of gender implications and risks in subject related policies, programmes and strategies, and establish M&E system, which will use validated/ tested tools for collecting accurate | Strengthened policies/strategies/ plans that include gender sensitivity, inclusiveness and gender-balanced participation in implementing measures to climate change adaptation in water sector. |

| N/N | Recommendation | Justification | Proposed Activities | Expected Outcomes |
|---|---|---|---|---|
| | | sensitive planning accordingly. Moreover, the desk review of available assessments showed that the participation rate of women in water management is quite low. One of main goals stipulated in RA Gender Policy Strategic Program 2019-2023 is the improvement of the national mechanism for the promotion of women, equal participation of men and women in governance and decision-making. Thus, it is crucial to include women in water management design, planning and implemention process and thus contribute to gender equality mainstreaming and reducing the climate change impacts on women, men, boys, and girls. | sex-disaggregated data, track gender sensitive indicators and provide relevant recommendations. Also, strengthen the participation of women in decision-making and management of climate change adaptation in water sector, through capacity building, awareness raising campaigns for gender balanced participation in design and implementation of policies, programmes and strategies on climate change adaptation in water management. | |

## 4.4. RECOMMENDATIONS ON MODERNIZATION OF THE HYDROMETEOROLOGICAL OBSERVATION SYSTEM AND SERVICES

The hydrometeorological observation system of the Armenian Hydrometer Service (AHS) consists of 47 meteorological stations and 7 hydrological (river basins) stations with 93 hydrological posts as of January 2020. Based on the result of analysis on the present state of the hydrometeorological observation network in the country and revialed problems and gaps in the network, the recommandations are provided on improvement and modernization the hydrometeorological observation system and data providing. This recommendation was deemed necessary because the observation network provided the basis for the data on which the studies for assessment of water resources vulnerability to climate change were carried out.

Currently, there are several implemented or on-going projects aimed to improve the hydrometeorological observation system of the AHS in the country, such as upgraded 6 hydrological stations in the farme of the EUWI + project, and modernization of 23 meteorological stations are conducted in the frame of UNDP funded project (*see details of the projects in the report on Review of implemented and on-going climate change adaptation measures in water sector in Armenia*).

Within collaboration between the Government of Armenia and the World Bank Group a Road Map for Armenia to modernizing weather, climate and Hydrological Services was prepared in 2018. The roadmap is based on a technical evaluation and detailed assessment of needs and capacities of the Armenian Service for Hydrometeorology (AHS) and Active Impacts on Hydro-meteorological Phenomena within the Ministry of Environment. The document identifies the gaps and challenges in producing and delivering weather, climate and hydrological information and services. It recommends how to improve the capability of the AHS to save lives and livelihoods and to support social and economic development.

Three scenarios of AHS modernization have been presented in the document as follows:

- Scenario 1- Four areas for immediate high-impact priority activities have been identified and agreed to be implemented in 2017–2018 with support provided by the Bank/GFDRR grant of an estimated amount of US$0.35 million.
- Scenario 2- Intermediate modernization activities implemented in a medium -term perspective will focus on strengthening infrastructure of hydromet observation, data analysis and forecasting (US$6.0 million).
- Scenario 3- Full modernization implemented over longer period (hopefully before 2025) will focus on providing data, forecasts and services in support of safety of life and property and of economic development (US$19.0 million).

The modernization of the hydrometric service's observation points should be carried out according to the priority.

Based on the World Bank assessment report and taking into account the priority of upgrading the hydrological observation point of the AHS, we propose to modernize the existing 4 hydrological observation points of the Hydromet Service.

The priority of recommendation is that these 4 observation points are located in the rivers mouths and the modernization will increase the accuracy of the observation data, which will create an opportunity for relable water balance and picture of the assessment of water vulnerability under climate change.

The modernization of the other hydrometric service points of view should be carried out in stages according to the priorities.

In 4 hydrological observation points located in rivers mouths construction or repair works (construction or repair of hydrometric bridges for measuring river flow, rope crossings, or installation of remote systems) should be conducted, as well as an automatic level registration of water level, a radar system for data online transmission and hydrometric screws should be installed. The locations of proposed 4 hydrological observation stations are provided in Table 49.

**Table 49. Exsiting hydrological stations which are subject to modernization**

| № | Name | Coordinates | |
|---|---|---|---|
| | | Latitude | Longitude |
| 1 | Hrazdan-Hovtashen (Masis) | 40,022792 | 44,441909 |
| 2 | Metsamor-Ranchpar | 40,030705 | 44,367952 |
| 3 | Arpa-Areni | 39,732152 | 45,200463 |
| 4 | Vorotan-Tatev HPP | 39,427253 | 46,373272 |

In order to conduct more accurate assessment and forecast of river flow changes in the country under climate change, it is recommended to establish 14 new hydrological stations at flow formation zones of the river basins for conducting regular measurement of water level, river flow, water and air temperature (Table 50).

**Table 50. Proposed new hydrological stations**

| № | Name | Coordinates | |
|---|---|---|---|
| | | Latitude | Longitude |
| 1 | Shoghvak-Dzoragyux | 40.184327 | 45.223670 |
| 2 | Ashocq-Hartashen | 41,014947 | 43,907141 |
| 3 | Halavar-Meliqgyugh | 40,663768 | 44,36223 |
| 4 | Gegharot-Aragats village | 40,489964 | 44,322115 |
| 5 | Mili-Mets Gilanlar | 40,093079 | 44,774018 |
| 6 | Vedi-Khosrov | 39,974052 | 44,87633 |
| 7 | Azat-Lanjazat | 40,062023 | 44,589812 |
| 8 | Yeghegis-Getikvanq | 39,927188 | 45,516609 |
| 9 | Geghi-Ajabaj | 39,157006 | 46,105089 |
| 10 | Masrik-Nerqin Shoja | 40,110562 | 45,838023 |
| 11 | Chichkhan- Bashgyugh | 40,945098 | 43,963259 |
| 12 | Aghstev-Krivoymost | 40,981183 | 45,189308 |
| 13 | Sisian-Arevis | 39.395866 | 45.890322 |
| 14 | Loradzor-Shenatagh | 39.371491 | 46.127047 |

For a more accurate assessment and prediction of climate change impact on meteorological characteristics of highland zones, it is recommended to established 5 new meteorological stations and reconstruct/modernize 2 existing highland meteorological stations (**Table 51** and **Table 52**).

**Table 51. Proposed new metorological stations**

| № | Name | Coordinates | | Altitude /m/ |
|---|---|---|---|---|
| | | Latitude | Longitude | H |
| **1** | Yeghnajur | 40,863618 | 44,000658 | 1940 |
| **2** | Jajuri lernancq | 41,092535 | 43,569502 | 2150 |
| **3** | Sotq | 40,226447 | 45,943969 | 2205 |
| **4** | Tashtuni-Lernancq | 39,115929 | 46,160964 | 2358 |
| **5** | Sevaberd | 40,273507 | 44,805496 | 2075 |

**Table 52. Exsiting highland meteorological stations which are subject to modernization**

| № | Name | Coordinates | | Altitude /m/ |
|---|---|---|---|---|
| | | Latitude | Longitude | H |
| 1 | Semyonovka | 40,65972 | 44,89806 | 2104 |
| 2 | Vardenyac (Yanikh) | 40,00500 | 45,24194 | 2334 |

The proposed recommendation for improving the hydrological and meteorological observation systems in the AHS are shown in Figure Figure 28 and Figure 29, accordingly.

**Activities:** A field surveys should be conducted to determine the optimal locations for installation of the new observation stations. The good international practice should be studied and automated stations with data recording, storage, transmission, that are resistant to flooding or hot summer conditions, should be suggested to select and install.


**Figure 28. Locations of hydrological stations for a comprehensive and systematic assessment of water vulnerability to climate change.**


**Figure 29. Locations of the meteorological stations for a comprehensive and systematic assessment of water vulnerability to climate change.**

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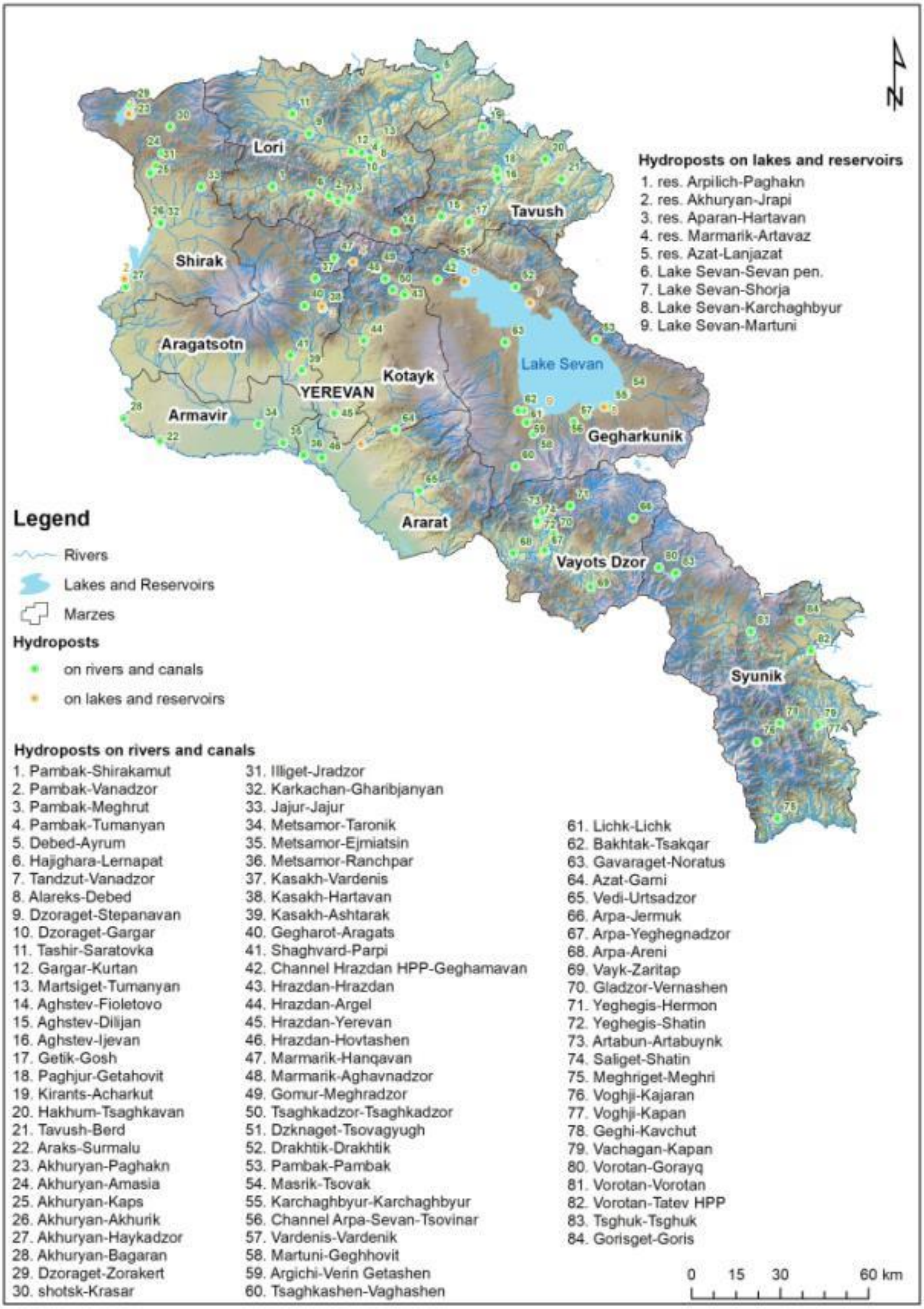
# ANNEXES

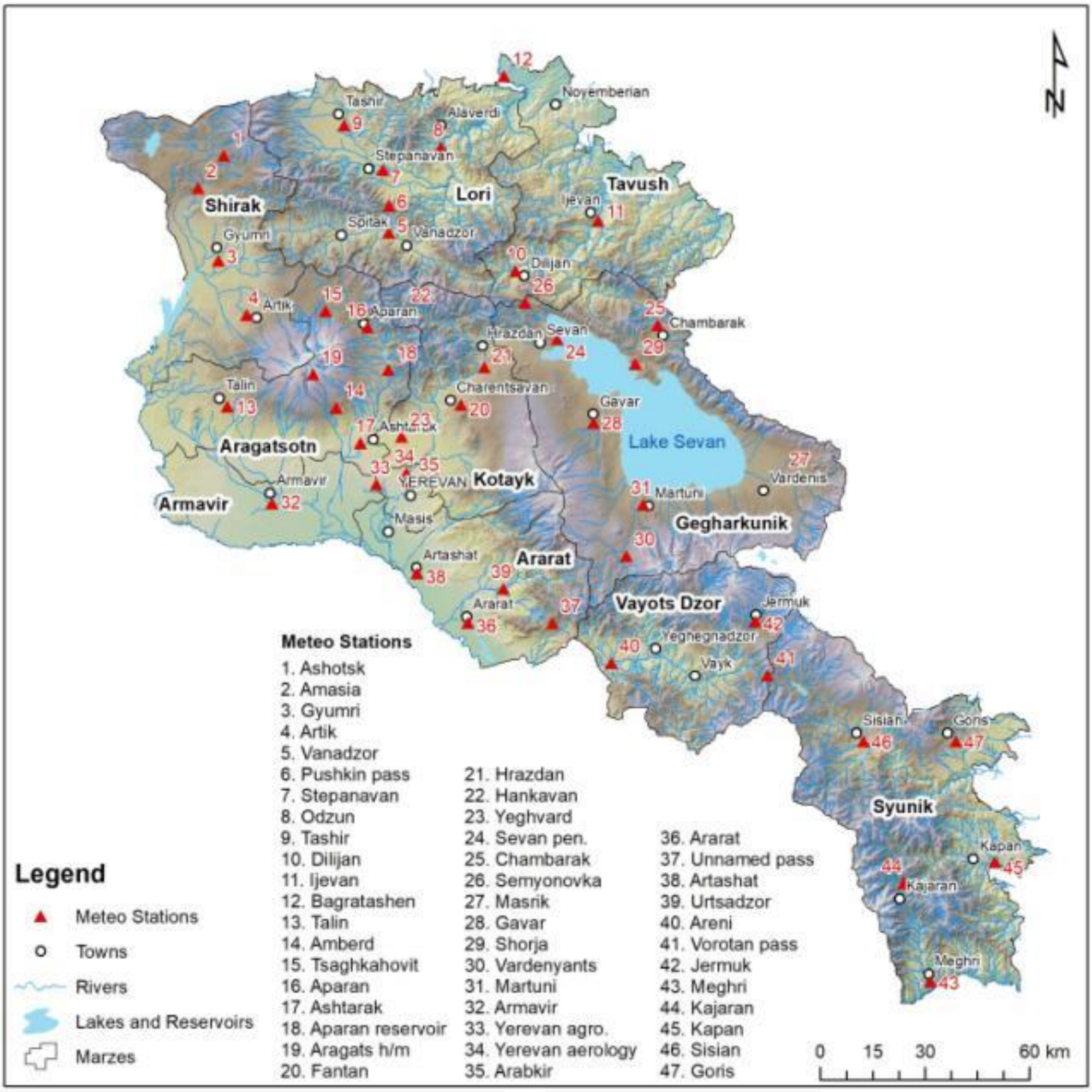
## Annex 1. Legal acts that used in the report

1. Constitution of the Republic of Armenia (source: RA Official Bulletin 2015.12.21. Special issue, Article 1118, adopted on 06.12.2015).
2. Water Code of the Republic of Armenia (source: RA Official Bulletin 2002.07.10 / 24 (199) Article 581, adopted on 04.06.2002).
3. RA Law on National Water Policy (source: RA Official Bulletin 2005.06.15 / 37 (409) Article 653, adopted on 03.05.2005).
4. RA Law on the National Water Program (source: RA Official Bulletin 2006.12.25 / 66 (521) Article 1384, adopted on 27.11.2006).
5. RA Law on Lake Svan (source: RA Official Bulletin 2001.07.04 / 19 (151), adopted on 05.15.2001).
6. RA Law on Freedom of Information (source: RA Official Bulletin 2003.11.05 / 55 (290), adopted on 23.09.2003).
7. Convention on Availability of Information on Environmental Issues, Public Participation in Decision-Making and Access to Justice, Denmark 1998, https://www.unece.org/fileadmin/DAM/env/pp/documents/ACtext/Aarhus_Convention_Armenian.pdf
8. UN Framework Convention on Climate Change
9. IPCC Kyoto Protocol
10. Paris Agreement
11. UN Convention on Biological Diversity
12. Decision 81-N of the Government of the Republic of Armenia of January 30, 2010 to reorganize the organization, to make changes in the decisions of the Government of the Republic of Armenia of June 20, 2001 n 552, of March 18, 2004 n 349 In order to invalidate a number of decisions of the Government of the Republic of Armenia.
13. On 07.03.2003 of the Government of the Republic of Armenia Decision No. 217-N (source: RA Official Bulletin 2003.04.02 / 17 (252) Article 287).
14. RA Government "On Approval of the Procedure for Providing Water Use Permit" March 7, 2003 Decision N 218-N (source: RA Official Bulletin 2003.04.02 / 17 (252) Article 288).
15. Decision No. N 639-N of the Government of the Republic of Armenia of May 22, 2003 on the Approval of the Procedure for the Implementation of Water Resources Monitoring and Reporting (source: RA Official Bulletin 2003.06.25 / 34 (269) Article 581).
16. "On approving the procedure for maintaining the State Water Cadastre Cadastre" №68-N decision (source: RA Official Bulletin 2017.02.08 / 9 (1284) Article 113).
17. "On approving the 2018 annual program of measures for restoration, preservation, reproduction, normal development and use of ecosystems of Lake Sevan" №1187-N decision (source: RA Official Bulletin 2002.01.15 / 4 (179) Article 10).
18. "On Approval of the Procedure for Establishment, Collection, Registration, Summarization and Provision of a Unified Electronic Database of Lake Svan Lake and its Collection Monitoring Database" №947-N decision (source: ARPA 2002.01.15 / 4 (179) Article 10).
19. Decision No. 75-N of the Government of the Republic of Armenia of January 30, 2003 on the Recognition of the Authorized Water Resources Management and Protection Body (source: RA Official Bulletin 2003.02.26 / 12 (247) Article 203).

20. The Government of the Republic of Armenia Decision N 338-N of May 31, 2016 on approving the priority measures for the Ararat Basin management area in 2016-2021 and the priority measures for effective management.
21. The Government of the Republic of Armenia Resolution N 539-N of May 26, 2016 on approving the priority measures for the South Basin managment area and the priority measures for effective management.
22. The Government of the Republic of Armenia Resolution N 240-N of March 9, 2017 on approving the priority measures for the Akhuryan Basin managment area and the priority measures for effective management for 2017-2022.
23. https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF

## Annex 2. Hydrometeorological monitoring network of Armenia




Shirak
Lori
Tavush
Aragatsotn
Armavir
Kotayk
Gegharkunik
Ararat
Vayots Dzor
Syunik
Lake Sevan
Tashir
Alaverdi
Noyemberian
Stepanavan
Ijevan
Spitak
Vanadzor
Gyumri
Dilijan
Artik
Aparan
Chambarak
Hrazdan
Sevan
Talin
Charentsavan
Gavar
Ashtarak
Armavir
YEREVAN
Martuni
Vardenis
Masis
Artashat
Ararat
Jermuk
Yeghegnadzor
Vayk
Sisian
Goris
Kapan
Kajaran
Meghri
Meteo Stations
1. Ashotsk
2. Amasia
3. Gyumri
4. Artik
5. Vanadzor
6. Pushkin pass
7. Stepanavan
8. Odzun
9. Tashir
10. Dilijan
11. Ijevan
12. Bagratashen
13. Talin
14. Amberd
15. Tsaghkahovit
16. Aparan
17. Ashtarak
18. Aparan reservoir
19. Aragats h/m
20. Fantan
21. Hrazdan
22. Hankavan
23. Yeghvard
24. Sevan pen.
25. Chambarak
26. Semyonovka
27. Masrik
28. Gavar
29. Shorja
30. Vardenyants
31. Martuni
32. Armavir
33. Yerevan agro.
34. Yerevan aerology
35. Arabkir
36. Ararat
37. Unnamed pass
38. Artashat
39. Urtsadzor
40. Areni
41. Vorotan pass
42. Jermuk
43. Meghri
44. Kajaran
45. Kapan
46. Sisian
47. Goris
Legend
Meteo Stations
Towns
Rivers
Lakes and Reservoirs
Marzes
0 15 30 60 km
N

## Annex 3. Average multi-year values of rivers flow and their deviation against to basline period of 1961-1990.

| № | Hydrological observation stations | Up to 2007, mln $m^3$ | Baseline period from 1961-1990, mln $m^3$ | Deviation, % |
|---|---|---|---|---|
| 1 | Pambak-Meghrut | 253.9 | 251.2 | -1.07 |
| 2 | Dzoraget- downstream Gargar | 486.4 | 480.4 | -1.25 |
| 3 | Pambak-Tumanyan | 348.0 | 336.1 | -3.54 |
| 4 | Debed-Ayrum | 1046.4 | 1063.4 | 1.60 |
| 5 | Aghstev-Fioletovo | 39.5 | 40.0 | 1.25 |
| 6 | Aghstev-Dilijan | 97.5 | 107.1 | 8.96 |
| 7 | Aghstev-Ijevan | 304.2 | 243.8 | -24.8 |
| 8 | Getik-Gosh | 111.0 | 109.5 | -1.37 |
| 9 | Paghjur-Getahovit | 59.1 | 63.1 | 6.34 |
| 10 | Hakhum-Tsakhavan | 48.4 | 49.4 | 2.02 |
| 11 | Tavush-Berd | 20.2 | 18.4 | -9.78 |
| 12 | Akhuryan-Akhurik | 231.8 | 225.8 | -2.66 |
| 13 | Akhuryan-Haykadzor | 922.6 | 952.0 | 3.09 |
| 14 | Kasakh-Vardenis | 40.6 | 48.7 | 16.6 |
| 15 | Kasakh-Ashtarak | 144.0 | 124.1 | -16.0 |
| 16 | Metsamor-Taronik | 469.4 | 497.2 | 5.59 |
| 17 | Hrazdan-Hrazdan | 247.7 | 243.4 | -1.77 |
| 18 | Marmarik-Aghavnadzor | 150.8 | 145.6 | -3.57 |
| 19 | Dzknaget-Tsovagyugh | 34.7 | 34.2 | -1.46 |
| 20 | Masrik-Tsovak | 106.0 | 102.2 | -3.72 |
| 21 | Karchaghbyur-Karchaghbyur | 32.0 | 32.7 | 2.14 |
| 22 | Vardenis-Vardenik | 51.1 | 56.1 | 8.91 |
| 23 | Martuni-Geghovit | 56.7 | 55.9 | -1.43 |
| 24 | Argichi-Verin Getashen | 176.3 | 192.3 | 8.32 |
| 25 | Lichkh-Lichkh | 63.4 | 63.6 | 0.31 |
| 26 | Bakhtak-Tsakhqar | 20.4 | 21.7 | 5.99 |
| 27 | Gavaraget-Noratus | 109.8 | 105.8 | -3.78 |
| 28 | Azat-Garni | 119.6 | 119.04 | -0.47 |
| 29 | Vedi-Urcadzor | 53.8 | 58.8 | 8.50 |
| 30 | Arpa-Jermuk | 166.2 | 168.3 | 1.25 |
| 31 | Meghriget-Meghri | 91.2 | 93.8 | 2.77 |
| 32 | Voghji-Kapan | 330.0 | 379.6 | 13.1 |
| 33 | Vorotan-Vorotan | 358.7 | 440.5 | 18.6 |

## Annex 4. Changes in actual river flow in Armenia during 1991-2017 against to baseline period of 1961-1990.

| № | Hydrological observation stations | Avearage river flow, mln $m^3$ | | | |
|---|---|---|---|---|---|
| | | 1961-1990 | 1991-2017 | Deviation | |
| | | | | mln $m^3$ | % |
| 1 | Pambak-Tumanyan | 335.9 | 391.4 | 55.5 | 16.5 |
| 2 | Debed-Ayrum | 1054.5 | 1055.9 | 1.47 | 0.14 |
| 3 | Dzoraget-downstream Gargar | 479.9 | 478.4 | -1.55 | -0.32 |
| 4 | Aghstev-Ijevan | 296.4 | 345.7 | 49.3 | 16.6 |
| 5 | Getik-Gosh | 109.5 | 116.5 | 7.08 | 6.47 |
| 6 | Araks-Surmalu | 2660.3 | 2314.1 | -346.17 | -13.0 |
| 7 | Akhuryan-Akhurik | 225.7 | 248.1 | 22.45 | 9.9 |
| 8 | Hrazdan-Hrazdan | 242.4 | 248.6 | 6.14 | 2.53 |
| 9 | Argitchi-Verin Getashen | 194.7 | 170.5 | -24.15 | -12.41 |
| 10 | Gavaraget-Noratus | 105.7 | 112.7 | 7.04 | 6.66 |
| 11 | Azat-Garni | 138.3 | 130.9 | -7.39 | -5.35 |
| 12 | Vedi-Urcadzor | 57.9 | 44.9 | -13.0 | -22.5 |
| 13 | Arpa-Jermuk | 167.7 | 161.9 | -5.71 | -3.41 |
| 14 | Voghji-Kapan | 379.6 | 214.7 | -164.9 | -43.4 |
| 15 | Tashir-Saratovka | 81.1 | 85.2 | 4.07 | 5.02 |
| 16 | Gargar-Kurtan | 36.9 | 43.9 | 6.98 | 18.9 |
| 17 | Hakhum-Tsakhavan | 49.4 | 41.9 | -7.53 | -15.2 |
| 18 | Tavush-Berd | 18.4 | 23.6 | 5.17 | 28.1 |
| 19 | Metsamor-Taronik | 498.1 | 307.0 | -191.1 | -38.4 |
| 20 | Metsamor-Ejmiatsin | 686.8 | 434.2 | -252.6 | -36.8 |
| 21 | Kasakh-Vardenis | 48.7 | 28.8 | -19.9 | -40.9 |
| 22 | Kasakh-Ashtarak | 111.8 | 98.4 | -13.4 | -12.0 |
| 23 | Hrazdan-Lusakert | 135.9 | 140.7 | 4.75 | 3.50 |
| 24 | Marmarik-Hankhavan | 54.4 | 53.1 | -1.31 | -2.41 |
| 25 | Dzknaget-Tsovagyugh | 34.2 | 35.1 | 0.86 | 2.52 |
| 26 | Masrik-Tsovak | 99.6 | 108.2 | 8.64 | 8.67 |
| 27 | Vardenik-Vardenik | 56.1 | 40.8 | -15.26 | -27.2 |
| 28 | Martuni-Geghovit | 55.9 | 54.0 | -1.85 | -3.31 |
| 29 | Bakhtak-Tsakkhar | 21.7 | 19.8 | -1.88 | -8.68 |
| 30 | Meghriget-Meghri | 93.8 | 91.4 | -2.47 | -2.63 |
| 31 | Vorotan-Gorhaykh | 116.1 | 123.5 | 7.42 | 6.40 |
| 32 | Tsghuk-Tsghuk | 33.2 | 38.6 | 5.43 | 16.4 |

## Annex 5. Review of adaptation measures following the draft 4th National Communication

The table below provides an analysis of the implementation of the adaptation measures for water resources in the Fourth National Communication on Climate Change as of February 2020.

| N/N | Measure | Action description | Course as of February 2020 |
|---|---|---|---|
| 1 | Developing Basin Management Plans taking into account climate change factor | • The Basin Management Plans for Ararat (2016-2021), Southern (2016-2021) and Akhuryan (2017-2022) water basins, as well as the Government Decisions on Approving the Priority Measures for Effective Management (№338-N as of 31.03.2016; №539-N as of 26.05.2016; №240-N 09.03.2017 respectively) were developed and officially adopted. However, in support of the Ministry of Environment of the Republic of Armenia, the revision of the Akhuryan Water Basin Management Plan started in 2019, within the framework of the EUWI plus program.<br>• Sevan and Hrazdan Water Basin Management Plans are currently being developed and the final drafts will be submitted to stakeholders for discussion in May-June 2020. | • Works for making changes to the Akhuryan Basin Management Plan approved by Decision No. 240-N as of 09.03.2017 have been completed. It was planned to review the protected areas and to calculate the environmental flows of surface water bodies of the basin in accordance with the requirements of Decision No. 57-N as of 25.01.2018.<br>• Works are being carried out within the framework of EUWI plus project by two local organizations: GEOCOM LLC and the Institute of Chemical Physics after A.B. Nalbandyan. The works are expected to be completed in June 2020. |
| | Institutional reforms | A number of institutional reforms have taken place resulting in changes in authorities implementing water management functions. In particular:<br>• The Draft Government Resolution on introducing a Unified State Monitoring System to merge the EMIC SNCO, "Service of the Hydrometeorology and Active Influence on Atmospheric Phenomena" SNCO and “Forest Monitoring Center” SNCO (https://www.e-draft.am/projects/1949/about) was put into official circulation in 2019. The draft is based on the concept of unified provision of "environmental monitoring" and the policy of its development and implementation in accordance with paragraph 6 of the Annex to the Law on Structure and Activities of the Government. | • The design was adopted by the RA Government Decision №81-N as of 30 January 2020. |

| N/N | Measure | Action description | Course as of February 2020 |
|---|---|---|---|
| | | • Assistance in water resources management is being provided within the EU Water Initiative Plus Program (October 2016-September 2020), Institutional and legislative reforms in water sector are implemented in line with the EU Water Framework Directive and Integrated Water Resources Management principles. In particular, the country's surface and groundwater monitoring system is being strengthened, international accreditation of the EMIC SNCO laboratory, as well as decision-making is being supported through the development of data collection and processing capacities.<br>• Support to the enhancement and development of chemical and hydro morphological monitoring, as well as implementation of hydro-biological monitoring in Armenia was provided within the framework of the EU Environmental Protection of International River Basins Program (March 2012 - October 2016). | • Within the framework of this project 6 hydrological observation posts operating in the Sevan and Hrazdan basins were repaired/re-equipped and upgraded in 2019 (the observation posts were equipped with radar sensors with automatic water level monitoring and online data transmission systems).<br>• Within funding of this project, the Akhuryan-Akhurik hydrological observation post of the Hydromet service was renovated, a gauging footbridge and a radar level meter for automatic data recording and transmission was installed. |

| N/N | Measure | Action description | Course as of February 2020 |
|---|---|---|---|
| Economic and technical measures | Irrigation improvement projects | A number of projects are being implemented to improve the irrigation sector with the support of the World Bank, the Eurasian Development Bank, the French Development Agency and the German Development Bank. Withn the framework of the implemented projects, irrigation systems have been constructed with transition from mechanical to gravity irrigation (Meghri, Geghardalich, Kaghtsrashen, Norakert), irrigation systems have been improved and upgraded, reducing operation and maintenance costs, leakage, as well as electricity consumption.<br>Introdcuing of non-conventional irrigation systems in the Republic is envisaged. With the financial support of USAID, Coca-Cola Hellenic Armenia (CCHBCA) Company and UNDP-GEF Small Grants Program, a pilot project was implemented in the village of Hayanist in 2017 aimed at using fish farm water for community irrigation needs.<br>The program of subsidizing interest rates on loans for the introduction of drip irrigation systems has been developed, whereby the interest rate on such loans is less than 2%. The project aims to promote the effective irrigation methods of perennial plants - fruit orchards and high value crops. Within the framework of the project it is envisaged to install drip irrigation systems in 1.6-1.7 thousand hectares of land annually during 2018-2022. | • Construction of dams and ancillary structures for Vedi reservoir (with a total capacity of 29 million $m^3$) (2017-2021), preparation of detailed design and construction tender documents of Kaps reservoir (2016-2020) are in the course of implementation.<br>• The feasibility study for the construction of the Mastara reservoir (with a total capacity of 10.2 million $m^3$) has been completed. |
| | Drinking water supply and sanitation service improvement projects | Projects are being implemented with the support of the European Bank for Reconstruction and Development, the European Investment Bank, the German Development Bank and the European Neighborhood Investment Facility for the improvement of drinking water supply and sanitation services. The water supply and wastewater network of Yerevan is being improved as part of the implemented projects, emergency sections of water supply and wastewater systems of 6 towns and 37 rural settlements of the country are being restored, water supply and wastewater systems rehabilitation project is being developed for 560 self-serviced rural areas. | • The projects are in the course of implementation. |

| N/N | Measure | Action description | Course as of February 2020 |
| --- | --- | --- | --- |
| Research and information | Assessment of underground water resources | • Within the framework of the “Armenia Advanced Science & Partnerships for Integrated Resource Development” (ASPIRED) Program (2016-2020) Ararat Valley wells, natural springs, and fish farms were inventoried, the possibility of using the return water from fish farming for irrigation was studied. Assistance is provided with the establishment of a centralized, online automated management system for fish farming, as well as the creation of a tool for supporting decision-making on the Ararat groundwater basin through modelling.<br>• Within the framework of the EU “Environmental Protection of International River Basins” Program (March 2012 - October 2016) surface and groundwater bodies of the Akhuryan river basin were assessed.<br>• Within the framework of the EU Water Initiative Plus project, a methodology for assessment of underground water natural resources in mountainous regions was developed for Armenia in 2019, with application of which the underground water resources of the Sevan and Hrazdan water basins were assessed. | • The projects are in the course of implementation and will be completed in October 2020. |

| N/N | Measure | Action description | Course as of February 2020 |
|---|---|---|---|
| | Intergrated water resources management study | • Within the framework of SevaMod Armenian-German Joint Research Program (2017-2019), a Lake Sevan model is being developed as a tool for sustainable management and use of natural resources and understanding the ecology of the lake. The project envisages collection and evaluation of data on Lake Sevan, its tributaries and catchment basin, regular measurements of water temperature at different depths of the lake, geochemical survey of the lake sediment to study phosphorus and its behavior, aquaculture assessment.<br>• Within the framework of the Armenian-Russian Joint Research Program on “Paleolimnological Aspects of the Study of the Evolution of Ecosystems of High-Mountainous Lakes in Russia and Armenia” (March 2018 - February 2020), paleolimnological, geomorphological, hydrological, geochemical, biochemical and biographical characteristics of four high-altitude lakes of Armenia located 3,000 m above sea level (Qari, Akna, Umroy, Sev) are being studied. The results, combined with meteorological data, will allow identifying multi-year climate change in the region and making forecasts.<br>• Within the framework of the EU “Implementation of the Principles and Practices of the Shared Environmental Information System in the Eastern Partnership countries “ (2016-2020), assistance in strengthening of national governance potential for water sector data, statistics and information management and use aimed at decision-making is being implemented. | • The results of the first phase of the creation of the 1D hydrodynamic model of Lake Sevan were presented to stakeholders in 2019.<br>• The project was completed in February 2020. The results of the project were published in paper on Sapelko T. V. et. al. "First Multy-Proxy Studies of High-Mountain Lakes in Armenia: Preliminary Results”, GES, 2019.<br>• The project is in completion phase. |

## Annex 6. Review of Marz Development Strategies for 2017-2025

The Armenian marzes' development strategies for 2017-2025, implementation of measures for reduction of water resources vulnerability to climate change and adaptation in different water user sectors have been considered and analyzed. The results of the analysis by marz are given below.

**Aragatsotn Marz**

Among the priorities of the marz's 2017-2025 development strategy plan are rational and sustainable management of water resources, improvement and modernization of agricultural efficiency. No water projects are foreseen in the strategic plans.

**Ararat Marz**

One of the priorities of the strategic plan of the marz is assessment of the vulnerability of water resources to possible climate changes and implementation of adaptation measures.

Strategic plans include improvement of water supply and system management condition, construction of Vedi reservoir (2017-2021), development of intensive agriculture - introduction of modern technologies.

**Armavir Marz**

Improvement of water supply and sanitation systems and their management condition, development of intensive agriculture are among the strategic priorities of the marz.

Strategic plans include the construction of Baghramyan-Norakert irrigation gravity system, improvement of water supply and sanitation systems in Armavir city. It is planned to construct a sewage system and a treatment plant in Metsamor city, improve water supply and sanitation systems.

**Gegharkunik Marz**

Among the priorities of the marz's 2017-2025 development strategy plan are sustainable use of Lake Sevan and other water resources, protection of Lake Sevan ecosystem. Strategic plans include the restoration and protection of Lake Sevan ecosystem, modernization of agriculture, as well as sustainable management of forests and pastures to reduce climate change impacts (implemented by EU, UNDP Yerevan Office).

**Lori Marz**

Among the priorities of the marz's 2017-2025 development strategy plan is improvement of water supply and development of intensive agriculture. There are no plans for irrigation and other sectors in the strategic plans.

**Kotayk Marz**

Among the priorities of the marz's 2017-2025 development strategy plan is rational use of water resources, modernization and development of agriculture. The strategic plan does not provide any plans for the irrigation sector directly. However, projects are planned, which include measures for improvement of water resource efficiency issues.

**Shirak Marz**

Among the issues regarding water resources in the marz's 2017-2025 development strategy plan the rehabilitation of wastewater treatment biological plants, renovation of sewage disposal systems are mentioned. One of the priorities of the marz's plan is the rational and sustainable use of water resources, and the strategic plans include the construction of the Kaps reservoir. The issue of potential vulnerability of water resources to climate change is not included in the preliminary assessment package of the reservoir construction.

**Syunik Marz**

Among the priorities of the marz's 2017-2025 development strategy plan is rational and sustainable use of water resources, modernization of agriculture and rural areas. There is nothing envisaged in the Strategic Plans regarding the water resource vulnerability assessment and adaptation measures to climate change.

**Vayots Dzor Marz**

Among the priorities of the marz's 2017-2025 development strategy plan is improvement of water supply and sanitation, renovation of irrigation and drinking water pipelines, modernization of agriculture and rural areas. Construction of wastewater treatment plants in Yeghegnadzor and Vayk towns is mentioned among the priorities of the marz's plan for the field of water resources.

The strategic plan does not provide for projects and activities directly related to the irrigation sector. However, there are other projects that also imply improvement of the irrigation system and adaptation measures.

**Tavush Marz**

One of the environmental problems of the marz is the pollution of rivers. Priorities include rational and sustainable use of water resources, development of modern and adaptive agriculture and improvement of rural areas. The Strategic Plan does not include any projects related to water resources, however, there are plans that imply adaptation measures.

**Measures for adaptation of water resources to climate change included in the strategic plans of the RA marzes for 2017-2025**

| № | Marz | Water resources environmental problems | Priorities for 2017-2025 | Strtegic plans for 2017-2025 |
|---|---|---|---|---|
| 1 | Aragatsotn | Effective management and use of water resources, prevention of soil degradation, reduction of anthropogenic factors contributing to desertification | Sustainable use of natural resources and water resources | Immediate adaptation measures are not foreseen |
| 2 | Ararat | Water resources are used as a source of irrigation, hydropower and water supply. Therefore, in the event of a possible climate change, their vulnerability assessment and implementation of adaptation measures are vital. | Assessment of water resources vulnerability to climate change and implementation of required adaptation measures | Improvement of water supply and sanitation systems' management condition, construction of Vedi reservoir, development of intensive agriculture - introduction of new technologies |
| 3 | Armavir | The volume of water resources has faced serious changes in recent years, as a result of climate change and the inadvertent and inefficient use of groundwater resources in Armavir Marz. | Improvement of water supply and sanitation systems and their management, development of intensive agriculture | Construction of Baghramyan-Norakert gravity irrigation system, improvement of water supply and sanitation systems in Armavir city |
| 4 | Gegharkunik | Problems related to the recovery and conservation of Lake Sevan and its ecosystem. Absence of wastewater treatment plants on the rivers flowing into Lake Sevan | Sustainable use of Lake Sevan's and other water resources | Raising Lake Sevan level, improving water quality, restoring and preserving flora and fauna, modernization of agriculture |
| 5 | Lori | Water resources pollution due to lack of wastewater treatment plants | Implementation of relevant measures against pollution of water basins, improvement of water supply, development of intensive agriculture | Immediate adaptation measures are not foreseen |
| 6 | Kotayk | Pollution of the Hrazdan, Marmarik, Tsaghkadzor, Meghradzor rivers with wastewater | Rational and sustainable use of water resources, modernization and development of agriculture | Immediate adaptation measures are not foreseen |
| 7 | Shirak | Rational use of water resources, construction of wastewater treatment plants, in particular | Rational and sustainable use of water resources | Construction of Kaps reservoir and irrigation infrastructure |

| № | Marz | Water resources environmental problems | Priorities for 2017-2025 | Strtegic plans for 2017-2025 |
|---|---|---|---|---|
| | | Gyumri treatment plant, issuing status of specially protected nature area to Mantash reservoir and adjacent areas | | |
| 8 | Syunik | Problems with the quality of water resources, mainly due to the mining industry | Rational and sustainable use of water resources, modernization of agriculture and rural areas | Immediate adaptation measures are not foreseen |
| 9 | Vayots Dzor | Problems with water quality protection<br>Lack of wastewater treatment plants | Improvement of water supply and sanitation, renovation of irrigation and drinking water pipelines, modernization of agriculture and rural areas | Immediate adaptation measures are not foreseen |
| 10 | Tavush | Problems related to pollution of rivers with wastewater | Rational and sustainable use of water resources, development of modern and adaptive agriculture and improvement of rural areas | Immediate adaptation measures are not foreseen |

## Annex 7. Hydropower in Armenia

In Armenia, design and construction of hydroelectric and water economic objects began in 1920s. In 1920-1930s, hydropower plants (HPPs) N1 and N2 of Yerevan and HPP of Gyumri were constructed. In 1927, the construction of Dzoraget HPP began. The first aggregate of Dzoraget HPP with capacity of 7400 kW was put in operation in 1932, in a year it worked with capacity of 22320 kW, in terms of water quantity – with average annual capacity of 14920 kW. Creation of powerful energy base became possible after development of the HrazdanRiver and Lake Sevan.

At present,water resources are the most widely used among the renewable energy resources. Utilization of the whole hydro potential will be obtained by using the existing two major HPPs cascades (Sevan-Hrazdan HPPs Cascade and Vorotan HPPs Cascade), construction of three new middle size HPPs and utilization of small HPPs potential.

**Sevan-Hrazdan Cascade**

Sevan-Hrazdan HPPs Cascade includes 7 HPPs: Sevan (34 MW), Hrazdan (81 MW), Argel (224 MW), Arzni(70 MW), Kanaker (102 MW), Yerevan-1 (44 MW), and Yerevan-3 (5 MW) HPPs with 560 MW of total installed capacity and 2.32 bln.kWh annualgeneration of electricity. The HPPs are placed on the HrazdanRiver and at present they use irrigation water flow from Lake Sevan and stream waters of the Hrazdan River.

**Vorotan HPPs Cascade**

Vorotan HPPs cascade consists of 3 hydro power plants, placed on the River Vorotan in the territory of Syunik region, and they use both the river and streams waters. HPPs Cascade consists of Spandaryan (76 MW), Shamb (171 MW), and Tatev (157 MW) HPPs with 404 MW total installed capacity and 1.16 bln.kWh annual generation of electricity.

**Small HPPs of Armenia**

Construction of small HPPs (SHPP) in Armenia is a leading course of action towards development of renewable energy sector and securing the energy independence in Armenia.

The majority of SHPPs in Armenia which are designed, under construction or operation are derivationalstations on natural water flows.

As of the 1st of July, 2019,there were 187 small HPPs in Armenia with about total 370 MW installed capacity. In 2018, the generation of the electricity from small HPPs was around 1 billion kWh.

As of the 1st of July, 2019, and according to the provided licenses, 28 additional SHPPs are under construction, with about total projected 59 MW capacity and 203 million kWh electricity annual supply.
It should be mentioned that the Republic of Armenia has created numerous mechanisms, promoting the use of renewable energy sources, for example:

According to the Article 59 of the “Law on Energy” of RA, adopted on March 7, 2001, it is guaranteed the purchase of the whole electricity generated by renewable energy sources according to the established order: 15 years for SHPPs, and 20 years for solar, wind, biomass and geothermal.

By the decision of the Public Services Regulatory Commission, the procedure for determining the electricity tariff produced by the power plants using the renewable energy sources was approved. According to it, the tariff for the hydroenergy is set on an annual basis. According to the decision of the Public Services Regulatory Commission N 159-N dated 29 May, 2019, the tariff for electricity, produced by SHPPs, constructed on natural steams amounts 24.276 AMD / kWh excluding VAT, for electricity, produced by SHPPs, constructed on irrigation systems - 16.181 AMD / kWh excluding VAT, for electricity, produced by SHPPs, constructed on drinking water canals - 10.788 AMD / kWh excluding VAT.

This tariff is determined and revised due to the definite method adopted by the Commission decision N 88-N dated 22 April, 2015.

In accordance with the above-mentioned procedure, in the end of every year the tariff for the hydro energy is indexed due to the fluctuations in the national currency of Armenia against the USD for a certain period of time and due to the changes of consumer prices in the Republic of Armenia.[64]

[64] http://www.minenergy.am/en/page/448

## Annex 8. Protocol Decision No 41, 10 September, 2015 of the Government of the Republic of Armenia: Intended Nationally Determined Contribution of the Republic of Armenia under the UN Climate Change Framework Convention

The Republic of Armenia ratified the UN Framework Convention on Climate Change (UNFCCC) in May 1993 as a developing country not included in Annex I to the Convention. In December 2002, Armenia ratified the UNFCCC Kyoto Protocol.

The geographical location of the Republic of Armenia (landlocked mountainous country with vulnerable ecosystems), and the country's need to ensure its national security, necessitates the prioritization of climate change adaptation.

The Republic of Armenia stated its position on the limitation of greenhouse gas emissions in subsequent national communications to the UNFCCC and in the Republic of Armenia's Statement on Association with Copenhagen Accords:

In relation to low carbon development Armenia describes the term 'fairness' by applying the UNFCCC definition of 'common, but differentiated responsibility', which considers the different levels of historical responsibility among countries in contributing to the increase of greenhouse gas concentration in the atmosphere, leading to climate change.

The climate change mitigation actions should not reverse the social and economic trends, but contribute to the socioeconomic development of the Republic of Armenia. These actions must be based on an 'ecosystem approach', which is preferred by the Republic of Armenia, since it allows to maximize the synergies between mitigation and adaptation actions in most sectors of the economy, facilitating fair regional cooperation and contributing to solidarity.

Intended Nationally Determined Contributions (INDC):

**1. INDC underlying principles**

1. Limit global greenhouse gas (GHG) emissions to such a level that the global average temperature does not exceed 2°C
2. Ensure distribution of the GHG emissions limitation burden between countries based on the principle of equity, taking into account the rights of present and future generations to use resources, and the equal rights of humans to impact the climatic system.
3. Apply an ecosystem-based approach to mitigation and adaptation actions, giving preference to balanced and combined actions.
4. The Republic of Armenia stays in the status of non-Annex I developing country under the UNFCCC , and is prepared to undertake certain quantitative contribution to limit its GHG emissions growth

based on the above mentioned principle of equity, and subject to adequate financial, technological and technical support.

5. The INDC shall be based on the principle of 'Green economy' and be compatible with the social and economic development goals of the Republic of Armenia.

**2. Mitigation of climate change**

1) Applied definitions

a. GHG emissions limiting volume - the total volume of GHG emissions, which ensures the limitation of an increase in the average global atmosphere temperature to below 2°C, according to the IPCC Fifth Assessment Report this is equal to 1.000 giga tons (Gt) carbon dioxide equivalent.

b. GHG neutral emissions volume - the total annual volume of GHG emissions, which can be fully absorbed by the earth's ecosystems (ocean, land vegetation, soil) and be irreversibly accumulated in the ecosystems (around 11 Gt/year) carbon dioxide equivalent.

2) Calculation basis

a. The 'GHG limitation quantitative indicator' is calculated based on the per capita emissions of the global population,

b. For global population consider the fixed estimate as of 1990, equal to 5.3 billion people (3.35 million was the Republic of Armenia's population in 1990),

c. The per capita emissions limiting volume on the global levels equal to 189 tons/ per capita (1.000 Gt/5.3 billion people)

d. To set the total aggregate quantitative contribution of the Republic of Armenia under INDC equal to **633 million tons carbon dioxide equivalent** (189 tons per capita x 3.35 million people) for the period of 2015-2050 or an annual average of 5.4 tons per capita. In 2010, Armenia's GHG emissions comprised 2.14 tons per capita.

The Republic of Armenia strives to achieve ecosystem neutral GHG emissions in 2050 (2.07 tons/per capita annual) with the support of adequate (necessary and sufficient) international financial, technological and capacity building assistance.

In case of non-exceeding its total emissions quota (633 million tons) set for the period of 2015-2050 Armenia can credit non-utilized reduction to 'carbon market', or transfer it to the balance of emissions limitation envisaged for the period of 2050-2100.

3) Timeframe

The timeframe for the INDC is 2015-2030, including:

a) 2015-2019 - the period of voluntary preparatory contributions. Accept those contributions, beyond the INDC start date in 2020, as «ambitious actions» in accordance with the development index of the Republic of Armenia, stated by forecast “mitigation measures” scenario of the Third National Communication to UNFCCC". The scenario includes commitments undertaken by the city authorities of the country under the Covenant of Mayors.
b) 2020-2050 - the period of contribution under the new UNFCCC agreement.
c) 2030 - interim review of the mitigation regime, taking into account possible changes of indexes mentioned uner Para 2, points 2) a and b.

4) The main sectors included in the mitigation contribution are:

a. Energy (including renewable energy and energy efficiency)
b. Transport (including development of electrical transport)
c. Urban development (including buildings and construction)
d. Industrial processes (construction materials and chemical production)
e. Waste management (solid waste, waste water, agricultural waste)
f. Land use and Forestry (afforestation, forest protection, carbon storage in soil)

Consider 20.1 per cent as an optimal forest cover indicator of the territory of the Republic of Armenia according to the Armenia`s First National Communication to UNFCCC (1998) and Government Decision No 1232 of 21 July 2005 “On Adoption of the National Forest Program of the Republic of Armenia”. To achieve that indicator by 2050 and consider the obtained organic carbon absorptions and accumulations in the INDC and expand the impact period up that measure till 2100.

Ensure organic carbon conservation, accumulation and storage in all categories of lands through comprehensive measures and include achieved balance in the INDC.

Apply the Nationally Appropriate Mitigation Actions (NAMA) format: as well as national and international Measuring Reporting and Verification (MRV) system for implementation of INDC mitigation component.

5) Greenhouse gases considered:

Define that considered greenhouse gases are:

a. Carbon dioxide ($CO_2$),
b. Methane ($CH_4$),
c. Nitrous oxide ($N_2O$),
d. Hydrofluorocarbons (HFCs)

The emissions and absorption of mentioned gases are calculated in $CO_2$ equivalent, according to the "global warming potential" defined by IPCC Second Assessment Report".

**3. Adaptation to climate change**

Basis and approaches to adaptation:

Adaptation strategy and contributions are based on the requirement of the UNFCCC Article 2 "Objective", which stipulates to restrain climate change within timeframe sufficient to allow ecosystems to adapt naturally to climate change. Thus, the natural ecosystems adaptation approach in INDC is considered pivotal for Armenia's adaptation strategy and actions (contributions), and a basis for the development of the national adaptation plan.

The Republic of Armenia embraces the ecosystem approach for adapting to climate change. The approach is in harmony with the environmental policy of the country, can ensure synergy with other international environmental conventions and treaties, will lay the ground for inter-sectoral coordination, and will support establishment of cross-border cooperation and solidarity environment.

Adaptation activities will be prioritized based on the most vulnerable sectors to climate change:

a. Natural ecosystems (aquatic and terrestrial, including forest ecosystems, biodiversity and land cover)
b. Human health
c. Water resource management
d. Agriculture, including fishery and forests
e. Energy
f. Human settlements and infrastructures
g. Tourism

**4. Technology transfer**

Ensure adequate technological assistance and create a favorable environment for technology development and transfer.

Establish institutional mechanisms to overcome barriers for the introduction of innovative technologies for climate change mitigation and adaptation, including strengthening the system of legal protection of intellectual property right.

Ensure an open and transparent system of technology introduction and transfer as a contribution to the INDC, such as through the cooperation and experience exchange with "Climate Technology Center and Network" (CTCN) and through the establishment of a similar mechanism in the country (ArmCTCN).

**5. Capacity strengthening**

Strengthen the operations of Intergovernmental Council on Climate Change, established by the Decision No 955 of the Prime Minister of the Republic of Armenia of 02 October 2012 and its Working Group.

Establish consistent process for professional training and education on climate change-related issues, as well as enhance cooperation at the international and regional levels.

**6. Finance**

Develop an appropriate legislative and institutional framework for adequate financial assistance. For this purpose, a targeted financial mechanism consisting of two components should be created to finance climate change mitigation and adaptation projects:

1. The first - internal (domestic) climate revolving civil fund, to be replenished on permanent base by allocations from environmental fees, ecosystem service fees, including “carbon taxing”.
2. The second - external (international) financial mechanisms with resource provision following the principle of additionality, such as the Green Climate Fund, the Adaptation Fund, the Global Environmental Facility, bilateral and multilateral funds, and other sources.

The emerging financial mechanism will:

a. Create realistic and operational grounds for establishment and development of the reliable public-private partnerships (PPP),
b. Ensure the right of future generations to ‘use climate resources’.

**7. Transparency**

Transparency of mitigation and adaptation actions will be ensured through:

1. The introduction of national and international MRV system,
2. Open and accessible information system, participatory process.

The open and transparent cooperation between public service providing bodies and civil society organizations ensured through establishing and strengthening effective legal incentives.

## Annex 9. List and a brief description of the conducted or on-going measures to climate change adaptation in water sectors

### Agriculture

***Groundwater wells suspension and closing of fisheries within the framework of the State Program of the Ministry of Environment of the Republic of Armenia, 2017-2020***

Adaptation measures to mitigate the vulnerability of water resources include closure and suspension of the existing wells in the artesian basin of the Ararat Valley.

According to the RA Government's decision N1257-N dated 19.09.2019, AMD 37 million 954 thousand has been allocated from the state budget of the Republic of Armenia for solving the problems of deep wells in the Ararat Valley, within the framework of which 8 wells were closed in the Ararat valley, saving 500.0 l/s of water, and 43 wells were suspended, saving 828.8 l/s of water. In addition, of the deep wells with free flow in the land owned by water users 28 wells were closed down at the expense of private water users, saving 441.0 l/s of water.

**Indicators of liquidation and closing down of Ararat Valley wells**

| Indicator | 2018 | 2019 |
|---|---|---|
| Number of closed down boreholes (wells) | - | 8 |
| Number of suspended boreholes (wells) | - | 70 |
| Number of boreholes (wells) brought to valve mode | 11 | 20 |
| Saved water amounts | 715 l/s | 3013.8 l/s |

As a result of closing and suspension of deep wells with free flow in the Ararat valley, 1765.8l/sec of water has been saved. Twenty deep wells were brought to valve mode, saving 1248 l/sec of water. A total 3017.8 l/s of water was saved in 2019.

***World Bank, Irrigation System Enhancement Project, 2013-2018***

The project goals are to reduce the amount of energy used and to improve the irrigation conveyance efficiency in targeted irrigation schemes and to improve the availability and reliability of important sector data and information for decision-makers and other stakeholders.

The project is aimed at conversion and reconstruction of several pumping schemes into gravity systems, rehabilitation of canals as well as capacity building of the entities involved in water management. The economic results of the gravity irrigation system construction and operation will include the increased crop yields and higher incomes of water users. These will be facilitated by the adoption of more efficient on-farm water management practices.

The project implemented by “Water Sector Projects Implementation Unit” State Agency of the State Committee of Water Economy and funded by IBRD.

The project is relevant to the Adaptation Planning for "Water resource management", “Agriculture” and "Energy" sectors. The project had valuable elements, which can contribute for further improvements of both sectors. Project supported the improved water resource management and improved data collection (installed at 83 observation points) may be linked to climate related information to improve trend analysis. Conversion and reconstruction of several pumping schemes into gravity systems (19 pump stations shut down after construction of 4 gravity irrigation schemes) and rehabilitation of canals (about 57 km) are the guarantees of water savings.

***EUWI Plus for the Eastern Partnership (EUWI+ 4 EaP) project, 2016-2020***

The main objective of the project is to improve the management of water resources, in particular trans-boundary rivers, developing tools to improve the quality of water in the long term, and its availability for all.

Directions of the project are as follows:

- Support to further reforms of water policies, establishment of an adequate governance framework, and development of institutional capacities in support of policy implementation.
- Support the transition from pilot basin to country scale timely implementation of EU Water Framework Directive (WFD) principles for integrated water resources management and River Basin Management Plan harmonization in transboundary basins.
- Strengthening of the monitoring of the water bodies status and upgrade needed infrastructure and quality management.
- Institutional capacity building to insure sustainable results.

The project is relevant to the CC Adaptation Planning for "Water resource management" sector. The implementation of efficient management of water resources are in line with CC adaptation in water resources sector. Particularly establishment of a system for regular monitoring (collecting data, tracking tendency) may be very useful for CC related information trend analysis.

River Basin Management Plans are recommended planning tools that give the overall orientation of water management in the basin and the objectives to be reached, and the priorities in the actions to be developed. In Armenia, the Sevan and Hrazdan River Basin Districts are selected as pilot areas for the EUWI+ project. One of the expected outputs of the project is to have adequate infrastructure available for sound monitoring of water quality and quantity in pilot areas, to support the process of development of RBMPs in the project countries.

For this purpose, the detailed assessment of modern flow measurement equipment needs for irrigation water accounting in Sevan and Hrazdan pilot basins was conducted in the frame of the project.

The project had valuable elements, which can contribute for further improvements of the irrigation and water resources management sectors. Besides CC adaptation measures, public awareness, communication, and data/information management and communication with stakeholders might be beneficial to use in NAP planning stage. Some of those activities/measures are recommended to scale-up. It is recommended to consider the lessons learned from this project.

***"Irrigation System Modernization Project", 2016-2021***

The Irrigation Systems Modernization Project is being implemented with the financial support of the RA and the Anti-Crisis Fund of the Eurasian Bank. The total cost of the five-year project is USD 50.0 million. The project includes construction of systems replacing the mechanical irrigation of Ararat Valley and foothill zone with gravity irrigation, repair of main and secondary canals, upgrading of some WUAs' tertiary systems. Investments will result in the following benefits:

- electricity savings (14.37 million kWh, about USD 1.26 million annually);
- operating and maintenance cost savings, approximately USD 0.67 million annually;
- The actually irrigated (24467.9 ha) land area may be increased by 10432.6 hectares.

The loan project was launched on 10 June 2016. The project envisages rehabilitation of the most urgent sections of 4 main canals, 22 secondary canals, 103 tertiary canals in 103 communities of 6 marzes of the Republic and construction of 8 gravity irrigation systems (all works are in progress).

***Armenia Rural Finance Facility Project, 2019-2024***

The goal of the project is to improve the irrigation system of 5,000 hectares (or 5% of total irrigated land in Armenia) of land, in particular:

- reduce water losses due to degraded irrigation systems and old technologies;
- enable small farms to install drip systems and move to high-value, high-yield crop cultivation.

The total cost of the project is EUR 50 million with 3 tranches – EUR 20, 15 and 15 million, funding source: EIB Loan EUR 50 million, co-financing of the Republic of Armenia – EUR 10 million. The project commecnement: 2019 with an implementation period of 5 years.

The anticipated results of the project are:

- as a result of the project implementation, 30-50% water will be saved in the field (or up to 20 million cubic meters, which will make up to 70 million cubic meters at the water source);
- 7-10 thousand small farms (up to 50 thousand rural population) will be the direct beneficiaries of the project.

The project is relevant to the CC Adaptation Planning for "Agriculture" and for "Water resource management" sectors. The project is aimed to ensure a sustainable use of water, to decrease water loses and to install innovation technologies in irrigation sector.

Due to climate change, the volume of water stored in the reservoirs has decreased significantly and in the recent 8 years there has been a need to carry out additional abstraction from Lake Sevan 5 times, whereas in the previous 10 years there was no such need. Losses in the irrigation system amount to 60-75%. Surface irrigation that is more costly in terms of water quantity is widely used. There is no alternative to saving and efficient use of water in Armenia in the near future.

***Armenia Advanced Science & Partnerships for Integrated Resource Development (ASPIRED) Project, 2015-2020***

The purpose of the ASPIRED Project is to support sustainable water resource management and sustainable practices of water users in the Ararat Valley through the use of science, technology, innovation and partnership initiatives. The ultimate goal is to reduce the rate of groundwater extraction in the Ararat Valley to sustainable levels. The implementation of sustainable water resource management and sustainable practices of water users are in line with CC adaptation in water resources sector.

In 2017-2018, within the framework of ASPIRED project the pilot project was implemented in Sayat-Nova and Hayanist communities, Ararat Marz in order to improve irrigation services.

Hayanist community in Ararat Marz is the first village in Armenia to practice an unconventional method of irrigation by reusing the water from a nearby fishery to meet the community's irrigation needs. The pilot project was done with financial support from USAID, the Coca-Cola Hellenic Bottling Company Armenia (CCHBCA), and the UNDP GEF Small Grants Programme. The project helped address a longtime irrigation issue by building a new pumping station at the water discharge point of the fishery, while conducting a quality analysis to ensure the water meets necessary quality standards for irrigation. The project also installed a new, more efficient irrigation pipe network as well as provided community training on sustainable farming practices. Under the pilot program it was possible to save 1.1 million m3 of groundwater annually and irrigate of 40 hectares of extra arable land.

The Sayat-Nova project was implemented with partnership of the the Fund for Armenian Relief, the Partnerships for Rural Prosperity project, which is funded by USAID and implemented by SME DNC.

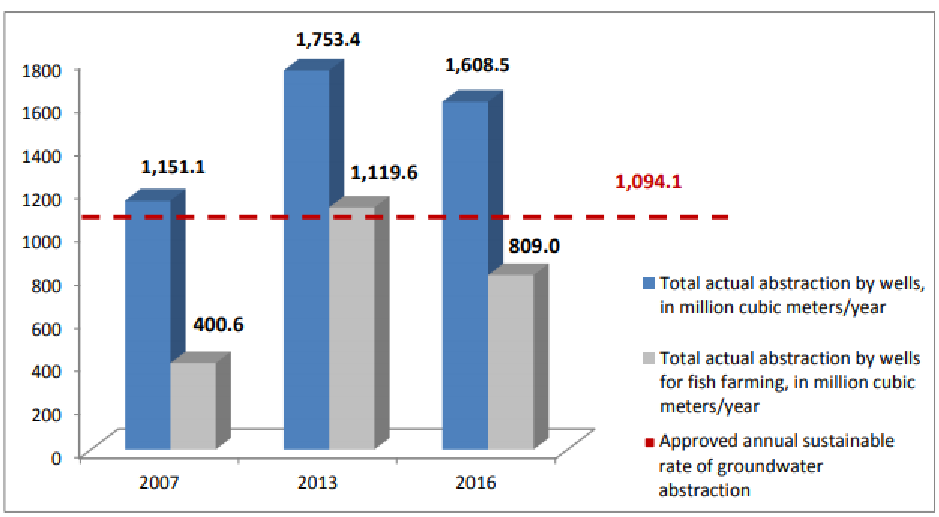
The new system provides more affordable irrigation services and more efficient groundwater use to irrigate 60 hectares of community land by reusing the outlet water from the Masis Dzuk fishery near Sayat-Nova rather than dumping it into the drainage network. Through the public-private partnership between the community and Masis Dzuk, a new pumping station was built at the outlet section of the fishery and a new irrigation network was installed with durable polyethylene pipes. The laboratory analysis of the water's quality proved that the outlet water from the fish farm can be safely used for the production of crops. In partnership with the Center for Agribusiness and Rural Development (CARD) Foundation, USAID also trained local beneficiaries on sustainable farming practices to ensure lasting results. Sayat-Nova is the community to put in place this method of irrigation using water from a nearby fishery, and the first community that has applied this method for large-scale irrigation. Under the pilot program it was possible to save 1.9 million m$^3$ of groundwater annually and irrigate of 60 hectares of extra arable land.

Within the project, the innovation pilot technologies were installed in the Poqr Vedi and Khachpar Communities of Ararat Marz to improve irrigation system. Due to the new technologies it becomes possible to save 936 000. 0 m$^3$ water, 342 000. 0 kWh energy and irrigate of 150 ha of extra arable land in Poqr Vedi Communit, as well as irrigate of 100 ha of extra arable land in Khachpar community.

Within ASPIRED project the optimization of community irrigation wells was also conducted, particularly in Sipanik (saved 0.5 million m$^3$ of groundwater annually and irrigate of 20 hectares of extra arable land) and Hovtashen (saved 1.5 million m$^3$ of groundwater annually and irrigate of 60 hectares of extra arable land) villages.

As of 2018, within the USAID-funded ASPIRED project 5 online streaming devices have been installed in each of fish farms, including Max Fish, Interacva and Golden Fish.

Within the framework of the USAID ASPIRED program also Ararat Valley wells, natural springs, and fish farms were inventoried, the possibility of using the return water from fish farming for irrigation was studied. In total, 2807 wells, 14 natural spring groups, 235 fish farms were inventoried and registered, a database was created in MS Excel format, and the results were accepted by the Government of Armenia as the baseline. Within the framework of the project, the water balance of the Ararat Valley has been prepared, modeling of the groundwater basin of the Ararat Valley is being carried out and a water atlas is being developed.




**Groundwater abstraction data in Ararat Valley.**

*Data source: Assessment Study of Groundwater Resources of the Ararat Valley. Final report, USAID Clean Energy and Water Program, 2014; Preliminary Results of Inventory of Groundwater Wells, Natural Springs and Fish Farms in the Ararat Valley, USAID Advanced Science and Partnerships for Integrated Resource Development Project, 2016.*

Assistance is provided with the establishment of a centralized, online automated management system for fish farming, as well as the creation of a tool for supporting decision-making on the Ararat groundwater basin through modelling. The annual maximum threshold for groundwater abstraction from the Ararat Artesian Basin has been assessed and provided, which will contribute to the restoration of the basin's water resources (Figure 3).

**FAO/ Alternative Utilization of Water Resources in Armenia in the Field of Fish Production, 2015-2017**

The overall objective of the project was to ensure a sustainable utilization of underground water resources in the Ararat Valley of Armenia while maintaining aquaculture production.

The Specific objectives of the project were:

- to significantly reduce overexploitation of underground water resources resulting from the rapid development of fish production;
- to maintain quantity and quality of fish produced previously.

The project outcome is more efficient yet sustainable utilization of water resources.

A new water reuse unit was designed based on local conditions with the aim to significantly reduce water consumption of fish farming by maintaining production. The new unit was designed in a way that provides the possibility of updating to ensure higher water saving. The new unit was installed into the fish farm of the Beneficiary. Equipment of the water reuse unit was purchased by FAO, while the establishment of an appropriate environment (eg. electricity requirements, proper space for the equipment etc.) was the task of the Beneficiary. An International Expert was present during the installation procedure to ensure a proper installation of the water reuse equipment and to inform, update, clarify and explain the Beneficiary all steps, aspects and characteristics of the design, installation and operation of the new unit.

The project is relevant to the CC Adaptation Planning for "Agriculture, including fishery" and for "Water resource management" sectors. The project aimed to ensure a sustainable utilization of underground water resources in the Ararat Valley of Armenia while maintaining aquaculture production. It is expected that water resource management and pisciculture practices will be improved and the farm will become a model farm in the region. The objective to reduce overexploitation of underground water resources due to the rapid development of fish production is in harmony with CC Adaptation. The project had valuable elements, which can contribute for further improvements of the sector. Particularly, the water-reuse technology in pond aquaculture and model farm can be considered as adaptive practice and scale-up or adapt in different regions having geographic, climatic and landscape similarities. In general, the project has scaling up opportunities under the NAP process.

**FAO/ Sustainable Fisheries for Enhanced Water Resources in Armenia, 2015-2019**

The main goal of the Sustainable Fisheries for Enhanced Water Resources in Armenia (SFEWRA) project is to develop efficient water usage models, including Recirculating Aquaculture systems (RAS) for small and medium fish farms located in Ararat Valley.

The main objective of the project is to introduce efficient and environmentally friendly fish farming practices in Ararat Valley fish farms to sustain fish production levels and to reduce negative water-related environmental impacts by the pisciculture industry in Armenia. In the scope of the project a grant was provided to one of the fish farm located in Ararat valley for installation of RAS system for farm intensification, including installation of Aquaponics system, and water efficient use.

The project was implemented by International Center for Agribusiness Research and Education Foundation (ICARE) and funded by FAO.

The project is relevant to the CC Adaptation Planning for "Agriculture, including fishery" and for "Water resource management" sectors. As was mentioned above the project is going to introduce efficient and environmentally friendly fish farming practices in Ararat Valley fish farms to sustain fish production levels and to reduce negative water-related environmental impacts by the pisciculture industry in Armenia. The project is similar to the previous project funded by FAO and by itself is very important and had potential to contribute for further improvements of the sector. Particularly, introduction of the efficient water usage models, including Recirculating Aquaculture systems (RAS) for small and medium is considered as adaptive practice and needs to be scaled-up and/or adapt by other farmer involved in pisciculture in different regions with geographic, climatic and landscape similarities.

## Drinking water supply and sanitation

***Government investments. Investment Proposal 2018-2023***

The preliminary version of the investment plan has been developed based on the fact that the Republic of Armenia intends to continue its cooperation with international institutions and it is planned to invest about USD 200 million in water supply and sanitation sector during 2018-2020.

The investment plan is intended to be implemented throughout the Republic of Armenia. The plan covers 207 settlements in the “Veolia Djur ” CJSC’s service area, including 31 urban communities and 176 rural areas. The proposed investment plan has been evaluated and divided into two groups: short-term - up to 3 years and mid-term - up to 5 years. The implementation of short-term projects is conditioned by the criteria for population health and safety, the safety of water systems operation and their protection, as well as the effective use of water resources. Mid-term projects must finalize the short-term projects and are largely driven by water supply continuity and customer satisfaction criteria.

***Armenia Advanced Science & Partnerships for Integrated Resource Development (ASPIRED) Project, 2015-2020***

The detailed description of the project was provided in sector of Agriculture of this annex. Regarding to the drinking water supply and sanitation sector, the following activities were conducted in the frame of the project:

- Improvement of drinking watersupply systems in:

- Aratashen community, around 560,000 $m^3$ of water saved annually; around 205,000 kWh of energy saved annually; 2,700 people benefited.
- Yeghegnut community, around 300,000 $m^3$ of water saved annually; -around 115,000 kWh of energy saved annually; 2,200 people benefited.

The above-mantioned activities of the project are relevant to the CC Adaptation Planning for "Water resource management" sector. The project had valuable elements, which can contribute for further improvements of the sector.

***USAID-funded "Clean Water and Energy" Project, 2011-2015***

The program was designed to support the country's water and energy security and improve climate resilience by providing technical assistance to support activities on integrated energy and water planning. It also worked at the community-level to improve energy and water management practices through capacity building and the implementation of small-scale pilot projects to demonstrate to public and private sectors, and to communities the benefits of applying new approaches and innovative technologies.

The project is relevant to the CC Adaptation Planning for "Water resource management" and "Energy" sectors. The project had valuable elements, which can contribute for further improvements of the above-mentioned sectors. The project targeted both water and energy sector and demonstrated integrated approach to clean energy and water best practices including drinking water access and sanitation. The activities directed to the Water resource management were incorporated climate change mitigation and adaptation strategies, contributing to the community resilience.

Through utilizing modern efficiency-based approaches to drinking water supply, LED street-lighting, radiant and solar heating, indoor lighting and improvement of general building conditions, CEWP has completed 14 demonstration projects in six regions of Armenia, thus providing nearly 50,000 people in the poverty-stricken rural and small urban centers of Armenia with improved energy and water services.

***World Bank, Municipal Water Project***

The goal of the Project is to ensure better quality and wider access to water supply in beneficiary communities and consequently to improve the socioeconomic and health conditions of residents in beneficiary communities, and to ensure a higher level of satisfaction with water supply and sanitation services among residents of communities in the Project area.

The project was implemented by Armenian Water and Sewerage CJSC and funded by World Bank.
In the frame of the project the following activities were carried out:

(i) rehabilitation of water systems in the cities of Masis, Echmiadzin, and Ashtarak, including their neighboring rural settlements,
(ii) water meter replacement and installation of meter chambers in several cities and villages throughout the AWSC Service Area to reduce commercial losses;
(iii) automation of pumping stations and reservoirs; and (iv) procurement of equipment and machinery for improved O&M system of AWSC.

The project is relevant to the CC Adaptation Planning for "Water resource management" sector. The project had valuable elements, which can contribute for further improvements of the sector. Considering those CC adaptation measures in NAP planning stage will be beneficial. The project was favourable for the Water Resource saving. The leakages and illegal water-use was eliminated, the water measurement and management helped to save potable water resources.

***WB/IBRD Municipal Water Supply and Wastewater Project – Additional Financing, 2012-2015***

The Project Development Objective is to support improvement of the quality and availability of water supply in selected service areas of the Armenian Water and Sewerage Company. The additional financing of Municipal Water Supply and Wastewater Project II would support the scaling up of the ongoing program of water system rehabilitation and improvements, including extension of the ongoing management contract. The proposed additional financing helps to enhance the sustainability, impact and development effectiveness of the ongoing project, maximizes its development outcomes as well as continues with the institutional and financial capacity building of AWSC.

The project was implemented by Armenian Water and Sewerage CJSC and funded by International Bank for reconstruction and development (IBRD).

The Project coverage area includes Masis, Echmiatsin and Ashtarak cities and adjacent villages (11 settlements; 3 urban and 8 rural) where a number of activities are implemented, such as renovation of the water supply system, replacement of water meters, installation of water meter chambers, automation of pumping stations and water reservoirs, improvement of operation and maintenance systems. The Project coverage includes 17,703 subscribers or beneficiary households.

The project is relevant to the CC Adaptation Planning for "Water resource management" sector. The project had valuable elements, which can contribute for further improvements of the sector. Considering those CC adaptation measures in NAP planning stage will be beneficial. Project supported the development of adaptive capacity for improved water resource management, improves water storage capacity in rural areas.

***KfW/EIB/EU Communal Infrastructure Program (CIP) II, Phase 3, 2016-2020***

The Project covers the *third phase* of the Communal Infrastructure Program that aims for sustainable improvement of water supply and sewerage for the population in the Armenia, thus raising of the living and health conditions. The project objective concerns the rehabilitation, renewal and extension of the water supply network as well as some urgent measures in the sewer system. Thus, the continuously and demand oriented supply of the population with hygienic sound drinking water shall be achieved.

The ultimate objective of the project was to make a sustainable contribution to reducing drinking-water-related health risks to the population in the programme region, while also using scarce drinking water resources more efficiently. The programme objective was to provide the population in the programme region with a continuous, economically efficient and hygienically safe water supply in accordance with local needs, as well as sewage disposal services that do not pose any direct risks to public health. Also, one of KfW Development Bank's primary objectives is to establish a hygienically safe water supply and adequate sewage disposal systems. (Sewage disposal also does not meet minimum standards: sewage is routed to the surrounding bodies of water or is transported directly to the groundwater by rain. The risks for the environment and health are high.)

The project implemented agency is “Water Sector Projects Implementation Unit” State Agency of the State Committee of Water Economy and is funded by KfW, EIB, EU.

The project is relevant to the CC Adaptation Planning for "Water resource management" sector. The project is still in design and tender stage, but the objectives are very important for Armenia. Project plans to support the development of adaptive capacity for improved water resource management, improves water storage capacity in rural areas. The objective of building sewage treatment plant (with biological treatment methods) and sewer collector construction are very important for Armenian settlements

***ADB / Water Supply and Sanitation Sector Project, 2008-2012***

Project aimed at improving the public health and environment for about 600,000 people living in 21 towns and about 101 villages where was an urgent need for Water Supply and Sanitation improvements through safe and reliable water supply and only urgent improvement of sewerage and sanitation facilities. Goal of the project was to improve the public health and environment for about 576,000 people living in 16 towns and about 125 villages through safe and reliable water supply and improved sewerage and sanitation facilities. Based on the submission made by the Government of the Republic of

Armenia (GRA) and as appraised by the Asian Development Bank (ADB), there were approximately 18 subprojects covering towns and villages where there was an urgent need for Water Supply and Sanitation (WSS) improvements. The Project helpt the Government to provide the required institutional and management support to the Armenia Water and Sewerage Company (AWSC) and local municipal governments to enable them to be more self-disciplined in financial, managerial, and technical aspects.

The project was implemented by Armenian Water and Sewerage CJSC and funded by ADB.

The project is relevant to the CC Adaptation Planning for "Water resource management" sector. The project aimed to reach potable water resource saving, which is highly recommended for CC adaptation purposes. Should be make sure that the future similar projects have CC adaptation section, where current sources of water need be evaluated, and CC scenarios took into account for each specific region where water sources are located. The huge investments should be done taking into account water availability for several decades in the future (considering both scenarios for 2070 and for 2100).

***ADB/Water Supply and Sanitation Sector Project- Additional Financing, 2012-2017***

The Project was aimed to improve public health and environment for about 400,000 people (households and other consumers) through safe, reliable and sustainable water supply through rehabilitation, replacement and/or extension of water distribution systems. The additional financing was ensure further public health and environmental improvements by providing potable and reliable water supply to households in approximately 18 towns and 92 villages in the provinces of Aragatsotn, Ararat, Amavir, Geharqunik, Tavush, Lori, Kotayq, Shirak, Syunik, and Vayotz-Dzor. The Asian Development Bank (ADB) loan was form part of a larger sector capital investment by the government of Armenia and other international financial institutions including the World Bank and the European Bank for Reconstruction and Development.

The project was implemented by Armenian Water and Sewerage CJSC.

In the frame of the project access to safe, reliable, and sustainable WSS in about 29 towns and up to 160 project villages was improved. Effective project implementation resulted in almost all project output indicator targets being achieved. Water supply systems in 29 towns and 160 villages were rehabilitated, replaced in full or part, and/ or extended by 2017, with 57,600 water meter chambers installed (target 40,000). By 2016, households in project towns and villages had access to reliable supplies of potable water that meets Armenian water quality standards for more than 16 hours per day on average (target 15 hours).
The project output indicator target for NRW loss reduction was achieved, with the level of losses within the overall AWSC service perimeter, including the project area (based on the AWSC's third quarterly report, 2016), reduced to 67.3% by September 2016. Under Loan 2363, NRW loss was reduced to 72.7% (by 2012) and under Loan 2860 it was reduced to 78.3% (by 2015). The project achieved tariff collection efficiency on average (in all towns and villages under the AWSC service area) of about 91.0%, as of December 2015.

The project is relevant to the CC Adaptation Planning for "Water resource management" sector. The project aimed to reach potable water resource saving, which is highly recommended for CC adaptation purposes. Should be make sure that the future similar projects have CC adaptation section, where current sources of water need be evaluated, and CC scenarios took into account for each specific region where water sources are located. The huge investments should be done taking into account water availability for several decades in the future (considering both scenarios for 2070 and for 2100).

***Water, Climate and Development in CACENA Region (Central Asia and Caucasus), 2012-2016***

In 2013, within the framework of “Water Climate and Development Programme in Central Asia and Caucasus” a pilot project was implemented by Country Water Partnership NGO. A domestic wastewater treatment plant was constructed in Paraqar community in the place of the WWTP existing during the soviet period. The construction was over in 2014 and was funded by UK Department for International Development.

A 1600m$^3$ capacity, 1000m$^3$ daily volume domestic wastewater treatment plant was constructed with a basin for mechanical treatment and a biological pond. The biological pond use water treatment method by water hyacinth.

Since 2015, the WWTP was operated and maintained by the local-self Government of the Parakhar community. The local government did not establish the wastewater discharge fee for residents of the community, due to the O&M of the WWTP required small expenses: cleaning the biological ponds and follow the system operation. The local Government has paid only for electricity for a pump operation. The pump worked automatically and switched on when the pond was becoming full. Due to the water hyacinth, the biological pond became a park and a nice place for the daily rest of the residents.

The wastewaters were treated in the basin for mechanical treatment first, and then flow into the biological pond, and after sedimentation were flow out from the pond treated. The ecological benefit of the WWTP was that the treated wastewater was discharged to the irrigation canal and was used by the small farmers in summer without water use fee. Before the WWTP operation, the irrigation canal collected the untreated wastewater, which further was used for irrigation proposes or polluted the Hrazdan River and surrounding. Due to operation of the WWTP, in the community there was about 10 l/s of additional irrigation water (treated wastewater) which was used to irrigate an area of 7.2 ha.

According to the process technology, the WWTP was designed to reduce the 260 mg $BOD_5$ per liter of wastewater up to 40 mg/l. The WWTP operation should be reduce the land degradation level, as well as will prevent the annual 12 tons of nitrogen and 6 tons of phosphorus to annually enter into ground waters. Anouther ecological benefit of the WWTP, was the sludge that was removed after cleaning the pond. The sludge was used by local people as a fertilizer or forage. The residents did not pay for the sludge use.

Since 2017, when the Veolia Jur has assumed the responsibilities of the Unified Operator for 15 years starting, the community handed duties of the WWTP to the Veolia Jur. During these transfer, some technical disagreements were raised, which later solved by the community, however, the Veolia Jur could not operate the WWTP. As of today, the WWTP does not operate, as well as the biological pond needs to be restored. The Veolia Jur wants to give back the O&M of the WWTP to the community, as well as the Parakhar community also willing to return the WWTP back. However, both of them do not have many for restoration of the pond.

The project is relevant to the CC Adaptation Planning for "Water resource management" and "Human Health" sectors. However, this failed due to improper management and maintenance of the system.

***EBRD/Lake Sevan Environmental project, 2009-2012***

On 26 April 2007 the Republic of Armenia and the European Bank for Reconstruction and Development (EBRD) signed the Loan agreement and on the same date EBRD and “Armenian Water and Sewerage” CJSC signed the Agreement on Investment Grant Co-financing for implementation of Lake Sevan Environmental project.

The goal of the project was construction of Mechanical Waste Water Treatment Plants (WWTPs) in Gavar, Vardenis and Martuni towns and rehabilitation of wastewater networks in Gavar, Vardenis, Martuni, Jermuk and Sevan. Lake Sevan Environmental Project constituted one step of a long-term capital investment program of the AWSC CJSC to improve efficiency and reduce operation and maintenance costs, water losses and discharges of untreated sewerage into Lake Sevan and Hrazdan River.

In 2013 mechanical Wastewater Treatment Plants (WWTPs) in Gavar (capacity` 10.476 m3 /day), Vardenis (capacity` 5.018 m3 /day) and Martuni (4.626 m3 /day) was constructed and operated, as well as wastewater networks (sewer pipelines) in Gavar (8,1km), Vardenis(4,1km), Martuni(5,0km), Jermuk (2,8km) and Sevan (5,5km) were rehabilitated.

The project is relevant to the CC Adaptation Planning for "Water resource management" and "Human Health" sectors. The project constructed mechanical wastewater treatment plants (WWTP), which is only removing solid matter from wastewater that may be floating or dispersed (plastic bags, rags, leaves, pieces of wood or other substances). It means those WWTPs are able to do only Primary treatment: In Armenia there is no biological cleaning, sludge removal or methane extraction during wastewater treatment. In addition to concentrating pollutant loads from WWTPs during prolonged dry periods, climate change can lead to increases in raw water turbidity and natural organic matter, including disinfection by-product precursor concentrations. It is estimated that climate change has a dual effect on WWTPs. Due to increased scarcity of water resources, wastewater reuse will become more necessary as climate change accelerates. On the other hand, during wastewater treatment, greenhouse gases (GHGs) including carbon dioxide ($CO_2$) from aerobic (oxidation processes), methane ($CH_4$) from anaerobic processes (3–19 % of global anthropogenic methane emissions), and nitrous oxide

($N_2O$) (3 % of $N_2O$ emissions from all sources) associated with nitrification/denitrification (NDN) processes, as an intermediate product, can be emitted to the atmosphere. In case of extreme hydrological events pose a big challenge to water utilities' daily operations. Demand patterns and flows in water mains and sewers will become more dynamic as a result of rainstorms and droughts. Treatment works will be challenged with more variable sewage flows, either diluted (rainstorms) or concentrated (droughts), sewers may not be able to cope with rainstorms, leading to sewer overflows and backflushing of sewage to street level, etc. This may lead to serious public health issues. Therefore, in NAP, a special emphasis should be given to the wastewater treatment plants adaptation requirements and necessity of having adaptive management strategies. For example, treatment wetlands have emerged as a viable option for wastewater treatment.

***EBRD/ Armenian Small Municipalities Water Project, 2012-2015***

On 14 July 2011 the Republic of Armenia and the European Bank for Reconstruction and Development (EBRD) signed the Loan agreement and on the same date EBRD and "Armenian Water and Sewerage" CJSC signed the Project Agreement for implementation of "Armenian Small Municipalities Water Project".

On 20 January 2011 the Republic of Armenia and European Union represented by the European Commission through the Neighborhood Investment Facility and "Armenian Water and Sewerage" CJSC signed Financing Agreement ("Grant-Co-Financing") for the implementation of the same Project. The Project foresees the contribution of the technical grants from other donor organizations.

The main objectives of the project were improvement of municipal water supply in Tavush, Lori, Shirak, Gegharkunik, Kotayk, Syunk and Vayots Dzor marzes and rehabilitation of wastewater treatment plants and sewerage collectors in the Tavush (town of Dilijan) and Vayots Dzor (town of Jermuk) marzes.

At the end of the project the wastewater treatment plants and sewerage collectors in the Tavush (town of Dilijan) and Vayots Dzor (town of Jermuk) marzes were rehabilitated/constructed, as well as municipal water supply in Tavush, Lori, Shirak, Gegharkunik, Kotayk, Syunk and Vayots Dzor marzes were improved. The project was implemented by Armenian Water and Sewerage CJSC and funded by EBRD.

The project is relevant to the CC Adaptation Planning for "Water resource management" and "Human Health" sectors. The project constructed mechanical wastewater treatment plants (WWTP), which is only removing solid matter from wastewater that may be floating or dispersed (plastic bags, rags, leaves, pieces of wood or other substances).

## Hydropower generation

***Main Issues, Status, Development Barriers, and Future Development of Small Hydro Power, 2010***

This program focuses on assisting the energy sector of Armenia to improve potential for supply independence and security. It presents 115 possible resource sites with a capacity of 147 MW, and with annual generation capacity of 540 GWh. It provides detailed indicators of 65 licensed (yet not constructed) small HHPs with potential capacity of 158 MW and with annual generation of 500 GWh. It also presents data for various financial indicators and possible financing schemes.

***Renewable Energy Expansion Project, 2014***

The project outlines the renewable energy technologies and projects, which can best contribute to the country's energy, economic and environmental development, as well as the steps towards the implementation of the mentioned projects. Without production of major hydroelectric power plants, renewable energy production in 2014 accounted for 8.9%[65] of total energy production. The Government of Armenia targets to achieve 21% by 2020 and 26% by 2025.

The project is implemented with financial support of Climate Investment Fund.

***2014-2020 Action Plan for ensuring implementation of the RA Energy Security Concept Provisions, 2014***

The plan outlines concrete actions, which must be carried out for implementation of the RA energy security concept and renewable energy expansion project objectives.

***RA Energy sector long-term (until 2036) development ways, 2015***

The project is aimed at providing sustainable development of energy sector, based on development of nuclear energy, efficient use of renewable resources. construction of combined -cycle thermal power plants and diversification of energy resources import routes.

In 2018 the Ministry of Territorial Administration and Infrastructure, with USAID's support, undertook the development of a new long-term energy system development strategy for the country, to provide more ambitious development of renewable energy sources, diversification of the fuel supply chains through implementation of regional cooperation and integration projects.

***Eastern Partnership Programme, 2016-2021***

[65] "Computing Center" CJSC, Analysis of Feasibility Indicators, 2014.

Numerous projects are being implemented within the framework of the Eastern Partnership (EaP) programme at present, aimed at climate change mitigation, involving a wide range of different sectors of the economy, marzes and cities of Armenia.

*Covenant of Mayors East* (2011). The project is aimed at bringing together local governments and regional authorities with universal voluntary commitment in favour of “green” economic growth and life quality improvement. The Covenant signatory communities have voluntarily agreed to implement consistent actions within their administrative areas in ES and renewable energy sectors, which will allow reducing carbon dioxide ($CO_2$) emissions by at least 20% until 2020. To achieve this goal, the municipal authorities have agreed to develop and implement Sustainable energy development action plans.

As of 2019, twenty-four cities have joined the Covenant, and 10 cities have developed Sustainable energy development action plans.

EU for Environment Regional Programme (2019). The programme will support policy development and legislative reformations in six EaP countries (Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine) through 'green' planning and investments, incorporation of innovative technology, adoption of new business models, and creation of 'green' jobs.

EU for Climate (EU4Climate) Regional Programme (2019). The goal of the programme is to support the development and implementation of climate policies of six EaP countries, which will contribute to the sustainable development of the countries under conditions of low emissions and climate change and to the implementation of the UNFCCC commitments under the Paris Agreement.

EU for Energy (EU4Energy) Regional Programme (2017). The programme aims to improve the quality of energy data and statistics in six beneficiary countries, to formulate regional policy discussions, to strengthen legislative and regulatory frameworks and to improve access to information in partner countries.

In addition, the programme provides technical assistance to the six EaP countries for main investments in legislative and regulatory framework and energy infrastructure.

Eastern Europe Energy Efficiency and Environment Partnership Programme (E5P) (2015). To join the Eastern Europe Energy Efficiency and Environment Partnership Foundation (E5P Foundation), an investment agreement was signed between the RA Ministry of Energy and Natural Resources and the EBRD in 2015. It enables involving E5P grants and soft loans from international financial institutions to implement heating, power supply, energy saving and renewable energy projects in various sectors of economy. Armenia has been provided with a grant of approximately EUR 20 million, and another EUR 3 million through the EBRD to finance projects to be implemented.

Currently, solid waste management projects in Kotayk and Gegharkunik Marzes, as well as in Yerevan, Gyumri Street Lighting, Yerevan Street Lighting and Yerevan Energy Efficiency projects are being implemented under the E5P Foundation.

***Supporting new reforms in SHPP sector through CSO-government dialogue, 2014-2016***

In 2014-2016 "EcoLur" NGO in partnership with RA Nature Protection Ministry implemented the project on "Support to SHPP-relating reforms through the dialogue of public and RA Nature Protection Ministry for Sustainable Use of River Ecosystems" funded by the GEF-SGP.

The project results created necessary basis for advancement and policy reforms in SHPP sector. Aiming to improve small hydro design and development processes, the project developed a package of proposals submitted to governmental agencies and departments in SHPP sector, to agree on optimal solutions adopting environmental approaches.

The main objective of the project is to implement reforms in small hydro sector through formation of a dialogue between CSOs and the government. To achieve this objective the project plans to i) complement the SHPP information database by adding the results of the SHPP that have not yet been studied; ii) create a permanent forum for cooperation on SHPP sector - a council including public,state and business players, thus enhancing transparency of public institutions and making small hydro reforms process more inclusive, and iii) develop "Draft Concept on National SHPP Sector Development Strategy", incorporating environmental considerations, institutional and policy reforms aimed at the conservation of river ecosystems.

With the adoption of this resolution, it's expected to promote the preservation of water ecosystem and to ensure balance in case of SHPP construction and operation.

## Construction of water reservoir

***KfW / Management of water resources of the border Akhurian River, 2015-2022***

The construction of 25 mln. $m^3$ of Kaps reservoir will increase the water supply level of the lands adjacent to Shirak and Akhuryan Canals. About 12,325 hectares of land, which is served by Shirak WUA (Shirak main canal) are located under the coverage of Kaps reservoir. Regular and reliable irrigation will increase the production of agricultural products as well as farmers will start to process more profitable crops.

The main goals of the project are:

- (i) replace mechanical irrigation with gravity,
- (ii) increase water availability,

(iii) ensure reliable and uninterrupted irrigation,

(iv) increase the area of the new cultivated land plots.

The project is implemented by “Water Sector Projects Implementation Unit” State Agency of the State Committee of Water Economy and is funded by KfW. The project is consists in two phases: Phase 1 started in 2015-2018 and phase 2 started in 2019-2022.

The project is being implemented with the credit of the Government of the Federal Republic of Germany (KfW) and co-financing by the Government of the Republic of Armenia. Funds will be provided through the Recovery Credit Facility. During the project implementation (2014-2015) with financial support (grant) from the German Bank for Reconstruction and Development (KFW), “CES Consulting Engineers Salzgitter GmbH”, “AHT Group AG Management & Engineering” and “Yerevan State University of Architecture and Construction” JV conducted a feasibility study on "IWRM/ Construction of Akhuryan River-Kaps Reservoir and Kaps Gravity Irrigation System”. Following the Feasibility study, the tender process for the “ Consulting Services for Detailed Design and Tender Documentation” was conducted.

On March 10, 2016, the preparation of detailed design and tender documents of the "IWRM/ Akhuryan River, Phase 1, Construction of Kaps Reservoir and Kaps Gravity Irrigation System”. Project was launched. The Stage 1, Phase 1 of construction of the Kaps reservoir envisages the reconstruction and construction of the Kaps reservoir with a total capacity of 25 million $m^3$, in case of which the height of the dam will be H = 55 m, as well as establishment of a regular monitoring process, including the reconstruction of the existing water metering points and construction of new / additional water metering points along the upper stream of the Akhuryan River. During the first phase, the dam base will be built in a manner, to allow its raising to a maximum of 60 million $m^3$ volume during the second phase.

The first part of the Environmental and Social Impact Assessment (BMZ ID 2014 67 950) report on the “Construction of the Kaps Reservoir and Gravity Irrigation System” presents the expected impacts of the reservoir construction on climate or the water flow changes in the Akhuryan River due to climate change. The assessment and analysis is based on the results of the Akhuryan River Basin Management Plan, as well as on the 3rd and 4th national communications of Armenia.

According to the assessment, it is expected that the flow of the Akhuryan River is expected to rise by + 4.5% and + 9.1% in 2100 against the baseline data of 1961-1990. At present, the efficiency of water use for irrigation purposes is very low, which results in high water losses. Reducing overall irrigation water demand will therefore help to combat the outflow due to climate change. According to the expert assessment, irrigation efficiency can be increased by 45%, branched irrigation lines can lead to 50-60% efficiency, and drip and sprinkler irrigation can provide much higher efficiency. The potential impacts of the project implementation on climate change will be small. The future reservoir can affect the microclimate and climate of the surrounding area due to high evaporation. Tree cutting and removal prior to filling the reservoir is mandatory to avoid greenhouse gas emissions from submerged vegetation. Removal of other organic matter and humus topsoil will prevent future greenhouse gas emissions from the reservoir. It is also to be clarified that the Project will contribute to the reduction of greenhouse gas emissions, as well as to energy savings through the transition from pumped to gravity irrigation system.

The expected impacts on climate or climate change represented in the ESIA section on the expected environmental and social impacts after the implementation of the mitigation measures were assessed as low.

These measures are as follows:

- Reducing the total irrigation water demand by increasing the efficiency of the irrigation system (e.g. water loss reduction, drip irrigation, etc.) can support in combatting the impacts on flow due to climate change.
- Before filling the reservoir, remove vegetation and humus-rich soil layer from the reservoir area to avoid further GHG emission (approximately 2500 trees).

The project is relevant to the CC Adaptation Planning for "Water resource management" and “Agriculture” sectors. The project by itself is very important CC adaptation measure and has adaptive capacity building aspects, which can contribute for further improvements of the sector. Construction of new small water reservoirs is technical measure enhancing adaptive capacity and improving water resource management. Considering similar projects in NAP will be beneficial from water resource effective management perspective.

***French Development Agency / Vedi Reservoir Construction, 2016-2021***

The Vedi reservoir is planned to be constructed in Ararat province, on the right side of the Vedi River, on the Kotuc mudflow. Construction of 29 mln. $m^3$ of Vedi reservoir will increase the water supply to 3,200 hectares of land served by Vedi and Ararat WUAs. The exploitation of 13 pump stations will be stopped; as a result of the shift to the gravity system about 19 mln. kWh per hour energy will be saved. In addition, as a result of reconstruction of the second-tertiary canals and modernization of the network, irrigation water losses, as well as exploitation and maintenance costs will be reduced. Currently, the network efficiency is estimated at 50-60%. As a result of the project implementation, the network's efficiency will reach 80-85%.

The Vedi reservoir was designed in 1991 to irrigate 4.0 thousand hectares of Ararat valley lands, of which 2.8 thousand hectares - replacement of mechanical irrigation by gravity irrigation.

With financial support of French Development Agency (GDA) grant, the feasibility study for the “Vedi Reservoir and Irrigation System Construction Project” was commenced and completed in 2013-2014.

“Vedi Dam and Irrigation System Construction” Project was launched in March 2017, with the loan of the French Development Agency and EUR 15 million co-financing by the Government of Armenia. The project with a total cost of EUR 90 million has several components: in addition to the construction of the reservoir, the project includes the construction of water intakes and water transmission systems on the Vedi and Khosrov rivers, reconstruction of irrigation system and tertiary irrigation network.

Water from the Vedi reservoir will be supplied through a 36.2 km pipeline to eight communities: Urtsadzor, Vedi, Dashtakar, Gorvan, Ararat, Aygevan, Noyakert and Avshar, over 3220 hectares of irrigated land.

The construction of Vedi Reservoir will be completed in 2022; however, it is envisaged to make partial irrigation from the reservoir in 2020.

The paper on "Construction of the Vedi Reservoir for Irrigation in the Ararat Valley" addresses the assessment data of climate change impacts on the Vedi River. The third National Communication of the Republic of Armenia served a basis for the analysis. According to the analysis, due to climate change impacts on the Vedi River basins, it is projected[66]:

- By 2040, there will be a 2-3% increase in annual river flow ;
- In 2041-2070, there is projected decrease in river flows which will reach 3-4% in 2070;
- In 2100, the projected decrease will reach to 12-14%.

These data served a basis for the design works for the construction of the Vedi reservoir. Therewith, a decrease of 14 % on inflows for calculations (Year 2100), with the 75% probability year was considered.

The project is relevant to the CC Adaptation Planning for "Water resource management" and “Agriculture” sectors. The project by itself is very important CC adaptation measure and has adaptive capacity building aspects, which can contribute for further improvements of the sector. Construction of new small water reservoirs is technical measure enhancing adaptive capacity and improving water resource management. Considering similar projects in NAP will be beneficial from water resource effective management perspective.

***World Bank / Eurasian Development Bank Mastara Reservoir Preparation***

The Mastara reservoir project envisages to enhance irrigation water demand shortage in 6 communities of in Armavir Marz and to extend fertile lands of Ararat Valley by increasing irrigated lands with 675 ha of non-cultivated land. The Project will make it possible to provide gravity irrigation water to those areas of beneficiary communities that use pumped water (from deep wells) saving on operation expenses and the energy.

[66] Climate change projections for the Vedi river basin was assessed using the CCSM4 model. Future change forecasts for ambient air temperature and rainfall have been developed up until 2100.

The construction of the reservoir is aimed for subsidiary water conveyance to Armavir main canal to improve irrigation in 6 communities of the Hatsik (1,081ha), Myasnikyan (836 ha), Khanjyan (533.5 ha), Lukashin (689.4 ha), Norapat (252.9 ha) and Noravan (315.6 ha) which are in the Armavir Marz (Province) by irrigating 3,708 ha: In addition, the reservoir will provide water for additional 675 ha in Hacik (60.6 ha), Myasnikyan (517 ha), Khanjyan (22 ha), Lukashin (54.8 ha), Norapat (20 ha) and Noravan (1 ha) which are currently non-irrigated arable lands. In 2017 the total irrigated area in these communities was 3,708 ha of land. With the construction of the reservoir additional 675 ha of land will be irrigated in Hatsik.

On the whole there is a need to provide water to 4,384 ha of land. These communities are annually supplied with 18.2mln $m^3$ irrigation water (2013-2016) out of which 2.31mln $m^3$ from deep wells and 0.33mln $m^3$ from pumping stations, however, there is a need for additional 6.9mln $m^3$ irrigation water to cover the entire demand.

The Government of the RA makes major efforts to solve significant challenges related to the lack of modern irrigation systems, including both its own resources and those of the international organizations. With the World Bank (WB) support the Government of the RA implemented the Irrigation Development Project, and the Dam Safety Projects I and II. These projects conducted the most critical interventions helping to secure operation of 8 major irrigation systems. Another World Bank supported project is the Irrigation Rehabilitation Emergency Project (IREP). At present, the Irrigation System Enhancement Project (ISEP) including construction of gravity schemes and rehabilitation of main and secondary canals funded by the WB, as well as construction of Baghramyan-Norakert tertiary network by the WB additional funding are nearing to end. Meanwhile, a new Irrigation Systems Modernization Project funded by Eurasian Development Bank (EDB) has commenced including construction of gravity schemes, rehabilitation of main and secondary canals and tertiary networks.

RA has received a grant from the Europe and Central Asia Region Capacity Development Multi-Donor Trust Fund governed by the World Bank (WB). The development objective of the Grant-financed operation is to carry out the feasibility study, prepare the Preliminary Design and undertake Environmental and Social Impact Assessment (ESIA) for the construction of Mastara Reservoir, as well as preparation of other Project documents. The Project also aims at strengthening capacity of the Water Sector Project Implementation Unit State Agency (WSPIU) of the State Committee of Water Economy under the Ministry of Energy Infrastructure and Natural Resources in the areas of procurement, monitoring and assessment for the preparation and execution of the Project.

The hydrological report on Selav Mastara and Akhuryan River Basins prepared by “Module 2015” LLC (Armenia), “National University of Architecture and Construction of Armenia” Foundation and “Tusab Consulting Eng” indicates that during the period of 1931-2006 the river flow change dynamics has a tendency to decrease up to 5-3% in the Akhuryan and Selav Mastara River Basins The report assessed the vulnerability of surface water resources of the Selav-Mastara and Akhuryan rivers in 2017-2040, 2041-2070, and 2071-2100.The water resource vulnerability of the rivers was assessed according to CCSM4 (Climate System Model 4) model data based on RCP8.5 (previously adopted A2 equivalent) and

RCP6.0 (B2) emission scenarios. It has been shown that due to global climate change the natural flow of the Selav Mastara River basin can decrease by 10%, and that of the Akhuryan River Basin – by 10% to 20% by 2040.

The project is relevant to the CC Adaptation Planning for "Water resource management" and “Agriculture” sectors. The project by itself is very important CC adaptation measure and has adaptive capacity building aspects, which can contribute for further improvements of the sector. Construction of new small water reservoirs is technical measure enhancing adaptive capacity and improving water resource management. Considering similar projects in NAP will be beneficial from water resource effective management perspective.

This project is in the preparation phase, preliminary assessment and documentation was prepared by Irrigation PIU, but for further advancement (main Design and implementation (construction) needs donor agency.

***Construction of Yeghvard Reservoir***

The design for construction of Yeghvard reservoir was made in the 1970s as one of Lake Sevan environmental protective measures. Later on in the 1980s the construction works of a 228 mln $m^3$ capacity reservoir were started, but the works were stopped because of financial problems. In the 1990s due to the second recorded drop of the Lake Sevan water level, a return was made to the reservoir construction and the Yeghvard reservoir plan was considered as one of the steps to prevent the lake's decline. During the years of independence, the reservoir volume was revised and decreased up to 90 mln $m^3$.

In 2012, the Japan International Cooperation Agency (JICA) developed an interim report on feasibility studies for the "Improvement of Yeghvard Irrigation System" project, which should have been followed by construction work. However, construction work has not yet started.

## Annex 10. Climate change adaptation measures to improve the monitoring network on hydrometeorological service

The hydrometeorological monitoring system of the Armenian hydrometer service consists of 47 meteorological stations and 7 hydrological (river basins) stations with 94 gauges. The hydrological monitoring system includes 93 hydrological observations, for 84 river, 5 reservoirs (Arpilich, Akhuryan, Aparan, Marmarik, Azat) and 4 lakes (Lake Sevan). Five meteorological stations are functioning over 100 years.

Hydro-meteorological monitoring system needs to be renovated and installed of a state-of-the-art observation network. Hydrometeorological monitoring network upgrades have been implemented with the support of a number of donor organizations to improve climate change monitoring and data acquisition.

***Modernizing Weather, Climate and Hydrological Services: A Road Map for Armenia, 2018***
***World Bank's Armenia National Disaster Risk Management Program***[67]

The Road map is prepared as part of the World Bank's Armenia National Disaster Risk Management Program and presents a potential scenario to strengthen the country's hydrological and meteorological (hydromet) services based on the needs of the user community. The initative was launched in 2018.

Specifically, the Road Map posits three scenarios for modernizing the Armenian Service for Hydrometeorology (AHS) based on the potential cost and benefits of each while aiming for a greater national and regional public good.

The proposed scenarios target the AHS capacity:

(i) to produce, manage, translate and communicate hydrometeorological (hydromet) information to the user community;
(ii) to assist the community in accessing, interpreting and using the information;
(iii) to better disseminate and respond to warnings for public safety and economic security; and
(iv) to inform planning and decision-making for cost-effective investments in climate-resilient development. Strengthening these four pillars can help solidify Armenia's resilience to natural hazards and climate change. And help enhance the economic performance of such weather-dependent sectors as agriculture, energy, transport and water resources management.

[67] http://documents.worldbank.org/curated/en/684751548347371395/pdf/134019-WP-P167315-Hydrometeorological-Report-Armenia-September2018-Final.pdf

Strengthening these four pillars can help solidify Armenia's resilience to natural hazards and climate change. And help enhance the economic performance of such weather-dependent sectors as agriculture, energy, transport and water resources management. In the end, the purpose of this analysis is to support the government of Armenia in saving lives and livelihoods and in protecting gains in social and economic development through a robust but discerning hydromet system.

***EUWI Plus for the Eastern Partnership (EUWI+ 4 EaP) project, 2016-2020***

Within the framework of this project, 6 hydrological observation posts located in Sevan and Hrazdan regions were renovated (5 observation posts on the rivers and 1 on the Aparan reservoir, Table). In two hydrological observation points, a hydrometric bridge and 3 ropeway crossings were installed. MicroStep water level monitoring radar have been installed at six posts.

**Up-to-date hydrologic observation points recommended in the framework EUWI+ project**

| № | Name | Coordinates | |
|---|---|---|---|
| | | X | Y |
| 1 | Hrazdan-Hrazdan | 40,5224 | 44,7682 |
| 2 | Hrazdan-Argel (Lusakert) | 40,3809 | 44,6054 |
| 3 | Hrazdan-Yerevan | 40,1593 | 44,4898 |
| 4 | Marmarik-Aghavnadzor | 40,5715 | 44,6910 |
| 5 | Qasakh-Hartavan | 40,4788 | 44,4411 |
| 6 | Aparan reservoir-Hartavan | 40,4848 | 44,4382 |

**Increase Resilience of Armenia to Climate Change through Modernization of Armenia's Hydrometeorological Service*, UNDP 2019-2020***

The overall goal of the project is to improve climate change adaptation planning and programming in Armenia through enhancing the capacity of national hydro-meteorological observation and warning services, for strengthening Armenia`s resilience to Climate Change risks. The project focuses on strengthening the technical and professional capacities of the Armenia Hydrometeorological Service (AHS) to ensure adequate forecast and warning services for contributing to climate resilient development. A substantial modernization program for the Armenia Hydrometeorological Service will include three directions.

The project was launched in January 2019 and should be completed in December 2020.

Project objectives are as follows:

1. Hydro-meteorological observation and forecasting system enhanced and modernized.
2. Hydrometeorological observation and warning infrastructure improved.
3. Hydro-meteorological service delivery and early warning mechanisms enhanced.

The list of meteorological observation posts that will be upgraded as part of the program is presented in the table below:

| № | Station name | Marz | Altitude (m) | Coordinates | |
|---|---|---|---|---|---|
| | | | | X | Y |
| 1 | Ashocq | Shirak | 2012 | 41,0325 | 43,8700 |
| 2 | Amasia | Shirak | 1849 | 40,9503 | 43,7836 |
| 3 | Gyumri | Shirak | 1528 | 40,7628 | 43,8558 |
| 4 | Artik | Shirak | 1724 | 40,6233 | 43,9550 |
| 5 | Vanadzor | Lori | 1376 | 40,8389 | 44,4344 |
| 6 | Pushkini pass | Lori | 2066 | 40,9092 | 44,4347 |
| 7 | Stepanavan | Lori | 1397 | 41,0019 | 44,4128 |
| 8 | Odzun | Lori | 1105 | 41,0603 | 44,6103 |
| 9 | Tashir | Lori | 1507 | 41,1167 | 44,2792 |
| 10 | Talin | Aragatsotn | 1637 | 40,3864 | 43,8931 |
| 11 | Amberd | Aragatsotn | 2071 | 40,3850 | 44,2603 |
| 12 | Tsaghkahovit | Aragatsotn | 2101 | 40,6361 | 44,2211 |
| 13 | Aparan | Aragatsotn | 1889 | 40,5944 | 44,3639 |
| 14 | Ashtarak | Aragatsotn | 1090 | 40,2944 | 44,3428 |
| 15 | Aparan reservoir | Aragatsotn | 1843 | 40,4844 | 44,4361 |
| 16 | Aragats H/M | Aragatsotn | 3227 | 40,4722 | 44,1811 |
| 17 | Armavir | Armavir | 870 | 40,1372 | 44,0475 |
| 18 | Yerevan/Agro | Yerevan | 942 | 40,1886 | 44,3986 |
| 19 | Yerevan/Aero | Yerevan | 1134 | 40,2172 | 44,4997 |
| 20 | Ananun pass | Ararat | 2122 | 39,8306 | 44,9919 |
| 21 | Areni | Vayots Dzor | 1009 | 39,7272 | 45,1883 |
| 22 | Vorotani pass | Vayots Dzor | 2387 | 39,6931 | 45,7117 |
| 23 | Jermuk | Vayots Dzor | 2064 | 39,8339 | 45,6711 |

***Improvement of the hydrometorological monitoring network in frame of the KfW /* "IWRM/Akhuryan river, Phase 1" project*, 2015-2022***

Within the «IWRM/Akhuryan river, Phase 1» project on constructing Kaps water, the document on the renovation of existing hydrological observation posts and the establishment of new ones in Akhuryan River Basin was drafted.

The proposed new observation posts and those which will be renovated are presented in table below:

| № | Name | Status | Coordinates | |
|---|---|---|---|---|
| | | | X | Y |
| 1 | Akhuryan-Paghakn | rehabilitation | 41,0651 | 43,6621 |
| 2 | Akhuryan-Amasia | rehabilitation | 40,9490 | 43,7901 |
| 3 | Akhuryan-Kaps DS | new | - | - |
| 4 | Akhuryan-Jradzor | new | - | - |
| 5 | Ashocq-Krasar | rehabilitation | 41,0301 | 43,8206 |
| 6 | Illiget-Goghovit | new-rehabilitation | 40,9229 | 43,8301 |
| 7 | Karkachun-Gharibjanyan | rehabilitation | 40,7343 | 43,7874 |
| 8 | Jajur-Jajur | rehabilitation | 40,8476 | 43,9474 |

***"Establishment of a national climate service" initiative in the frame of the UNDP National Adaptation Plan to Advance Medium and Long-Term Adaptation Planning in Armenia Project, 2020***

In January, 2020 the new initative on "Establishment of a national climate service" within the UNDP National Adaptation Plan to Advance Medium and Long-Term Adaptation Planning in Armenia Project was launched. The initative is implemented by experts of Zoi Environmental Nnetwork.

The program aims to improve the quality and capabilities of climate services in Armenia, making hydro-meteorological and climatic information available for public use.

The National Climate Services Framework (NCSF) is being developed under the auspices of the Global Climate Services Framework (GCSF) and the Global Facility for Disaster Reduction and Recovery (GFDRR).

Four main actions are envisaged that will contribute to the development of an effective and national NCSF:

- NCSF Consulting Workshop. This event will launch the process of developing NCSF, uniting all the major producers and users of climate services in Armenia to discuss the formation of the NCSF and related action plan.
- Drafting the NCSF. Based on the results of the consulting workshop, a draft verison of the NCSF will be prepared jointly with the Armenian Hydrometeorological Service.
- The NCSF approval workshop. Following the development of the final draft of the NCSF and Action Plan, a second national workshop will be initiated to discuss the draft version, possible changes, and finally approvement.
- Develop a user-friendly information brochure that describes the needs, structure, and outcomes of the NCSF.