1. **ASSESSMENT AND ANALYSIS OF WATER SUPPLY AND DEMAND IN THE ARARAT RIVER BASIN MANAGEMENT AREA**

**12.1 Water resource supply by individual water resources**

The water sector legislation of the Republic of Armenia emphasizes the importance of economic and financial mechanisms in the management of water resources. Article 5 of the Water Code of Armenia highlights that water possesses both environmental and economic value, regardless of its utilization. The economic value of water encompasses its contributions to drinking water supply, environmental preservation, energy production, and agricultural activities. As such, the economic value of water must be considered in the processes of water use, distribution, and protection. The Water Code of Armenia lays down principles for the economic regulation of water resource management, water supply, sanitation systems, restoration, and protection. Article 76 emphasizes the need for efficient water distribution and the establishment of fair pricing for water. Article 79 addresses the setting of tariffs for water use, taking into account different river basins, various categories of water use, and quality indicators based on water resource classification.

For the economic analysis of water use in the Ararat River Basin (Ararat RBD), the System of Environmental-Economic Accounting for Water (SEEA-Water) and Article 5 of the Water Framework Directive (WFD) recommend analyzing the following five sectors: agriculture, industry, energy, fisheries, and households.

The Ararat River Basin Management (RBM) area encompasses a diverse hydrological landscape, with both surface and groundwater resources playing crucial roles in the region's water supply. This section provides an in-depth analysis of the water resources within the Ararat RBM, based on data collected from 2020 to 2023.

As illustrated in Table 1, surface water is the main contributor to the annual water intake volume in the Ararat River Basin. The table demonstrates the distribution of water intake between surface waters and groundwaters in 2023, providing a clear visual representation of the basin's water resource utilization.

Table 1. The Annual Water Abstraction in Ararat RBD by Sectors and Water Source (2023, Thousand m³).

| Sector | Groundwater | Surface water | Grand Total | Grand Total (%) |
| --- | --- | --- | --- | --- |
| Absorption | 6.80 | 0.00 | 6.80 | 0.28% |
| Bottling | 0.25 | 0.00 | 0.25 | 0.01% |
| Fishing | 7.17 | 22.86 | 30.03 | 1.25% |
| Household | 24.76 | 0.00 | 24.76 | 1.03% |
| Industry | 4.24 | 1.68 | 5.91 | 0.25% |
| Irrigation | 23.72 | 414.60 | 438.33 | 18.22% |
| Electricity | 0.00 | 1,899.41 | 1,899.41 | 78.96% |
| Grand Total | 66.93 | 2,338.56 | 2,405.48 | 100.00% |

**12.1.1 Surface water resources**

Surface water resources play a dominant role in the Ararat River Basin's water supply system. As evidenced by the data in Table 1, surface waters contribute significantly to various sectors, particularly electricity generation and irrigation. In 2023, surface water accounted for 2,338.56 thousand m³ of the total water abstraction in the basin, representing 97.22% of the total water use.

Key observations for surface water use include:

1. Electricity Generation: This sector is by far the largest user of surface water, accounting for 1,899.41 thousand m³ (78.96% of total water use) in 2023. However, it's crucial to note that this use is largely non-consumptive, as discussed in the special consideration for hydropower plants.
2. Irrigation: The second-largest consumer of surface water, using 414.60 thousand m³ (17.22% of total surface water use) in 2023.
3. Fishing sector also relies significantly on surface water, using 22.86 thousand m³ in 2023.
4. Industrial use of surface water is relatively small at 1.68 thousand m³.

The distribution of surface water use across different administrative regions (as shown in Chart 2) indicates that Vayots Dzor and Ararat regions are the primary users of surface water resources, particularly for electricity generation and irrigation.

**12.1.2 Groundwater resources**

While groundwater resources constitute a smaller portion of the water supply in the Ararat River Basin compared to surface water, they play a crucial role in certain sectors. According to Table 1, groundwater abstraction in 2023 totaled 66.93 thousand m³, which is 2.78% of the total water usage.

Key points regarding groundwater use include:

1. Household use is the largest consumer of groundwater, using 24.76 thousand m³ in 2023. This suggests that groundwater is a critical source for domestic water supply in the basin.
2. Irrigation is the second-largest user of groundwater, abstracting 23.72 thousand m³ in 2023.
3. Fishing, industry, and absorption also utilize groundwater resources, though to a lesser extent.
4. Notably, the electricity generation sector does not use groundwater resources according to this data.

The reliance on groundwater for household use and irrigation underscores the importance of sustainable management and monitoring of these resources to prevent overexploitation and ensure long-term availability for these critical needs.

Key findings from the regional analysis include:

1. Vayots Dzor: This region consistently shows the highest water intake, primarily due to its significant use of surface water for electricity generation and irrigation. In 2023, Vayots Dzor accounted for 1,769,396 thousand m³ (83.51%) of surface water used for electricity and 318,966 thousand m³ (15.05%) for irrigation.
2. Ararat: The Ararat region shows diverse water use, with significant volumes for irrigation (117,616 thousand m³ or 55.82% in 2023) and electricity generation (56,268 thousand m³ or 26.70% in 2023).
3. Kotayk: This region primarily uses surface water for electricity generation, with 52,767 thousand m³ (95.96%) used for this purpose in 2023.
4. Lori: While Lori shows relatively lower water intake volumes, it's notable that 100% of its recorded water use in 2023 (20,980 thousand m³) was for electricity generation.

By examining the water abstraction volumes and associated costs in these critical sectors, we can gain valuable insights into the water utilization patterns and financial implications within the Ararat River Basin. This analysis serves as a fundamental component in formulating effective water resource management strategies, ensuring the sustainable and equitable distribution of water resources while considering the economic value of water for the overall socio-economic development of the basin.

**12.1.3 Usable, Strategic and National Water Reserves**

The Republic of Armenia's National Water Program sets forth fundamental principles for estimating national, strategic, and usable water reserves, as well as assessing water supply and demand, addressing key issues, and outlining perspectives for water sector protection and development. In light of the limited availability of water, its significance for human well-being and ecosystem preservation, the program emphasizes evaluating water resources in relation to demand to maintain ecological balance within both water and broader ecosystems.

The National Water Program defines estimates for usable, strategic, and national water reserves across all 6 River Basin Districts (RBDs).

Usable Water Resources: These are the water resources available for consumptive use without compromising the National Water Reserve. They encompass river flow generated within Armenia's territory, a portion of river flows, and renewable groundwater resources, excluding ecological flow. Water usage permissions cannot exceed the usable resources allocated to specific water bodies according to basin management plans.

Strategic Water Reserve: This pertains to the quality and quantity of water necessary to meet essential human needs and safeguard water ecosystems during emergency situations such as droughts, ecological disasters, and energy crises. Strategic groundwater reserves are derived from consistent use of flows from existing wells and those newly drilled. The strategic reserves undergo periodic adjustments by the Government of Armenia and are utilized based on government decisions.

National Water Reserve: This encompasses the quality and quantity of water needed to fulfill current and future human needs, protect aquatic ecosystems, and ensure sustainable development and utilization of water resources. The national water reserve is calculated as the difference between Armenia's overall water resources and the sum of usable and strategic water reserves.

The use of the National Water Reserve is generally prohibited except in cases of strategic water reserve depletion. Such decisions are made by the Government of the Republic of Armenia, following the recommendations of the National Water Council of Armenia. The national water reserve comprises elements such as lake volumes, deep groundwater resources, and glaciers prior to melting.

**12.1.4 Current and Future Water Supply in Ararat RBD**

This section focuses on the assessment of surface water supply within the primary river basins of the Ararat River Basin District (RBD). Table 2 presents the surface water supply data for various hydrological observation points across the Ararat RBD. These data provide crucial insights into the availability and distribution of water resources throughout the basin.

It is important to note that comprehensive data for groundwater resources in the Ararat RBD are currently limited. Moreover, groundwater discharge represents only a small fraction of the overall water usage in the basin. Due to these factors, a detailed calculation of groundwater supply and demand cannot be accurately performed at this stage.

The focus on surface water is justified by its predominant role in the basin's water dynamics, as evidenced by the water usage data presented earlier. Surface water sources, particularly those utilized by the hydropower and irrigation sectors, constitute the majority of water use in the Ararat RBD.

This analysis of surface water supply serves as a foundation for understanding the basin's water resources and will inform subsequent discussions on water allocation, management strategies, and potential challenges in meeting various sectoral demands.

Table 2. Average Surface Water Supply in Ararat RBD.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Hydrological observation points** | Azat-Garni | Vedi-Urtsadzor | Arpa-Jermuk | Arpa-Yeghegna-dzor | Arpa-Areni | Vaik-Zaritap | Yeghe-gis-Hermon | Yeghe-gis-Shatin | Selima-get-Shatin | Artabun-Artabyunk |
| **Annual, mil m3** | 129.5 | 56.5 | 127.0 | 437.6 | 730.4 | 12.8 | 158.9 | 270.7 | 66.1 | 34.1 |

\* The average is calculated on the observation data from 2010 to 2023

To calculate the seasonal water supply in the Ararat RBD for the year 2023, the main characteristics of average annual and seasonal runoff have been considered. The Ararat River exhibits distinct stages throughout the year, including spring high water, summer-autumn flow, and low water periods. The majority of the annual flow, approximately 70%, occurs during the flood season. The remaining 30% of the annual flow takes place during other months. The table below outlines the seasonal water supply based on monthly percentages.

Table 3. Average Seasonal Water Supply in the Ararat RBD.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Month** |  | **XII** | **I** | **II** | **III** | **IV** | **V** | **VI** | **VII** | **VIII** | **IX** | **X** | **XI** |
| **Seasonal %** | 100% | 14% | | | 70% | | | | 16% | | | | |
| **Monthly %** | 100% | 4.7% | 4.7% | 4.7% | 17.5% | 17.5% | 17.5% | 17.5% | 3.2% | 3.2% | 3.2% | 3.2% | 3.2% |
| Annual Use (mil m3) | | Daily seasonal use (thousand m3) | | | | | | | | | | | |
| **Azat-Garni** | 129 | 6 | 6 | 6 | 23 | 23 | 23 | 23 | 4 | 4 | 4 | 4 | 4 |
| **Vedi-Urtsadzor** | 57 | 3 | 3 | 3 | 10 | 10 | 10 | 10 | 2 | 2 | 2 | 2 | 2 |
| **Arpa-Jermuk** | 127 | 6 | 6 | 6 | 22 | 22 | 22 | 22 | 4 | 4 | 4 | 4 | 4 |
| **Arpa-Yeghegnadzor** | 438 | 21 | 21 | 21 | 77 | 77 | 77 | 77 | 14 | 14 | 14 | 14 | 14 |
| **Arpa-Areni** | 730 | 34 | 34 | 34 | 128 | 128 | 128 | 128 | 23 | 23 | 23 | 23 | 23 |
| **Vaik-Zaritap** | 13 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| **Yeghegis-Hermon** | 159 | 7 | 7 | 7 | 28 | 28 | 28 | 28 | 5 | 5 | 5 | 5 | 5 |
| **Yeghegis-Shatin** | 271 | 13 | 13 | 13 | 47 | 47 | 47 | 47 | 9 | 9 | 9 | 9 | 9 |
| **Selimaget-Shatin** | 66 | 3 | 3 | 3 | 12 | 12 | 12 | 12 | 2 | 2 | 2 | 2 | 2 |
| **Artabun-Artabyunk** | 34 | 2 | 2 | 2 | 6 | 6 | 6 | 6 | 1 | 1 | 1 | 1 | 1 |
| **Total Supply** | 2024 | 95 | 95 | 95 | 354 | 354 | 354 | 1354 | 65 | 65 | 65 | 65 | 65 |

\* The average is calculated on the observation data from 2010 to 2023

Furthermore, the groundwater supply, specifically the usable groundwater resources, is derived from various sources within the Ararat RBD. The table above presents the usable groundwater and surface water resources for the individual rivers within the region.

This assessment is based on data from the year 2023 and provides valuable insights into the current and future water supply scenario within the Ararat River Basin District.

**12.2 Assessment of water demand by individual water resources and water use purposes**

The water usage demand forecast for the River Basin Management Plan in the Ararat River Basin in Armenia considers different sectors, including SHHP, Household, Irrigation, Industry, and Bottling. The forecast aims to estimate future water consumption based on specific factors relevant to each sector.

**12.2.1 Surface water resources**

The forecast for surface water usage in the Ararat River Basin is estimated using sector-specific methodologies:

Household Water Usage Forecast:

Future Household Water Usage = Current Household Water Usage \* (Projected Population / Current Population) \* (Projected Household Water Consumption per Capita)

The "Projected Population" represents the estimated population for the future year under consideration, and "Current Population" corresponds to the current population in the basin. The factor "Projected Household Water Consumption per Capita" is assumed to increase at a rate of 0.995 per year, representing a 0.5% improvement in water efficiency annually. This increase is in line with the development path of European countries with similar socio-economic characteristics.

Irrigation Water Usage Forecast:

Future Irrigation Water Usage = Current Irrigation Water Usage \* (Projected Population / Current Population) \* (Projected Irrigation Efficiency Factor)

The "Projected Population" represents the estimated population for the future year, and "Current Population" corresponds to the current population in the basin. The factor "Projected Irrigation Efficiency Factor" is assumed to increase at a rate of 0.995 per year, reflecting a 0.5% improvement in irrigation efficiency annually. This value is based on the average water usage in irrigation in European countries with similar agricultural practices.

SHHP Water Usage Forecast:

The water usage forecast for Small Hydropower Plants (SHHP) in the Ararat River Basin requires a distinct approach due to its unique characteristics. Unlike other sectors, SHHP water usage is not directly linked to population growth but is influenced by broader national energy demands and regulatory factors.

In the short term (0-10 years), SHHP water usage is expected to remain constant at current levels, reflecting the stabilization of SHHP licenses in the region and the full utilization of existing capacities. During this period, the forecast can be expressed as:

Future SHHP Water Usage (0-10 years) = Current SHHP Water Usage

For long-term projections beyond 10 years, the forecast considers the interplay between national electricity demand trends and efficiency improvements in the hydropower sector. The future SHHP water usage is calculated using the following equation:

Future SHHP Water Usage (10+ years) = Current SHHP Water Usage \* Electricity Demand Factor \* Efficiency Factor

Where: Electricity Demand Factor = Projected National Electricity Demand / Current National Electricity Demand Efficiency Factor = (1 - Annual Efficiency Improvement)^(Number of Years from Base Year)

The Electricity Demand Factor is derived from projected national electricity demand, taking into account the adoption of electric vehicles, shifts to electric heating, and the growing contribution of solar energy to the national grid. The Efficiency Factor incorporates anticipated technological advancements and infrastructure modernization in the hydropower sector.

This methodology also accounts for potential impacts of climate change on water availability for hydropower generation. Regular updates to the forecast based on actual data, policy changes, and energy sector developments are essential for maintaining its accuracy and relevance.

Industry Water Usage Forecast:

Future Industrial Water Usage = Current Industrial Water Usage \* (Projected Population / Current Population)

The water usage for the Industry sector is assumed to be directly linked to population growth without additional factors due to the difficulty in evaluating future industrial water demands accurately.

Bottling Water Usage Forecast:

Future Bottling Water Usage = Current Bottling Water Usage \* (Projected Population / Current Population) \* (Projected Bottled Water Consumption per Capita)

The factor "Projected Bottled Water Consumption per Capita" is assumed to increase at a rate of 0.005 per year, reflecting a 0.5% growth in bottled water usage annually. This increase is based on observed trends in the growth of bottled water consumption.

Fishing Water Usage Forecast:

Future Fishing Water Usage = Current Fishing Water Usage

The water usage for Fishing in the Ararat River Basin is relatively stable and not directly influenced by population growth. Fishing water usage is closely related to the natural fish populations in the river and surrounding water bodies.

Absorption Water Usage Forecast:

Future Absorption Water Usage = Current Absorption Water Usage

The water usage for Absorption in the Ararat River Basin, which includes water absorbed by natural ecosystems, is relatively stable and not directly linked to population growth or human activities.

**12.2.2 Groundwater resources**

The groundwater usage forecast in the Ararat River Basin follows similar methodologies to surface water for sectors such as Household, Industry, and Bottling. However, it's important to note that groundwater usage is significantly lower than surface water usage in the basin.

Household Groundwater Usage Forecast:

Future Household Groundwater Usage = Current Household Groundwater Usage \* (Projected Population / Current Population) \* (Projected Household Water Consumption per Capita)

The assumptions for population projection and water consumption efficiency improvements remain the same as for surface water.

Industry Groundwater Usage Forecast:

Future Industrial Groundwater Usage = Current Industrial Groundwater Usage \* (Projected Population / Current Population)

Bottling Groundwater Usage Forecast:

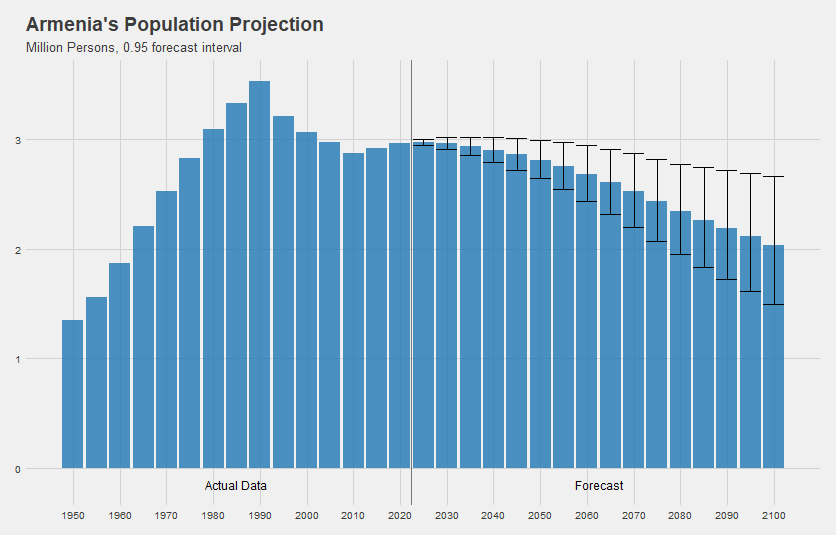
Future Bottling Groundwater Usage = Current Bottling Groundwater Usage \* (Projected Population / Current Population) \* (Projected Bottled Water Consumption per Capita)

The assumptions for bottled water consumption growth remain the same as for surface water.

It's worth noting that sectors such as SHHP and large-scale irrigation primarily rely on surface water, so their impact on groundwater usage is minimal.

[[Based on the provided data and forecasts, it's evident that surface water resources play a dominant role in meeting the water demand across various sectors in the Ararat River Basin. Groundwater resources, while crucial for certain sectors like household use, represent a smaller portion of the overall water usage. This distribution underscores the importance of sustainable management practices for both surface and groundwater resources to ensure long-term water security in the basin.]]

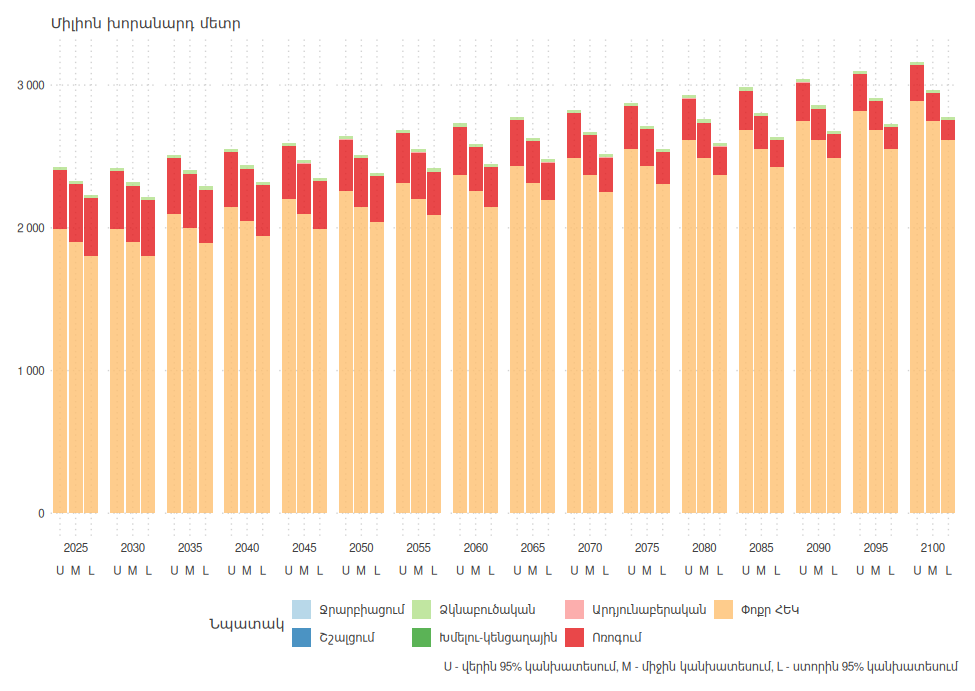
Figure 1. Armenia's Population Projection



*Source: World Population Prospects 2019*

Based on the population projections and the implementation of forecasts for different sectors, the river demand forecast figures are given below.

Figure 2. Ararat Water Basin Surface Water Demand Projection by Sectors



**12.3 Analysis and forecast scenarios of changes in water supply and demand**

The water balance allows for the determination of water demand and water supply of a River Basin District (RBD) or its individual parts. It determines the surplus or deficit of water resources in a given river basin or any part of it.

The water balance is important for decision-makers, enabling water use permits to be issued based on reliable information as well as realistic objectives of river basin management and conservation, thereby contributing to identifying the environmental objectives required for the implementation of the river basin management plan.

Water supply in the tables below is analyzed for the multi-year period (average, high-water year, low-water year), as well as projected till 2100. Two climate change scenarios were used for water supply projection: optimistic (IPCC RCP6.0) and pessimistic (IPCC RCP8.5).

July-September is a critical season for water use, as in this period the supply is critically low due to low precipitation, and the demand is high, with maximum water use. It is necessary to analyze the possible water shortages in these months.

Table 4. Current and Future Annual Surface Water Supply and Demand in Ararat RBD (mil m³).

The analysis of current and projected water supply and demand in the Ararat River Basin District (RBD) reveals complex dynamics that require careful interpretation and management. Several key points emerge from this analysis:

1. Apparent Water Deficit: At first glance, the water balance (supply minus demand) appears negative and worsening over time. However, this initial impression is misleading due to the unique nature of water use in Small Hydropower Plants (SHPPs).
2. Special Consideration for SHPPs: Unlike consumptive uses such as irrigation, water used in hydropower generation is not depleted from the system. The same water can be reused multiple times in cascading SHPPs, leading to a "double counting" effect in usage statistics. This explains the large volumes attributed to SHPPs in the demand projections.
3. Adjusted Water Balance: When excluding SHPP usage, the water balance becomes significantly positive. Only about 22% of usable water in the Ararat RBD in 2023 is actually discharged for consumptive purposes. This suggests a more sustainable water use scenario than initially apparent.
4. Climate Change Impact: Both upper and lower bound projections indicate a gradual decrease in water supply over time, likely due to climate change effects. This trend underscores the need for adaptive management strategies.
5. Sectoral Demands: While SHPP usage dominates the demand figures, irrigation remains the largest consumptive water user. Projected decreases in irrigation demand could be due to anticipated improvements in irrigation efficiency or changes in agricultural practices.
6. Seasonal Considerations: The critical period of July-September, characterized by low supply and high demand, requires special attention in water management planning.
7. Long-term Sustainability: Despite the overall positive water balance (excluding SHPPs), the declining trend in water supply and potential increases in demand necessitate proactive management approaches.

**12.3.1 Methodology for Water Usage Data Analysis**

The analysis of water usage in the Ararat River Basin was conducted using water use permit databases provided by the Republic of Armenia Ministry of Environment. This methodology was developed to ensure a comprehensive and accurate assessment of water consumption patterns across various sectors, with a particular focus on Small Hydropower Plants (SHPPs) due to their significant water usage in the basin.

Data Collection and Preparation: Water use permit data was collected for the period from 2016 to 2024. This timeframe was selected to provide a comprehensive view of water usage trends over recent years and to capture the most up-to-date information available. The data included information on permit holders, water sources (surface or groundwater), permitted volumes, and usage purposes.

Data Cleaning and Estimation: During the analysis, it was observed that some records, particularly those related to SHPPs, contained incomplete or missing data. To address this issue, a series of data cleaning and estimation techniques were employed. These techniques included:

1. Estimating annual water usage for SHPPs where this data was not provided, using available monthly data.
2. Estimating monthly water usage patterns for SHPPs where only annual data was available, based on average monthly usage patterns observed in complete records.
3. Filling in missing daily and per-second flow rate data using the available annual or monthly data.

Time Series Analysis: To understand the temporal patterns of water usage, the data was aggregated into monthly time series from 2016 to 2024. This approach allowed for the identification of seasonal trends and long-term changes in water consumption across different sectors.

Limitations: It's important to note several limitations of this methodology:

1. The accuracy of the analysis is dependent on the completeness and accuracy of the original water use permit data.
2. Estimates for missing data, while based on observed patterns, may not perfectly reflect actual usage.
3. The methodology assumes that water usage aligns with permitted volumes, which may not always be the case in practice.
4. Future projections based on this data may be limited, as they do not account for potential changes in water permit issuance policies or environmental conditions.

**12.3.2 Time Period Selection for Water Usage Calculation**

For the calculation of water usage from 2020 to 2023, a specific time range was chosen based on the available water use permit data. This selection was determined by considering the earliest starting date and the latest ending date of all water permits in the dataset.

To ensure comprehensive coverage of all water permit data, the time frame was set from the beginning of 2020 to the end of 2023. This selection was made because the maximum reliable starting date of any water permit was found to be at the beginning of 2020, while the minimum reliable ending date of any water permit was at the end of 2023.

By encompassing the period from 2020 to the end of 2023, it was ensured that all water use permit data were included in the analysis. This approach provides a complete and consistent dataset for estimating the annual water usage over the specified years, allowing for a thorough assessment of water consumption patterns in the Ararat River Basin.

[[The methodology and time period selection described above form the foundation for the water usage analysis in the Ararat River Basin. These approaches ensure a comprehensive and accurate representation of water consumption patterns, while acknowledging the limitations and challenges inherent in the available data. The results of this analysis provide valuable insights for water resource management and policy development in the basin.]]

**12.4 Brief summary of water supply and demand assessment**

The assessment of water supply and demand in the Ararat River Basin Management Area reveals a complex interplay of hydrological, economic, and environmental factors. This summary highlights the key findings and implications for water resource management in the region:

1. Resource Distribution: Surface water dominates the water supply, accounting for over 97% of total water use. Groundwater, while less utilized, remains crucial for specific sectors such as household use and small-scale irrigation.
2. Sectoral Demands: The energy sector, particularly Small Hydropower Plants (SHPPs), is the largest water user, followed by irrigation. However, the non-consumptive nature of hydropower water use necessitates careful interpretation of usage statistics.
3. Seasonal Variability: The basin experiences significant seasonal fluctuations in water availability, with critical periods of low supply and high demand during summer months (July-September).
4. Climate Change Impacts: Projections indicate a gradual decrease in water supply over time, highlighting the need for adaptive management strategies to address potential future shortages.
5. Efficiency Improvements: Forecasts suggest potential increases in water use efficiency across sectors, particularly in irrigation and household use, which could partially offset growing demands.
6. Data Limitations: While the analysis provides valuable insights, limitations in data availability and quality for certain aspects, especially groundwater resources, underscore the need for improved monitoring and data collection systems.
7. Regional Variations: Significant differences in water use patterns exist among different regions within the basin, reflecting diverse economic activities and natural resource distributions.
8. Long-term Sustainability: Despite current positive water balances when excluding non-consumptive uses, long-term trends in supply and demand emphasize the importance of sustainable water management practices.
9. Policy Implications: The complex water use landscape in the Ararat River Basin calls for integrated policy approaches that balance economic development with environmental conservation and equitable resource allocation.

This summary underscores the need for continued research, monitoring, and adaptive management to ensure the long-term sustainability of water resources in the Ararat River Basin. It also highlights the importance of considering both quantitative data and qualitative factors in water resource planning and decision-making processes.

[[This summary provides a concise overview of the key findings from the water supply and demand assessment, integrating insights from various sections of the document. It aims to give readers a comprehensive understanding of the water resource situation in the Ararat River Basin, while pointing towards areas that require further attention in water management and policy development.]]

1. **ECONOMIC ANALYSIS OF WATER USE**

**13.1 Economic analysis of different water use sectors**

**13.1.1. Water Users in the Ararat River Basin in 2023**

Figure 1 provides a comprehensive overview of the major water users in the Ararat River Basin for the year 2023. This treemap visualization offers valuable insights into the distribution of water usage among various entities, categorized by volume and purpose.

[Insert Figure 1 here]

Key Observations:

1. Dominant Water Users:
   * The Arpa-Sevan Hydrocomplex (Water) is the largest single water user, consuming 273.8 thousand m³ per year, which accounts for 11.4% of the total water usage in the basin.
   * Arpa-Energy LLC follows closely, using 252.2 thousand m³ (10.5% of the total).
   * Areni HPP CJSC Areni SHPP is the third-largest consumer, utilizing 211.5 thousand m³ (8.8%).
2. Small Hydropower Plants (SHPPs):
   * SHPPs collectively form a significant portion of water users. Notable among these are:
     + H.H.N.M.S LLC (126.1 thousand m³, 5.2%)
     + Rael Gas LLC (125.2 thousand m³, 5.2%)
     + Jermuk Turboshin LLC (87.5 thousand m³, 3.6%)
3. Other Significant Users:
   * Jrar CJSC (75.7 thousand m³, 3.1%)
   * Syunyats Water LLC (43.2 thousand m³, 1.8%)
   * Various smaller entities each consuming between 1-3% of the total water volume
4. Distribution by Purpose:
   * The chart distinguishes between "Small HPP" (shown in blue) and "Others" (shown in red).
   * Small HPPs collectively account for a substantial portion of water usage, highlighting the importance of hydropower in the basin's water consumption pattern.
5. Diverse User Base:
   * The visualization reveals a diverse range of water users, including energy companies, water utilities, and various local enterprises.
   * This diversity suggests a complex water management landscape in the Ararat River Basin, requiring tailored approaches for different user types.
6. Implications for Water Management:
   * The concentration of water usage among a few large consumers (particularly in hydropower) suggests that targeted efficiency improvements in these sectors could have significant impacts on overall water consumption in the basin.
   * The presence of numerous smaller users indicates the need for comprehensive water management strategies that can address both large-scale and small-scale consumption patterns.

This detailed breakdown of water users provides crucial information for policymakers and water resource managers. It highlights the need for balanced strategies that can address the needs of major consumers like hydropower plants while also considering the collective impact of numerous smaller users. Future water management plans in the Ararat River Basin should take into account this diverse user base to ensure sustainable and equitable water distribution.

**13.1.2. Monthly Water Usage of Small Hydropower Plants in the Ararat River Basin**

Figure 2 illustrates the monthly water usage of Small Hydropower Plants (SHPPs) in the Ararat River Basin from 2016 to 2024, along with the number of operating licenses for these plants.

[Insert Figure 2 here]

Key Observations:

1. Seasonal Variation:
   * The graph shows pronounced seasonal fluctuations in water usage, with peaks typically occurring in spring and early summer (April to June).
   * These peaks likely correspond to periods of increased river flow due to snowmelt and spring rains.
   * Lower usage is observed in late summer, autumn, and winter months, reflecting reduced water availability.
2. Long-term Trend:
   * The blue trend line indicates a gradual increase in average monthly water usage over the years.
   * This upward trend correlates with the increasing number of operating licenses, as shown at the bottom of the graph.
3. License Growth:
   * The number of operating licenses for SHPPs has more than doubled, from 24 in 2016 to 51 in 2024.
   * This increase in licenses has contributed to the overall growth in water usage.
4. Variability:
   * The gray shaded area represents the range of variability in water usage.
   * This variability has increased over time, particularly from 2022 onwards, suggesting greater fluctuations in water availability or demand.
5. Recent Developments:
   * Notable spikes in water usage are observed in 2023 and 2024, with peaks reaching nearly 110 m³/s.
   * These recent increases coincide with the highest number of operating licenses.

Special Considerations:

It's crucial to interpret this data with the understanding that water use in hydropower plants differs fundamentally from consumptive uses in other sectors. As noted in the previous analysis:

1. Non-consumptive Use: Water used for hydropower generation is not consumed but rather diverted through turbines and returned to the river system.
2. Potential for Reuse: The same volume of water can be used multiple times as it flows through a series of HPPs along a river.
3. Impact on Water Balance: While the volumes shown represent significant water use, they do not equate to water removed from the system in the same way as irrigation or industrial uses.
4. Cascade Effect: The potential for water reuse in cascading HPPs means that the actual impact on water availability downstream may be less than the total volume used suggests.

Implications for Water Management:

1. While the graph shows increasing water usage by SHPPs, this trend cannot be directly extrapolated to predict future water use in the Ararat River Basin. The growth has been primarily driven by the increase in the number of licenses, a factor that may not continue at the same rate.
2. The seasonal variation in water use by SHPPs aligns with natural hydrological cycles, potentially minimizing conflicts with other water uses during low-flow periods.
3. The recent spikes in usage (2023-2024) warrant close monitoring to ensure they do not negatively impact other water users or ecological flows.
4. Future water management strategies should consider the non-consumptive nature of hydropower water use while also addressing potential impacts on river flow regimes and aquatic ecosystems.
5. Coordination among SHPP operators, especially in cascading systems, could optimize water use efficiency and minimize environmental impacts.

This analysis underscores the complexity of water resource management in the Ararat River Basin, highlighting the need for a nuanced understanding of different water uses and their impacts on the overall water balance.

**13.1.3 Analyzing Household Living Conditions in Ararat and Vayots Dzor Marzes**

Analyzing the Household's Integrated Living Conditions Survey anonymized microdata databases for Ararat and Vayots Dzor marzes from 2004 to 2022 is crucial in gaining a comprehensive understanding of dwelling conditions and water usage in these marzes. As these marzes account for most of the Ararat RB water intake, the information obtained from these databases provides valuable insights into the living conditions and water-related practices of the majority of the basin's population.

The following key variables from the databases are of particular significance in the context of Ararat RB:

1. Type of Dwelling: Understanding the types of dwellings prevalent in Ararat and Vayots Dzor marzes provides insights into the housing infrastructure in these regions. Different types of dwellings may have varying water usage patterns and access to water sources, which can impact water demand and availability in the basin.
2. Main Source of Water for Drinking: Identifying the primary source of drinking water for households in these marzes is essential in assessing the dependency on local water sources. This information can shed light on the reliability and quality of the water supply and the potential for water scarcity or contamination issues.
3. Water Tap Location: Knowing where the water taps are located in households can reveal the accessibility and convenience of water supply. It can also highlight disparities in access to water infrastructure, especially in rural areas, where water availability may be limited or inconsistent.
4. Principal Method of Garbage Disposal: The garbage disposal method used by households is relevant in understanding waste management practices in Ararat and Vayots Dzor marzes. Proper waste disposal can impact water quality and ecosystem health, as improper waste management can lead to water pollution and environmental degradation.

Figure 3. Residence Types in Ararat and Vayots Dzor Marzes (2005-2022)

[Insert Figure 3 here]

Figure 3 illustrates the evolution of residence types in Ararat and Vayots Dzor marzes:

1. Ararat Marz:
   * Houses have remained the predominant dwelling type, increasing from 53% in 2005 to 62% in 2022.
   * Apartments have decreased from 43% in 2005 to 38% in 2022.
   * Temporary lodgings and containers have significantly decreased from 4% in 2005 to less than 1% in 2022.
2. Vayots Dzor Marz:
   * Houses have become increasingly prevalent, rising from 52% in 2005 to 73% in 2022.
   * Apartments have decreased from 48% in 2005 to 27% in 2022.
   * Temporary lodgings have been virtually non-existent throughout the period.

The trend towards individual houses in both marzes may have implications for water distribution and usage patterns in the Ararat River Basin.

Figure 4. Primary sources of drinking water

[Insert Figure 4 here]

Figure 4 shows the primary sources of drinking water:

1. Ararat Marz:
   * Centralized water supply has been the dominant source, increasing from 94% in 2005 to 98% in 2022.
   * Own water systems and other sources have decreased from 6% to about 2%.
2. Vayots Dzor Marz:
   * Centralized water supply has also been predominant, increasing from 96% in 2005 to 98% in 2022.
   * Other sources, including own systems, have decreased from 4% to about 2%.

The high reliance on centralized water systems in both marzes indicates a well-developed water infrastructure in the Ararat River Basin.

Figure 5. Water tap locations

[Insert Figure 5 here]

Figure 5 demonstrates significant improvements in water tap locations:

1. Ararat Marz:
   * Indoor taps have increased dramatically from 59% in 2005 to 97% in 2022.
   * Yard taps have decreased from 38% to 3%.
   * Street taps have been almost completely eliminated, dropping from 3% to nearly 0%.
2. Vayots Dzor Marz:
   * Indoor taps have increased from 75% in 2005 to 91% in 2022.
   * Yard taps have decreased from 23% to 9%.
   * Street taps have been virtually eliminated, decreasing from 2% to 0%.

These improvements indicate enhanced water accessibility and potentially more efficient water use in both marzes.

Figure 6. Garbage Collection in Ararat and Vayots Dzor Marzes

[Insert Figure 6 here]

Figure 6 shows significant progress in waste management:

1. Ararat Marz:
   * Use of rubbish evacuation systems increased from 33% in 2005 to 55% in 2022.
   * Garbage collection services increased from 33% to 45%.
   * Dumping by households decreased dramatically from 37% to 0%.
   * Burning by households reduced from 19% to 0%.
2. Vayots Dzor Marz:
   * Rubbish evacuation systems usage grew from 40% in 2005 to 72% in 2022.
   * Garbage collection services decreased slightly from 40% to 27%.
   * Household dumping reduced significantly from 14% to 1%.
   * Burning by households decreased from 13% to 0%.

This improvement in waste management practices is crucial for protecting water resources and overall environmental health in the Ararat River Basin.

These trends provide valuable insights for policymakers and stakeholders in the Ararat River Basin. They highlight areas of substantial progress, particularly in water infrastructure and waste management. The shift towards more houses and improved water access suggests changing water demand patterns that need to be considered in future water management strategies. The advancements in waste management practices contribute significantly to protecting water quality in the basin.

[[By integrating these socio-economic factors with hydrological data, decision-makers can develop more comprehensive and effective strategies for sustainable water management in the Ararat River Basin. The focus should be on maintaining the positive trends in water access and waste management while addressing any emerging challenges related to changing residence patterns and water demand.]]

**13.2 Analysis of the application of cost recovery principles and water supply services**

There are still many issues in the economic management of water resources in the Ararat RBD. Significant losses in the water system are not clearly calculated, which substantially affects the cost of water. The irrigation system is not efficient, and the level of drip irrigation is low, which in turn affects the price of agricultural products.

The water costs should be considered in these directions:

1. Cost of ensuring the quantity and reliability of water supply. This makes it possible to fully satisfy the demand for water. Water supply must be completed on time, depending on the demand.
2. Costs to reduce water losses. These costs allow for the conservation of water resources. The reduction of leakages substantially increases the profitability of a water supplier, which creates conditions for lower water prices.
3. Costs to improve water quality. These costs allow for a significant reduction in the risk of disease outbreaks and spread. It also significantly increases household water use. This measure can decrease the use of bottled water, which is harmful to the environment due to disposable plastic bottles.
4. Projects for wastewater treatment. These costs are mainly aimed at protecting the environment. They have major ecological and environmental importance and are needed to maintain water quality. These costs also prevent the spread of diseases.

It should be noted that the assistance of international organizations, including the European Union, is mainly aimed at solving the environmental problems of the Ararat RBD. It is necessary to evaluate the economic efficiency of costs solely aimed at environmental problems. This should be done with a systematic view of water use issues, including from the point of environmental protection.

**13.2.1 Economic Analysis of Water Use and Water Costs Recovery in Ararat RB**

In most cases, the supplies of water which can be used for forecasts resulted from long-term observations and analyses of the current situation. Several water management tasks have to rely on prediction, quantification, and assessment of possible scenarios which could influence the decision-making process in complex water management systems. For the purpose of forecasting, it is essential to evaluate and apply an educated qualitative estimate with quantitative data for current development of water needs and water consumption. As it is difficult to include all variables in individual models, it is necessary to make early preparation and time-optimized planning of water demand for the sources of water. For this, all available means should be used. A theoretical basis for all estimates and plans is the prognostic work which considers trends in water economy and water supplies for that territory. An important part is the statistics which makes it possible to forecast the future situation with a certain degree of probability for a certain phenomenon.

**13.2.2 Water use forecasts and costs Recovery for Ararat RBD**

In the Ararat River Basin District (RBD), the projected water balance between water supply and demand reveals critical insights into the region's future water resource management. The water balance serves as a vital tool for policymakers and decision-makers, enabling the issuance of water use permits based on accurate information and realistic objectives for effective river basin management and conservation.

The comprehensive analysis of water supply presented in the tables underscores the multi-year perspective of water availability. The inclusion of average, high-water year, and low-water year scenarios, coupled with projections until 2100 under optimistic (IPCC RCP6.0) and pessimistic (IPCC RCP8.5) climate change scenarios, offers a comprehensive view of the challenges and opportunities that lie ahead.

The analysis of current and projected water supply and demand in the Ararat River Basin District (RBD) reveals complex dynamics that require careful interpretation and management. Several key points emerge from this analysis:

1. Apparent Water Deficit: At first glance, the water balance (supply minus demand) appears negative and worsening over time. However, this initial impression is misleading due to the unique nature of water use in Small Hydropower Plants (SHPPs).
2. Special Consideration for SHPPs: Unlike consumptive uses such as irrigation, water used in hydropower generation is not depleted from the system. The same water can be reused multiple times in cascading SHPPs, leading to a "double counting" effect in usage statistics. This explains the large volumes attributed to SHPPs in the demand projections.
3. Adjusted Water Balance: When excluding SHPP usage, the water balance becomes significantly positive. Only about 22% of usable water in the Ararat RBD in 2023 is actually discharged for consumptive purposes. This suggests a more sustainable water use scenario than initially apparent.
4. Climate Change Impact: Both upper and lower bound projections indicate a gradual decrease in water supply over time, likely due to climate change effects. This trend underscores the need for adaptive management strategies.
5. Sectoral Demands: While SHPP usage dominates the demand figures, irrigation remains the largest consumptive water user. Projected decreases in irrigation demand could be due to anticipated improvements in irrigation efficiency or changes in agricultural practices.
6. Seasonal Considerations: The critical period of July-September, characterized by low supply and high demand, requires special attention in water management planning.
7. Long-term Sustainability: Despite the overall positive water balance (excluding SHPPs), the declining trend in water supply and potential increases in demand necessitate proactive management approaches.

**Conclusion:**

The economic analysis of water use and cost recovery in the Ararat River Basin District highlights the complex interplay between water resource management, environmental sustainability, and economic development. The assessment of water costs across various sectors – from ensuring reliable supply to improving water quality and treating wastewater – underscores the multifaceted nature of water resource economics in the region.

The forecasting methodologies employed, which consider long-term observations and current analyses, provide a robust framework for predicting future water needs and consumption patterns. These predictions are crucial for informed decision-making in water management, particularly in the face of changing climate conditions and evolving socio-economic factors.

The water balance analysis reveals a nuanced picture of water availability and use in the Ararat RBD. While initial figures suggest a water deficit, closer examination, particularly when considering the non-consumptive nature of hydropower water use, indicates a more sustainable scenario. This underscores the importance of context-specific interpretation of water use data, especially in basins with significant hydropower presence.

Climate change emerges as a critical factor influencing long-term water availability, necessitating adaptive management strategies. The projected gradual decrease in water supply over time highlights the urgency of implementing water conservation measures and exploring innovative water management techniques.

The seasonal variability in water availability, particularly the critical low-supply period of July-September, calls for targeted management approaches. This may include improved water storage solutions, demand management strategies, and potentially, the exploration of alternative water sources for peak demand periods.

While the overall water balance appears positive when excluding non-consumptive uses, the long-term trends in both supply and demand underscore the need for continued vigilance and proactive management. This includes ongoing efforts to improve water use efficiency across all sectors, particularly in irrigation, which remains the largest consumptive water user.

In conclusion, the economic analysis of water use in the Ararat RBD provides a foundation for developing sustainable water management policies. It highlights the need for a balanced approach that considers environmental conservation, economic development, and social equity. Future water management strategies should focus on enhancing water use efficiency, promoting water-saving technologies, and fostering a culture of water conservation among all users. Additionally, continued investment in water infrastructure, including both supply systems and wastewater treatment facilities, will be crucial for ensuring long-term water security in the region.

[[The comprehensive economic analysis presented here serves as a valuable tool for policymakers, water managers, and stakeholders in the Ararat River Basin. It provides a solid basis for developing targeted interventions, prioritizing investments, and formulating policies that promote sustainable water use while supporting economic growth and environmental protection. As the region faces challenges such as climate change and increasing water demand, this analysis will be instrumental in guiding adaptive management strategies and ensuring the long-term sustainability of water resources in the Ararat River Basin District.]]