ARAGVI RIVER BASIN WATER BALANCE

APPROXIMATION BASED ON AVAILABLE DATA

USAID GOVERNING FOR GROWTH (G4G) IN GEORGIA

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REPRESENTATIVE: REVAZ ORMOTSADZE

AUTHOR(S): GAMMA CONSULTING LTD

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Reviewed by:	Georg Petersen, Davit Mujirishvili, Elene Ghubianuri, Keti Skhireli, Mariam Bakhtadze
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ACRONYMS

C	Celsius
EC	European Commission
EC	European Commission
ET	Real Evapotranspiration
ETo	Reference Evapotranspiration
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
G4G	Governing for Growth in Georgia
GEL	Georgian Lari
GSE	Georgian State Electricity System
GWP	Georgian Water and Power Ltd
ha	Hectare
HPP	Hydro Power Plant
km2	Square Kilometer
l/s	Liter Per Second
LTD	Limited Company
m	Meter
m/s	Meter Per Second
m^3/s	Cubic Meter Per Second
masl	Meter Above the Sea Level
MENRP	Ministry of Environment and Natural Resource Protection
mill m3	Million Cubic Meter
mm	Millimeter
MS	Member States
MW	Megawatt
NEA	National Environmental Agency
RBMP	River Basin Management Plans
RBMP	River Basin Management Plans
USAID	United States Agency for International Development
UWSC	United Water Supply Company of Georgia
WFD	Water Framework Directive
WFD	Water Framework Directive

CONTENTS

1. EXECUTIVE SUMMARY

The new draft of Water Resource Management Law brings back the permitting system for the surface water abstraction and authorizes Ministry of Environment and Natural Resource Protection (MENRP) to issue the permit by administrative act. To be able to issue such permits MENRP requires the comprehensive information for the analysis of the basins and some tool to issue the permits.

Water balance calculation is recognized as a modern tool in many countries for determination of availability of water resources and its consumption considering sustainable resource use. In this regard a monthly water-balance model has been used to examine the various components of the hydrologic cycle (for example, precipitation, evapotranspiration, and runoff).

This report presents a description of a monthly water-balance model of Aragvi River Basin developed in the Microsoft Excel. It is a user-friendly model, which allows the user to easily modify water-balance parameters and provide useful estimates of water-balance components for a specified location. The model can be used as a research tool, an assessment tool, and as a tool for capacity building.

The estimation of water balance largely depends on data availability and reliability. The more accurate the available data, the lower the uncertainties and the higher the achievable level of confidence in the results are.

The meteorological and hydrological data available within Aragvi River basin is limited. Moreover an up to date methodology to determine the environmental flow requirements is not yet developed and approved. Active gauging stations are located only upstream of the Jinvali Dam whilst the runoff formed on the catchment downstream the dam which is 1610 km^2 remains unmeasured since almost 20 years. There is only one meteorological station operating within the basin that has multiyear data series including 2015 (Dusheti meteorological station). More than 20 years there was no systematic monitoring on ground water parameters in Aragvi River Basin as well as in the country.

The Jinvali dam separates the catchment into an upstream and a downstream area (the latter being 1610 km^2). In terms of water use more than 99 % of water users are located downstream the dam (not considering hydropower demands at Jinvali Dam), whilst most of the runoff is formed upstream of the dam.

Jinvali reservoir can store more than 500 mill m^3 of water greatly affecting the hydrological regime. The absence of respective reservoir operation information, challenges the determination of the river runoff and water availability downstream the dam. Further, there is no gauge measuring basin outflow and there is no groundwater observation network for monitoring groundwater behavior, to respectively understand how precipitation is infiltrating and feeding the groundwater horizon and what are the patterns of recharging the horizon due to the feeding the river runoff.

With the consideration of the limitation on data the equitation used in the model is as follows:

P+Dd+Dind+Dirr+ Ddom -ETreal-Airr-Aind- Adom -Tout=Rr

Where:

P Precipitation downstream the Jinvali dam
Dd Water discharged from the Jinvali Reservoir
Dind Return flow to the river formed by industry discharge
Dirr Return flow to the river formed by the Irrigation
Ddom Return flow formed by the domestic sector located in the boundaries of basin
ETreal Real Evapotranspiration downstream the Jinvali Dam
Airr Abstraction of the water for Irrigation
Aind Abstraction of the water for industry
Adom Abstraction of the water for local domestic sector
Tout Transfer of water out of the boundaries of basin
Rr River runoff leaving the basin

The subtraction of the water devoted for environmental flow from river runoff leaving the basin (Rr) allows estimation of the water remaining available for use in the basin, considering there are no further downstream water demands that have to be considered.

Ef+Wa=Rr

Where:

Ef – Environmental Flow
Wa - Water available for use

As it is indicated on Figure 1, the use of above equation resulted in Water Balance which has **Wa** positive values for each month in terms of water available for water use after the subtraction of the volume of the water required for Ef from Rr.

Figure 1: Water Available for the Use

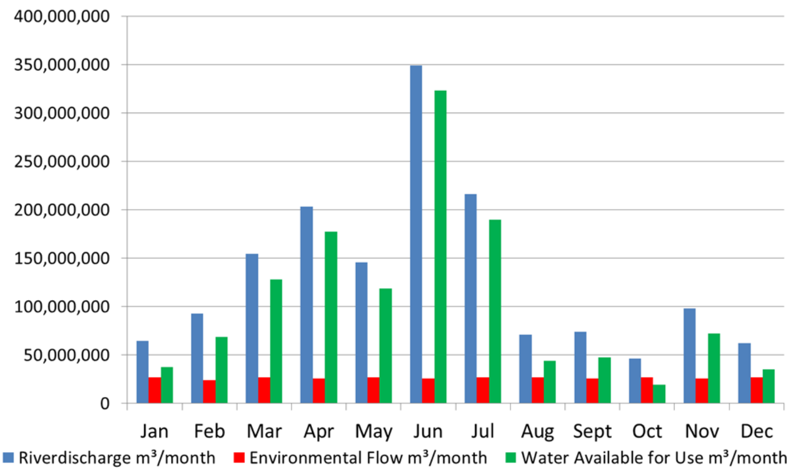


Figure 1 indicates the results of the monthly water balance estimation.

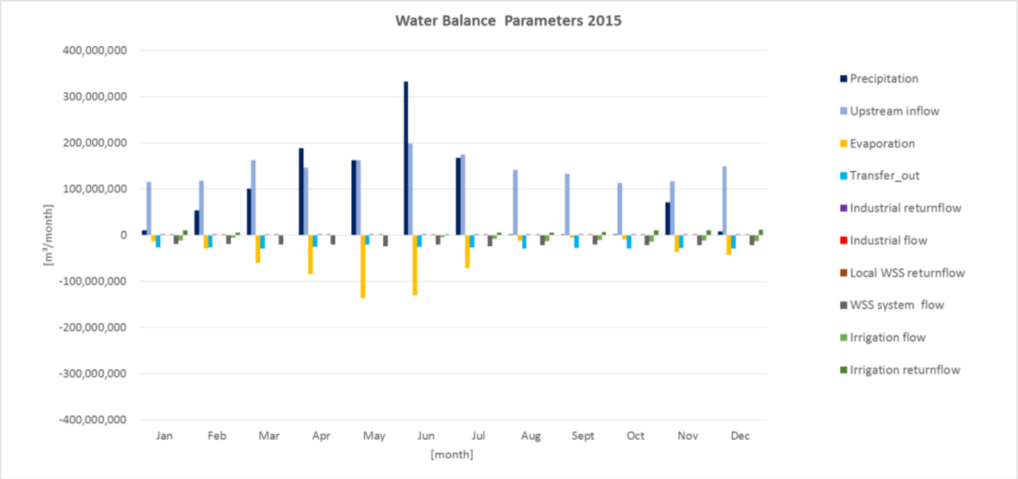
Figure 1 Example presents the amount of water available in the lower Aragvi basin based on 2015 data with the assumption of constant environmental flow requirements which is based on Jinvali Dam Environmental Impact Assessment[1]. Environmental flow requirements might be revised in the future.

Patterns of reservoir operation as well as water abstractions of the different sectors driven by the demand increase and climate change may change in future, leading to higher demands and respectively the water available for use **Wa** as a positive number wouldn't be challenged and environmental flow requirements may be violated.

Different parameters of the water balance are shown on the Figure 2.

[1] Jinvali HPP operation Environmental Impact Assessment LTD Geo Consulting 2014 y.

Figure 2: Water Balance Overview for Aragvi Basin Based on Available Data



The water balance model considers various parameters, including:

- Precipitation, determined based on 2015 daily precipitation data records from Dusheti meteorological station;
- Upstream runoff entering the lower Aragvi basin downstream of Jinvali Dam, determined through averaging the discharge of the reservoir for 1996-1997;
- Mean daily temperature from Dusheti meteorological station;
- Catchment area of the lower Aragvi basin (downstream of Jinvali Dam);
- Volume of actual withdrawal and actual return flow of water users in the basin based on MENRP data;

Each parameter was determined either on the bases of direct reference, such as water usage data, or estimation based on available hydrological and meteorological data.

Evapotranspiration calculations according the Blaney Criddle method were used and the resulting numbers reduced based on a relation to rainy days per month to estimate actual evapotranspiration based on water availability.

2. BACKGROUND

Due to climatic and landscape characteristics of Georgia, the demand on water is growing year by year. Numerous hydropower facilities operate and are under construction in the west of Georgia. Consumption of water resources is significant for development of agriculture in the country and due to the state programs to support the sector and rehabilitate the infrastructure irrigation sector tends to become the biggest consumptive water user at the end of the 2020. The information on an alternative to export the available water resources out of the Georgia is appearing from time to time[2] in news headlines.

MENRP is in charge of water resources management in the country, which exercise its power through subordinate or other state institutions.

The National Environmental Agency (NEA) which is under the MENRP holds a significant place in this scheme, because it maintains the network of hydro meteorological stations for assessment of surface and groundwater resources and is responsible for issuing the license for abstraction of groundwater.

In the nearest future water users and those wanting to carry out economic activities on a water body may apply for a permit. The development and implementation of the permit system is in need of surface water allocation plans in quantitative and time scale terms, and the development of conditions under which water users can take water.

In case of referring to the version of the active Water Resource Management Law before the amendments made in 2008, for the MENRP to be able to issue the above said permit, the existence of preliminary Water Balances, adopted by the MENRP (catchments and regional) and Integral Plans on Water Use is a must. According to the requirement in now abolished articles[3] it was possible to issue license on abstraction and discharge only based on approved balances and plans. To develop the above mentioned balance and plan MENRP and Ministry of Economy were authorized to jointly approve the appropriate methodology. Amendments to the law made in 2008 removed the requirement for a permit on abstraction of the surface water together with the requirement on adoption of the balances and plans and an appropriate methodology for their development.

In 2015 the final version of the Guidance Document on the Application of Water Balances[4] for Supporting the Implementation of the Water Framework Directive (WFD) was promulgated, stating that ''water balances can be seen as a supportive tool for the development of River Basin Management Plans (RBMP) by providing a coherent framework to cross-evaluate the information on drivers, pressures and impacts on water quantity (including the coherence between water abstraction and water discharge. The document describes the application of water balances for supporting RBMP development processes and the implementation of the WFD in the EU. The guidance was developed under the joint agreement of Member States (MS) and the European Commission (EC) with the main objective to support the development and use of water balances at the river basin and/or catchment scales in the context of the EU WFD implementation, as pre-requisite to sound and sustainable quantitative management of water resources.

With the consideration of all above mentioned the development of water balances can be seen as a useful tool for guiding water policy and management at different decision making scales, in particular with regards to the quantitative management and efficient allocation of water resources[5].

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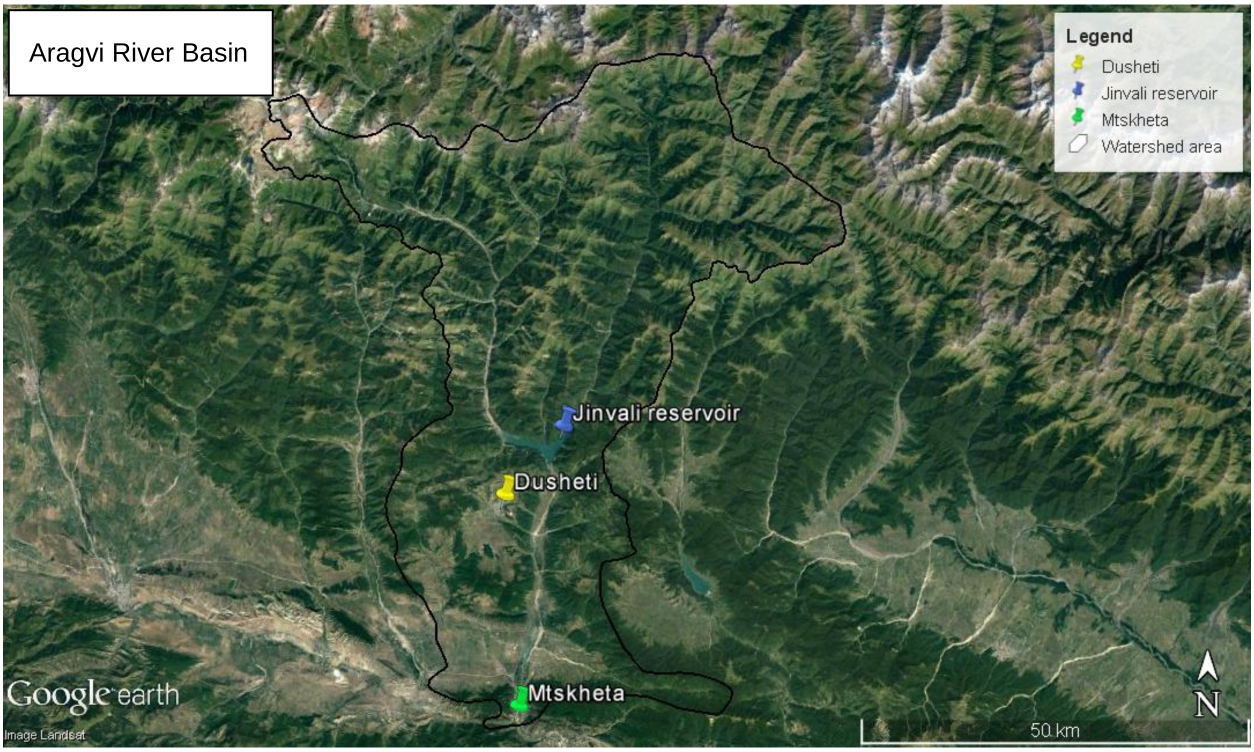
[2] http://cbw.ge/business/georgias-water-exports-infrastructure-project-waiting-1-5-billion-usd-investment/
http://araznews.org/en/archives/2709
[3] Article 51. Rule to issue permit on water discharge
Article 78. Water Balances
Article 79. Water use and protection integrated plans
Article84. Norms for Water Protection and Use
[4] Guidance document on the application of water balances for supporting the implementation of the WFD Final – Version 6.1 – 18/05/2015
[5] Guidance document on the application of water balances for supporting the implementation of the WFD Par 1.1 Context

3. ARAGVI RIVER BASIN DESCRIPTION

DESCRIPTION OF THE PROJECT AREA

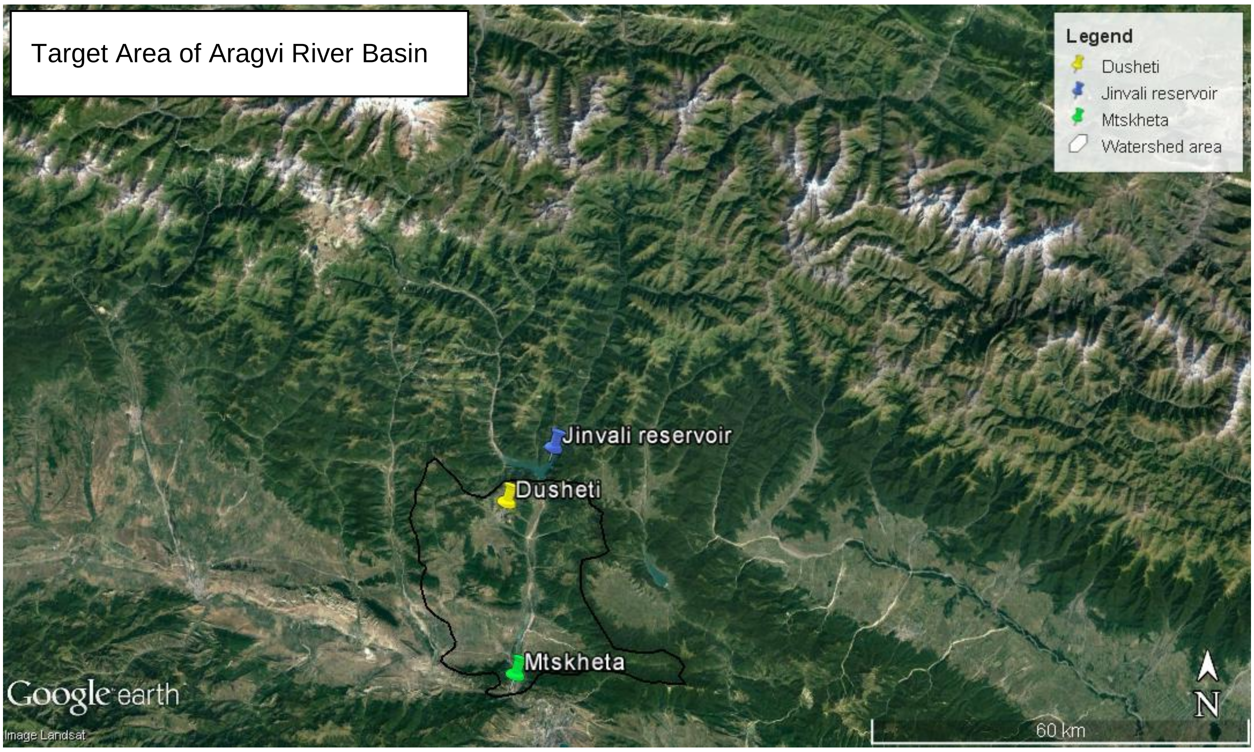
The Aragvi River basin is located in the East of Georgia and belongs to Mtkvari River basin. The river basin administratively is located in Mtskheta-Mtianeti region. It originates in Kazbegi municipality, crosses Dusheti municipality and joins Mtkvari River in Mtskheta Municipality. It is surrounded by Central Caucasian Range from the North, from the East by Kartli Ridge, and from the West by Lomis-Alevi Range. The length of the river is 122 km, and the catchment area is 2,724 km². The Aragvi River system is formed by the following rivers: Mtiuletian Aragvi (White Aragvi) (41 km), Gudamakari Aragvi (30 km), Arkala (12 km), Khorkhula (15 km), Pshavis Aragvi (56 km), Dushetiskhevi (13 km), Tsirdaliskhevi (15 km), Abanoskhevi (12 km), Akhatniskhevi (16 km), Tezami (28 km) and Narekvavi (41 km)Aragvi is a mountain river in its upper and middle reaches, while in its lower reaches it stretches over the Mukhrani-Saguramo plain, crossing Skhaltba and Saguramo ridges and joining Mtkvari River near Mtskheta city.

Picture 1: Aragvi River Basin



During the water balance preparation, the study area was determined to be the section from the middle to the lower reaches of the basin. The reason was the existence of Jinvali reservoir, which is an artificial reservoir, dividing the basin in an upper and a lower section, modifying the hydrological regime of the river. The majority of water resources consumers are located in the lower reaches of Aragvi River (settlements, industrial facilities, irrigation systems).

Picture 2: Target Area of Aragvi River Basin



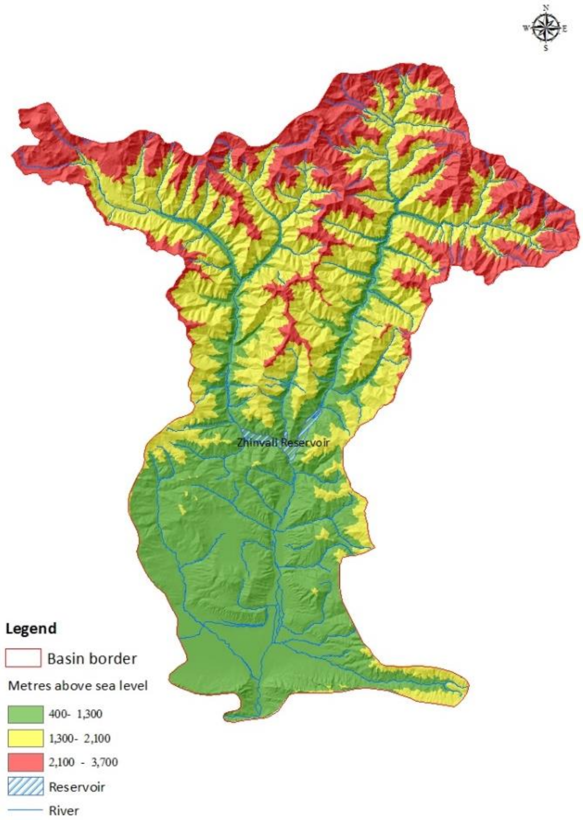
The major part of Aragvi River basin is located above 1,000 masl[6].. The relief is fragmented. The basin can be divided in three main parts based on orographic structure:

1. Caucasian Mountains (2,000-3,500 m)
2. Medium height zone and lowland (800-2,000 m)
3. Foothill (500-800 m)

Middle and upper sections of Aragvi River basin are heavily fractured by erosive valleys of the rivers. These valleys are separated from each other by horizontally stretched ridges. Valleys mainly have V-shaped, broad profile and steep slopes. In the lower zone of the middle reaches the relief is mainly hilly; main orographic units within this zone are Bazaleti plateau and Dusheti depression. At Ananuri village (900 m-asl) the river leaves the mountainous section of the basin and flows on the plain of the foothill and then, from the village Natakhtari (500 m-asl) flows on Mukhran-Saguramo plain. The major part of this plain corresponds to the first terrace, at 5-8 m height from the floodplain.

6 Pilot watershed management plan for river Aragvi – Georgia. 2011. Tbilisi

Map 1: Height Distribution of Aragvi River Basin



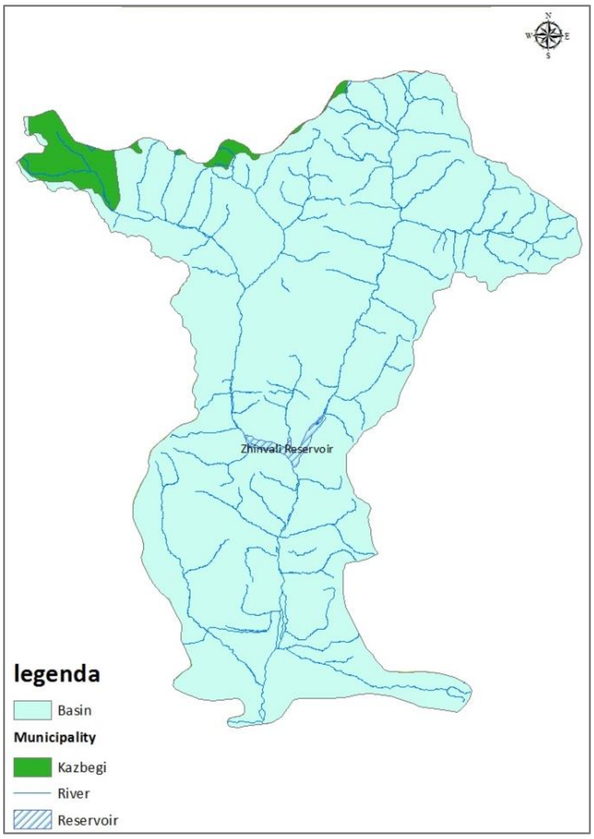
DESCRIPTION OF ADMINISTRATIVE UNITS WITHIN THE PROJECT AREA

KAZBEGI MUNICIPALITY

Aragvi River basin covers only a small part of Kazbegi municipality, its area is 96 km^2. Gudauri town is located here. It is a ski resort and several dozen middle and small sized hotels are located here. The number of permanent residents of Gudauri is 140 persons[7]. Construction of residential complexes is going on for visitors of Gudauri. Gudauri hydropower station is located at Gudauri town, in Aragvi River valley, the installed capacity of which is 8 MW.

[7] Gudauri research regarding Kazbegi population development. 29 April, 2016. Geowel Research.

Map 2: Kazbegi Municipality Area within Aragvi River Basin



DUSHETI MUNICIPALITY

Physical-geographic Characteristics: Dusheti municipality is located in the northern part of Shida Kartli plain, on the southern slopes of the Central Caucasus Range. Three main climate types are presented in Dusheti municipality:

- Moderate humid climate, with moderate cold winter and long warm summer;
- Humid climate, with cold winter and short cool summer;
- Highland humid climate, with permanent snow and glaciers.

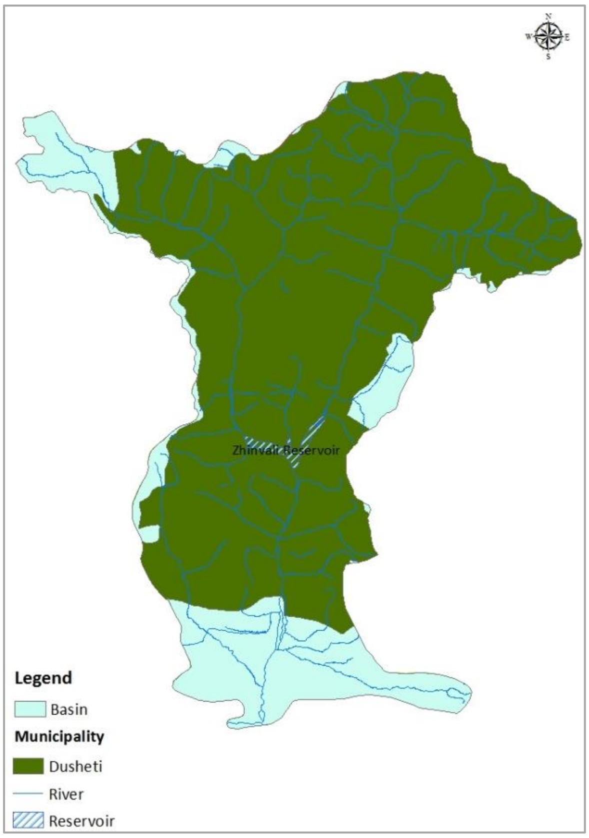
Dusheti municipality is rich with hydrological resources. Rivers, lakes, ground water and glaciers are presented here. The major part of the municipality is within Aragvi River basin. Main rivers of Caucasus Mountain Range – Arghuni and Asa, flow on the territory of the municipality. Mostly grey and brown forest soils are observed. Black humus carbonate soils can be found on Bazaleti plateau. Meadow and meadow turfy soils are met in subalpine and alpine zones[8].

Socio-economic condition: The area of Dusheti municipality, got within the river basin, is 2,176 km^2. It includes the city Dusheti, town Pasanauri, town Jinvali and 283 villages of the municipality. Total number of population was 33,700 as for January 1, 2013. Population density 11.4 person/km^2, is relatively less than the average density value of the population of Georgia (67 person/km^2). Population is unevenly distributed within the municipality. The number of population in Dusheti is 7 thousands. 80% of population of the municipality lives in villages. The main activity of the local population is agricultural activity (husbandry, livestock raising, agriculture) in spite of the fact that the most of the territory is middle and high mountain zone. The area of the scarce agricultural land plots of the municipality is 136,543 ha, from where arable lands cover 10,240 ha (7% of agricultural lands), perennial plants - 1,481 ha (1%), and mowing-grazing lands - 124,538 ha (91%).

Jinvali hydropower unit is located in the municipality, which supplies the capital with drinking water and generates electricity. Significant irrigation systems of the region originate from here.

[8] Climate Change Adaptation and Mitigation of the impact at the local level, the situation in Dusheti. 2012. Mtskheta-Mtianeti region Development strategy for the year 2016-2020. 2015)

Map 3: Dusheti Municipality Area within Aragvi River Basin



MTSKHETA MUNICIPALITY

Physical-geographic Characteristics: Total area of Mtskheta municipality is 805 km^2, 338 km^2 from the mentioned territory gets within Aragvi River basin. The North-West section of the municipality area is stretched on Mukhran-Saguramo plain. From the South it is bordered by Tsleva-Troti and Skhaltba ridges, from the East – Kartli and Saguramo ridges. Humid subtropical climate is characteristic to the municipality. The average air temperature for the territory of Mtskheta municipality is +11^{0}C.

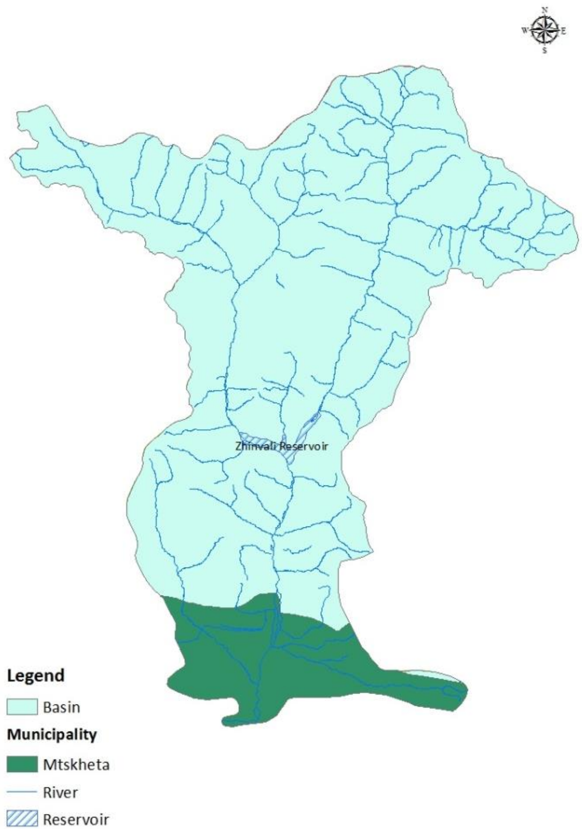
Mtskheta municipality gets within five main river basins, these are: Mtkvari, Aragvi, Narekvavi, Ksani and Tezami. There are meadow alluvial, carbonate, meadow brown and forest brown soils here[9].

Socio-economic condition: According to 2013 data, the population of Mtskheta municipality was 57,400 persons. The average monthly income of local employed people was 775 GEL. Municipality belongs to the category of municipalities with low living standards, where there are more than 9,900 socially vulnerable families. The crucial force of the local economy is: Natakhtari and Zedazeni Brewery, Food Producing factory Barambo, Ksani Glass Factory, Paper Processing and Producing Facilities. Agriculture and tourism take significant place in local economy. Total area of agricultural land plots is 23,636 ha, from here arable lands cover 12,195 ha; perennial plants – 3,905 ha; mowing – 271 ha; grazing – 7,265 ha; the Forest Fund Area is 27,166 ha; Protected Areas (natural reserve) 22,425 ha.

Mtskheta city, which is the center of the region, is the most touristic direction in Georgia.

[9] Mtskheta-Mtianeti region Development strategy for the year 2016-2020. Georgia.2015

Map 4: Mtskheta Municipality Area within Aragvi River Basin

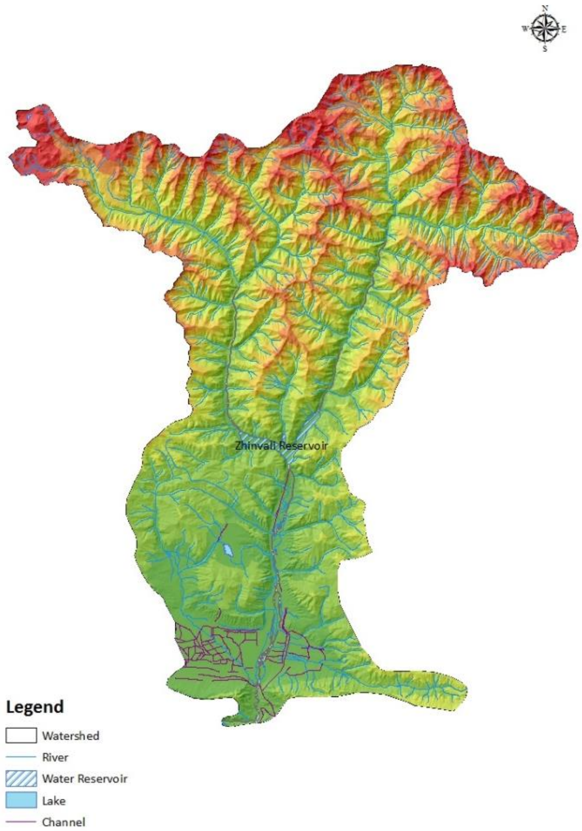


HYDROLOGICAL DESCRIPTION OF THE PROJECT AREA

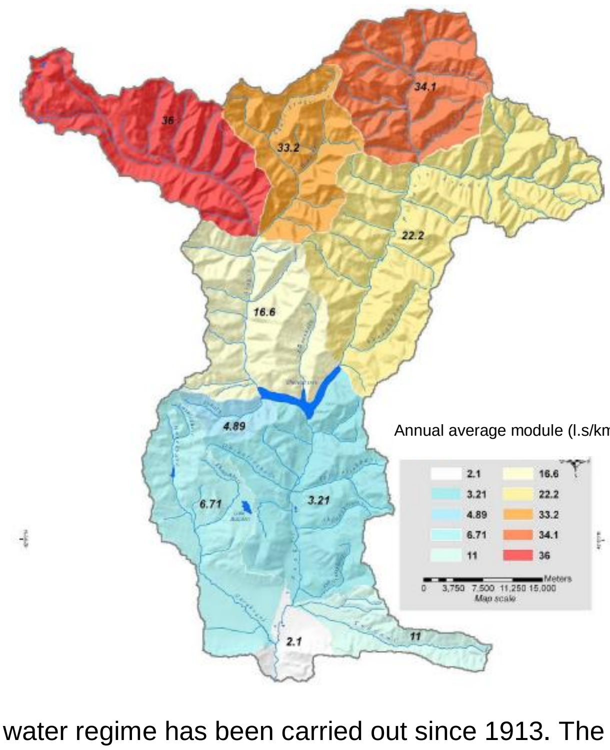
The hydrographic network of Aragvi River basin is quite well developed, its density is 0,7 km/km^2. The total fall of the river is 2,683 m, the average gradient - 9,1%, average height of the basin – 1,600 m asl. There are 716 rivers within the basin, including Mukhrani channel, with total length of 1,926 km. There are following main tributaries, flowing directly into Aragvi: Mtiuletian Aragvi (White Aragvi) (41 km), Gudamakari Aragvi (30 km), Arkala (12 km), Khorkhula (15 km), Pshavi Aragvi (56 km), Dushetiskhevi (13 km), Tsirdaliskhevi (15 km), Abanoskhevi (12 km), Akhatniskhevi (16 km), Tezami (28 km) and Narekvavi (41 km). The eastern part of Aragvi basin is more developed on the expense of Pshav Aragvi basin. In many places of Aragvi River basin ground water flows out in the form of streams – yield of the Natakhtari streams is 1,2 m^3/s, Saguramo stream yield - 0,26 m^3/s, Bulachauri - 0,125 m^3/s. The river width at the source is - 10-12 m, at the village Bulachauri it is up to 46 m; depth is 0,6-1,2 m at Choporti village, and at Saguramo it is 2,1-2,2 m; water flow speed at Pavleuri village is - 0.7 m/s, at Tsitliankari village - 1.6 m/s. Several natural and artificial ponds can be found in Aragvi River basin, including Bazaleti Lake, which is connected through channels and small rivers to Narekvavi reservoir that is used for irrigation.

There is a great difference in average annual runoff numbers between the sections of Aragvi river basin (max. - 36 l/s per km^2, min. - 2.1 l/s per km^2), it is caused by significant difference between number of precipitation and air temperature on the territory of the basin. Maximum runoff in the basin can be observed in high Caucasus Mountains, and minimum – in dry and hot places of the lowland within the basin.

Map 5: Hydrographic Network of Aragvi River Basin



Map 6: Aragvi River Basin Runoff Module. Source – Management Plan of the Pilot River Basin for Aragvi River – Georgia



Observations on Aragvi River water regime has been carried out since 1913. The river is fed by snow (23.9 %), rain (24.9 %) and ground (51.2 %) water. Feeding from glaciers is insignificant.

CLIMATIC CHARECTERISTICS

Climatic peculiarity of Aragvi River Basin is determined by the geographical location of the territory and its morphological boundedness. This stipulates that several different climatic zones are singled out within the region:

1. Moderately humid climatic zone with mild cold winter and warm long summer (up to 600-1,100 m);
2. Moderately humid climatic zone, with cold winter and long summer (up to 1,700 m);
3. Mountainous humid climate with permanent snow and glaciers.

Lower reaches of the basin, which comprises the most part of Mtskheta municipality, is located within the moderately humid subtropical climatic zone. Hot summer climate that is transitional from moderately warm steppe to moderately humid climate dominates on Mukhrani-Saguramo Plain, in Mtkvari River Valley and Dighomi Plain, average air temperature is +10.8°C +12°C, precipitations - 575-638 mm per year. Moderately humid climate with moderate cold winter and long warm summer is typical for Skhaltba, Trialeti, Saguramo and Qartli Range and the south foothill of the Caucasus.

Middle and upper reaches of the basin is situated in humid subtropical climatic zone and is characterized by altitudinal zoning. Climate is moderately humid with moderate cold winter and long warm summer in the lower part of the region. Mountainous moderately humid climate with lack of summer is typical for the mountainous area. High mountainous climate with permanent snow and glaciers dominates above 3,300-3,400 m. On the territory of Mtskheta municipality the average air temperature is +11°C in the lowland, temperature is 0°C on 2,350 m and above this altitude temperature is significantly low. Average air temperature of January is less than 0°C in the lower part of Mtskheta municipality and in mountainous part it drops even less than -15°C. Average temperature of July is +22.5 and +24°C. About 700 mm precipitations are recorded on the lowland in a year. More than 1,700 mm precipitations are typical for the upper basin of white (Mtiuleti) Aragvi River, 800-1,500 mm precipitations – Pshavi Aragvi and Khevsureti Aragvi River basins, 600-1,400 mm precipitations – upper reaches of Arkhotistskali River and Arghuni River. Maximum amount of precipitations are expected in spring (May), snow comes in the entire region in winter and its cover is insignificant in the lowland, as for the mountainous part, its height reaches even 3.5 m in some certain years[10].

ASSESSMENT OF WATER CONSUMPTION

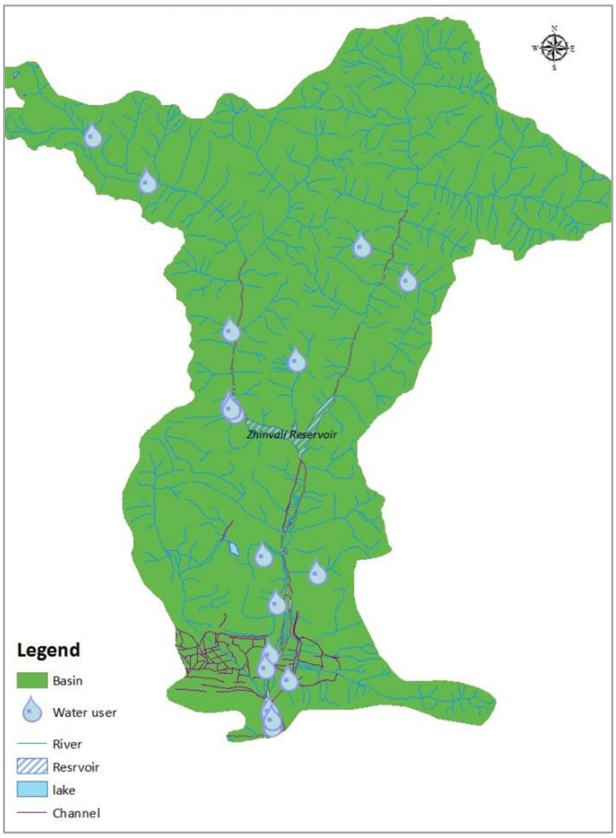
Development of water balance methodology for the basin of any climatic conditions needs existence of information about current and/or potential water users.

Since January 2008, permit for using water resources is no longer required in Georgia that considerably weakened the mechanisms of strict and reliable control on water consumption. Water Resource Management Service of the MENRP of Georgia is responsible for gathering, keeping and analysis of information on water consumption in Georgia.

Water users are required to fill in corresponding forms annually, where general information about water user (physical entity or organization), data of water withdrawal according to the months, types of water consumptions, as well as water supply for other water users (if any) and discharge of pollutants (amount and permitted borders) are given. Water users should specify information about source of water withdrawal (with indicating water body or water user from where the latter takes water). Water users should also indicate the distance from the confluence of the river, but precise geographical coordinates are not required. The department annually publishes reports about water consumption with the data of the previous year. Information is summarized according to administrative districts, rivers, types of water use and other indicators.

[10] Geography of Georgia: Part. 1: Physical Geography / Georgia. Science. Acad; Institute of Geography. Z. Tatashidze at al. – 2000; "Mtskheta-Mtianeti region's relief and geodynamic processes" Avaliani Elisabed Master's Thesis, 2013 Tbilisi) [10]

Map 7: Water Users Recorded in Aragvi River Basin



Information about the amount of withdrawn and returned water to the system by water users within the basin of Aragvi River is given in Table 1.

Table 1: Water Users – Water Abstraction on Discharge

Consumer	Water Abstraction- m3												Annual	Discharge	Sector
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
Kvakutkhedi	21460	25680	28660	20040	22540	28970	28270	25290	24070	28490	20150	22640	296260	**260000**	Tsikhisdziri Industry
Mining+	4000	5000	6000	13000	33000	20000	25000	24000	17000	18000	8000	11000	184000	**182000**	
Gonio	4350	4610	6610	4400	7690	8460	7820	7790	7920	6800	5390	7310	79150	**70000**	
Ananuri	1977	4361	6101	3306	3038	3136	4445	5502	7566	8471	8496	3420	59819	**59819**	
Ltd Lomisi; Brewery "Natakhtari"-Well.	25708	28364	34474	38304	39394	42920	42388	45632	34220	25545	16930	27989	401868	**301050**	Natakhtari Industry
Ltd Barambo - Well	4000	4000	5000	6000	6000	11000	11000	14000	12000	5000	4000	9000	91000	**60000**	
Natakhtari Spring	360	247	218	177	131	132	176	160	188	125	89	71	2074	**1900**	
Ltd "Sakartvelos samkhedro gza"	6000	0	2790	2550	5940	6000	6000	9300	3240	6000	6000	5040	58860	**51000**	
Ltd gia mamatsashvili	0	0	0	0	3600	4650	5500	4900	900	1500	2200	0	23250	**17000**	Industry Other
i/e Tevdore	0	0	0	1	2	1.8	2	1.4	1.8	2.2	1.8	0	14	**0**	
LTD Libra	49	990	4350	2100	2980	42	0	0	49	0	0	0	10560	**10560**	
Ltd GDS	0	500	2180	3170	830	9400	10110	7200	8240	9930	8890	4130	64580	**56000**	
Ltd Truso	35	35	35	0	35	35	35	35	35	35	0	35	350	**300**	
I/e Naira yorSemanaSvili	0	60	70	70	70	70	70	70	70	70	60	60	740	**300**	
I/e Murad Buchukuri	0	0	0	5	5	5	5	5	5	5	5	0	40	**0**	
I/e Levan Amiridze	0	0	10	10	10	10	10	10	10	0	0	0	70	**0**	
Geo-monataji	0	0	1980	1450	3110	1390	670	4740	3400	4850	5180	2680	29450	**25000**	
I/e davit khoranauli	0	8000	2400	2400	2400	2400	2400	2400	2400	2400	2400	800	30400	**20800**	
I/e eldar chobanadze	5	5	5	5	5	5	5	5	5	5	5	5	60	**50**	
Bekanisi	0	4920	12300	2520	3060	9060	5580	11460	9890	10560	13440	7680	90470	**80000**	
Gudaurmsheni	0	0	0	0	0	0	0	0	2420	6470	240	0	9130	**8000**	
udzilaurta HPP	0	0	0	0	0	0	0	0	0	0	3640	7340	10980	**9000**	
Aragvi-Saguramo magistral line	0	0	0	0	0	69000	191000	301000	135000	11000	0	0	707000		Irrigation
Aragvi-Lami-Misaktsieli	11498000	5510000	0	0	0	4838000	7560000	13003000	10584000	15120000	12452000	12753000	93318000	**6742000**	
Ghrmaghele Station/Jinvali reservoire	2,719,840	2,453,350	2,690,400	2,620,720	2,708,680	2,432,110	2,632,370	2,662,460	2,633,280	2,808,250	2,680,850	2,707,960	328333000	**0**	Tbilisi Water Supply system
Natakhtari Syphone	2,719,840	2,453,350	2,690,400	2,620,720	2,708,680	2,432,110	2,632,370	2,662,460	2,633,280	2,808,250	2,680,850	2,707,960	31,750,270		
Bulachauri	2,618,600	3,591,500	3,875,770	3,560,740	3,483,960	3,517,790	3,988,930	3,707,750	3,594,560	3,741,610	3,756,810	3,759,460	43,197,480		
Natakhtari springs	5,812,110	5,249,610	5,312,110	5,624,620	5,812,110	5,624,680	5,842,110	5,812,110	5,624,620	5,882,180	5,824,620	5,812,110	68,232,990		
Choporti_misaktsieli	4,799,850	4,325,560	4,722,250	4,645,110	7,122,250	4,245,110	7,299,250	4,122,250	4,245,110	4,828,110	4,645,400	4,222,250	59,222,500		

Mukhrani	160,670	213,820	412,940	659,470	1,612,600	1,147,730	1,327,820	1,629,430	1,005,070	1,372,220	1,732,770	1,941,260	13,215,800		
Saguramo	3,583,400.00	3,238,350.00	3,583,400.00	3,468,000.00	3,583,400.00	3,468,000.00	3,583,500.00	3,883,400.00	3,468,000.00	3,583,400.00	3,468,000.00	3,583,400.00	42,494,250		
Bodorna	26784000	27302400	29462000	25228800	21254000	25358000	27371000	29203000	28512000	29462000	28599000	29782000	328,317,200		
Dusheti UWSC-Jinvali Reservoire infiltrated waters	151200	136600	151200	146300	151200	146300	151200	151200	146300	151200	146300	151200	1780200	521000	Dusheti-Mtsketa Water Supply-Mettered customers
Dusheti UWSC - Underground Horizon	69400	61800	69400	64100	69400	67100	69400	69400	67100	69400	67100	69900	813500		
Dusheti UWSC-Underground Horizon	13400	12300	13400	12900	13400	12900	13400	13400	12900	13400	12900	13400	157700	100000	
Mtskheta-Tserovani (tbilisi Central network)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	60000	0	

4. DATA AVAILABILITY

Data Limitation

Water demand data as well as hydro meteorological data in the Aragvi basin is limited. Currently, there is no structured and complete database available on water consumption by the different water users (domestic, agricultural and industrial use) at the water resources management service of MENRP (water resources management service is responsible for water consumption calculation). Data about water users in the basin is not complete as not all water users provide detailed information on water abstracted and discharge. In addition, water abstraction information is available by months while water return flow information is available only by years.

Hydrometeorological datasets are limited and partly inconsistent. There are cases when data for several years from meteorological observation is missing (e.g. data from Dusheti meteorological station for 1995 and 2005 series is completely absent). Currently only one meteorological station is operating within the basin that has multiyear data series (Dusheti meteorological station). Consequently, calculation for meteorological parameters for the 1,610 km^2 (Aragvi River basin area downstream the dam) was used only from this station. Two years ago, one more station (Mukhrani meteorological station) was added within the basin but datasets are yet too short to be used.

Flow data within the Aragvi River basin is also limited due to the lack of monitoring stations. There are ongoing hydrological observations for 3 stations upstream from Jinvali dam (Aragvi of Pshavi at the Village of Magharoskari; Shavi Aragvi at the confluence close to Pasanauri; Tetri Aragvi at the township of Pasanauri). While downstream of river Aragvi, below the Jinvali dam, previously existing stations have ceased to operate.

For more than 20 years there was no systematic monitoring on ground water parameters in Aragvi River basin as well as in the country.

DATA ACCESSIBILITY

Hydro-meteorological data for Aragvi river basin is available at the NEA. The hydro-meteorological database is property of NEA and is handled as a commercial product. The data is not publicly published or stored on web-portal. Any interested party should pay for the needed data. In addition, it has to be highlighted that one of the biggest water user in Aragvi basin - Georgian Water and Power Ltd (GWP) is operating hydrological station on Jinvali reservoir, however the information owned by the company and is not shared with other parties.

Considering the data challenges, the Aragvi River basin water balance calculation were carried out with limited available data that partly has been substituted through interpolations, estimates or calculations based on secondary datasets. These limitations result in respective uncertainties related to the achieved results.

5. METHODOLOGY

The below provided approach for water balance calculation facilitates hydrological process understanding in a basin and is used to describe the flows of water within a system. A monthly time step is used for the calculations.

The monthly water-balance model of Aragvi River basin developed in the environment of Microsoft Excel permits the user to easily modify water-balance parameters and provide useful estimates of water-balance components for a specified location.

Inputs to the model are hydrometeorological parameters including precipitation, mean daily temperature, basin area and water inflow as well as various parameters describing the anthropogenic extractions and return flows in the system, including irrigation, hydropower, domestic, industrial and transfer use.

The Equitation used for the estimation of Aragvi River basin Water Balance is as follows, further detailed in Table 2:

P+Dr+Dind+Dirr+Ddom-ETreal-Airr-Aind-Adom-Tout=Rr
Ef+Wa=Rr

Table 2: Parameters for Water Balance Calculation

Parameter	Term	Type of Contribution	Unit	Input Type
P	Precipitation downstream the Jinvali dam	Inflow	m3/month	Estimated/actual data
Dd	Water discharged from the Jinvali Reservoir	Inflow	m3/month	Estimated
Dind	Return flow to the river formed by industry discharge	Inflow	m3/month	Actual
Dirr	Return flow to the river formed by the Irrigation	Inflow	m3/month	Estimated/actual
Ddom	Return flow formed by the domestic sector located in the boundaries of basin downstream the dam	Inflow	m3/month	Actual
ETreal	Evapotranspiration downstream the Jinvali Dam	outflow	m3/month	Estimated
Airr	Abstraction of the water for Irrigation	outflow	m3/month	Actual
Aind	Abstraction of the water for industry	outflow	m3/month	Actual
Adom	Abstraction of the water for Domestic	outflow	m3/month	Actual
Tout	Transfer of water out of the boundaries of basin	outflow	m3/month	Actual
Rr	River Runoff	result	m3/month	
Ef	Environmental Flow		m3/month	Assumption
Wa	Water available for use	result	m3/month	

Input parameters in Table 2 are classified as inflow and outflow parameters. The Inflow parameters contributing to the river discharge and the outflow parameters, in negative numbers in the equation, contributing to extraction of water from the basin.

PRECIPITATION

The first computation of the water-balance model is the calculation of the amount of monthly precipitation (P) in the lower basin downstream the Jinvali Dam. In case of Aragvi River basin, monthly water balance parameters were calculated based on daily precipitation data obtained from the National Environmental Agency (NEA) for Dusheti meteorological station. (The annual precipitation at Dusheti is 576.8mm).

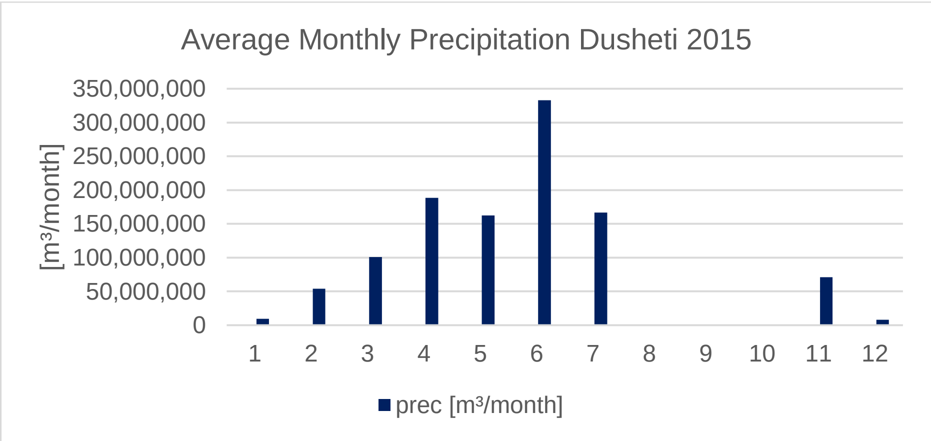
Table 3: Dusheti Meteorological Station Records 2015

Month	Prec [mm/month]	Prec [m³/month]
January	6.00	9,660,000.00
February	33.40	53,774,000.00
March	62.60	100,786,000.00
April	117.00	188,370,000.00
May	100.80	162,288,000.00
June	206.80	332,948,000.00

July	0.00	166,796,000.00
August	0.40	644,000.00
September	0.20	322,000.00
October	0.40	644,000.00
November	44.20	71,162,000.00
December	5.00	8,050,000.00

Prec [mm/month] $= \sum_X^1 \mathrm{P\ mm/day}$
Prec [m³/month]= $\mathrm{Prec\ mm/month} \ * \ 1610000000$sq/m
Where 1610000000 m^2 is the catchment area below the Jinvali Dam

Figure 3: Monthly Precipitation at Dusheti



Calculation Approach

Precipitation in the lower Aragvi basin falls as rain as well as snow. Considering temperature conditions in the basin, monthly precipitation was calculated on the basis of meteorological data records of Dusheti station together with the assumption that snow is melted during the month it falls, respectively adding to liquid precipitation.

The assumption used for this approach is that the Prec mm/month = Prec rain + Prec snow. For calculating runoff evapotranspiration was subtracted from precipitation.

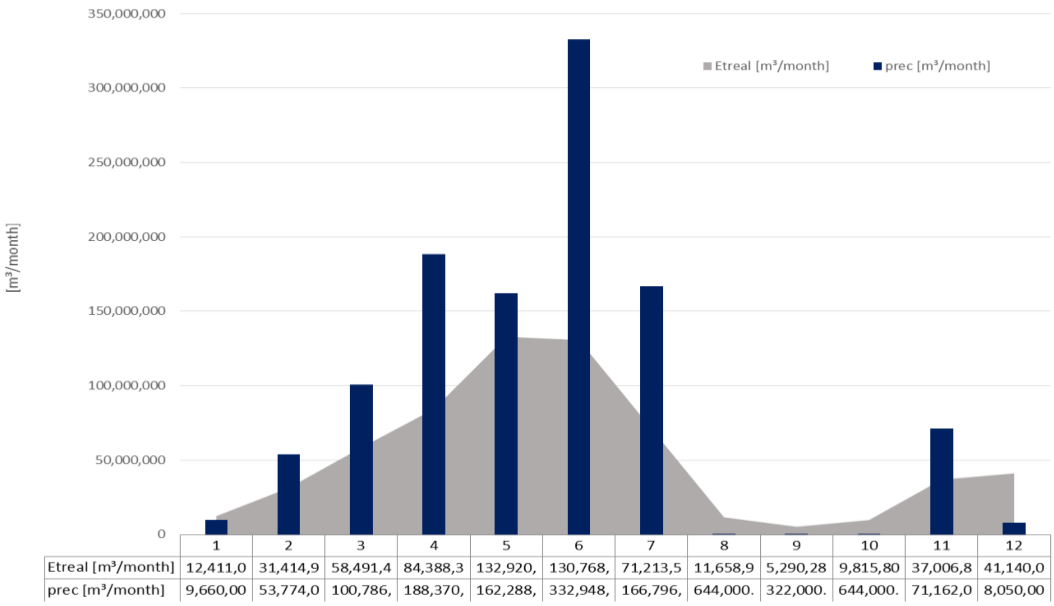
The basis of above provided assumption was the following factors:

- Dusheti station is the only meteorological station in the basin having a sufficiently long record and being located at a somehow representative altitude at an intermediate elevation in the basin
- Only the lower basin has been considered in the calculation. The upper basin is characterized by a strongly time delayed snowmelt regime while in the lower basin rainfall prevails. The outflow from the upper basin is anyhow buffered by Jinvali dam for which outflow data has been used to consider inflow into the lower basin.
- The historic data obtained from records of Dusheti meteorological station (1973-1983) located downstream the Jinvali Dam indicates that snow cover very rarely lasts more than 20 days and respectively contributes to the monthly river runoff.
- The snow cover data records for 2015 is not available for the area downstream the Jinvali Dam.

REAL EVAPOTRANSPIRATION

To determine the volume of water feeding the river Aragvi from precipitation, evapotranspiration has been calculated and subtracted from precipitation.

Figure 4: Monthly Precipitation and -Evapotranspiration in Lower Aragvi Basin



Calculation Approach

Blaney Criddle method was used to calculate potential evapotranspiration, reducing the amount of water contributing to river runoff from precipitation. The Blaney Criddle approach allows the calculation of evapotranspiration based on mean daily temperature, assuming a reference crop situation without spatially discretizing individual land cover variations.

ETo = p (0.46 T mean +8)

Where:

ETo = evapotranspiration (mm/day) as an average for a period of 1 month
T mean = mean daily temperature (°C)
p = mean daily percentage of annual daytime hours

"Air Average Temperature °C" daily values for 2015 from data provided by the NEA on meteorological records of Dusheti station were used to supply mean daily temperature data.

The parameter p was derived from Table 4 [11], selecting the values referring to 40° latitude, closely representing the latitude of the lower Aragvi basin.

Table 4: Mean Daily Percentage (P) of Annual Daytime Hours for Different Latitudes

Latitude	North	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	South	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
60°		0.15	0.20	0.26	0.32	0.38	0.41	0.40	0.34	0.28	0.22	0.17	0.13
55		0.17	0.21	0.26	0.32	0.36	0.39	0.38	0.33	0.28	0.23	0.18	0.16
50		0.19	0.23	0.27	0.31	0.34	0.36	0.35	0.32	0.28	0.27	0.27	0.27
45		0.20	0.23	0.27	0.30	0.34	0.35	0.34	0.32	0.28	0.27	0.27	0.27
40		0.22	0.24	0.27	0.30	0.32	0.34	0.33	0.31	0.28	0.27	0.27	0.27
35		0.23	0.25	0.27	0.29	0.31	0.32	0.32	0.30	0.28	0.27	0.27	0.27
30		0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.27	0.27	0.27
25		0.24	0.26	0.27	0.29	0.30	0.31	0.31	0.29	0.28	0.27	0.27	0.27
20		0.25	0.26	0.27	0.28	0.29	0.30	0.30	0.29	0.28	0.27	0.27	0.27
15		0.26	0.26	0.27	0.28	0.29	0.29	0.29	0.28	0.28	0.27	0.27	0.27
10		0.26	0.27	0.27	0.28	0.28	0.29	0.29	0.28	0.28	0.27	0.27	0.27

[11] FAO Irrigation Water Management : Irrigation Water Needs CHAPTER 3: CROP WATER NEEDS Table 4 MEAN DAILY PERCENTAGE (p) OF ANNUAL DAYTIME HOURS FOR DIFFERENT LATITUDES

5		0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27
0		0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27

Following the calculation of potential evapotranspiration, the values were reduced to represent actual evapotranspiration, i.e. considering the moisture actually available for evapotranspiration. In the absence of measurements, this was achieved through approximating moisture availability based on rainy days in a month.

The number of rainy days per month in 2015 was defined based on daily precipitation data. Later the number of rainy days per month was used to calculate the share of rainy days per month as a % -age to be used as a conversion factor of ETo to ET real.

Table 5: Parameter for Calculation of Real Evapotranspiration

Month	Monthly sum average 2015 Eto [mm/month]	Coefficient for calculation Eto to Etreal	Etreal [mm/month]	Etreal [m³/month]
January	47.79	0.16	7.71	**12,411,054**
February	60.71	0.32	19.51	**31,414,900**
March	86.63	0.42	36.33	**58,491,437**
April	104.83	0.50	52.42	**84,388,311**
May	142.18	0.58	82.56	**132,920,005**
June	174.05	0.47	81.22	**130,768,094**
July	175.20	0.00	0.00	**71,213,535**
August	112.24	0.06	7.24	**11,658,976**
September	98.58	0.03	3.29	**5,290,288**
October	94.50	0.06	6.10	**9,815,806**
November	86.20	0.27	22.99	**37,006,816**
December	88.02	0.29	25.55	**41,140,008**

ETo [mm/month] = $\sum_X^1 \mathrm{ETo\ mm/day}$
ET real [mm/month]= $\sum_X^1 \mathrm{ETo\ mm/day} \ast \mathrm{Coeficient}$
ET real [m^3/month]= $\sum_X^1 \mathrm{ETo\ mm/day} \ast \mathrm{Coeficient} \ast 1610000000\mathrm{sq/m}$

Where:

Coefficient is the values for coefficient for calculation Eto to ETtreal
1610000000 m^2 is the catchment area below the Jinvali Dam

Considering data gaps, the dataset partly had to be corrected. The value for ET real [m3/month] for July is averaged between the numbers for August and June. The reason being that the difference between the meteorological data recordings for July 2015 of Dusheti Station comparative to historical June records between 1957-2006 showed likely station malfunctioning (no rain).

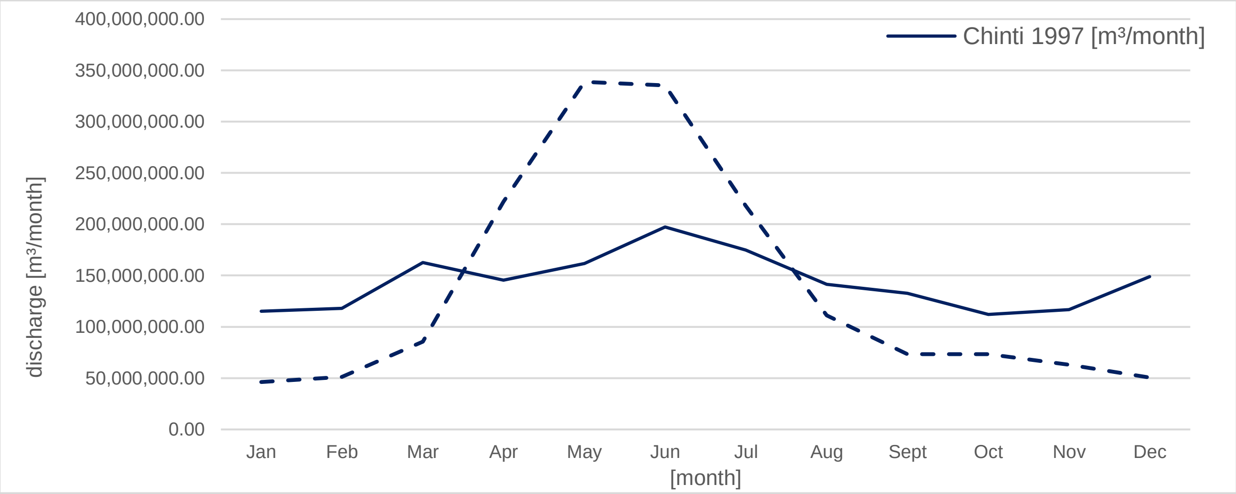
UPSTREAM INFLOW

The approach used to calculate the upstream inflow into the lower Aragvi basin (actual discharge of Jinvali dam) is based on averaging the monthly discharges data as available for 1976- 1980 from gauging station located in village Chinti[12] and for 1996-1997 for Jinvali Reservior water balance[13].

Since the data from Chinti station represents the discharge before the start of the operation of the dam, the averaged values from 1996-1997 were taken to approximate a theoretical discharge of the dam for 2015.

[12] State Water Cadastre – multy annual data on surface water regime and resources - Vol. VI, Leningrad, Gidrometizdat.1987
[13] Source - Hard Copy Jinvali Reservoir water balance. Tbilisi, 1998.

Figure 5: The Runoff Curves Before and after the Construction of the Dam



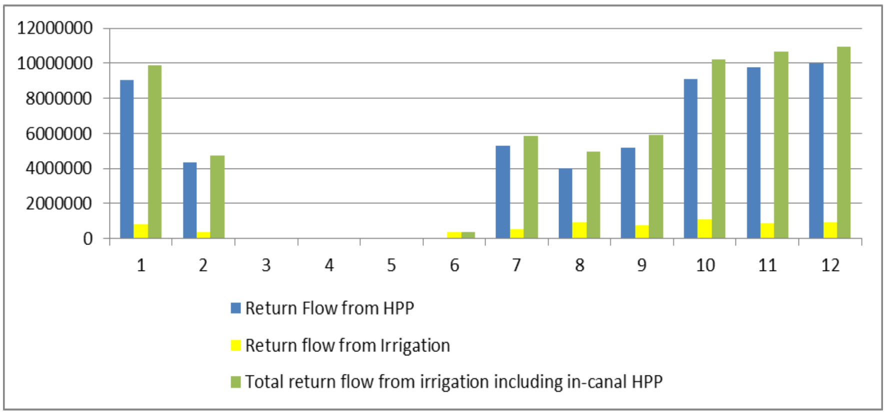
The Jinvali Dam can store more than 500 mill. m^3 of water, greatly affecting the hydrological regime of the river downstream the dam. Moreover it affects the runoff surges downstream the dam because of electricity peak generation patterns which depends on operational regimes set by the transmission and dispatch licensee the Georgian State Electricity System (GSE).

Other approaches would be to include turbine discharge based on power production and turbine characteristics, but this approach would neglect dam bottom outlet- and spillway flows. Considering that the joint discharge capacity of the bottom outlet and spillway can be more than 2000 m^3/s, this would lead to a significant underestimation of the actual dam discharges in specific cases.

Return Flow - Irrigation

The irrigation return flow is estimated on the basis of information submitted to the MENRP. In addition actual generation of electricity in 2015 by the Misaktsieli Hydro Power Plant (HPP) which is supplied by the water from Lami Misakcieli irrigation channel has been used to calculate HP flow requirements and respective return flows, assuming that all water used in the turbine is going back to the river. These HPP return flows have been added to the reported irrigation return flows and contribute a significant percentage of the total return flows as shown in Figure 6.

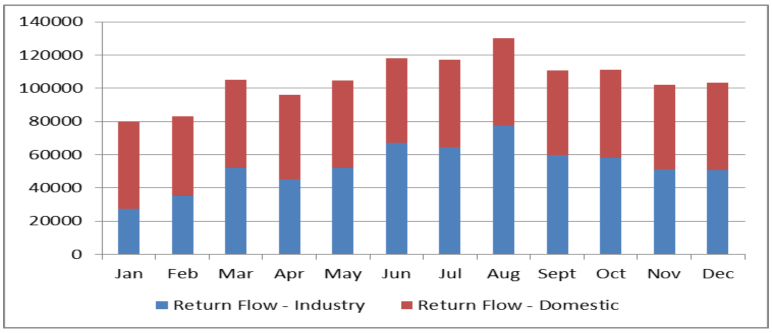
Figure 6: Return Flows from Irrigation and in-Canal Hydropower Facilities



RETURN FLOW – INDUSTRY AND DOMESTIC

Information regarding domestic and industrial return flow has been available as annual numbers. In order to calculate monthly values, return flow was correlated to abstractions in the respective months and monthly return flow values calculated. The results are shown in Figure 7.

Figure 7: Domestic and Industrial Return Flow in the Aragvi Basin



SECTORAL WATER ABSTRACTION AND TRANSFER OUT

Irrigation Abstraction

Abstraction of water for irrigation and some in-canal electricity generation purposes is conducted through the Mukhrani and Saguramo irrigation systems which were designed to irrigate 17 thousand hectare of arable lands. A significant part of the main channels has been rehabilitated whilst the condition of a remaining part of the main canals as well as distribution networks (secondary and tertiary channels) still cause high water losses. The small Misaktsieli HPP with an installed capacity of three megawatt which is supplied through the Mukhrani Irrigation System is located in Misaktsieli village.

Domestic Abstraction

In the Aragvi basin, only one city and winter resort have the centralized domestic water supply system, in Dusheti and Gudauri (the winter resort). Moreover, not the whole population of the above settlements is connected to the water supply system, but only about - 70 %. In Dusheti the domestic sector is served by the United Water Supply Company (UWSC) Dusheti branch. Water is abstracted from underground galleries near the Bazaleti Lake and Mtskheta-Tserovani, which is connected to the Tbilisi water supply main network. (Tbilisi Central network)

In the water balance equation considered the abstraction of water from riv. Aragvi through the raw water collection and storage facilities (except the Bodorna buffer reservoir and the tunnel - Transfer out) which are the part of GWP water supply system.

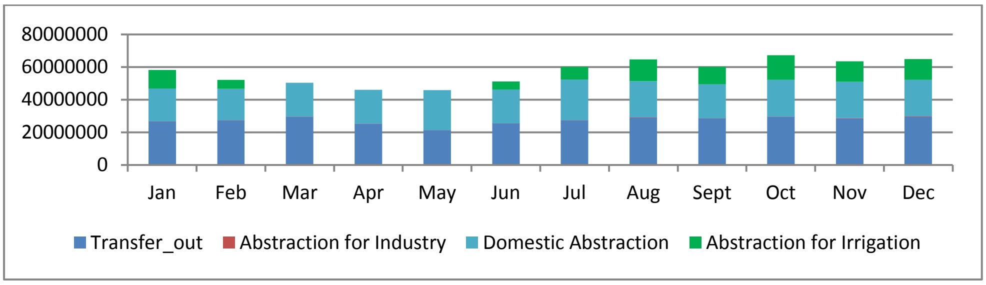
Industrial Abstraction

Industrial sector water abstractions are mainly used for processing agricultural products, poultry meat and eggs, bakery products, mining and processing industry (construction materials), alcoholic and non-alcoholic beverage production and other located in Mtskheta municipality.

Transfer Out

Transfer water as reported by MENRP is withdrawn from Bodorna buffer reservoir to provide Tbilisi with drinking and utility water. The transfer is conducted via a 42km and 5,5m diameter tunnel, with 12m^3/s discharge capacity[14]. Abstractions are shown in Figure 8.

Figure 8: Water Abstraction from the Basin Downstream the Dam

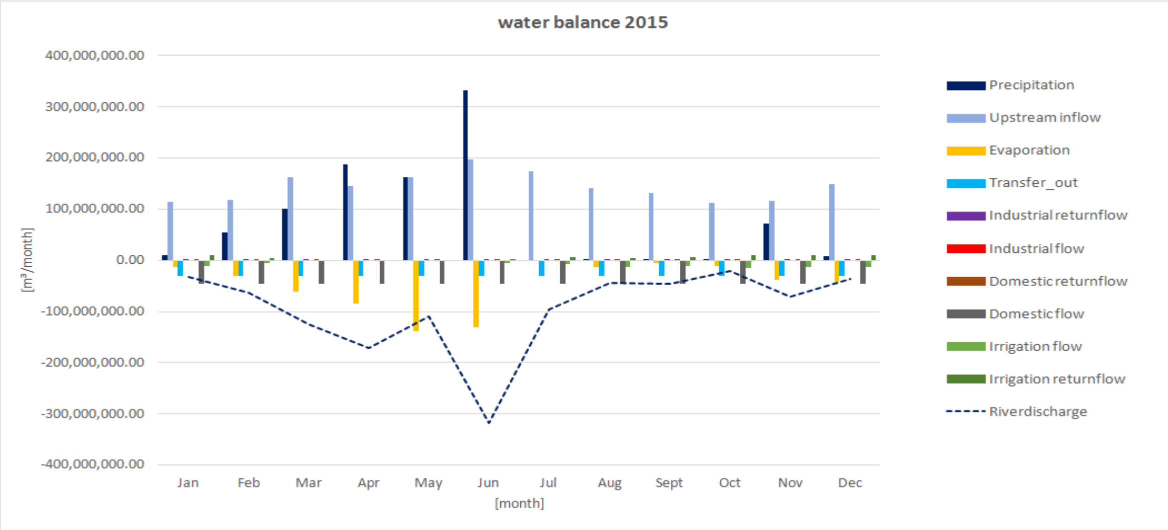


[14] http://www.gwp.ge/en/watersources

6. FINDINGS

Water balances for the Aragvi basin have been calculated based on available and estimated datasets and results checked for their plausibility, leading to a comprehensive overview of the current water resources situation in the basin. An overview for 2015 data is shown in Figure 9.

Figure 9: Monthly Water Balance Overview for Aragvi Basin Showing Abstractions (Flow) and Return Flows. River Discharge is Leaving the Aragvi Basin at its Lower Outlet.



River discharge as shown in Figure 9 above is in principle available for other uses, though environmental flow requirements will have to be considered and have to maintain in the river when planning for future water resources use. Current environmental flow requirements are based on an environmental impact assessment study conducted during the planning phase for Jinvali Dam, constructed in the 1980-es. It should be considered that environmental flow requirements may be revised with up to date knowledge and approaches leading to different reserve numbers to ensure environmental sustainability including the respective ecosystem service functions and livelihood support of the river. In addition also the sectoral water demands are subject to future change depending on anthropogenic development scenarios in the basin.

Considering current conditions the analysis shows that current surplus river discharges (environmental flow requirements considered) are in the order of 7 to 125 m^3/s as shown in detail in Table 6. This water could in principle be used for other demands though it should be noted that for the month of October the remaining flows are already very limited and that in a dry year environmental flow requirements could already be affected or violated. Potential uncertainties in the results based on the partly challenging data situation should be considered as well. Further, potential downstream uses that have not been considered in this study should be taken into account when planning future water resources developments in Aragvi basin.

Table 6: Calculated Aragvi River Discharges Leaving the Basin (2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Surplus river discharge (m^3/s)*	14	29	47	68	43	125	71	16	18	7	28	13

* Flow leaving the basin

USAID Governing for Growth (G4G) in Georgia
Deloitte Consulting Overseas Projects LLP
Address: 85 Z. Paliashvili Street, Tbilisi
Phone: +995 322 240115 / 16
E-mail: info@g4g.ge