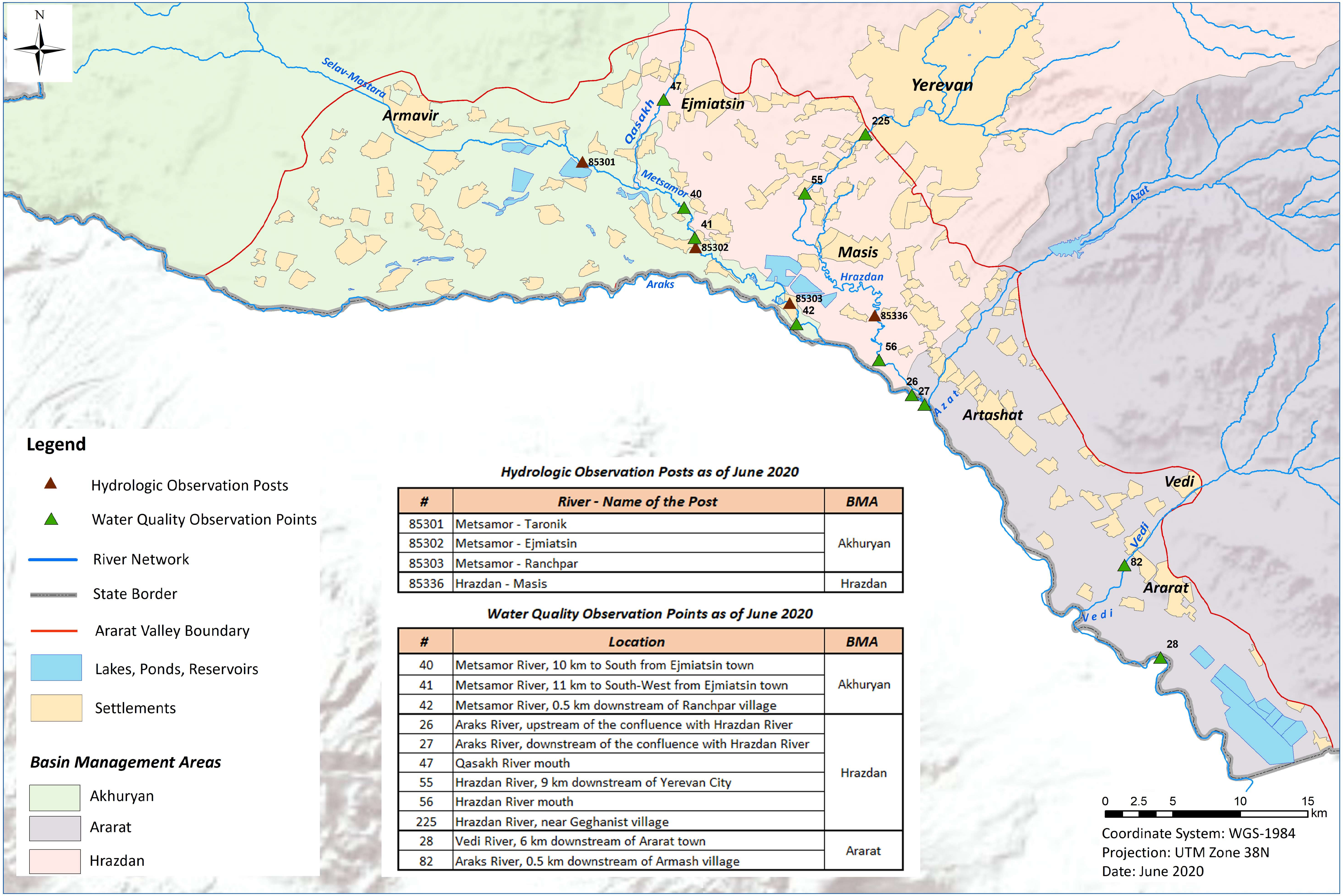
Monitoring of Surface Water Resources in the Ararat Valley



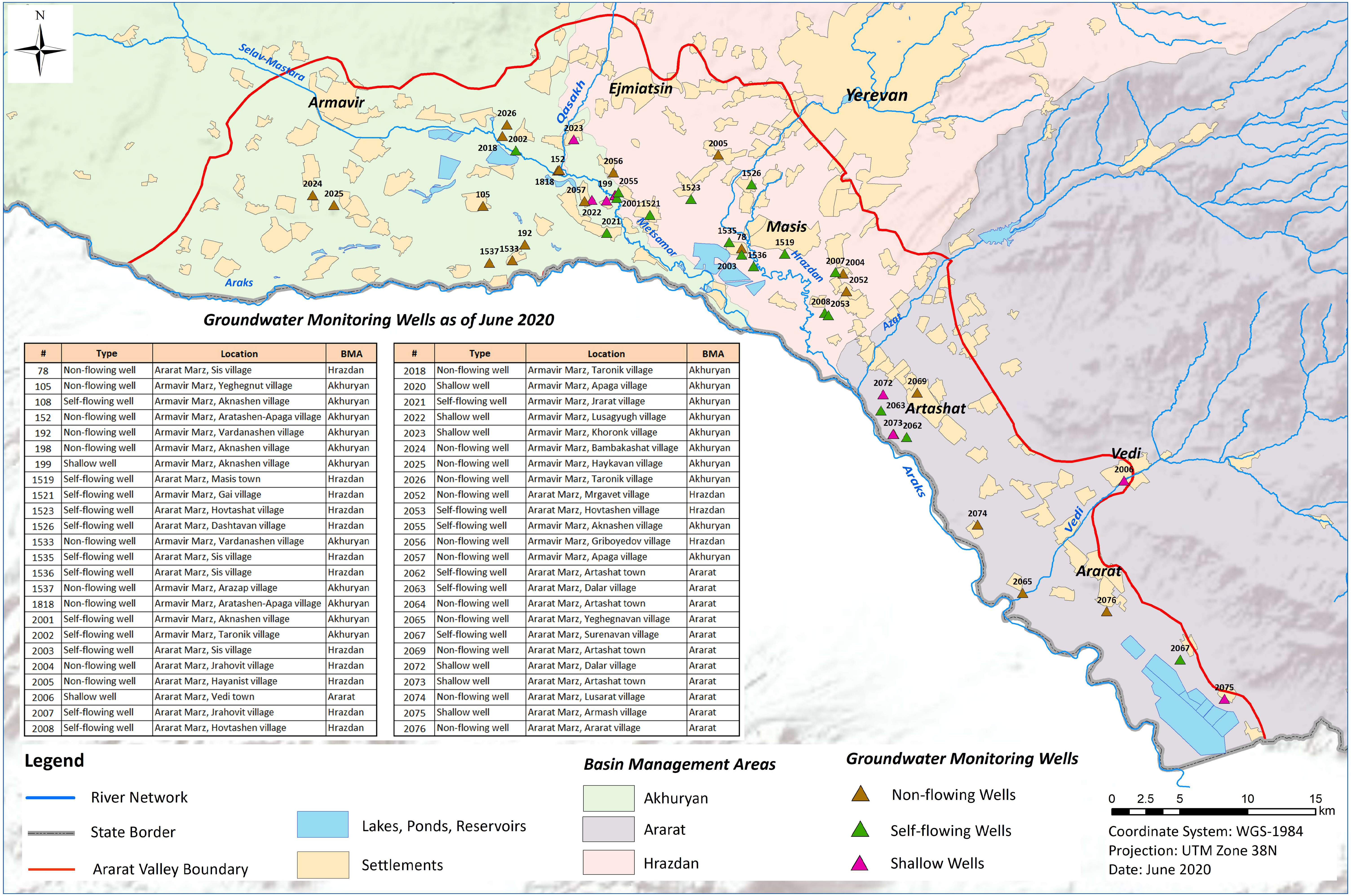
Hydrologic Observation Posts as of June 2020

#	River - Name of the Post	BMA
85301	Metsamor - Taronik	Akhuryan
85302	Metsamor - Ejmiatsin	
85303	Metsamor - Ranchpar	
85336	Hrazdan - Masis	Hrazdan

Water Quality Observation Points as of June 2020

#	Location	BMA
40	Metsamor River, 10 km to South from Ejmiatsin town	Akhuryan
41	Metsamor River, 11 km to South-West from Ejmiatsin town	
42	Metsamor River, 0.5 km downstream of Ranchpar village	
26	Araks River, upstream of the confluence with Hrazdan River	Hrazdan
27	Araks River, downstream of the confluence with Hrazdan River	
47	Qasakh River mouth	
55	Hrazdan River, 9 km downstream of Yerevan City	
56	Hrazdan River mouth	
225	Hrazdan River, near Geghanist village	
28	Vedi River, 6 km downstream of Ararat town	Ararat
82	Araks River, 0.5 km downstream of Armash village	

Monitoring of Groundwater Resources in the Ararat Valley



Groundwater Monitoring Wells as of June 2020

#	Type	Location	BMA
78	Non-flowing well	Ararat Marz, Sis village	Hrazdan
105	Non-flowing well	Armavir Marz, Yeghegnut village	Akhuryan
108	Self-flowing well	Armavir Marz, Aknashen village	Akhuryan
152	Non-flowing well	Armavir Marz, Aratashen-Apaga village	Akhuryan
192	Non-flowing well	Armavir Marz, Vardanashen village	Akhuryan
198	Non-flowing well	Armavir Marz, Aknashen village	Akhuryan
199	Shallow well	Armavir Marz, Aknashen village	Akhuryan
1519	Self-flowing well	Ararat Marz, Masis town	Hrazdan
1521	Self-flowing well	Armavir Marz, Gai village	Hrazdan
1523	Self-flowing well	Ararat Marz, Hovtashat village	Hrazdan
1526	Self-flowing well	Ararat Marz, Dashtavan village	Hrazdan
1533	Non-flowing well	Armavir Marz, Vardanashen village	Akhuryan
1535	Self-flowing well	Ararat Marz, Sis village	Hrazdan
1536	Self-flowing well	Ararat Marz, Sis village	Hrazdan
1537	Non-flowing well	Armavir Marz, Arazap village	Akhuryan
1818	Non-flowing well	Armavir Marz, Aratashen-Apaga village	Akhuryan
2001	Self-flowing well	Armavir Marz, Aknashen village	Akhuryan
2002	Self-flowing well	Armavir Marz, Taronik village	Akhuryan
2003	Self-flowing well	Ararat Marz, Sis village	Hrazdan
2004	Non-flowing well	Ararat Marz, Jrahovit village	Hrazdan
2005	Non-flowing well	Ararat Marz, Hayanist village	Hrazdan
2006	Shallow well	Ararat Marz, Vedi town	Ararat
2007	Self-flowing well	Ararat Marz, Jrahovit village	Hrazdan
2008	Self-flowing well	Ararat Marz, Hovtashen village	Hrazdan

#	Type	Location	BMA
2018	Non-flowing well	Armavir Marz, Taronik village	Akhuryan
2020	Shallow well	Armavir Marz, Apaga village	Akhuryan
2021	Self-flowing well	Armavir Marz, Jrarat village	Akhuryan
2022	Shallow well	Armavir Marz, Lusagyugh village	Akhuryan
2023	Shallow well	Armavir Marz, Khoronk village	Akhuryan
2024	Non-flowing well	Armavir Marz, Bambakashat village	Akhuryan
2025	Non-flowing well	Armavir Marz, Haykavan village	Akhuryan
2026	Non-flowing well	Armavir Marz, Taronik village	Akhuryan
2052	Non-flowing well	Ararat Marz, Mrgavet village	Hrazdan
2053	Self-flowing well	Ararat Marz, Hovtashen village	Hrazdan
2055	Self-flowing well	Armavir Marz, Aknashen village	Akhuryan
2056	Non-flowing well	Armavir Marz, Griboyedov village	Hrazdan
2057	Non-flowing well	Armavir Marz, Apaga village	Akhuryan
2062	Self-flowing well	Ararat Marz, Artashat town	Ararat
2063	Self-flowing well	Ararat Marz, Dalar village	Ararat
2064	Non-flowing well	Ararat Marz, Artashat town	Ararat
2065	Non-flowing well	Ararat Marz, Yeghegnavan village	Ararat
2067	Self-flowing well	Ararat Marz, Surenavan village	Ararat
2069	Non-flowing well	Ararat Marz, Artashat town	Ararat
2072	Shallow well	Ararat Marz, Dalar village	Ararat
2073	Shallow well	Ararat Marz, Artashat town	Ararat
2074	Non-flowing well	Ararat Marz, Lusarat village	Ararat
2075	Shallow well	Ararat Marz, Armash village	Ararat
2076	Non-flowing well	Ararat Marz, Ararat village	Ararat

Section 2. Inventory of Groundwater Wells, Natural Springs and Fish Farms in the Ararat Valley

In 2016, the ASPIRED Project inventoried a total of 2,807 wells (including 570 wells in fish farms), 14 groups of natural springs, and 235 fish farms to describe the baseline situation on groundwater resources and groundwater use in the Ararat Valley.

Results of the Groundwater Wells Inventory

The inventory covered all wells from the confined aquifers in the Ararat Valley with a depth exceeding 50 meters, and wells from the unconfined aquifer with a depth less than 50 meters which were used frequently or permanently. The 2,807 groundwater wells inventoried include 1,795 operational wells, 700 non-operational wells, 123 temporarily closed wells, 4 wells that were permanently closed after the inventory, 158 wells not suitable for operation (as a result of damaged well structures, being filled with stones or garbage, etc.) , and 27 sealed wells. Overall, 36% of the inventoried wells were not operational at the time of the inventory.

Based on the inventory data, 680 wells out of operational 1,795 wells were self-flowing in 2016, with 31,596.3 liters per second total measured discharge, which comprises 996.5 million m^3 per year. The remaining 1,115 wells were operated with pumps, with total discharge estimated at 32,387.3 liters per second or 1,021.5 million m^3 per year, calculated based on the capacity of the pumps. In the same period, water discharge from non-operational wells was estimated at 1,114.5 liters per second or 35.2 million m^3 per year, which is 2% of the total discharge of the wells (Figure 1).

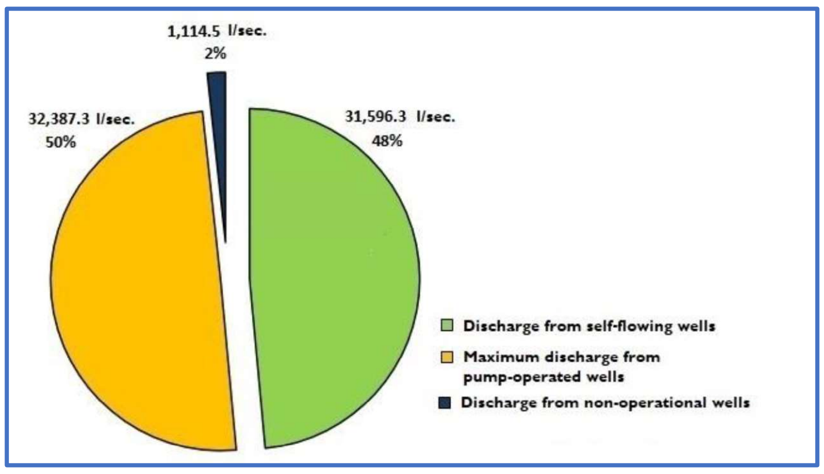


Figure 1: Discharge Rates from Self-flowing, Pump-operated and Non-operational wells in 2016

Figure 2 presents statistics on the status of non-operational wells in 2016.

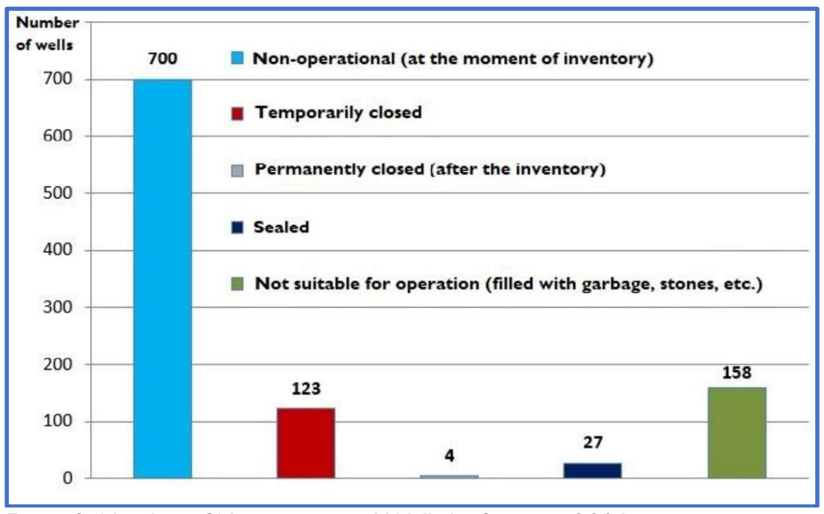


Figure 2: Number of Non-operational Wells by Status in 2016

The groundwater wells were used for the following purposes:

- Drinking-household: 500 wells, including 212 self-flowing wells and 288 wells operated by pumps;
- Irrigation: 924 wells, including 162 self-flowing wells and 762 wells operated by pumps;
- Fish farming: 336 wells, including 302 self-flowing wells and 34 wells operated by pumps; and
- Industrial: 35 wells, including 4 self-flowing wells and 31 wells operated by pumps.

Data on discharge of the operational wells in liters per second, purpose of use, and operation type of the wells are presented in Figure 3 below:

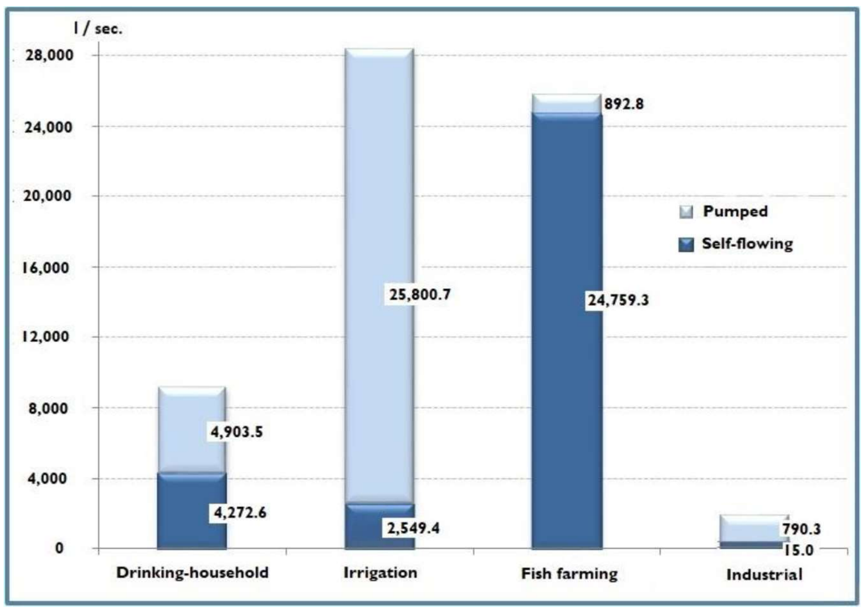


Figure 3: Discharge Rates from the Pump-operated and Self-flowing Wells Used by Various Sectors in 2016 (note: Armenian Nuclear Power Plant receives water from the wells grouped under the drinking-household and industrial use purposes)

Results of the Natural Springs Inventory

A total of 14 groups of natural springs and the headwaters of these springs were inventoried. Nine of the natural springs were operational and were characterized as small shallow lakes with water flow. Fields of the other five groups of natural springs were characterized as wet areas or wetlands, with no water flow observed. In some sites, water discharge was observed downstream from the headwaters of previously operational springs, flowing in ditches with up to one-meter depth. At the time of the inventory in 2016, the total yield of the described 14 springs was 3,306.6 liters per second or 104.3 million m^3 per year. This included 2,106.6 liters per second or 66.5 million m^3 per year of gravitational water flow and 1,200 liters per second or 37.8 million m^3 per year of pumped from small lakes fed by natural springs.

Results of the Fish Farms Inventory

A total of 235 fish farms were inventoried in the Ararat Valley, which held a total of 570 groundwater wells. Hundred fish farms were not operational and 135 were operational at the time of the inventory with a total of 336 groundwater wells in use. Total water abstraction by these operational fish farms was 25,652.1 liters per second or 809.1 million m^3 per year. Self-flowing wells accounted for 24,759.2 liters per second or 780.9 million m^3 per year, and wells operated by pumps accounted for 892.9 liters per second or 28.2 million m^3 per year. In addition, the inventory revealed that 96 out of 234 groundwater wells in 100 non-operational fish farms had a total discharge of 948.1 liters per second, which comprises 29.9 million m^3 per year (Figure 4).

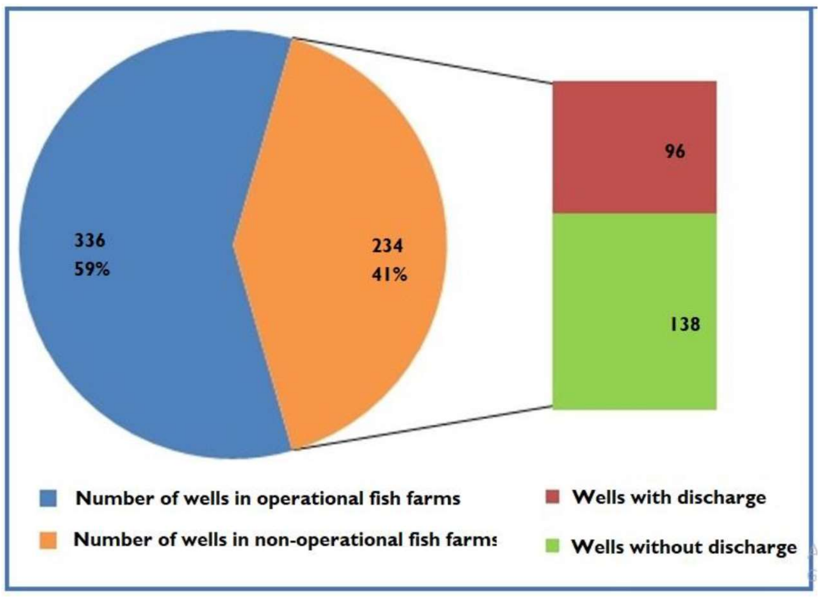
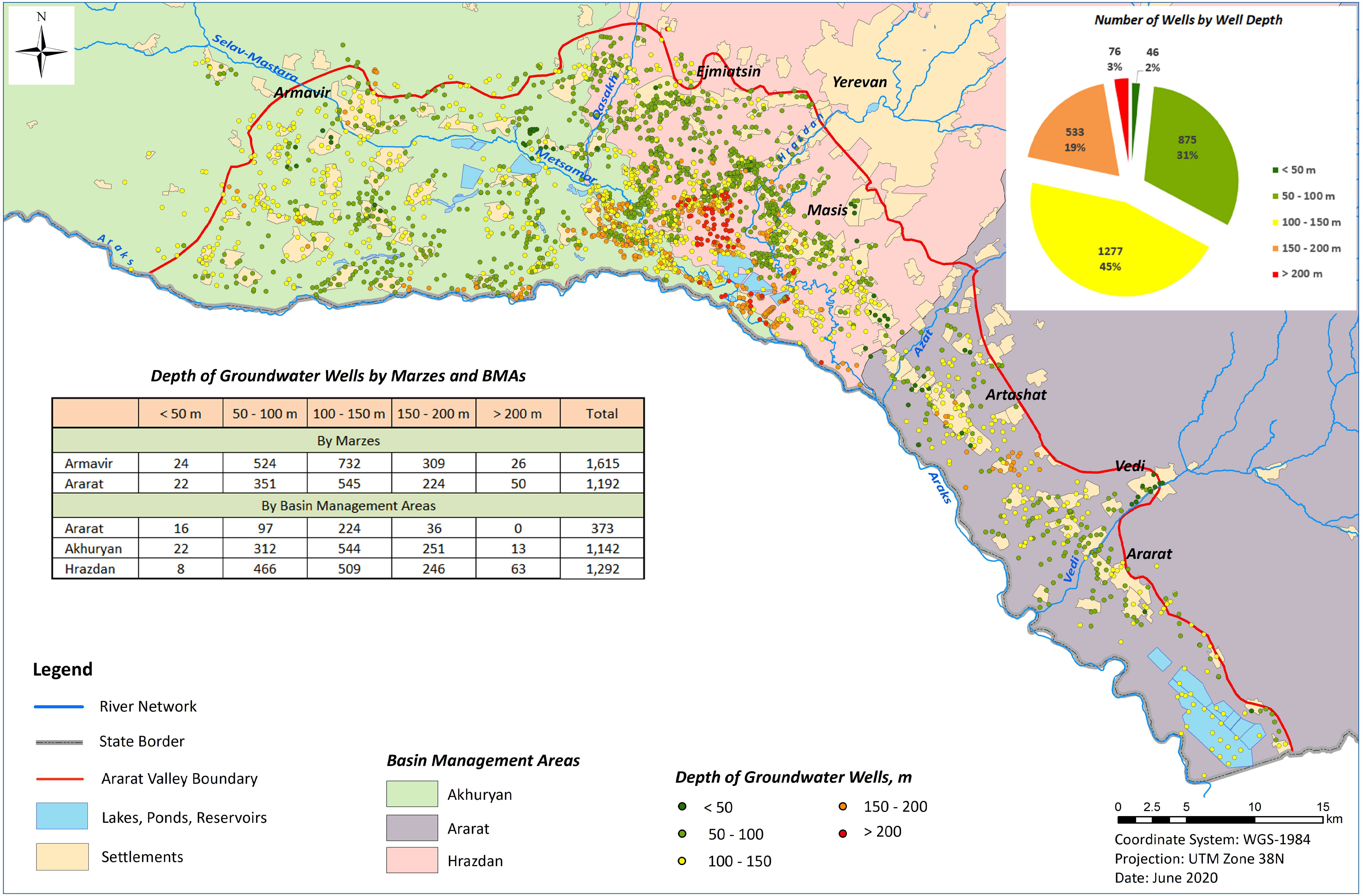


Figure 4: Number of Groundwater Wells in Operational and Non-operational Fish Farms in 2016

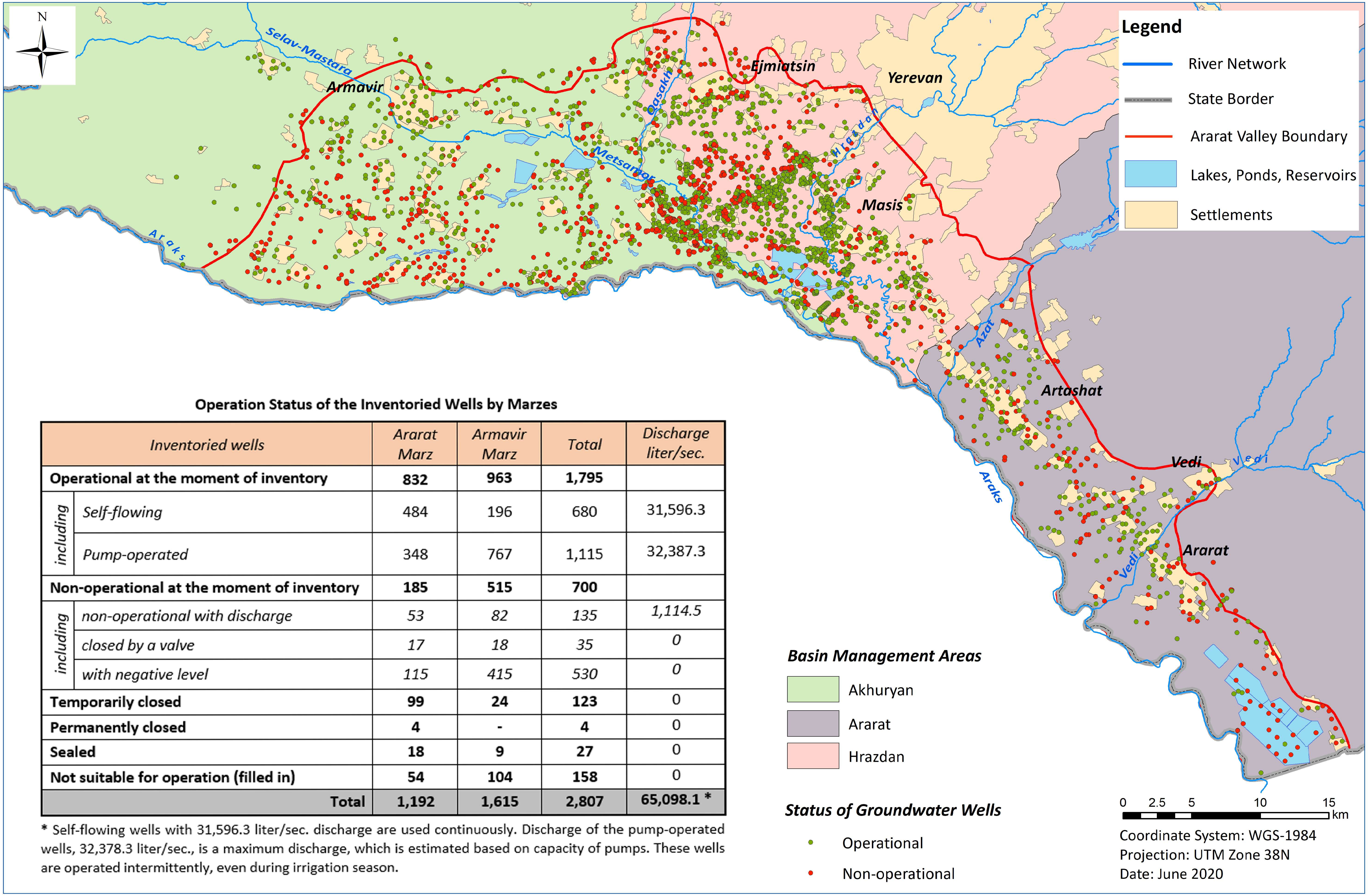
Groundwater Wells in the Ararat Valley Grouped by Well Depth in 2016



Depth of Groundwater Wells by Marzes and BMAs

	< 50 m	50 - 100 m	100 - 150 m	150 - 200 m	> 200 m	Total
By Marzes						
Armavir	24	524	732	309	26	1,615
Ararat	22	351	545	224	50	1,192
By Basin Management Areas						
Ararat	16	97	224	36	0	373
Akhuryan	22	312	544	251	13	1,142
Hrazdan	8	466	509	246	63	1,292

Groundwater Wells in the Ararat Valley Grouped by Operation Status in 2016

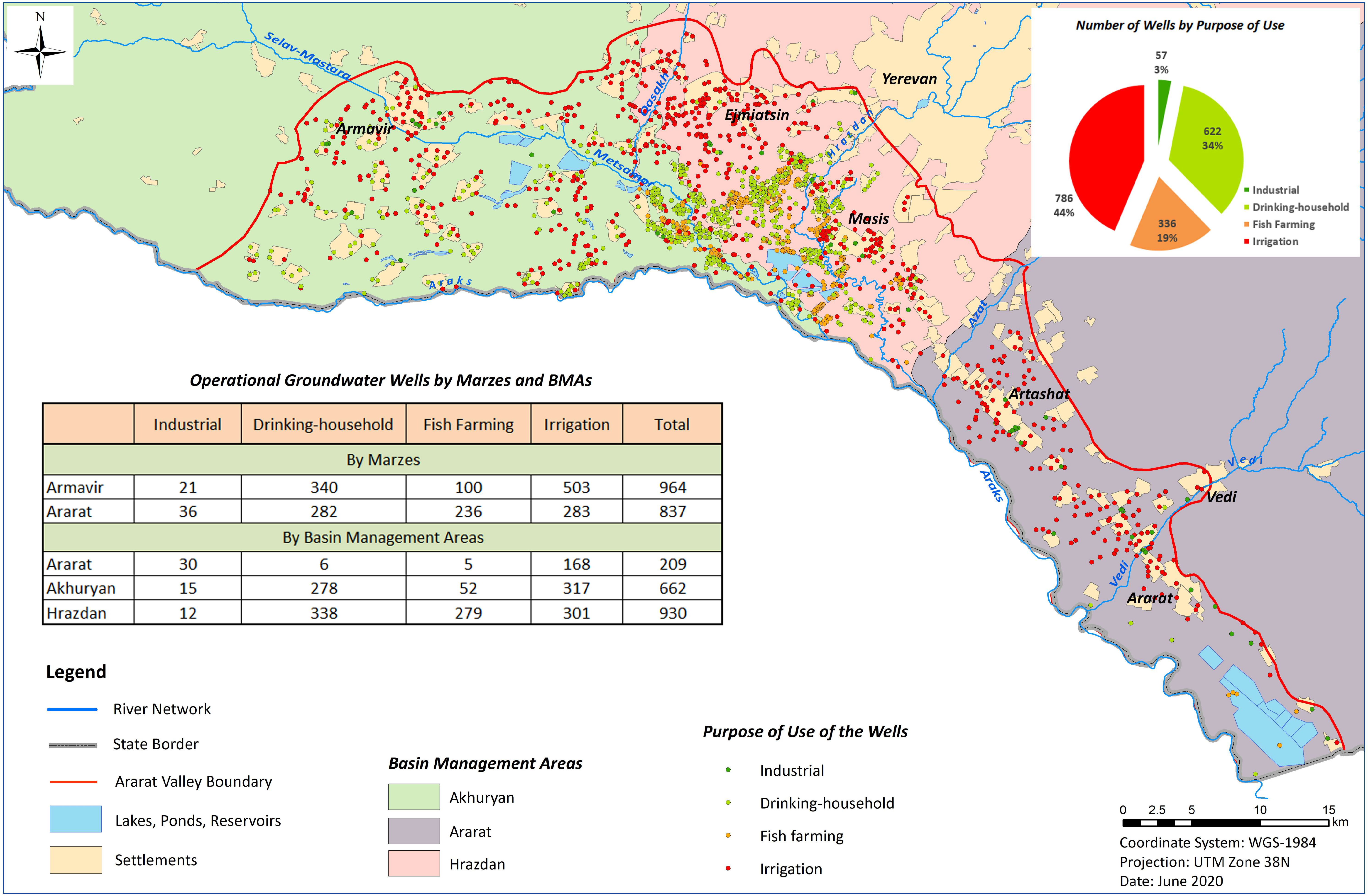


Operation Status of the Inventoried Wells by Marzes

	Inventoried wells	*Ararat Marz*	*Armavir Marz*	*Total*	*Discharge liter/sec.*
Operational at the moment of inventory		**832**	**963**	**1,795**	
including	*Self-flowing*	484	196	680	31,596.3
	Pump-operated	348	767	1,115	32,387.3
Non-operational at the moment of inventory		**185**	**515**	**700**	
including	*non-operational with discharge*	*53*	*82*	*135*	*1,114.5*
	closed by a valve	*17*	*18*	*35*	*0*
	with negative level	*115*	*415*	*530*	*0*
Temporarily closed		**99**	**24**	**123**	0
Permanently closed		**4**	**-**	**4**	0
Sealed		**18**	**9**	**27**	0
Not suitable for operation (filled in)		**54**	**104**	**158**	0
	Total	**1,192**	**1,615**	**2,807**	**65,098.1 ***

* Self-flowing wells with 31,596.3 liter/sec. discharge are used continuously. Discharge of the pump-operated wells, 32,378.3 liter/sec., is a maximum discharge, which is estimated based on capacity of pumps. These wells are operated intermittently, even during irrigation season.

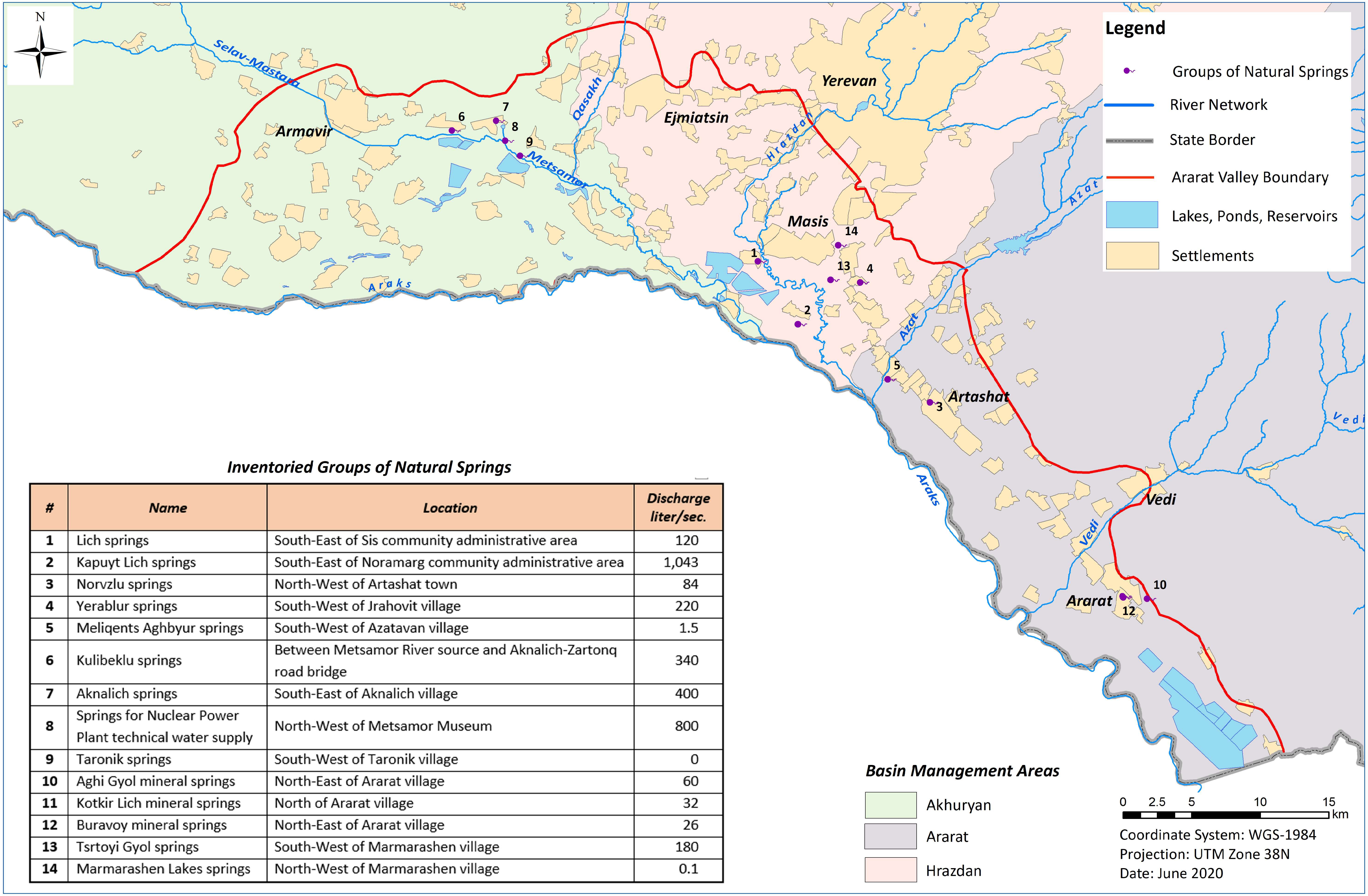
Groundwater Wells in the Ararat Valley Grouped by Purpose of Use in 2016



Operational Groundwater Wells by Marzes and BMAs

	Industrial	Drinking-household	Fish Farming	Irrigation	Total
By Marzes					
Armavir	21	340	100	503	964
Ararat	36	282	236	283	837
By Basin Management Areas					
Ararat	30	6	5	168	209
Akhuryan	15	278	52	317	662
Hrazdan	12	338	279	301	930

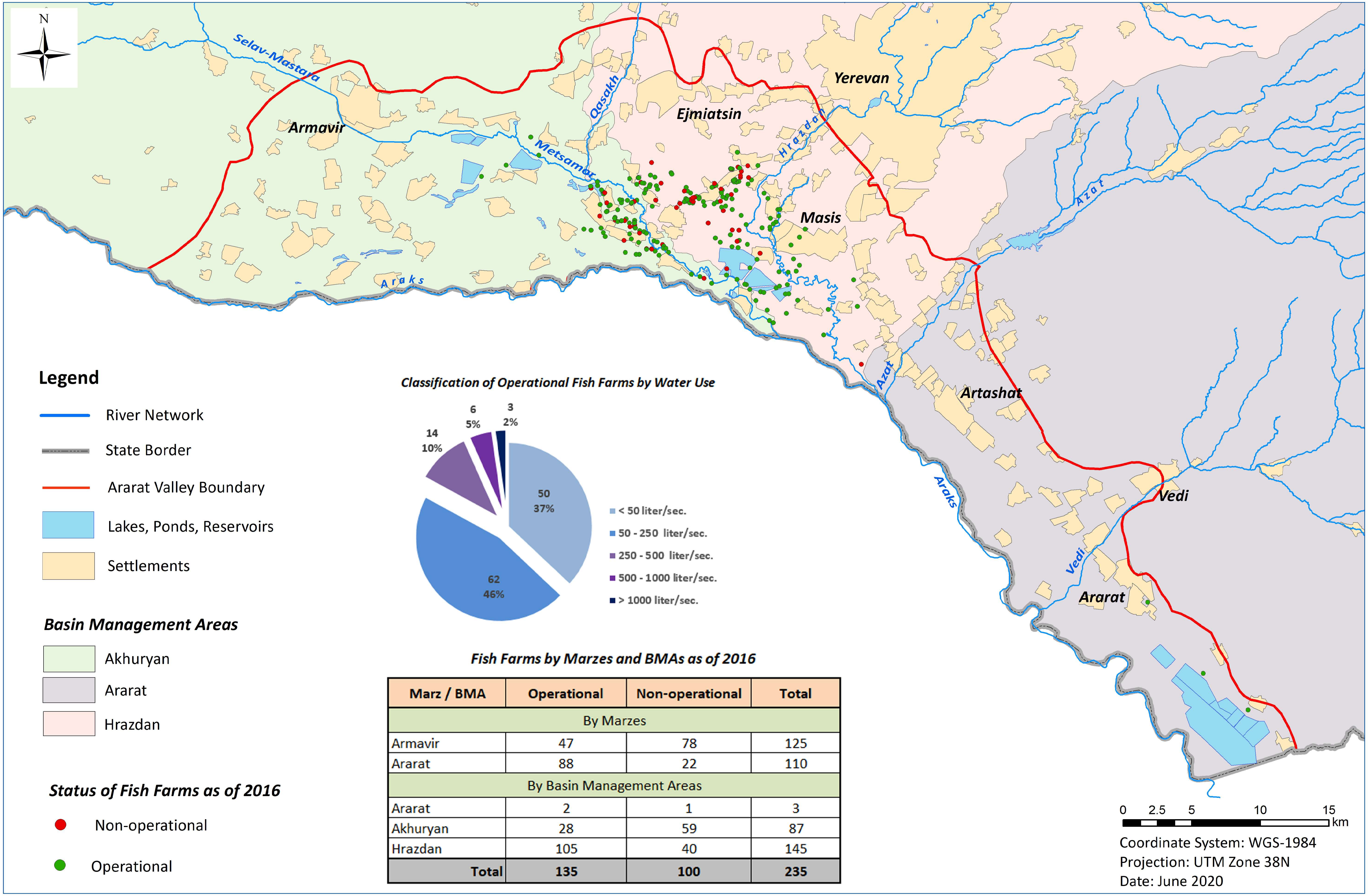
Groups of Natural Springs in the Ararat Valley in 2016



Inventoried Groups of Natural Springs

#	Name	Location	Discharge liter/sec.
1	Lich springs	South-East of Sis community administrative area	120
2	Kapuyt Lich springs	South-East of Noramarg community administrative area	1,043
3	Norvzlu springs	North-West of Artashat town	84
4	Yerablur springs	South-West of Jrahovit village	220
5	Meliqents Aghbyur springs	South-West of Azatavan village	1.5
6	Kulibeklu springs	Between Metsamor River source and Aknalich-Zartonq road bridge	340
7	Aknalich springs	South-East of Aknalich village	400
8	Springs for Nuclear Power Plant technical water supply	North-West of Metsamor Museum	800
9	Taronik springs	South-West of Taronik village	0
10	Aghi Gyol mineral springs	North-East of Ararat village	60
11	Kotkir Lich mineral springs	North of Ararat village	32
12	Buravoy mineral springs	North-East of Ararat village	26
13	Tsrtoyi Gyol springs	South-West of Marmarashen village	180
14	Marmarashen Lakes springs	North-West of Marmarashen village	0.1

Status of Fish Farms in the Ararat Valley in 2016



Fish Farms by Marzes and BMAs as of 2016

Marz / BMA	Operational	Non-operational	Total
By Marzes			
Armavir	47	78	125
Ararat	88	22	110
By Basin Management Areas			
Ararat	2	1	3
Akhuryan	28	59	87
Hrazdan	105	40	145
Total	135	100	235

Section 3. Water Balance and Water Supply and Demand Balance of the Ararat Valley

Methodology for Water Balance Calculation

The water balance or hydrologic balance of any area over a given time period (multiannual, annual, seasonal) is the ratio of inflow, outflow, and change in storage of the water resource within the given area in natural conditions. To obtain the water balance for a given area, values are calculated for precipitation, evapotranspiration, and natural flow, including both surface and groundwater flow. These components of the water balance are calculated using data series collected from the meteorological stations and hydrologic observation posts located within the area of interest.

The water balance of the Ararat Valley catchment area by river basins was calculated based on annual average values of precipitation, evapotranspiration, and natural surface and groundwater flows in the sections of river basins of the catchment area outside the Ararat Valley. The following equation is used:

$$P = ET + SW + GW$$

P *is the value of total precipitation within the river basin during the given period (in mm or million m^3)*
ET *is the value of average evapotranspiration within the river basin during the given period (in mm or million m^3)*
SW *is the value of surface water flow within the river basin during the given period (in mm or million m^3)*
GW *is the value of groundwater flow within the river basin during the given period (in mm or million m^3)*

The water balance of the Ararat Valley was calculated based on annual average values of precipitation, evapotranspiration, natural surface inflow and outflow, as well as groundwater inflow and outflow. It is the expression of the annual changes in the volume of water in the Ararat Valley in natural conditions, in terms of water inflow and outflow, and both surface water and groundwater resources. The following equation is used:

$$P + SW_{in} + GW_{in} = ET + SW_{out} + GW_{out} + \Delta$$

The inflow components (the left side of the equation):
P *is the value of total precipitation within the Ararat Valley for the given period (in million m^3)*
SW_{in} *is the value of surface water inflow into the Ararat Valley during the given period (in million m^3)*
GW_{in} *is the value of groundwater inflow into the Ararat Valley groundwater basin during the given period (in million m^3)*

The outflow components (the right side of the equation):
ET *is the value of average evapotranspiration within the Ararat Valley for the given period (in million m^3)*
SW_{out} *is the value of surface water outflow from the Ararat Valley for the given period (in million m^3)*
GW_{out} *is the value of groundwater outflow from the Ararat Valley groundwater basin for the given period (in million m^3)*
Δ *is the difference between water inflow and outflow in the Ararat Valley for the given period (in million m^3).*

Each component of the water balance equation can be calculated both in millimeters (mm) and cubic meters (m^3). The values in millimeters are converted to the values in cubic meters by multiplying by the total area of the Ararat Valley in the territory of RA equal to **1,177 km²**. Volume of water discharge per second in cubic meters (m^3/sec.) is converted to the annual water volume in million cubic meters (million m^3/year) by multiplying by the number of seconds within the year (31,536,000) and dividing by 10^6.

The following steps demonstrate the process used to determine the water balance of the Ararat Valley:

1. Determine the values of precipitation and evapotranspiration for the six river basins of the Ararat Valley catchment area: Akhuryan (including Kars), Metsamor, Qasakh, Hrazdan, Azat and Vedi. The values of these components serve as input data to determine surface and groundwater inflow into the Ararat Valley.
2. Determine the values of precipitation and evapotranspiration in the Ararat Valley. Those values are generated based on the outputs of Step 1, since the territory of the Ararat Valley is comprised of downstream sections of the six river basins.
3. Convert the actual river flow measured at all hydrologic observation posts located in the six river basins of the Ararat Valley catchment area to the natural river flow.
4. Calculate natural surface inflow and natural surface outflow in the territory of Ararat Valley, using the outputs from Step 3.
5. Calculate the values of natural surface flow generated within the territory of the Ararat Valley, using the "precipitation-runoff" curve approach. This approach is based on the Runoff Curve Number method, which was developed by the Soil Conservation Service of the US Department of Agriculture. This methodology is used to estimate surface runoff based on the values of precipitation, land cover/land use category, and the soil types within the river basin or its sub-basin. The runoff Curve Number (CN) is an empirical parameter representing the percentage of the potential surface runoff from the total precipitation within a specific area. The CN has a range from 30 to 100, with lower numbers indicating low runoff potential and higher numbers indicating increased runoff potential. A lower curve number indicates more permeable soil in the area.
6. Determine the values of groundwater inflow into the Ararat Valley based on the outputs of Step 1, and groundwater outflow from the Ararat Valley based on the outputs of Steps 4 and 5.
7. Insert all the calculated values into the water balance equation, and calculate the difference between the inflow and outflow values (Δ), i.e. Δ is determined based on the difference between inflow (precipitation occurred in the Ararat Valley, surface and groundwater inflows into the valley) and outflow (surface and groundwater outflows, as well as evapotranspiration from the valley).

Water Balance of the Ararat Valley Catchment Area

The annual water balance of the Ararat Valley catchment area by river basins for 2016, as well as multiannual average water balance of the Ararat Valley catchment area for the period of 1961-2016 were determined according to the described methodology applying the $P = ET + SW + GW$ equation. The calculations were based on the 1961-2016 time-series data from hydrologic observation posts and meteorological stations located in the Ararat Valley catchment area. The results are summarized in Tables 1-2 below by the river basins of the catchment area.

Table 1: Annual Values of Water Balance Components of the Ararat Valley Catchment Area in 2016

River Basin	Inflow	Outflow		
	Precipitation million m^3	Evapo-transpiration million m^3	Surface Water Flow million m^3	Groundwater Flow million m^3
Akhuryan, including Kars	6,076.9	2,901.5	1,687.7	1,487.7
Qasakh	858.9	402.1	290.2	166.6
Metsamor	841.9	626.8	315.0	-99.9
Hrazdan	1,418.2	695.6	581.8	140.8
Azat	413.0	231.9	154.9	26.2
Vedi	405.1	258.0	136.6	10.5

Table 2: Multiannual Average Values of Water Balance Components of the Ararat Valley Catchment Area for the Period of 1961-2016

River Basin	Inflow	Outflow		
	Precipitation million m^3	Evapo-transpiration million m^3	Surface Water Flow million m^3	Groundwater Flow million m^3
Akhuryan, including Kars	6,009.9	2,757.8	1,640.7	1,611.4
Qasakh	825.4	412.1	266.8	146.5
Metsamor	927.5	667.1	582.9	-323.3
Hrazdan	1,453.8	719.4	602.2	131.5
Azat	414.6	247.5	126.2	40.8
Vedi	408.3	269.7	105.6	33.0

Water Balance of the Ararat Valley

The annual water balance of the Ararat Valley for 2016 was calculated by applying the $P + SW_{in} + GW_{in} = ET + SW_{out} + GW_{out} + \Delta$ equation, following the above-described methodology.

The values of precipitation and evapotranspiration were calculated based on the 2016 data from hydrologic observation posts and meteorological stations located in the Ararat Valley.

The values of natural surface inflow to the Ararat Valley and natural surface outflow from the Ararat Valley for the year 2016 were calculated based on the data received from the hydrologic observation posts presented on the map below. The values of the surface runoff generated in the Ararat Valley are reflected in the calculation of the total surface outflow from the Ararat Valley.

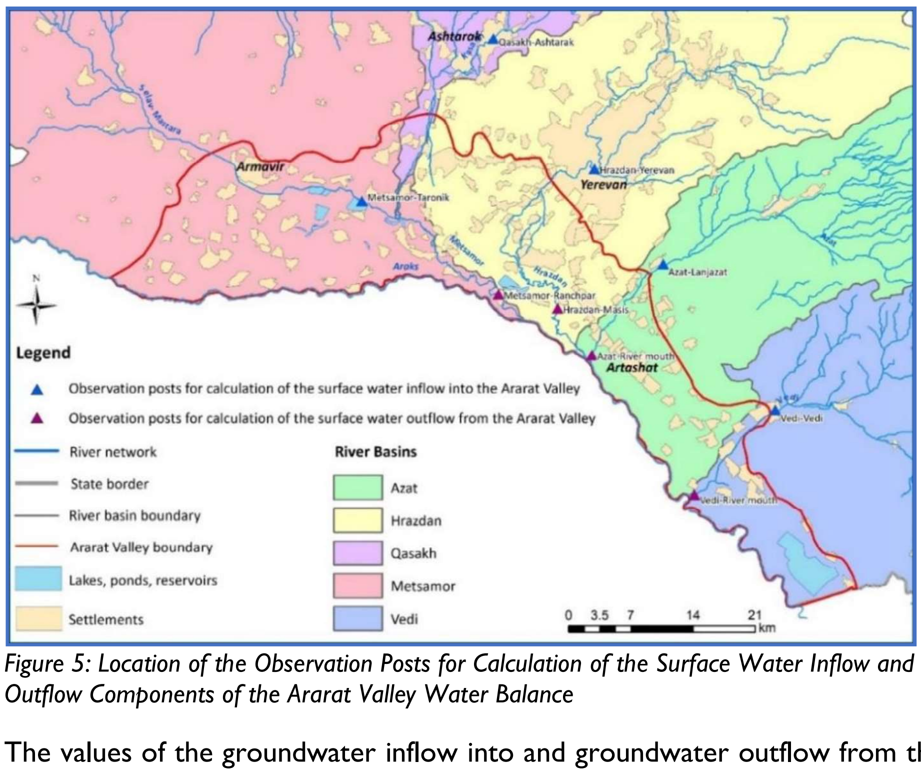


Figure 5: Location of the Observation Posts for Calculation of the Surface Water Inflow and Outflow Components of the Ararat Valley Water Balance

The values of the groundwater inflow into and groundwater outflow from the Ararat Valley were calculated by applying spatial analysis tools within the ArcGIS environment, along the main inflow and outflow directions presented on the next map.

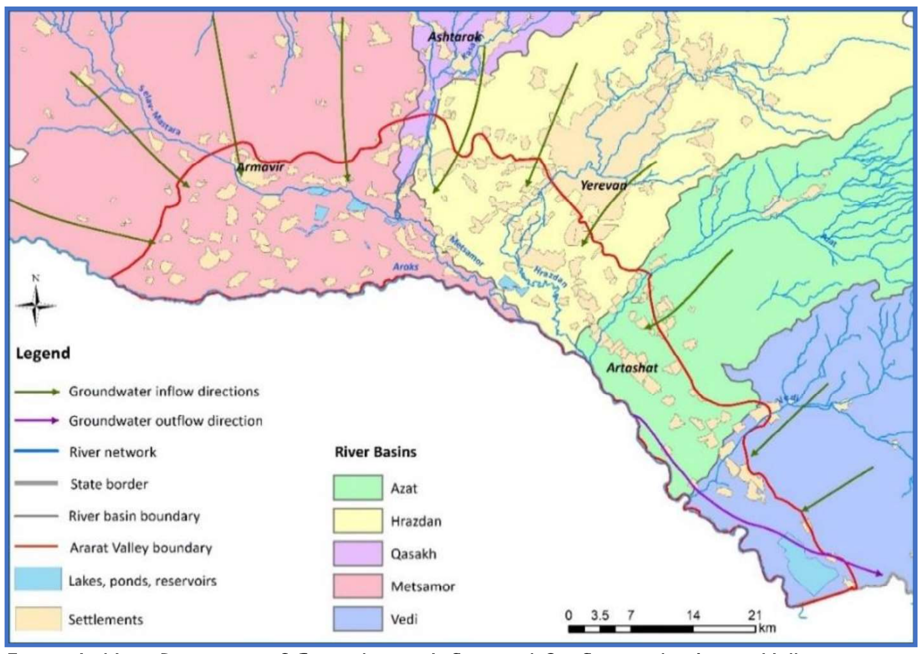
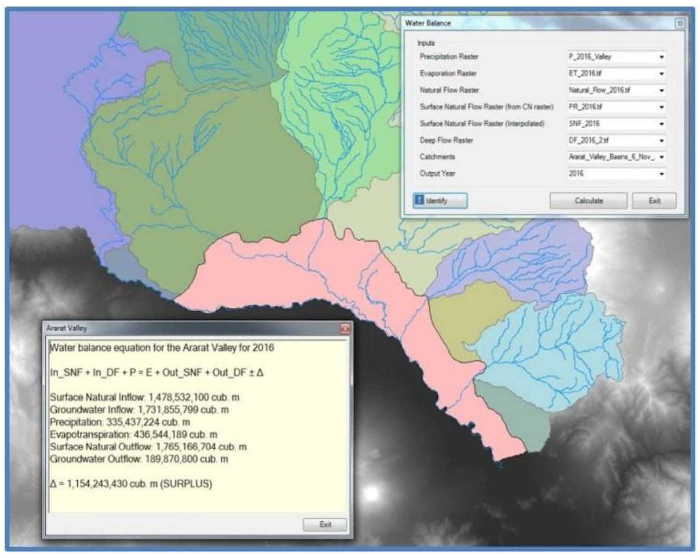


Figure 6: Main Directions of Groundwater Inflow and Outflow in the Ararat Valley

Results of the water balance calculations for the Ararat Valley are presented in Figures 7-8 below.



$P = 335.4$ mln. m^3

$SW_{in}= 1,478.5$ mln. m^3

$GW_{in}= 1,731.9$ mln. m^3

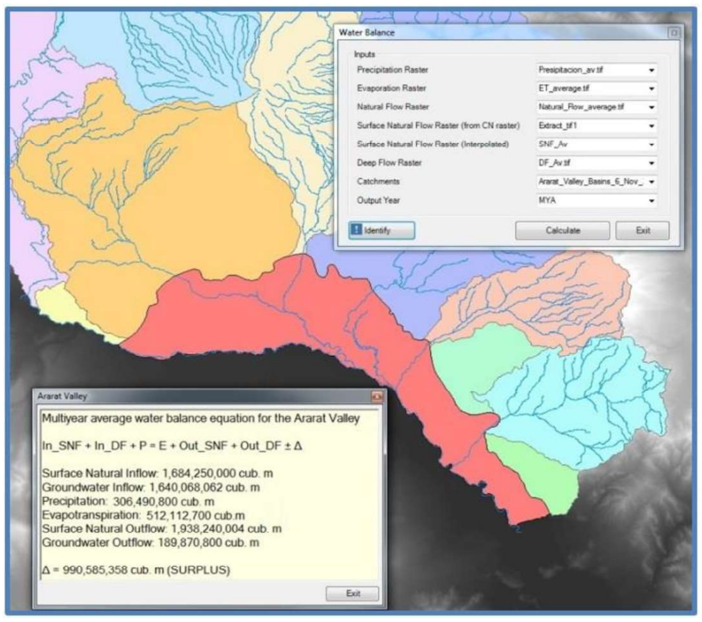
$ET = 436.5$ mln. m^3

$SW_{out}= 1,765.2$ mln. m^3

$GW_{out} = 189.9$ mln. m^3

$\Delta= 1,154.3$ mln. m^3

Figure 7: Annual Water Balance of the Ararat Valley in 2016



$P = 306.5$ mln m^3

$SW_{in}= 1,684.3$ mln m^3

$GW_{in}= 1,640.0$ mln m^3

$ET = 512.1$ mln m^3

$SW_{out}= 1,938.2$ mln m^3

$GW_{out} = 189.9$ mln m^3

$\Delta = 990.6$ mln m^3

Figure 8: Multiannual Average Water Balance of the Ararat Valley for the Period of 1961-2016

Methodology for Water Supply and Demand Balance Calculation

The water supply and demand balance in a river basin, a section of river basin, or any geographic area, is the ratio between the volume of the available water resources and the volume of demand for the water in the area, considering human economic activity within the given area during the given time period. The water supply and demand balance equation shows the water shortage (deficit) or water surplus within the given area for the given time period considering human economic activity.

The numeric values of the water supply and demand balance components of the Ararat Valley for 2016 were calculated using the following equation:

$$P + GW_{in\_actual} + SW_{in\_actual} + T_{in} + Y_{return} = ET + GW_{out} + SW_{out\_actual} + T_{out} + Y_{abst} \pm \Delta S$$

Supply components (the left side of the equation):

P is the annual value of precipitation

GW_{in_actual} is the annual value of actual groundwater inflow

SW_{in_actual} is the annual value of actual surface water inflow

T_{in} is the annual value of transit inflow into the valley

Y_{return} is the annual total volume of water return from the water use in the valley

Demand components (the right side of the equation):

ET is the annual value of evapotranspiration

GW_{out} is the annual value of natural groundwater outflow

SW_{out_actual} is the annual value of actual surface water outflow

T_{out} is the annual value of transit outflow from the Ararat Valley

Y_{abst} is the annual total volume of water abstraction in the Ararat Valley

ΔS is the difference of water supply and water demand in the Ararat Valley showing either the water surplus (if a positive) or water deficit (if negative).

Water Supply and Demand Balance of the Ararat Valley in 2016

The annual values of precipitation and evapotranspiration in the Ararat Valley, as well as the value of annual natural groundwater outflow from the Ararat Valley were determined during the calculation of the water balance.

The value of annual actual groundwater inflow was calculated as the difference between the natural groundwater inflow into the Ararat Valley from the Akhuryan, Qasakh, Hrazdan, Azat and Vedi river basins of the Ararat Valley catchment area and the annual total groundwater use in the river basin areas upstream of the Ararat Valley.

The value of annual actual surface water inflow into the Ararat Valley was calculated as a sum of actual surface water inflow in the Metsamor-Taronik, Qasakh-Ashtarak, Hrazdan-Yerevan, Azat-Lanjazat, and Vedi-Vedi hydrologic observation posts.

The value of annual transit inflow into the Ararat Valley was calculated as a sum of annual transit inflow through the Armavir and Talin main canals and annual inflow from Lake Sevan.

The annual actual surface water outflow from the Ararat Valley was calculated as a sum of actual surface water flow at the Metsamor-Ranchpar and Hrazdan-Masis hydrological posts as well as the actual surface water flow generated in inter-basin areas of the Ararat Valley.

The volume of outflow through the Araks-Hrazdan drainage-collector system was considered the annual transit outflow from the Ararat Valley.

The total annual volumes of the water abstraction and return flows from water use in the Ararat Valley were considered in the calculations.

The water supply and demand balance of the Ararat Valley in 2016 showed the negative difference between available water supply and water demand in the Ararat Valley, which amounted to **1,120.46 million m³** (Table 3).

Table 3: Calculated Values of Water Supply and Demand Balance Components of the Ararat Valley in 2016

Component	Notation	Value, million m^3
Water Supply		
Precipitation	P	335.44
Actual groundwater inflow	GW_{in_actual}	1,341.53
Actual surface water inflow	SW_{in_actual}	391.52
Inflow by transfer	T_{in}	700.00
Total return flows from water use	Y_{return}	404.24
	Total water supply	**3,172.73**
Water Demand		
Evapotranspiration	ET	436.54
Groundwater outflow	GW_{out}	189.87
Actual surface water outflow	SW_{out_actual}	1,028.79
Outflow by transfer	T_{out}	548.07
Total water abstraction	Y_{abst}	2,089.92
	Total water demand	**4,293.19**
	Difference	**-1,120.46**

The values of ecological flow in the selected hydrologic observation posts and sites of the Ararat Valley were calculated following the requirements of Government Resolution #57-N (2018). The calculated values of the ecological flow were compared with the values of actual surface water flow in the same observation posts, and the results demonstrate that the required ecological flow was not maintained in most of the sites (Table 4).

Table 4: Calculated Values of Ecological Flow in the Rivers of the Ararat Valley in 2016

Hydrologic observation post or site	Actual flow million m^3	Ecological flow million m^3	Difference million m^3
Ararat Valley inflow			
Metsamor - Taronik	15.45	18.29	**-2.84**
Qasakh Ashtarak	194.71	120.26	**74.45**
Hrazdan - Yerevan	90.84	211.34	**-120.5**
Azat - Lanjazat	48.26	55.87	**-7.61**
Vedi - Vedi	42.26	9.66	**32.6**
Ararat Valley outflow			
Metsamor - Ranchpar	246.01	97.78	**148.23**
Hrazdan - Masis	775.88	318.55	**457.33**
Azat - River mouth	0.01	62.00	**-61.99**
Vedi - River mouth	0.01	10.00	**-9.99**

Main Outcomes and Conclusions

The estimated values of the water supply and demand balance components of the Ararat Valley for 2016 demonstrate a significant water deficit in the study area due to intensive human activities in the Ararat Valley and its catchment area. The negative difference between water availability and water demand for the year 2016 amounted to **1,120.46 million m³**.

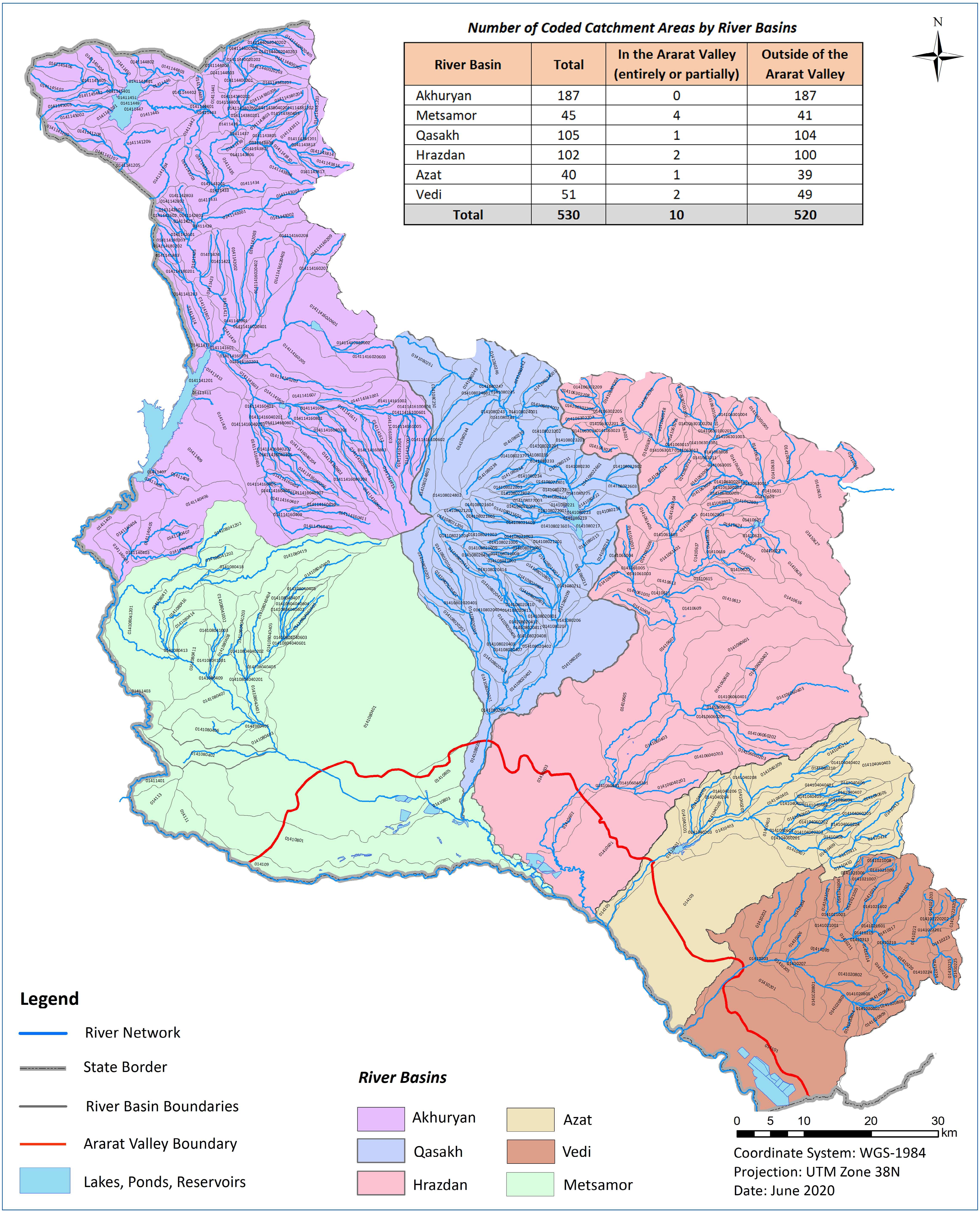
According to the field inventory data from 2016, the actual volume of groundwater abstraction was **1,608.07 million m³**, while the annual value of sustainable groundwater use was determined to be **926.73 million m³** for the same period. The estimated overuse of groundwater resources in the Ararat Valley was **681.34 million m³**.

Both the groundwater overuse and the remaining water deficit of **439.12 million m³** shall be mitigated by regulating the water use in the Ararat Valley and its catchment area, according to the Decision N: 39-L of the Government of Armenia, adopted in 2019, on approving the Concept of Introducing Water Saving Technologies and Program of Measures for the Concept Implementation. Regulation of water uses in the upstream sections of the river basins of the Ararat Valley catchment area, and within the Ararat Valley shall also ensure maintenance of the estimated values of ecological flow in the selected hydrologic observation posts and representative sites of the Ararat Valley.

Coded Catchment Areas of the Ararat Valley

Number of Coded Catchment Areas by River Basins

River Basin	Total	In the Ararat Valley (entirely or partially)	Outside of the Ararat Valley
Akhuryan	187	0	187
Metsamor	45	4	41
Qasakh	105	1	104
Hrazdan	102	2	100
Azat	40	1	39
Vedi	51	2	49
Total	**530**	**10**	**520**



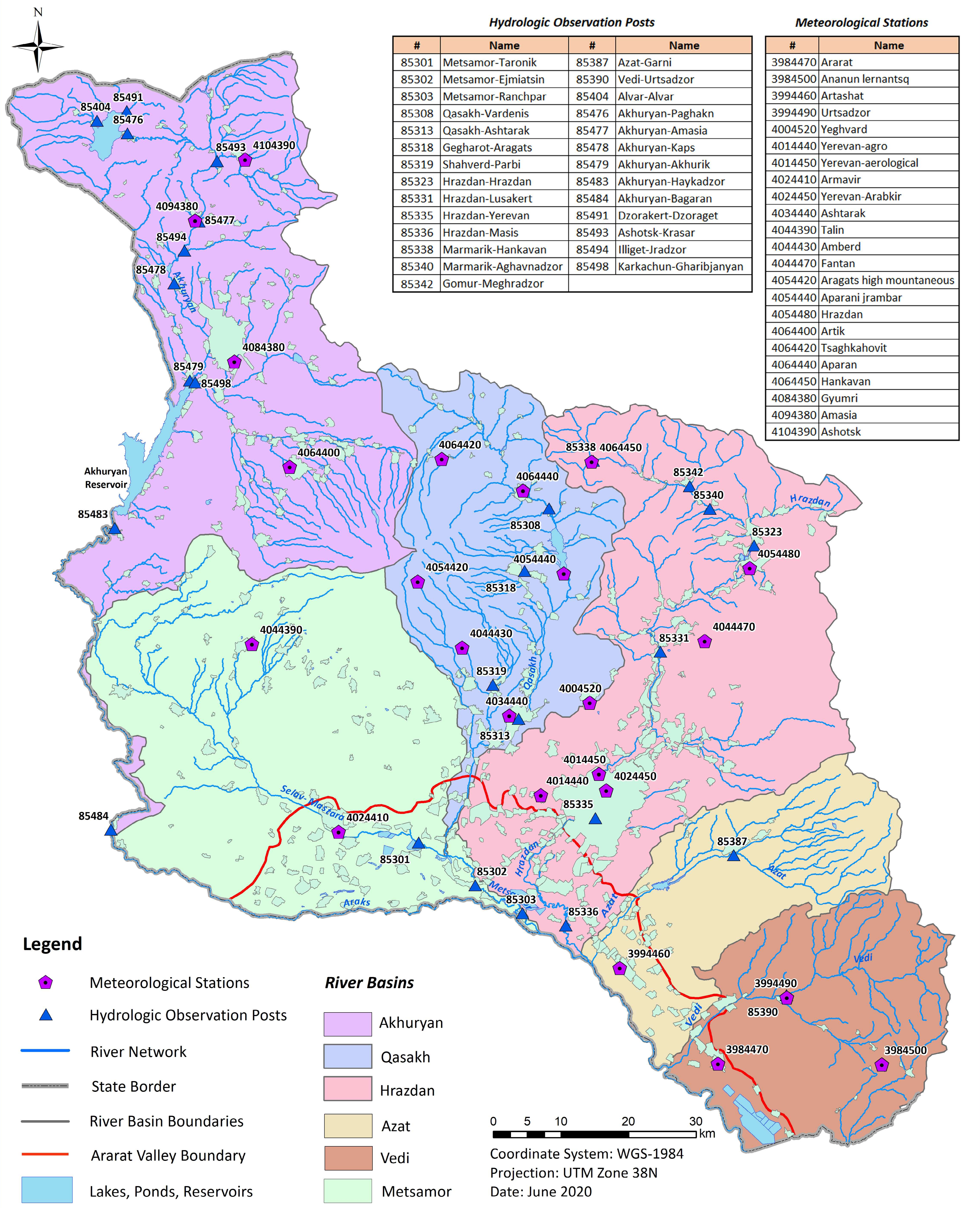
Hydrologic Observation Posts and Meteorological Stations in the Ararat Valley Catchment Area

Hydrologic Observation Posts

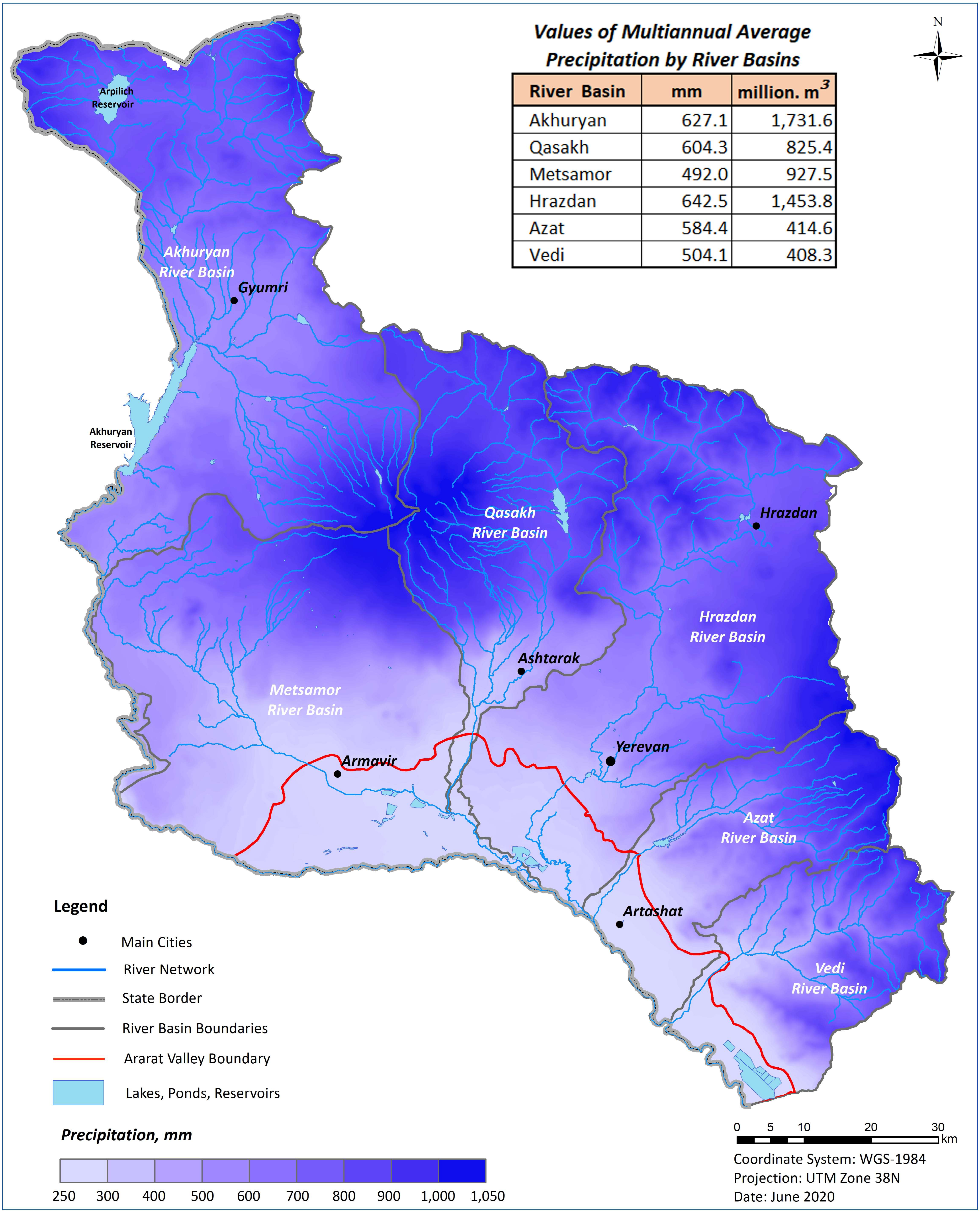
#	Name	#	Name
85301	Metsamor-Taronik	85387	Azat-Garni
85302	Metsamor-Ejmiatsin	85390	Vedi-Urtsadzor
85303	Metsamor-Ranchpar	85404	Alvar-Alvar
85308	Qasakh-Vardenis	85476	Akhuryan-Paghakn
85313	Qasakh-Ashtarak	85477	Akhuryan-Amasia
85318	Gegharot-Aragats	85478	Akhuryan-Kaps
85319	Shahverd-Parbi	85479	Akhuryan-Akhurik
85323	Hrazdan-Hrazdan	85483	Akhuryan-Haykadzor
85331	Hrazdan-Lusakert	85484	Akhuryan-Bagaran
85335	Hrazdan-Yerevan	85491	Dzorakert-Dzoraget
85336	Hrazdan-Masis	85493	Ashotsk-Krasar
85338	Marmarik-Hankavan	85494	Illiget-Jradzor
85340	Marmarik-Aghavnadzor	85498	Karkachun-Gharibjanyan
85342	Gomur-Meghradzor		

Meteorological Stations

#	Name
3984470	Ararat
3984500	Ananun lernantsq
3994460	Artashat
3994490	Urtsadzor
4004520	Yeghvard
4014440	Yerevan-agro
4014450	Yerevan-aerological
4024410	Armavir
4024450	Yerevan-Arabkir
4034440	Ashtarak
4044390	Talin
4044430	Amberd
4044470	Fantan
4054420	Aragats high mountaneous
4054440	Aparani jrambar
4054480	Hrazdan
4064400	Artik
4064420	Tsaghkahovit
4064440	Aparan
4064450	Hankavan
4084380	Gyumri
4094380	Amasia
4104390	Ashotsk



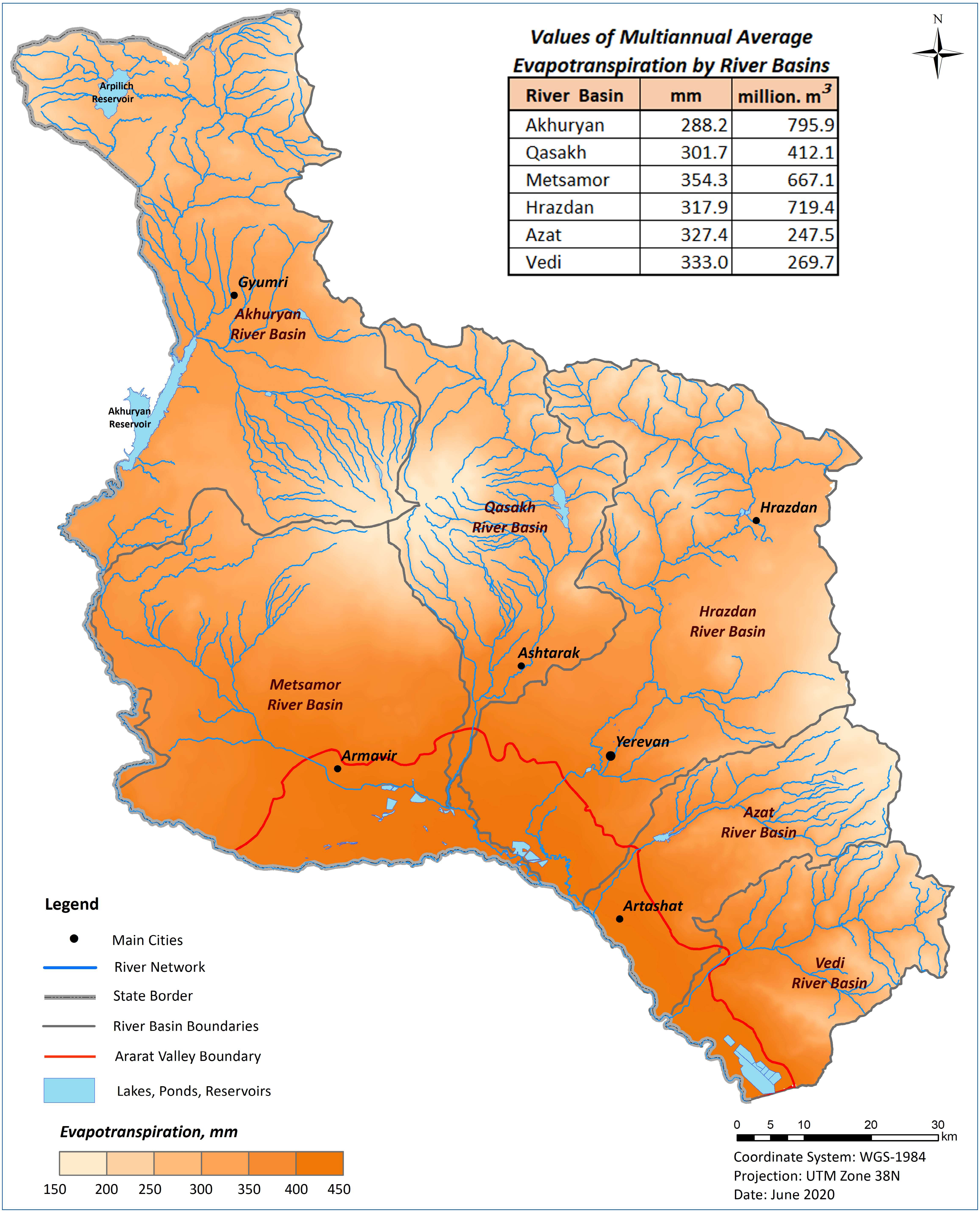
Distribution of the Multiannual Average Precipitation in the Ararat Valley Catchment Area for the Period of 1961-2016



Values of Multiannual Average Precipitation by River Basins

River Basin	mm	million. m^3
Akhuryan	627.1	1,731.6
Qasakh	604.3	825.4
Metsamor	492.0	927.5
Hrazdan	642.5	1,453.8
Azat	584.4	414.6
Vedi	504.1	408.3

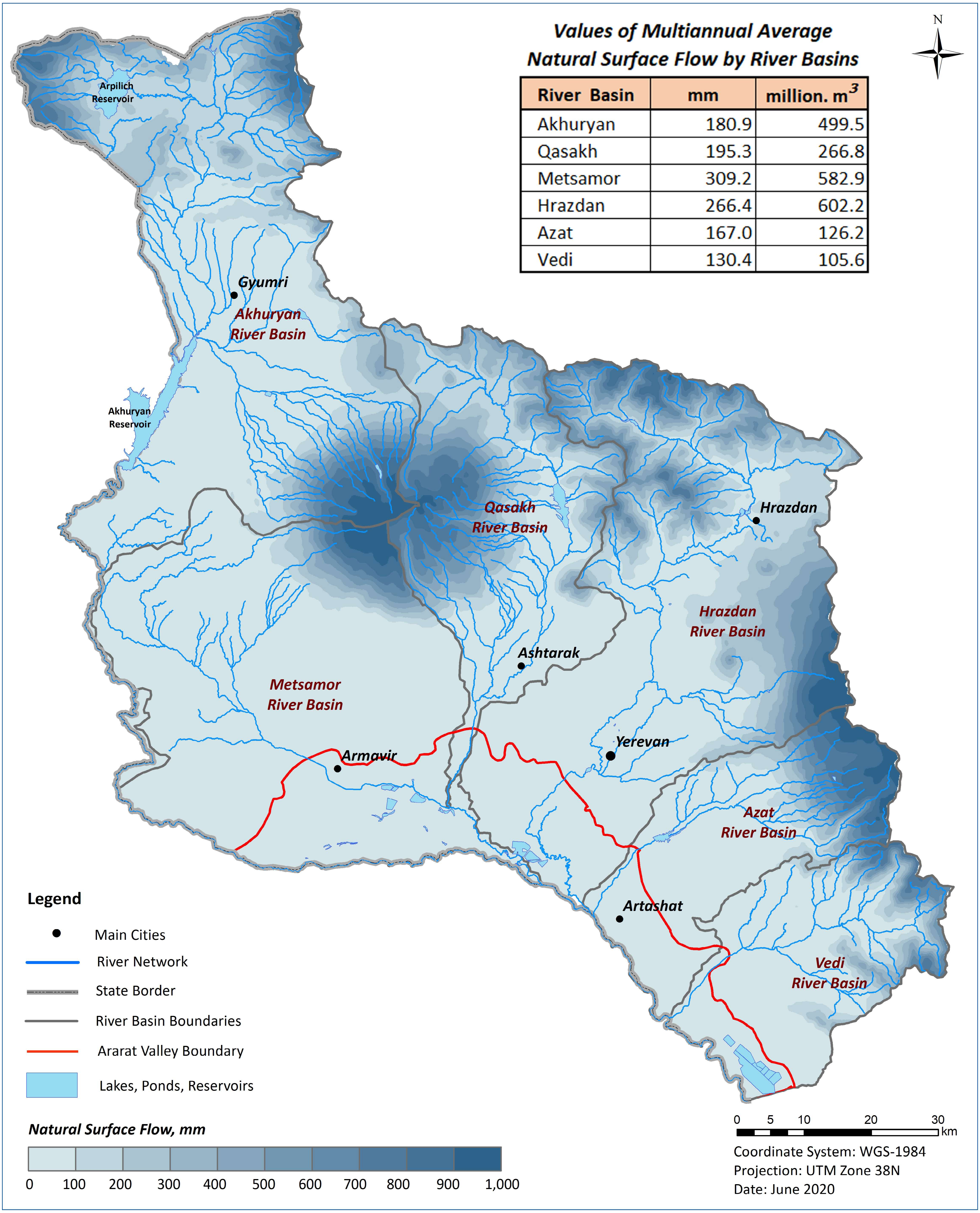
Distribution of the Multiannual Average Evapotranspiration in the Ararat Valley Catchment Area for the Period of 1961-2016



Values of Multiannual Average Evapotranspiration by River Basins

River Basin	mm	million. m^3
Akhuryan	288.2	795.9
Qasakh	301.7	412.1
Metsamor	354.3	667.1
Hrazdan	317.9	719.4
Azat	327.4	247.5
Vedi	333.0	269.7

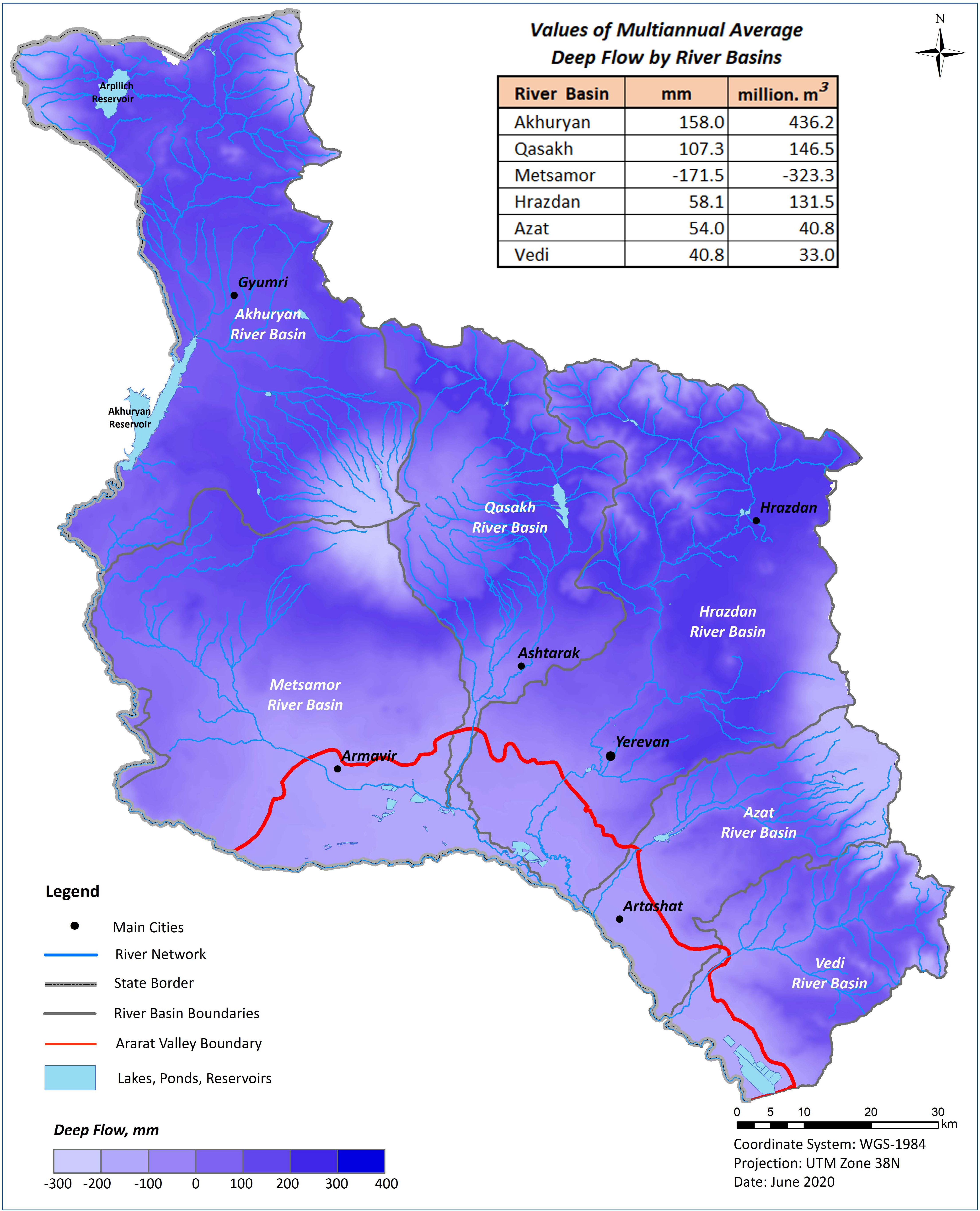
Distribution of the Multiannual Average Natural Surface Flow in the Ararat Valley Catchment Area for the Period of 1961-2016



Values of Multiannual Average Natural Surface Flow by River Basins

River Basin	mm	million. m^3
Akhuryan	180.9	499.5
Qasakh	195.3	266.8
Metsamor	309.2	582.9
Hrazdan	266.4	602.2
Azat	167.0	126.2
Vedi	130.4	105.6

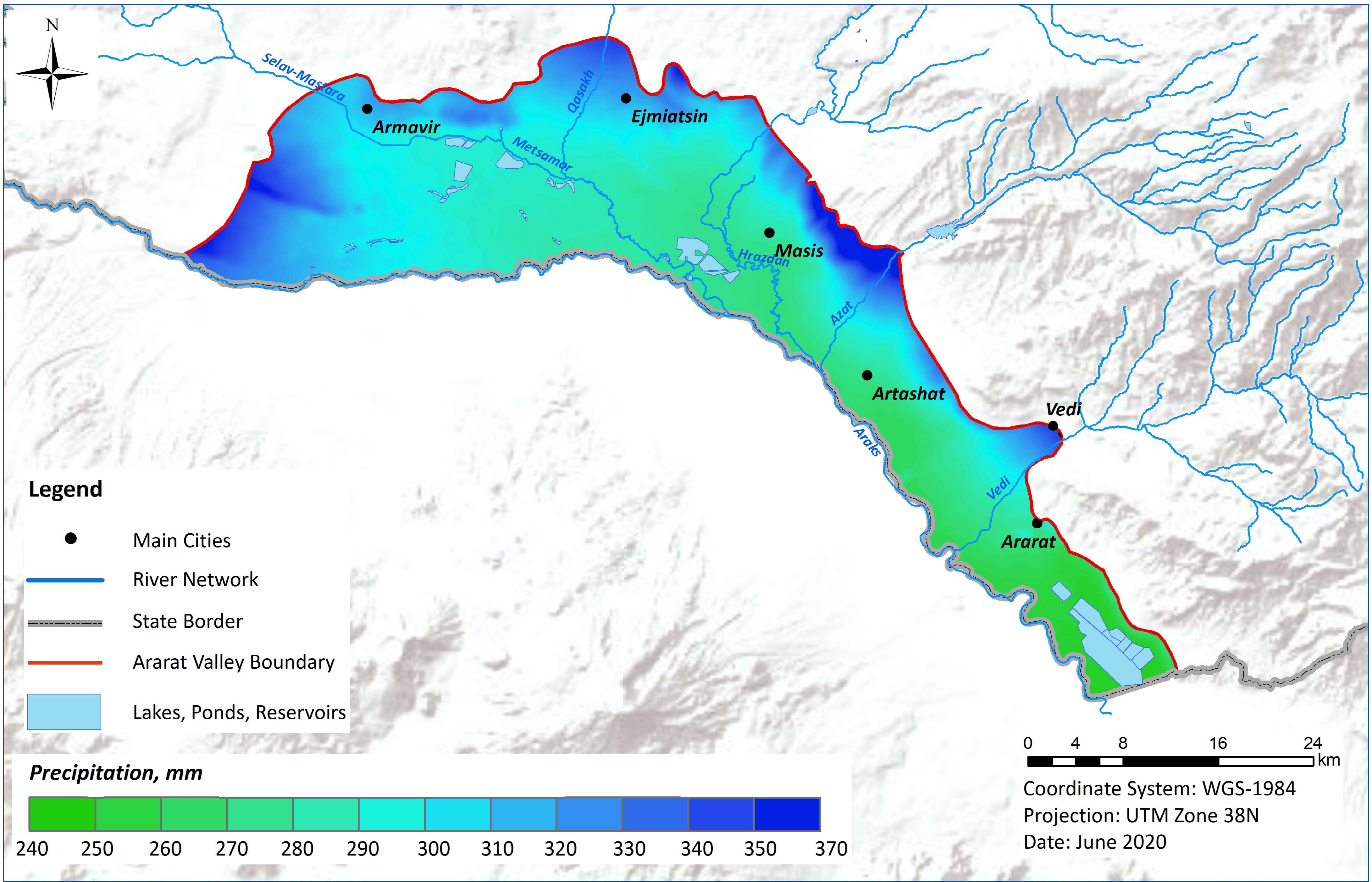
Distribution of the Multiannual Average Deep Flow in the Ararat Valley Catchment Area for the Period of 1961-2016

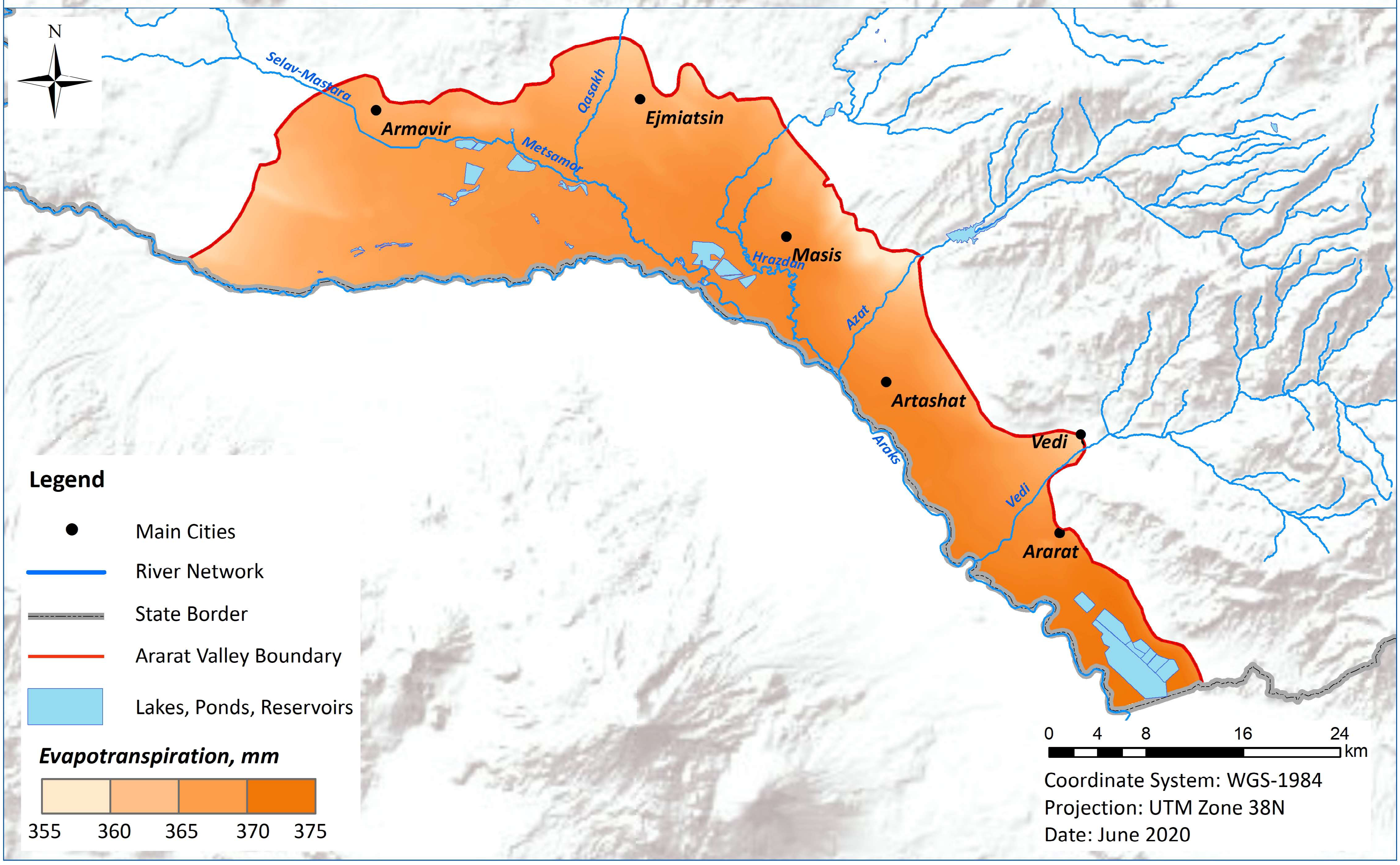


Values of Multiannual Average Deep Flow by River Basins

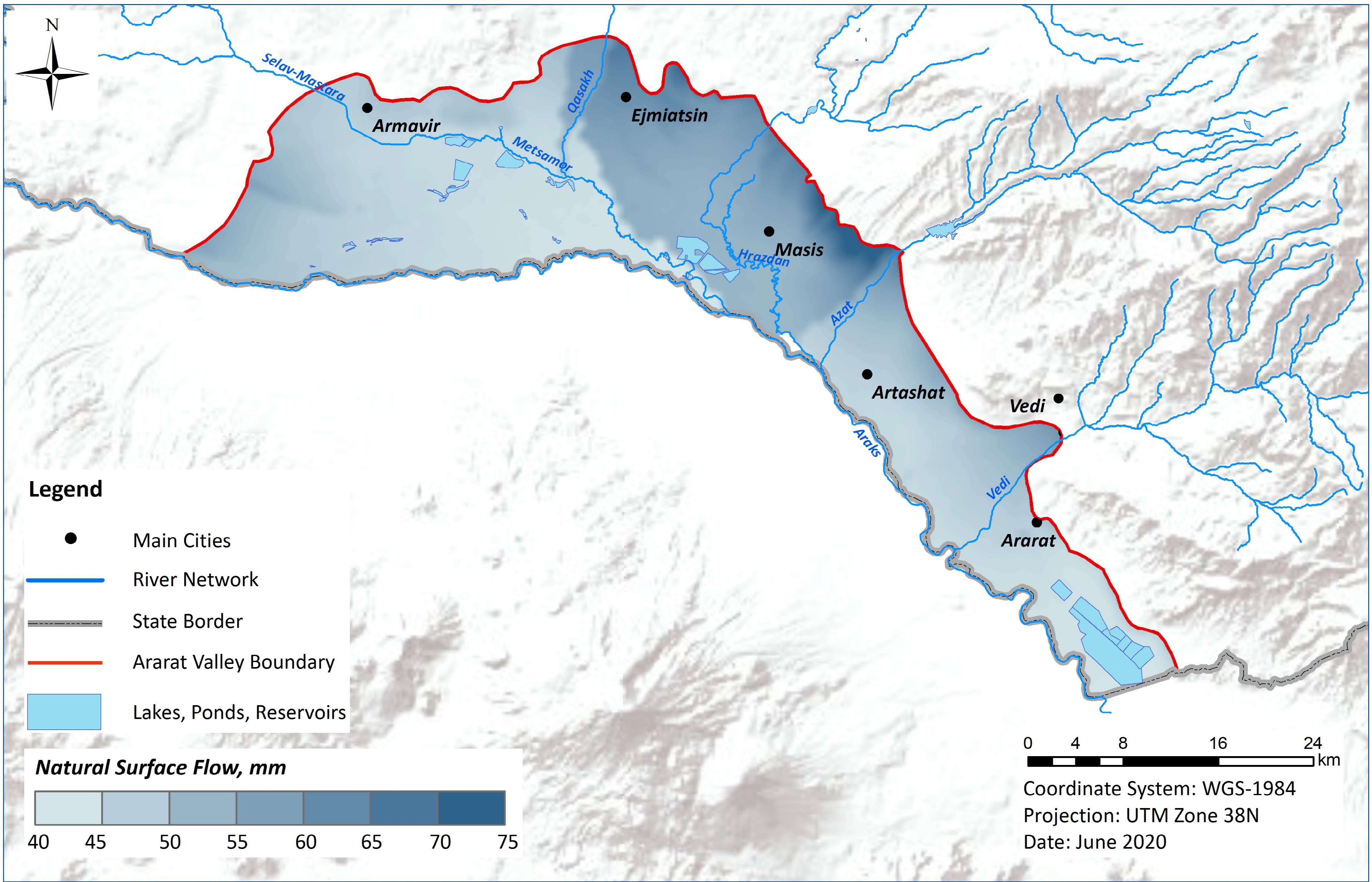
River Basin	mm	million. m^3
Akhuryan	158.0	436.2
Qasakh	107.3	146.5
Metsamor	-171.5	-323.3
Hrazdan	58.1	131.5
Azat	54.0	40.8
Vedi	40.8	33.0

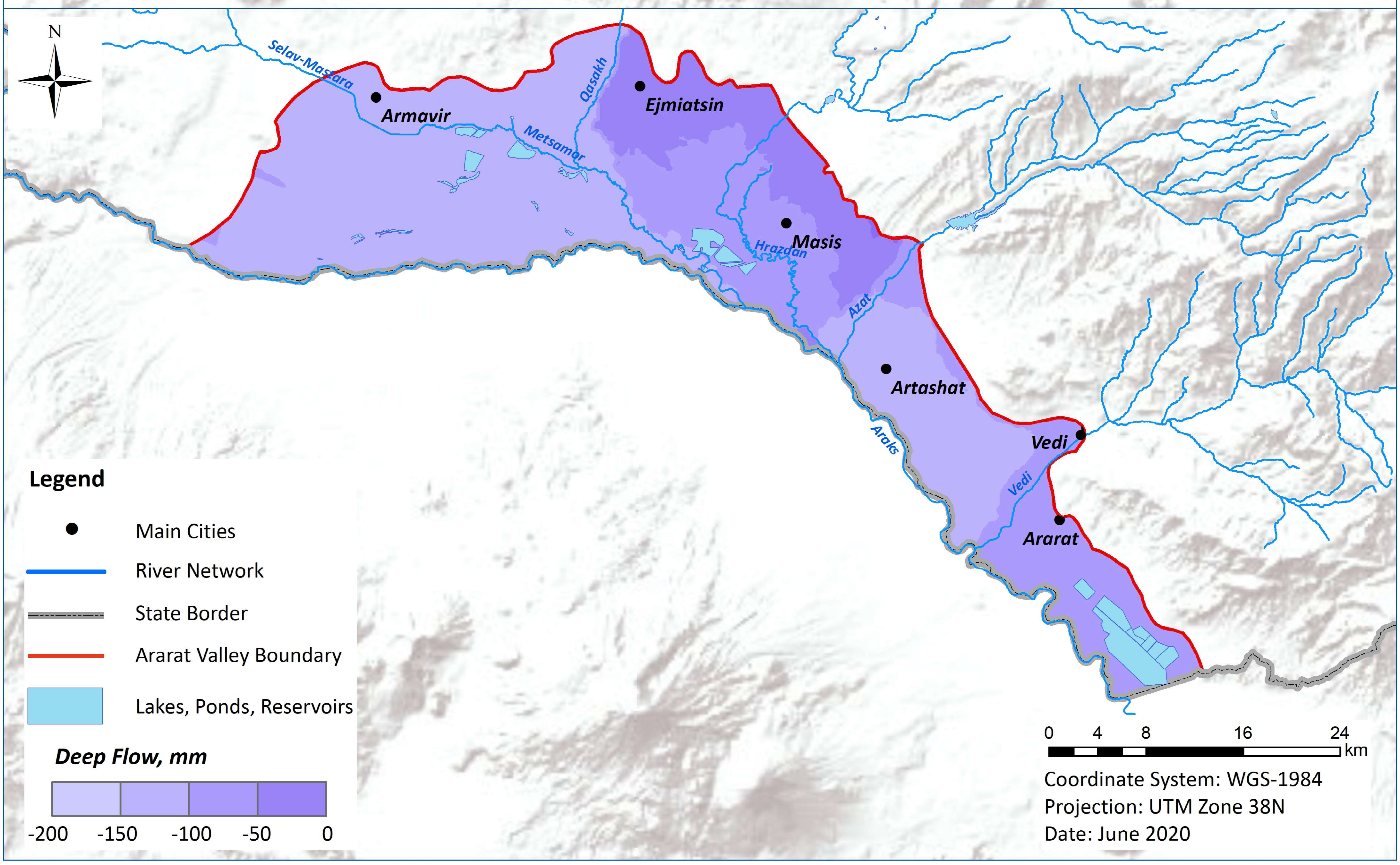
Distribution of the Annual Precipitation and Evapotranspiration in the Ararat Valley in 2016



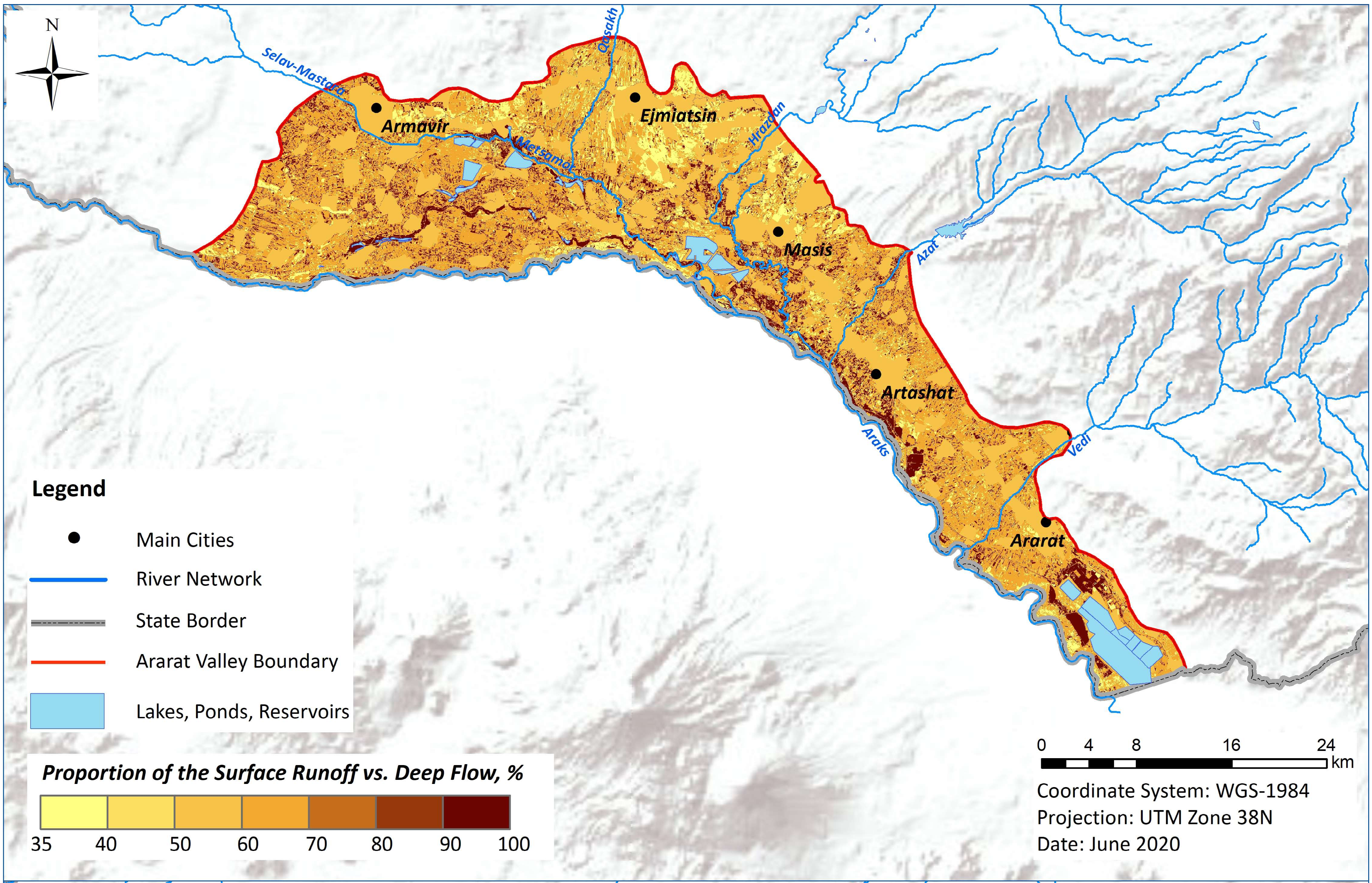


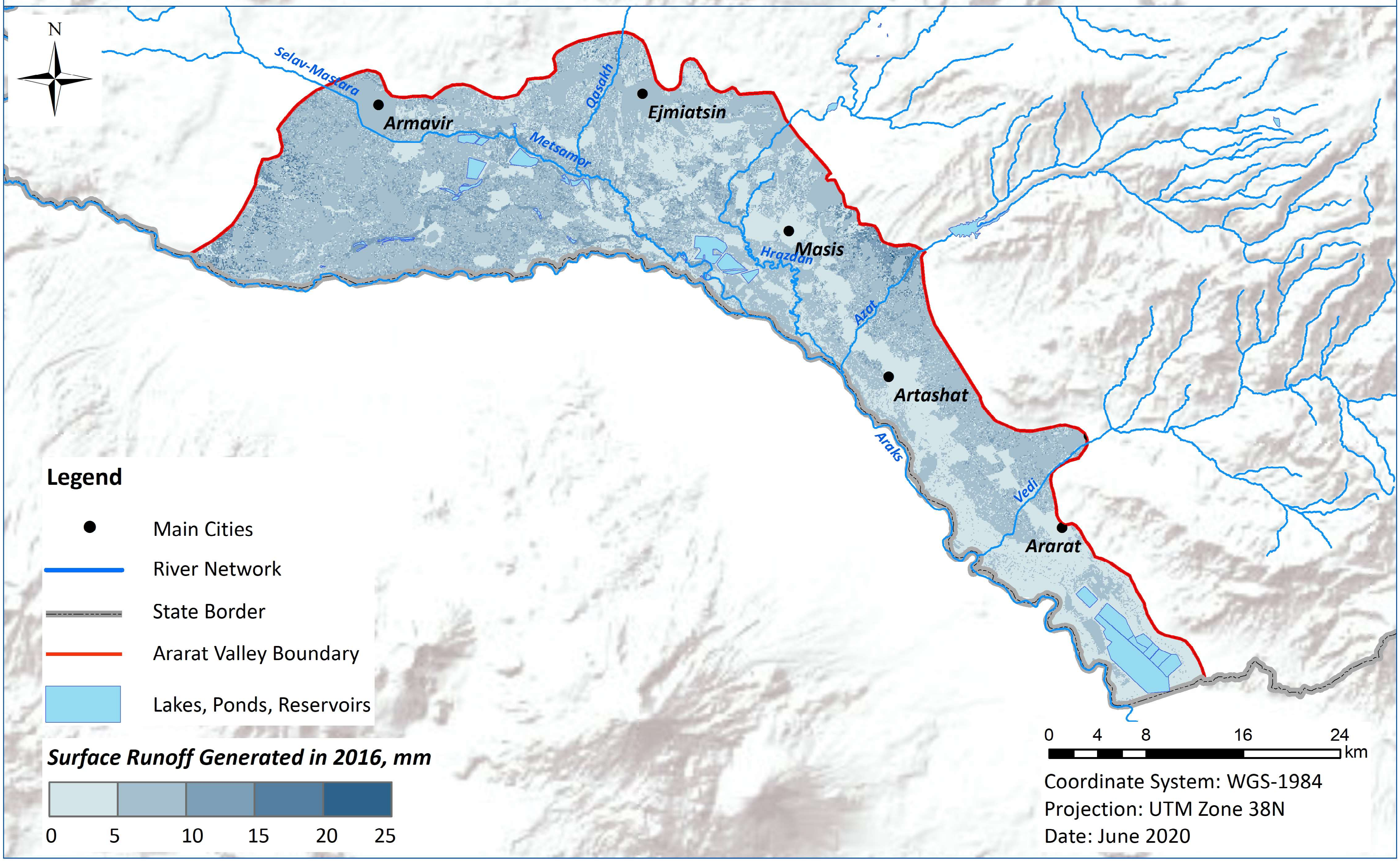
Distribution of the Annual Natural Surface Flow and Deep Flow in the Ararat Valley in 2016



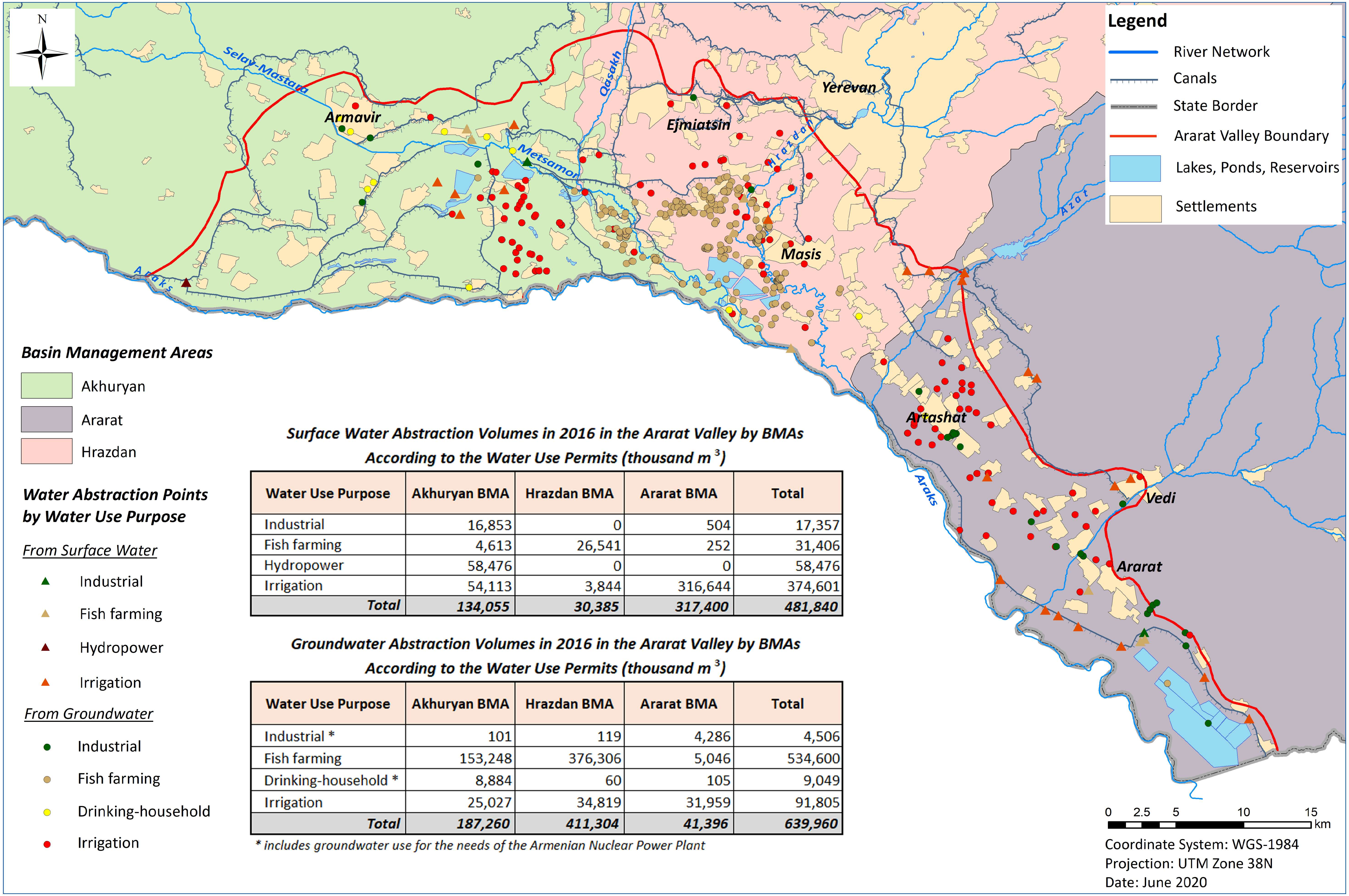


Proportion and Distribution of the Surface Runoff Generated in the Ararat Valley in 2016





Surface Water and Groundwater Abstraction in the Ararat Valley in 2016 According to the Water Use Permits Issued by the Ministry of Environment



Surface Water Abstraction Volumes in 2016 in the Ararat Valley by BMAs According to the Water Use Permits (thousand m ^{3})

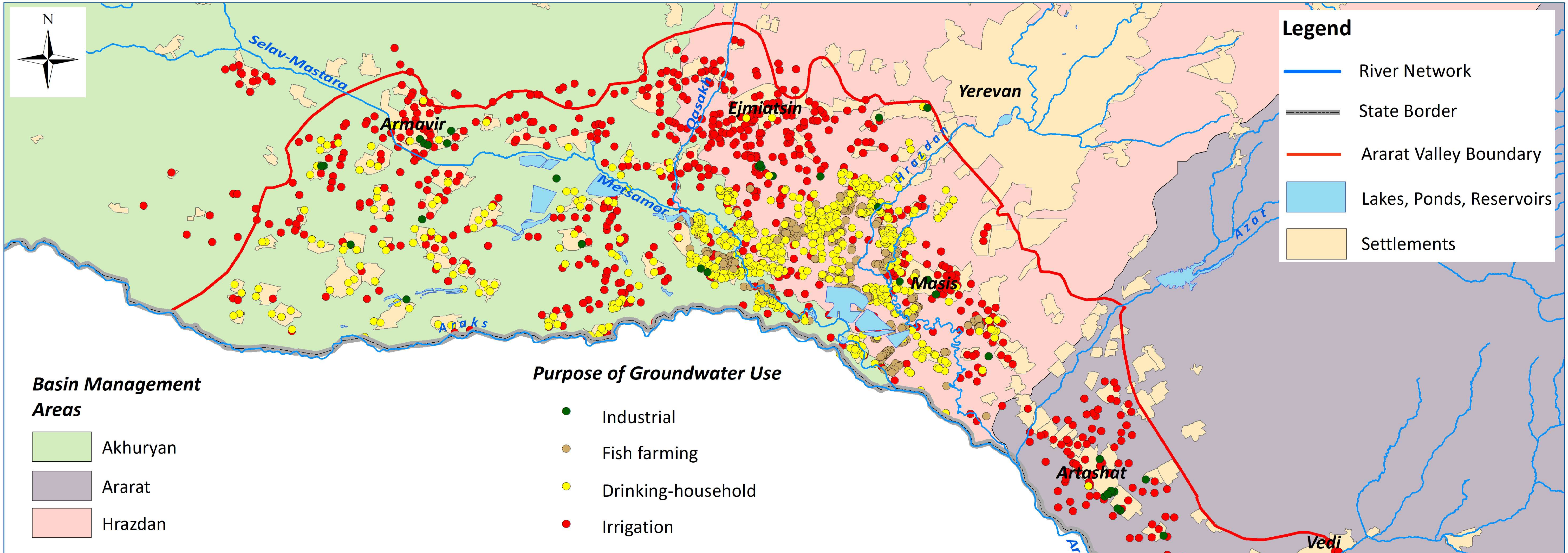
Water Use Purpose	Akhuryan BMA	Hrazdan BMA	Ararat BMA	Total
Industrial	16,853	0	504	17,357
Fish farming	4,613	26,541	252	31,406
Hydropower	58,476	0	0	58,476
Irrigation	54,113	3,844	316,644	374,601
Total	***134,055***	***30,385***	***317,400***	***481,840***

Groundwater Abstraction Volumes in 2016 in the Ararat Valley by BMAs According to the Water Use Permits (thousand m ^{3})

Water Use Purpose	Akhuryan BMA	Hrazdan BMA	Ararat BMA	Total
Industrial *	101	119	4,286	4,506
Fish farming	153,248	376,306	5,046	534,600
Drinking-household *	8,884	60	105	9,049
Irrigation	25,027	34,819	31,959	91,805
Total	***187,260***	***411,304***	***41,396***	***639,960***

** includes groundwater use for the needs of the Armenian Nuclear Power Plant*

Actual Groundwater Use in the Ararat Valley in 2016 According to the Groundwater Wells Inventory Data



Actual Groundwater Use in the Ararat Valley in 2016 by Marzes and BMAs According to the Inventory Data

Water Use Purpose	Ararat Marz		Armavir Marz		Total	
	liter/sec.	thous. m^3/year	liter/sec.	thous. m^3/year	liter/sec.	thous. m^3/year
Industrial *	335.6	10,584.8	460.2	14,515.3	795.8	25,100.2
Fish farming	21,847.8	689,079.6	3,804.3	119,987.6	25,652.1	809,067.2
Drinking-household *	3,011.8	94,993.3	3,096.1	97,651.9	6,108.0	192,645.2
Irrigation **	6,025.3	190,037.4	12,403.8	391,217.2	18,429.1	581,254.6
Total	***31,220.5***	***984,695.1***	***19,764.5***	***623,372.1***	***50,985.0***	***1,608,067.2***

Water Use Purpose	Akhuryan BMA		Ararat BMA		Hrazdan BMA	
	liter/sec.	thous. m^3/year	liter/sec.	thous. m^3/year	liter/sec.	thous. m^3/year
Industrial *	339.3	10,701.0	280.0	8,832.1	176.5	5,567.1
Fish farming	1,640.6	51,744.2	228.0	7,190.2	23,783.5	750,132.8
Drinking-household *	2,844.9	89,729.7	7.5	235.6	3,255.5	102,679.9
Irrigation **	8,406.2	265,131.9	3,695.5	116,555.9	6,327.4	199,566.8
Total	***13,231.0***	***417,306.8***	***4,211.0***	***132,813.8***	***33,543.0***	***1,057,946.6***

** includes groundwater use for the needs of the Armenian Nuclear Power Plant*

*** the 7/12 coefficient is used to calculate the annual actual groundwater use for irrigation purpose, taking into considertion the number of months in the irrigation season within the year.*