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THE TENDENCIES OF HYDRAULIC ENERGY DURING XXI CENTURY BETWEEN PRESERVATION AND ECONOMIC DEVELOPMENT. CASE STUDY: FAGARAS MOUNTAINS, ROMANIA

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Abstract: Fagaras Mountains, with the highest altitudes and slopes on the territory of Romania, presents a high hydro energetic potential, characteristic of small rivers. The unique mountain landscape from Romania contributed to the declaration of a large area as protected zone. Due to this reason, the initiative of building the production units is limited. Given the fact that micro-hydro plants do not affect the environment, they can receive the construction notice. The designed micro-hydro plants will be placed on Balea brook, near SC Viromet SA catchment. It will use the water already collected by the synthetic resins plant and is going to be placed underground. The study is based on the water resource assessment in satisfying the requirements of economical units from study area (SC Viromet SA and SC Cartisoara Hydroenergy SRL).

Keywords: servitude discharge, green energy, micro-hydro plant, hydro-energetic potential, water resources, Fagaras Mts.

1. INTRODUCTION

During communist regime, Romania has used the hydraulic energy in an extremely efficient way in order to become energetically independent. The economic collapse that followed the events at the end of 1989 has urged the development of alternative and non-polluting energy. For this reason, attempts have been made on producing electric energy through micro-hydro plants along the watercourse or that use the water already collected for other uses.

Most hydrotechnical arrangements in the world, and implicitly in Romania, aim for a complex utilization (flood mitigation, industrial and fresh water, electricity production, fish farming, recreation) (Banaduc et al., 2016; Brili & Polic, 2005; Čech & Čech, 2013; Choi et al., 2016; Cojoc et al., 2014; Corduneanu et al., 2016; Dumitriu, 2016; Gavrilovic et al., 2012; Breaban et al., 2014; Hapciuc et al., 2016; Kominkova et al., 2016; Loczy, 2012; Loczy et al., 2014; Cruceanu et al., 2015; Cozma et al., 2015; Milelli et al., 2006; Plattner et al., 2006; Radevski et al., 2016; Raška, 2015; Reti et al., 2014; Romanescu & Nistor, 2011; Romanescu et al., 2011a,b, 2013a,b, 2014, 2015a,b, 2016a,b, 2017; Romanescu & Stoleriu, 2013). Specialty studies focus on the formation of lakes that can store a significant amount of water (Bosona & Gebrebenbet, 2010; Romanescu, 2013; Romanescu et al., 2011a,b, 2013a,b; Tirnovan et al., 2014; Yang et al., 2014; Mihu-Pintilie et al., 2014a,b) or the placement of isolated or in cascade micro-hydro plants that can produce electricity at local level and rarely at national level (Ashaary et al., 2015; Barbu et al., 2013; Driscoll, 2008; Georgescu et al., 2016; Hosseini et al., 2005; Islam et al., 2013; Mishra et al., 2012; Montes et al., 2005; Muntean et al., 2016; Paish, 2002; Uhunmwangho & Okedu, 2009; Zelenkova et al., 2013). Most studies for the installation of micro-hydro plans are conducted in South-East Asia (Chamamahattana et al., 2005; Dinkar & Mosankar, 2015; Hanafi & Riman, 2015).

The objectives of the current study are: (i) determining total maximum discharge that can be reached by including all catchments in order to find out whether it is sufficient for operating the two micro-hydro plants owned by economical unit (SC Viromet SA) and the one that is going to be built; (ii) identifying if the two micro-hydro plants owned by SC Viromet SA and the industrial platform would still be functional after completely stopping the water flow collected by Balea catchment; (iii) writing a hydrologic study about Cartisoara brook - „Captarea Balea" Section from Olt hydrographic basin that comprises additional elements for a feasibility study in order to build a micro-hydro plant on Balea brook (calculation of average multiannual flow; calculation of duration curve of average daily flows; servitude discharge). Finally, it must be determined whether the micro-hydro plant can be installed and if the environment is compromised.

1.1. Study area

Cartisoara basin occupies a central position in Romania and represents the left tributary of Olt River. Its spring is located in Fagaras Mountains (the highest in Romania) and crosses the steep and wet northern slope of Southern Carpathians. Due to this reason, the average multiannual flow is high although its surface is reduced (Fig. 1). On its valley was built the most spectacular mountain road from Europe: The Transfagarasan. It was called Cartisoara only after the confluence of Laita and Balea brooks. After the confluence with Seaca the main course appears and flows into Olt River near Carta locality.

2. DATABASE AND METHODS

Hydrological data (flows and levels) were achieved from National Administration of Romanian Waters – Olt Water Basin, Ramnicu Valcea (Cartisoara hydrometric station). The data concerning the water use were purchased from SC Viromet SA, headquartered in Victoria City (Brasov County). For a better understanding of the phenomenon related to the proper placement of micro-hydro plants it was studied the national and international methodology (Conrad et al., 2015; Diaconu et al., 2016; Kádár, 2014; Lazarova et al., 2014; Li et al., 2015, 2016; Mierla et al., 2014; Napoli & Garcia-Tellez, 2016; Revuelto et al., 2014; Safta et al., 2013; Sanders, 2016; Simič et al., 2014; Türk et al., 2016; Van Leeuwen et al., 2016; Wrzesiński et al., 2015).

Thematic maps were created based on topographic maps in scale 1:25,000. They were generated in ArcView (ArcGIS) licensed for the Faculty of Geography and Geology from Alexandru Ioan Cuza University of Iasi. For the update were used data recorded from orthophoto plans, edition 2015. Field observations contribute to determining characteristics specific for mountain area of Fagaras.

3. RESULTS

Installing a micro-hydro plant on Balea brook, downstream Balea catchment, depends on the total maximum discharge that can be reached by including all catchments held by economical unit because it distributes some of the water necessary to operate. The SC Viromet SA helds 9 catchments (Table 1). The total water requirement is: max. 295,736 m^3/day; avg. 82,722 m^3/day; min. 31,500 m^3/day. The total water demand: max. 134,328 m^3/day; avg. 41,559 m^3/day; min. 12,000 m^3/day. The degree of internal recycling of water is 62%. The volumes and flows of industrial water authorised for catchment according to the Water Management Authorisation No. 292/30.10.2007: 1. Max. daily: 98,928 m^3 (1,145 L/s); Annual max.: 36,108 m^3; 2. Avg. daily: 25,229 m^3 (292 L/s); Annual avg.: 9,208 m^3; 3. Min. daily: 12,000 m^3 (139 L/s); Annual min.: 4,380 m^3 (Table 2).

Therefore, the maximum possible capture is 265,000 m^3/day (3,067.13 L/s or 3 m^3/s). The Water Management Authorisation from 19.07.2013 approves a 25% reduction. Since SC Viromet SA has substantially reduced activity today is captured only a max. daily flow of 115,200m^3/day (1,334 L/s) with 43.5% lower than the max. daily flow that can be captured. The installed flow of both micro-hydro plants owned by SC Viromet SA is of 940 L/s (0.94 m^3/s) which represents 30.64% of the maximum flow that can be captured (3,067.13 L/s) or 70.46% of the maximum flow captured today as a result of the reduction operated by SC Viromet SA (1,334 L/s).

The question arises as to whether the flow calculated this way is sufficient for the operation of the two micro-hydro plants owned by SC Viromet SA (build inside the plant) and the designed micro-hydro plant for which was requested the approval and issuance of Water Management Authorisation for Zonal Urban Plan (ZUP). The investment given the current functioning conditions for economical unit, taking into account the contract no. 003/12/11/2013 that requested a reduction of water catchment due to the fact that the plant is no longer functioning at full capacity.

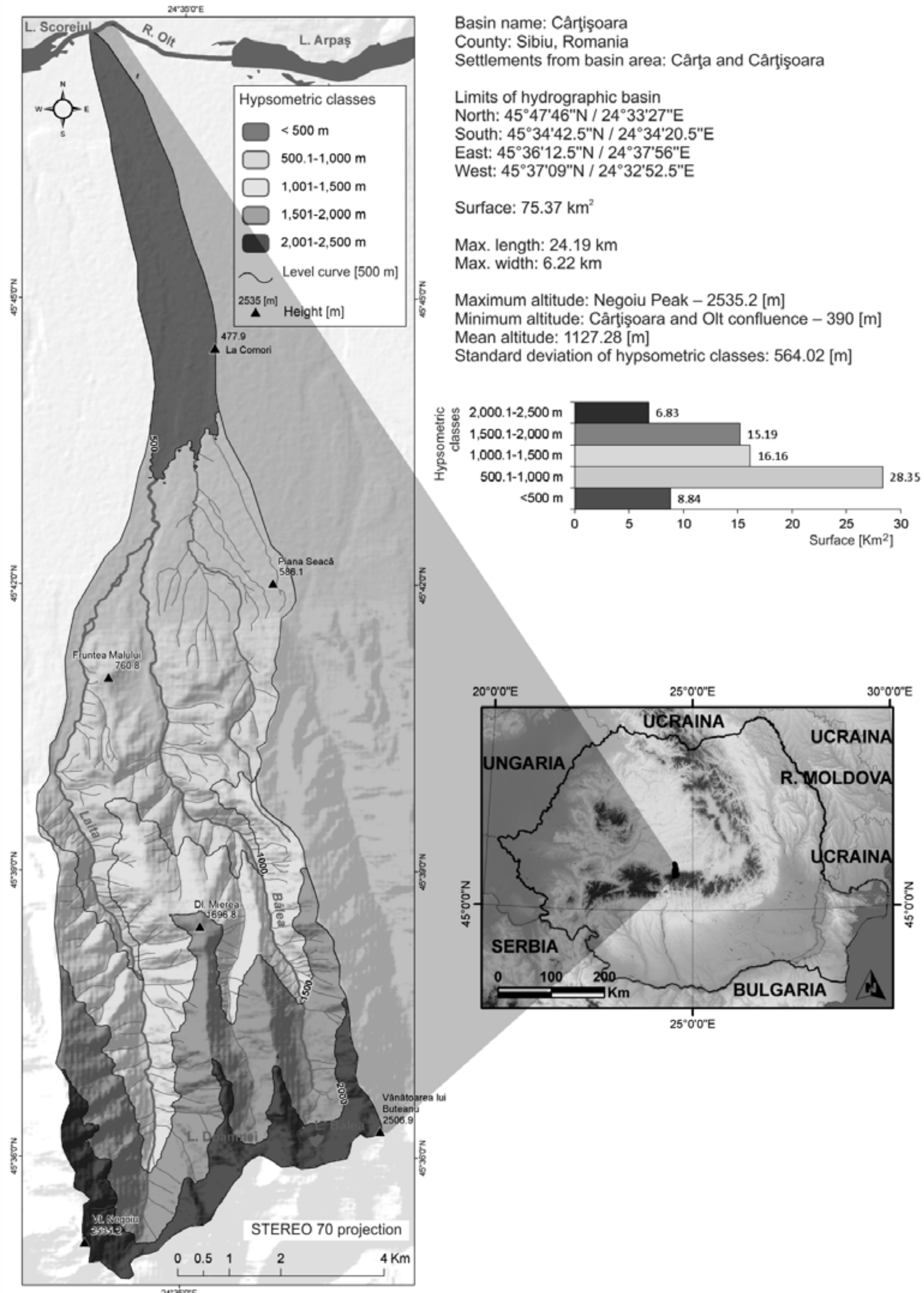

Figure 1. Geographical location of Cartisoara hydrographic basin in Fagaras Mts.

The micro-hydro plant 1 (MHP1) generates 110 kW and operates based on industrial water with max. flow Q_{max} = 0.29 m^3/s (290 L/s). The micro-hydro plant 2 (MHP2) produces 300 kW and works based on industrial water with max. flow Q_{max} = 0.65 m^3/s (650 L/s). Thus, the total is 0.94 m^3/s (940 L/s).

The maximum flow exploited by SC Viromet SA is 1,334 L/s (1.334 m^3/s). At current flow can function both micro-hydro plants owned by SC Viromet SA and alternatively (with methanol sections III and IV), the micro-hydro plant SC Cartisoara Hydroenergy SRL. The entire amount of water captured from Balea can be used by SC Cartisoara Hydroenergy SRL during the time the two sections of methanol do not work. The two micro-hydro plants can operate using nearest sources even if the methanol section is not functioning. By completely stopping the water flow collected from Balea catchment (on Balea brook), the discharge calculated at point No. 1 would ensure the functioning of the two micro-hydro plants of SC Viromet SA and the industrial platform (taking into account the contract No. 003/12/11/2013).

Table 1. The water supply for drinking and technological purpose for SC Viromet SA

No.	Stream / Surface	Q_{max} captured		Q_{med} captured		Q_{min} captured	
		L/s	m^3/H	L/s	m^3/H	L/s	m^3/H
1.	Balea	152	547	107	385	0	0
2.	Ucea [c.b.h. VIII.1.104., hm 165]	92	331	45	163	14	52
3.	Ucisoara [c.b.h. VIII.1.103]	85	306	42	152	12	42
4.	Vistea [c.b.h. VIII.1.101., km 81]	241	867	91	327	13	46
5.	Vistisoara [c.b.h. VIII.1.101.1., hm 82]	76	273	32	115	9	34
6.	Sambata [c.b.h. VIII.1.97., hm 218]	315	1,134	109	392	62	223
7.	Lisa [c.b.h. VIII.1.97.1., hm 60]	105	378	33	119	17	61
8.	Brescioara [Cbh. VIII.1.96.1., hm 117]	122	439	9	32	5	18
9.	Pojorata (Breaza) [Cbh. VIII.1.96., hm 102]	146	525	12	43	7	24
Total		1,334	4,800	480	1,728	139	500

Table 2. Water consumer uses in SC Viromet SA

Consumer		Q_{max} [L/s]	V_{max} [m^3/day]	Q_{med} [L/s]	V_{med} [m^3/day]
SC VIROMET SA		1,195	103,192	412	35,597
Others	SC PUROLITE SA	78	6,739	54	4,665
	Lisa Village Hall	44	3,801	8.67	750
	SC Pirochim SA, SC Transchim SA, Pompieri T.B.BV and SC Maxam SA	17	1,468	5.5	475
	Subtotal others	139	12008	68	5,890
Total		1,334	115,200	480	41,472

The maximum flow exploited by SC Viromet SA is 1,334 L/s (1.334 m^3/s). The max. discharge captured from Balea is 152 L/s (0.15 m^3/s). If the flow captured from Balea would be completely eliminated, the industrial platform would use 1,182 L/s (1.182 m^3/s). Out of this amount, only 940 L/s (0.94 m^3/s) were used for the two micro-hydro plants (located downstream, at the outlet from the industrial platform and therefore cannot affect the industrial process). Given the conditions of alternative or total functioning (with methanol sections III and IV) the micro-hydro plant designed by SC Cartisoara Hydroenergy SRL can operate at its current flow. If it is required to supplement the flow, the new micro-hydro plant can fully function as long as SC Viromet SA operates at reduced capacity. The practical capacity of capture from Balea is 200 L/s (0.20 m^3/s) with the possibility of increasing by 10% (220 L/s which is 0.22 m^3/s).

The water resource is given by the hydrologic study on Cartisoara River - „Captarea Balea" Section from Olt hydrographic basin that includes: calculation of average multiannual flow; calculation of duration curve of average daily flows; servitude discharge. Cartisoara hydrographic basin has three major sub-basins: Laita (28.02 km^2), Balea (25.95 km^2) and Seaca (13.1 km^2) (Fig. 2). The confluence of Balea and Laita streams is situated at north from Cartisoara Hydrometric Station (which does not record the flows of Seaca stream) (Fig. 3). This confluence of streams gives the name Cartisoara. Downstream the hydrometric station it receives Seaca stream as a left tributary. It flows in Olt River near Carta locality. The maximum rainfall is recorded in the upper basins of the three sub-basins. The high slopes generate high water speed and frequent floods due to torrential rain.

The data regarding the morphometry and morphography of Cartisoara basin are found in the thematic maps. The data can be read for hydrographic basins related to Cartisoara basin. The maps are processed based on cartographic material in scale 1:25,000. It was used ArcGIS software licensed for the Geoarchaeology Laboratory within the Faculty of Geography and Geology, Alexandru Ioan Cuza University, Iasi.

4. DISCUSSIONS

4.1. Calculation of average multiannual flow

Cartisoara Hydrometric Station records the flows of Laita and Balea streams (Figs. 4, 5). The average multiannual flow is 2.065 m^3/s (Fig. 6). According to calculations described in this study the average multiannual flow of Balea stream is 0.825 m^3/s and of Laita stream is 1.240 m^3/s. Balea catchment is located upstream the confluence of Laita and Balea streams (Fig. 7). It captures only the waters from Balea hydrographic sub-basin. The current maximum flow captured from Balea is 152 L/s (0.15 m^3/s) (decreased by demand due to the fact that SC Viromet SA is not operating at full capacity), but the practical capacity of catchment from Balea is 200 L/s (0.20 m^3/s). Other morpho-hydrographic characteristics influence the flow in each sub-basin. These characteristics are very similar in Laita and

Balea hydrographic sub-basins that influence the hydrologic characteristics from Cartisoara Hydrometric Station (Figs. 7, 8).

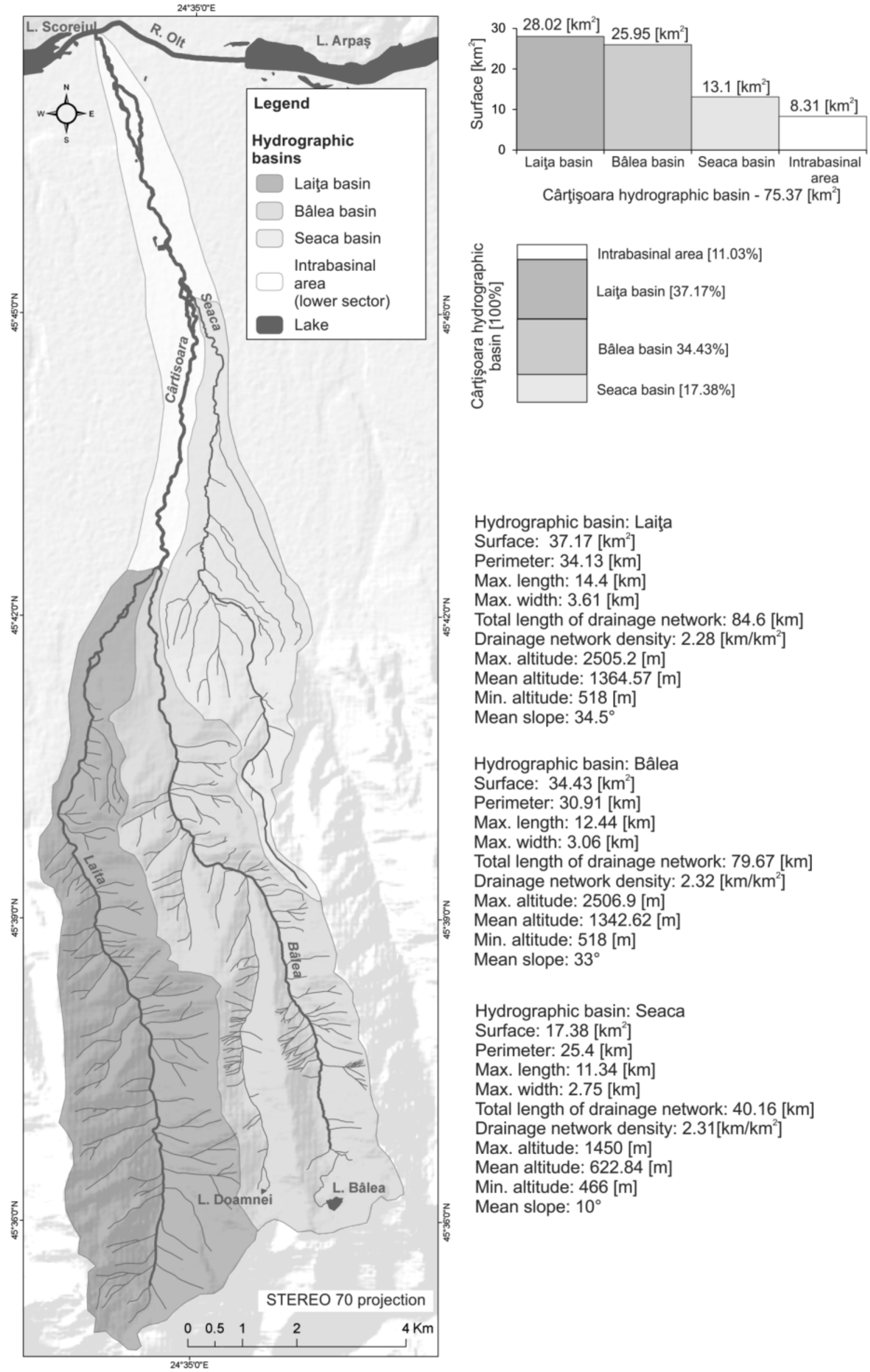

Figure 2. Morpho-hydrographic characteristics of Cartisoara hydrographic basin and component sub-basins

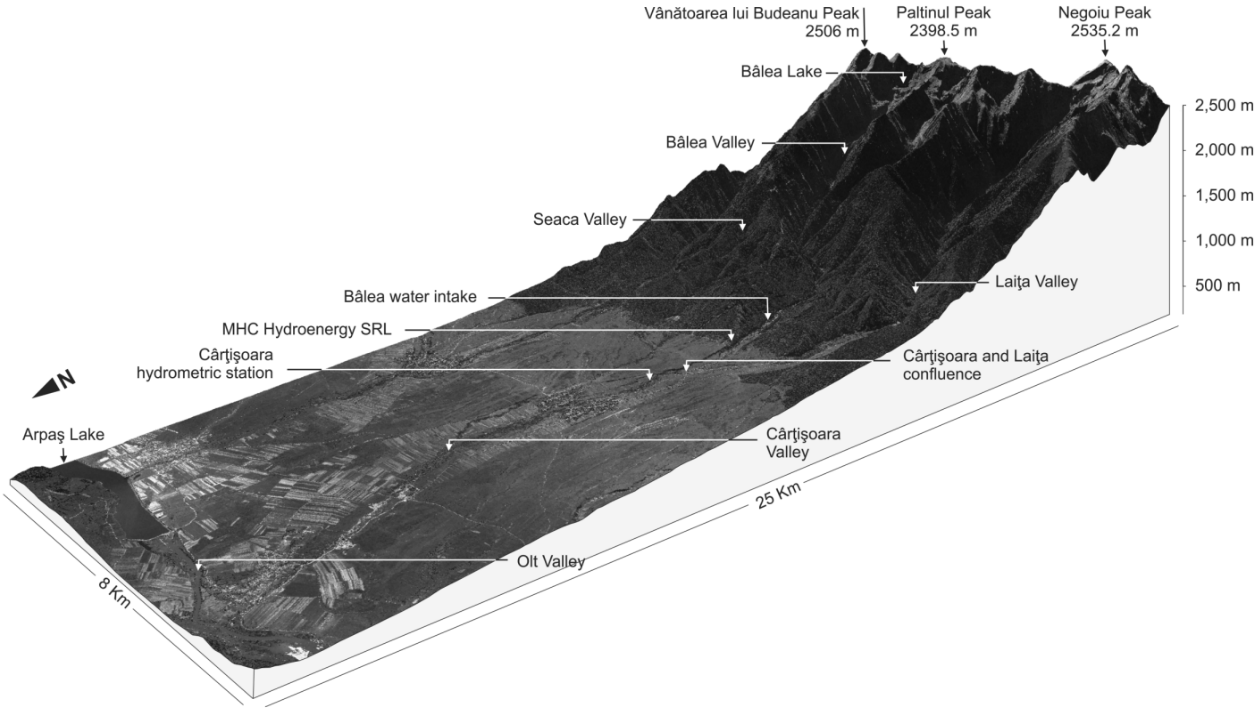

Figure 3. The confluence of Balea and Laiţa brooks and the location of Balea catchment, micro-hydro pland SC Cartisoara Hydroenergy SRL and Cartisoara Hydrometric Station

Figure 4. Balea stream in the upper sector

4.2. Calculation of duration curve of average daily flows

The duration curve of average daily flows represents a graphic of the average daily flow of a river drawn according to the probability of exceedance. This curve is created in order to determine the probability to produce (record) a value *(A)* and is generally noted with *p(A)*. In this case, *p(A)* represents the ratio between the ”a” number of favourable results to the production of *A* and the ”b” total number of *p(A)* possible results. In practice, most of the times the *a* number of favourable situations and the *b* number of possible results are unknown, so it is not known the likelihood of the phenomenon. For this reason, the number of favourable results can be counted from the string values of average daily flows.

Figure 5. Cartisoara River near Cartisoara Hydrometric Station, after the confluence of Balea and Laita brooks

In this context the calculation of the phenomenon probability (calculating the curve) is conducted in several stages: preparing organizing the chronological string of values; arranging the values in descending order; assigning an order number for the new string achieved; creating the empirical curve of insurance by comparing the values obtained after using the calculation formula on a graphic with logarithmic scale; establishing frequencies and durations of values on preset stages; determining the parameters of analytical curves of probability distribution.

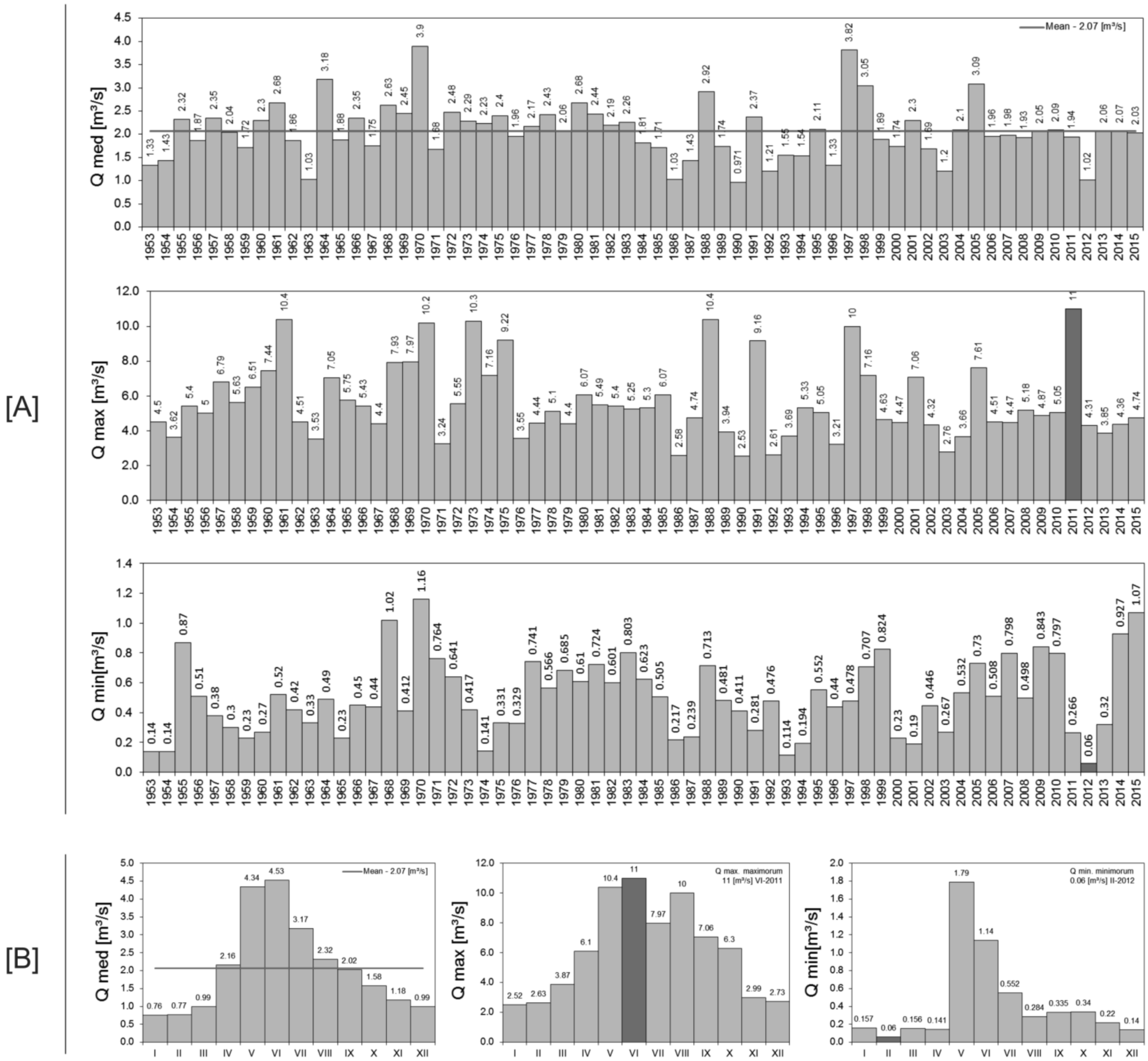

Figure 6. The average, maximum and minimum multiannual flow [A] and monthly multiannual flow [B] at Cartisoara Hydrometric Station (1953 – 2015)

The general formula (1) used is:

(1) p = m/n*100

where: m represents the order number and n represents the number of elements in the string.

In this case, for Cartisoara River, the value of average daily flow with a probability of 95% is 0.280 m^3/s (Fig. 9).

4.3. Servitude discharge

The servitude discharge represents the minimum discharge required to permanently flow downstream through a section of a watercourse. It is the flow with 95% duration from the duration curve of average daily flows corresponding to the natural regime. It consists of the sanitary discharge and the minimum discharge required by downstream water users (Law 107/1996). The sanitary discharge represents the minimum discharge required to flow downstream through a section of a watercourse to ensure the natural conditions of life from aquatic ecosystems (Law 107/1996). Balea Section has a sanitary discharge of 0.150 m^3/s (18.18%). The servitude discharge is identical to the sanitary discharge only is case that downstream are no water users (http://webworld.unesco.org/water, INHGA, 2015a,b).

For the calculation of sanitary discharge from Balea section was used the hydrologic analogy with Cartisoara hydrometric station, from the river with the same name, located downstream. From

Cartisoara hydrometric station were taken the average daily flows in natural regime of flow during 1953–2015, being transmitted in the section near Balea catchment. The flows generated the duration curve from which Q95% was extracted and it is considered a servitude discharge. The transmission was conducted with the *k* coefficient resulted from the ratio of average discharges from Balea catchment section and Cartisoara hydrometric station. The methodology is in accordance with the one used by the National Institute of Hydrology and Water Management Bucharest (cf. 550/2015) (INHGA, 2015a) (Table 3).

Maximum flows are analysed by the National Institute of Hydrology and Water Management Bucharest in the year 2015 (INHGA, 2015a). The transition from Q_{max}1% to discharges corresponding 2% and 5% probabilities was conducted through Pearson III distribution curve with Cv and Cs adopted by the National Institute of Hydrology and Water Management Bucharest.

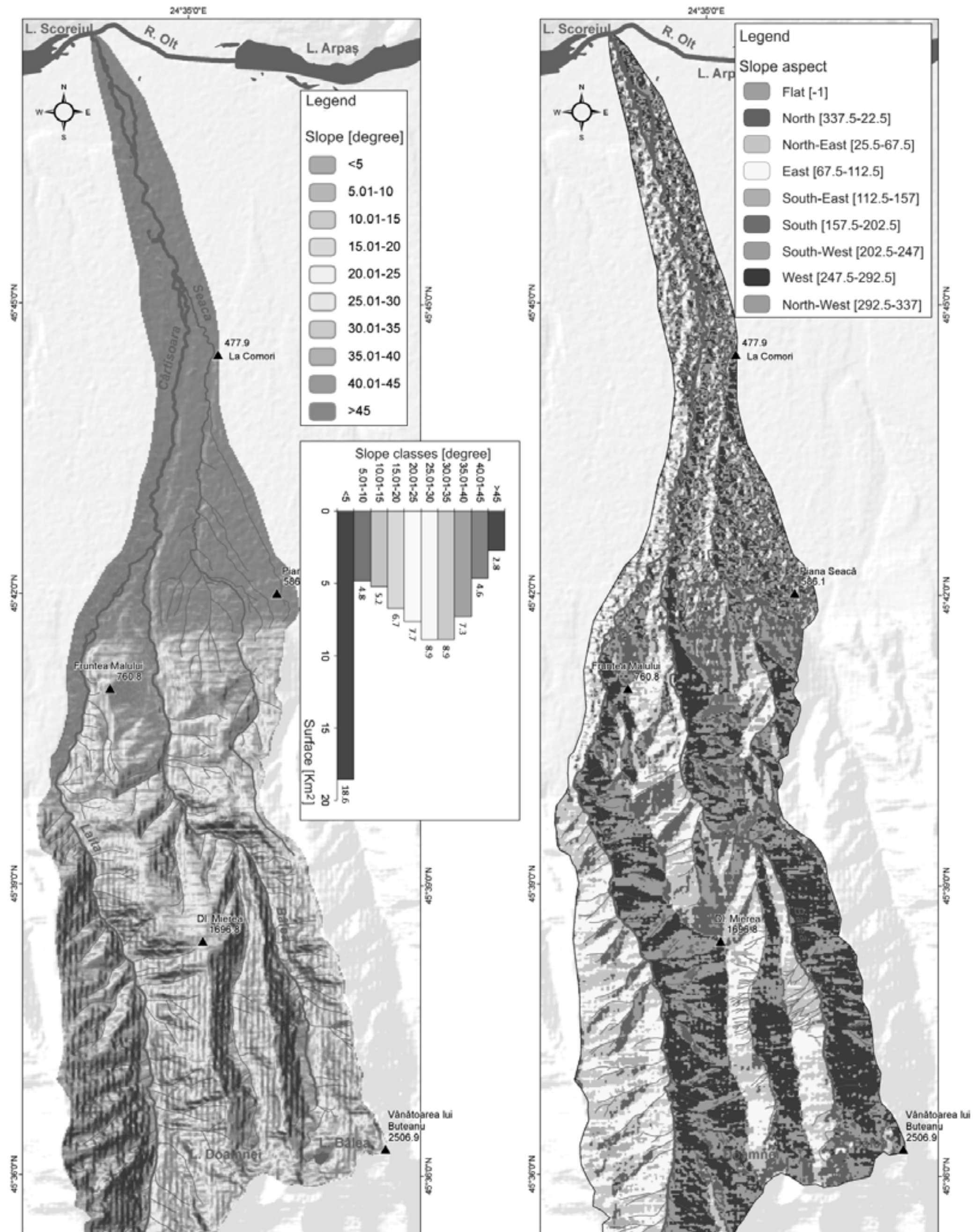

Figure 7. Slope and aspect-slope map of Cartisoara hydrographic basin

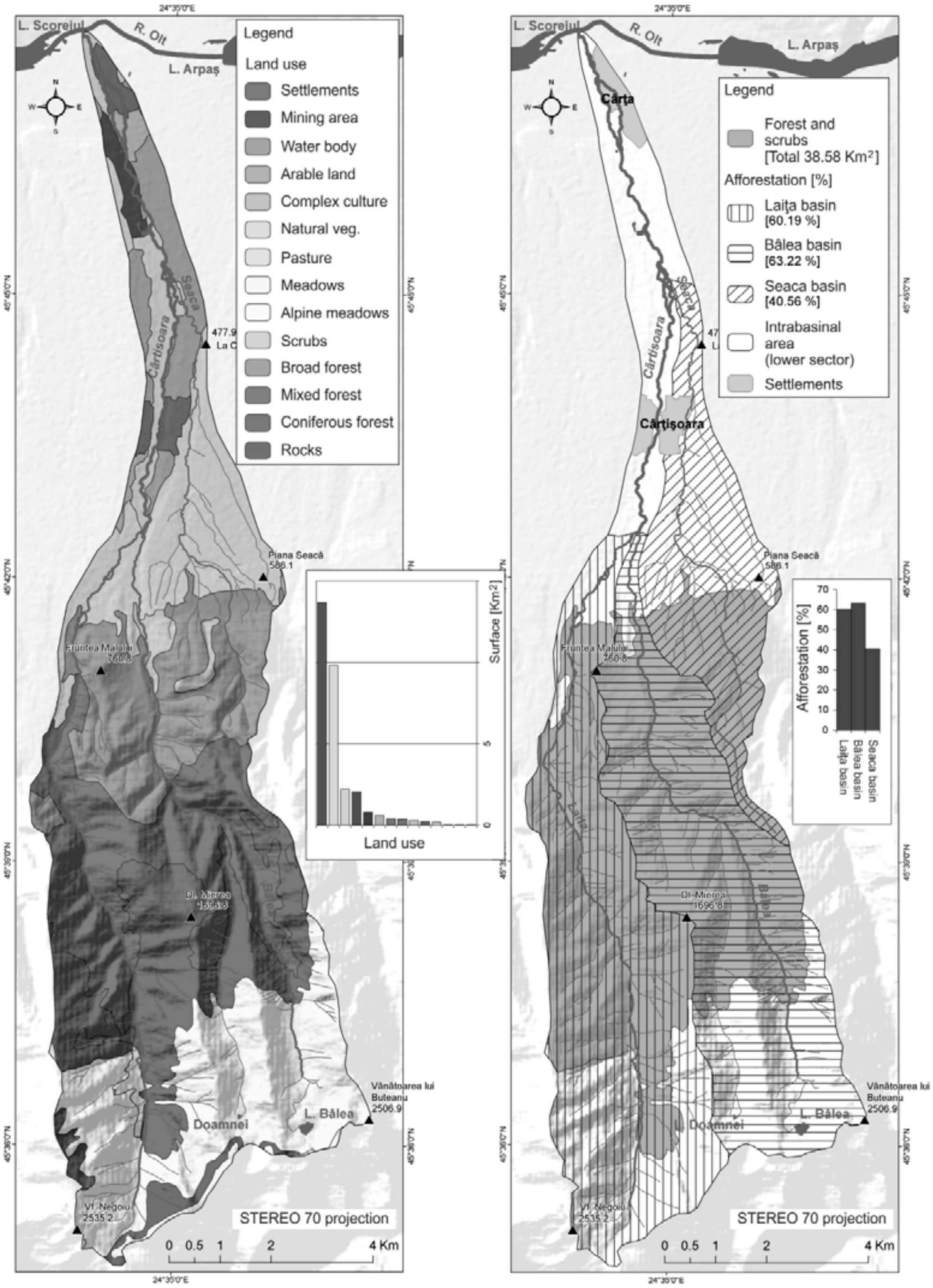

Figure 8. Map of land use and afforestation degree in Cartisoara hydrographic basin

The average multiannual flow of Cartisoara brook during 1953 – 2015 is 2.065 m^3/s (Balea 0.825 m^3/s and Laita 1.240 m^3/s). The highest average multiannual flow is recorded in the spring and summer (May and June) and the lowest in the winter (January and February) (Table 4).

The servitude discharge from Balea section (Balea stream from Cartisoara hydrographic basin) consists of the sanitary discharge and requirements discharge for Agnita City (Q_{captat} - 0.074 m^3/s) = 0.224 m^3/s (27% of the average multiannual flow) (Table 5) (INHGA, 2015a,b). For Agnita City must be calculated the demand from Cartisoara section because the average multiannual flow is totally different. In this case, the servitude discharge corresponds to the sanitary discharge in Balea section. The natural flow remained after ensuring the servitude discharge can secure the functioning of the micro-hydro plant Hydroenergy SRL. The flow on Cartisoara brook occurs under conditions of multiannual average of rainfall: 737.43 mm (period 1995 – 2015) (Table 6). The western slope of Fagaras Mountains is under the influence of oceanic air masses and altitudinal zonation of climate.

Table 3. Hydrologic characteristics for Balea catchment section SC Viromet SA – Altitude: 730 m (INHGA, 2015a)

River	Section	Surface [km^2]	Mean altitude [m]	Q mean multiannual [m^3/s]	Q salubrious [m^3/s]	Q_{max} probability of exceeding [m^3/s]		
						1%	2%	5%
Cartisoara	Balea catchment (730 m alt.) SC VIROMET SA	17	1,644	0.825	0.150	87	69	47

SC Viromet SA represents another symbol of chemical industry in Romania. The building site of this plant was open in 1939. The name of *Combinatul Chimic Victoria* is taken in 1954. It is the leading producer of methanol, formaldehyde, synthetic resins. Currently operates only at 20 – 25% of its capacity which represents a minus for the revision of the Water Management Authorisation (19.07.2013). It is supplied with fresh and technological water from surface sources: Balea stream, Ucea stream, Ucisoara stream, Vistea stream, Vistisoara stream, Sambata stream, Lisa stream, Brescioara stream, Pojorta stream (Breaza).

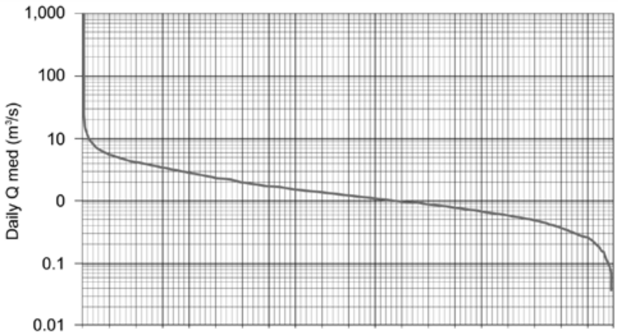

Figure 9. The duration curve of average daily flows at Cartisoara Hydrometric Station during 1985 – 2015

SC Viromet SA and SC Cartisoara Hydroenergy SRL signed a contract for the exploitation of hydro energetic potential of Balea catchment to use the collected water for the operation of micro-hydro plant when the methanol section is not functional or the plant is operating at reduced capacity. Balea catchment operates under a free fall regime. SC Cartisoara Hydroenergy SRL plans to build an electricity generating unit and connect it to the National Energetic System. The injected power of the micro-hydro plant is 0.32 MWh. The water supply that starts the turbine comes from the pipe buried under a property of SC Viromet SA. The turbine is Pelton type with 350 KW power, horizontal, with wo jets, 750 rpm, Hitzinger asynchronous generator, 360 KW, 400 V and 50 Hz frequency. The water passing through the turbine will be discharged directly in Balea River (0.28 m^3/s).

The micro-hydro plant designed by SC Cartisoara Hydroenergy SRL is situated in the protected area ROSCI0122 – Fagaras Mountains. The micro-hydro plant involves the contruction of a dam, a supplementary pipeline or a hydro aggregate construction that would bring a significant impact to the protected area. The impact cannot be greater than that of building a home. The micro-hydro plant is underground and the infrastructure already exists. Environmental impact is zero.

Within Laita hydrographic basin, with a surface of 28.02 km^2, there is a micro hydro-plant located in the mountain sector. Both hydrographic basins (Laita and Balea) present a high and identical hydro energetic potential. The high hydro energetic potential is the result of flows and high slopes. The high water speed makes frost difficult to install, even during winter. *”Vantul Mare”* (High Wind), also known as *”Mancatorul de zapada”* (Snow eater), makes the spring water levels to increase even at the end of winter, although the basins are located in the mountain sector (Fig. 10).

Figure 10. Balea catchment (SC Viromet SA)

On Balea brook, in downstream sector, it was built a catchment that supplies SC Viromet SA with water. The water supply can be permanent because the discharges of Balea stream are relatively constant. The lowest average multiannual flows are recorded during winter, in January (0.761 m^3/s) and February (0.767 m^3/s) due to extremely low temperatures that cause an emphasized frost. The high degree of afforestation determines a significant amount of water retention in soil which supplies the streams from the underground. The existence of the forest makes the discharges to be relatively constant.

The development of mountain tourism leads to the preservation of most significant natural areas. Due to this reason, a great part of Fagaras mountain

Table 4. Avg. multiannual and monthly annual and multiannual flows at Cartisoara Hydrometric Station 1953 – 2015

Year	Month												Mean
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	
1953	0.98	0.63	0.6	2.9	4.5	2.5	1.22	0.83	0.87	0.52	0.22	0.14	1.33
1954	0.17	0.14	0.94	0.79	3.62	2.85	2.34	1.22	0.93	1.57	0.69	1.92	1.43
1955	1.9	0.88	0.98	1.36	2.37	5.4	5.2	3.3	2.7	0.87	1.78	1.12	2.32
1956	0.66	1.19	0.77	2.77	3.84	5	4.02	1.32	0.8	0.82	0.7	0.51	1.87
1957	0.38	0.47	0.64	2.55	5.85	6.79	2.35	2.01	1.9	1.04	1.54	2.73	2.35
1958	0.3	0.33	1.14	3.26	5.63	2.41	1.18	1.79	2.59	2.31	2.03	1.51	2.04
1959	1.47	1.02	1.95	1.21	2.5	6.51	2.25	1.78	0.91	0.49	0.34	0.23	1.72
1960	0.27	1.82	1.6	1.53	5.22	7.44	2.86	3.17	1.05	0.59	0.94	1.05	2.3
1961	0.58	0.57	2.09	5.68	10.4	7.2	2.09	0.98	0.59	0.52	0.71	0.8	2.68
1962	0.57	0.7	2.55	2.62	4.51	4.13	3.52	1.11	0.76	0.42	0.76	0.66	1.86
1963	0.33	0.68	0.47	1.08	3.53	2.38	0.88	0.79	0.73	0.53	0.52	0.5	1.03
1964	0.49	0.49	0.64	1.43	3.22	3.54	5.14	7.05	6.46	6.3	1.99	2.5	3.18
1965	1.68	1.74	2.19	1	4.82	5.75	2.3	1.09	0.8	0.6	0.23	0.28	1.88
1966	0.45	1.74	1.19	4.46	5.43	4.57	3.33	2.68	1.9	0.6	1.28	0.62	2.35
1967	0.44	0.77	1.36	3.09	4.09	4.4	2.67	0.75	0.56	0.83	1.01	0.99	1.75
1968	1.11	1.02	1.03	1.75	2.6	1.23	1.51	7.93	3.89	5.62	2.14	1.73	2.63
1969	1.52	1.42	0.584	0.412	1.79	5.64	7.97	3.38	2.58	1.74	1.45	1.35	2.45
1970	2.52	2.63	3.87	6.1	10.2	7.28	4.97	3.26	1.82	1.62	1.38	1.16	3.9
1971	1.46	0.914	0.764	1.13	2.93	2.38	3.24	1.37	2.84	1.13	1.06	1.01	1.68
1972	0.728	0.641	0.692	1.87	2.6	1.95	2.06	5.35	3.63	5.55	2.66	2.05	2.48
1973	0.542	0.476	0.687	2.45	10.3	4.89	2.77	2.18	1.63	0.514	0.417	0.509	2.29
1974	0.238	0.273	0.156	0.141	3.13	5.53	7.16	2.02	1.63	3.3	2.04	1.18	2.23
1975	0.699	0.331	0.791	2.22	5.02	9.22	6.54	1.48	0.895	0.678	0.478	0.47	2.4
1976	0.401	0.329	0.384	2.74	3.55	2.99	2.08	3.27	2.58	1.94	1.77	1.53	1.96
1977	1.21	1.07	1.16	2.97	3.48	3.68	4.44	3.03	2.08	0.89	0.8	0.741	2.17
1978	0.566	0.83	1.24	1.66	4.19	4.98	4.98	1.33	5.1	2.32	1.08	0.972	2.43
1979	0.967	1.22	0.709	2.39	4.4	4.01	3.57	4.03	1.17	0.685	0.757	0.746	2.06
1980	0.61	0.756	0.797	1.92	3.81	6.07	4.46	3.75	1.47	4.77	2.29	1.4	2.68
1981	0.801	0.724	2.01	1.72	5.49	4.8	5.2	1.52	1.95	1.74	1.72	1.57	2.44
1982	1.32	1.03	0.992	1.82	5.4	5.1	4.39	2.32	1.75	0.937	0.607	0.601	2.19
1983	0.803	0.927	1.57	3.07	3.35	5.25	3.85	3.52	1.44	1.28	0.87	1.13	2.26
1984	0.922	0.623	0.84	1.82	5.3	3.65	2.98	1.78	1.09	1.05	0.924	0.772	1.81
1985	0.573	0.505	0.683	1.19	3.6	6.07	3.64	1.29	1.07	0.596	0.664	0.677	1.71
1986	0.617	0.432	0.43	1.38	2.29	2.58	2.21	1.02	0.437	0.37	0.361	0.217	1.03
1987	0.239	0.379	0.294	1.11	4.74	4.42	1.63	1.97	0.946	0.51	0.592	0.797	1.43
1988	0.713	0.745	0.846	2.82	5.4	10.4	4.85	2.06	3.98	1.16	1.03	1.06	2.92
1989	0.667	0.481	0.777	1.61	3.21	2.49	1.21	1.11	3.94	2.41	2.01	0.873	1.74
1990	0.572	0.945	0.45	0.713	2.36	2.53	1.74	0.447	0.456	0.496	0.411	0.528	0.971
1991	0.458	0.281	0.384	1.3	5.09	9.16	4.61	2.26	1.75	1.55	0.957	0.607	2.37
1992	0.476	0.508	0.873	1.67	2.61	2.58	1.5	0.667	0.576	1.17	1.2	0.711	1.21
1993	0.275	0.114	0.871	1.62	3.18	2.13	2.06	2.1	3.69	1.56	0.575	0.484	1.55
1994	0.196	0.194	0.396	1.79	2.78	5.33	1.89	1.68	1.62	1.56	0.573	0.494	1.54
1995	0.552	0.706	0.643	1.71	5.05	4.71	3.02	1.62	3.27	1.23	1.62	1.21	2.11
1996	1.13	0.525	0.44	1.13	3.21	1.65	0.907	1.64	2.63	1	0.812	0.845	1.33
1997	0.68	0.478	0.568	1.94	8.56	6.63	4.84	10	5.78	3.27	1.75	1.39	3.82
1998	1.27	1.61	0.707	3.96	5.66	7.16	5.65	1.5	2.9	3.42	1.82	0.922	3.05
1999	0.824	0.845	1.67	2.16	4.63	4.03	2.19	1.7	1.65	1.02	1.01	0.922	1.89
2000	0.546	0.61	0.997	4.47	3.93	2.33	3.46	0.815	2.38	0.735	0.386	0.23	1.74

Table 4. (Continued)

Year	Month												Mean
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	
2001	0.264	0.19	0.474	1.79	3.56	4.97	3.05	2.09	7.06	2.58	1.07	0.561	2.3
2002	0.446	0.754	0.622	1.46	3.15	3.27	1.29	4.32	1.76	1.37	1.23	0.636	1.69
2003	0.499	0.267	0.444	0.971	2.76	1.14	1.45	0.996	1.01	2.15	1.78	0.913	1.2
2004	0.532	1.29	1.6	2.59	2.98	3.17	2.58	3.66	2.14	0.924	2.21	1.49	2.1
2005	0.73	1.08	1.86	3.33	7.61	5.5	5.82	5.11	1.81	1.4	1.38	1.4	3.09
2006	0.888	0.508	1.1	3.21	3.13	4.51	2.07	2.16	2.36	1.02	1.59	0.971	1.96
2007	0.798	0.863	0.915	0.915	4.39	2.35	1.08	2.23	4.47	2	2.22	1.56	1.98
2008	0.67	0.498	0.539	2.85	5.18	3.51	2.57	1.13	0.813	2.64	1.03	1.7	1.93
2009	1.12	0.931	1.27	2.84	2.61	2.86	4.87	1.27	0.843	1.66	2.99	1.35	2.05
2010	1.44	1.01	1.27	2	4.64	5.05	4.25	1.57	1.02	0.855	0.797	1.21	2.09
2011	0.813	0.612	0.582	1.63	3.22	11	2.3	1.69	0.531	0.355	0.288	0.266	1.94
2012	0.157	0.06	0.294	3.11	4.31	2.23	0.552	0.284	0.335	0.34	0.374	0.247	1.02
2013	0.32	0.37	0.772	2.59	3.85	3.82	3.1	1.99	2.03	2.99	1.68	1.25	2.06
2014	0.928	0.927	0.951	2.61	4.09	4.36	3.42	1.88	1.34	1.42	1.41	1.47	2.07
2015	1.44	1.24	1.17	1.76	4.74	3.62	2.48	2.29	1.66	1.71	1.16	1.07	2.03
Mean	0.761	0.767	0.989	2.161	4.343	4.525	3.172	2.316	2.021	1.575	1.177	0.993	2.065

Table 5. The servitude discharge for rivers supplying SC Viromet SA (INHGA, 2015a)

No.	River	Section	Surface [km^2]	Mean altitude [m]	Q [m^3/s]
1	Cartisoara (Balea catchment)	Altitude: 730 m	17	1,644	0,224
2	Arpasul Mare	Altitude: 651 m	25	1,541	0.218
3	Ucea	Altitude: 727 m	13.6	1,545	0.119
4	UcisoaraVistea	Altitude: 728 m	9.3	1,510	0.079
5	Vistea	Altitude: 745 m	14.7	1,545	0.141
6	Vistisoara	Altitude: 693 m	13.8	1,432	0.119
7	Sambata	Altitude: 705 m	23	1,502	0.215
8	Lisa	Altitude: 739 m	10.6	1,396	0.087
9	Brescioara	Altitude: 734 m	21	1,614	0.219
10	Breaza (Pojorata)	Altitude: 727 m	25	1,668	0.273

Table 6. Annual and average multiannual rainfall at Crrtisoara Hydrometric Station (1995-2015)

Year	Mean precipitation amounts [mm]
2015	604.4
2014	601.7
2013	630.6
2012	468.9
2011	520.2
2010	696.6
2009	554.0
2008	560.4
2007	724.9
2006	671.3
2005	1,054.7
2004	784.1
2003	585.0
2002	721.7
2001	1,033.0

Table 6. (Continued)

Year	Mean precipitation amounts [mm]
2000	614.5
1999	843.1
1998	1,140.2
1997	1,011.4
1996	710.7
1995	954.7
Multiannual mean	737.43

area is under protected area restrictions. Investments regarding the green electricity production are welcome if do not affect the environment. An underground micro-hydro plant that uses the water already collected by SC Viromet SA cannot involve negative effects.

5. CONCLUSIONS

Although the hydro energetic potential of Cartisoara River is high (at local lever), it is not fully exploited because it takes place in a protected area in terms of landscape. The need for cheap energy, renewable and with no implications in deteriorating the geographic space, leads to exploitation of all resources existing in the area. For this reason, the private initiative is welcome and can be used with maximum efficiency.

The average multiannual flow, the type of micro-hydro plant and the space to occupy this installation represent favourable factors for the notice of construction. The micro-hydro plant will use water already captured by SC Viromet SA. The electricity produced is distributed to the National Energetic System.

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