# SOME ASPECTS OF DETERMINATION GALBENA VALLEY HYDROPOWER CHARACTERISTICS, USING METHOD FOR DETERMINING THE FLOW FROM THE POSSIBLE LOCATIONS OF SMALL HYDROPOWER (MHC)

**Sabău Nicu Cornel* Iovan Ioan Călin***

*University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048 Oradea, Romania, e-mail: nsabau@uoradea.ro

## *Abstract*

*Water Energy is one of the most important renewable energy source, is used mainly to produce electricity in small hydropower (MHC).*

*In MHC construction in Romania have been reported numerous negative environmental impact problems, especially in protected areas, the destruction of the flora and endangered aquatic species protected. Given the increasing trend MHC on small water streams in remote areas without hydrometric measurements, determining the flow characteristic problems of their locations sections. Of these easements flow of particular importance in order to avoid problems related to the protection of aquatic species during operation. The objective of this study is to evaluate the hydraulic characteristics values (theoretical hydropower potential, theoretical energy, potential linear, linear energy, the amount of theoretical potential, technical potential arranged and installed flow, on Galbena Valley from Apuseni Mountains, in the event of lack of flow measurements.*

*The most accurate estimates of installed flow measurements are obtained when the hydrometric ratchets, the average differences are -1.05% of from the reference flow (23***). Given the impact on the environment MHC is recommended to estimate flow, method with hydrometric ratchets measurements, which provides the nearest determination the easement flow.*

**Key words:** mycrohydropower (MHC), theoretical hydropower potential, theoretical energy, technical potential conversion, easement flow, installed flow.

## INTRODUCTION

Among renewables energy, solar, wind, biomass and water, the latter is used increasingly more, especially for electricity production. In Romania last decades were built numerous small hydro (MHC) due to tradition, low price and installations that capture and low maintenance costs.

MHC construction was driven mostly by European Community Directive (EC) 20/20/20 wich proposing to reduce by 2020 greenhouse gas emissions from energy production from conventional sources and increasing energy by 20% produced from renewable sources, including hydroelectric, 20%. Romania aims at achieving by 2020 a renewable energy share of 24%. (EC Directive 28, 2009).

In order to stimulate energy production from renewable sources, EC grants subsidies in our country, The law act 220/2008 stipulates that renewable energy producers receive 3 green certificates for each MWh, produced in MHC with installed capacity of at least 10 MW and supplied to the national energy system.

Economic and environmental benefits of hydropower recognized led to increased interest in hydropower development of small water courses in mountain areas, isolated, where there are sights to supply small communities or small companies. On these rivers often uncadaster (without hydrological measurements) suitable building minimycrohydropower (PHC) whose installed is below 5 kW (Wiliams A.A. et Simpson R., 2009; Williamson S.J. et al., 2011; Teuşdea A.C. et al., 2012).

And hydroelectric works are considered environmentally friendly in their implementation were highlighted certain negative effects on biodiversity conservation, especially when it crossed the natural course of water, which makes it compulsory equipping these dams with fish ladders. Also during execution are taken out of certain areas of land forest, mountain scenery intervenes brutally by the intervention of earthmoving equipment used in riverbed. During the operation there is a risk of emptying the water of the river downstream capture, especially in dry seasons, when producers tend to process all flow neglecting legal obligation to remain within the framework of the "easement flow" (Lengyel P., 2012).

The problems of maintaining the flow channel of the easement is tied and confused its definition. The easements flow rate is the minimum flow necessary, left on a section of a watercourse downstream a dam, consisting of sanitary discharge and minimum flow downstream water users. Sanitary discharge flow is the minimum flow necesary required in a section on a watercourse, to ensure the living conditions of the existing aquatic ecosystems. Sanitation flow is established as characteristic flow with ensuring 95% (Law 107/1996).

The phrase " characteristic flow " means that the legislature refers to the minimum flow, but there are many categories of minimum flow (minimum flow average of annual, average flow monthly, average minimum annual minimum flow average monthly annual average daily flow minimum annual minimum flow, the average annual daily) and they have different values. The greater the flow, the flow processed to produce electricity is lower.

To establish the most favorable locations of MHC hydropower, will be determineted characteristics of water bodies (potential theory, linear theoretical potential, theoretical energy, power and linear theoretical total power) calculated based on the annual average flow.

The characteristic values necessary for characterization hydro flows of rivers are determined from the registration hydrometric stations (23***), but if small watercourses, in remote areas, uncadaster these measurements are missing. In this case, estimating flows are prepared using data recorded hydrological studies on water courses nearby, morphological and morphometric similar (ANAR-INHGA, 2010).

Characteristic flows on small isolated mountain rivers can be estimated through other methods, such as using basin characteristics, depending on the rainfall recorded at weather stations near and measurements (Sabău N. C., Iovan C. I., 2014).

For the conditions of small basins located in the forest in the mountainous area were established correlations between maximum flow, average and minimum (multi) by area, perimeter, the form factor of the basin, the maximum length of the river network and coverage with forest (Iovan C.I., Sabău N.C., 2012), and that bi and tri factorial linear correlations, significant and distinct significant statistically (Sabău N.C., Iovan C.I., 2013).

Herschy W.R. 1995, states that in the context of lack of flow measurements and recordings of precipitation measurements are recommended measurements in specific sections of rivers, and if they can not perform with hydrometric ratchets method can be used surface floats method.

Law 23/2014, approving Government Emergency Ordinance 57/2013 for amending and supplementing Law 220/2008 for establishing the system for promoting energy from renewable sources, that "in the period July 1st 2013 - March 31st, 2017 is postponed temporarily trading of a number of green certificates from those provided in par. (2) ", for each 1 MWh produced and delivered by producers of electricity from renewable sources ... "due to environmental problems in Romania recorded the construction MHC.

However no question of abandoning this renewable energy source, the Energy Strategy of Romania for the period 2007 - 2020 stating the need to develop new sources of renewable energy in terms of environmental compliance and improve competitiveness.

The main objective of this work is the study hydropower characteristics of Galbena Valley, if the lack of records of the control flow and establish methods for estimating influence on the characteristics of its hydro flows.

## MATERIAL AND METHOD

Galbena Valley has a small basin of 31,07 km$^2$, approximately the length of the valley 8 km, average gradient of 110 ‰, located in the mountainous area, with an average rate of 1077 m, flows from Galbena emergence, Padiş plateau in the Apuseni Mountains and flows into Crişul

Pietros river. It is a natural course of water with high flow, (Iovan C. I., 2012).

To assess the main features hydropower characteristic of Galbena Valley were set possible locations of MHC sites downstream of the spill some tributaries and in the control section, which added three sections in which the measurements were cutting float summer months (VI-IX) of the years 2006-2008 and hydrometric ratchets in the same months of 2008-2010. On satellite images of the basin, obtined from Google Earth were scored 8 sections labeled $S_1 – S_8$.

Sections defining characteristic so defined the Galbena Valley sectors in eight, denoted by $K_1$ ... $K_8$, from source to estuary, where hydropower characteristics were determined using relations (Iovan C. I., 2013):

Theoretical hydropower potential P(kW)

$$\text{P(kW)} = K_1 \frac{Q_i + Q_{iav} + Q_{i+1am}}{2} \Delta\text{H}; \qquad [1.]$$

Energia teoretică E (kWh)

$$\text{E (kWh)} = K_2 \frac{Q_i + Q_{iav} + Q_{i+1am}}{2} \Delta\text{H}; \qquad [2.]$$

Potențialul teoretic unitar $p_i$ (kW/km)

$$p_i \text{ (kW/km)} = \frac{P_i}{L_i} \qquad [3.]$$

Energia teoretică unitară $e_i$ (kWh/km)

$$e_i = \frac{E_i}{L_i}\left(\frac{kWh}{an}, km\right) \qquad [4.]$$

where:

$K_1$ şi $K_2$ have values 9,81 and respectively 9,81 x 8760;

$Q_{i\ av}$ şi $Q_{i+1\ am}$ ($m^3/s$) represents the annual average flow at the ends $k_i$ sector of the watercourse;

*ΔH* (m) represents fall (difference in level) on the $k_i$ sector of the watercourse;

*ΔL* (km), the length of the $k_i$ sector river considered;

Term average flow were calculated using records from the control section flow (1991-2010), submitted to the upstream sections using specific medium flow and surface water collecting appropriate section. These flows were taken as reference flows estimated by other methods.

Determination partial area of the basin of rates section characteristic of length sectors $k_i$, and the other characteristics of hydrigraphic basin used to estimate flows (perimeter, course length, average rate, etc.) was done using the spatial pattern of 3D terrain (Fig.1.) and facilities Toposys programs (Marton H., 2007).

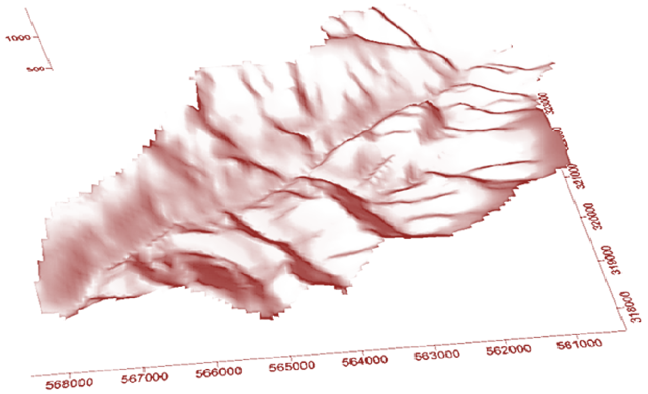

Fig.1. The space model of the field (3D) in the hydrographical basin of Galbena Valley

Methods for estimating the flow characteristic sections ($S_1$ - $S_8$) studied the flow estimation by: basin characteristics: surface S ($Km^2$), P Perimeter (Km) and hydrographic network length L (Km). They were established significant correlations and distinctly significant between average, maximum and minimum values flow of the sections considered and these characteristics (Iovan C.I., Sabău N.C., 2013).

Flow measurements were conducted in the summer months (VI-IX) in a feature section with hydrometric ratchets (2008-2010) and in three sections, with the floats method (2006-2010) following the methodology indicated by the literature.

The estimated flow comparisons with these methods and reference flows (23 ***) showed that the closest results are obtained if the measurements made in the summer months (VI-IX) with ratchets hydrometric and floats method.

As measured flows in summer months correspond with the annual monthly minimum flows, Iovan C.I. 2012 proposes to use to calculate the characteristics of watercourses uncadaster hydropower, the annual minimum flows, providing of not exceeding 20% (Ienciu A. et al., 2004; Sabău N. C., 2009):

$$p(\%)=\left(1-\frac{i}{n+1}\right)X100 \qquad [5.]$$

where:

i represents serial number decreasing flow in their enumeration;

n represents total values used for calculation;

Reconstruction minimum flows of insurance exceeded 20% of the control sections regardless of surface water collection S (Km), the average altitude C (m) and afforestation P (%), using a logarithmically correlation distinct statistically significant Q = f (S / C x P).

Given that Galbena Valley water not exists users of water, easement flow is identical with sanitation flow, wich representing the average daily ensuring overcome 95%. Because we do not have daily flow records to estimate flow sanitation account was taken of the method applied in the study NARW-INHGA, 2010, to estimate flows Sebeş Valley, a tributary of Drăgan Valley from hydrographic basin Crișul Repede, where sanitation flow is about 20% of the average daily flow multiannual.

Technical or electrical power with conversion potential of MHC are just some of the theoretical potential, due to losses in the turbine hydraulic load, volumetric water loss, mechanical loss. Smuda E. and Mugea N., 2001 proposes to determine electrical power relationship:

$$P_e = P_{AB} \bullet \eta_1 \bullet \eta_2 \bullet \eta_3 \bullet \eta_4 = 9{,}81 \bullet Q \bullet H \bullet \eta_1 \bullet \eta_2 \bullet \eta_3 \bullet \eta_4 \quad (kW)\ [6.]$$

where: $\eta_1$,$\eta_2$,$\eta_3$ şi $\eta_4$ are hydraulics components yields, which represent approximately 50% of the theoretical power;

Stematiu D., 2008, show that electrical power MHC choice must take account of MHC operating period of a year, that it is dependent on the multiannual average flow of the location, whereas other values of relationship [6] can be considered constant, reason which states that an MHC can only process a maximum of 60% of the installed flow.

## RESULTS AND DISSCUSIONS

For comparisons between the rates assessed by different methods, characteristic sections of the Galbena Valley, use the control sections entries (23 ***) from 1991-2000, considered a witness. Average annual values calculated in this section are: average annual monthly maximum flow $Q_{max}$ = 1706 $m^3/s$; average monthly average flows $Q_{med}$=1.485 $m^3/s$; average monthly minimum flow $Q_{min}$=1.263 $m^3/s$.

Reconstruction flows of sections locations MHC on Galbena Valley ($S_2$-$S_8$) to take account of the average specific flow $q_{sp\ avr}$ (l/s & ha) and specific flow of easement $q_{sp\ eas.}$ = 0.095 l/s & ha and the surface basin of the water collection. The easement flow assimilated on case Galbena Valley with sanitation flow was set percentage of annual average flow, $Q_{avr}$ ($m^3/s$) from the control section (23***), (Table 1.).

*Table 1*

Average multiannual flows $Q_{avr}$ and easement $Q_{eas.}$ ($m^3/s$) on MHC sections locations

| Sections | Rom.W (1991-2000) | | | | | Average multiannual flows | |
|---|---|---|---|---|---|---|---|
| | $Q_{avr}$ ($m^3/s$) | $Q_{eas}$ ($m^3/s$) | $q_{sp\ avr}$ (l/s & ha) | $q_{sp\ eas}$ (l/s & ha) | Surface (ha) | $Q_{avr}$ ($m^3/s$) | $Q_{eas}$ ($m^3/s$) |
| S1-Control | 1.482 | 0.296 | 0.477 | 0.095 | 3107 | 1.485 | 0.296 |
| S2 | | | | | 2861 | 1.365 | 0.281 |
| S3 | | | | | 2304 | 1.099 | 0.219 |
| S4- downstream | | | | | 2037 | 0.972 | 0.194 |
| S5- middle | | | | | 2011 | 0.959 | 0.191 |
| S6- upstream | | | | | 2000 | 0.954 | 0.190 |
| S7 | | | | | 1957 | 0.933 | 0.186 |
| S8 | | | | | 1118 | 0.533 | 0.106 |

Average multiannual flows ($Q_{avr}$) from sections considered favorable locations are between 1.485 $m^3/s$ on downstream and 0.533 $m^3/s$ on upstream ($S_8$) and easement flows ($Q_{eas}$) between 0.296 $m^3/s$, respectively 0.106 $m^3/s$. Average multiannual flows estimated using measurements made in the summer months with ratchets and hydrometric floats method and ensuring that minimum flow method of not exceeding 20%, measured as floats, are to varied (Table 2.).

Overstate of the reference medium flow (23 ***) were obtained in the case of measurement by means of the floats (21.55 %) and the flow measured by the hydrometric ratchets measurements are closer, the lower - 1,8 %. If flows using minimal rainfall ensuring constituted of not exceeding 20%, redistributed using logarithmic correlation Q = 0.5669 ln (S /CXP)+1.3226 distinct significant statistically (R2 = 0.9994), the differences are variable between 78.32% on downstream and 58.35% on upstream.

Theoretical hydropower potential P(kW) and energy theoretical E (kWh) determined by flow estimated MHC locations, using studied methods, evolution keeps the same trend, in proportion to the estimated average flow values (Figure 2 and 3).

*Table 2*

Average flows($Q_{avr}$) from the MHC locations evaluated by different methods

| **Sections characteristic** | **Rom.W (1991-2000)** | **Estimation methods** | | |
|---|---|---|---|---|
| | | **Hydrometric ratchets (2008-2010)** | **Floats (2006-2010)** | **$Q_{min}$ with insurance exceeded 20%** |
| | ($m^3/s$) | ($m^3/s$) | ($m^3/s$) | Q ($m^3/s$) = f (S/CxP) |
| S1 | 1.485 | 1.466 | 1.805 | 1.163 |
| S2 | 1.365 | 1.350 | 1.662 | 0.971 |
| S3 | 1.099 | 1.087 | 1.339 | 0.820 |
| S4- downstream | 0.972 | 0.961 | 1.184 | 0.735 |
| S5- middle | 0.959 | 0.949 | 1.168 | 0.728 |
| S6- upstream | 0.954 | 0.944 | 1.162 | 0.712 |
| S7 | 0.933 | 0.924 | 1.137 | 0.647 |
| S8 | 0.533 | 0.528 | 0.650 | 0.311 |

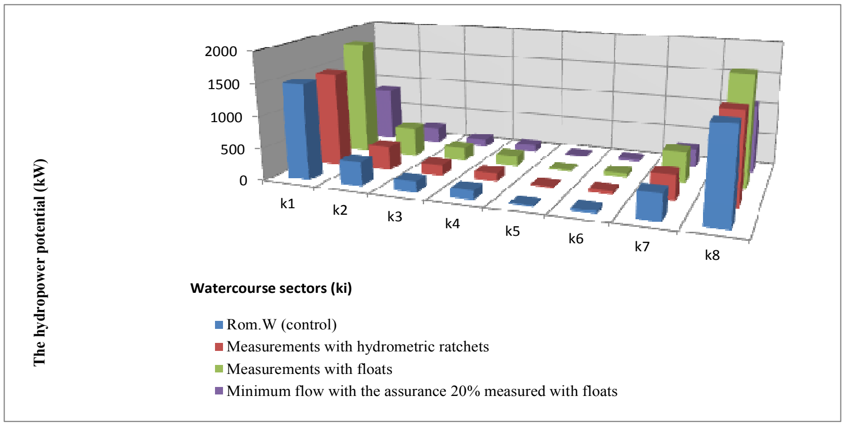

Fig. 2. Theoretical hydropower potential (kW) of sectors delimited $k_1$- $k_8$ on Galbena Valley, depending on the methods used to assess the flow from MHC locations

In both cases it is noted that the nearest assessments are obtained when measurements are made with hydrometric ratchets (98.95%) while for measurements with floats, the calculated values are higher (121.8%). Using ensuring minimum flow of 20% exceeded, reconstituted using logarithmic function, depending on the surface (S), the average altitude (C) and afforestation (P), characteristics evaluated hydropower accounts for 41.7% of the sector upstream (S1) and 25.0% downstream of the reference values (23***).

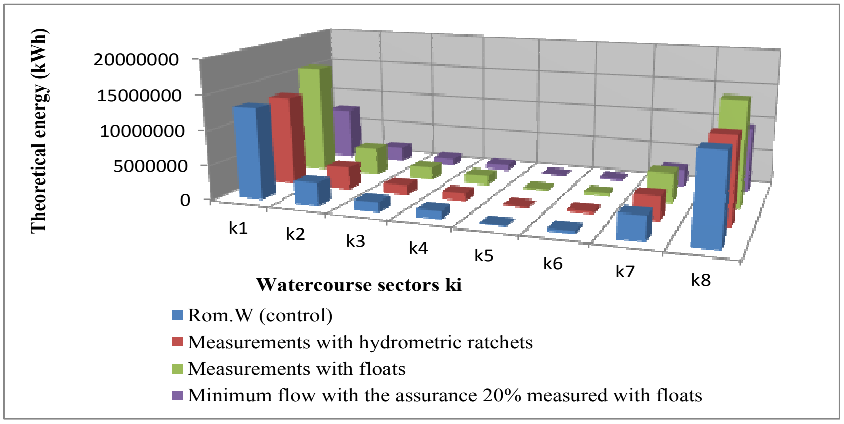

Fig. 3. Theoretical energy (kW) of sectors delimited $k_1$- $k_8$ on Galbena Valley, depending on the methods used to assess the flow from MHC locations

In all cases analyzed, it is noted small amounts of potential and energy sectors on the average ($K_2$ - $K_7$), where sectors lengths of sections where measurements flow were made are very low,of approximately 100 m.

For comparison is useful assessment of the potential hydro theoretical amount, determined by flow measured. Theoretical potential total, cumulative over the entire length of the course, keep the same trends, namely the nearest forecast values for determining the flow of hydrometric ratchets overestimating values for measurements with floats and respectively lower values for the use of minimum flow with insurance not exceeding 20 %, which is 67.6% (Table 3).

But technical potential developed is represented by the theoretical potential, less losses considered to be 50% of the theoretical potential. Also bear in mind that the easement flow, in terms of the MHC with deviation can not be captured to ensure the sanitary discharge of the watercourse. Easement flow $Q_{eas.}$ ($m^3/s$), which is similar to the sanitary discharge, where Galbena Valley is estimated at 20% of multiannual average flow $Q_{avr}$ ($m^3/ha$). In these circumstances the installed flow $Q_i=0,5\ Q_{avr.} - Q_{eas.}$ (Table 4).

*Table 3*

The sum of theoretical hydropower potential of the delineated sectors Galbena Valley

| **Sectors** | **Limits** | **Length ki (km)** | **The sum of theoretical potential $Pk_1$-$k_i$ (kW)** | | | |
|---|---|---|---|---|---|---|
| | | | **Rom.W** | **Hydrometric ratchets** | **Floats** | **$Q_{min}$ asig 20 %** |
| k1 | source-S8 | 1.71 | 1493.603 | 1477.947 | 1819.253 | 871.0348 |
| k2 | S8-S7 | 0.27 | 1867 | 1847.429 | 2274.06 | 1114.912 |
| k3 | S7-S6 | 0.82 | 2034.572 | 2013.245 | 2478.168 | 1235.565 |
| k4 | S6-S5 | 0.10 | 2165.954 | 2143.251 | 2638.196 | 1334.45 |
| k5 | S5-S4 | 0.10 | 2180.161 | 2157.308 | 2655.5 | 1345.214 |
| k6 | S4-S3 | 0.11 | 2225.866 | 2202.534 | 2711.17 | 1379.537 |
| k7 | S3-S2 | 1.80 | 2624.653 | 2597.141 | 3196.905 | 1669.437 |
| k8 | S2-S1 | 1.79 | 4048.904 | 4006.462 | 4931.684 | 2737.098 |

*Table 4*

The installed flow ($Q_i$ $m^3/s$) of MHC from characteristic sections of the Galbena Valley

| **Sections** | **Rom.W** | **Hydrometric ratchets** | | | **Floats** | | | **$Q_{min\ 20\ \%}$** | |
|---|---|---|---|---|---|---|---|---|---|
| | **$Q_i$ ($m^3/s$)** | **$Q_{eas.}$ (m3/s)** | **$Q_i$ ($m^3/s$)** | **% from Rom.W** | **$Q_{eas.}$ (m3/s)** | **$Q_i$ ($m^3/s$)** | **% from Rom.W** | **$Q_i$ ($m^3/s$)** | **% from Rom.W** |
| | **$Q_i = 0.5\ Q_m - Q_{eas.}$** | | | | | | | **$Q_i = 0.5\ Q_{min}$** | |
| S1 | 0.445 | 0.293 | 0.440 | 98.95 | 0.361 | 0.542 | 121.80 | 0.582 | 130.79 |
| S2 | 0.409 | 0.270 | 0.405 | 98.95 | 0.332 | 0.499 | 121.80 | 0.486 | 118.59 |
| S3 | 0.330 | 0.217 | 0.326 | 98.95 | 0.268 | 0.402 | 121.80 | 0.410 | 124.35 |
| S4 | 0.291 | 0.192 | 0.288 | 98.95 | 0.237 | 0.355 | 121.80 | 0.368 | 126.07 |
| S5 | 0.288 | 0.190 | 0.285 | 98.95 | 0.234 | 0.351 | 121.80 | 0.364 | 126.49 |
| S6 | 0.286 | 0.189 | 0.283 | 98.95 | 0.232 | 0.349 | 121.80 | 0.356 | 124.39 |
| S7 | 0.280 | 0.185 | 0.277 | 98.95 | 0.227 | 0.341 | 121.80 | 0.324 | 115.52 |
| S8 | 0.160 | 0.106 | 0.158 | 98.95 | 0.130 | 0.195 | 121.80 | 0.156 | 97.20 |
| **Average** | | | | 98.95 | | | 121.80 | | 120.42 |

Comparative analysis of the installed flow obtained from measurements made in the summer months, with hydrometric ratchets for three consecutive years (2008-2010) and through the method floats consecutive five years (2006-2010) with the measurements made from processing control section for 20 years (1991-2010), considered the reference shows that the hydrometric ratchets measurements lead to the nearest installed flow, with average differences are -1.05%, when of floats method measurements overestimate their value on average by +21.8%.

Using ensuring minimum flow of 20% exceeded, measured as floats, which reconstitution flow of the sites took into account, in addition to surface water collecting average share S and average altitude C and respectively afforestation P, lead to estimates similar to those obtained using float method respectively + 20.42%, provided neglecting easement flow ($Q_{eas} = 0$).

As is known MHC negative impact of non-compliance to service assessment flow, it is recommended that in the absence of Rom.W measurements, flow estimation installed to make measurements with hydrometric ratchets, which provides the best determination of flow easement.

## CONCLUSIONS

Determination of flow measurements with hydrometric ratchets and floats method in the summer months for 3 years and 5 years respectively, have estimated flow of potential locations of MHC, flows very close to the benchmark (-1.8%) in the first case and overestimated (21.55%) in the second case.

Reconstruction flows with help of minimum flows with insurance exceeded 20% using surface water collection, the average altitude and afforestation, leading to an underestimation of the flow reference with – 21.68% downstream and – 41.65% upstream.

As the installed flow used in hydropower aggregates choice of MHC is dependent on the multiannual average flow and easement flow, its most precise estimates are obtained if the hydrometric ratchets measurements, an average difference are -1.05% from the reference flow Rom.W. The other two methods used lead to overestimated installed close reference flow , with 21.8% when measured with floats and 20.42%, respectively, when used with minimum flow with ensuring exceeding 20%, measured by floats method.

Given the trend of higher flow processing than the installed flow, it is recommended to estimate them with hydrometric ratchets measurements, in which values are obtained nearest the easement flow.

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