FLOOD FREQUENCY ASSESSMENT IN DATA POOR ENVIRONMENT CASE STUDY MAGLAJ-POLJICE ON THE RIVER BOSNA

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Abstract. A truly important challenge in flood frequency assessment (FFA) in Bosnia and Herzegovina is lack of continuous gaged flow data, because the reliability of FFA results depends on the length and quality of flow records. At the case study location - hydrologic station (HS) Maglaj on the river Bosna the reference period for flow record is 1961-1990. The research goal in this paper is to exploit the water stage gauge data and information (1933-1960) for the extension of flow dataset from 30 to 58 years. We apply the original rating curve from the period 1960-1970 to the water table record to generate daily flow datasets. Anticipating three rating curve change developments, we generate six longer flow datasets -with and without instantaneous maxima, for the period 1933-1990 at HS Maglaj - Poljice. Together with two reference period flow datasets we arrive at the total of eight datasets/scenarios and subject these datasets to FFA on the annual maxima series and partial duration series. For the former, we use conventional statistical analysis (CSA) and for the latter, the peak over threshold (POT) method. The FFA results show no significant difference in the values of the selected quantiles for scenarios involving time extrapolation. The quantiles for the reference period 1961-1990 are generally higher, among both CSA and POT results. We find the absence of instantaneous maxima a major influence on FFA.
Key words: floods, rating curve, flow record extension, flood frequency analysis, hydrologic station Maglaj - Poljice

1. Introduction and Motivation

In many parts of the world, flooding is a major problem. In 2007, the European Union adopted the Directive on the assessment and management of flood risks [1], focusing on the following flood events: extreme events - of a low probability; a medium probability (likely return period ≥ 100 years); a high probability of occurrence. The assessment of rare flood occurrences involves large extrapolation of a probability function (PF). In a data poor environment with short systematic gauge records it leads to less reliable flood estimates. To overcome this deficiency, some practical solutions include adopting the values from the upper limit of PF confidence interval [2] and use of all available information and data. The research goal in this paper is to use the flow information from longer water stage record to extend the flow record from period 1960-1990 and compare FFA results obtained by two methods on extended and original discharge at a typical gauge station in B&H where water stage record starts in 1930s.

2. Methodology

Input data. Our selection for the case study is hydrologic station (HS) Maglaj in the midcourse of the river Bosna, relocated to 2.5 km downstream HS Poljice in 1973 (Fig. 1). We use the concatenated flow record HS Maglaj-Poljice for the reference period 1961-1990, rating curve from the period 1961-1970 at HS Maglaj (Fig. 2) and water stage records at HS Maglaj in the period 1933-1960.

Data record extension and testing. Anticipating three rating curve developments in the period 1933-1960: original, +8% and -8% [3], we generate six longer flow datasets for the period 1933-1990 by distinguishing datasets comprising mean daily maxima (DM) and instantaneous maxima (IM). The total of eight scenarios/datasets also comprise observed flow records with DM only and IM in the reference period 1961-1990 (Tab. 1). All the datasets satisfy conditions for flood frequency assessment (FFA), according to usual statistical testing results in view of homogenity (Pearson, Levene, Mann-Witney), trend (Mann-Kendall) and outlier detection (McCuen) [4].

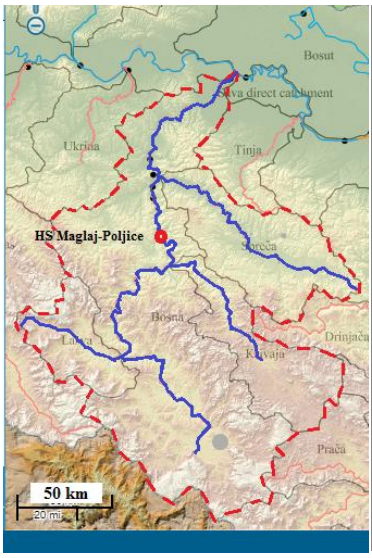

Figure 1 Bosna river basin and location of HS Maglaj-Poljice (modified from ISRBC web site, http://savagis.org/map)

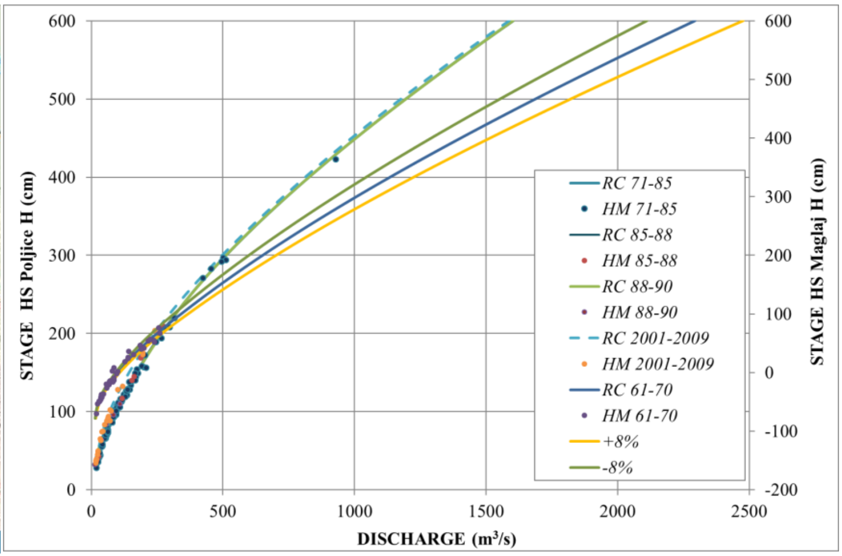

Figure 2 Rating curves (RC) at the river Bosna location(s): HS Maglaj (left) and HS Poljice (right). HM- hydrometric measurements in different time periods indicated.

Table 1 Studied datasets from different flow record extension scenarios. Number of instantenious flow maxima in the datasets given in the IM column. n – sample size. Original & transformed datset statistics: *x=Q, y=log Q*

SCEN.	PERIOD	RC	IM	n	Mean,x	StDev,x	Skew,x	CVar,x	Mean,y	StDev,y	Skew,y	Cvar,y
SC1	1961-1990	Gauged	17	**30**	1032.2	373.6	1.189	0.362	2.989	0.147	0.377	0.049
SC2	1933-1990	1961-1970	17	**58**	995.2	343.7	0.957	0.345	2.974	0.146	0.095	0.049
SC3	1933-1990	+8%	17	**58**	1032.1	352.5	0.864	0.342	2.990	0.145	0.093	0.048
SC4	1933-1990	-8%	17	**58**	958.3	340.0	1.063	0.355	2.956	0.149	0.092	0.050
SC5	1961-1990	Gauged	0	**30**	975.7	354.2	1.087	0.363	2.964	0.146	0.484	0.049
SC6	1933-1990	1961-1970	0	**58**	965.9	331.0	0.827	0.343	2.961	0.145	0.147	0.049
SC7	1933-1990	+8%	0	**58**	1002.8	343.3	0.753	0.342	2.977	0.145	0.143	0.049
SC8	1933-1990	-8%	0	**58**	929.0	323.7	0.929	0.348	2.944	0.146	0.144	0.050

Flood frequency Assessment (FFA). We subject eight datasets to flood frequency analysis on both the annual maxima series (AMS) and partial duration series (PDS). PF parameters are estimated by the method of conventional moments, suitable for short datasets exhibiting low skew [4]. For the AMS we use conventional statistical analysis (CSA) considering Log-Normal 2, Gumbel, Pearson 3 and Log-Pearson 3 (LP3) PFs, and we find LPT3 the best fit with empirical distribution estimated by Weibull plotting position formula. In many countries and regionwide, LP3 is proven the most adequate in FFA on AMS e.g. [4]- [8]. On the PDS we apply the peak over threshold (POT) method where we use four threshold values (Q_b = 500; 700; 900; 1100 m^3/s) employing a Binomial-Weibull model with a binomial distribution for the number of peak occurrence and Weibull 2 PF for peak values [7]. Reliable flood quantile estimates are assessed for return periods up to $T=(2\text{-}5)\cdot n$, n being dataset size [6]. Hence, we use 100 (0.01) and 200-year (0.005) quantiles as indicative in our research.

Uncertainty. We use 95% confidence interval to quantify quantile estimate uncertainty.

3. Results and discussion

Quantiles from AMS. The results show no significant difference in the values of the selected quantiles for scenarios involving time extrapolation (SC2-SC4), regardless of employed PF. The LP3 quantiles estimated from the reference period 1961-1990 dataset are generally significantly higher (around 17%) than for all other scenarios – longer datasets. Its 95% confidence interval upper limit deviates from the rest of the intervals, indicating both significance of IM presence in the dataset and its smaller size, therefore, higher uncertainty. An indicative FFA result, 100- year quantile, spans from 2347 m^3/s to 1992 m^3/s across scenarios estimated by CSA (Fig. 3).

Quantiles from PDS. The POT method gives similar results for considered four thresholds (500, 700, 900 and 1100 m^3/s) within each scenario (SC1-SC8), indicating the insensitivity to the threshold value, while the difference in 100 and 200-year quantile is up to 13% for the datasets including IM for related scenarios (SC1 vs. SC5, etc.) as shown in Fig.4. 100- year quantile, spans from 2219 m^3/s to 1928 m^3/s across scenarios estimated by POT (Fig. 4).

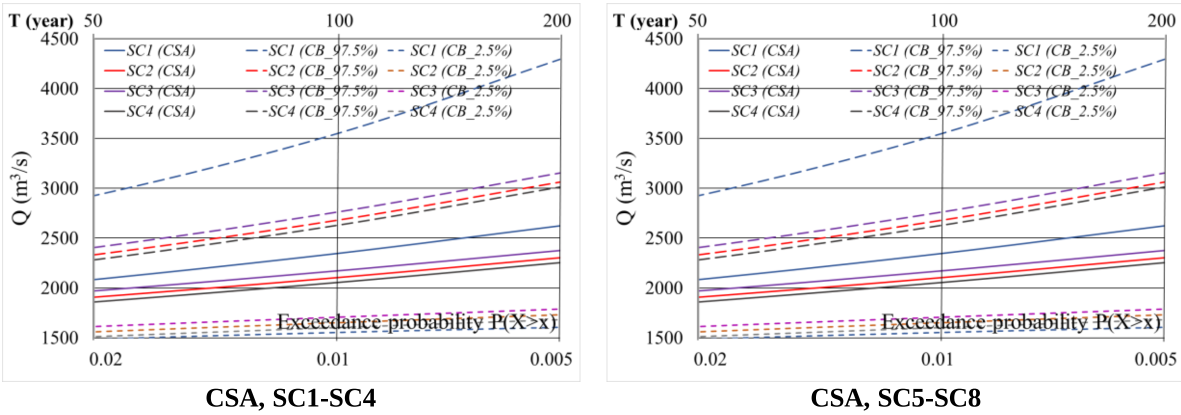

Figure 3 LP3 probability plots of FFA results by CSA on AMS with IM (left) and without IM (right)**.** The upper and lower envelopes included.

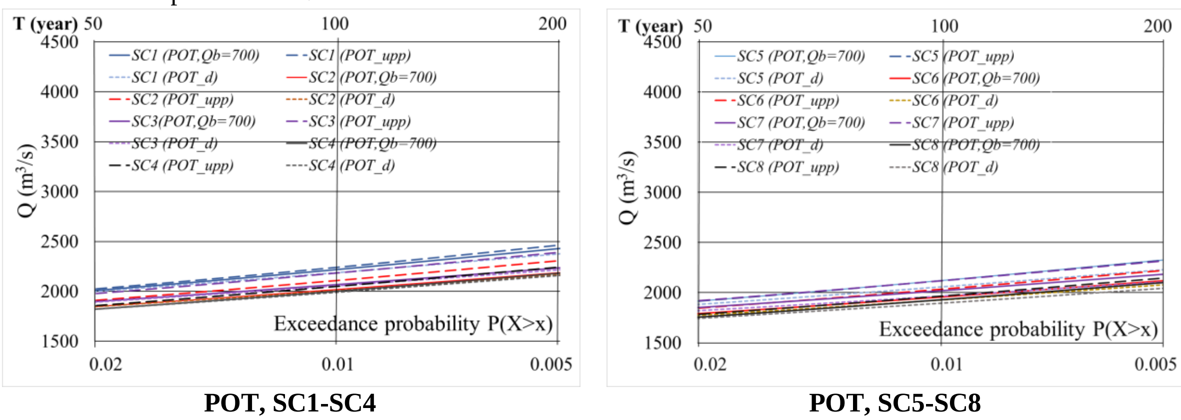

Figure 4 Weibull 2 probability plots of FFA results by POT on PDS with IM (left) and without IM (right)**.** The upper lower envelope included.

Quantile cross-comparison. In both Fig.3 and Fig. 4 the probability paper is shown in the range over T=50 years, the start of comparable T-year quantile estimates by both CSA and POT methods [5]. The comparison between scenarios for CSA and POT estimates indicates the dataset extension benefit to FFA in narrowing down uncertainty as shown in Fig. 3 and Fig. 4 by the 95% confidence interval, although a part of this shrink may be attributed to the absence of IM in the longer datasets. The quantile estimates by POT method both with and without IM not only disperse less but are lower compared to those estimated by CSA for all scenarios and return periods studied (Fig. 5).

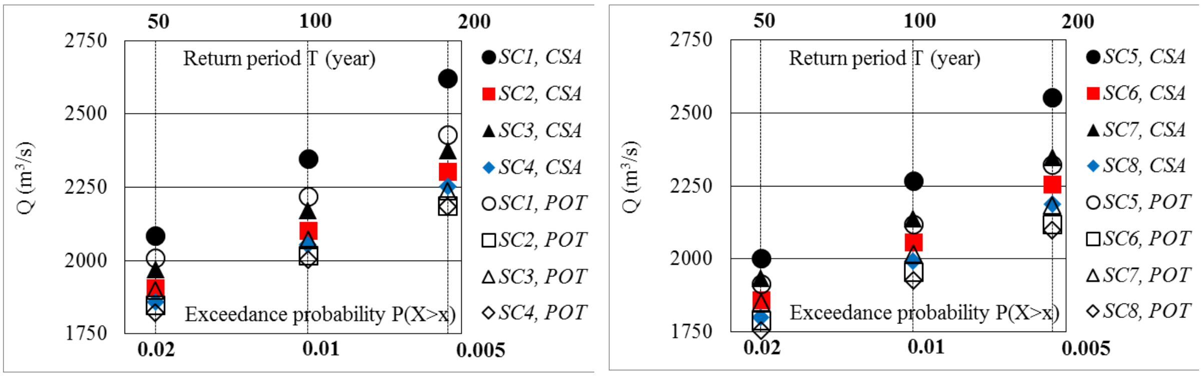

Figure 5 Quantile estimates by CSA and POT with IM (left) and without IM (right).

4. Conclusion

In the research paper we suggest a simple approach applicable in engineering practice to exploit the water stage gauge data and information for the extension of flow dataset for FFA. While extending dataset size contributes to uncertainty decrease in quantile estimates, the absence of IM in the flow datsets arises as an issue in FFA by both CSA and POT method. Adjustment of DM to assess IM needs to be done in datasets, because it influences a PF fit to empirical distribution and other uncertainty measures like standard error of estimate. The results confirm higher robustness of POT method to both sample size and absence of IM [5], [8]. For more reliable conclusions the datasets containing IM are needed. The studied case has shown that in poor data environment the way should be given to use of all available information and data instead of adopting the values from the upper limit of PF confidence interval [2]. Here, short datasets with their upper limit of PF confidence interval would yield more than two times higher quantiles for probabilities of exceedance considered in flood studies. The results shown in the paper are the first phase of the broader research underway, where we will fill the existing data gap for the period 1991-2010 by various technics and methods, intervene on the extrapolated 1933-1960 data to overcome the IM absence problem, and perform FFA on the datasets in the period 1933 - today.

5. Acknowledgement

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References

[1] European Parliament and the Council of European Union. *Directive 2007/60/EC on the assessment and management of flood risks*, 2007.

[2] Z. Radić, V. Mihailović, J. Plavšić. *Uporedna analiza statističkih metoda za proračun velikih voda*, 16. Savetovanje SDHI i SDH, Donji Milanovac, Srbija, 2012.

[3] I. Stanišić, D. Pavlović, J. Plavšić. *Neizvesnosti u rezultatima hidrometrijskih merenja protoka*, International conference Contemporary achievements in civil engineering 24. April 2015. Subotica, Serbia, pp 559-564, 2015.

[4] R. McCuen. *Modeling Hydrologic Change*, Lewis Publisher, 2003.

[5] Topalović, Ž., Plavšić, J. *Praktični problemi određivanja mjerodavnih velikih voda za potrebe projektovanja sistema odbrane od poplava*, 17. Savetovanje SDHI i SDH, Vršac, Srbija, pp......2015.

[6] Vukmirović, V. (1990): *Analiza verovatnoće pojave hidroloških veličina*, Građevinski fakultet Beograd i Naučna knjiga, Beograd, 1990

[7] Mulaomerović, A., Lazović, N., Hadžić, E., Milišić, H., L.ozančić, Ž. *Method of Annual Extreme and Peaks Over Threshold in Analysis of Maximum Discharge*, International Symposium on Innovative and Interdisciplinary Applications of Advanced Technologies, Springer, pp. 157-174, 2018

[8] Bezak N., Mikoš M., Šraj M.: *Comparison between the peaks-over-threshold method and the annual maximum method for flood frequency analysis*, Hydrological Sciences Journal. 59 (5), pp. 959-977, 2014