Nonparametric design hydrograph in the gauged cross sections of the Vistula and Odra basin

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Abstract. The Archer method for construction of nonparametric hydrographs was regarded as the basic one for constructing design hydrographs in gauged cross sections. The hydrographs designed using this method belong to a group of non-formalized hydrology. Unlike the commonly used formalized methods, where a nonparametric hydrograph is strictly determined and defined, the hydrographs defined in this way are constructed on the assumption, that flow is the main determined parameter. On the other hand, the Archer method assumes that the basic parameter is time, which is determined for assigned standardized flow, called a flow percentile. Hydrographs constructed using this method are the basis for constructing parametric design hydrographs used for engineering computations.

The Archer method is relatively new and should be verified for various regions. Presented manuscript compares the results obtained using this method in the middle Odra and upper Vistula basins with the nonparametric method developed at the Cracow University of Technology, called the Cracow method. The obtained results show, that four highest registered flood waves are sufficient to construct a nonparametric design hydrograph, whereas semi-standardized volumes above descriptors W75 and W50 and the duration time of the descriptors are bigger than the volumes and duration times calculated by means of the Cracow method in the Vistula River basin, and approximate with regard to the values in the Odra River basin.

Keywords: the Cracow method, nonparametric hydrograph, the Archer method, flow descriptor, semi-standardized volume

1. Introduction

A design flood is usually of parametric type and is constructed on the basis of a nonparametric hydrograph course. By a design hydrograph, the authors understand a flow hydrograph presenting the typical course of a flood wave for a determined cross-section, and which is used for design purposes. Such a flood hydrograph represents a typical basin flood response to heavy rainfall.

Parametric waves are most frequently used for solving problems connected with widely understood flood risk (Vrijling et al. 1998; Apel et al. 2006; Criss, Winston 2008; Hattermann, Kundzewicz 2010; Kriščiukaitienė et al. 2015). Hydrological models are used for their construction (Wałęga 2013; Pietrusiewicz et al. 2014; Wałęga, Grzebi-noga 2014). A determined flood wave is the result of an applied model and the assumed distribution of rainfall over time (hyetograph). It is often assumed that the probability of the maximum 24-hour rainfall is the same as the probability of the runoff from a modelled basin. This assumption does

not always correspond with real flood development, as has been demonstrated by computational simulations (Gądek, Bodziony 2015). Additional problems involve constructing a hyetograph with an assigned probability of exceedance (Wypych et al. 2014). Rainfall data remains a problem in hydrological modelling, especially in Poland. However, in many countries, for example in the USA, there are recommendations for the design of the shape of hyetographs (Huff 1990; Oliveira, Stolpa 2003). Many researchers seek a solution through the application of integrated hydrological models with distributed parameters, where the limitations connected with basin size are smaller and the models include, in principle, baseflow in the hydrographs (Downer et al. 2000; Ozga-Zielińska et al. 2002). Exponential replacement recessions are also used; these need developing GIS thematic layers for the uniform determination of physical catchment descriptors. Irrespective of the assumed solution, rainfall data remains a problem in hydrological modelling (Jurczyk et al. 2015). As long as this problem remains unresolved, the models must give way to design hydrographs.

A parametric flood hydrograph is understood as one or two equations describing a nonparametric hydrograph. The methods used for the construction of nonparametric hydrographs comprise methods developed by the Warsaw University of Technology (Gądek 2012), Hydroproject (Gądek, Środula 2014) and the Cracow method (Cracow University of Technology) (Gądek, Tokarczyk 2015), in which hydrographs are constructed using a traditional scheme regarding the flow, and the Archer method using averaging by time (Archer et al. 2000). Parametric hydrographs are constructed using equations developed by: Strupczewski (1964), Baptista and Michel (1990), McEnroe (1992), Ciepielowski (2001) and also parabolic functions (Reed, Marshall 1999) using Gamma distribution, Inverse Gaussian, and Negative Binominal curve (O'Connor et al. 2014), Weibull and Hayashi curve (1986). Another solution is the application of volume formula for basins of less than 400 km^2 (Gądek 2014).

This present paper aims to compare hydrographs obtained using the Archer method with hydrographs developed using the Cracow method. In terms of methods of determining hydrograph courses, these methods are totally different. It was assumed that the Cracow method would be modified to make possible the comparison of the values of flow descriptors W75 and W50 and the coefficient of skewness s, but also the volume of hydrographs above flow descriptors W75 and W50.

2. Synthetic description of the Archer nonparametric method

A nonparametric hydrograph construction method after Archer (Archer et al. 2000) belongs to a group of topics defined as "new hydrology". Figure 1 shows a hydrograph constructed with this method. A nonparametri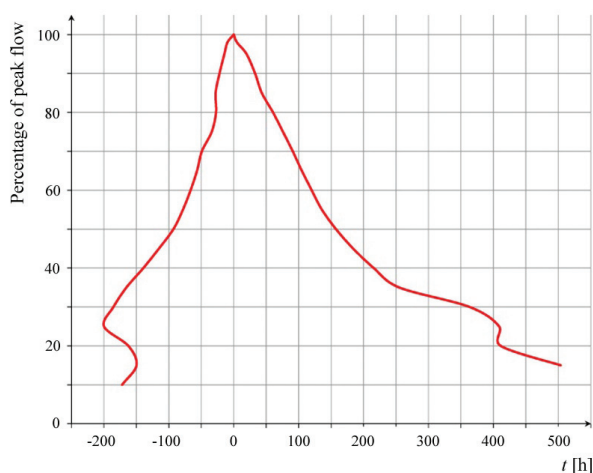c hydrograph, according to the Archer method, has an independent rising and alling limbs. It is presented in a semi-standard layout, where flow is referred to as a percentile in the range 0 to 100%, while the horizontal axis is the duration time of individual percentile values. In the rising part of the hydrograph, the time assumes negative values and the maximum percentile value of 100% occurs at the time $t = 0$. For the falling part of the hydrograph, the time has positive values and is counted from the maximum percentile value. Individual percentile values are the median values of the flows from the rising limb of the input hydrographs; this is the same for the falling limb. Although the values may be determined using the arithmetic mean, a median is recommended (O'Connor et al. 2014). Input hydrographs should represent the maximum registered floods, not only unimodal, but also multimodal. There is a basic difference in the approach to seeking a hydrograph average reflecting conditions between the Archer method and traditional methods (Gądek, Środula 2014; Gądek, Tokarczyk 2015). No less than 4 hydrographs should be used. However, it should be remembered that this number applies to the hydrographs for which the 75th percentile value may be determined on both limbs. If this condition is not fulfilled, the number should be increased.

The rising limb of a flood hydrograph used to construct a nonparametric design hydrograph should represent nondeclining flows. Individual percentile values result from normalisation through dividing the individual flow ordinates by the maximum value of the hydrograph. The maximum value of such a normalised hydrograph is 1.0, which corresponds to the 100th percentile value of the peak flow. The percentile values for the falling limb are determined in the same way.

3. Synthetic description of the Cracow method

The Cracow method was developed at the Cracow University of Technology in compliance with the principles of formalised hydrology. A normalised unit hydrograph, constructed on the basis of at least 6 or 8 of the highest registered unimodal hydrographs, is used for the construction of a nonparametric hydrograph. The normalised shape of the hydrograph assumes that the flow value changes in the range from 0 to 1 and the hydrograph duration time changes from 0 to 1 for the rising part and from 1 to 2 for the falling part of the hydrograph. The time of the rising limb and falling limb are standardised independently, however, the value of maximum flow is reduced by the flow value $Q_{50\%}$ ($Q_{50\%} = Q_{med}$ – median annual flood). Additionally, two linear realationships are determined in this method – describing the relationship between the flood duration time from the rising time, and the reduced volume
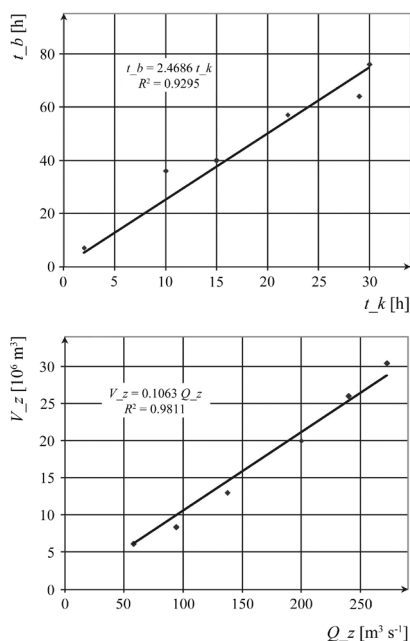

Fig. 1. Nonparametric design hydrograph estimated according to the Archer method

Fig. 2. Dependence of base time t_b on rising time t_k and reduced volume V_z (volume above the base flow $Q_{50\%}$) on reduced Q_z; source: own results

Table 1. Short characteristics of the basins selected for the comparative calculations; source: own study

No.	River – gauging station	Basin area [km²]	Basin type
	The Vistula River basin		
1	Grajcarek – Szczawnica	73,6	mountain
2	Uszwica – Borzęcin	265	upland
3	Wisła – Skoczów	296	submontane
4	Raba - Stróża	644	submontane
5	Przemsza – Jeleń	2 006	upland
6	Poprad – Stary Sącz	2 071	submontane
7	Nida – Brzegi	3 359	lowland
8	San – Przemyśl	3 686	submontane
9	Dunajec – Żabno	6 735	upland
10	Wisła – Zawichost	50 732	lowland
	The Odra River basin		
11	Nysa Kłodzka – Międzylesie	49,7	mountain
12	Bystrzyca – Jugowice	122	mountain
13	Czarna Woda – Gniechowice	251	submontane
14	Biała Głuchołaska – Głuchołazy	283	submontane
15	Bóbr – Wojanów	535	mountain
16	Bystrzyca – Jarnołtów	1 721	upland
17	Nysa Kłodzka – Bardo	1 744	submontane
18	Bóbr – Szprotawa	2 879	upland
19	Bóbr – Żagań	4 255	upland
20	Odra – Cigacice	39 900	lowland

(computed for the flows over $Q_{50\%}$) of the maximum reduced flow (flows diminished by $Q_{50\%}$) (Gądek, Tokarczyk 2015). The dependencies are presented in Fig. 2.

In this method, a nonparametric hydrograph is constructed by optimisation, where the rising time is sought for the specified maximum flow. The algorithm involves computing the hydrograph volume from the linear dependence in Fig. 2 and adjusting the rising time so that the computed volume is the most approximate to the specified one established from the dependence $V\_z = f(Q\_z)$ (Gądek, Tokarczyk 2015).

4. Characteristics of the selected basins

Analysis of the results was conducted on the basis of flow hydrographs observed in 20 gauging cross-sections situated in the area of the upper Vistula and middle Odra river basins. These selected basins represent areas with varied topography. The selection was made so that the basins represented mountainous and submontane, upland and lowland areas. Their characteristics are briefly presented in Table 1, where the gauging stations are ordered according to their belonging to river basins: from 1 to 10 the Vistula River basin and from 11 to 20 the Odra River basin, and regarding their basin areas.

5. Methods

In order to conduct comparative analyses it was necessary to modernise a nonparametric hydrograph designed by means of the Cracow method. Therefore, nonparametric hydrographs constructed for the specified value of maximum flow were transformed to the shape corresponding to a design nonparametric hydrograph determined using the Archer method. This standardisation is shown with the following dependence:

$$q_i = \frac{Q_i + Q_{50\%}}{Q_{max}} 100\% \qquad (1)$$

where: q_i – a percentile of flow at the i-th time step [%], Q_i – temporary flow of nonparametric hydrograph at the i-th time step in the Cracow method without taking into account the base flow [m³ s⁻¹], $Q_{50\%}$ – maximum flow with assigned exceedance probability p = 50% [m³ s⁻¹], Q_{max} – maximum flow of nonparametric flood according to the Cracow method [m³ s⁻¹].

The conducted standardisation of the nonparametric flow hydrograph value makes the percentile presentation in the range of 0 to 100% possible.

For comparison of nonparametric hydrographs constructed using the Archer method and the Cracow method, descriptors W75 and W50 were adopted as reliable indica-

tors describing the shape of the flood hydrograph. Descriptor W75 is the duration time of the 75th percentile, while descriptor W50 is the duration time for the 50th percentile. Additionally, the coefficient of skewness *s* describing the proportion between the rising and falling limb for both descriptors of flow was computed from the following dependence:

$$s = \frac{W_W}{W} \tag{2}$$

where: *s* – coefficient of skewness for descriptor W50 or W75 [-], W_w – rising time for descriptor W50 or W75 [h], *W* – duration time of descriptor W50 or W75 [h].

The volumes of nonparametric hydrographs above the assumed flow descriptors W75 and W50 were compared. A relative deviation of the nonparametric hydrograph volume estimated using the Cracow method in relation to the volume of nonparametric hydrograph computed using the Archer method was assumed for the estimation:

$$ErV = \frac{V_k - V_A}{V_A} \, 100\% \tag{3}$$

where: *ErV* – relative deviation of the nonparametric hydrograph volume computed using the Archer method for descriptors W75 and W50 [%], V_k – volume of non-

parametric hydrograph above descriptor W75 or W50 estimated by the Cracow method [h], V_A – volume of nonparametric hydrograph above descriptor W75 or W50 estimated with the Archer method [h].

The 8 largest flood waves registered for each gauging station were selected for analysis. Three different scenarios were conducted with the Archer method, differentiated by the number of largest flood waves used for computation: 4, 6 and 8 respectively. On the basis of these, 3 nonparametric design hydrographs were constructed. If one or more flood wave had an incomplete rising or falling limb, where they did not reach the 75th percentile, the nonparametric hydrograph using 8 flood waves was not determined. 6 of the greatest unimodal flood waves were used for the Cracow method.

6. Results

The results of descriptors W75 and W50 and their corresponding coefficient of skewness *s* for individual gauging stations are ordered according to the basin area and are shown separately for the Vistula basin in Table 2 and for the Odra basin in Table 3. Sample nonparametric hydrographs, 3 per each basin, are shown in Fig. 3.

Analysing the obtained results, it can be concluded that the Archer method and the Cracow method are similar in the Odra River basin with regard to the flow descriptors
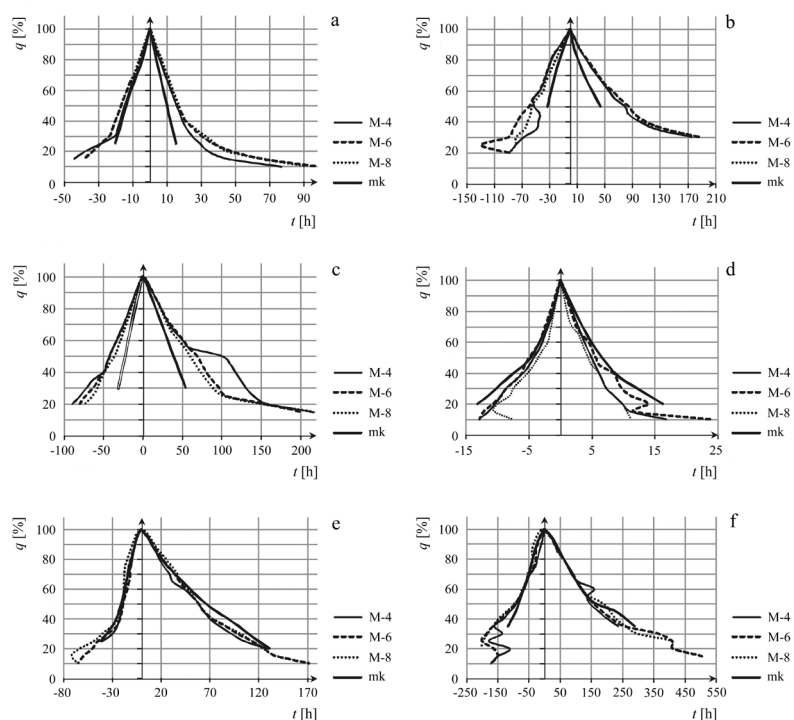

Fig. 3. Nonparametric hydrographs constructed with the Archer method for 4, 6 and 8 flood waves (respectively hydrographs M-4, M-6 and M-8) and by the modified Cracow method (mk hydrograph) for the following gauging stations: a. Grajcarek – Szczawnica, b. Przemsza – Jeleń, c. Wisła – Zawichost, d. Nysa Kłodzka – Międzylesie, e. Bystrzyca – Jarnołtów, f. Odra – Cigacice; source: own results

Table 2. List of duration times of descriptors W75 and W50 and coefficient of skewness *s* at the application of the 4 largest flood waves to determine mid-range M-4, taking into consideration 6 flood waves M-6 and 8 flood waves M-8 in the Archer method and the same descriptors and coefficient of skewness *s* for nonparametric hydrographs constructed using the modified Cracow method (mk) in the Vistula basin, source: own study

No	River-gauging station	Descriptor	The Archer method						The Cracow method	
			M-4 [h]	S [-]	M-6 [h]	s [-]	M-8 [h]	s [-]	mk [h]	s [-]
1	Grajcarek – Szczawnica	W75	13.3	0.45	14.5	0.50	16.3	0.49	10.7	0.54
		W50	30.1	0.48	32.5	0.52	33.6	0.50	23.7	0.58
2	Uszwica – Borzęcin	W75	17.4	0.40	15.3	0.44	14.2	0.40	18.6	0.52
		W50	34.2	0.42	31.0	0.45	28.4	0.39	34.8	0.55
3	Wisła – Skoczów	W75	12.8	0.37	13.0	0.34	13.4	0.35	9.1	0.34
		W50	24.6	0.39	26.8	0.33	27.6	0.34	18.3	0.36
4	Raba - Stróża	W75	11.2	0.51	12.6	0.45	12.6	0.45	6.5	0.45
		W50	23.8	0.50	29.7	0.50	31.5	0.47	14.5	0.50
5	Przemsza – Jeleń	W75	62.2	0.5	65.2	0.48	58.5	0.45	34.0	0.54
		W50	131.7	0.4	143.9	0.41	140.3	0.4	77.3	0.43
6	Poprad - Stary Sącz	W75	27.9	0.49	25.0	0.43	23.0	0.47	16.5	0.52
		W50	54.8	0.51	48.3	0.45	46.8	0.45	33.8	0.54
7	Nida – Brzegi	W75	32.3	0.33	32.8	0.34	33.0	0.34	38.9	0.38
		W50	69.2	0.30	64.4	0.33	65.1	0.33	78.3	0.38
8	San – Przemyśl	W75	34.2	0.64	30.0	0.66	27.1	0.70	26.8	0.68
		W50	58.3	0.62	66.7	0.69	55.2	0.67	53.6	0.69
9	Dunajec - Żabno	W75	27.9	0.58	25.3	0.54	21.7	0.50	26.2	0.60
		W50	57.2	0.58	49.9	0.51	54.1	0.47	55.1	0.57
10	Wisła – Zawichost	W75	48.4	0.42	48.4	0.42	44.2	0.41	32.9	0.37
		W50	143.8	0.29	111.4	0.38	95.9	0.38	61.3	0.36

Table 3. List of duration times of descriptors W75 and W50 and coefficient of skewness *s* at the application of the 4 largest flood waves to determine mid-range M-4, taking into consideration 6 flood waves M-6 and 8 flood waves M-8 in the Archer method and the same descriptors and coefficient of skewness *s* for nonparametric hydrographs constructed using the modified Cracow method (mk) in the Odra basin; source: own study

No	River-gauging station	Descriptor	The Archer method						The Cracow method	
			M-4 [h]	s [-]	M-6 [h]	s [-]	M-8 [h]	s [-]	mk [h]	s [-]
1	Nysa Kłodzka – Międzylesie	W75	3.9	0.37	4.1	0.50	-	-	4.6	0.37
		W50	9.1	0.45	10.6	0.47	-	-	11.3	0.41
2	Bystrzyca – Jugowice	W75	8.7	0.38	8.7	0.38	-	-	12.0	0.54
		W50	18.2	0.53	18.2	0.53	-	-	28.8	0.47
3	Czarna Woda - Gniechowice	W75	39.9	0.43	38.8	0.43	38.1	0.42	39.0	0.42
		W50	75.3	0.39	75.3	0.39	65.3	0.38	69.5	0.37
4	Biała Głuchołaska – Głuchołazy	W75	6.4	0.58	5.8	0.55	-	-	11.1	0.55
		W50	15.9	0.29	12.2	0.41	-	-	30.5	0.44
5	Bóbr – Wojanów	W75	15.7	0.38	20.7	0.53	20.6	0.53	28.9	0.64
		W50	38.2	0.40	38.2	0.40	34.6	0.44	51.0	0.53
6	Bystrzyca – Jarnołtów	W75	36.3	0.35	40.1	0.31	47.9	0.34	38.3	0.29
		W50	77.5	0.24	77.0	0.24	77.5	0.25	87.0	0.24
7	Nysa Kłodzka – Bardo	W75	10.7	0.31	11.0	0.33	-	-	10.7	0.45
		W50	26.3	0.42	28.6	0.44	-	-	24.8	0.43
8	Bóbr – Szprotawa	W75	35.3	0.25	37.1	0.29	-	-	43.8	0.36
		W50	98.4	0.19	103.8	0.24	-	-	127.8	0.38
9	Bóbr – Żagań	W75	45.2	0.23	49.3	0.29	48.8	0.33	49.6	0.34
		W50	114.8	0.25	111.6	0.26	113.2	0.27	128.7	0.24
10	Odra – Cigacice	W75	105	0.28	109.8	0.31	117.0	0.35	119.3	0.38
		W50	235.7	0.38	250.4	0.37	285.2	0.34	248.1	0.33

Table 4. List of nonparametric hydrograph volumes constructed with the Archer method for 4, 6 and 8 of the largest flood waves and with the Cracow method above flow descriptors W75 and W50; source: own study

| No	River-gauging station	Nonparametric hydrograph volumes above descriptors [h]							
		Descriptor W75				Descriptor W50			
		V_M-4	V_M-6	V_M-8	V_mk	V_M-4	V_M-6	V_M-8	V_mk
	The Vistula River basin								
1	Grajcarek – Szczawnica	161	181	204	126	708	773	829	560
2	Uszwica – Borzęcin	203	192	179	243	837	771	712	912
3	Wisła – Skoczów	181	170	175	113	637	654	674	454
4	Raba – Stróża	140	158	154	80	563	667	667	339
5	Przemsza – Jeleń	791	791	696	413	3170	3296	3079	1806
6	Poprad – Stary Sącz	349	313	288	203	1382	1229	1157	832
7	Nida – Brzegi	121	111	112	128	247	232	234	273
8	San – Przemyśl	468	376	370	349	1624	1546	1347	1354
9	Dunajec – Żabno	388	322	286	321	1464	1260	1246	1336
10	Wisła – Zawichost	647	650	615	434	2680	2613	2331	1611
	The Odra River basin								
11	Nysa Kłodzka – Międzylesie	48	51	-	54	206	228	-	247
12	Bystrzyca – Jugowice	119	115	-	131	447	443	-	624
13	Czarna Woda – Gniechowice	651	565	563	546	2021	1908	1836	1887
14	Biała Głuchołaska – Głuchołazy	105	82	-	113	348	290	-	460
15	Bóbr – Wojanów	286	319	323	351	922	1018	997	1351
16	Bystrzyca – Jarnołtów	491	538	661	504	1872	1956	2213	2056
17	Nysa Kłodzka – Bardo	125	127	-	129	588	604	-	564
18	Bóbr – Szprotawa	441	448	-	575	2210	2327	-	2639
19	Bóbr – Żagań	580	667	649	628	2399	2566	2611	2803
20	Odra – Cigacice	1303	1515	1762	1688	5819	5925	6357	6099
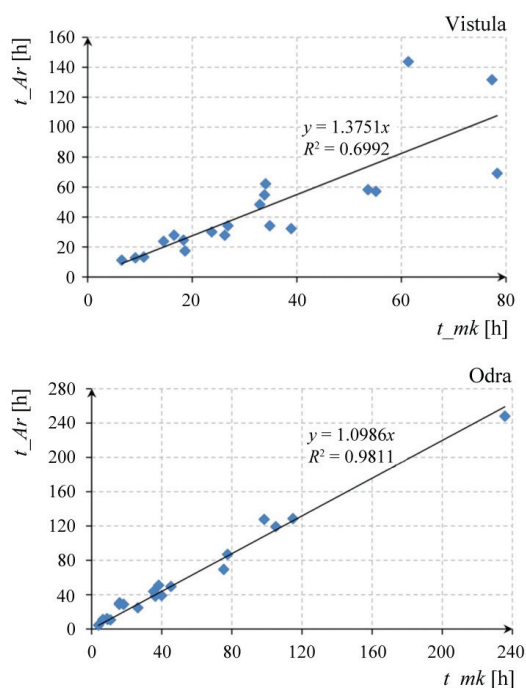
Fig. 4. Dependence of the duration time of flow descriptors W75 and W50 calculated with the Archer method t_Ar for the 4 largest hydrographs on duration time of the descriptors W75 and W50 calculated by the Cracow method t_mk for: Vistula River basin and Odra River basin
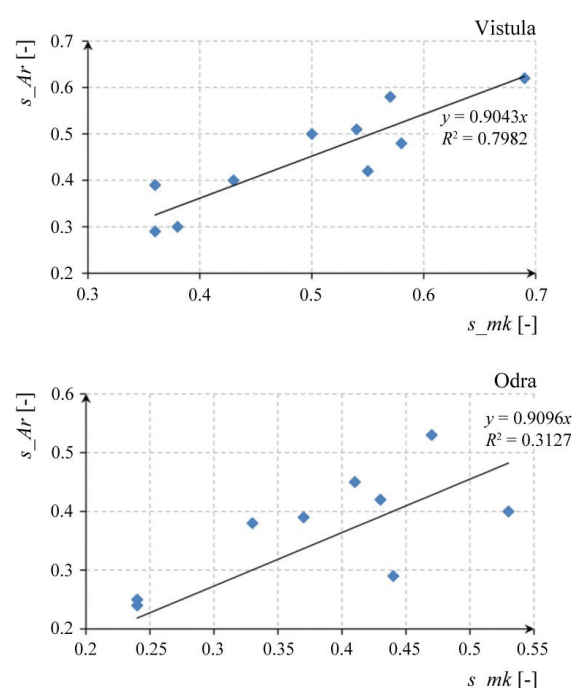
Fig. 5. Dependence of coefficient of skewness s for the flow descriptor W50 calculated with the Archer method s_Ar for the 4 largest hydrographs on coefficient of skewness s for the flow descriptor W50 calculated with the Cracow method s_mk for Vistula River basin and Odra River basin

Table 5. List of relative deviations of nonparametric hydrographs constructed with the Cracow method with reference to nonparametric design hydrographs constructed with the Archer method (formula 3) for the 4, 6 and 8 largest flood waves, for hydrograph volumes above flow descriptors W75 and W50; source: own study

No.	River-gauging station	Relative volume error acc. to formula 3 [%]					
		Descriptor W75			Descriptor W50		
		M-4	M-6	M-8	M-4	M-6	M-8
Vistula River basin							
1	Grajcarek – Szczawnica	–21.7	–30.4	–38.2	–20.9	–27.6	–32.4
2	Uszwica – Borzęcin	19.7	26.6	35.8	9.0	18.3	28.1
3	Wisła – Skoczów	–37.6	–33.5	–35.4	–28.7	–30.6	–32.6
4	Raba – Stróża	–42.9	–49.4	–48.1	–39.8	–49.2	–49.2
5	Przemsza – Jeleń	–47.8	–47.8	–40.7	–43.0	–45.2	–41.3
6	Poprad – Stary Sącz	–41.8	–35.1	–29.5	–39.8	–32.3	–28.1
7	Nida – Brzegi	5.8	15.3	14.3	10.5	17.7	16.7
8	San – Przemyśl	–25.4	–7.2	–5.7	–16.6	–12.4	0.5
9	Dunajec – Żabno	–17.3	–0.3	12.2	–8.7	6.0	7.2
10	Wisła – Zawichost	–32.9	–33.2	–29.4	–39.9	–38.3	–30.9
Odra River basin							
11	Nysa Kłodzka – Międzylesie	12.5	5.9	-	19.9	8.3	-
12	Bystrzyca – Jugowice	10.1	13.9	-	39.6	40.9	-
13	Czarna Woda – Gniechowice	–16.1	–3.4	–3.0	–6.6	–1.1	2.8
14	Biała Głuchołaska – Głuchołazy	7.6	39.5	-	32.6	58.6	-
15	Bóbr – Wojanów	22.7	10.0	8.7	46.5	32.7	35.5
16	Bystrzyca – Jarnołtów	2.6	–6.3	–23.8	9.8	5.1	–7.1
17	Nysa Kłodzka – Bardo	3.2	1.6	-	–4.1	–6.6	-
18	Bóbr – Szprotawa	30.4	28.3	-	19.4	13.4	-
19	Bóbr – Żagań	8.3	–5.8	–3.2	16.8	9.2	7.4
20	Odra – Cigacice	29.5	11.4	–4.2	4.8	2.9	–4.1

W75 and W50. For the Vistula River basin the results are much worse. Figure 4 shows a dependence on the values of descriptors W50 for both methods and in both basins. The opposite relation is found for the coefficient of skewness *s*. A better compliance with both methods was achieved for the Vistula River basin than for the Odra River basin, as shown in Fig. 5. The trend of change was similar for both methods.

The results mainly depend on the data. For the Odra River basin, standard data were available, supplemented with observations of exceptional events; for the Vistula River basin, only daily data with an additional specified term and the maximum flow value were available. However, this does not explain the impact of the number of hydrographs included in the Archer method on the compliance of W50 and W75 in both methods. The greater number of hydrographs included in the Archer method, the greater compliance for both flow descriptors in the methods.

7. Summary and Conclusions

In contrast to earlier methods used to determine the nonparametric hydrographs in the Archer method, only the 4 biggest flood hydrographs are required and for their selection there is no restriction on the number of peak flows. The methods used so far in hydrology to determine nonparametric hydrographs could use only unimodal hydrographs, which limited significantly the amount of possible input data, and usually flood hydrographs included in the calculation do not represent the highest recorded flow values.

The conducted analyses revealed that in a majority of cases the nonparametric design hydrographs determined with the Archer method have a larger volume in the Vistula River basin when compared to nonparametric hydrographs determined with the Cracow method. In the Odra River basin these hydrographs reveal much more compliance, not only regarding the volume but also the duration time for descriptors W75 and W50. Contrary to the nonparametric design hydrographs, the coefficient of skewness *s* for the flow descriptors revealed a greater compliance in the Vistula River basin. Considering the versatility of the Archer method and the simple procedure for the determination of design hydrographs, this method is highly recommended for use in both basins.

The basin area and its location were not observed to fundamentally affected the values of volume and duration

time of the descriptors in the either of the basins when the Archer method was applied. The Cracow method unfortunately has limitations arising from its complex calculation procedure, which makes it difficult to use.

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