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THE VISTULA RIVER LOW FLOWS IN WARSAW IN THE 21ST CENTURY

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ABSTRACT

The aim of the paper is an analysis of low flows – a phenomenon of persistent low water levels and flows in the riverbed – of the Vistula River at the Warszawa-Nadwilanówka gauging station. The study concerned the beginning of the 21st century, against the 1951–2000 period. In order to determine the low flows on the daily flows hydrographs, they were cut-off by the threshold level method. According to the adopted criterion, low flows are rather rare on the Vistula in Warsaw.

The longest and most severe drought in terms of outflow deficit occurred in 1951. In the last years of the studied period (2003, 2012, 2015), droughts have reached a considerable sizes, but were no greater than the low flow observed in 1951. Since 1985 no winter low flows have been recorded.

Keywords: low flows, hydrological drought, Vistula River

INTRODUCTION

Intensification of greenhouse effect, rising temperature and other climate changes have already caused – on the global scale – significant disturbances in the hydrological cycle and water resources, and it is expected that in the future these will be affected even more (Kundzewicz 2014). In Poland, periodic droughts with deep low flows of rivers, as well as floods, are characteristic of this climate (see: Table 1). In September of 2015, during the last droughts, up to 99 gauging stations have recorded water levels lower than the minimum observed until now (to 2013) (Biuletyn PSHM 2015). In the Vistula basin at the Warszawa water gauge (located below the Warszawa-Nadwilanówka station), on August 29, 2015, a remarkably low water level was recorded – 42 cm (see: Fig. 1). The level was so low that it was impossible to cross the ferry of the Metropolitan Water Transport through the Vistula at Podzamcze. The drop in water levels also revealed numerous archaeological relics drowned in the past centuries, especially near the Żoliborz Reef. Vistula's bed in Warsaw consists of grounds resistant to washing (mottled, ribbon-like slit and boulder clays), spreading transversely to the river's course along the entire width of the riverbed, favouring the formation of natural thresholds (reefs) that stabilize vertical layout of the Vistula bed, of which Żoliborz reef is one of the most dominant of this type of structure (Sosnowska 2015).

The classification of the early 21st century in terms of water abundance, based on the assessment of total outflow of Polish rivers in 1951–2016, showed that 2003, 2012, 2015 and 2016 were dry. Over the years, 2015 turned out to be the least water abundant ($V = 40.8$ km^3) – the outflow volume was so small that in the last 66 years (1951–2016) only 1954 was drier – with the outflow equal to 37.3 km^3 (Biuletyn PSHM 2016) (see: Fig. 2).

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Table 1. Calendar of hydrological droughts on the country's scale (Fal 2004, Kaznowska 2011)

Period	Years with low flows								
1901–2000	1901	1904	1911	1913	1920	1921	1925	1928	1929
	1930	1934	1943	1947	1948	1949	1950	1951	1952
	1953	1954	1959	1961	1963	1964	1969	1970	1983
	1985	1989	1990	1992	1993	1994			
2001–2016	2002	2003	2005	2006	2008	2012	2015		

Fig. 1. Warsaw gauging station on August 29, 2015 on the river Vistula. Water level – 42 cm

Fig. 2. The exposed Vistula riverbed in Warsaw, August 2015

The aim of the paper is to characterise low flows of the middle course of Vistula, at the gauging station of Warszawa-Nadwilanówka, at the beginning of the 21st century, in relation to the 1951–2000 period. Previously, low flows of Vistula at this station were developed by, e.g. Farat et al. (1995) and Fal (2007).

MATERIAL AND METHODS

The hydrological characteristics of Vistula in Warsaw and the source data

The section that stretches between the estuaries of San and Narew Rivers is Central Vistula. The Warszawa-Nadwilanówka gauging station closes off the catchment of 84,540 km^2. The study used data on daily flows from the Institute of Meteorology and Water Management – PIB (National Research Institute) from the 1951–2016 period. The indicated data series contains the results of the observations led until 1967 in Warszawa gauging station (A = 84,557,2 km^2) and in the Warszawa-Nadwilanówka station. Since 1967, when Warszawa-Nadwilanówka station was established, the hydrometric measurements and flows assessment of Warszawa gauging station were recorded there. A small (0.4%) increase of the catchment area of the Vistula River between the Warsaw's gauging stations allows for assessments of flows from Nadwilanówka as authoritative for Warsaw (Fal and Dąbrowski 2001).

The average flow, calculated in regard to the annual average flows (*SSQ*) from the 1951–2000 period, for Warszawa-Nadwilanówka is 571 m$^3 \cdot$ s^{-1}. It is a bit smaller (0.35%) for the entire analysed period – 569 m$^3 \cdot$ s^{-1}. Since 1951, the annual average flows do not show a tendency to change (see: Fig. 3), as in the period of 1921–2000 (Fal and Dąbrowski 2001). Though, there is a slight upward trend (see: Fig. 3) in the course of the minimum annual flow values (*NQ*). The average flow of the minimum annual flows (*SNQ*) for years 1951–2000 is 215 m$^3 \cdot$ s^{-1}, while for the 1951–2016 period – 217 m$^3 \cdot$ s^{-1}. The lowest flow (*NQ*) in the considered period has occurred during the winter low flow in the hydrological year of 1960 – 8 December 1959 (see: Table 2). According to Fal and Dąbrowski (2001), the volatility of the average

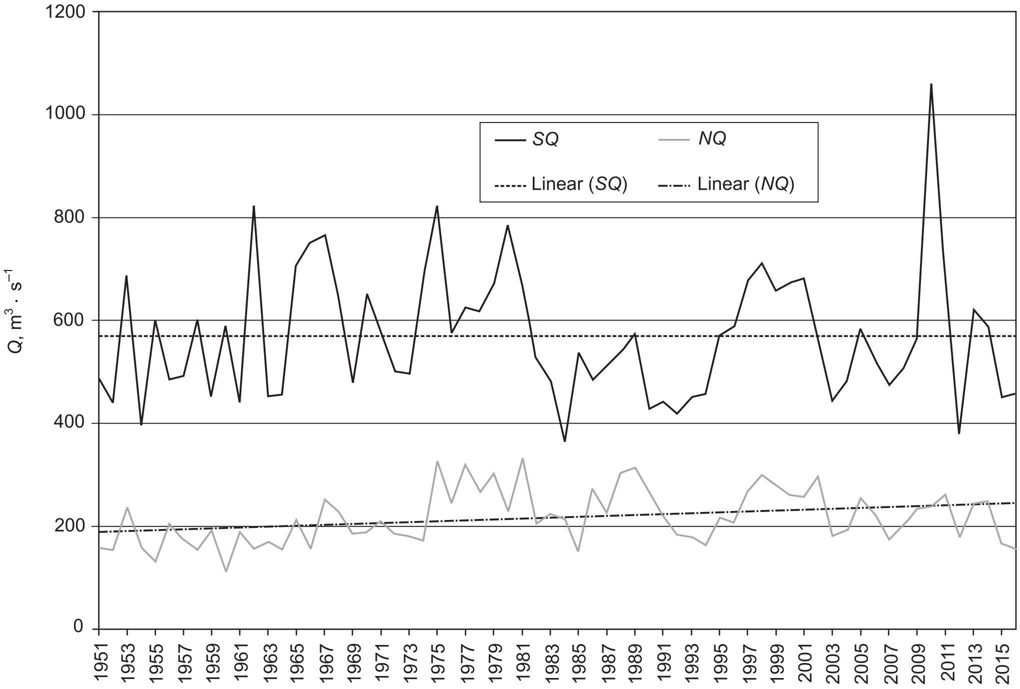

Fig. 3. The low (*NQ*) and the average (*SQ*) annual flows in the period of 1951–2016 at the Warszawa-Nadwilanówka gauging station

annual flows of the Vistula in Warsaw is not large, as in case of many other rivers in the country. However, the volatility of instantaneous flow, i.e. the ratio of the smallest to largest, is relatively high and amounts to 1 : 86. The largest flow during the 1921–2000 period, has taken place on March 27, 1924, and has had a size of 5860 $m^3 \cdot s^{-1}$, whereas the smallest (68.2 $m^3 \cdot s^{-1}$) was observed on January 15, 1947.

Analysing the averaged flow values for each day of the hydrological year between 1951 and 2000 (see: Fig. 4) it can be noticed that the most abundant in water are April, March, and May. While, September and October are feature the smallest average flows. This period has the highest frequency of low flows. Usually, low flows were registered between September and December. According to Fal and Dąbrowski (2001) long-lasting low flow are rare for the Vistula in Warsaw due to its high volatility of daily states and flows. The largest known low flow took place in 1921, covering significant areas of the country and lasted in Warsaw for over 3 months, with a minimum flow of 113 $m^3 \cdot s^{-1}$. Equally long was the summer-autumn low flow in 1951, which began in the last decade of August and ended in the first days of December. The minimum flow of this low flow, however, was almost one and a half times larger than the one in 1921. Nonetheless, Fal and Dąbrowski's (2001) studies indicate the deepest Vistula's low flow occurred in winter (from mid-December of 1946 to mid-March of 1947), formed during the ice cover. The minimum flow of this low flow (mentioned above) was registered on January 15, 1947, and its value was measured under the ice. The calculated reduction coefficient $k = 0.23$ indicates a deep freezing of the river and high movement resistance under the ice. It should be noted that the winter 1947 low flow was preceded by a summer-autumn low flow in 1946.

Accelerating erosion of the Vistula's bed has an impact on lowering of the water levels in Warsaw. Magnuszewski and Guty-Korycka (2009) point to a number of operations from the end of the 19th century to the beginning of 20th century that caused narrowing of the river bed within the city – like the construction of bridges and railway embankments, too narrow gauge of banks on the midtown section or improperly performed regulatory works in the second half of the

Table 2. Characteristics of low flows of the Vistula at the Warsaw-Nadwilanówka gauging station

Date dd.mm.yyyy	Characteristics of low flows							
	Type	T_n	V_n	$Q_{śr,n}$	$Q_{min,n}$	date $Q_{min,n}$	$I_{śr,,n}$	
		days	th. m^3	m^3 · s^{-1}	m^3 · s^{-1}	dd.mm.yyyy	th. m^3	%
06.08.1951–05.10.1951	L	59	193 018	178	158	14.09.1951	3271	0,018
10.10.1951–10.12.1951	Z	62	222 195	173	153	08.11.1951	3583	0,020
15.07.1952–13.09.1952	L	61	184 896	180	153	11.08.1952	3031	0,017
03.02.1954–04.03.1954	Z	30	7 205	187	175	26.02.1954	2041	0,011
03.09.1954–10.11.1954	L	63	105 840	198	180	11.09.1954	1680	0,009
15.09.1959–10.11.1959	L	54	71 194	201	191	10,24.10.1954	1318	0,007
22.11.1959–25.12.1959	Z	32	71 280	191	112	08.12.1959	2228	0,012
08.09.1961–10.11.1961	L	62	98 323	197	188	10.10.1961	1586	0,009
22.07.1963–05.09.1963	L	37	76 378	201	169	15.08.1963	2064	0,011
10.01.1964–04.02.1964	Z	26	92 362	174	154	19.01.1964	3552	0,020
25.07.1964–17.08.1964	L	24	40 954	195	184	07.08.1964	1706	0,009
04.09.1964–27.09.1964	L	24	55 296	188	174	24.09.1964	2304	0,013
09.10.1969–19.11.1969	L	42	60 307	198	185	27.10.1969	1436	0,008
07.09.1973–30.09.1973	L	24	35 597	198	182	24.09.1973	1483	0,008
04.01.1985–25.01.1985	Z	22	81 043	172	149	11.01.1985	3684	0,021
01.08.1992–09.09.1992	L	40	64 022	196	184	05.09.1992	1601	0,009
27.07.1994–23.08.1994	L	24	15 725	209	200	07.08.1994	655	0,004
13.08.2003–08.10.2003	L	57	106 877	193	182	26.09.2003	1875	0,010
25.07.2007–17.08.2007	L	24	50 630	191	175	04.08.2007	2110	0,012
29.08.2012–05.10.2012	L	37	80 266	191	178	17.09.2012	2169	0,012
05.08.2015–26.09.2015	L	53	157 248	181	168	4,19.09.2015	2966	0,017
Period Type	$\sum ni$	$\sum Tni$	$T_{śr,n}$	$T_{max,n}$	$V_{śr,n}$	$V_{max,n}$	$I_{śr,,n}$	
			days		th. m^3		th. m^3	%
1951–2000 L	16	685	43	63	87286	193018	2034	0,011
1951–2000 L[1]	16	747	46	121	101423	419213	2172	0,012
1951–2000 Z	5	172	34	62	108589	222195	3157	0,018
1951–2000 Z[2]	4	110	28	32	79186	92362	2879	0,016

[1] both summer and winter low flow of 1951
[2] without winter low flow from 1951
Symbols in the text

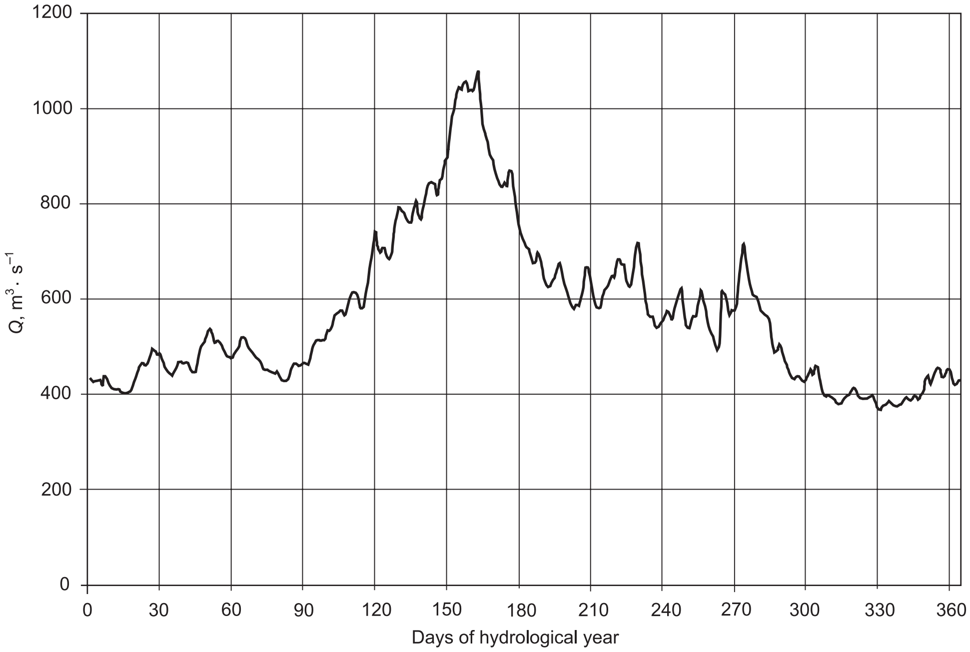

Fig. 4. Distribution of average daily flows over the period of 1951–2000 in the Vistula

20th century. According to Fal and Dąbrowski (2001), the analysis of the course of the minimum annual states (*NW*) and minimum flows (*NQ*) in the period of 1921–2000 of the Vistula in Warsaw showed incompatibility between both factors. Despite the continuous fall in the rates of minimum annual states (*NW*), the minimum annual flows (*NQ*) do not decrease, and even increase slightly, as documented in the Figure 3, which summarises data compiled for the period of 1951–2016. The quoted volatility of minimum water states in the long-term perspective prove that the Vistula's bed on the Warsaw section is deepening.

The truncation level and low flows' characteristics

Low flow is a conventional term used to interpret the condition of a river with regard to the amount of water flowing through a riverbed. The definition of low flow also depends on the aim of the research. The most common one recognises low flow as a period during which flows are equal and lower than the adopted threshold. A number of characteristics applied to determine low flows can be found in the literature, and studies often do not settle on only one but several selected truncation levels (Tallaksen et al. 1997). The paper follows the SNQ criterion (the average of the lowest annual flows). Its value is often used to determine the limit rates of low flows on the country's scale (Farat et al. 1995, Kępińska-Kasprzak 2015), especially low flows of the Vistula (Fal 2007). An additional criterion for distinguishing low flows on the hydrograph of daily flows was the parameter of the minimum duration of flow below the threshold value of 20 days. Such a long minimum duration of the phenomenon was adopted due to a possibility of comparing the results with the characteristics of low flows of the Vistula already described in the literature, which took on the 20 day minimum duration.

The hydrographs of daily flows at the Warszawa and Warszawa-Nadwilanówka stations for the 1951–2016 period distinguish low flows cut off by *SNQ* flow equal to 215 m$^3 \cdot$ s^{-1} that was designated from the period between 1951 and 2000. The summer and winter low flows were described by quantitative parameters: the minimum flow ($Q_{\min,n}$), the average flow ($Q_{śr,n}$), duration (T_n) and the water deficit volume (V_n) expressed by the surface of field between the hydrograph's line and the adopted truncation level. These parameters were set by the model Niżówka 2003 (Jakubowski and Radczuk 2004). The following characteristics were used to assess the severity of low flows: $T_{śr,n}$ – the average duration of a low flow (days); $V_{śr,n}$ – the average low flow deficit volume (in thousands of m^3); $T_{max,n}$, – the maximum duration of a low flow in the studied period (days); $V_{max,n}$ – the maximum low flow deficit volume in the studied period (thousands m^3); $I_{śr,n}$ – the average low flow intensity in the studied period calculated as the quotient of the volume of the deficit of the outflow to the number of days with the low flows in the studied period. This indicates what the rate of outflow deficit falls on one day of a low flow. This value has been converted into the percentage of the average annual outflow per one day of a low flow. Detailed methodology for determining the above measurements can be found in the paper of Kaznowska and Banasik (2009).

RESULTS AND DISCUSSION

Low flows of the period of 1951–2000

In the period between 1951 and 2000 – against which the analysis of low flows of the beginning of the 21st century was made – low flows of the Vistula in Warsaw were not frequent. Only 17 low flows cut off with the *SNQ* limit flow on hydrographs were recorded in these 50 years (see: Table 2, Fig. 5 and 6). A small number of low flows result from the adopted truncation levels. For the Warszawa-Nadwilanówka gauging station the *SNQ* rate, obtained for the 1951–2000 period, is 215 $m^3 \cdot s^{-1}$ and corresponds to the flow value $Q_{95\%}$ read from the curve of the sum of flow durations along with higher

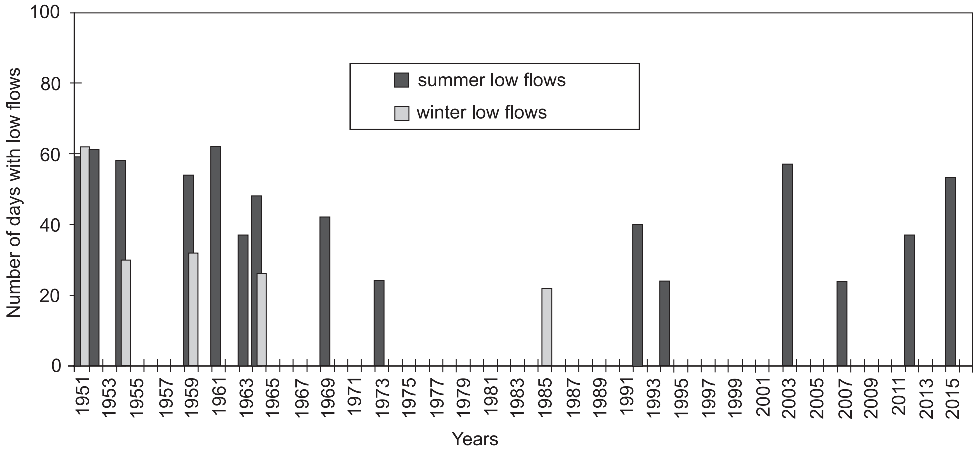

Fig. 5. Number of days of low flows in the 1951–2016 period in the Warszawa-Nawilanówka gauging station

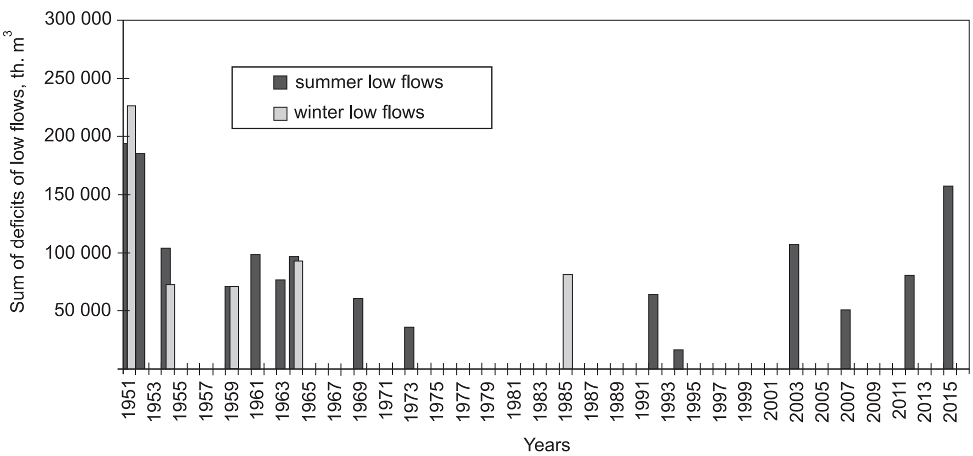

Fig. 6. Deficits of low flows in the 1951–2016 period in the Warszawa-Nadwilanówka gauging station

ones, which indicates deep low flows on the hydrographs (Tomaszewski 2016, Marszelewski et al. 2017), with a lower incidence than shallow low flows.

Definitely, the Warszawa-Nadwilanówka station is dominated by summer low flows. When comparing the amount of winter low flows in Warsaw, as well as in the upper and middle Vistula, a smaller number is recorded in the middle of the river's course (Fal 2007). The summer low flows of the Vistula begin to appear, cut off by the *SNQ* parameter, usually in September – however, it can happen in July and August, too. The phenomenon ends normally in September, less often in August, and sometimes low flows last until November and December (the summer-autumn low flows). Kępińska-Kasprzak (2015), on the basis of the 1951–2000 period, proves that the catchment of middle Vistula is threatened by a large and a very large degree of summer-autumn low flows risk (according to the author low flows are defined by the *SNQ* limit flow and minimum 21 days of duration). Winter low flows of the Vistula in Warsaw mostly begin in January, rarely in November, December and February. The average duration of summer low flows is over 40 days, the winter ones are a bit shorter – over 30 days (see: Table 2). The winter low flows are more intensive on average than the summer ones, due to the larger reduction in the flow rate during the winter episodes. However, the volume deficits of the winter low flows are not as great as the summer low flows, because of their shorter duration (see: Table 2).

In the period between 1951 and 2000 (50 years), taking into account the water deficit volume to the *SNQ* limit flow, the largest summer-autumn low flow took place from the first decade of August to the first days of December 1951 (see: Fig. 7) and lasted over 121 days (see: Table 2). The 1951 low flow has been split into summer and winter part in Table 2 and Figures 5 and 6 due to the time of their occurrence (06.08.1951––05.10.1951 and 10.10.1951–10.12.1951), however, they should be considered jointly (Farat et al. 1995). The sum of the 1951 low flow deficit totalled (both the summer and the winter one) 415 213 thou. m^3 (see: Table 2) and is four times greater than the average low flow deficit from the period of 1951–2000. The duration of this low flow was three times longer than the average for this period. According to Farat et al. (1995) the 1951 summer-autumn low flow was an effect of exceptionally large shortage of precipitation, which was recorded in some regions of the country already in April. The hydrological drought of surface waters, with the exception of few outposts, occurred in the basins of both the Vistula and Odra, despite that

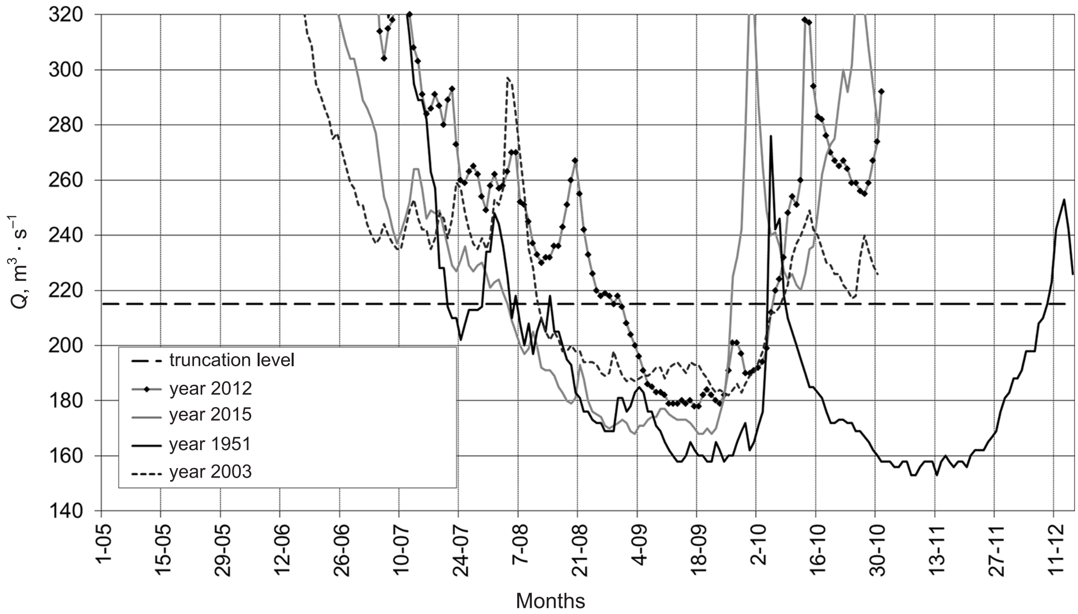

Fig. 7. Selected low flows in the period of 1951–2016 at the Warszawa-Nadwilanówka gauging station

the winter 1950/1951 was relatively humid. Total precipitation from November 1950 to April 1951 predominantly exceeded the norms. The conditions for storing water in soil were good. The warming was progressing gradually. The atmospheric drought began in April for the western parts of Poland, and in May for the south. In June the Mazovian Lowland were already affected by catastrophic (Warsaw-Nadwilanówka) deficit in precipitation. The deterioration of the situation proceeded there through July and August (as well as in the Lesser Poland and Lublin Uplands – the basin of the Vistula). At the end of August, vast majority of the country saw a long, especially in the central part, over 60-day period without any precipitation. The atmospheric drought of 1951 led to significant decrease of the first level of groundwater table lasting 14 months, i.e. until the hydrological drought developed in Poland at the turn of 1951/1952 (Farat et al. 1995). However, flows during low flows of the Vistula in Warsaw were not the lowest. Deeper low flows for the 1951–2000 period have been reported in the following year of 1952, and during winter low flows in hydrological years 1960, 1965 and 1985, too (see: Table 2).

Low flows of the Vistula in Warsaw continued for more than two months in 1952, 1954, 1961. Coinciding with these periods are summer-autumn low flows that reach broad areas of the country. The hydrological drought, especially in 1961, affected the upper and middle parts of the Vistula basin, although, in the middle course of the Vistula it featured relatively high levels of lowest and average flows and average water deficit comparing with other dry periods.

After a short and intense low flow in September 1973 (see: Table 2), in the period of 1951–2000 summer low flows of the Vistula in Warsaw occurred only twice: in 1992 and 1994. Particularly disastrous was the drought in 1992, which in August covered almost the entire country. According to Słota et al. (1992), the main cause of the drought of 1992 was a significant lowering of groundwater since 1989. Because of snowless winters, only in few regions of the country the levels of groundwater were rebuilt, while for the rest of the country the following spring began with low levels of groundwater. Considerable depletion of river basin retention was an effect of very deep low flows. On the national scale, none of the draughts from the 1951–1992 period had such an intensity and large range as the one in 1992. However, low flows with such an intensity as in 1992 were a very rare phenomenon for smaller rivers (repeating once every 100 years) and quite rare for the upper Vistula, too (repeating once for a few decades). Whereas, on bigger rivers, like the middle (the Warszawa-Nadwilanówka station) and lower Vistula, a low flow like that from 1992 is not an uncommon phenomenon as its repeatability is assessed at once every few years.

Low flows of 2001–2016

Over the last 16 years, since 2000, low flows occurred four times: in 2003, 2007, 2012 and 2015 in view of the parameters of *SNQ* and minimum 20-day duration. There were no winter low flows. The quantitative parameters of the 2007 low flow: duration and volume of the deficit did not reach the average rates for the studied period, being only half as big (see: Table 2). As for low flows of 2003, 2012 and 2015, they coincided with the least water abundant years, with catastrophic droughts that covered large areas of Poland, and also neighbouring countries.

The low flow from 2003 (see: Fig. 7) lasted on the Vistula at the Warszawa-Nadwilanówka station from mid-August to the beginning of October, i.e. almost two months, while the volume deficit was slightly above the average for the period and the intensity did not reach the average value for the 1951–2000 period. The medium and minimum rates of low flows of 2003 were also relatively high (see: Table 2).

Although the 2012 low flow was 20 days shorter than the one from 2003, its intensity equaled the average for the period (see: Fig. 7, Table 2). The deficit of the low flow from 2012 (80 266 thou. m^3) accounted for almost 80% of the average deficit of low flows for the 1951–2000 period (101 425 thou. m^3), but it was five times smaller than the deficit volume of the largest low flow from 1951 ($V_{max,n}$ = 419 213 thou. m^3). The low flow from 2012 began at the end of August and lasted until the beginning of October, and its minimum flow equalled the average rate of the 1951 low flow. According to the Bulletin of PSHM (Biuletyn PSHM 2012), the hydrological year 2012 was preceded by three months of monthly average precipitation below the norms. A series of months with monthly precipitation sum below the norms lasted for 5 months – from August to December. In the first month of the hydrological year 2012 – i.e. the extremely dry November of 2011 – the average monthly precipitation was only 7% (of the norm). Large drops in flow volume were observed on the Vistula from August to the end of the 2011 hydrological year due to low precipitation. From the beginning of the hydrological year 2012 the flows exceeded the *SNQ* only a little, and did not reach the *SNQ* rates in February (2 days) and at the end of summer and the beginning of autumn.

The 2015 low flow developed similarly to the one in 2012, with precipitation sums much below norms. However, in some months precipitation rates differed a lot from the monthly average for the period (from extremely dry: November 2014, February, August 2015, to very humid January 2015) (Biuletyn PSHM 2015). In the fourth quarter of the hydrological year of 2014 most of the PSH observation stations reported lowering of the average groundwater table levels. In October as a result of high air temperatures and a low sum of precipitation – recorded mainly in the central and northern parts of the country – low flows were reported in 72% of the observation stations within water management systems with unconfined and confined aquifers. This trend continued in the following months (Komunikat PSH 2014). In southern and south-western Poland winter of 2014/2015 was warmer with lower precipitation than the average for this period. Precipitation deficit in the spring of 2015 affected western, south-western and central Poland, and in August was reported throughout the country, along with a 4–5°C air temperature rise and high potential evapotranspiration (Otop 2016). However, the 2015 low flow was smaller than the one from 1951, with deficit (157 248 thou. m^3) over 1.5 times higher than the average for the period (101 423 thou. m^3), but about 2.5 times smaller than the deficit of (419 213 thou. m^3) 1951 low flow. As long as 53 days (from the beginning of August to end of September), the low flow was a few days longer than the period's average – 46 days. The intensity of the 2015 low flow (0.017%) was significantly higher than for the period (0.012%) and came close to the intensity of the low flow from 1951 (0.019%). The average and minimum rate of the low flow was lower than the corresponding values for the low flow in 2012, but did not drop below the largest recorded summer-autumn low flow from 1951. During the low flow in 2015 on the Vistula in Warsaw the lowest water level so far was recorded, similarly to almost 100 other gauge stations across the country, but it was not the deepest low flow in terms of flow rates, yet. Lower flows have already been reported in the summer-autumn low flow of 1951 and during the winter low flow in 1959 (1960 – hydrological year) (see: Table 2), which proves the lowering of Vistula's bed in Warsaw.

SUMMARY

Based on long-term observations of low flows on the Vistula in Warsaw, defined by the *SNQ* and minimum 21 days of duration, it can be said that the phenomenon of deep low flows is quite rare, which is also confirmed by the studies of other researchers. Low flows were recorded both in summer and winter, though, the latter definitely occurred less often, and between 1985 and 2016 none were reported. Low flows usually appear at the end of summer and the beginning of the autumn. The summer low flows that dominate at the Warszawa-Nadwilanówka station can be described with following parameters: duration and volume of the deficit, which for the period between 1951 and 2000 are respectively: 46 days and 101, 423 thou. m^3. The winter low flows are shorter, but more intensive than summer ones.

In a long-term observations of minimum annual flows no worrying decrease in their values was noticed, and even a slight increase. The alarming information about the record low water levels in the year 2015 are not confirmed by a record deep low flow rate of the Vistula in Warsaw. Until now, the biggest low flow in the period of 1951–2016, with the longest duration and the largest deficit, was the low flow from 1951. Low flows from the beginning of the 21st century, like these from 2003, 2012 and 2015, do not match its size. After analysing low flows in the twentieth century, it turned out that the low flow from 1951 was not the largest; the record belongs to the one from 1921.

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PRZEPŁYWY NIŻÓWKOWE WISŁY W WARSZAWIE W XXI WIEKU

ABSTRAKT

Celem pracy jest ocena zjawiska niżówki, będącej okresem utrzymywania się niskich stanów wody i przepływów w korycie rzeki. Analiza ich występowania w profilu Warszawa-Nadwilanówka na Wiśle, dotyczy początku XXI wieku, została wykonana w odniesieniu do wielolecia 1951–2000. W celu wyznaczenia niżówek na hydrogramach dobowych przepływów odcięto je za pomocą przepływu granicznego. Według przyjętego kryterium niżówki na Wiśle w Warszawie występują rzadko. Najdłuższa i najsurowsza pod względem deficytu odpływu była niżówka w 1951 roku. W ostatnich latach badanego wielolecia (2003, 2012, 2015) niżówki osiągnęły znaczne rozmiary, lecz nie były większe od dotychczas zaobserwowanej niżówki z 1951 roku. Od roku 1985 nie zanotowano niżówek zimowych.

Słowa kluczowe: niżówka, susza hydrologiczna, Wisła