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ASSESSMENT OF HYDROLOGICAL CHANGES IN THE ŠUŠVĖ RIVER

Gražina ŽIBIENĖ, Hydraulic Engineering Institute, Faculty of Water and Land Management, Aleksandras Stulginskis University, Universiteto g. 10, Akademija, LT–53361, Kaunas raj., Lithuania, grazina.zibiene@asu.lt *(corresponding author)*
Alvydas ŽIBAS, Faculty of Water and Land Management, Hydraulic Engineering Institute, Studentų g. 11, Akademija, LT–53361, Kaunas raj., Lithuania, alvydas.zibas@lzuu.lt
Goda BLAŽAITYTĖ Faculty of Wataer and Land Management, Aleksandras Stulginskis University, Universiteto g. 10, Akademija LT–53361, Kaunas raj., Lithuania, godablazaityte@gmail.com

The construction of dams in rivers negatively affects ecosystems because dams violate the continuity of rivers, transform the biological and physical structure of the river channels, and the most importantly – alter the hydrological regime. The impact on the hydrology of the river can occur through reducing or increasing flows, altering seasonality of flows, changing the frequency, duration and timing of flow events, etc. In order to determine the extent of the mentioned changes, The Indicators of Hydrologic Alteration (IHA) software was used in this paper. The results showed that after the construction of Angiriai dam, such changes occurred in IHA Parameters group as: the water conditions of April month decreased by 31 %; 1-day, 3-days, 7-days and 30-days maximum flow decreased; the date of minimum flow occurred 21 days later; duration of high and low pulses and the frequency of low pulses decreased, but the frequency of high pulses increased, etc. The analysis of the Environmental Flow Components showed, that the essential differences were recorded in groups of the small and large floods, when, after the establishment of the Šušvė Reservoir, the large floods no longer took place and the probability of frequency of the small floods didn't exceed 1 time per year.

Keywords: flow regime, antropogenic activity, Indicators of Hydrologic Alteration (IHA).

INTRODUCTION

River run-off is one of the most important links of water circulation in the nature that depends on climatic, physical-geographic and anthropogenic factors. Even though for a long time it was the nature of activity athmospheric circulation and of the Sun that was thought to be the reason for the climatic elements of and changes of the run-off, nowadays, anthropogenic activity is usually thought of as the prevalent activity (Jablonskis, 2012). One of the components of this activity is construction of dams on rivers.

The construction of dams on rivers in order to generate electricity, control floods, and facilitate navigation, and so on can alter the downstream runoff regime by affecting the total runoff quantity, water quality magnitude of runoff, duration of extreme runoff, and result in hydrologic alteration both longitudinally and laterally (Zhao et al., 2011).

The changes in hydrological regime, caused by the construction of dams on rivers has been extensively studied and established by scientists from USA and China. According to the latter, evaluating these changes in the context of the effects of dam construction is complicated, especially is the river is dammed in several locations (Yang et al., 2008). After conducting analysis the authors concluded that the natural regime of the Yellow River was affected by the construction of Xiaolongdi dam. The changes that occured were as follows: the medium flow of June, July and September decreased significantly, as well as the maximum and minimum flow of 1, 3, 7, 30 and 90 days, the number of high and low pulses increased, changes in the medium day flow decreased.

Scientists from the USA contributed vastly towards hydrological research not only in their own country, but in other countries as well. Maingi and Marsh (2002), when analyzing the effects of Masinga dam, which is one of the five biggest dams on Tana river (Kenya), concluded that medium flow of the month of May and the maximum of 7-day, 30-day and 90-day flow have significantly decreased, low pulse duration descreased by 6.7 days, but the medium fall rates increased significantly (*p* (0)01) from 15.7 m^3/s to 21. 6 m^3/s.

Pegg and colleaques (2003), analyzing the hydrological data from river Missouri, concluded that the changes after the contruction of the dam manifested in increased annual flow, the increase of minimum 1-day, 7-day and 30-day flow, changes in flood and minimum flow duration, the increase of high pulse number and duration and decresed number of low pulses, etc.

Lajoie and colleaques (2006), after analysing characteristics of monthly flow among natural (76 stations) and dammed (25 stations) rivers in Canada, concluded that the scope of changes in hydrological regime highly depends on the size of the basin and the season analyzed. The highest monthly flows in dammed rivers during the research period occured most often in winter (December to February), while in natural rivers – almost exclusively in spring. The minimum monthly flows mostly occured during January–March in natural rivers, while in dammed rivers it happened during April and May. The authors conclude that, depending on the size of the river basin, the hydrological changes can affect only small or large basins.

In Europe, the most up to date research, exploring the impact of constructin of dams, has been conducted by Minea and Barbulescu (2014). They conclude that after the construction of Siriu dam on Buzau river, the flow of the month of January increased by 30.2 % and significant changes occurred during May-July period, when the flow decreased by 13–25 %. According to the authors, the extreme values registered the most significant decrement in the post – impact period: the (90-day max)'s minimum – from 28.6 to 16.4 m^3/s, and the (90-day max)'s maximum – from 92.6 to 69.8 m^3/s. Contrary, the maximum of 90 - day minimum increased with 45.8 %.

In Lithuania, the changes in hydrological regime of dammed rivers have been mostly researched by Gailiušis and colleagues (2000). After such a reconstruction, according to the authors, the spring run-off decreases by 3.1–14.6 %, summer-autums run-off increases by 0.9–11.7 %, and the winter run-off increases by 5.3%. Pauliukevičius (2004), while analyzing the particularities of the run-off of river Šušvė beside the town of Josvainiai, estimated that the regulating effect of Angiriai dam manifested itself during the warm season, when in an event of drought, the flow released was higher than environmental flow. During the cold season, the difference between the flow two consecutive days could go up to 18.5 m^3/s, while during the warm season the differences were less significant – up to 5.4 m^3/s.

The purpose of the research – evaluation of hydrological changes of Šušvė river using IHA (Indicators of Hydrologic Alteration) program.

OBJECT AND RESEARCH METHODS

Research Object – dammed Šušvė river, the largest affluent of Nevėžis river. Angiriai dam, 16 metres in height, was constructed in 1980, near Angiriai village and as a result a 248 hectare pond was formed. For this reason, the previous natural river run-off regime had changed: the 15500000 m^3 of accumulated water didn't flow through the natural river bed, but was passed through two 1.5x1.5 m bottom discharger and the floods flows (up to $Q_{1\%}$=296 m^3/s) through spillway (Vaikasas et. al., 2009)

The data used for analysis was collected from hydrological annals (Гидрологические..., 1933–1944; Гидрологический..., 1945–1962; Основные..., 1963–1975; Гидрологический..., 1976–1977; Ежегодные..., 1978 –1989; Hidrologijos..., 1990–2010) from the period from 1940 to 2010.

All hydrological parameters in the IHA programme are calculated and rendered in a form of tables and graphic representations. IHA and MS Office Excel programmes are used to generalize the information gathered during the research: there are two classes of factors examined in the IHA program – IHA parameters and components of environmental flow. Category of IHA parameters consists of five groups: magnitude of monthly water condition, magnitude and duration of annual extreme water condition, timing of annual extreme water condition, frequency and duration of high and low pulses and rate and frequency of water condition changes. Threre are total of 33 factors analysed in the above mentioned groups:

- mean and median value fore each calendar month
- Annual minima and maxima of 1, 3, 7, 30, 90 day
- number of zero-flow days;
- base flow index;
- Julian date of each annual 1–day minimum and maximum;
- Number of low and high pulses within each water year;
- Mean and median duration of flow pulses (day);
- duration of low and high pulses (day);
- Mean or median of all positive and negative differences between consecutive daily values.

Components of environmental flow are also divided into five groups: monthly low flows, extreme low flow, high flow pulses, small and large floods. There are 34 factors analyzed in these groups:

- mean or median values pf low flow during each calendar month;
- frequency of extreme flow,high flow and low and large floods;
- duration (days) of extreme flow,high flow and low and large floods;
- extreme small flow;
- peak of extreme flow, high flow and low and large floods;
- timing of extreme low, high floods pulses and low and high floods;
- Rates of high flow pulses, low and high floods rise and fall rates.

RESULTS OF RESEARCH

Results are analyzed in separate parameter groups of each category. The flow values during the months from January to December from the periods of 1940–1979 and 1981–2010 are analyzed firstly (Table 1).

As illustrated in Table 1, there is quite high variation amplitude of each monthly flows during both examined periods: 1940–1979 and 1980–2010. The minimum flow values after the construction of the dam on Šušvė river increased from a few percent to several times the value: the smallest changes in increase of the minimum flow during the examined period were recorded in November – 1.56 %, the largest – in January (3.35 times the value). The change in decreased flows of the months of May, June, July and August after the construction of Angiriai pond reached 5–50 %, the smallest change was recorded during the month of June, the largest – the month of August.

Table 1. Flow in Šušvė river from January to December

Month	1940–1979 year period flows, m^3/s			1981–2010 year period flows, m^3/s		
	Minimum	Maximum	Medium	Minimum	Maximum	Medium
January	0.17	16.30	1.87	0.74	16.00	4.74
February	0.20	30.55	1.59	0.73	20.20	3.54
March	0.31	28.20	4.01	0.44	28.00	8.25
April	2.00	66.85	10.53	2.38	28.00	7.26
May	0.84	12.00	2.77	0.44	12.20	3.21
June	0.40	3.23	1.20	0.38	8.02	1.52
July	0.24	4.12	0.71	0.20	12.40	0.93
August	0.20	4.46	0.86	0.10	4.41	0.55
September	0.18	9.30	0.76	0.27	6.42	0.54
October	0.18	20.40	1.34	0.22	14.20	1.91
November	0.32	27.55	2.73	0.33	13.40	3.40
December	0.27	22.80	2.93	0.40	14.20	5.72

The maximum flow values in the periods of 1940–1979 and 1981–2010 are distributed unequally as well. After the reconstruction of Šušvė river, increased maximum flow values manifested during the months of May, June and July, 1.67 %, 148.14 % and 200.97 % respectively. The differences between the decreased maximum values reached 1.12–58.12 %: the flow value of the month of August has decreased the least, the flow value of the month of April decreased the most.

Analyzing the mediun flows values of Šušvė river before and after the dam construction (pre-impact and post-impact), it can be seen that after the construction of Angiriai pond, the values of all months, except for April, August and September, increased. The changes in the increased medium flows constituted 15.70–153.48 % (during the months of May and January respectively), in the meantine the decrease in medium flows values – 28.81–35.67 % (during the months of September and August respectively).

Analyzing the extreme flow range – minimum and maximum values during a particular period, the most important factor in the extent of Lithuania is the 30-day minimum flow (Figure 1).

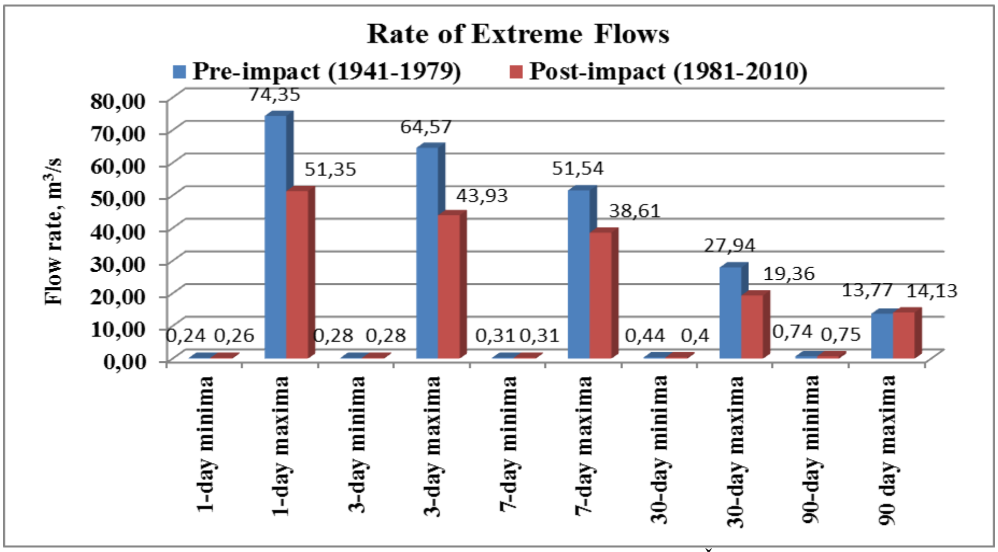

Figure 1. Particular period range of extremum flow in Šušvė river

From Figure 1 we can see that after the construction of Angiriai dam, almost every maximum flows have decreased, except for 90-day flow which increased. The changes in the decreased flows variated from 25 % to 32 % and the 90-day maxima only increased by 2.6 %. The opposite situation is seen in the minimum flows of the corresponding periods that did not change or only slightly increased (by 1.79–8.33 %). More significant changes were recorded in the 30-day minimum flows values that decreased by 8.86 %.

It is also important to analyze the duration of extreme run-off conditions – Julian dates of maxima and minima flow events. Figure 2 represents the dates of minimum flow events during corresponding years.

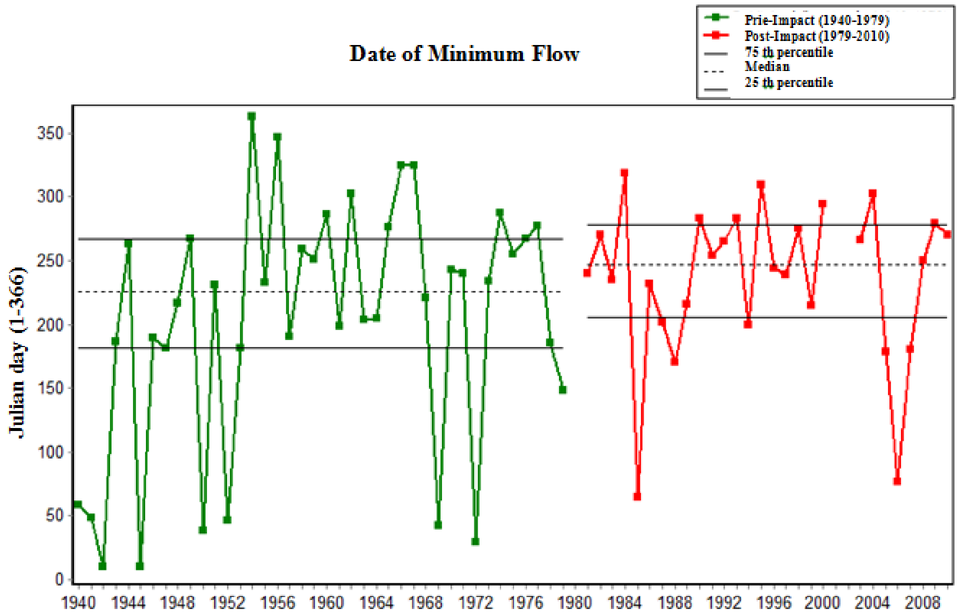

Figure 2. The event date of minimum flow in Šušvė river

As seen in Figure 2, that the fluctuation amplitude of the date of the minimum flow event is quite high: before the reconstruction of Šušvė river, the minimum flow occured on the 10th day, as well as on the 363rd day, while after the reconstruction – on the 65th and 319th days. The median date of the minimum flow event during the period of 1940–1979 was around the 226th day (13th of August), while after the construction of Angiriai dam, the minimum flow event moved forward by 21 days and occured on around the 247th day (3rd of September). In the meantime, the maximum flow event during the period of 1940–1979 occured on 91st day (31st of March), while during the period of 1981–2010 – on around the 93rd day (2nd of April). It can be stated that the construction of Angiriai dam had more influence on the minimum flow event, when it occured three weeks later.

Touching upon the variation of flow, number of low and high pulses within each water year and their duration in days, we see quite significant changes after the construction of Angiriai dam on Šušvė river.

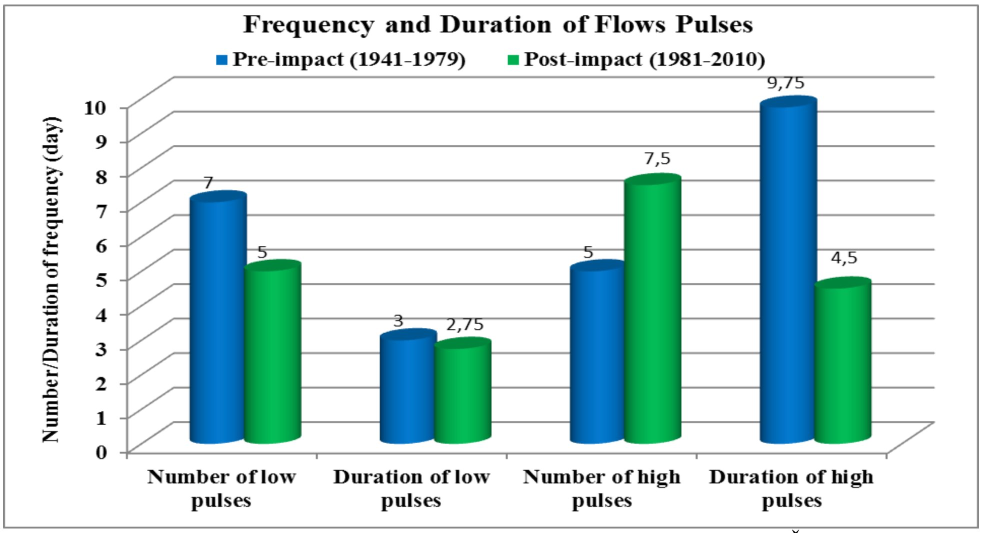

Figure 3. Number and duration of low and high pulses in river Šušvė

Analyzing the changes in pulse number after the construction of dam on Šušvė river it was estimated that the value of low pulses decreased by 28.5 %, while the number of high pulses increased by 50 %. From analyzing the duration of pulses in days, it is seen that the more significant changes are recorded in the duration of high pulses that decreased by more than two times.

In the last group of IHA parameters of daily changes it was estimated that the increase of the flow in regards to the previous day after the construction of Angiriai dam increased by more than 55 %, that is from 0.20 m^3/s to 0.30 m^3/s. The decrease of the flow amounted to 18.75 % when it increased from -0.24 m^3/s to -0.29 m^3/s.

Analyzing the first group of environmental flow components – low flow values, it was estimated that after the construction of the dam on Šušvė river, the low flows that increased the most were that of the month of December – by 59.12 %, the low flows that increased the least – the month of June – by only 4.72 %. Analyzing the period after the construction of Angiriai dam it was estimated that the change in the decreased flows reached 1.23–38.57 %. The flows of the month of January changed the least, those of the month of September – the most.

Dates of high flow pulse events before theconstruction of Angiriai dam occured on around the 302nd day (28th of October) and after the dam construction on river Šušvė it was recorded almost twice as earlier: on around the 158th day (the 6th of June)

The fundamental differences in river Šušvė after the construction of Angiriai dam were recorded during small and large floods, when the number of their frequency was decreased to a minimum: to 1 time a year for small floods, while there were no large floods after the reconstruction of river Šušvė. It can be concluded that, in the case analyzed, the construction of the dam executed the function of controlling floods.

CONCLUSIONS

1. After completing the analysis of hydrological changes of the river Šušvė it was estimated that after the construction of the dam on Šušvė river, the flow of every calendar month, except for those of the months of April, August and September, have increased. The change in the increased flows variated from 15.70% to 153.48 %, while that of the decreased flows variated from 28.81 % to 35.67 %.
2. After the construction of Angiriai dam, the maximum 1-day, 3-day, 7-day and 30-day flows decreased by 25–32 % and minimum 30-day flow decreased by 8.86 %.
3. Significant changes were recorded in the group of minimum flow event, when after the reconstruction of the river Šušvė it occured 21 days later (moved from the 13th of August to 3rd of September).
4. After the construction of Angiriai pond, the number of low pulses decreased, as well as the the duration of low and high pulses, but the number of high pulses increased.
5. After the construction of the dam on the river Šušvė, the increase and decrease of the flows in regards to the previous day has the tendency to increase. The mentioned factors increased by 55 % and 18.75 % respectively.
6. The fundamental differences after the construction of Angiriai dam were recorded in the groups of small and large floods, when, after the reconstruction no large floods occured, while the likelihood of small floods was never higher than once a year.

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