"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.083
DOI: https://doi.org/10.3846/enviro.2017.083

The Influence of Neogene Lithology on the Šventoji River Hydrologic Regime

Andrius Litvinaitis[1], Lina Bagdžiūnaitė-Litvinaitienė[2], Laurynas Šaučiūnas[3]

[1,2,3]Department of Water engineering, Vilnius Gediminas Technical University, Vilnius, Lithuania
[2]Department and/or Faculty, University, City, Country
E-mails: [1]andrius.litvinaitis@vgtu.lt (corresponding author); [2]lina.litvinaitiene@vgtu.lt; laurynas.sauciunas@stud.vgtu.lt

Abstract. Due to the recently increasing frequency of extreme changes in river runoff regime, scientific literature deals with the characteristics of runoff formation. Works are carried out in analyzing climate changes and a lot of attention falls on land–use structures. Following thorough analysis of the lithological structure of river basins in separate costal zones, this article aims at evaluating river runoff formation characteristics. The basin lithological factor (sandy, loamy, argillaceous) was calculated based on Quaternary map of Lithuania M 1:200000 and Lithuanian river map M 1:50000 using ArcGis software. In order to carry out more thorough analysis of the influence of lithology in given territories, sections of 0–20 m, 50–200 m, 200–500 m, 500–800 m, 800–1000 m and >1000 m were established, calculating the distance in meters from the riverbank. The period of the years 1984–2014 was analyzed, years with the greatest, average and lowest amounts of precipitation (according to probability) was analysed and relation between the runoff and precipitation was established as well as that with the lithological structure, estab-lished following a derivation of a hydromodule.

Keywords: lithology, river runoff, precipitation, basin.

Conference topic: Water engineering.

Introduction

The distribution of river runoff throughout the year is determined by climatic and bedrock surface factors. Climate influences the overall wateriness during the year and runoff regime phase periods. Bedrock surface (the size of a river basin, its lithological composition, and forest area in the river basin) might cause fundamental changes to the runoff regime formed by climatic factors (Gailiušis *et al.* 2001; Uhlenbrook *et al.* 2001).

Recently, cases of ill–timed floods throughout the world have come to the news more and more frequently. It has been estimated that the amount and intensity of precipitation has increased 10 times during the second half of the 20th century (Pfister *et al.* 2004).

In the context of global climate change, Lithuanian climatologists have not yet recorded fundamental changes in multi–annual precipitation patterns but have established its clear seasonal distribution, i.e. winter season precipitation has increased significantly while that of summer season has seen a significant decrease (Galvonaitė, Valiukas 2005; Bukantis *et al.* 2001; Bukantis, Rimkus 2005).

A number of researchers engage in the analysis of runoff formation conditions, particularly while analyzing the impact of land–use structures on river runoff (Jones, Grant 1996; Ashagrie *et al.* 2006). H. Pauliukevičius (2006) looked into the impact of land–use on small river basins runoff. The research has demonstrated slight and moderate inverse correlation of average annual runoff module with forest area and direct correlation with arable land area in small river basins with varied land–use in the end of a low–wateriness period and the beginning of a higher wateriness period.

However, the number of scientific research focusing on the aspects of runoff formation in terms of lithological structure of a river basin is scarce; moreover, the existing ones deal with it in terms of water quality since infiltration characteristics of lithological structures determine the quality of both runoff and water (Kevin *et al.* 2000; Alan *et al.* 2004).

Following thorough analysis of the lithological structure of river basin, this article aims at evaluating river runoff formation characteristics.

Materials and Methods

Three parts of basin of Šventoji river were selected according to long–term water measurement stations: above Anykščiai, Anykščiai-Ukmergė, below Ukmergė (Fig. 1). The lithological factor of the basin and parts of the basin was calculated based on Quaternary map of Lithuania M 1:200000 and Lithuanian river map M 1:50000 using ArcGis software. Four classes were identified according to soil composition: 1 sand, 2 loam–sandy loam (further on referred to as loam), 3 clay and 4 peat, with relative infiltration indices ascribed to them for the purpose of further analysis. Lithological analysis of selected parts was carried out of the influence of lithology in given territories, sections of 0–50 m, 50–200 m, 200–500 m, 500–800 m, 800–1000 m and >1000 m were identified, calculating the distance in meters from the riverbank. Each sections' lithological structure was established. Water balance equation (WBE) was used

$$R = \sum_{i=1}^{f} \left[\left(K_f - E_f \right) \cdot A_f \cdot \left(\frac{1}{2} \cdot \frac{L_f}{v_f} + \sum_{i=1}^{f+1} \frac{L_{f+1}}{v_{f+1}} \right) \right],$$

where: R – height of leakage (mm); f – section; K_f – rainfall per section (mm/d); E_f – evapotranspiration per section (mm/d); A_f – area of section (km^2); L_f – width of section (m); L_{f+1} – width of section closer to the river (m); v_f – water filtration rate of section (m/d); v_{f+1} – water filtration rate of section closer to the river (m/d). This equation is applicable in cases where the rainfall does not surface runoff. Annual evaporation from land and water surface evaluated on the basis of maps prepared by A. Konstantinov method (Gailiušis *et al.* 2001). Evaporation of seasonal periods estimated using Blaney and Criddle equation (Taminskas *et al.* 2008; Papadopoulou *et al.* 2003).

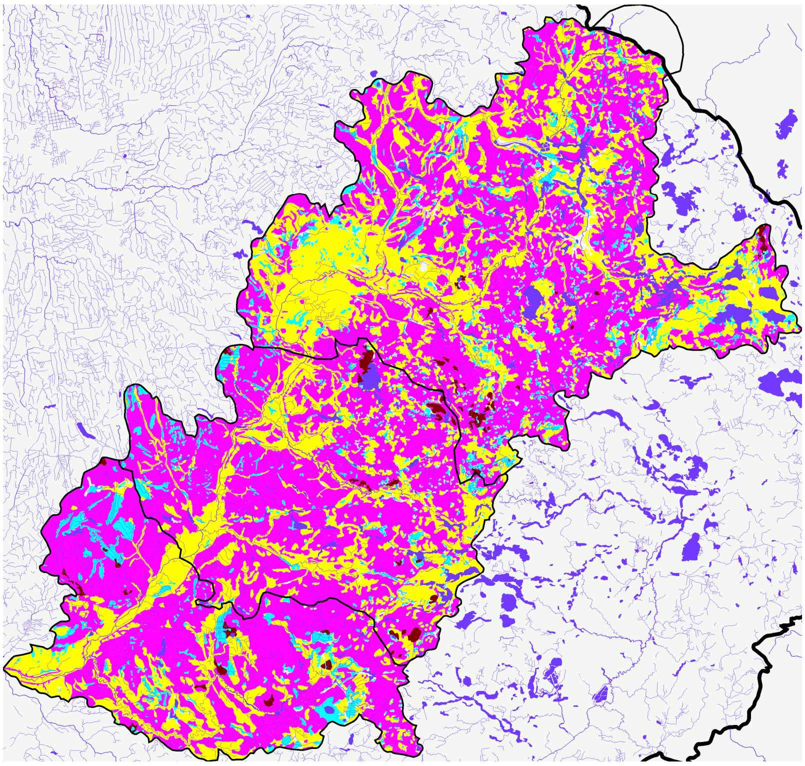

Fig. 1. Basin of Šventoji river, distribution of sediments

Lithuanian Hydrometeorological Service (LHS) data of runoff and meteorological conditions (precipitation) of the year 1984–2014 were used. The year with the greatest, average and lowest amounts of precipitation (according to probability) was analysed and relation between the runoff and precipitation was established as well as that with the lithological structure, established following a derivation of a hydromodule.

Results and Discussion

The distribution of sections areas in the Šventoji basin was analysed. The calculation of the percentage of sections area in the parts of basin revealed that distribution of areas of sections are equivalent in all parts of the basin. More than 70% of the basin territory is covered by sections of 50–200 m, 200–500 m, and 500–800 m. 12–14% of basin territory is covered by sections 800–1000 m and over 1000 m, and 14–15% of basin is covered by section 0–50 m. This distribution of section areas is directly influenced by the density of hydrographic net (Jablonskis *et al.* 2007). This structure was considered in further calculations (Table 1).

Šventoji basin is covered by loam in 57% of the overall 6888.8 km^2 of basin area within its territory. Almost 33% is covered by sand, 1% is covered by clay and 9% is covered by swamps and peat bogs (Table 2). Clay is distributed in areas of an average from 0.5 to 4.8 km^2. The percentage of loam moving further from the riverbank increases gradually from almost 41% of the section 0–50 m area to 64% of the section 500–800 m area. The sand areas of sections cover more evenly, it decreases from more than 37% of the section 0–50 m to 30% of the section 500–800 m. All sections a covered by clay in 0.6–1.1%. Sections 0–50 m in 21% and 50–200 m in 13% are covered by swamps and peat bogs. Further sections are covered of 4–7% (Fig. 2).

Table 1. Areas of sections in percents of overall and parts of Šventoji basin

Parts of basin	0–50 m	50–200 m	200–500 m	500–800 m	800–1000 m	over 1000 m
All	14.5	23.4	27.5	20.4	6.3	7.9
above Anykščiai	15.3	22.4	26.8	20.9	6.6	8.0
Anykščiai-–Ukmergė	14.7	24.3	28.1	20.4	6.4	6.1
below Ukmergė	14.2	26.5	28.8	18.7	5.2	6.6

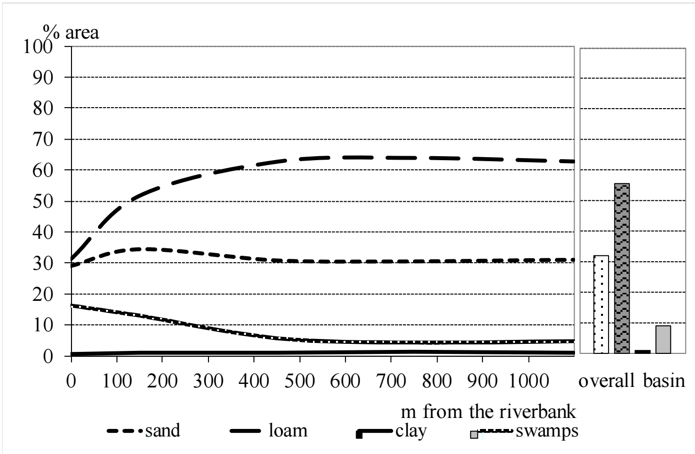

Fig. 2. Change of lithological formations of the Šventoji basin, distance from the bank

The part above Anykščiai is covered by loam in almost 52% of the 3451.4 km^2 of part of basin area. More than 38% is covered by sand, 0.6% is covered by clay and 9% is covered by swamps and peat bogs. The loam increases from 34.5% of the section 0–50 m area to 62% of the section 800–1000 m area. The sand decreases from 42.5% of the section 0–50 m to 32% of the section 800–1000 m. The clay covers from 0.0 to 0.8% of areas of sections. Sections 0–50 m in 22.4% and 50–200 m in 12.8% are covered by swamps and peat bogs. Further sections are covered 4.8–8.4% (Fig. 3).

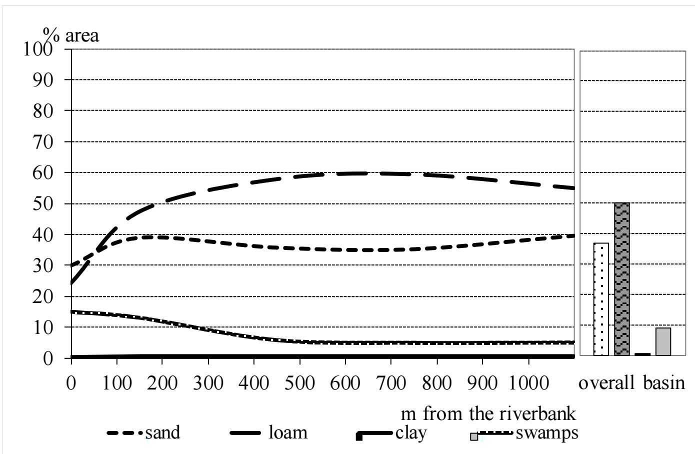

Fig. 3. Change of lithological formations of the Šventoji basin part above Anykščiai, distance from the bank

The part Anykščiai–Ukmergė is covered by loam in almost 62% of the 1903.2 km^2 of part of basin area. More than 29% is covered by sand, 1.3% is covered by clay and 7.6% is covered by swamps and peat bogs. The loam increases gradually from 45% of the section 0–50 m area to 72% of the section over 1000 m area. The sand decreases from 36% of the section 0–50 m to 21% of the section over 1000 m. The clay covers more than 2% of areas of sections from 500–800 m to overs 1000 m. Sections 0–50 m and 50–200 m in 18–11% are covered by swamps and peat bogs. Further sections are covered in 3.2–4.5%.

The part below Ukmergė is covered by loam in more than 61% of the 1534.2 km^2 of part of basin area. Almost 27% is covered by sand, 1.3% is covered by clay and 10.8% is covered by swamps and peat bogs. The loam increases from more than 46% of the section 0–50 m area to 70% of the section 500–800 m area. The sand decreases from almost 30% of the section 0–50 m to more than 24% of the section 500–800 m. The clay covers more than 1.5% of areas of sections 0–50 m and 50–200 m. Sections 0–50 m and 50–200 m in 22–15% are covered by swamps and peat bogs. Further sections are covered in 4.3–6.4%.

Table 2. Lithological structure of the of overall and parts of Šventoji basin

Parts of basin	Section	Lithological structure, %			
		sand	loam	clay	swamps and peat bogs
All basin	All	32.8	57.1	1.0	9.1
	0–50 m	37.4	40.7	0.9	21.0
	50–200 m	34.1	52.0	0.9	13.0
	200–500 m	30.9	62.5	1.0	5.6
	500–800 m	30.3	64.2	1.1	4.4
	800–1000 m	32.5	61.8	0.8	4.9
	over 1000 m	35.3	56.8	0.6	7.3
above Anykščiai	All	38.2	51.9	0.6	9.3
	0–50 m	42.5	34.5	0.6	22.4
	50–200 m	38.9	47.5	0.8	12.8
	200–500 m	35.6	57.7	0.8	5.9
	500–800 m	37.2	57.3	0.7	4.8
	800–1000 m	31.9	62.0	0.2	5.9
	over 1000 m	45.5	46.1	0.0	8.4
Anykščiai–Ukmergė	All	29.4	61.7	1.3	7.6
	0–50 m	36.3	44.6	0.7	18.4
	50–200 m	32.6	55.7	0.8	10.9
	200–500 m	28.5	65.8	1.2	4.5
	500–800 m	26.2	68.6	2.0	3.2
	800–1000 m	25.4	69.0	2.0	3.6
	over 1000 m	21.2	71.9	2.4	4.5
below Ukmergė	All	26.5	61.4	1.3	10.8
	0–50 m	29.6	46.4	1.7	22.3
	50–200 m	28.1	55.1	1.5	15.3
	200–500 m	25.2	67.4	1	6.4
	500–800 m	24.5	70.3	0.9	4.3
	800–1000 m	27.5	66.6	0.7	5.2
	over 1000 m	27.5	66.6	0.7	5.2

This basin and parts of basin structure considering infiltration characteristics of wet loam and clay is likely to influence rapid change of runoff in terms of precipitation.

Waters, especially rivers pollution depends on the run-off, and the nature of the mode is affected by factors such as climate, anthropogenic and natural geographical conditions. Pauliukevičius (2006) found that these factors lead to about 88% of the annual runoff in height, 85% of the maximum and the minimum 92% of the runoff change. The annual runoff most affected by climate factors, the maximum and minimum run-off the natural geographical and anthropogenic factors.

750 mm of rainfall falls in the Šventoji basin over the year on average, 32 % on cold season. Coefficient of water runoff of the year $\eta = 0.42$, the average flow at the estuary is about 56.5 m^3/s (according to Baltromiškės VMS). Leakage is naturally adjusted $\varphi = 0.70$, 40% of it is consists of underground waters, and snow and rain – respectively

32 ir 28%. The river has a hybrid feeding, because none of the dietary sources is not more 50% (Kilkus, Stonevičius 2011). Hydrologic indicators are not unanimous in a separate basin parts. The annual hydromodule of 7 l/s km^2 is the smallest of the upper reaches – part of the basin above Anykščiai. Hydromodule of 7.3–8.2 l/s km^2 in the basin part Anykščiai–Ukmergė.

Analysis of the 1984–2014 period shows years of very big, medium and small runoff. 1994–1995, 1998–1999 and 2010–2011 years of very big runoff. Average runoff was around 60 m^3/s, annual presipitation 793 mm. The probability of such runoff is 5.6%. 1995–1996, 1999–2000 and 2005–2006 are years of medium runoff of average 40.7 m^3/s, with the annual presipitation of 617.7 mm. Probability of years of medium runoff is 51.6%. 1984–1985, 2002–2003 and 2008–2009 are years of small runoff of average 29 m^3/s runoff, precipitation of 531 mm. Probability of years of small runoff is 94.4%.

Repartition or hydrological regime is best reflected during the runoff hydrograph (Gailiušis *et al.* 2001). Hydrograph analysis together with precipitation and runoff data performed. x axis indicates the days in the figure, translated into hydrological months. It was accepted that every month has 31 days; recalculated runoff using water balance formula plaset in bigger (30 m^3/s) value to stand out from the runoff LHS – thus avoiding random estimation errors and are easier to compare the results (Fig. 4 and 5). Runoff data provided of the data of Lithuanian Hydrometeorological Service and the data of calculation using water balance equation.

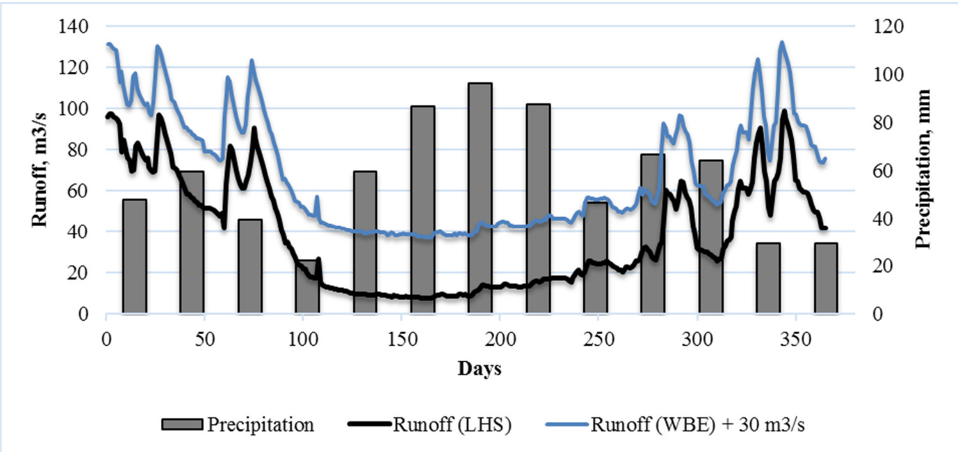

Fig. 4. Hydrograph of the Šventoji of 1992

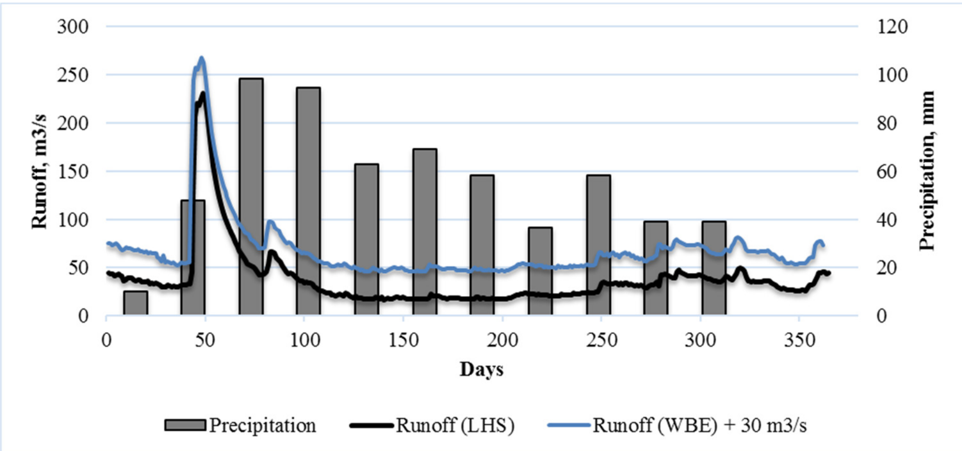

Fig. 5. Hydrograph of the Šventoji of 2013

Annual runoff was of 40 m^3/s in 1992. Runoff increases to 100 m^3/s in spring because of increasing temperature and melting snow. As the temperature increases slowly, snow melts slowly, and the flow rate varies of the first two months of spring. It is because of frocend ground and absent of infiltration into sediments. Precipitation starts to cause flow rate directly on May, but with delay because of infiltrations proceses through the sediments started. Unusual flooding (runoff reached 225 m^3/s.) was caused by a sudden rise of temperature and hight precipitation at the same time in spring of 2013. The river is feeding by underground water in summer. Only higher rainfall which creates surface runoff increases runoff with short delay (2–5 days), but just from heavy sediments: loam and clay. Sand, especially swamps accumulates rainfall. Influence of precipitation to runoff and the delay of it explained using water balace formula. Correlation coefficient was 0.89 (reliability 0.02) calculated between precipitation and runoff. Therefore, it has been established that in rainy periods with high amounts of precipitation, close-grained lithological structures are capable of preventing infiltration, which results in the water reaching the river channel through surface flow thus increasing the river runoff.

Conclusions

Dissemination of sediments is uniform in basin of Šventoji river. The basin is covered by loam in average 57% by sand in 33% of the overall and of the parts of the basin. Loam areas in the sections increase moving to the direction opposite the river bank from 40% to 64% of section area; sand areas are the largest near the river, in the section 0–50 m; clay areas are distributed unequally. Sand and swamp areas had inversely proportionate influence on river runoff. Correlation coefficient of 0.89 (reliability 0.02) obtained using the Water balance formula, it can be used for runoff calculations in Šventoji basin.

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