ENVIRONMENTAL ENGINEERING

The 8th International Conference
May 19–20, 2011, Vilnius, Lithuania
Selected papers

ISSN 2029-7106 print / ISSN 2029-7092 online
ISBN 978-9955-28-828-2 (2 Volume)
ISBN 978-9955-28-827-5 (3 Volume)
http://enviro.vgtu.lt

ASSESSMENT OF THE IMPACT OF ANTHROPOGENIC ACTIVITIES ON THE FLOW OF THE RIVER VILNIA BASIN

Migle Vedrickaite[1], Lina Bagdziunaite-Litvinaitiene[2]

Faculty of Environmental engineering, Department of Hydraulics, Vilnius Gediminas Technical University Saulėtekio ave.11, SRK-II, LT-10223 Vilnius, Lithuania.
E-mails: [1]mig.vedr@gmail.com; [2]lina.litvinaitiene@vgtu.lt

Abstract. River flow is one of the most important links of the water circulation in the nature which describes general water yield and potential water resources of a river basin. Since the range of the flow change is best illustrated by very long-term data of water measuring stations that include flow measurement sequences and the Lithuanian Hydrometeorological Service is carrying out hydrological observations of the river concerned in one spot- in Vilnius, at the point before Vilnia flows into the river Neris - this data is not enough in order to assess the distribution of the river flow before the pond (potential anthropological impact on the flow) and after it. During the investigation, water level was being measured in selected measurement points of the river. According to measured water levels average monthly debits were derived and coefficients closely related to the measurement points were calculated. Recalculated average monthly debits for the sequence of 1993-2009 have showed that the biggest leap of the flow occurs between points 1 and 2; sudden increase of the flow of this section was influenced by the pond Margiai. In spring, water which is collected in the pond after the snowmelt is released in small quantities to the river Vilnia. Distribution of the flow is most distinct at the end of limiting seasons. The most sudden changes occur in the months of April-May and August-September.

Keywords: flow, anthropogenic activities, water level, debits.

1. Introduction

Long-term observation data of the flow change allows assessing the flow of the rivers of Lithuanian in different aspects: to identify average values-norms, to evaluate the nature of fluctuations, the amplitude of extreme values, typical and exclusive features of the hydrological regime. The flow of the rivers depends on many natural factors that may be classified into 3 main groups: climatological, physical-geographical and anthropogenic factors (Meilutytė-Barauskienė *et al.* 2008; Kiprijan 2007).

Investigations of cyclical fluctuations of the flow of the Lithuanian rivers started more than 50 years ago (Macevičius 1959; Jablonskis 1980). During the investigations it was found out that the nature of cycles of the water yields is climatological (between the flow and temperature reverse dependency was observed) and the change of the flow is determined by the air temperature (Bagdžiūnaitė-Litvinaitienė 2005). According to Pauliukevičius (2007), climate conditions determine the amount of water which gets into the basin of the river together with precipitation; the annual flow is mostly affected by the climate factors and the biggest and the smallest flow is affected by physical-geographical and anthropogenic factors. Influence of the climate variations on geographical processes in Lithuania has been investigated by Bukantis *et al* (2001); climate change has been also addressed by Balevičius et al (2007), Bukantis et al (1994; 2007), Stankūnavičius (2006) Stankūnavičius et al (2007), Valiuškevičius *et al* (2005) and many other authors. In their articles they state that according to the future forecasts, there will be more frequent high waters in all year seasons, smaller spring floods and higher possibility of the minimum flow in summer, which will increase the biological pollution in the summer and decrease the general pollution in the spring. Due to more frequent recurrence of extreme precipitation, the risk of very strong high waters localised in unusual locations will increase. Upon increase of the air and water temperature, the rate eutrophication processes will increase and the quality of water resources will deteriorate.

Results of the anthropogenic activities that are carried out at the basin of the river can have direct influence on the flow conditions, for example, farming activities, i. e. drainage, pond installation; the flow may also change due to indirect anthropogenic activities (by changing physical-geographical factors): swamp drainage, variation of agricultural area in use. The significance of such factors to the flow regime is unlike and more difficult to assess (Pauliukevičius 2007). After a pond is installed in a river basin, annual distribution of the river flow as well as evaporative loss are changed. Whereas ponds are usually installed for irrigation or recreation purposes, each banked up water body also affects its environment (Pašvenskas 2000; Pauliukevičius

2004, Kriaučiūnienė 1998). Changes of indicators of the seasonal flow of banked up rivers show that the annual flow distribution in the rivers of the southeast Lithuania is the most even - it becomes even because of abundant underground supply during abatements: the flow of the spring flood decreases by 3.1-14.6%, summer-autumn flow increases by 0.9-11.7%, and the winter flow increases on average by 5.3 % (Gailiušis *et al* 2000). According to the data of long-term observation analysis, months March-April are defined as the spring season, as Gailiušis *et al* (2001) has noted that the spring flood in average rivers usually ends in the third decade of April and in small rivers it usually ends in the first-second decade. Months May-August are attributed to the summer season, autumn-winter season consists of September-December and January and February of the next calendar year (Lukianas and Ruminaitė 2009).

When there is uneven annual flow distribution, water consumers face big problems as the water demand is almost the same during all year seasons; however, in most rivers of Lithuania 30-50 % of the entire annual flow flows during 2 months of the spring and if the year is dry, this number amounts to 60 %. Actual assessment of possibilities to use the resources of the surface flow is possible only after comprehensive evaluation of indicators of the flow distribution - coefficients of the flow variation and natural adjustment (Gailiušis *et al* 2001).

The objective of the research is to evaluate the influence of long-term anthropogenic activities (pond Margiai) on the flow of the river Vilnia.

2. Research subject and methodology

The river Vilnia, which was selected for the research, belongs to the river basin district of Nemunas, Nemunas basin, and the sub-basin of small tributaries of the river Neris (including Neris). The source of the river Vilnia is not far from Vindžiūnai village, 5 km south from Šumskas. The length of the river is 81.6 km; the area of the basin is 623 km^2.

The basin belongs to the main Southeast plain and Vilnia plain. In territorial point of view, it is dominated by forests that take up 50.13 % of the basin area, cultivated areas take up 34.85 %, urban territory -12.14 % and meadows take up 1.41 % of the basin area. River-network density is 0.50 km/ km2. (Gailiušis *et al* 2001). Precipitation in the concerned area is not abundant (approx. 700 mm). Vilnia is floating an average yield of 6 m^3/s to Neris and during especially dry summers, the minimum daily yield can be 1.8 m^3/s.

Different human farming activities have been carried out (and are still being carried out) at the river basin of Vilnia: installation of ponds, irrigation (drainage) works, agricultural activities (ploughing, meadows and grazing land). 22 % of the basin area has been irrigated. 2 major ponds are known in the area - Margiai and Rokantiškės.

Hydrological measuring station in the river Vilnia was installed in 1927. The embankment of Rokantiškės was installed at the time when observations were not being carried out in the river basin (in 1823), therefore it is difficult to assess the possible influence of the pond on the river. This can be done by using a method of the river analogue or by applying simulation. Whereas the volume of the embankment of Rokantiškės is relatively small (126 000 m^3), its influence on the flow of the river Vilnia will be not assessed in the present research. However, the volume of the pond Margiai, which was embanked in 1972, is 3.6 times bigger than that of Rokantiškės (454 000 m^3).

The assessment of the influence of a pond on a river is easier to make when this pond is closer to the gauging station. Lithuanian Hydrometeorological Service (LHMS) is carrying out hydrological observations in the river Vilnia only in Vilnius, before Vilnia flows into Neris, yet for the assessment of the distribution of the river flow before and after the pond Margiai this data is not enough. There is a distance of 54.4 km between the pond Margiai and the estuary, therefore 4 measuring points (Fig. 1) were selected for the assessment of the flow distribution.

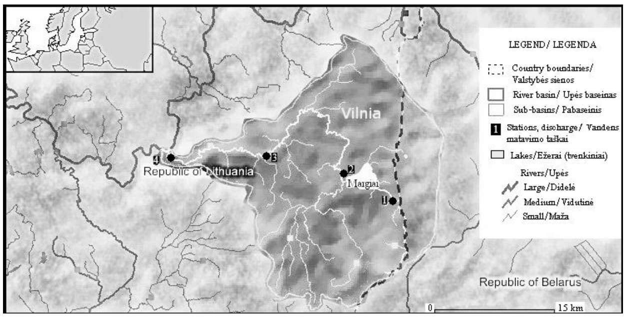

Fig 1. Locations of the selected observation points in the river basin of Vilnia

The first measuring point was selected near the frontier of Belarus not far from Užtilčiai settlement. The second point was selected near the village of Pabražuolė, after the pond Margiai near the former embankment (hydroelectric power station of Lavoriškės). The biggest tributary of Vilnia - Kena - is meeting the river berween the first and the second points; in this stretch, there are also 2 diffused pollution sources. The third measuring point was selected approximately 20 km to the estuary of Vilnia after Mickūnai settlement. Between the second and the third measuring points, there are also 2 diffused pollution sources. The fourth point is near the gauging station installed by the LHMS in Vilnius city, before Vilnia flows into Neris and 400metres to the estuary. During the reporting period, in the stretch 3-4, there were 4 diffused pollution sources. Boundaries of Vilnia river basin, locations of measuring points and ponds are shovvn in figure 1.

For the Identification of the flow distribution during the year in different water yield period, the alternation of the flow variation coefficients d was analysed in two different ways: by calculating the distribution of the flow variation coefficient d for one year and by calculating the flow variation coefficient with eliminated influence of the basin area, lake percentage and sandy ground. Indicator of the flow variation coefficient does not depend on the annual water yield, is characteristic of low alternation and therefore even small changes of it can be crucial.

During the assessment of the annual flow distribution at different water yield periods, the alternation of the flow variation coefficients d is analysed in two ways. In the first case, a variation coefficient d defines annual distribution of the flow between watery and dry seasons and provides quantitative evaluation of the flow deficit up to the value of average annual debit; calculations are based on the method described by Gailiušis *et al* (2001) and by applying the following formula (1):

$$d = \frac{\sum Q_p - Qt_p}{365(6) \cdot Q}, \qquad [1]$$

where: ΣQ_p – daily sum of flows during the period t_p where flows Q_p are bigger than the average yearly flow Q.

In the second case runoff's saltatory coefficient is calculated by eliminating physical-geographical features – the size of the basin, the geomorphological structure of the basin, the composition of the soils and lakiness of the basin (Gailiušis and others 2001):

$$d = \left[d_{500} - c \lg \frac{A+1}{500} \right] \cdot \left[1 - 0{,}15 \sqrt[5]{A_{e\check{z}}^2} \right] \cdot \left[1 - 0{,}6 A_{sm} \right] \qquad [2]$$

where: d_{500} – a value of runoff's saltatory coefficient in a hydrological area to the river's basin that has an area of A = 500 km^2, d_{500} accordingly to its distribution in Lithuania it is equal to 0,45 (Gailiušis and others 2001), c – tangent of the angle of bank of linking line (in southeastern Lithuania c = 0,08), A – area of river basin, km^2, $A_{e\check{z}}$ – lakiness of a basin, %, A_{sm} – sandiness of a basin. The amount of sand soils in the basin is evaluated not in percent but in parts (A_{sm} = 52 %).

3. Results and its analysis

When assessing the seasonal distribution of the flow, water level was measured once a month at 4 measuring points and according to the results, average monthly debits for locations of measuring points were calculated. Comparison of the data of the 4th measuring point - which is closest to the LHMS water measuring station - with long-term hydrological observation data (fig. 2) shows that the reporting year belongs to one of the most watery periods: annual debits of the aquaculture of 2008-2009 were the greatest (Q_{sum} = 278.9 m^3/s) in the 16 year observation period (1993-2009); during the same period, there were greatest debits of the limiting period (drought with a debit of 97.6 m^3/s) and the greatest debit of the limiting season (summer) (38.5 m^3/s).

When assessing the influence of the pond Margiai on the flow, experimental research, which was carried out by measuring water level once a month for a year, was used. Coefficients were found out by additionally using data collected by the LHMS for the year 1993-2009, according to the average multi-annual debit (5.24 m^3/s) and average monthly debits of the year observed in the research. Coefficients were used for recalculation of the seasonal distribution of the flow in locations of 4 measurement points for the period of 1993-2009 (fig. 3).

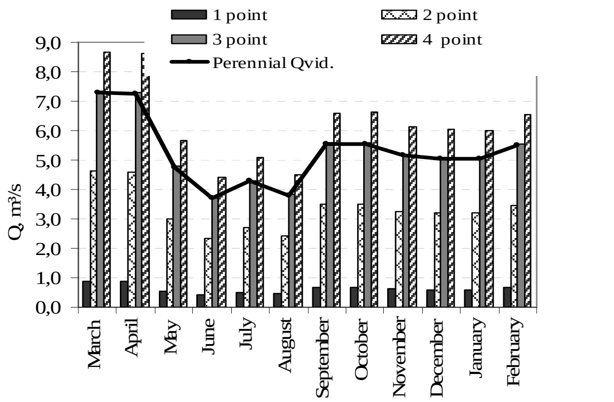

Fig 2. The characteristic discharges by Vilnia river at Vilnius (54°41'06.75"N and 25°17'45.57"S) Water Measurement Station

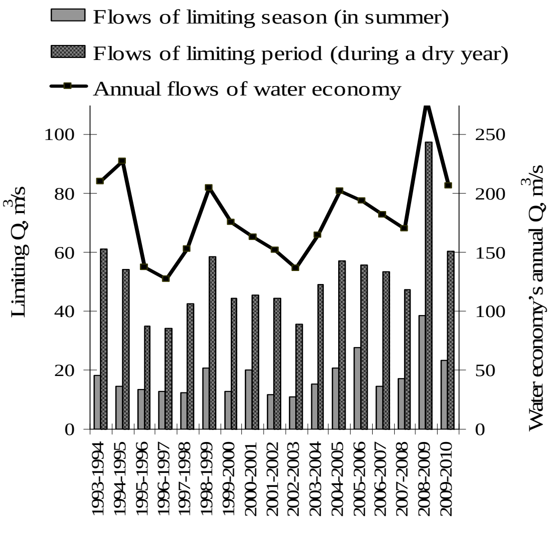

Fig 3. The distribution of a runoff of Vilnia river during the selected period (1993-2009)

Based on the research results and graph in figure 4, it was found out that the most sudden leaps of the flow occurred between points 1 and 2; in this section, the rivers Bražylė and Kena, the latter being the biggest tributary of Vilnia, flow into the river. The pond Margiai is between these points. On average the flow between the points increases by 2.70 m^3/s; maximum difference of the flow between the points occurred in the months of March-April (3.75 and 3.73 m^3/s), minimum difference occurred in June (1.90 m^3/s). There is 11.3 km distance between the measurement points, height altitude from the point 1 to the point 2 falls by 10 metres. Increase of the flow between measurement points 2 and 3 changes by 1.38-2.72 m^3/s, on average the flow increases by 1.96. The tributary Taurija flows into Vilnia in the section under investigation, the length of which is 32.6 km, height altitude falls by 15.8 metres. Between the points 3 and 4, the height altitude falls by 50.4 metres but the debit is the most constant (alternates by 0.85 m^3/s). Length of the section is 20.7 km; tributary - Kyvė.

The suddenly increased difference of the spring flow between the points 1 and 2 is influenced by the pond Margiai, which is intersected by the river Vilnia; the pond performs the function of water accumulation - the water from the melted snow is collected in the pond and it is later, during the dry season, released in small quantities to the river Vilnia.

We will not compare the influence on the flow before and after the pond Margiai was installed as it has been done by Gailiušis et al (2000) when analysing banked rivers of Lithuania. For their analysis, they have used the debit values of the river Vilnia (confluence) of the period 1952-1992; after they had calculated variation coefficients d of the seasonal flow before and after the installation of the pond, they noticed that the alteration of the seasonal flow of the river Vilnia downstream the pond Margiai was the biggest of all analysed rivers (14.6 %).

The biggest part of the summer-autumn season flow (44.2%) is also attributed to Vilnia. Gailiušis et al (2000), in their work, have found out that the influence of the pond on the summer-autumn season flow is the weakest when compared to other seasons and after the river had been embanked (in 1972) the flow increased by 11.7 %. After the embankment, the winter season flow has increased by 2.9 %. Having compared the flow of each day of one year (2008) with the average multi-annual seasonal flow (1993-2008), we see that in the entire spring season (months of March-April), the flow *b* exceeds the average multi-annual debit ($Q_{vid} = 5.23$ m^3/s).

The comparison of 1993-2008 seasonal flow variation shows that the biggest flow occurs in spring (fig. 5). The flow values b of 2008 for the spring season were up to 1.929 times greater than the average multi-annual debit (fig. 6) and those of 1993-2008 were 0.915 times greater. During the entire period, averagely smallest debits occur in the dry period, i. e. months of May-September. The biggest flow variation d becomes apparent in August when there are the smallest debits in the river.

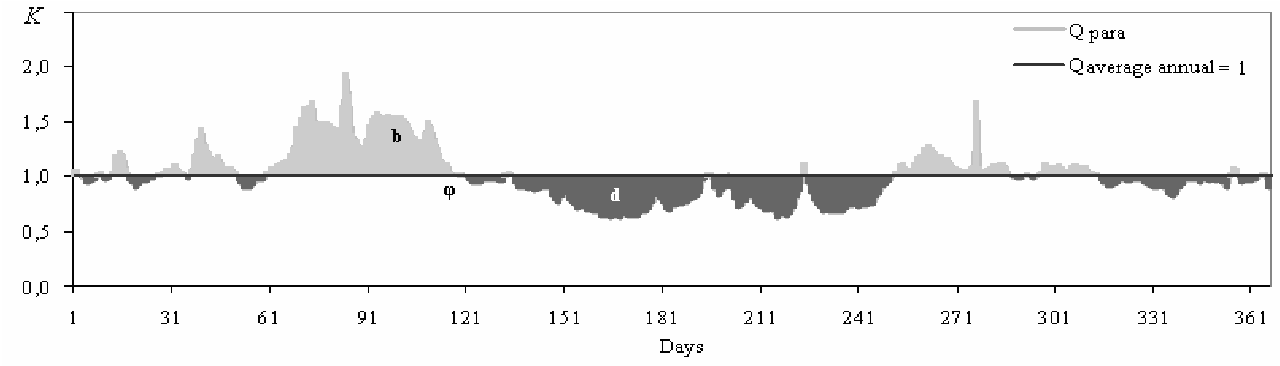

Fig 5. During the period of 1993 –2008 the distribution of distortion coefficients *d* and *φ* of the annual runoff (*K* – ratio of a daily flow with an average annual flow; *d* – distortion coefficient of a runoff; *φ* – a natural adjustment coefficient of a runoff; *b* – runoff above an average flow)

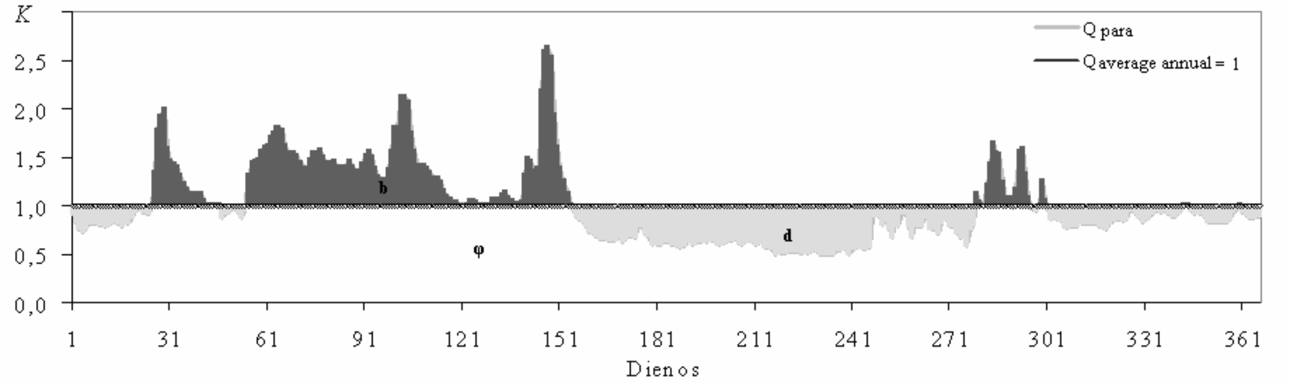

Fig 6. During the period of 2008 the distribution of distortion coefficients *d* and *φ* of the annual runof (*K* – ratio of a daily flow with an average annual flow; *d* – distortion coefficient of a runoff; *φ* – a natural adjustment coefficient of a runoff; *b* – runoff above an average flow)

In the analysis of seasonal flow variations of a single year (2008) (fig. 6), the biggest variation was observed in the summer season at the end of May when the flow *b* was 2.65 times bigger than Q_{vid} (13.73 m^3/s). The smallest flow occurred in the dry period on August 27 - the debit then was 2.32 m^3/s. The biggest flow variation *d* was 0.495 times smaller than Q_{vid}. In 2008, the flow variation occurred not only in August but also in the beginning of September, in November, December and January - variation values were 0.495-0.996 time smaller than the average debit; the flow b exceeding Q_{vid} was also recorded in January-February intersection (2.005) and in October(1.66).

Comparison of curves in figures 5 and 6 show that the distribution of the variation coefficient *d* of the seasonal flow defines the annual distribution of the flow between wet and dry seasons and provides quantitative evaluation of the flow deficit up to the value of the average annual debit. Seasonal flow variation coefficient *d* values calculated according to the formula (1), in the analysis of a single year (2008), falls up to 0.495 times and in the analysis of long-term observation data, they fall up to 0.383 times (difference is 0.11). Whereas according to the formula (2), by eliminating physical-geographical characteristics of Vilnia river basin, when it is taken into account that geomorphologic structure of the river basin, composition of the soil and lake percentage have big influence on the hydrological regime of the Rover and in the territory of Vilnia river basin lake percentage is 1.4 % and it is predominated by sandy soil (51.74 % of total basin area), the flow variation coefficient is 0.416. Differences of the flow variation coefficients calculated according to formulas (1) and (2) are not big: the difference of the year 2008 is 0.079 and that of 1993-2008 is 0.031. According to the assessment of the seasonal distribution of the flow in a single year, the difference is bigger since uneven distribution of the river flow depends also on the relation of climate factors with individual seasons. The calculated difference of the flovv variation coefficients might have been influenced by unusual amount of precipitation - namely, in 2008, average monthly amounts of precipitation were significantly different from multi-annual ones and in the months of March-May, the amount of precipitation was relatively big.

4. Conclusions

Different human farming activities have been carried out (and are still being carried out) at the river basin of Vilnia: installation of ponds, irrigation (drainage) works, agricultural activities (ploughing, meadows and grazing land). 22 % of the basin area has been irrigated. 2 major ponds are known in the area - Margiai and Rokantiškės.

After seasonal distribution of the flow at 4 measurement points for the years 1993-2009 was recalculated, the biggest flow leap between points 1 and 2 was noticed (debit increases up to 3.75 m^3/s). The increase of the flow in the spring season between points 1 and 2 was influenced by the exploitation of the pond Margiai. The pond performed water accumulation function: the water from the melted snow is collected in the pond and it is later, during the dry season, released in small quantities to the river Vilnia.

The variation *d* of the seasonal flow, when calculated according to different methods, differed; in the first case, when individual year was analysed (2008), the values fall up to 0.495 time when compared to the average debit and according to the long-term observation data, they fall up to 0.383 (difference is 0.11). These differences occurred due to the climate change in individual seasons. When physical-geographical characteristics of the basin are eliminated, the flow variation coefficient is 0.416.

References

Gailiušis, B.; Kovalenkienė, M.; Rimavičiūtė, E. 2000. Tvenkinių poveikis Lietuvos upių nuotėkio režimui, [Influence on regime of rivers flow in Lithuania]. *Geografijos metraštis* [Annual of Geography] 33, ISSN 0132-3156.

Gailiušis, B.; Jablonskis, J.; Kovalenkovienė, M. 2001. Lietuvos upės. Hidrografija ir nuotėkis [Lithuanian rivers. Hydrography and runoff], Kaunas: Lietuvos energetikos institutas. 790 p.

Lukianas, A.; Ruminaitė, R. 2009. Periodiškai šlapių žemių sausinimo drenažu įtaka upių nuotėkiui [Impact of land drainage on the rivers runoff], *Journal of environmental engineering and landscape management*, 17(4): 226–235.

Meilutytė-Barauskienė, D.; Kovalenkienė, M.; Irbinskas, V. 2008. Lietuvos upių vandens ištekliai klimato kaitos fone [Water resources of Lithuanian rivers and their relations to climate change]. *Geografija* [Geography] 44(2): 1–8.

Pauliukevičius, H. 2007. Nuotėkį lemiančių veiksnių santykinė reikšmė ir regresijos lygčių taikymo galimybės [Relative significance of the runoff formating factors and possibilities to apply the regression equations]. *Vandens ūkio inžinerija* [Water Management Engineering], 31(51): 58–65. ISSN 1392-2335.