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

RUNOFF FLUCTUATION IN RIVER BASINS OF DIFFERENT SIZE IN REGARD TO METEOROLOGICAL CONDITIONS

Lina Bagdziunaite – Litvinaitiene[1], Vilma Vertelkaite[2]

Vilnius Gediminas technical university, Saulėtekio ave. 11, LT–10223 Vilnius, Lithuania.
E–mails: [1]lina.litvinaitiene@vgtu.lt; [2]v.vertelkaite@gmail.com

Abstract. It is very important to keep a close watch on river runoff, because this is one of the indicators that show changes in the climate. Meteorological conditions alter with climate getting warmer and therefore influence river runoff. The purpose of this article is to determine the influence of the changing meteorological conditions to the run-off of different size river basins. Two river basins are being analysed (Venta by Papile and Krazante by Pluskiai), both located in Western hydrological area. The average daily flow and meteorological data (precipitation and average temperature) are of the period 1968–2008. It shows the most watery years for the rivers and helps evaluate the influence of the meteorological conditions to the runoff. Statistical and regressive analysis and coefficients of correlation are established as well. Evaluated influence of percipitation is unquestionable though variable. Sometimes even a small amount of percipitation challenges big changes in runoff, though next time having big percipitation runoff flactuates just marginally. In large river basins such influence is noticable few days later, and in small ones percipitation often changes the runoff the same day.

Keywords: runoff, river, precipitation, air temperature, climate, basin, flow.

1. Introduction

Closed water circuit provides inexhaustible water resources. However, this circuit is a constant redistribution of water resources in time and space. Quantity and distribution of water supplies depend on climatic and meteorological conditions of the specific area and changes every year – there are very watery or very dry periods (Miseckaitė 2010).

The relevant and frequent subject of recent is a climate warming. It also affects water supplies. The climate influences watery of the year, runoff phase periods. Runoff is also determined by surface of the floor – size of a river basin, lithologic composition, and quantity of forests, lakes and wetlands in a basin area (Litvinaitis 2010). According to A. Dumbrauskas (2000), the process of surface runoff formation largely depends on rainfall structure. The distribution of rain intensity during the storm depends on significantly changing meteorological conditions.

It is important to keep track of climate change, to capture, analyze and predict the impact they may have on the environment, particularly how it may affect river runoff (Meilutyte–Barauskiene 2009).

J. Kriauciuniene (2009) and her colleagues analyzed climate change influence on runoff by using the new ECHAM5 and HadCM3 climate scenarios in Merkys river and found that from 2001 to 2100, the average flow rate can be reduced by 50 percent in comparison with the background period from 1975 to 1984. K Kilkus, A. Staras, E. Rimkus and G. Valiuskevicius (2006) also examined the impact of climate change on water balance changes. They also found decreasing trends of runoff. Many of the calculations showed the future decline in the spring floods. It is also likely that autumn floods in the rivers of Western Lithuania almost become one with the spring floods. Runoff is expected to increase at the beginning of warm periods, but it is likely to decline slightly afterwards.

Annual and seasonal precipitation changes has been also analyzed a number of times. It was found that the average annual air temperature of a period 1991–2006 compared with 1961–1990 rose from 0,7 to 1 ° C, which indicates a rapid climate warming. The most prominent warming trends were in Western and Northern Lithuania, precipitation during the same period have changed differently however: in the whole country precipitation decreased in September, November and December, but increased in January, February and October. In Western Lithuania precipitation decreased even by 18–35 per cent in July, where in June precipitation decreased by 21–22 percent in Central and Eastern Lithuania. (Bukantis *et al.* 2009; Rimkus *et al.* 2007).

Foreign scientists recognize as well that the climate is warming rapidly. A .S. Goudie (2010) analyzed the changing climate in his works, and found that there is clear evidence that during recent increasingly warming years precipitation become more intense. I. Pfister (2004) and his colleagues confirmed that during the second half of the twentieth century the quantity and intensity of precipitation increased 10 times. That can be seen by monitoring the recent more and more frequent unseasonable floods all around the world.

The aim of this work is to determine the influence of meteorological conditions to the runoff of different size river basins.

2. Materials and Methods

Two Western hydrological area rivers of the different size river basins have been selected for the research : the Venta (near Papile) and Krazante (near Pluskiai) (Fig1). In this area, the main power source for the river is rain. It makes up 40–70 percent of the total runoff (Jablonskis and Janukėnienė 1978).

Winters with frequent thaws and lots of precipitation are typical for the Western region of Lithuania. Sometimes it rains even in winter, as it was in 2007–2008 (Ciuberskis *et al.* 2010). This region is characterized not only by mellow winter, but also by longer rainy autumn and later spring and summer.

Venta – one of the longest rivers in Lithuania, located in the Northwest. Its total length 343,3 km and has a length of 91,2 km up to Papilė water measurement station. At this point, basin area equals to 1570 km^2. The dominant river–bed depth is from 1 to 2 m. Papilė hydrological field was installed in 1933 and it is used for measurements of flow, water level, water temperature, precipitation and water supplies in the snow. Forest in Venta river basin cover 30 percent, lakes – 1,1 percent and wetlands – 8 percent. Predominant sediment distribution in Venta (near Papile) basin are as follows: sandy loam on loam – 53,15 percent, loam – 21,93 percent, sandy loam on sand – 7,77 percent, sand – 5,00 percent, clay – 3,96 percent, a lowland peat loam – 3,92 percent. The distribution of other deposits is negligible (Fig2).

Another analysed river is Krazante – the largest tributary of Dubysa river. Its overall length is 87,4 km. Its basin area at Pluskiai hydrological station is 221 km^2. This station set flow rates, water levels, water temperature and precipitation. Forests in Krazante basin cover 22 percent, lakes – 0,3 percent and wetlands – 16 percent. Predominant sediment distribution in Krazante basin are as follows: sandy loam on loam – 43,75 percent, loam – 33,39 percent, sand – 6,78 percent, a lowland peat loam – 4,78 percent, lowland peat in the sand – 4,61 percent, clay – 4,00 percent. Other deposits also constitutes a very negligible part (Fig 2).

Venta (near Papile) and Krazante (near Pluskiai) basins and Laukuva and Siauliai meteorological stations are presented in Figure 1.

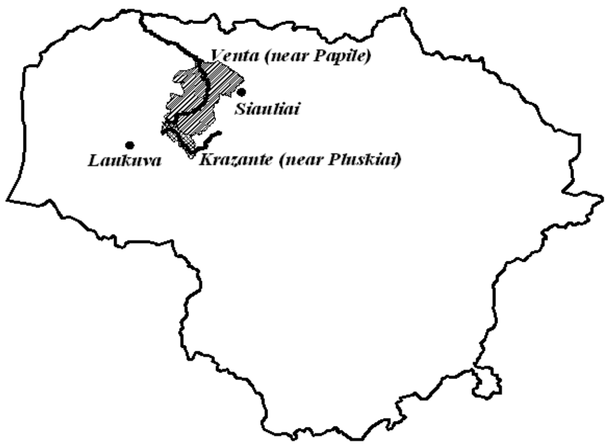

Fig 1. The basins of Venta (at Papile) and Krazante (at Pluskiai)

Distribution of sediments in Venta and Krazante basins are presented in Figure 2.

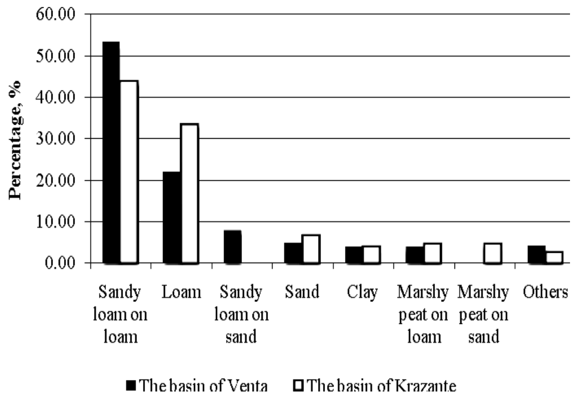

Fig 2. Sediment distribution in Venta and Krazante river basins

The paper analyzes the maximum, medium and minimum watery years in both rivers over forty years period (1968–2008). The hydrologic and meteorological parameters such as flow, precipitation and average air temperature were chosen for the investigation. The data have been taken from the Lithuanian Hydrometeorological Service (LHS).

Homogeneous data series have been established for forty years period. By using statistical analysis of nonparametric Mann–Kendall test, which is recommended by the World Meteorological Organization, the parameters of river flow trends have been established (30% confidence level) as well as significant positive or negative trends (5% confidence level) (Irbinskas *et al.* 2008). According to probabilities maximum, medium and minimum watery years are distinguished. The election of two years is made to ensure the reliability of the results. Then, the reliability and correlation relations between flow and precipitation of each month of selected years are determined.

It was found, how many days it took until Venta (near Papile) and Krazante (near Pluskiai) basins reacted to the out fallen precipitation.

Detail analysis was carried for the days when for a certain time there was no precipitation but flow changes were recorded. Also the dates are examined when there was lots of precipitation but it absolutely had no effect on runoff.

The infiltration coefficients of two selected basins at one of the most intense rainfalls, and average water resources resulting from precipitation have been calculated.

3. Results and Discussion

The evolution of analyzed rivers runoff during forty years period (1968–2008), can be seen in Figure 3. Venta (near Papile) and Krazante (near Pluskiai) flow rates have similar trends.

In both rivers frequency rate of flow repetition is almost the same, but because of more precipitation, which can lead to bigger changes in smaller basin, Krazante river distinguishes with more frequent watery increase. There are four time different flow rates in a seven time bigger basin areas. Also there are visible Venta (near Papile) river flow increasing trends and a slight flow decrease in Krazante (near Pluskiai).

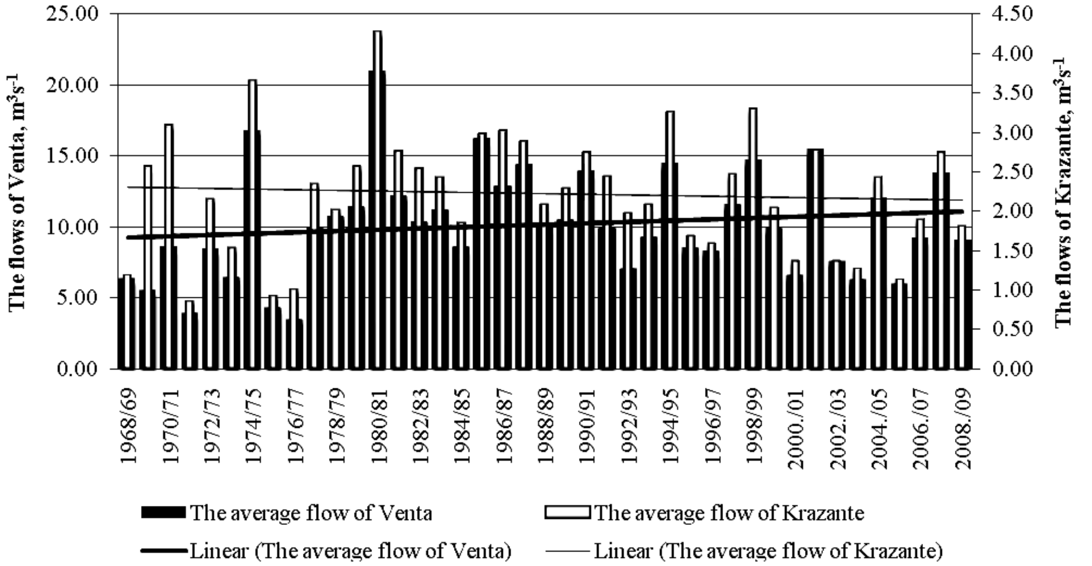

Fig 3. The maximum flow of the rivers Venta (near Papile) and Krazante (near Pluskiai) in 1968–2008 meteorological station

Precipitation – the main surface element of the Earth involved in water balance. The moisture quantity of the Earth's surface cover, watery of the rivers, level of floods or duration of droughts all depend on the amount of out fallen precipitation (Miseckaite 2010).

The data in Figure 4 shows that at the meteorological station Laukuva there are 30 percent more precipitation recorded than at the Siauliai meteorological station. It is likely that this phenomenon is influenced by the geographical position of Laukuva meteorological station.

The amount of precipitation has increased about 20 percent in both stations in spring in the last decade, and has only increased about 10 percent in winter. Also, in both stations summer and autumn seasons distinguishes by abundant precipitation during the second and fourth decades. As it is typical for the western region of Lithuania, the least precipitation falls in spring (Ciuberskis *et al.* 2010).

It is clear that the average air temperature measured at Siauliai meteorological station has risen by about 1 ° C during all seasons in the last decade, but at the meteorological station Laukuva 1 ° C temperature rise can be seen in spring and winter only. There is a visible increase in temperature during other seasons as well, which is likely to be influenced by climate change, but it is not very significant – about 0,1 to 0,2 ° C.

It also shows that during three out of four decades, the average air temperature in Siauliai meteorological station has been recorded higher than in Laukuva. Only in the second decade (1978–1987) air temperature in both meteorological stations leveled up.

After having evaluated the infiltration of the two rivers in question at one of the most intense storm during the whole forty years (1968–2008), it was found that almost all precipitation is absorbed, except in urban areas on the clay loam and soil. There, because of a variety of impervious surfaces water runs off into surface water bodies.

After calculating the average annual water resources in Venta (near Papile) river basin, it appears that 16440300 m^3 of water accumulates in the basin, where after calculating the same average annual water resources in Krazante, it appears only 8354694 m^3 of water accumulates. It shows that the precipitation resulting in two different river basins differ twice.

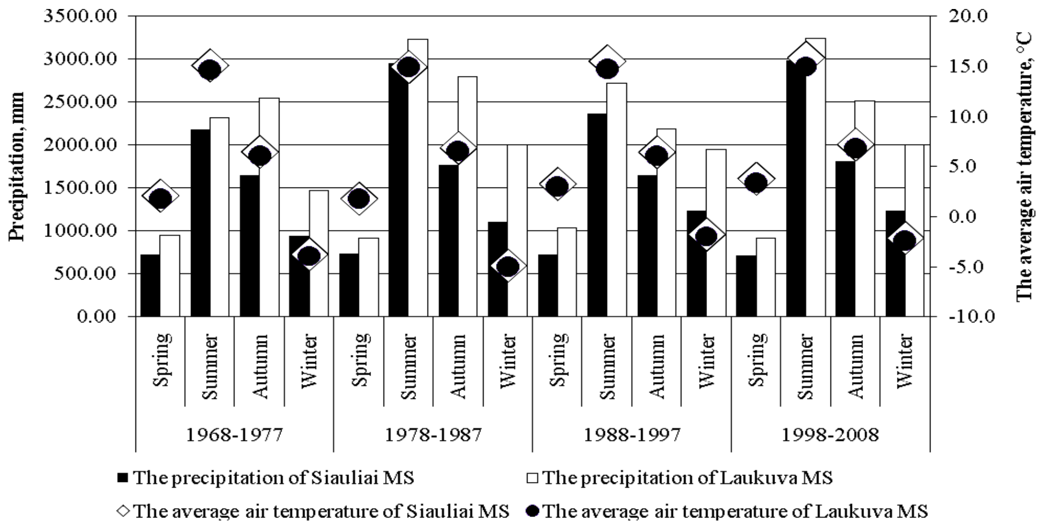

Fig 4. Precipation and average air temperature in Siauliai and Laukuva meteorological station 1968–2008

After four decades of statistical analysis nonparametric Mann–Kendall test, the results show more significant trends than the overall seasonal analysis of forty years. Here, three important negative and one significant positive trends are determined in all five–year spring seasons in Krazante river, and it shows the decrease of runoff. Previous calculations showed that the period of 1978–1987 is most watery, so the significant positive trends are visible in Krazante and Venta rivers, indicating the increase of runoff. During 1968–1977 period Spearman's Rho test shows significant negative trends in Venta river in spring, and significant positive trends in winter. Decreasing trends in river Krazante are visible in winter. The general analysis of a period 1968–2008 indicates significant negative trends in spring for both rivers and significant positive boost to Venta river in winter.

Examination of the Venta (near Papile) and Krazante (near Pluskiai) rivers during forty years (1968–2008), average flows and percipitation, the six maximum, medium and minimum watery years were determined according to the probabilities. The maximum watery years in Venta (near Papile) are 1980 and 1974, the medium watery years – 1991 and 1999, and minimal watery years – 1971 and 1976. In Krazante (near Pluskiai) maximum watery years were also 1980 and 1974, medium watery years – 1989 and 1972 and minimum watery year – 1975 and 1971.

According to the precipitation maximum watery years in Venta (near Papile) were 1998 and 1980, medium watery years – 2006 and 1993 and minimum watery years – 1976 and 2005. Year 1980 coincides perfectly with the maximum watery flow rates. Therefore, it is not surprising that the heavy precipitation that year formed a big runoff. In other watery years, precipitation also equals, although is not as accurate (differ in 1–3 positions).

In Krazante (near Pluskiai) the maximum watery years according to precipitation were under 1981 and 1990, medium watery years – 1994 and 1987, and minimum watery – 1996 and 1971. Here year 1971 coincide perfectly – as minimum watery years. This also explains why the minimum river runoff was fixed. Distribution of precipitation according to probabilities also equals to the distribution of flow rates, although it is not exact. (The difference in the river Krazante is a bit higher by 3–7positions).

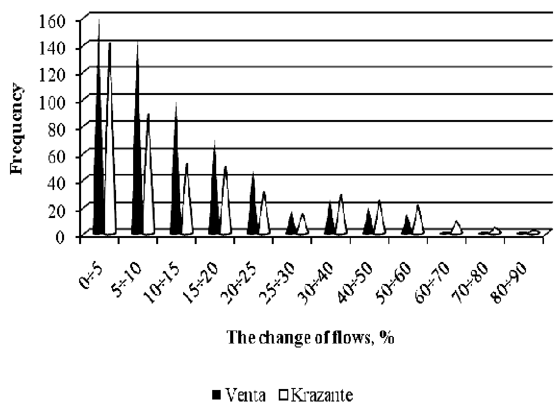

Fig 5. The frequency of flows discharges during 1968–2008 period in Venta and Krazante rivers

Figure 5 shows changes in Venta (near Papile) and Krazante (near Pluskiai) river flows in maximum, medium and minimum watery years, influenced by precipitation. As can be seen in both rivers often flow rates changed very little – up to 5 percent. A based visible decline from 5 to 25 percent in Venta while a change of precipitation in the same number of times from 10 to 20 percent in Krazante. From 30 to 60 percent flow rates in Venta changed very rarely, and from 60 to 90 percent have not changed at all during all the years analyzed. Since the basin of Krazante river is much smaller, it caused almost double flows, although they were not often. The largest impact precipitation had on Krazante in August, September, October, December and February. In December and January runoff significantly changed at the time when the weather got warmer and from negative temperature became positive (temperature rose to about 2°).

Also, there have been determined monthly correlation relations between flows and precipitation of the analyzed six years. Reliable correlation relations were obtained (when $p < 0,05$), but only in some months. During the maximum watery years of 1980 in Venta (near Papile) reliable crelations were every month, except November and they ranged from 0,37 to 0,83. Another maximum watery year – 1974, where the correlation relations were in May, November and January. Here the correlation coefficients ranged around 0,50. During medium watery years – 1991 and 1999 the correlation determined in months of June and November, and ranged from 0,42 to 0,72. In 1971, minimum watery years a reliable relations were only in May (0,51), and in 1976 July and September (~ 0,50).

There are more reliable correlations relations found in Krazante (near Pluskiai) river and the ties are stronger. It is influenced by smaller basin area in which environmental factors have stronger effects. During maximum watery years of 1980 a correlation was found in June, July, August, September, October, December and February. Here the correlation coefficients ranged from 0,53 to 0,88. In 1974, a correlation is visible in July, August, October and January (0,42 to 0,76). During medium watery years of 1989 and 1972, the correlation was established in May and June (0,51 to 0,81). In 1989 August, November, January and February reliable correlation ranged from 0,67 to 0,76. During minimum watery years of 1975 and 1971 the correlation was also established. Here it appeared in May, July, August and November, and changed within the range of 0,44 to 0,73.

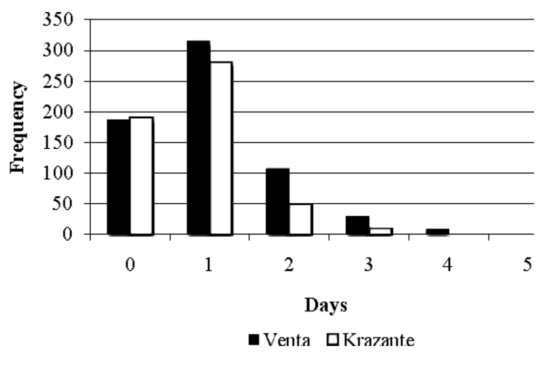

Fig 6. The period where the flow changes due to influence of precipitation

Figure 6 shows the changes of flows influenced by few days precipitation.

In Krazante river, due to the smaller size of a basin, which can react more quickly to changes, runoff often responded the same day. One day after more often in Venta than in Krazante precipitation affected runoff. Having larger basin of Venta it is more often visible the reaction in two, three, four and even five (only once) days. Four or five days after the reaction in Krazante are not observed. However, the calculation shows that 122 times more often the precipitation caused runoff in Venta than in Krazante.

Throughout the six analyzed years there were cases when the runoff suddenly rose but the precipitation did not appear for about a week. There were also cases where quite a large amount of precipitation dropped, but the runoff did not respond to them at all.

In Venta (near Papile) during maximum watery years unclear increase of the flows almost not occurred (four times). And those several times were in spring when the outdoor temperature rose above 0°C. Here, however, flow rates changed only about 10 percent. During medium watery years flow rates changed more frequently (13 times) and changes were more prominent. The most visible changes can be seen in September, they range to 21–44 percent and it happened because the temperature increased. During minimum watery years the changes in flows result in a very large number (34 times). Most of them are not very high, ranging from 30 to 20 percent. The changes appear bigger in July, August, September, and then range from 20 to 50 percent.

In Krazante (near Pluskiai) trends are the same: during maximum watery years flow rates rarely increase without precipitation (also four times), and during minimum watery years – the changes in flow are very common (23 times). Flow rates in Krazante river change negligibly: only 10 percent. And only during minimum watery years occurr the cases (two times), when the flow rates increase to 60 percent. Temperature increase can be seen during bigger changes of flows.

It is noted that in Venta during maximum watery yeasr there are many cases (12 times), when precipitation does not affect anything. In most cases this happens when temperature drops by 1–2°C. During medium watery years such cases strongly decrease (five times). Here the precipitation do not affect the flow rates when temperature is decreasing but the temperature drop even to 0,1 to 6,9°C. During minimum watery years the precipitation just a few times (3 times) does not affect the flow and it occurs when the temperature goes up about 3 degrees. This happens only in middle of June.

Opposite trend prevail in Krazante river. Here during maximum watery years the precipitation does not affect the flow 15 times. This occurs when the temperature drops about 0,9 to 5,8°C. During medium watery years relatively high precipitation does not affect the runoff, but at the time when the temperature rises about 2 degrees. And during minimum watery years the precipitation appears much more frequently (28 times) than in Venta river, even though are not much when temperature decrease.

4. Conclusions

According to the probabilities of flows maximum watery years were detected in Venta (near Papile) river – 1980 and 1974. Medium watery years – 1991 and 1999, and minimum watery years – 1971 and 1976. In Krazante (near Pluskiai) river maximum watery years are exactly the same, medium watery years – 1989 and 1972, and minimum watery years – in 1975 and 1971. According to the chance of precipitation watery of the year is the same.

Laukuva station recorded 30 percent more precipitation than Siauliai station, but the water resources resulting from precipitation from Siauliai station is two times higher.

Following the relations of correlation between precipitation and flow in analyzed river basins, there was revealed that there are much more reliable correlations in Krazante (near Pluskiai) river and those ties are stronger. In Venta (near Papile) during maximum watery years in 1980 reliable correlation relations ranged from 0,37 to 0,8. During medium watery years – in 1991 and 1999 correlation coefficients ranged from 0,42 to 0,72.

In Krazante (near Pluskiai) during maximum watery years in 1980, correlation coefficients ranged from 0,53 to 0,88. In 1974 a correlation is from 0,42 to 0,76 range. During medium watery years in 1989 and 1972, the correlation coefficients are from 0,51 to 0,81. In 1989, correlation ranged from 0,67 to 0,76. During minimum watery years in 1975 and 1971 there was also the correlation established, there it changes from 0,44 to 0,73.

Runoffs in the basins of the analyzed rivers, which are influenced by precipitation, usually changed very slightly – up to 5 percent. From 60 to 90 percent. in Venta river they have not changed at all during the years analyzed, and in Krazante due to the smaller basin area changes have been recorded 15 times.

In Krazante river runoff often react the same day. One day after the precipitation more often afftect runoff in Venta than in Kražante. Because of the bigger Venta (at Papile) basin the reaction is often visible after two, three, four and even five (only once) days. The reaction after four or five days in Krazante river is not observed.

During the maximum watery years in Venta river the increase of flows that were not affected by the precipitation were almost none (only four times), but during minimum watery years such cases had occurred even 34 times. In Krazante (at Pluskiai) trends are similar: during maximum watery years such occasions were only four and during minimum watery years – 23 times. In Venta river it happened when the temperature rose, and in Krazante river – when the temperature fell.

In Venta river during maximum watery years 12 times out fallen precipitation did not affect thel runoff. It happened when the temperature decreased. During minimum watery years it only happened three times, and at that time the temperature rose. The opposite trends prevailed in Krazante: during maximum watery years the precipitation did not affect the runoff 15 times, while during the minimum watery years almost two times more: 28. In both cases, this happened when temperature dropped.

References

Čiuberskis, S.; Karčauskienė D.; Bernotas S. 2010. Klimato kaita ir žemės dirbimo minimalizavimas Vakarų Lietuvos regione [Climate Variation and Reduced Soil Tillage in Western Lithuania]. Research papers: Akademija. 88(41), 14–21. ISSN 1648–116X.

Dumbrauskas, A. 2000. Liūčių struktūros analizė ir paviršinio nuotėkio formavimosi skaitmeninis eksperimentas [The analysis of rainfall structure and the digital experiment of surface runoff formation]. Water management enginee-ring. 12(34).

Goudie, A. S. 2009. *Impacts of climate change* [online]. [viewed on January 08, 2010]. Available on the Internet: <http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t265.e203>

Irbinskas, V.; Meilutytė – Barauskienė, D.; Kovalenkovienė M. 2008. Lietuvos upių vandens ištekliai klimato kaitos fone. Geografija. Kaunas. 44(2), 1–8.

Jablonskis, J.; Janukėnienė R. 1978. *Lietuvos upių nuotėkio kaita* [Runoff changes of Lithuanian rivers]. Vilnius: Mokslas. 176 p.

Kažys, J.,; Rimkus, E.; Bukantis, A. 2009. Gausūs krituliai Lietuvoje 1961 – 2008 metais [Heavy Precipitation Events in Lithuania in 1961 – 2008]. *Geography.* Vilnius, T. 45(1), 44 -53.

Kilkus, K.; Štaras, A.; Rimkus, E.; Valiuškevičius G. 2006. Changes in Water Balance Structure of Lithuanian Rivers under Different Climate Change Scenarios. *Environmental research, engineering and management.* 2(36), 3–10.

Kriaučiūnienė, J.; Šarauskienė, D.; Gailiušis, B. 2009. Estimation of Uncertainty in Catchment–Scale Modeling of Climate Change Impact (Case of the Merkys River, Lithuania). *Environmental Research, Engineering and Management.* 1(47), 30–39.

Litvinaitis A. 2010. Pietryčių Lietuvos upių baseinų litologijos įtaka hidrologiniam režimui [The influence of lithology on the hydrological regime of Southeast Lithuanian rivers]. *In the 13th Young Scientists Conference „Science – Lithuanian's future", 2010, Vilnius, Lithuania.* Vilnius: Technika, 62–67.

Meilutytė – Barauskienė, D. 2009. Impact of climate change on runoff of the Lithuanian rivers, *Summary of Doctoral Dissertation*, Kaunas, 37 p.

Miseckaitė, O. 2010. Kritulių ir oro temperatūros įtaka sausinimo sistemų drenažu nuotėkio kiekiui [Influence of Precipitation and Air Temperature on the Amount of Drainage Run–off]. Research papers: Akademija. 88(41), 63–70. ISSN 1648–116X.

Pfister, L.; Kwadijk, J.; Musy, A.; Bronstert A.; Hoffmann, L. 2004. Climate change, Land use change and runoff prediction in the Rhine – Meuse basins. River Res. 20: 229–241.

Rimkus, E.; Kažys, J.; Junevičiūtė, J.; Stonevičius, E. 2007. Lietuvos klimato pokyčių XXI a. prognozė [Climate Change Predictions for the 21st Century in Lithuania]. Geography. Vilnius. 43(2), 37–47.