World Meteorological Organization

STUDY OF HISTORICAL FLOODS IN CENTRAL AND EASTERN EUROPE FROM AN INTEGRATED FLOOD MANAGEMENT VIEWPOINT

LITHUANIA

Submitted by: Lithuanian Hydrometeorological Service, Vilnius

For the WMO/GWP Associated Programme on Flood Management

Lithuania lies on the western fridge of the East European Plain in the area of the middle and lower course of the River Nemunas. Meridian orientated hilly uplands are vast accumulations of glacial drift, left behind by the melting inland ice especially at the contact of neighbouring ice lobes. Plains were formed in those places of the ice lobes, where the surface had been covered with ground moraine (Zinkus, J. 1986).

The climate in Lithuania is mainly influenced by the circulation of air masses what is characteristic of moderate latitudes. The mean annual precipitation (75 percent in the form of rain) varies from 540 mm in the central part of Lithuania to 930 mm on the south - western slopes of the Zemaitija Upland. In winter the greatest amount of it falls in the west and in summer in the east. Westerly winds are prevailing. The mean annual velocity of the wind on the Baltic coast is from 5 to 6 m/s and from 5 to 30 days a year the velocity of the wind exceeds 15m/s.

About 99 km of the Baltic south - eastern coastline belongs to Lithuania. Here the bottom of the sea is gently - sloping and the coast is low - lying with wide sand beaches and coastal dunes (marine depression, which is 15-20 km wide, with absolute heights up to 50 m and minus to 1.3 m). South - westerly winds, which dominate here, formed a long narrow coastal barrier, which separated from the sea a lagoon (Curonian Lagoon) that is connected to the Baltic Sea by the Klaipeda Strait (390 m wide). The eastern coast of the lagoon are low - lying and water - logged.

Located in the zone of excessive humidity, Lithuania has a dense river network. All Lithuanian rivers drain into the Baltic Sea: 72% via the Nemunas, 13% via the Lielupe, 8% via the Venta, 3% via the Dauguva and 4% via the others rivers. In Lithuania main rivers discharges 35-60% of the annual flow in spring. Extreme floods in Lithuania are in general caused by critical combination of flood generating factor such as heavy rainfall, saturated soils and intense snowmelt rather than by extreme precipitation alone. The discharge of rivers in western part of Lithuania varies considerably from others.

Climatic factor is one of the deterministic factors in the flood development processes. Warmer weather, cyclones, or storms that bring moisture and positive air temperature inland from the Atlantic ocean, can cause floods in the winter and early spring in the western areas of Lithuania and cause to break the river ice into huge slabs that the current pushes downstream. When these slabs pile up against some obstacle, they form a dam that causes water to pool upstream - and flooding results. Floods caused by ice jams are of high probability event in Lithuania. Ice jams in a short period of time can lead to flooding of big areas and cause flash flooding as well. Flash flood generating from ice jams can be slow, or fast rising depending on weather and river conditions over a period of hours or days (See example at Figure 1).

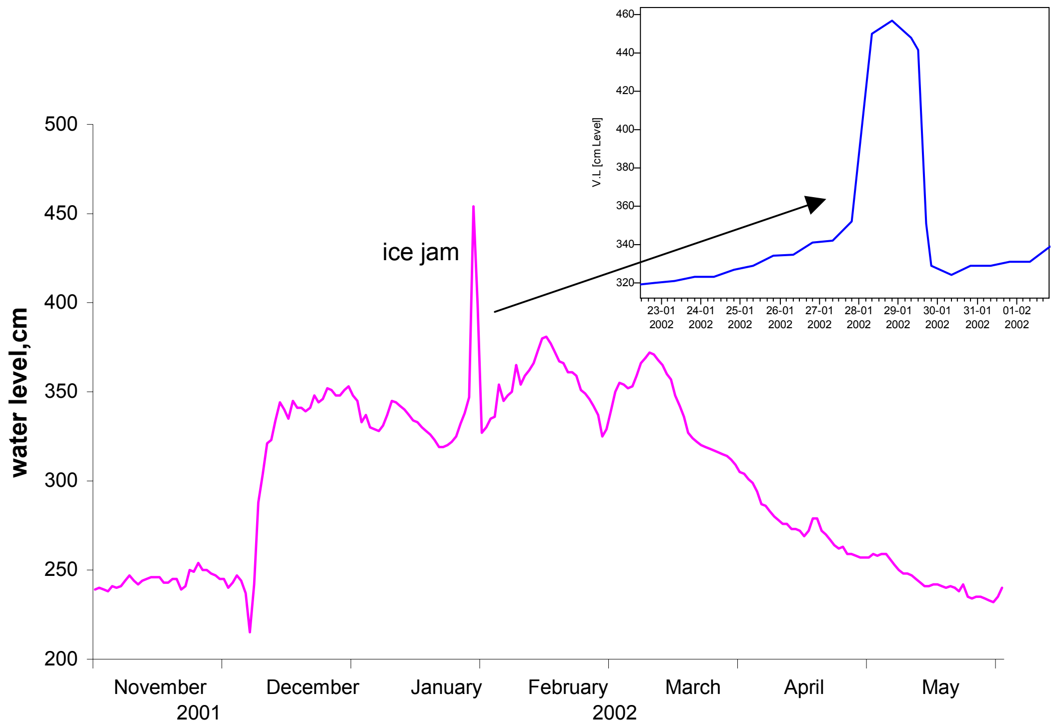

Figure 1. Ice jam level reached max in 20 hours and naturally collapsed next day.

There is no place so regularly affected by floods in Lithuania as the swampy Nemunas delta (Basalykas,1965). The most severe floods in the 20th century occurred here in 1917, 1951, 1958, 1994 (Barisas. A. 1977)

The delta of the River Nemunas starts at 48.1 km from the mouth, where the main river splits into two parts - Rusne and Gilija. The delta itself is shared by Lithuania and Russia. The whole area of the delta is equal to 930 square km. The biggest part of the delta belongs to the Kaliningrad District. In case of extreme flood, more than 700 square km of Kaliningrad side of the delta are being flooded. On the Lithuanian side an area of up to 500 square km will be flooded as well. Owing to the dike system built in 19th century (the first dikes were built in 1613-1616), the Kaliningrad District has the flood-protected area of 250 square km. The Lithuanian side of the Nemunas delta has been used for the extensive agriculture for a long time and was protected by the artificial polder system (where the excessive water is being removed by pumping) constructed in the beginning of the XX century. The polder system has recently become ineffective in protecting from floods and should be reconstructed due to the whole polder region is still remains an important area of agricultural production.

The flood development mechanism of the River Nemunas downstream is very complicated and depends on the amount of water equivalent of snow and soil conditions in the catchment's area, ice jams, freeze - up situation in the river mouth and Curonian Lagoon, storm-surge backwater level, meteorological conditions, regulating influence of the Kaunas Hydro-electric Power Station.

In an unstable winter regime with alternating periods of thawing and freezing when one or more break-ups of the ice cover may occur big areas are exposed to the danger and damage.

Every flood of the River Nemunas is caused economical damages. It is impossible to avoid any damages caused by extreme floods nowhere. The extent of floods is different from year to year. The frequency of extreme events in the delta is about 7-8 years. During extreme floods the extent of submersion reaches 30-40 thousand hectares of settlements, roads, hydrotechnical installations, communication lines causing damages to human property and nature.

1. Flood 1958

In April 1958 disastrous flood hit central and western part of Lithuania. It was the most grandiose flood in the delta of the River Nemunas known till 60th. The possibility of a recurrence of flood like this is once per 100 year. Flood was caused by intensive rain over a period of a few days. In 1958 spring had come unusually late (10-16, April), mean annual date is 18-22 in March. Nevertheless, the water equivalent of snow was high (up to 109 mm in some parts of the basin) and soil was strongly frozen (up to 60-95 cm). The spring flood in 1958 was extremely large. The area of 74 000 hectare in Kaliningrad District and 57000 hectare in Lithuania side was flooded. A lot of structures had been demolished, many dams washed out, protected areas suffered from overflowed waters. This flood was nominated as catastrophic. Mean annual discharge was exceeded 2,5 times and was 7000-8000 m^3/s. The velocity rose to 1.68 m/s (maximum observed is equal to 1.01 m/s) mainly due to a big difference in water level in the Curonian Lagoon and the Baltic Sea (124 cm instead of 10-15 cm). The mean intensity in the rise of water for duration to 1 day was close to 20 cm. The graph below (Figure 2) shows development of water level measured through January and June 1958 at Druskininkai (450 km from the mouth of the river), Smalininkai (112 km), Panemune (Sovetsk 59 km), Rusne (13 km).

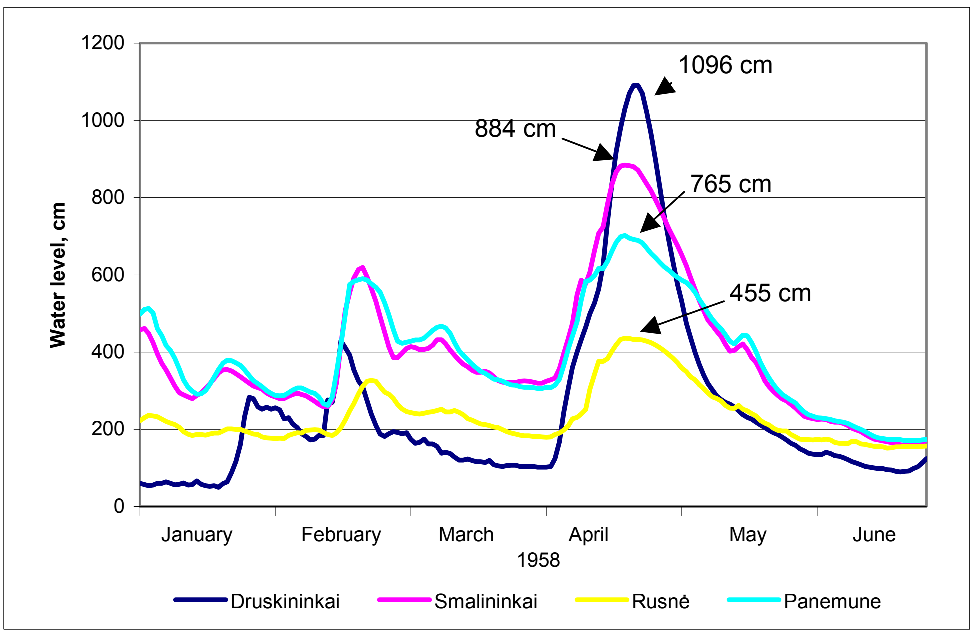

Figure 2. Historical flood levels towards downstream the River Nemunas, 1958

In 1959 Kaunas Hydro-electro Power Plant was set into operation (227 km from the mouth of the River Nemunas) and from this time the same flood by its magnitude like in 1958 was not observed till now yet.

For the last decade of 20th century the flood in 1994 was extremely large in so far as was accompanied by the ice jams caused the water level to rise. In delta area the maximum water depth on the main road Rusne - Silute reached 1.4 m and the surrounding area was covered by water for 49 days. The loss due to extreme floods during the past 50 years period in the downstream region of the River Nemunas varies from 0.1-1.0 million USD.

The flood of 1994 was caused by rainfall on snow during the spring snow - melting. The water equivalent of snow was quite normal. In early March an air temperature suddenly rose above 0^0C. On 10-12 March the max air temperature reached 10^0C. Intensive snowmelt has started accompanied with precipitation. The situation was aggravated by unusually high water level in the river before the flood started. Ice jam dammed the water up to a dangerous level of 765 cm near Panemune (59 km from the mouth of the river). It was the highest observed water level there since 1901. 19 villages and 168 farmsteads with 656 inhabitants were flooded in the District of Silute causing damage amounting to USD 77,000.

1.1 The maximum observed flood in 1958

Without any doubt any forecast for extreme events is based on historical data. It is important to keep in mind that the knowledge of the maximum observed floods and their analysis always support and contribute to more accurate prediction of possible huge floods.

December 1957 was categorized as cold since the mean temperature at the meteorological stations located in or nearby the delta of the River Nemunas was about normal. See Figure 3 with the map of distribution of the meteorological stations downstream the River Nemunas where meteorological data were obtained.

Figure 3. Meteorological and hydrological network downstream the River Nemunas.

The mean temperature, for example, at Raseiniai (meteorological station) in December was -2.7^{0}C that was equal to normal (mean annual is -2.8^{0}C). During January and February air temperature was near the normal except March, when air temperature was much lower the normal. At Raseiniai (meteorological station) mean temperature was equal -5.2^{0}C (mean annual is -0.9^{0}C).

Examining the mean air temperatures from the following table (Table 1) and in Fig. 4 showing a comparison of the multi - annual and mean monthly temperatures we can see actually a small deviation from normal over the month as a whole. So, winter period can't be concluded as an extremely cold and there were no extreme conditions concerning air temperature except sufficient deviation from normal in March.

Table 1. Air temperature, 1958

Year	Silute		Laukuva		Raseiniai	
	mean	normal	mean	normal	mean	normal
XII - 1957	-1.2	-1.3	-2.4	-2.8	-2.7	-2.8
I - 1958	-4	-3.9	-4.8	-5.2	-4.9	-5.3
II - 1958	-3.1	-3.3	-4.6	-4.7	-4.4	-4.7
III - 1958	-3.7	0.3	-5.7	-1.2	-5.2	-0.9
IV -1958	3.3	5.7	2.1	4.8	2.5	5.3

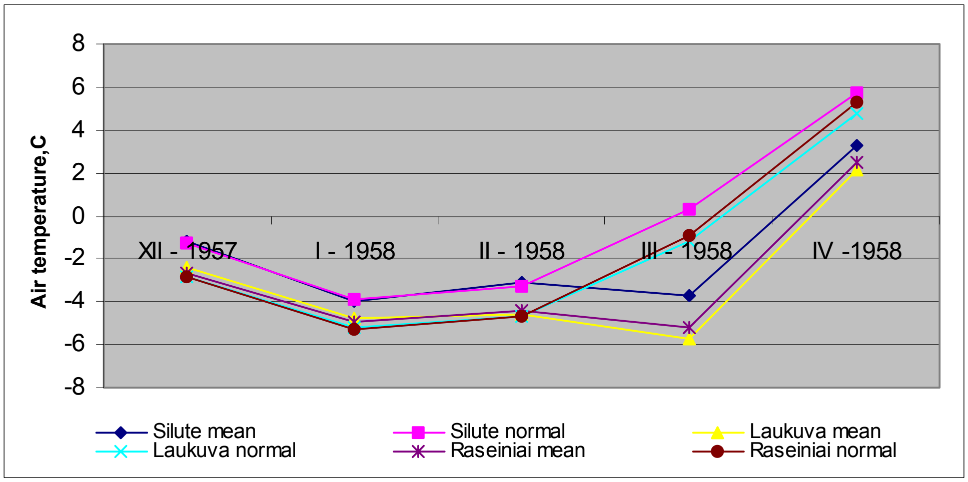

Figure 4. Comparison of the multi - annual and mean monthly air temperatures for three stations in delta of the River Nemunas

A lot of snow was accumulated in the catchment's area of the River Nemunas after intense snowfall and low temperature during December 1957 and March 1958. In winter of 1957-1958 it snowed repeatedly. Many meteorological stations in the western region as Silute, Raseiniai, Laukuva of Lithuania recorded precipitation amounts much higher than usual. In Fig. 5 is presented the precipitation amount at the meteorological stations in comparison to normal. February snowfall amounts was up to three times more than normal in the downstream area and the water equivalent of snow within the catchment's area was exceeded at Pabrade (hydrological station) 100 mm, at Kaunas 70 mm, at Birstonas 65 mm. Winter was stable and never disturbed by alternating periods of thawing and freezing or rainfall.

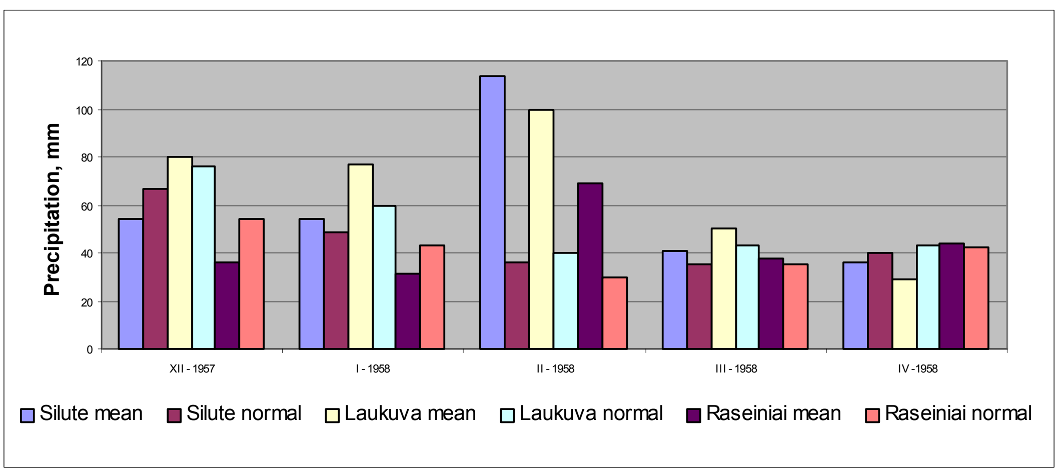

Figure 5. Monthly distribution of multi - annual and mean monthly precipitation from December 1957 to April 1958 in the lowest part of the catchment's area of the River Nemunas.

Finally, from two major parameters that mostly contribute to runoff development only water equivalent of snow is worth looking. Air temperature was near normal till March and due to this an early snowmelt was avoided.

It is important to stress some particularities of the downstream areas of the River Nemunas especially backwater effect due to the western winds. In the delta area the western winds are prevailing. On the Baltic coast the mean velocity of the wind is from 5.0 to 6.0 m/s, maximum recorded is 26 m/s. On the average the backwater effects causes the water level to rise up to 50 cm in the mouth of the river and 150 cm in the southeast part of the Curonian Lagoon. The backwater effect is seen up to 48 km from the mouth of the River Nemunas and may cause an additional threat for surrounding areas.

Spring 1958 had started respectively late, one month later than usually. The spring snow – melt begins mostly in March (on 18-22 March), while in 1958 it was observed on 10-16 April. On April 10, temperatures throughout the catchment's area suddenly started to rise. In the middle of April rapid snow – melting was initiated due to prevailing warm weather and rain. Melting water ran fast from the easterly tributaries to Nemunas and had the highest runoff intensities (20 cm per day) due to a big part of the river basin was deeply frozen (depth of frozen ground through the winter had reached 35-50 cm) and infiltration was low or absent. Moreover, the ground was fully saturated by water due to rainy autumn. The flood peaked simultaneously over a 100 km long stretch of the River Nemunas in April 22nd. The volume of water was very big and vast areas of the Nemunas valley and delta were flooded. The snowmelt contribution amounted to approximately 45 percent of total runoff. The highest in history water level rise was recorded. The following table (Table 2) shows historical water levels that were exceeded by maximum water levels observed at Druskininkai, Panemune (Sovetsk) and Rusne in 1958.

Station	Maximum water level, cm		Date of historical water level	Water level deviation from historical level
	1958 max	Historical max		
Druskininkai	1096	809	1931	287
Panemune(Sovetsk)	703	731	1942	-28
Rusne	438	429	1914	9

It took one month for the water level in Nemunas to reach initial level. Maximun water discharge was recorded for three days. Those days flooded Nemunas carried approximately 7-8 thousand cubic meter per second towards Curonian Lagoon (usually Nemunas discharges 2.5-3.0 thousand cubic meter per second during a spring flood). Huge amount of water couldn't find a through passage via the narrow Klaipeda strait (normally its throughput ranges from 4.0 to 5.0 thousand cubic meter per second) and historical level was reached on 25 April and exceeded later. Areas of settlements, fields, communication lines, roads and all around were covered by water. Near the city Rusne water level rose 2.5 m and that was 9 cm higher than historical level. Flood caused big damages, all preparations had been made to sustain even higher water level were in vain. The polder system wasn't able to manage with so big amount of water and was sunken under the 1.5 m layer. Area of about 20 km wide to the east from the River Nemunas was flooded.

Historically Lithuania is an agricultural country. 53 per cent of total country territory is used for agricultural purposes. Practically the catchment's area of the River Nemunas is used as natural pastures and meadows, 50 per cent of downstream area consists of arable land and is used for livestock production. It is important to stress that 80 per cent of Lithuanian population is settled down within the Nemunas basin. Average population density in Nemunas river basin is 54 inhabitants per square km and that is twice denser than are in the neighbouring catchments. Delta of the River Nemunas is one of the densely populated areas. The most populated city is Klaipeda. Klaipeda is located at a strait connecting the Curonian Lagoon with the Baltic Sea. Smaller towns as Silute, Rusne, Jurbarkas are located along the right bank of the Nemunas River and are affected by floods water almost every year. See photo of flooded house at Silute region.

2. Flood 1994

The second largest flood for the last decade of XX century was recorded in 1994. The following photos illustrate some episodes from areas of inundation as flooded roads near Silute and inpatient people captured by flood.

Flood in 1994 was caused by snow - melting and ice jams over the long stretch of the River Nemunas. In general the weather was not unusual, excepted cold and reach of snow February (LHMC, 1995). Air temperature was extremely low. At this time precipitation recorded for March was particularly heavy 84 mm, the same amount of precipitation was observed only two time in XX century, namely in 1950 and 1983. The weather in January 1994 was warm, the mean temperature throughout the catchment area was positive. Mean monthly temperature varied from plus 1.5^0C to minus 1.3^0C (it is 4.6 - 6.0^0C was higher than multi - annual temperature for January). Winter precipitation distributed unequally. In January amount of precipitation was bigger than normal, 130 - 170% of normal. In February was near the normal but eastern part, where amount of precipitation was 140 - 180% of normal. The pick of precipitation was recorded for the last week in February in prevailing cyclone weather. See Figure 6 and 7 with precipitation and air temperature distributions, measured by meteorological station located in Silute (delta area of the River Nemunas):

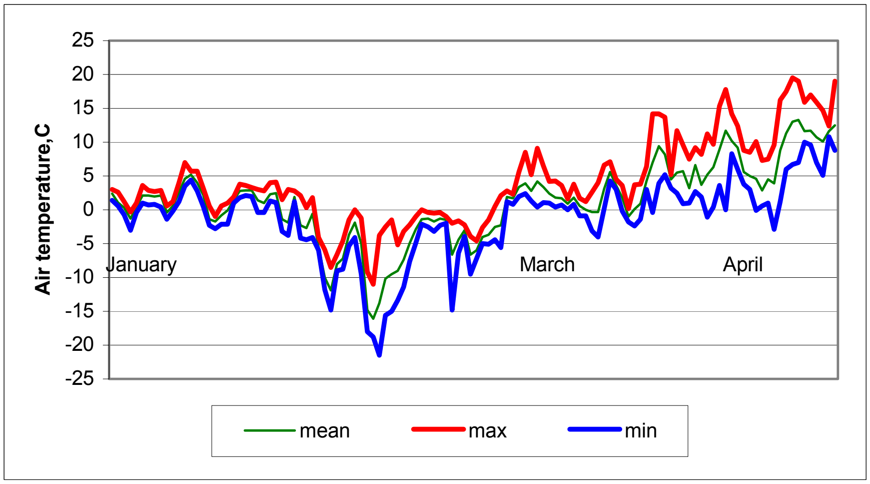

Fig 6. Distribution of air temperature, Silute, 1994

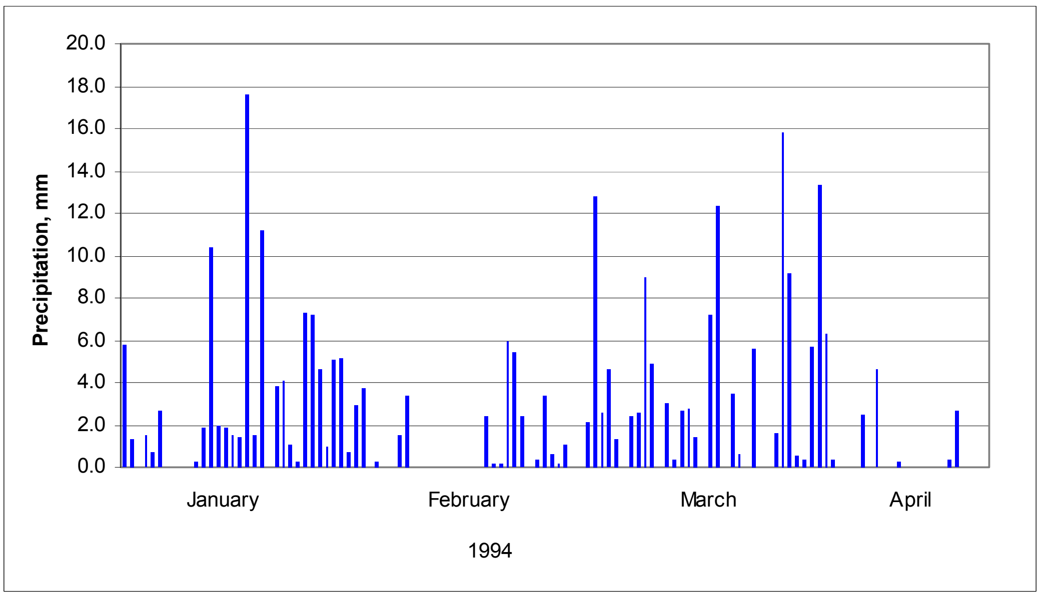

Fig 7. Precipitation, measured at meteorological station in delta area, Silute, 1994

Snow height rose to 20-30 cm but in downstream areas the height of snow did not exceed 8 - 16 cm. Mean depth of frozen soil was 15 - 40 cm till February, later, due to the low temperatures the depth of frozen soil reached 30 - 60 cm over the eastern and central parts of the basin. February was absolutely different. Nights temperatures reached minus 10 – 15^0 C and sometimes in the eastern part of the basin was 29 – 31^0 C. Mean monthly temperature was 1.9 – 4.4^0 C lower than multi - annual temperature. March characterized with high precipitation intensity (2-3 monthly norms). Only 6 days in March were recorded without precipitation. Air temperature was 0.2 - 1.4^0 C higher than multi - annual values. On March 7 temperature over the whole basin area started to rise, rising by as much as 10 degrees Celsius in the course of four days. Rapid snowmelt was initiated in the basin. Runoff accelerated, in the tributaries in particular and river began filling up within short time. See hydrographs (Fig.7) showing water level rise due to ice jams at hydrological stations downstream the River Nemunas.

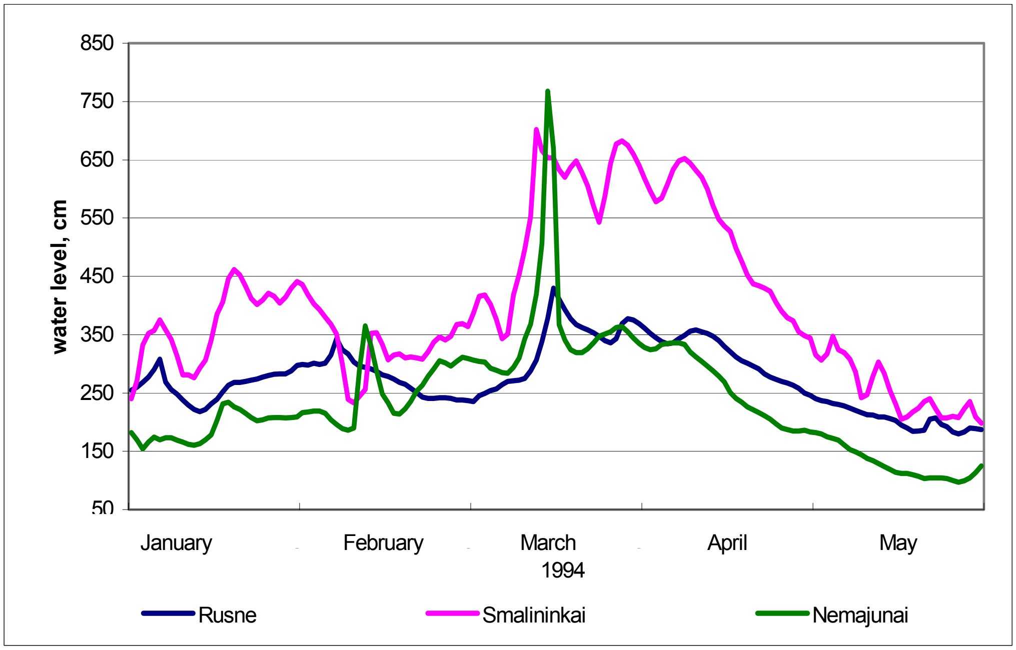

Fig 7. Water level rise due to ice jams recorded by stations located downstream the River Nemunas.

Ice jam phenomenon is known as a powerful driving force during a flood period. Temperature regime of rivers in Lithuania is determined by cold air masses from Arctic or warm air masses from Atlantic. Those factors are not constant in space and time, and river's regime strongly depends on their fluctuations, especially in winter.

The prevailing weather situation during February and March in 1994 is shown on the map of meteorological conditions (see Fig. 8)

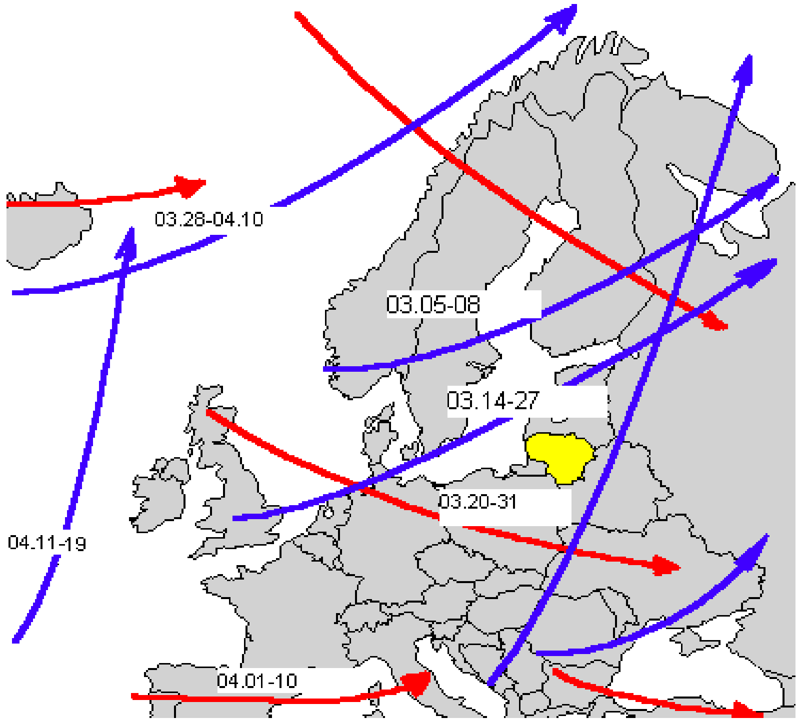

Fig 8. Meteorological conditions in March, 1994.

Analysis of the meteorological data in early March shows 3- 10-days period with positive air temperature with maximum air temperature equal 8.2°C. Coming of warm air masses and rainfall during thaw period intensified snow-melting process and led to a sharp increase of water level, especially due to the frozen ground and low infiltration. Ice cover was broken and ice movement has started.
See example (Fig. 9) showing development of air temperature and precipitation and their contribution to the formation of ice jam at Nemajunai (337 km from the mouth of the river).

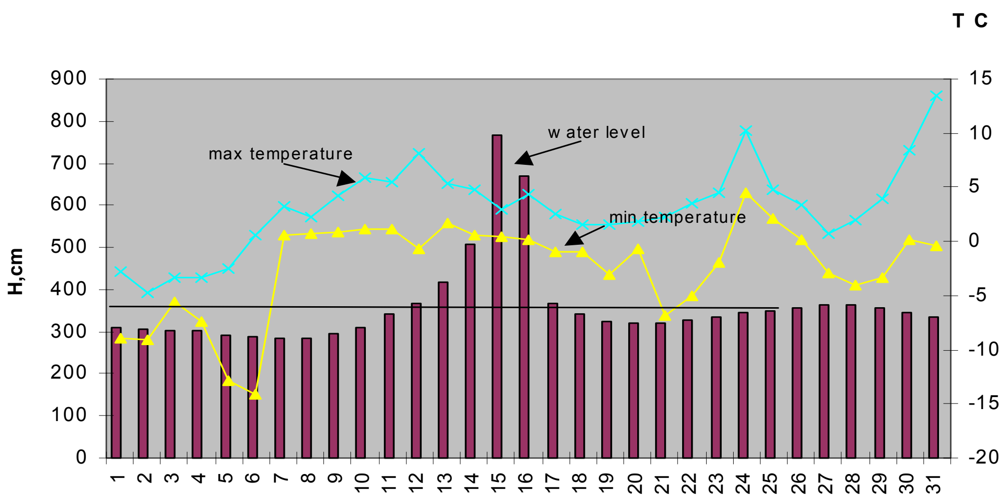

Fig 9. Course of air temperature, precipitation and water level, March 1994, Nemajunai (337 km from the mouth of the river).

It is worth attention, that backwater effect in February due to ice formation and transport of frazil slash lasted till 15 of March. The increased resistance to the flow due to the ice - jams caused the water to rise to levels approaches extreme values. Ice movement had started on 13 March and at the same time causes new ice – jams downstream the river (See Fig. 7).

2.1 Forecasting and warning system in Lithuania

To predict and forecast coming flood a lot of subjective interpretations are getting involved. First of all there are not enough stations in the delta area of the River Nemunas for the near real-time information needed before and from the very beginning of flood. 4 stream gauge stations are carried out hydrological and meteorological observations (precipitation) regularly. Water level observations are carried out by the observers two times per day but in period of rapid increase or decrease in water level observations are being made more often, every hour or more. Very valuable meteorological information is delivered from 2 stationary working meteorological stations. To close the gap and to get more information on development of ice cover before ice is broken an air survey is being done every time for forecasting purposes. “Hot” spots is being marked, afterwards a new seasonal stations may be founded. Due to all hydrological observations are manual, observers are provided with the mobile phones in case of necessity. Our forecast division is the first in the chain who is being informed on going changes with ice. After the first announcement of flooding many responsible organizations are switch on into the work for people safety. Primary warning system that is the background for the further safety actions was developed by the LHMS. This system combines the first response of our hydrological network to the changes in the river and further actions of our forecasting division.

First notification of dangerous phenomena is being registered by a person on duty and immediately is being passed to the LHMS administration (director) and LHMS forecaster division’s responsible persons. Director is one who takes a decision on call of Extreme situation management centre and he is the person who is responsible for the final decision on call of the Extreme management centre meeting’s.
LHMS is the organization that takes all responsibilities for the first notification and warnings of dangerous phenomena. In case of emergency Civil Defence and Rescue Department (CDRD) is the main leader and coordinator of measures taken during and after dangerous flood. A plan of action shall be made in advance. By this plan LHMS shall constantly inform CDRD on going situation and provide regional administrative organizations and citizens with recommendations in case of emergency. LHMS informs mass media means on decisions made and people treatment.

In order to protect the environment, to reduce losses as much as possible and save people’s life during the flood LHMS has established contacts with the relevant institutions and persons within the Lithuania and with responsible organisations from neighbouring countries as well. Relevant information and data are freely available and are constantly disseminated via telephone lines, radio, TV and INTERNET. Warnings are processed to inform the society and avoid a severe damage.

There is the general list of organizations involved in warnings and rescue operations:

- LHMS
- Civil Defence and Rescue Department
- Health care organizations
- Municipalities
- Food and veterinary service
- Military service
- Medical service
- Fire-Rescue and Safety Service
- Regional and municipal environmental protection agencies
- Line service
- Mass media
- Police service

2.2 The route of notification

LHMS via the telephone line, e-mail and fax informs and issues warnings for the following organizations:

- Civil Defence and Rescue Department
- Mass media
- Government
- Energy sector
- Railway administration
- Transport administration
- Line service
- Fire-safety and rescue Department
- Forestry and Land protection Department
- Meteo and hydro stations
- Latvia HMA
- Belarus HMB
- Russia (Kaliningrad) HMC
- Police Department

Two persons from LHMS participate in a work of a Headquarter of the Extreme management centre and municipal extreme management centre.

3. Conclusions

It is important to be sure that the lessons learned from an every flood can move the situation from a big losses and damages to satisfactorily low level. That is possible if the system of early warnings includes well developed hydrological network combined with the improved weather forecasting system, in particular the quantitative forecast of precipitation and is supported with modern technical measures for data collection and processing and hydrodynamic simulation methods (Hall. A., 1981 and IMGW, 1999). Today LHMS does not operate any numerical model, although has started preliminary work on HBV - model application for flood forecasting and it adjustment to the Lithuanian conditions. Developed hydrological network means not only quantity of stations in the area of delta but their maintenance and equipage. Reliable real – time information is the priority for the near future of LHMS and is urgently needed for the accurate flood forecast of hydrological phenomena and more important is needed for the early warnings release.

Lithuania is not prone to the flash floods except the flash floods resulted from intense localised ice-slash or broken ice. It is difficult and almost impossible to predict flash floods and in this context any knowledge from countries experienced such events are welcome and valuable.

The flood in the delta area of the River Nemunas in 1958 was recorded into the history of Lithuanian hydrology as the greatest flood never seen before.

The flood 1958 was caused by specific weather and ice conditions in the river. The rapid growth of air temperature and following rainfall intensified heavy snow melting and ice jams. Natural conditions and undisturbed water flow by manmade constructions in the river let the river run naturally in spring 1958. If the flood 1958 considering is equal to 1% of probability for the River Nemunas all successive floods have never overcome it due to the dam constructed in the middle of the river Nemunas (223 km from the mouth) in 1959 (Gailiusis. B, 2001).

References

- Basalykas, A. 1965. *Geography of Lithuania.* Vilnius, 1965, pp 75-80.
- Gailiusis, B., Jablonskis, J., Kovalenkoviene, M. *Lithuanian Rivers. Hydrography and Runoff.* Kaunas. Lithuanian Energy Institute. 2001, pp 248.
- Ginko, S. and Barisas, A. 1977. *Catastrophe on the River Banks*. Mokslas. Vilnius, 1982, pp 150-169.
- Hall, A. 1981. *Flash Flood Forecasting.* World Meteorological Organization, Operational Hydrology Report No 18, Vol. WMO No 577, pp 4-17.
- Institute of Meteorology and Water Management (IMGW). 1999. *The Hydrological and Meteorological Monitoring, Forecasting and Protection System.* Warsaw, 1999, pp 19-21.
- Lithuanian Hydrometeorological Centre (LHMC). 1995. *Hydrometeorological Conditions in 1994*. Vilnius, 1995, pp 2-8.
- Rainys, A. 1961.*The Greatest Flood in the Delta's Area of the River Nemunas.* Geographical Yearbook, Vol. IV, pp 163-172.
- Zinkus, J. 1986. *An Encyclopedic Survey.* Vilnius. 1986, pp 10-22.