REPORT

PRELIMINARY EVALUATION OF FLOOD RISK

UKRAINE – ROMANIA – REPUBLIC OF MOLDOVA

European Union

EAST AVERT

Romania-Ukraine-Republic of Moldova

Content

1. Introduction

Floods are natural phenomena that are part of normal leakage events chain representing the peak moments in the evolution of a river's flow. However, when they are extreme, they generate flooding, respectively overpasses the banks of the low-flow channel and temporary water covering some areas of the floodplain which normally are not below the water level.

From human perspective, a flood it occurs when there are material damage and loss of life and or when the water level threatens the livelihood of society.

Floods are among the most important weather-related loss events in Europe due to their large economic consequences, producing total losses of over 50 billion over the past decade. Extreme precipitation events and floods are frequent, and projected to increase, in many European countries, with a great concern in Eastern Europe - one of the existing flood hot spots. Eastern Europe is considered as highly exposed to natural disasters including earthquakes, floods and landslides.

In the last five years most rivers in eastern Romania (Rivers Siret, Prut, Trotus, etc.) far exceeded historical flows and damage to property (Figure 1) or losses of life are increasing. Romanian literature on risky hydrological phenomena in the eastern part of the country, or on its entire territory, is well represented.

Figure 1. 2008 extreme floods on Prut River, Radauti Prut settlement

The Directive 2007/60/EC on the assessment and management of flood risks aims to reduce the negative consequences for human health, the environment, cultural heritage and economic activity associated with floods. In this respect Member States have the obligation to identify river basins and coastal areas at risk from flooding, to draw up flood risk maps at different level of risk from flood hazard and develop flood risk management plans for these areas.

The implementation of the Directive is performed in three steps: preliminary flood risk assessment (PFRA), preparation of hazard and flood risk maps, and development of flood risk management plans (Figure 2).

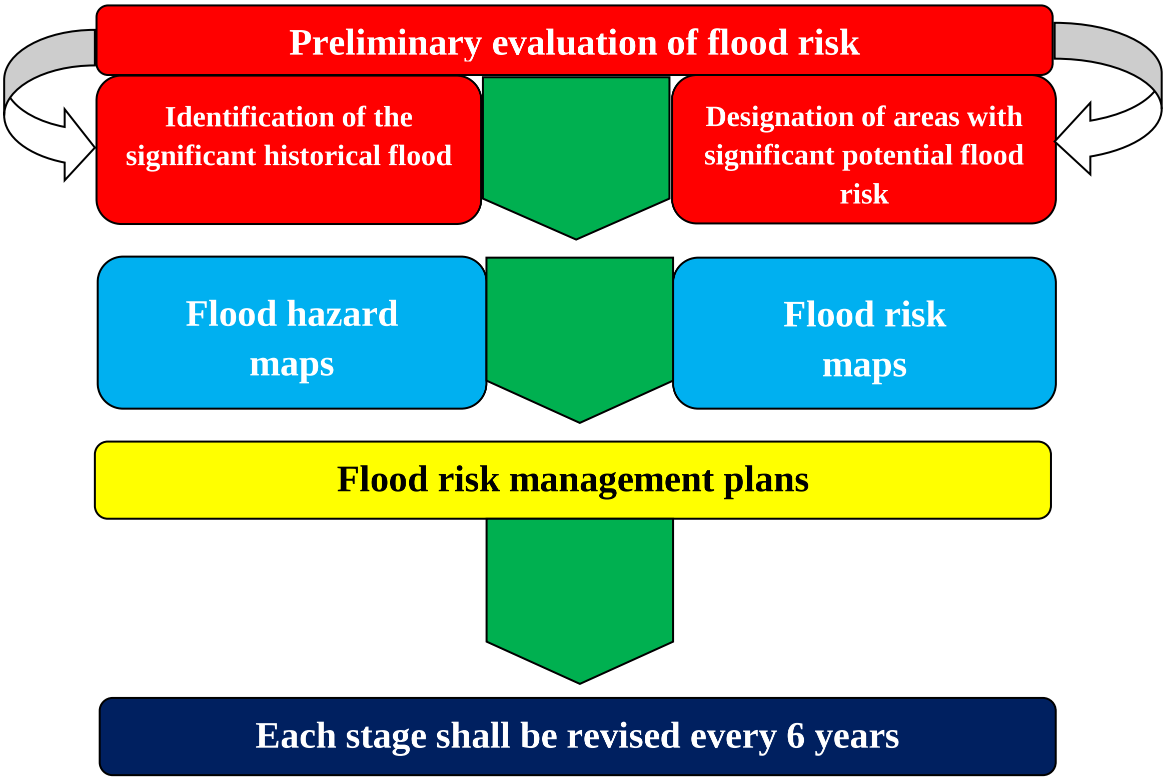


Figure 2. Stages for the implementation of the Floods Directive and deadlines

PFRA involves the identification of significant historical floods that had significant consequences to: human activity, environment, cultural heritage and economic activity, but also the delimitation of areas with significant potential flood risk, in other words, areas where flooding may occur in the future.

This preliminary assessment was based on information currently available and / or easily deductible so that to avoid increasing the administrative costs in relation to reporting, but still gathering adequate information to allow to check compliance with the preliminary flood risk assessment, (Figure 3). The main aim is to select those areas on which to undertake flood mapping and flood risk management plans.

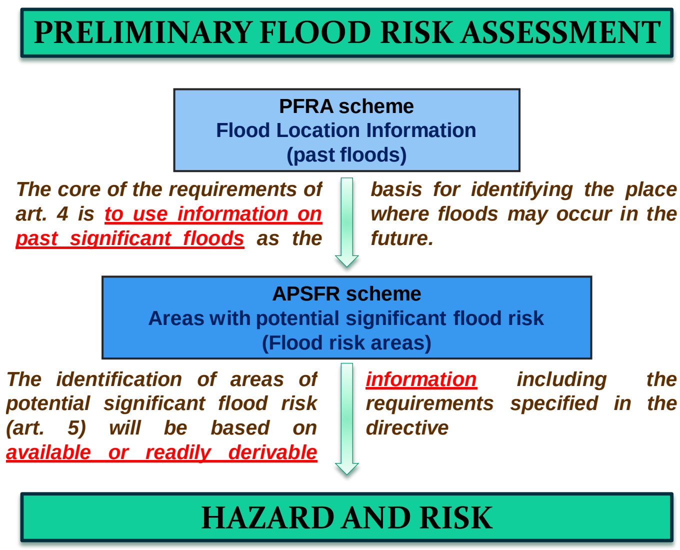


Figure 3. Main steps of PFRA in order to avoid increasing the administrative costs in relation to reporting

Flood mapping comprising of hazard maps and risk maps are useful tools for national and local authorities in order to establish feature common measures for protection of the exposed areas. The flood hazard maps should cover the geographical areas which could be flooded according to different scenarios; the flood risk maps shall show the potential adverse consequences associated with floods under those scenarios;

Flood risk management plans shall indicate, on the basis of the previous maps, the objectives of the flood risk management in the concerned areas, and the measures that aim to achieve these objectives.

As shown in Flood Directive, effective flood prevention and mitigation requires cooperation with third countries. This is in line with international principles of flood risk management, which can be achieved only if the parties located in a transnational river basin (EU Member States and non-Member States) cooperate. Siret and Prut are two of the Romanian transborder basins, the first collecting streams from a surface of 2,091 km2 before entering the territory.

More detailed information should however be provided for floods that occur in the future during subsequent implementation cycles, and which will be considered as past floods for the review of those cycles.

2. Obligations for implementation of Directive 2007/60EU

This report considers **the preliminary assessment of flood risk** in the upper Siret and Prut River Basins (transborder area) district, under Article 4 of the Directive (Figure 4); on this basis there will be carried out (also in the first stage of implementation) **the identification of areas with potential significant flood risk**.

Further, **areas with significant potential flood risk** will become subject to the following two stages of implementing the Directive, namely **the elaboration of hazard and flood risk maps** and the elaboration of the **Flood Risk Management Plan**.

In essence, the preliminary flood risk assessment (PFRA) involved the following steps:

- **Gathering information on historical floods** (in the past) and **assembling information in Excel files**; the information recorded in excel files are the basis of the information to be reported to the EC;
- **Correcting the information submitted by other holders, identification of historical events and selection of significant events** based on nationally agreed criteria;
- **Mapping of the historical floods location (GIS)**, made at the level of the river basin district and subsequently adjusted to the WISE reporting requirements;
- **Identification of areas with significant potential flood risk** based on the data, studies and project results available and their mapping in GIS environment.

In Romania, there are approved a series of normative acts on flood risk management. Among them, of a vital for the implementation of the Floods Directive are:

- HG 846/2010 on the approval of the National Strategy for Flood Risk Management on medium and long term
- OU 3/2010 for amending and completing Water Law 107/1996 - fully transposes the provisions of 2007/60/EC Directive

According to the article 1071 of Water Code of Ukraine, point 7 of Action plan for realization Conception of risk management in case of occurrence emergencies of man-made and natural character for 2015-2020, approved by the order of the Cabinet of Ministers of Ukraine from March 25, 2015. No. 419-p. with a view to implement the provisions of Directive 2007/60 / EU of the European Parliament and Council from 23 October, 2007 on the assessment and management of flood risks "Method of preliminary assessment of flood risks" was approved on December 1, 2017 by the order of the Ministry of Internal Affairs of Ukraine, "Method of developing maps of threats and risks of flooding" and "Procedure for developing a flood risk management plan" were developed and approved by the Cabinet of Ministers of Ukraine.

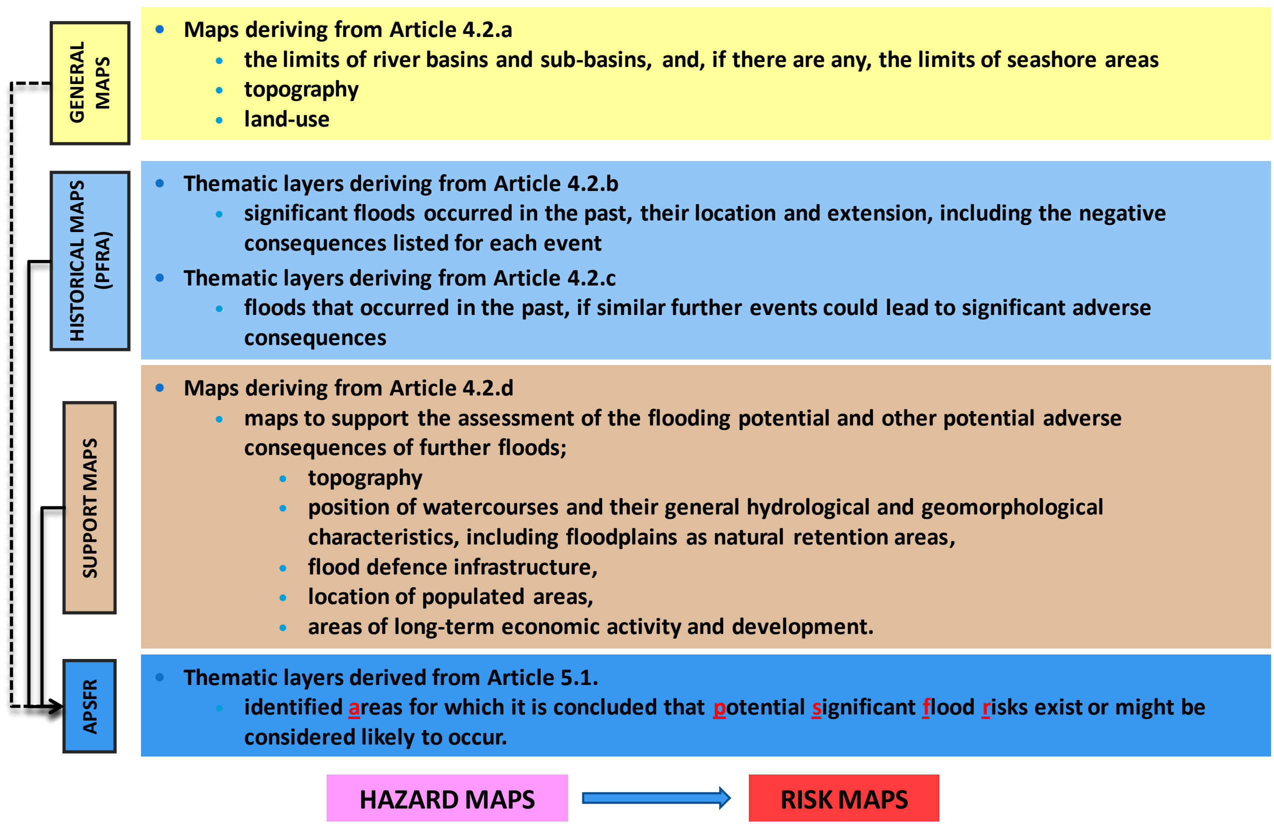


Figure 4. Main products of PFRA under Flood Directive

The analysis of historical flood events for the identified significant flood risk areas refers both to the identification of flooded areas in the past, and the assessing of their consequences magnitude (socio-economic losses, environmental impacts, etc.). The resulting flood inventory will help to establish the historical affected zones and prioritise the required measures and investments for flood protection.

Identification of the significant historical floods in Siret and Prut river basins will establish a support for flood management (establishing measures to prevent flood risk in areas that have registered significant historical floods), EU Flood Directive, models calibration for detailed hazard mapping and forecasting activity.

Collecting essential information on historical floods (especially extents and consequences) will improve the understanding of extreme events and flood management. This information is mandatory in flood risk preparedness and planning of protection measures. The floods happening today tend to follow the same routes as similar ancient flows.

Selection of significant historical flood is performed by applying the criteria own to each country, Directive providing freedom to each Member State in definition of significant historical flood term. The criteria that led to the identification of historical floods were the hydrological criteria and criteria regarding the negative effects of floods on the four categories of consequences set out in the directive: human health, environment, cultural heritage and economic activity.

3. Physical and geographical conditions for the formation of flow of the basins of the Prut and Siret rivers

3.1. Location

The Prut hydrographic area is located in the north - eastern part of the Danube basin and bordered by the Tisza River to the north-east, Siret River to the west and Nistru River to the north and east. The total area of the basin is about 28450 km^2 (Table 1), from which 72% located in Romania (11,000 km^2). The second longest tributary of the Danube River, the Prut River (952.9 km) forms the border between Ukraine and Romania on 31 km and between Romania and Republic of Moldova on 711 km.

Table 1. Surface of Siret and Prut River Basins per country

BASIN	COUNTRY	Surface (km^2)
Siret	Ukraine	2091.46
Siret	Romania	42959.39
Prut	Ukraine	9291.75
Prut	Romania	11014.40
Prut	Moldova	8127.15
Siret Total		***45050.85***
Prut Total		***28433.31***

The Prut River has its source on the southeastern slopes of the Hoverla Mountain (Wooded Carpathians of Ukraine) in the Ivano-Frankivsk region, 15 km southwest of the village Vorokhta, in the mountain range of Chornogora at an altitude of 1580 m. It flows through the territory of the Chernivtsi region, the Republic of Moldova and Romania, flowing into the Danube at an altitude of 2 m. The total length of the hydrographic network is 4540 km and has a density of 0.413 km/km^2. The average altitude varies between 130 m in the central area and 2 m at the confluence. The average slope of the basin is 2 ‰. The Prut river basin is located on the territory of three countries: Ukraine, Romania and Moldova (Figure 5).

On the Ukrainean teritory, the basin of river Prut occupies the territory of Ivano-Frankivsk and Chernivtsi regions.

The river valley is wide, filled with stones and sand. The slopes of the valley are sloping. The Prut River flows into the Danube River from the left bank at 164 km from the estuary (0.5 km south-east from the village of Giurgiulesti Republic of Moldova)

A feature of the Prut river basin covering the Romania is its elongated shape with an average width of about 30 km. River basins of the encoded tributaries keep the same high elongation and orientation parallel to the Carpathian Mountains. The main tributaries of the River Prut are: Baseu (F = 965 km2, L = 118 km), Jijia (F = 5757 km2, L = 275 km), Sitna (F =

925 km2, L = 65 km), Miletin (F = 663 km2, L = 87 km), Bahlui (F = 959 km2, L = 110 km), Bahluet (F = 558 km2, L = 50.1 km), Elanul (F = 589 km2, L = 69.9 km), Chineja Valley (F = 766 km2, L = 73 km).

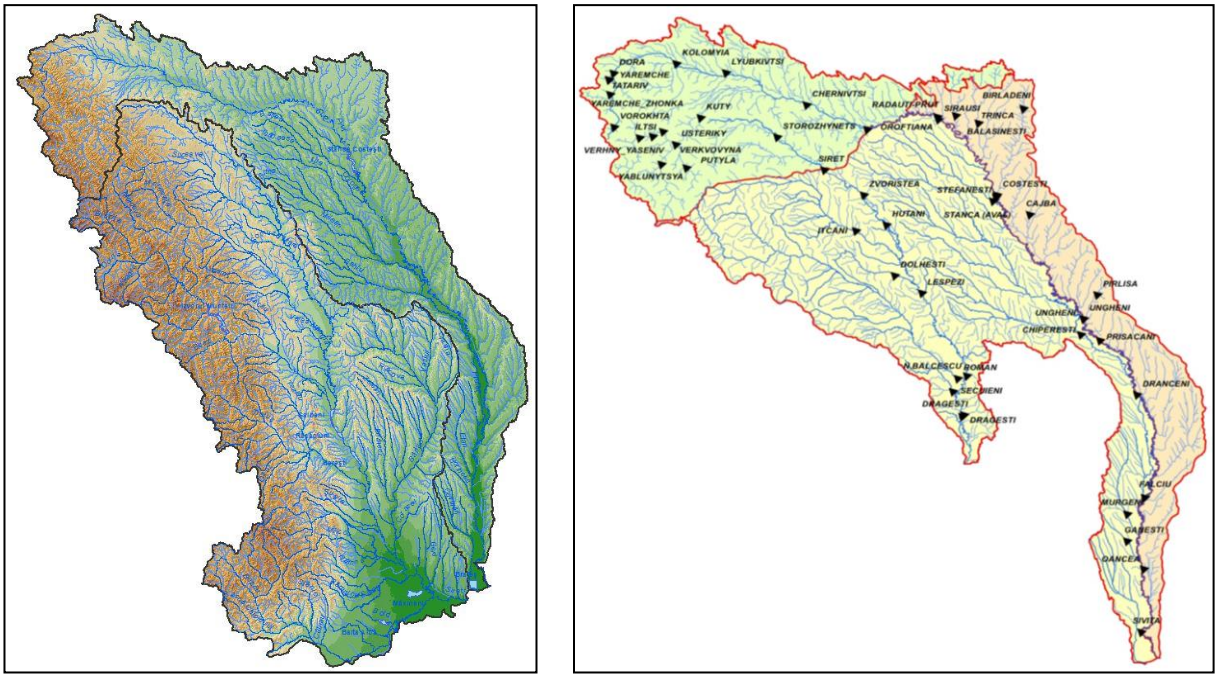


Figure 5. Siret and Prut River Basins: a) entire catchement areas; b) study area splited by 3 country

Basin of river Siret covers the territory of the Chernivtsi region and Romania. The river Siret originates from the confluence of the mountain streams Cheremosh and Buretzky near the village Petrovets Chernivtsi region, at an altitude of 740 m abs. The length of the river is 513 km (100 km on the territory of Ukraine), the catchment area is 47600 km2 (within Ukraine - 2070 km2). The overall fall is 435 m, the average slope is 4.40 / 00, the coefficient of convolutability is 1.92

In the upper part (to the village of Beregomet), Siret is a typical mountain river, down the stream - a foothill plain with a wide valley, in some places - swampy. Falls in the Danube River at 187 km from its estuary at an altitude of 5 m abs. in the city of Galati on the territory of Romania.

The catchment in question has a total area of 45050 km^2 of which 42960 km^2 in Romania, assigned to a number of 8 main river basins, as follows: Suceava (2298 km^2), Moldova (4299 km^2), Bistrita (7039 km^2), Trotuş (4456 km^2), Bārlad (7220 km^2), Putna (2480 km^2), Ramnicu Sarat (1063 km^2) and Buzau (5264 km^2).

The surface of this area is drained by a river system consisting of 86 encoded water courses with a total length of 15157 km.

3.2. Climate

The climate plays an extremely important role in the hydrological regime of rivers and reservoirs. Such climatic parameters as precipitations and thermal regime, determine the basic hydrological characteristics - the value of river runoff, its distribution in time, the main phases of the hydrological regime.

It is the geographical position of the basins of the Prut and Siret rivers, the features of atmospheric circulation and local factors that determine the temperate continental climate in this area, which is characterized by not very hot summer, mild winters and sufficient rainfall. Throughout the year, it is under the influence of cyclones that emerge over the Atlantic Ocean.

In the downstream sector (Romania and Moldova) also the climate is temperate-continental, except the mountain region, where the specific mountain climate prevail, and the plains, where is influenced by the steppe climate.

Also, certain features of the climatic regime for river basins are due to the presence of the mountain range - the Carpathians. They are a barrier that protects the surrounding area from the spread of Arctic air. The presence of mountains also affects atmospheric circulation, contributes to the strengthening of ascending movements of air masses, resulting in significant increasing of precipitations in the mountains. Some influence on climatic characteristics also has the Black Sea. These factors determine the basic patterns of the distribution of air temperature and the amount of precipitation.

The flow of atmospheric processes is the main factor determining the amount of precipitation. Most of them fall out of the frontal clouds with the spread of cyclones.

The thermal and ice regimes of the rivers of the Siret and Prut basins are determined by their high position. The average duration of the period with ice phenomena on the rivers of Siret and Prut river basins at altitudes of 501-700 m is 105-125 days, at altitudes of 251-500 m - 95-115 days, less than 250 m – 85 - 110 days.

The ice regime of the river Siret is unstable; the average duration of the period with ice phenomena is 90 days. The first ice formations appear at the end of November - beginning of December. The average thickness of the ice is 10-25 cm, the maximum - 60 cm.

Carpathians are one of the dangerous areas in mudflows. Mud floods are observed in the basins of the rivers Prut and Siret, and especially in the mountainous part of the Prut basin.

In the midel and lower sector, the climate of the Siret basin is individualized on the major relief units, from wet and cold in the mountain area to a transition climate in the Subcarpathian and the Continental in the Central Moldavian Plateau and the Siret Meadow. Precipitation decreases from West to East, from multi-year averages of 600 - 1100 mm in the Oriental Carpathians to 500 - 700 mm in Subcarpathians and 450 - 600 mm in the eastern area.

In the lower areas of the Prut basin there is a steppe climate and in the highest areas a climate specific to the wooden areas. The average multiannual temperature is 9 ^{0} C. In Prut hydrographic area, the average multiannual rainfall varies between 400 mm and 600 mm per year. The average multiannual rainfall in the Prut River Basin is 550 mm.

Due to these conditions imposed by climate and relief, natural flows are lower in dry years and in the summer periods, especially in plain area.

3.3. Landforms and geology

River Siret. The upper part of the Siret river basin is located in the Eastern Carpathians, in the Pokutsko-Bukovinsky Carpathians and in the Bukovina piedmont hill. The mountainous area is composed of Paleozoic mica and other metamorphic shale, the forge part - sandstones, clay slates and limestone (mainly Cretaceous), the plain part - sandstones, marls, limestones and clay slates. In layers of sand and sandstone at a depth of 250-300 m there are aquifers with water that is suitable for drinking and other technical purposes, but they do not have a continuous spread.

In Romania, the surface of the Siret basin implies a wide variety of all elements of the physical-geographic frame. Of particular importance are the areas crossed by the main tributaries (Siretul Mic, Suceava, Somuzurile, on the right side) which drains mainly the mountain region, characterized by a rich drainage. Also, the plateau area is important for the high torrential flow of runoff and the presence of drought phenomena.

The relief of the upper Siret basin is characterized by the following forms of relief:

- Eastern Carpathians:
  - volcanic area of the Calimani Massif;
  - crystalline - mesosoic area (with Maramaresului, Rodnei, Suhardului mountains);
  - flish deposits area (Obcina Mestecanis, Obcina Feredeu, Obcina Mare).
- The Central Moldavian Plateau is one of the typical platform units, covering the space from the Eastern Carpathians to the Prut River. The geological formations have a weak south-souteast fall and a dense network of rivers has divided the plateau into a series of peaks with characteristic asymmetrical profiles

Basin of river Prut. The mountainous part of the river Prut consists of Mesozoic deposits (shales, quartzites), which are covered with flushes (sandstone, clay, marl, limestone) on top, as well as the layer of alluvial formations.

Flowing along the Volyn-Podilsky hill, which is part of the Eastern European platform, the river Prut crosses the surface of the upper Proterozoic, Paleozoic, Mesozoic-covered sedimentary rocks. The Precambrian crystalline foundation lies at a depth of approximately 1500-3000 m. The oldest breeds from which the foundation of the board forms is granites. Tretinous deposits are represented here by the sedimentary rocks of the Paleogene flush - gray-green and gray limestone sandstones, marls covered with clay of Jurassic time.

The relief of the Prut hydrographic basin belongs to the Moldavian Plateau and the northeastern part of the Romanian Plain. The units of relief included in the Prut basin are:

- Moldavian Plain, situated entirely in the Prut river basin, having an average height of approx. 150 m;
- Suceava Plateau, the western boundary of the Prut basin, where the maximum altitude (587 m in Dealu Mare - Tudora) is also found;
- Pliocene hills (Tutova, Falciului, Covurlui) with altitudes of over 400 m in the north and approx. 250 m in the south, separated by steep valleys, 100 to 150 m deep, with slopes that are strongly affected by soil erosion;
- Covurlui Plain, hill-type plain with widths of approx. 20 km in the south and heights between 60 and 200 m.

On the Prut basin territory siliceous rocks prevail, limestone being on small surfaces at the upper part of the plateaus in the Suceava Plateau and in the Prut Valley.

The analysis of the geological structure of the basins of the Prut and Siret rivers showed that the most water-rich are the aquifers in the southern part of the Precarpathian hogging. At the sites along the Prut left slope, the water is associated with alluvial deposits of the euplestocene and the lower pleistocene. The water-bearing rocks here are sand and gravel of floodplain terraces with a capacity of up to 20 m.

The main direction of the flow is north-east - in the direction of the valley Prut. The shallow erosion net and the predominance in the section of the water-bearing layer of waterproof clay, cause rather difficult supply and a small depth of modern drainage, and hence the small capacity of the zone of intensive water exchange.

Water-bearing horizonts in quaternary sediments are in the sphere of influence of physiographic and climatic factors. Their stocks are replenished, mainly due to direct infiltration of atmospheric precipitation, which is the most intense on the area of foothills, characterized by relatively small deviations of the surface.

3.4. Hydrological regime

Siret river basin. The upper part of the Siret river basin is located in the Eastern Carpathians, in the Pokutsko-Bukovinsky Carpathians and in the Bukovina piedmont hill. The average width of the basin is 23 km, there is a well-defined dividing line between the basin of river Cheremosh in the west and the river Prut in the east. The area of the basin is divided unevenly by high-altitude zones: up to 40% occupy areas with altitudes of 400-600 m, and only 0.7% belongs to areas where the height reaches more than 1200 m. The highest, south-western part of the basin is located on the spurs of the Carpathians.

Floodplain is two-way, 0.4-0.5 km wide, with a flat surface flooded with flood water during the summer for 5-6 days with a water layer of 2-3 m. The channel is winding, moderately branched. Often there are islands in length 40-350 m and width 8-150 m.

In the basin of the river Siret the main tributaries flow: right - Myhova (length 21 km), Malyi Siret (length 61 km); left - Mihidra (length 32 km), Kotovets (length 18 km).

The annual runoff of the Siret River is unevenly distributed in seasons: half of the annual runoff is spring runoff (42-43%), in the rich-watered years the summer runoff is prevalent (up to 60%), in winter it is about 10-12% of the annual runoff.

Maximum flow in the spring from melt water make 40-50 m^3/s, in summer (rain) 50-60 m^3/s. Minimum water flow (September) is from 0.30-1.82 m^3/s. In winter, water discharge is 0.2-0.7 m^3/s. Spring flood begins usually in early March, at the end of the month the change in level reaches 0.4-1.3 m. The lowest summer levels are more frequent in August-September. Winter levels are higher than summer intermediate, during the thaw they rise by 0.2-0.3 m.

Basin of river Prut. The upper part of the Prut river basin to the village Delyatyn and right bank to the estuary of the river Cheremosh is located within the forests of the Eastern Carpathians. Bilateral floodplain with a width of 0.3 to 3.0 km is divided into high and low. The riverine part is slightly wavy and intersected by elders, ducts and sleeves, often flooded. The high pre-slope and central part of the floodplain are even, flooded with water levels of 1.5-22.4 m above the pre-flood. The river bed is moderately winding with small islands in 1-6 km. The bottom is uneven sand and pebble and pebble-stony.

The main tributaries of the river Prut are: right - Luchka (length 42 km), Pistynka (57 km), Rybnytsia (56 km), Cheremosh (80 km), Derelui (of 34 km); left - Turka stream (40 km), Chernava (63 km), Beleluia (30 km), Sovytsia stream (39 km).

The annual rate of water levels in the Prut river basin is characterized by spring rise due to melting of snow and more often with rain floods, usually exceeding levels of spring flood.

For the autumn period, more stable and low levels are characteristic, although sometimes there are significant floods.

The highest annual level is observed during the spring flood. Raising the level at the same time is very intense. The usual rise in the level of spring flood is 0.5 - 2.5 m above the estimated water level.

The average annual water discharge varies from 5.90 m^3/s (Krementsi village) to 75.6 m^3/s. (Chernivtsi city). The modules of the average annual flow vary along the length of the river as follows: in the upper stream (to the city Yaremcha), the flow module increases from 14.6 to 25.6 l/s km^2, then it gradually decreases to 3.20 l/s km^2 near city Leovo. Fluctuations in average annual water discharge are significant and are: near Krementsi 2.81-3.37 m^3/s, Yaremcha 5.62-21.8 m^3/s, Chernivtsi 26.0-177 m^3/s, Korpach 42.4-128 m^3/s.

Intermediate levels can be observed throughout the year. Thus, the minimum summer water discharge can be observed in any month in the period after the end of spring flood and before the onset of ice break.

On Romanian teritory, the discharge of Siret river increased from 36 m^3/s to up to 2010 m^3/s due to the contribution of Suceava, Moldova, Bistriţa, Trotuş and Putna tributaries (Table 2). Along the Prut River, downstream to Stanca Costesti reservoir the average water floew increase slowly due to the lower altitudes.

Table 2. Hydrological parameters of water and sediment flow at the main stations from Siret and Prut River Basin

Nr. crt.	**Râul**	**Staţia hidrometrica**	**F**	**H_{med}**	**Parametrii hidrologici**			
					$Q_{med.multian.}$	**Q_{max} 1%**	**$Q_{med.\ lun.\ min.95\%}$**	**R**
			km^2	**m**	**m^3/s**	**m^3/s**	**m^3/s**	**kg/s**
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1.	Siret	Lespezi	5899	513	36.60	1825	3.55	67.60
2.	Siret	Drăgeşti	11899	525	77.10	2650	7.50	126.00
3.	Siret	Lungoci	36095	539	212,00	3950	33.30	349.00
4.	Suceava	Iţcani	2299	629	16.50	1725	1.75	11.30
5.	Moldova	Roman	4285	678	32.50	1925	3.40	40.00
6.	Bistriţa	Frumosu	2860	1172	37.90	1320	6.79	8.76
7.	Trotuş	Vrânceni	4077	734	34.90	2500	3.43	46.80
9.	Putna	Boţârlău	2460	554	16.20	1790	3.41	87.20
BH Prut								
10	Prut	Rădăuţi	9074	529	79,9	2150	7,5	46,1
11	Jijia	Victoria	3463	159	6,97	300	0,025	11,4
12	Bahlui	Iaşi	1717	150	3,46	480	0,080	-
13	Bahlui	Holboca	1922	155	4,05	480	0,057	8,00
14	Elan	Murgeni	410	168	0,439	253	0,007	-
15	Prut	Oancea	26874	279	92,8	1040	13,0	18,6

For the water regime of the rivers of the basins Prut and Siret distinguish four main phases of the hydrological regime: spring floods, summer-autumn floods, summer-autumn low water, winter low water. Melting processes in most cases occur slowly with the gradual increase in the water content of the river. Spring flood formation is usually from February to May, due to the melting of snow cover in the highlands of Ivano-Frankivsk oblast. The maximum outgo of thawing water is much less than the outgo of rain floods.

In these catchment areas, rain floods of various intensities are formed on average 10-15 times a year. Floods of 50% of security are marked once every 2 to 3 years, and catastrophic regional floods once every 10-15 years.

Prut - Chernivtsi

Floods of different intensity repeat on the river Prut on average 10-15 times a year. The maximum floods are characterized by rising levels up to 5-6 m, flooding of the coastal area. The width of the flood zone reaches 2-3 km. Such floods were observed in 1911, 1927, 1941, 1955, 1969. The maximum flood reached 5200 m^3/s. The lowest water flow was observed on December 14, 1961, with a value of 1.90 m^3/s. From 1992-1993 in the Carpathians the next high-water period began. During this period in the basin of the Prut river there were quite high floods, which were caused by intense storm rains (1994, 1995, 1096,1998 years).

Siret - Storozhynets

The maximum floods on Siret - Storozhynets are characterized by rising of levels up to 5 meters, flooding of coastal areas. The maximum flow of floods reached 898 m^3/s, July 25, 2008. The lowest water flow was observed on August 19, 1953, and amounted to 0.10 m^3/s. Often in the period between rain floods (July - September) on the river Siret there are rather low water levels.

Since the mid 90's of the twentieth century. and by 2009 in the basin of the river Siret began the next period of high water content. Since then, there were quite high floods, with the release of water for a floodplain and flooding of residential and economic objects that were caused by intense storm rains (29.06.1995, 19.08.2005, 25.07.2008).

Putyla - Putyla

The average value of flow for the Putyla river - Putyla in the long-term period is 2.60 m^3/s, the low level outgo in the summer period may decrease to 0.030 m^3/s, while during the floods they increase to 274 m^3/s. The fastest rainstorm flood in August 2012 was the largest in terms of maximum water discharge.

Iltsa - Iltsi

The average outgo of the Iltsa river - Iltsi for a long period of time is 1.66 m^3/s, the outgo in summer may decrease to 0.21 m^3/s, during the winter period it decreases to 0.034 m^3/s, while during the floods it increases to 192 m^3/s. The largest flood water outgo occurred in 1969, 1996 and 2008, which caused significant damage to the economic objectives.

Cheremosh - Usteriky

The average outgo of the river Cheremosh - Usteriky for a long period is 27.7 m^3/s, the outgo in summer may decreases to 0.51 m^3/s, and during flooding it increases to 1500 m^3/s. The highest maximum water discharge was catastrophic, with high rainfall rising in July 2008, causing significant damage to the national economy in the basin of the Cheremosh river.

Bilyi Cheremosh - Yablunytsia

The average value of the outgo on the river Bilyi Cheremosh during the long-term period is 9.63 m^3/s, the outgo in summer may decreases to 0.58 m^3/s, and during flooding it will increase to 750 m^3/s. The highest maximum water discharge was catastrophic, with high rainfall rising in July 2008, causing significant damage to the national economy in the basin of the Cheremosh river.

3.5. Protected territories

Floodplain lands are an integral part of the modern landscape. They serve as an important source of plant resources and perform a great soil protection function: they protect the soil and the banks of the rivers from the erosion, and the river from sedimentation. Floodplains, together with forests and swamps, act as a powerful biofilter of surface and underground drains, that is, they influence the formation of quantitative and qualitative characteristics of water bodies.

Within the water protection zones along rivers and around water bodies coastal protective strips fulfill a very important ecological buffer function. They are intended to preserve or create conditions for the natural purification of waters that flow from the catchment and enter the water bodies, interception of surface waters and their transfer to underground runoff. It also contributes to reducing the flow of sediment from the catchment as a result of erosion, preservation and renewal of natural water quality, improving water regime.

Coastal protective strips are installed on both banks of the rivers and around the reservoirs along the width of the water cut:

- for small rivers and streams, as well as ponds with an area of up to 5 hectares - 25m;
- for medium-sized rivers and ponds over 3 hectares - 50 m;
- for large rivers and reservoirs on them - 100 m.

If the steepness of the slopes is more than 3 degrees, the minimum width of the coastal strip doubles. Therefore for the rivers Prut and Siret the width of the coastal strip is - 50 m.

The coastal protection zone is a protected area with a limited economic activity regime, which prohibits plowing, gardening and gardening, the use and storage of pesticides and fertilizers, the placement of cemeteries, cattle mounds, garbage dumps, barn storage, liquid and solid waste storage facilities, washing and maintenance of transport means and equipment, filtration fields, discharges of untreated sewage using the terrain (beams, lower reaches, quarries, etc.), the construction of any facilities (except hydrometric, hydrotechnical and linear). The outer boundaries of the strip are determined by specially designed projects.

National Nature Park "Vyzhnytskyi" is a protected area in Ukraine, a national natural park with an area of 11238.0 hectares. It is located within the Vyzhnytsya district of Chernivtsi region, not far from Vyzhnytsia. According to the functional zoning of the territory, the reserve area is 2153.2 hectares, the area of regulated recreation is 5222.1 hectares, the zone of inpatient recreation is 49.2 hectares, the economic zone is 3811.1 hectares. The park is created for preservation, reproduction and rational use of natural landscapes of the Bukovyna Carpathians with unique historical and cultural complexes.

In Romania, knowledge of the protected areas, wetlands, areas and sites of scientific and touristic interes, as well as those requiring ecological recovery, is necessary for avoiding improper water management works in these places, achieve environmental protection, ecological recovery as well as for taking appropriate protective measures against destructive effects of the water.

In accordance with the requirements of the Water Directive and the Water Law (107/1996, amended and supplemented by 310/2004 Law), the Register of Protected Areas has been developed, which have a close connection with the aquatic environment.

This Register includes the following categories of protected areas:

- Protection areas for water catchment for drinking;

- Protection areas for aquatic species which are economically important (sterlet sturgeon, beluga, starry sturgeon, trout, etc);
- Protection areas for habitats and species where water is an important factor;
- Vulnerable areas at nitrates, identified on the areas of 30 communes.

Wetlands are defined by No.5/1991 on Romania's accession to Ramsar Convention, as ponds, marshes, moss, natural and artificial waters (permanent or temporary), where the water is stagnant or flowing, sweet, brackish or salty, including sea water, whose depth at reflux does not exceed 6 meters.

3.6. Administrative division and population

The disasters produced by floods are favored by man, due to the fact that he exposes himself to risk through the development of the settlements (Table 3), economic and agricultural activities, roads, bridges, etc., in the floodplains. The built-up area is one of the most socio-economic objectives affected by extreme events.

The river Siret starts at the confluence of the mountain streams Cheremosh and Buretsky near the village Petrovec, Chernivtsi region. It join the Danube River near the Galati city on the territory of Romania. Basin of river Prut begins on the southeast slope of the Hoverla Mountain (Ivano-Frankivsk region). It flows through two regions in Ukraine (Ivano-Frankivsk and Chernivtsi), as well as on the border with Moldova and Romania.

Table 3. Administrative and territorial division of the Prut river basin

№	Region	District	Types of settlements			River basin
			City	Township	Village	
1	Ivano-Frankivsk region	Verhovyna district	-	1	44	Prut
2	Ivano-Frankivsk region	Horodenka district	1	-	13	Prut
3	Ivano-Frankivsk region	Kolomyia district	-	2	65	Prut
4	Ivano-Frankivsk region	Kosiv district	1	2	42	Prut
5	Ivano-Frankivsk region	Nadvirna district	-	2	18	Prut
6	Ivano-Frankivsk region	Sniatyn district	1	1	47	Prut
7	Ivano-Frankivsk region	Tlumach district	-	1	6	Prut
8	Ivano-Frankivsk region	-	-	Vorohta	-	Prut
9	Ivano-Frankivsk region	-	Kolomyia	-	-	Prut
10	Ivano-Frankivsk region	-	Yaremche	-	-	Prut
11	Chernivtsi region	Vyzhnytsia district	2	1	31	Prut, Siret
12	Chernivtsi region	Hertsa district	1	-	23	Prut
13	Chernivtsi region	Hlyboka district	-	1	37	Prut, Siret
14	Chernivtsi region	Zastavna district	1	-	13	Prut
15	Chernivtsi region	Kelmentsi district	-	-	6	Prut
16	Chernivtsi region	Kitsman district	1	2	43	Prut
17	Chernivtsi region	Novoselytsia district	1	-	42	Prut
18	Chernivtsi region	Putyla district	-	1	50	Prut, Siret
19	Chernivtsi region	Storozhynets district	1	1	37	Prut, Siret
20	Chernivtsi region	Hotyn district	-	-	23	Prut
21	Chernivtsi region	-	Chernivtsi	-	-	Prut

In Romania, from administrative point of view, the study area occupies the entire county of Botosani and partly the counties of Suceava, Iasi, Vaslui, Galati (Table 4 and Table 5). The total number of inhabitants in these regions is 1935000 of which approximately 865000 are inside the flooded area.

Table 4. Administrative and territorial division of the Upper Siret and Prut river basins

№	Development Region	County	Types of settlements			River basin
			County Seat	City	Commune	
1	North-East	Botosani	1	6	71	Siret, Prut
2	North-East	Suceava	1	10	64	Siret
3	North-East	Iasi	1	3	68	Siret, Prut
4	North-East	Vaslui	0	2	22	Prut
5	South-East	Galati	1	2	17	Prut

Table 5. Administrative and territorial division of the Upper Siret and Prut river basins inside the flooded areas

№	Development Region	County	Types of settlements			River basin
			County Seat	City	Village	
1	North-East	Botosani	0	3	19	Siret, Prut
2	North-East	Suceava	0	3	9	Siret
3	North-East	Iasi	1	0	22	Siret, Prut
4	North-East	Vaslui	0	1	8	Prut
5	South-East	Galati	1	0	8	Prut

3.7. Main economical and social activity

In accordance with the sectoral structure of production, the region belongs to the industrial and agricultural category. In recent years, the region's economic activity has been characterized by a steady increase in many indicators. This is due to the active support of traditional activities.

In Ukraine, the leading is the production of oil and gas processing equipment; in the wood and woodworking industry - production of lumber, plywood, furniture; in the building materials industry - the production of bricks, tar paper, ceramics, reinforced concrete structures; in light industry - production of sewing and knitting fabrics, cotton fabrics; in the food industry - production of sugar, bakery products, alcohol, sunflower oil, meat, milk, canned fruits and vegetables. Industrial potential of the region is represented by more than 200 industrial enterprises, the volume of production of which is 0.4% of the national volume.

With a significant raw material base, the food industry, which employs almost a quarter of all employees in the industry, has concentrated on a fifth of fixed assets.

A significant component of the regional industrial complex is the light industry, which ranks third in the structure of industries and forms the domestic consumer market. The branch is represented by 23 enterprises. The priority area in the light industry of the region is the enterprises for sewing of the finished clothes, manufacture of footwear and the textile industry.

Machine building, repair and installation of machinery and equipment are developing at a high pace. The branch is represented by 13 enterprises, which mainly specialize in the manufacture of machinery and equipment, electrical and electronic equipment, equipment for the oil and gas, petrochemical and chemical industries.

Forests are of great importance in the economic and social development of the region. The total area of forests is 258 thousand hectares. Every year on the area of 1.3 thousand hectares, reforestation works are being carried out, which contributes to the increase of the forest fund and the increase of forest productivity. That is why the wood-processing industry is widely developed, which is one of the oldest branches. In terms of industrial production, the industry occupies the sixth place and is represented by 36 enterprises, which makes up 15.8% of the total number of enterprises in the region.

The industrialization in the Prut and the upper Siret basins in Romania is represented by all branches of industry: extractive industry, manufacturing, electrical and thermal energy, chemical industry, food and beverage industry, textile industry, woodworking, the industry of other non-metallic products, metallic and metal products, furniture and other industrial products, glassware and ceramics, steel industry.

The agriculture includes livestock farming, fish farming, arable land cultivation, mainly with corn, potatoes, sunflower, and sugar beet.

A total of 75 Territorial Administrative Units are potentially affected, more or less, by floods with a 1% probability that may occur in the analyzed sectors (Table 6). In total, there are 537 hospitals, 554 educational units, 166 social administrative objectives, 164 cult sites, 14 IPPC installations, 16 EPRTR objectives, 23 museums. For the above-mentioned objectives the maximum concentration can be found in Iasi UAT and Galati UAT.

Table 6. Main economical and social objectives on the Territorial Administrative Units potentially affected by floods with a 1% probability (Upper Siret and Prut river basins)

UAT	COUNTY	Hospital	Socio-Ec. Objectives	School	Church	EPRTR	IPPC	Museum
GALATI	GALATI	57	5	86	30	3	3	2
FOLTESTI	GALATI	0	2	2	1	0	0	0
MASTACANI	GALATI	0	1	1	1	0	0	0
VLADESTI	GALATI	0	2	3	0	0	0	0
CAVADINESTI	GALATI	0	2	6	1	0	0	0
BLAGESTI	VASLUI	0	1	2	0	0	0	0
MURGENI	VASLUI	1	1	2	0	0	0	0
FALCIU	VASLUI	0	3	3	0	0	0	0
BEREZENI	VASLUI	0	3	3	0	0	0	0
VETRISOAIA	VASLUI	0	2	4	0	0	0	0
LUNCA BANULUI	VASLUI	0	2	2	0	0	0	0
STANILESTI	VASLUI	0	2	6	0	0	0	0
DUDA-EPURENI	VASLUI	1	1	4	0	0	0	0
DRANCENI	VASLUI	0	2	3	0	0	0	0
UNGHENI	IASI	0	0	4	0	0	0	0
MOVILENI	IASI	0	2	4	0	0	0	0
LITENI	SUCEAVA	2	2	5	1	0	0	0
VORONA	BOTOSANI	1	2	8	5	0	0	0
FANTANELE	SUCEAVA	1	2	6	0	0	0	0

UAT	COUNTY	Hospital	Socio-Ec. Objectives	School	Church	EPRTR	IPPC	Museum
CALARASI	BOTOSANI	0	2	3	0	0	0	0
CORNI	BOTOSANI	0	2	7	1	0	0	0
SANTA MARE	BOTOSANI	0	4	5	0	0	0	0
ROMANESTI	BOTOSANI	0	3	3	0	0	0	0
HANTESTI	SUCEAVA	0	2	3	0	0	0	0
BUCECEA	BOTOSANI	0	3	12	1	0	1	0
STEFANESTI	BOTOSANI	0	2	2	0	0	0	0
ZVORISTEA	SUCEAVA	0	2	4	0	0	0	0
DOBARCENI	BOTOSANI	0	2	2	0	0	0	0
ZAMOSTEA	SUCEAVA	0	2	4	0	0	0	0
VARFU CAMPULUI	BOTOSANI	1	2	8	2	0	0	0
GRAMESTI	SUCEAVA	0	2	3	0	0	0	0
MIHALASENI	BOTOSANI	0	2	5	0	0	0	0
CANDESTI	BOTOSANI	0	2	3	1	0	0	0
RIPICENI	BOTOSANI	0	0	1	2	0	0	0
MUSENITA	SUCEAVA	0	2	4	0	0	0	0
MIHAILENI	BOTOSANI	0	1	1	1	0	0	1
MANOLEASA	BOTOSANI	0	2	4	0	0	0	0
MITOC	BOTOSANI	0	0	0	1	0	0	0
SUHARAU	BOTOSANI	0	1	7	1	0	0	0
COTUSCA	BOTOSANI	1	2	8	4	0	0	0
HUDESTI	BOTOSANI	0	2	4	1	0	0	0
DARABANI	BOTOSANI	0	4	9	3	0	0	0
RADAUTI-PRUT	BOTOSANI	0	2	6	0	0	0	0
PALTINIS	BOTOSANI	0	4	4	2	0	0	0
POPRICANI	IASI	0	2	2	1	0	0	0
TULUCESTI	GALATI	0	4	3	0	2	1	0
OANCEA	GALATI	0	2	1	1	0	0	0
SUCEVENI	GALATI	0	2	2	0	0	0	0
FRUMUSITA	GALATI	0	1	3	0	0	0	0
VANATORI	IASI	0	1	4	0	0	0	0
TRIFESTI	IASI	0	2	4	0	0	0	0
BIVOLARI	IASI	0	2	1	0	1	1	0
VERESTI	SUCEAVA	0	2	4	0	0	0	0
DUMBRAVENI	SUCEAVA	0	2	5	1	0	0	0
SIMINICEA	SUCEAVA	0	1	3	1	0	0	0
SIRET	SUCEAVA	8	3	11	11	0	0	1
DOLHASCA	SUCEAVA	3	3	17	9	0	0	0
GORBAN	IASI	0	2	3	0	0	0	0
GROZESTI	IASI	0	1	2	1	0	0	0
RADUCANENI	IASI	0	3	4	2	0	0	0
COSTULENI	IASI	0	1	4	0	0	0	0
COMARNA	IASI	0	2	6	0	0	0	0
TOMESTI	IASI	0	2	5	3	1	2	0
TUTORA	IASI	0	3	2	0	1	1	0

UAT	COUNTY	Hospital	Socio-Ec. Objectives	School	Church	EPRTR	IPPC	Museum
GOLAIESTI	IASI	0	2	4	0	0	0	0
VLADENI	IASI	1	2	4	1	0	0	0
TIGANASI	IASI	0	2	4	1	0	0	0
LESPEZI	IASI	1	3	3	0	0	0	0
GROPNITA	IASI	0	2	5	0	0	0	0
HOLBOCA	IASI	0	1	5	1	1	1	0
IASI	IASI	458	16	164	69	7	4	19
VICTORIA	IASI	0	2	4	0	0	0	0
TUDORA	BOTOSANI	0	2	4	1	0	0	0
PROBOTA	IASI	1	2	2	0	0	0	0
PRISACANI	IASI	0	2	3	2	0	0	0

3.8. Historical floods

Floods on the rivers of the Ukrainian Carpathians are formed by atmospheric precipitation. However, their formation begins when rainfall exceeds 20-30 mm per day. Physical-geographical conditions, especially the orographic features of the Carpathian Mountains, contribute to a significant increase in the amount and intensity of precipitation, the annual amount of which is three times more compared with the vast majority of the plain area of Ukraine. The daily rainfall in the Carpathian River basins often exceeds 100 mm and reaches 150-200 mm. Significant and intense storm rains lead to the formation of high floods, which often become dangerous, catastrophic, causing significant damage to territories, settlements, objects of management, etc.

A characteristic feature of the Prut and Siret river regime is the formation of floods throughout the year. Flood formation takes place in the process of interaction of a number of factors, the main of which are hydrometeorological and the nature of the underlying surface of the catchment: frequent precipitation significant precipitation throughout the year, and especially the rainfall nature of them in the warm period, sharp warming in the cold period, which are accompanied by intense precipitation.

A significant part of floods is characterized by the outflow of water to the floodplain with flooding of pastures and agricultural lands, residential and economic objects. Flood formation takes place in the process of interaction of a number of factors, the main of which are hydrometeorological and the nature of the underlying surface of the catchment: frequent precipitation throughout the year, and especially the storm in the warm period. Depending on the frequency of storm rainfall, the number of floods during the summer period reaches 4-5 times.

In the analised river basins, in the last years, there have been three major floods that can be considered "historical", in the years 2005, 2008 and 2010. Flood formation was favored by high rainfall due to temperate cyclone that affected north-east Romania, Republic of Moldova and Ukraine. Daily rainfall (or even hourly) data are essential for the hydrological modeling of the extreme phenomena. Torrential rains, whose values exceed in most cases 100 mm in 24 hours, even over several days, have produced catastrophic floods.

The hydrometric stations for which we obtained the necessary information for the description of selected floods was selected in accordance to the following criteria (Table 7):

- Hydrometric stations from all three countries on the rivers Prut and Siret;
- Hydrometric stations from the confluences with the main tributaries of the Siret and Prut rivers;
- Hydrometric stations in small river basins of the three countries, that allows the comparative analysis of the evolution of floods.

Table 7. The selected gauging stations

No.	Country	River Basin	River	Hydrometric Station
1	Ukraine	Siret	Siret	Storojinet
2	Romania		Siret	Siret
3			Siret	Lespezi
4			Suceava	Brodina
5			Suceava	Itcani
6			Moldova	Fundu Moldovei
7	Ukraine	Prut	Prut	Iaremcia
8			Prut	Kolomeea
9			Prut	Cernauti
10			Ceremus	Usteritchi
11			Ceremusul Alb	Verhovina
12			Putila	Putila
13	Romania		Prut	Radauti Prut
14			Prut	Stanca Aval
15			Prut	Ungheni
16			Volovat	Manoleasa
17			Jijia	Victoria
18			Bahlui	Iasi
19	Republic of Moldova		Prut	Sireuti
20			Prut	Costesti
21			Prut	Ungheni
21			Veljia	Balasinesti
23			Delia	Parlita

Before to 2005, the following dangerous, catastrophic rain floods can be identified within Ukraine ***for the Siret river basin***: 1911, 1969, 1974 and 1995.

The flood on July 8 - 9, 1911 was formed due to the fall of strong rainfalls. Levels of water on the river Siret - Storozhynets reached the highest marks, which were not exceeded during the entire period of hydrometric observations. Rise of water levels on the river Siret - Storozhynets was about 4 m.

Catastrophic flood 8 - 12 June 1969 who raise the highest levels exceeded all previous floods resulting from exceptionally heavy rains that swept the entire north-eastern slopes, an area of which is 22,000 km^2. The rainfall for June 7 - 10 exceeded the monthly rate.

Flood waters on the river Siret agricultural land, residential buildings were flooded in the district of hydropost, in Beregomet 35 km above the hydropost, in Lukivtsi 30 km above the hydropost, in Stara Zhadova 20 km above the hydropost, in Komarivtsi 15 km above the hydropost, in Klynivka 5 km above the hydropost. The maximum flow was 792 m^3/s.

The rainy flood resulting from the collapse of very heavy rainfall over 12-13 July 1969 on the territory of the Siret, Suceava basins, led to the formation of a catastrophic rainstorming flood which, according to levels and flows of water, exceeded the June flood of 1969. The daily rainfall in the upper part of the river Siret was about 90 mm. The maximum water discharge on the river Siret - Storozhynets was 816 m^3/s.

The intense precipitation caused by cyclonic activity over Romania led to the formation of a catastrophic rainstorm flood on the rivers of Siret basin on May 13, 1970. According to the water levels, this flood is most closely related to the flood 13.07. 1969. As a result of the flood, agricultural land, residential buildings were flooded in the district of hydropost, in Beregomet, Lukivtsi, Stara Zhadova, Komarivtsi, Klynivka. The maximum discharge on the river Siret - Storozhynets was 740 m^3/s.

July 1, 1974, due to the strong and very heavy precipitation on the river Siret formed rain flood. Flood caused flooding of agricultural land, residential buildings in the district of hydropost, in Beregomet, Lukivtsi, Stara Zhadova, Komarivtsi, Klynivka.

On June 28-29, 1995, on the rivers of the Siret catchment, a high raining flood occurred. Very heavy rainfall has caused significant local, power runoff and mudflows. The maximum discharge on the river Siret - Storozhynets was 308 m^3/s.

In the Prut river basin, remarkable floods are formed in two districts - the upper part of Prut and its tributary Cheremosh. Depending on the coincidence of the water masses coming from these parts of the catchment, the shape of the hydrograph and the maximum height of the flood in the Prut region below the Cheremosh fall depends on the water masses.

Very high rain floods previous to 2005 in the basin of the Prut were observed in 1911, 1927, 1941, 1955, 1964, 1969, 1970, 1974 and 1996.

The flood on July 8 - 9, 1911 was formed due to the fall of strong showers. The water levels on the river Prut - Chernivtsi reached the highest marks, which were not exceeded during the entire period of hydrometric observations.

The flood on August **30 - August 31, 1927,** occurred in the basin of river Prut. The water levels at hydropost Tatariv were the highest during the entire period of observations and amounted to 619 cm above the zero of the post. During the flood, traffic was blurred, the agricultural land was flooded, flooded residential and economic objects.

Storm rain on **September 1-21, 1941**, which covered the entire macro slope, led to the formation of a very high flood in the Prut basin. According to the marks on the river Prut - Chernivtsi and the records, this flood is most closely related to the 1969 flood.

In 1955, on the rivers of the mountainous part of the Prut basin, there were two maximum elevations of water levels (July 30 and August 10), but they were lower than the previous ones. The daily rainfall in the upper area of the Prut basin reached 100 - 110 mm. The maximum water discharge on August 10 at the Prut river in Chernivtsi was 2500 m^3/s.

July 3-4, 1964, due to very heavy rainfall on the rivers of the Prut basin formed a high rain flood. The maximum daily amount of precipitation in the upper part was more than 90 mm. The maximum water discharge on the river Prut - Chernivtsi was 2170 m^3/s.

The catastrophic flood on June 8-12, 1969, which, at hight of rising levels, exceeded all previous floods, was formed from exceptionally heavy rains that covered the entire northeast macro slope, an area of which was 22,000 km^2. The rainfall for June 7 - 10 in places exceeded the monthly rate.

In most places, main part of the precipitation dropped over the half day and amounted to 70 - 100% precipitation for the entire period of rain. The maximum rainfall intensity (1-2 mm/min for 5 minutes) was observed on June 8 in Chernivtsi and Seliatyn. The average intensity of the shower for half an hour at Dora ranged from 0.17 to 0.23 mm/min. The daily maximals at the hydroposts and meteorological stations of the Prut basin reached 8th of June from 75 (M Kolomyia) to 173 (M Yaremcha) mm. During the flood the water in the mountains was raised by 2-4 m, and in the foothills - by 5-7 m. This flood exceeded the maximum of all floods of the twentieth century and caused huge losses to the national economy. Water discharge on the river Prut - Chernivtsi was 5200 m^3/s.

During the catastrophic rain flood on the river Prut - Chernivtsi, significant territories were flooded under the factories and plants, namely: Mill factory № 3; WPP; Shoe factory № 33; Furniture factory; Watercatchment of electric station; Engineering factory; Power station; Glove and Garment Factory; Punch-industrial association; Sewing association "Trembita"; Butter-fat plant; Yeast Factory; Plant of Reinforced concrete products; Railway station; Bus station number 3; Rhinoparticle Plant; Factory of Enamelware; Factory of Reinforced concrete constructions; Sugar plant; Locomotive depot; Vtorchermet; Stadium of the stocking combine; Alcohol factory; Pump station "Beregova".

On May 13-14, 1970 the fall of very strong storm rainfall led to the formation of high rain floods. The amplitude of the rise of water levels on the foothills was more than 5 m. The maximum water discharge on the river Prut - Chernivtsi was 3050 m^3/s.

Strong and very heavy rainstorms caused the formation of a catastrophic rain flood on **July 21-22, 1974**. The maximum daily rainfall was about 90 - 100 mm. The precipitations fell on the pre-humidified catchment area. The maximum discharge on the river Prut - Chernivtsi was 3880 m^3/s; on the river Cheremosh - Usteriky maximum water discharge exceeded flood costs in 1969 and amounted to 1080 m^3/s.

On September 8, 1996, very heavy rainfall of 50-100 mm falling on the mountainous part of the Prut and Cheremosh catchment led to the formation of high rain floods. The rise of water levels on the river Prut amounted to 4 - 4.5 m. The maximum water discharge on the river Prut - Chernivtsi was 1940 m^3/s.

The flood from august 2005 in the Prut River Basin

From 17 to 19 August 2005, a natural hydrological phenomenon was observed due to the cyclone located above the Carpathians. Precipitations that fell during this period formed an intense rain flood. The total amplitude of the rising on the river Prut in the area of Kolomyia was the state border 3.75 m above the pre-flood values.

The amount of precipitation for the period from August 17 to August 19 was:

- Chernivtsi 123.3 mm;
- at meteostation Seliatyn – 156 mm;
- Yaremche – 104 mm.

The flood was accompanied by a water outlet on a floodplain, flooding of dwelling houses, agricultural lands located in floodplains.

According to the Ministry of Emergencies of Chernivtsi region:
- 142 settlements were blackouted;
- 68 settlements were without communication;
- in Hertsa, the dam broke through two own ponds, resulting in flooded homes, evacuated 120 people and property. There were no victims. In the village of horbovo, Hertsa district, dams were destroyed at their own ponds;
- in Chernivtsi there were flooded houses on 4 streets of Sadhora microdistrict (the left bank of the river Prut is located in a floodplain).

Maximum water flow on the river Prut - Chernivtsi was 1386 m^3/s.

In Romania, in the upper basin of the Prut River, between 18 and 21 August 2005 there were precipitations of over 120 mm. High rainfall occurred mainly in the vicinity of the Prut River in the upper basin of Jijia. The main core of the precipitations occurred on August 19, 2005 when values of over 80 mm were recorded, both on the river Prut (e.g. Oroftiana 92.6 mm, Radauti-Prut 86.2 mm, downstream Stanca 144.4 mm) and in the the upper Jijia river basin (e.g. Havarna 99.9 mm, Mileanca 109 mm, Targu Frumos 120 mm, Strunga 103.4 mm).

Maximum values of the total rainfall that generated the mentioned flood (18-21 August 2005) were recorded at Radauti Prut 179.1 mm, Padureni 151.4 mm, Mileanca 160 mm, Downstream Stanca 155.5 mm, Strunga 171.4 mm, Targu Frumos 195.5 mm (Table 8). In the same period, immediately downstream of the affected area, there were recorded rainfall of 15.4 mm at Iasi Airport, 28.5 mm in Iasi – Copou, 5.7 mm at Husi, 2.8 mm at Dranceni.

From the warning received from Ukraine, Chernivtsi Hydrometeorological Center, also resulted that in the Prut basin, in Ukraine, there have been significant rainfall. Significant rainfall recorded in the vicinity of the Prut River, upstream Stanca Reservoir, lead to the determination that on the territory of the Republic of Moldova and in the area upstream the reservoir, there were abundant rainfall.

Table 8. Precipitations which generated the flood from 18-24 august (mm)

Pluviometric post/ meteorological station	18 August	19 August	20 August	21 August	Total
Oroftiana	27.0	92.6	25.0	1.5	146.1
Radauti Prut	45.7	86.2	47.2	0.0	179.1
Padureni	40.0	78.8	24.8	7.8	151.4
Havarna	19.5	99.9	34.8	0.0	154.2
Pomarla	19.6	88.3	32.7	0.0	140.6
Mileanca acumulare	10.1	109.0	40.9	0.0	160.0
Ezareni acumulare	54.0	57.9	46.3	4.6	163.0
Tudora	34.0	100.0	0.0	0.0	134.0
Ungheni	*0.0*	*22.5*	*0.6*	*0.5*	*23.6*
Harlau	1.2	63.6	14.5	9.8	89.1
Iasi urban	*0.0*	*21.5*	*17.6*	*0.0*	*39.1*
Carjoaia	5.2	75.0	46.2	5.2	131.6
Strunga	0.0	103.4	68.0	0.0	171.4
Targu Frumos	6.9	120.1	68.5	0.0	195.5

From the comparative analysis of the maximum flow which occurred at several representative gauging stations, in August 2005 and during the determination of flows, resulted that the flood in August 2005 is far below those of 1969, 1988 and 1998, except for the hydrometric station Radauti Prut, on the river Prut, despite these precipitations with exceptional intensity and values (Table 9).

Occurrence in August 2005, of certain maximum discharges which were lower than those recorded during the operation of the existing hydrometric stations, amid high rainfall is due to a previous period of several months with little or no precipitation and proper management, based on hydrological forecasts, including pre-emptying small reservoirs used for fish farming.

Table 9. Comparative analysis of maximum dischargs in the Upper Prut River Basin

No.	Hydrometric station	River	Maximum discharge august 2005 (m^3/s)	Maximum discharge during the determination period (m^3/s)	Year of occurrence of the determined maximum discharge
1	Radauti Prut	Prut	2640	1960	1998
2	Padureni	Buhai	25.0	96.0	1998
3	Manoleasa	Volovat	25.0	69.0	1988
4	Dorohoi	Jijia	76.6	170	1969
5	Stefanesti	Baseu	125	330	1969

On the Prut River, upstream of the Stanca reservoir, there was available data regarding levels and discharges at Cernauti hydrometric station (Ukraine) at 8, 12, 16, 20 hours, with a frequency during the flood of 1-3 hours at Oroftiana in Romania, and water levels and discharges, with a frequency of once every 1-6 hours, depending on the existing gage height at Radauti Prut, Downsteam Stanca, Ungheni, Prisacani, Dranceni, Falciu, Oancea hydrometric stations.

The flood from July 2008

The rainy flood in the third decade of July 2008 formed on the background of a near and slightly lower than the average water content of the rivers in conditions of sufficient moisture and waterlogging of the meter layer of soil.

The most significant and intense were precipitation in the mountainous parts of the Siret basin, where powerful floods with large-scale negative impacts on the territory, settlements and infrastructure were formed. According to consequences of the 2008 floods in the Siret basin, it can be described as catastrophic. The formation of a high rise of a catastrophic flood was accompanied by the release of water on floodplains, flooding of agricultural objects, dwellings, the breakthrough of dams and ponds.

The maximum rise of water level on the river Siret - Storozhynets was more than 5m. The maximum water discharge on the river Siret - Storozhynets was 893 m^3/s.

On 23.06.2010, the fall of storm precipitation on the redeployment river basin of Siret caused the formation of high rain flood. Levels of water on the river Siret - Storozhynets exceeded the markings of the natural hydrometeorological phenomenon. As a result of the flood, agricultural land, residential houses were flooded. The maximum water flow on the river Siret - Storozhynets was 401 m^3/s.

In Prut basin, the rainy flood in the third decade of July 2008 formed on the background of a near and slightly lower than the average water content of the rivers in conditions of sufficient moisture and waterlogging of the meter layer of soil. The maximum rise of water level on the river Prut - Chernivtsi was 7.9 m. The maximum water discharge on the river Bilyi Cheremosh - Yablunytsia, the river Prut - Vorohta exceeded historical figures.

The most significant and intense rainfall was in the mountainous parts of the Prut basins, where powerful floods with large-scale negative impacts on the territory, settlements and infrastructure were formed.

The formation of a high rise of a catastrophic flood was accompanied by the outlet of water for floodplains, flooding of agricultural objects, dwelling houses, the breakthrough of dams and ponds. According to consecquences, the 2008 flood in the Prut basins can be characterized as catastrophic.

The flood of 22 – 28 July 2008 was due to large amounts of rainfall, the result of the retrograde front that fell mainly in the upper part of Siret and Prut river basins, in Ukraine and in the upper basin of the rivers Suceava and Moldova in Romania. Rainfall that fell in the period 23-27.07.2008 totaled large amounts characterized by a torrential regime, their volume manifesting as two cores: one on 24-25.07.2008 and the second on 25 - 26.07.2008. There were also heavy precipitation in the basins of the Prut river tributaries in the Republic of Moldova.

Thus, in Ukraine, where is located the upper course of the river Prut, there were recorded rainfall between 63 and 260 mm: Verhovina (186 mm), Putila (128 mm) and Kuti (133 mm) – Figure 6. The highest amount of rainfall - 225 mm fell in Ocniţa exceeding 10 times the decadal norm, which was reported for the first time in the entire period of measurements. At hydrometric stations in Romania there were also significant values (e.g. Cotnari meteorological station 203.2 mm in 24 hours).

Average rainfall at several stations in the Prut catchment in Romania, show values up to 150-200 mm in 40 days (178 mm at Botosani station or 209.1 mm at Cotnari station).

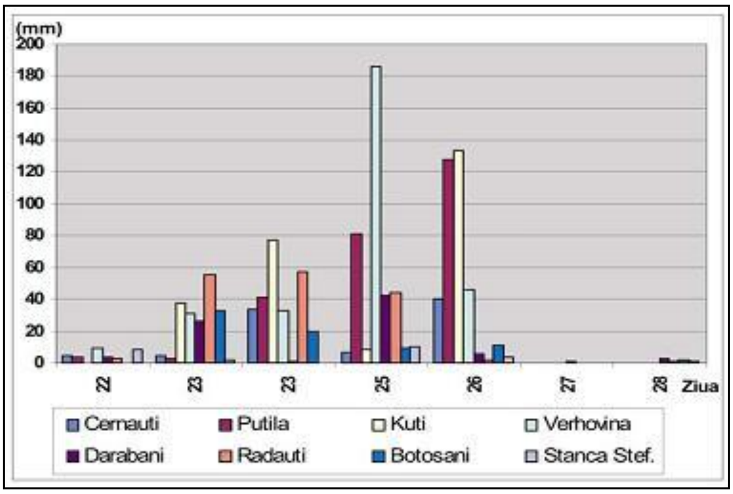


Figure 6. Siret and Prut River Basins:

a) entire catchement areas; b) study area splited by 3 country

The Prut River flood had a historic character justified by the size of the main parameters of the flood, i.e. peak flows and volumes drained.

On the Prut River, near the town of Chernivtsi (Ukraine) flood peaked at 7.9 m above the previous water level anterior to the flood, and maximum flow recorded was 3890 m^3/s on 27 July 2008. At Sireuti hydrological post (Republic of Moldova) maximum flow recorded was 4560 m^3/s (Table 10). At the Radauti – Prut hydrological station, the average flow in 2008 was 137 m^3/s, much exceeding (1.7%) the annual average of the 1950-2008 period (80.8 m^3/s). The highest mean monthly value being reached in July (568 m^3/s).

Table 10. Discharges on the river Prut, including the pluvial flood from the summer of 2008

River/Post	The normal value of monthly mean runoff Q max (m^3/s)		Multiannual characteristics Q max (m^3/s)		Flood from July – August 2008		Multiannual characteristics Q max (m^3/s)			
	July	August	Qmax (m^3/s)	Date	Qmax (m^3/s)	Date	July	date	august	date
Prut – Cernauti	94.6	70.5	5210	09.06.1969	3890	26.07	3880	23.07.1974	2820	11.08.1955
Prut – Sireuti	86.1	89.3	1980	22.05.1998	4560	28.07	856	17.07.2003	1820	21.08.2008
Prut	113	103	687	13.08	698	05.08	598	21.07.1998	687	13.08.1991

At Stanca hydrometric station, the mean discharge from 2008 was 132 m^3/s, also much higher (1.6%) compared to the multiannual average flow specific for the period 1950 - 2008 (84.1 m^3/s).

Basically, the Prut River floods begin on 24.07.2008, at 6:00 o'clock, at Chernovtsy station, when the rate rose sharply to a value of 387 m^3/s and the gage height reached 314 cm, 186 cm above the Attention Level (AL). On the same day at Radauti Prut station, at 20:00, a discharge of 434 m^3/s and gage height of 290 cm is recorded, triggering the Attention Level (AL). It should be noted that Stanca-Costesti reservoir, at the time, recorded a minimum volume of water as a result of prolonged drought (90 m from the Baltic Sea level).

Maximum discharges and water levels of the Prut River were recorded in the sector upstream the Stanca-Costesti Reservoir, at Radauti Prut section, being of 4240 m^3/s and 113 cm respectively. The Danger Level (DL), at Radauti Prut station, started on 26.07.2008, at 22:00, when the level stood at 625 cm (25 cm over the DL and discharge of 2090 m^3/s) and lasted until 30.07.2008, at 18:00, when the rate reached 608 cm (8 cm over the DL and a discharge of 1920 m^3/s). The highest values were recorded on 28.07.2008, between 21:00-24:00. At the same time the DL is established at Oroftiana station, and at the station Stanca Aval station the Flood Level (FL) was declared.

The attenuation role of the Stanca – Costesti Reservoir is obvious, but keeping the high level for 20-30 days, is determined by collecting a huge volume of water in the lake and its distribution downstream in a much longer period of time (Figure 7). The flooding problem downstream Stanca – Costesti reservoir started only on 26.07.2008, at 15:00, when they recorded the highest values in the lake.

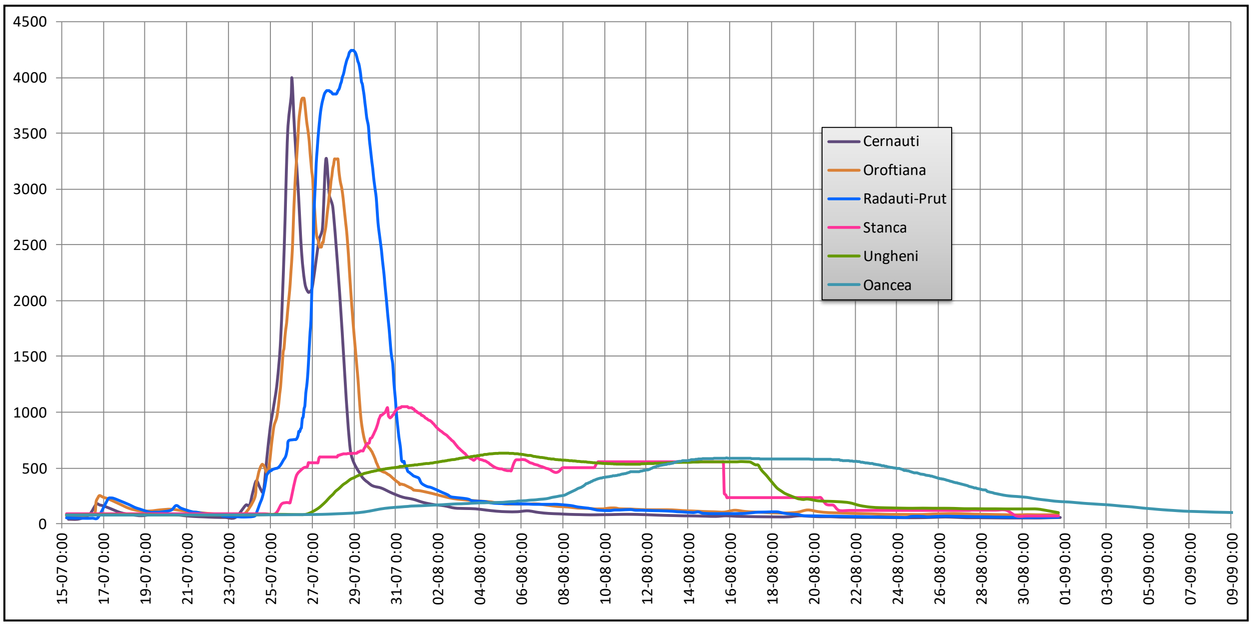


Figure 7. Discahrge hydrograph along the Prut River for July 2008 flood

The floods that followed downstream Stanca - Costesti is due, in part, to the excess water discharged from the lake and less intake of water from rainfall. The Attention Level (AL) from the Radauti Prut station was maintained only until 31.07.2088, at 20:00.

From the analysis of the existing data in the NIHW archive we notice that at the representative stations from the Prut Basin, the probability of the maximum flow recorded in 2008 are between 2.38% and 43.33%. (Table 11).

Table 11. Exceding probability of the maximum water flow recorded in July 2008

River	Hydrometric station	Year	Q max (m^3/s)	p(%)
Prut	Radauti Prut	2008	4240	2.38
Prut	Stanca Aval	2008	1050	3.13
Prut	Ungheni	2008	630	15.09
Jijia	Victoria	2008	67.2	43.33
Bahlui	Iasi	2008	38.2	36.67

Heavy rainfall also occurred in the upper catchment of the river Moldova, with floods in the Pojorata-Campulung - Stulpicani, and after about 24 hours another wave of precipitation affected catchments Suceava, upper Siret and Prut catchments (Figure 7).

The significant rainfall fallen in the Moldova river basin in the period 23-24.07.2008 basin totaled: 74.1 mm m at Fd. Moldova, Moldova River, 62.8 mm m at Prisaca Dorna on the river Moldova, 69.3 mm m at Gura Humorului on the river Moldova, 87.8 mm m at Pojorata on the river Moldova, 66.8 mm m at Lungulet on the Moldova River, 83.2 mm m at Dragoşa on the Moldova River, 85.8 mm m at Stulpicani on the Suha River.

It can be seen that the highest volumes fell in the Pojorata - Deli - Stulpicani where floods have occurred and there were significant material damage. Also, in the Moldova river basin, heavy rainfall occurred on 26 - 27 July 2008.

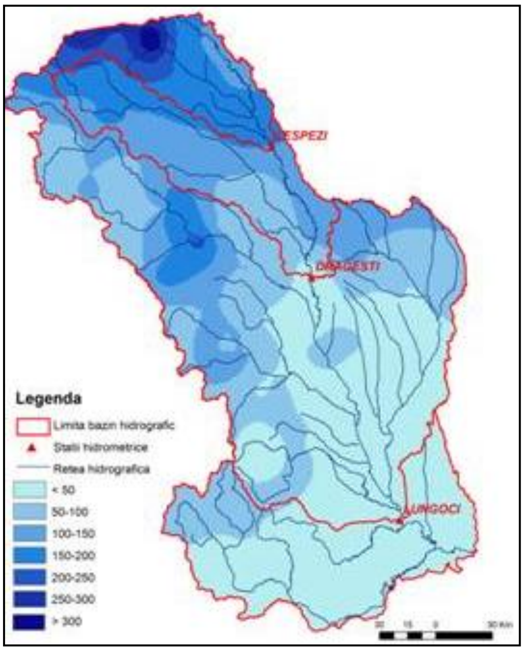


Figure 7. Distribution of cumulated rainfall between 22 - 28.07.2008 in Siret R.B.

The flood lead, in certain sub-basins, to substantial changes in the morphology of the riverbeds with shifts in the vertical plane.

Other heavy rainfall cycles occurred especially in the catchments of the rivers Suceava and upper Siret. The total amounts of rainfall which caused floods considered for the entire period, respectively 22 - 27 July 2008 had values of 262 mm m at Brodina- Suceava river, 192 mm m at Horodnic- Pozen river, 183 mm m at Sucevita – Sucevita river, 177.4 mm at Parhauti- Solonet river, 176 mm at Siret-Siret river, 173.4 mm at Tibeni- Suceava river, 130.3 mm Lespezi-Siret river etc.

Table 12. Daily precipitation fallen between 22 and 28.VII.2008

River	Hydrometric station	Daily precipitation fallen between 22 - 28.VII. 2008							Total 22-28. VII
		22	23	24	25	26	27	28	
Suceava	Brodina	3.2	23.8	52.7	102.3	107.7	10.2		299.9
Putna	Putna	3.1	27.9	107.3	39.6	25	18.4		221.3
Pozen	Horodnic	4.1	15.2	73.2	143	81.7	37.2		354.4

The maximum flow of Siret River recorded a significant increasing do to the contribution of Siret (1710 m^3/s) and Moldova river (Figure 8). Between Hutani and Lespezi gauging station, water flow increase by 3 times.

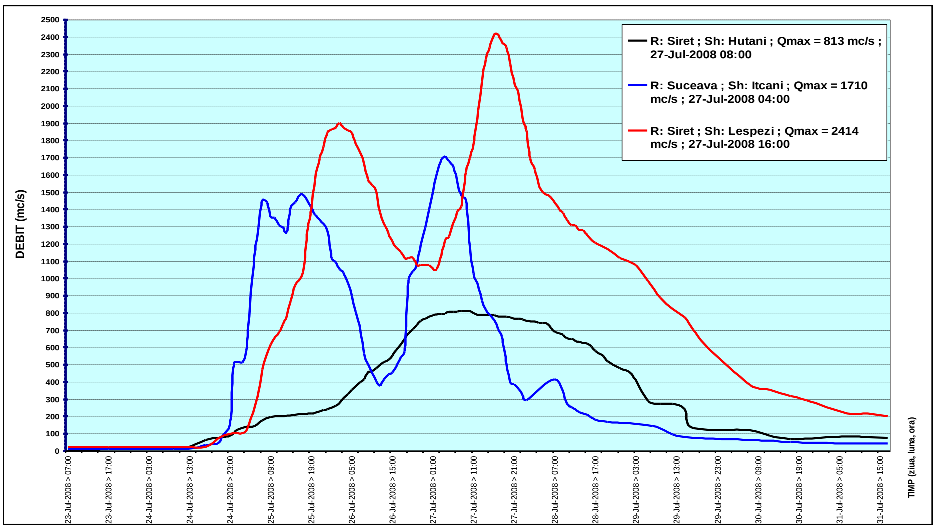


Figure 8. The maximum discharges hydrograph from the Siret – Lespezi sector (July 2008)

Flood from 20 June-3 July 2010

In the first decade of July 2010, high rain floods were noted. The flood was formed due to the precipitation of very strong storm rainfall. The maximum daily rainfall in the upper part of the river Prut was about 120 mm.

From the point of view of the occurrence area, the common element of the floods of 2008 and 2010 is in their transboundary evolution. In 2008, the phenomenon also occurred in Ukraine (upper and middle basins of the rivers Suceava, Siret and Prut) and in 2010 floods also affected Moldova (middle and lower basin of the Prut River).

In terms of weather, heavy rains were due to the combination of two synoptic: on one hand maintaining the ridge of the Azores Anti-Cyclone over Central Europe (which ensured the supply of polar cold air over Romania on a predominantly northern circulation) and on the other hand the advection of tropical air over the Balkan Peninsula towards the regions east from the Carpathian Mountains, including the one situated in western Ukraine.

The flood of June-July 2010, as the one in 2008 occurred in both basins (Siret and Prut), it still lacking the scale of the one from 2008.

In the basins of rivers Suceava, Moldova, Jijia, on the upper course of the Siret river and in the upper basin of the Prut River, there were large amounts of rainfall in 3 intervals (June 21 to 24, 26 to 27 June and 28 June and 1 July), which led to the formation of consecutive floods at short intervals with high values of the maximum flow (Figure 9).

Between June 21 and June 24, there were recorded precipitation amounts between 50-150 mm in the middle and lower basin of Suceava and in the upper basins of Moldova, Prut and Jijia (e.g. Itcani-107.8 mm, Oroftiana 105 mm).

Between 25 and 27 June, the precipitation amounts totaled frequent values between 50-100 mm, on the same rivers in Siret basin. Over 90% of the above only fell on 26 and 27.06.2010.

The third wave of significant rainfall (June 28-July 1) frequently totaled over 100 mm, in the catchments of Suceava, Moldova Rivers, and on the upper courses of Siret, Prut and Jijia. Heavy rainfall in the first part of the day (28.06.2010) caused floods in the south-eastern part of Suceava County (Dolhasca, Liteni and Udeşti) as well as in the northeastern part of the county (Zamostea, Zvoristea, Grămeşti, Dărmăneşti Dorneşti, Pătrăuţi, Şerbăuţi etc.) – Figure 10.

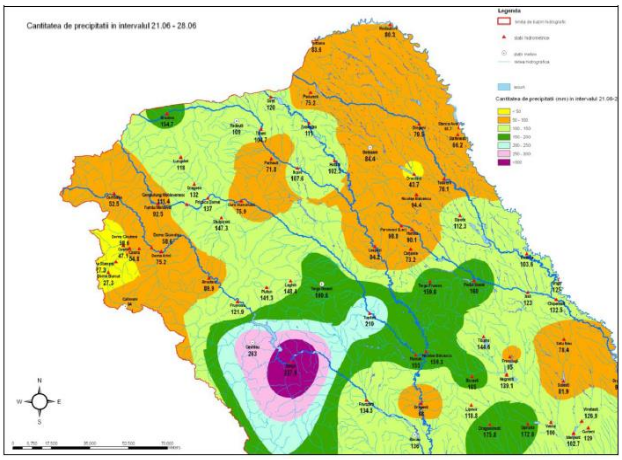


Figure 9. The precipitation amount between 21 – 28 June 2010.

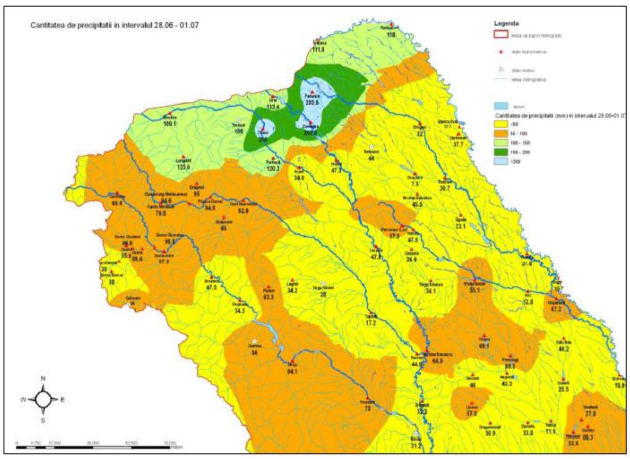


Figure 10. The third wave of significant rainfall

There were almost instantaneous real cloudburst, rainfall measured at some stations showing 150-200 mm values in only 2 hours. Table 13 presents a few examples of precipitations recorded at hydrometric station in the period 28.06-1.07.2010.

A lot of this precipitation had a torrential character, thus recording large quantities in short time (e.g. Zvoristea- 76.0 mm in 90 minutes, Oroftiana 51.5 mm in 50 minutes).

Table 13. Daily precipitation fallen between 28.06-1.07.2010

No.	River	Hydrometric station	Rainfall mm
1	Siret	Siret	133.4
2		Zvoristea	202.5
3	Suceava	Brodina	109.1
4		Tibeni	209.7
5		Itcani	32.8
6	Pozen	Horodnic	115.2

No.	River	Hydrometric station	Rainfall mm
7	Moldova	Fd. Moldovei	79.8
8	Moldovita	Lungulet	125.6
9		Dragosa	96.7
10	Suha	Stulpicani	66.0
11	Buhai	Padureni	206
12		Pomarla	110

In the period May to July 2010, and in Western Ukraine, fell important quantities of precipitations, far surpassing the multiannual average for this time of year. By this front of precipitations Republic of Moldova was also affected. For example, during 1.05-15.06.2010 amounts of rainfall that affected a large part of Moldovan territory constituted 200-400 mm, exceeding 1.5-2 times the multiannual average for this period of time. Isolatedly, in some localities in the central and northern part of the country (Briceni Sirauti, Soroca, Riscan, Costesti, Camenca, Ribnita, Costesti Hrusca and Carpineni), the amount of rainfall was even higher, reaching at Edinet 471 mm (292% of the norm for this period).

This succession of precipitations determined the formation of exceptional floods, which during the period of the third interval lead to exceedance of Danger Levels. The Şomuzurile and their tributaries flooded more than 100 households, important sectors of county and communal roads and rail sections. Following the reconstitution of the maximum flow of Ruda River in Dorneşti showed that flood had produced on 28.06.2010 a flow of 290 m^3/s, exceeding the normal ensurance of 1% which was 175 m^3/s.

Analyzing the flood hydrographs from Suceava and Moldova river basins, there were two significant peaks of the composed flood. The second flood peak on the Suceava river (with a rate higher than that of the first peak) mixed with the flows discharged from Bucecea reservoir (reduced by maneuvers) and propagated downstream on the river Siret.

Rainfall recorded both in the upper basin of the Prut (Ukraine) and the Romanian territory led to significant increases in levels exceeding the Defense Levels.

On the Prut River, at the Radauti Prut hydrometric station, flows recorded were lower than historical highs in 2008, but the feature of this period was that there were four consecutive maximum flow at short intervals of time, their values being 1805 m^3/s, 2020 m^3/s, 2200 m^3/s and 2310 m^3/s. The maximum flow on the river Prut - Chernivtsi was 2081 m^3/s.

Hydrometric stations at which the analysis of flows and volumes for the mentioned period were made, are base stations on the main course of the Siret River to which were added that closing stations on tributaries Suceava and Moldova.

Basin analysis of the maximum runoff, having as control points the sections of the mentioned hydrometric stations, was conducted according to the following methodology:

- there were determined for each hydrometric station the average values of drained precipitation on the river basin (hp). The layer derived from liquid precipitation (hp) was calculated based on the spatial distribution map of cumulative rainfall during flood analysis presented in the previous figure,
- Drained volumes during floods were calculated (Ws) as well as drained layers (hs).
- Average runoff coefficients were calculated (α) on the river basins afferent to the the hydrometric stations, as a ratio between hs and hp – Table 14.

Table 14. The elements of the flood waves at the main stations from the Siret river basin

River	Section	F (km²)	June-July 2010 flood				
			Q max (m^3/s)	**Ws ($10^6 m^3$)**	**Hs (mm)**	**Hp (mm)**	**α**
Siret	s.h. Siret	1637	1125	226	138		
Siret	s.h. Huţani	2152	875	424	197		
Suceva	s.h. Iţcani	2300	960	283	123		
Siret	s.h. Lespezi	5900	2049	765	130	210	0,62
Siret	s.h. N. Bălcescu	6906	1825	793			
Moldova	s.h. Roman	4285	925	336			
Siret	s.h.Drăgeşti	11900	2884	1342	113	186	0,60

On the Prut River (Chernivtsi) on June 26, the discharge was 1740 m^3/s. On entering the Stanca Reservoir, the discharge fluctuated between 1440 and 1350 m^3/s. On June 29 – 30 another flood wave formed, which until July 2nd, created discharges from 1740 to 1930 m^3/s.

The total volume of the pluvial flood runoff in the summer of 2010 constituted at the Sirauti hydrometric station on the Prut - 3084.4 mil. m3; The Stanca-Costesti Hydrotechnical Node spilled 2562.3 mil.m3; the Ungheni hydrometric station - 2524.0 mil.m3.

It was noted the flooding of agricultural land and individual residential buildings:

- Chernivtsi «Kalynivskyi» market (flooding of 1st trading row);
- Tarasivtsi 40 km lower from hydropost (flooding of agricultural lands);
- Road Novoselytsia - Hertsa (flooding of road);
- Frontiers № 18, 19 Kostychany – Mamalyga 45 km lower from hydropost;
- Frontier № 17 Tarasivtsi – Vanchykivtsi 40 km lower from hydropost;
- Marshyntsi (flooding);

As a result of the enormous amount of rain fallen on the territory of Western Ukraine, in the upper basins of the Siret and Prut, from May 18, 2010, there have formed several large pluvial floods, which, on the Moldovan territory overlapped to form a single flood wave, as the water level did not decrease until the anti-flood level.

Floods from the analyzed period, which occurred on the Siret and Prut river basins can be compared with those which occurred in 2005 and 2008, when historical values were achieved except on the river Siret at Siret hydrometric station, on the river Jijia at Dorohoi hydrometric station, Todireni hydrometric station on the river Sitna and hydrometric stations on the river Miletin where historical values were recorded that year.

Probabilities of exceeding the maximum flows were estimated at 2-5% for the Siret hydrometric station, 05-1% for Pozen gauging station, Horodnic River.

3.9. Existing structural measures of protection against the negative effects of floods

In order to protect against the harmful effects of water in the basins of Prut and Siret in Chernivtsi region, a large complex of flood control structures was built, consisting of 76.9 km of protective dikes, 62.3 km of bank strengthenings and 988 riverbed structures (semi-barages). 81.5 km of dikes were built in the Prut river basin in Ivano-Frankivsk region.

A special role in shaping the hydrological regime is played by artificially created reservoirs. Construction of these structures has both positive and negative consequences. Flooding and accumulating volumes allow you to "cut" the peak of the flood, thereby reducing the hydraulic load on the river bed. Creation of reservoirs substantially changes the landscape of river valleys, and regulation of their drain changes the natural hydrological and hydrochemical regimes of the river within the foothills. Changes in the hydrological regime, caused by the creation of water reservoirs, occur also in the lower sewage of hydro-units, sometimes for dozens of kilometers. Particular importance is the decrease in flood, resulting in deteriorating conditions for spawning of fish and the growth of grasses on floodplain meadows. Reducing the velocity of the current causes the loss of sediment and sedimentation of reservoirs; the temperature and ice conditions change, in the lower sewage there is a frost free winter allotment.

Table 15. The list of reservoirs in Prut river basin

Name	**River basin**	**Purpose**	**Full volume, million m^3**
Reseervoir on river Cherleni Vanchykivtsi	Prut	according to the design – flood protection, anti-erosion is used for fishery needs	3,16
Reservoir on river Shcherbyntsi Kostychany	Prut	according to the design – flood protection, anti-erosion is used for fishery needs	1,37

On the teritory of Suceava county, the flood water volume of Siret river are reduced through Rogojeşti Reservoir that have a capacity of 37 bilions m^3. The other reservoirs have lower volumes (table 16). Also, 3 non-permanent reservoir protect the Horodnic water cource (Table 17).

Table 16. Main permanent storage reservoires

No	**Name**	**County**	**Water course apă**	**Volume at NNR (1,000 m^3)**	**Volume attenuation floods (1,000 m^3)**	**Volume mitigations ratio of volume at NNR (%)**
1	Rogojeşti	SV/BT	Siret	37.300	17.400	46,65
2	Grăniceşti	SV	Horaiţ	1.570	627	39,94
3	Solca	SV	Solcuţa	96	27	28,12
4	Şerbăuţi	SV	Hătnuţa	1.000	590	59
5	Şomuz I Liteni	SV	Şomuzu Mare	1.557	643	41,3
6	Şomuz II Moara	SV	Şomuzu Mare	7.400	3.900	52,7

Table 17. Main non-permanent storage reservoires

Nr. crt.	Name	Water course	Volume (1,000 m^3)
1	Polder Horodnic I, com. Horodnic, jud. Suceava	Horodnic	840
2	Polder Horodnic II, com. Horodnic, jud. Suceava	Horodnic	515
3	Polder Horodnic III com. Horodnic, jud. Suceava	Horodnic	504
	Total		1859

In the Prut river basin, on Romanian teritory, there are 393 storage reservoires which have the role of flood control, of which 23 are non-permanent, with a volume of 112,8 mil. m^3 and 370 are complex with a total mitigation volume of 1139 mil. m^3 (Table 18).

Table 18. Main permanent and non-permanent storage reservoires

Nr. crt.	Name	Water course	County	Volume at NNR (million m^3)	Mitigation volume (million m^3)	Full volume, million m^3)	Mitigation volume ratio of volume at NNR
1	STÂNCA - COSTEŞTI	Prut	Botoşani	735	665	1400	0.90
2	HĂLCENI	Miletin	Iaşi	11.249	20.379	39.398	1.81
3	NEGRENI	Başeu	Botoşani	9.942	8.703	25.869	0.88
4	CĂTĂMĂRĂŞTI	Sitna	Botoşani	4.403	6.585	12.400	1.50
5	TANSA - BELCEŞTI	Bahlui	Iaşi	6.787	20.076	27.12	2.96
6	DRĂCŞANI	Sitna	Botoşani	5.021	19.241	23.053	3.83
7	MILEANCA	Podriga	Botoşani	4.412	4.549	11.116	1.03
8	CAL ALB	Başeu	Botoşani	4.969	7.970	15.787	1.60
9	CHIRIŢA	Chiriţa	Iaşi	4.000	6.830	8.230	1.708
10	PLOPI	Gurguiata	Iaşi	4.296	8.017	11.293	1.87
11	EZER	Jijia	Botoşani	-	9.602	10.330	-
12	POŞTA ELAN	Elan	Vaslui	3.354	3.076	6.610	0.92
13	PODU ILOAIEI	Bahlueţ	Iaşi	3.699	24.399	34.677	6.60
14	CUCUTENI	Voineşti	Iaşi	1.734	8.099	12.541	4.67
15	SÂRCA	Valea Oii	Iaşi	3.300	10.674	21.130	3.23
16	CIURBEŞTI	Valea Locei	Iaşi	1.910	5.707	11.065	2.99
17	PÂRCOVACI	Bahlui	Iaşi	1.769	4.909	7.050	2.78
18	ARONEANU	Ciric	Iaşi	1.118	4.044	6.602	3.62
19	CURTEŞTI	Dresleuca	Iaşi	0.61	0.663	1.694	1.09
20	EZĂRENI	Ezăreni	Iaşi	0.78	2.532	4.300	3.25
21	REDIU	Rediu	Iaşi	0.369	0.287	0.675	0.78
22	CIRIC 3	Ciric	Iaşi	0.248	1.246	1.600	5.02
23	CERCHEZOAIA	Cerchezoaia	Iaşi	0.192	0.476	1.316	2.48

Embankment works in Prut basin have a length of approx. 467,8 km (267 km on Prut river). Other works of shore regularization and protections means 80 regularizations on over 360 km length and 105 shore defenses on approx. 52 km.

4. Methodology for selecting the largest historical floods

The selection of historical significant floods from Siret and Prut river basins was based on the following main criteria:

- The amplitude of maximum discharge;
- Size of the area on which the flood occurred;
- The amount of information available in the three countries participant in the EAST AVERT project;
- Extent of the damages;
- Accessibility to specialized publications;

Romanian approach was aplied first time under the Flood Directive and it was detailed for Siret and Prut project in the framework of EAST Avert project. In the first phase, an inventory of the major floods that occurred in the past in the Prut - Barlad basin district was made on the basis of information gathered from documentary sources (NIHWM archive). This inventory identifies significant floods, either in terms of hazard or impact (recorded damage). In general, floods for which the probability of occurrence is greater than 10% are not taken into account, the study focusing on high intensity events (maximum levels and/or debits); the approach was based on the methodology developed by NIHWM;

The inventory was sent in the territory, where, at the Prut - Barlad WBA level, the flood events list was completed with other flood events, possibly located on smaller water courses, which are known to have caused special damages (especially if there were victims).

The analysis included the description of the significant floods, namely the spatial and temporal location of the flood event, its extent, the flood probability, the flood type, the magnitude of the associated negative consequences, etc.

In the third phase, significant historical and local-related events (for the territory managed by ABA) were selected according to the socio-economic, environmental, etc. consequences; the approach was based on the methodological criteria developed by INHGA. Thus, categories of criteria have been defined according to the consequences of the flood (consequences for human health, consequences on economic activity, consequences on the environment, consequences on cultural heritage). For each of these types of consequences, indicators and associated threshold values have been established, on the basis of which floods are designated as "significant" at national level (in terms of damage).

If there was no information on the associated consequences for certain flood events, those events were not considered to have "significant negative consequences"; they can be described but will not be reported to the EC.

Further, the selection of events was amended by the "flood typology criterion": if there were several historical floods on the same water course, e.g. 3 – 5 significant floods with similar occuring typologies, only the first 1 - 2 flood events have been taking into account for reporting to the EC, the main criterion being the one related to the damage.

In Ukraine , following breakdowns was aplied for selected floods that was documented in the first step:

1) Description and evaluation of previous flooding include:
   - a description of flooding that has caused significant damage to people's health, the environment, cultural heritage and economic activity (objects of damage), and the likelihood of repetition of which remains high;
   - a description of significant flood events that have occurred in the past and for which it is possible to predict the significant negative consequences of repeating similar events in the future.
2) Types and subtypes of objects of damage due to flooding for preliminary estimation of flood risks.
3) Determination of types of flooding is based on the national practice of flood risk management in accordance with:
   - National Classification of Emergencies of Ukraine
   - SC № 019:2010, approved by the order of the State Committee of Ukraine on Technical Regulation and Consumer Policy from 11.10.2010 № 457;
   - Classification signs of emergencies, approved by the order of the Ministry of Emergency Situations of Ukraine from 12.12.2012 № 1400, registered in the Ministry of Justice of Ukraine on January 3,2013 № 40/22572.
4) The types of flood sources subject to a preliminary assessment of the risks of flooding shall be:
   - river flood source (flooding with river water) - flood waters with water from a part of a natural or artificial water object. This source includes flooding caused by river waters, artificial, mountain and temporary watercourses, as well as flooding, which arise as a result of jams, ice break;
   - atmospheric precipitation as a source of flooding - flooding caused directly by atmospheric precipitation falling to or through the surface of the earth. This source includes waste water discharged from the built-up area on which they were formed as a result of precipitation and other surface runoff formed as a result of excess rainwater or snowmaking;
   - ground water as a source of flood - the flooding of the territories by the water, rising from below the earth's surface, to a level above the surface of the earth;
   - seawater as a source of flooding (flooding by sea) - flooding the territory with inland seawater and transitional waters. This source includes the flooding by the sea (in particular, the strong sea waves and marine congestion and avalanche phenomena);
   - artificial structures as a source of flooding - the flooding of the water by water due to its overflow through artificial structures that delay the water or as a result of an accident on them. This source includes flooding from drainage systems (storm and household sewage), water supply and sewage treatment systems, other artificial watercourses;
   - other sources of flooding.

5) Description of flooding includes flood extent, scenarios for possible development, as well as an assessment of the negative effects of flooding. The description also contains information on the respective areas of the river basin, sources of flood, reasons and characteristics of flooding..

6) During the preliminary flood risk assessment, the following types of flood can be excluded:
   - in general, minor flooding, taking into account the negative effects and occasional events, the place, the probability and the extent of the consequences of which can not be foreseen;
   - there is no evidence of the occurrence of specific types of flooding;
   - there is no evidence of significant risks from such flooding;
   - flooding, the probability of which is extremely low (in particular, the breakthrough of a dam or the breakthrough of specially constructed protective structures).

7) The risk of flooding is considered potentially significant in areas where flooding in the past has had a negative impact on human health, the environment, cultural heritage and economic activity.

8) The risk of flooding in sparsely populated or unpopulated areas or areas of low economic or ecological significance is considered insignificant.

5. Significant historical floods

In order to satisfy Floods Directive requirements, collected data and information have to allow the identification of floods that occurred in the past and that have significant negative effects on human health, environment, cultural heritage and economic activity.

The reporting schemes, description of the codes and the attributes used, including data type, description of the relationships between the various elements, were developed at EU level and were the subject of Reference books for reporting within Directive. (Maidens and Wolstrup, 2011; Atkins Danmark, 2011). The structure of this database was imposed by the technical specifications adopted according to the Floods Directive.

Based on the process presented in the chapter 4 of the present report, 20 significant historical floods were selected (Table 19).

Table 19. Selected significant historical flood events

Country	Flood event name	Date event
Uktraine	Siret - Storozhynets	08.07.1911
	Prut - Chernivtsi	08.07.1911
	Prut - Tatariv	30.08.1927
	Siret - Storozhynets	12.07.1969
	Prut - Seliatyn	08.06.1969
	Prut -Kolomyia	17.08.2005
	Siret - Storozhynets	20.07.2008
	Prut - Vorohta	20.07.2008
	Prut - Marshyntsi	20.07.2010
Romania	Bistrița mai 1970	12.05.1970
	Moldova iulie 1991	24.07.1991
	Tazlău distrugere baraj Belci iulie 1991	28.07.1991
	Siret iulie 2005	8.07.2005
	Arbore iunie 2006	30.06.2006
	Siret iulie 2008	21.07.2008
	Siret iunie 2010	17.06.2010
	Prut iunie 1985	17.06.1985
	Tecucel septembrie 2007	05.09.2007
Romania and Moldova	Prut iulie 2008	24.07.2008
	Prut iunie 2010	21.06.2010

In the analised river basins, in the last years, there have been three major floods that can be considered "historical", in the years 2005, 2008 and 2010. The floods in 2005 mainly affected the lower basin of the Siret river (downstream of Movileni accumulation), being less relevant for transboundary area. Instead, the floods in 2008 and 2010 have many common features in terms of the evolution of the extreme events on the Siret and Prut watercourses (we note that floods from 2008 and 2010 occurred in both basins).

Based on the some criteria and the selectted hydrometric stations in Romania, there were selected the floods for each basin to be analised:

- Siret River Basin: July 2008; June 2010;
- Prut River Basin: August 2005; July-August 2008; June 2010.

Available data for the analyzed significant floods as requested by the Flood Directive during the current stage are presented in the table 20.

Table 20. Information about selected floods under the Flood Directive.

River Basin	**Flood**	**Flood characteristics**		**Flood source**			**Flooding mechanism**		
		Natural	**Deep Flood**	**Fluvial**	**Pluvial**	**Artifiicial water bearing**	**Natural Exceedance**	**Blockage/ Restriction**	**Defence Exceedance**
Siret	July-2008	X	X	X	X		X		X
	June 2010	X	X	X	X		X		X
Prut	August 2005	X	X	X	X		X	X	
	July-2008	X	X	X	X		X	X	
	June 2010	X	X	X	X		X		X

The preliminary assessment of the risks of flooding is carried out for each of the 9 regions of the river basins of Ukraine: the basins of Wisla, Danube, Dnister, Southern Bug, Dniper, Don, the Black Sea, the Azov Sea and the Crimea.

The preliminary assessment of flood risks and the beginning of the time period for its implementation is determined taking into account:

- the type of water object or its individual sections (in particular for rivers according to the slope of the bottom: mountain, plains);
- the established values of water discharge of various exceding probability, namely: 1%, 5%, 10%, 20%, 50%.

In case of sharing with the Member States of the European Union international river basin districts (Wisla, Danube, Dnister), proper information exchange between the relevant competent authorities is nedeed. The content of the preliminary assessment of flood risks is given in Annex 1.

6. Areas with significant potential flood risk

The identification of Areas with significant potential flood risk (ASPFR) was based on 2 main different approaches, depending on the availability of data.

For Romania, in determining the areas with significant flood risk potential, in the first stage, the information available at that time has been taken into consideration, namely the results obtained in the PHARE 2005/017-690.01.01 project: "Contributions to the management strategy development flood risk "(Beneficiary - Ministry of Environment and Forests and National Administration "Romanian Waters"):

- potentially flood-prone areas, as the envelope of extreme historical flood events;
- assessment of the potential impact of the flood (potential consequences).

Thus, based on topographic maps and ortho-photographic interpretations, GIS layers were created within the project to complement the database of goods from potentially flood-prone areas (inside the envelope of extreme historical floods). The elements considered for damage assessment are: population, roads and railways, bridges, adjustment works, buildings, agricultural areas.

In the previous project, a Methodology for assessing flood damage was developed and the average damage values were extracted. It has to be mentioned that this extraction was partial and possible only for categories of goods that could clearly be identified as relevant to Romania and which had enough elements for a statistical analysis. The evaluation is presented in the form of text and maps representing the results of the calculation of the above-mentioned indicators. A synthesis (analysis) of the potential consequences is carried out at each ABA level, and later it is integrated at the national level. This led to a preliminary identification of areas with significant potential flood risks delimited by water courses.

Obviously, the methods used and the results obtained within the project involve certain limits; they are, however, the most complete and detailed flood risk analysis at national level that could be exploited at that time to identify A.P.S.F.R. (Areas with Potential Significant Flood Risk).

It is noted that in a second stage, the delimitation of potentially flood-prone areas, i.e. the envelope of extreme historical floods, has been improved; the development of the GIS layers of these areas was carried out at national level, with the support of A.N.A.R., through the Basin Water Administrations, coordinated by the Ministry of Environment and Forests and with the scientific guidance of the IN.H.G.A. (2009 - 2010) for the implementation of the flood and ice, hydrological drought, hydrotechnical accident and accidental pollution Protection Plans.

For flood events without clear information to provide the envelope of historical flood events, expert judgment and local knowledge of the events were addressed; moreover, for the main rivers, a semi-automatic GIS analysis was conducted based on the MDT and the levels recorded at the hydrometric stations. In this way the areas potentially affected by the great historical floods could be identified.

In the third stage of identification of A.P.S.F.R., areas protected against floods with hydrotechnical works were taken into acount, based on:

- the technical design rules in force - STAS 4273/83 regarding the construction category and its importance class, determined on the basis of the flooded house values or the number of affected / evacuated inhabitants and flood-protected areas, and taking into account the probability of exceeding the flow calculated levels.
- the current technical state of hydrotechnical works as a result of periodic visual inspections.

In other words, all floods that have occurred in the past and have had a significant negative impact on human health, the environment, cultural heritage and economic activity have been considered, without removing from that list those floods that can occur on sectors that have been hydrographically improved (dyked).

Similarly, the technological risk of embankment works was taken into consideration for those areas which, although protected for certain categories of events (and which were not subject to the inventory of areas affected by historical floods), could be flooded in the case of:

- potential dam (especially C or D type) or dykes breaks;
- extreme events, higher than the protection objective established by the project.

For floods for which the potential flood-prone area is not delimited (it was not possible to provide the flood envelope) - for example, dam reservoir, the impact indicators are not calculated. In this case, A.P.S.F.R. take into account only the expert judgment and the local knowledge of the events.

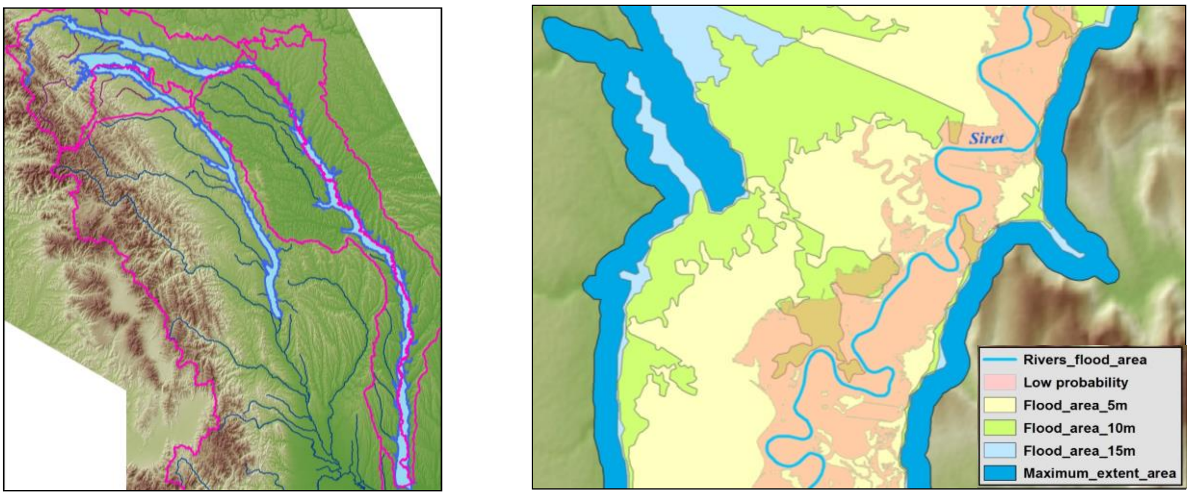
Therefore, it can be concluded that the assessment of the potential consequences of future flooding (on various categories of elements) is an important selection criterion for A.P.S.F.R. However, other criteria or elements have been considered, that are not measurable and are based on expert judgment.

In the preliminary assessment, the flooded areas could be considered to be not very precise, with a greater lateral extent. In the phase of the hazard maps, a more accurate extension of the flooding area will be delineated.

"Water level rise" method consists in a simplified procedure, based on GIS tools, that has been developed in order to achieve ***a preliminary evaluation of flood-prone areas*** by using basic data: DEM (Digital Elevation Model), river line (riverbed thalweg) and the increasing of water level in different points (or profiles). It is well-known that in many cases, the floodplains are wider in the lower part of the watersheds. The discharge that exceed riverbed is often characterized by a smaller layer of water comparing to the upstream sections.

DEM quality is very important in dikes areas, too. The relative small width of dikes (5 – 10 m generally) makes important not only the accuracy of the DEM, but also its resolution, especially when topographical maps are used as information source for elevation, or when field measurements are required. In these cases, a lower resolution averages a large range for altitudes, leading to distortions of real dike elevation.

To use different values for "water level rise", rivers must be connected from source to outlet. If the rivers are broken at confluences (as it is the case of the automatically generated by ArcHydro), it's easier to use a constant value - for example 5 m, 10 m or 15 m along entire river (Figure 11 and Figure 12).



a) +15 m increasing of water level

b) Different extent of area of interest computed based on water level rising

Figure 11. Preliminary maximum flood-prone areas computed based on water level rising

Basin	Country	Surface for different water level rising		
		+ 5 m	+ 10 m	+ 15 m
Prut	Ukraine	652	862	986
	Moldova	714	802	867
	Romania	1212	1274	1340
Siret	Ukraine	298	378	434
	Romania	679	854	980
TOTAL		3555	4169	4607

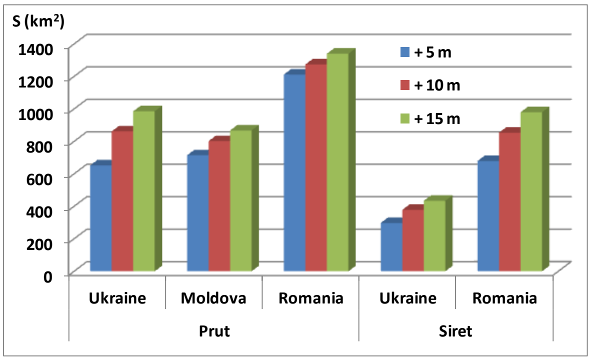


Figure 12. Surface per country obtained for flood-prone areas computed based on water level rising

Acoording to Danube River Basin GIS Maps and Layers Documentation, data on areas of potentially significant flood risks (hereinafter referred to as APSFR) are indicated on maps of river basin districts in such geometric configurations.:

- polygon APSFR – for zones with area ≥ 100 km^2;
- polyline APSFR – for rivers with length ≥ 50 km;
- point APSFRb – for zones with area < 100 km^2 or for rivers with length < 50 km.

National APSFR it is recommended to mark in red and by letter «N». Approved cross-border APSFR it is recommended to mark in yellow and by letter «Y». Not approved cross-border APSFR (for which the discussion is ongoing) APSFR it is recommended to mark in purple and by letter «U».

The stage of APSFR designation based on the shown criteria, led to the establishing of 54 such areas in the Siret River Basin, 21 areas in the Barlad River Basin (a tributary of Siret river but administrated by Prut-Barlad Water Basin Administration) and 14 areas for prut river and its tributaries.

Among these significant flood-prone areas, 21 are situated on Siret upstream to Suceava River and in Suceava River Basin and 16 APSFR are located on the next sector in the Siret River Basin - upstream to Bacau city (Table 21).

Table 21. Areas with significant potential flood risk in Siret W.B.A.

Sector	APSFR code	APSFR name	APSFR type	Length km
APSFR upstream to Suceava River	RO10-12.01.....-01A	r. Siret - av. graniță, am. loc. Movileni, sect. îndig.	plg.	427.1
	RO10-12.01.....-02A	r. Siret - av. loc. Movileni, sect. îndig.	plg.	122.2
	RO10-12.01.007....-01A	r. Molnița - av. loc. Mihăileni	plg.	14.4
	RO10-12.01.007a....-01A	r. Baranca - av. loc. Zamostea	line	9.3
	RO10-12.01.012....-01A	r. Hănțești - loc. Hănțești	line	8.8
	RO10-12.01.017....-02A	r. Suceava - av. loc. Ulma, sect. îndig.	plg.	138.4
	RO10-12.01.017.12...-01A	r. Putna - loc. Putna	plg.	7.8
	RO10-12.01.017.16...-01A	r. Voitinel - loc. Voitinel	line	4.5
	RO10-12.01.017.16...-02A	r. Voitinel - av. loc. Voitinel, sect. îndig.	line	7.3
	RO10-12.01.017.21...-01A	r. Pozen - loc. Horodnic de Sus	line	4.8
	RO10-12.01.017.21...-02A	r. Pozen - sect.av.loc.Horodnic de Sus,am.loc.Rădăuți, îndig	line	8.7
	RO10-12.01.017.21...-03A	r. Pozen - av. loc. Rădăuți	line	10.7
	RO10-12.01.017.22...-01A	r. Sucevița - av. loc. Sucevița	plg.	32.9
	RO10-12.01.017.24...-01A	r. Solca - av. loc. Solca	line	27.2
	RO10-12.01.017.24.02.01.-01A	r. Clit	line	9.3
	RO10-12.01.017.24.04..-01A	r. Iaslovăț - loc. Iaslovăț	line	10.4
	RO10-12.01.017.24a...-01A	r. Horaiț - av. loc. Bălcăuți	line	19.1
	RO10-12.01.017.25...-01A	r. Soloneț - av. loc. Pârteștii de Sus	plg.	35.5
	RO10-12.01.017.27...-01A	r. Hătnuța - av. confl. Bocancea	line	14.2
	RO10-12.01.017.28...-01A	r. Pătrăuțeanca - av. loc. Pătrăuți	line	7.9
	RO10-12.01.017.30...-01A	r. Dragomirna - av. loc. Mitocu Dragomirnei	line	12.6
APSFR upstream to Bacau city	RO10-12.01.021.08...-01A	r. Târgul - loc. Fălticeni	line	7.1
	RO10-12.01.026a....-01A	r. Ruja - av. loc. Valea Seacă, sect. îndig.	line	6.9
	RO10-12.01.030....-01A	r. Sohodol - av. loc Boșteni, sect. îndig.	line	7.2
	RO10-12.01.040....-01A	r. Moldova - av. loc. Câmpulung Moldovenesc, sect. îndig.	plg.	174.8
	RO10-12.01.040.20...-01A	r. Moldovița - av. loc. Moldovița	plg.	24.2
	RO10-12.01.040.27...-01A	r. Humor - av. loc. Mănăstirea Humorului, sect. îndig.	line	6.4
	RO10-12.01.040.39a...-01A	r. Sărata	line	24.3
	RO10-12.01.040.41...-01A	r. Neamț - av. loc. Pipirig	plg.	48.0
	RO10-12.01.040.44...-01A	r. Toplița - av. loc. Topolița	line	40.9
	RO10-12.01.053....-01A	r. Bistrița - sect. av. loc. Lunca, am. lac Bicaz	plg.	31.6
	RO10-12.01.053....-02A	r. Bistrița - av. loc. Piatra Neamț	plg.	81.9
	RO10-12.01.053.34...-01A	r. Sabasa - loc. Sabasa	line	10.8
	RO10-12.01.053.57...-01A	r. Cuejdiu - av. loc. Cuejdiu	line	22.6
	RO10-12.01.053.60...-01A	r. Cracău - av. loc. Magazia	plg.	53.4
	RO10-12.01.053.60.04..-01A	r. Almaș - av. loc Almaș	line	16.7
	RO10-12.01.053.66...-01A	r. Români - av. loc. Români	line	13.9
Prut River Basin	RO11-13.01.....-01A	r. Prut - sect. av. loc. Oroftiana am. loc. Miorcani	plg.	69.5
	RO11-13.01.....-02A	r. Prut - av. loc. Crasnaleuca am. loc. Cucuneștii Vech	plg.	52.5
	RO11-13.01.....-03A	r. Prut - sector av. loc. Stânca am. loc. Românești	plg.	27.2
	RO11-13.01.....-04A	r. Prut - av. loc. Zaboloteni, sect. îndig.	plg.	511.6
	RO11-13.01.015....-01A	r. Jijia - sect. av.confl. Pârâul lui Martin am.cfl. Jirinc	plg.	298.9
	RO11-13.01.015.03...-01A	r. Buhai - av. Pădureni și afl.Pârâul Intors av.Văculești	plg.	11.9
	RO11-13.01.015.25...-01A	r. Miletin - av. confl. Valea Rea	line	36.6
	RO11-13.01.015.32...-01A	r. Bahlui - av. loc. Pârcovaci am. confl. Băhlueț	line	60.7
	RO11-13.01.015.32...-02A	r. Bahlui - av. loc. Pârcovaci, sect. îndig.	line	43.7
	RO11-13.01.015.32.12..-01A	r. Băhlueț - av. confl. Pășcănia	line	36.6
	RO11-13.01.015.32.12.03.-01A	r. Cucuteni - av. loc. Cucuteni	line	10.5
	RO11-13.01.015.32.12.06.-01A	r. Albești - av. loc. Brăești	line	12.2
	RO11-13.01.016....-01A	r. Bohotin - sect. îndig.	line	6.8

Plg. - polygon

Ukrainian additional steps for APSFR designation approach

At the initial stages, research on archival data was conducted. The data was presented with orthophotomaps with a resolution of 50 cm / pixel, digital terrain models with an accuracy of 1 meter in plain areas and up to 2 meters in mountainous areas with a scale of 1:50,000 and an area of coverage of about 11 000 km^2 (Figure 13). The analysis of archival data made it possible to conduct a general assessment of the territory, which in turn made it possible to determine the availability and relevance of information on terrain, density, location characteristics and parametric fullness of objects and areas of potential risk from flood flooding.

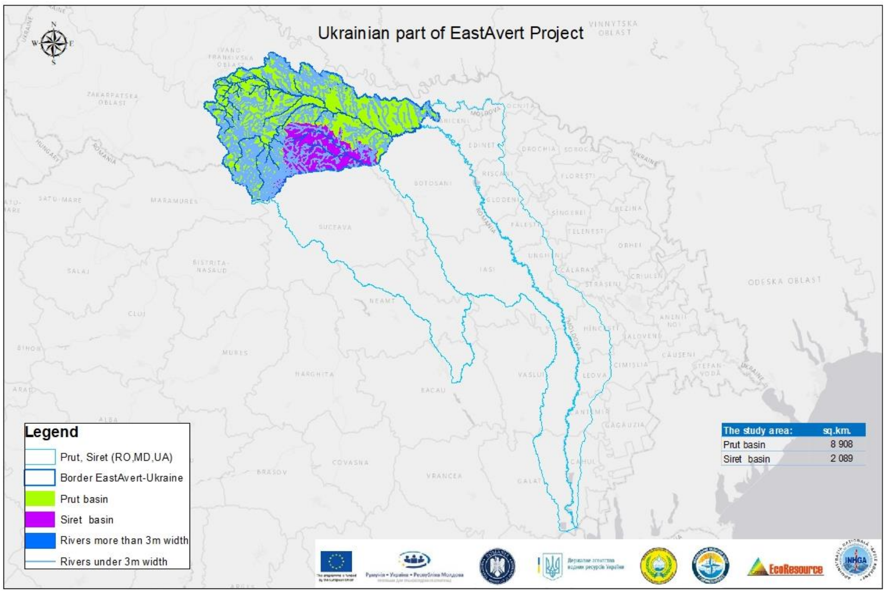


Figure 13. Ukrainian part of project EART AVERT

An important component of the project was the zoning of the territory for the risks of flooding from historical highs, which resulted in the identification of the 18 most flood-hazardous areas (Figure 14 and Table 22).

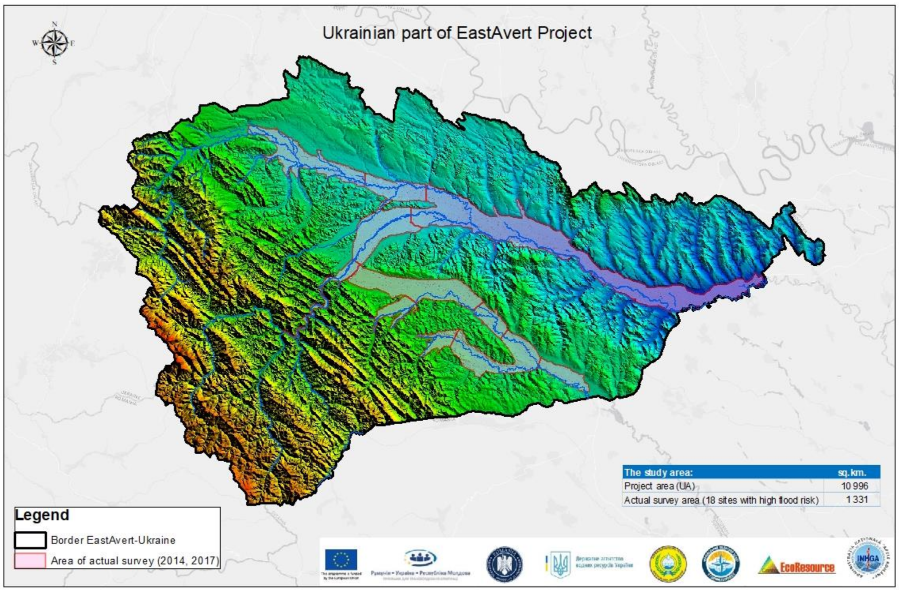


Figure 14. Zoning of territory

Table 22. Zoning of the territory as a result of flood risks

№ of block	Object	Settlement	Area (km²)
1	Prut	Mamalyga-Tarasivtsi	66,01
2	Prut	Marshyntsi-Zelenyi Gai	71,56
3	Prut	Boianivka-Novyi Kyseliv	74,45
4	Prut	Novyi Kyseliv-Dubivtsi	136,93
5	Prut	Klokuchka- Sloboda Banyliv-Prutivka	139,46
6	Siret	Petrychanka-Cherepkivtsi	44,37
7	Siret	Beregomet-Lukivtsi	39,92
8	Siret	Banyliv Pidgirnyi	33,72
9	Cheremosh	Chornoguzy-Tiudiv	21,88
10	Cheremosh	Marynychi-Shpetky	2,95
11	Prut	Kolomyia-Borshchiv	143,01
12	Siret	Storozhynets-Panka	37,88
13	Siret	Chornoguzy-Panka	165,94
14	Siret	Ropcha-Cheresh	140,47
15	Prut	Hlibychyn-Vydyniv	70,90
16	Rybnytsia	Rudnyky-Dzhuriv	3,94
17	Cheremosh	Dragasymiv-Slobidka	124,75
18	Cheremosh	Mizhbrody-Shpetky	13,48
	Total:		**1331,62**

The system's geodatabase is created using a component Active Database Object (ADO .Net) and a special data management application from ESRI: Spatial DataBase Engine – SDE. The structure of the geodatabase is to accommodate the following segments of the spatial information - table 23.

Table 23. The structure of the geodatabase

Name of layer	Type	Attributes	Name in UKR
Actual_survey_boundaries	**plg.**	Area	**Межі ділянок детальних досліджень**
Border	**plg.**	Area	**Кордони**
Bridges	**polyline**		**Мости**
		Lengths	Довжина
		Width	Ширина
		Material	Тип матеріалу
		Note	
Buildings	**plg.**		**Будівлі**
		Storeys	Кількість поверхів
		Type	Тип матеріалу
Bushes	**plg.**	id	**Луги**
Canals	**polyline**	id	**Канали**
Cemetries	**plg.**	id	**Кладовища**
Dams and Riverbank Protection	**polyline**		**Дамби та берегозахисні споруди**
		Location	Розташування

Name of layer	Type	Attributes	Name in UKR
		Asset_mana	
		State	Держава
		Type	Тип матеріалу
		Year_of_Go	Рік створення
		Lengths	Довжина
		Number_of_section	Кількість секцій
		Section	
		Inventary_	Інвентарний номер
		Note	
Dried_up_riverbeds	**polyline**	id	**Сухі русла**
Forest	**plg.**	id	**Ліси**
Forest_Belts	**polyline**	id	**Лісові смуги**
Gas_stations	**point**	Name	**Безозаправки**
Industrial_objects	**plg.**	Name	**Промислові об'єкти**
Lakes	**plg.**	Name	**Озера**
Lands	**plg.**	Land_type	**Тип землекористування**
Oblast_boundary	**plg.**	Name_obl	**Межі областей**
Open_mines	**plg.**		**Відкриті гірничі виробки**
		Name	Назва
		Mineral	Тип корисних копалин
Pipelines	**polyline**	Type	**Трубопроводи**
Power Line Crossing	**polyline**	Voltage	**Лінії електропередач**
Rada_boundary	**plg.**		**Межі сільрад**
		Name_rayon	Назва району
		Name_rada	Назва сільради
Railways	**polyline**	id	**Залізниці**
Rayon_boundary	**plg.**		**Межі районів**
		Name_obl	Назва області
		Name_rayon	Назва району
Reservoirs	**plg.**	Name	**Водосховища**
Risk Points	**point**	Risk_Point	**Об'єкти ризику**
		Note	
Rivers_more_than_3m_width	**plg.**	Name	**Річки, шириною більше 3 м.**
Rivers_under_3m_width	**polyline**	Name	**Річки, шириною менше 3 м.**
Roads	**polyline**		**Дороги**
		Road_type	Тип дороги
		Surfacing	Покриття
		Number	Номер
Roads_other	**polyline**		**Інші дороги**
		Road_type	Тип дороги
		Surfacing	Покриття
		Number	Номер
Settlement_boundary	**plg.**		**Населені пункти**
		Name	Назва
		Name_obl	Назва області
		Name_rayon	Назва району
		Name_rada	Назва сільради

Name of layer	Type	Attributes	Name in UKR
		Type_settl	Тип населеного пункту
Sport_Center	**plg.**	id	**Спортивні споруди**
Streams	**polyline**	Name	**Струмки**
Swamps	**plg.**	id	**Болота**

The digital model of terrain was created by determining the markings of nodes of a regular grid in a stereo mode with a step of 5x5 m in the area and the construction of structural lines in places of sharp difference of relief with a difference in height of 1 meter, which made it possible to provide an average-quadratic error of 0.5 m geometric accuracy of orthophotomaps (Figure 15).

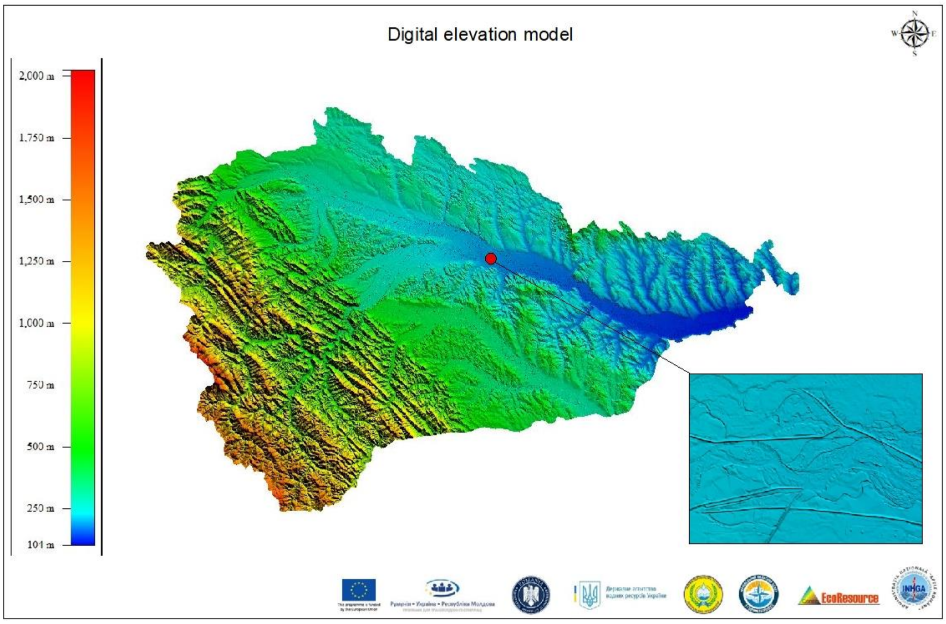


Figure 15. Digital Elevation Model

The purpose of the preliminary spatial modeling was to determine the indicative boundaries between the sites of possible flooding by hypothetical increase of water level at the maximum possible value. According to the recommendation of the experts of the Ukrainian Hydrometeorological Center, for the region of research sufficient was determined to accept a hypothetical rise of water at 5 m.