World Meteorological Organization

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

BULGARIA

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For the WMO/GWP Associated Programme on Flood Management

1. FORMATION OF FLOODS

1.1 Definition

River floods are states of the rivers, characterized by rising water level, respectively water discharge, as a result of which the river flow splashes outside the riverbed and covers the adjacent flooded river terrace. Their duration and intensity are different depending of the conditions of their formation.

Under the conditions of Bulgaria, torrent floods of rivers are short-termed phenomena, lasting generally for only several hours and in very rare cases – for up to several days .

Such a conclusion is corroborated by the numerous sporadic floods recorded in different regions of this country in recent years, like for instance the following:

- the flood along the rivers Dgermen and Skakavitsa in the northern section of Rila Mountain on 11 and 12 April 1998, the damages of which have been estimated to above BGN 1 500 000;
- the flood during the early several days of September 1999 in Bourgas Region, at the southern Black Sea coast, when four people perished. The losses have been estimated to above BGN 2 500 000.
- The multiple floods along the river Arda basin, etc.

Torrent floods of rivers are the focus of research under this project. They are calamities for which there is a limited amount of reliable information. Based on it L. Ziapkov (1987) has developed a map of threatened areas in the country by the torrents – Fig.1. The application of the map might be in a better prediction of floods and preliminary work to reduce the damages.

Appropriate scientific methods for their forecasting are lacking. The short duration of torrent floods, including their formation, do not make possible the organization of effective protection measures, the population does not possess the required training to take-in seriously the urgency of the notification or warnings about a brewing calamity, it has no it time to react adequately. For the above-mentioned reasons quite often the inhabitants' reaction is of spontaneous nature and is hard to manage and organize. As a consequence the amount of damage and losses is greater.

1.2 Torrent rainfall

Torrent rainfall floods (more than 70-80% of all the studied cases) form the highest influx yield of water volumes - 50-100 $l/s/km^2$ and 300-350 $l/s/km^2$ on the average.

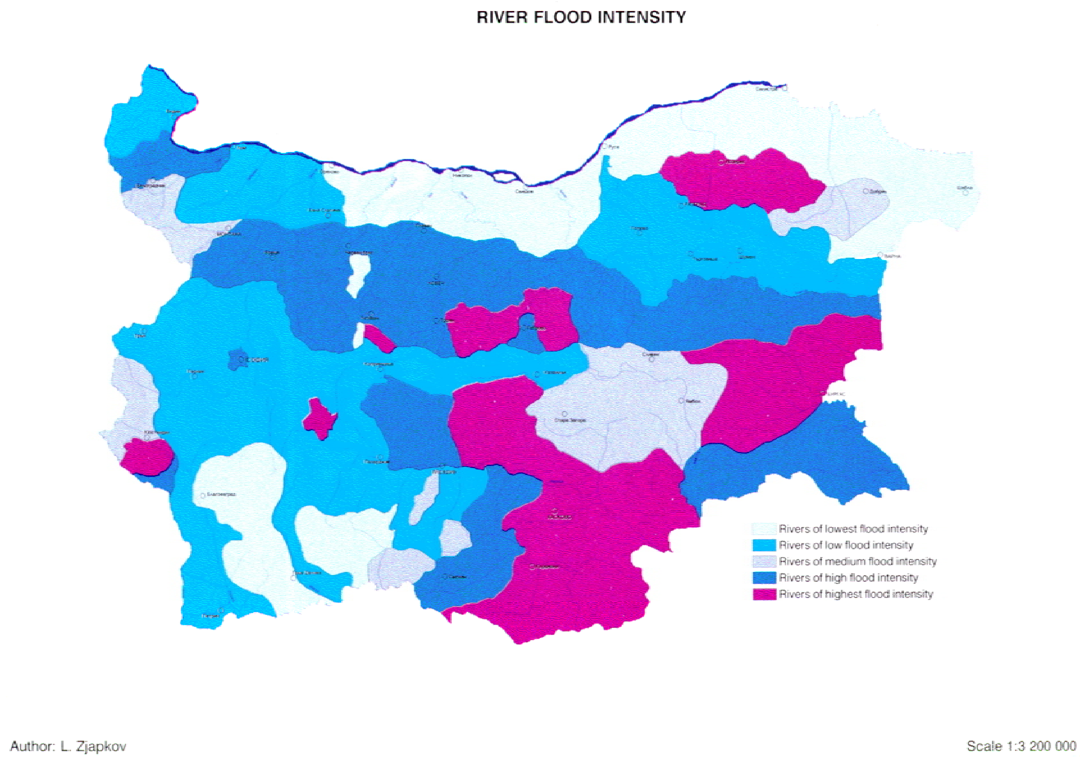


Fig 1. Map of threatened by the flash floods areas in Bulgaria.

It is considered that the main reasons for their formation are the torrent rainfalls due to the inrush of Mediterranean cyclones, characterized by high humidity and air temperature. Their intensity is the highest during the months of November and December-March.

About 37 situations of high precipitation rate (above 30 mm) and from 30-35 up to 150-158 cases of torrential rainfalls have been identified almost everywhere or over a significant portion of the area of the country (Stefanov, 1972, 1975, 1978, 1979; Kyuchukova, Ivanov, Subeva, 1986). Torrential rainfalls of intensity up to 0.420-0.480 mm/min and duration of up to 15-29 min. predominate. The frequency of rainfalls of intensity above 0.300 mm/min account for between 20-30 and 50-60 cases per year, while in the case of those with intensity above 0.600 mm/min the frequency diminishes to between 7-10 and 25-30 cases per year. Rainfalls of maximum intensity with duration of 5 min have been recorded near the *Studen Kladenets* Dam – 5.90 mm/min (17 May 1973), Srednogortsi – 5.36 mm/min (19 August 1976), Pazardjik – 4.26 mm/min (21 June 1975). Intensive rainfalls with duration of 60 min have been recorded in Evksinovgrad – 2.29 mm/min (July 1899), Varna – 1.64 mm/min (20 August 1951) and Stara Zagora – 1.39 mm/min (15 July 1959).

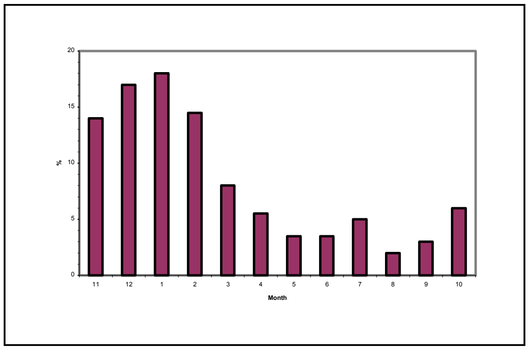
Effective rainfall quantities, for instance during the time of the rainfall-based torrent floods, account for between 3-5 and 80-90%. Usually, the efficiency of precipitation grows during the cold months of the year (especially during November-March), when the losses due to evaporation diminish and the humidity reserves of the soil increase. The rainfall-based quantities during this period exceed the evaporation rate.

The intensity of rainfalls has a more significant impact on the efficiency of water formation in small water areas having relatively short time of travel of the water influx.

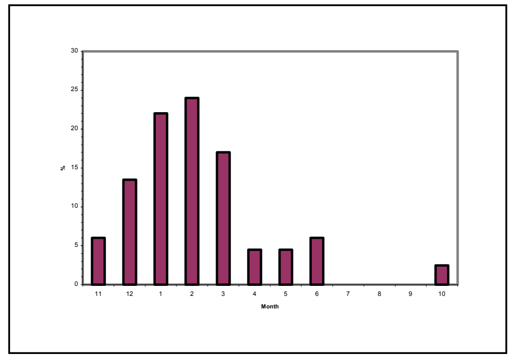
1.3 Flood frequency

The available so far hydrological information reveals, that irrespective of the ascending drought the frequency and dimensions of the torrent floods remain unchanged during the preceding period.

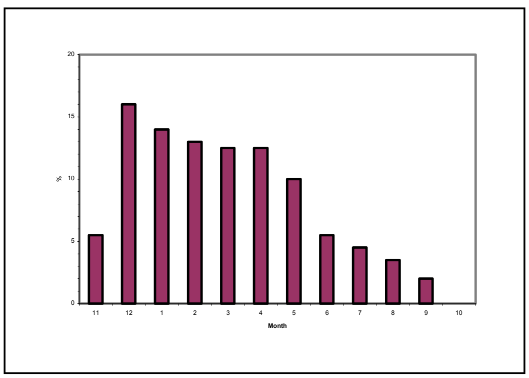
Floods everywhere are the most frequent (more than 40-50% of all cases throughout the year) mainly during the spring-summer high water season (March or February-June of July) or during the summer-winter high water seasons (November-March), and the least frequent (30-35%) during the major summer-autumn low water season (August-October) (Fig. 2). In the high mountain river valleys, for instance at the offspring of the early tributaries of the rivers Rilska, Iskar, Maritsa, Mesta etc., characterized by significant snow cover reserves and stable snow retention capacity, their minimum recurrence has been established for the period January-March.



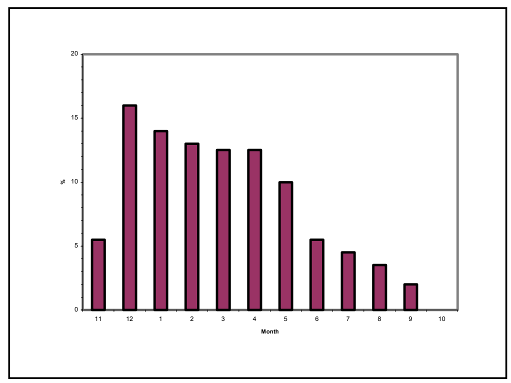
River Vubitsa in Djebel



River Veleka in Zvezdets



River Vit in Yasen



River Kamchiya in Preslav

Fig 2. Frequency of floods during the years 1966, 1967, 1968 on different river in Bulgaria

The bigger part of the torrent floods is of snow-rainfall origin and is typical for the river valleys in the hilly and low-lying mountain areas in Southern Bulgaria, particularly in the Eastern Rhodope Mountain, Sakar, Strandja and also the Ossogovska Mountain, the Central and Eastern Balkan. Their recurrence has been noted to be at the rate of 1.0-3.0 cases a year, while the instantaneous influx of water quantities reaches up to 500-800 $l/s/km^2$.

Presented on the figure below is the monthly distribution of the number of floods for several hydrometric stations. The diversity in the climatic conditions and nature factors lead to the formation of torrent floods and corroborated by the different outlines on the indicated diagrams.

In compliance with their genesis, floods are formed by surface waters (between 50% and 80% of the aggregate water masses on the average), while ground water forms floods solely in the areas of Karst rivers (for instance Panega, Kalnik, Blato, Iskretska, Iztok, Tekirska, Muldavska, etc.).

1.4 Factors of formation

Usually, different factors and combinations of factors are pointed as the reasons for the emergence of floods. We distinguish between:

- Climatic reasons
- Meteorological reasons
- Hydrological reasons, including water accumulation in the snow cover or in lakes
- Nature calamities
- Anthropogenic reasons.

The conditions for precipitation, caused by hot air masses intrusion by of Mediterranean cyclones play the biggest role for the formation of floods during the cold months of the year, while during the warm months the cold air fronts of Atlantic cyclones are the determinant factor. During the warm summer months the role of local rainfalls increases. They extend over more limited areas of the watershed as compared by the front-based precipitation rates.

The inrush of humid air masses takes place usually from the Southwest to Northeastern direction. Sometimes, the cyclone inrush causes intensive snow thawing, which fosters the effect of torrent floods.

There are studies by Bulgarian meteorologists (Sharov, Martinov, etc.) which have discovered a trend towards a shift of the trajectories of torrent floods in northern direction shaped in the recent decades. According to the authors, this is a manifestation of the slowly ascending climate change on the Balkan Peninsula in the direction of desertification. In the future this development might become the reason for aggravation, increased frequency and duration of drought periods, similar to the situation during the period 1982-1995.

The type of vegetation and soil cover and the relief of the watershed basin play a great role in the process of formation of torrent floods. Mountains in Bulgaria account for a high percentage of its area (69%), therefore river valleys are characterized by steep slopes. This favours the rapid drainage of rainwater into the river stream and the beginning of formation of river floods.

In many cases the demolition torrential processes are catalyzed by the predominant types of soil (gray, chromic and brown) and vegetation, characterized by poor infiltration and water-retaining features. Humus soils (especially carbonated humus soils) and meadow soils (fluvisols and leptosols) can have a stabilizing effect, because of their high water regulation properties. Aged plantations of deciduous and coniferous species (aged 100 years and featuring a spread of 0.8-0.9), ground and Karst basins can also play such a role (Dimitrov, 1978; Yolevska et al., 1982, Antonov, Danchev, 1980).

1.5 Time of travel

In support of the thesis about the rapid flood formation one can quote data about the time of travel of surface water to a given point for various river valleys in Bulgaria. The time of travel is usually measured within several hours because of the mountainous nature of the areas and their high indentation. This has its proof at the analyses of the schemes for time of travel distribution calculated for several mountain reaches of the rivers in Bulgaria. For instance:

- The total Arda watershed area
- The Maritsa River

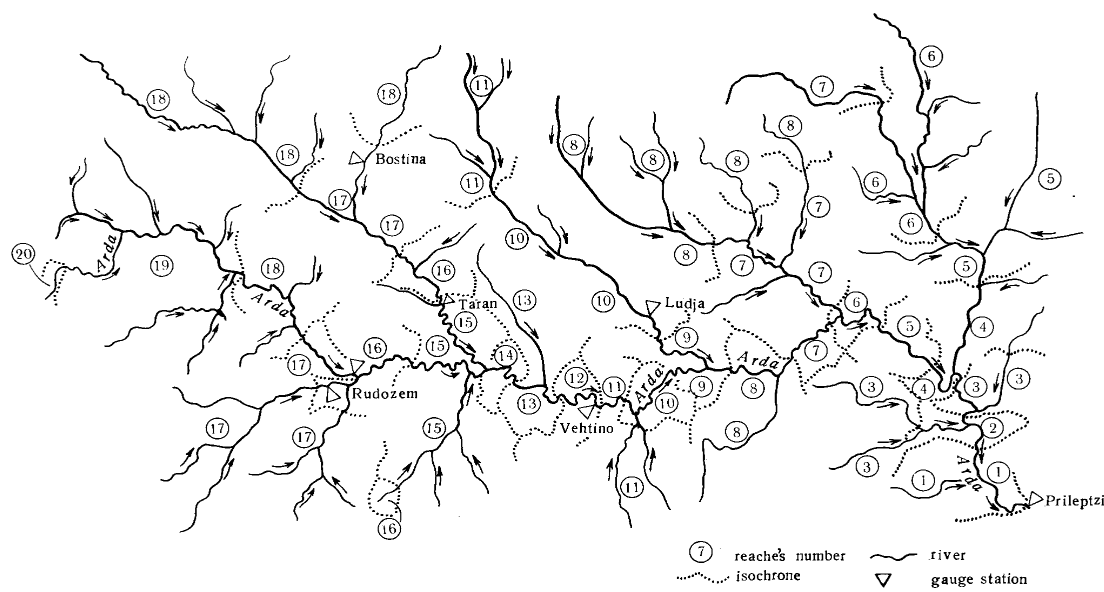


Fig 3. The map of upper and middle course of the Arda River.

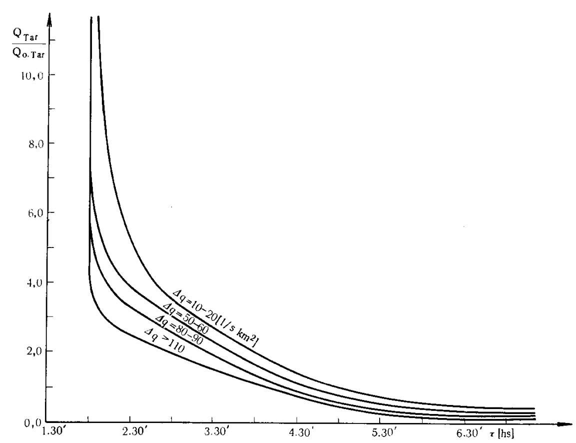


Fig 4. Time of travel along the Arda River with different inflow from the tributaries.

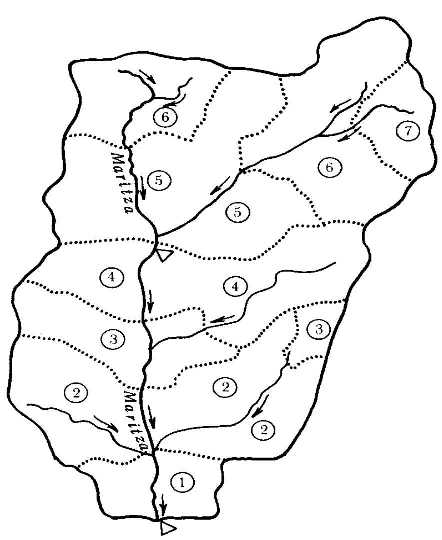


Fig 5. The map of the upper course of the Maritza River.

1.6 Sediments in torrent floods

In certain mountainous areas of Bulgaria the water drainage is accelerated because of the absence of vegetation cover. In these sections the soil cover is thin, featuring high sand content and deficiency of bonding substance. This creates conditions for intensive development of soil erosion and its characteristic surface and in-depth forms during intensive rainfalls. For this reason torrent floods in rivers are frequently related to the transportation by the river stream of large quantities of coarse and unprocessed rock and soil particles, gravel and stone of different sizes. One part of them fall down in rivers and is carried downstream discretely in time as a component part of the structural sediment formations. Under specific conditions – diminishing riverbed ingredient in the flat river sections or cease of the rainfall and of the torrential water influx - rapid deposition of the sediments on the bottom occur until the next emergence of adequate hydrological, respective hydraulic conditions. The consequence of this can be formation of piles of rock materials on the riverbed and even its abrupt blocking like a barrage, generated from the piled stone sediments. The setting down of sediment material on the riverbed after the transition of the torrent leads to clogging of the riverbed, which in turn creates conditions for an even graver flush flood on the agricultural land areas or human settlements situated on the river banks as early as during the first following case of torrent flood. On the Nedelinska River, a left hand tributary of the Varbitsa River one should find such cases (Report, 2000).

In other cases a shift of the riverbed has been observed, which can create a threat of demolition of near-by located engineering facilities, residential estates, etc.

Another important factor for the formation of torrent floods is the anthropogenic activity. Its impact is usually manifested in the creation of conditions, which accelerate the process of drainage of the surface runoff. In practice this is realized through application of wrong agrotechnical activities for soil treatment, creation of solid coverings – roads, sidewalks, building roofs, etc. In other cases flood can be recorded in the event of emergency release of water from dams or overflow through dam spillways, or yet in the event of partial or full breakdown of dam walls, breakdown of equalizing and retention reservoirs. In recent years, according to reports in the Bulgarian press, such wrecks have occurred several times in the recent years after torrential rainfalls when the reservoirs have been full.

1.7 Registered floods

Floods under the described schemes are every year recorded in different regions of Bulgaria. The more heavy floods among them in the recent several years are presented in a systematic manner in the table below, together with their brief characteristics.

Table 1. Large floods on many rivers in Bulgaria

№	Data	Area of floods
1	31.8-1.9.1958	Maritsa River and its tributaries
2	7.1911	Maritsa River and its tributaries
3	27.6.-2.7.1957	Maritsa River and its tributaries, Iskar River, Struma River, Mesta River
4	3-7.2.1963	Kamchia River, Iskar River, Struma River, Mesta River , Arda River
5	11.1913	Maritsa River and its tributaries
6	13-14.2.1956	Struma River, Arda River , River in Bourgas area
7	5-7.9.1957	Ogosta River, Maritsa River, Topolnitsa River, Shirokolushka River
8	26.4.1964	North-West Bulgaria, Ogosta River and West area of its
9	4-5.6.1966	Yantra River, Vit River, Tundga River
10	11-12.5.1980	Devnenska River close to Town Provadia
11	21.9.1983	River in Bourgas area
12	6.7.1991	Yantra River, Dryanovska River, Belishka River
13	28.6.1939	Rossitsa River, Vidima River
14	9.3.1940	Erma River
15	2.7.1947	Bely Lom River close to Town Razgrad
16	2.7.1954	Blagoevgradska Bistritsa close to Town Blagoevgrad
17	1.4.1987	Soushitska River above Town Kroupnik
18	3.7.1987	Stara River close to town Karlovo
19	12.1990	Varbitsa River
20	1944	Yantra River
21	08.1924	Tundga River
22	08.1928	Omourovska River
23	06.1911	Maritsa River
24	2004	Varna
25	2003	Kroumovgrad
26	2002	Kroumovitsa
27	1997	Momchilgrad
28	1995	Gabrovo

- In the city of Varna in August 1951. It was the consequence of a torrential rain within 6 hours at maximum intensity 1.64 mm/min;
- Along the river Rossitsa in June 1939;
- Along the river Arda in January 1958;
- Along the river Varbitsa in December 1990;
- Along the river Yantra in 1944;
- Along the river Tundja in August 1924;
- Along the river Omourovska in August 1924;
- Along the river Arda in January 1958;
- Along the river Maritsa in June 1911.

Presented in Table 2 data is presented about recorded floods in the period 1935-1957 and some measures of floods for some major rivers in Bulgaria.

Two floods, which, by their rare recurrence rate and the inflicted damage left notable traces in the history of this kind of elemental calamity, were recorded in Bulgaria during the hydrological year 1990/1991 (November 1990 - October 1991). The first one was observed on the river Varbitsa, a right-hand tributary of the river Arda. It occurred on 12 December 1990 and caused the death of ten solders. The second one occurred at the upper and middle stretches of the river Yantra on 6 July 1991 and inflicted great material damage on the area of the cities of Gabrovo, Dryanovo, Veliko Tirnovo and some other smaller human settlements in the region.

Table 2. Recorded floods in the period 1935-1957 for some major rivers in Bulgaria

№	River	Locality of Gage Station (HMS)	Q_{max} m^3/s	F κm^2	MQ_{max}, $l/s/\kappa m^2$	Data	Q_{max}/Q_0
1	Erma	Trun	180	358	503	22.VI.1948	65
2	Ogosta	Glojene	1120	3112	360	7.XI.1957	62
3	Iskar	Pasarel	420	1035	406	24.V.1937	32
4	Iskar	Kourilo	457	3662	125	24.VI.1948	21
5	Iskar	Oryahovitsa	1514	8366	181	14.I.1938	29
6	Vit	Yasen	534	2407	222	23.VI.1948	38
7	Osam	Gradishte	353	1771	200	17.VI.1955	42
8	Yantra	Vetrentsy	692	476	1455	28.VI.1957	138
9	Yantra	Cholakovtsy	1307	1289	1014	14.VII.1944	143
10	Yantra	Radnevo	1336	6574	203	29.VI.1957	33
11	Rossitsa	Karam	1975	203	9720	28.VI.1939	660
12	Rossitsa	Sevlievo	2755	1084	2542	28.VI.1939	300
13	Rossitsa	Vodolei	1100	1856	592	28.VI.1957	100
14	Vidima	Sevlievo	690	560	1332	28.VI.1939	160
15	Rous.Lom	Besarabovo	124	2813	44	26.VI.1955	25
16	Provadiiska	Provadia	68,8	1304	53	22.I.1940	75
17	Provadiiska	Sindel	49,9	1856	27	13.II.1956	26
18	Devnya	Devnya	55,0	182	308	22.I.1940	-
19	Kamchiya	Preslav	626	1010	620	6.XI.1957	118
20	Kamchiya	Grozdevo	428	4857	88	4.V.1937	19
21	Vrana	Kochovo	81,7	380	93	6.III.1954	50
22	L. Kamchiya	Asparouh.	536	1521	352	17.XII.1953	65
23	Maritsa	Belovo	1014	741	1370	5.IX.1957	117
24	Maritsa	Pazardjik.	895	4126	217	29.VI.1957	45
25	Maritsa	Polatovo	960	5440	176	29.VI.1957	32
26	Maritsa	Plovdiv	1375	8006	171	29.VI.1957	29
27	Maritsa	Purvomai	1050	12729	83	11.I.1955	14
28	Maritsa	Svilangrad	2285	20837	110	11.XII.1941	23
29	Mutivir	Sersemkale	210	162	1070	5.IX.1957	175
30	Chepinska	Varvara	333	885	376	29.VI.1957	46
31	Topolnitsa	Poibrene	176	904	195	29.VI.1957	28
32	Topolnitsa	Lesichevo	750	1617	464	5.IX.1957	81
33	Stryama	Bahya	165	833	178	2.XII.1956	-
34	Arda	Prileptsy	1885	1900	993	2.XII.1956	63
35	Varbitsa	Djebel	2620	1149	2280	9.I.1956	137
36	Tundga	Banya	360	2234	161	9.I.1956	20
37	Mesta	Kremen	521	1511	345	24.V.1937	54
38	Struma	Rugdavitsa	343	2195	164	13.II.1956	36
39	Struma	Mar.Pole	1000	10243	93	10.I.1955	14
40	Dragovishtitsa	Goranovtsy	867	570	1532	9.VII.1940	98
41	Bistritsa	Sovolyano	116	257	452	28.VI.1957	52
42	Djerman	Doupnitsa	432	396	1090	31.VII.1953	100
43	Stroumeshtitsa	Mitinovo	285	1893	150	3.XII.1947	25

The data about the runoff module, shown in this table, provide examples for floods, which have produced high "yield" of the surface runoff. For instance, this is evidence about the well known to the specialists case of the river Rossitsa in 1939, when the module at Karamichevtsi Neighborhood has reached 19 9720 $l/s.km^2$. Indicated in the table are several cases when the module has exceeded 1000 $l/s.km^2$. In many other cases floods have been observed even at lower values of the runoff module. The floods in such cases are the result of local factors, determining the throughput capacity of the river section. For the Maritsa River S.Gerasimov has calculated thus the average multi-annual modules of Q_M with respect to the area F of the basin will be $M_m = Q_m / F / m^3 s^{-1} km^{-2}$ (they indicate territorial changes from 0.015 to 2.60 at 0.292 average value); the variation coefficients C_v fluctuate between 0.31 and 2.84 at an average of 0.832; the coefficient of asymmetry C_s varies from 0-0.6 to 20 at an average value of 3.43. As a result of this strong modality large floods of disastrous nature are very rare phenomena and can hardly take place at a given location during the period of observation.

The common feature of these too floods was that they were caused by inrush of torrent river water as a consequence of abundant and intensive rainfalls. In terms of intensity and manifestation, however, they were quite different – the former, despite it relatively low intensity, took a toll of human life, while the latter, marked by a higher intensity, caused material damage estimated at more than BGN 220 million, however no human peril.

The biggest flood, ever recorded in Bulgaria, was that of 31st aug.-01st sept.1858 along the river Maritsa when te river banks in the town of Plovdiv have been flooded by 1-1.2 m. of water. Further downstream, after the confluences of the Tundja and Arda River the flood has covered the town of Edirne (Odrin) with lots of damages. At the same time downtown area of Pazardjik, upstream of Plovdiv, had been inundated by 1.8-2.0 m. of water. There still is a mark on the charge wall remembering that date. Exactly the same disastrous flood took place one hundred years later – in June-Sept.1957. Another big flood, which has caused lasting damage, happened in the city of Vidin in March 1942, when the city was sunk into 1.40 m deep water.

The most ancient data for a devastating flood comes from the Turcish novelist Hadji Halfa. It concerns the Edirne (Odrin) flood in 1361. The river had inundated the town after heavy rain and intensive snowmelt. More than 400 houses had been demolished along the river and its tributaries, according to the archieves.

Examples of torrent floods, which have occurred at instances in the distant past, are also known. No documentary evidence, nor assessments, has been preserved so far for the majority of them. In such cases the collaboration between historians or paleontologists can be very useful, as it has been proven by the case with the archeological excavations near the village of Vetren. It has been found out that the Maritsa riverbed in this section has undergone a significant shift southward until it has achieved its present outline and location.

1.8 Torrents feature of Bulgarian rivers

Torrent floods in Bulgaria have been studied in depth by Prof. Luka Zyapkov from the Institute of Geography at the Bulgarian Academy of Sciences. He has explored the genesis of this phenomenon and developed a typology of its manifestations, followed by division of the country into regions according to the indicator for torrent risk, developed by him (according to Zyapkov, 1988):

- least torrential: with average frequency below 2-3 cases per year (for instance, the small rivers in the Danube Plain at an altitude below 200-300 m.a.s.l., in the Rila and Rhodope massif and in Vitosha at an altitude above 1600-1700 m);
- moderate torrential: with average frequency up to 4-6 cases per year (for instance the rivers Rusenski Lom, Vrana, Topolovets, Ogosta in the low stretches, Nishava, Gorna Struma and Sredna Struma – without the tributaries in the Osogovska mountain, Topolnitsa, Chepinska, Satovchanska Bistritsa, Kanina, the middle stretches of the river Iskar, etc.);
- average torrential: with average frequency up to 6-7 cases per year (for instance Lom, the upper stretches of Ogosta, Sredna Tundga, Sazliyka, Treklyanska, Dragovishtitsa, the upper stretches of Vucha);
- heavily torrential: with significant average frequency up to 8-9 cases per year (for instance Botunya, Vit, Osam, the middle stretches of Rossitsa, Dgulyunitsa, the upper stretches of Golyana Kamchiya, Luda Kamchiya, Fakiyska, Veleka);

- utmost torrential: with the highest average frequency above 8-9 cases per year (for instance the upper stretches of Rossitsa, Draynovska, Sovolyanska Bistritsa, Omourovska, the middle stretches of Arda, Russokastrenska, Sredetska, Mutivir, etc.).

The grades of torrential capacity have been presented schematically on a map.

The predominant areas with heavy or utmost torrential capacity put forwards the need of targeted program for limitation and enforcement of torrent and reduction of erosion, by improvement of the water courses and flexible river training works.

1.9 Typology of floods

We distinguish two principal types of floods depending on their genesis: floods caused in the spring humid season by intensive rainfall and another floods, sporadically formed intensive precipitation, sometimes combined with intensive snow thawing.

The Executive Agency of Civil Defense (EACD) has introduced the following categories of floods, depending on their size, frequency and duration:

- Small floods

  They are characterized by low intensity and frequent recurrence – once in 10-20 years. These are floods bearing the lowest grade of risk (danger). They do not cause damage and do not leave long-lasting traces in the memory of the local population.

- Dangerous floods

  Their characteristics are average intensity and probability of emergence once in 20-40 years. They cause damage to the immediately adjacent to the river agricultural land, buildings and facilities. They pose danger for the people and animals not only in the river valley proper, but also on the flooded river terraces.

- Very dangerous floods

  Their characteristics are high intensity and probability of emergence once in 40-80 years. They cause damages to bridges, water catchments, embankments along river corrections, adjacent land, buildings and engineering structures. They pose great danger for people and animals along the banks of the river.

- Devastating floods

  Their characteristics include high intensity and probability of emergence once in 80-150 years. They cause great changes in the river course with grave pitting, meander breaking, destruction of banks, retaining walls, heavy damages and destruction of bridges, hydro-engineering facilities, sites situated near the river etc. They cause huge material damages and the peril of people and animals.

- Calamitous floods

  Their characteristics are very high intensity and probability of emergence once in 150-200 years. They cause sharp changes in the riverbed – pitting and destruction of old meanders. In the mountain sections the river course carries huge stone blocks of up to and above 2-3 m in size. At the point of exit of the river out of the mountain and into the flat land large, several meters thick torrential cones might emerge, made up of block piles, gravel and sand or sludge. In the flat land end the river valleys got covered with a thick layer of slime. Hydro-engineering and building facilities and sites, situated along the river banks, such as reservoirs, bridges, roads, barrages, buildings etc. get entirely demolished or gravely damaged. Devastation and catastrophic material damages are inflicted and there are great losses of human life and animals.

The indicated categorization of floods might be improved through the introduction of certain numerical characteristics, which will increase the objectivity of the estimates. Such a parameter is the value "maximum runoff module" MQ_{max}, l/s.km^2.

$$MQ_{max} = W_{max}/T.\ A_c$$

The runoff module is a unit, which takes into account the size of the formed evenly distributed maximum surface runoff in the watershed, the so-called "yield" of maximum runoff. It is determined irrespective of the size of the watershed basin and thus it makes possible to conduct comparative studies between floods that occurre in different rivers or at different points of time.

In terms areal of territorial coverage of the spread, the EACD, Bulgaria distinguishes the following types of floods:

- ***Local floods***. They emerge on individual rivers or river sections
- ***Medium-range floods*** (medium-scale, mezo-scale). They emerge in a given area on several rivers.
- **Large coverage** (large-scale) **floods**. They extend over large areas with many rivers or the course of a big river, such as the Danube river and the adjacent flooded terrace of the territory of the country.

1.10 Characteristics of the floods

The hydrological analysis of flash floods is based on data provided by hydrometric and precipitation gauge stations and posts operated by the National Hydro-Meteorological Network. The other source of data are the measurements by specific hydrological expeditions and surveys, and on-the-spot surveys of the hydro-engineering facilities along the river valleys.

The National Hydrometric gauge network comprises 206 stations. The beginning of the mass hydrometric measurements and observations dates back to 1935, although such measurements have been organized as early as in 1920 at certain sites.

From the total number of stations 137 are equipped with operating daily or weekly lymnigraphs (Russian made), 120 feature overhung equipment, 87 are located on existing road or railway bridges and 4 are fitted on specifically erected hanging bridge structures. A total of 12 automatic hydrometric facilities are installed in the country on the rivers Struma, Varbitsa, Dgulyunitsa, Arda. In addition to these, the Ministry of Environment and Water possesses another set of automated hydrometric gauge stations, working on-line. The National Electric Company runs its own hydrometric network. The hydrometric network on the river Danube is organized and operated by the State Agency for Maintaining of the River Danube Naval Route (headquarters in the city of Rousse).

From the total number of hydrometric stations 12 provide regular information about the water level on a daily basis, which is used for information exchange with abroad. From another 34 stations operative information is received once a week for incorporation in the weekly bulletin of the National Institute of Meteorology and Hydrology. Some years ago there was a practice for daily reporting of this information as well, and on this basis hydrological forecasts used to be worked out and submitted to the competent governmental institutions in the field of water resources management.

The measurements of the water quantities are performed most frequently by means of a hydrometric current meter (Russian made) (NIMH) and at the Ministry of Environment and Water – by means of A.OTT Кемptеn or SEBA equipment. In the majority of stations the current meter is lowered by means of a rope with a weight unit of inadequate weight. It is a general practice in the case of flood to perform the water discharge measurements by means of surface float units. Unfortunately, the conversion coefficients to the average flow speed are determined by means of obsolete, archive information about parallel measurements conducted by means of hydrometric current meter or by literary sources.

Numerous digital parameters of the floods are used in hydrology, like for instance time of rise and time of fall of the flood, achieved water level maximum, average and maximum flow speed of the water current, size and duration of the flood, frequency and duration of the emergence, ingredient of the free water surface of the water current, time of concentration and travel of the high wave, altitude and intensity of the rainfall, state of the ground cover, preliminary moisture content of the watershed basin, etc.

From the large number of parameters, we have used only a few for the purposes of this study. Some of them have been included in the description of floods along the river Varbitsa at Djebel in the period 1955-1956 – Table 3.

Table 3. Data about recorded floods along the Varbitsa River at Djebel in the period 1955-1956

Data of flood	Q_{max} m^3/s	QM_{max} $l/s.km^2$	W_{max} $10^6 m^3$	W/F 10^3 m^3/km^2
19.XI.1955	270	235	70,5	61,3
13.II.1956	2350	2040	200	174,0
16.II.1956	320	278	7,2	6,3
19.II.1956	620	540	23,4	20,4
20.II.1956	950	826	50,5	43,9
14.III.1956	610	530	37,0	32,2
12.V.1956	510	443	27,0	23,5
4.VI.1956	170	148	1,3	1,1

The data about the runoff module, shown in this table, provide examples for floods, which have produced high “yield” of the surface runoff. In another case for the Rossitsa River, in 1939 the module at Karamichevtsi Neighborhood has reached
19 9720 $l/s.km^2$. In many other cases floods have been observed even at lower values of the runoff module, as a result of local factors, determining the throughput capacity of the river section.

An idea about the chronology of the large floods during the last century can be obtained from Fig. 1 made by S.Gerasimov, on which the average values of the standard deviations ψ_m=(Qm - Qm)/σ_m have been marked: where σ_m for five points along the main stream of a river. One can note for the Maritsa River case two outstanding peaks: in 1911 and in 1957, whereat the height (the intensity) of the latter exceeds the 1911 peak by almost 1. A flood of significantly lesser intensity has taken place in 1923 (ψ=1.7 /, 1913 / 1.33 / and 1976 / 1.14).

For mitigation of the damages from floods in urbanized areas the following actions are recommended:

- Regular cleaning of the main river bed from willows, poplars and bushes, urban solid waste and large-size industrial waste along the river course in and before the human settlements, cleaning of the river bottom from clogged sediments.
- Removal of the unfeasible from a hydrological point of view man-made break walls along the rivers on the area of human settlements.
- Conducting of expert assessment of the throughput capacity of the river corrections and of all the bridges and hydro-engineering facilities, which present a potential risk of blocking of the river course, and implementation of measures for their alignment to the conclusions and recommendations of the expert assessment.
- Construction of protective facilities on the flood-threatened river banks (in compliance with the conclusions of the expert assessment), built-up with residential or industrial and agricultural buildings.
- The construction of embankments on the rivers, especially on the area outside the human settlements, is not feasible, since it will diminish the attenuation capacity of the water-meadows in the river valley and will increase the potential risk of larger floods and the farther below situated human settlements.
- The design of any new large-scale hydro-engineering facility, road facility, residential or industrial building etc. sites along the river banks should be accompanied by an adequately performed engineering-hydrological investigation.

2. FLASH FLOODS IN THE ARDA AND YANTRA RIVER BASIN

2.1 THE ARDA RIVER

The River Arda watershed is situated in the far southern end of BULGARIA (the Rhodope Mountain) and it is subjected to the strong Mediterranean climatic influence. The area is mountainous, with poor forest coverage, and gravely affected by erosion. It is characterized by torrent rainfalls, generated in the event of penetration of Mediterranean cyclones. The mountain slopes and the river currents are characterized by large slopes, which favours the rapid formation of high floods and casts torrential features of the river currents.

The recorded maximum precipitation rates in the area are as follows: Kardjali – 85 mm (0209.1940); Momchilgrad - 117 mm (3112.1957); Ardino – 118 mm (0812.1945); Zlatograd – 120 mm (0609.1957) etc. Some of the rainfalls are torrential with high intensity, which according to Dimitrov (1974), has reached as high as up to 6 mm/min. According to this indicator the River Arda basin ranks in the first group of regions in this country manifesting the highest torrential features.

Table 1. Intensity in l/(s.ha) of rainfall of different duration (April-October)

Gage Station	Duration (min)									
	5	10	15	20	25	30	40	50	60	>60
Zlatograd	73.0	68.1	64.2	62.5	60.8	60.2	56.7	55.7	53.3	50.8
Djebel	83.3	75.5	67.8	64.2	60.1	58.5	53.1	48.3	44.8	40.8

We have observed, in the Climate of Bulgaria (1991), a specific graphical relationship for the town of Zlatograd between the frequency of occurrence, intensive precipitation and the duration of rainfall, which can be used for a variety of studies or mathematical modeling.

The physic-geographical conditions of the watershed, the characteristics of the soil and vegetation cover on it, the intensive anthropogenic activities favour the torrent floods of Arda River. The long term hydrometrical measurements proof this.

The wide range of change of the river runoff in the time span – from the formation of almost annual floods in winter to almost full drying of the rivers in the region in summer gives rise to extremely unfavorable living conditions for the people and the stock, as well as for the development of agriculture and industry.

Several large dams have been constructed on the Arda River system – *Ivaylovgrad, Studen Kladenets, Kardjali, Borovitsa, Zlatograd* and the *Benkovski* and over 200 small man-made lakes, constructed to protect the area from erosion. Their accumulated water volume is used mainly for irrigation , water power production and flood protection.

Active mining is underway in the mountainous portion of the watershed basin, extending over vast areas – Rudozem, Madan, Madgarovo, Krumovgrad, Smolyan, Zlatograd etc.

The river Arda basin gives rise to a variety of economic, social and technical problems, related to the peculiarities of the water regimes of the rivers in the basin. It will be appropriate to add to them two more aspects – protection of the population against floods and environmental problems.

The watershed of the Arda River and its tributaries become our choice for the presented study of the APFM Program, because of high frequency of flash floods, their size and the damages, which have happened. The other reason for such a choice comes from the sharp social problems of the region, being very poor with high unemployment, heavy pollution of the air, water and soils by the mining industry, tobacco crop etc.

The last, but not the least is the ethnic problem, as the bigger part of the population are Turkish men, which suffers some Islamic influence and activities. The cultural level of the people is rather low, the social communications are impeded, because of linguistic barriers and the local state authorities are not sufficiently effective.

The most strong floods, soil erosion and registered damages due to flash floods have been registered in the Varbitsa River basin so far and its right hand side tributary – the Kroumovitsa River, which spreads over the South and East part of the region.

2.2 The Varbitsa River

The river Varbitsa is a big right-hand tributary of the river Arda, known as a strongly torrential river, with periodically recurring calamity floods, which have caused the perish of human lives and grave material damages – Fig. 1.

Varbitsa river runs through 8 municipalities, 6 of them within the Kardjali region and 2 – in the Smolian region. Both regions have mixed ethnic population, poor economy and large unemployment and poverty. The population of the Varbitsa River basin in 1985 was above 200 000 residents. The economically active part of the population is about 56-58%, the population under 18 years reaches 35-38 per cent. At present the demographic characteristics are worse because of the strong emigration of ethnic Turks. The start of the exile wave began in 1986-89, based on political reason, while later it turns to economical. The main, traditional means of living in the Varnitsa river basin is connected to the ore output and the cultivation of tobacco. At present there is high rate of unemployment (above 60%). Tobacco growing was introduced as a compulsory mono-culture industry for the rural areas of the region in the 1960s, under Comecon “division of labor”.

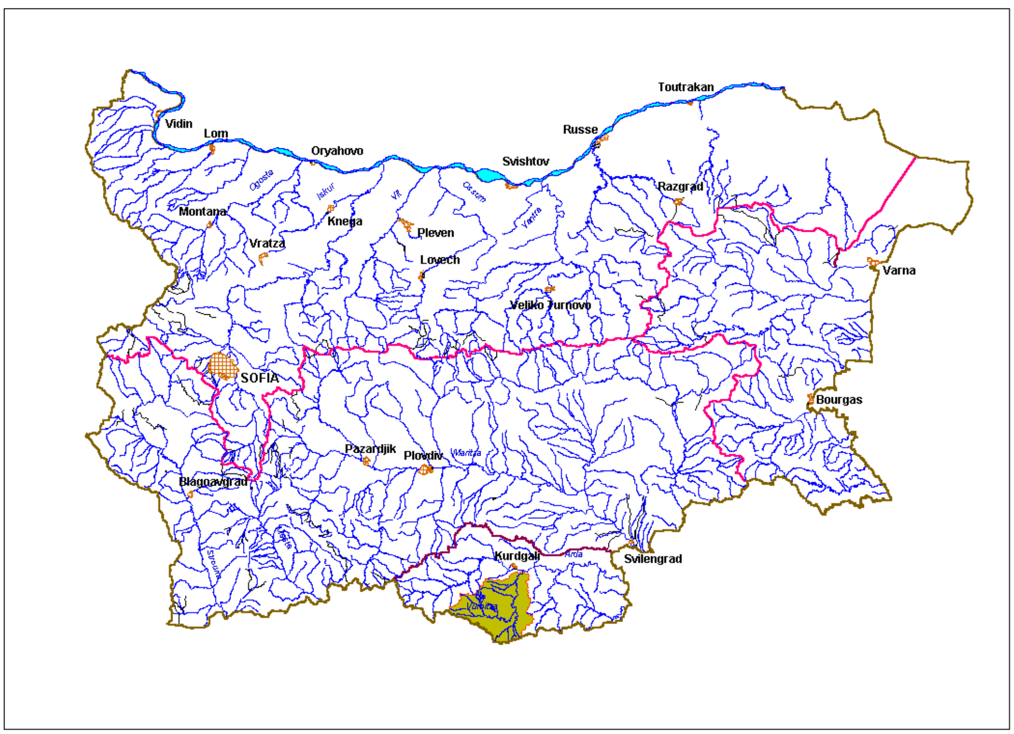


Fig 1. Situation of watershed of Varbitsa River.

The catchment area of the river is 1203.9 m^2 and this is 23% of the Bulgarian part of the Arda catchment area. The total length of the Varbitsa River is 99.1 km. The catchment area is mountainous, the average altitude is 546 m – Fig.2 and the average slope of the basin is 26%o.

In terms of altitudes, the Varbitsa River watershed is situated between 1240 m.a.s.l. at the village of Shterka in the western end of the basin, 960 m.a.s.l. at the village of Sindeltsi in the eastern end and 584 m.a.s.l. at its mouth in the river Arda. The average altitude of the watershed basin at the hydrological gauge station (HMS) No. 312 has been identified as 584 m.a.s.l. The middle and lower river stretches run entirely through areas of average altitude below 700-750 m.a.s.l. Only a small section of the watershed basin (about 15-20%) is situated in the higher parts of the mountain. This kind of vertical zoning of the region explains the absence of a constant and strong snow cover on the area of the river basin.

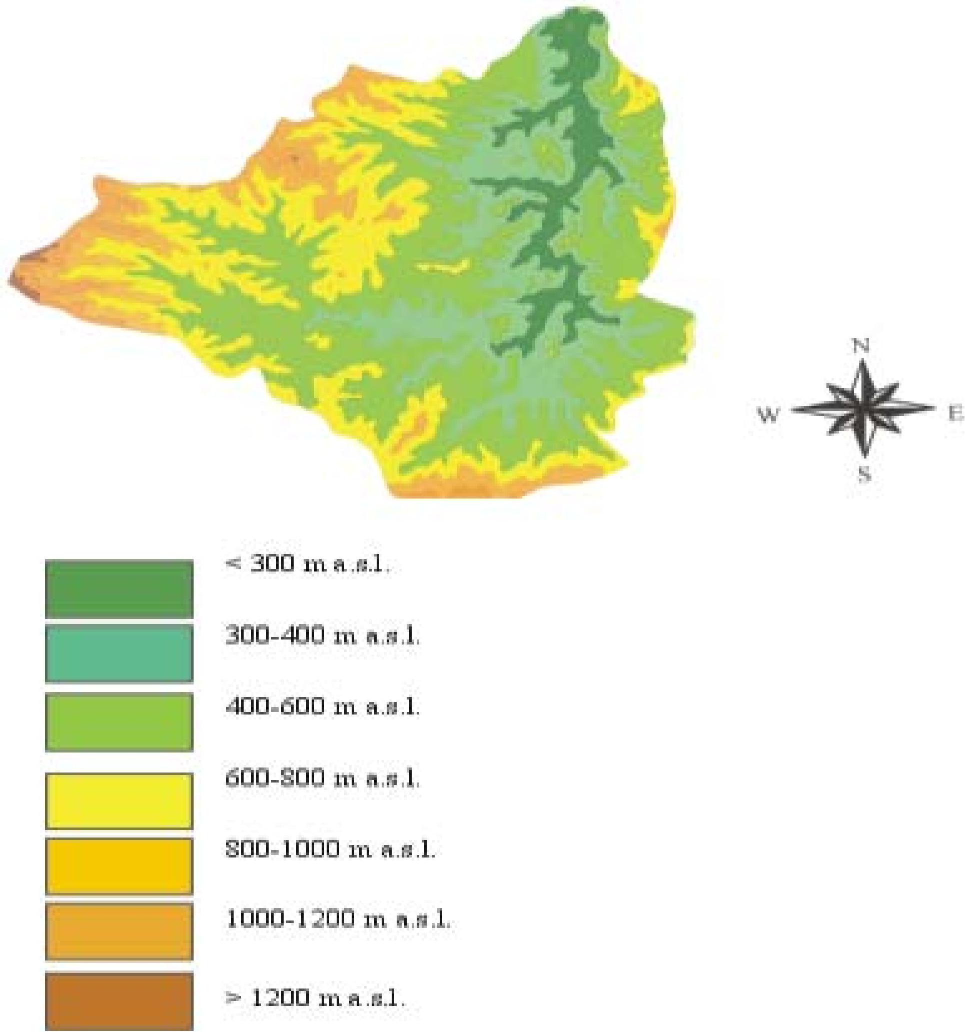


Fig 2. Vertical zoning of the region.

36% of the catchment area of the Varbitsa River is forested. The areas under cultivation are a bit under 20% of the catchment area. The urbanized areas (settlements, roads, etc.) are about 10% of the total catchment area. The soil is sandy and unproductive- Fig.3

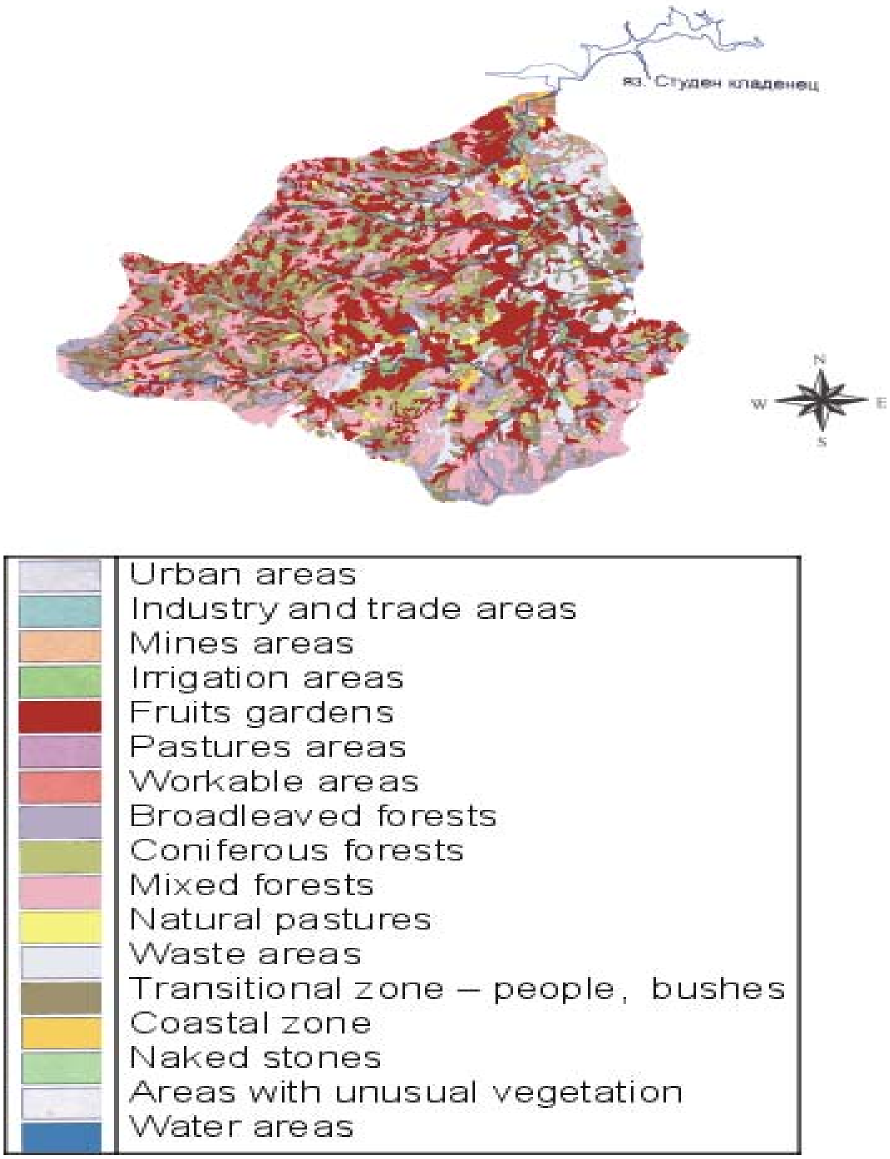


Fig 3. Soil in watershed of Varbitsa River.

The climate is affected by the Mediterranean sea and might be characterized as mild humid with lots of rain during the winter time. The average annual temperature and rainfall are higher than the average ones for Bulgaria. The average annual rainfall is 800 mm while the average value for Bulgaria is 670 mm.

Table 2. Major hydrographic characteristics of the hydrological gauge stations, used for the purposes of this study

№	River / Station	№ of Gage station (HMS)	Length of the river (km)	Area (km^2)	Altitude of the Watershed (m a.s.l.)	Slope of the River (%)	Slope of the Water shed %	Fores-tation (%)
1	Varbitsa / Varli dol	313	54.85	471.2	647.0	18.4	0.282	
2	Varbitsa / Djebel	312	88.15	1149.0	584.0	12.1	0.242	43,3
3	Kroumovitsa/Kroumovgrad	311	37.30	497.6	494.0	19.0	0.206	35,3
4	Arda/Dolno Cherkovishte	347	178.30	4460.0				

The natural conditions are unfavorable – high temperatures, intensive erosion, deforestation, thin soil cover and humus-deficient soils.

Hydrological gauge stations, whose main characteristics are indicated in Table 3 below, have been set up for recording of the hydrolocial phenomena in the Varbitsa river basin.

The average annual flow of the Varbitsa River is about 640 million m^3 which is about 27% of the flow of Arda River in its Bulgarian part. If the year is dry the flow decreases to its half. The floods are frequent and very often they cause large damages.

The catchment area of the Varbitsa River includes the whole territories of 4 municipalities (Nedelino, Zlatograd, Djebel and Kirkovo) and parts of the territories of three other municipalities (Momchilgrad, Kurdjali and Ardino). The water supply is expensive as it is realized by pumps. Because of the irregular hydrological regime of the river and bad infrastructure for potable water supply, most of the settlements suffer strong water supply restrictions

2.3 Hodograph of the water discharge

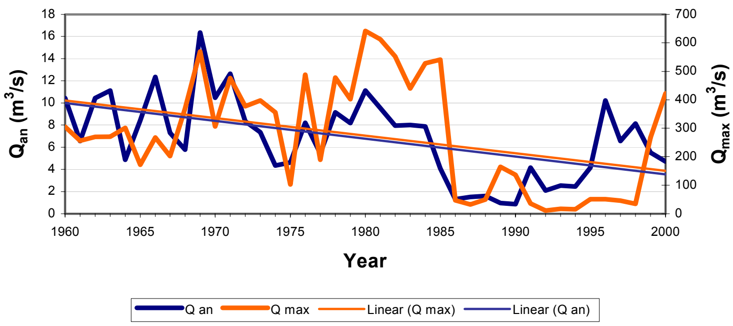
A study by T. Panayotov and D. Ch. Lou (1981) reveals, in a comparative table, that for at HMS No. 315 at the village of Vehtino on the river Arda the majority of the high torrent floods amount to between 10- and 20-fold and even 40, 50 folds the value of the average multi-annual water discharge, while in the case of the Varbitsa River predominant are the cases of floods with $Q_{max}>20Q_m$, i.e. extremely high floods are formed in the region during almost any type of precipitation rate.

For the Varbitsa River this ratio reaches 150 with a maximum yield of MQ_{max}=2280 l/s.km^2 (Hydrology of Bulgaria, 1961).

Table 3. Summary and average number of floods with maximum water discharge above a specific threshold during the period 1965/66 – 1978/97

Months	Arda – Vhtino				Varbitsa - Djebel			
	$Q_{max} \geq 10Q_{annual\ average}$		$Q_{max} \geq 20Q_{annual\ average}$		$Q_{max} \geq 10Q_{annual\ average}$		$Q_{max} \geq 20Q_{annual\ average}$	
XI	4	0.29	2	0.14	10	0.71	7	0.50
XII	8	0.57	7	0.50	18	1.29	13	0.93
I	9	0.64	3	0.21	17	1.21	10	0.71
II	9	0.64	5	0.36	14	1.00	7	0.50
III	3	0.21	1	0.07	3	0.21	1	0.07
IV	2	0.14			2	0.14	1	0.07
V	1	0.07			3	0.21		
VI					1	0.07		
VII	1	0.07	1	0.07	2	0.17	1	0.07
VIII								
IX					1	0.07		
X	1	0.07	1	0.07	9	0.64	5	0.36
Year	33	2.71	20	1.43	80	5.71	45	3.21

Hodographs of the average annual water discharges of the two HMSs along the Varbitsa River (No. 312 and 313) are presented on Fig. 4 together with their trend lines (Table . 4).



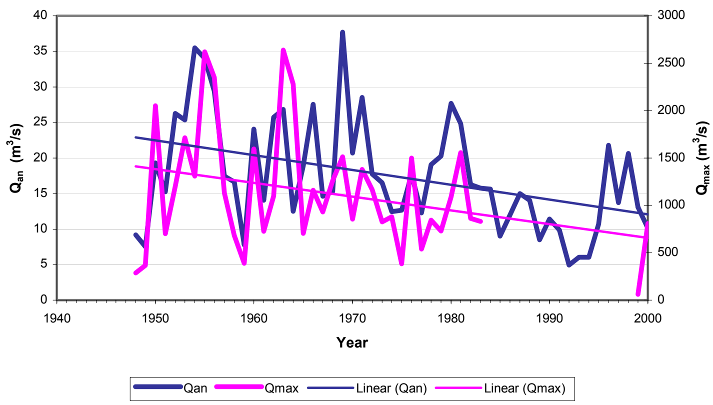


Fig 4. Hodographs and trend lines of the average annual water discharges of HMS No. 311 and HMS No.312.

Table 4. Tendency of change of average annual water discharges of HMS No. 311 and HMS No. 312

River	Gage station (HMS)	Parameter	Trend	Period
Varbitsa	Vurly dol	Q an	Q = 10.151-0,1607*t	1960-2000
		Q max	Q = 404,34-6,1832*t	1960-2000
Varbitsa	Dgebel	Q an	Q = 23,093-0,2085*t	1948-2000
		Q max	Q = 1426,5-14,525*t	1948-2000

The trends of the changes in the water discharges in the presented graphs are poorly manifested, which is an indication for stationarity in the progress of hydrological processes without visible changes as a result of human activities.
The maximum water discharges in thes case of HMS No. 313 vary from 1300 m^3/s to 2600 m^3/s.
During the winter (from January to April) 65% of the river flow runs, while during the summer (from July to August) the flow decreases to 1-2% to 6-8%.
Table 5 shows the annual run-off of the Varbitsa river and its monthly distribution in % for years of different humidity

Table 5. Monthly distribution in %

Station	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX
Kurdjaly	5.30	7.62	13.80	12.71	12.16	13.95	11.18	8.12	6.77	4.16	2.34	6.80
Djebel	3.84	9.26	17.10	21.20	14.73	13.38	8.15	4.42	3.65	1.93	1.13	1.00

2.4 Monthly water discharge and rainfall distribution

In *Hydrology of Bulgaria* (1961) it is reported that the precipitation amount in winter in the Rhodope mountain reaches up to 350 mm, which is significantly (up to 2-3 and more times) higher than in the rest of the country. Their monthly distribution is shown in Table 5.

The table reveals the full synchrony in the seasonal distribution of the precipitation and the runoff, whereas the highest values are noted for the winter months, when more than 60% of the annual runoff of the river takes place. During the summer low-water season barely few percentage of the annual runoff takes place, which means in practical terms almost complete drying of the main river course and of the majority of the river tributaries.

The close causal relationship and dependence between the river runoff and the precipitation is manifested in the formation of analogous schemes about their distribution through the year. Obviously, the distribution of the runoff through the year is of the single-module type, reaching the highest values during the months of December through March.

2.5 Runoff coefficient

The combination between low ambient temperatures and the almost total absence of vegetation, the high degree of moisture saturation of the surface soil layer and the reduced water losses from evaporation in winter, the high ingredient of the slopes of the watershed basin and other factors predetermine the favorable runoff conditions in the Varbitsa watershed basin during the rain season, measured by a high runoff coefficient -$\propto$.

According to a study by T. Panayotov (1981) the winter runoff accounts for the largest share of the annual water flux of the rivers in the area. Some researchers (Hydrology of Bulgaria, 1961) note the possibility for recording the $\propto$ values above 1.0 in the cases of torrential rainfalls which extend over the snow-covered higher-altitude areas of the watershed basin and thus cause intensive thawing.

It has been detected that in the river Varbitsa basin the cases of high torrent floods in summer are rare. The formation of floods in summer is rare because of the high air temperatures, which predetermine great water losses both from precipitation and infiltration of surface water into the soil. Than for certain floods these losses might reach up to 80%.

On the basis of empirical data, T. Panayotov (1981) defines the runoff characteristics, respectively the runoff coefficient of the entire Arda River basin, including the Varbitsa river. The higher values of this coefficient for the average annual runoff, shown on Table 6 corroborate the thesis about the water abundance in the area.

Table 6. Average runoff coefficients by hydrological seasons and for the hydrological year for the HMSs along the Arda River Basin (according to T. Panayotov, 1981)

Gage Station	F (km^2)	Level (m a.s.l.)	Winter season	Spring season	Sumer-Automn season	Hydrologycal year
Varbitsa-Vurli dol	471	647	0.810	0.631	0.181	0.606
Varbitsa-Djebel	1149	584	0.794	0.585	0.167	0.583
Krumovitsa-Krumovgr	498	494	0.897	0.672	0.112	0.592

2.6 Time of travel of the high torrent floods

For the purposes of this study a comparative analysis has been made of the lymnigrams at the two hydrological gauge stations HMS No. 313 and HMS No. 312 for the period 1989-1991 and the time of travel has been determined.. The calculations show the following:

- The time of travel between HMS 312 and 313 along the Varbitsa River at water level of about 130 cm goes up to 3:30 h. Therefore, the average speed of the flood propagation is defined to be about 10.01 km/h or 2.78 m/s, which characterizes a calm water flow for a river in a mountainous region.

- The time of travel for the same river at water level in the range of 700-900 cm at the "top", measured at HMS No. 312, has diminished sharply and comes to about 60 minutes. Therefore, the average flow speed is defined to be about 33.3 km/h or 9.25 m/s. There are other values of this kind as well, which corroborate the calculations made by the authors as follows:

Table 7. Measured maximum speeds of the river Arda water current

HMS / Year	Arda-Vehtino	Arda-Prileptsi	Arda-Kurdjali	Ch.Reka-Turun	Varbitsa-Djebel
1941			2.07		1.190
1942			1.10		1.400
1943			0.72		2.520
1945			1.12		0.650
1946			1.07		0.618
1947			0.75		0.565
1948			1.64		0.990
1949			1.26		0.860
1950		1.96	2.00		1.090
1951		4.00		1.33	1.570
1952	3.00	6.32		1.87	3.330

A study by Gergov (1971) reveals the distribution of the time of travel along the riverbed for the entire river network of the Arda River on the basis of a genuine methodology developed by the author . It permits the elaboration of a basin-based early warning system in the event of formation of devastating floods.

Apparently, the time of travel along the riverbed in the Arda River basin is very short and this fact does not allow the performance of "additional studies or co-ordination of measures for protection of the population or even its evacuation in the event of torrential rainfalls.

2.7 Examples of recorded recent high torrential flash floods on the Varbitsa River

The torrential nature of the river Varbitsa and its floods is the object of many years of observations and recording by means of automated devices and therefore rich amount of empirical information has been collected. Many cases of floods have been reported and reviewed in a number of research publications .

In the course of conducted analyses of existing archive lymnigraphic records of high floods, it has been found out that in the majority of cases the floods are characterized by almost vertical head front, which corresponds to a very sudent increase of the water discharges within very short time and very steep drop. Such an example has been presented for HMS No. 312 for 1946 by T.Panayotov, when within 1-2 hours the water discharge has increased from some dozens m^3/s to more than 1000 m^3/s. Other graphic examples in the archive documents of the National Institute of Meteorology and Hydrology corroborate the above statement about the rapid concentration of the surface runoff in the river network and the rapid travel of the high runoff along the river system.

The flood formation process is accompanied by the transportation of huge amounts of sediment material, including large-size gravel, stone and rock materials, which is deposited on the riverbed at the slightest change in the hydraulic conditions of the stream.

It is very poor that the sand-gravel-stone temporary depositions are not a proper subject of studies, though they might cause a sudden rise in the water level, followed by heavy destructions after the “barrages” are washed out.

2.7.1 Case 1

The flood, which appeared on the Varbitsa River, caused by abundant rainfall on 11th and 12th December 1990, has originated from the precipitation amounts of 28-64 mm on 12 December or 39-73 mm total (average intensity of 2.5-5.0 mm/min) at the rainfall gauge stations Zlatograd, Benkovski, Kirkovo, Chorbadgiysko. The rain has started during the night of the 10th December, went on without break during the day of the 11th and featured its highest intensity in the night of 12th December. The flood of the river Varbitsa at HMS No312 at Djebel began smoothly during the night of the 12th, its intensity growing by 10:00 hours and the “top” peak rushed through at 16:00 h on 12th December, featuring water level H_{max} = 641 cm. From the regional empirical curves of the distribution of probabilities of the 24-hours continuous maximum rainfall [according to S.Gerasimov] one can determine very low empirical probability of the rainfall. The maximum water discharge for the case 1 amounted to 1450 m^3/s (q_{max}= 1.26 $m^3/s.km^2$ at 1150 km^2 total area of the basin). According to S. Gerasimov (19…) the dimensionless intensity of ψ=0.428 and integral probability of the excessive quantity is about 25%, i.e. once in 4 years. It is obvious that this maximum does not fall under the category of the rare flush floods, however it is in the group of the quite frequently occurring floods for the river Varbitsa.

During the same hydrological year, on 15 June 1991, a flood of peak of 630 cm and intensity of 1440 m^3/s had rushed through the riverbed. Because of the great depth and speeds of the water currents, however, these phenomena, although quite frequent, present a risk for human activities in the vicinity of the rivers bed.

2.7.2 Case 2

The lack of consideration for this special characteristic of the local water courses has caused the peril of ten soldiers during forcing of the river Varbitsa on training purposes on 12 December 1990.

Officials from the EACD-Bg describe the latest large flood on the river Varbitsa and the river Krumovitsa in 2003 on the basis of their personal impressions and specific targeted measurements and rescue actions.

The flood occurred on 22-24 December 2003 in the area of the river Krumovitsa after a continuous rainfall for about 36 hours with only brief breaks. There had been snowfall on part of the watershed basin the night before, because of the low ambient temperatures. The snow had thawed quickly because of the rainfall and had thus increased the influx of water to the rivers.

The survey of the area conducted by the experts had revealed the following:

- By 11:00 h on 23 December 2003 a rise of the water level of the three rivers in this area – Arda, Varbitsa and Kroumovitsa - had been observed;
- The water level at the bridge above the river Kroumovitsa on the Kroumovgrad-Momchilgrad road had risen by about 2 m in the time from 20:00 hours on 23 December 2003 till 12:30 – 13:00 h on the next day
- About 10:30 – 11:00 h the water level at the bridge above the river Varbitsa on the Kroumovgrad-Momchilgrad road had risen to slightly less than 2 m below the road level, i.e. the level of the river water had risen by about 4 – 4.5 m.
- The water level at the bridge above the Arda River – the Arda Bridge – had risen by nearly 2 m within 24 h.
- According to visual estimates the water quantity in the river Kroumovitsa at the city of Kroumovgrad had reached 1200 m^3/s.
- The stormy water current, the high mud content and the visible transportation of large-grain gravel and stones had made instrumental measurement risky and hard-to-implement.
- According to the preliminary estimate of the Civil Defense experts the inflicted material damages in the region amount to about BGN 150-200 thousand.

With respect to the floods of 20 July 2003 and 31 July 2003 the recognized damages amount to approximately another BGN 103,430 (Euro 52,883).

2.7.3 Case 3

For one of the human settlements – the village of Podem – we are in possession of additional information, which makes it evident that flooding of similar size have happened in this village on 11 June 2002, 20 July 2002 and 31 July 2002 after a rainfall lasting for more than 3 h on the area of the villages of Podem, Komarevo, Riben and Bozhuritsa. The following material damages have been reported:

- One house had been fully demolished;
- There were cases of drowned stock;
- The flood had developed mainly along two streets – "3 Mart" and "Vit", which are the major natural drainage collectors of rainwater in the village;
- The asphalt and crushed-stone road pavement had been washed away along a strip of 7.80 m in width and 1341 m in length. Part of the demolition goes to a depth of 1.10 m. Some of the dug-out material had been deposited in the lower end of the road at a height of 0.5-0.6 m. At the bridge across the river nearly 1 m deep pits had been formed in a dangerous closeness to its foundations. After the bridge there are another 1081 m of the road cover, whose asphalt pavement had been carried away at a depth of up to 0.2 m and pits have been dug to a depth of 0.9 m. Deposited sediment material had been observed along the road after the pitted section. Some of these piles feature up to 0.5 m in height and 10 to 30 m in length.
- Eyewitnesses report that the depth of the water current rushing along the street was more the 1.8 m, nearly 2.0 m.
- The inflicted damages are estimated to amount to:
  - BGN 552,257 (Euro 282,364) for the flood of 18 June 2002; and
  - BGN 631,467 (Euro322, 864) for the flood of 25 June 2002.
  - For compensation of the losses, incurred by the population on the above-mentioned dates, the state has paid out benefits to the total amount of BGN 161,443 (Euro 82,544).

The described flood is corroborated also by the officials of the Bulgarian State Railways, who maintain and safeguard the railroad and railway facilities in the region. They confirm reports about 3-4 h intensive rainfall, as a consequence of which the drainage pits and pipelines have been filled over the brim and were no more able to take in the incoming water from the slopes. As a result of their overflowing the water had flooded the upper section of the railroad and the near-by switch and had rushed into the yard of the linesman's lodge. After the withering of the elemental calamity it was found that the drainage pits and pipeline were filled with stone, asphalt pieces, trees and sediment materials. Also recorded were the following damages: demolished railing and railway station platform, clogging of the railroad by sediment materials at a length of more than 150 m, damage on 4 offices at the railway station and the passenger waiting room including the furniture. The basement of the buildings was clogged with sand and sludge. The barrier of the near-by road was demolished.

The damages in the area of Podem Railway Station have been estimated at about BGN 834,260.78 (Euro 426, 550) and those of the adjacent section – at approximately BGN 417,130 (Euro 213,275).

Illustrated damages in the Box 1. are some of the inflicted on this area by the described flood.






Box 1. Photos of flash floods in the Podem Village - Vit River Basin on June 2002.

For the most cases, the Arda River indicators of dissolved oxygen, BOD_5, and permanganate oxidation comply with the surface water quality norms of I and II categories. There were episodic suspended solids high concentrations measured mainly in rains and floods periods. A local hot spot of Arda River is Varbitsa River before the tailing depot of Gorubso-Zlatograd AD. There is a pollution with heavy metals from the mines in the area. The biological monitoring of surface water in Varbitsa river basin is shown in Fig.5.

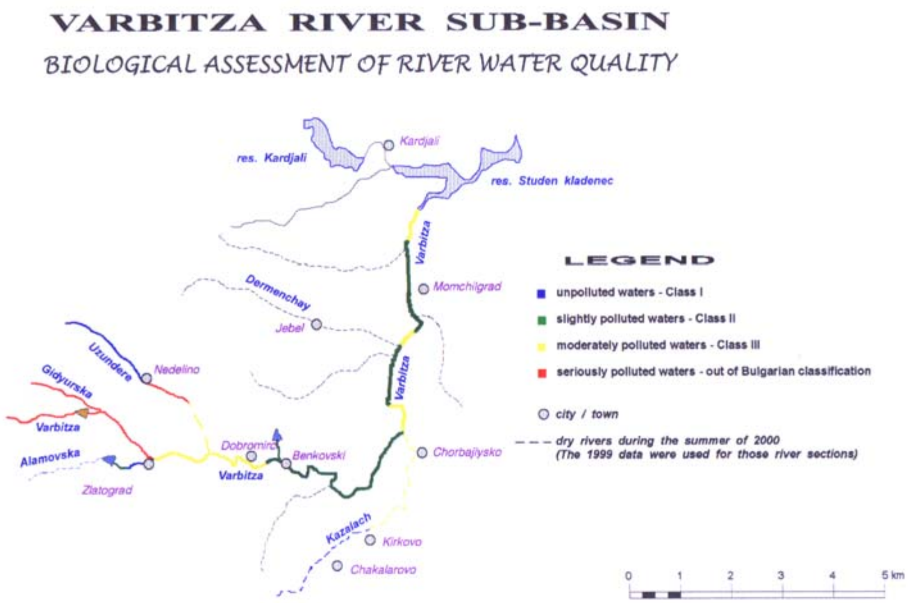


Fig. 5. Biodiversity of the Varbitza River basin.

2.8 Recent cases of flash floods on the Yantra River

The floods in the upper stretches of the river Yantra valley in the area of Gabrovo, Dryanovo and Veliko Tirnovo on 6 July 1991 were caused by the rise of the waters of the river Yantra and its main tributaries – the rivers Dryanovska and Belitsa – as a result of the strong and abundant rainfall above the watersheds of these rivers on 5th and 6th July, lasting for nearly 12 h.

The sudden rise of the water level in the river and the change in the water quantity from about 15 m^3/s to more than 240 m^3/s, i.e. a change of more than 16 times in the water flow rate, is quite obvious and easy to note.

The precipitation quantities recorded on the 5th and 6th July for nearly 12 h, were in the range of 52-104 mm (rainfall measurement stations Veliko Tirnovo, Dryanovo, Tryavna, Krastenets, Gabrovo, Lyutatsite and Peak Botev) at an average intensity of 4.3-8.0 mm/h. What is typical in this case is that this runoff-forming rainfall fell on highly humid soils as a consequence of previous grave rainfall, which had occurred on the 2nd and 3rd July (20-50 mm/24h). The rise of the river started in the early hours of 6th July and went on intensively during the morning and midday hours, when the peak of the high wave rushed through the upper stretches of the river (*Hristo Smirnenski* Dam, Etara, Gabrovo) about noon and by about 18:00 – 20:00 h signs of flooding were observed in the lower stretches (Veliko Tirnovo, Samovodene, Dolna Oryahovitsa).

The floods spread along the river Yantra course from Etara to Samovodene and along the tributaries of the river in that section. For the purposes of outlining the spatial development of the phenomena the river sections were investigated by an expedition. The characteristics of the maximums at typical points (a total of 14) were determined, including the hydrometric gage stations Gabrovo and Cholakovtsi for the river Yantra; Varbitsa for the river Druanovska, and for the rest – near the tailing points of large tributaries: the rivers Sivyak, Zhaltesh, Panicharka, Dryanovska and Belitsa. The balance calculations show a good throughput capacity. The quantitative characteristics of the investigated points are presented below.

The biggest overflows have taken place along the low-lying terraces and water meadows of the river Yantra in the section between Gabrovo and the mouths of the rivers Belitsa and Dryanovska (below the village of Ledenika), where large areas of arable land have been flooded. As a consequence of the spread of flooding in breadth the maximum was attenuated from 686 m^3/s at Gabrovo to 432 m^3/s at the village of Ledenika. The attenuation of flood was less expressed in the section between the city of Veliko Tirnovo and the village of Samovodene and the village of Dolna Oryahovitsa (1300-1240 m^3/s). The city of Gabrovo suffered the biggest damages (more than BGN 220 million or Euro 112.5 million). The damages at Dryanovo, Veliko Tirnovo and some smaller human settlements were lesser.

The investigation conducted by the expedition reveals that the flood had been aggravated by the construction of bridges over the rivers, river training works, construction of industrial and residential buildings on flooded river terraces without taking due consideration of the hydrological conditions of the rivers, as well as by the lack of care to clean the riverbed from branches and bush, waste and sludge. Typical examples are the bridges in Gabrovo, which below the mouth of the river Zhaltesh downstream, have been often partially blocked by trees and bushes carried by the river water due to the reduced overhead cross sections of bridge structures lying close above the river bottom, narrow openings between the pillars of the bridges and the man-made wave-breakers. Thus, for instance, the cross-sections of the openings of the arch-shaped *Bichkenski* Bridge (above the river Zhaltesh mouth) have been preliminary strongly diminished at the lower end by about 1.5 m sludge deposits due to the impact of the wave-breakers built about 50 m below and an embankment next to it on the right-hand bank. The cross-section of the river at the gate of *Dyado Nikola* Works is narrowed by sediment sludge deposits on the bottom as a result of the river wave-breakers constructed at some distance downstream and because of not complying with the hydrological characteristics low-lying bearing structure of the bridge, etc. At the time of the flood the bridge was clogged, the water had flowed over it and had demolished its railing and spilled over the area of the factory, flooding it with a 1.5 m deep water layer. The breaking through these odd-type of “dam walls” had caused secondary rise of the high water peak down to the next bridge. As a consequence of this situation, the parameters of the high wave (mainly the water stand), determined at the city of Gabrovo are exceeding the natural ones for this river section.

Many residential buildings (Gabrovo) and industrial or agricultural buildings (Gabrovo, Dryanovo, Veliko Tirnovo) are built on flooded river terraces and are not safeguarded by high waters of relatively high recurrence rate – once in 20 to 50 years. A typical example in this respect is the *Panayot Venkov* Factory in Dryanovo, which was flooded by a 1.2 m deep water layer during the flood, because of its location on a low-lying flooded river terrace and the overflowing of the river due to clogging of the bridge from a low-lying bearing structure, close to the river bottom and the absence of basic protection against floods.

2.9 CONCLUSIONS

The study on the flash floods in Bulgaria has been done in accordance with the APFM Program, mainly for two tributaries of the Arda River and the Yantra River in Bulgaria. The reasons the watershed basins have been chosen follow:

- Arda River is located in the most South part of the country, while the Yantra River is a Danube tributary in North Bulgaria.
- The Arda River suffers the Mediterranean sea influence. There is no much vegetation on it, but the soil is heavily eroded. The floods are frequent and very sudden. Lots of damages and human victims have been reported during the time passed.
- The local authorities face insufficiency of the financial support from the state budget. They do not apply the integral management of water resources as the methods are not enough flexible for the purpose of flash floods.

Based on the study presented some conclusions have been made:

- There isn't enough reliable data for flash floods;
- The number and the location of the hydrometric and rainfall gauge stations do not suffice the requirements for the hydrological forecasts and alarming the inhabitants of the region;
- Because of the torrent flux and poor maintenance of the river bed they have much reduced transient capabilities to pass the water. Some of the bridges are rather low and impede the transport of large floating issues;
- The safety buildings and diversity of protection measures goes step by step, according to the local counties financial possibilities. Because of that the effect is rather low;
- The population has no any special skill and training for diversity of safety and protection activities. Because of that their reaction is chaotic and panic;
- The local authorities do not have in possession of specialized technical equipment and personnel for safety and protection activities on the site;
- There is insufficient state financial support for the bank protection, erosion control, new communication line buildings, dam and barrages construction to accumulate and redistribute the water resources.

2.10 INFERENCES

After the study has been done and the Conclusions listed above one might come to the Inferences:

- It is rather necessary to continue the flash flood study giving much attention on: social and economical aspects of floods; the along side building programs; training the inhabitants of the area, but mainly the young people in getting and making use of the warning information for coming flood. This might require some joint programs between the EACD and the Ministry of education of the country. Special text books should be provided to all aged pupils.
- It is rather necessary to continue the crop of the information and its specialized treatment for the flash floods in respect of their forecastings and warning affairs.
- It is rather necessary to continue the efforts for the Integrated Water Resources Management (IWRM) application, especially approved for the flash flood events
- It is rather necessary to start a large scientific based study on the origin, formation, regularities and propagation of flash floods. The flash floods in Bulgaria are not well understood because there isn't regular studies on them and so, they are not sufficiently well known neither discussed. There is no special and complete understanding on the event among the state administration and media activities. That's why we insist on going further ahead by a long term action plan for 18-20 months, including a scientific studies. So far it is necessary to:
  - Take new set of detailed hydrometrical and meteorological measurements and special field studies;
  - Collect new information about water quality; the impact of the floods on the biodiversity, river bed features, stability of river bank engineering facilities, safetiness of the roads and river ecosystems etc.;
  - Develop a new school program, devoted to civil defence;
  - Start an educational program for the county administration about IWRM and civil defence in flash floods;
  - Assurance of the potable water supply for the inhabitants during the floods and any measures and precautions to reduce the environment protection and the increase of the efficiency of the purification facilities etc.

We do hope that such a program might be done if a proper financing should be available. The rough assessment of the needed support for all mentioned activities is made to about Euro 65,000-68,000 for Bulgarian team. The experts are open for further discussion on working plan, time shedule and budget of Phase II.

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