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Facts and Myths about Floods

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Abstract

The article analyzes the causes, course and effect of the extreme flood in August 2002 in the Czech Republic. The analysis is stemming from meteorological and hydrological point of wiew and is framed by the broader context of historical experience with extreme flooding and current flood protection and prevention system in the Czech Republic. There are also pointed out the possibilities and limits of flood mitigation measures and the shift in experience after preceding large-scale flood in 1997.

Key words: floods, extremes, flood protection

1. Introduction

Floods hitting the Czech Republic in recent years have stirred an unprecedented general debate on resistance and protection of the environment against devastating effects of floods.

Within a relatively short period of time from 1997 to 2003, the value of flood incurred damage has risen sky-high 142 billions of crowns, thousands of houses, buildings and farms including agricultural land have been shattered or damaged, and whole cities had to be evacuated. What's the worst – despite all scientific and technical progress – 92 people have died. The overall damage to the environment and its quality clearly prove that its vulnerability to extreme floods in Central Europe has a rising tendency. Indirect flood consequences also reflect increasingly spreading negative chain responses in the social and economic spheres that are mostly difficult to translate into numbers, e.g. bankruptcy of small entrepreneurs, market paralysation, unemployment rise, damage to physical and mental health of general public etc. Although large floods don't affect whole territories of countries at once, budgetary sources show higher sensitivity to flood consequences as loss indemnification usually influences the overall economical situation.

It seems to be an ironic play of nature that the impetus for a radical revision of flood control strategies had to be given by nature itself. In 1997, inhabitants in the eastern part of the Czech Republic were surprised by massive and unusually long rains and the apocalypse caused by water spilling out of river beds and rushing through the country as an extremely huge flood wave. After such a disaster that in Moravia and

Silesia hadn't been experienced for hundreds of years, hardly anybody expected that it would repeat shortly after five years in the west, particularly in the Vltava river basin, escalating in a dramatic situation in the capital city of Prague.

In 2002, nature undermined the myth that a large flood when it occurs exhausts the probability of its immediate repetition and can be expected again only after many years. Although floods hitting subsequently the same aren't common in historical terms, the Czech history of floods, however, proves and warns that grouping of such catastrophic events in shorter periods is possible. Such a claim is supported by frequent floods occurring in 1890 on the river Vltava, in 1897 in the Jizera river basin and on the headstream Elbe, and in 1903 in the headstream area of the Oder. Assumptions that the year 1997 marks commencement of another period of frequent floods are sustained, besides the two major disasters, by other flood events occurring before 2002 and causing above-average damage despite their spatially limited impact.

Studies on all recent floods have proved that continuous reduction of potential losses can't be ensured without deep understanding of regional causes clarifying flood origins and flood intensification as well as growing runoff from areas affected by human activities, and without interdisciplinary and integrated measures in the fields of water management and environmental protection.

The word "disaster" is unknown to nature. Floods form an integrated, inseparable, and in terms of time and space irregular part of the water cycle. Their erosive, sedimentary, transporting, mechanical and other effects represent one of the logical pieces in the chain of long-term processes of landscape development. Damage is incurred to people and caused by forces beyond their control. Therefore the public perceives floods as a destructive and stressing factor. Floods, however, have been always quite typical for the territory of today's Czech Republic and therefore shouldn't be disregarded in the future.

Floods don't leave the same marks; each one is unique as fingerprints in dactyloscopy. Flood-triggering mechanisms in the same types of river basins may be similar, but flood dynamics and the impact on the environment are mostly quite specific. To mitigate damage, we have to learn from each flood event and broaden our knowledge and experience to ensure better protection from damaging effects of such disasters.

The 1997 and 2002 floods due to their extremity, massive volume and disastrous consequences required particularly thorough documentation and extraordinary mapping. The Czech government provided sufficient subsidies for this purpose and commissioned elaboration of assessment projects. Now it is important to apply such dearly acquired data and knowledge as soon as possible in practice to improve flood control and change traditional views on its further development.

2. Life with Floods and What It Looks Like

The 20th century, mainly its second half, was relatively low in major floods in comparison with the 19th century. In the historical context, flood control was on decline despite adoption of many preventive measures. While the capital volume spent on one average unit of landscape was increasing, the means invested in flood protection were

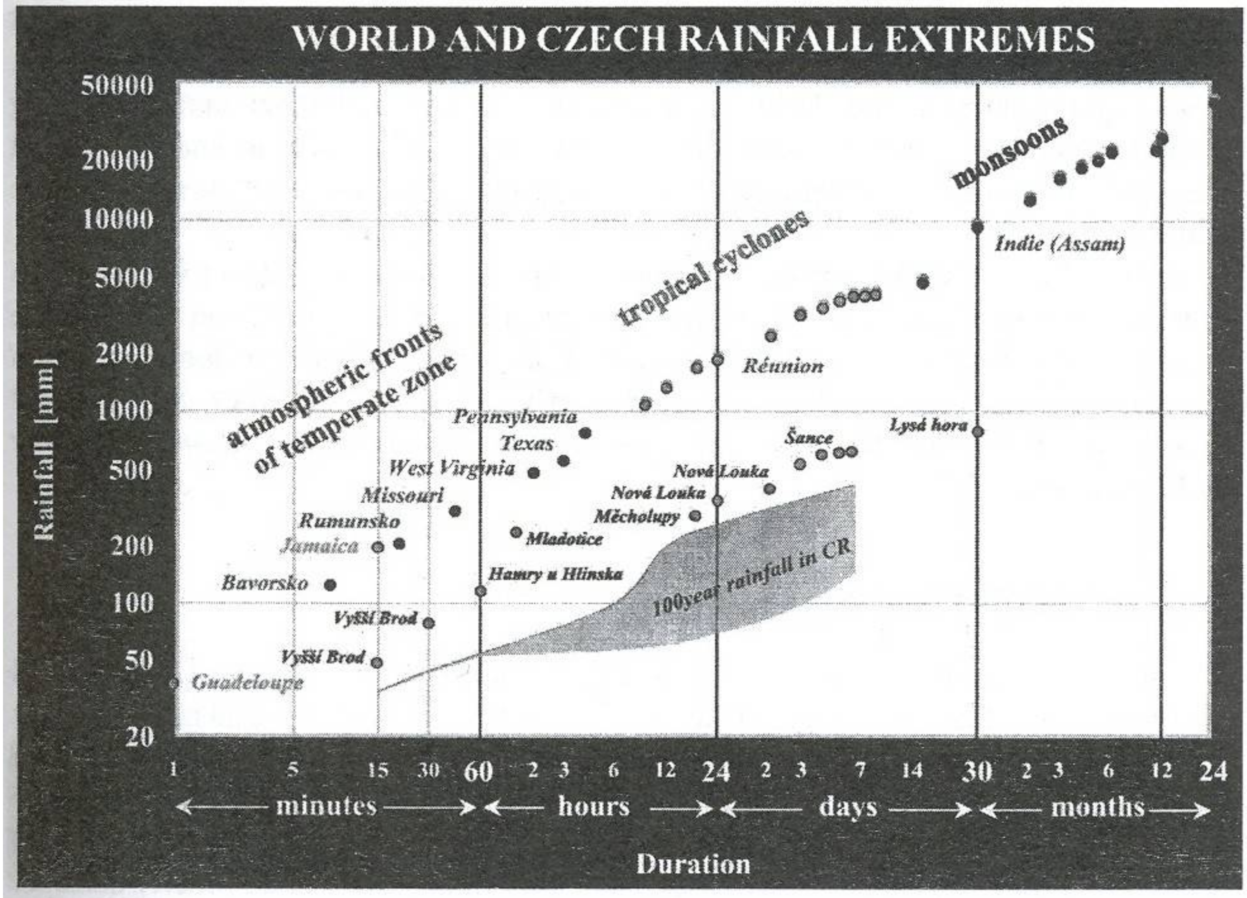

Fig. 1 Comparison of most extreme flood records

inadequate or even zero. People were slowly starting to lose memories of previous generations that had experienced consequences of major floods.

Due to the "pseudo-absence" of heavy floods and under influence of various lobbying groups, construction works were spreading into flood plains without any official or systematic protests. Mainly in postwar decades, economic activities were pursued close to rivers or even on riverbanks. People seemed to have forgotten that flood plains had always served as natural flow corridors providing space for any volume of flood runoff.

At that time, most efforts were focused to channelling floodwaters off from affected areas as quickly as possible. Only at the end of the 20th century prevailed the approach to retain excessive volumes of flood rainfall locally by applying appropriate methods to reduce runoff concentration in rivers and damaging peak flows. However, until the 80s of the 20th century, rivers were artificially channelled loosing their meandering forms, which resulted in steeper water-surface slopes and accelerated runoff processes. In many cases, watercourse sections impeding construction works were channelled into tubes or transferred while original riverbeds were filled and developed. In the Czech Republic, 13 000 km of natural watercourses out of a total length of 60 711 km were altered, which resulted in overall reduction by 4 600km. However, basins of smaller streams with area lower than 5 km^2 represent 51.5% of the total length of all streams.

The whole situation was further worsened by changes in land use. Comparing the last decades of the two halves of the 20th century, we come to a surprising conclusion that in mountainous areas, despite prevailing opinions, the volume of permanent vegetation (forests, meadows) increased. The same, however, didn't apply to lowlands. It was quite alarming that built-up, transport, handling and other areas, dumping grounds, opencast mines etc. were enlarged by 142%. It is common knowledge that such areas increase surface runoff concentrations and aggravate development of future floods.

In July 1997, disastrous floods revealed all hidden and accumulated wrongdoings in prevention policies of the past. The August 2002 catastrophe again stressed the unpalatable truth that any hesitation, omission or underestimation of flood protection will have to be sooner or later paid much dearly by substantial losses. Such painful lessons taught by nature have always the same motto. *"What floods pardon least is the lack of preparation".*

3. Flood Take the Leading Position

The Czech Republic is not the only country threatened by flood risks. On the global scale, the value of tangible losses incurred by natural disasters of any kind has been eight times higher in the last decade than in the 60s of the past century and 70% of all such events have been caused by dangerous meteorological or hydrological conditions. In the overall assessment, floods occupy a leading position. In terms of total damage incurred by all natural disasters, floods have caused one third of all deaths and property damage.

Such sad numbers indicate that proportions in the Czech Republic are similar. Average flood damage characteristics and their relations to triggering meteorological and hydrological causes should be used as decisive materials to determine flood prevention budgets. However, the highest priority of responsible authorities should be to reduce flood damage. Foreign econometric studies prove that appropriate preventive measures, well functioning and modern warning and forecast services, and participation of all citizens, well informed and trained to discipline and fast response, help reduce flood related losses by 30% of their actual amount depending on the flood scope. In case of major floods, the ceiling of flood damage reduction is obviously lower.

UN Secretary-General Kofi Annan commented on principles of protection against damaging consequences of floods and other natural disasters by saying: *"We must, above all, shift from a culture of reaction to a culture of prevention."* Economic analysis prove that $ 1 invested in preventive measures may in terms of overall damage incurred by natural catastrophes result in saving values of $ 100 – $ 1000 depending on specific conditions. Therefore, it should be worthwhile for countries permanently endangered by floods to improve their systems of flood protection building up on new experience from previous floods and getting ready for the next.

4. Chimera of Absolute Flood Protection

Efforts to increase land retention capacity undoubtedly rank among the most ambitious approaches to mitigation of flood damage. However, it is still unclear up to what maximum extent such a method may lighten the burden. Model simulations of effects caused by landscape changes that calculate virtual consequences of controlled overflowing in polders and use of retention reservoirs in relation to runoff indicate that even such types of prevention have their limits when tested by such extreme floods as occurred in July 1997 and August 2002. This opinion is also supported by experience from abroad. The University in Kaiserlautern in Germany has made a quantitative assessment of major anthropogenic interventions into the hydrological regime of the Rhine river basin (deforestation, urbanisation etc.) over the last 50 years. Results of simulated calculations indicate that the water level in the midstream reach has risen approximately by 20 cm. However, catastrophic floods on the river Rhine in 1993 and 1995 made the water level in the same area rise by almost 6 m. The myth that floods can be reduced to insignificant events by changes in landscape probably applies only to minor floods. Limits of such floods vary depending on specific physicogeographical conditions and should be studied separately for each river basin.

Damage could be reduced with relatively better results only under the condition that the approach mentioned above is integrated into one system comprising also other measures. This method lays down one of the principles of flood protection applicable in the Czech Republic – to provide sufficient area as large as possible allowing for controlled overflow, to clear flood plains, impede further urbanisation of inundation areas, and in socially and economically justifiable cases try to transfer buildings located in risky areas. Other zones where such methods can't be applied should be protected by adopting technical measures forming an integrated system and taking into account actual water retention capacities of the land.

However, absolute protection against floods is unrealistic. It is vital to work with socially and economically suitable prevention options differentiated by specific conditions of individual areas. Fighting floods, it is important to take into account risks of such threats that would exceed protective effects of any current flood control measures. Under such circumstances, rescue works effectiveness tends to be lower and its achievement more complicated. At the end, individuals trained to resist raging elements and early warning systems are vital for rescue of human lives. Informative campaigns among endangered inhabitants and regular training of staff involved in the system of protection against damaging flood effects should become one of the priorities and continuously performed flood control activities.

4.1 Are Extreme Floods on the Rise?

There are two groups of experts, each defending different views on rising flood damage. The larger group advocates one of traditional opinions that there are neither less nor more floods. They explain increase in damage by expansion of economic activities in flood plains and by rising prices of flooded property. Unlike in the past, internal equipment of houses, garages included, is today often more valuable than houses themselves.

The others, however, take into account higher frequency and severity of floods brought about by global warming.

Among scientists, there are several prevailing opinions on causes of current warming and related climatic changes:

1) The largest group of experts finds the greenhouse effect to be the dominant cause and builds on the results of the International Panel on Climatic Changes (IPCC – associates around 2000 experts from the whole world).
2) Experts coming mostly from the astronomical field stress the impact of extraterrestrial phenomena, mainly the Sun, that, as they claim, in the first half of the 21st century evoke intensified hysteresis of geophysical processes on the Earth, e.g. volcanic eruptions, seismic tremors, hydrometeorological extreme events etc.
3) The 3rd group takes into account effects and teleconections of global thermodynamic oscillations in the physical climatic system and biogeochemical cycle of the Earth (El Niño – ENSO, North Atlantic Oscillations – NAO, etc.).
4) The 4th group finds long-term changes of warm and cold periods to be the key factor.

The current state integrates all of the approaches mentioned above. We can't deny that warming is a real and measurable phenomenon. The end of the 20th century has been the warmest decade ever since scientists started to take temperature measures by exact instruments in the territory of the Czech Republic, and event the World Meteorological Organisation has classified it as probably the warmest period of the last millennium.

According to IPCC, significant atmosphere warming will be reflected in increased weather extremity potentially leading to more floods of increased intensity and changes in their seasonal distribution. In a simplified picture, further warming of the Earth's surface will result in increased evapotranspiration and accumulation of bigger volumes of water in the atmosphere. Excessive water, by definition, has to fall back in the form of longer lasting rainfall or rainstorms potentially intensifying flood events.

Relatively higher number of major floods occurring in Central Europe and similarly in the Czech Republic over the last decade seems to add validity to indicated assumptions. However, regarding the scale of global climatic changes, it is still quite a short period to provide an exact confirmation of the theory of intensified and more frequent floods. Comparative analysis of the highest precipitation amounts recorded in the Czech Republic during the last two catastrophic floods, in 1997 and 2002, show that they still remain at the level derived on the basis of previous historical cases. Rainfall extremity measured in relation to rainfall duration so far hasn't changed.

Although flood intensification is still a hypothesis, it is recommendable to stick to the principle of preliminary care and to count with a greater flood danger in designing further flood protection measures in the Czech Republic.

5. Floods Are Born in the Atmosphere

Major summer floods with devastating effects occurring in the Czech Republic are caused by certain circulation conditions in the atmosphere resulting in widespread heavy rains lasting from one to several days. Generally, precipitation is triggered by rising airflows caused by thermal convections accompanied by storm clouds, by orographic windward side effects, by cyclone air movements and in the regions of atmospheric fronts. Mostly, flood rainfall is caused by several or all of the factors mentioned above.

It can be assumed that out of major devastating floods occurring in the Vltava river basin from the last millennium; those classified under the summer type were caused by similar dynamic atmospheric phenomena. Unfortunately, collection of exact data started only at the beginning of the 20th century and there aren't enough materials to back such a deduction on a broader historical scale. The analysis of synoptic charts of weather prevailing in the atmospheric surface layer allowed us to document, drawing on data of major floods occurring over the last 100 years, that airflows rise for several days when cyclones move along their classical route V_b, classified according to the track classification system of cyclone centres by van Bebber. Under such circumstances, warm and humid Mediterranean air becomes involved in cyclone precipitation-triggering processes in atmospheric surface layers and moves through "high air channels" from the region above northern Italy, across Austria, the Czech Republic, Poland, and further to the Baltic Sea. Passage of "flood cyclones" is characterised by heavy regional rains intensified by orographic effects of mountainous areas causing further surge of airflows. Such characteristics mark the cyclone passing over the Czech Republic in the first decade of July in 1997 and the second decade in August 2002. In comparison with other types of meteorological flood causes, this type of atmospheric circulation is the most frequent and dangerous driving factor of floods in the Czech Republic. It usually affects river basins of the Oder, upstream Morava, Vltava, and Elbe and causes floods also in other countries along the cyclone trajectory.

However, such meteorological situations occur in summer quite frequently without bringing flood-driving rains. Analysis of symptoms signalling arrival of "flood--bearing" situations with a larger time reserve than today is quite significant not only for improvement of meteorological forecast models, but also from the perspective of increasing effectiveness of flood protection systems.

Further problems are caused by a relatively broad spread of cyclone centre tracks. Taking into account all historical cases, the V_b type creates a fan-shaped form affecting the area from eastern Switzerland to the western Ukraine. Location of tracks is influenced by many factors. Whether rains hit the Odra or Vltava river basins is decisively influenced, as assumed, by geographical location of anticyclones. During the July 1997 floods, it was the anticyclone moving from the region above the United Kingdom towards Scandinavia that prevented a cyclone, the source of steady rains in the Morava and Oder river basins, from moving in the northeast direction. The cyclone underwent a retrograde turn resulting in prolongation of rainfalls over the eastern region of the Czech Republic worsening the overall flood situation. In August 2002, the key anticyclone was located further inside the continent and the track of the second cyclone was situated westwards across the Vltava river basin in the south-north direction.

Most studies indicate that individual flood-triggering atmospheric processes shouldn't be assessed individually, but in systematic groups. It is vital to take into account inseparable relations of causal circulatory conditions to resulting precipitation fields in the given physicogeographical environment, and the river system runoff response. Solutions should be always first produced by drawing on macroscale situations and by further downscaling to mesoscale dimensions of river basins where hydrological agencies monitor runoff values.

6. Specific Character of Disastrous Floods in August 2002

It was the last one in the series of major floods that have occurred since initiation of systematic hydrological monitoring, i.e. since 1827, on the territory Czech Republic. In terms of flood-triggering processes, time and spatial dimensions of its progress and extremity of accompanying features, it is comparable only to floods recorded in 1890 and 1997.

It is quite remarkable that all of the three floods mentioned above were caused by two subsequent precipitation events forming accompanying waves that preceded the main flood wave by several days (1890, 2002), or lagged behind (1997). In hydrological terms, the first case is worse because a river basin become saturated by water from the first precipitation portion and can't absorb the volume from the second precipitation event.

Precipitation inducing floods in September 1890 on the Vltava river affected almost the same area as in 2002, but were somewhat smaller and distributed in more days. Therefore, peak flow values were also marked by a lower extremity.

The flood occurring in July 1997 in the river basins of Morava, Oder, and upstream Elbe were dominantly affected by spatial constancy of precipitation and their prolonged duration. Related orographic intensification contributed even further to highly extreme peak values of flood waves, particularly in mountainous areas and foothills of northern Moravia. Although causal precipitation of the 1997 flood were heavier than during the 2002 flood, the overall incurred damage was higher in Bohemia. The August flood affected more big cities including Prague and progressed across an area of dense infrastructure.

According to flood marks in Prague, the maximum level on the Vltava river in 2002 was higher than any recorded historical levels, including those measured by the oldest water gauge – the stone head of a bearded man (Bradáč) – carved into the embankment wall close to the Charles Bridge. The informative value of such past floods witnesses is however very limited. Comparison of the heights above the sea level indicated by old water gauges also provides only approximate values because discharge capacities of profiles were changing in the course of time due to construction activities and morphological changes of the river-bed. In several cases high-water marks have been moved. According to estimates, the August 2002 flood was probably the heaviest one in Prague since 1432.

The Institute of Atmospheric Physics under the Academy of Sciences has derived probable maximum precipitation values (PMP) applicable to the territory of the Czech Republic that can possibly happen at the given geographical location. Accordingly, precipitation volumes recorded in 1997 and 2002 in affected river basins of different sizes reached maximally 68% of PMP. As absolute PMP values applicable to Moravia are higher, rains in 1997 was slightly more extreme than in the Vltava river basin. The facts mentioned above imply that Moravia, Silesia and Bohemia may be in the future affected by even heavier rains than in July 1997 and August 2002.

6.1. Meteorological Flood Causes

In the summer months of 2002 (June, July, August), the country was under the influence of repeated tropical air inflows moving northwards. Individual cyclones and frontal systems were moving from the Mediterranean southwards to Central Europe accompanied by unusually heavy precipitation.

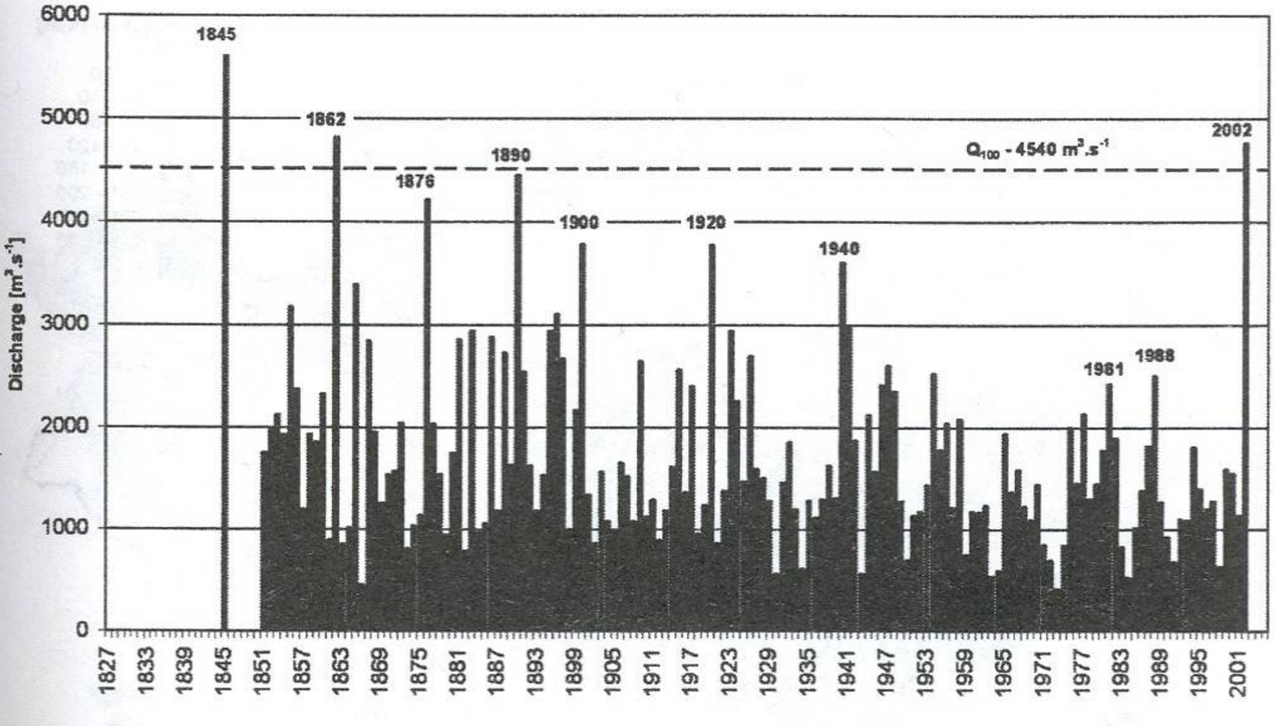

Fig. 2 Flood peak discharges – Labe at Děčín 1851–2002

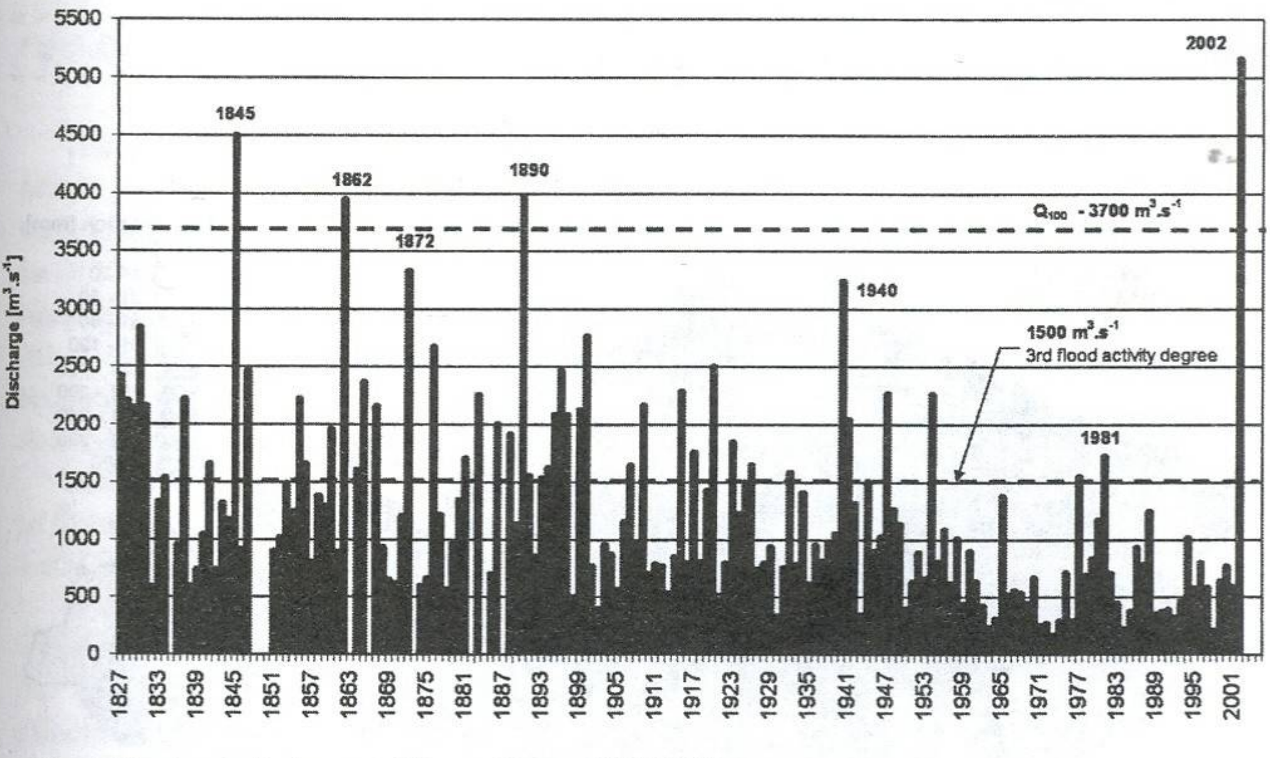

Fig. 3 Flood peak discharges – Vltava at Prague 1827–2002

The most widespread rains were recorded in August. In the Mediterranean on the western coast of Greece, peak volumes were by 500% higher than climatological normal. At that time, circulation above the Atlantic and the European continent was dominantly meridional. In the first half of the month, such conditions led to creation of two significant cyclones proceeding consecutively in short time intervals towards Central Europe and causing catastrophic floods.

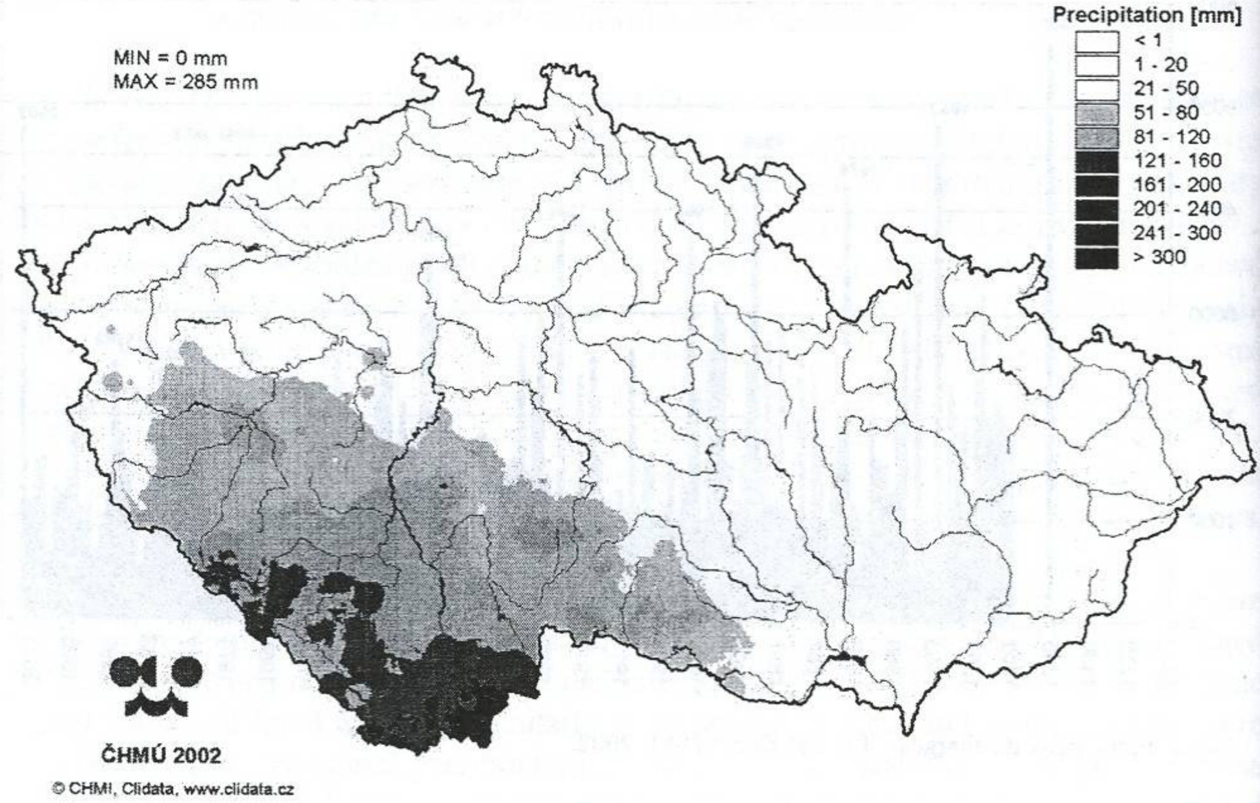

Fig. 4 Flood in August 2002 – precipitation distribution 6.–7. 8. 2002

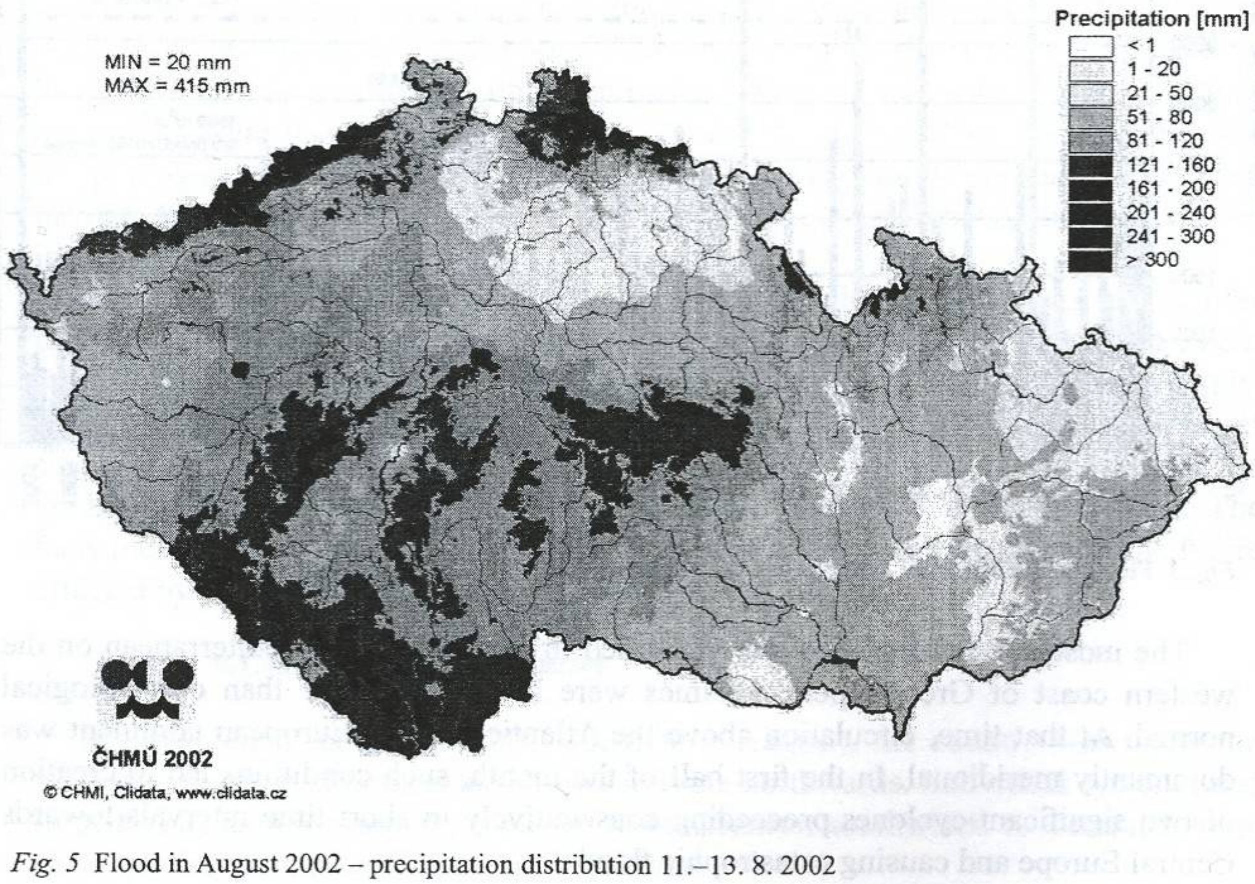

Fig. 5 Flood in August 2002 – precipitation distribution 11.–13. 8. 2002

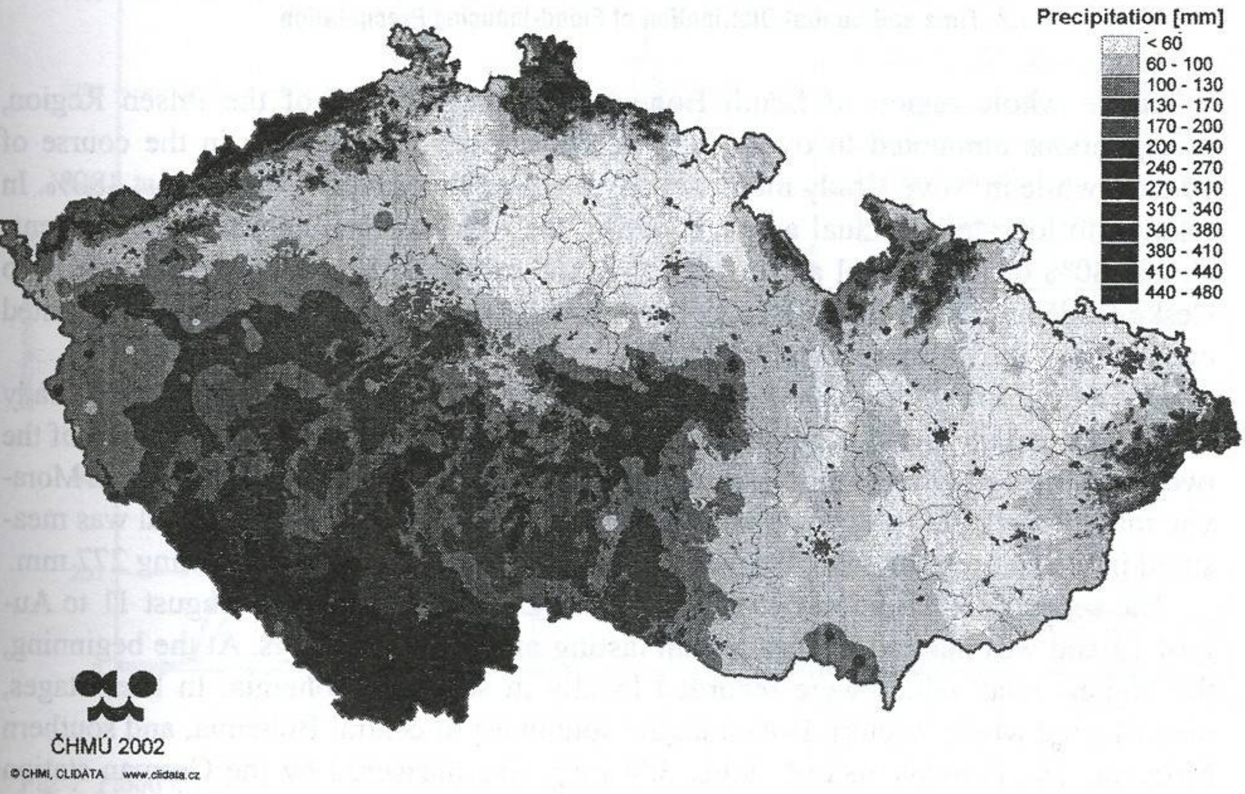

Fig. 6 Flood in August 2002 – precipitation distribution 5.–13. 8. 2002

The precipitation zone of the first cyclone progressing from the Mediterranean across northern Italy, Bavaria, Austria, and southern Bohemia was manifested already on August 6 and 8 in the afternoon by heavy widespread rain and local storm rainfalls. In southern Bohemia and Moravia on August 7 and 8, rain was further intensified by orographic effects, that were notable in particular under north-eastern air circulation, on the windward side of Šumava and the Nové Hrady mountains. The precipitation zone remained in southern Bohemia without changing its location until the evening hours of August 7 and 8, when it started to move towards the Balkan countries.

In the river basins of Vltava down to Lužnice mouth, Lužnice, Otava and Berounka in Šumava, precipitation values in the course of the two days reached approximately 1.634 billion m^3 of water.

Within the following three days, another cyclone centred over the Po river lowlands was moving in the northeast direction. Later, it changed its course and headed northwards due to the anticyclone over Eastern Europe blocking its way. Its precipitation zone affected again all river basins rising in southern and southwest Bohemia (including the Dyje in southern Moravia), later the whole Vltava river basin and almost whole Bohemia. Intensity of widespread precipitation was locally very strong and further increased by windward side effects in Šumava, the Nové Hrady mountains and, later upon passage of occluded front, in ridge areas of Krušné and Jizerské mountains. On August 12, occurrence of local storms was intensified and on August 13, the precipitation zone moved from Bohemia to Moravia and Silesia.

From August 6 to August 13, the precipitation volume in the Vltava river delimited by the confluence with the Elbe reached almost 5 billion m^3, i.e. almost 5 km^3 of water.

6.2. Time and Spatial Distribution of Flood-Inducing Precipitation

In the whole region of South Bohemia and in one half of the Pilsen Region, precipitations amounted to over 200% of the normal month value in the course of 10 days while in Nové Hrady mountains at the Austrian border, it was almost 480%. In relation to long-term annual average values, the August precipitation total represents almost 30% of the normal annual value. In the upstream Vltava river basin down to České Budějovice and in the Blanice river basin, the August precipitation represented even 60% of the normal annual total value.

During the first precipitation event on August 6 and 7, rainfalls in the Nové Hrady mountains and the Český Krumlov area came to 130–250 mm just in the course of the two days. These portions of precipitation affected also western Bohemia and southern Moravia, mainly the Dyje river basin with 60–130 mm. Record precipitation total was measured in the station of Podhorská Ves in the Nové Hrady mountains reaching 277 mm.

The second precipitation event came mainly in the period from August 11 to August 13 and was marked by steady rain lasting mostly for two days. At the beginning, the highest total values were recorded locally in southern Bohemia. In later stages, rain affected whole western Bohemia, the southwest of central Bohemia, and southern Moravia. The two-day record value, 380 mm, was measured by the German station Zinwald (Cínovec). This was an absolutely extreme value because rain actually lasted less than 48 hours. High total values of 250–280 mm were also recorded in the ridge areas of Jizerské mountains. Here, station Knajpa reported the second highest total volume since 1897.

6.3. Hydrological Situation

The first precipitation event led to overflows and inundations on all streams in southern Bohemia. Relatively the highest discharge values were recorded in the Malše river basin above the Římov waterworks. Pořešín on the river Černá reported record peak discharge values with statistical return period 200 or even 500 years, which was even higher than during the second flood wave. Outflow from Římov dam reservoir were also assessed with the return period of 200 or 500 years. Discharge values recognized on the Vltava river past the confluence with the Malše river reached the level corresponding to the statistical return period longer than 1000 years. The upstream Lužnice reported 50-year peak values and the midstream and the downstream Otava and its tributaries 20-year peak values.

During the second precipitation episode, water levels surged very quickly due to high saturations of river basins and full riverbeds filled by previous rains. In comparison to the first wave, peak values showed increased extremity. Many profiles recorded historically the highest water levels and discharge values. Floods spread to the Berounka, and Sázava river basins and significantly affected also the Dyje basin. Water levels leading to declaration of flood activity degree III (flood danger) were reported by majority of water measuring stations situated in the affected area.

Development of the flood situation in Prague was determined by interference both of flood waves coming from cascade of reservoirs on the Vltava river and the Berounka

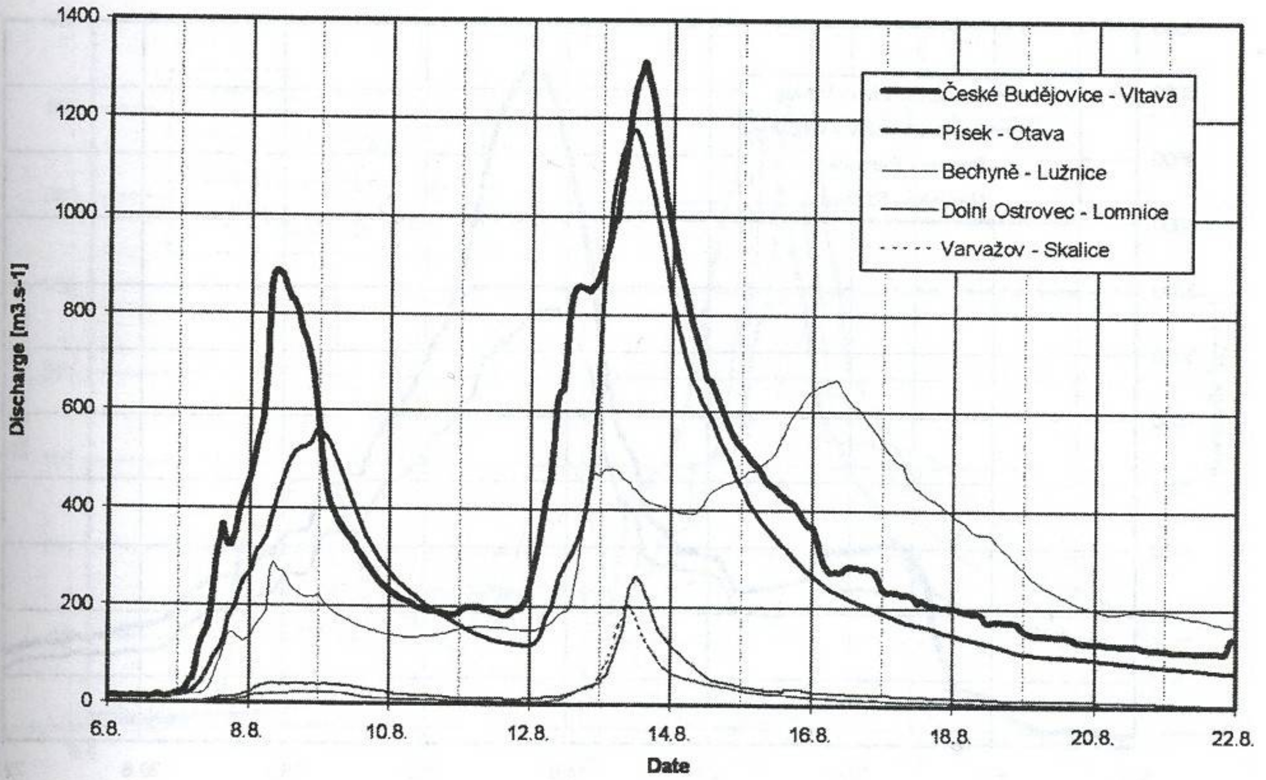

Fig. 7 Flood in August 2002 – flood progress at Orlík reservoir dam inflows

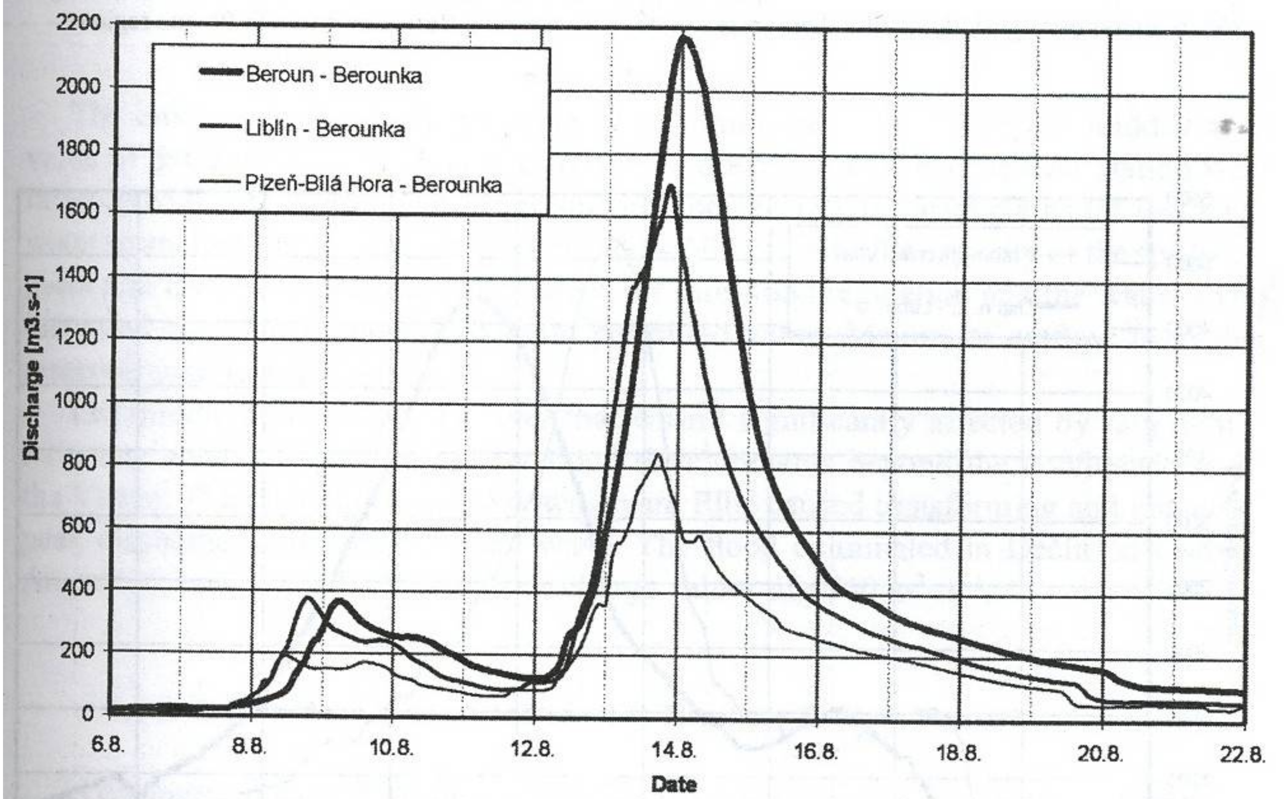

Fig. 8 Flood in August 2002 – flood progress in the Berounka river basin

river. Their culmination phases seem to have collided. The Vltava culminated in Prague on Wednesday, August 14, at noon reaching 782 cm and discharge of 5160 $m^3 \cdot s^{-1}$, which corresponds to 500-year values. The flood incurred adequately high damage as the infrastructure around Prague is very dense.

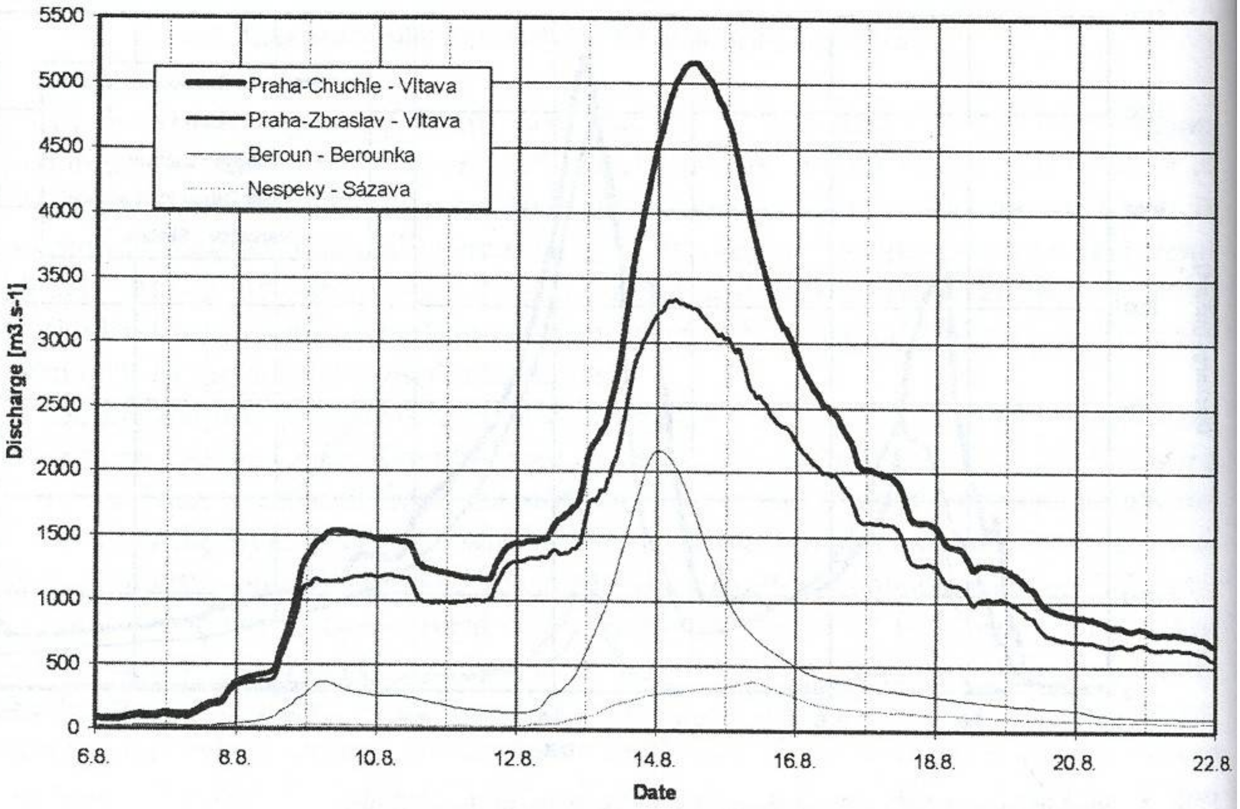

Fig. 9 Flood in August 2002 – flood progress at Vltava, Sázava and Berounka rivers in Prague region

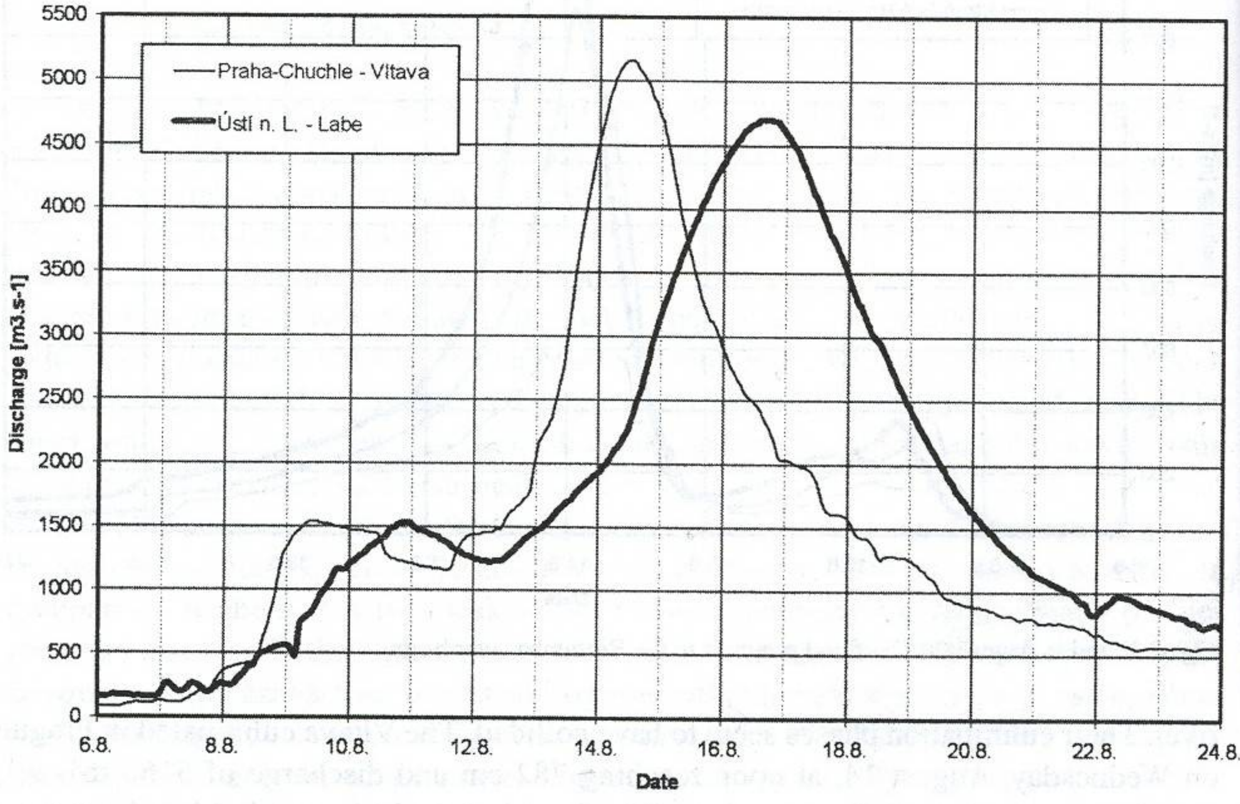

Fig. 10 Flood in August 2002 – flood progress at Vltava at Prague and Elbe at Ústí nad Labem

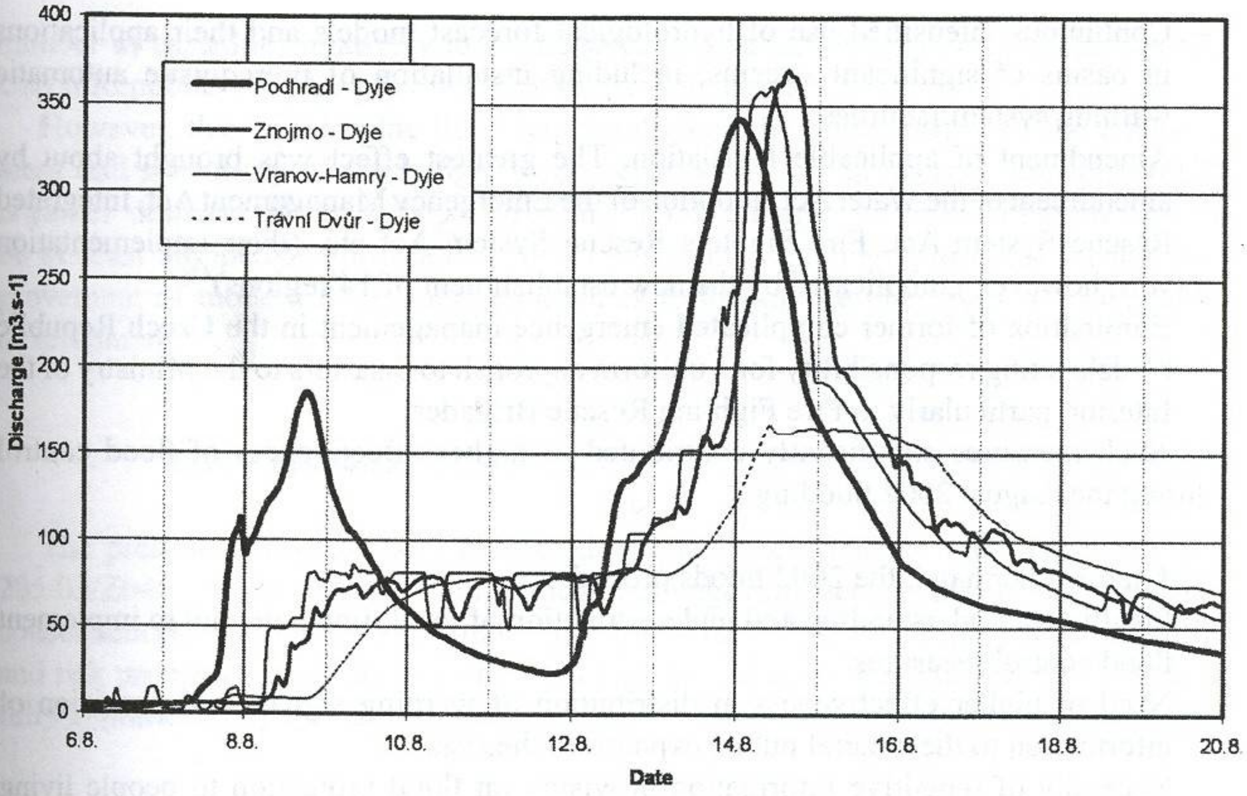

Fig. 11 Flood in August 2002 – flood progress at Dyje river basin

The inflow into the Orlík dam reservoir culminated on 13 August at midday at a value of 3900 $m^3 \cdot s^{-1}$. At about that time, the operation of a hydropower station was interrupted due to flooding and consequently the capacity of installations for realising water from the reservoir was reduced by about 600 $m^3 \cdot s^{-1}$. The capacity of the spillway gates and bottom outlets was insufficient for safe flood regulation and the water level increased by 1,57 m above maximum permitted value. Maximum outflow from the reservoir was 3100 $m^3 \cdot s^{-1}$.

The middle part of the Elbe river that wasn't significantly affected by rain didn't have any serious impact on further flood developments beyond the confluence with the Vltava. The inundation on the downstream Elbe caused transforming and reducing peak discharge values of the flood wave. The flood culminated in Děčín on Friday, August 16, reaching 100–200-year discharge values of 4760 $m^3 \cdot s^{-1}$.

7. Have We Learned any Lessons from Disastrous Floods in Moravia?

In comparison with 1997, many negative aspects of flood control were undoubtedly tackled. Large project titled "Assessment of Floods in July 1997" provided valuable data and paved the way for further development activities. In terms of key non-structural measures related to meteorology and hydrology, the advances mainly comprised:

- Improvement of meteorological models and lead-time prolongation of quantitative rainfall forecasts.
- Improvement of radar monitoring of rainfall cells motions.

- Continuous intensified use of hydrological forecast models and their applications in basins of significant streams, including installation of prerequisite automatic warning system facilities.
- Amendment of applicable legislation. The greatest effect was brought about by amendment of the Water Act, adoption of the Emergency Management Act, Integrated Rescue System Act, Fire Fighters Rescue System Act etc. (their implementation was, however, complicated by the new establishment of 14 regions).
- Elimination of former complicated emergence management in the Czech Republic by delegating responsibility for a uniform approach to disasters to the Ministry of the Interior, particularly to Fire Fighting Rescue Brigades.

Such measures significantly contributed to higher effectiveness of flood control during the August 2002 flooding.

On the other hand, the 2002 floods proved:
- Insufficient understanding and underestimation of local time potential to implement flood control measures.
- Need of higher effectiveness in distribution of warning signals and provision of information to the general public exposed to the risk.
- Necessity of repetitive information provision on flood protection to people living close to rivers all over the country and even in the areas that haven't been affected by floods in the lifetime of current generations.
- Need to introduce a regular training system of staff involved in flood management,
- Insufficient resistance of certain buildings, including many gauging and reporting stations, to wetting and inundation.

Tab. 1 Comparison of flood damages between in 1997 and 2002

Measures	1997 Flood	2002 Flood
Total affected area	11 000 km^2	17 000 km^2
Share on the total area of affected districts	38.5%	43%
Affected regions	8	10
Affected districts	34	43
Victims	60	19
Affected population	2 855 000	3 200 000
Share of affected population on the total population in affected districts	63%	66%

8. Conclusions

The August 2002 flooding had such extreme characteristics that its scope and consequences were worse than any floods occurring in the Czech Republic at least over the last 200 years. Citizens, emergency management bodies, rescue teams and other institutions involved in flood protection should be praised for having managed such a complicated situation putting in a considerable deal of effort and maintaining the number of casualties relatively low. The same evaluation of the flood situation in the Czech Republic was also provided by experts from abroad.

However, this catastrophic flood has highlighted the vulnerability of the environment and sensitivity of the budget to consequences of such natural disasters. What is rather dramatic is the trend of growing flood damage. Its intensification should be at least stopped if not reduced by a consistent implementation and further improvement of modern flood control measures following the principles of sustainable development.

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FAKTA A MÝTY O POVODNÍCH

Résumé

Povodňové situace z několika posledních let v České republice rozbouřily u současně žijících generací občanů hladinu veřejného mínění o odolnosti a ochraně životního prostředí před ničivými účinky povodňových pohrom tak jako nikdy předtím.

Během poměrně krátkého období od roku 1997 dosáhly škody z historického hlediska závratné výše 142 miliard Kč, byly devastovány nebo poškozeny tisíce obydlí, budov a hospodářských objektů včetně tisíců hektarů zemědělských pozemků, statisíce lidí bylo třeba evakuovat. Co je však nejhorší – navzdory veškerému vědecko-technickému pokroku – 92 lidí v průběhu povodňových událostí zahynulo. Celkové újmy na kvalitě životního prostředí zřetelně signalizují, že jeho zranitelnost extrémními povodněmi v tomto prostoru střední Evropy vykazuje stále rostoucí tendenci. Rovněž nepřímé následky povodní dokumentují čím dál

rozsáhlejší negativní řetězové reakce v socio-ekonomické sféře, jejichž důsledky se již obvykle jen stěží dají hodnotově vyčíslit, např. bankroty zejména drobných podnikatelů, ochromení tržní sféry, růst nezaměstnanosti, újmy na zdraví a psychice obyvatelstva atp. Příroda v roce 2002 tak zpochybnila jeden z mýtů, že pravděpodobnost nástupu velké povodně se jejím uskutečněním vyčerpá a další povodňovou katastrofu lze pak očekávat až po mnoha letech. Dějepis povodní z území České republiky však nejen prozrazuje, ale i varuje, že časové seskupování povodňových epizod do kratších údobí je možné, byť z hlediska historického a zásahu stejného území nejde o běžný jev. Dokumentují to např. výskyty velkých povodní z let 1890 na Vltavě, 1897 v povodích Jizery a horního Labe a 1903 na horní Odře.

Příroda nezná pojem „pohroma". Povodně, pokud jde o jejich vznik, jsou neoddělitelnou, prostorově i časově nepravidelnou součástí oběhu vody. Svými erozními, sedimentačními, transportními, mechanickými a jinými účinky představují zákonitý článek dlouhodobých vývojových procesů krajiny. Škody vznikají teprve lidem, a to silami, které jsou mimo jejich kontrolu. Proto veřejnost tento povodňový projev přírodních sil pojímá jako destruktivní a stresový faktor. Ten se v prostoru území dnešní České republiky však vždy vyskytoval a je třeba s ním proto počítat i v budoucnu.

Žádná povodeň není svým projevem stejná, je jedinečná jako jsou v daktyloskopii otisky lidských rukou. Mechanismy vzniku u téhož druhu povodní se mohou sice podobat, ale dynamika vyvolané situace v povodí a účinky na životní prostředí mají obvykle svá specifika. Z toho pro zmírňování škod vyplývá, že z každé povodňové situace je nutno se poučit a rozšiřovat si stále poznatky i zkušenosti, jak se před škodlivými důsledky těchto pohrom dokonaleji chránit.

Srpnová povodeň 2002 byla natolik extrémní, že svým rozsahem a dopady překonala všechny povodně v Čechách minimálně v posledních 200 letech. Je třeba ocenit, že občané, orgány krizového řízení, záchranné sbory a další složky zapojené do povodňové ochrany tuto velmi složitou situaci s vypětím všech sil v podstatě zvládli, a to s poměrně malými ztrátami na životech. Takto hodnotily povodňovou situaci v České republice i odborné kruhy v zahraničí.

Zároveň tato povodňová pohroma znovu upozornila na vysoký stupeň zranitelnosti našeho životního prostředí a na citlivost státního rozpočtu ve vztahu k dopadům tohoto přírodního extrému. Co je však dramatické, je stále rostoucí trend povodňových škod. Jejich zesilování je třeba aspoň zastavit, ne-li zvrátit, a to důslednou realizací a permanentním rozvíjením moderní povodňové ochrany v duchu zásad udržitelného rozvoje.

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