Some Principal Problems in Flood Risk Assessment

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Abstract

The problems related to flood risks are still not well developed and understood in the engineering practice of many countries. The report considers some theoretical principal issues connected with the natural flood risk assessment for various sites of the territorial infrastructure.

Special attention is paid to the identification of the "flood risk" concept. It is interpreted from the viewpoint of the complex "cause – flood – consequence" relationship, which is still not sufficiently well realized in the engineering practice.

An attempt has been made for comprehension of the diverse forms of floods in a methodologically well sustained classification by means of two hierarchical levels – "flooding object" and "flood cause", which are differentiated at deeper inferior levels depending on the other systematization features. The obtained rich scheme of the different possible cases provides the possibilities of applying a systematic approach to flood risk assessment in the territorial structure of any country.

The specific peculiarities of the natural flood hazard are discussed further on with critical remarks on its erroneous identification with the normative probability in the design of hydrotechnical equipment.

The basic theoretical principles for the flood risk determination are presented briefly for different practical cases: in natural river sections, in regulated river sections, in river sections below dams, in settlement areas, in polders and wetlands, in sites of low-rise and underground construction.

Finally the importance of flood risk assessment in humanitarian, economic, ecological and administrative-legislative aspect is pointed out.

The study is directed towards the activities for creation of a methodologically sound scientific basis and well-grounded orientation of measures for guaranteeing the safety of population and reducing the harmful flood consequences.

Key words: Floods, natural risk, river, high wave, retention wave, river overflow, intensive precipitation, dam, river correction, settlements, rain sewerage, polders, underground construction

1. Identification of the "risk" concept

The problems related to flood risks are still not sufficiently well developed and understood in the engineering practice of many countries. This is probably due to many reasons but the basic one consists in the specific interdisciplinary character of the "risk – flood" combination, which falls within the thematic field of the mathematical, geographical, economic, technical, biological and other sciences.

The "risk" concept represents a mathematical category consisting of two independent components: the statistical probability for the occurrence of a certain unfavourable event and the annual amount of the damages provoked by it. Besides, the damages may be considered from various aspects – humanitarian, economic, biological, technical, etc. [1, 2, 3, 4, 5, 6].

This concept is further sub-divided in the applied sphere as natural risks and risks ensuing from human activities. Natural risks are related with regularly occurring unfavourable for people phenomena resulting from the natural development of geoplanetary processes, which are not influenced by anthropogenic activity. In contrast to them, the artificially created risks are entirely the result of human activity connected with the production processes or with other purposeful impacts on the natural environment. In a number of cases these two types are interwoven and mutually determined.

Risk assessment is a broad area of scientific knowledge, which has been developed in accordance with the realized necessity of taking systematic practical measures for reducing or restricting their harmful effects.

2. Identification of the "flood" concept

The most general definition of the "flood" concept has been formulated for long time and regardless of the various editorial nuances, which may be found in reference literature, its meaning consists in the following: "flood is unregulated occurrence and overflow of significant volumes of water forming continuous water level, under which remain terrains, sites and facilities intended to exist under dry conditions". The truthfulness and linguistic accuracy of this formulation is obvious. Nevertheless, diverse modifications were made subsequently of this definition, mainly due to the various targets set for research of this widely spread phenomenon on Earth. Numerous similar or differing definitions are found in recent publications, which describe extensively or concisely the diverse nature of floods [2, 7, 8, 9, 10, 11].

A great part of the definitions have strongly restricted character and others are quite descriptive and do not correspond to the idea of a definition. They reflect the "flood" phenomenon for different forms of its occurrence, sometimes with rather irrelevant formulation, but they are always clearly comprehensible direction for implementation.

The development of so many different definitions for the "flood" concept during the recent years is not an accidental fact. It shows unambiguously that the problem is not in the formulation of the event but in the identification of the conditions for its emergence. All the efforts for developing new definitions of the "flood" concept are directed just to this purpose – identification of the floods with respect to their type and conditions for occurrence. And despite of this, there is no definition, even the most complete one, which may be used as a criterion for the flood emergence.

The logical development of these problems focuses the attention rather not towards new definitions of floods but to suitable forms of classification of floods as occurring events. Another particularization is necessary – where does the flood take place, because the criteria for the event identification cannot be derived without information concerning what or who are threatened by it. These questions need to be clearly defined, mainly in connection with determining the probability of their emergence and the quantitative risk evaluation.

In this context, the following definitions have been accepted in this study:

Flood: emergence and overflow of water volumes forming water level, under which remain objects that exist normally under dry conditions.

Object of the flood: Natural terrain forms and complexes of the territorial social-economic infrastructure threatened by flooding.

Identification criteria: Provisionally accepted circumstances treated as reliable evidence that flood has taken place.

2.1 Flood types

Floods are phenomena which have different nature and may be displayed in various forms. Regardless of this, all flood varieties correspond to the above mentioned definition.

The following flood types may be distinguished on the basis of historical data:

- floods in river terraces and lowlands
- floods in settlement terrains
- floods in polders
- floods in wetlands
- floods in terrain depressions and no-effluent areas
- floods in underground and low-rise construction (tunnels, mines, caverns, subways, garages, basements, cellars, etc.)
- floods on terrains in bays and estuaries due to sea tides
- floods on terrains due to sea waves caused by strong winds and storms (tornados, typhoons, cyclones)
- floods on terrains due to tsunami (sea waves provoked by earthquake phenomena)
- floods in navigation vessels
- industrial floods
- household floods
- others.

The mentioned flood types differ mainly with respect to the object, where they are taking place, and in some of the cases the cause provoking them is one and the same.

The specificity of the various threatened objects imposes the necessity of applying a differentiated approach to the study of floods and all the other problems concerning the required protection measures.

The different flood types cannot be considered separately without taking into account the causes provoking them. The cause-effect relation plays an important role in this case and it may be with the same, similar or quite different character, but is always specifically intrinsic to each flood type.

2.2 Causes provoking the floods

The causes for flood emergence are usually with a complex character. They result from the combination of the dynamic geophysical factors with the landscape conditions of the threatened object.

The complex cause-effect relationships between the climatic, meteorological, hydrographic, orographic, geological, soil-vegetation and other factors are important in this respect.

However, more simplified consideration of the phenomenon is required for the applied research. In most of the cases it is not necessary to study thoroughly the genesis of the event but it is sufficient to analyze only the most direct and main cause that has provoked the flood regardless of its complex dependence on all the other factors.

This approach has been adopted in the present study and the following main causes for flood emergence may be pointed out on the basis of it:

- river overflows
- sea overflows
- intensive water formation on the Earth's surface
- geodynamic phenomena
- accidents
- incorrect (or careless) management of hydrotechnical structures
- military actions
- causes of household and other character.

Without pretensions of being fully exhaustive this schematization might turn to be useful in selecting the adequate methodology for flood study.

2.3 Systematization of floods

The great diversity of floods with respect to nature, forms and causes imposes the necessity of applying the systematic approach to their study. The basis of any systematization is to introduce hierarchical levels for the features of the investigated object observing the principle "from the general – to the particular".

An attempt of such systematization of floods is presented in Fig. 1. Two features have been selected as major hierarchical levels here – object and cause of the flood. The possible cross relations between these two features are not shown in the scheme for simplicity.

The already world widespread awareness that active measures have to be taken for restricting the harmful impacts of floods, requires that more thorough and specialized research work is carried out. The priority direction of the studies is determined by the geographic, climatic and social-economic conditions of each country. The contemporary level of the scientific subject-matter related with floods is characterized by numerous descriptions, investigations and problem solutions within a broad range – from communications about single extreme floods to serious theoretical analyses for determining the risks and social-economic effectiveness of the protective measures that have been undertaken.

The aim of the systematization is to facilitate and concentrate the efforts on the stages for composing scientifically substantiated national strategy for flooding, which corresponds to the European directives for sustainable development and management of the water sector.

A basic stage of the above strategy should be the risk assessment for the most often encountered flood types, occurring mainly due to natural causes. On this basis, the following tasks of risk mapping and plans for risk management have to be performed in stages.

The correct determination of the probability for flood occurrence represents a task of crucial importance. It is directly related with the flood object and causes. Even the first analysis of Fig. 1 indicates that this is not an elementary task. The possible "object – cause" combinations define a set of sub-tasks requiring a different methodological approach, different identification criteria and differing composition of the necessary initial data.

3. PROBABILITY FOR FLOOD EMERGENCE

As already mentioned above, the probability for flood emergence is directly related with the object and causes of its origin. But even if the flood cause is one and the same, the probability for its emergence is different for the different objects. For example, the flood provoked by river overflow affects a great number of objects situated in the valley. However, the different objects may be affected to a different extent and there are also objects, which are not affected at all. Hence, a different probability of flooding exists for each of the objects. Here, the importance of the "flood probability – object" relationship comes to the forth.

The establishment of the "flood probability – object" relationship itself represents also a complex and different for generalization problem. Its solution is founded, first of all, on the selection of a criterion determining what are the conditions when flood emergence may be assumed to have taken place for a given object – flooding of foundations, flooding of a part of it, total overflow, partial or full destruction, etc. Moreover, flood probability may be determined individually for each single object. It can be also determined by considering the objects in groups of equal probability. All these criteria and approaches lead to different methodological tools for fixing and calculating a system of quantities and parameters related to the flood.

3.1 Flood probability in the region of river sections

The ungrounded acceptance of the high water probability in the rivers also as a flood probability estimate is a frequently encountered practice. However, it has to be noted that high water in rivers is a phenomenon, which differs substantially from the flood phenomenon. Hence the high water probability, which is a probabilistic characteristic, cannot be indiscriminately identified with the probability for flood occurrence. As a simple example in this context, it may be pointed out that not every high-wave with its intrinsic probability for emergence and overtopping (i.e. probability) causes a flood in the river section! Theoretically considered, it turns out that for infinite number of high-waves with various probabilities higher than a certain lower limit the flood probability is equal to zero! The example is rather simple but it proves unambiguously that flood probability is a quantity with a physical meaning that cannot be identified with the high-wave probability.

The use of normative probability in the dimensioning of hydrotechnical structures as a flood probability indicator for the lower river section is also theoretically unsubstantiated. The normative probability of the maximal water amounts represents a provisional imposed by statute value for determining the water amount used in the design and dimensioning of hydrotechnical structures, so that they are ensured against damage or demolition due to the impact of the periodically passing high-waves [17]. With this its significance is exhausted because it does not consider the next actual state of all natural and artificial factors, on which the “flood” phenomenon depends.

In contrast, the flood probability represents a real value related to a particular object existing under real conditions, regardless of the causes for any alterations in them in the course of construction or after it as inobservance of normative regulations and changed natural settings, operation regimes, water economy and territorial infrastructure, etc.

In fact, here again two different phenomena are considered: the high-wave emergence with a certain probability and the flood emergence with another probability. In some particular cases these probabilities may coincide but from probabilistic point of view they represent two different events.

The combined consideration of both events in the case of river sections with or without hydrotechnical construction exhibits characteristic features that may be used for establishing a relationship between them:

- Flood is not caused by every high-wave.
- Flood may emerge only if a high-wave occurs.
- The flood probability of each single object in the endangered river section due to passing of one and the same wave is different.

These three specificities of the combined consideration of both events contain the essence of the scientific treatment of flood probability for the objects in the river sections.

3.1.1 River sections in a natural state

No hydrological investigations are usually carried out (not taking into account the passive runoff observations in eventually situated hydrometric stations) for river sections in a natural state, i.e. unaffected by realisations or intentions for any hydrotechnical measures. In such cases the flood risk assessment for the surrounding terrains should be made systematically according to priority succession with regard to the social or economic weight of the objects situated there. Principally, the best sustained approach is to carry out this assessment simultaneously for the whole river section, as in the case considered below.

The flood probability, as already mentioned, is always related with some particular object or group of objects. In this respect an explicit criterion should be stated about the event, which will be treated as flood emergence.

Having in mind that even the sub-flooding of the terrains, i.e. approaching of the groundwater level closer to the terrain surface, is capable of causing significant damages to the agricultural production and to a great part of the territorial infrastructure, the formulation of this criterion seems to come quite logically: the formation of a free water level at the object site, regardless of its overtopping above the terrain benchmark, is considered to be a flood.

With this treatment of the problem, the estimate of the flood probability should pass through the following stages:

- hydrological investigation of high waters for characteristic water balance points in the considered river section. As a result, the sizes of the maximal water amounts should be obtained with a probability falling within an expediently chosen range (for example from p = 0.01 % to p = 20 %);

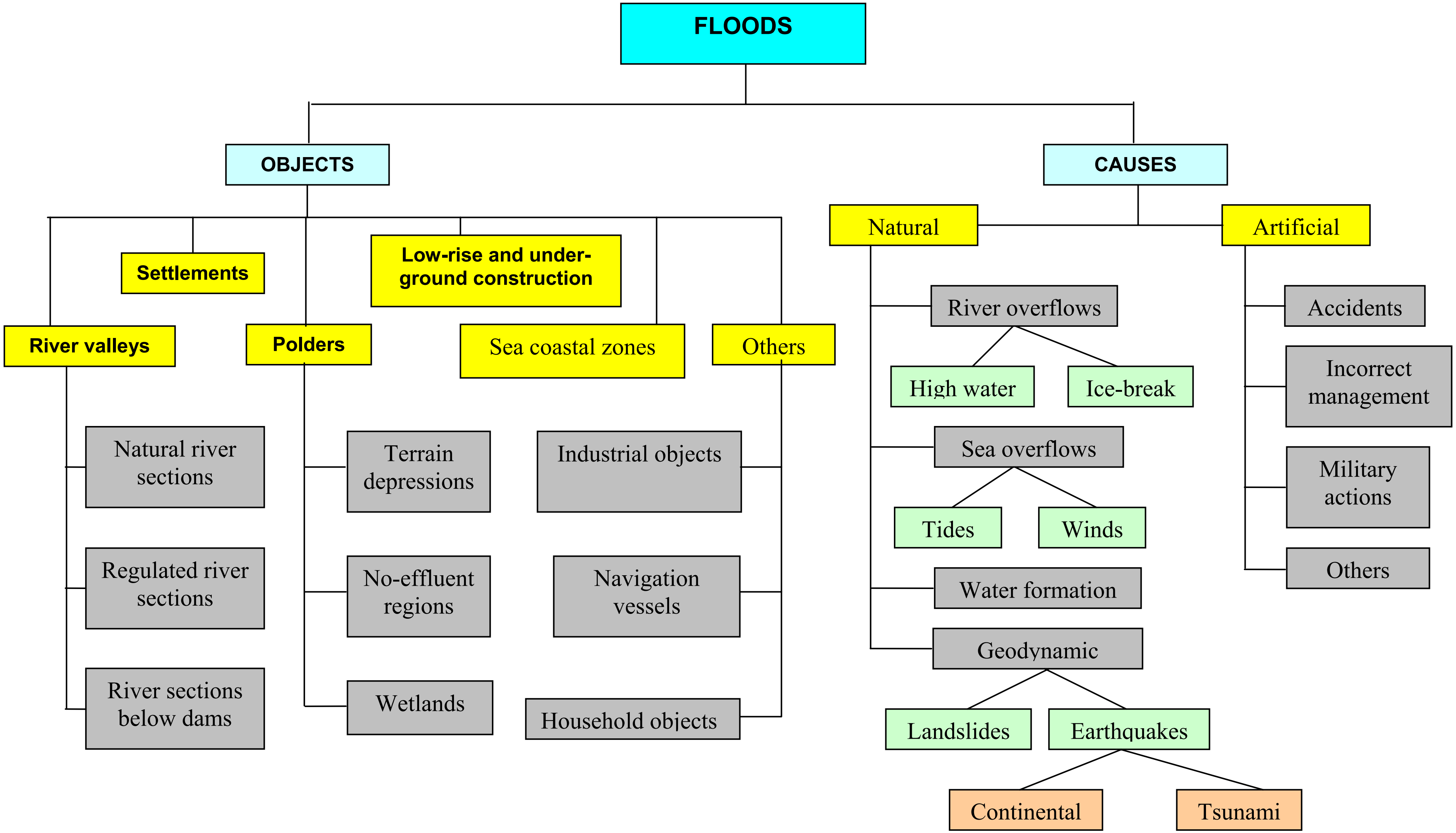

Fig. 1 Flood systematization

- hydraulic investigation of the river section. As a result, the water level benchmarks corresponding to the already determined water amounts for the whole longitudinal profile of the main river should be obtained;
- topographical investigation of the river valley along the river section. As a result, map for the entire region with isolines delineating the flooded areas for different probabilities of the maximal water discharges should be obtained.

In the considered case the flood probability value coincides with the probability of the maximal water amounts that have caused the flooding of the areas. Hence, by designating the obtained isolines with the probability of the corresponding water amounts, the desired zoning of the territory with respect to the flood probability is obtained. Using such map materials the individual risk for each single object situated in the considered territory may be determined.

Another flood probability has to be discussed too, which is due to ice-break during the initial phase of spring high water. This phenomenon is typical for the big rivers, where temporary barriers may be formed in the narrow river sections due to heaping of ice blocks, causing significant back up effects in the upper river sections. The floods provoked by this phenomenon known also as the "ice shock" may especially dangerous in river sections with low banks. Taking into account the considerable difficulties in establishing reliable "cause-effect" relationships for this complex phenomenon, the only way of evaluating its probability is the analysis of the historically accumulated direct information about the caused flooding within the course of a long period.

3.1.2 Regulated river sections

The regulated river sections represent changed natural riverbeds or artificially formed ones by means of engineering methods with the view of improving the flow conditions in a given region and decreasing the harmful effects caused by high waters.

The so-called calculation probability of high water is used in the design of the regulation works, which is normatively prescribed depending on the class of the measure. Hence the riverbed for high waters (including the dike river profile if any) is dimensioned for unobstructed leading away of the maximal water amounts corresponding to this probability.

In this case the following considerations have to be taken into account when establishing the criterion for flood emergence: it is obvious that the suggested criterion for the case considered earlier may be used for the threatened objects around the river sections. This means that in order to flow over their terrains, the water has first overtopped beyond the boundaries of the regulated river profile. And such overflow is practically related with partial destructions of the riverbed or the protective facilities, leading to unforeseen next development of the disaster. For this reason it is far more reasonable and exact to define the criterion for flood emergence as the occurrence of maximal water amounts, which are equal to or exceed the flow capacity of the regulated river profile.

It seems at first sight that with this prerequisite the problem of flood probability is solved – the probability of the flow capacity of the corrected river section is known (this is the normative probability for the design) and hence the flood probability is equal to this normative probability. In fact this is absolutely not so, which may be substantiated by the following circumstances:

- A "guarantee correction" of the dimensioning water amount is always accepted in the design of the regulated profile, which is not taken into account by the normative probability [18].
- The so-called "safety reserve" is obligatorily accepted in the cross profile calculation for the corrected section, which changes its real flow capacity [17].
- The maximal water amounts of the river are determined on the basis of observations carried out for the natural state of the riverbed, when considerably bigger overflows were occurred during high waters in the river valley. In many cases this had led to retention effects in the flooded areas and to smoothening of the observed maximal values used for the calculation of the probability curve during the design. After the correction construction these effects do not exist any longer.
- In the period of operation after the design and construction of the regulation the real flow capacity of the riverbed is inevitably changed due to various reasons.

The discussed causes contain sufficient argumentation against the *a priori* acceptance of the dimensioning probability used in the design of the regulation works as an estimate for flood probability.

The correct approach in the present case is as follows:

- hydraulic calculations for establishing the real flow capacity of the regulated riverbed. The minimal value from the calculations for all investigated profiles should be accepted as the trustworthy water amount;

- updating the probability curve for the maximal water amounts by means of data from observations after performing the regulation works and/or by approximate correction of old data with respect to the already not existing retention effect;
- the flood probability is recorded using the updated probability curve for the trustworthy maximal water amount (the glow capacity of the riverbed).

The flood probability for the objects situated in the region of the regulated river sections may be also calculated individually for each of them. But the social importance of this task is rather low and it is really reasonable only for the extremely important objects for the national strategy.

Measures for group protection of the objects by regulation or dike works are needed in the sections surrounded by existing urbanization or with planned economic activities and significant infrastructural investments. It is correct for these cases to refer the flood probability to overtopping the protective facilities by the flow stream, as already mentioned above.

3.1.3 River sections below dams

The assessment of the flood emergence probability in the river sections below dams represents a special interest for countries with strongly developed dam and river construction. This problem has not received sufficient attention until recently because it has been considered that this probability corresponds to the normatively prescribed probability of maximal waters in the dimensioning of the mitigation structures.

This is a theoretically incorrect assumption, which is in contradiction with the following circumstances:

- The most unfavourable case is accepted in dimensioning the mitigation strucrures in dam construction – the dimensioning high wave propagates in the reservoir when it is filled with water to the benchmark of the dam wall crest. This is an idealized particular case with respect to adversity with a much lower probability to occur during the real period of operation compared to the normatively accepted probability. Similar is the probability for display of the opposite boundary case – the high wave propagates in the reservoir when it is with entirely empty useful volume.
- A great part of the water reservoirs designed for annual or multi-annual runoff regulation are functioning with radically changed operation regimes imposed due to various objective reasons. Multi-annual regulation reservoirs have been transferred to a regime of seasonal runoff regulation and vice versa – seasonal regulation reservoirs are operated in an inadequate regime of multi-annual regulation. Moreover, this usually happens without reconstruction of the existing structures. Such management of the water reservoirs draws them far from the theoretical assumptions of their design, changing the conditions for transformation and conductance of high waters.
- The existing failures in the mitigation facilities, which often occur in dams of secondary importance functioning under insufficient financial and competent technical support, restrict their operative management under critical situations. This also changes their design prerequisites and is reflected on the real probability of accidents and floods.
- The carried out gradual or sharp changes in the social-economic life in every country lead to substantial alterations in the organization, maintenance and way of using the riverbeds and riparian terraces. The illegal or legalized in a suspicious manner invasion of economic activities and even of residential building places them under radically different conditions in comparison with the design prerequisites for high water conductance.
- The weakened state control or the ineffectiveness of the legal prevention for prohibiting illegal actions as filling up the riverbeds with waste, unsanctioned output of aggregate materials, incorrect interpretation of the responsibilities for maintaining the river structures and riverbed flow capacity, etc., lead to consequences strongly increasing the real flood probability. This hampers the normal operation of the water reservoirs by imposing technically inadequate restrictions in the prophylaxis of the facilities and in composing their emergency plans.

Since the river sections below dams are usually regulated, the exceeding of the corrected profile flow capacity may be also accepted as a criterion for flood emergence. Of course, other criteria may also be applied here, which would bring negligible changes in the calculation scheme presented below.

When there is no additional affluence to the river sections below dams, during the periods with maximal runoff, they conduct water amounts determined mainly by the transformed in the water reservoirs high waves. Hence flood probability here is defined by the statistical probability of the retained high waves.

The physical process of high wave transformation in the water reservoir contains two important components – accumulation of a part of the high wave volume in the unfilled capacity of the reservoir and blunting its crest due to its spreading over the significantly broader free water surface of the dam lake. These two components are considered together in numerous literature sources under the common name of "retention" of high waves [19, 20, 21]. In other treatments of the problem the prerequisite is introduced that accumulating volumes do not exist in the water reservoir during the time of the high wave and the retention takes place only due to its spreading on the lake surface above the crest benchmark [18, 21, 22, 23]. However, these assumptions concern the methods of dimensioning of the mitigation structurs from the view point of ensuring the dam wall safety. The separate consideration of both components is absolutely indispensable when the real flood risk has to be assessed for the section below the dam.

Dam construction is an engineering measure with complex purposes. Without stating the multi-layered structure of these complex purposes, it is important to mention that usually one of them is selected as the determinative one and all the rest have subordinate significance. One of these purposes named "flood prevention" needs some special comments.

This purpose imposes strongly contradictory and conflict manner of managing the water reservoirs with respect to all other purposes. It is necessary for the latter to maintain the possibly highest benchmarks of backwatering while the "flood prevention" purpose requires just the opposite – keeping the reservoirs if possible in an empty state ensuring large free capacity of accumulating the high waves formed in the upper section. To combine this purpose with the other ones for one and the same water reservoir is a difficult task to realize. For this reason it has been accepted in the world practice that specialized water reservoirs are built separately for the accumulation and retention of high waves in the rivers.

The climatic conditions in the countries falling within the zone of unstable moistening have imposed the broad use of water reservoirs for redistribution of river runoff as a vitally important natural resource for meeting the complex water necessities of society. Despite of this catastrophic floods are extremely rare phenomenon, which has not provided the grounds for investing resources in the construction of specialized retention water reservoirs. For this reason the merely resource essence of this problem is regarded as a strategic direction in the water economy of these countries. The flood prevention by retention volumes in the water reservoirs is treated as an additional subordinate function, i.e. it is reduced to the level of a useful secondary result during the achievement of the main goal – alleviation of the sharply expressed water deficiencies.

If a consideration is made in the context of this strategy about the nature of the periodically occurring retention high waves in the river sections below dams, it will be established that they are the product of two independent accidental events – on the one hand, the propagation of the naturally formed high wave to the entrance of the water reservoir, and on the other hand – the momentary state of the inevitably occurring free capacity within the frames of its useful volume. Moreover, this free capacity has an independent and entirely accidental character with respect to the high wave emergence in the river.

The probability assessment of retention waves may be performed according to the classical scheme by multiplying the probabilities of the two independent events or by mathematical modelling of the retention wave itself.

Entirely satisfactory solutions may be obtained if observations on the maximal runoff for water reservoirs are available. This condition exists almost always for big dams with more than 20-30 years of operation. The methodology is also applicable when no runoff observations are available but the inevitable analogue assumptions in the process of modelling introduce higher dose of uncertainty in the results.

On the basis of the contemporary level of knowledge in this area, the following principal scheme may be recommended for the flood risk assessment in river sections below dams:

- selecting the model of the dimensioning high wave by analysis of the available observations;
- composing the relationship between the equal-probability values of the maximal water amounts $Q_{m,p}$ and the volume of the observed high waves W_p (the relationship between the arranged in a descending order values of the two series) [10];
- modelling of an artificial series of the maximal annual water amounts with a length not smaller than 500 years;
- modelling of high wave hodographs by means of the above obtained results;
- generating a series for the unfilled volumes in the water reservoir as entirely independent random events corresponding to the number of the modelled high waves;
- calculating the series of the retention high waves;
- plotting the probability curve for the retention high waves;
- determining the flow capacity of the river section below the dam;

- reading the flood probability from the retention waves probability curve for a definite flow capacity of the riverbed;

It is seen that the task is not an elementary one at all but it is entirely possible to solve by means of the modern scientific tools of hydroinformatics.

3.2 Flood probability on settlement terrains

The floods on settlement terrains may occur due to two natural causes: river overflows and intensive surface water formation by rain. Hence the flood risks have to be considered in a differentiated manner due to quite different measures for their reduction.

The probability of flooding due to river overflows on settlement terrains does not differ essentially from the above described case with regulated river sections or river sections in a natural state.

However, the floods caused by intensive surface water formation during intensive precipitation or intensive snow thawing are also very important for the settlement terrains. The problem here consists in the restricted capacity of the settlement sewerage system, which is incapable of collecting and leading away the precipitation water under extreme circumstances.

The criterion for the emergence of this type of flood should be the intensity of the water formation exceeding the runoff modulus of the sewerage system.

Water formation is a quantity that is difficult to measure directly and in principle no systematic observations are organized for it. Its assessment is made by indirect methods on the basis of the observations on rain precipitation intensity. The assessment of the water formation due to intensive snow thawing is made with still more difficult and uncertainty. Here the assessment is based on the snow cover thickness and density, temperature of the air and wind velocity.

Having in mind the information available so far about this type of settlement floods, it may be established that the water formation due to intensive rainfall is the more frequently encountered case leading to floods of bigger dimensions. For this reason at the present stage it is sufficient to assess the risk of flooding caused by intensive rainfall precipitation.

The so-called “reduction curves” for intensive precipitation, developed for the corresponding region, represent the basis for calculating the probability of this flood type. They are empiric graphs for the highest precipitation sum (in the year) as a function of its probability to occur during different short periods of the duration of intensive precipitation [11, 12, 13]. The regional reduction curves for intensive precipitation have been already composed in a number of countries on the basis of long years of rainfall measurements.

On the basis of the methodology for dimensioning the rainfall canalization in settlement areas for the maximal precipitation in the year it is obtained for arrival time τ [14, 15]:

$$h_\tau = \frac{q.\tau}{K.\alpha}$$

where q – runoff modulus of the canalization section
α – runoff coefficient
K – dimensioning coefficient.

The probability p of the precipitation sum, which expresses in fact the flood risk, is determined from the reduction curves of intensive precipitation against the so obtained value of the precipitation sum h_τ.

It has to be taken into account that this is just the principal calculation scheme for known values of τ and q. In practice these values have to be determined in terms of the actual status of the sewerage systems in the investigated settlement region. The existing software packages for dimensioning and investigating the functioning of the sewerage systems with consideration of their topographic and hydraulic characteristics are especially useful in these calculations.

3.3 Flood probability in polders

Here terrain depressions are implied under the general term of polders, i.e. all terrain forms with surface that is characterized by lower benchmarks compared to the lowest water levels in the neighbouring water areas – rivers, lakes, seas. Wetlands and no-effluent terrain forms may be also included in this category, since their flood risk is determined in an analogous manner.

The main water influx to the polders is formed by means of seepage. But the regime of this underground feeding is characterized by relative constancy and small changes, which determine different equilibrium states of the natural hydraulic system. Protective facilities and drainage systems are built in many polders, which maintain artificially this equilibrium within a certain range. For this reason even the high values of the underground influx forming the equilibrium state is not treated here as a flood cause.

As a criterion for flood occurrence the condition should be set that surface runoff moduli appear, which are higher than the modulus of the drainage system or if there is no such system – that the formed water levels exceed some preliminary substantiated benchmark.

The flood probability for polders should be evaluated according to the above described methodology for the settlement regions.

3.4 Flood probability for low-rise and underground construction

This case is analogous to polder floods. The groundwater influx is also not considered hare as a cause for flooding. The anti-seepage and drainage measures are an obligatory tool for the normal functioning of these objects in the presence of high groundwater level. The causes for flooding related with their incorrect operation are classified as artificial factors and for this reason the flood risk caused by them is not considered here.

However, the objects of low-rise and underground construction are very vulnerable to surface water permeation and fast filling of their restricted functional volumes with water.

The criterion for flood emergence should be the formation of surface water level in front of any of their entrance, technological or communication outlets.

Flood may take place mainly because of two natural causes: river overflow or intensive surface water formation due to torrential rainfall. In the most general case, the flood probabilities for both cases are different and should be considered individually.

This may be done using the methodological approaches described above in accordance with the specific conditions for the considered cases.

When the objects are situated below the level of situated in the proximity water basins, flooding due to earthquakes should not be excluded. This is however, a very specific case of combined probability of an earthquake and flooding and its assessment strongly depends on the individual conditions of the objects. Regardless of the possible catastrophic consequences of such chain-proceeding event, the probability of its emergence is not considered here. It has to be pointed out that very serious interdisciplinary research should be carried out in this case.

4. Humanitarian aspect of the flood risk

From humanitarian point of view the floods are qualified as mass disasters threatening the life, health and vitally important material interests of large groups of people. And although it is impossible to determine the price of even one human life, the amount of the officially taken flood risk should be ranged by the number of people that might be affected. Moreover, this risk should not be treated as fatal fact for the inevitable doom of a certain percent of the population but as a starting point for undertaking effective measures for its protection. These measures should have a complex character and create a strictly regulated system, its correct functioning being the guarantee for preserving the life of each individual from the threatened community.

The humanitarian grading of the flood risk plays only the role of a priority scale for the stages of protective measures realization and provides economically substantiated gradation of their comfort for the population. Even the least comfortable version of the measures should ensure full collective guarantee for the life of the people.

The humanitarian ranging of the flood risk in the flood practice represents still one unsolved or partially solved problem. It needs reconsideration in each individual country and the development of the priority scales should be in conformity with the natural conditions, the social-economic development and the national life style.

5. Economic aspect of the flood risk

Except for the danger for the life of the population, the floods cause also considerable material and financial losses. The measures for reducing the losses are undertaken depending on the capital value of the threatened objects and the expected consequences from their damage or destruction. In this context ranging of flood risk is also necessary here with respect to their different significance.

The hydrotechnical structures are ensured against the impact of the maximal runoff in the rivers as early as during their design stage. Depending on their capital and social-economic importance they are ranged in classes with normatively prescribed probability for conducting high waters without accidents [1]. The prescribed norms are composed rather provisionally but despite of this they are the result of serious technical-economic assessments, analyses and generalizations that have received their worldwide acknowledgement. This refers however to the safety of the structures themselves.

The flood risk for all other threatened objects has to be ranged and in a similar manner. Almost nothing in this respect has been done in many countries, where the risk is identified quite formally with the prescribed high water probability. As already stated above, this formal approach is not well grounded theoretically in most of the considered cases. The flood risk exists for all objects regardless of the presence or absence of hydrotechnical structures in the considered river section.

It is entirely admissible for the threatened objects to be classified according to the already developed scales for the design of hydrotechnical structures. However, the normalized probability values in them have to be replaced by the real flood risk calculated in compliance with the already described methods.

The catastrophic floods often observed recently and the unfavourable predictions for the increase of their frequency put to the forth the economic balance between the necessary resources for the protective measures and the size of the damages depending on the insufficient degree of their structure completion. And this degree of completion is a function depending directly on the risk for flood emergence.

In this context a huge volume of work has to be performed for exploration, research and design-technical activities, zoning of risks and establishing the technical measures necessary to reduce them to the normalized values.

6. Ecological aspect of the flood risk

Flood emergence under natural conditions represents a regular geophysical process, to which the affected ecosystems have adapted themselves. The natural constructive and destructive factors have established secular ecological equilibrium, to which all biological species have adapted their existence. In this respect the periodically occurring floods do not represent an ecological threat for extinction, variation or origin of new formations in the biosphere composition.

The ecological impact of floods has to be considered in two directions: related to the global climatic changes leading to alterations in the frequency and size of the floods and related to their impact on the artificially created conditions for preserving rare biological species threatened by extinction due to other reasons.

The global climatic changes are a fact that has been established during the last decades in vast regions of the Earth territory. For the present only the trends of these changes have been found for our geographic latitudes. There are still no sufficiently reliable data and categorical conclusions that might be used as guidance for undertaking adequate practical measures. However the gradual development of this process is monitored by the scientists from all over the world and prerequisites are ensured for new purposeful investigations concerning the possible consequences due to further deepening of the changes. In this connection, re-estimation becomes necessary for the information available so far about the climatic, meteorological and hydrological factors, mainly with respect to the prognostic activities for the future development of the processes. An important place in this research is occupied by the studies on the increasing frequency and size of the floods exerting direct influence on the risk assessment of their emergence.

As far as the second direction concerning the artificial measures for artificial preserving of biodiversity, is considered, the problem is related to protection against the destructive effect of floods in reserves and protected natural regions. These objects may be referred to some of the above considered categories and the risk of flood emergence is evaluated according to the corresponding methodology.

7. Administrative-legal aspects of the flood risk

The humanitarian and economic interpretation of the flood risk leads logically to administrative-legal actions for its reduction by the establishment of regulations and norms for the construction, maintenance and organization of a constantly operating protective system. The technical measures for protection against flooding are known for ages and the contemporary development of the scientific-technical potential, the technological progress in the production sphere, the transport and communications, ensure favourable basis for their improvement, dissemination and growing from the position of seldom encountered exclusions to the level of routine widespread territorial infrastructure. It is self-understandable that except for the deep conviction and understanding on behalf of the national governing authorities, a respective financial basis is also necessary for investment and maintenance of the expediently selected measures. The role of the administrative-legal regulating mechanisms in this respect is extremely important, because the protection against floods is related with non-productive capital investments, which makes it unattractive for private initiative. It is necessary to redistribute the national budget funds at least partially by giving high priority to the activities against natural disasters and accidents. The legislative system should also stimulate the accumulation of material and financial funds for the development of the protective systems. This may be realized by legal tax and credit alleviations for capital investments, more stringent requirements concerning the safety measures towards the juridical persons occupied in economic activities in the water economy sector, constant state control on the adherence to the prescribed regulations and norms for safety of the population and property.

In the final reckoning, the effectiveness of all administrative-legal measures that have been undertaken is determined by the economic possibilities of the country, but their setting has to represent a constant and ranged with time vision with not very remote prospects.

8. REFERENCES

1. Environment Agency, Strategy for Flood Risk Management (2003/4 – 2007/8), Version 1.2, 2003.
2. European Environment Agency, Sustainable Water Use in Europe, Part 3: Extreme Hydrological Events: Floods and Droughts, Environmental issue report No 21, EEA, Copenhagen, 2001.
3. Dao Hy, P. Peduzzi, Global Evaluation of Human Risk and Vulnerability to Natural Hazards, Enviroinfo, Editions du Tricorneq Geneve, 2004.
4. Jonkman S. N., P.H.A.M. van Gelder, J.K. Vrijling, Flood Risk Calculated with Different Risk Measures, 2005.
5. Ashby G., V. Lenting, G. Chapman, S. Clarke, Thames Coast Flood Risk Assessment, Final Report, Environment Waikato and Thames-Coromandel District Council, Hamilton East, 2003.
6. Breton C., C. Marche, A Decision and Methodology for the Selection of Intervention in Floodplain Analysis, Rev. Sci Eau, 14/3,2001.
7. Commission of the European Communities, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and of the Regions, Flood Risk Management, Flood Prevention, Protection and Mitigation, Brussels, 2004.
8. Special Report of the San Bernardino Sun, L.A. Newspaper Group, 2004
9. National Weather Service Forecast Office, Definitions of Floods and Flash Floods, Morristown, TN, 2005;
10. FEMA, National Flood Insurance Program, Definitions, Washington, 2005
11. Elmore Country Flood Assistance – Acquisition Program (floodplain Buyout Program), 2005, USA – Floodplain Management Association, Santee, CA, 2005.
12. U.S. Geological Survey Kansas Water Science Center, Flood Definitions, 2005.
13. Flooding Public Safety, Meteorologist Jeff Haby, Flood Definitions, 2005.
14. National Weather Service USA, 2005.
15. USA - Floodplain Management Association, Definitions, Santee, CA, 2005.
16. Europe – Environment – Internet Consultation on Proposal for a Floods Directive, 2005.
17. Regulations and Norms for Design, Ministry of Construction, Sofia (in Bulgarian).
18. Marchinkov, B., Hydrology, Tehnika, Sofia, 1973 (in Bulgarian).
19. Zubkov, B. E., Hydrotechnical Structures, Handbook of the Designer, Stroyizdat, Moscow, 1983 (in Russian).
20. Svanidze, G. G. Mathematical Modelling of Hydrological Series, Gidrometeoizdat, Sanct Petersburg, 1977 (in Russian).
21. Zinger, V. N., Transformation of Maximal Discharges of Water Reservoirs, Gidrometeoizdat, Sanct Petersburg, 1960 (in Russian).
22. Marinov, I., Engineering Hydrology, Tehnika, Sofia, 1984 (in Bulgarian).
23. Papazchev, I., H. Abadzhiev, L. Sheitanov, D. Toshev, Manual for Design of Hydrotechnical Structures, Tehnika, Sofia, 1987 (in Bulgarian).