Preliminary flood risk assessment in the Hornád watershed

M. Zeleňáková
Institute of Building and Environmental Engineering,
Technical University of Košice, Slovakia

Abstract

Flood risk assessment evaluates the potential adverse impacts that floods have on humans and the environment. The risk assessment process in general provides a way to develop, organize and present scientific information so that it is relevant to environmental decisions in the watershed. The paper deals with preliminary flood risk assessment in watershed. Preliminary flood risk assessment includes a description of the floods which have occurred in the past and which had significant adverse impacts on human health, the environment, cultural heritage and economic activity and for which the likelihood of similar future events is still relevant, including their flood extent.

Keywords: flood risk, risk assessment, watershed, likelihood, adverse impacts, environmental risk.

1 Introduction

Floods have the potential to cause fatalities, displacement of people and damage to the environment. Floods are natural phenomena which cannot be prevented. However, some human activities (such as increasing human settlements and economic assets in floodplains and the reduction of the natural water retention by land use) and climate change contribute to an increase in the likelihood and adverse impacts of flood events Directive 2007/60/EC [1].

Flood risk management is a process which comprises pre-flood prevention, risk mitigation measures and preparedness, backed up by flood management actions during and after an event. Flood risk management deals with the societal task of analysing, assessing and reducing flood risks considering all relevant physical, environmental and societal processes. It is essential that action will

WIT Transactions on Ecology and the Environment, Vol 124, © 2009 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/RM090021

only be taken in areas where potential significant flood risks exist or are reasonably foreseeable in the future. If in a particular river basin, sub-basin or stretch of coastline no potential significant flood risk exists or is reasonably foreseeable in the future; EU Member States would be able to identify them in the preliminary flood risk assessment. For these river basins and sub-basins no further action would have to be taken [2].

The background for the process of flood risk assessment is environmental risk assessment. Environmental risk assessment evaluates the potential adverse effects that human activities have on the plants and animals that make up ecosystems. The risk assessment process provides a way to develop, organize and present scientific information so that it is relevant to environmental decisions (Badida and Vargová [3]). When conducted for a particular place such as a watershed, the environmental risk assessment process can be used to identify vulnerable and valued resources, prioritize data collection activity, and link human activities with their potential effects (Zeleňáková [4]). Environmental risk assessment is an objective, scientific process of identifying and evaluating the adverse risks associated with a hazardous substance, activity, lifestyle or natural phenomenon that may detrimentally affect the environment and human health [5]. When applied in a watershed context, risk assessment methods can help bring scientific data into environmental decisions. The aims of assessment are to introduce a sound science-based assessment method to people working in watersheds; and to point out how using the methodology makes environmental assessment data more useful to managers.

2 Process of flood risk assessment

Flood risk means the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event 2007/60/EC [1].

Based on available or readily derivable information, such as records and studies on long term developments, in particular impacts of climate change on the occurrence of floods, a preliminary flood risk assessment shall be undertaken to provide an assessment of potential risks. The assessment shall include a description of the floods which have occurred in the past and which had significant adverse impacts on human health, the environment, cultural heritage and economic activity and for which the likelihood of similar future events is still relevant, including their flood extent and conveyance routes and an assessment of the adverse impacts they have entailed.

According to 2007/60/EC [1] EU Member States shall complete the preliminary flood risk assessment by 22 December 2011. On the basis of this assessment they shall identify those areas for which they conclude that potential significant flood risks exist or might be considered likely to occur.

Above mentioned requests were taken into consideration to fulfil the aims of this paper. Background for the methodology of the preliminary flood risk assessment in the Hornád watershed (basin) is the general process of environmental risk assessment. The environmental risk assessment process consists of three main phases, seen in Figure 1: problem formulation, risk analysis and risk characterization EPA, Bendíková, Zeleňáková [6–10]. Three additional components appear in the flow chart: planning, risk management, and iterative monitoring and data acquisition.

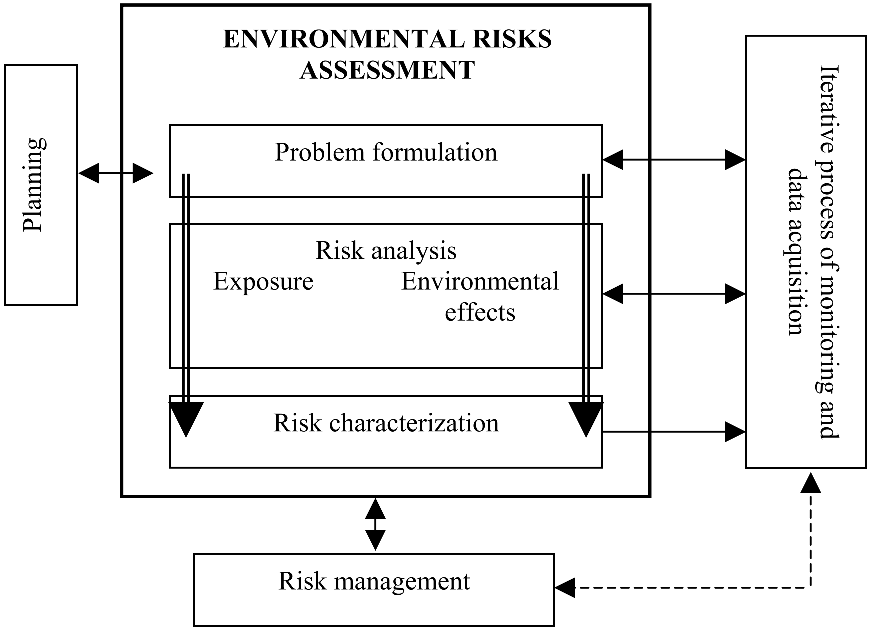

Figure 1: Flow chart of environmental risk assessment.

During planning, scientists and managers with input from stakeholders seek agreement on the focus, scope and complexity of an assessment. Then the formal risk assessment process commences with problem formulation during which key questions, conceptual models and an analysis plan are developed. The analysis phase evaluates the exposure of valued resources to stressors and the relationship between stressor levels and environmental effects. During risk characterization, the risks are described and if possible estimated quantitatively, forming the basis for the assessment's conclusions and a report. GIS tools are often used (Kozáková *et al.* [11]). Monitoring and new data acquisition may occur in support of any of these phases, wherever needed. After completion, the risk assessment's findings are communicated to the managers, who determine a course of action.

3 Flood risk assessment in the Hornád watershed

The watershed, a hydrologically-bounded ecosystem, is a logical unit for environmental risk management. Watershed managers need a process for determining which environmental features in the watershed are at risk and choosing the best actions to protect them (Bendíková [12]). The process of risk assessment is accomplished by evaluating the likelihood that adverse environmental effects may occur as a result of exposure to stressors. The Hornád watershed (Figure 2) is situated in the Hornád river valley, between the city of Košice, which is the second largest city in Slovakia and the Hungarian border.

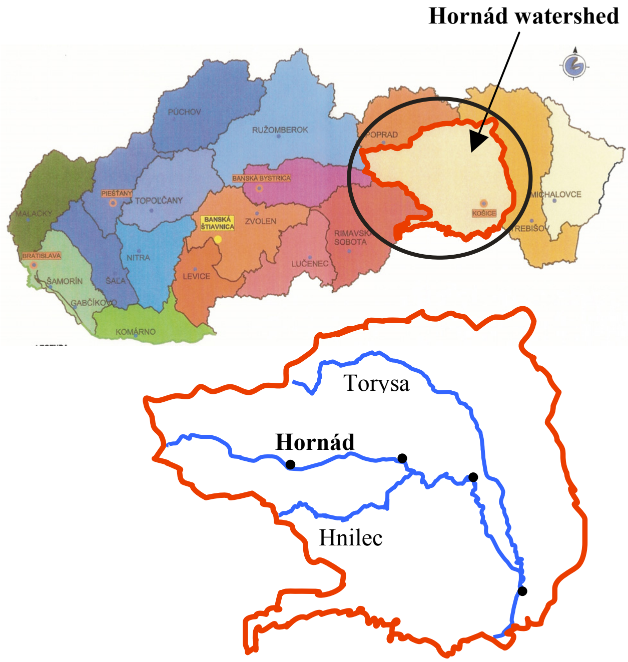

Figure 2: Hornád river watershed.

The source of the Hornád is in the Low Tatra mountains under the Kráľova hoľa hill, southwest of Poprad. It flows through the Slovak regions of Spiš and Abov, and through Hungary. It is 286 km long, 193 km of which are located on the territory of Slovakia. Cities along its course are Spišská Nová Ves and Košice and its tributaries include the rivers Hnilec and Torysa. It flows into the river Sajó southeast of Miskolc which is itself a tributary to the river Tisza.

The worst affected area by floods in Slovakia is eastern part, particularly in the Topľa, Ondava, Hornád, Torysa, and Laborec river basins in recent years [13]. Many floods had tragic consequences and caused huge material damages.

3.1 Problem formulation phase

Problem formulation phase includes gathering available information about the watershed, its valuable resources potentially at risk, stressors and exposure opportunities, and environmental effects are a practical starting point.

Available information on valuable resources, stressors and effects is used to:

- Identify and select the specific subjects of the assessment (the assessment endpoints) - assessment endpoints are selected which provide a link between what can be measured (e.g. water level in stream) and one or more management objectives (e.g. ensuring flood protection). Act No. 666/2004 of Slovak republic on the flood protection [14] states three grades of flood according to the water level in the stream. The levels differ for the different river stations. The four river stations in the Hornád stream with the height in centimetres for the different flood grades (FG) were assessed. For the purposes of preliminary flood risk assessment daily data of water levels in the river stations for eight years period were assessed. The data were provided by Slovak Water Management Enterprise, s.e. Košice.
- Produce a conceptual model and associated questions that the assessment may address - the conceptual model describes, in narrative and graphical form, relationships among human activities, stressors, and the effects on valued resources (Bendíková and Švecová [15]). At this point in the assessment these relationships are based on best professional judgement, but usually not yet quantified; yet the framework for analysis and assessment is clearly described therein. The simple example of the conceptual model is presented in Figure 3.

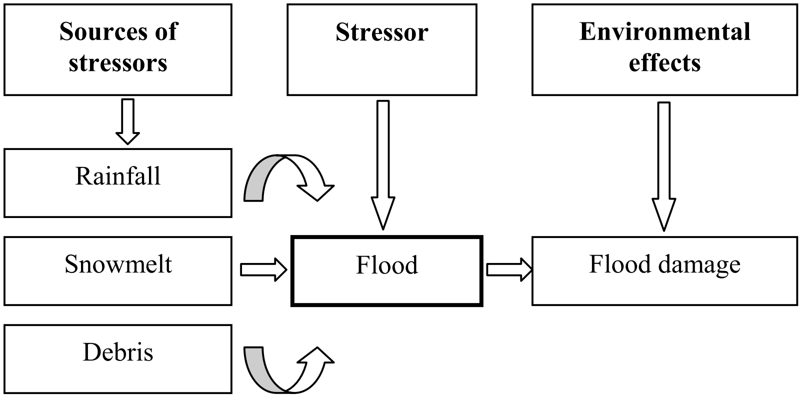

Figure 3: Conceptual model.

- Define a plan of action for the analysis phase and measurements that are needed - this analysis plan documents the exposure and effects relationships that will be quantified in the analysis phase, the data needed and measures to be used, and how risks will be described.

3.2 Risk analysis phase

Risk analysis phase focuses on the most important stressors, their exposure pathways, and the resulting environmental effects. The analysis phase includes characterisation of exposure – the manner in which a valuable resource contacts or co-occurs with a stressor – and characterisation of effects – the environmental response that occurs from exposure. The scope of the risk analysis may focus on the major stressor of concern or seek associations between stressor and impact. Flood is the major assessed stressor in this case. This phase analyses mainly:

- Exposure – analyzed by the temporal and spatial distribution of stressors in the environment. Maximal monthly heights of water level in each river station were evaluated in eight-year period. The example for river station Ždaňa is presented in Figure 4. High water levels appear in March, April, June, July and August mostly because of heavy rains (snowmelt in spring).

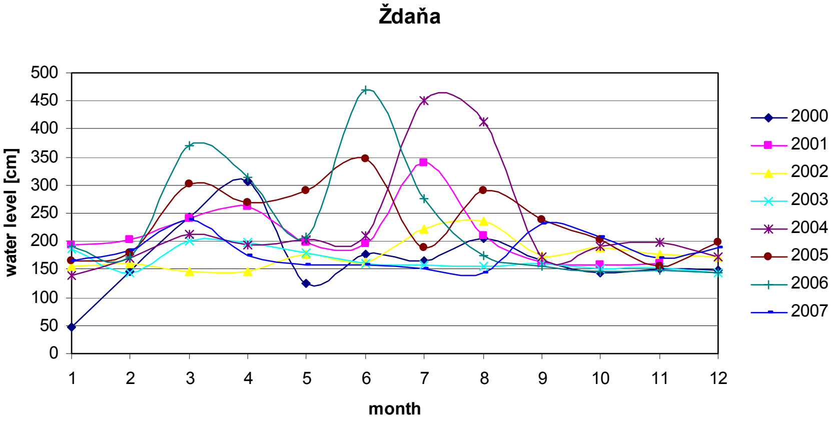

Figure 4: Heights of water level in Ždaňa river station.

- Environmental effects – analyzed by describing stressor-response relationships. Stressor-response profile development should try to relate the magnitude of the effect to the magnitude, duration, frequency, and timing of exposure. The number of flood situations in each river station was evaluated in period 2000-2007.

3.3 Risk characterization phase

In the final phase of assessment – risk characterization phase – the likelihood and significance of adverse effects due to exposure to stressors are evaluated. The phase includes two major steps: risk estimation and risk description.

- Risk estimation, the first step, integrates the exposure profiles and the stressor-response profiles developed in the analysis phase. The likelihood and significance of adverse effects are evaluated according to the occurrence of flood grades (I. or II. or III.) in river stations. Table 1 presents the average number (for the year) in the eight-year period of flood grade occurrence in each river station. Sources of uncertainty may include measurement data, conditions of observation or human error.

Table 1: Number of flood days at river stations.

River station/ Partial watershed	Number of I. FG	Number of II. FG	Number of III. FG
Spišská Nová Ves Hornád pod Brusníkom	0	0	0
Spišské Vlachy Hornád nad Hnilcom	2	1	0
Kysak Hornád - Kysak	17	2	1
Ždaňa Hornád pod Olšavou	38	3	1

- Risk description concludes the characterization phase with the preparation of an environmental risk summary and the interpretation of environmental significance (Table 2). Interpreting environmental significance translates possible risk estimates into a discussion of their consequences for the watershed. Risk was counted from eqn (1):

$$R_i = \sum_{i=1}^{n} (L_i \times C_i) = (L_1 \times C_1) + (L_2 + C_2) + (L_3 + C_3), \qquad (1)$$

where: R – risk,

L_i – likelihood (occurrence of flood grade – I. FG = 1, II. FG = 2, III. FG = 3),

C_i – consequences (number of flood grades).

Table 3 represents the acceptability (risk rate) of flood risks for each of the Hornád river watersheds zones.

The results from preliminary flood risk assessment in the partial Hornád watersheds shows that unacceptable flood risks are in the lower parts of the river watershed where its tributaries flow into river (Table 3).

Monitoring and data acquisition is iterative throughout all phases of the risk assessment process. Continued monitoring provides key feedback in that detection of continued adverse effects after risk management actions are in place indicates the need for more effective action.

A watershed management approach helps flood managers focus on the highest priority problems affecting surface waters in the watershed. Preliminary flood risk assessment can be particularly useful in watersheds as a scientific method that includes steps for integration with planning, priority-setting, and decision-making.

Table 2: Risk acceptability and its significance.

Risk rate	Risk acceptability	Scale of risk	Significance of flood risk in watershed
1	acceptable	1 – 10	Risks in watersheds are acceptable – current practice
2	moderate	11 – 20	Risks in watersheds are moderate – condition of continual monitoring
3	undesirable	21 – 30	Risks in watersheds are undesirable – flood protection
4	unacceptable	31 and more	Risks in watersheds are unacceptable – immediate flood protection

Table 3: Flood risk.

River station/ Partial watershed	Risk – quantitative assessment	Flood risk rate - acceptability
Spišská Nová Ves Hornád pod Brusníkom	0	1 - acceptable
Spišské Vlachy Hornád nad Hnilcom	4	1 - moderate
Kysak Hornád - Kysak	21	3 - undesirable
Ždaňa Hornád pod Olšavou	44	4 - unacceptable

4 Conclusion

Generally, watershed environmental risk assessment provides tools and information that may be used in managing risks. Risk management fills the crucial role of integrating the science-based assessment with the economic, social, legal, and political factors affecting management decisions and actions in the watershed (Bendíková [12]).

Preliminary flood risk assessment is focusing on the likelihood of adverse effects of floods as a basic philosophy for making environmental decisions related to flood measurements in the watershed. Making good watershed management decisions requires science-based information that can be evaluated and priority-ranked in terms of the risks to the watershed. The results of preliminary flood risk assessment in the Hornád watershed is the identification of unacceptable flood risks in the lower part of the Hornád stream in the Eastern Slovak Lowland. This part of Slovakia is frequently exposed to floods and considering the Hornád stream is prior for flood measurements design.

The risk characterization should interpret the major risks and the environmental significance of the findings. Maps, simplified scoring systems, clearly defined evaluative criteria and limiting the numbers of stressors and effects addressed all help to assess effectively. Graphs are one of the best analytical tools for describing relationships between investigated attributes and impacts. Summary tables are an effective approach to display the most meaningful information in one condensed exhibit.

Other benefits of using this process in watershed assessment are also evident. The improvements in the coordination associated with the planning can bring priority issues into focus and the increased awareness of watershed flood problems and their relative priority can prompt other independent actions to improve flood control.

Acknowledgement

The author is grateful to the Ministry of Education of Slovak Republic for financial support in frame of project NFP OPVaV with ITMS code 26220120018 and of VEGA project 1/0613/08.

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