International Scientific Conference *People, Buildings and Environment 2014* (PBE2014)
15-17 October, 2014, Kroměříž, Czech Republic, www.fce.vutbr.cz/ekr/PBE

KEYNOTE LECTURE

FLOOD RISK ASSESSMENT – APPROACH FOR ASSESSING ENVIRONMENTAL FLOOD RISK

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Abstract

The assessment of flood risk is an essential part of the risk management approach, which is the conceptual basis for the EU directive on the assessment and management of flood risk. Practical application of flood risk assessment still has some problems. One of them is that environmental and social flood risk is often neglected. The methodological framework presented in this paper tries to tackle environmental flood risk problem. Our basis for the assessment of flood risk is the definition of risk, which is taken as some product of probability and consequences. In other words this is the expected annual average negative consequence of flooding where negative consequences covers environmental damages. The paper presents how to environmental damages for flood-prone areas can be determined and evaluated based on classification of sources of pollution. This methodology can be presented to decision makers to support decisions regarding flood risk mitigation.

Key words

Flood; flood risk; environmental damages; sources of pollution; flood protection

To cite this paper: *Zeleňáková, M., Gaňová, L., Purcz, P. (2014). Flood risk assessment – approach for assessing environmental flood risk, In conference proceedings of People, Buildings and Environment 2014, an international scientific conference, Kroměříž, Czech Republic, pp. 28-34, ISSN: 1805-6784.*

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1 INTRODUCTION

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation [1]. The risk assessment process provides a way to develop, organize and present scientific information so that it is relevant to environmental decisions. The aims of assessment are to introduce a sound science-based assessment method to people working in river basins; and to point out how using the methodology makes environmental assessment data more useful to managers [2]. Risk assessment may require a multidisciplinary approach since risks may cover a wide range of causes and consequences [3].

According to the consequences the risk can be categorised as [4]:

- Individual risk
- Social risk
- Economic risk
- Environmental risk

Risk itself is defined as probability that a substance or situation will produce harm under specified conditions. Risk (R) is a combination of two factors and may be calculated as follows equal (1) [5], [6], [7]:

$$R = P \times C \tag{1}$$

where: P is probability that an adverse event will occur,
C is consequences of the adverse event (loss).

Flood losses can be classified into direct and indirect losses. Direct losses are those which occur due to the physical contact of the flood water with humans, property or any other objects. Indirect losses are induced by a flood, but occur, in space or time, outside the actual event. Usually, both types of losses are further classified into tangible and intangible damage, depending on whether or not they can be assessed in monetary value [8].

Examples for the different types of damage are [9]:

- Direct, tangible: damage to private buildings and contents; destruction of infrastructure such as roads, railroads; erosion of agricultural soil; destruction of harvest; damage to livestock; evacuation and rescue measures; business interruption inside the flooded area; clean-up costs.
- Direct, intangible: loss of life; injuries; loss of memorabilia; psychological distress, damage to cultural heritage; negative effects on ecosystems.
- Indirect, tangible: disruption of public services outside the flooded area; induced production losses to companies outside the flooded area (e.g. suppliers of flooded companies); cost of traffic disruption; loss of tax revenue due to migration of companies in the aftermath of floods.
- Indirect, intangible: trauma; loss of trust in authorities.

Although flood damage assessment is an essential part of flood risk management, it has not received much scientific attention. The consideration of flood damage within the decision-making process of flood risk management is still relatively new.

This paper presents mainly on flood risk that consider environmental damage as consequences. Environmental risk assessment is the process of identifying, evaluating, selecting and implementing action to reduce risk to ecosystems [10].

2 METHODOLOGY

In this section methodological approach to flood direct intangible damage (negative effects on environment) assessment is presented. Overall, an accurate estimation of negative effects on environment is important in order to be able to determine the environmental flood risk level in a system and the effects of risk reducing measures.

2.1 Creation of a set of criteria and determination of their importance for the consequences calculation

Consequences are determined based on the categorization of potential sources of pollution which affect water quality in case of flooding. Sources of pollution are divided into two groups: point and diffuse sources of pollution (Tab. 1).

Tab. 1: Sources of pollution

Point sources of pollution		**Diffuse sources of pollution**	
Industrial enterprises		Landfill sites	
Wastewater treatment plants		Impoundments	
Petrol station		Population without sewerage	
		Agriculture	
		Environmental burden	

Flooding of mentioned sources of pollution may leak out pollutants and thus deteriorate the quality of surface water, groundwater, and soils, which can lead to environmental disasters, such as damage of habitats, fauna and flora as well as diseases and epidemics occurrence.

Table 2 gives information about importance of source (range from 1 to 5) and weight of source's category. The inverse ranking was applied to these sources of pollution: the least important = 1, next least important = 2, etc. Each source was divided into categories based on literature studying and also inverse ranking was applied to these source's categories. The purpose of the categories of sources of pollution weighting is to express the importance of each category relative to the other category. The more important categories had the greater weight in the overall evaluation. This classification shall enter into a narrative or numeric character, as shown in Tab. 2.

Tab. 2: Importance of source pollution, category of source and its weight

Source of pollution	**Importance of source**	**Category of source**	**Weight**
Point sources of pollution			
Industrial enterprises	5	Unclassified	0.2
		A	0.3
		B	0.5
Wastewater treatment plants	5	< 2000 population equivalent	0.14
		2000 – 10 000 population equivalent	0.21
		10 000 – 100 000 population equivalent	0.29
		100 000 and more population equivalent	0.38
Petrol stations	3	-	1
Diffuse sources of pollution			
Landfills	5	Landfills for inert waste	0.12
		Landfills for non-hazardous waste	0.29
		Landfills for hazardous waste	0.59
Impoundments	3	-	1
Population without sewerage	4	0 – 40%	0.12
		40 – 60%	0.29
		60 – 100%	0.59
Agriculture	3	0 – 40% flooded area	0.12
		40 – 60% flooded area	0.29
		60 – 100% flooded area	0.59
Environmental burden	3	Environmental burden is likely	0.29
		Environmental burden is confirmed	0.59
		Land reclamation	0.12

2.2 Assessment of the consequences

The overall consequence defines a negative impact on the environment and is calculated as the sum of points assigned to each source of pollution located in the floodplains (in the Q_N probability of flooding) multiplied by its weight according Tab. 2.

Consequence's rates (Tab. 3) were divided using Box plot method. The Box plot method is based to creating so-called Box graph. There are 4 groups created by this method. Each of the group has the identical number of the data and in mathematical statistic it is called as a quartile [11].

Value of the resulted consequence is considered as a threat of environmental pollution during floods from all sources of pollution in the flooded area.

Tab. 3: Consequence's rates

Consequence rate	Scale of consequence	Consequence acceptability	Significance of consequence
1	0 - 6,85	marginal	Minimal or no degradation of environment
2	6,86 – 12,25	minor	Disruption of biological communities, which are reversible and limited in time and space, or the number of affected individuals / populations.
3	12,26 – 17,65	intermediate	Disruption of biological communities that are widespread but reversible or in limited severity.
4	17,66 – 25,03	major	Extensive biological and physical disturbance of entire ecosystems, communities or whole species that persists over time, or is not readily reversible.

2.3 Environmental flood risk quantification

Environmental flood risk assessment means that the negative consequences on environment have to be evaluated for flood events for different probability. Based on the above information regarding consequences, the total environmental flood risk is quantified according the following formula (2):

$$EnR = \sum EnRp_i \tag{2}$$

where: $EnRp_i$ is partial risk for recurrence interval *a* and *b* (Fig. 1) (3):

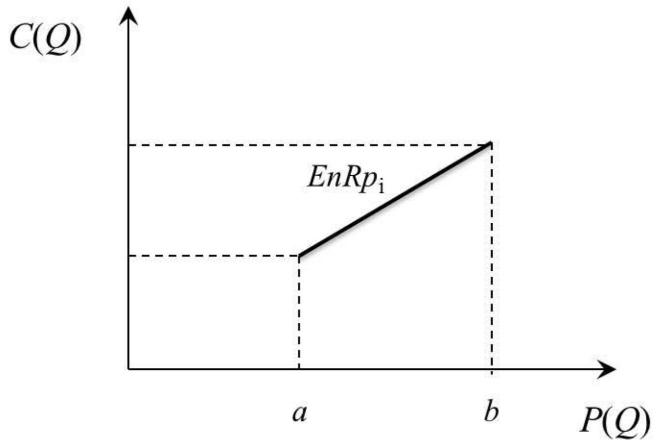

Fig. 1: Partial risk for recurrence interval times a and b

$$EnRp_i = \int_a^b C(Q)dP(Q) \approx \sum_{j=1}^{n}\left[\left(\frac{C_j + C_{j+1}}{2}\right)\left(P_j - P_{j-1}\right)\right] \tag{3}$$

where: C is consequence according Table 2,
P is occurrence of probability of hazard scenario (return period $N(Q)$ – Q_5, Q_{10}, Q_{50}, Q_{100}) calculated according formula (4):

$$P(Q) = 1 - N(Q) = 1 - \frac{1}{P(Q)} \tag{4}$$

Total environmental risk can be used to compare effectiveness of flood mitigation measures to reduce negative effects of floods on the environment.

3 RESULTS

If the determined risk levels are considered to be unacceptably high, it can be decided to reduce the risk. A distinction can be made between measures that reduce the flooding probability and measures that reduce the consequences [12].

Effectiveness of measures to reduce the environmental flood risk is calculated as benefits in terms of risk reduction (*RR*) in percentage according formula (5):

$$RR = (100 - \frac{EnR(afterfloodprotection)}{EnR(beforefloodprotection)}) \times 100 \tag{5}$$

A higher value of this parameter (higher percentage) means greater effectiveness of flood measures regard to the protection of the environment.

In general, an analysis of effectiveness of measures requires insight into the necessary investments and the reduction of (expected) damages to economy, environment, and population [12].

4 CONCLUSION

Flood risk assessment can be roughly divided into two parts: flood risk analysis and assessment on the one hand and risk mitigation on the other. Broadly speaking, the purpose of flood risk assessment is to establish where risk is unacceptably high, i.e. where mitigation actions would be necessary. Risk mitigation means to propose, evaluate and select measures to alleviate risks in these areas [13].

The objective of this article was to show how to environmental flood risk for such flood-prone areas can be determined and evaluated. This methodology can be presented to decision makers to support decisions regarding environmental flood risk reduction measures. We trying to introduce the methodology for environmental flood risk assessment based on point and diffuse sources of pollution classification, as main environmental damages during the floods are caused because of pollution in the flooded area.

ACKNOWLEDGEMENT

The contribution is written thanks to support of project VEGA 1/0609/14.

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