IMPACT ASSESSMENT OF STRUCTURAL FLOOD MITIGATION MEASURES

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ABSTRACT. – Impact assessment of structural flood mitigation measures. The objective of the paper is to propose a methodology for assessing water constructions, which will allow impact assessment of water constructions on the environment and hence select the best option for the permission process. The result is "Guideline for environmental impact assessment of flood protection object", which uses the method of UMRA (universal matrix of risk analysis), which is one of the methods of risk analysis proposed not only to enhance the transparency and sensitivity of the evaluation process, but also to cope with the requirements of the EIA system in the Slovakia and Europe Union.

Keywords: environmental impact assessment (EIA); flood mitigation measure (FMM); risk analysis (RA).

1. INTRODUCTION

In the European Region, floods are the most common disasters, causing extensive damage and disruption. Flood mitigation measures are being undertaken throughout the centuries to reduce flood damages and losses. All proposed flood mitigation measures in Slovakia are subject of environmental impact assessment process before its approval.

The environmental effects of development can be difficult to predict. Predictions must often be made when there is still uncertainty about outcomes, negative or positive. Because EIA is a predictive tool it deals with uncertainty and risk. EIA is information and knowledge dependent - knowledge about environmental values that may be at risk from proposed development, knowledge about the nature, extent and duration of risks to which those environmental values may be exposed, knowledge about what can be done to prevent, avoid or mitigate those risks and identify opportunities, and knowledge about whether those identified risks were indeed controlled. It is tension about how much information and knowledge is necessary to have confidence in predictions about impacts that is at the heart of EIA (EPA, 2009). Risk assessment and EIA are similar in concept as they both deal with the prediction of the future impacts or consequences arising from proposals and uncertainties about the exact nature, probability, frequency and magnitude of impact or consequences. Both seek to inform the decision making

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process about the significance of detrimental impacts and the appropriateness of risk treatments or mitigation measures. Notwithstanding this affinity, these approaches have been developing in parallel with little mutual cross fertilisation.

The European Union has encouraged its members to apply risk assessment in EIA, particularly to extreme events but very little specific guidance is available on how to apply risk assessment in EIA (Lexer et al., 2006).

A risk-based approach is capable of being applied to key stages of the EIA process from scoping to mitigation. The application of a risk-based approach early in the process should contribute to early identification of key issues which would become the focus of subsequent detailed assessment phases. This approach recognises that the level of information and knowledge regarding risks would increase during the environmental impact assessment process (EPA, 2009).

The use of risk-based methods in environmental impact assessment is limited. Only in Australia (and possibly New Zealand) is risk analysis now starting to be used as a methodology for environmental impact assessment (FAO, 2009). The wider use of risk-based approaches is recognized as potentially helpful to define more precisely the environmental risks and enabling focus in key issues in environmental management and monitoring (GESAMP, 2008).

A more explicit emphasis on risk analysis at all levels of assessment, and particularly in screening and scoping, should improve focus and administrative efficiency (FAO, 2009).

The objective of the paper is to propose a methodology for assessing environmental impact of flood protection objects. The paper present the application of the proposed methodology based on universal matrix of risk analysis in Siba municipality, which belongs to one of flood vulnerable areas in Slovakia. It analyse and discuss the results of the impact assessment and offer some recommendations and conclusions with the aim of providing valuable insights for decision makers, planners and policy makers for the improvement of the EIA practice in the Slovakia.

2. STUDY AREA

The proposed methodology using risk analysis for determining the risks associated with the flood mitigation measures and choosing the best alternative for the activity is applied to the flood protection object proposal in the village of Šiba (Fig. 1). Siba is a village and municipality in Bardejov District in the Presov, region of north-east Slovakia. It is located on the Sibska voda stream. This stream is a constant threat of flooding and it is inevitable to propose and construct flood mitigation measures to protect inhabitants and property.

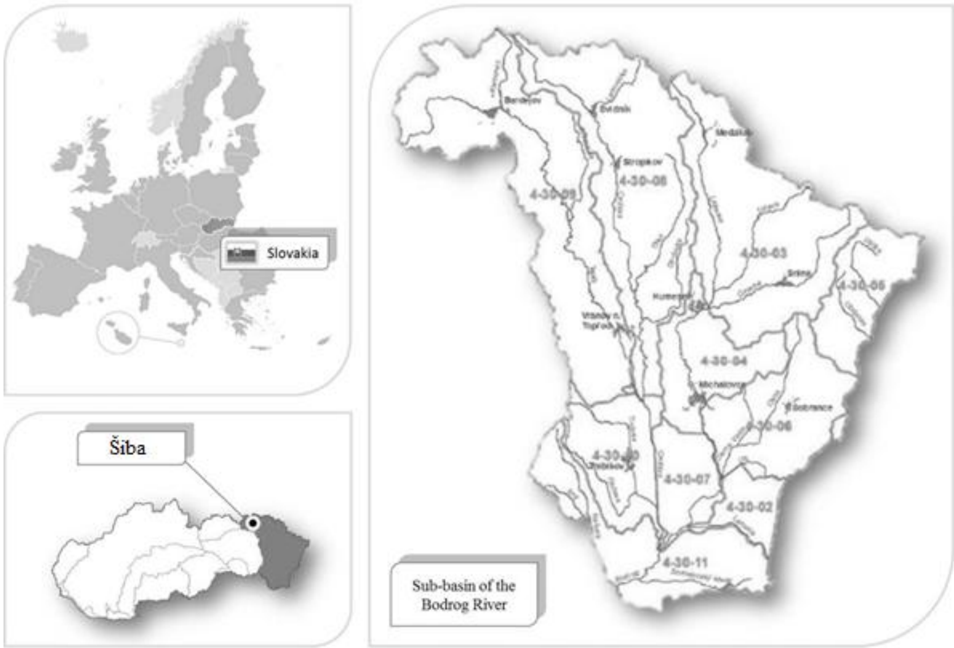

Fig. 1. ***Geographic location of Siba, north-eastern Slovakia***

Basic information's about the current state of the environment in the affected area was published by Zelenakova et al. (2014).

Sibska voda stream, in the village of Siba, is a constant threat of flooding in the village. In recent years there have been wide-ranging consequences of floods particularly for the environment and the property of residents and municipality, as is documented in Table 1.

Table 1. ***Summary of the causes and consequences of floods (MoE and SWME, 2011)***

Village	**Water stream/section**	**Year**	**Brief description of flood**	**Affected property**
Siba	Sibska voda	1999, 2004	rainfall	damaged banks of the stream, damaged right bank fortification
		2006	rainfall	damaged bank fortification, damaged stream weir
		2008	rainfall	damaged banks of the stream
		2009	rainfall	rkm 0.3000-1.000: damaged bank fortification
		2010	rainfall	damaged bank fortification

It is therefore necessary to increase the flood protection of the inhabitants and environment in the village. Increasing the flood protection in the village Siba can be achieved by various measures, ranging from less effective measures of increasing the retention capacity and erosion control of the landscape to highly effective technical flood protection objects.

The purpose of the proposed flood mitigation measures is to regulate runoff in order to improve flood protection in the village Siba. The proposed alternatives for proposed activity are:

Alternative 0: stream bed will not be regulated – the current state.

Alternative I: stream bed will be regulated and a polder will be constructed above the village.

Alternative II: stream bed in the village will be regulated for Q_{100}.

The purpose of the proposed action – flood protection object – is regulation of drainage conditions in order to improve flood protection.

3. RESULTS

The proposed identification of the environmental impacts of stressors is based on the modified method of risk analysis – UMRA (universal matrix of risk analysis).

Potential stressors associated with the proposed activities in the field of water management have been systematically identified through a series of studied references, consultation with experts and expert estimation. The main objective of this task was to identify pollutants or activities that may alter the natural environment as a result of the planned activities. Designated stressors associated with the above-mentioned issues are proposed in Table 2.

In accordance with established practice of EIA, the impact of stressors is assessed and subsequent risk analysis is carried out for these environmental components: population, rocks and minerals, geodynamic phenomena and geomorphological conditions, climatic conditions, air and water conditions, soil, flora, fauna and their habitats; country - the structure and land use, landscape character, protected areas and their buffer zones; territorial system of ecological stability; urban environment and land use, cultural and historical heritage, cultural and historical values, archaeological and paleontological sites and important geological sites and other effects.

Prediction of impacts is based on the fact that there is a relationship between the proposed activity and the environment. These relationships can be described as a string of probabilities and consequences of stressor on environmental components.

Table 2. ***UMRA for identification the environmental impacts of stressors***

STRESSOR - SOURCE OF RISK	**FIELD OF IMPACT**													
	population	the mineral environment, mineral raw materials, geodynamic phenomena and geomorphologic conditions	climatic conditions	atmosphere	water conditions	soil	fauna and flora and their biotopes	landscape, structure and use of landscape, scenic aspects of the landscape	the protected areas and their protective zones	the territorial system of ecological stability	the urban environment and land use	cultural and historical monuments, cultural values of an intangible nature	archaeological and paleontological sites and important geological localities	other
AIR														
emission	●1		●2	●3			●4		●5		●6			
WATER														
floods	●7				●8	●9	●10	●11	●12	●13	●14	●15	●16	
drought			●17		●18	●19	●20							
sediments	●21	●22			●23	●24	●25	●26					●27	
pollutants	●28	●29			●30		●31		●32					
SOIL														
erosion			●33	●34	●35	●36		●37						
landslides	●38	●39			●40	●41	●42	●43	●44		●45	●46	●47	
pollutants	●48				●49	●50	●51				●52			
GENERAL														
noise	●53						●54	●55	●56					
vibration	●57	●58								●59		●60		
waste	●61				●62	●63	●64		●65	●66				
radiation	●67						●68		●69	●70				

For the determination of the probability "P_i" (0.25 to 1), which enters into the calculation of the individual risk of each identified stressor effect on components of the environment, it is necessary to propose an indicator of probability and different levels of criteria.

To determine the value of the consequence "C_i" (0.25 to 1), which enters into the calculation of the individual risk of each identified stressor impact on components of the environment, it is necessary to propose an indicator of consequence and different levels of criteria.

Probabilities and consequences are proposed in Annex E – List of stressors in the thesis Zvijakova (2013). Four levels of probability and consequence were proposed based on the literature studied, such as by (Australian Government, 2005) or (Department of Defense, 2000).

Evaluation of potential impacts of the activity on the environment is the most important step in the EIA process. For evaluation of impacts the calculation of individual risk Ri is required, which is done using the following equation (1):

$$R_i = P_i \times C_i \qquad (1)$$

where

R_i is individual risk of each stressor impact on the component of the environment,

P_i is probability,

C_i is consequence.

Risks R_i are calculated individually for each stressor which has an impact on the components of the environment for each considered variant for determination of risk index *IR*j.

The application shows that the impacts of stressors on components of the environment achieve different levels of risk in the environment.

For Alternative 0 the high risk to the environment lies in impacts of stressors with the ID: 7, 8, 9, 10, 18, 23, 35 and 40 as follows: 7 – impact of floods on the population; 8 – impact of floods on water conditions; 9 – impact of floods on the land; 10 –impact of floods on the flora, fauna and their habitats; 18 – impact of drought on water conditions, 23 – influence of sediments on water conditions, 35 – impact of erosion on water conditions and 40 – impact of landslides on water conditions.

For Alternative I high risk of environmental impact lies in sediments to water ratios with ID 23.

For Alternative II, these impacts of stressors present high risk for the environment: 34 – effect of erosion on the air; 55 – noise impact on landscape structure and land use, and 58 – impact of vibration on rocks and minerals, geodynamic phenomena.

Characteristics and estimation of the level of individual risks is illustrated using a simple matrix (see Table 3). Through this matrix of risk analysis we can estimate the level of risk that can be classified into four levels: negligible, low, middle and high. With the increasing level of risk (hazard ratio) increases the risk significance.

Table 3. ***Matrix of qualitative risk analysis*** **(Zvijakova, 2013)**

		Consequence			
		Marginal 0.25	Small 0.5	Medium 0.75	Large 1
Probability	Negligible 0.25	Negligible 0.625	Negligible 0.125	Low 0.1875	Medium 0.25
	Unlikely 0.5	Negligible 0.125	Low 0.25	Medium 0.375	High 0.5
	Likely 0.75	Negligible 0.1875	Low 0.375	High 0.5625	High 0.75
	Highly unlikely 1	Low 0.25	Medium 0.5	High 0.75	High 1

The objective of this risk matrix is to provide guidance to characterize the relationship between probabilities and consequences of individual risks. Assessments of probability and consequence are combined in order to set the risk of individual stressors to environmental components. The risk matrix is a tool for obtaining a risk assessment of the proposed activity on the environment.

Risk index IR_{j} reflects what risk for the environment is posed by each proposed action. Index of risk IR_{j} is calculated using the following equation (2):

$$IR_j = \sum_{i=1}^{n} P_i \times C_i \qquad (2)$$

where
IR is risk index,
L is probability,
C is consequence,
j is rank of the alternative,
n is number of considered impacts of stressors to environmental components (n = 1, 2, 3,...,70),
i is rank of likelihood and consequences.

According to equation (2) the resulting risk indices are calculated. For Alternative 0 IR_0 = 15.75; Alternative I has a value of IR_{I} = 14.3125 and Alternative II has IR_{II} = 15.25.

Proposal of the optimum alternative is based on comparison of the levels of risk of the proposed activities on the environment, on the basis of which the suitability of the assessed alternatives is prioritized as follows:

Alternative I,
Alternative II,
Alternative 0.

The first place represents an alternative that is optimal in terms of the degree of risk posed to the environment. The second place is an alternative which is less acceptable and the third place is the alternative that is least acceptable and the most risky in terms of the level of risk to the environment.

4. CONCLUSIONS

This paper explores the benefits of using the risk assessment/analysis technique in the evaluation of flood mitigation measure by examining the results of the EIA for a selected planned flood protection object in Slovakia. The aim is to improve transparency and minimize subjectivity in the EIA process specifically in the projects of flood protection object proposal. This methodology is intended to streamline the process of environmental impact assessment of constructions in the field of the water management.

Calculation of the risk index IR_i determines the risk for the environment posed by water structures. It is directly related to the environmental impact assessment of activities under Law No. 24/2006 Coll in the Slovak Republic. Under this law it is necessary to compare alternatives for the proposed activity and produce a proposal for the optimum alternative. This proposal of the activity, which involves creating a set of criteria of risk factors to determine the assessment of each alternative, can be used as a reference element for selection of the optimum alternative, or to determine the suitability of the assessed alternative. It serves as a basis for justification of the optimum alternative.

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