Flood Protection of the Non-Urban Area

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Abstract: - Due to global warming, the risk of floods is constantly increasing due to the drying up of the soil, followed by more intense rain showers and storms. Therefore, it is essential to pay more attention to this topic now. The article deals with the design of flood protection in the municipality. A flood control measure is proposed for each type of slope of the soil relief in which the municipality is located. Based on the proposed measures, the article aims to minimize the level of flood risk to the lowest possible level with the use of flood protection aimed at the non-urban area of the municipality. The proposed measures are intended not only for smaller municipalities but also for cities.

Key-Words: Flood; Protection, Non-urban Area; Slope of the Relief; Safety; Territory

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1 Introduction

Due to climate change, flood activity is constantly increasing in the territory of municipalities in the form of floods or inundations. Therefore, it is essential to prepare for this and minimize possible future risks to the lowest possible level.

The most significant floods in the territory of the Czech Republic since the 20th century include floods in southern Moravia in 1970 (35 dead), floods in the territory of Moravia, Silesia, and eastern Bohemia in 1997 (50 dead), floods in the vicinity of the Vltava and Elbe in 2002 (17 dead), floods in Moravia in 2009 (19 dead), floods in northern Bohemia in 2010 (5 dead) and floods around the Vltava and Elbe rivers in 2013 (7 dead). Property damage from these major floods was in the hundreds of millions of Czech crowns, [1].

Based on the history of floods that caused extraordinary damage, it is necessary to monitor the development of these threats and actively create prevention to increase the security situation in the given environment. It is appropriate to observe not only the floods themselves but also their ways of occurrence, their development, and the overall impact on society, [2], [3].

Other ways to evaluate flood protection are creating calculation scenarios, flood hazard classes, and descriptions of independent variables. Based on these factors, the places with the most probable occurrence of floods can be evaluated. Moreover, it is advisable to apply flood protection to these places, [4], subsequently.

The article deals with flood protection of the municipality, wherein the first part, describes and characterizes the municipality, [5]. The next part focuses on defining the slope of the relief and its most common types. Based on these types, the next chapter of the article focuses on the design of flood protection, [6]. The proposal characterizes and proposes the construction of a flood protection rig on the outskirts of the municipality, [7]. This type of anti-flood rig would be located on the outskirts of the municipality according to the slope of the relief, in which the municipality is situated to retain as much water as possible so that it does not get into separate houses and streets. In the last part of the article, a SWOT analysis is created, describing the proposed measure's strengths, weaknesses, opportunities, and threats.

The article aims to propose measures through anti-flood rigs in the non-urban area of the municipality to reduce the risk of floods and thereby increase the safety of citizens and their property.

The literature mentioned in the introduction deals more with flood protection in urban areas through the history of floods, their effects, and their development. The proposed measures in this article primarily deal with flood protection in non-urban areas based on comparing strengths, weaknesses, opportunities, and threats, from which a suitable strategy to minimize the risk of flooding is evaluated through mathematical operations.

The main advantage of the authors' analysis is comparing individual parts of the given proposal, the result of which is evaluating the resulting strategy. This strategy evaluates the results of comparing individual parts and describes in which direction it is appropriate to propose measures and then follow them to increase safety. The specific comparison is characterized in Chapter 5 – SWOT analysis proposal.

2 Non-urban Area

Regarding the area's nature, the municipality is divided into urban and non-urban. The built-up area is a built-up area of the municipality, [8].

This part includes all built-up and planned land for development, including roads and areas. The opposite of an urban area is an extra-urban area, characterized by an area located outside the built-up area or by a plan intended for the planned development. This category includes forest and agricultural land, buildings, water bodies, and settlements. The online cadastral map website directly defines whether a specific area belongs to an urban or non-urban area, [6]. Figure 1 shows an example of urban and non-urban areas of a municipality.

Fig. 1: Example of an urban area and non-urban area, [9]

3 Slope of the Relief

This chapter defines the slope of the relief and the most common types in which the municipalities are located. The slope of the relief is a morphometric indicator of the relief. The slope angles with their direction are determined using the slope methodology, [7].

The most common types of slopes in terms of their direction include:

- slope of the relief – 1 side,
- slope of the relief – 2 sides,
- slope of the relief – 3 sides,
- slope of the relief – 4 sides, [10].

The individual types of relief are shown in Figure 2, Figure 3, Figure 4, and Figure 5.

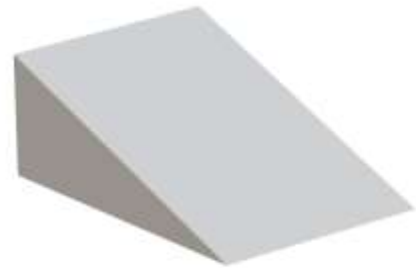

Fig. 2: Slope of the relief – 1 side, [10]

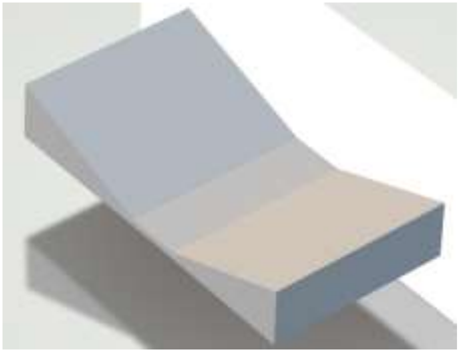

Fig. 3: Slope of the relief – 2 sides, [10]

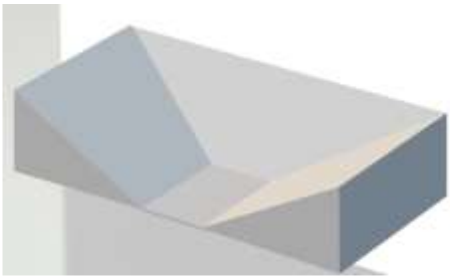

Fig. 4: Slope of the relief – 3 sides, [10]

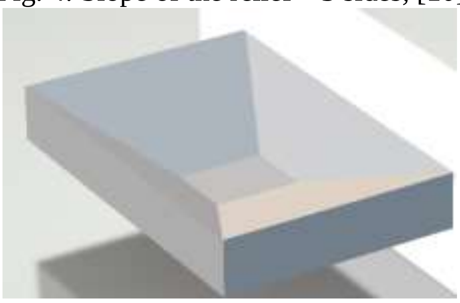

Fig. 5: Slope of the relief – 4 sides, [10]

4 Flood Protection Proposal

Within the design of flood protection in the municipality, it is essential to characterize the difference between flood and inundation. A flood occurs due to an increase in the level of rivers, streams, or reservoirs above a specified level and the consequent water spillage. The flood is caused by heavier or persistent rain or melting snow, [6].

Floods cause more frequent way of damage to property by water, [11]. Therefore, the article deals primarily with them.

4.1 Anti-flood Rig

For the security measures within the municipality's flood protection, it is proposed to create an excavation rig in the municipality to prevent damage to lives and property in the municipality. A standard concrete slab measuring 50 x 50 x 5 cm, [7], is used when designing a separate anti-flood rig, as shown in Figure 6.

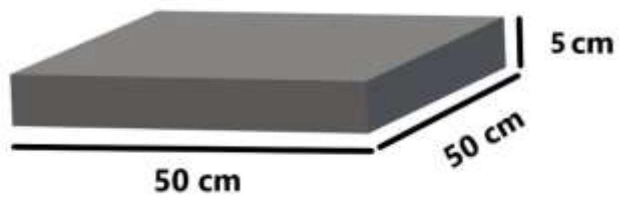

Fig. 6: Concrete block, [10]

The essential part of the anti-flood rig is created when connecting three concrete blocks.

Six concrete blocks are needed for a 1-meter-long flood protection rig. The price of one concrete slab is around 3.5 euros. The 1 meter flood protection rig without assembly work costs 21 euros, [10]. The primary part (scheme) of the anti-flood rig is presented in Figure 7.

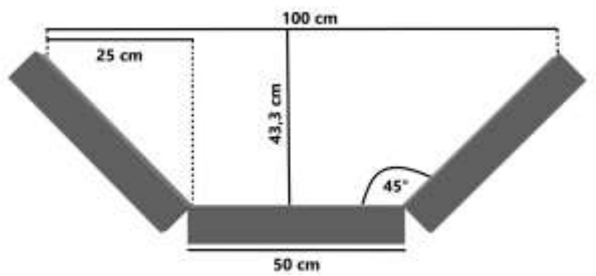

Fig. 7: The primary part (scheme) of the anti-flood rig, [10]

4.1.1 Calculation of the Volume of the Anti-Flood Rig

The fundamental basis of the anti-flood rig is a trapezoid. This means that the following mathematical formula is used to calculate meter long flood protection rig:

$$V = \left[\frac{1}{2} \times h \times (a + c)\right] \times l \qquad (1)$$

Where:
V – volume,
h – height,
a – bottom side of the trapezoid,
c – upper side of the trapezoid,
l – length.

Equations (2) and (3) calculate the volume of the anti-flood rig in the length of 1 meter. The values in the equation are expressed in centimeters.

$$V = \left[\frac{1}{2} \times 43{,}3 \times (50 + 100)\right] \times 100 \qquad (2)$$

$$V = 324\ 750\ cm^3 = 324{,}75\ litres \qquad (3)$$

Where:
V – volume,
cm^3 – cubic centimeter.

From equation (3), it is clear that the anti-flood rig with a length of 1 meter can fit 324.75 liters at total capacity. Table 1 shows the full capacities of the anti-flood rig volume depending on its size.

Table 1. The volume of the rig depends on its length and the cost of its construction [author]

Rig length [meter]	Volume [liter]	Volume [m^3]	Costs [€]
10	3 247,5	3.2475	210
20	6 495	6.495	420
50	16 237	16.237	1 050
100	32 475	32.475	2 100
200	64 950	64.95	4 200
500	162 375	162.375	10 500
1 000	324 750	342.75	21 000
2 000	649 500	649.5	42 000
5 000	1 623 750	1623.75	105 000

This fundamental part of the anti-flood rig will gradually settle into the ground, directly into the soil on the outskirts of the municipality. Figure 8 shows an example of a flooded rig filled with water.

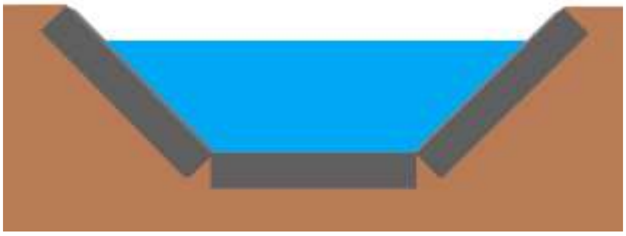

Fig. 8: Filled anti-flood rig with water, [10]

4.2 Application of Anti-Flood Rig to the Slope of the Relief

This is a proposal for the location of an anti-flood rig based on the type of slope of the relief. In this part, it is the application of the anti-flood rig to the slope of the relief on the outskirts of the municipality, [12].

In Figure 9, Figure 10, Figure 11, and Figure 12, the individual locations are shown graphically.

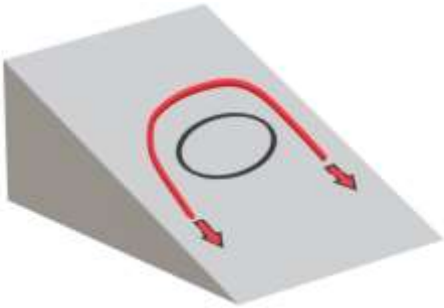

Fig. 9: Slope of the relief – 1 side, [10]

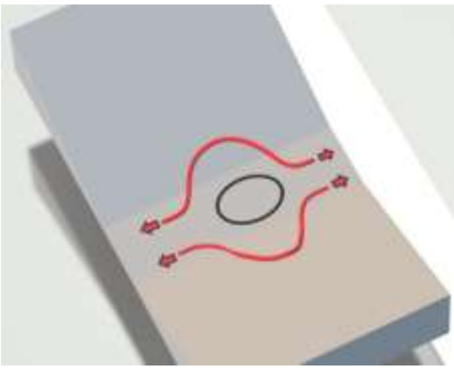

Fig. 10: Slope of the relief – 2 sides, [10]

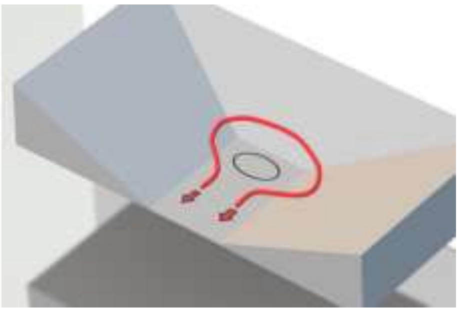

Fig. 11: Slope of the relief – 3 sides, [10]

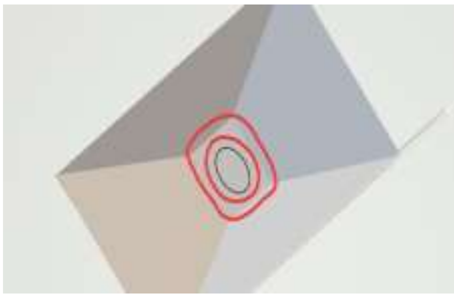

Fig. 12: Slope of the relief – 4 sides, [10]

The red line around the municipality is the location of the anti-flood rig, and the red arrows indicate the direction of water outflow. For the relief of the relief from 1 and 3 sides, it is proposed to create one continuous anti-flood rig, and for the slope of the relief of 2 and 4 sides, the creation of two continuous anti-flood rigs. The slope of the relief from 4 sides involves the creation of two continuous rigs around the municipality at two different distances for a higher risk of flooding due to the enclosed space. The most suitable way to flow water from the anti-flood rig is into the water area, whether it is through rivers, streams, lakes, or dams. If it is necessary to cross vehicles or pedestrians, it is proposed to place a concrete slab for two-way traffic with sufficient load-bearing capacity, [13].

Specifically, it is an anti-flood rig described and shown in Figure 7, and Figure 8. The ideal distance between the urban area of the municipality and the anti-flood rig should be at least 50 meters. In the case of the anti-flood rig for the slope of the relief (four sides), the individual anti-flood rigs should be at least 50 meters from each other. The anti-flood rig should be placed in the ground in such a way that it can drain a sufficient amount of water in case of torrential rain. This means that it should have an adequate slope so that water does not leak into the urban area of the municipality.

5 SWOT Analysis Proposal

The SWOT analysis consists of 4 parts: strengths, weaknesses, opportunities, and threats.

Strengths:

- minimizing flood activity in the municipality (S1),
- minimizing damage to the possible lives and property of citizens in the municipality (S2),
- increasing the level of need and feeling of security of the municipality's inhabitants (S3).

Weaknesses:
- costs of building the anti-flood rig (W1),
- anti-flood rig cleaning (W2),
- repairs of the anti-flood rig due to its damage (W3),
- intervention in the land of the inhabitants where the anti-flood rig would be built (W4).

Opportunities:
- greater interest in staying in the municipality due to greater security (O1),
- increasing the population in the municipality (O2),
- a better quality of life for citizens (O3).

Threats:
- dissent of the inhabitants for the creation of the anti-flood rig on their land on the outskirts of the municipality (T1),
- There may be a forest in the extra-urban area, and its construction is very demanding (T2),
- not allowing the construction of the anti-flood rig if it is located on the territory of the state lands (T3).

For the quantitative evaluation of the SWOT analysis, a weight and a point value are assigned to each type.

Table 2. SWOT analysis [author]

Category	Type	Weight value	Point value	Multiplic -ation	Sum
S	S1	0.3	5	1,5	**3,9**
	S2	0.5	4	2,0	
	S3	0.2	2	0,4	
W	W1	0.4	-4	-1,6	**-3**
	W2	0.1	-1	-0,1	
	W3	0.2	-2	-0,4	
	W4	0.3	-3	-0,9	
O	O1	0.4	4	1,6	**3,4**
	O2	0.3	2	0,6	
	O3	0.3	4	1,2	
T	T1	0.4	-3	-1,2	**-2,7**
	T2	0.3	-2	-0,6	
	T3	0.3	-3	-0,9	
Sum of the internal environment (S + W)					**0,9**
Sum of the external environment (O + T)					**0,7**

The most significant values of:
- strengths – minimizing flood activity in the municipality,
- weaknesses – the costs of building the anti-flood rig,
- opportunities – greater interest in staying in the municipality due to greater security,
- threats – the dissent of the inhabitants for creating the anti-flood rig on their land on the outskirts of the municipality.

Based on the SWOT analysis from Table 2, the sum of the internal environment (strengths and weaknesses) and the sum of the external environment (opportunities and threats) are in positive numerical value.

The evaluation of SWOT analysis is based on strategies that are created by combining selected quadrants. The first strategy called the alliance strategy, compares strengths and opportunities. The strategy asks how to use strengths to take advantage of opportunities. The second strategy, offensive strategy, is based on weaknesses and opportunities, that is, how to use opportunities to reduce or eliminate weaknesses. The third strategy, the so-called liquidation strategy, is based on strengths and threats, and here strengths are used to avert threats. Furthermore, the last fourth strategy, the so-called defensive strategy, is based on threats and weaknesses. In this strategy, we ask how to reduce threats concerning our weaknesses, [14].

In Figure 13, individual strategies are graphically displayed and divided into four quadrants. The resulting value from Table 2 is shown in this figure. Specifically, it is the resulting value of the sum of the internal environment (strengths and weaknesses) and the sum of the external environment (opportunities and threats). From the internal environment, the value is positive, which means that it will be based on the positive x-axis (strengths), and from the external environment, the value is also positive, which means that the value will be based on the positive y-axis (opportunities). The connection of these two axes determines the resulting point, and based on the location of the point in the given quadrant, the resulting strategy is determined.

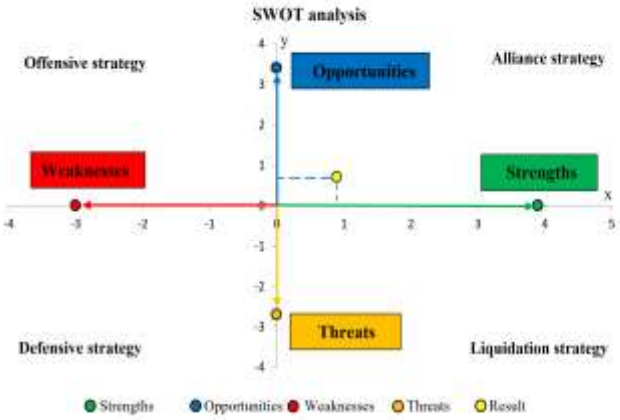

Fig. 13: SWOT analysis [author]

In this case, it results from the alliance strategy - how to use strengths to take advantage of opportunities. The concrete result is the main focus on minimizing flood activity in the municipality, minimizing damage to the possible lives and property of citizens in the municipality, and increasing the level of need and feeling of security of the municipality's inhabitants. Furthermore, a greater interest in staying in the municipality due to greater safety, increasing the population in the municipality, and a better quality of life for citizens. In conclusion, these strengths and opportunities should prevail over weaknesses and threats.

6 Conclusion

The article dealt with flood protection in the non-urban area of the municipality. In the first part, it described and characterized the non-urban area of the municipality. The following chapter defines the slope of the relief and its most common types. Based on these types of relief slopes, a flood protection proposal was created for the exterior of the municipality. A separate proposal was the creation of an anti-flood channel to channel as much water as possible due to a flood. The location of the ditch depends on the type of relief in which the non-urban area of the municipality is located. The direction of the outflow of water from the anti-flood channel should go directly to the body of water, be it rivers, streams, lakes, dams, or other bodies of water. Suppose there is no type of water surface near the water outlet from the anti-flood channel. In that case, it is ideal to direct it so that there is no flood activity in the municipality by creating an artificial dam or water reservoir. The last part of the article deals with the SWOT analysis of the proposal itself, where it describes its strengths, weaknesses, opportunities, and threats. The result of the SWOT analysis is the final value that characterizes the allied alliance - how to use strengths to take advantage of opportunities due to the development of the climate. The risk of possible floods is constantly increasing. Therefore, it is essential to create practical ways to reduce this risk in the future.

To sum up, these strengths and opportunities should prevail over weaknesses and threats. The concrete result is the main focus on minimizing flood activity in the municipality, minimizing damage to the possible lives and property of citizens in the municipality, and increasing the level of need and feeling of security of the municipality's inhabitants. Furthermore, a greater interest in staying in the municipality due to greater safety, increasing the population in the municipality, and a better quality of life for citizens. Creating an anti-flood rig minimizes the risk of flooding in the urban area of municipalities, but this does not mean it is complete protection. To increase safety, it is necessary to apply additional preventive measures. Specifically, it can be about digging canals in the municipality (if it does not have them there yet or the municipality has no sewage system). Another measure is creating an effective flood prevention plan for the municipality, where individual procedures and methods will be described as a system of prevention and subsequent repression in the event of a flood.

From other various types of research, [15], it is clear that flooding is a worldwide problem. The most significant floods are not only in Europe, [16], but also in America, [17], Asia, [18], Australia, [19], and even in Africa, [20]. Therefore, it is necessary to address this topic and solve it constantly.

The limit of the given issue is other parameters that can affect the correct calculations for water drainage. Another limit is non-urban areas, where the terrain is more difficult for the possible location of the anti-flood rig. Another disadvantage of the proposal is the occasional cleaning of the anti-flood rig, where it still needs to be precisely determined who should be in charge of this cleaning.

As part of future research, applying other coefficients for more correct calculations and creating different possible variants for placing the anti-flood rig for the given relief is advisable. It is also advisable to develop a study on the most suitable materials for the anti-flood rig to drain water over a more extended period so that natural or social threats cause no or minimum damage.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.