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FLOOD RETENTION CAPABILITIES IN A MOUNTAIN CATCHMENT: CASE STUDY OF THE COMMUNE OF SPYTKOWICE

Kinga Kuraś, Elżbieta Jarosińska
Cracow University of Technology

Summary

The experience of flooding from 2010 in the Commune of Spytkowice showed a dire need to define the factors behind the floods repeating every year in the region and to propose the best solutions for eliminating or limiting damage in the risk area. On account of the catchment's location in mountainous area, the main intention was to propose actions that would mainly increase the catchment retention capacity in the upper reach of the Skawa river and its tributary, Pożoga. By slowing down the flow, these actions may considerably contribute to the protection of the most flood-sensitive areas located in the lower part of the catchment. Two solutions have been proposed based on the idea of building dry water reservoirs and providing the possibility to resettle inhabitants from the flooded area. The choice of the best solution for the Commune of Spytkowice depends on the topography of the valleys of rivers Skawa and Pożoga, as well as the financial situation concerning the project.

Key words: flood retention, dry reservoir, mountain catchment, flood hazard

INTRODUCTION

Because of the natural topography, mountain catchments are far more prone to risk of flooding or partial inundations than their lowland counterparts. Unfortunately, not only are these events impossible to be fully prevented from occurring, but also their effects are severe to local inhabitants. Many years of

experience show now that confining water within increasingly higher flood barriers actually proves to be counterproductive. Additionally, any levee malfunction may cause colossal damage – far more serious than potential damage that would be caused without the presence of such a facility in a particular catchment (Jokiel P. 2013).

More often than not, the conventional methods of flood control that have been in use until now (levees, river channels regulation) in the upper parts of catchment fail to be effective, or could even be damaging. This is because they increase the water flow rate, thus speeding up the runoff from catchment and consequently pose harm to the areas located lower in the catchment.

The shift in perspective on flooding events has resulted in change of understanding the concept of "flood control". Rather than to prevent the occurrence of flood, which is often impossible, the aim is to manage the flood risk, which, in consequence, leads to adaptive management. What is becoming increasingly essential is the method of natural reduction of flood flow height and volume in catchment by giving the rivers their space back. This is possible provided that there are large, vacant land spaces left within the inundation area which, in case of any risk, could be flooded under control. This kind of action often proves to have beneficial effect on natural ecosystems. According to Bojarski *et al.* (2005) it is necessary to retrieve the possibility to retain flood flows, that has been earlier diminished by urban developments, e.g., deforestation, road or residential housing engineering.

Water retention, so far mainly associated with small reservoir retention (Kardel I. *et al*. 2011), has been now understood as a complex of technical, agricultural or other kinds of actions that aim at increasing the water retention capacity of a given area, extending the water circulation path by slowing down rainfall runoff, and limiting water evaporation. Rise in water retention can be obtained by building dry water reservoirs as recommended, in reasonable cases, for small mountain catchments (Bednarczyk *et al*. 2006), including the tributaries of the Carpathian rivers (Bojarski A. 2012). Previous experiences show that flood flow reduction level with the use of a dry reservoir for flood water (dry reservoir) may come to 47-65% (Lenar-Matyas A. *et al*. 2009), and this is further acknowledged by Wałęga and Cupak (2012).

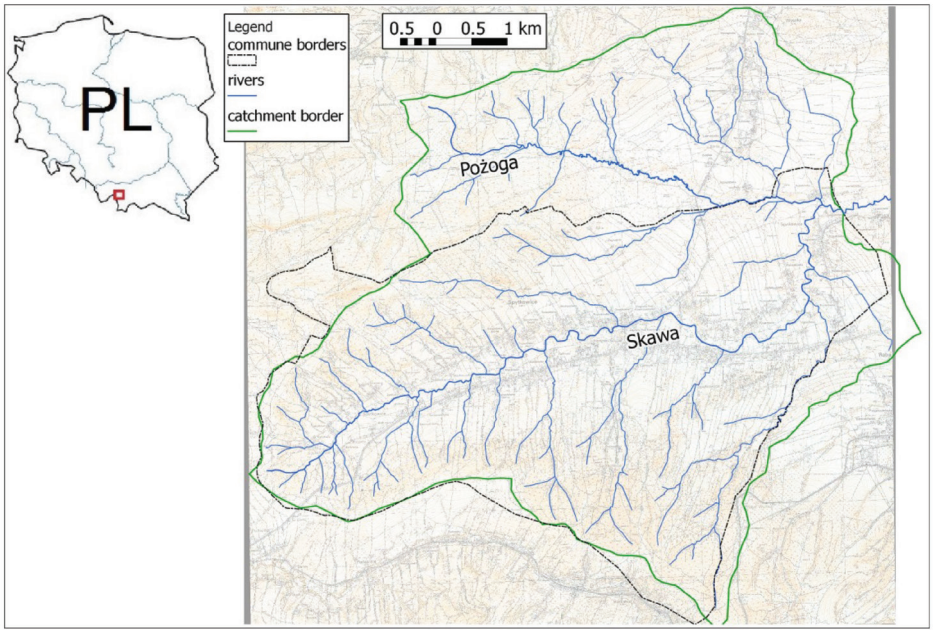
The problem of flood hazard management should be viewed not only from a local but also global perspective – in the risk area as well as in the top-down direction in the catchment itself. This is because the protection of the lower areas in catchment often depends on applying accurate technical or non-technical solutions in the upper areas. Additionally, what should be especially emphasized is the persistent problem of building developments in the flood hazard areas. Building permits are still being granted in many such areas. The 2010 events of

high water levels clearly indicate that increasing water retention can improve the safety of urban areas, as well as reduce the threat to channel stability and improve the safety of bridges (Bojarski A. 2012).

The article identifies the factors behind the flood hazard in the Commune of Spytkowice, Skawa catchment and proposes the best solutions based on retaining water in order to eliminate or reduce flood damage that occurs annually.

FLOOD HAZARD IN THE COMMUNE OF SPYTKOWICE

The Commune of Spytkowice is located in the Małopolska province, Nowy Targ district, with the area of 32 km^2 (GUS 2012). The district occupies mountainous area and includes the 12,5-kilometer headwaters of the Skawa River. The catchment of this reach, closed with a cross-section on the border of the Commune of Spytkowice, occupies area of approximately 46 km^2 (Fig.1) and extends over a few administrative units: mainly the Communes of Spytkowice and Jordanów.



Source: own work

Figure 1. Skawa River catchment – the area of flood development in the Commune of Spytkowice

On account of its natural features and location, the catchment of the examined reach of the Skawa is highly susceptible to flood hazard, both in the commune and below its territory. Elements such as steep land slopes (up to 130 ‰), large content of poorly permeable residual clay on the hillsides, as well as heavy (up to 900 mm per year) and frequent rainfall (mainly in form of heavy rainstorms and continuous rains) all contribute to large surface runoff share in catchment water balance, and relatively short runoff concentration time.

The volume of surface runoff is also influenced by anthropogenic factors, mainly by the catchment usage. Nearly half of the catchment's area is made up of arable lands (approx. 43%), and their being used against good agricultural practice leaves the potential of retention capabilities largely untapped. Equally large share of the catchment is made up of woodlands (approx. 40%). Unfortunately, their retention capability – as for a woods area – is relatively low on account of the large share of a shallow root system kind of spruce in the tree stand, and poor content of the forest cover and undergrowth (Ziętara T. 1997). At present, only about 10% of the catchment's area is made up of fully sealed surface, i.e. of building and traffic areas. As the commune is developing, however, it keeps increasing and the loss of retention capability is not observed to be compensated for.

During rainfall, retention capability limited by both natural and anthropogenic factors contributes to formation of flash floods in river and stream channels. This results in higher flood hazard both in the commune and the lower-lying areas.

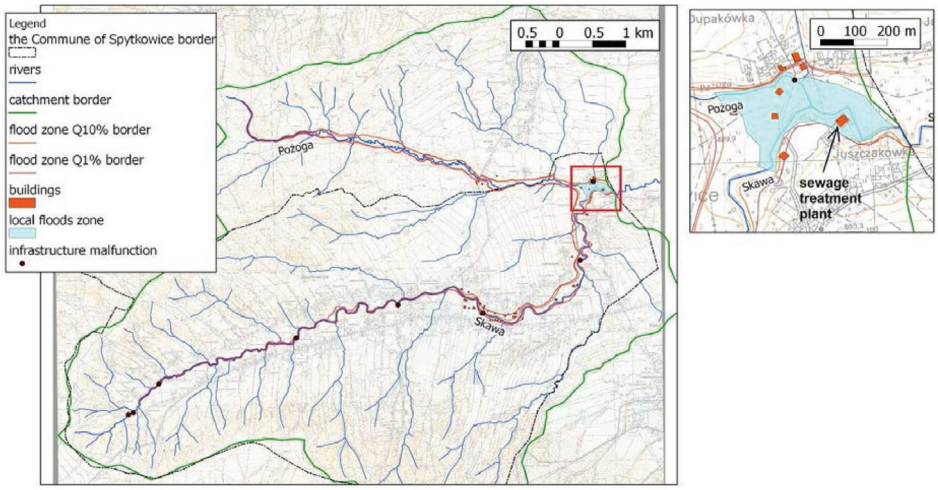


Figure 2. Buildings and areas in the Commune of Spytkowice damaged by flooding in the years 2007-2010

The flood hazard zone in the Commune of Spytkowice is relatively small, and it stretches mainly over a fragment of the Skawa River valley and an area at the outlet of the Pożoga stream (Fig. 2). Annually repeated floods as a result of summer rainfalls cause serious financial and social damage in the region.

Photo 1. Flood on the Pożoga, scouring of bridges and bridgeheads – June 2010 (source: commune archives)

Photo 2. Local flood in the Commune of Spytkowice, flooded gardens and buildings – June 2010 (source: commune archives)

Photo 3. Local flood in the Commune of Spytkowice, flooded unmade roads and surrounding grasslands and farm fields – September 2010 (source: commune archives)

Photo 4. Intense surface runoff, erosion of channel banks and riverside infrastructure elements – September 2010 (source: commune archives)

Flood losses to the Commune of Spytkowice in the years 2007-2010 accounted for 25-55% of the commune's own incomes. They included mostly the damage to transport infrastructure (roads, bridges, passes), the elements of regulation and stream armouring, as well as flooded buildings (residential houses and farm buildings) and adjacent equipment (Photo. 1-4). So far, the largest flood and also the largest loss in the Commune of Spytkowice occurred in 2010. The flow rate that then occurred was estimated as the 10-year water. It threatened to flood

the local sewage treatment plant that would have resulted in damaging in-building installations and systems, and shutting the facility down, which would consequently lead to considerable pollution.

Despite annually repeated floods in the region, the Commune of Spytkowice does not have at its disposal any flood protection measures. There is no funding available for flood protection due to the local community paying little attention to the matter. One known exception is listing the flood risk areas in Studium (2012), a publication that limits the possibility of erecting new construction projects in the said areas, and includes the need for deciding on the means to increase catchment retention and improve the monitoring system.

Unfortunately, these objectives have yet to be translated into action. While addressing the problem of flood hazard for the existing facilities in the catchment, the focus seems to concentrate only on flood damage repair, and the problem of hazardous runoff from catchment to the lower-lying areas still have not been resolved.

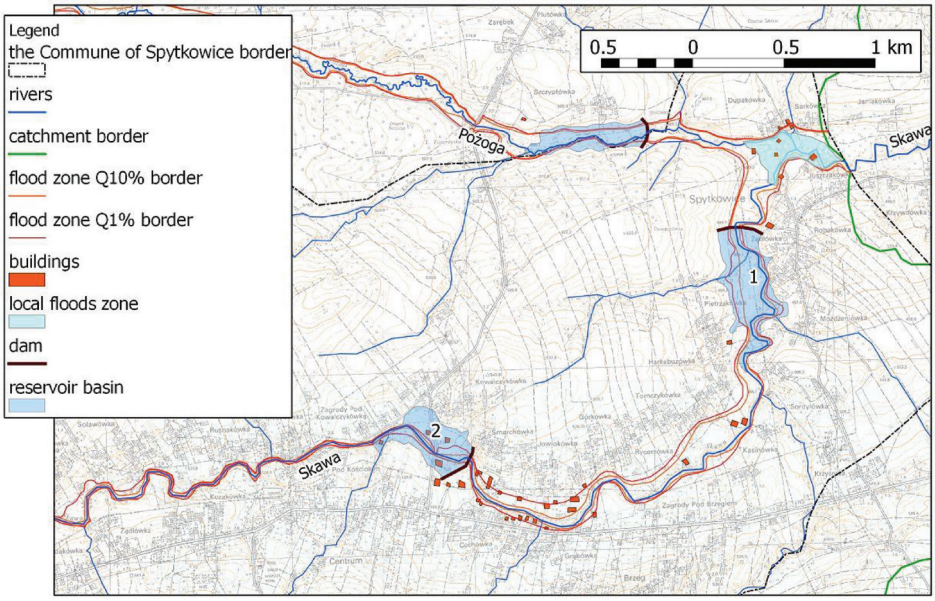


Figure 3. Proposed locations of a dry water reservoir in the Commune of Spytkowice

SOLUTIONS PROPOSALS

The best solution to the present flood hazard in the Commune of Spytkowice would be controlled retaining of water in the catchment's area, and thus

increasing natural retention capability in the upper part of the catchment. To this end, technical or non-technical solutions can be applied.

Flood hazard as a consequence to the intensity of floods on the Skawa river and Pożoga stream in the Commune of Spytkowice, as well as the lie of the Skawa and Pożoga valleys, are the determining factors behind choosing a dry water reservoir as a technical solution of prevention. Its great advantage is lower building cost comparing to that of a storage reservoir, as well as reduced tampering with natural environment, and a possibility to further use the reservoir basin as hayfields or pasture areas. Its location mostly depends on the land topography, and also on the level and development of the lower terrace, including the location of the most threatened area.

An analysis of the above-mentioned factors resulted in proposing three possible locations for dry water reservoirs in the Commune of Spytkowice (Fig. 3) – each of different characteristics (Table 1).

Table 1. Characteristics of proposed dry reservoirs (Characteristics result from morphology and land development, they are not based on a hydrological analysis of catchment.)

Reservoir	Skawa 1	Skawa 2	Pożoga
Catchment area to dam site (km^2)	28	17	11
Reservoir basin area at full capacity (ha)	14	10	8
Approximate dam height (m)	5	5	5
Approximate reservoir volume (million m^3)	0,31	0,23	0,18

Choosing the best reservoir from among the proposed options depends on the scales of protection and the location of the facilities in question. At this point, two flood protection variants can be distinguished: VARIANT 1 – protection against $Q_{10\%}$ flood, and VARIANT 2 – against $Q_{1\%}$ flood.

To ensure protection against $Q_{10\%}$ flood, VARIANT 1 requires building a dry reservoir on the Skawa (Skawa 1). This entails ensuring protection of the area at greatest risk in terms of flood frequency, also called local flood area. Reservoir Skawa 1 could also partially protect valley areas below the examined catchment – in the Communes of Raba Wyżna and Jordanów. The choice of this reservoir location is valid in terms of economic and social point of view. As the basin of the proposed reservoir lies in an undeveloped part of the valley, the need for resettlement or road reconstruction becomes eliminated. Considering this variant in connection with local flood area protection, another solution should be given thought to as well. The fact of small number of buildings in the risk area would allow for resettling its inhabitants. The expected downside to this variant will be social factors connected with local people's protest against

moving, as well as economic element in terms of rebuilding costs. What is more, this solution does not offer protection of the local sewage treatment plant, and would require additional measures.

VARIANT 1 does not take account of protecting facilities located in the Skawa valley above reservoir Skawa 1. Flood hazard is related to the location of these facilities in the flood zone of flow $Q_{1\%}$. Such flow poses serious threat because of increasingly more frequent extreme weather events connected with climate change. Thus, to ensure protection, it is necessary to introduce VARIANT 2 and build dry reservoir Skawa 2. This way, the reservoir could protect the facilities located in the valley of the Skawa below the dam as well as in the local flood area at the Pożoga estuary, and further below the examined catchment. A significant disadvantage of this reservoir's location is, again, the necessity to resettle the inhabitants of the basin, and redevelopment of the existing technical and transport infrastructure. This involves high investment costs and long realisation time. In consequence, this choice would require public consultation, and its profitability – a careful economic review.

On account of the increased risk posed by the Pożoga, to ensure more complete protection of the local flood areas as well as areas located below the catchment, it has been proposed, as an addition to the two above-mentioned variants, to build a dry reservoir on the Pożoga. The designed reservoir basin includes undeveloped areas which benefits the investment. The downside, however, is that its fragment would have to lie over the borders of the neighbouring Commune of Jordanów (the Sucha district). Still, the Commune of Jordanów is located in the lower part of the Skawa catchment, and building the reservoir might thus partially lower the flood hazard in its area. Resolving the problem in collaboration of both communes should, therefore, prove advantageous for cooperative investment realisation.

One of the main reasons behind limited use of flood protection measures is high technical costs. This kind of solution, however, should not be rejected completely because a flood protection facility, such as dry reservoir, is capable of significant decreasing, or even eliminating the costs incurred every year as a result of flood damage. This means that the investment may become profitable over a period of a few decades. In order to choose the best of the proposed options, it is necessary to carry out a careful analysis of realisation costs and correlate them to the financial capability of investment. Limiting flood damage as a result of building a reservoir concerns not only the Commune of Spytkowice where the facility would be located, but also those communes that lie in the lower parts of the catchment. This argument should underlie obtaining financial help from the central budget and provincial funds, as well as cooperating with neighbouring administrative units in investment preparation and realisation.

Non-technical methods of flood protection, which are becoming increasingly popular and widespread in use, work by increasing catchment retention

capability through retaining water, for example in soil, plant cover and recess areas. Increasing the Skawa catchment retention capability in the Commune of Spytkowice involves a lot of work both from the commune and its residents, especially that due to problematic conditions in the catchment, e.g. varying land slopes, the effectiveness of their activity might be insufficient. They should not be renounced altogether. Non-technical solutions should be applied simultaneously with technical solutions. Gradual increasing of community's awareness concerning direct and indirect advantages of water retention and the methods of retention increasing can greatly contribute in the future to their effectiveness, or restoration of retention lost due to commune's development.

SUMMARY AND CONCLUSIONS

Flood prevention planning in the Commune of Spytkowice is a problem case. It requires special consideration for a number of natural and anthropogenic factors present in the catchment, as well as careful review of the influence that the proposed solutions could have on the quality of environmental, social and economic elements. Having extensively diagnosised the present flood hazard situation in the lower part of the catchment in the Commune of Spytkowice, it can be observed that the commune has got at its disposal retention capability in its upper area, and the two proposed solution variants of risk areas protection have every chance of successful realisation.

Human activities will not guarantee complete flood prevention for the areas at annual risk of flooding, however they can certainly diminish the probability of its occurrence. Thus, it is highly recommended that measures of decreasing catchment runoff are taken for the protection of submontane areas.

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inż. Kinga Kuraś, student
Cracow University of Technology
Institute of Water Engineering and Water Management
ul. Warszawska 24, 31-155 Kraków
Dr inż. Elżbieta Jarosińska
Cracow University of Technology
Institute of Water Engineering and Water Management
ul. Warszawska 24, 31-155 Kraków
ejarosin3@gmail.com