MORPHOLOGICAL ROLE OF FLOODS IN THE SHAPING OF STREAM CHANNELS IN THE GORCE MOUNTAINS (EXEMPLIFIED BY JASZCZE AND JAMNE STREAM VALLEYS)

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Anna Bucała: Morphological role of floods in the shaping of stream channels in the Gorce Mountains (exemplified by Jaszcze and Jamne stream valleys). Geomorphologia Slovaca et Bohemica, 10, 2010, 1, 7 figs., 27 refs.

The article describes the morphological role of downpours in the shaping of valley bottoms in the Gorce Mountains, exemplified by the Jaszcze and the Jamne stream valleys during the rainfalls that took place in 1997 and 2008. The results of the flood from the first decade of July 1997 were specified on the basis of air photos analysis. On the other hand, in July 2008 direct observations of rainfall and its effects were conducted. Geomorphological mapping has shown that changes in the Jamne stream channel were more significant than those in the Jaszcze stream valley due to lower forest cover and denser drainage network. The results were compared with other streams in the Gorce Mountains.

Key words: channel processes, floods, Gorce Mountains, the Jamne and the Jaszcze stream valleys

INTRODUCTION

Morphological importance of floods is based on the sediment transport by flowing water, removing of all sediments from steeper part of streams beds as well as up building of the lower stream channels and flood-plains through the accumulation of gravels (KLIMASZEWSKI 1934).

A large amount of research has been carried out in the Polish Carpathians to investigate the geomorphological role of floods in the contemporary evolution of mountain valleys (ZIĘTARA 1968, KASZOWSKI 1973, NIEMIROWSKI 1974 or KRZEMIEŃ 1984).

Heavy downpours and continuous rainfalls accelerate the denudation processes on slopes as well as the erosion and accumulation processes on the valley bottoms (SŁUPIK 1981, STARKEL 1996 or GIL 1998). The intensity of floods and their geomorphological effects depend not only on the amount and duration of rainfall, but also on their intensity and spatial extent.

Heavy downpours overlapping with period of continuous rainfall that can last for several days are a frequent phenomenon. Such a situation took place in July 1997 in the western part of Polish Carpathians and to the cast in the Dunajec river basin during five days followed sequence of downpours which repeated every afternoon (GRELA et al. (eds.) 1999).

This case has been recorded in the Homerka stream (Beskid Sądecki Mts.), where during last downpour on 9th July 1997 rainfall exceeded 2 mm/min and single boulders with a diameter of 55 – 75 cm were transported (FROEHLICH 1998). Similar situation has been described from Łososina catchment (Beskid Wyspowy Mts.), where during last day water level raised 2.8 m (GERMAN 1998). As well as in the Uszwica river valley where the severe downpours of 7th, 8th and 9th of July, respectively of 50, 80 and 120 mm, were reported. Undercutting and suspension of the outlet sections of side valleys and the accumulation of gravelly material on the flood plain occurred (PATKOWSKI 2002).

The aim of this article is to present the morphological role of floods in the Gorce Mts. based on of the Jamne and the Jaszcze stream channels study in reference to the events observed in surrounding areas.

METHOD OF RESEARCH AND STUDY AREA

On the base of air photos at scale 1:9 000, taken directly after the rainfalls in July 1997, as well as geomorphological mapping conducted during the rainfalls in July and September 2008 it was analyzed the morphological role of floods in the formation of stream beds. On the 400 m section of the stream Jamne the size of

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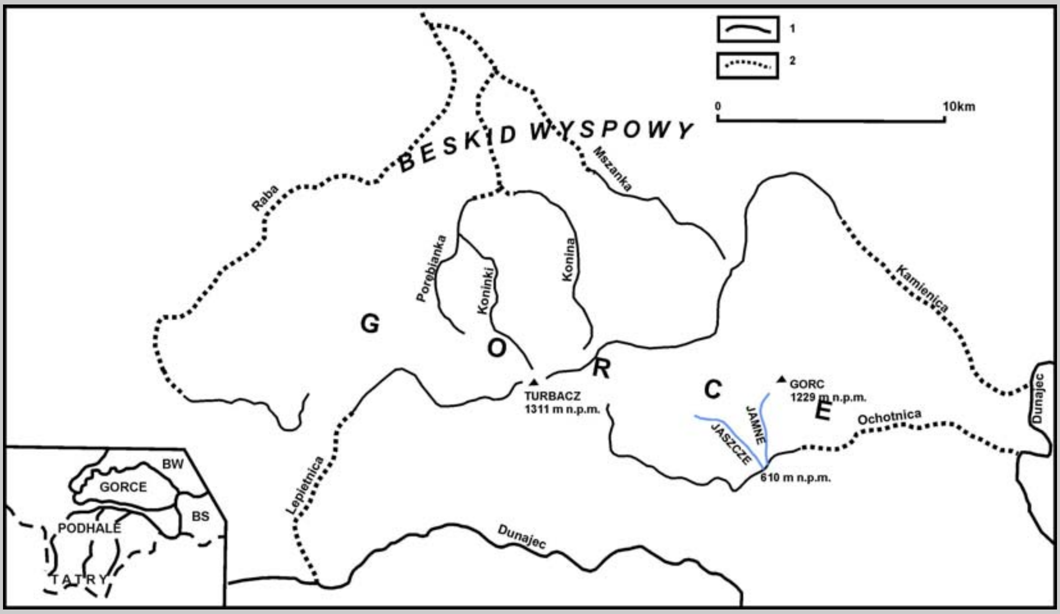

Fig. 1 Study area
1 – rocky stream – channel, 2 – alluvial stream – channel
BS – Beskid Sądecki Mts. BW – Beskid Wyspowy Mts.
Source: based on: Krzemień 1984

gravel bars formed there after the floods in July 1997 was estimated using GIS technics. Due to similar precipitation totals the effects of 1997 the flood were compared to the results of 1970 floods (NIEMIROWSKI 1972 and 1974). M. NIEMIROWSKI (1974) has conducted researches on stream processes in the catchments of the Jamne and the Jaszcze after the flood in 1970. The Head of the Gorce National Park provided access to the air photos, made in 1997.

The Gorce Mts. are middle mountains, characterized by radiate pattern of mountain ridges that spread in multiple directions from the highest peak of the Turbacz (1311 m a. s. l.). The river valleys drain water in SW, S and E directions to the Dunajec river, as well as in W, NW and partially N directions to the Raba river (KONDRACKI 2002 or CIESZKOWSKI 2006). Two synclines dominate in geological structure of the Gorce Mts. Synclinal flanks built with resistant sandstones form distinct denudational steps limiting the massif.

The landscape of domal elevations, reaching 1100 – 1300 m, is surrounded with a 700 – 900 m high level with flat top. Regressive terraces and waterfalls are a common features in the narrow valley bottoms, deliver evidence of their contemporary deepening (STARKEL 1972). The Gorce Mts. show present day tendency to tectonic uplift (ZUCHIEWICZ 1978). Slopes of narrow V-shaped and deeply incised stream valleys are steep. At the outlets of valleys alluvial cones are formed. Meandering course of stream beds and unlevelled gradients are imposed by the diverse geological structure and alternatively layered shales and sandstones. Streams in the Gorce Mts. have channels incised in the rocks of different resistance as well as alluvial channels cut in alluvia with dominance of coarse sandstones. The border between rocky and alluvial parts does not always correspond to lithological contacts. The gradients of the streams are unlevelled and they are as follows: the Konina 57.0 ‰, the Koninki 74.1 ‰, the Porębianka 35.4 ‰, the Jaszcze 62.0 ‰, the Jamne 51.0 ‰. Their tributaries are often hanged in relation to the main valleys (NIEMIROWSKI 1974 and KRZEMIEŃ 1984).

The upper part of the Jaszcze and the Jamne stream channels are of erosive character what is typical for upper parts of streams in the Gorce Mts. (**Fig. 1**). These left-bank tributaries of the Ochotnica river have V-shaped and deeply incised valleys (up to 300 m) and narrow channels with numerous rock steps. More than 61 % of slopes has inclination above 18°. The lower parts of slopes are even steeper.

The catchment of the Jamne stream is build mainly from the marl-silicate series, while in the Jaszcze catchments more resistant quartz-silicate rocks occur. Differences in lithology are reflected in shape and inclination of slopes as well as in soils between discussed catchments. Those differences cause divers participation of forest cover (76.70% in the Jaszcze and 55.46 % in the Jamne).

Soils have depth of (80 – 100 cm) and contain many skeletal parts. The parent rocks are covered with a clay-loamy waste up to 2 m thick (NIEMIROWSKA and NIEMIROWSKI 1968, ADAMCZYK and KOMORNICKI 1969). The mean annual precipitation for the period 1970 – 2007 for the study area is 832 mm at Ochotnica Górna station.

The catchment of the Jaszcze stream is a narrow valley with very steep slopes exposed mainly to south and north-east and forested in the upper part. The higher parts of valley slopes are covered with forests, meadows and pastures. In the lower parts there dominate arable lands. The Jamne valley is wider. Its slopes are not so steep and they are exposed to the south. They are mainly deforested and arable lands here extend up to 1100 m a. s. l. (MEDWECKA-KORNAŚ, KORNAŚ 1968 or BUCAŁA 2009).

The channels of both streams in their source segments are about 1 m wide and their gradient is more than 60 ‰. They are shaped mainly by the bottom erosion. In lower parts of valleys, channels are wider, up to 1.5 m of width and their gradient decline to 30 ‰ in these segments. The valley bottoms are flat. The lateral erosion and accumulation are dominant features. The stream channels of both discussed valleys are cut in solid rocks. Numerous rocky steps and outcrops occur, except of the lower part of the Jamne stream channel, where the stream bottom is covered with alluvial sediments. Between rocky parts, there are relatively large gravel bars, especially at the outlets of smaller valleys where the width of the river

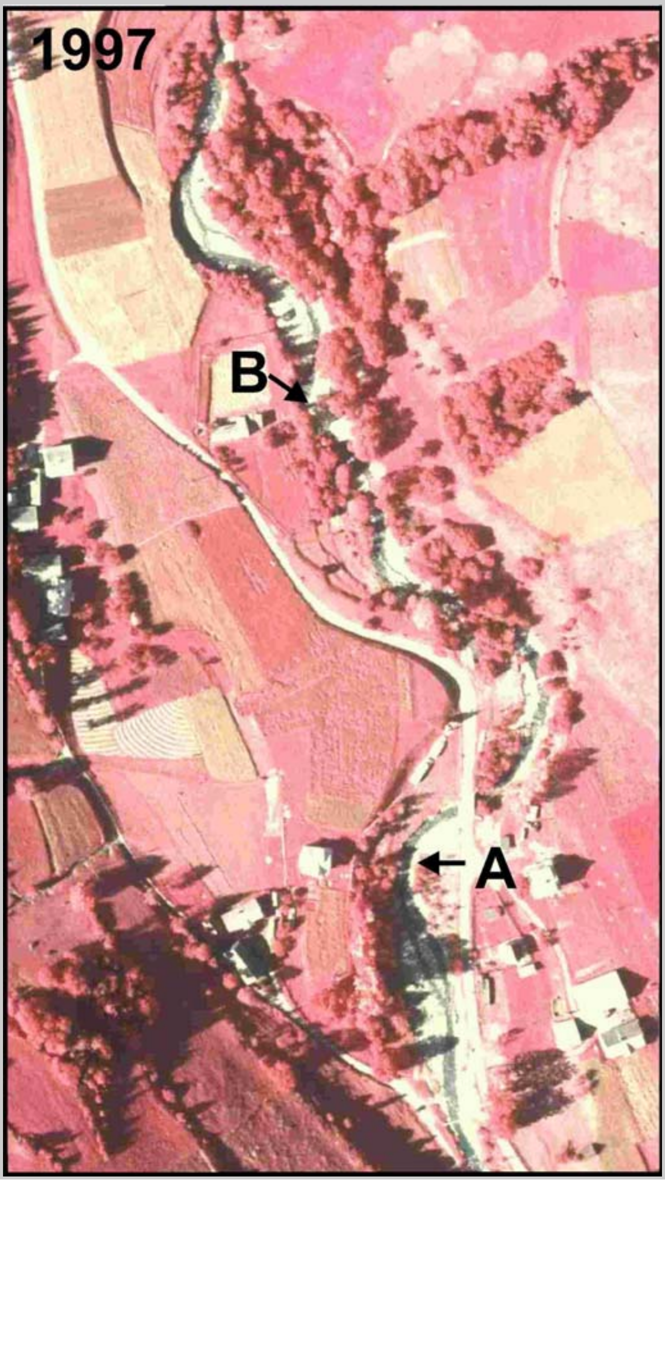

Fig. 2 Jamne river bed in its lower part, 400 m long in 1997

A – gravel bar, B – erosive undercut

Source: the Gorce National Park

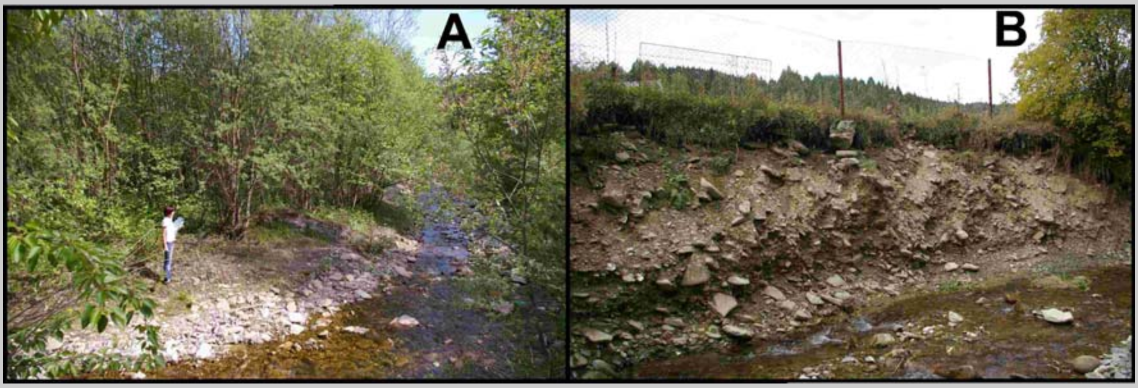

Fig. 3 Retained river bed forms in the Jamne river in 2008

A – gravel bar created in 1997 (photo taken in 2008), B – an erosive undercut modelled by several floods (photo taken in 2008)

Photo: Anna Bucała

bed is up to 10 m (Jamne stream), that undergo transformation with every occurring flood event in the region. The network density is 4.26 km/km^2 in the catchment Jaszcze, and 5.33 km/km^2 in the Jamne catchment (NIEMIROWSKA and NIEMIROWSKI 1968).

FLOOD ACTIVITY IN THE GORCE MOUNTAINS

Floods in the streams of the Gorce Mts. occur most frequently in summer and spring. Spring floods are the result of the rapid melting of snow accumulated during the winter. Summer floods (June, July) are either the result of continuous rainfalls, sums of which can exceed 250 mm during 3 – 5 days or the effects heavy downpours, lasting 60 – 120 minutes, during which 40 – 60 mm of rainfalls while their spatial extend is limited to no more then few dozen of square kilometers. The intensity of such rainfalls can even reach 2 – 4 mm/min (SOJA 2006).

Similar events were reported in the Jamne and the Jaszcze streams. Daily precipitation of 154.9 mm, triggered the catastrophic flood in 1970 (NIEMIROWSKI 1974). However, the direct cause of the transformation of stream channels in 1997 were short lasting downpours during 8 – 9 July (124.5 mm). The flood in July 2007 was prompted by the daily precipitation of 76.3 mm (data by IMGW). Similar rainfall totals occurred in the Konina stream valley in 1973. The rainfall of 121.0 mm caused the extreme flood with the culmination of 162 cm (KRZEMIEŃ 1976).

The flood frequency in both rivers is similar. But in the deforested Jamne catchment the raises of water level are more frequent (NIEMIROWSKI 1974).

EFECTS OF 1997 FLOODS IN THE JASZCZE AND JAMNE STREMS WITH COMPARED THE 1970 FLOODS

After the downpour during the first decade of July in 1997 the stream channels were transformed, but it could not be registered on air photos due to low width and afforestation of the Jamne and the Jaszcze channel.

However in the Jaszcze stream was found a change of channel course at 30 m long distance, after analyse of topographic map (scale 1:10 000) and some field research. Whereas the changes in the Jamne stream were noticed depicting a 400 – meter-long forestless part of stream bed in lower segment of the stream. The size of gravel bars formed there after the flood in July 1997 was estimated using GIS technics. Their area was 3 629 m^2. Bars are built by relatively coarse gravel, with max. size of single gravels exceeding 60 cm. Similar gravel of sizes up to 80 cm were transported during flood in 1973 in the Konina stream (KRZEMIEŃ 1976) and 55 – 75 cm in 1997 in the Homerka stream (the Beskid Sądecki Mts) (FROEHLICH 1998).

The examined part of the Jamne stream channel has been transformed during flood in 1997, and at present it is revegetated. Gravel bars are inactive, covered with bush and tree vegetation. During smaller floods they remain neither incised, nor upbuild (**Fig. 3A marked on Fig. 2**).

A characteristic erosional forms in the lower part of the Jamne stream is the undercut of the right river bank (**Fig. 3B marked on Fig. 2**), which is being constantly retreated during every larger flood. It was also modelled during the 2008 flood. An evidence of the erosive activity is a fence that is now suspended

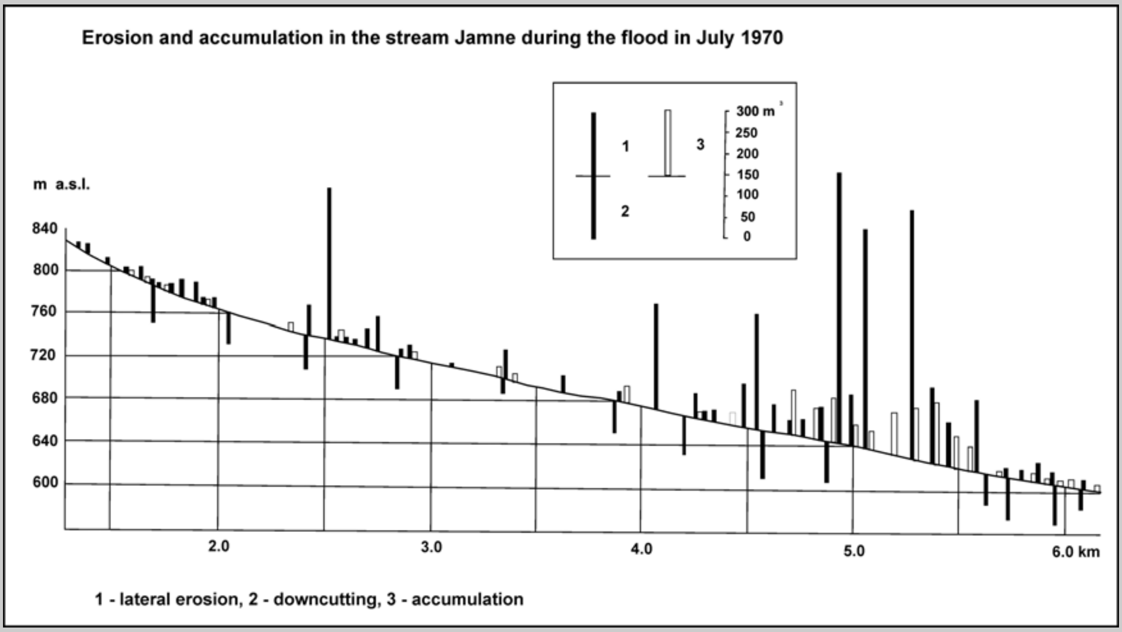

Fig. 4 Erosion and accumulation in the stream Jamne during the flood in July 1970
Source: Niemirowski 1974

about 80 cm above the stream bottom. The stream bank in this part has been retreated 3.0 – 3.5 m (personal communication), a fact confirmed by comparison of air photos from 1997 and 2004.

Apart from geomorphological effects, local damages of houses, bridges and roads occurred during the flood in 1997. Penetration system under roads bridges was blocked with wood dams that served as barrages (personal communication).

A similar event took place in 1997 in the Kamienica Łącka stream (Gorce Mts.), where due to bank erosion and mass movements a large portion of wood debris was delivered to the stream (KACZKA 1999a). In upper part the energy of stream was lower due to wood debris causing deposition of transported debris material in the form of gravel bars. In the lower parts of the stream wood debris created only minor gravel „shades". The wood debris themselves, however, were subject to further transport and sedimentation due to the activity of water during the flood. The biggest influence on a velocity of water flow and wood debris transport have the logs that dam the stream bed completely. They build dams often 1 m high. Wood dams are halted in the upstream part and water coming down from the bar creates erosion of pots. These bars are the cause of local deep erosion rising and force aggradations in the stream bed upstream the dam (KACZKA 1999b).

Due to similar precipitation totals the effects of 1997 flood were compared with an event in the Jamne and the Jaszcze streams on the 18th of July 1970 (NIEMIROWSKI 1974). During that event the transport of wood dams encompassed all the fractions, 95 cm including. The undercut banks retreated to 1.2 m in the Jaszcze stream, and in the alluvial channel of the Jamne stream even up to 7 m. The total length of undercuts in the Jamne was 468 m on the left, and 770 m on the right stream banks. In the Jaszcze stream bed the undercuts on left bank was 154 m long, on the right 166 m long. The gravel bars in flood-plains of both streams have undergone total transformation. Accumulation in the Jaszcze stream was small, because only 191 m^3 of debris were deposited within the valley bottom, whereas in the stream bottom of the Jamne 1474 m^3 of debris was deposited (NIEMIROWSKI 1974) (**Fig. 4 and 5**). The distinct difference in accumulation size between the discussed catchments is connected with redeposition of debris that builds gentle footslopes and terraces.

ROLE OF 2008 DOWNPOURS AND FLASH FLOOD IN THE SHAPING OF STREAM CHANNELS

During the field work in 2008 the course and effects of downpours were directly observed. The highest water level (about 1 m) in the Jaszcze and the Jamne streams occurred on the 23rd of July at 5 pm. The largest changes took place in the Jamne stream bed due to faster water outflow connected with extensive

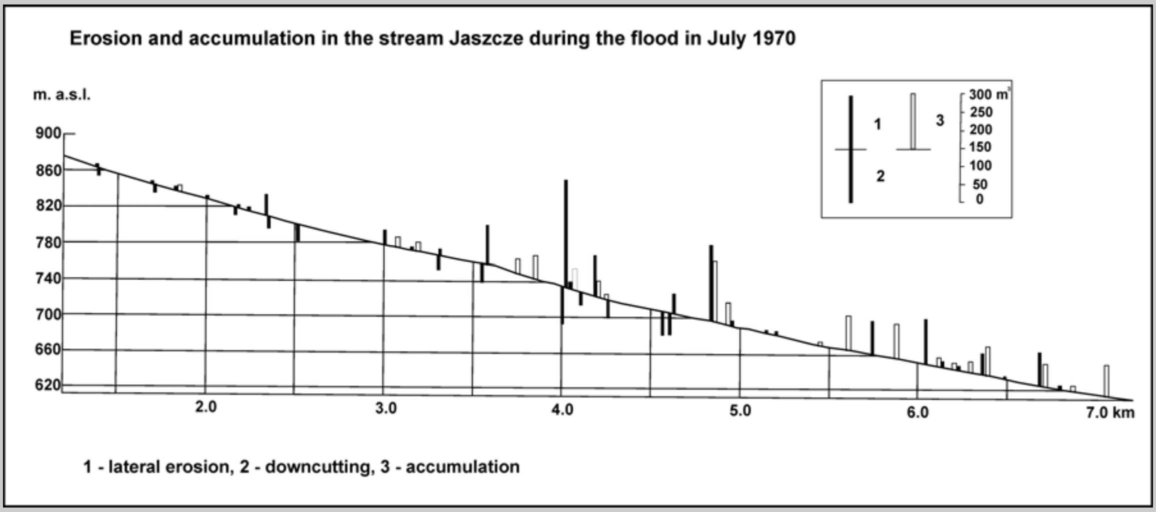

Fig. 5. Erosion and accumulation in the stream Jaszcze during the flood in July 1970
Source: Niemirowski 1974

deforested areas and higher stream network density compared to the Jaszcze stream. The whole of the examined stream bed was influenced by either erosion, or by deposition of debris. Lateral erosion influenced both stream banks wherever narrowing of stream were present, while wherever the river was meandering, lateral erosion influenced only the concave valley sides **(Fig. 6 and 7)**.

In the Jamne stream lateral erosion strongly dominated over deep erosion, causing the rejuvenation of old erosive undercuts and the creating of new ones to 3.5 m high. The transported material was derived from slopes and fluvial covers in the valley. Jamne transported gravels up to 25 cm. It was accumulated in the stream channel downstream. The bigger gravels and boulders were transported by saltation, what was indicated by noise accompanying their movement. Existing gravel bars were cut and upbuilt, and new ones were created. After flood in 2008 a geomorphological mapping of 400-meter-long forestless part of Jamne stream was undertaken. It was found that fresh gravel bars occupy on area of only 415 m^2. In this relatively small bars dominate material fraction of about 15 cm. Probably during every downpour event follows similar transformation as it was during the flood in July 2008.

During every single more significant flood in the streams of the Gorce Mts. lateral erosion is dominant process. It creates new bank undercuts and the renewal of the old ones. Similar changes were observed in the Konina stream in 1973, where the river bank was pushed back to 2.5 m on a 50 m long distance (KRZEMIEŃ 1976).

DISCUSSION AND CONCLUSIONS

Extreme floods play the most significant role in the morphodynamics of in the Gorce Mts. streams (NIEMIROWSKI 1974, KRZEMIEŃ 1976). An intensive input of material comes from slopes via a system of roads and from undercuttings of old accumulation levels. Also the deposition of gravel bars takes place during such floods. The thickness of accumulation covers in stream channels decrease in the forest areas, opposite to the role of deep erosion (KRZEMIEŃ 1984).

M. NIEMIROWSKI (1974) in the stream beds of the Jamne and the Jaszcze stated that floods with a discharge less than 0,8 – 1,0 m^3/s are those which don't cause significant changes.

During higher discharge local lateral and bottom erosion takes place. It causes the erosion of river steps formed within thin and medium layers of sandstones and the enrichment of the bottom debris with new material, that is visible in the increase of maximum fraction size. The largest changes take place in channel of the main stream. It happens especially in the segment of the main channels blocked by floating wood logs and tree branches, which can also be the cause of damages to hydrotechnical infrastructure, as was observed by author also in the Jamne and the Jaszcze stream channels.

In the Jamne and the Jaszcze streams lateral erosion is the most important factor during the floods. The role of incision is not so significant, while rock outcrops are very resistant to erosion. The alluvial covers are mostly delivered mainly from undercutting. The changes in

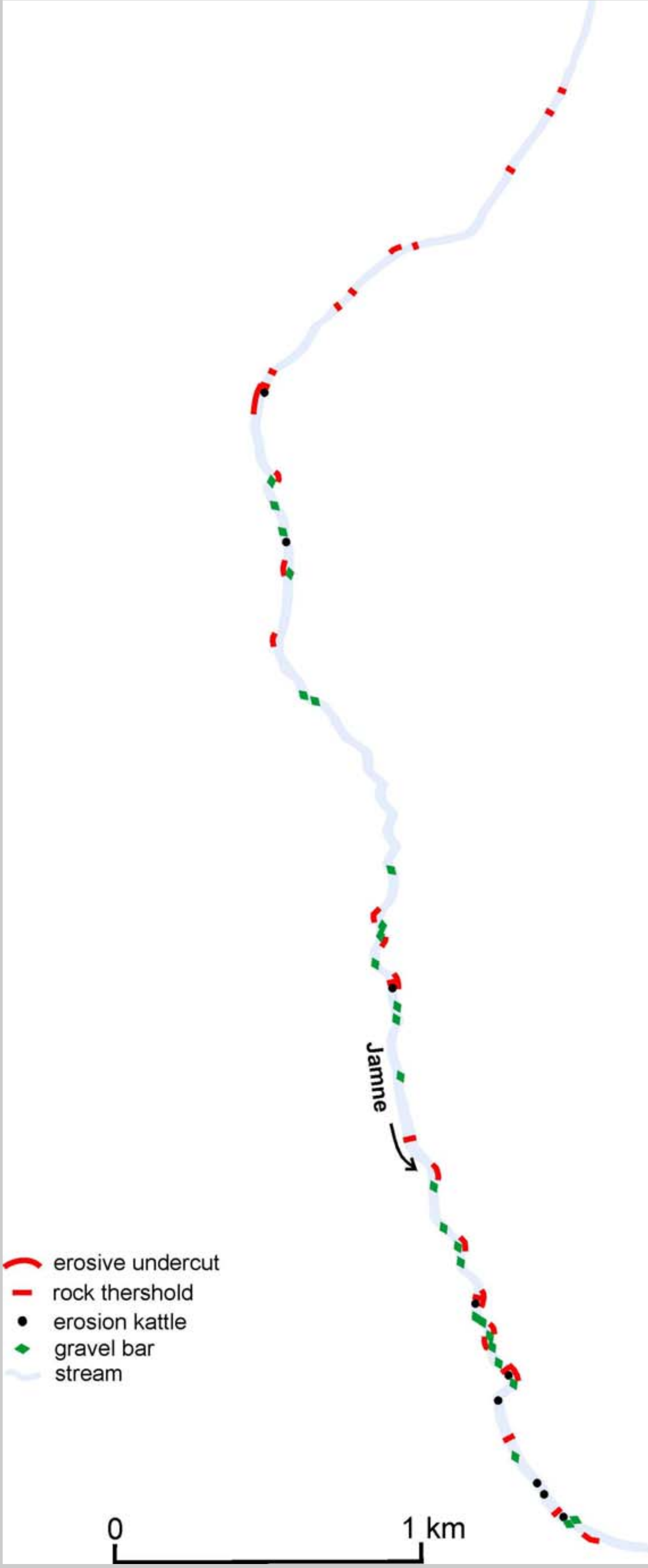

Fig. 6 Natural forms in the stream Jamne after the flood in July 2008

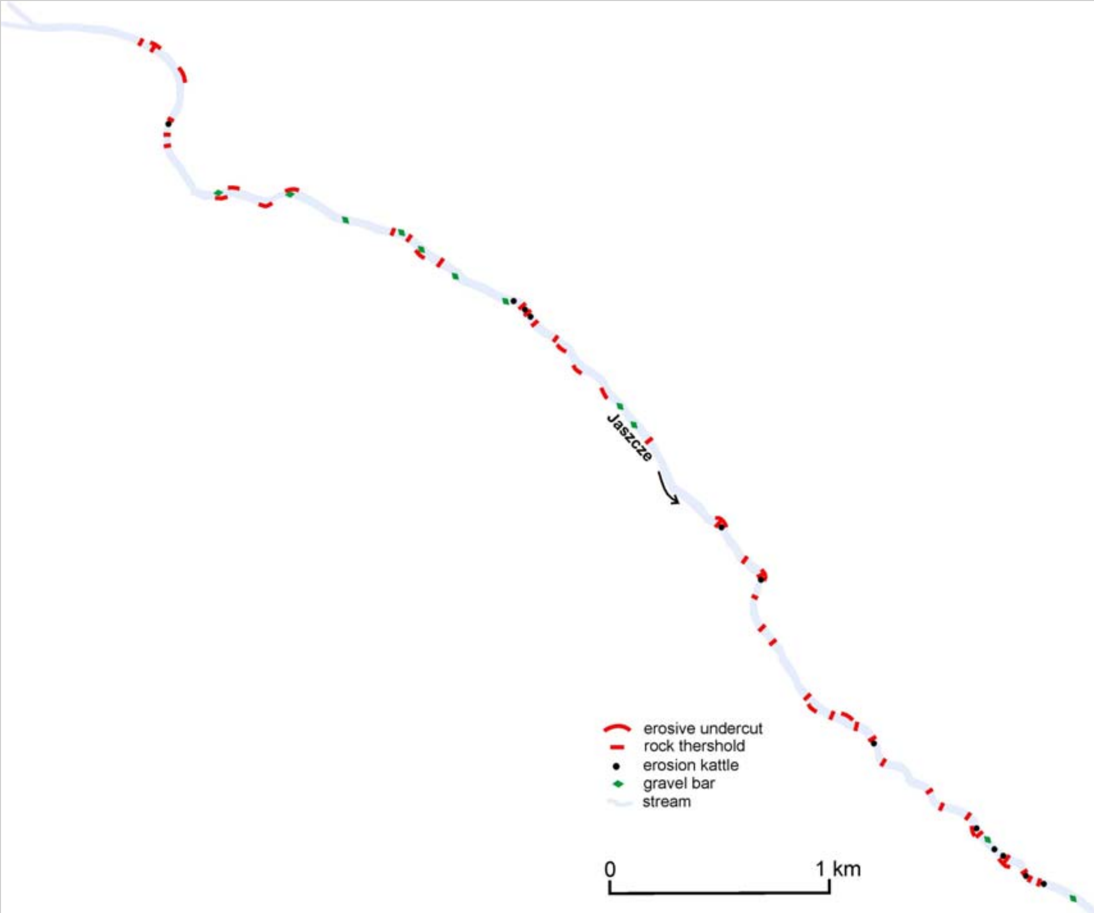

Fig. 7 Natural forms in the stream Jaszcze after the flood in July 2008

the Jamne stream valley were much bigger than the ones in the catchment of the Jaszcze stream. It is a result of difference in land use, causing the rapid outflow and moving of alluvial fills from in the Jamne catchment. The amount of material removed during the flood in 1970 in the Jaszcze stream catchment was 15 times lower and the incision rate 10 times lower than that in the Jamne stream catchment (NIEMIROWSKI 1974). The intensity of fluvial processes was also much higher in the Jamne than in the Jaszcze during the flood from 23rd July 2008.

The events of the 23rd of July 2008 are likely to occur every year. It could be expected that further changes in the land use, among them the reduction of forest exploitation due to the creating of the Gorce National Park, will result in the lowering of intensity of fluvial transport. Due to this lower supply, it is likely that bottom erosion will occur more often as a result of the underload of stream beds. The other important reason is reduction of supply of material from cultivated fields, because their area is dramatically diminishing.

Comparing the rainfalls triggering the analysed floods with long series of extreme rainfalls (CEBULAK 1998 – 1999), the discussed floods could be considered as common and characteristic for the Gorce Mts. The observed widening of stream beds is evidence of gradual adaptation of section of stream beds to the larger discharges, probably occurred more often during recent decades.

ACKNOWLEDGEMENT

I would like to thank to the Cracow Institute of Meteorology and Water Management for providing me with the precipitation data from IMGW station in Ochotnica Górna, as well as to the Head of the Gorce National Park for the air photos.

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