CULTURAL HERITAGE IN A SITE IMPACTED BY AN EXCEPTIONAL SNOW-AVALANCHE A FEW DECADES AGO: WHAT TO DO? A TENTATIVE EXAMPLE IN SVANETI, GEORGIA

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ABSTRACT: In 1987, Upper Svaneti in the Georgian Caucasus faced an exceptional meteorological phenomenon, which was a mix of snow and rain and caused catastrophic avalanches. Several villages were impacted with many houses made uninhabitable, dozens of victims and ultimately these villages and hamlets abandoned. Unfortunately, a fairly classic scenario for avalanche disasters. Except that Upper Svaneti also represents a major cultural and historical heritage, recognized internationally by UNESCO thanks to its famous Svan Towers, and is particularly important for the state of Georgia.

With the objective of revitalizing these villages through quality tourism, the question quickly arose: which is the best combination between the level of avalanche hazard to consider, acceptable residual risks and types of protection to be deployed? Indeed, this heritage is part of equally exceptional landscapes and it would not make sense to revive a historic village in an environment completely transformed by modern protective infrastructures. But, how can we respond to an extreme avalanche event with an optimal level of protection based on infrastructures with minimal visual impact? Alongside the classic responses (but with a serious impact on the environment), an original response was also proposed: a compromise between the acceptable level of avalanche hazard versus the use of existing buildings to protect others.

The main objective was to make maximum use of what already exists to contribute to the protection of the most important part of the village while conserving the cultural heritage and minimizing the need for new “artificial” protection. This approach along with other – more traditional – solutions, are still currently under evaluation

KEYWORDS: cultural heritage, exceptional event, integrated protection

1. INTRODUCTION

Preserved by its long isolation, the Upper Svaneti region of the Georgian Caucasus is an exceptional example of mountain scenery with medieval-type villages, dominated by typical Svan towers. Among settlements of the Mestia (1450 m asl) district, Ushguli (2100m asl) is a UNESCO World Heritage Site for its authenticity.

At the same time, this region faces hard mountains conditions regarding altitude climate and natural hazards. The avalanche situation is well known there (Salukvadze, 2021) but only partly documented or mapped (with new initiatives to improve this, Ammann, 2021).

In the history, some hamlets experienced exceptional events, especially in 1987. One of them occurred at Murkmeli, the lowest settlement of Ushguli, and is analyzed here: in the context of state-organized resettlement plans, it contributed to increase a severe loss of population begun in the early 1980s, which finally led to the outmigration of about 50% of the population (Applis, 2022).

In contrast to these events, strengths have emerged in recent years with the development of significant tourism potential which explains local authorities request to protect this village, in order then to renovate ruins and make it completely habitable again.

The challenge is to achieve this goal without compromising the quality and the beauty of the cultural and historic heritage including a wonderful landscape scenery.

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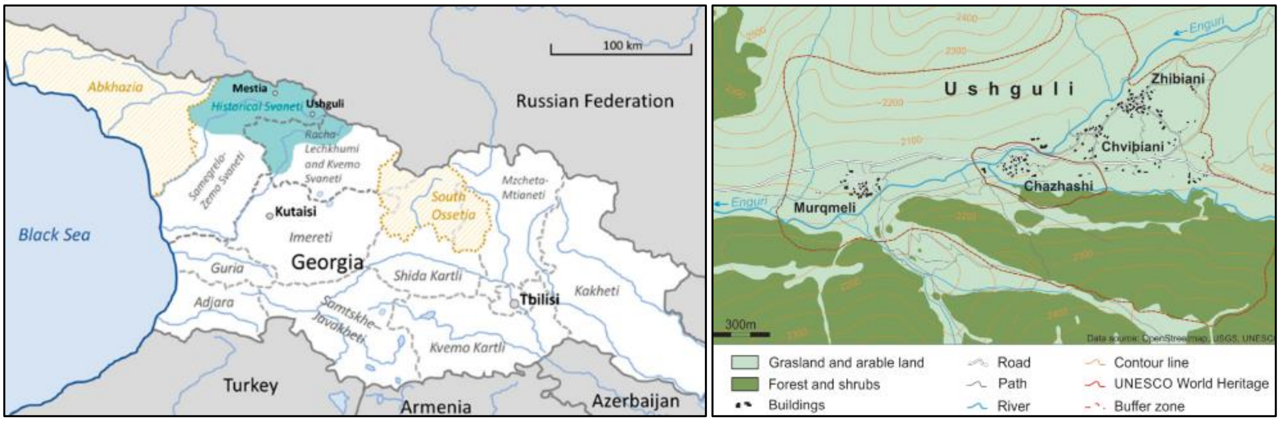

Figure 1: Left, placement of the historical region of Svaneti (in green) in the recent political map of Georgia according to regions with the zones of the Abkhazian and South Ossetian conflict (Applis, 2022). Right, Ushguli hamlets (Applis 2019)

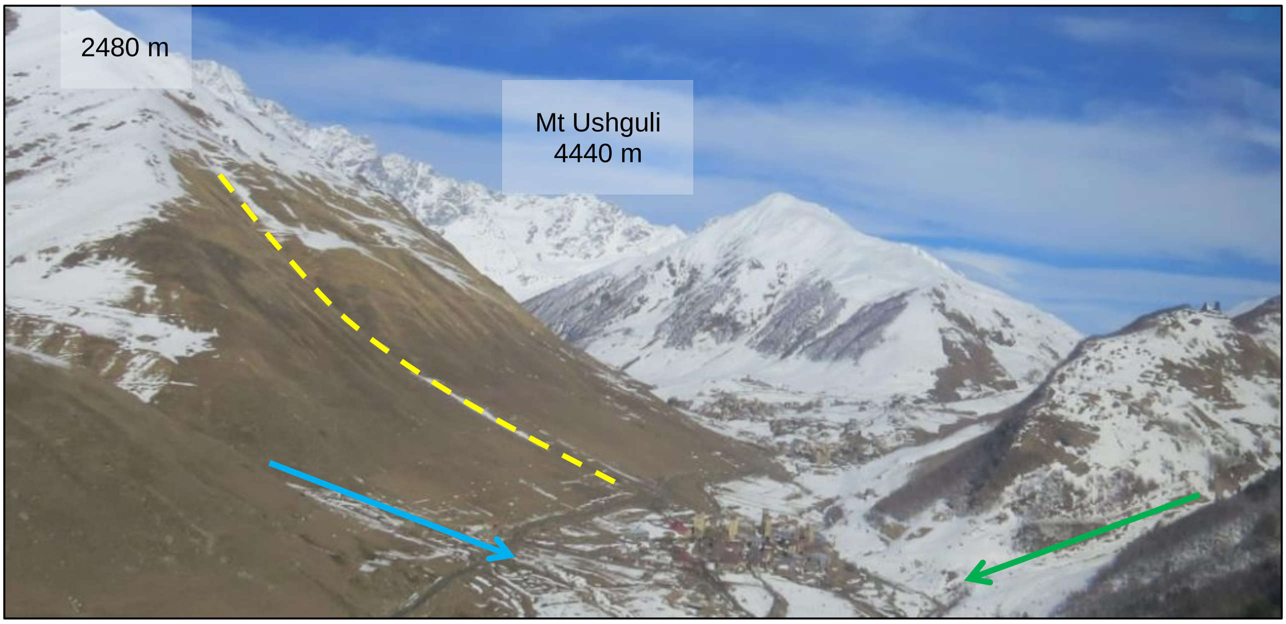

Figure 2: Situation of Ushguli hamlets with Murkmeli (2060 m asl) in the foreground, dominated to the north by the slopes (up to 2480 m asl) of the 1987 destructive avalanche, including the main thalweg (yellow dotted lines) and surrounded by the exits of lateral valleys to the northwest (in blue) and south (in green).

2. 1987 EXCEPTIONAL AVALANCHE AT MURKMELI

Though this hamlet was already impacted in 1976 within ‘’normal’’ snow conditions, 1987 sequence was totally exceptional in term of snow and weather conditions (Figure 3). According to official statements, conditions at that time started with an unusually powerful persistent anticyclone above the European part of USSR, which caused strong/rapid recooling of air and blocked the common way of Atlantic cyclones to the Caucasus. Relatively warm and over-moistening air masses rushed to Georgia from south-west. South slopes of Great Caucasus became the barriers for them to induce cool and warm air masses collision and so heavy snowfalls, typical of the ‘’pole of precipitation and snowiness” (Troshkina et al., 2001).

According to local testimonies at Murkmeli, on January 9th, 1987, a first snow-avalanche occurred in the south valley, on the north-east slopes of Gvibari summit (in green in Figure 2): some houses were damaged in the south-western side of the village and the St Barbara chapel was submerged. According to Bakhsoliani et al. (2008), most damages were logically due to a powder cloud air blast. Houses were damaged also on the western border of the village (surely by another avalanche coming from the north-western valley, in blue on Figure 2).

Then, snow continued to accumulate for weeks, up to 5 m snowpack in the mountains. As warned by above-mentioned avalanches at the beginning of the sequence, many people, afraid of this accumulation, started to evacuate their houses in the north side to gather in the central part of the village.

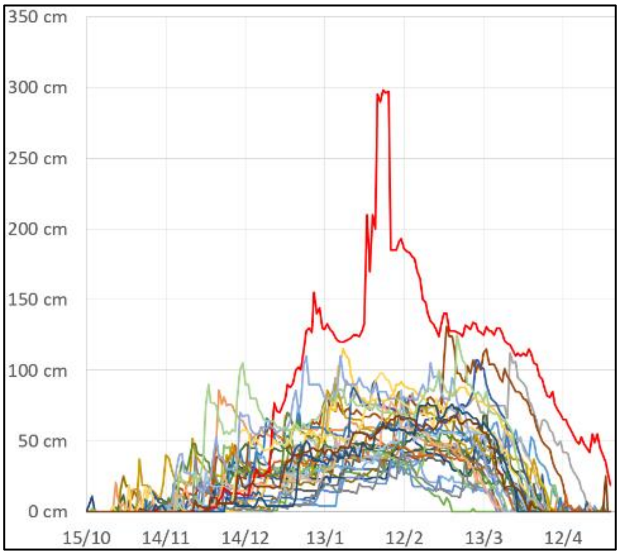

Figure 3 : Seasonal snowpack height at 1448 m asl showing the exceptional situation of winter 1986-87 (in red) – other curves cover the 1960-1992 period – source: Georgian National Environmental Agency

Figure 4 : Historical picture of 1987 main avalanche from south-facing slopes (top) and identification of visible elements on a recent picture (bottom) (red circle: tower top damaged after 1987 avalanche impact, still standing in 2018 but now collapsed)

This saved them, whereas a family living in a house in the western part and fearing an avalanche from the valley to the north-west dramatically moved to a house that was finally destroyed: 7 dead. This main avalanche started from the south-facing slopes just above the road (on the left on Figure 2): as reported by local testimonies, the whole mountain side simultaneously released ,and a blast effect was clearly felt.

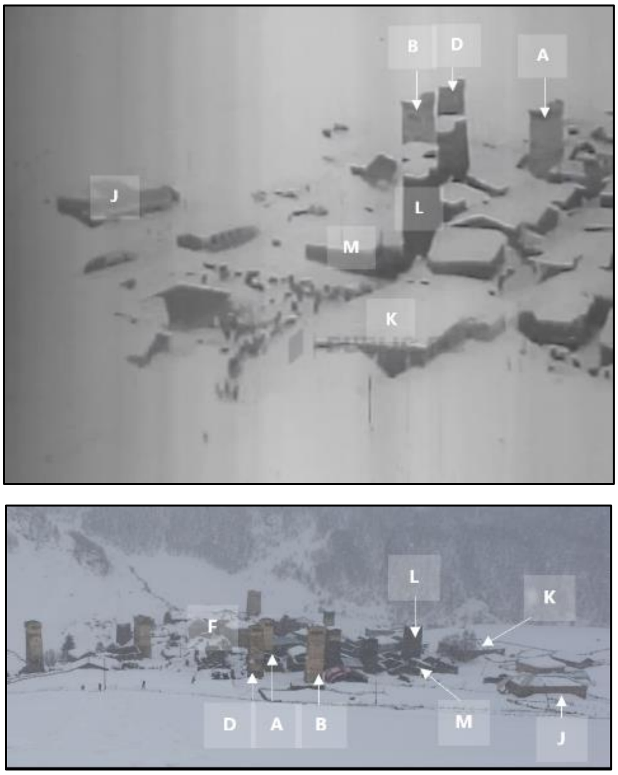

Figure 5 : TV footage of 1987 avalanche rescue (top) and identification of visible elements on recent pictures (right) [2]

These slopes are a juxtaposition of different more or less concave channels: the deepest and highest one (yellow dotted lines on Figure 2) is directed to north-east border of the village. Many ruins exist nowadays and most of them are due to these 1987 snow-avalanches; though some of them are also the result of the combination of avalanche impact and snow overloading (Troshkina et al., 2001). Most ruins concern house buildings and many Svan towers in the avalanche runout are still standing (in spite of a recent collapse but due to a lack of maintenance/reinforcement).

Figure 6 : Location of 1987 main destruction limits inside the village (yellow dashes) from south-facing slopes avalanche – current towers appear in red.

(Few) pictures at that time and TV report footages (Figure 4 & Figure 5) allowed to draw this 1987 main avalanche outline (Figure 6) inside the village. This limit is uncertain due to the fact that the avalanche flow interacted with more or less resistant buildings which partly stopped the still moving flow and that some building outside of the main urban area were reached but not fully destroyed (like J on Figure 5). A back-analysis on the damages showed that the event was mainly a cold dry flowing avalanche, surely including a suspension layer. The main cause of destruction was related to the core layer.

3. DETAILED ANALYSIS

After a preliminary analysis performed in 2018, mainly based on the modeling of the dense avalanche flow with RAMMS Operational (Christen et al., 2010a e 2010b) , a more detailed analysis was performed in 2023 with additional on-site visits, new testimonies recovery and modeling. In particular, more reliable snow data were collected and the avalanche was simulated with the model RAMMS::extended (Bartelt et al. 2016) which is able to simulate both the dense (core) and the powder part (suspension layer). Including previous results, it was confirmed that the most dangerous avalanche path starts from the main south-facing channel, and more precisely from its right upper border where slopes are steeper (yellow dotted lines on Figure 2). However, the release zone has to be extended also to the west to reproduce the 1987 situation near the central-north part of the village (Figure 7).

Therefore, the avalanche protection of Murkmeli from an equivalent situation as 1987 cannot just focus only on the main channel. At the same time, the analysis shows 3 quasi-independent (therefore to be protected with different strategies) avalanche paths: the eastern one (Figure 7 on the right) corresponds exactly to the largest damaged zone; the central one corresponds to secondary ruins zone and the western one is already outside of the village. These results are obtained modelling the avalanche on the DTM, without the presence ofany buildings.

What is noticeable is that most uphill buildings which resisted in 1987 (or seemed to, J and uphill to B on Figure 5) are situated exactly between these flow path in low intensity zones: they were undamaged not because of their resistance but more obviously thanks to their ''lucky'' location as naturally outside the main flows.

Finally, this set of modeling results is considered as sufficiently representative of the 1987 exceptional conditions and gives also an overview of quantitative parameters (flow height, pressure…) to be used in hazard zoning and land use planning. These results are useful also to answer to local authorities which requested protection measures consistent with this 1987 event, even if exceptional (and further than the former 1% ''soviet'' rule which correspond to a 100-years return period scenario).

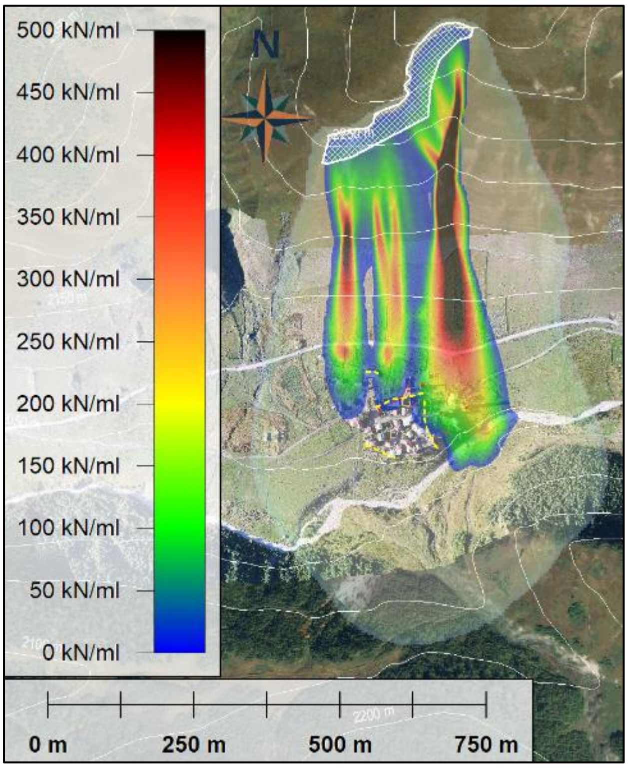

Figure 7 : Max core ''intensity'', obtained by multiplying avalanche maximum flow height and impact pressure given by RAMMS::extended in ''1987 conditions'' from the north slopes above Murkmeli and using the most optimal starting zone (white hatched) - in Yellow dashes = 1987 damages limit. Whited zone = cloud extension

4. PROTECTION STRATEGIES

4.1 *Classic solutions*

In such a situation and framework (the choice of the reference return period could be also discussed to reduce the requirement), protective solutions like passive catching and/or deflecting dam(s) and/or snow supporting structures are rather evident.

Dams already show some constraints and limitations: based on the state-of-the-art analyses (Johannesson et al., 2009) and consistently with observations, the western and central part of the village might be protected with dams of realistic heights, whereas the eastern zone, where most damages occurred, would need huge structures. For instance, the central part could be protected by a 8 m high dam located just below the road, which would itself not be protected: to locate the dam above the road would increase the height up to about 10 m. Obviously the dam height can be reduced getting closer to the runout distance, but this position would be nearer to buildings and cultural heritage towers with a dramatic visual impact. That is the main reason why protecting the eastern ''old'' part of the village and then developing its urbanization thanks to a dam seemed not appropriate: According to this point of view, this might mean that the eastern part cannot be protected with these classical solutions or need another protection strategy or even no protection at all, keeping the current place like a memorial.

The second classical protective solution are active supporting structures, at least in the main channel. Considering the smooth and regular morphology and in order to minimize the visual impact, snow nets have been preferred and prioritized only in the largest upper release zones; in parallel, an afforestation of the intervention area at lower altitude could also be performed (consistently with the forest condition in the surrounding mountain at similar elevation). The presence – in exceptional conditions like in 1987 – of a snowpack exceeding the characteristic snow net height (Dk) can't be ruled out and the use of reinforced structures/foundations (like marginal element) has to be taken into account.

These classic solutions which could be even positively combined (dam to the west, snow nets and afforestation to the east) can be normally reliably mastered, even in Georgia where such works are not so common.

However, they both induce a major incompressible visual impact which might be incompatible with UNESCO labels.

4.2 Original auto-protected solution

Based on previous analyses, next figure shows the hazard zoning corresponding to the current situation regarding a reference scenario like 1987 avalanche and based on a simple approach: the red zone indicates the area where a building gets completely destroyed in case of such event whereas the blue zone indicates the area where a building gets "only" damaged. Here, the red zone covers most of the ruins but also many towers and some inhabited houses. Several inhabited houses are located within the blue zone (Dark/purple for dense flows, light for powder cloud) but are surely not reinforced consistently.

Anyway, this map seems more pessimistic than figures given in Tarraguel et al. (2012), which classifies Ushguli in moderate hazard zone (at 56 %) and high hazard (at 38 %). But as admitted by the authors, "a separate susceptibility assessment for the run-out or travel distance for […] snow avalanches could not be included due to the lack of data but need to be included in future work as well''.

Figure 8 : Hazard zoning of Murkmeli in the current situation (no protection) by reference to 1987 event where relevant

Starting from the fact that most of the Svan towers are located in high hazard/red zone, it seems necessary to consider possible specific protections instead of global ones which respect environment and landscape with hard difficulty (see previous point in addition to their financial consistency). The idea is the following with a double goal:

- Protecting specifically some towers will indirectly protect stakes in their shadow.
- If towers cannot be directly reinforced, Murkmeli is already studded with ruins exactly in the zone where obstacles could be useful to protect stakes downhill. Why not rehabilitate these ruins as punctual protections ?

At the same time and for instance according to Whilelm (1997), buildings present anyway a certain resistance consistent with construction materials and methods, even if they are not ''avalanche proof'' designed. This means that if they are in zones of limited avalanche intensity (i.e. pressure on a certain height of application) below their resistance threshold, they can become like an obstacle to the flow and act like a protection to other objects downhill.

Here, an intrinsic reasonable resistance of about 10 to 15 kPa can be assumed for houses (due to their conception, towers are in fact more adapted against shear forces). Regarding now isolines of intensity (obtained by multiplying avalanche maximum flow height and impact pressure from RAMMS results, Figure 9), most buildings which resisted in 1987 are located in places where the intensity is about 30 kN/ml or 60 kN/ml : these values correspond to their theoretical resistance according to the previous reference with an application on 2 to 4 meters high, which is fully consistent with modeling results. On the contrary, the main damaged zone to the east is where the intensity is over 90 kN/ml, that cannot be withstanded by such structures.

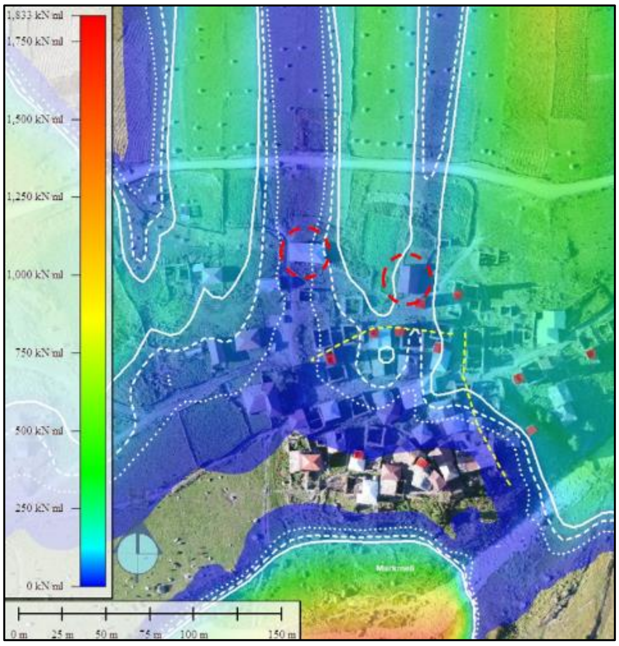

Figure 9 : Avalanche intensity (= avalanche height x pressure) map around Murkmeli with 90kN/ml (line), 60 kN/ml (dash) and 30 kN/ml (dots) limits

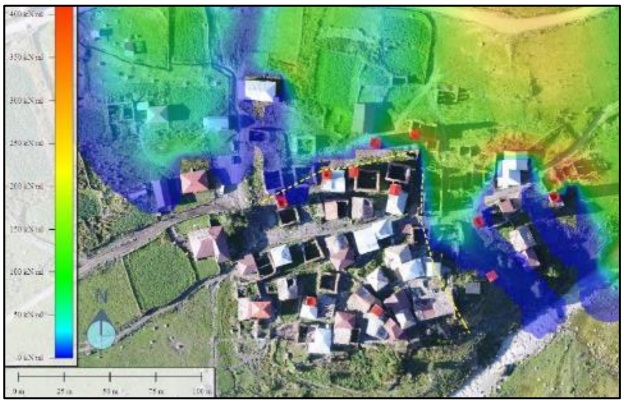

Figure 10 : Zoom on Murkmeli avalanche intensity map including interaction with still standing buildings (considered as perfect obstacles in RAMMS modeling)

Then and assuming that resistant buildings (including towers with a higher resistance) effectively faced the flow to include them as ‘’perfect obstacles’’ in RAMMS modeling (in fact, no flux cells in the numerical resolution scheme), a result even closer (in comparison to results on the original DTM free of any buildings) to local testimonies is obtained (Figure 10): indeed the village was crossed like this in the eastern part to almost perfectly fit ruins evidences.

Finally, and to go further, as shown in Figure 11 by applying simply Salm’s rule of thumb (Salm et al., 1990), most towers and many inhabited buildings are located where the necessary height for an obstacle to influence/stop the flow is ‘’only’’ 2 to 4 meters. So, in the same way obstacles like earth mounds could be used as protection, the idea is to renovate ruins, not as buildings but as protections for their vicinity.

This work should be done with an architect: all these new structures could be arranged so that they do not appear simply as a cubic volume of stones but ‘’like’’ an Upper Svaneti style house (and why not including a roof and fake windows to respect as much as possible local typical architecture…). In certain case, the renovation could also include an internal reinforcement (concrete wall) so that (a part of) the volume could be still used for storage function. With more ambition and provided they would be strictly ‘’avalanche proof’’ designed and built, some of these volumes could be also rehabilitated for public function: toilets, tourist information, cultural heritage museum, refuge for pic-nic, multi-function rooms especially to offer better accommodation in summertime.

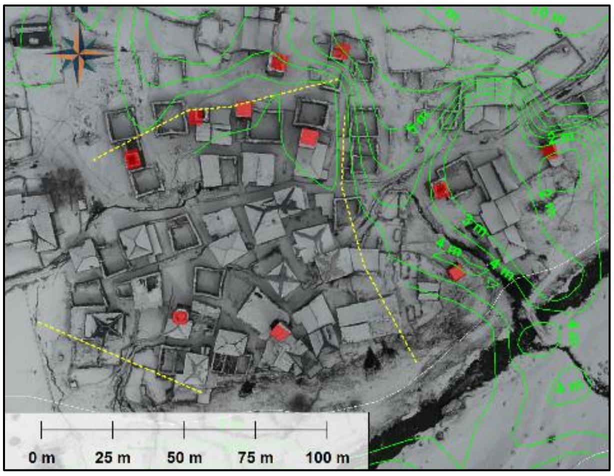

Figure 11 : Iso-contours of necessary obstacle efficient height according to Salm’s rule of thumb with λ = 3 (indirectly calculated from RAMMS dense modeling).

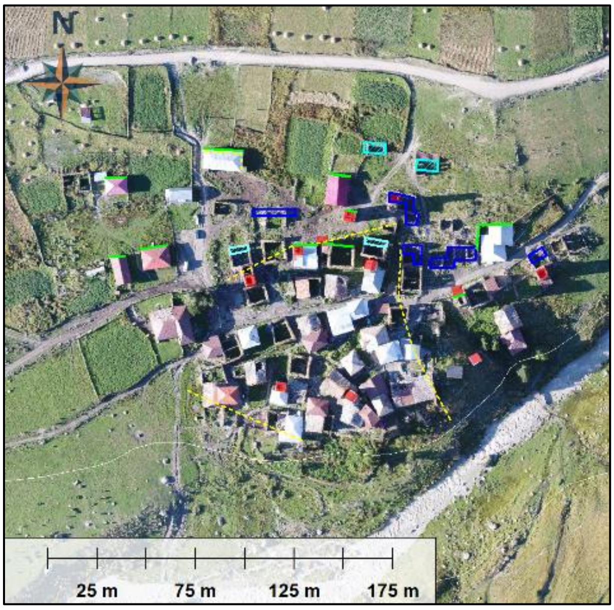

Figure 12 : Identification of ruins to be rehabilitated as protections (dark blue: priority 1 / light blue: priority 2) and wall resistance to be checked or reinforced (green lines)

Based on this principle and identifying which ruins would be interesting to rehabilitate as protection and assuming that some walls have a sufficient resistance (to be checked) or would be consistently reinforced (Figure 12), additional numerical modeling were performed on a refined grid (Figure 13) and confirm that the eastern side of the village could be saved for future urbanization.

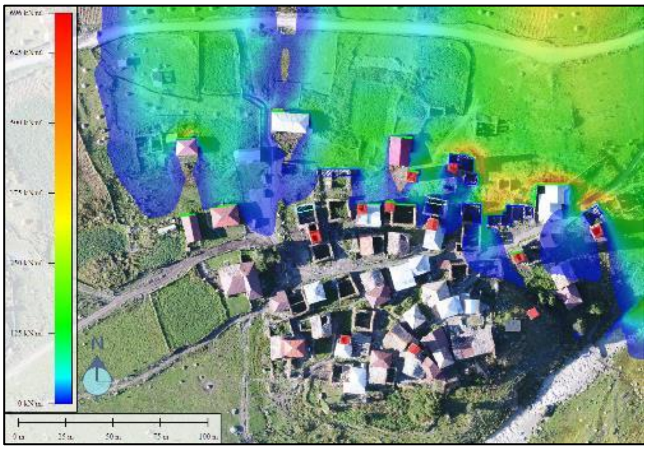

Figure 13 : Modified avalanche intensity map considering only priority 1 renovations and reinforced walls

5. DISCUSSION AND CONCLUSION

As requested by local authorities and consistently with the local tourism development during recent years, the global goal of this study was to give possible solutions to protect the village including (possible new) inhabitants and cultural heritage. In fact, a lot of people have left since the beginning of the 1980s and especially after 1987 disaster: only few are still here. So, the additional question is: does Murkmeli need to recover its previous perimeter including a new/re-development? The potential for tourism is obvious including guest houses for instance for ski-tourers or daily recreationists welcome. It seems also that some past inhabitants would like to come back (Applis, 2022).

So, a new 1987-type avalanche could effectively be prevented by one of the two classic protection schemes presented in paragraph 4.1. They could be also positively mixed using dams for the central-(western) part and supporting structures for the eastern one. But this would be a huge investment for a very partial answer, for instance not avoiding totally cloud blast effects without specific reinforcements on houses.

Due to the complexity of the context, a more general point of view is necessary to include all stakes, even not physical: access management and safety ? possible or suitable development ? This opens large questions which overpasses the avalanche analysis and which shall be answered by authorities.

To go ahead, the alternative/balanced proposal focuses on the following points by order of importance in the current situation:

- Because they are really a specificity, cultural heritage Svan towers shall be first protected. Without an obvious view of their intrinsic resistance and capability to face avalanche impact, they could be either reinforced or specifically protected.
- Because they are still here and because cultural heritage objects cannot stand without a real life around, remaining buildings and inhabitants shall also be protected.
- Because a minimal development is the best guaranty for the future local life, possible space for new buildings shall be assessed and protected in the meantime.
- Because landscape and environment are also key points to valorize the overall heritage, protection scheme(s) shall be optimized and integrated as much as possible.
- Because all these efforts would be nothing without a reliable (and so sufficiently safe) access, previous goals are possible only if a deep analysis is also initiated regarding the road general improvement and/or alternatives: for now, it is sometimes classified among the most threatening road (or track) in the World (Figure 14). This shall be fully consistent with the high-level quality of Ushguli cultural heritage.

At this stage, it is also important to underline that all three avalanche paths (south and north-western lateral valleys and north slopes) present like a “threshold behavior”: they normally stop far from the village but in extreme snow conditions, they can generate huge events: it is not a progressive process and the protection strategy has also to take this into account. For instance, designing protections regarding short return period avalanches would make mainly no sense as corresponding avalanches would even not reach them. About that, it has also to be kept in mind that no dangerous avalanches have occurred since 1987.

Finally, past avalanches have also ‘’automatically’’ delimited safe locations where few/no damages occurred, hence the priority given to hazard zoning and corresponding prescriptions: one of the best solution remains anyway to avoid endangered zones! From this point of view, new buildings are not a real problem as soon as they can be located at the right place. Finally, the main concern is about Svan towers (and existing buildings) as they are where they are and need to be protected at their location.

Figure 14 : Typical section of the only road access to Ushguli Upper Svaneti valley.

Figure 15 : One of the last remarkable avalanches in the north slopes above Murkmeli in February 2024.

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