

## **Avalanche hazard mapping and mitigation for settlements in Iceland – an overview**

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### **ABSTRACT**

After two catastrophic avalanches in 1995, that killed 34 people in their homes, laws and regulations regarding avalanche hazard in Iceland were changed and the hazard management responsibilities of the involved governmental agencies and institutes were clarified. Since then, hazard zoning has been carried out for 23 towns and villages in Iceland where there is some avalanche hazard. Local governments are required to take actions to mitigate the risk for settlement with some residential houses in red zones according to the hazard maps. Most of the houses in the worst areas have been protected. The Icelandic Meteorological Office is responsible for avalanche monitoring for settlements and evacuation of houses during avalanche cycles. Without avalanche protection, the areas with the greatest hazard would often be evacuated. The protection measures that have been built both improve safety and reduce the discomfort associated with avalanche cycles for the inhabitants. They also make the daily avalanche monitoring for settlements easier by reducing number of areas that need monitoring during “normal” avalanche cycles. Avalanche hazard assessment has also been carried out for a great number of farms and recreational buildings in rural areas where the new regulations require hazard assessments for all new buildings.

### **1. INTRODUCTION**

After two catastrophic avalanches in 1995, that killed 34 people in their homes, laws and regulations regarding avalanche hazard in Iceland were changed and the hazard management responsibilities of the involved governmental agencies and institutes were clarified. The Icelandic Meteorological Office became responsible for hazard zoning, avalanche monitoring, evacuation of endangered areas in collaboration with civil defence authorities and technical advice to the government regarding avalanche protection measures.

### **2. HAZARD MAPPING**

According to laws and regulations about avalanche safety, the Icelandic Meteorological Office (IMO) is responsible for hazard zoning in Iceland. It has been decided to use annual probability of an individual being killed in an avalanche as a measure of avalanche risk (Jónasson and others, 1999). The acceptable risk according to the regulation is 0.2 of 10.000 per year (local risk of 0.3 of 10.000 per year if continuous presence in the endangered area is assumed) and areas with unacceptable risk are divided into three hazard zones (A, B and C, also denoted with the colours yellow, blue and red) with increasing level of risk with the C-zones having the highest risk.

After the regulation change, following the avalanche accidents in 1995, hazard zoning has been carried out for 23 towns and villages where some avalanche hazard was considered likely. Hazard zoning has, furthermore, been carried out for two ski areas. Avalanche hazard assessments have also been carried out for a great number of farms, recreational buildings, hotels and other constructions in rural areas where the new regulations require hazard assessments for all new buildings. This type of hazard assessment has become more important in recent years with increased tourism in Iceland. Hazard assessments have now been made for over 130 such locations in rural areas, see Figure 1. Hazard management related to thawing permafrost and landslides on downwasting glaciers due to warming climate has also come up as an urgent task in recent years.



Figure 1 Areas where hazard due to snow avalanches and landslides has been assessed in Iceland since 1995. The black points show settlements and ski areas. The white points denote locations in rural areas where hazard assessments have been made.

### 3. AVALANCHE PROTECTION

Local governments are required to act to mitigate the risk for settlements with some residential houses located in C-zones according to hazard maps. Many houses in the worst areas have been protected with avalanche defence structures but several areas with some residential houses in red zones remain to be protected. The avalanche hazard zoning of protected areas is updated to take into account the improved safety provided by the protection measures.

### 4. EVACUATIONS

The IMO is responsible for monitoring of avalanche danger for settlements and evacuation of houses during avalanche cycles in collaboration with civil defence authorities. There is a high

uncertainty in avalanche monitoring. Those involved try to be on the safe side and expect to evacuate houses many times without the houses being hit by an avalanche. Without avalanche protection measures, the areas with the greatest avalanche hazard would often need to be evacuated, in some cases many times in the same winter.

The settlement of Bolungarvík, for example, had the most frequent evacuations of all settlements in Iceland before it was protected by two catching dams and a row of braking mounds, built between 2008 and 2012. Figure 2 shows the number of houses evacuated in the settlement as a function of time. For comparison, evacuations of an industrial area in the neighbouring town of Ísafjörður is also shown in the figure. The area in Ísafjörður is unprotected and is thus still regularly evacuated. There are roughly 10 km between the areas and the mountains above have similar aspect. When both areas were unprotected, houses were always evacuated in Bolungarvík when an evacuation was ordered in Ísafjörður and in some additional cases in Bolungarvík. It cannot be stated that this pattern would have continued but it is clear that without the protection measures, the buildings in the affected area in Bolungarvík would have been evacuated several times since the dams were built. The protection measures that have been built since 1995 have greatly improved the hazard situation in many settlements in Iceland. They both provide safety and reduce the discomfort associated with avalanche cycles for the inhabitants. They also make the daily avalanche monitoring for settlements easier by reducing number of areas that need monitoring during “normal” avalanche cycles because protected areas such as in Bolungarvík are not of regular concern.

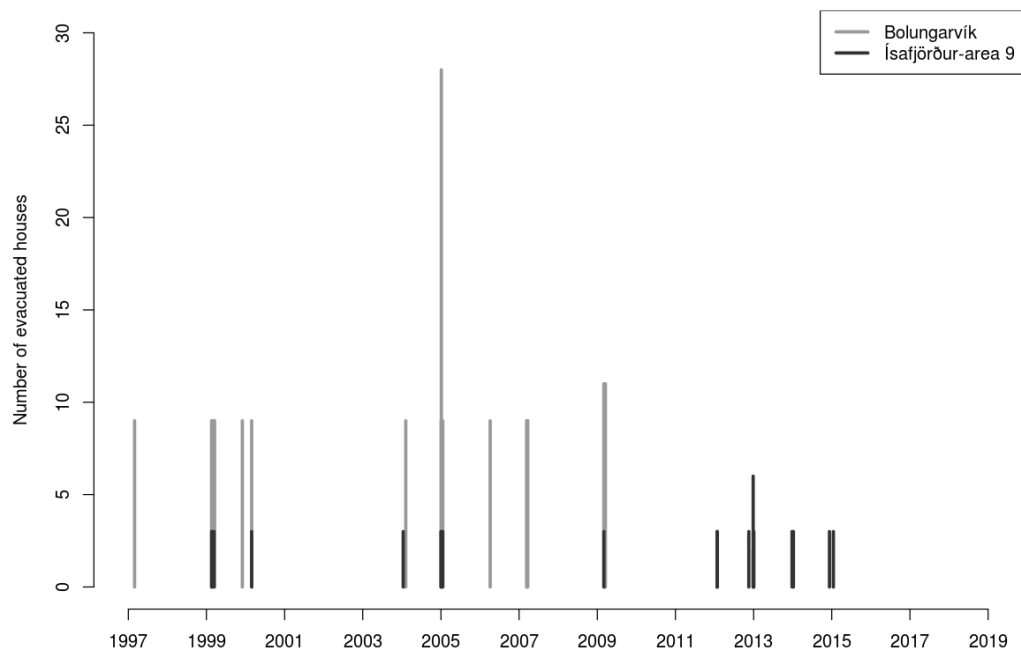


Figure 2 The number of evacuation of houses in Bolungarvík and the most exposed evacuation area in the neighbouring town of Ísafjörður. The settlement in Bolungarvík has been protected with two catching dams and a row of braking mounds built, between 2008 and 2012.

## 5. CONCLUSIONS

The presentation will give an overview of the status of hazard zoning in Iceland with a focus on changes in hazard management after a substantial number of settlements have been protected with permanent structures, and on future tasks and challenges. The protection measures that have been built, following hazard zoning where residential houses have been judged to be located in C-zones, both provide safety and reduce the discomfort associated with avalanche cycles for the inhabitants. They also make the daily avalanche monitoring for settlements easier by reducing number of areas that need monitoring during “normal” avalanche cycles. An increasing number of requests for hazard zoning have been received in recent years in connection with buildings in rural areas, in particular recreational buildings and buildings associated with tourism. It is foreseen that future hazard assessment work in Iceland will mainly deal with avalanche hazard in ski areas, rural areas and reassessment of hazard where protection measures have been constructed as hazard assessments have now been made for all threatened towns and villages. Hazards due to landslides from thawing permafrost and steep slopes above downwasting glaciers are also of growing concern.

## REFERENCES

- Lög um varnir gegn snjóflóðum og skriðuföllum (Act on protective measures against avalanches and landslides) no. 49/1997.
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