CASE MOSJØEN - CHALLENGING RISK MITIGATION IN THE TOWN CENTER DUE TO POWDER CLOUD AND AVALANCHE GENERATED FLOOD WAVES

Priska Helene Hiller[1]*, Anne Bruland Høyen[1]

[1] *Norwegian Water Resources and Energy Directorate, Trondheim, Norway*

ABSTRACT: Parts of the center of the Norwegian town Mosjøen are prone to avalanche hazard. A river divides the town center from the steep slope of the mountain Øyfjellet. Hence, the avalanche hazard in the building area mainly consists of the pressure by the powder cloud, and flood waves caused by the impact when avalanches hit the river. The main challenges to mitigate avalanche risk in Mosjøen are connected to: i) Tools and understanding of the propagation and impact of powder clouds and impulse waves caused by snow avalanches; ii) Uncertainty on the effect and feasibility of mitigation measures.

The current situation is a burden on the community as they need to balance risk mitigation and the development of the town center. Spatial development is at this moment limited due to the hazard zones. Physical mitigation measures will be costly within a range of 280-680 million NOK (about 24-58 mill. EUR) and will take time to be designed and constructed. This contribution focuses on risk mitigation and its technical and physical as well as legal, political and other non-technical challenges. The case will be presented with a timeline focusing on the mentioned challenges, ring actions and collaboration.

KEYWORDS: risk mitigation, powder cloud, flood wave, snow avalanche

1. INTRODUCTION

The small town Mosjøen, Vefsn community, is located on a fjord not far from the polar circle in Norway. The steep slopes of the 800 m high mountain Øyfjellet rise west of the town center, see Figure 1.

Figure 1: Town of Mosjøen seen from the mountain Øyfjellet. The river flows from south to north (right to left in the picture). (Foto: Priska Hiller, NVE)

Snow avalanches from Øyfjellet threaten parts of the town center including the historic Sjøgata from the 19th century. Due to the ca. 200 meter wide river Vefsna between the mountain and the town, it is unlikely that the dense parts of avalanches will reach the houses. However, a possible powder cloud or flood waves can cause damages, if an avalanche reaches the river. Damages caused by either one are documented in Mosjøen.

The Norwegian Water Resources and Energy Directorate (NVE) is the national authority dealing with natural hazards including snow avalanches. NVE administers natural hazard management including hazard mapping, land use planning, regional flood, landslide and avalanche warning, emergency assistance, expert help and financial support for natural hazard risk mitigation. In the case of Mosjøen, NVE assists the community of Vefsn with expert guidance including project lead for the mitigation measures planning.

This contribution focuses on the investigations since 2019, the ongoing preliminary design study and the challenges for the community. Below, you find a timeline to provide a broad overview of the project.

1.1 Timeline

1780, 1890, 1923, 1954, 1993: Documented damages in Mosjøen caused by snow avalanches (Sweco, 2019)

1996: Powder cloud of an avalanche causes several damages in Mosjøen (Figure 2). This is the best documented event. The Norwegian Geotechnical Institute (NGI) analyzed the event and described some mitigation measures for the community (NGI, 1996).

2011: Evacuation due to avalanche danger, but no avalanche event reached the town (Sweco, 2019).

* *Corresponding author address:*
Priska Helene Hiller, Norwegian Water Resources and Energy Directorate, 7030 Trondheim, Norway;
tel: +47 91002108;
email: phh@nve.no

2019: Hazard map (Sweco, 2019) delivered to municipality by consultant as part of spatial planning work.

2020: Feasibility study for mitigation measures (NGI, 2020)

Since winter 2020/21: Established site-specific avalanche warning including a webcam and since 2021/22 a local weather station 151.73 Middagseidklumpen at 630 masl. (https://sildre.nve.no/station/151.73.0)

2021/22: Expert group working on hazard understanding, including simulations of powder cloud.

2022: Flood wave analysis (NGI, 2022)

2023 - Ongoing: Preliminary design study

Figure 2: Snow deposits and damages in Mosjøen after the avalanche in 1996. (Foto: NGI, from NGI 2020)

1.2 Legal framework and buildings at risk

Safety for buildings against natural hazards are prescribed in the technical building regulation (byggteknisk forskrift, TEK17), §7 (DiBK, 2024). It claims safe sites for buildings. The acceptable risk is described by connecting safety classes for buildings with a highest nominal annual probability for significant damages as shown in Table 1. The regulation is valid for all new buildings, and changes made to existing buildings, which require a building permit. It has no retroactive effect.

Table 1: Safety classes when placing buildings in avalanche hazard zones. Typical buildings in the safety classes include: garages, small buildings, storage with no permanent stay in S1; living houses, minor working places in S2; and residential houses with more than 10 flats, working places for more than 25 people, schools, retirement home in S3 (DiBK, 2024).

Safety class	Consequence	Highest nominal annual probability
S1	Small	1/100
S2	Medium	1/1000
S3	Large	1/5000

In the case of Mosjøen there are about 75 buildings in safety class S3 and S2 within the 1/1000 hazard zone, including a hotel, a bank, a shopping center and the town center marked place, see Figure 3. Most of the historic houses along the famous Sjøgata are even within the 1/100 hazard zone. Sjøgata is the first road parallel to the river, ca. 50 m from the shore. Those houses, mainly wharves, are especially vulnerable as they are constructed of wood and some of them founded on poles partly in the river.

Figure 3: Mosjøen seen from south to north in 3D visualization including the avalanche hazard zones. The red zone implies an annual nominal return interval of 1/100, orange 1/1000 and yellow 1/5000. (Screenshot of NVEs temakart available on https://temakart.nve.no/prosjekt/360d1931-d392-4a74-b6c0-d7725798632e)

2. COMPLEX AVALANCHE HAZARD

The avalanche hazard for the buildings in Mosjøen is mainly caused by the pressure from the powder cloud or impulse waves in the river. The 800 m high mountain with an average slope of 32 degrees, steepest in the upper half, leads to high intensity of the avalanche when it hits the river. Depending on the type of avalanche, the powder cloud or a flood

wave can propagate over the river and damage buildings in the town center. Both impact types are not fully understood and there is uncertainty connected to the available tools to calculate intensity and extension.

2.1 Powder cloud

An expert group was established to discuss and define the possible impact of a powder cloud for the buildings in Mosjøen. The group consisted of consultants from NGI, Skred AS, Verkis and professionals from NVE. They analyzed recommendations and cases in relation to powder clouds. They also ran simulations for Mosjøen with the programs SAMOS AT and RAMMS::Extended (version 2.7.94). The group confirmed the existing hazards zones based on the simulations and expert judgement. Furthermore, they agreed on a technical note (NVE, 2022) which required and recommended pressure values to cope with the avalanche risk within the town. E.g. to design S1 buildings to endure 10 kPa and S2 buildings 20 kPa, accordingly. S3 buildings are not acceptable within the 1/100 zone. Those values were implemented in the land use planning.

2.2 Flood waves

Wet and heavy avalanches can cause flood waves when they reach the river. Such impulse waves are more known in connection with landslides. Hence, NVE had a development and application project with NGI. During the development, part of a model in OpenFoam and based on landslides was adapted to snow, i.e. to model the impact of snow avalanches into water. Further, the developed model was applied to the topography in Mosjøen. The simulations of a bigger and a smaller event resulted in a wave run up on the town side to 5 masl. Corresponding roughly to the flood wave in 1923 which reached the Sjøgata (NGI, 2022).

3. RISK MITIGATION

As a consequence of the hazard zones, site-specific avalanche warning was established in winter 2020/21. Vefsn community made a specific emergency action plan concerning snow avalanches which completes the site-specific warning to a risk reduction measure.

After further investigation of the avalanche hazard described in chapter 2, a preliminary design study was tendered. The mandate is to design physical mitigation measures to remove either the 100-years hazard zone or the 1000-years hazard zone from the town center.

Risk mitigation faces technical, physical, legal and political challenges which we amplify below.

3.1 Technical and physical challenges

On the one hand, there are uncertainties on certain measures such as the effect of catching dams on powder clouds. On the other hand, there is a large potential of snow drift into the starting zones, which gives a huge potential of snow up to 12-14 meters in the most extreme gullies (Skred AS, 2024). This is challenging for the planning of snow supporting structures in the starting zones. The effect of snow drift measures will be crucial for the design of supporting structures. Furthermore, the steep starting zone is partly also prone to rock fall.

Space is limited due to the topography; the mountain slope flattens just a little bit before it meets the river. A catching dam will in that case face high velocities, resulting in a high (up to 25 m) and wide construction. Vefsna is a protected river and the habitat for the Atlantic salmon. Furthermore, a dam partly in the river, can increase flood risk for Mosjøen city center and is a potential hinder for ice runs in the river.

Keeping the mentioned challenges in mind, the preliminary design study (Skred AS, 2024) recommends a mitigation concept combining supporting structures and snowdrift fences. Furthermore, wind baffels might be necessary to limit cornices. Placement and dimensioning are, however, demanding because of the terrain and the large amounts of drifting snow into the starting zones. The mentioned challenges are elaborated more in detail in mitigation of the Stortuva avalanche by Nordbrøden et al. (2024).

3.2 Non-technical issues

Despite of a technical solution which is physical possible to construct, there are also some non-technical issues to cope with:

- The river Vefsna is protected, habitat for the Atlantic salmon and flood risk should not be increased.
- Øyfjellet serves also as reindeer gazing area. Physical measures must be adapted to the needs of the reindeer. A good dialog with the owners is important.
- Environmental effects
- Hazard and risk communication
- Financing, including maintenance over time
- Stakeholders prone to avalanche hazard and/or in the areas of planned mitigation measures, e.g. landowners, outdoor facilities such as trails
- Historic Sjøgata area, a cultural heritage site within the 1/100 hazard zone
- Hampered development of town center due to the hazard zones

Especially the two last points are part of a dilemma: on the one hand the amount of people staying within the hazardous areas should be limited to reduce risk. On the other hand, it is important that people can live in buildings in the center, including the historic houses. Otherwise, the buildings will probably be poorly maintained. A living center is the heart of a town, and the restrictions hamper the development of Mosjøen. Hence, a good dialogue with the community is key to balance risk awareness and town development.

3.4 Financing

The preliminary design study has investigated different possibilities for mitigation. A rough calculation has been made for how much it will cost to establish the different mitigation measures, and it is estimated to extend from about 280 to 680 million NOK (24 – 58 mil. EUR, by August 2024). The concept which is under further investigation is about 280-450 million NOK (24 – 38 mil. EUR) investment costs and 2.8-5.2 million NOK (0.3-0.5 mil. EUR) in annual maintenance.

The investment costs are about the same size as NVEs annual allocation by the National Budget, i.e. 330 million NOK (28 mil. EUR) for 2024 (Prop. 104 S, 2023-2024, p.140). Hence, the preliminary design study will also serve as background for further work with specific financing of the project which has not got any funding yet.

4. KEY POINTS TO BE SOLVED AND OUTLOOK

Avalanche risk mitigation in Mosjøen is challenging. Coming key points in the near future are:

- Placing measures in the challenging terrain and design
- Financing of the investment and a good plan for maintaining
- Continuous work on the non-technical issues

At the same time, good information and dialogue with the community as well as all the stakeholders are important for the progress of the project.

The most suitable risk mitigation seems to be site-specific warning on short term, and on long term a stepwise implementation of a mitigation measure consisting of supporting structures and snowdrift fences. However, a detailed cost/benefit analysis will be the base for further decisions, amongst others a political decision in the community. Non-technical issues such as the cultural heritage must be included in the analysis. Furthermore, Mosjøen is one of several costly mitigation projects in Norway pushing the need for a good financial solution including maintenance forward.

The case Mosjøen shows that such challenging cases contribute to development of the subject in general while finding a specific solution. Simulation of the powder cloud with two different numerical programs as well as the discussion in the expert group, increase understanding. Furthermore, a model for landslide generated flood waves was adapted to snow avalanches and applied in Mosjøen. The valuable collaboration within the project is appreciated.

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