Longyearbyen Svalbard – Mitigation Measures for Sukkertoppen and Vannledningsdalen

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ABSTRACT

After a deadly avalanche in December 2015 and material damages due to an avalanche in February 2017 the national and local authorities in Norway have initiated mitigation work in Longyearbyen, Svalbard. Snow fences were built in the mountain side above the town in February 2018 and supporting structures and a drainage canal are near completion late fall 2018. Further work on planning of mitigation measures below the Sukkertoppen mountain and Vannledningsdalen valley is in progress and a plan for construction start is set at the beginning of the summer 2019.

The ongoing work on the mitigation is focusing on two main areas: the area just above the town centre and the area on and around the delta below Vannledningsdalen valley. Vannledningsdalen, a nearly 2 km long valley, has a history of slush flows, some of them fatal. For mitigation here, two main concepts are being studied: deflecting walls along the stream to the main river Longyearelva and a curved up to 15 m high deflecting wall which directs the slush flow out of the main stream to an open area below Sukkertoppen. For the centre area supporting structures are being studied in combination with a small catching dam for debris flows, or a row of braking mounds in combination with approx. 13 m high catching dam. The effect of expected climate change is uncertain but plays a large role in the final choice of the mitigation concept. Permafrost and solifluction are one of the greatest concerns for these structures, as it is unclear if the permafrost ground can carry the weight of these large dams. Ground- and surface water is also a big issue as the permafrost limits the drainage possibilities.

1. INTRODUCTION

The avalanche danger in Longyearbyen (Figure 1) has been known for a long time and has been described by Erik Hestnes and others in several NGI reports such as (Norges Geotekniske Institutt NGI, 2001). In December 2015 and February 2017 avalanches hit residential buildings at the root of the Sukkertoppen mountain (location Lia) killing two persons in the December incidence and caused considerable material damages in both incidences. The 2015 incidence has been described in (DSB, 2016), (Issler et al., 2016), (Jaedicke et al., 2016), (Hestnes et al., 2016), (Brattlien et al., 2016), and the 2017 incidence and mitigation work in (NVE, 2017), (Jonsson and Jaedicke, 2017) and (Jonsson et al., 2018b).

Svalbard archipelago lies in the permafrost belt north of 64°. The mean year temperature has increased by approx. 3°C since 1900 but there have been large variations between years and between decades (Isaksen et al., 2017). From 1970 the temperature increase on Svalbard is amongst highest registered on earth. In the period 1971–2000 the mean year temperature was

Figure 1. Overview over the habitation below Sukkertoppen mountain and on the delta below Vannledningsdalen. Black polygon boundary depicts the area that poses threat to the people and buildings in the runout zone. Blue dotted polygon to the left of Sukkertoppen depicts the area protected in 2018.

–5.9°C but in 2016 the mean year temperature was –0.1°C (Isaksen et al., 2017). The report also predicts for the “best” scenario an increase in temperature of 3.6°C by the end of the 21st century and the “worst” which is 9.2°C. Further details on this worst case scenario are given in (I. Hanssen-Bauer et al., 2019).

All changes in climate in these arctic regions will affect the permafrost and thus existing and new/future infrastructures including mitigation measures for natural hazards such as snow avalanches, slush- and debris flows. As an example of this change the permafrost temperature has increased at rates between 0.06°C and 0.15°C at 10 m depth from 2009 and at Adventdalen and Janssonhaugen the active layer depth has increased by 0.6 cm to 1.6 cm per year (I. Hanssen-Bauer et al., 2019).

This project describes an ongoing mitigation work for the area below Sukkertoppen mountain Longyearbyen, see Figure 1. The client is The Norwegian Water Resources and Energy Directorate (NVE) on behalf of Longyearbyen lokalstyre (LL) and the main work is carried out by HNIT consulting Iceland, Skred AS Norway and the geotechnical consultant Rambøll Norge AS. Information in this article is based on a report from the first phase of the hazard assessment and the preliminary phase of the mitigation work (Jónsson et al., 2018a).

2. HAZARD ASSESSMENT

Prior to 2015 various hazard assessments had been worked out by NGI, (Norges Geotekniske Institutt NGI, 2015a) for various residential sites in Longyearbyen. In the wake of the fatal accident in December 2015 NVE initiated a new and complete hazard assessment for Longyearbyen and surroundings (Multiconsult AS, 2016) but after the avalanche accident in February 2017 the reliability of the report and hazard zoning has been questioned. A new workgroup was formed by NVE in 2017, the group consisted of three consultants i.e. Skred AS, Norwegian Geotechnical Institute (NGI) and UNIS in Svalbard, and it included also one representative from NVE. The workgroup delivered a new hazard map for the area below Sukkertoppen mountain early 2018 (Figure 2). Hazard assessment for the delta area below Vannledningsdalen (Haugen residential area) had been prepared by NGI in 2015 (Norges Geotekniske Institutt NGI, 2015b) and Multiconsult AS in 2016 (Multiconsult AS, 2016). The

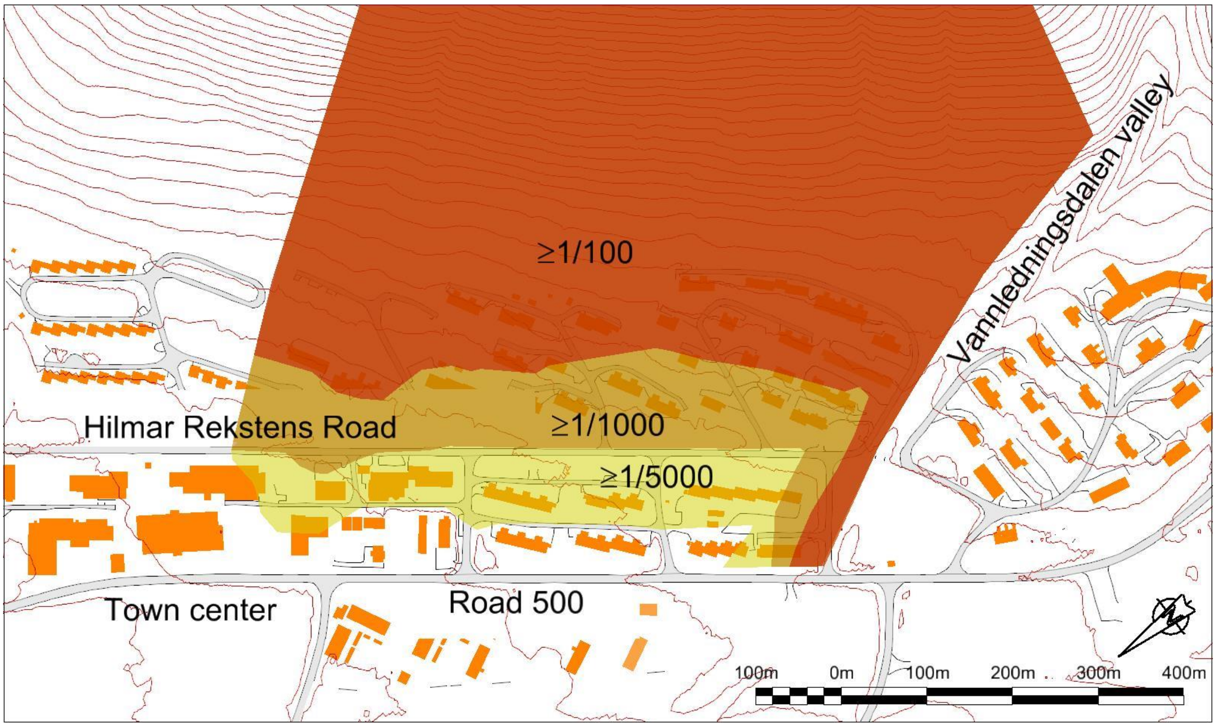

Figure 2. Hazard zoning for the Sukkertoppen area in Longyearbyen. Vannledningsdalen and the area on Haugen is not included in this hazard zoning.

criteria of these assessments have been questioned and it was therefore important to work on new criteria and hazard assessment for the ongoing mitigation work.

3. PLANNING FOR MITIGATION MEASURES

Through the years the discussion on mitigation measures in Longyearbyen has first and foremost been around Vannledningsdalen (slush flows) and Lia above town centre (dry snow avalanches) (Norges Geotekniske Institutt NGI, 2013, 1992, 1991). After the fatal accident in December 2015 the authorities initiated a hazard assessment work (Multiconsult AS, 2016) and at the same time a work on mitigation measures in arctic areas was introduced (Larsen, 2016). Mitigation work started in 2018 when the first phase of mitigation measures (snow fences, drainage canal and supporting structures) were built for the town centre (Jonsson et al., 2018b).

The second phase of the mitigation work was initiated in 2018 when NVE engaged consultants to work out a plan for mitigation measures for the area from town centre to Vannledningsdalen, see Figure 1. A preliminary report with various mitigation combinations and hazard zoning was delivered in December 2018 (Jonsson et al., 2018a).

3.1 Design criteria

One of the main challenges in this work was the lack of information on snow height in Sukkertoppen mountainside and Vannledningsdalen. This is information affects both hazard assessment and mitigation work. Two measurements, five cross sections from one “normal” winter are available from Vannledningsdalen and provide us an indication on the snow height. Observed annual precipitation at Svalbard airport is only 196 mm for the reference period 1971-2000 (Isaksen et al., 2017) and it is expected to increase with several tens of percent’s by the

Figure 3. The avalanche site during rescue operation in December 2015. This photo is one of the best information on snow conditions in Lia. The fracture line to the left is approx. 3 m and approx. 1 m to the right with estimated average height of 2 m and volume of approx. 15000 m³. Photo: Svalbardposten.no.

end of the 21st century. However, this scant observed annual precipitation does not say much about possible 24h precipitation in winter. The December 2015 event (Figure 3) is probably one of those cases where intense precipitation in combination with strong winds brings in a lot of snow due to a long fetch behind the slope and forms unstable snow cover. The snow height was roughly estimated to be in the range of 5-6 m on northern part of Lia (Norges Geotekniske Institutt NGI, 2018) but the height of accumulated snow on the northern shoulder of Sukkertoppen mountain is unknown. The release height of the avalanche in Feb. 2017 was measured to be approx. one meter at the fracture at top but neither the snow height nor the snow distribution elsewhere in the mountainside are known. However, there are several photos available from “normal” winters that show the distribution in the mountain side and that indicates large quantities at the shoulder and little snow in the middle of the mountain side.

The area to be protected can be divided into three locations, 1) the town centre, 2) Vannledningsdalen and Haugen area and 3) the area between those two areas, the “middle area”. In the ongoing work, areas 1) and 2) had the highest priority.

3.2 Mitigation alternatives

In (Larsen, 2016) protection of the residential area below Sukkertoppen mountain is discussed briefly and earlier NGI has proposed mitigation measures for the same area. In early 2017 NVE initiated a mitigation work for the 2015 avalanche accident area (Lia), shortly described in (Jonsson et al., 2018b). The second phase of the mitigation work was initiated in 2018 and a preliminary report on proposed mitigation measures was delivered in December 2018.

The initial work was a delivery of nine sketches or combinations of which five where chosen to be worked on further. For the town center two main concepts were studied, i) supporting structures in the starting zone and ii) a catching dam with or without braking mounds. For the

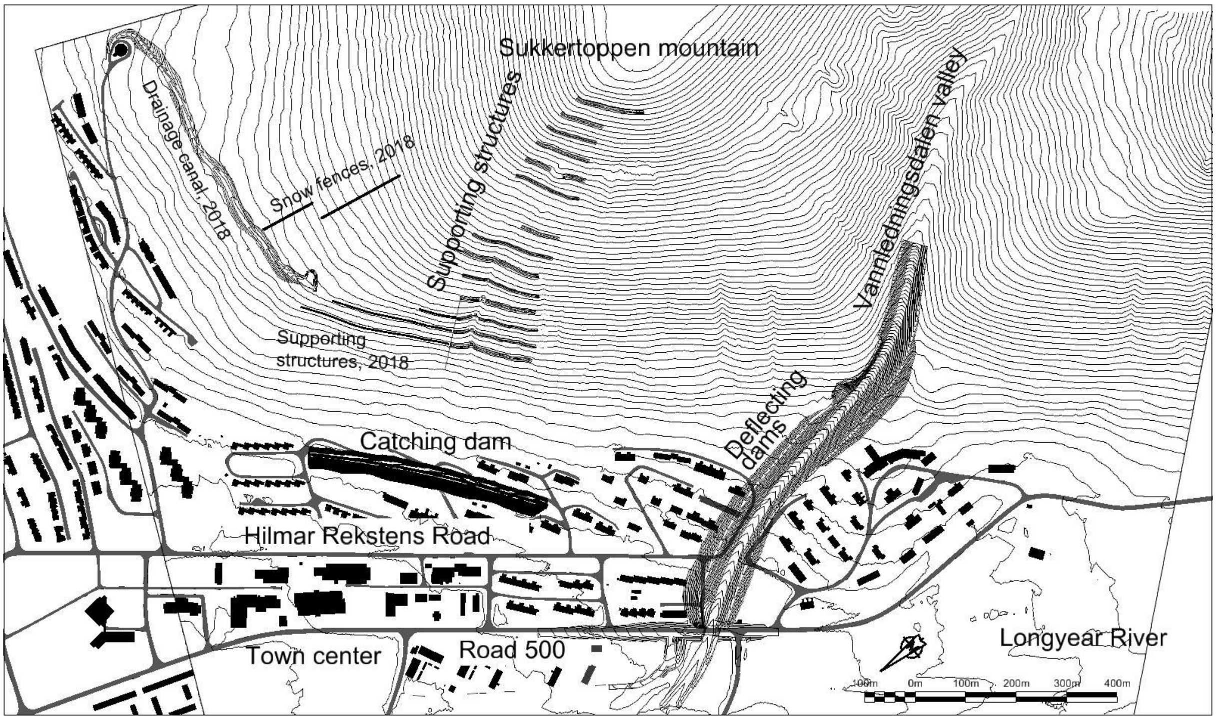

Figure 4. The figure shows Sukkertoppen mountain, Vannledningsdalen, town center and the residential area. Supporting structures, catching dam and deflecting dams are the chosen alternatives for Longyearbyen municipality. Mitigation measures built in 2018 are shown on the left side of the figure. The area between the catching dam and deflecting dams is according to cost/benefit analysis not feasible to protect and the buildings and other infrastructure will most likely be sanitated. Contour lines equidistance is 5 m.

Vannledningsdalen two concepts were studied, i) a curved deflecting dam (called "swing dam") that starts as deflecting dams but gradually diverts the flow out of the stream to an open space north of the valley, and ii) deflecting dams on both sides of the stream from Vannledningsdalen.

The chosen alternatives (Figure 4) shows approx. 1500 m of supporting structures with Dk height varying from 3.5 m to 5.0 m. The catching dam below the supporting structures is approx. 5.5 m high and its purpose is to stop small flows such as small avalanches, slush flow and debris flow from entering the town center. The impact side of the dam is supposed to be steep and of reinforced facing material. Total length of the catching dam is approx. 360 m.

The deflecting dams and canal between them is approx. 600 m long. The maximum height of the dams is approx. 14 m but most of the length above Road 500 it is 12 m. Below Road 500 the height is max. 7 m. The cross section of the dams is for the gentlest slope like 1:2 but it is necessary to build steeper walls to cope with the slush flow undulation. Fine tuning is still not finished.

It will be necessary to cut off Hilmar Rekstens road at the dams/canal but the bridge on the main Road 500 must be rebuilt to let most of the slush flow under. The crossing of the road and canal/dams will be challenging as the flow must pass the road with as little as possible of the flow masses flowing in direction of buildings. At the same time an aesthetic as well as wind and drifting snow must be considered for a dam which is 10+ m high at the road shoulder. In normal summer the river water never reaches Road 500 as surface water it is infiltrated higher up in the riverbed and it seems as part of it sinks out at the residential buildings near Road 500. To stop this infiltration can be a difficult task.

The permafrost conditions are a challenge here for all mentioned structures, especially when changes in climate are considered. Snow fence built in the winter and spring 2018 on northern side of Sukkertoppen mountain indicates a movement (solifluction) of 3–5 cm/y in slope inclination of 15–20°. The solifluction will affect the foundation of the supporting structures as well as the frost jacking which is considerable. The weight of the dams is of great concern as (Isaksen et al., 2017) and (I. Hanssen-Bauer et al., 2019) estimate that the permafrost will have disappeared in Longyearbyen by the year 2100. The consequences for the dams are uncertain but it might cause some settling of the dams and failure in the foundations.

3.3 Landscaping

Landscaping is an important part of this mitigation work specially the design of dams just above town center and the deflecting dams along the stream Vannledningselva. As of today, the involvement of landscaping architect has been minimal as the work until now has been conceptual rather than on details. Hints have though been given on some of the important and most visual part of these constructions. The landscaping work will be in close cooperation with the local authorities.

3.4 Hazard zoning

To make possible a cost/benefit analysis of the different mitigation concepts, hazard zones were made for each concept. These hazard zones were then used to evaluate which buildings could be left in the area after the measures were implemented, and which have to be removed.

4. EPILOG

The client NVE and LL decide to go for supporting structures as a mitigation measures for the town centre and deflecting dams along both sides of the stream from Vannledningsdalen.

When this article was written the work on the technical design and tender documents for supporting structures has just started.

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