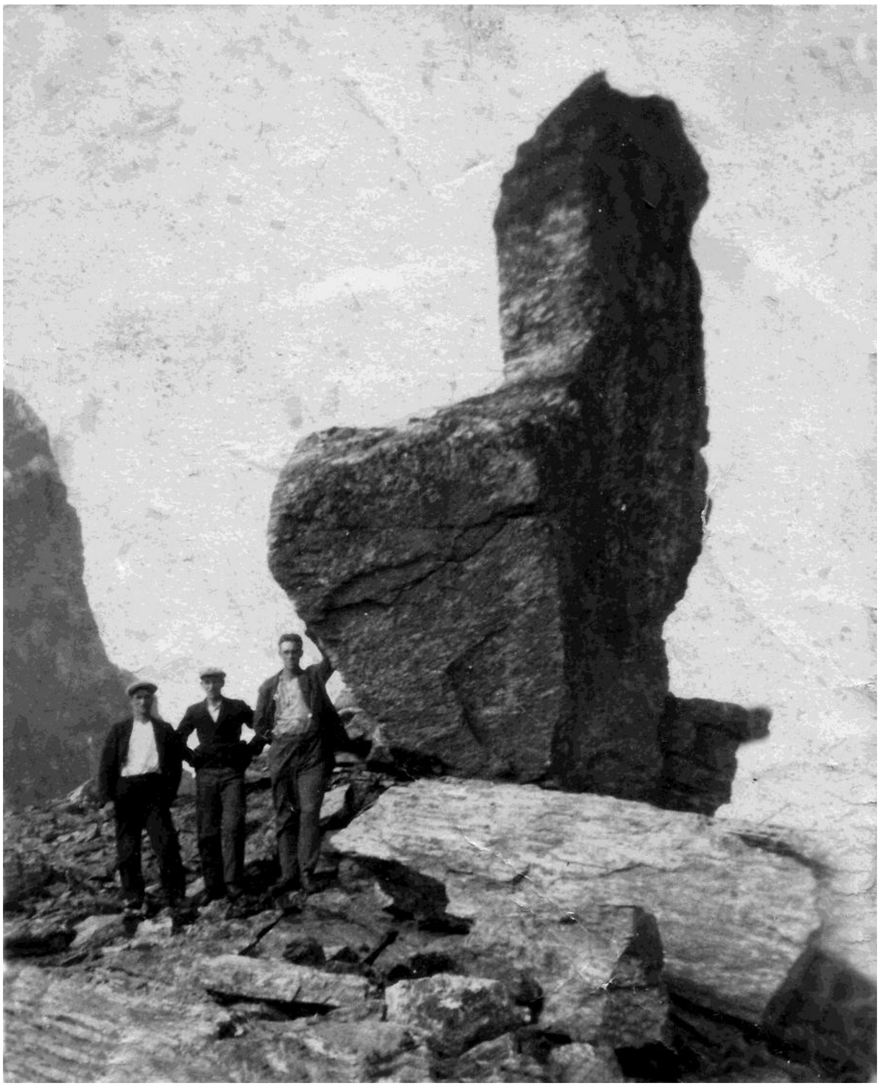
ÅKNES

Åknes Report 03 2010

Mannen in Romsdalen: Monitoring and data analyses



Summary

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Title	Mannen in Romsdalen: Monitoring and data analyses
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Summary:

Documentation, analysis and interpretation of data are important parts of the quality routines for Åknes/Tafjord Early Warning Centre. This report presents the scenarios, data analysis of the existing monitoring systems and the planned instrumentation in 2010. It is a base for the established advisory group for the Åknes/Tafjord Early Warning Centre.

The existing and planned monitoring at Mannen is based on the need of redundancy, the large consequences of failure and the regulations in Norwegian building codes.

The monitoring systems today include lasers, extensometers, tiltmeters, a ground-based radar and a meteorological station. The data so far shows movements comparable of what have been expected based on periodic measurements.

Content

Introduction

Documentation, analysis and interpretation of data are important parts of the quality routines for operative early-warning systems. This report is a part of the documentation procedures and is an important base for review by the established advisory group for the Åknes/Tafjord Early Warning Centre.

The report presents the scenarios, analysis of the existing monitoring systems and data, and the planned instrumentation in 2010. In addition to existing monitoring systems, also the plans for instrumentation in 2010 are presented. So far, data from two lasers, five tiltmeters, ground-based radar and the meteorological station is available. Data-series from each instrument is presented following a brief assessment of the noise level of the dataset.

Scenarios

The unstable area is situated at 1300 m altitude on the southwest side of Romsdalen in Rauma municipality (Fig. 1). Geological mapping has demonstrated large open fracture systems, and periodic GPS measurements shows annual movement of up to 5 cm in an area of at least 2-3 mill m^3 (scenario A on Figure 1) (Dahle et al., 2008, 2010; NVE, 2009). The total volume (scenarios A + B on Figure 1) is estimated to be up to 15-25 mill m^3. A rockslide will cross the valley and cover large areas, in addition to the damming of the river Rauma. A dam collapse can cause serious consequences further down the valley.

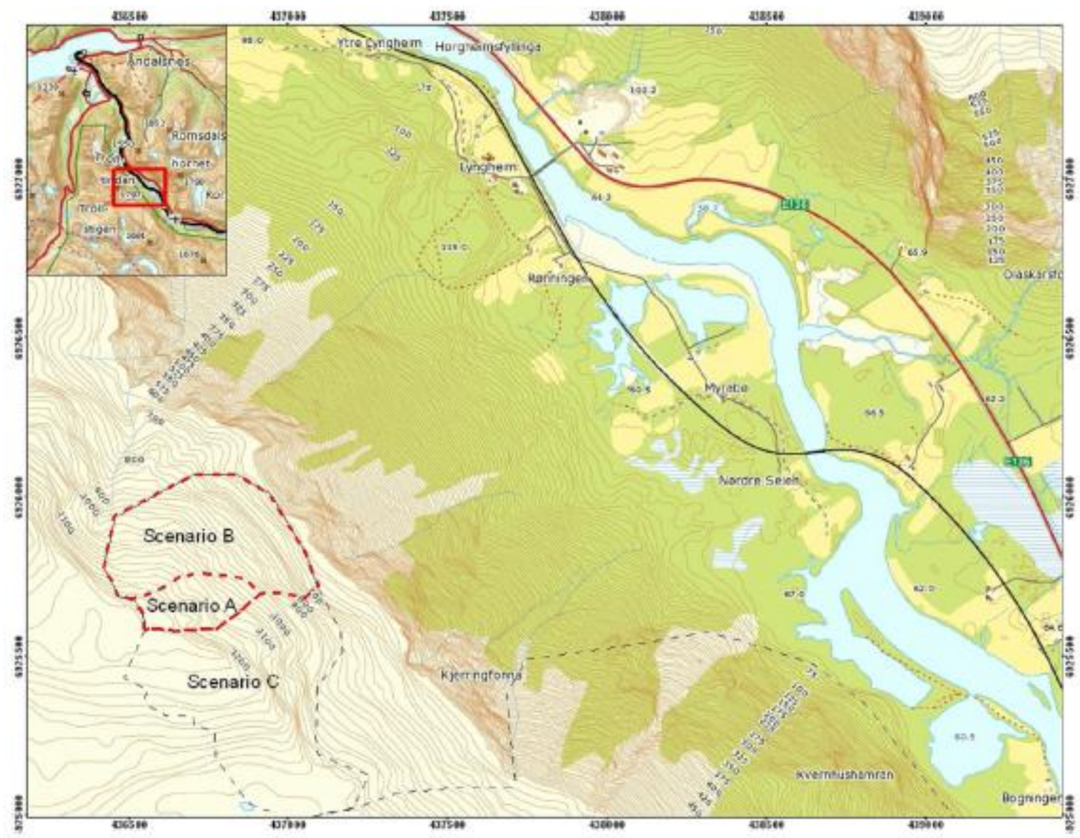

FIGURE 1. THE UNSTABLE AREA AT MANNEN WITH SCENARIO A (2-3 MILL M^3), B (15-25 MILL M^3) AND C (FROM DAHLE ET AL., 2010).

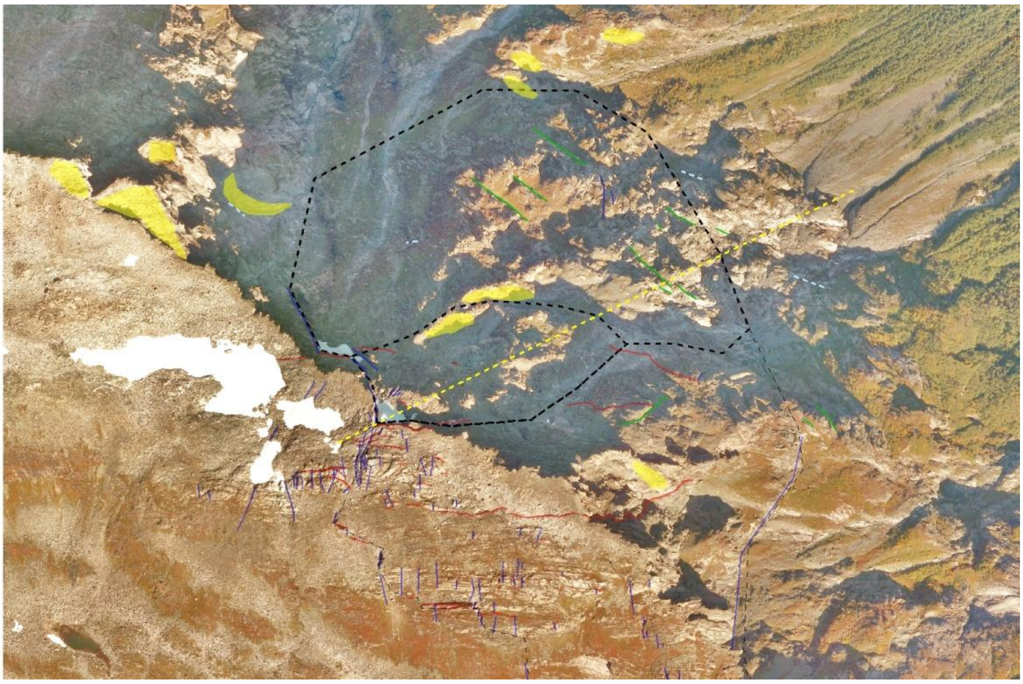

FIGURE 2. POSSIBLE SCENARIOS AND THE LOCATION OF THE PROFILE IN FIGURE 14DRAWN ON AN ORTHOPHOTO (DAHLE ET AL., 2010).

Instrumentation

Instrumentation was initiated at Mannen in the summer/autumn 2009 (Figure 3) and so far the following has been established:

1. Surface monitoring.
    a. 7 extensometers (Figure 3G & Figure 7)
    b. 5 tiltmeters (Figure 8)
    c. 2 single lasers with heated reflector plates (Fig. Figure 3E, Figure 3F & Figure 4)
2. Meteorological station (Figure 3D)
3. Ground-based radar in Romsdalen. (Figure 3H)
4. Bunker with power supply and communication system (Figure 3C & Figure 3F)

Due to an early snowfall in fall 2009, some sensors are still not connected.

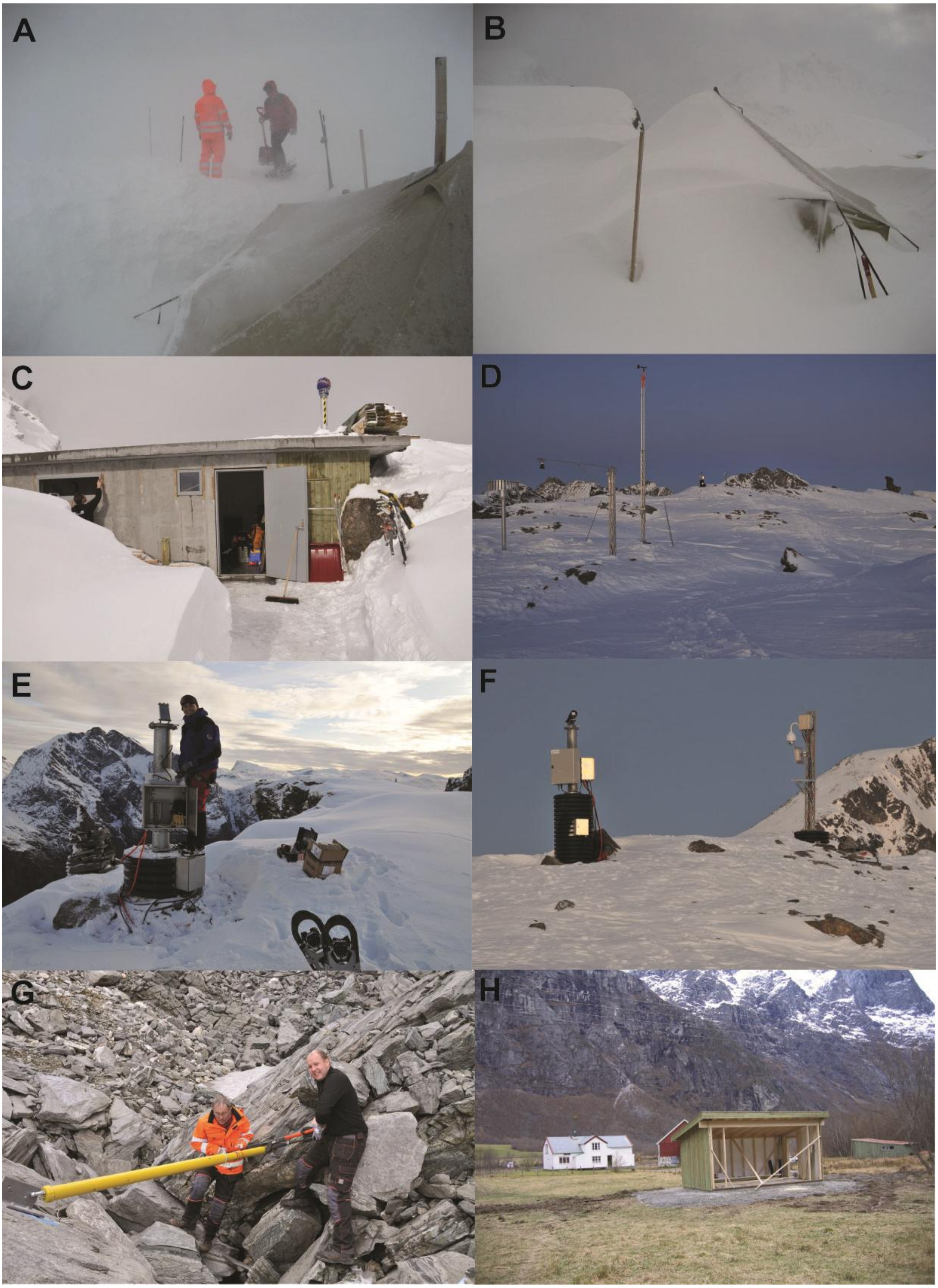

FIGURE 3. PHOTOS FROM ESTABLISHMENT OF DIFFERENT MONITORING ON MANNEN IN 2009. A) AND B) SNOW STORM AND THE TENT CAMP IN OCTOBER; C) BUNKER; D) METEOROLOGICAL STATION; E) ESTABLISHMENT OF LASER SYSTEM LASER SYSTEM; F) LASER TO THE LEFT AND COMMUNICATION ANTENNA AND WEB CAMERA TO THE RIGHT; G) EXTENSOMETER; H) BUILDING FOR THE GROUND-BASED RADAR IN ROMSDALEN.

Lasers

Two lasers are measuring movement across a large crack in the mountain (Figure 4); data-plots can be seen in Figure 5 and Figure 6.

The laser-data contain considerable noise with spikes up to 20 mm, but the many spikes should be overlooked as they are caused by meteorological event. Doing that it is easy to see a clear trend of increased displacements from both lasers. Measured visually on the graph, laser 1 has moved 5.3 mm from the 1th of December 2009 to 21th of May 2010, averaging to 11 mm/yr. Laser 2 has moved 12 mm from the 1th of December 2009 to 21th of May 2010 averaging to 25.6 mm/yr. The movement was largest in the late part of 2009.

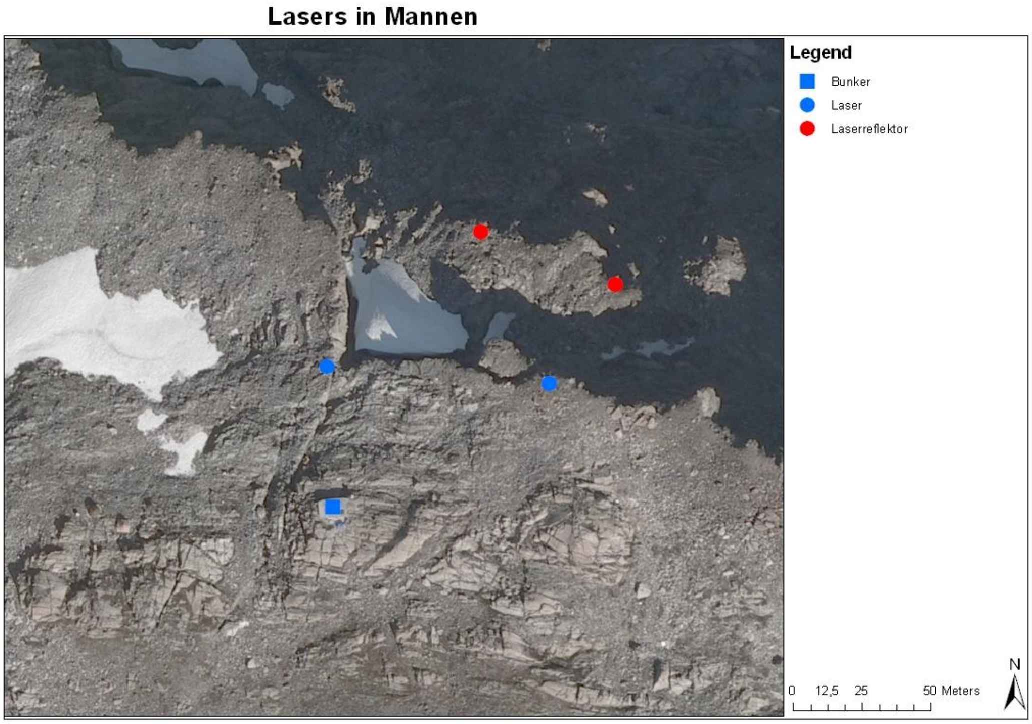

FIGURE 4. LOCATION OF SINGLE LASERS AND REFLECTORS AT MANNEN.

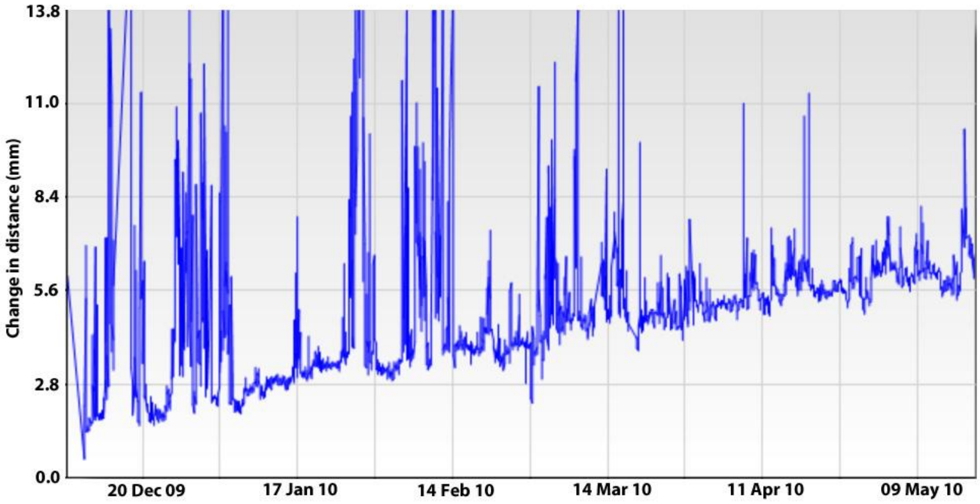

FIGURE 5. LASER 1 FROM 6 DECEMBER TO 21 MAY.

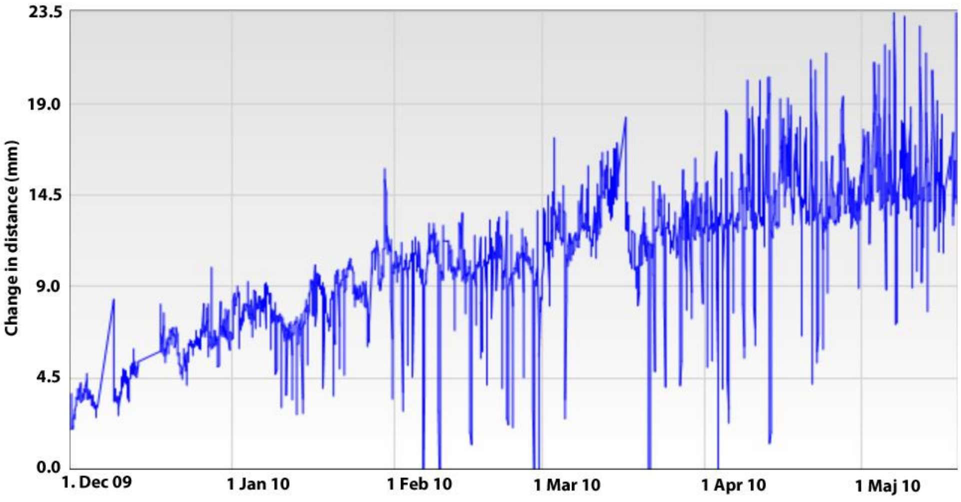

FIGURE 6. LASER 2 FROM 1 DECEMBER 2009 TO 21 MAY 2010.

Extensometers

Seven extensometers were installed in different smaller cracks in the upper area of Mannen in late 2009 (Figure 7). They were not connected to a datalogger that autumn, and therefore no data from the extensometers is presented.

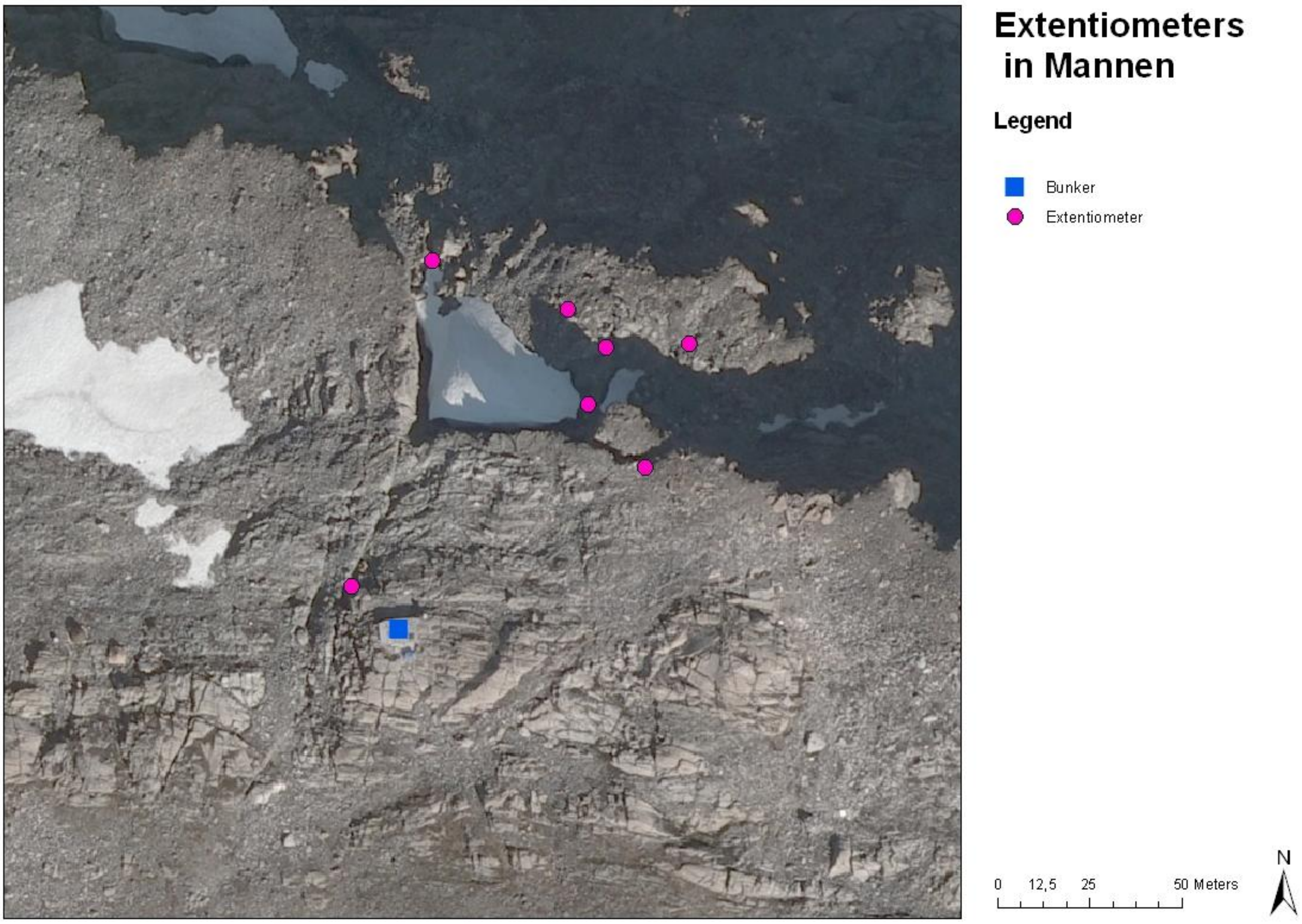

FIGURE 7. LOCATION OF EXTENSOMETERS AND THE BUNKER.

Tiltmeters

Four tiltmeters were established at different places at Mannen (Figure 8). The system has just been implemented in the integrated web-based monitoring system by Cautas Geo. The data seem to be quite stable although no detailed evaluation and interpretation has been performed. The noise level seems to be in the order of 0,2-0,7 mm/m (Figure 9). One of the tiltmeters demonstrates movements in the rage of 1 mm in the 5 month measuring period (Figure 9 & Figure 10).

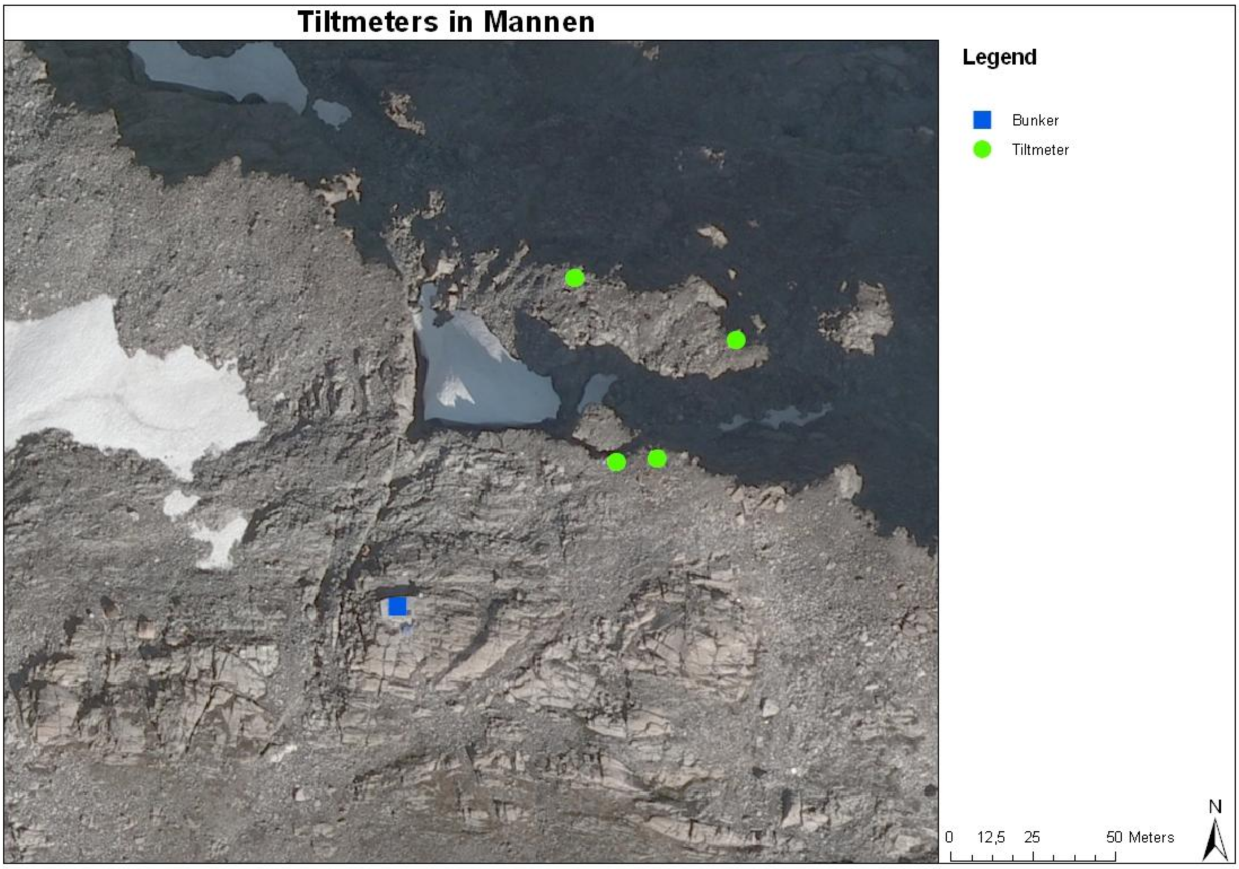

FIGURE 8. LOCATION OF TILTMETERS AND THE BUNKER. TILTMETER 3 SHOWN IN FIGURE 9 AND 10 IS LOCATED ON UPPER RIGHT HAND SIDE AT LASER REFLECTOR 1.

FIGURE 9. ONE WEEK DATA FROM TILTMETER 3, A AXIS (NORTH-SOUTH), AT MANNEN.

FIGURE 10. DATA FROM TILTMETER 3, B AXIS (EAST-WEST) AT MANNEN IN THE PERIOD FROM THE 18TH OF DECEMBER TO THE 28TH OF MAY 2010.

Meteorological station

A meteorological station was established by the Norwegian meteorological Institute in autumn 2009, but was not connected correctly to the datalogger before 29th of April 2010. More snow than expected built up during the winter, and buried the air temperature and humidity sensors and almost the precipitation sensor, resulting in almost constant readings until 16 May (Figure 11) reflecting only in-snow conditions. The sensors will be placed higher in the summer 2010. Figure 11 shows only a few days of good measurements, after the snow had disappeared from the sensors.

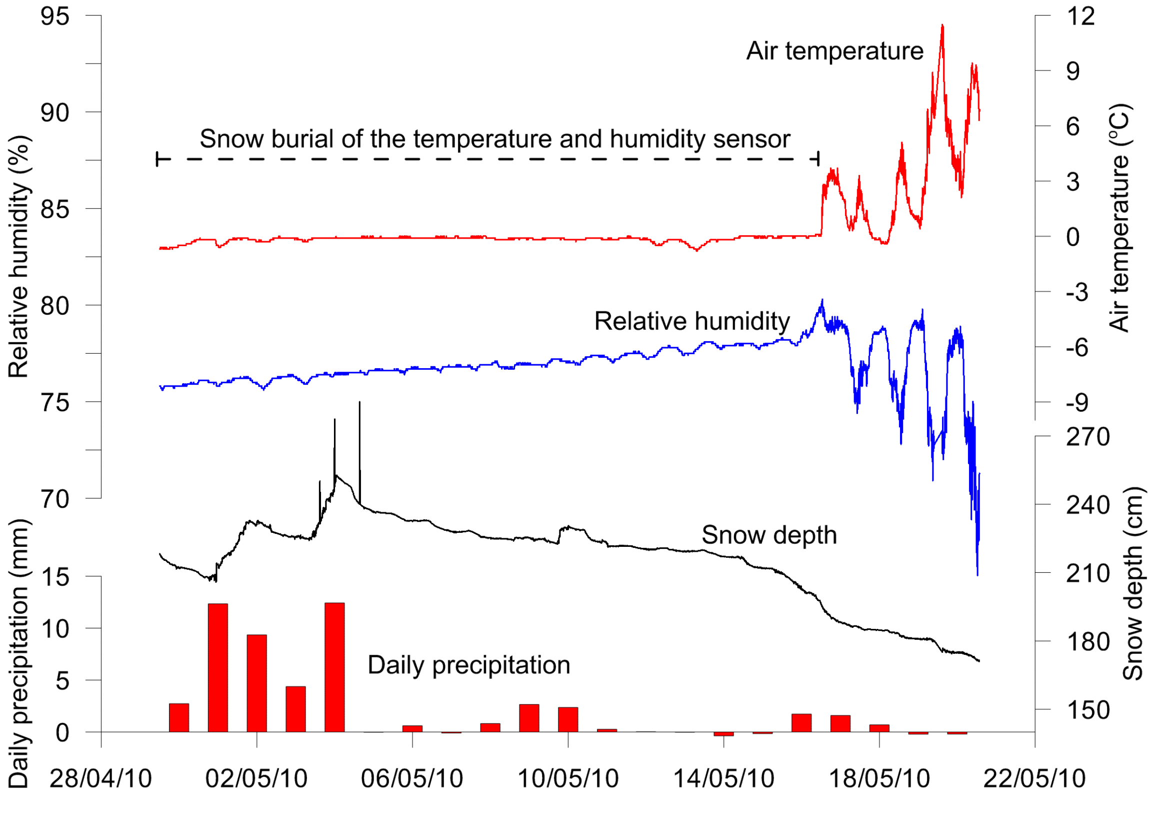

FIGURE 11. DATA FROM THE METEOROLOGICAL STATION AT MANNEN.

Radar measurements

A ground based InSAR system (LiSALab from Ellegi srl) was installed for permanent monitoring of Mannen the 3rd of February 2010. The radar is placed in the bottom of the valley Romsdalen and has a possibility to see a large part of the mountain slope measuring an area of 2200 m across and with a maximum distance to the field of view of 2700 m (Figure 12).

The radar will hopefully provide spatially distributed information on movement from interferograms as well as displacement of 10 points of interest that we have selected. An example of an interferogram projected onto a DEM can be seen in Figure 12.

The locations of the points of interest can be seen on Figure 13 and a plot of the displacement of the points is shown in Figure 14. So far it is difficult to evaluate the performance of the radar. However, some of the individual points shows a displacement of up to 4,5 mm during 3 months, which is comparable of what has been seen from the laser measurements.

A broken cable and problems with the router caused some problems with the radar system in April – May.

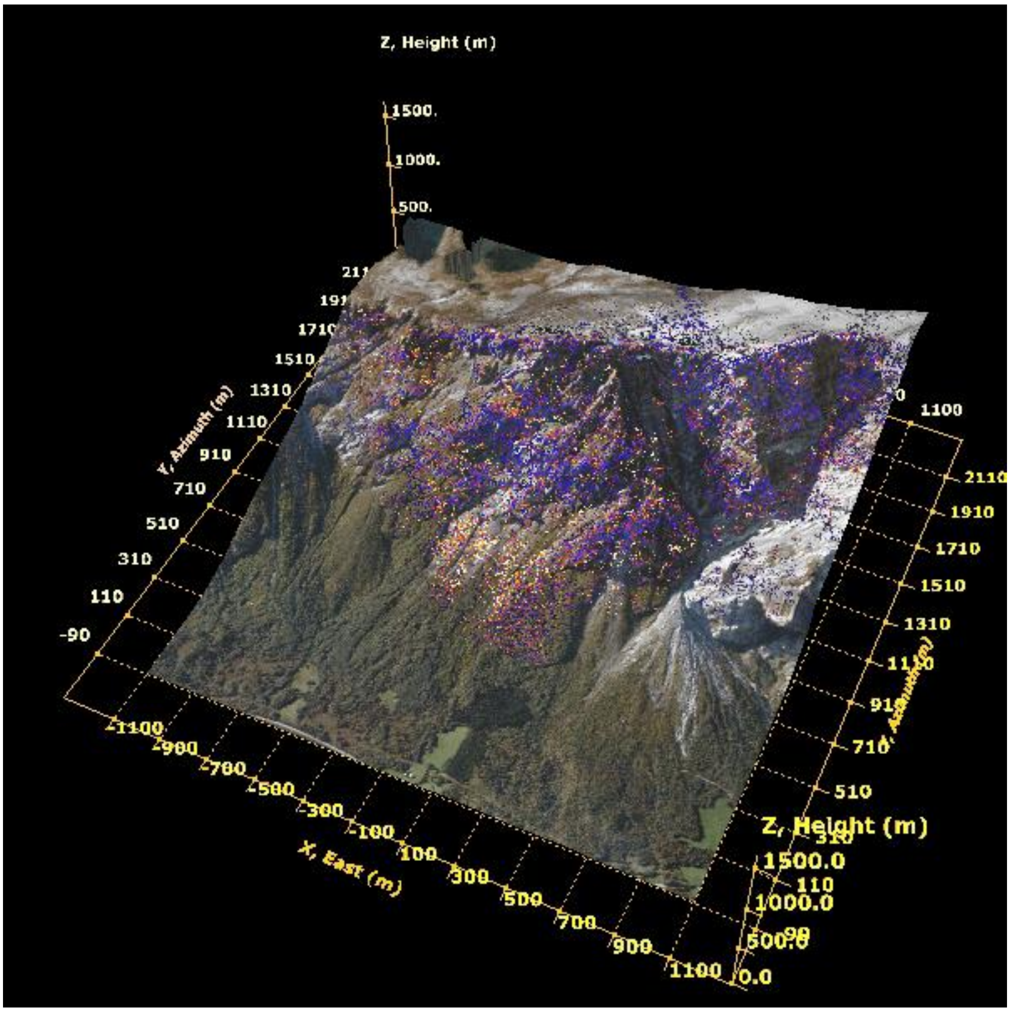

FIGURE 12. INTERFEROGRAM PROJECTED ON A DEM WITH A DRAPED ORTHOPHOTO.

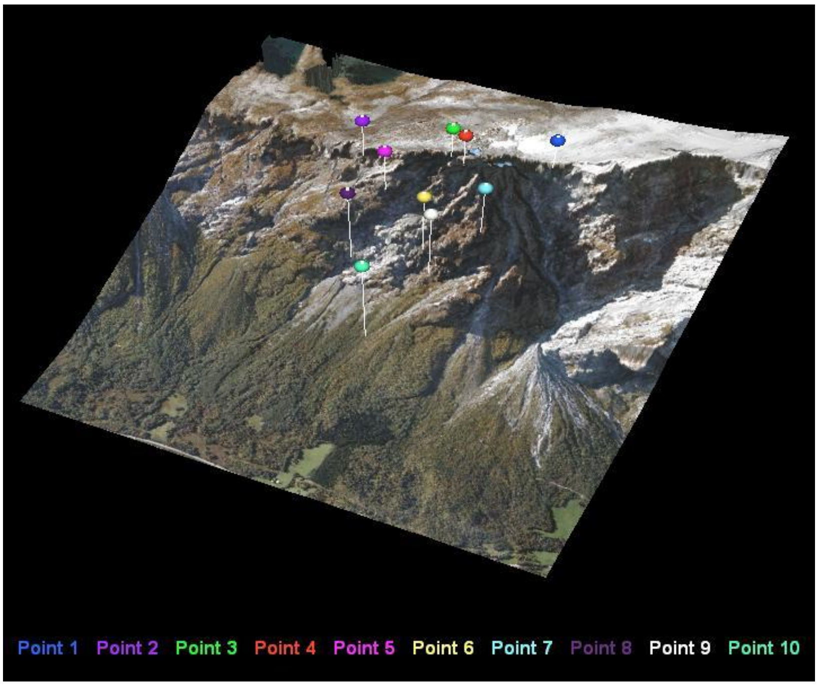

FIGURE 13. LOCATION OF THE 10 SELECTED POINTS OF INTEREST.

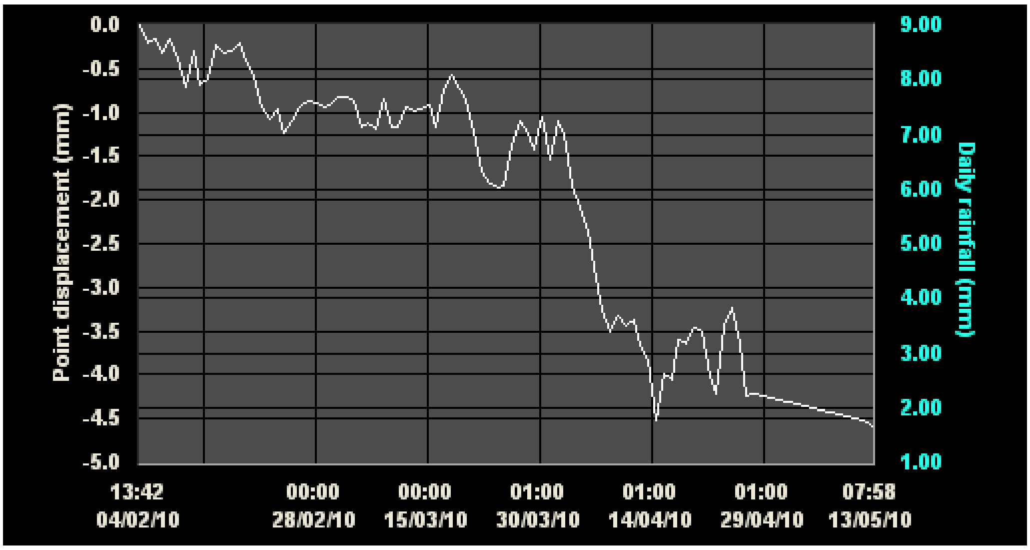

FIGURE 14. DISPLACEMENT OF POINT 7 INDICATING MOVEMENT OF 4 TO 5 MM FROM THE 2ND OF FEBRUARY TO THE 13TH OF MAY.

Alarm levels and SMS messages

Although the existing monitoring system is part of operative system at Åknes/Tafjord Early Warning Centre, the system is not yet fully operative. The different alarm levels and SMS message system has not yet been implemented, but will likely be based on the same principles as that of the Åknes rockslide (Kristensen et al., 2010).

From the existing data it seems realistic to implement SMS messages from the ground-based radar, tiltmeters, and probably the extensometers. The lasers seem to record too much noise to be used for SMS messages (up to 20 mm spikes). SMS message system is already implemented for the ground-based radar within the contract with Ellegi srl who has established the LiSALab system. It is stressed that SMS messages will never be used alone to change alarm levels, but is an important support and help for the persons on duty.

Plans for 2010

New Norwegian building codes have several requirements regarding operational early-warning systems. This includes both the need for monitoring systems, power supply and communication systems. The need of duplication of systems and redundancy is stressed in the building codes. The plans for 2010 are to fulfil these requirements, including establishment of a GPS network and to perform two deep core drillings (Figure 15 & Figure 16).

The GPS network is important in order to have reliable systems measuring total movement during the entire year. The ground-based radar may have problems due to snow coverage during winter time.

Boreholes are important in order to identify sliding planes and understand the dynamics of the rockslide, but are also a very reliable system for early warning. In this area we may also have permafrost conditions, which complicate the understanding of the kinematics. It is proposed to have one borehole on the moving block, and one on the backside, but still within open fracture systems (Figure 15 and Figure 16). If practical possible, a borehole further down the slope should be prioritized before the borehole on the topmost part. The boreholes will be logged by different geophysical methods before establishment of casing and instrumentation (DMS column).

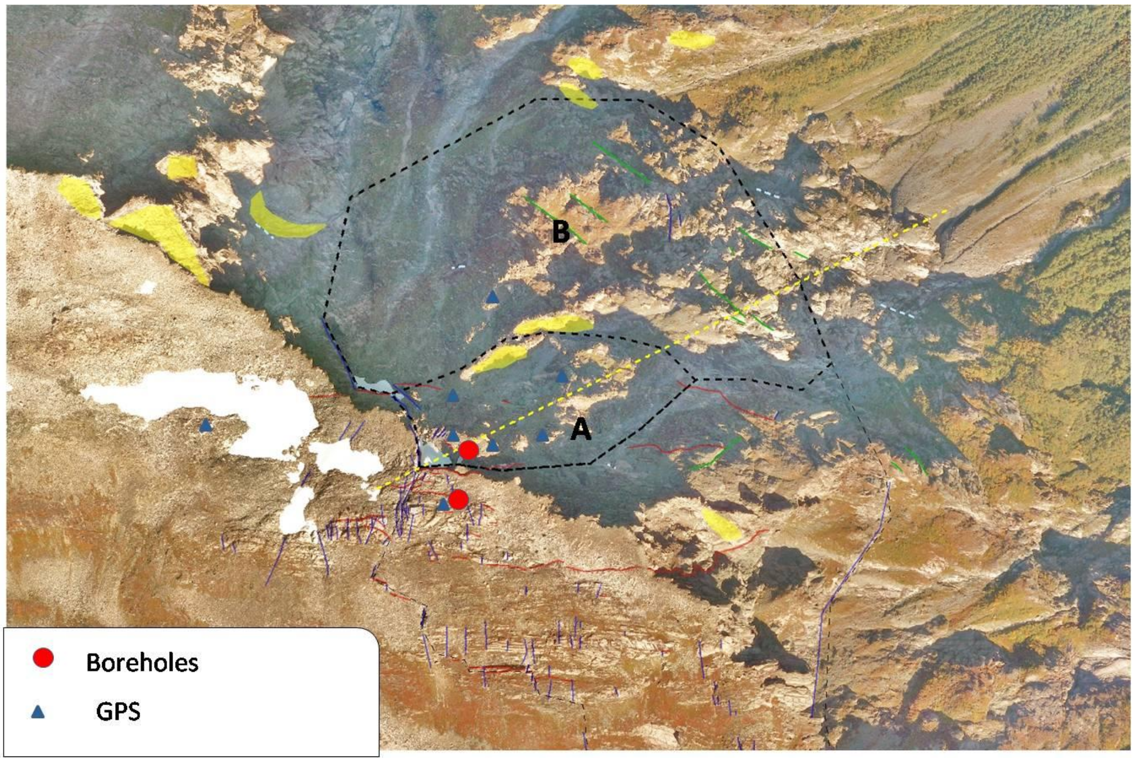

FIGURE 15. PROPOSED LOCATION OF GPS NETWORK AND BOREHOLES. THE LOCATION OF THE BOREHOLES AND GPS ANTENNAS HAS TO BE ADJUSTED ON THE BASIS OF DETAILED FIELD INSPECTION AND DATA FROM THE GROUND-BASED RADAR. A AND B IS THE TWO DIFFERENT SCENARIOS.

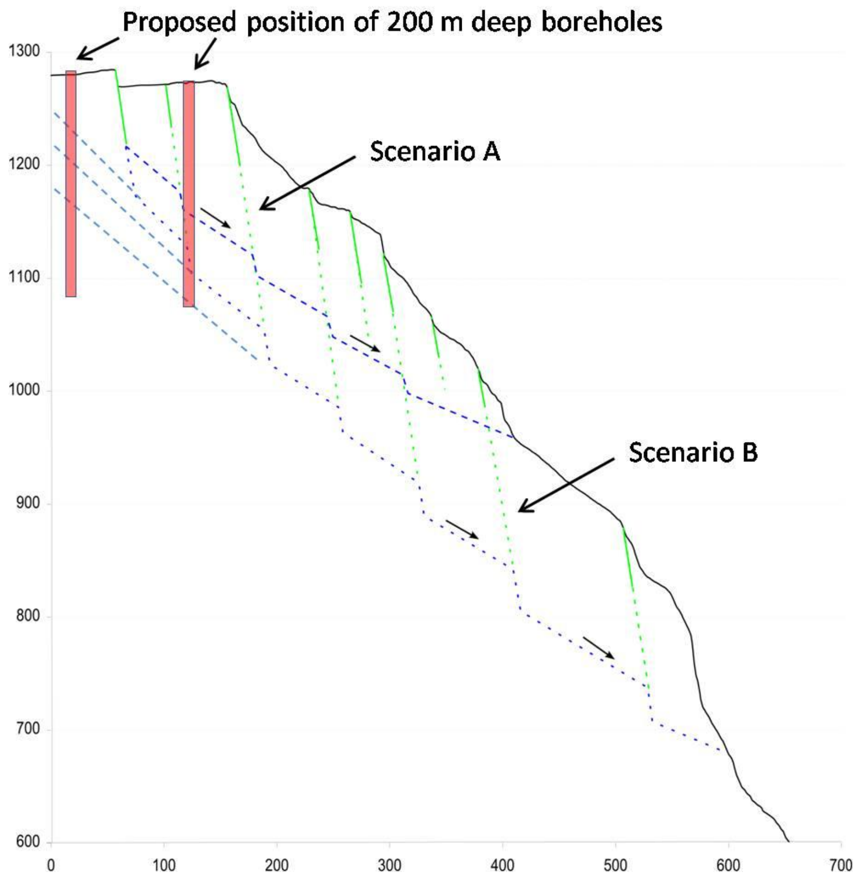

FIGURE 16. TENTATIVE POSITION OF THE BOREHOLES ON A SCHEMATIC CROSS PROFILE. BOREHOLE LOCATION FURTHER DOWN THE SLOPE WILL BE EVALUATED DURING THE SPRING 2010.

References

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