AVALANCHE MANAGEMENT IN A LARGE CHILEAN COPPER MINE

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ABSTRACT: The Andina copper mine is located at an elevation of 4200 m. in the Rio Blanco Valley north of Santiago de Chile. It is one of the world's most productive copper mines. The primary service road is 35 km long and threatened by 148 avalanche paths. Workers, mine communications and important installations are threatened by both dry powder snow and wet snow avalanches. Mining staff in charge of road safety use different approaches to forecast avalanche danger. However, additional measures are still needed to reduce the residual risk. The problem here is the question, "how safe is safe enough?" This question cannot be answered in purely scientific-technical terms because subjective factors, based on experience and intuition play an important role. In addition risk calculations are affected by different permanent and temporary protection measures. For example, to reduce the road closure hours, the avalanche safety team uses different avalanche control system such as Helibombing, GAZEX. CATEX, and AVALANCHEUR. The goal must be to guarantee that the risk during transportation of mine personnel on the service road is comparable to all (obviously accepted) risks during working hours. The safety decisions for closure of the road are often complex and not popular for mine operators. Ultimately the risk analysis is the most important measure to control road access. In this way Codelco Andina uses a network of automatic weather stations, snow profile and different software tools to predict the avalanche risk level. However, because the residual risk remains high and the requests for opening roads are increasing each winter, big challenges in the upcoming years lie ahead.

KEYWORDS: avalanche, management, risk, operation, mining.

1. INTRODUCTION

High-altitude mining has a tragic relationship with snow avalanches. Three of the most deadly snow avalanche accidents have occurred in mining operations. On December 5th, 1935, a large avalanche released from Mount Iukspor in a Soviet apatite mine in the Khibiny mountains killing 89 people. On the 8th of August, 1944, the Teniente copper mine in the central Andes was struck by a catastrophic avalanche, killing more than 100 workers in the Sewell mining camp. The worst mining avalanche disaster occurred on February 9th, 1945, when an avalanche buried the living quarters of the coal mine October on Sakhalin island, killing 131 people, (see Podolski, 2014, and Vera, 2016).

Mine operators set high production objectives that place huge pressures on engineering staff. This pressure is translated to the natural hazards safety department who must objectively assess specific hazards, specifically avalanche hazard or debris flow hazards resulting from extreme rainfall. They must often make difficult decisions under high time pressure. The mine presented on this paper is located in the central Andes, 150 km northeast from Santiago, Chile and is in operation since the late 60's. The winter safety operation guidelines were formulated in 1965 by the engineer M. Atwater, author of the 'Avalanche Hunters' book. Atwater was clearly aware of the extreme terrain where the mine was located (see Atwater, 1965). Since the 1960s the mine has increased its size and activity by a factor three. Therefore the avalanche winter risk is increasing – not decreasing.

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Fig.1. Road clearing staff working after a snow storm. The road team has cut a path through 10m high avalanche deposits.

2. MINE OPERATION

The Codelco andina mine operates in the 'Cajon del rio Blanco valley. A 35 km long road connects the mine entry at 1700 m.a.s.l. with the open pit at 4200 m.a.s.l. The road is threatened by 148 active avalanche paths (see Vera 2016). The mine operates 365 days a year with two daily 12 hours working shifts. Every working shift is composed of 1500 mine workers who must travel on the industrial road twice a day. A total of 6000 people use the road per day.

The mine has a special winter regulation during the months of May and October. During this time the winter operation crew manages the industrial road and is responsible for opening/closure decisions and therefore decides when working shifts can change.

The mine winter regulations have a system of alerts based on the meteorological conditions. Every alert has its own operation implications:

- Alert 1: Notification that stormy weather is approaching. Non-basic workers for the mine operations are not allowed to enter to the mine operations area. Operations chefs should check on their supply and equipment situation.
- Alert 2: Commencement of the storm. Operation chefs will take actions to prepare for restrictions or closures. All the movements on surface must be authorized by the winter operation crew.
- Alert 3: Hazard situation exists. All activity in mine surface is strictly forbidden. The winter operation crew will announce the operation plan every eight hours until the conditions change.
- Alert 4: Post-storm. Only vehicles and staff from the winter operation crew and road clearing are allowed to work on the surface. The winter operation crew forecasts the road opening/closure hours to the mine operations chefs. All the movements on surface must be authorized by the winter operation crew

The winter operation crew publishes a so-called 'risk bulletin' twice a day. The bulletin informs minors of any natural hazard dangers and possible consequences. The bulletin is valid until the next bulletin is published.

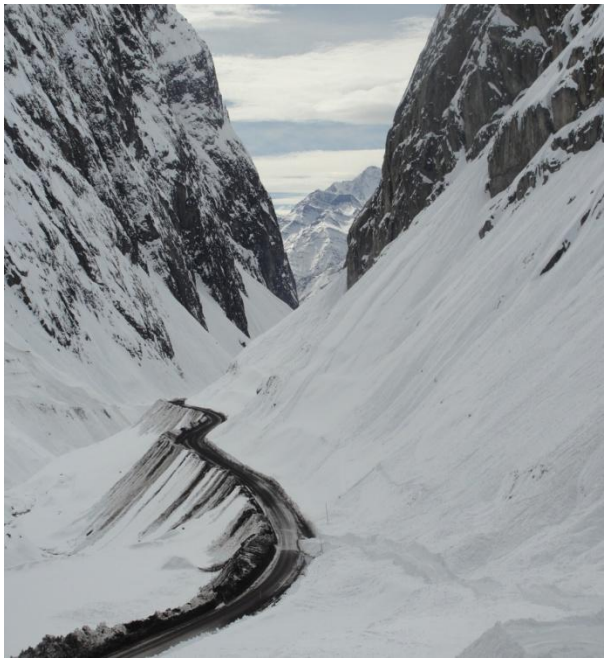

Fig.2. Industrial road after the clearing, August, 2015. The industrial road cross along steep slopes for 10 km.

3. AVALANCHE CONTROL AND AVALANCHE RECORDS

The mine has a set of avalanche control systems (Gaz- ex, Catex and Avalancheur) located at several strategic avalanche paths threatening sensible buildings. However, none of these systems is installed to ensure the road. The road is controlled after the storm either by helicopter bombing or hand charges -- when the conditions allow. The results from these controls give the winter team a good indication of the current avalanche risk situation.

The avalanche activity is recorded in a database together with the current meteorological and snowcover observation creating a valuable source of information for future decision making strategies.

Fig.4. Avalanche deposits interrupting the industrial road, October, 2015. (see Vera, 2016).

4. DECISION MAKING

The winter operation crew consists of two teams with three specialists each: snow and avalanche observer, winter hazards supervisor and meteorology expert. The teams are based in the Lagunitas camp at 2770 m.a.s.l. and in the open pit mine at 4200 m.a.s.l. Both teams are under the charge of the mine natural hazards director. The team uses the following sources of information:

- Meteorological forecasts.
- Field observations: snow pits, helicopter flights and road surveillance.
- A network of automatic weather stations (See Vera, 2016)
- Output from the SNOWPACK and RAMMS models running operationally (see Vera, 2016).

The winter operation team publishes a bulletin twice a day at 9:00 in the morning and at 17:00 in the afternoon. The bulletin describes the hazard situation and states the operation for the next working shift. The bulletin applies to all the mining employees.

4.1 Implicactions of the bulletin

Once the bulletin is published and all operation chefs informed, the mine sets up the operation plan, which will be valid until the next bulletin is published or further communication from the winter operation crew is announced.

The largest problem for the winter operation crew is to assess the avalanche risk without been influenced by the mining operators. The mining business is based on the optimal use of operation hour. Therefore closures due to natural hazards are not popular. The winter operation crew remain independent and withstand the external pressure. This is not easy when the mine directors need to operate.

Fig.5 Helicopter bombing mission after snowfall, August 2012.

The use of 'up-to-date' snowcover and avalanche dynamics models such as SNOWPACK and RAMMS has helped the winter operation crew enormously to defend unpopular decisions. The modern visualization techniques from these models allow the team to explain its reasoning visually. The modeled avalanche risk can be compared with past avalanche events and published in the report to help the winter operation tool to communicate its decisions to a broad public within the mine.

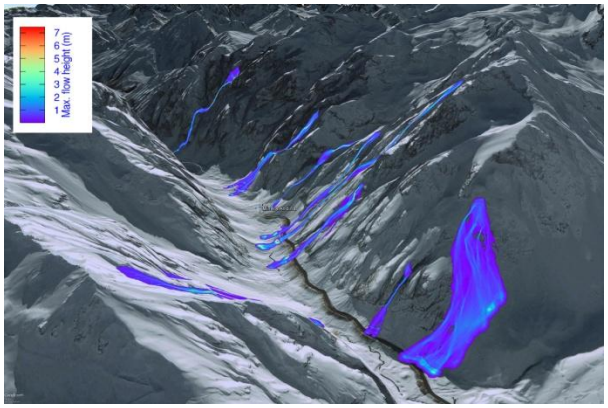

Fig.6. 3D visualization of RAMMS simulations with the current avalanche situation.

5. CONCLUSIONS

The winter operation team is responsible of the road management during the winter months. In this time they have to decide about the road operation and therefore the entire mine operation. In spite of all the avalanche control together with other information systems, the team has to make decisions under the pressure of the mine operators. Every decision taken by the team has carefully taken since the mine has to operate a maximum operation time with a tolerable risk. Challenges come not only by the decision making but also by decision communications.

ACKNOWLEDGEMENTS

We would like to acknowledge to all the CDA members from Codelco and the Mountain Safety winter crew for the support and hard work during the last four winters in the Codelco Andina mine

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