COUGAR CORNER – THE LARGEST SNOW NET INSTALLATION IN THE WESTERN HEMISPHERE

Brian Gould[1]*, Cam Campbell[1], and Andi Buechi[2]

[1] *Alpine Solutions Avalanche Services*
[2] *Geobrugg AG*

ABSTRACT: For over half a century, the Rogers Pass area in Glacier National Park, British Columbia has represented the epicenter of avalanche mitigation in Canada. Over 134 avalanche paths are known to affect the Trans-Canada highway, a major transportation route that winds its way through the pass. Since the early 1960s, avalanche protection for the highway has involved a mixture of snow sheds, diversion berms, retarding mounds, and an operational program that includes ongoing forecasting and artillery-based control using 105mm Howitzers operated by the Canadian Armed Forces.

While the combination of these measures has functioned well, increasing traffic volumes and decreased tolerance for road delays has resulted in a need for new mitigation measures. One of these new measures is the Cougar Corner snow net system, which at almost 2 km in length, is the largest installation of snowpack supporting structures in the western hemisphere. Over two summers (2016 and 2017), this snow net system was installed in Cougar Corner 6, 7, and 8 - three steep avalanche paths involving a steep, complex, and rocky terrain.

The design and layout of the system involved desktop terrain analysis using GIS, on site GPS survey, and numerous days of hands on measuring in complex terrain accessed via a combination of vertical ropes and via ferrata-type fixed traverse systems. Swiss-based design parameters were incorporated. Challenging terrain for snow net installation encountered during the layout process included sloping benches and incised gullies. Innovative solutions employed to overcome these challenges included the use of three debris flow barriers in a gully that was too incised to accommodate traditional snow nets. The site conditions during summer construction were complex and hazardous requiring the expertise of engineering consultants, mountain guides, drilling experts, as well as safety and helicopter logistics to complete the project.

This abstract explores the design, layout, and installation of the Cougar Corner system and includes a summary of various methods and techniques that were incorporated. Challenges to the project that required innovative solutions are described. Feedback to date from two winters with above average snowpack height, indicate the snow net system is performing well.

KEYWORDS: snow avalanche engineering, mitigation, snow nets, debris flow nets, design.

1. INTRODUCTION

When the Trans-Canada Highway opened in 1962, snow sheds and earthworks were constructed to protect travelers from the most frequent avalanche paths. These measures have since been supplemented by operational avalanche mitigation which incorporates temporary closures, and highway-based Howitzers (operated by the Canadian Armed Forces) to trigger avalanches when the hazard is high. In recent years, increasing traffic volumes and decreasing tolerance for travel delays has led to a demand for more robust avalanche mitigation measures.

* *Corresponding author address:*
Brian Gould, Alpine Solutions Avalanche Services, Box 417, Squamish, BC, Canada
tel: +1 604-815-8196
email: bgould@avalancheservices.ca

Recently, a large installation of 'snow net' snowpack supporting structures was commissioned by Parks Canada in Glacier National Park to protect an exposed section of the Trans-Canada Highway (TCH) near Rogers Pass. The design-build project involved extremely challenging terrain, both from a design and installation perspective. This paper discusses the methodology used and presents some of the challenges encountered.

2. PROJECT OVERVIEW

The snow net project is located approximately 9 km west of Rogers Pass between Golden and Revelstoke in southern British Columbia. Rogers Pass is well known for its heavy snowfall, with an average of 14 m of snow falling annually at treeline elevations (J. Goodrich, personal communication, 18 July 2017). The section of highway over the Rogers Pass travels through the tracks and runout zones of approximately 134 avalanche

paths, several of which impact the highway annually, resulting in closures and sometimes lengthy traffic delays.

The three avalanche paths designated for the installation of snow nets are Cougar Corner 6, 7, and 8 (Figures 1-2). The starting zone elevation of the three avalanche paths range between 1400 m and 1700 m. The approximate areal extent of all three starting zones is 24,726 m^2, as illustrated in Figure 2.

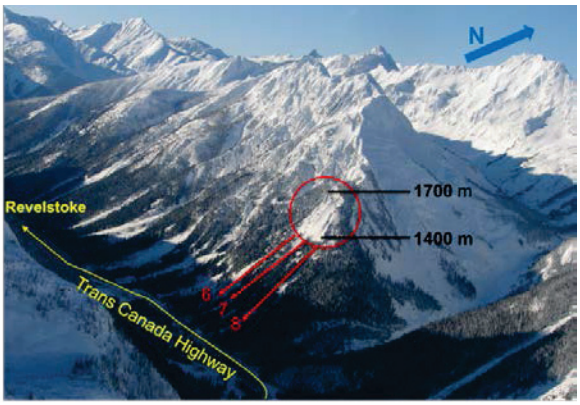

Figure 1: Overview of snow net location.

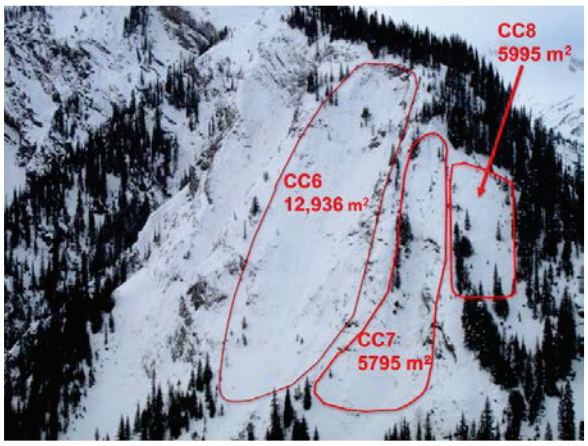

Figure 2: Cougar Corner (CC) paths.

The Cougar Corner site is steep, rugged, and rocky with limited tree cover or vegetation except in Cougar Corner 8 (Figure 3). Terrain is primarily non-planar with several complex rock features interrupting the continuity of the slope.

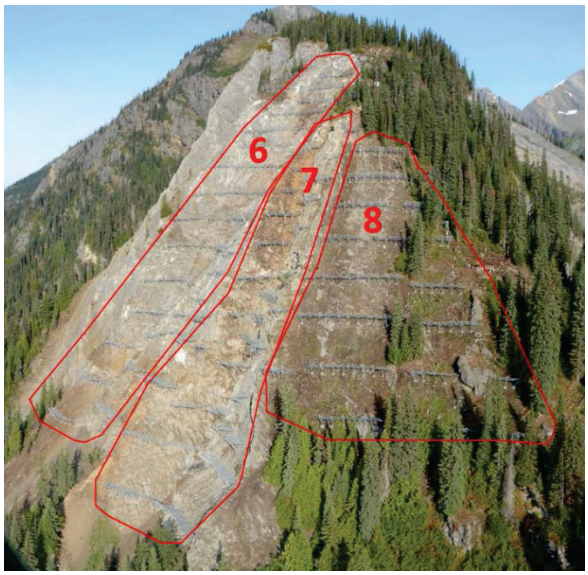

Figure 3: Cougar Corner site with snow nets installed in 2016 & 2017. Paths outlined in red.

3. METHODS

3.1 The Swiss Guidelines

The "Technical Guidelines for Avalanche Defense Structures in Avalanche Starting Zones" published in 1990 and revised in 2007 (Margreth, 2007) serve as the basis for the development and approval in Switzerland. The Cougar Corner snow nets were designed according to these 'Swiss Guidelines', which have become the international standard for snow supporting structures in avalanche starting zones. These guidelines specify:

- Fundamental principles for general arrangement and coverage in order to effectively stop large avalanches from releasing, including minimum fence height and maximum separation between adjacent fence segments in a row.
- Maximum distance between rows of fences down a slope, in order to withstand static snow creep and glide forces.

3.2 Initial Desktop Design

The goals of the initial desktop terrain analysis and snow net layout included:

- Estimation of material needed to within ten percent of the final as-built layout.
- Identification of areas where field-layout will be straight forward and closely match the initial desktop layout.
- Identification of terrain features that pose challenges for layout and require detailed field investigations and fitting.

A high resolution (1 m) Digital Elevation Model (DEM) acquired through LiDAR survey of the site

when it was snow free, was used to determine slope shape and incline, identify constraining terrain features, and plan an initial layout (Figure 4).

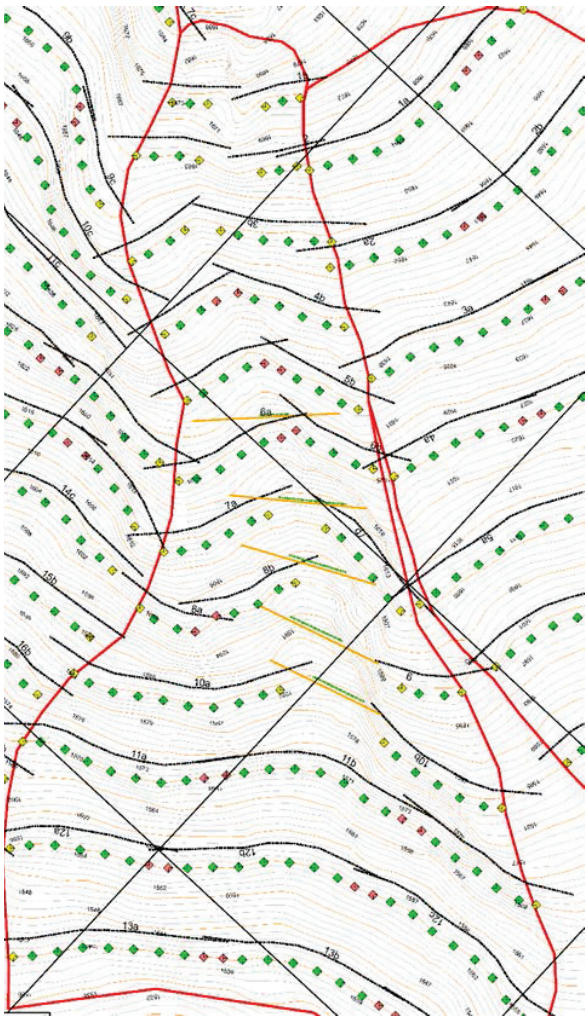

Figure 4: Screenshot of the initial desktop snow fence layout drawing for Cougar Corner 7 showing the avalanche starting zone boundary (red line), post type and locations (green, yellow and pink squares), uphill toe-edge of the Spider nets (black hashed line), and proposed debris flow net locations (orange and green lines).

Gumbel extreme value analysis of historical snow depth data from nearby weather stations was used in conjunction with analysis of snow drifting patterns in historical photographs to determine minimum fence heights. Avalanche starting zone boundaries were delineated from initial outlines provided by Parks Canada and detailed terrain analysis using the 1 m DEM and terrain photographs.

3.3 Field Investigations and Layout

Initial field investigations involved analysis of both the large features that were noticed during the desktop phase, and micro-features such as small steps, overhangs, and grooves that generally were not recognizable. These micro-features perhaps posed the most significant challenge on the project, as snow net systems require a certain degree of terrain uniformity and consistent (and competent) rock for the high strength anchors required to sustain the high snow creep and glide forces.

In addition to providing a challenge for the design and layout of the snow nets, the steepness and ruggedness of the terrain presented significant safety risk for personnel on site due to both falling, and rockfall from above. As a result, fall protection (primarily rope access) and rockfall management systems, including extensive scaling, were employed anywhere these hazards exist, which included approximately 75 % of the project site. Although these safety systems resulted in reduced speed and increased time to complete the project, they ensured a safe worksite for the many drillers, installers, and engineers that were on site on a daily basis.

As is typical with snow nets, layout was completed using a combination of cable jigs provided by Geobrugg, measuring tape, inclinometers, and rangefinders. A high-accuracy Global Positioning System (GPS) with base station incorporating correction was used regularly to position the layout crew in locations designated on the initial desktop design. Dimensions for layout require accuracy for the snow nets to be supported properly in the terrain. Final layout relied extensively on judgement and experience of snow and avalanche engineers, and Geobrugg's technical representatives.

3.4 Quality Control

Ongoing quality control occurred during the field layout phase to ensure the layout conformed to the Swiss Guidelines and Geobrugg specifications. The high-accuracy GPS system was used to survey anchor and post locations that were laid out in the field according to the methods outlined in Section 3.3. These coordinates were analyzed using a Geographical Information System (GIS) to determine spacing between points, distance between rows of fences, separation between adjacent fence segments and inflection angles at post locations (Figure 5).

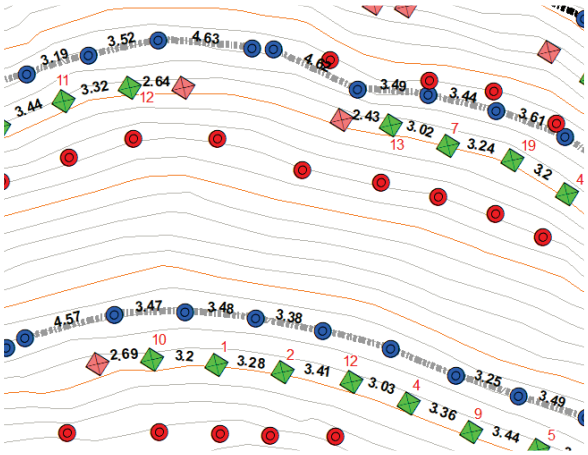

Figure 5: Screenshot of the layout drawing for the lower section of the Cougar Corner 7 starting zone (red outline) showing post (green and pink squares) and anchor (red and blue circles) locations with spacing distances between points (black numbers (m)) and post inflection angles (red numbers (°)).

These parameters were then compared to the Swiss Guidelines and Geobrugg specifications and areas that needed adjustment in the field were highlighted. This was an ongoing iterative process with feedback to the field layout crew and new survey points to the GIS technician on a daily basis.

4. CHALLENGES

Although several challenges were encountered throughout the design, drilling, and installation of the snow nets, there were a few design situations that required innovative thinking, and concepts that had not been used previously. These challenges mainly revolved around the complexity of the terrain that included several discontinuous features, and an incised gully.

5.1. Discontinuous Terrain

Initial field investigations discovered extensive discontinuous terrain, sloping benches, rock fins and ribs, and other complex micro-terrain features that would not allow for a continuous snow net system (Figure 6). In order to adapt to the discontinuous terrain, as well as wildlife permeability and practical installation considerations, fence segments of 7 to 30 m in length, were used. However, there were several isolated slope features that would only accommodate a single central panel of net with two triangle end panels, which was referred to as a 'two-post system' (Figure 7). Although these 7 m two-post systems had isolated use previous to this project, Cougar Corner incorporated 23 such systems, which accounted for 24 % of the rows.

Figure 6: Continuous snow net system.

Figure 7: A 7 m two-post system.

5.1.CC7 Gully

The central section of Cougar Corner 7 path is a narrow converging gully that is over 5 m deep and 10 to 15 m wide at its narrowest point. Terrain investigations determined that standard snow nets were not suitable for this location. After discussing with the manufacturer's technical representatives, it was realized that a debris flow barrier system could effectively be employed. The system is designed for significant loading from debris flow mass, which is much denser and heavier than even the densest snow pack. And the debris flow nets could act as a catchment for any loose snow sloughs that occur between rows of nets. The final installation is illustrated in Figure 8.

Figure 8: Use of debris flow net barrier in CC7 gully.

5. CONCLUSION

The Cougar Corner snow net project represents a milestone for avalanche mitigation in Canada and the world. Not only is it the installation significant in size, it also incorporates innovative design concepts that would not have been possible without the collaborative effort that ensued on the project. Installations have successfully protected the TCH throughout winters of 2016-17 and 2017-18 (Figure 9).

Figure 9: Cougar Corner 7 and 8 path snow nets, March 2018.

6. ACKNOWLEDGEMENTS

The authors would like to acknowledge the following primary organizations and companies that were involved in the Cougar Corner snow net project:

- Parks Canada – the owner.
- McElhanney Consulting Inc. & Dynamic Avalanche Consulting Inc. – the owner's engineer.
- BAT Construction – the prime contractor.
- Geobrugg AG – the snow net manufacturer.

REFERENCES

Margreth, S. 2007. Defense structures in avalanche starting zones. Technical guideline as an aid to enforcement. Environment in Practice no. 0704. Federal Office for the Environment, Bern; WSL Swiss Federal Institute for Snow and Avalanche Research SLF, Davos. 134 pp...