# AADS BEAR PASS: FROM PILOT TO DAILY USE OF THE RADAR-BASED AUTOMATED AVALANCHE DETECTION SYSTEM FOR IMPROVED ROAD MANAGEMENT OF HIGHWAY 37

Susanne Wahlen[1]*, Ryan Boyle[2], and Lino Schmid[1]

*[1] Geoprevent part of Hexagon, Zurich, ZH, Switzerland*
*[2] Ministry of Transportation and Infrastructure, Stewart, BC, Canada*

ABSTRACT: Bear Pass Hwy 37A towards Stewart, BC, is an important link for tourism and transportation of goods to the port. The harsh weather conditions present a major challenge for winter maintenance of Hwy 37A over Bear Pass with its 72 avalanche paths. While the Bear Pass Avalanche Program had a well-established and thorough avalanche forecasting process, it lacked accurate, quantitative data of avalanche events. To improve safety, a radar-based automatic avalanche detection system (AADS) was installed and put into trial operation in 2019. The system was developed for the challenging conditions at Bear Pass and is designed to function fully autonomously in all weather conditions. Since installation, the system has detected and verified more than 6500 avalanche events at two notorious locations, George Copper and Little Bears, each with multiple avalanche tracks. The radar-based AADS has proven to be a reliable and very effective tool in providing timely avalanche information and significantly supporting the avalanche team in their work on to keep Hwy 37A safe.

KEYWORDS: avalanche detection, monitoring, remote sensing, Doppler radar, long-range.

## 1. INTRODUCTION

### *1.1 Situation*

Bear Pass Hwy 37A is the only overland access to the coastal towns of Stewart, BC, and Hyder, Alaska. It is an important link for tourism and transportation of goods from Canada's northernmost year-round ice-free port. The harsh weather conditions characterized by heavy precipitation and arctic winds are challenging for winter road operations. Bear Pass has 72 avalanche paths, ranging from 0 to 2400 m asl and affecting the highway from all aspects and elevations. Some avalanche paths are active year-round with icefall activity.

Bear Pass is on average closed 100 hours annually for avalanche mitigation. The corridor is open and operated at considerable hazard (BC MoTI Hazard scale) for 600-900hrs per winter when avalanches have potential to impact the highway with dust events, plunging out of the steep overhead terrain, creating visibility and traction issues. Closures and delays due to avalanches isolate the community and can cause significant disruption to commercial traffic and travelers alike. The avalanche team works hard to mitigate closure impacts by pre-warning stakeholders of planned or forecast avalanche related events.

The Bear Pass - Stewart Avalanche Program had a well-established and thorough avalanche forecasting process that mainly relied on manual tracking and mitigating avalanche problems as they developed and became active throughout the course of a season. However, the program lacked accurate, quantitative data on timing and character of avalanche events as they occurred, night and day, good weather or bad.

In order to increase safety on Highway 37A, a radar-based automatic avalanche detection system (AADS) was installed and put into pilot operation in 2019.

This paper presents the overall setup of the pilot project for radar-based avalanche detection at Bear pass and provides a large dataset of avalanche events from the last 4 winter seasons. Operational aspects and benefits to the avalanche programme are highlighted and data from the last 4 years is presented.

## 2. AADS SETUP

The radar-based automatic avalanche detection system (AADS) consists of two independent radar stations at the notorious sites of Little Bears and George Copper and covers a total of 10 avalanche paths at safe distance. The advantageous properties of avalanche radar technology in the 10 GHz range enable reliable detection of avalanches in all weather conditions and at great distances (up to to 3.5 km).

* *Corresponding author address:*
Susanne Wahlen, GEOPREVENT,
8045 Zurich, Switzerland;
tel: +41 44 419 91 10
email: susnane.wahlen@geoprevent.com

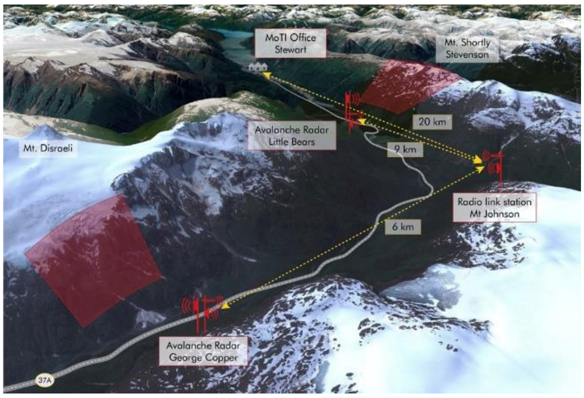


Figure 1: AADS network setup with two avalanche radar detection stations at Little Bears and George Copper, a repeater station at Mt Johnson and the receiver station in Stewart at the MoTI office.

Due to the remoteness of the sites, neither grid power nor mobile phone network is available, except for the MoTi office site in Stewart. Given that the radar stations do not have a direct line of sight to Stewart, an elevated repeater station was set up on Mount Johnson to transmit avalanche data from the radar stations to Stewart, 20km away. There, the data is uploaded to the Geoprevent servers via MoTI's internet connection and is made available to the user in an online data portal.

The repeater station further includes a weather station and a remotely controllable camera with pan, tilt and zoom functionality for automated recording of various image sections or for live views of the current situation. Data transmission from the stations via repeater to Stewart is based on a redundant setup with a broadband and a narrowband radio link.

The radar systems are completely energy self-sufficient and are designed for autonomous operation for at least a complete winter season. Energy supply is provided by a combination of a methanol fuel cell with several tanks and a number of solar panels. The two technologies are complementary: if the solar yield is not sufficient, the fuel cell takes over. The George Copper site is completely shaded from the mountain from November to early February.

The radar station contains a long-range, wide-angle radar unit with an aperture angle of 90 degrees horizontally and 20 degrees vertically according to the applications described in Meier et al. (2018) or Persson et al. (2018). The station further includes a high-resolution camera for status and event images, as well as a radar camera for monitoring of the radar status. The radar mount has an integrated anti-snow system to keep the radar head free from snow accumulation and to guarantee reliable operation under the harshest conditions. A patent for the anti-snow system was obtained in 2021.

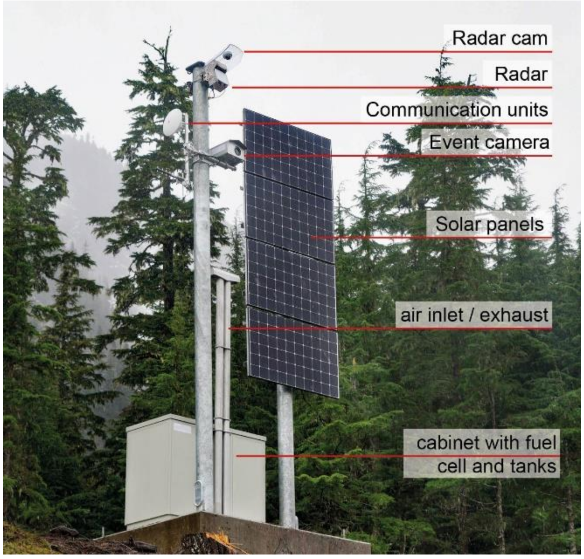


Figure 2: Station design of the autonomous avalanche radar station at Bear Pass, George Copper site.

## 3. RESULTS

Data presentation and interpretation Upon detection of an avalanche event, the system notifies the Avalanche Program by SMS and uploads the events onto an online portal map view along with parameters such as event duration, size, length, frontal velocity, and high-resolution event images. Figure 3 shows an example of a mapped avalanche as it is displayed in the online data portal accessible via smart phone, tablet or PC. Basic information about the event is already provided in the SMS and hence informs the Avalanche Program in real-time about a detection at one of the locations.

The forecasters extrapolate this timely avalanche character data across the greater forecast area, improving risk assessment accuracy while reducing uncertainty and closure time along with it.

### *3.1 <u>Data set 2019-2023</u>*

Since its installation at the end of 2019, the over-all system has detected over 6500 avalanche events. Between Nov 1, 2019 and August 31, 2023, the radar station at George Copper de-tected 4209 events and at Little Bears 2363 events, respectively. This represents one of the largest datasets of automated avalanche radar stations. Table 1 shows the number of avalanche events per month and year. An avalanche event is an event detected by the radar with a duration ranging from a few seconds to several minutes

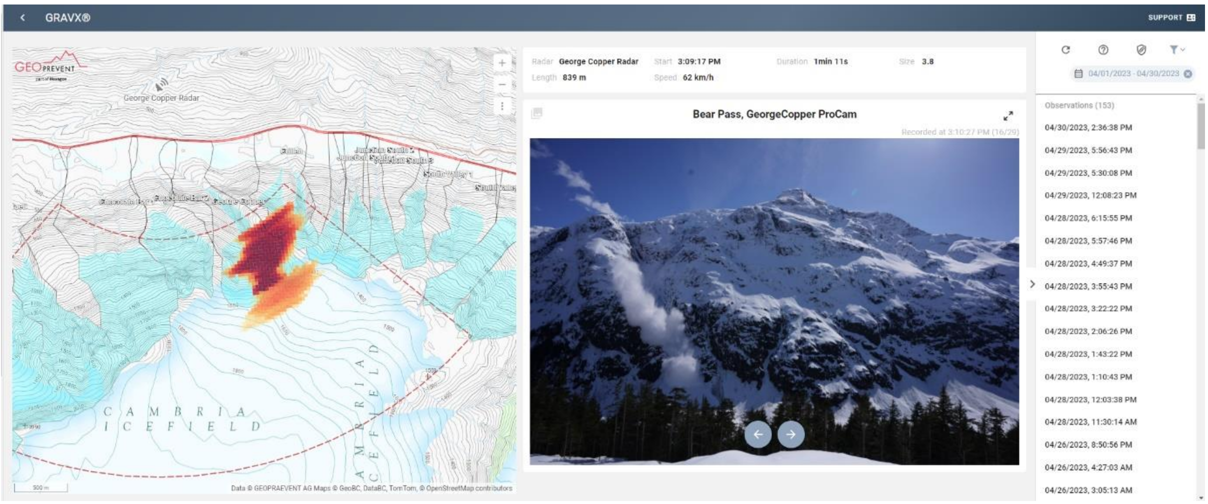


Figure 3: All detected events are displayed on a map with the relevant data along with it, e.g. event duration, length, average front speed, a rough size estimate and a series of event images if the visibility conditions allow.

and a length from a few meters to 2500m. Simultaneous events or temporally overlapping events are counted as one event in this study. Especially during storm cycles, it was observed that up to 4 events occurred in parallel on the same slope. These multiple events were not separated in this study and the parameters of the largest event were included in the statistics.

### 3.2 George Copper site

Table 1 shows the number of events per month and year at the George Copper site. Figure 4 gives a comparison of the monthly number of events over the past 4 winter seasons. The data clearly shows that the season is long at Bear Pass and usually lasts from October to June. The George Copper site also includes an ice fall, which is responsible for a large number of the events and accounts for the events detected in summer. This radar stations runs all year round due to the ice fall and potential ice avalanches during the summer months.

The avalanche data of the seasons 2019/20 and 2022/23 were analysed in more detail considering avalanche length, velocity and duration as well as visibility conditions. Figure 5 shows the evaluation of the visibility conditions during the avalanche events. We distinguish between dark (weather situation unknown), fog, partial visibility/fog, good visibility and no images (e.g. snowed in, camera error). According to this data, only 10% of the events are visually recognisable due to the lack of visibility. The data for the 2019/20 season is shown in Figure 6 and is in the same range as season 2022/23. Similar analyses from Zermatt (Geoprevent infographic, 2020) and Norway by (Persson et al. (2018)) show a similar distribution.

The average event length for season 2022/23 was 664m (median 570m), and the maximum was 2488m and the minimum 90m. As for the average front speed, the mean was 55km/h (median 52 km/h) with the fastest event being 193 km/h and the slowest 19 km/h. Slower movements are cut off with the selected settings.

| | 19/20 | 20/21 | 21/22 | 22/23 |
|---|---|---|---|---|
| October | | 40 | 82 | 86 |
| November | 99 | 167 | 232 | 116 |
| December | 114 | 174 | 97 | 73 |
| January | 134 | 204 | 217 | 137 |
| February | 167 | 194 | 134 | 178 |
| March | 108 | 201 | 184 | 73 |
| April | 69 | 102 | 111 | 153 |
| May | 38 | 73 | 125 | 30 |
| June | 26 | 33 | 28 | 17 |
| July | 5 | 3 | 2 | 2 |
| August | 3 | 1 | 1 | 1 |
| September | 2 | 6 | 1 | |
| **Total** | **765** | **1198** | **1214** | **866** |

Table 1: Number of events per month and year at George Copper site detected by the avalanche radar.

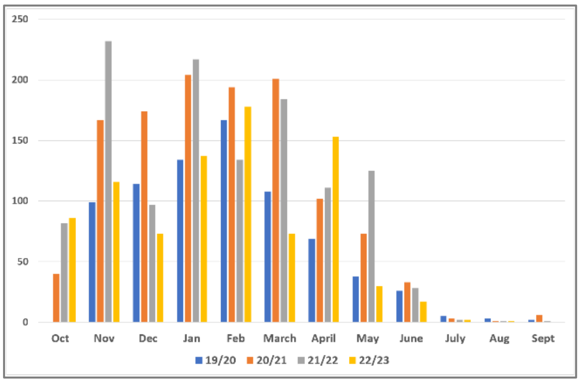


Figure 4: Avalanche events per month for 4 winter seasons 19/2, 20/21, 21/22 and 22/23 for the George Copper site. The radar was installed in mid-November 2019.

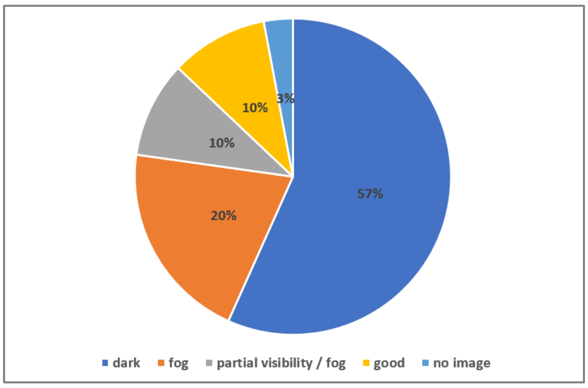


Figure 5: Visibility conditions during detected avalanche events between Oct 1, 2022, and May 17, 2023.

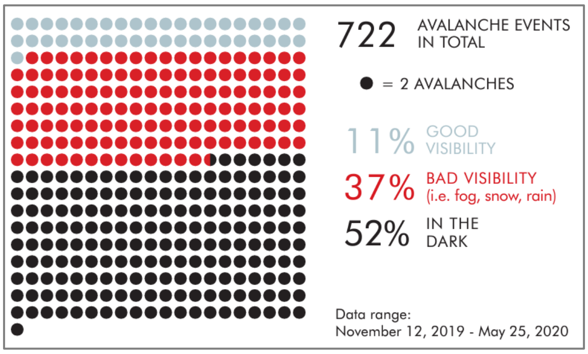


Figure 6: Visibility condition evaluation at George Copper for 2019/2020.

### 3.3 Little Bears site

The evaluations for the Little Bears site are shown below. Compared to the north-facing George Copper site with its ice fall, Little Bears has an east exposure and contains 4 avalanche paths. However, some events were also observed in further neighbouring avalanche paths. Table 2 shows the number of events per month and year while Figure 7 shows the monthly number of events for the last 4 winter seasons. The season at Little Bears generally ends earlier than at George Copper. The radar system is switched off in summer to safe power.

The avalanche data of the seasons 2019/20 and 2022/23 were analysed in more detail for the Little Bears site as well. Figure 8 shows the evaluation of the visibility conditions during the avalanche events. According to this data, only 4% for 2022/23 and 2% for 2019/20 events are visually recognisable.

The average event length for season 2022/23 was 681m (median 540m), and the maximum was 2458m and the minimum 60m. As for the average front speed, the mean was 55km/h (median 50 km/h) with the fastest event being 144 km/h and the slowest 18 km/h. Slower movements are cut off with the selected settings.

| | 19/20 | 20/21 | 21/22 | 22/23 |
|---|---|---|---|---|
| October | | 0 | 28 | 37 |
| November | 14 | 88 | 26 | 82 |
| December | 94 | 112 | 12 | 16 |
| January | 85 | 172 | 44 | 122 |
| February | 177 | 161 | 163 | 192 |
| March | 83 | 246 | 95 | 48 |
| April | 53 | 67 | 14 | 48 |
| May | 10 | 22 | 40 | 10 |
| June | 1 | 0 | 1 | 0 |
| **Total** | **517** | **868** | **423** | **555** |

Table 2: Number of events per month and year at Little Bears site detected by the avalanche radar.

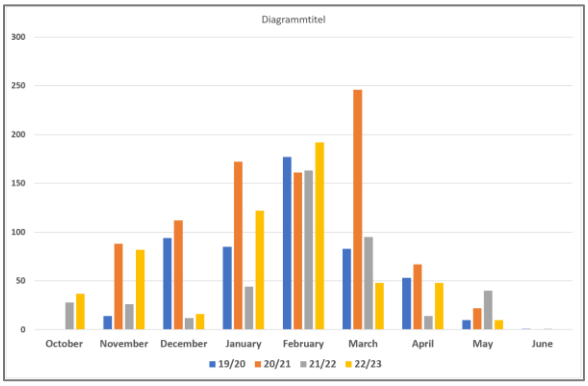


Figure 7: Avalanche events per month for 4 winter seasons 19/20, 20/21, 21/22 and 22/23 for the Little Bears site.

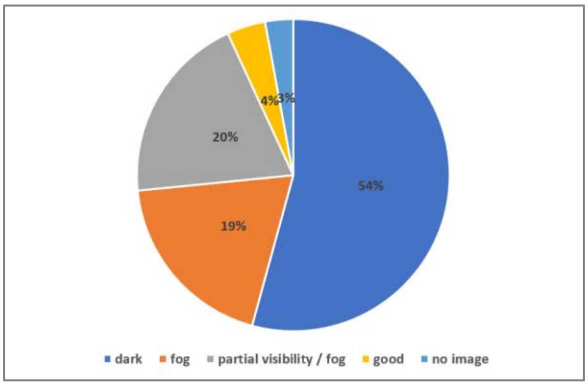


Figure 8: Visibility conditions during detected avalanche events between Oct 1, 2022, and May 17, 2023.

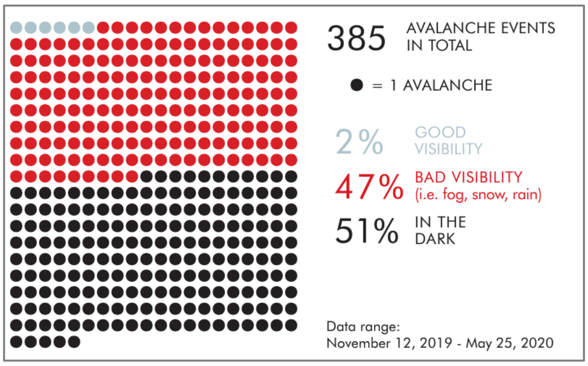


Figure 9: Visibility condition evaluation at Little Bears for 2019/2020.

## 4. DISCUSSION

The timely data from the AADS significantly supported the Avalanche Programme in assessing the current avalanche situation and enables a better understanding of the regional avalanche conditions. This allows to verify the accuracy of the forecasts and to significantly reduce the closure times of the highway. In its first winter of operation, Highway 37A was already closed 40% less than average.

### *4.1 Future work*

The overall system performance is considered very good and consistent. False detections are rare at both sites and are below 5 events per year. Considering the extreme and challenging climatic conditions, it is worth noting that the individual stations as well as the overall system run very stable and reliably and even during heavy storms reliably detect events and notify the Avalanche team in Stewart.

However, some imporvements are currently in progress, e.g.. to automatically distinguish between multiple events and individual avalanche paths. A corresponding solution has been developed and will be implemented.

The important parameter of mean frontal velocity is occasionally determined incorrectly, particularly in certain weather conditions and if the events are rather large. However, the mean frontal velocity can be reevaluated manually retrospectively. This circumstance is to be further improved in the future. Multiple events

## 5. CONCLUSIONS

The AADS has proven to be a very powerful tool and has is indispensable for the Avalanche Programme at Bear Pass. The AADS setup is to be expanded in 2024 to include additional radar stations and a repeater station. The longterm goal will be to upgrade the system to an alarm system and to automatically close road sections at risk in case of an event.


## ACKNOWLEDGEMENT

Thank You.


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