# Multi-level avalanche risk reduction on the Trans-Canada Highway – Three Valley Gap RACS

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ABSTRACT
The reliability of the Trans-Canada Highway (TCH) in BC during winter is largely driven by avalanche risk. The Three Valley Gap avalanche area, 20 km west of Revelstoke is one of the highest priority avalanche areas on the TCH, which averages approximately 40 hours of avalanche related closures per winter. In 2016 and 2017 nine remote avalanche control systems (RACS) were installed in this traffic corridor, which helped to reduce risk to workers performing avalanche control, the travelling public, and of avalanche related highway closures. In the first year of operation some operational benefits of the installed RACS included a reduction of time needed to perform avalanche control from about 30-60 minutes to 5-15 minutes and the overall highway closure times were reduced from 2-3 hours to 1 hour. The pre-mission preparation time was reduced significantly, thus freeing up worker resources to manage the many other avalanche areas in the highway corridor. Avalanche control missions are now possible in the dark, when lower traffic volumes are present on the highway.

La fiabilité de la route transcanadienne (Transcanadienne) en Colombie-Britannique durant l'hiver est largement attribuable au risque d'avalanche. La zone d'avalanche de Three Valley Gap, située à 20 km à l'ouest de Revelstoke, est l'une des zones d'avalanche les plus prioritaires de la Transcanadienne, qui compte en moyenne environ 40 heures de fermeture par avalanche par hiver. En 2016 et 2017, neuf systèmes de contrôle des avalanches (RACS) ont été installés dans ce couloir de circulation, ce qui a permis de réduire les risques pour les travailleurs effectuant des contrôles d'avalanche, le public voyageur et les fermetures d'autoroute liées aux avalanches. Au cours de la première année d'exploitation, les avantages opérationnels du système RACS comprenaient une réduction du temps requis pour effectuer le contrôle des avalanches d'environ 30-60 minutes à 5-15 minutes et une réduction des temps de fermeture de l'autoroute de 2-3 heures à 1 heure . Le temps de préparation avant la mission a été considérablement réduit, libérant ainsi les ressources des travailleurs pour gérer les nombreuses autres zones d'avalanche dans le corridor routier. Les missions de contrôle des avalanches sont maintenant possibles dans l'obscurité, lorsque les volumes de circulation sont plus faibles sur l'autoroute.

## 1 INTRODUCTION

The reliability of traffic routes has a significant impact on the larger scale (regional) as well as the local economy. Furthermore, the increased mobility of the public puts pressure on the authorities to keep road closures to a minimum. To achieve more efficient road closures, a variety of avalanche control measures and systems are operationally applied such as Remote Avalanche Control Systems (RACS). RACS can preventively control avalanches at any time (24/7) and all weather conditions by releasing the snow in controlled and small avalanches. RACS are an established tool to manage avalanche risks for ski resorts, roads, railways and settlements in avalanche paths in the European Alps and North America. Additionally, other industrial applications world-wide such as mining benefit from RACS.

The terminology used in this document is based on the commonly used definition of risk in the avalanche industry: Risk = Hazard x Exposure x Vulnerability.

### 1.1 Three Valley Gap and project description

The Three Valley Gap (3VG) corridor is one of the narrowest and most avalanche prone areas along the Trans-Canada Highway 1 (TCH) between Vancouver and Calgary. Keeping this road section open is crucial for the local economy of Revelstoke as well as to ensure the transportation of goods along this traffic route is maintained. The shortest detour when the highway is closed takes an additional 6 hours, and its reliability is often also affected by avalanches and winter conditions. The terrain is very steep, rocky and heavily forested with gullies that produce avalanches up to Size 3 (potentially destructive to vehicles) and usually reach the road once snow is released (Figure 1). This area is also very prone to vehicle accidents during the winter, which increases the risk to the travelling public.

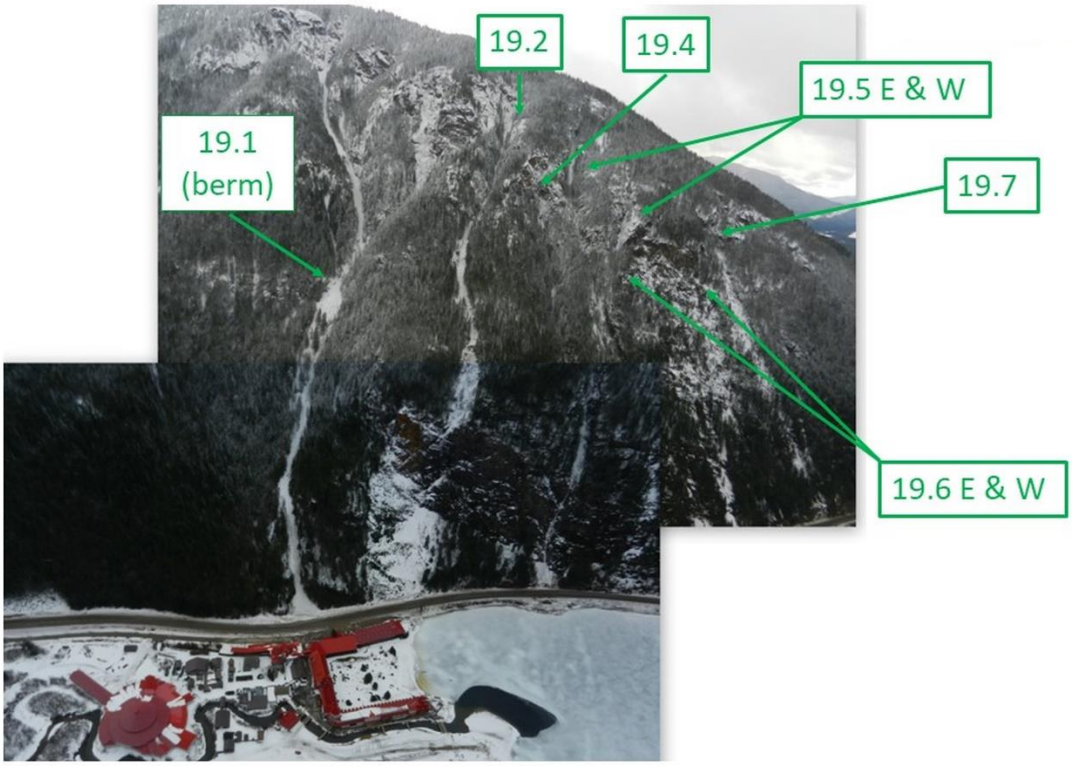

Figure 1. Overview of the 3 Valley Gap area with path names Photo: Dynamic Avalanche Consulting).

In a public tender the British Columbia Ministry of Transportation and Infrastructure (MoTI) awarded Wyssen Avalanche Control the installation of nine avalanche towers in the 3VG corridor. This RACS consists of a steel tower with a deployment box on top that can be installed and removed via helicopter without personnel required on-site (Figure 2). The RACS holds 12 explosive charges of up to 5 kg of explosives. Via a web-based interface, the avalanche control team can deploy single charges, or multiple towers at the same time (Figure 3), which are dropped and detonate hanging on a cord below the tower thus delivering a 360 degree air blast in the avalanche starting zone.

The footprint of each RACS is small, with each RACS foundation occupying an area of 1 $m^2$, with a typical ground disturbance area limited to approximately 100 $m^2$.

## 2 EXISTING RISKS AT 3VG

Even though we briefly discuss other natural hazards in the 3VG area and consider other hazards affecting the highway reliability, we mainly focus on avalanche related risks. We separated the risk management steps that affect the general reliability of the highway and public, the avalanche control team during their operational work and the construction phase.

### 2.1 Public risk management

- Highway closure time
- Lower traffic volume
- Natural avalanches
- Rockfall (not addressed with RACS)

The overall aim of the project was to improve the reliability of Highway 1, mainly by reducing avalanche related closures times. This was achieved by reducing the time required to perform avalanche control which corresponds to an (economic) risk reduction for the highway itself. Efficiency in timing of explosive control can be furthermore increased by simultaneous ignitions of multiple RACS minimize the time needed to operate the system (Figure 3).

Furthermore, the timing of the control missions could be optimized since, compared to the initial situation with only helicopter avalanche control, the RACS can be operated at night when traffic volumes are lower. This also allows RACS to control avalanche hazard at the “ideal” time during the day or night. The frequent release of snow from the paths and the release areas between the starting zone and highway minimizes the risk of larger natural avalanches occurring when the highway is open.

A challenge that remains, especially in the 3VG corridor, that is not addressed with the RACS is the natural rock fall hazard. More information on rock fall hazard in the 3VG area and its corresponding risk management during construction is discussed in *Geotechnical Challenges Associated with the Design and Construction of the Three Valley Gap Remote Avalanche Control System Project* by

the Ecora Engineering & Resource Group (Laws et al. 2018).

## 2.2 Operational risk management

- Worker safety (risks related to: Helicopters, explosives, avalanches)
- Make resources available (personnel and machinery)
- System reliability

A significant level of risk reduction was achieved at the worker safety level by installation of RACS at 3VG. The weather conditions during avalanche control missions in the 3VG corridor are known to be notoriously difficult and often last for quite a long time, and are frequently subject to delay. This was forcing the control team to operate in challenging flying conditions due to wind, snow and valley fog. The explosive charges dropped from the helicopter had to be thrown precisely at small ledges in the terrain – thus requiring the pilot to fly very close to ground. There is also the risk of a charge not reaching the ledge and sliding, potentially resulting an exploded charge on or near the highway. Helicopter operations for these paths are now reduced to seasonal deployment and reloading of the boxes – which can be done during favorable flying conditions and on days when no avalanche control is needed.

The application of RACS furthermore separates the risks of managing explosives from the risks when managing avalanches. This can be achieved by loading of the RACS with explosives and deployment to their operational sites in the Fall and therefore without avalanche hazard. When managing the avalanche risk, no direct exposure to explosives exists.

Figure 2. System description of RACS tower used in 3VG.

The regional MoTI avalanche control team is responsible for the management of avalanches along approximately 111 km of highway. Along this traffic routes around 109 avalanche paths have the potential to affect the road. As critical avalanche situations usually do not affect only a single area but can reach large parts of the operational area the management of resources (personnel and machinery such as helicopters and loaders) is key to achieve an optimized “global” risk reduction. With the now existing infrastructure only 1 avalanche technician can perform avalanche control within minutes compared to the previous situation where 2 or more technicians had to spend multiple hours to prepare explosive charges and do avalanche control.

State-of-the-art RACS continuously monitor the system status and deliver relevant information such as confirmation of detonation at each tower location. Monitoring of crucial system variables by the manufacturer ensures that the system can be operated reliably and efficiently by the control team when needed. For example, confirmation of detonation informs the control team that the applied measure affected the release area as planned and the consequent risk reduction was achieved.

## 2.3 Construction risk management

- Construction equipment
- Work site access and working at heights
- Rockfall
- Helicopter
- Weather

The construction team at 3VG had to manage a variety of general construction and site-specific risks. One of the main challenges was the difficult access to many of the planned RACS locations (mostly rope based access) and the rockfall risk for workers as well as the public on the highway below the workers. As only a limited amount of road closures was granted, the objective was to minimize the team size and the overall impact on the terrain as much as possible. Also, the potential rockfall risk during construction activities for the public was managed with special focus and trained personnel as well as requiring that the construction equipment be secured at all times. In addition, temporary rockfall nets were installed below the worksites.

The tower locations were chosen to minimize the potential for towers to be impacted by overhead rockfall hazards. This both reduced the risk to the towers, and minimized the long-term maintenance costs to MoTI for maintaining rockfall protection structures.

The chosen approach enabled the entire project to be completed in 2 construction phases in the Fall of 2016 and the Spring of 2017 (the initial plan was to use 3) without any injuries or incidents affecting the public or workers.

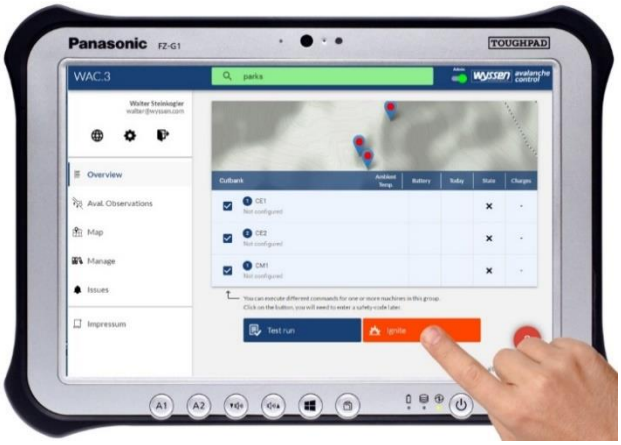


Figure 3. User interface WAC.3 allowing for simultaneous ignition of multiple RACS for increased efficiency.

## 3. OPERATIONAL EXPERIENCE

The first four towers were ready for operational use (Figure *4*) by Winter 2016/17. All nine towers were fully operational by Winter 2017/18. During the initial winter 10 control missions were performed. Already with only four RACS the closure times were reduced by about half in the first season. Furthermore, the time needed to perform avalanche control was reduced from 2-3 hours (2 personnel for 2 hours building charges, loading and flying them to 3VG) to 5 – 15 minutes (and one avalanche technician) once the blast area is secured.

Table 1. Operational experience summary

| | Control missions | Total seasonal closure time (hours) | Time needed to perform avalanche control |
|---|---|---|---|
| On average | 0 | 40 | 2-3 hours |
| Winter 2016/17 (4 RACS) | 10 | 19 | 5-15 minutes |
| Winter 2017/18 (9 RACS) | 12[1] | -[1] | 5-15 minutes |

[1]seasonal operations still ongoing at time of publication

Figure 4. Active avalanche control on February 2nd, 2018.

## 4. COST-BENEFIT ANALYSIS

A reasonable average cost for a closure of Highway 1 seems to be around $100 000 CAD for the first hour(s). It is assumed that this number is higher when considering “downstream” costs, i.e. due to effects that do not only affect the local traffic but further away, that occur during longer closure times. Furthermore, the costs are expected to increase exponentially with the length of the closure, especially for closures longer than 3 to 6 hours. The overall project costs were around $2.3 Million CAD. With a reduction of closure times by 20 hours during the first operational winter (with only 4 out of 9 RACS installed) this results in almost a full return on investment for the province during only the first year. Assuming that an even greater reduction in closure times will be achieved in future years with the full 9 RACS installed, the economic benefit of this system can be easily demonstrated. This economic benefit combined with the reduction of risk to the travelling public and MoTI workers speaks highly to the benefits of using RACS for key highways locations.

## 5. CONCLUSIONS

The 3VG project has demonstrated that a significant reduction of risk for the public combined with an increase in reliability of Highway 1 could be achieved with a positive cost-benefit ratio of return in investment nearly in the first year of operation. This can be demonstrated simply using a direct cost analysis; consideration of downstream economic effects would be expected to show an even higher positive cost-benefit ratio.

The risk to personnel during their avalanche control operations was significantly reduced by separating the management of avalanche risks from explosives and helicopter hazards. At the same time the time savings frees personnel and machinery resources that can be applied at other locations within their operations area.

The construction of the project was executed within a relatively short time period with minimized impact on the travelling public. The footprint of the RACS themselves are very small ($1m^2$) and were optimized with respect to minimizing overhead rockfall hazards.

## 6. OUTLOOK

Although the 3VG RACS installation will result in improved reliability of this highway section, there are still other nearby avalanche paths that will affect the highway at the same time as these paths. These areas will still require the use of conventional helicopter explosives deployment, and occasionally overnight highway closures due to elevated avalanche hazard. The 3VG RACS installation and operations are a significant risk reduction and improvement for the public and workers. Yet, with the “big picture” in mind other hazards that present a risk to the public, such as vehicle crashes and rock fall incidents that close the highway, also need to be considered.

RACS are a cost-efficient measure to mitigate avalanche hazard. Yet, different measures should be evaluated and compared in the planning phase. Furthermore, during the selection of a suitable mitigation measure other natural hazards should be considered as well and ideally multiple hazards can be mitigated at the same time.

Further technological developments of RACS such as avalanche detection systems and automatic weather stations as additional information sources on the RACS will continue to improve the effectiveness of avalanche control teams even further.

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