MULTI-LEVEL AVALANCHE RISK REDUCTION ON THE TRANS-CANADA HIGHWAY – THREE VALLEY GAP REMOTE AVALANCHE CONTROL SYSTEM (RACS)

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ABSTRACT: Three Valley Gap, located 20 km west of Revelstoke, is one of the highest priority avalanche areas on the Trans-Canada Highway (TCH). During 2007-2016, avalanche related closures averaged 46.5 hours per winter during 12 closure periods, many of which exceeded 2 hours. These closures present a major disruption to commercial traffic and the local economy. Increasing traffic volumes continue to increase avalanche risk, and compound traffic flow problems. During 2016 and 2017, nine remote avalanche control systems (RACS) were installed at Three Valley Gap. This system reduces risk to public and commercial vehicles, risk to workers performing avalanche control, and will reduce the duration of avalanche related closures. Benefits of RACS during the first two winters included a reduction of time for avalanche control from about 30-60 to 5-15 minutes, and the reduction of the average time per closure from 3.9 hours (during 2007-2016) to 1.5 and 1.7 hours during the 2017 and 2018 winters, respectively. The pre-mission preparation time was reduced, allowing workers to manage other avalanche areas in the highway corridor. Avalanche control missions are now possible in the dark, when lower traffic volumes are present, further reducing the impact of closures on traffic. A cost-benefit discussion is presented that highlights the economic value of this project, suggesting a full return on investment for the public during the first two years of operation. The economic benefit combined with the reduction of risk to the public and workers speaks highly to the benefits of RACS for important highway corridors.

KEYWORDS: Avalanche control, highway, avalanche risk, explosives, remote avalanche control system.

1. INTRODUCTION

The reliability of highway corridors during winter has a significant impact on both the local and regional economy. In western Canada, increasing traffic volumes and public expectations increases pressure on highway managers to keep traffic flowing and reduce highway closures. To achieve more efficient highway closures, a variety of avalanche control measures are applied, including Remote Avalanche Control Systems (RACS). RACS can control avalanches at any time and during any weather conditions, and reduce avalanche magnitude by triggering smaller, more frequent avalanches. RACS are a well-established tool for managing avalanche risks for ski resorts, highways and railways in Europe and North America. Additionally, private industries, such as mines, are increasingly installing RACS as economic considerations make their capital investment beneficial.

A case study of a RACS installation in western Canada is presented that demonstrates the safety and economic risk reduction benefits of RACS for a highway corridor.

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1.1 Three Valley Gap and project description

The reliability of the Trans-Canada Highway (TCH) corridor through British Columbia (BC) is largely driven by avalanche risk during the winter. Three Valley Gap (3VG) is a narrow mountain pass and one of the most active avalanche areas on the TCH. 3VG is located 20 km west of Revelstoke, BC, in a transitional (intermountain) snow climate (Haegeli and McClung, 2003). The project area presented below includes eight high-frequency avalanche paths that can produce avalanches that are hazardous to traffic with as little as 20 mm of precipitation.

The terrain in 3VG is steep and densely forested, with gullies that produce frequent avalanches up to Size 3. Once avalanches initiate, they usually reach the TCH due to the steep terrain (Figure 1). Several of the paths can produce plunging avalanches which increase the potential hazard from avalanches impacting the highway (Schaerer, 1989) (Figure 3).

The safety and reliability of the TCH through 3VG has a direct and significant effect on the economy of the province and the country (NovaTrans, 2010). When closed, traffic is unlikely to seek alternative routes (Morrall, 1995), which requires additional time (e.g. 6 hours or more) and whose reliability is also dependent on avalanche hazard.

Traffic volumes through 3VG have substantially increased in recent decades. Winter average daily traffic (WADT) has increased from around 1000 vehicles per day (vpd) in 1980 to nearly 4000 vpd in

2010. WADT is forecast to reach 6000 vpd by 2030 (NovaTrans, 2010). Approximately 58% of the WADT comprises heavy commercial vehicles in the winter. The percentage of heavy commercial vehicles is substantially higher in the winter compared to the summer, further highlighting the important of maintaining traffic flow in the winter.

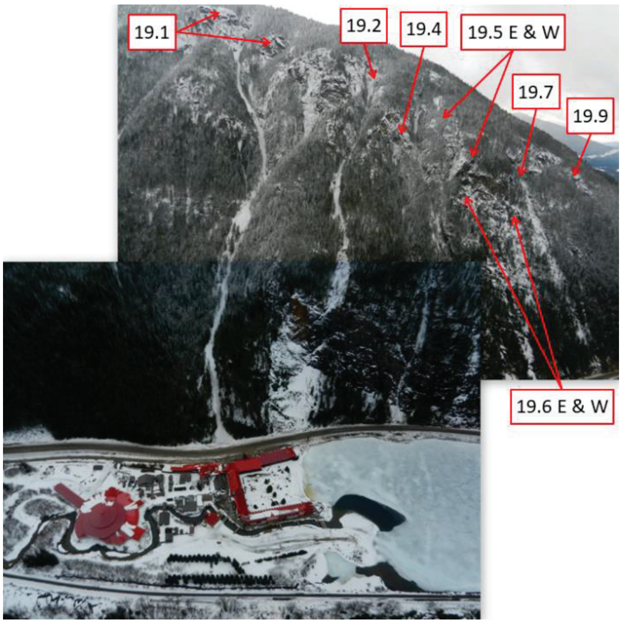

Figure 1: Overview of Three Valley Gap avalanche area (Path 11.7 location not shown). A. Jones photo.

In 2016, the BC Ministry of Transportation and Infrastructure (MoTI) contracted Wyssen Avalanche Control to supply and install nine RACS in seven avalanche paths during a two-year construction period. Five towers were installed in 2016, followed by the remaining 4 towers in 2017. This was the first installation of this type of RACS in North America.

The selected RACS (Wyssen Tower) consists of an 8-10 m high steel tower with a removable steel deployment box on top that can be installed and removed via helicopter without personnel required on-site (Figure 2). Each deployment box holds 12 charge containers with up to 5 kg of explosives each.

The RACS is operated from the highway by an avalanche technician using a web-based interface connected by mobile phone network or radio. Towers can be operated individually, or multiple towers can simultaneously deploy charges to control multiple paths at once. Charges are dropped from the deployment box and suspended by a cord above the snow surface. The detonation delivers a 360-degree air blast to the adjacent avalanche start zone.

Figure 2: RACS installation at 3VG.

2. MANAGEMENT OF RISK AT 3VG

2.1 Construction risk management

The RACS installation team at 3VG managed a variety of general construction and site-specific risks. One of the main challenges included the difficult access to many of the installation locations (mostly rope-based access), which resulted in potential rockfall risk for workers as well as rockfall risk to vehicles on the highway below. As only a limited amount of road closures were permitted, this risk was managed by minimizing the work team size and the overall impact on the terrain as much as possible. For example, specific marked access routes were maintained to reduce the amount of loose material available to produce rockfall during daily site access.

Potential rockfall risk during construction was managed with special focus and trained personnel, temporary (up- and downslope) rockfall protection, as well as requiring that the construction equipment be secured at all times.

The chosen approach allowed the entire project to be completed in 91 work days during two construction phases. There were no injuries or incidents affecting the public or workers during construction.

2.2 Public risk management

The goal of this project was to improve the reliability of the TCH, 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. Avalanche control efficiency can be further increased by simultaneous detonation of multiple RACS, minimizing the time needed to operate the system.

The timing of the control missions can be optimized since, compared to the previous helicopter avalanche control method, RACS can be operated at night or early morning when traffic volumes are much lower. This also allows RACS to control avalanche hazard at the optimal time during the storm, which is as likely to occur at night as it is during the day. The frequent release of small avalanches from the paths reduces the likelihood of larger natural avalanches occurring when the highway is open, which may result in an unplanned and more logistically complex closure.

Despite the improvement in avalanche hazard management in the 3VG corridor, the natural rockfall hazard still presents a significant risk to the public. More information on rock fall hazard in the 3VG area and its corresponding risk management during construction is discussed in Laws et al. (2018).

2.3 Operational risk management (workers)

A significant level of risk reduction for workers was achieved with installation of RACS at 3VG. Weather conditions in the 3VG corridor are notoriously difficult for flying helicopters, which can delay or prevent helicopter avalanche control blasting. When weather conditions permit flying, the avalanche control team is often required to operate in challenging flying conditions, which presents increased risk to avalanche technicians and pilots. The explosive charges dropped from the helicopter need to be deployed precisely at small ledges to prevent them from sliding to the highway, requiring the pilot to fly close to the slope. Following the RACS installation, helicopter operations are now reduced to seasonal deployment and reloading of the boxes which can be scheduled during favorable flying conditions.

The application of RACS separates the risks of handling explosives from the risk due to avalanche hazards. This is achieved by loading and deploying the RACS deployment boxes in the fall (e.g. October), prior to the winter avalanche hazard. When managing the avalanche risk during the winter, no direct exposure to explosive risk is present.

The Revelstoke based MoTI Columbia Program is responsible for the management of avalanches along approximately 370 km of highway. Within this large area, around 250 avalanche paths have the potential to affect highways. The management of resources (personnel and machinery such as helicopters and heavy equipment) is key to achieving an optimized risk reduction for all areas during elevated regional avalanche hazard. RACS will allow personnel to be freed up sooner from 3VG (usually the highest priority area) to more effectively manage risks at other areas, which better maintains traffic flow in adjacent highway sections.

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 using geophones during periods of reduced visibility informs the control team that the applied measure affected the release area as planned, and the resulting risk reduction was achieved.

3. OPERATIONAL EXPERIENCE

The first four towers were ready for use (Figure 3) for the 2016/17 winter, and all nine towers were fully operational for the 2017/18 winter.

Figure 3: A plunging avalanche from 3VG impacts the Trans-Canada highway (BC MoTI photo).

Operational benefits of these RACS during the first two winters included a reduction of time needed to perform avalanche control in Three Valley Gap from approximately 30-60 minutes to 5-15 minutes (Visotzky, 2017), and an overall reduction in closure times (Table 1). The pre-mission preparation time was reduced substantially, allowing workers to manage other avalanche areas in the highway corridor. Avalanche control missions are now possible in the dark (typically during early morning hours), when lower traffic volumes are present on the highway, decreasing traffic disruption and thus economic impacts.

The 2017-18 winter was a very active avalanche winter, with snowfall accumulations approximately 10-15% above average at 3VG. Total closure time of

29.1 hours was required to manage avalanche risk, which is a significant reduction in total closure hours compared to the 46.5-hour average for the 2007-2016 period (Table 1). More importantly, the distribution of closure times has shifted, such that the number and combined time of short closures (e.g. < 1 hour) have increased, while the number and combined time of longer closures (> 2 hours) are reduced compared to historical averages (Figure 4). This strategy of shorter closure periods is consistent with the goal of adjacent avalanche areas (e.g. Rogers Pass, 90 km to the east), and the province-wide goal of improving winter highway reliability (combination of safety and accessibility) for the public.

Table 1: Summary of avalanche closures in 3VG comparing data from 2007-2016 and the first two winters following RACS installation.

	Closures per year	Closure time per year (hours)	Average time per closure (hours)	Time needed to perform avalanche control[1]
Average 2007-2016	12	46.5	3.9	30-60 minutes
Winter 2016/17 (4 RACS)	13	21.7	1.7	5-15 minutes
Winter 2017/18 (9 RACS)	19	29.1	1.5	5-15 minutes

[1]Closure times and numbers based on BC MoTI records; times for avalanche control are approximate and do not include securing the road (sweep) and explosives preparation (Visotzky, 2017).

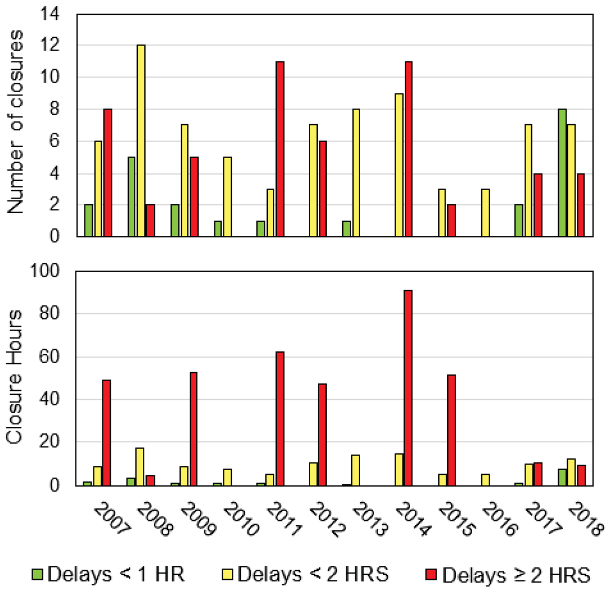

Figure 4: Annual number of closures (upper graph) and closure time (lower graph) for Three Valley Gap during 2007-2018, classified by length of closure.

4. COST-BENEFIT

Previous studies (e.g. Morrall, 1995; NovaTrans, 2010) have indicated an average closure cost of the TCH at Three Valley Gap on the order of $100,000 CAD for the first hour(s), considered in 2018 costs. When “downstream” costs are also considered (e.g. delays to commercial goods shipments), the total cost of closures is expected to be substantially higher than this, especially for longer closures.

Morrall and Abdelwahab (1992) show that the number of vehicles delayed during closures increases non-linearly with the length of the closure, which implies a corresponding non-linear increase in closure costs, especially for closures longer than three hours. This compounding traffic effect and loss of vehicle storage capacity is one of the reasons avalanche personnel try to keep closures at Three Valley Gap and adjacent avalanche areas (e.g. Rogers Pass in Glacier National Park) below two hours.

For a four-day (89 hour) avalanche related closure of the I-90 highway in Washington State, USA, in 2008, the total loss in economic input to Washington was estimated to be USD $27.9 Million (WSDOT, 2008). On an hourly basis this can be approximated as USD $300,000 per hour for an extended, highly disruptive closure. The I-90 corridor has much higher traffic volumes and commercial traffic than the TCH, but this estimate provides a scaled estimate by which the importance of short and long closure economic impacts can be considered.

The overall 3VG project costs were approximately $2.3 Million CAD. Compared to the average annual closure hours of 46.5 hours, a closure hour reduction of 25 hours during the first winter (with 4 of 9 RACS installed) and 17 hours during the second winter (with all 9 RACS installed) suggests a full return on investment for the public during the first two years of operation. This demonstrates the economic benefit of this system which, combined with the reduction of risk to the travelling public and workers, speaks highly to the benefits of using RACS for important highway corridors.

Figure 5: Avalanche deposit removal at 3VG.

5. CONCLUSION

The Three Valley Gap RACS installation project has demonstrated that a substantial 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 on investment in the first two years of operation.

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

The construction of the project was completed within a relatively short time period with minimized impact on the travelling public (closures). The footprints of the RACS themselves are very small and were optimized with respect to rockfall.

6. OUTLOOK

Although completion of the 3VG RACS installations will improve the reliability of this highway section, there are still adjacent avalanche areas without RACS that will still affect the highway at the same time, resulting in closure of the highway for other avalanche hazards. To better address this problem, MoTI plans to install an additional two RACS in this project area during 2019. These RACS will be installed at Path 19.1 (Figure 1), which will further improve avalanche hazard management efficiency, and allow for complete control of avalanches by RACS in this area.

The reliability of the highway during winter will still be affected by other hazards, including relatively frequent vehicle accidents that result from difficult winter driving conditions. Rockfall hazards will also continue to present challenges in this area.

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 optimize the work of avalanche control teams even further.

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