

TRAFFIC MANAGEMENT FOR AVALANCHE SAFETY -
TRANS-CANADA HIGHWAY
ROGERS PASS BRITISH COLUMBIA

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ABSTRACT

The Rogers Pass area in the Selkirk mountain range of British Columbia receives some of the heaviest snowfalls in Canada with an average of about 1000 cm annually at the 1300 m elevation and 1500 cm at 1900 m. The heavy snowfall combined with mountainous terrain result in this section of the Trans-Canada Highway being subjected to severe avalanche activity.

There are 107 avalanche paths affecting the highway within the 44 km section through Glacier National Park. To provide avalanche safety and minimize closures of the highway, the Snow Research and Avalanche Warning Section (SRAWS) of the Canadian Parks Service operates one of the largest mobile control programs in the world. Utilizing a 105 mm howitzer, artillery fire can be directed at over 200 designated targets. During periods of avalanche stabilization or in the event of a natural avalanche affecting the road, it is necessary to close the Trans-Canada Highway to traffic for which a traffic management plan was developed.

The four fold increase in traffic since the highway opened in 1962 has led to difficulties in maintaining traditional levels of traffic delays without compromising public safety. In 30 years of highway operations, no member of the travelling public has been injured as a result of avalanches in Rogers Pass. Road closures have averaged 130 hours annually with the majority of individual closures not exceeding 3 hours. To maintain these standards it became necessary to reassess the traffic management plan. Traffic parameters such as volume, flow pattern and composition have a significant impact on avalanche safety and, as such, must be considered in operating avalanche control programs for highways.

This paper presents an overview of the traffic management plan for avalanche safety in Rogers Pass as well as the findings of a recently completed study. The objectives of the study were to collect traffic data, analyze the data and make recommendations for improvements to the traffic management plan.

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INTRODUCTION

One of the most expensive sections of the Trans-Canada Highway in terms of capital and maintenance cost lies in Glacier National Park, British Columbia. The mountain section of the Trans-Canada Highway, shown in Figure 1, was officially opened on September 3, 1962, at Rogers Pass. The Rogers Pass in the Selkirk mountain range of British Columbia receives some of the heaviest snowfalls in Canada with an average of about 1000 cm annually at the 1300 m elevation and 1500 cm at 1900 m elevation. The heavy snowfall combined with mountainous terrain result in the section of the Trans-Canada Highway. There are 107 avalanche paths affecting the highway within the 44 km section through Glacier National Park. To provide avalanche safety and minimize closure of the highway, the Snow Research and Avalanche Warning Section (SRAWS) of the Canadian Parks Service operates one of the largest mobile control programs in the world. Utilizing a 105 mm howitzer, artillery fire can be directed at over 200 designated targets. During periods of avalanche stabilization or in the event of a natural avalanche affecting the road, it is necessary to close the Trans-Canada Highway to traffic for which a traffic management plan was developed. A four fold increase in winter traffic volumes since the highway opened in 1962 has led to difficulties in maintaining a long established objective of minimizing delays during avalanche stabilization without compromising public safety. In 30 years of highway operations, no member of the travelling public has been injured as a result of avalanches in Rogers Pass. Road closures have averaged 130 hours annually with the majority of individual closures not exceeding 3 hours. To maintain the long established objectives of minimizing delay it has been necessary to reassess the traffic management plan. This paper presents an overview of a recently completed study directed toward the development of a traffic management plan based on observed traffic flow and composition during avalanche stabilization over a four year period.

PROBLEM DEFINITION

Since the Trans-Canada Highway opened in 1962 winter average daily traffic has increased from approximately 400 to 2000 veh/day in 1992. Winter average daily traffic is based on the period December 1 to April 30. Until recently, sections of highway not in avalanche zones have provided adequate capacity for vehicular storage (also known as ponding areas) during stabilization shoots. However, the growth of traffic (the Trans-Canada Highway through Rogers Pass carried approximately 1.4 million vehicles in 1990) coupled with an increasing percentage of trucks in the traffic stream has resulted in a shortfall of ponding area capacity. In addition to trucks increasing in absolute and relative terms, the trucks are longer and heavier than when the mobile avalanche control program was established more than 25 years ago. In 1962 the maximum length of a heavy truck was 15.2 metres and the maximum gross vehicle weight (GVW) 32.7 tonnes. Since 1989 the maximum length of a heavy truck (B train double) has been 25 metres and the maximum GVW 62.5 tonnes. This represents a 64% increase in length and 91% increase in GVW which have contributed to operational problems at ponding areas. Also exacerbating the ponding area capacity problem are the high peak traffic periods during winter holiday weekends (such as Christmas, New Years, and Easter), which have become more pronounced in the past decade.

STUDY METHOD

Traffic flow problems on the Trans-Canada Highway in winter cannot be studied in isolation from the summer traffic problems, hence, the study method was based on the fact that traffic flow characteristics, highway conditions, and operational requirements vary considerably from season to season. Thus, the analysis was broken into two basic parts, namely, a separate analysis of winter and summer conditions. Design year traffic forecasts for the winter period were used as input to the analysis of ponding area requirements for avalanche control. As part of the winter analysis, data were collected on traffic characteristics from the 1987-88 winter season to the 1990-91 winter season. A traffic model was developed to determine the time required to reach the stacking capacity of a ponding area for a given flow rate. Ponding areas are located on level, tangent sections of the highway away from avalanche paths, and their locations have been refined through the mobile avalanche control program by SRAWS since 1962. The level-of-service analysis and the determination of the design life of the highway as a two-way, two-lane facility were based on year-round and summer traffic characteristics and forecasts. As traffic volumes are highest during summer, the basic traffic problem on the highway is the lack of passing opportunities required to maintain an acceptable level of service. A traffic simulation model was utilized to determine the impact of a passing and climbing lane system on the level of service.

TRAFFIC CHARACTERISTICS

The highest volume recorded in the winter of 1990/91 was 787 veh/h. The 500th highest hour for the same year was 123 veh/h. In other words, in the winter of 1990/91, there were more than 500 hours with volumes greater than 123 veh/h. Typically the highest volumes in the winter period correspond to the 30th to 50th highest hour of the annual traffic flow. The high flow problem is further exacerbated by the fact that many of the highest volumes occur on consecutive hours. For example, of the highest 500 hours, during the winter of 1990/91, 470 hours were consecutive, with a total of 16 consecutive hours on March 28/29 (Easter holiday traffic). Typically, holiday and weekend traffic account for almost 100% of the highest 50 hours of the winter period. Thus the problem with high traffic volumes during winter is not only their magnitude but the fact that they are sustained over an extended period of time especially during the holiday periods such as Christmas, New Years, and Easter.

Three surveys of vehicle length, spacing, and vehicle occupancy were undertaken at the Summit ponding area during avalanche stabilization in December 1990 and January 1991. It was snowing during all surveys and road conditions were compact snow with icy sections. Average truck length was found to be 24.4 metres, auto length 4.10 metres and average spacing between parked vehicles 2.95 metres. This information was used to determine the storage capacity during avalanche stabilization. For example, assuming 50% heavy trucks, approximately 60 vehicle could be stored per kilometre.

VEHICLE DELAYS DURING AVALANCHE STABILIZATIONS

In the winter of 1990/91 a total of 7486 vehicles were delayed during avalanche stabilization and 47% of the vehicles delayed were heavy trucks. In total 9420 hours of delay

were incurred resulting in an average delay of 1.26 hours per vehicle. It is noted that the number of vehicles delayed and the hours of delay incurred is a function of vehicular flow and the number and timing of road closures during avalanche stabilization. Vehicular delay was calculated using a traffic delay model specifically developed for the Rogers Pass project. The main features of the model are as follows:

- (i) closure time is estimated and input into the model by the user
- (ii) the expected traffic flow rate during the closure period is also user supplied.
- (iii) vehicular arrivals are approximated by a Poisson distribution, however, the model contains an adjustment procedure which can emulate platooning
- (iv) vehicles queued during the closure period dissipate immediately after the highway reopened at a user supplied departure rate.

While the number of vehicles affected and the total hours of delay incurred can vary from year to year, the general trend has been upwards due to the growth in traffic. The average delay per vehicle has not increased, however, due to the SRAWS objective of keeping delays short and the fact that stabilization minimizes the risk of a prolonged closure due to large natural avalanches. It has been estimated that the cost of a two hour delay in terms of drivers and passengers time and vehicle operating costs is approximately \$50,000 when 30% of the vehicles delayed are heavy trucks.

THE MOBILE AVALANCHE CONTROL PROGRAM

The mobile avalanches control program is directed by SRAWS who determine the timing and location of a stabilization shoot. The timing of avalanche stabilization is based on a method of analysis of snow conditions developed by the SRAWS group and data on weather and instability from remote high elevations. The locations for stabilization involve over 200 designated targets which are engaged from 18 gun positions strategically located along the 44 km section of the Trans-Canada Highway. Within the boundaries of Glacier National Park over 200 avalanches can affect the entire length of highway at 107 locations between the ponding areas. For purposes of operations the Trans-Canada Highway is divided into two sections, referred to in this paper as the east and west slopes.

The east slope is defined as the section of highway between Rogers Pass and the East Park Boundary. Ponding areas such as Beaver and East Gate in this section are used for westbound vehicular storage. The Summit East ponding area located at Rogers Pass is for the storage of eastbound vehicles while Summit South is used for westbound vehicles. The west slope is defined as the section of highway between Rogers Pass and the South Park Boundary. Cougar Tangent and Gunners ponding areas on the west slope section are used for both eastbound and westbound vehicle storage. Flat Creek and Generals ponding areas are used for eastbound and westbound vehicle storage respectively. Ponding areas are used in pairs in the initial stages of avalanche stabilization. For example, during stabilization shoots in the vicinity of the snowsheds on the east slope, the Beaver ponding area is used to store westbound vehicles while the Summit East ponding area is used to store eastbound vehicles. If the Summit East ponding area approaches storage capacity, eastbound traffic can be stopped in the next upstream ponding area of Cougar Tangent or Generals. Once stabilization work is completed in this case,

traffic would be released, and the crew re-deployed to another area if required and the process of traffic control repeated. The objective of SRAWS is to minimize the danger of natural avalanches through stabilization and at the same time minimize the delays to traffic on the Trans-Canada Highway by allowing traffic to flow between periods of stabilization control. It is noted that avalanche stabilization takes precedence over concerns of traffic delay and depending on the snow conditions several stabilization shoots may be required before traffic flow is allowed to resume.

Stopping traffic outside the Park boundaries at Golden and Revelstoke rather than at the ponding areas for all avalanche stabilization work would greatly increase delays and could increase the exposure of more vehicles to the dangers of natural avalanches. Delays would increase because once westbound traffic was stopped at Golden and eastbound traffic stopped at Revelstoke, avalanche stabilization could not commence until the last vehicles had cleared this section and the wardens swept the entire highway to ensure that no vehicles remained within the area. As this section of highway is considerably longer than the sections normally worked between ponding areas, the total time to clear traffic, complete a stabilization shoot, and reopen the highway would be much longer than that currently incurred. Due to the highway being closed for longer periods, a greater number of vehicles would be queued resulting in long platoons passing through avalanche zones. Thus more vehicles would be exposed at one time to the risk of natural avalanches as opposed to a smaller number of vehicles which accumulate during current operations.

For a typical highway closure, four wardens are required for traffic control. A warden remains at the head of each ponding area to ensure that no vehicles proceed into the closed area while the shoot is in progress. Before the shoot begins, two wardens (one from the west at Summit East and one from the east at Beaver for the example cited) carry out a sweep of the closed section of highway. After meeting at approximately the mid-way point, the wardens return to their respective starting points and assist with traffic control at the ponding areas and inform drivers of the anticipated length of closure and answer inquiries.

The ponding areas are located on level tangent highway sections between avalanche zones. The locations of ponding areas and associated traffic control procedures have been continually refined over the years by SRAWS personnel. Since 1970, however, it has become increasingly apparent that although the ponding areas are in the proper location, they have inadequate storage capacity during periods of moderate to heavy traffic flow. Ponding area capacity is based on length and width of highway and traffic composition at the time of a stabilization shoot. Capacity also depends on how close vehicles are parked, which in turn depends on traffic control and prevailing weather and highway conditions.

In order to determine ponding area capacities for a given flow rate, traffic data was collected for each closure for four winter seasons. Data collection included the block location, the number of cars and trucks, and time of highway closure and opening. Twenty-four hour classification counts were taken during periods of peak flow, such as the Easter weekend.

DEVELOPMENT OF A TRAFFIC MODEL TO DETERMINE VEHICLE STORAGE REQUIREMENTS DURING AVALANCHE STABILIZATION

One objective of the study reported in this paper was to develop a model which could be used for both planning and operations. In order to determine vehicle storage requirements during avalanche control, it was necessary to develop a traffic model to determine when storage capacity would be reached for a given flow rate. The basic traffic model is as follows:

$$L = [Q \cdot t (P_t \cdot L_t + P_a \cdot L_a + S)] \quad [1]$$

where: L = storage length in metres; Q = traffic flow in veh/h; t = closure time in hours; P_a = % automobiles; L_a = average length of automobiles in metres; P_t = % trucks; L_t = average length of trucks in metres; and S = spacing between vehicles in metres.

The time to reach capacity at ponding area for a given flow is as follows:

$$T_{i,s}^{(1)} = \frac{L_{i,s}}{Q[P_t \cdot L_t + P_a \cdot L_a + S]} \quad [2]$$

where: $T_{i,s}^{(1)}$ = time to reach capacity at ponding location i for stacking configuration s ; $L_{i,s}$ = length of storage at ponding location i and stacking configuration s ; and s = 1 single stack, 2: double stack, 3: triple stack, 4: quadruple stack.

Equation [2] was used to determine the time to reach capacity for single, double, and triple and quadruple stacking for a given flow rate. In addition, Equation [2] was further modified to determine the time after stopping traffic at a ponding area that traffic should be stopped at the next upstream ponding area in order to avoid exceeding the capacity of the first ponding area as follows:

$$T_{i,s}^2 = \frac{L_{i,s} - \left(\frac{d \cdot Q}{70}\right) (\bar{L} + 3.0)}{Q(\bar{L} + 3.0)} \quad [3]$$

where: $T_{i,s}^{(2)}$ = time after stopping traffic at the first ponding area that traffic should be stopped at the next upstream ponding area for ponding area i and stacking configuration s ; d = distance between ponding areas; and \bar{L} = weighted average of vehicle lengths.

Equation [3] accounts for the number of vehicles between ponding areas that would add to the vehicles already stopped and assumes that vehicles travel at an average speed of 70 km/h.

EXAMPLES OF TRAFFIC MANAGEMENT USING THE MODEL

Three stages of traffic management were developed which are dependent on the time and location to execute avalanche control and the traffic volume and traffic composition.

- Stage 1: In periods of light traffic flow (up to approximately 45 veh/h each way), avalanche control for a three hour period can be carried out by stopping vehicles at the ponding areas. However, for shorter periods of avalanche control, higher vehicular flows can be accommodated. In both cases, the expected number of vehicles would be accommodated within the limits of triple or quadruple stacking.
- Stage 2: During periods of moderate traffic flow (up to 90 veh/h), and depending on the time required to complete avalanche control, it will be necessary to stop vehicles at secondary ponding areas or at the Park Boundaries or Park Gates to avoid exceeding stacking capacities. By continuously monitoring the traffic flow SRAWS would be able to ascertain how long after closing the barricades at a given block that traffic should be stopped at other ponding areas or the Park Boundaries or Gates in order to avoid exceeding the stacking capacity.
- Stage 3: During periods of heavy flow, such as Christmas and Easter, it will be necessary to immediately stop traffic at Golden and Revelstoke prior to avalanche control being initiated. The high traffic flows during these periods would exceed the stacking capacities of the ponding areas and Park Boundaries in a very short period of time. During a prolonged closure, it may be necessary to divert eastbound traffic via the Yellowhead Highway at Kamloops and westbound traffic via Highway 2 at Calgary and Highway 16 or Highway 3 as shown in Figure 1. This may be considered a Stage 4 traffic management strategy.

TRAFFIC OPERATIONS DURING AVALANCHE STABILIZATION

The staged traffic management system has proven to be a cost-effect technique to maintaining SRAWS objectives of minimizing delay. Several problems have arisen, however, which can disrupt the orderly and timely release of traffic from ponding areas. Depending on the blocks being worked traffic may move more quicker in one direction than the other. One such example are the Beaver and Summit East ponding areas from which traffic travels a 6% upgrade and a 6% downgrade respectively.

This problem can be partially offset by releasing the slower moving direction (in this case Beaver) first to avoid having a moving platoon meet a standing platoon on the downgrade. A problem of secondary blocks is the timing of the release of the secondary blocks with respect to the first blocks. For example, a simultaneous release could result in the first vehicles from the second blocks reaching the first block while the end of the first block is still stationary. For example, westbound traffic from the East Gate ponding area reaching stationary traffic at the Beaver ponding area. This could have several undesirable consequences. Firstly, the vehicles from the second block could be left standing in an avalanche zone until the last vehicles from the first block have dispersed. Secondly, for those blocks ending on upgrades, problems getting moving from a standing start on an up-grade could arise. The net effect of the aforementioned problems is that stabilization operations are disrupted. This in turn reduces the margin of safety

to the travelling public. These problems, however, for most operations can be managed by experienced crews using radio communications.

Other problems such as the large number of heavy trucks along with their poor operational performance on icy surfaces can disrupt the timely release of traffic. It is noted that conditions such as black ice, compact snow, freezing rain, slush, and slippery sections prevail on the highway almost 60% of the days during winter. The impact of a stalled vehicle is that a traffic lane is blocked, plowing and sanding operations disrupted, and stabilization shoots in progress are prolonged or delayed. The net result is that if the stabilization work is disrupted the margin of safety to the travelling public is reduced. Lack of a mandatory chain-up for vehicles over 5,500 kg and vehicles pulling trailers also has contributed to vehicle traction problem (although chain-up became mandatory in 1991/92). Finally, it is noted that multiple stacking of vehicles under adverse weather conditions can be very difficult in terms of assigning vehicles to specific lanes. The problem here is due to not only factors such as poor visibility due to blowing snow, but also the fact that vehicles can arrive at blocks in platoons, rather than randomly, due to the fact that the effect of slow moving vehicles on the traffic stream is more pronounced during inclement weather.

CONCLUSIONS

1. Traffic is a specialized, complex field which has a direct impact on many aspects of avalanche control for roadways. Study and analysis of individual situations should be carried out by a traffic engineer to determine the requirements of a "traffic management plan". A comprehensive traffic management plan will enable avalanche control programs to be "proactive" in handling traffic rather than "reactive".
2. Traffic factors such as vehicle flow rates, average vehicle speed, platooning, and composition have an impact on the degree of hazard and, as such, should be considered in making an avalanche hazard assessment. Not unlike the factors of weather and avalanche occurrence, this requires routine, standard observations as well as an historical data base to formulate critical values.
3. Traffic forecasts, in all its aspects, must be considered in the long term planning process for avalanche control programs.
4. Public demands and expectations will continue to escalate. To meet these expectations, avalanche control programs will need to develop improved methods of communication and information as well as expanding the area of public education.
5. Liability will continue to be an issue. In this current era of indiscriminate litigation for almost any reason, avalanche control programs must continue to evolve to avoid potential liability. The area of traffic management can not be ignored in this regard.

FUTURE DEVELOPMENTS FOR ROGERS PASS

This paper has demonstrated that low cost operational improvements such as passing lanes achieved through wider cross-sections, and a traffic management plan for the mobile avalanche control program can be used to extend the design life of the Trans-Canada Highway as a two-way, two-lane facility to the year 2005. Other recommendations of the Rogers Pass study included the acquisition of technology to provide SRAWS with real time traffic information and an automated road closure system. A traffic counter/classifier which can measure traffic volume and traffic composition on an hour-by-hour basis would provide SRAWS with real time traffic information. This would allow SRAWS to determine how soon ponding areas for any given block would reach capacity and thus traffic could be stopped at the next upstream ponding area preventing overflow. Such a system is being installed for the 1992/93 winter.

At the present time manned gatehouses at the east park boundary of Glacier National Park and the south park boundary of Revelstoke National Park serve many purposes including the ability to effect an emergency road closure, provision of information, advance notification of road closures and avalanche hazards, and a communications relay point. However, it has been recognized for some time that the existing manned gate system is a very inefficient use of resources in addition to the fact that one gatehouse lies in an avalanche path. Thus the proposal to replace the existing manned gate system with an automated road closure system will be subject of a detailed technical study by the Canadian Parks Service.

Without the implementation of the passing lane system the level of service in summer months will continue to deteriorate. Similarly, without the staged traffic management plan and increased ponding area capacity delays to traffic in winter months will increase and the margin of safety eroded. Acquisition of new technology such as a traffic monitor and an automated road closure system will enhance SRAWS operational capability and allow human and financial resources to be deployed more effectively in other areas.

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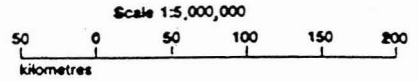


FIGURE 1. Regional Setting of Glacier National Park.