



BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION
&
INFRASTRUCTURE

AVALANCHE AND WEATHER PROGRAMS

THRESHOLD GUIDELINES FOR AVALANCHE SAFETY MEASURES

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Avalanche & Weather Programs

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Introduction	1
Purpose.....	1
Scope	2
Avalanche Hazard Forecasts	2
Avalanche Hazard Levels.....	3
Site-Specific Safety Measures	4
Primary Avalanche Risk Factors	5
Avalanche Termination Point	5
Avalanche Size Expectations	6
Avalanche Frequency Expectations	6
Terrain Features.....	7
Traffic Flow Characteristics	8
Primary Avalanche Risk Factors - Summary.....	9
Appendix 1 – Avalanche Size Classifications.....	10
Appendix 2 – Definitions.....	11

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Threshold Guidelines for Avalanche Safety Measures

Introduction

There are over 1400 avalanche paths that have the potential to affect the Provincial Highway Network. The mandate of the Avalanche and Weather Program is to ensure safety to highway users, while minimizing interruptions to traffic. This is primarily accomplished through on-going evaluation and forecasting of avalanche conditions and the application of specific operational procedures that provide appropriate avalanche safety measures for highway users.

Throughout the winter season, Ministry Avalanche Technicians monitor and evaluate avalanche conditions. Forecasting the size, frequency and termination point of avalanches relative to terrain features and location of a highway are guiding principles in determining avalanche risk and avalanche hazard levels.

Increasingly stringent safety measures are applied as avalanche hazard levels increase. This permits a highway to remain open with an acceptable degree of safety. When avalanche risk conditions indicate that the threshold for safety may be surpassed, a recommendation is made to the local District Manager of Transportation (DMT) that the exposed section of highway be closed until conditions improve. Active avalanche control measures (i.e. use of explosives) may be applied to reduce the avalanche risk and/or minimize closure times.

Given the vast array of avalanche related variables and the complex ways that they interact with one another, it is understood that avalanche risk assessments cannot be precise in every instance. Hence, there may be times when avalanche related road closures are implemented where no avalanches affect the highway and times when avalanches affect roadways while they are open.

Purpose

The purpose of defining threshold guidelines for avalanche safety measures is to establish a consistent understanding of:

- The primary factors that must be considered when determining avalanche hazard levels;
- How combinations and interactions of primary avalanche risk predictors influence hazard level assessments;
- How site-specific safety measures can delay or prevent road closures, while continuing to provide acceptable levels of safety to highway users;

Scope

Avalanche risk management involves a complex process of avalanche risk analysis that ultimately leads to a decision to:

1. Apply one of five avalanche hazard forecast levels (Low, Moderate, Considerable, High, Extreme);
2. Maintain an open highway, subject to specific operational procedures and safety measures associated with each assessed hazard level;
3. Recommend (to District Manager of Transportation) minor delays of a highway section and conduct active (i.e. explosives) avalanche control missions;
4. Recommend (to District Manager of Transportation) a preventive closure of a highway section due to High or Extreme avalanche hazard conditions;
5. Re-open a highway, after it has been closed (due to explosive control or preventive closure).

Ministry Avalanche Technicians will make recommendations to District Managers of Transportation when they believe highway closures are required. The responsibility for provincial highway closures rests with District Managers of Transportation, however, it is understood that, when warranted, the authority to close provincial highways is delegated to District avalanche forecasters under mutual agreement with their District Manager. District avalanche staff ensures that their supervisors are fully informed and aware of avalanche related road closures.

The definitions of avalanche hazard levels presented in this document are from the Avalanche Forecasts and Specific Operational Procedures (the five level hazard scale) from the Snow Avalanche Safety Measures for Highways Manual. The primary contributing factors that are used in the process of avalanche hazard assessment are presented. Operational guidelines are presented in consideration of primary avalanche hazard predictors that will define threshold limits while continuing to provide acceptable levels of safety to highway users.

Avalanche Hazard Forecasts

Ministry Avalanche Technicians analyze current and historical information about local terrain, weather, snowpack, avalanche occurrences and weather forecasts to determine the probability of avalanche activity above, on or beyond the highway.

Human and environmental factors that influence avalanche risk and hazard levels are monitored and assessed continuously throughout the winter season. Based on these assessments, avalanche technicians determine avalanche hazard levels in approximately 60 highway locations within the Province. This information is provided to Ministry and Maintenance Contractor personnel. Posted avalanche hazard levels remain in effect until there is a change in conditions that prompts a revised posting.

Avalanche Hazard Levels

Avalanche hazard levels are evaluated in consideration of maintaining safety to persons traveling in passenger vehicles within avalanche areas. The avalanche hazard level will determine operational safety procedures for workers within avalanche areas.

The Ministry has defined avalanche hazard levels based on expected avalanche activity in the Avalanche Forecasts and Specific Operational Procedures as follows:

Low:

Avalanches are unlikely;

OR

Small avalanches are possible, but are expected to terminate far above the highway.

Moderate:

Small avalanches are probable but are expected to terminate above the highway;

AND/OR

Large avalanches are possible, but are expected to terminate far above the highway.

Considerable:

Small avalanches may affect the highway;

AND/OR

Large avalanches are probable, but are expected to terminate above the highway;

AND/OR

Snow dust events may affect the highway.

High:

Numerous small avalanches are expected to affect the highway;

AND/OR

One or more large avalanches are expected to affect the highway.

Extreme:

Numerous, large avalanches are expected to affect the highway.

Site-Specific Safety Measures

The Ministry prescribes avalanche safety guidelines to ensure safety to highway users and to minimize avalanche related road closures (Snow Avalanche Safety Measures for Highways Manual). These safety measures can be applied in all Provincial avalanche program locations.

Unique features in some avalanche areas lend themselves well to the use of additional traffic control measures, which can allow a road segment to remain open. Site Specific Safety Measures are designed through a process of consultation and collaboration between District and HQ personnel to ensure all safety considerations have been made. Ministry Avalanche Technicians may also exercise their discretion to recommend closure of an exposed highway section rather than implement site-specific safety measures.

Unique avalanche area features where site-specific safety measures may be considered include:

- Short stretch of highway (1-2km in length. Anything greater creates difficulties in dealing with incidents, should they occur);
- Steep terrain with numerous avalanche paths above the highway;
- Presence of terrain traps (i.e. cliffs or bodies of water beyond highway);
- Inclined road surface (where there is potential for vehicles to slow or stop in adverse weather and road conditions);
- High speed, high traffic volume areas (where there is an increased probability for avalanche incident(s) or MVA to occur);
- Safe areas for traffic to stop at avalanche area exit and entry points;

Implementation of site-specific safety measures most appropriately occurs at the high end of a Considerable hazard forecast level. Training for all Ministry and Maintenance Contractor staff involved in provision of enhanced safety measures must occur prior to implementation.

Site-specific safety measures may include some or all of the following:

- High visibility signs to warn motorists that they are entering an active avalanche area and to reduce speed;
- Maintenance equipment readily available to clear small deposits off the road;
- Flagging personnel at avalanche area entry and exit points;
- Pedestrian traffic is strictly prohibited within the avalanche area;
- One way alternating traffic (on the lane least affected by avalanches);
- Ongoing road patrols by trained personnel to monitor and assess conditions;
- Immediate readiness to deal with an incident;
- Immediate readiness to sweep and close the highway if necessary.

In summary:

- ***Site-specific safety measures can reduce road closure times while continuing to provide acceptable levels of safety to highway users.***

Primary Avalanche Risk Factors

Ministry Avalanche Technicians must consider numerous factors when predicting avalanche hazard levels. Factors such as weather, snowpack structure, terrain and traffic flow characteristics are considered as stand alone items in addition to how they interact with one another. Within each of these factors there is a range of conditions. The extent of this range and their combined effects will influence the final determination of an avalanche hazard level assessment.

In order to ensure safety to highway users when assessing avalanche hazard levels, it is necessary to consider primary avalanche risk factors, which consist of:

- Avalanche terminus
- Avalanche size
- Avalanche frequency
- Terrain features
- Traffic flow characteristics

After considering these primary avalanche risk factors in conjunction with their assessment of forecast avalanche activity, avalanche technicians employ Specific Operational Procedures to ensure the safety of highway users.

Avalanche Termination Point

The maximum distance that an avalanche is expected to travel relative to the highway must be considered when assessing avalanche hazard levels. First and foremost, safety to highway users must be provided. At the discretion of the Ministry Avalanche Technician, implementation of approved site-specific safety measures can be recommended, a temporary closure to conduct avalanche control missions can be performed, or a preventive closure can be recommended.

In locations where site specific safety measures can be employed, it may be possible for traffic to be safely diverted around small avalanche deposits that have reached the highway.

Trying to precisely predict the maximum extent that avalanche mass or dust will terminate under variable conditions is extremely difficult. There are however, conditions where predictable small avalanche events may affect a portion of a highway under acceptable levels of safety. In those cases the avalanche forecaster must consider the possibility that even small avalanche deposits may block traffic or otherwise interfere with the safe passage of motorists.

Avalanches may affect a highway with either mass or snow dust. Avalanche snow dust will travel a greater distance than avalanche mass. Although avalanche dust does not usually result in significant amounts of debris on a highway, it can impair a driver's visibility and compromise road conditions.

In summary:

- ***Avalanche risk assessments must consider the potential for avalanches (mass and/or dust) that reach the highway to adversely affect the safety of highway users.***

Avalanche Size Expectations

Avalanches are defined in the Canadian avalanche size classification system by destructive potential (See Appendix 1). Size classifications range from size 1.0 (relatively harmless to people) to size 5.0 (could destroy a village or forest of 40 hectares). Half sizes are not defined, but may be used by experienced practitioners for avalanches which are midway between defined avalanche size classes (i.e. size 2.5).

The critical size with respect to managing the avalanche risk and ensuring the safety to highway users is greatly influenced by the primary avalanche risk factors. Motor vehicles offer some protection from the impacts of avalanches. The primary consideration (with respect to maximum avalanche size expectations on an open highway) must be the safety of occupants inside a passenger size vehicle from the destructive impacts of an avalanche. With respect to avalanches that threaten provincial highways, it is understood that "small" avalanches lack the destructive potential to injure or kill a person traveling in a passenger size vehicle.

Given the inherent challenges of predicting exactly where and when avalanches may occur, what size they may be and how far they may run, it is understood that on rare occasions, large avalanches may affect a highway before it can be closed.

In summary:

- ***Ministry Avalanche Technicians recommend closure of provincial highways before large avalanches that have the destructive potential to harm a person traveling in a passenger size vehicle affect the highway.***

Avalanche Frequency Expectations

The extent of either small or large avalanches reaching a portion of the highway surface will directly affect the level of safety to highway users. The probability for vehicle incidents increases with a corresponding increase in both avalanche size and frequency.

Infrequent, small avalanches that reach a portion of the highway can be quickly and easily removed by road maintenance equipment. This will continue to ensure an acceptable level of safety. Safety is compromised when avalanche frequency increases, especially in areas where

maintenance equipment is not readily available and/or in areas where traffic has slowed or stopped.

In summary:

- ***When there is an expectation that a singular large avalanche may affect a highway, or that numerous small avalanches may interfere with the safe passage of motorists, a closure should be implemented until conditions improve. Site specific safety measures may be applied when small numerous avalanches are occurring and still provide acceptable levels of safety to highway users.***

Terrain Features

Terrain considerations exist both above and beyond the highway surface. Fortunately, the majority of provincial highways are located in valley bottoms (avalanche runout zones), where exposure is less than highways that intersect mid portions (tracks) of avalanche terrain.

Terrain above a highway may range from isolated, infrequent avalanche paths to multiple paths with close proximity adjacent to and/or across a valley from one another.

Terrain beyond a highway may range from a flat extension of the road surface to steep cliffs and/or proximal bodies of water (terrain trap). Vehicles that may be deflected or pushed off a highway by avalanches into terrain traps represent a greater concern for safety than areas where no terrain traps exist.

Depending on terrain features, avalanche flow characteristics may range from deposits that gradually move across a highway surface to avalanches that plunge off steep slopes/cliffs, directly onto the highway surface with highly destructive impact pressure.

Where terrain configuration is likely to increase the harm from relatively low avalanche mass, avalanche technicians must consider this factor in their assessment of the hazard level.

In summary:

- ***Avalanche forecast personnel must consider how terrain features above and beyond a highway may affect safety to highway users. Adverse terrain conditions influence the destructive potential of avalanches. The presence or absence of terrain traps will influence avalanche risk assessments.***

Traffic Flow Characteristics

Avalanche cycles are typically associated with weather and visibility conditions that challenge maintenance of the highway. When the highway surface is subject to accumulations of snow/slush/ice, the natural flow of traffic can be adversely affected (particularly on road grades).

In situations where the flow of traffic becomes congested due to an uncontrolled reduction in traffic speed, the extended exposure below avalanche paths corresponds to an increased risk of interaction between vehicles and avalanches. When traffic unexpectedly stops within avalanche areas there can be a sudden and serious increase in avalanche risk to the highway user, especially if it is difficult for vehicles to back up from, or move around obstructions (i.e. stuck or spun out vehicles).

It is also recognized that slow moving or stuck vehicles are exposed to impact from rear end collisions and the consequences of subsequent avalanche activity. Under such adverse conditions, there is the added risk that occupants are inclined to leave their vehicles in attempts to shovel away deposits or to inspect obstructions. Persons on foot within active avalanche areas are at much greater vulnerability and at greater risk than people inside their vehicles, especially if terrain traps are present.

In summary:

- ***Ministry Avalanche Technicians must monitor and anticipate traffic flow characteristics within avalanche areas. Impaired movement or stalled traffic within avalanche areas can result in elevated risk to highway users. Site specific safety measures may be considered or road closures recommended in order to ensure a reasonable level of safety is maintained. (Operational Risk Band)***

Primary Avalanche Risk Factors - Summary

The five primary factors that must be considered by Ministry Avalanche Technicians rarely exist in isolation from one another. Typically, two or more factors interact in complex and unique ways that must be evaluated by trained and experienced Ministry Avalanche Technicians.

Site-specific safety measures may be applied in selected areas under various conditions at the discretion of the avalanche forecaster in order to ensure acceptable levels of safety for highway users. Ministry Avalanche Technicians must mindfully consider the consequences of interactions between avalanches and vehicles when assessing avalanche hazard levels. It is understood that ensuring safety is paramount and takes precedence over any attempts at maintaining an open road when threshold levels have been surpassed.

It is impossible to describe every possible combination of avalanche risk scenarios; however, it is possible to summarize individual primary threshold factors as follows:

Avalanche Termination Point:

- *Avalanche risk assessments must consider the potential for avalanches (mass and/or dust) that reach the highway to adversely affect the safety of highway users.*

Avalanche Size Expectations:

- *Ministry Avalanche Technicians recommend closure of provincial highways before large avalanches that have the destructive potential to harm a person traveling in a passenger size vehicle affect the highway.*

Avalanche Frequency Expectations:

- *When there is an expectation that a singular large avalanche may affect a highway, or that numerous small avalanches may interfere with the safe passage of motorists, a closure should be implemented until conditions improve. Site specific safety measures may be applied when small numerous avalanches are occurring and still provide acceptable levels of safety to highway users.*

Terrain Features:

- *Ministry Avalanche Technicians must consider how terrain features above and beyond a highway may affect safety to highway users. Adverse terrain conditions influence the destructive potential of avalanches. The presence or absence of terrain traps will influence avalanche hazard level assessments.*

Traffic Flow Characteristics:

- *Ministry Avalanche Technicians must monitor and anticipate traffic flow characteristics within avalanche areas. Impaired movement or stalled traffic within avalanche areas can result in elevated risk to highway users. Site specific safety measures may be considered or road closures recommended in order to ensure a reasonable level of safety is maintained. (Operational Risk Band)*

Canadian classification system for avalanche size (McClung and Schaerer, 2006).

For each size class, the table lists: typical impact pressures in kilopascals (kPa); typical mass in tonnes (t); typical path length in meters (m); and a description of the destructive potential, including the approximate forest area in hectares (ha) that could be destroyed. Size and data code represent destructive potential, typical mass, typical path length and typical impact pressure.

Size and data code	Destructive potential	Typical mass	Typical path length	Typical impact pressure
1	Relatively harmless to people.	<10 t	10 m	1 kPa
2	Could bury, injure or kill a person.	10 ² t	100 m	10 kPa
3	Could bury and destroy a car, damage a truck, destroy a wood-frame house or break a few trees.	10 ³ t	1,000 m	100 kPa
4	Could destroy a railway car, large truck, several buildings or a forest area of approximately 4 ha.	10 ⁴ t	2,000 m	500 kPa
5	Largest snow avalanche known. Could destroy a village or a forest area of approximately 40 ha.	10 ⁵ t	3,000 m	1,000 kPa

Definitions

Avalanche: Specifically refers to snow avalanche.

Snow avalanche: A volume of snow, usually more than several cubic meters, moved by gravity at perceptible speed. Snow avalanche may contain rock, broken trees, ice or other material.

Ministry avalanche areas: A set of geographically associated avalanche paths. These may affect a specific element at risk, or multiple elements at risk.

Avalanche path: A fixed locality within which avalanches start, run and stop. Paths consist of a starting zone, a track and a runout zone and sometimes an air blast zone.

Avalanche terrain: The area and topography within the physical boundary of the potential formation, movement and effect of an avalanche.

Avalanche forecasting: The prediction, over a specified scale of terrain, of current and/or future avalanche hazard/risk based on the expected likelihood of triggering, avalanche size and runout extent.

Avalanche size: A reporting system for observed avalanches based on the estimated potential destructive effects (McClung and Schaerer, 2006).

Avalanche frequency: The expected (average) number of avalanches per unit of time reaching or exceeding a location. Normally it has units of avalanche(s) per year(s) and is expressed as a ratio (eg 1:1, 1:3, 1:10, 1:30 etc.) This is determined from empirical evidence in the field, avalanche occurrence records.

Avalanche risk: Avalanche Risk is the probability or chance of harm resulting from interactions between avalanche hazard and specific element(s) at risk. Avalanche risk is determined by the exposure of that element, and its vulnerability to the avalanche hazard.

Avalanche hazard: A source of potential harm or loss. The potential for an avalanche(s) to cause damage to something of value. It is a function of the likelihood of triggering or frequency, and the avalanche size or magnitude.

Avalanche hazard assessment: A process that includes the steps of avalanche hazard identification, analysis and evaluation.

Avalanche hazard analysis: The data collection and study of environmental condition that contribute to the hazard. In planning, it includes an estimation of the probabilities and the dimensions of the physical impact of potential avalanches. In operations, it involves the systematic observation, monitoring, and investigation of avalanche activity, snowpack and weather conditions.

Avalanche season: The snowpack depth within an avalanche area reaches threshold. The avalanche season generally starts in early November and ends in late April. The District Avalanche Supervisor will make the determination of when the avalanche season begins and when the season ends based on the avalanche risk for a particular avalanche area or avalanche path.

Avalanche hazard identification: A process that includes the identification of avalanche terrain, recognition of avalanche potential, and recording and representing its location.

Avalanche hazard evaluation: Entails comparing the results of the analysis against evaluation criteria that rate or rank the hazard

Ministry avalanche technicians: Manager, Avalanche and Weather Programs, Senior Avalanche Officer(s), District Avalanche Supervisor, District Avalanche Technicians and Assistant Avalanche Technicians.

Risk owner: Person or entity with the accountability and/or authority to manage a risk.