Snow Avalanches

Learning Objectives

- Understand the causes and triggers of snow avalanches
- Know the different types of avalanches
- Know the geographic regions where avalanches occur
- Recognize links between avalanches and other hazards, as well as the natural service functions of avalanches
- Understand how humans interact with avalanche hazards
- Know what can be done to minimize the risk from avalanches

Introduction

- What is a **snow avalanche**?
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- May travel as a coherent block or it may rapidly disintegrate into small particles that move independently of one another

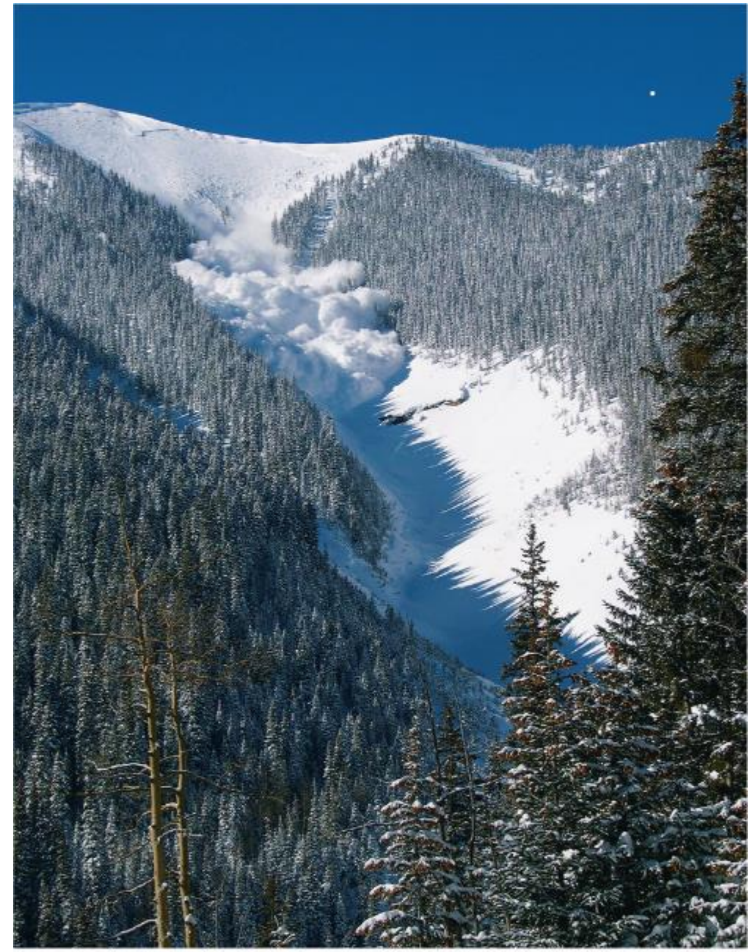
- Most occur in remote, uninhabited mountains during fall, winter, and spring

TABLE 7.1 Avalanche Size

Size	Run-Out	Potential Damage	Length and Volume
Sluff	Small snow slide that normally does not bury a person	Relatively harmless	Length < 50 m Volume < 100 m^3
Small	Avalanche stops on the slope	Can bury, injure, or kill a person	Length < 100 m Volume < 1000 m^3
Medium	Avalanche runs to the bottom of the slope	Can bury and destroy a car, damage a truck, destroy small buildings, or break trees	Length < 1000 m Volume $< 10\,000$ m^3
Large	Avalanche runs out over areas significantly less steep than 30°; may reach the valley bottom and run up the lower part of the opposing slope	Can bury and destroy large trucks and trains, large buildings, and forested areas	Length > 1000 m Volume $> 10\,000$ m^3

Snow Climatology

- The length of the snow season depends mainly on ______________________
- The amount of snow on the ground depends on slope od the land, elevation, amount of snowfall, and winds
  - Snow accumulates on slopes less than _____________



▲ **FIGURE 7.2 LARGE AVALANCHE** A large avalanche moves down a chute in the San Juan Mountains, Colorado. It started when a slab of snow near the ridge crest suddenly failed. The avalanche descended 830 m to the valley floor and then climbed up the opposite slope, burying 245 m of U.S. Highway 550 beneath 1 m of snow. *(Mark Rawsthorne)*

Types of Avalanches

- **Point-release avalanches**
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- **Slab avalanches**
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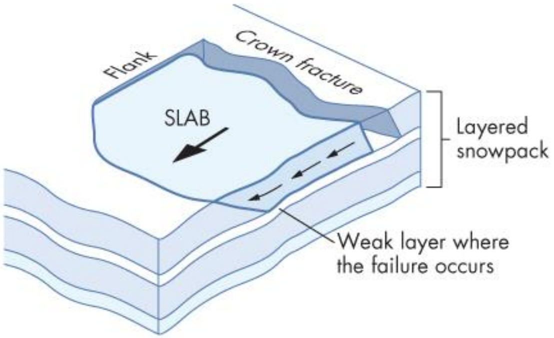
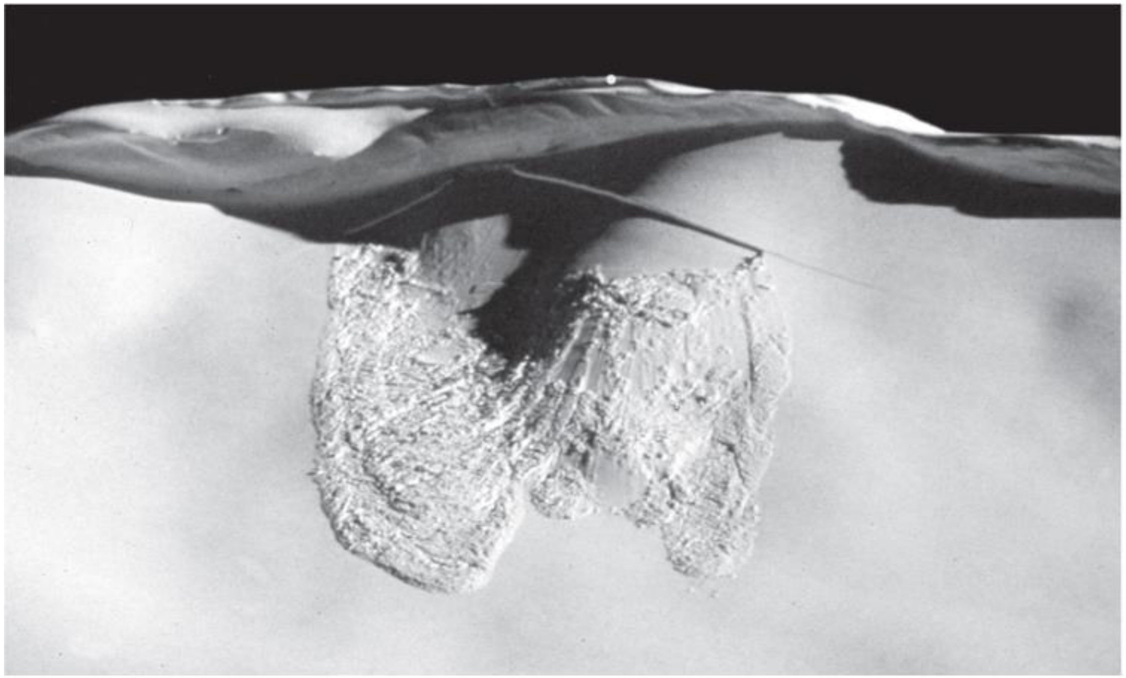


▲ FIGURE 7.5 **SLAB AVALANCHE WEAK LAYER** Slab avalanches begin when snow fails along a mechanically weak layer parallel to the surface. This diagram shows some of the terms used by avalanche scientists and safety personnel when referring to slab avalanches. *(Reproduced or adapted with the permission of Natural Resources Canada 2013, courtesy of the Geological Survey of Canada (Bulletin 548))*

▲ FIGURE 7.3 **POINT-RELEASE AVALANCHE** A point-release avalanche, as the name implies, results from initial failure of a small amount of snow. More snow becomes incorporated into the avalanche as it moves downslope, giving rise to the distinctive inverted-V shape seen in this example. *(B. Jamieson/Geological Survey of Canada)*



◄ **FIGURE 7.4 SLAB AVALANCHE** This avalanche occurred when a slab of snow slipped along a weak layer, shearing away from near-vertical crown and lateral scarps. The slab rapidly disintegrated as it moved downslope. *(B. Jamieson/ Geological Survey of Canada)*

Snowpack Structure

- New snow that has not had time to bond to the layer below is susceptible to sliding.

- Compacted snow is less likely to move than light powdery snow.

- Weak layers required for slab avalanches can form by:
  - ___________
    - Blowing snow can build up on sheltered lee slopes
    - A __________is a body of thick, poorly bonded snow deposited by wind

Snowpack Structure,

- Formation of hoar at depth in the snowpack
  - ______ - Ice crystals deposited on snow when air is moist and cold
  - Layers of hoar generally have lower strength than the rest of the snowpack
  - Forms from air occupying spaces between snow crystals

- Formation of hoar at the surface
  - Ice crystals change slowly once buried
  - Overlying and underlying snow layers gain strength, leaving the buried surface hoar as a weak layer

Avalanche Motion

- Within a few tens of metres, a slab avalanche disintegrates into smaller fragments
- Dry avalanches generate a cloud of powdered snow that billows above the flowing mass
- Wet avalanches contain liquid water and do not achieve the high velocities of dry avalanches
- Dry avalanches have been clocked at 200 km/h
  - May have sufficient momentum to climb opposing slopes

Avalanche Triggering

- Most avalanches occur naturally during or soon after snowstorms
- Some happen when normal daytime heating or an inflow of warm air raises the temperature of the snowpack
- In most recreational accidents, a person triggers the avalanche
- Some avalanches are triggered intentionally as part of avalanche-control programs

Avalanche Paths

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  - Where the snowpack fails
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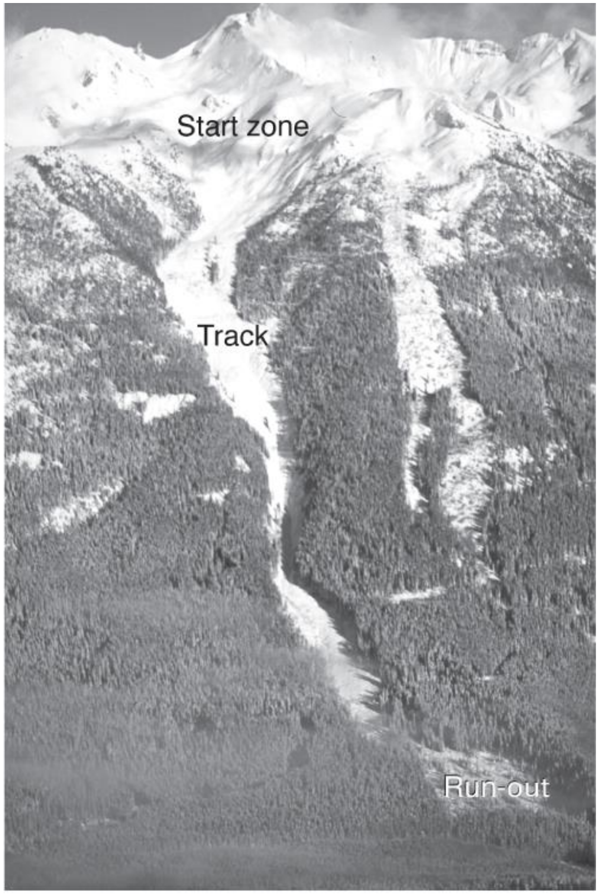
  - Path of acceleration and maximum velocity
-
  - Deceleration and deposition



▲ **FIGURE 7.6 COMPONENTS OF AN AVALANCHE PATH** A large avalanche path with a start zone, a track extending through forest, and a run-out zone on the valley floor. *(B. Jamieson/Geological Survey of Canada)*

Terrain Factors

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  - The most important terrain factor for avalanche formation
  - Avalanches tend to occur on slopes with angles between 25 and 60 degrees
  - Most large avalanches occur between 30 and 45 degrees

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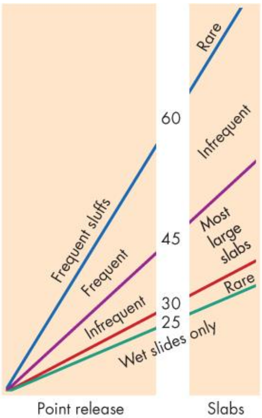
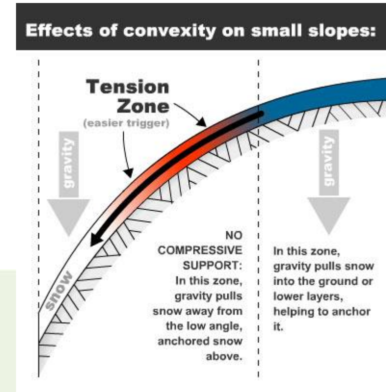
  - Leeward slopes are more likely to have avalanches
  - Sun-facing slopes are more prone to avalanches during sunny, warm weather; shaded slopes are more prone to avalanches in cold weather



▲ **FIGURE 7.7 RELATION BETWEEN SLOPE ANGLE AND AVALANCHE TYPE AND FREQUENCY** Slopes less than 25° and steeper than 60° have a low avalanche risk. Little snow accumulates on steep slopes, and snow does not easily slide on gentle ones. Most large avalanches happen on slopes of 30° to 45°. Wet avalanches, however, are more common on slopes less than 30°. *(Reproduced or adapted with the permission of Natural Resources Canada 2013, courtesy of the Geological Survey of Canada (Bulletin 548))*

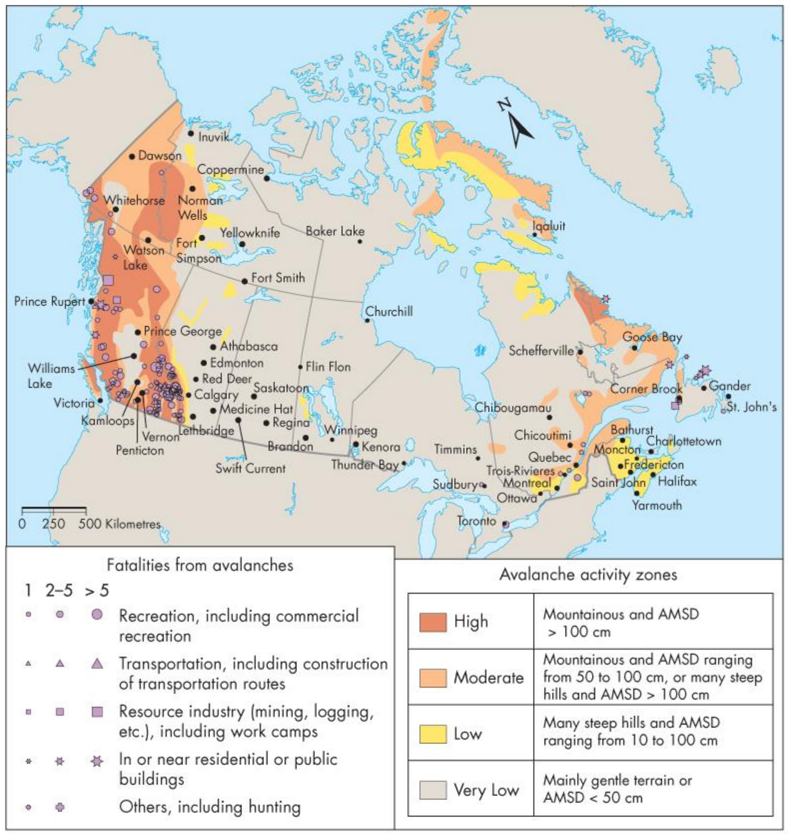
Terrain Factors

- Other factors
  - Convex slopes are more dangerous than concave ones
  - Avalanches are more common on smooth slopes
  - Vegetation may anchor the snowpack
  - Gullies or ravines can funnel avalanches, increasing their destructive force



▲ FIGURE 7.8 DOWNWED TREES AVALANCHE PATH COLORADO Avalanches generally initiate in non-forested areas, but they can run into and destroy mature forest. *(© Aurora Photos/Alamy)*

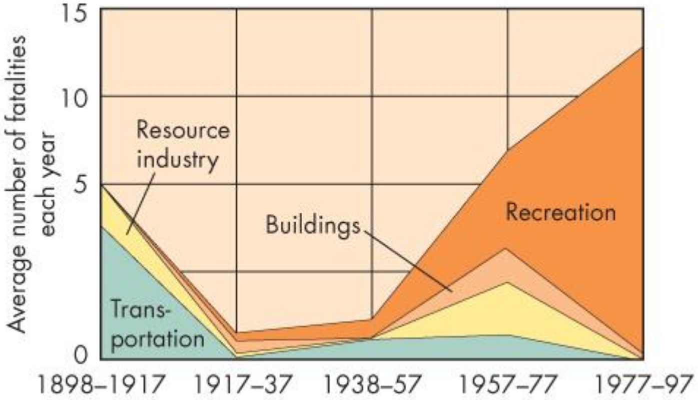
Geographic Regions at Risk of Avalanches



▲ FIGURE 7.9 **AVALANCHES IN CANADA** This map shows the regional occurrence of avalanches in Canada. It is necessarily generalized and does not take into account, for example, isolated steep areas and isolated areas of heavy snowfall or strong winds. AMSD is annual mean snow depth. *(Reproduced or adapted with the permission of Natural Resources Canada 2013, courtesy of the Geological Survey of Canada (Bulletin 548))*

Impacts of Avalanches

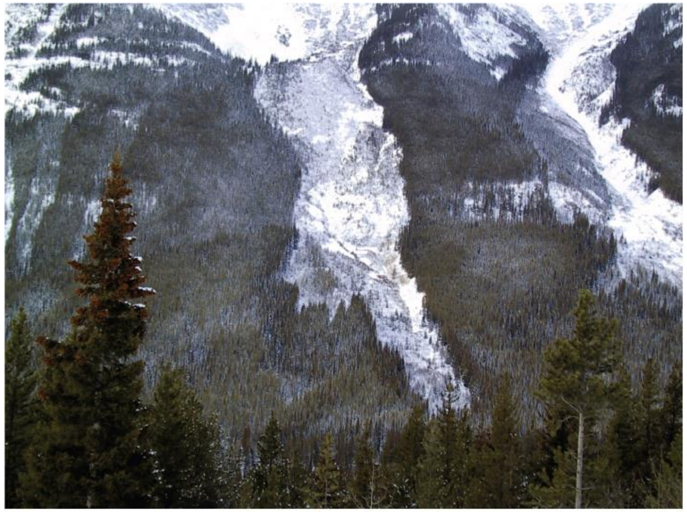
- Human deaths (600 in Canada since mid 1800s)
- Economic losses (destruction and blockage of roads, property damage)
- Damage to forests; soil removal



▲ **FIGURE 7.10 AVALANCHE DEATHS IN CANADA** The distribution of avalanche fatalities in Canada according to the activity of the victims at the time of the accident. Categories include recreation (skiing, snowboarding, and snowmobiling); transportation, including highway and railway construction; resource industry, including accidents at work camps; and residential and commercial buildings. Some accidents have been excluded because they do not fit any of these categories. In the past 50 years, the number of recreational accidents has increased dramatically, whereas the number of other accidents has decreased. *(Reproduced or adapted with the permission of Natural Resources Canada 2013, courtesy of the Geological Survey of Canada (Bulletin 548))*

Links and Natural Service Functions

- Links to other Natural Hazards
  - Earthquakes can trigger avalanches
  - Climate change may increase snowfall
- Natural Service Functions
  - Increase local plant and animal diversity
  - Provides open areas for wildlife



◄ FIGURE 7.11 **ECOLOGICAL BENEFITS OF AVALANCHES** Avalanches are an important shaper of vegetation in high mountain valleys, such as this one in Kananaskis Valley in the Alberta Rocky Mountains. They renew vegetation on the valley walls seen in this photograph. *(John J. Clague)*

Human Interaction and Minimizing Risk

- Increased human interaction with avalanches
  - Building developments are encroaching into areas prone to avalanches
  - Winter leisure and recreation activities have increased in popularity

- How do we minimize risk?
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  -
  -
  -
  -

Minimizing Risk

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  - Risk is estimated by determining avalanche frequency, distribution, size
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  - Fences, nets, berms, and avalanche sheds are used for protection
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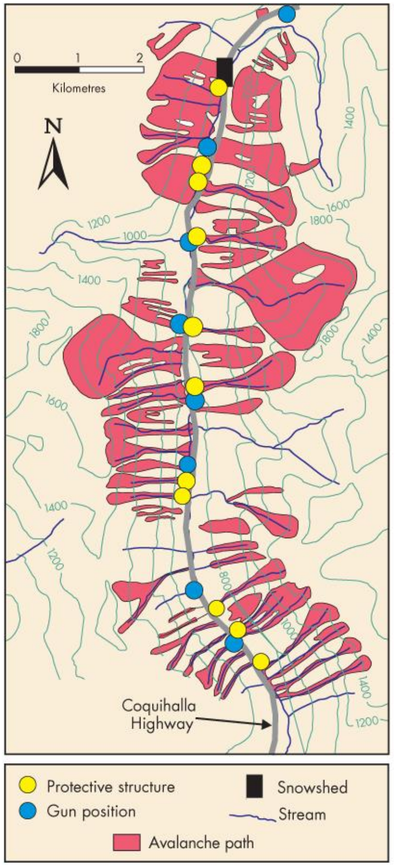
  - Explosive charges are projected from cannons, fired by artillery, or dropped from helicopters



▲ FIGURE 7.12 **MAP OF AVALANCHE PATHS** Avalanche paths are shown in pink on this map of a section of Coquihalla highway between Hope and Merritt, British Columbia. Protective structures were built to reduce the chance of avalanches reaching the highway. The green lines are contours, which are lines of equal elevation; in this case, the vertical spacing between contours is 200 m. *("Geoscape Vancouver: Mountain corridors," www.geopanorama.rncan.gc.ca/vancouver/mountain_e.php © Natural Resources Canada. All rights reserved)*

▲ FIGURE 7.14 **AVALANCHE SUPPORT STRUCTURE** Support structures in an avalanche start zone above Davos, Switzerland. Such structures prevent large avalanches from starting, but they are expensive and are generally used only where people and property are at high risk. *(B. Jamieson/GeologicalSurvey of Canada)*

◄ FIGURE 7.15 **PROTECTION AGAINST AVALANCHES** Avalanche braking mounds and catch dam at Neskaupstaður, Iceland. *(© Tómas Jóhannesson, Icelandic Meteorological Office)*

▲ **FIGURE 7.16 AVALANCHE SHED** An avalanche shed on the Coquihalla highway, west of Coquihalla Pass, British Columbia. The shed was constructed at a cost of CAD$12 million to carry avalanches over the highway. *(John J. Clague)*

Minimizing Risk

- Forecasting
  - Based on four types of information:
    - Observed occurrences of avalanches
    - Stability and strength tests: shovel, compression, and rutschblock tests
    - Snowpack observations
    - Weather

▲ FIGURE 7.17 **SNOW COMPRESSION TEST** A field compression test is used to locate weak layers in the snowpack and provide an index of stability. Note the weak layer that has fractured to the right of the man's elbow (dark band). *(B. Jamieson/Geological Survey of Canada)*

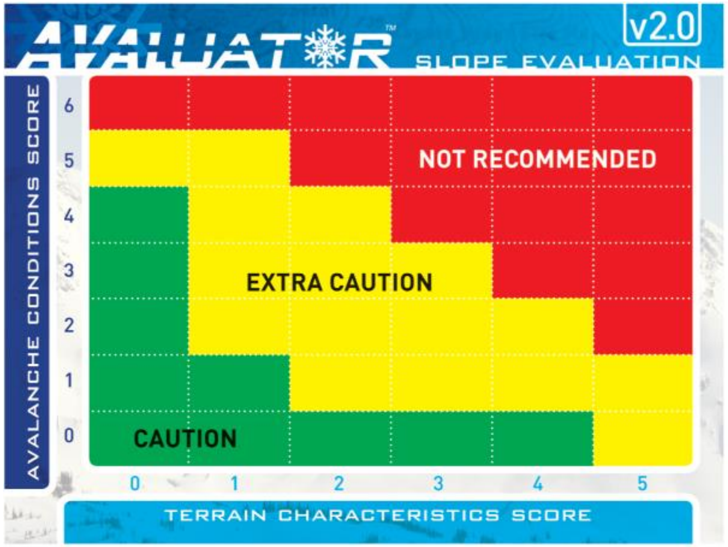
Avalanche Safety

- People involved in winter recreation in mountainous areas should consider these questions:

- Is the slope prone to avalanches?
  - Consider the slope angle and orientation

- Is the snowpack unstable?
  - Bulletins, recent avalanches, tests, weather

- What are the consequences of being caught in an avalanche in this terrain?
  - Size, type, wet or dry, topography of area (cliffs, trees, boulders)



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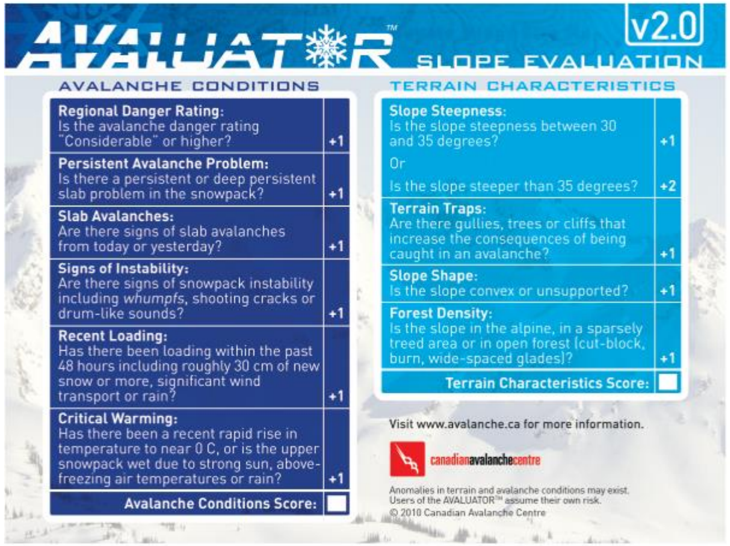

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◄ **FIGURE 7.18 THE AVALUATOR** The decision aids of the Avaluator include (a) a trip planner, which provides a general assessment of the expected risk of a trip into avalanche terrain, and (b) a slope evaluation tool for assessing the seriousness of individual route options during a backcountry trip. *(From the Canadian Avalanche Centre. Reprinted with permission.)*

Avalanche Rescue and Survival

- Survival depends on the length of time the person is buried and the burial depth
  - 92% survive if rescued within 15 minutes, only 30% survive after 35 minutes, almost 0% after 2 hours
  - Only 5 to 10% survive burial in more than 1.5 m of snow
- Rescue