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THE AVALANCHE HANDBOOK

DAVID McCLUNG AND PETER SCHAERER

THE MOUNTAINEERS BOOKS
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THE ABCS FOR BACKCOUNTRY AVALANCHE FORECASTING AND DECISIONS

You’ve got to know when to hold ’em, know when to fold ’em
—Kenny Rogers, “The Gambler”

PHILOSOPHY AND BACKCOUNTRY AVALANCHE FORECASTING

In order to describe avalanche forecasting, decisions, and actions, a philosophy must be attached. To deny that there are different methods and ideas about forecasting avalanches is like denying that there are different types of people: it is not believable. The avalanche forecasting described here is based on a combination of physical principles and realistic human behavior, which is well structured with a logical sequence of actions to condition decisions. The philosophy is based on an attempt to structure the problem in an ABC format and to make it as objective as possible. It is grounded on a long history of development with a combination of research results, deep thinking about what other people have written, and long years of personal experience. It is intended to be comprehensive and compatible with human behavior.

The reasons for such a choice of philosophy are several. First, the physical and human aspects of the problem are well enough known to enable a structure to be developed. However, this has only been true for a short while. Second, if the tide is to be turned away from deaths and injury in the backcountry, targeted education and experience need to be professed and learned at the grassroots level: every backcountry traveler is potentially an avalanche forecaster. It is simply much easier to teach and, more importantly, for most people to learn, if a formal structure is put on a subject. Thus, when the description below is read, it should be kept in mind that the philosophy described here is attached, but there are other philosophies and ideas about forecasting.

What Backcountry Avalanche Forecasting Is Not

Only two things are infinite, the universe and human stupidity, and I am not sure about the former.
—Albert Einstein

When you come to a fork in the road, take it.
—Yogi Berra

Proper backcountry avalanche forecasting does not consist of some mystical, intuitive guessing process, mostly based on art and practiced correctly only by some high priest or avalanche guru with thirty years of experience. Furthermore, the decision process is not analogous to a Top Gun pilot or firefighter making rapid, high-stakes decisions by reverting to one or two simple principles learned at an early stage of training.

Investing is another risk-based activity, but it is not like backcountry avalanche forecasting. Warren Buffet, arguably the most successful investor in history, relies on the principles of value investing. Value investing has a basis with some very simple rules due to the enormous human variability and complexity of the problem. His system works because he is right most of the time.

It is not acceptable to be right “most of the time” for backcountry avalanche forecasting. This is one reason that computer programs cannot be used for backcountry avalanche forecasting: they are only right “most of the time.” Real, not “artificial” intelligence, is needed before a free rider climbs/descends a slope in avalanche terrain. One reason we have a chance to be right more often is that the same failure sequence happens every time for release of the dry slab avalanche. Thus, the laws of physics play a role unlike the investing problem. The right decisions in
avalanche terrain are also a result of good procedures combined with a sufficient margin of safety.

Lionel Terray, the greatest expedition climber of his day, stated: “Only a lengthy experience, enabling observations to be stored up in both memory and the subconscious, endows a few climbers with a sort of instinct not only for detecting danger, but for estimating its seriousness.” Terray’s statement refers to the importance of experience and case histories and he is referring to climbing. But listen, if you believe that backcountry avalanche forecasting is within the realm of some mystical concept like instinct based on experience alone and couched in abstract terms like “art,” “pucker factor,” “gut feeling,” “heuristics,” “right brain,” and “intuition,” you are a candidate to join Terray’s fate for a premature “six-foot dirt nap.” The suggestion that avalanche forecasting and decisions are based only on experience characterized by such descriptors obscures how decisions arise and relegates them to the realm of pseudoscience. Avalanche forecasting and decisions should be based on well-founded principles that are easily taught and learned. The concepts are accessible to everyone, not just a few.

What Backcountry Avalanche Forecasting Is

*I consider the word probability as meaning the state of mind with respect to an assertion, a coming event, or any other matter on which absolute knowledge does not exist.*

— August De Morgan

*Probability is not really about numbers; it is about the structure of reasoning.*

— Glenn Shafer

*Risk in avalanche matters may be taken as the probability or chance of death or losses (including injury).*

— David McClung

An intuitive process in backcountry avalanche forecasting and decisions is the

*understanding that occurs naturally, based on past experience, combined with physical principles applied to the situation at hand.*

— David McClung

Forecasting avalanches in the backcountry is a probabilistic, risk-based activity involving continuous, thoughtful evaluation of factors. This evaluation begins prior to entering avalanche terrain and does not end until leaving the avalanche terrain. Since it involves prediction of avalanches, there are physical aspects to the problem, and since it involves human decisions followed by human action, there are human aspects to the problem. Furthermore, the forecaster is directly subject to the consequences of the forecast, since the terrain to be traveled is undertaken by the forecaster. This is unlike weather forecasters for which the consequences are incurred by someone else. One can think of backcountry avalanche forecasting and decisions in terms of six “dimensions”: (1–3) three dimensions of terrain, (4) variations in snow properties, (5) time, and (6) the human aspects.

It is useful to think of backcountry forecasting and decisions in terms of a combination of two reasoning processes: (1) an objective reasoning process, based on analysis of physical factors combined with human factors, and (2) an intuitive reasoning process. The forecasting/decision process typically involves more than one spatial scale. In practice, the objective process tends to dominate at the largest spatial scale (e.g., consideration of the Danger Scale and weather at the start of a trip), and the intuitive process tends to dominate at the smallest scale (e.g., at the micro-scale when a piece of terrain is under consideration). Thus, a mix of these reasoning processes depends on a decision-making skill level as described below and the spatial scale considered.

The ABC system described below is targeted at the objective part of the risk-estimation process to provide its structure for Basic and Intermediate decision-makers. Proficiency at the subjective, intuitive reasoning process is heavily based on experience and
practice. Treatment of it is beyond the scope here. The subjective reasoning process can be described, but it cannot be learned from a book.

The causes of avalanches are well known and the information that reaches human senses, allowing decisions, can be classified, explained, and used. The residual risk arises because the snowpack is inherently variable and key parameters representing instability cannot be determined: slab fracture toughness cannot be calculated or measured, and the locations of weak spots are largely unknown. The root cause of human-triggered avalanches (accounting for more than 80% of backcountry fatalities) is failure in human perception about the state of instability. Failure in perception is the root cause since if people have triggered avalanches, their perception about instability and its consequences has not matched reality (the conditions at hand). However, the basic elements of human perception in avalanche forecasting are known and they can be dealt with.

Risk estimation and decisions in backcountry avalanche terrain involve four main categories of factors:
1. Chance of avalanching (analogous to frequency in engineering-risk problems)
2. Consequences if avalanching takes place
3. Exposure of people in time and space
4. Human factors that affect and are involved in decisions

The sections that follow include all these factors.

DECISION-MAKING LEVELS

Decision-making is an acquired skill and proficiency improves with practice. Skill is an important component of risk-taking propensity. In backcountry avalanche forecasting, the skill is embodied in decision-making. It is dangerous to confuse travel skills (e.g., expertise in skiing or riding) with decision-making skills related to avalanche hazards. Higher levels of decision-making skill should promote greater freedom without sacrificing safety. Decision-making in avalanche matters improves slowly over time as experience, targeted education, and learning from expert or master decision-makers accrue.

A simple classification for decision-makers in avalanche matters may be denoted in terms of learning stage. These are: Basic (including novice and advanced beginner), Intermediate (including competent and proficient), and Advanced (including expert and master). The six levels in parentheses are described by Dreyfus (2001). Any system for making decisions has to be targeted to one of these three levels. Here the primary targets are Intermediate and Basic. The Intermediate level is dealt with first and then a Basic-level travel structure is presented. At the Basic and Intermediate levels, emphasis is more on the objective, analytic process, whereas at the Advanced level, emphasis is on the intuitive process. At the Advanced level, objective, analytic thinking can, and does, clarify and sharpen the intuitive process. Thus, both objective (analytic) and intuitive processes are used in backcountry decision-making at all levels, but the mix changes with the decision-making level. The ABC system is formulated to be profitable for decision-makers at all three levels, and systems for both the Basic and Intermediate levels are given (Table 8.1).

At the Basic level, people are learning the facts, procedures, and science to understand the problem coupled with some exposure to real situations. At this level, there is a need to simplify the problem with the use of simple rules if decisions are to be made. Two courses of action are appropriate: use very simple fixed rules, which must result in and be based on very conservative plans or travel under the care of a more advanced decision-maker, for example, a guide. It is dangerous for Basic-level people to attempt decision-making beyond what they have acquired in practice. Basic-level decision-making is mostly characterized by simple rules about avoidance. People who always rely on simple rules will have difficulty reaching the Intermediate level. A cyclist using training wheels should not ride on the street and will never ride in the Tour de France. At the Basic level, the intuitive process in risk estimation and decisions is largely undeveloped. Table 8.1 illustrates the decision-level classes and descriptors.

At the Advanced level, an expert is defined as a person with ample amounts of targeted education
and experience combined with years of decision-making practice. A master is all of the above but more advanced with an individual style developed and capable of being a mentor to all five levels below. Winter and ski mountain guides at various levels should fit into the Advanced level. A fixed set of simple, unconditional rules is unrealistic for a person at the Advanced level.

Such a system would be too rigid and produce travel plans too conservative for an Advanced decision-maker. At the Advanced level, the intuitive process in risk estimation and decisions is well developed and occurs naturally.

**Intermediate** decision-makers are those with targeted education and experience but who may need the formalism of a structure. However, for these people, a fixed, simple set of unconditional rules is often too conservative. Typically, Intermediate decision-makers are those who can conduct a trip without a guide or an Advanced decision-maker along, for example, a personal ski tour. Intermediate decision-makers are those making the shift from the simple avoidance principles of Basic decision-makers to risk management with a structure such as the structure: A precedes B, which precedes C. At the Intermediate level, the intuitive process is being developed.

There is another class of backcountry travelers: the unaware, with virtually no combination of targeted education and experience on avalanche matters. People at this level do not generally qualify as decision-makers and are excluded from the discussion below. However, if they report factual information about instability or other conditions that may influence party safety, they should be listened to.

---

### Table 8.1 Decision-Level Classes and Descriptors

<table>
<thead>
<tr>
<th>Decision Skill Level</th>
<th>Subclasses</th>
<th>Primary Decision Process</th>
<th>Intuitive Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>Novice, Advanced beginner</td>
<td>Objective, analytical, rule-based</td>
<td>Undeveloped</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Competent, Proficient</td>
<td>Objective, rule-based</td>
<td>Developing</td>
</tr>
<tr>
<td>Advanced</td>
<td>Expert, Master</td>
<td>Intuitive</td>
<td>Developed</td>
</tr>
</tbody>
</table>

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**THE ABCS: SECTIONS**

The structure presented here is in four sections and two appendices. Each section is structured in an ABC format: A → B → C in sequence.

**Section I: The Decision Structure in Three Parts** *(Basic and Intermediate Levels)*

A (Analysis) → B (Acceptability) → C (Decision)

**Section II: Guidelines to Condition Decisions** *(Intermediate Level)*

A (Terrain) → B (Snowpack) → C (Human)

**Section III: Action List for Backcountry Travel** *(Intermediate Level)*

A (Terrain) → B (Snowpack) → C (Human)

**Section IV: Basic Rule-Based Guidelines and Action System** *(Basic Level)*

A (Terrain) → B (Snowpack) → C (Human)

**Appendix A: Risk-Reduction Factors** *(Basic Level)*

**Appendix B: Classes of Forecasts and Their Trend for Backcountry Travel** *(Basic and Intermediate Levels): Class A → Class B → Class C*

**Section I: Decision Structure (Basic and Intermediate Levels)**

Travel in the backcountry does not consist of one big decision: to proceed or not. Instead, it consists of a series of decisions with the approximate structure below. In summary form, the decision structure is in three parts:

A (Analysis)

↓

B (Acceptable risk)

↓

C (Decision)
ABC Decision Structure for Backcountry Travel in Avalanche Terrain

A. Primary Information Sources and Analysis

Primary information sources include:
1. Terrain features (shape, size, steepness)
2. Danger-scale rating: instability on the large scale
3. Class I and Class II information about instability
4. Information about increasing instability (Class III): snow loading, temperature increases

Analysis: The evidence is considered in combination as to whether it points to instability or not. When evidence mounts in favor of instability, alternate plans are in order. However, one piece of evidence about instability can clinch a decision in spite of all previous analysis.

For example, if a “whumph” is experienced on steep, exposed terrain, alternatives must be considered. Conversely, if no weak layer is present at a location, slab avalanches are not possible there.

B. Decision Character and Acceptability

Decision character: Decisions should be neither too conservative nor too risky. Realistic human behavior suggests decisions will be between the middle and upper limit of the Operational Risk Band (see Chapter 6, Figure 6.3).

Acceptability: What is unacceptable? A basic definition of unacceptable risk in backcountry travel comes from the Canadian avalanche-size classification system.

It is unacceptable if there is a significant chance of triggering (or being struck by) an avalanche of size 2 or larger. Size 2 is a small slab that can bury, injure, or kill a traveler (skier, rider, sledder, or other). The approximate size is somewhat more than 10 m in downslope length. When weak layers are buried greater than about 20 cm, typically avalanche size will approach size 2.

Secondary factors that reduce acceptable risk and call for more conservative decisions (after the primary information sources are considered) can include:
1. Increasing group size
2. Terrain exposure below the party, including cliffs, terrain traps
3. Obstacles below, which may be struck, including trees
4. Condition of the group (if tired physically) and time of day (if late in the day)

Implementation of these factors involves terrain and group management conditioned by instability information.

C. Decision Choices

There are only three decision choices:
1. Proceed.
2. Collect more relevant information about instability.
3. Choose an alternative (including turning back).

Implementation of a travel-decision choice (1 or 3) involves terrain and group management conditioned by instability information. At the Basic level, only choices 1 and 3 are normally available. Travel decisions follow the action lists in Sections III and IV for Intermediate and Basic decision-makers.

Section II: Guidelines to Condition Decisions (Intermediate Level)

The ABCs for Determining Actions: Guidelines

The avalanche-forecasting problem is complex, but there are some general guidelines—backed by research, physical principles, and experience combined—that can condition decisions. Like any rule or guideline, they do not suffice individually, and since human factors are involved, there will be overlap. Individual rules of thumb do not normally apply to proper avalanche forecasting and human decisions. Reliance on rules of thumb can work in the short term, but eventually, faulty decisions will arise. Unconditional statements and declarations rarely apply to a probabilistic activity such as avalanche forecasting. Avalanche forecasting and decisions are concerned with conditional probabilities and chances. Rules or guidelines couched in unconditional descriptors, such as “always” or “never,” have doubtful applicability in avalanche forecasting and most decisions.

The suggestions below include all four categories involved in risk (chance, consequences, exposure,
and human factors) and many of the main needs, but the list is not complete. If you are seeking a complete list, you are not an Advanced decision-maker and you have yet to completely appreciate the true character of decisions in avalanche forecasting. The list applies mostly to dry slab avalanches—the greatest source of accidents—and it is to be regarded as a skeleton list. In a 10-year study of human-triggered avalanches from Switzerland (Schweizer and Lütschg, 2001) for hundreds of cases, 99% were slab avalanches and, of these, only one was a wet slab.

The rules and suggestions could be grouped under the four major risk factors, but below, they are grouped under three categories:

A: Terrain

B: Snowpack

C: Human factors and decisions

The categories are listed in the approximate order that backcountry forecasters use them in practice. Not surprisingly, the human factors and their connection to decisions contain the largest number of suggestions. The mix is A: Terrain (25%), B: Snowpack (25%), and C: Human (50%).

From the rules and suggestions, a structured action list is given in Section III for Intermediate decision-makers.

Suggestions for Conditioning Backcountry Avalanche Forecasting and Decisions and Improving Safety (Intermediate Level)

A. Factors Mostly about Terrain

1. **Terrain management is essential.** It is the first, and probably most important, skill to be mastered for safe backcountry travel. A route should be envisioned in terms of the features on it. Thus, management includes not just slope angles, but terrain forms (convex/concave); size, shape (Figure 8.1), and effects of deposition; and wind packing. Mountainous terrain is complex and normally routes have micro-scale features (Figure 8.2) that are more dangerous than in the remainder of the terrain. In a study of human-triggered avalanches in Switzerland, Schweizer and Lütschg (2001) found that of 470 cases reported, more than half were close to ridge tops (52%), with about 53% of those near ridge tops associated with bowls and gullies below the ridge. These data suggest that it is wise to consider combinations of terrain features
(e.g., ridge top + bowl), not just simple terrain shape. Under these conditions, both the terrain and the snowpack are changing. The fundamentals of terrain recognition are taught in all good backcountry avalanche courses. Table 8.2 contains a data summary from Schweizer and Lütschg (2001).

2. **Risk increases with slope angle.** Frequency of skier triggering increases strongly with slope angles above 25°. Figure 8.3 shows a cumulative plot of data compiled by Schweizer and Jamieson (2001) for 809 slope angles at fracture lines of skier-triggered avalanches. The curve may be taken as an index of risk frequency with extremely high-risk increase as slope angles increase above 30°. Approximately half of the events are between 35° and 40°. Slope angles considered for backcountry travel should be the maximum encountered taken over a suitable slope length of somewhat more than 10 m: the characteristic length of slab that presents danger to backcountry travelers. Not only does the chance of triggering increase dramatically with slope angle, so does the consequence: on steeper slopes, the downslope gravitational driving force is higher and slabs pick up speed rapidly. For the same slab size, a 50° slope is more dangerous than a 30° slope: the downslope gravitational force increases by more than 50%. Concern about slope angles is not limited to the slopes actually traveled. When unstable persistent layers are a concern, avalanches can be triggered on gentle slopes (below 25°) to release

![Figure 8.2. Illustration of a V-shaped valley that served as a terrain trap. A skier was buried under 5m of snow in this instance. (Photo by D. Gallagher)](image)

![Table 8.2 Terrain Factors in Human Triggering](image)

<table>
<thead>
<tr>
<th>Terrain Combinations in Triggering</th>
<th>% of Cases: 253 Total Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close to ridge top + bowl</td>
<td>32</td>
</tr>
<tr>
<td>Close to ridge top + gully</td>
<td>21</td>
</tr>
<tr>
<td>Close to ridge top + open slope</td>
<td>20</td>
</tr>
<tr>
<td>Close to ridge top + below rock wall</td>
<td>8</td>
</tr>
<tr>
<td>Close to ridge top + glacier</td>
<td>4</td>
</tr>
<tr>
<td>Forest, open forest + gully</td>
<td>6</td>
</tr>
<tr>
<td>Below rock wall + bowl or open slope</td>
<td>9</td>
</tr>
</tbody>
</table>

![Figure 8.3. Cumulative plot of slope-angle data from 809 skier-triggered avalanches from Schweizer and Jamieson. Risk increases substantially as slope angles increase above 30 degrees.](image)
accidents and incidents is our primary information source to estimate the likelihood of an accident. History is important, not only of the slope in question, but of similar situations in the past and case histories. Any history for the current winter may be important (e.g., previous skiing or avalanche activity). Check with other people who have been there if you have not. Discard Henry Ford’s prescription: “History is more or less bunk.” Instead, follow the Dalai Lama’s advice: “When you lose, don’t lose the lesson.” History shows that avalanches occur where they are not normally expected. The phrase “I have never seen an avalanche there” is very common after avalanches have occurred. Skiing is a test of instability, so treat it like any other instability test. Previous tracks present on a slope are not definitive proof of stability.

6. Minimize exposure under avalanche paths and start zones when instability is known to be elevated or increasing, including loading by new snow, loading by drifting snow (often under blue skies), and times when snowpack temperatures are increasing. Schweizer and Lütschg (2001) studied avalanche fatalities over a ten-year period in Switzerland. They found that natural releases accounted for 14% of the fatalities (about 10% in backcountry travel), and of these 14%, 52% were caused by wet-snow avalanches (45% wet slabs and 7% wet loose snow). Wet-snow avalanches are normally a product of warming and/or rainfall.

7. Minimize exposure in the terrain for suspect slopes or under suspect slopes (Figure 8.4). Minimize exposure with respect to your partners on the same slope as well as minimizing any effects you might have on partners below. This requires your own thinking, even in guided parties; don’t blindly follow the herd. Bowls and gullies are primary terrain features where people tend to cluster and avalanches are likely to happen.
B. Factors Mostly Concerned with the Snowpack

8. Risk increases with the Danger Scale level. Current research (Grímsdóttir, 2004) has shown this to be true as expected. The Danger Scale applies to large areal extent, such as synoptic-scale, so it must be supplemented by information about the specifics of the slopes in question to make decisions relevant to the meso-scale or micro-scale. The bulletin with the Danger Scale should be read and digested. Don’t take away a color, such as Yellow, or a one-word descriptor, such as Moderate, as the information you derive from the forecast. Instead, focus on the relevant aspects, elevations, terrain features, and presence of persistent layers. Beware of level 3 or Considerable: it is the level with the highest number of fatalities and for which variations in human perception are expected to be largest about the avalanche risk; human biases may have great effect. Under Extreme, most people avoid avalanche terrain or stay home. Be prepared to revise the information given in the Danger Scale; it may be incorrect or inappropriate for the places you are traveling.

9. Persistent forms call for extra caution. Persistent forms constitute the overwhelming majority found in weak layers that account for skier triggering and big accidents. Since instability persists, the persistent forms may be buried deeply but still maintain low-fracture toughness to increase the chance of large avalanches. Approximate ranking of frequency for human triggering includes: (1) surface hoar, (2) facets, (3) crusts with weak bonds (e.g., facets) to the slab, including radiation recrystallization, and (4) depth hoar. The rankings will change from one mountain range to another and possibly from one year to the next. In their study of skier triggering, Schweizer and Jamieson (2001) suggested that persistent forms were involved in 67% of weak layer and interface failures. Figure 8.5 shows their data for 186 skier-triggered avalanches. If persistent layers are present somewhere, be aware of factors that can change their presence spatially. Surface hoar is prevented from forming underneath forest canopy, but if you suddenly move into a logged clear-cut or open forest glade, an almost instantaneous change in conditions can develop.

Figure 8.4. Avalanche descending to the right of the main climbing route on Broad Peak, Karakoram, Pakistan. (Photo: SLF archives)

Mountain guides call clear-cuts "surface-hoar farms." Sometimes wind destroys surface hoar in alpine terrain so that travel is actually more dangerous in terrain below the wind-scoured alpine region or in locations sheltered by the wind. Facets, surface hoar, and depth hoar dominate the statistics (Figure 8.5).

10. Aspect and elevation band are weak predictors. Persistent layers often form more often on cer-
tain aspects [e.g., shady slopes: northerly in northern hemisphere (NW, N, NE)], but risk-based research shows that general statements about aspect and elevation bands are too weak to have any predictive merit. In popular books, simple statements such as “Around 60% of fatal accidents occur in north-facing slopes” are used to justify fixed rules about such aspects. However, such statistics do not include the number of people using the aspects. Sunlight (sunny aspects) destroys powder snow and creates sun crusts. These characteristics, related to snow quality, have a big influence on increasing the number of people on shady aspects. The Avalanche Bulletin (level of instability) also has a major influence on the number of people in relation to elevation and aspect. When the numbers of people are accounted for, research (Grímsdóttir, 2004) has shown that aspect becomes a weak predictor. Figure 8.6 shows historical risk versus aspect from accidental skier-triggered avalanches derived from 45,000 skier days from the Columbia Mountains of Canada. Most avalanches were triggered on N, NE, and E aspects. However, when slope usage is taken into account (number of people), aspect as a predictor is too weak. If anything, the risk is slightly higher on east than west aspects, and north-south aspects form a mirror image of each other in this Canadian data set. In west central Colorado, the snowpack tends to be thinner on south-facing slopes, with a greater prevalence of facets and weaker snow, so a rule suggesting avoiding north aspects might be dangerous. South-facing slopes sometimes become dangerous due to rapid warming and a high likelihood for the presence of buried sun crusts. Singular data about the present situation, for example, from the Avalanche Bulletin, are normally much more accurate than some fixed rule about aspect, which would need many “if,” “then,” “but” qualifiers. Be cautious of shady slopes, but recognize that there are many possible conditionals which can apply (Figure 8.6). Information at the site is preferred over historical risk data for decisions. Statistics on accidental skier triggering (Grímsdóttir, 2004) show that elevation band
(e.g., alpine, tree line, and below tree line) is also a weak predictor along with aspect. The only significant reduction effect on triggering with elevation band in Grímsdóttir’s (2004) study comes from below tree line where forest cover is present.

11. **Assume that ample amounts of new snow will contain instabilities.** Fredston and Fesler call new snow (e.g., in lee zones) or wind-affected snow in excess of 30 cm **bull’s-eye information** (implied as Class I). Without snow-structure information, new snow amounts are Class III. However, new snow in large amounts almost always contains weak layers and instabilities so it is better to assume it is Class I. Since new snow is found near the surface, perception about instability is generally better than for deep, persistent weak layers. Often, instabilities in new snow are not of much consequence, probably because there is not enough contrast between weak-layer hardness and slab material, but sometimes, when wind affected, they are, so look for the exceptions, not the rule. An inconclusive test result at one location may be entirely different than other locations subject to wind packing (previously or at present) for which there is enough contrast, or future conditions when slab settlement increases the contrast in hardness. Snow temperatures at the weak layer are primary for determining how long instability persists (colder temperatures imply longer persistence) as well as the load (slab thickness) over the weak layer. Increases in either (or both) weak-layer temperature or load over the weak layer can help to build fracture toughness, which decreases instability over time. Effective evaluation of instabilities in new snow (or lack of) is very important; the most pleasurable travel (i.e., powder surfing) is found in new snow.

12. **Assume instability tests only provide truly useful information if they show instability.** Otherwise the results are inconclusive. Be aware that results of instability tests have an extremely local meaning, whether they show instability or not. Repeatability of test results is important, but forget about any precise analysis or average score to represent a location. Such concepts have very little meaning in relation to avalanche forecasting. Instability tests are primary tools to detect weak layers and, if weak layers are found (Figure 8.7), it should be expected that somewhere avalanches are possible. Instability tests are taught in all good backcountry avalanche courses and are easy to learn. Single Rutschblock (RB) test scores of 6 and 7 have been found during accident investigations, and studies of spatial variability consistently show scores of 2 mixed with 6 or 7 on the same slope.
The results of a study of RB scores (Schweizer and Jamieson, 2001) on slopes adjacent to 106 skier-triggered avalanches are shown in Figure 8.8. Their results show more than 20% have RB scores of 5 or higher, about half have scores of 4 or higher, and the distribution is skewed toward the higher scores (4 or more). A score of 3 or less gives some direction, but a score of more than 3 is inconclusive. Given an unstable situation, the data show that a single test on a slope (RB 5 in the data set) still results in a 20% chance of an avalanche. Russian roulette, excluding the bullet weight, gives a 17% chance. This refers to the asymmetry in the use of data and respect for targeted sampling and spatial variability. Instability tests provide more relevant Class I information if conclusive evidence is revealed. Shear quality Q1 signifies potentially dangerous conditions, whereas Q3 is inconclusive since the same layer structure may show Q1 elsewhere. A combination of shear quality and instability test scores gives a better assessment than test scores alone.

13. **Pay attention to classes of information and data.** Class I factors can reveal definitive signs of instability, including avalanches, “whumphs,” and cracks; shear quality; and results of instability tests. Any positive signs of instability from such factors must be given the utmost attention (Figure 8.9). You should not proceed into steep avalanche terrain when these sources of information indicating instability are present. *Class*

![Figure 8.8. Rutschblock scores on slopes next to 106 skier-triggered avalanches.](image)

![Figure 8.9. Slab release by skier. The fracture line at upper right indicates high instability—an extremely important indicator. (Photo by R. Ludwig)](image)
information can reveal the presence of weak layers and interfaces combined with slab structure, which are essential for slab-avalanche formation. Class III factors contain wind and deposition patterns and air temperatures.

14. **Study the Applied Rules of Avalanche Formation** (Appendix 4A, Chapter 4) and recognize the three types of uncertainty: spatial and temporal variability, changes induced by snow and weather factors, and variations in human perception and estimation.

C. Factors Mostly about Human Aspects, Decisions, and Group Management

15. **Combine ample amounts of targeted education and experience.** Always combine them; neither is effective by itself. Education teaches the rules, experience teaches the exceptions. Both are essential.

16. **Have an open mind.** Discard your ego and break out of the subculture ghetto you reside in (mountain guides, skiers, sledders, riders, gender classes, teenagers, managers, snow scientists, and avalanche forecasters). Application of the scientific method (combined with targeted education and experience) is your best protection. To envision that all the answers reside in your own subculture is wishful thinking. Avalanches consistently invade past the narrow boundaries of subcultures and they strike preferentially in some subcultures more than others, especially those whose members have a weak combination of targeted education and experience.

17. **Learn, collect, and study human biases** (also called human-decision traps). Learn to recognize when they are having an effect. Human biases are least expected in judges’ chambers and baby carriages, not backcountry-skiing parties (see Appendix 6A, Chapter 6).

18. **Learn to live with risk, manage it, and love it.** The goal of decisions is to be within the Operational Risk Band, not to minimize risk. The philosophy of “minimizing avalanche risks” is not compatible with realistic human behavior in backcountry travel. Effective risk management instead of simple avoidance rules is a major distinguishing feature of decision-makers who are beyond the Basic level. Risk and reward most always increase together, but most bad accidents (not all) involve a combination of errors and mistakes. Learn to recognize when the first mistake has been made. For example, if you enter avalanche terrain without a transceiver, the first mistake has been made, or if you enter avalanche terrain in the last, fading moments of daylight or when your party is tired, a mistake has been made. Human decisions are made so that they are not too risky (a Type I error) and not too conservative (a Type II error) (Figure 8.10). The goal of good decisions in backcountry avalanche forecasting is well defined to be within the Operational Risk Band (ORB). The great Swiss climber Erhard Loretan, underwriter of bold new routes in the Himalaya, stated: “Fear and dread are my life insurance.” Your “life insurance” involves personal backup systems: keep fit, keep mentally alert, learn all you can, know your equipment and how to use it. Have an open, objective, humble mind and maintain a healthy but not fearful respect for the risks you are

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**Figure 8.10.** Human decisions are made such that they are not too risky (a Type I error) and not too conservative (a Type II error). The goal of good decisions in backcountry avalanche forecasting is well defined to be within the Operational Risk Band (ORB).
undertaking. If any of these elements is missing, the first mistake has been made. To envision that you can enjoy the "benefits" of risky activities without the "costs" of adequate preparation is wishful thinking.

19. **Try to make decisions that are not too conservative.** If your decisions are too conservative, reread suggestion 15 above and implement it. Discard the unconditional "first and second cardinal rules" of ski touring: (1) "Stay off avalanche paths and especially out of avalanche-release zones." (Every slope over 25° is a potential release zone.) (2) "Always conduct the march in such a fashion that only one person at a time is exposed to avalanche danger." (When in avalanche terrain, people are nearly always exposed to avalanche danger to a certain degree and it is unrealistic to suggest that people are always spaced as suggested.) Instead, replace these mostly sensible suggestions with realistic, conditional assessments compatible with human behavior and the situation at hand. Discard fixed rules about aspect (i.e., avoid shady aspects) and new snow amounts (suggestion 11 above). Instead, replace fixed rules with conditional assessments based on singular data (the current situation).

20. **Reduce your reliance on luck.** Experiencing luck means that you got by when you probably should not have. You will need some of it to survive if you travel in the backcountry often. Experience suggests instances calling for luck diminish as targeted education and experience build, perhaps because overall risk-taking propensity changes or forecasting improves (or both). Golf great Gary Player made a statement that catches the flavor: "The harder I work, the luckier I get." Your reliance on luck and your risk both increase when the first mistake has been made.

21. **Adopt a holistic approach to decisions conditioned by both inductive and deductive reasoning.** Avalanche forecasting is a continuous process of evaluation to build a foundation for decisions. It starts by reading the Danger Scale or Avalanche Bulletin with analysis prior to entering avalanche terrain and includes the current and future weather conditions. Lots of evidence is available, but one piece of evidence found, for example, by targeted sampling can negate all the analysis—a primary characteristic of inductive reasoning. Only relevant data and information bits matter, but these may come from diverse sources. When the evidence from several sources indicates a condition of instability, uncertainty is reduced and decisions become less subjective.

22. **Group decisions with good risk communication are best.** Don't accept an argument that is not backed by facts and watch for biases in the positions presented. One good argument based on facts can negate all the others. Appoint a leader who is not too conservative, not an extreme risk taker, and with a good mix of targeted education and experience. Forget "Uncle Joe" Stalin's idea about consensus: "It doesn't matter how the people vote." Instead, follow Al Capone: "Vote early and vote often." The latter statement sums up good risk communication nicely: it is a continuous process. Good risk communication also includes prompt reporting of definite signs of instability (e.g., Class I information) to your group members.

23. **Use a formalized decision process.** One reason for the good safety record of helicopter skiing in Canada is the presence of a formalized structure for decisions. An outline of a decision-action structure for backcountry travel contained in the next section is based on the rules and suggestions here. A good decision structure contains continuous checks before the trip begins, again when contemplating the route on arrival at the location, at the beginning stages, and while traveling.

24. **Group management is essential.** For suspect slopes, minimize the exposure by proceeding one at a time with large spacing, try to move between islands of safety (Figure 8.1), travel with
a partner, and keep that person in sight. Make sure you have a partner; don’t rely on the leader to organize this. Maintain communication, especially if instability is sensed. Statistics (Schweizer and Lütschg, 2001; Grímsdóttir, 2004) show that skier triggering most often happens for the first person down the slope. Keep to the same track as the first person on suspect slopes to minimize spatial sampling. Remember: this may not always work since the first person can start the deformation process, leaving you to achieve fracture-propagation conditions.

25. **Make allowances for risk increase with group size.** Risk increases and acceptable risk decreases with the number of people in the group. More people in the group means that plans should be more conservative than for a party of two; there is a greater chance of something happening, a greater chance of more people being caught, and communication problems multiply. More people on the slope implies more spatial sampling of the snow cover and a greater chance of triggering an avalanche. When grouping up, deformation can be induced over a larger area or deformation can be additive when a region is influenced by more than one person crossing. The concept, espoused in popular books, that more people implies greater weight added to the weak layer to affect avalanching is not correct. (See Chapter 4 for more information). Avalanches initiate from imperfections or weak spots that are typically less than 1 m across. This distance is less than skier spacing. Stresses due to skiers are also localized; they do not overlap significantly with adjacent skiers to produce much higher stresses.

26. **Be prepared to consider alternatives.** If you have trouble making a decision, there are only two rational sources of action: either seek more relevant information about instability or choose an alternative (one of which is turning back). There is a potential reward for turning back or choosing a safer alternative: you can remain among the best skiers and climbers (the ones that are alive).

27. **Always have a transceiver, probe, and shovel** and check that all transceivers are operating (both receive and transmit) before entering avalanche terrain. Practice the use of these tools periodically to save crucial time. All skiers should have release bindings, and riders should have a release system. Don’t use ski straps or wrist loops on poles.

28. **Be aware of the extra energy delivered by snowmobiles and differences in perception.** Avalanche forecasting involves considering the energy delivered to the snowpack by a trigger. If you are a sledder driving a 450-kg snowmobile at high speed over a snowpack, an avalanche forecast can be different for you than for a skier or rider in many instances: you are delivering about 5 times the energy of a skier or rider, which could release avalanches in hard (Figures 8.11 and 8.15) or deep snow. This does not mean that

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**Figure 8.11.** Severe riming suggests very hard snow at the surface. (Photo: SLF archives)
snowmobiles are 5 times more likely to trigger avalanches than a skier or rider or that they are a “super trigger.” For thin slabs, with the same spatial sampling, the chance is probably comparable or somewhat higher. Once fracture toughness is exceeded, it does not matter by how much. However, when buried persistent layers are deeper than about 1 m, instances of skier triggering become rare, while snowmobiles may still trigger avalanches readily. Human perception is also different: a person on skis or a board is directly connected to the snow to sense slab cohesiveness and snow texture whereas a snowmobiler is not. Due to faster travel over more terrain, snowmobilers should take into account that snowpack-sampling habits will be different from skiers and riders.

Section III: Action List for Backcountry Travel (Intermediate Level)

The ABCs of Backcountry Avalanche Actions Cycle through the ABCs at each stage of the trip and be prepared for alternatives at each stage. Through the time progression, the spatial scale decreases from large scale (synoptic) through meso-scale to micro-scale. The reasoning process progresses mostly from objective toward subjective (intuitive).

Actions

Before: Large scale
A (Terrain)  
↓
B (Snowpack)  
↓
C (Human)

Beginning: Intermediate scale
A (Terrain)  
↓
B (Snowpack)  
↓
C (Human)

During: Micro-scale
A (Terrain)  
↓
B (Snowpack)  
↓
C (Human)

Action list: Intermediate-level decision-makers. The list below is fairly comprehensive. Some items take seconds to complete, and the conditional nature of the suggestions means many will not be appropriate in some situations. The important concept is the ongoing review of the factors (A → B → C) and the structure. The idea is not to memorize the list but to be familiar with the concepts and structure. Avalanche forecasting and travel are both dynamic. Be prepared for a revision of plans as more information becomes available to influence perception. If a bulletin is not available, more information will have to be sought at the site. As risk increases, more potential action items appear.

Part I: Before the Trip (Large Spatial-Scale Analysis)

A. Terrain
1. Get and check a map with the largest scale (greatest detail) available. Check guidebooks and any photos available. For risk-based decisions, the best routes have alternatives.
2. Check any expert opinions or local experience for the area you are contemplating, including any current information or history. It is usually more informative to actually talk to a local forecaster than to read a posted bulletin.

B. Snow and Weather Conditions
1. Read and digest the Avalanche Bulletin. Concentrate mostly on the details of the bulletin, not one-word descriptors or colors. Note any critical aspects and elevations from the Bulletin.
2. Check the weather forecast and try to determine whether the avalanche danger is increasing or decreasing or whether there is not much
change expected. If large amounts of new snow are present or forecast, a good assumption is that there will be instability in the snow cover.

C. Human Factors

1. Discuss the objective as a group and appoint a leader. Concentrate on facts and weed out biases.
2. Conduct a group check. Check the targeted education, experience, skill level, and avalanche equipment of each group member (transceiver, probe, and shovel). Confirm that all members know how to use the equipment. Practice a transceiver search if one has not been done recently. Briefly review the principles of self-organized rescue if needed.

Part II: Beginning Stages (Intermediate Spatial-Scale Analysis)

A. Terrain

1. Concentrate on: (a) terrain features of the entire route, including slope convexity, gullies, terrain traps, and places where conditions may change rapidly in the terrain (e.g., combinations of terrain features) and (b) slope angles (the maximum to be traversed).
2. Be alert for exposed, steep slopes and their size and spatial extent on terrain that you are contemplating travel over (see Figure 8.4). Consider alternatives to avoid such places.
3. Review or update information (from the Avalanche Bulletin or local avalanche forecasters) on instability in terms of aspect, elevation band, and terrain features of your planned route.

B. Snow and Weather Conditions

1. Look for Class I information: avalanche occurrences, cracking of the snow cover, “whumphs,” and significant amounts of new snow or snow deposition by wind (the bull’s-eye information of Fredston and Fesler). Revise the synoptic-scale information of the Avalanche Bulletin to the site if necessary (Figures 8.12-8.15).
2. Be wary of persistent layers and their spatial patterns, including depth (depth < 1 m), which determines avalanche size. Use targeted sampling, extrapolate to the worst case, and be aware of thin spots. The presence of persistent layers along with slab structure is among the most important Class II information.

3. Try to determine if the danger is elevated or increasing to assess travel under avalanche paths and start zones. Look for wind drifting higher up and be alert for rising temperatures. If mountain weather stations are available, try to get information on the conditions at the top of the mountains. Wind loading under blue skies can be just as effective as storm loading in producing avalanches.

C. Human Factors

1. Check that all transceivers are operating and set on “transmit.” Don’t use ski safety straps and wrist loops on poles.

2. Discuss within the group whether the objective is still viable in light of the new information at the site and consider alternatives. Normally, if one group member brings forth factual information that supports rejection of the plan, an alternative should be sought or more relevant information should be gathered.

3. Ask directly whether everyone is comfortable with the plan. Many people remain silent until their opinions are directly sought.

Part III: During Travel (Micro-scale Analysis)

A. Terrain

1. Think about the whole route to be traveled and try to pinpoint potentially dangerous and/or steep micro-scale terrain features that could be avoided while still maintaining a pleasurable experience. Be cautious of places below ridge tops where the snowpack and terrain change rapidly (Figures 8.13 and 8.14 and Table 8.2).

2. Think about exposure from people on the slope above and to people below. Do not crowd people into positions with terrain traps and gullies.

3. Think about exposure above cliffs, drop-offs, and obstacles that may be struck, where even a small avalanche may be very serious.

4. Think about exposure of the party while traveling under avalanche terrain; not all accidents involve triggering by the victims. Think about the positions of rest stops.

B. Snowpack Factors

1. Be alert for Class I information found while traveling (e.g., “whumphs,” cracking) and report any such information to your group members quickly.

2. Be alert for changes in wind-deposition patterns and snowpack properties for the terrain you are traversing. If there are signs of instability at a location, it is likely that avalanches are possible nearby due to more contrast in slab and weak-layer hardness in wind-affected snow.

3. Think about consequences in relation to weak-layer depth, a major determiner of slab size. If the weak layer is deep (> 1 m), try to assess where thin spots might be.

4. Be alert for increasing instability by warming, wind, or snow loading.
C. Human Factors

1. Travel/ski with a designated partner, keep that person in sight, and be aware of the positions of other group members. Make sure you have a partner; don’t rely on the leader to organize this. Maintain communication, particularly if instability is sensed. A whistle is a very effective means of communication; the sound carries much better than the human voice.

2. Have generous spacing when traversing suspect slopes: one at a time. Keep to the same track as previous people if instability is evident.

3. Move between islands of safety if instability is suspected—one at a time (Figure 8.1)—and keep the moving skiers in sight.

4. If instability is expected, don’t stray widely out into the slope if possible. For example, if forest cover is available, stay within it or near the edge of the forest cover if warranted. Some people don’t have the skiing/riding skill to make tight turns down the fall line near the edge of forest cover so be aware of this.

Section IV: Basic Guidelines and Rule-Based Action System (Basic Level)

Basic-level decision-makers will have to follow rules in order to travel in avalanche terrain. In this case, the normal guidelines convert into unconditional rules and plans will have to be conservative.

It should be possible to conduct backcountry travel in almost any conditions but the restrictions multiply as risk increases. The snow-craft skills, such as slope tests (including targeted sampling), available to Intermediate and Advanced decision-makers may not be completely available to Basic decision-makers. Furthermore, assessment of complex issues may not be appropriate. These can include increasing the Danger Scale level in avalanche-starting zones due to loading or temperature increases, increasing the risk in runout zones, or accounting for multiple Danger Scale levels for different elevation bands (and aspects), such as alpine, tree line, and below tree line. Also, decisions about complex terrain features may not be manageable for Basic decision-makers.

The Basic system requires the following inputs and skills:

- Input: Danger Scale level
- Input: retaining instability information from the Avalanche Bulletin about aspect and elevation, particularly buried, persistent weak layers
- Skill: recognizing clearly observable Class I information: cracks, whumphs, and recent avalanches
- Skill: recognizing basic terrain, including estimating slope angles (within a range of about 5°; “Is it 30° or 35°?” is a typical question), appreciating terrain features (concave/convex, size, and exposure), locating lee zones where deposition is prevalent, and locating terrain traps
- Skill: recognizing established avalanche paths (see Figures 5.2 and 5.3 in Chapter 5)

At the Basic level, only two decision options are normally available: proceed or consider alternatives (including turning back). The important guidelines from Section II applicable for Basic-level decision-makers are listed below. If text appears along with the title, it is modified from Section II; otherwise the text from Section II can be read as is.

The travel suggestions, like the Reduction Method of Werner Munter (1999), are built on risk-reduction factors based mostly on avoidance. The reduction factors for the Basic system here are listed in Appendix A.

Guidelines for Conditioning Decisions for Basic-Level Decision-makers

1. Terrain management is essential. Important skills include estimating slope angles and appreciating potentially risky terrain features: concave/convex, large size, and exposure; locating lee zones where deposition is prevalent; and locating terrain traps.

2. Risk increases with slope angle (see Section II).

6. Minimize exposure under avalanche paths (see Section II).

8. Risk increases with the Danger Scale level.

9. Persistent forms call for extra caution. Pay close
attention to any information from the Avalanche Bulletin about unstable persistent layers and their aspects and elevations.

11. Assume that ample amounts of new snow will contain instabilities. If there is new or wind-affected snow (e.g., in lee zones) of about 30 cm, a good assumption is that instability is present. Normally, the best powder surfing is in new snow so it is important to determine if there is instability and if any instability found is significant. A more advanced decision-maker in the party (Intermediate or Advanced) can be very valuable in this regard.

13. Pay attention to classes of information and data. Look for Class I information. Class I factors can reveal definitive signs of instability, including avalanches, “whumphs,” and cracks. Any positive signs of instability from such factors must be given the utmost attention. You should not proceed into steep avalanche terrain when these sources of information suggest not to.

22. Group decisions with good risk communication are best. Don’t accept an argument that is not backed by facts and watch for biases in the positions presented. One good argument based on facts can negate all the others. Appoint a leader who is not too conservative, not an extreme risk taker, and with a good mix of targeted education and experience. When the Danger Scale is higher than Moderate, an Intermediate or Advanced decision-maker should be the leader. See the action list below.

24. Group management is essential.
27. Always have a transceiver, probe, and shovel.
28. Be aware of the extra energy delivered by snowmobiles and differences in perception.

Action List: Basic-Level Decision-makers

Part I: Before the Trip: Large Spatial-Scale Analysis

A. Terrain

1. Get and check a map with the largest scale (greatest detail) available. Check guidebooks and any photos available. For risk-based decisions, the best routes have alternatives.

2. Check any expert opinions or local experience for the area you are contemplating, including any current information or history. It is usually more informative to actually talk to a local forecaster than to read a posted bulletin.

B. Snow and Weather Conditions

1. Read and digest the Avalanche Bulletin. Concentrate mostly on the details of the bulletin, not one-word descriptors or colors. Note the details of the critical aspect, elevations, and the presence of persistent layers.

2. Check the weather forecast and try to determine whether the avalanche danger is increasing, decreasing, or whether there is not much change. If large amounts of new snow are present or forecast, a good assumption is that there will be instability in the snow cover. If large changes in temperature are expected, instability may be anticipated.

C. Human Factors

1. Discuss the objective as a group and appoint a leader. The leader should be an Intermediate or Advanced decision-maker if the Danger Scale is higher than Moderate. Concentrate on facts and weed out biases.

2. Conduct a group check. Check the targeted education, experience, skill level, and avalanche equipment of the group members (transceiver, probe, and shovel). Confirm that all members know how to use the equipment. Practice a transceiver search if one has not been done recently. Briefly review the principles of self-organized rescue if needed.

Part II: During the Trip: Rule/Action List (Basic Level)

Under the Danger Scale level Extreme, travel in avalanche terrain is not recommended (Figure 8.14). People normally travel within forest cover or gentle terrain not exposed to avalanches from above if they travel at
all. There will be a significant chance of natural avalanching and there may be a possibility of triggering avalanches from gentle terrain if unstable persistent layers are present.

The Danger Scale does not take into account variations in human perception and estimation. Convert the descriptors into some that do:

Converted Danger Scale
Level 1: Low → Low
Level 2: Moderate → Moderate
Level 3: Considerable → High
Level 4: High → Extreme
Level 5: Extreme → Travel not recommended in avalanche terrain

If the Converted Danger Scale is Low or Moderate, choose one of three options:
A. Travel/ski with and follow an Intermediate or Advanced decision-maker. It is expected that the Intermediate-level action list will be followed if an Intermediate decision-maker leads with Basic-level decision-makers participating in decisions.
B. If any Class I visible or audible signs of instability are evident at the site or along the way (cracking, recent avalanche occurrences, instability within large amounts of new or wind-affected snow, “whumphs”), adjust the Converted Danger Scale upward once more: Low, Moderate → Extreme. In this case, minimize use of slopes over 25° and follow the travel rules 1–4 of the list below for Extreme on such slopes.
C. Do not travel slopes over 35° and

For slopes over 30°:
1. Travel/ski with a designated partner, keep that person in sight, and be aware of the positions of other group members.
2. Have generous spacing: one at a time.
3.避 critical aspects and elevations mentioned in the Avalanche Bulletin, especially for persistent layers.

If the Converted Danger Scale is High, do all of the following:
A. Travel/ski with and follow an Intermediate or Advanced decision-maker.
B. Do not travel slopes over 35° and
C. For slopes over 30°:
1. Travel/ski with a designated partner, keep that person in sight and be aware of the positions of other group members.
2. Have generous spacing: one at a time.
3. Pay close attention to critical aspects and elevations mentioned in the Avalanche Bulletin, especially for persistent layers.

If the Converted Danger Scale is Extreme, do all of the following:
A. Travel/ski with and follow an Advanced decision-maker.
B. Do not travel slopes over 30° and
C. For slopes over 25°:
1. Travel/ski with a designated partner, keep that person in sight, and be aware of the positions of other group members.
2. Have generous spacing: one at a time.
3. Move between islands of safety—one at a time—and keep the moving skiers in sight.
4. Don’t stray widely out on the slope. If forest cover is available, stay within it or near the edge if forest cover is not passable. Some people don’t have the skiing/riding skill to make tight turns down the fall line near the edge of forest cover so be aware of this.
5. The Danger Scale suggests a significant chance of natural avalanches: minimize the time in runout zones of avalanche paths and travel one at a time through them.

Appendix A: Risk-Reduction Factors
(Basic Level)
The strategy in Section III is based on risk-reduction factors to reduce all components of the risk (chance, consequences, exposure, and human factors). Seven
ABOUT THE AUTHORS

David McClung heads the avalanche research group at the University of British Columbia and is Professor in the Departments of Geography and Civil Engineering. His early studies in geophysics with Professor Ed LaChapelle at the University of Washington led to thirty-five years of avalanche research and consulting in Canada, the United States, and Norway. McClung has published 150 papers on snow and avalanches. An active skier and mountaineer with expedition experience in the Himalaya, Karakoram, Pamirs, Andes, Mongolia, and Alaska, he lives in Vancouver, British Columbia.

Peter Schaerer’s Swiss and Canadian experience with avalanches spans more than fifty years. He spent most of his career as a senior research officer and head of the Avalanche Research Center of the National Research Council of Canada. Schaerer was instrumental in forming the Canadian Avalanche Association and in setting up professional avalanche training programs in western Canada. A Vancouver resident, he is active as an avalanche consultant and is an avid backcountry skier.

THE MOUNTAINEERS, founded in 1906, is a nonprofit outdoor activity and conservation club, whose mission is “to explore, study, preserve, and enjoy the natural beauty of the outdoors...” Based in Seattle, Washington, the club is now one of the largest such organizations in the United States, with seven branches throughout Washington State.

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David McClung and Peter Schaerer have distilled decades of experience studying avalanches into The Avalanche Handbook. In this fully revised edition, they present all the latest information, techniques, and research on understanding and surviving avalanches. The extensive text covers all the fundamental concepts, from the formation and control of avalanches to traveling safely and rescue methods. With more than 50 updated illustrations, photographs, and examples, this guide is an essential reference for backcountry travelers everywhere.

David McClung heads the avalanche research group at the University of British Columbia and is a professor in the Department of Geography. Peter Schaerer spent most of his career as a senior research officer and head of the Avalanche Research Center of the National Research Council of Canada.