Avalanche Observations

3.1 Introduction

Observations of past and present avalanche activity are of the utmost importance for any avalanche forecasting operation. These data should be recorded and organized in a manner that allows personnel to visualize temporal and spatial patterns in recent avalanche activity. Objectives for observing avalanches are presented in Section 3.2. A standard avalanche observation is presented in Section 3.4. The remainder of this chapter provides methods for observing a wide variety of avalanche related phenomena. Parameters are divided into avalanche path characteristics and avalanche event characteristics. Parameters in the standard avalanche observation are marked with a ✧ symbol. Individual operations can chose to observe and record parameters beyond those included in the standard observation. The parameters collected will depend on the type of operation and the snow climate of the forecast area.

3.2 Objectives

Observations and records of avalanche occurrences have the following applications:

- Information about avalanche occurrences and non-occurrences is used in association with other observations in evaluating snow stability.
- Observations identify areas where avalanches released earlier in the winter or storm/avalanche cycle. Snow stability may vary between these sites and nearby undisturbed slopes.
- Avalanche observation data are essential when protective works and facilities are planned, when the effectiveness of control measures is assessed, and when forecasting models are developed by correlating past weather and snow conditions with avalanche occurrences.
- Understanding the avalanche phenomenon through research.

All avalanches that are significant to an operation should be recorded. Noting the non-occurrence of avalanches is also important for snow stability evaluation and during hazard reduction missions.

3.3 Identification of Avalanche Paths

Avalanche paths should be identified by a key name, number, aspect, or a similar identifier which should be referred to on lists, maps, or photographs. For roads, railway lines and power lines it is convenient to refer to avalanche paths by the running mile or kilometer. Every effort should be made to retain historical names. Changing historical names creates confusing records and decreases the usefulness of past data records. Historical paths that have multiple starting zones can be reclassified with subcategories of the original name. Any reclassification should be clearly explained in the metadata (see Appendix C).

Avalanche paths with multiple starting zones are often divided into sub zones. Separate targets for explosive placement may be identified within each starting zone.

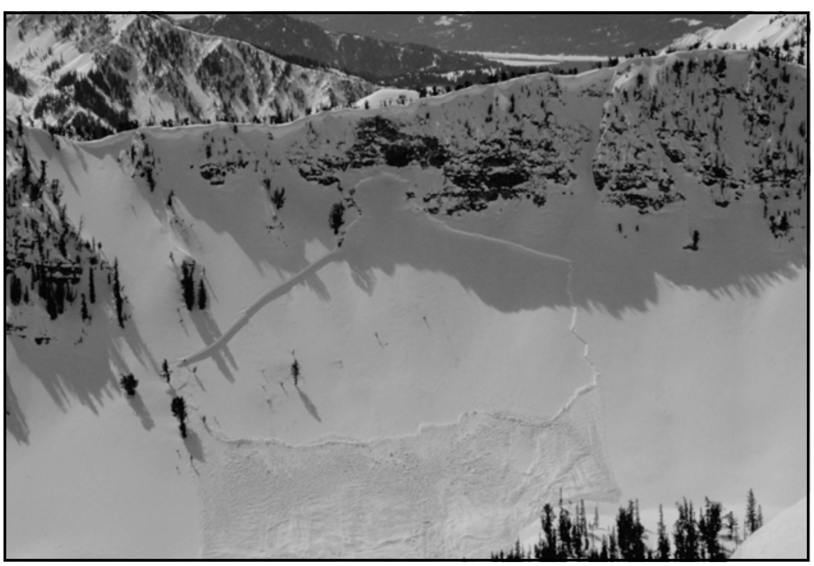

Figure 3.1 A slab avalanche (photograph by Jim Woodmencey).

3.4 Standard Avalanche Observation

This section outlines a standard avalanche observation for single avalanche events. Suggestions for summarizing multiple avalanche events are discussed in Section 3.7. Storm cycles and access to starting zones may make it difficult to observe every parameter for every avalanche that occurs within a forecast area. In this case the avalanche size characteristics should be estimated, and some of the snow specific parameters can be marked N/O for not observed.

The parameters have been separated into avalanche path characteristics and avalanche event characteristics. Operations that deal with a "fixed" number of paths documented in an avalanche atlas replace the path specific parameters with path name or number.

1) Date – record the date on which the avalanche occurred (YYYYMMDD).

2) Time – record the local time at which the avalanche occurred to the hour or minute if possible. Time codes of 2405 and 2417 can be used for avalanches that released at an unknown time during the AM and PM respectively. Time ranges or start and end times of control missions can also be used.

3) Observer – record the name or names of the personnel that made the observation.

4) Path Characteristics (Section 3.5)

- *a. Observation Location* – record the name or number of the path where the avalanche occurred, the latitude and longitude, or the nearest prominent topographic landmark (mountain, pass, drainage, etc.) or political landmark (town, road mile, etc.).
- *b. Aspect* – record the direction the slope faces where the avalanche occurred (i.e. N, NE, E, SE, S, SW, W, NW).
- *c. Slope Angle in Starting Zone* – record the **average** slope angle in the starting zone where the avalanche released. When possible, a number of locations in the starting zone should be measured so that a maximum, minimum, and average value can be reported.
- *d. Elevation* – record the elevation of the crown face in feet (meters).

5) Event Characteristics (Section 3.6)

- *a. Type* – record the avalanche type.
- *b. Trigger* – record the event that triggered the avalanche.
- *c. Size* – record the size of the avalanche.
- *d. Snow Properties*
    - *i. Bed Surface* – record the location of the bed surface as: In new snow, New/old interface, in Old snow, or Ground. If the site was visited, record the hand hardness, grain type, and grain size.
    - *ii.Weak Layer* – record the grain type and date of burial if known. If the site was visited record the hand hardness, grain type, and grain size.
    - *iii. Slab* – record the hand hardness, grain type, and grain size.
- *e. Dimensions*
    - *i. Slab Thickness* – record the **average** (and maximum) height of the crown face to the nearest 0.25 m (or whole foot).
    - *ii.Width* – record the width (horizontal distance) of the avalanche to the nearest 10 m (or 25 feet).
    - *iii. Vertical Fall* – record the vertical fall of the avalanche to the nearest 50 m (or 100 ft).
- *f. Location of Start Zone* – record the location of the crown face, as viewed from below, within the starting zone as top (T), middle (M), or bottom (B).
- g. *Terminus* – record the location of the debris within the avalanche path.

3.5 Avalanche Path Characteristics

3.5.1 Area and Path ✧

Enter the name of the operation or avalanche area where the avalanche path is located.

> *Note: It is not necessary to note the area in every entry of a field notebook if that book is not taken from area to area.*

Enter the identifier (name or number) of the avalanche path.

Some road operations may name their paths by the running mile or kilometer. In this case two decimal places may be used to identify paths within a whole mile or kilometer.

3.5.2 Aspect ✧

Use the eight points of compass to specify the avalanche's central aspect in the starting zone. Compass degrees or the sixteen major points (i.e. NNE, ENE, etc.) can be used to convey greater detail. A range in aspect can be specified for large or highly curved starting zones.

Table 3.1 Slope Aspect

Direction	N	NE	E	SE	S	SW	W	NW
Degrees	0	45	90	135	180	225	270	315

3.5.3 Slope Angle ✧

Record the average slope angle in the starting zone where the avalanche released. When possible, a number of locations in the starting zone should be measured so that a maximum, minimum and average value can be reported.

Figure 3.2 Measuring the slope angle of a slab avalanche (photograph by Bruce Tremper).

3.5.4 Elevation ✦

Record the elevation of the starting zone or crown face in feet (or meters) above sea level (ASL).

3.6 Avalanche Event Characteristics

3.6.1 Date ✦

Record year, month and day of the avalanche occurrence (avoid spaces, commas, etc.) i.e. December 15, 2001, is noted as 20011215 (YYYYMMDD).

3.6.2 Time ✦

Estimate the time of occurrence and record it by hour and minute in local standard time.

Record the time of occurrence on the 24-hour clock (avoid spaces, colons etc.) i.e. 5:10 p.m. is noted as 1710.

Use local standard time (i.e. Pacific, Mountain, etc.). Operations that overlap time zones should standardize to one time.

When the precise time of occurrence is unknown, use 2405 and 2417 for avalanches that released during the AM and PM respectively. Time ranges or start and end times of control missions can also be used.

3.6.3 Avalanche Type ✦

Record the type of avalanche as described in Table 3.2.

> *Note: A hard slab has an average density equal to or greater than 300 kg/m^3. Informal distinctions can be made between hard and soft slab avalanches based on the form of the deposit and the hand hardness of the slab. Hard slab avalanches generally have a slab hardness of one finger or greater. Debris piles from hard slab avalanches are typically composed of angular blocks of snows.*

Table 3.2 Avalanche Type

Data Code	Type
L	Loose-snow avalanche
WL	Wet loose-snow avalanche
SS	Soft slab avalanche
HS	Hard slab avalanche
WS	Wet slab avalanche
I	Ice fall or avalanche
SF	Slush flow
C	Cornice fall (w/o additional avalanche)
R	Roof avalanche
U	Unknown

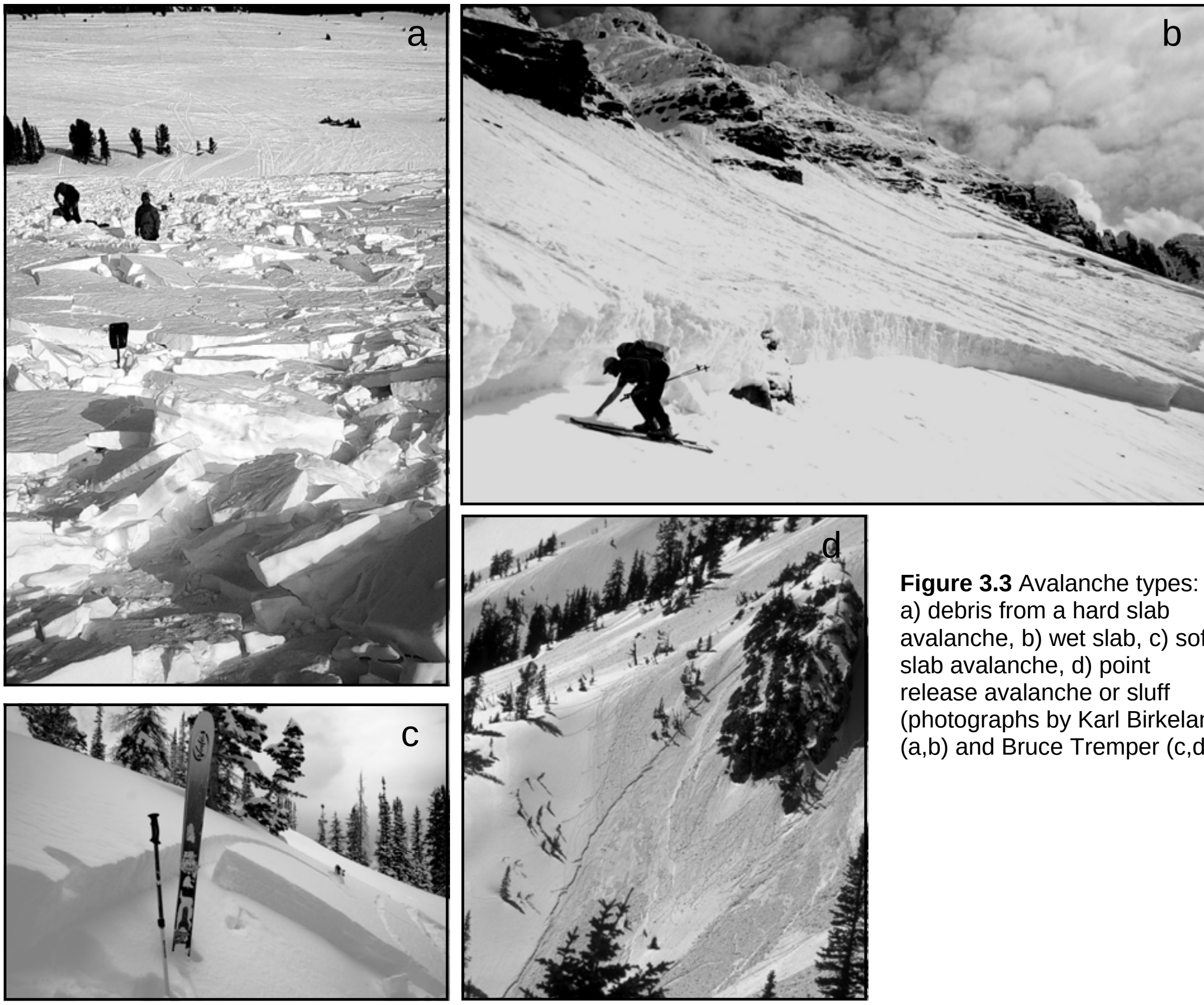

Figure 3.3 Avalanche types: a) debris from a hard slab avalanche, b) wet slab, c) soft slab avalanche, d) point release avalanche or sluff (photographs by Karl Birkeland (a,b) and Bruce Tremper (c,d))

3.6.4 Trigger ✧

Indicate the mechanism that caused avalanche release with a primary code, secondary code when possible, and modifier when appropriate. The secondary codes have been separated into two categories with separate modifiers for each. Operations may devise other trigger sub-classes that apply to their specific conditions in consultation with the American Avalanche Association. Guidelines for reporting avalanche involvements are listed in Appendix H. Examples of coding structure are given in Section 3.6.12.

Table 3.3 Avalanche Trigger Codes - Primary

Data Code	**Cause of Avalanche Release**
N	Natural or Spontaneous
A	Artificial
U	Unknown

Table 3.4 Avalanche Trigger Codes – Secondary-Natural and Explosive Releases

Data Code	**Cause of Avalanche Release**
Natural Triggers	
N	Natural trigger
NC	Cornice fall
NE	Earthquake
NI	Ice fall
NL	Avalanche triggered by loose snow avalanche
NS	Avalanche triggered by slab avalanche
NR	Rock fall
NO	Unclassified natural trigger (specify in comments)
Artificial Triggers: Explosive	
AA	Artillery
AE	An explosive thrown or placed on or under the snow surface by hand
AL	Avalauncher
AB	An explosive detonated above the snow surface (air blast)
AC	Cornice fall triggered by human or explosive action
AX	Gas exploder
AH	Explosives placed via helicopter
AP	Pre-placed, remotely detonated explosive charge
Artificial Triggers: Miscellaneous	
AW	Wildlife
AU	Unknown artificial trigger
AO	Unclassified artificial trigger (specify in comments)

Table 3.5 Avalanche Trigger Codes – Modifiers for Natural and Explosive Caused Releases

Data Code	**Cause of Avalanche Release**
r	A remote avalanche released by the indicated trigger
y	An avalanche released in sympathy with another avalanche

Note: For remote and sympathetic avalanches the distance between the trigger and the avalanche should be recorded in the comments.

Table 3.6 Avalanche Trigger Codes – Secondary-Human Triggered Avalanches

Data Code		Cause of Avalanche Release
Artificial Triggers: Vehicle		
	AM	Snowmobile
	AK	Snowcat
	AV	Vehicle (specify vehicle type in comments)
Artificial Triggers: Human		
	AS	Skier
	AR	Snowboarder
	AI	Snowshoer
	AF	Foot penetration
	AC	Cornice fall produced by human or explosive action
Artificial Triggers: Miscellaneous		
	AU	Unknown artificial trigger
	AO	Unclassified artificial trigger (specify in comments)

Table 3.7 Avalanche Trigger Codes – Modifiers for Human Triggered Avalanches

Data Code	Cause of Avalanche Release
c	A controlled or intentional release by the indicated trigger (i.e. slope cut, intentional cornice drop, etc.).
u	An unintentional release.
r	A remote avalanche released by the indicated trigger
y	An avalanche released in sympathy with another avalanche

Note: For remote and sympathetic avalanches the distance between the trigger and the avalanche should be recorded in the comments.

Avalanches that start when a helicopter or other aircraft flies overhead should be considered natural if the aircraft is a significant distance above the ground.

Avalanches triggered by helicopters when in "ground effect" should be considered artificially triggered. Ground effect can be observed when significant rotor wash (blowing snow) is noticed on the snow surface below the helicopter. Use your best judgment.

3.6.5 Size ✧

The two commonly used avalanche size classification schemes are: Relative to Path and Destructive Force. Both systems use a scale that varies from 1 to 5. These guidelines recommend observing and recording avalanche size in both systems. Using both systems will maintain long-term data sets and provide the most useful information to active forecasting programs. However, forecasting program managers should decide whether to use one or both schemes. Each system provides different and useful information, but the numerical categories of each scale are often not comparable.

3.6.5.1 Size – Destructive Force

Estimate the destructive potential of the avalanche from the mass of deposited snow, and assign a size number. Imagine that the objects on the following list (people, cars, trees) were located in the track or at the beginning of the runout zone and estimate the harm the avalanche would have caused.

Table 3.8 Avalanche Size – Destructive Force (after CAA, 2007; Perla, 1980)

Data Code	Avalanche Destructive Potential	Typical Mass	Typical Path Length
D1	Relatively harmless to people	<10 t	10 m
D2	Could bury, injure, or kill a person.	10^2 t	100 m
D3	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
D4	Could destroy a railway car, large truck, several buildings, or a substantial amount of forest.	10^4 t	2,000 m
D5	Could gouge the landscape. Largest snow avalanche known.	10^5 t	3,000 m

Note: The use of half-sizes may be used to signify an avalanche that is on the high end of a single class.

The destructive potential of avalanches is a function of their mass, speed and density as well as the length and cross-section of the avalanche path.

Typical impact pressures for each size number are given in McClung and Schaerer (1981).

The number "0" may be used to indicate no release of an avalanche following the application of mitigation measures.

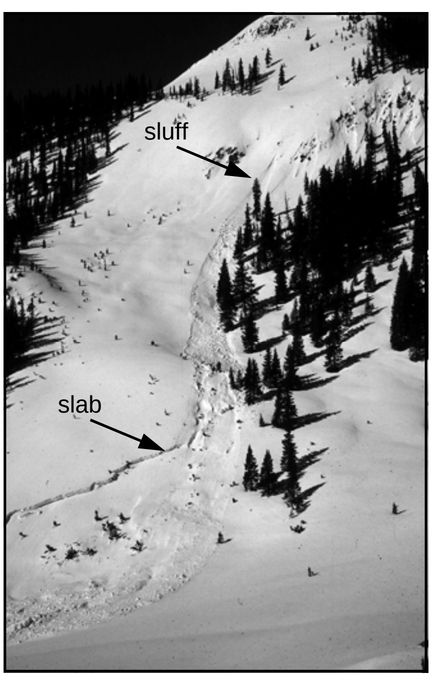

Figure 3.4 Slab avalanche triggered by a loose-snow avalanche (photograph by Andy Gleason).

3.6.5.2 Size – Relative to Path

The size—relative to path classification is a general measure and takes into account many factors, including the horizontal extent and vertical depth of the fracture, the volume and mass of the debris, and the runout distance of the avalanche. The observer estimates the size of the avalanche relative to the terrain feature or avalanche path where it occurred. A “small” avalanche is one that is relatively small compared to what that particular avalanche path could produce, while a “large” avalanche is, or is close to, the largest avalanche that the particular avalanche path could produce.

Table 3.9 Avalanche Size – Relative to Path

Data Code	Avalanche Size
R1	Very small, relative to the path.
R2	Small, relative to the path
R3	Medium, relative to the path
R4	Large, relative to the path
R5	Major or maximum, relative to the path

Note: Half-sizes should not be used for the size-relative to path scale.

The number “0” may be used to indicate no release of an avalanche following the application of mitigation measures.

The size classification pertains to both the horizontal extent and the vertical depth of the fracture, as well as the volume and runout distance of the avalanche.

3.6.6 Snow Properties

3.6.6.1 Bed Surface ✧

Level of Bed Surface

Record the level of the bed surface (the upper surface of the layer over which a slab slid) in the snowpack. If the avalanche involved more than one bed surface, all applicable codes should be included.

Table 3.10 Avalanche Bed Surface

Data Code	Bed Surface
S	The avalanche released within a layer of recent storm snow.
I	The avalanche released at the new snow/old snow interface.
O	The avalanche released within the old snow.
G	The avalanche released at the ground, glacial ice or firn.
U	Unknown

Note: Storm snow is defined here as all snow deposited during a recent storm.

Form and Age of Fracture Plane

Record the predominant grain form observed in the layer below the fracture plane using the *International Classification for Seasonal Snow on the Ground* (refer to Appendix F). Where possible identify the failure plane by its probable date of burial. Use the comments section to note the occurrence of a fracture that steps down to other layers.

3.6.6.2 Weak Layer ✧

Record the grain type using the *International Classification for Seasonal Snow on the Ground* (see Appendix F), grain size (mm), and hand hardness of the weak layer.

3.6.6.3 Slab ✧

Record the grain type using the *International Classification for Seasonal Snow on the Ground* (see Appendix F), grain size (mm), and hand hardness of the slab directly above the weak layer.

3.6.6.4 Liquid Water Content in Starting Zone and Deposit

Determine the liquid water content of the avalanche snow in the starting zone and deposit at the time of failure and deposition. The liquid water content can be different in the starting zone and deposit. Although these observations use the same data code, they can be recorded as two separate items to include more information.

Table 3.11 Liquid Water Content of Snow in Avalanche Starting Zone

Data Code	Liquid Water Content
D	Dry snow
M	Moist snow
W	Wet snow
U	Unknown

Note: See Table 2.4 for water content definitions.

3.6.7 Avalanche Dimensions

3.6.7.1 Slab Thickness ✧

If practical, estimate or measure the average and maximum thickness of the slab normal to the slope to the nearest 25 centimeters (or whole foot), the average thickness of the slab at the fracture line. Add "M" when thickness is actually measured. If only one value is reported it should be the **average** dimension.

3.6.7.2 Slab Width ✧

In a slab avalanche, record the width (horizontal distance) in meters (feet) of the slab between the flanks near the fracture line. Add "M" when width is actually measured**.**

3.6.7.3 Vertical Fall ✧

Using an altimeter or contour map, calculate the elevation difference in feet (meters) between the fracture line and the toe of the debris.

3.6.7.4 Length of Path Run

Some operations may wish to record the estimated distance an avalanche ran along a slope. Record the distance between the fracture line and the toe of the debris. Up to a distance of 300 m (~ 1000 ft) estimate the distance traveled to nearest 25 m (~ 100 ft). Beyond a distance of 300 m estimate the distance run to nearest 100 m (~ 300 ft).

Note: All dimensions are assumed to be estimates unless the values are followed with the letter M (measured).

Dimensions are assumed to be in meters. Measurements or estimates in feet should be indicated with a ' after the number (i.e. 3').

3.6.8 Location of Avalanche Start ✧

Position in Starting Zone

Describe the location of the avalanche fracture with one of the following code letters, physical features or elevation *and*, when applicable, add the data code for the starting sub-zone or the target.

Note: For this code gunner's left and right should be used. Gunner's perspective is looking up at the starting zone (opposite of skier's perspective).

Figure 3.5 An avalanche remotely triggered by a skier (SS-ASr-R2/D2-O) in the Wasatch Mountains, Utah (photograph by Bruce Tremper).

3.6.9 Terminus ✧

Describe the location of the tip of the avalanche deposit with a code letter.

Table 3.12 Location of Avalanche Start

Data Code	Vertical Location within Starting Zone from Gunner's Perspective
T (L, R, C)	At the top of the starting zone (left, right, or center)
M (L, R, C)	In the middle of the starting zone(left, right, or center)
B (L, R, C)	At the bottom of the starting zone (left, right, or center)
U	Unknown

Note: The codes TP, MP and BP are applicable for short paths where the starting zone, track and runout zone cannot be easily separated.

Table 3.13 Terminus of Avalanche Debris

Data Code	Terminus for long paths
SZ	The avalanche stopped in the starting zone.
TK	The avalanche stopped in the track
TR	The avalanche stopped at the top part of the runout zone
MR	The avalanche stopped in the middle part of the runout zone
BR	The avalanche stopped in the bottom part of the runout zone
U	Unknown

Data Code	Terminus for short paths
TP	The avalanche stopped near the top of the path
MP	The avalanche stopped near the middle part of the path
BP	The avalanche stopped near the bottom part of the path

Operations that have large avalanche paths with well-defined features may apply additional codes (See Table 3.14).

Table 3.14 Detailed Terminus Codes

Data Code	Terminus
1F	Stopped on top ¼ of the fan
2F	Stopped halfway down the fan
3F	Stopped ¾ of way down the fan

3.6.10 Total Deposit Dimensions

Record the average width and length of the deposited avalanche snow in meters (feet).

Record the average deposit depth in meters and tenths of a meter. Add an "M" after each value if measured by tape or probe.

3.6.11 Avalanche Runout

The angle between the horizontal and a line drawn from the highest portion of the crown face and the toe of the debris can be used as a relative measure of avalanche runout. This angle, known as the *alpha angle* (α), has been used by landslide investigators since the late 1800's and has been applied to avalanche studies to describe extreme (~100 year) events. Although in avalanche research α has generally been reserved for very large events, guide services, engineers, scientists, and forecasters may find the subcategories defined in Table 3.15 useful.

Table 3.15 Alpha Angle Subcategories

Data Code	Description
α_i	The measured alpha angle for any individual avalanche.
α_e	The alpha angle of an extreme event. The smallest alpha angle (furthest avalanche runout) observed in a specific avalanche path, determined by historical records, tree ring analysis, or direct observation.
α_{number}	A calculated value of the smallest alpha angle (furthest avalanche runout) in a specific avalanche path during a defined time period. Where the designated time period (return period) in years is listed in the subscript (α_{10}, α_{50}, α_{100}).

Statistical studies suggest that alpha angles in a specific mountain range can cluster around a characteristic value. This value may be governed by terrain and snowpack conditions characteristic of the range (McClung and Schaerer, 2006; Mears, 1992; McClung and others, 1989; Lied and Bakkehøi, 1980).

3.6.12 Coding Avalanche Observations

Avalanche observations can be recorded in tabular format with a separate column for each data code. Common data codes can also be recorded in one string.

Example:

HS-AA-R2-D2: a hard slab avalanche triggered artificially by artillery
SS-AE-R4-D3: a soft slab avalanche triggered artificially by a hand charge
L-N-R1-D1: a small loose snow avalanche triggered by a natural event
HS-ASr-R3-D3-O: a hard slab avalanche triggered remotely by a skier and broke into old snow layers (see Section 3.6.4)
HS-ACu-R4-D3: a hard slab avalanche triggered by an unintentional artificial cornice fall
HS-ACc-R2-D3: a hard slab avalanche triggered by an intentional artificial cornice fall
HS-AC-R2-D3: a hard slab avalanche triggered by a cornice drop produced by explosives
WS-NS-R4-D3: a wet slab triggered by a natural slab avalanche.
AC-0: An intentionally triggered cornice that did not produce an avalanche.

3.6.13 Comments

Enter information about damage and accidents caused by the avalanche and any other significant information. Note when the avalanche was triggered artificially. Use as much space as required.

Table 3.15 Multiple Avalanche Events – Recording Example

Parameter	Criteria	Examples
Date or date range	Record beginning of cycle and end of cycle when possible.	20010212 or 20010212 – 20010214
Time range	Digits	0000 – 1000
Area (location)	Text (80 characters max.)	Mt. Timpanogos
Size	Attempt to limit the size range to 2 classes. Significant or very large avalanches should be recorded as individual events.	D1.5 – D2.0 R2 -R3
Trigger	Data code (do not mix natural and artificial triggers in this report)	AE, U
Type	Data code (group slab and loose avalanches separately)	HS, SS, U or WL, U
Aspect (of starting zone)	A single, range, or a combination of compass directions.	All, W, SW – NW
Elevation (at fracture)	Group events by elevation range. Use separate reports for significant elevation ranges as applicable to forecast area.	5,000 – 6,500 and 8,000 –10,000 ft
Slope Angle (at fracture)	Record range in average starting zone angle and max and min	32–42, 30, 45
Level of bed surface	Key letter (do not mix storm snow, old snow, and ground)	S, O, G, or U
Hardness of bed surface	Hand hardness scale	1F
Weak layer grain form	Grain form abbreviation (Fierz et al., 2009)	SH
Hardness of weak layer	Hand hardness scale	4F
Age of failure plane	Probable date of burial	20011204
Slab width	Range (in meters)	60 – 110 m
Slab thickness	Range (in centimeters)	10 – 30 cm
Hardness of slab	Hand hardness scale	P
Vertical Fall	Range (in meters)	500 – 1500 m
Comments	Max. of 5 lines by 80 characters per line	

3.7 Multiple Avalanche Events

An operation may wish to group large numbers of similar avalanche events (avalanche cycle) into one record or report, especially if that information is to be sent to a central information exchange. Grouping is achieved by allowing certain fields to hold a range of values (i.e. by specifying lower and upper bounds, separated by a dash). The report should be repeated for different types of activity (i.e. natural versus artificially released avalanches).

Note: Significant avalanches (larger than size D3 or R3), and events involving incident, damage or injury should be described individually.

3.8 Additional Observations

Additional observations may be selected as applicable from those listed in this section. Certain additional observations are valuable in areas where avalanches are either controlled or affect traffic and/ or communication lines.

3.8.1 Avalanche Hazard Mitigation Missions

3.8.1.1 Number of Explosive Charges / Number of Detonations

Record the number of projectiles or explosive charges applied to a target.

Record the number of confirmed detonations.

> *Note: The difference in the two values gives a dud count.*

3.8.1.2 Size of Explosive Charge

Note the mass (kg) of the explosive charge used at each shot location.

3.8.2 Road and Railway Operations

3.8.2.1 Deposit on Road or Railway

Record in meters (feet) the length of road, railway line, ski run, power line, or other facility buried in avalanche snow.

Record average depth at center line and maximum depth of avalanche snow on the road, etc., in meters and tenths of a meter (feet/inches). Add “M” when length and depth are measured.

3.8.2.2 Distance to Toe of Deposited Mass

Measure or estimate the distance between the uphill edge of the road, or other development, and the farthest point reached by the mass of avalanche. Negative values are used when the deposited mass failed to reach the road or facility.

> *Note: Some operations may also wish to document the occurrence of snow dust on the road. Dust results from the fallout of an avalanche’s powder cloud. Its main impact is on driver visibility.*

3.8.2.3 Road / Line Status

Transportation operations should record the status (open or closed) and danger rating (Appendix G) in effect for any roads or railway lines at the time when the avalanche occurred. During closures due to control missions or avalanche activity, the start and end time of the closure should be recorded.

Figure 3.6 An avalanche triggered by glide of the snowpack (photograph by Bruce Tremper).