New Zealand Guidelines and Recordings Standards for Weather, Snowpack and Avalanche Observations

Fourth edition, revised 2017

OUTDOOR SAFETY
NEW ZEALAND MOUNTAIN SAFETY COUNCIL
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SAFER PLACES, SAFER ACTIVITIES, SAFER PEOPLE

ABOUT THE NEW ZEALAND MOUNTAIN SAFETY COUNCIL

MSC is a national organisation who has been working for more than 50 years with a mandate to encourage safe participation in land-based outdoor activities. We do this through the development and promotion of safety messaging, by identifying and responding to insights provided by the ongoing collection and analysis of data, and by building partnerships with relevant organisations.

The MSC Mandate:

Our Vision – Safer places, safer activities, safer people.

Our Mission – Enabling people to enjoy their outdoor recreation safely.

Our values:

- Professionalism: We will collaborate with the rest of the sector and share what we know.
- Integrity: We will be open and honest in everything we do.
- Trust: We will be the organisation people look to for how to get prepared and stay safe outdoors.

For more information about the MSC please visit mountainsafety.org.nz/about-us

The Council gratefully acknowledges the ongoing support of:

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New Zealand Guidelines and Recording Standards for Weather, Snowpack and Avalanche Observations

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NEW ZEALAND GUIDELINES AND RECORDING STANDARDS FOR WEATHER, SNOWPACK AND AVALANCHE OBSERVATIONS

2017 Edition

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PREFACE

Having regularly updated information about the weather, snowpack condition and avalanche occurrences is essential for decision making regarding avalanche safety in mountain operations. This includes but is not limited to ski areas, ski touring, heli-ski guiding as well as road works. In the long term data is required for the development of avalanche forecasting techniques, hazard studies and for control programmes. As such, standardised methods of observation and terminology assist in the exchange of information and are essential to enable the development of information storage and retrieval systems.

The "*New Zealand Guidelines and Recording Standards for Weather, Snowpack, and Avalanche Observations*" are based on techniques originally developed by the avalanche research and forecasting programme at Rogers Pass, Canada. These techniques have been standardised and adopted by snow and avalanche operations in Canada for over two decades. Observation techniques are taught at avalanche courses originally organised by the National Research Council of Canada, the British Columbia Institute of Technology, and more recently by the Canadian Avalanche Association. In 1980, Peter Schaerer P. Eng., in consultation with senior field personnel from avalanche safety operations in Western Canada, revised the course material and compiled it to form the Canadian Guidelines for Weather, Snowpack and Avalanche Observations, subsequently published and revised by the NRCC's Associate Committee on Geotechnical Research. The most recent edition was published in December, 2007.

In 1986, the New Zealand Mountain Safety Council (MSC) organised a seminar at Craigieburn Forest Park for snow industry and safety personnel to discuss avalanche training. The first New Zealand 'Guidelines for Weather, Snowpack and Avalanche Observations' were produced following that seminar, based on the early Canadian document. A further seminar of avalanche professionals was held at Porter Heights in June 1992 and resulted in the 1993 revision of "*Guidelines for Weather, Snowpack and Avalanche Observations.*"

In 1999 the 'Snow And Avalanche Committee' of the New Zealand Mountain Safety Council called for submissions on the 'guidelines' and convened a working group of representatives from a broad range of industry sectors and educational institutions to review the 1993 edition. The Committee unanimously recommended the adoption of the 1998 Canadian guidelines, with minor amendments and adoption of an additional field test.

In 2002, a second working group comprised of ski area workers, heli-ski and ski touring guides, as well as educators from various universities and polytechnics throughout New Zealand reviewed the 2000 Edition. It was decided that an update of the guidelines was appropriate with a New Zealand based perspective as the next evolution of the *"New Zealand Guidelines and Recording Standards for Weather, Snowpack and Avalanche Observations."*

The MSC recognises that data observed and recorded in a standard format can assist research and enhance avalanche safety. This edition is the result of an ongoing commitment by MSC and the snow and avalanche community.

Both the MSC and the Snow and Avalanche Committee recommend that these revised guidelines be adopted as standard procedure by all groups carrying out avalanche observations and hazard evaluations.

The 'guidelines' are also recommended as the basis for professional avalanche training courses in New Zealand, such as those organised by tertiary Institutes. The MSC will continue to provide these guidelines to the sector and will conduct reviews of the publication on an as needed basis.

This edition is recommended for operational use in New Zealand from the beginning of the 2017 winter.

ACKNOWLEDGMENTS

Historically, the Canadian Avalanche Association (CAA) gave permission for MSC to use and adapt the 1998 edition of the Canadian 'Guidelines'. The MSC has continued to maintain a relationship with the CAA and with subsequent updates of the *Canadian Guidelines* taking place the MSC has used the revised versions to influence the New Zealand Guidelines. The MSC wishes to acknowledge and thank the CAA for their co-operation and willingness to share their standards and guidelines. The MSC wishes to thank Peter Schaerer P. Eng., for his early efforts in Canada and New Zealand in advancing the cause of avalanche education and for producing the original guidelines.

The MSC wishes to thank the following individuals for their support and input in creating this 2017 revised edition. Jamie Robertson, Kevin Boekholt, Nicholas Cullen, Don Bogie, John Hooker, Ryan Leong, Andy Hoyle and Peter Bilous.

1.0 SNOW AND WEATHER OBSERVATIONS

1.1 OBJECTIVES

Snow and weather observations represent a series of meteorological and snow surface measurements taken at a properly instrumented study plot (refer to Appendix A - Observation Sites). Observational data taken at regular intervals provides the basis for recognising changes in the stability of the snow cover and the state of the weather.

In the short term, the sharing of safety information is of a great benefit to operations and the sector as a whole, by improving awareness of conditions across the region and enhancing the ability to manage operational avalanche risks. For industry, the documenting and sharing of safety information also satisfies many Department of Labour requirements.

In the long-term, the observations can be used to improve the ability to forecast the avalanche danger by statistical and numerical techniques and to increase knowledge of the weather patterns as they relate to avalanche formation and their impact on people and property. The observations should be made regularly, be complete, accurate and recorded in a uniform manner.

1.2 TYPES OF OBSERVATIONS

1.2.1 Standard Observation

An observation made at a regular daily time is referred to as a *standard observation*. Preferably it should be carried out between 0400 and 1000 hours, but the type of operation and availability of observers might require a different time. Note that the New Zealand standard time for daily climatological observations is 0900 hours. Recording instruments are reset only when taking a 'standard' observation.

1.2.2 Interval Observations

Observations other than the standard observations are referred to as *interval observations*. Interval observations should be carried out when the snow stability is changing rapidly, e.g. on days with heavy snowfall. Interval observations may contain a few selected observations or a complete set of observations.

1.2.3 Intermittent Observations

Observations taken at irregular times are referred to as *intermittent observations*. They are appropriate for sites that are only visited on an infrequent basis; visits will typically be more than 24 hours apart and need not be regular (e.g. in a heli ski operation). Intermittent observations may contain only a few selected observations or a complete set of observations.

1.3 EQUIPMENT

A study plot usually contains the following equipment:

- Stevenson Screen for housing thermometers (height adjustable)
- Maximum thermometer
- Minimum/present thermometer
- Three snow boards (about 40 cm x 40 cm) designated as the 24-hour board, a storm board and an interval board
- Snow stake, a snow depth marker, (graduated in cm) and levelling stick

- Ruler (graduated in cm)
- Snow density cutter and weigh scale (graduated in grams (g)), or precipitation gauge
- Knife or plate for cutting snow samples
- Field-book (water resistant paper)
- Loupe and crystal screen
- Compass

The following additional equipment is useful:

- Hygrothermograph located in a Stevenson screen
- Recording precipitation gauge or rain gauge
- One to three additional snow boards
- Barograph (in the office) or barometer/altimeter
- Anemometer at a separate wind station with radio or cable link to a recording instrument
- Box (shelter) for the equipment
- Small broom
- Snow shovel
- Snow thermometer

1.4 PROCEDURE

Record the location and elevation of the study plot at the top of the field book page, or on the title page. Record the observer's name or initials. Carry out and record the observations in the sequence listed below. <u>Wear gloves when touching the instruments.</u>

1.4.1 Date

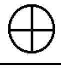
Record the year, month and date (avoid spaces, commas etc.). e.g., August 1, 2017, is noted as 02 Aug 17.

1.4.2 Time and Type

Record the time of observation on the 24-hour scale (avoid spaces, colons etc.). e.g. 9AM is noted as 0900. Standard (S), Interval (I), Intermittent (I).

1.4.3 Sky Condition

Classify the amount of cloud-cover and record it with one of the symbols below.

Class	**Field Symbol**	**Data Code**	**Definition**
Clear		CLR	No Clouds
Few		FEW	Few clouds: up to 2/8 of the sky is covered with clouds
Scattered		SCT	Partially cloudy: 3/8 to 4/8 of the sky is covered with clouds
Broken		BKN	Cloudy: more than half but not all of the sky is covered with clouds (more than 4/8 but less than 8/8 cover)
Overcast		OVC	Overcast: the sky is completely covered (8/8 cover)
Obscured		X	A surface based layer (e.g. fog) or a non-cloud layer (e.g. heavy snowfall) prevents observer from seeing cloud cover.

Valley Fog/Cloud

Where low level cloud, valley fog or inversion cloud exists, estimate the elevation of the bottom and top of the fog layer in metres (m) above sea level. Record VF in comments with bottom and top elevations separated by a hyphen. Give the elevation to the nearest 50 m.

For example: clear sky with valley fog between 1050m and 1200m is coded as CLR VF 1050-1200.

Thin Cloud

The amount of cloud, not the opacity is the primary classification criterion. Thin cloud has minimal opacity such that the disk of the sun would still be clearly visible through the clouds if they were between the observer and the sun, and shadows would still be cast on the ground. When the sky condition features a thin *scattered, broken* or *overcast* cloud layer then precede the symbol with the letter 'T', e.g. *a sky completely covered with thin clouds is recorded as* **T⊕** *and coded as* **T OVC**.

1.4.4 Precipitation Type and Intensity

Note the type and rate of precipitation at the time of observation. Snowfall is recorded in centimetres (cm) of snow accumulation per hour. Rainfall rate is observed in millimetres (mm) of rain per hour.

Precipitation Type:

Symbol & Data Code	**Description**
NIL	No Precipitation
R	Rain
S	Snow
RS	Mixed Rain and Snow
G	Graupel and Hail
ZR	Freezing Rain

Precipitation Rate (specify for rain and snow only):

Symbol & Data Code	**Description**
Snowfall intensity (this system is open ended; any appropriate rate may be specified)	
S -1	Snow accumulates at a rate of less than 1 cm per hour
S1	Snow accumulates at a rate of about 1 cm per hour
S2	Snow accumulates at a rate of about 2 cm per hour
S3	Snow accumulates at a rate of about 3 cm per hour
S10	Snow accumulates at a rate of about 10 cm per hour
Rainfall intensity	
RV	Very light rain; would not wet or cover a surface regardless of duration
RL	Light rain; accumulation of up to 2.5 mm of water per hour
RM	Moderate rain; accumulation of 2.6 to 7.5 mm of water per hour
RH	Heavy rain; accumulation of more than 7.5 mm of water per hour

1.4.5 Air Temperature

Refer to Appendix A for detailed procedures on the use of thermometers, thermographs and hygrographs.

Immediately after opening the Stevenson screen read the maximum thermometer.

Secondly, read the present air temperature (dry bulb) from the minimum thermometer.

Thirdly, read the minimum temperature from the minimum thermometer.

> *Note: Read all air temperatures to the nearest 0.5°C (analogue; 0.1^{0}C for digital). Avoid breathing on the instruments.*

Read the air temperature from the thermograph and record to the nearest 1.0°C. Use an arrow symbol to record the temperature trend shown on the thermograph trace over the preceding **three** hours.

Symbol	Data Code	Description
↑	RR	Temperature rising rapidly (> 5 degree increase in past 3 hours)
↗	R	Temperature rising slowly (1 to 5 degree increase in past 3 hours)
→	S	Temperature steady (< 1 degree change in past 3 hours)
↘	F	Temperature falling slowly (1 to 5 degree decrease in past 3 hours)
↓	FR	Temperature falling rapidly (> 5 degree decrease in past 3 hours)

At the end of the temperature observation:

- Remove any snow that might have drifted into or accumulated on top of the screen.
- Reset the thermometers after the standard observations so that all thermometers are reading the present temperature (refer to Appendix A).
- If the Stevenson Screen is fitted with a height adjustment mechanism ensure that the screen base is in the range of 1.2 to 1.4 m above the snow surface.
- Check that the screen door still faces south if any adjustments are made.

1.4.6 Relative Humidity (RH)

Read the relative humidity to the nearest five percent (5%) from the hygrograph.

> *Note: Hygrographs are inaccurate at low temperatures. Furthermore, the accuracy of any mechanical hygrograph is unlikely to be better than five percent (5%) but trends may be important especially at high RH values. Refer to Appendix A for information on instrument calibration.*

Humidity measurements are more relevant from mid-slope or upper-elevation sites than from valley-bottom sites.

1.4.7 Snow Temperatures

Snow surface temperatures (T0): *Measure snow surface temperature by placing the thermometer on the snow surface. Shade the thermometer.*

10cm snow temperature (T10): Insert the thermometer horizontally 10 cm below the snow surface and allow it to come to equilibrium with the snow. *Shade the snow surface above the thermometer.*

Allow thermometers to come to equilibrium and then read while the bulb or thermistor is still in the snow. Observe to the nearest fraction of a degree based on the accuracy of the instrument.

> *Note: Digital thermometers are preferred as most display in increments of 0.1°C.*

1.4.8 Depth of Snowfall

Use a ruler graduated in cm to measure the depth of snow, at several spots, on boards that have been placed on the snow surface. Average the measurements and record to the nearest centimetre. Record "0.1" when the depth is less than 0.5 cm. *Record "W" when wind has affected the boards.* Do not consider surface hoar on the boards as snowfall; clear it off after every observation.

Clear the snow board after sampling the weight of new snow. Deposit snow in the depression left by the snow board then re-position the board so it is level with the surrounding snow surface.

> *Note: The snowfall should be measured on at least two snow boards, the "24 hour" or "HN24"; the "storm" or "HST" board. Additional snow boards (i.e. interval, twice a day, or shoot) may be used as required by the operation.*

Board naming conventions

24 Hour (HN24): The HN24 board is used to measure the accumulated snow (and snow density should there be 4cm or more deposited) over a 24-hour period. It is cleared at the end of the morning standard observation.

Twice a day (H2D): An H2D board is used to measure the depth of snow that has accumulated since the last standard observation. The H2D board is cleared at the end of each standard observation. *(If readings are limited to one standard observation the H2D board is not used).*

Storm (HST): Storm snowfall is the depth of snow that has accumulated since the beginning of a storm. The storm board is cleared at the end of a standard observation prior to the next storm and after useful settlement observations have been obtained. The symbol "C" is appended to the recorded data when the storm board is cleared.

Interval (HIN): An interval board is used to measure the accumulated snow in periods shorter than the time between standard observations. The interval board is cleared at the end of every observation.

Intermittent (HIT): Snow boards may be used at sites that are visited on an occasional basis. Snow that accumulates on the board may result from more than one storm. The intermittent snow board is cleared at the end of each observation.

Shoot Board (HSB): The shoot board holds the snow accumulated since the last time avalanches were controlled by explosives. The symbol 'C' is appended to the recorded data when the shoot board is cleared.

1.4.9 Total Depth of Snowpack (HS)

Observe the total depth of the snow cover on the ground by reading the calibrated, permanent stake to the closest centimetre. If necessary, level settling cones, wells, drifts, etc. around the stake.

> *Note: Snow board and HS values are always measured vertically (i.e., line of plumb).*

1.4.10 Mass of New Snow

Determine the mass of new snow when the depth is 4cm or greater. Take a sample from the same snow board from which the depth measurement is known. With a sampling tube cut a sample of snow vertically from the snow board and weigh it. Record the mass of snow in grams (g).

Take a sample from the interval (HIN) board for interval observations.

> *Note: Similar measurements can be taken from other boards.*

Make a note of the cross-section area of the sampling tube (cm^2) at the top of the page or on the title page of the field book.

> *Note: The cross-section area of a circular sampling tube in cm^2 is given by:*

$$A = \pi \times r^2$$

Where A is the cross-section area (cm^2);
π is 3.14;
r is cross-section radius (cm) = inside diameter x 0.5.

e.g. a tube with inside diameter of 50mm (5 cm) has a radius of 2.5 cm and
Cross-section area = $3.14 \times 2.5^2 = 3.14 \times 6.25 = 19.6$ cm^2

1.4.11 Water Equivalent of New Snow (HN24W or HINW)

Calculate the water equivalent of the new snow as follows:

Divide the mass of new snow by the cross-section area of the sampling tube and multiply by 10. Record the water equivalent to the tenth of a millimetre.

$$\textbf{HN24W } (\boldsymbol{mm}) = \frac{\textbf{Mass of new snow } (\boldsymbol{g})}{\textbf{Cross-section area of sampling tube } (\boldsymbol{cm^2})} \times \textbf{10}$$

> *Note: The water equivalent is the depth of the layer of water that would form if the snow on the board melted. It is equivalent to the amount of precipitation.*
>
> *The water equivalent of the new snow can be obtained either by melting a sample of snow and measuring the amount of melt water (e.g., with the aid of a rain gauge) or by weighing a snow sample. Weighing is commonly applied for avalanche operations because of its ease. The simplicity of conversion is an additional advantage as 1 cm^3 of water weighs 1 g.*

Snow depth must be recorded in centimetres (cm) but water equivalent of snow, as well as rainfall must be recorded in millimetres (mm)

1.4.12 Density of New Snow (ρ)

Density is a measure of *mass* per unit v*olume*; density must be expressed in SI units of kg/m$^{3.}$
The Greek symbol rho (ρ) is used to represent density.

Calculate the density as follows: divide the mass (g) of new snow by the sample volume (cm^3) and multiply by 1000 to express the result in kilograms per cubic metre***(kg/m³)***. Record as a whole number.

$$\rho\ (kg/m^3) = \frac{\textbf{Mass of new snow (g)}}{\textbf{Sample Volume}(cm^3)} \times 1000$$

Where:
sample volume =*Area of sample tube* (cm^2) *X Height of new snow (cm)*

Alternatively, if the water equivalent of a snow sample is available, density can be computed as follows:

Divide the water equivalent of the snow on the snow board by the snow height from that board and multiply by 100. Record as a whole number.

$$\rho\ (kg/m^3) = \frac{\textbf{HN24W Water equivalent of snow sample (mm)}}{\textbf{HN24 Height of snow sample (cm)}} \times 100$$

For measurements from standard observations:

$$\rho\ (kg/m^3) = \textbf{H2DW(mm)/H2D(cm) x100}$$

1.4.13 Rain

Measure the amount of rain that has accumulated in the rain gauge to the nearest millimetre. Empty the gauge at each standard observation.

> Note: *A manual rain gauge should be placed on the ground or on the snow surface when rainfall is likely to occur. It is unfortunate that in New Zealand snow is often mixed with rain in these instruments. Further, there is a need to monitor total accumulation as in many regions significant rainfall may require the gauge to be emptied as part of interval or intermittent observations. Records should be noted when these adjustments are required.*

1.4.14 Precipitation

Record the amount of precipitation accumulated in the precipitation gauge to the nearest millimetre.

> Note: *Precipitation gauges collect snowfall, rainfall and other forms of precipitation and continuously record their water equivalent.*

1.4.15 Surface Penetrability (P)

An indication of the snowpack's ability to support a given load and a relative measure of snow available for wind transport can be gained by the following tests.

Foot Penetration (PF)
Step into undisturbed snow and gently put full body weight on one foot. Measure the depth of the footprint to the nearest centimetre from 0 to 5 cm and thereafter, to the nearest increment of five (5) centimetres.

> *Note: Footprint depth varies between observers. It is recommended that all observers working on the same programme compare their foot penetration. Observers who consistently produce penetrations more than 10 cm above or below the average should not record foot penetrations.*

Ski/Snowboard Penetration (PS)
Step into undisturbed snow and gently put full body weight on one ski/snowboard. Measure the depth of the ski track to the nearest centimetre. *Note: Ski penetration is sensitive to the weight of the observer and the surface area of the ski.*

Ram Penetration (PR)
Let the first section of a standard ram penetrometer (cone diameter 40 mm, apex angle 60° and mass 1 kg) penetrate the snow slowly under its own weight by holding it vertically with the tip touching the snow surface and dropping it. Read the depth of penetration in cm.

1.4.16 Form and Size of Surface Snow
Record the form and size in millimetres of snow grains at the surface using the *International classification for Season Snow on the Ground*, (Fierz and others, 2009) basic classification (Appendix E).

Experienced observers may employ the "Crust" subclasses (Table 1.2) to discriminate between various types of surface deposits and crusts. (refer to Appendix E for more detailed information about the grain forms).

1.4.17 Wind
Observe and record the wind direction and speed in the vicinity of the observation plot.

Distinguish between *estimates* and *measurements* of wind. Measurements are made with an instrument located at a fixed point. Estimates are made without instruments but typically represent wind in a local area rather than at a point.

Wind observations (speed and direction) should be averaged over a two-minute period prior to the observation.

Wind Speed

Measured Wind Speed
The standard for observing and coding wind speed is km/hr.

> *Note: The SI unit for wind speed is metres/second (m/s). Refer to Appendix A of McClung and Schaerer (2006) for a discussion of SI units.*

Estimate the wind speed by observing the motion of trees, flags and snow.

Equivalent Measured Wind Speed			
Class	**Data Code**	**(km/h)**	**Typical indicator**
Calm	C	0	No air motion. Smoke rises vertically.
Light	L	1-20	Wind felt on face. Flags and twigs in motion
Moderate	M	21-40	Loose clothing starts to flap flags stretched. Loose snow begins to drift.
Strong	S	41-60	Wind stings face if temperature is below 1°C. Effort required to stand upright. Loose parkas inflate and pull against body.
Gale	G	61-90	Head pushed back when facing into wind. Progress markedly impeded. Loose parkas inflate and pull strongly.
Extreme	E	> 90	Impossible to stand without support. Structures may be damaged.

Note: The indicators used to estimate the wind speed are established by rule of thumb. Observers should develop their own relationships specific to their area.

Do not record a direction when the wind speed is zero (calm).

Note the occurrence of severe gusts in the comments section.

Wind Direction

Measured Wind Direction
Meteorological standards require that measured wind direction data from all sites including automatic stations be rounded to the nearest 10 degrees, e.g.: 184 degrees (just beyond South) is coded as 180; 45 degrees (North East) is coded as 050.

Estimated Wind Direction
Note the direction from which the wind blows at the site with respect to the eight points of the compass.

If the wind direction is erratic, record as Variable (VAR)

<u>Do not record a direction when the wind speed is 0 km/h or calm.</u>

1.4.18 Blowing Snow

Estimate the extent of transport and note the direction from which the snow is blowing to the closest cardinal point of the compass from which the snow is blowing.

Extent of snow transport			
Class	**Symbol and Data Code**	**Description**	**Typical Threshold Wind Speed**
Nil	Nil	No snow transport observed.	Calm
Previous	Prev	Snow transport has occurred since the last observation but there is no blowing snow activity at the time of observation	N/A
Light	L	Limited and localised blowing snow; snow is transported in rolling and saltation modes.	Light – Moderate
Moderate	M	Windward erosion and leeward deposition of blowing snow; snow is transported in saltation and turbulent suspension modes; visibility becomes obscured.	Strong – Gale
Intense	I	Widespread scouring; extensive downwind transport of snow in turbulent suspension mode; highly variable deposition.	Gale – Extreme
Unknown	U	Unknown as observation is impossible because of darkness, cloud or fog.	N/A

Record the wind direction as indicated by blowing snow.

1.4.19 Barometric Pressure at Station

The unit of hectopascals **(hPa)** is used for reporting pressure. Instruments need to be calibrated for the elevation where they are to be used.
A variety of instruments including barographs, barometers, altimeters and electronic sensors can be used to obtain a measure of the barometric pressure. Measurement units vary between hectopascal, kilopascal, millibars, millimetres and inches of mercury depending on instrument. Appendix G gives multipliers used to convert to hPa.

Absolute pressures and trends are valuable for weather forecasting while trend alone is often sufficient in avalanche operations.

Pressure Tendency
Use an arrow symbol to record the pressure tendency as indicated by the change of pressure in the three hours preceding the observation.

Record the change in barometric pressure in the past three hours.

Symbol	Data Code	Description
↑	RR	Pressure Rising Rapidly (>2 hPa rise per hour)
↗	R	Pressure Rising (<2 hPa rise per hour)
→	S	Pressure Steady (<1 hPa change in 3 hours)
↘	F	Pressure Falling (<2 hPa fall per hour)
↓	FR	Pressure Falling Rapidly (>2 hPa fall per hour)

Relative Pressure
Classify the level of pressure as "high", "medium", "low" when the units of pressure are uncertain or imprecise.

Symbol and Data Code	Description
H	Barometric pressure high
M	Barometric pressure medium
L	Barometric pressure low

Weather plot observations						
Sampling tube area __________(cm^2)						
Location	*Base Study Plot, Elevation: 1650m*					
Observer	*R.M.*	*R.M.*	*K.E.L.*	*K.E.L.*	*K.E.L.*	*K.E.L.*
Date	*020809*	*020809*	*020810*	*020810*	*020810*	*020811*
Time & Type	*0700Std*	*1600Int*	*0700Std*	*1140Int*	*1600Int*	*0700Std*
Sky	*O*	⊗	T⊕	⊕	⊕	*O*
Precip Type / Rate	*Nil*	*S -1*	*S1*	*S3*	*RL*	*Nil*
Max Temp (^{O}C)	*-2.5*	*-3.0*	*-3.0*	*-1.5*	*1.0*	*0.0*
Pres Temp (^{O}C)	*-6.5*	*-3.0*	*-4.0*	*-1.5*	*0.0*	*-10.0*
Min Temp (^{O}C)	*-7.0*	*-6.0*	*-4.5*	*-4.0*	*-4.0*	*-11.0*
Thermograph (^{O}C)	*-7*	*-3*	*-4*	*-1*	*-0*	*-10*
Thermograph Trend	↗	→	↗	↗	→	↘
Surface Temp (^{o} C)	*-12.5*	*-4.0*	*-3.0*	*-2.0*	*-3.0*	*-7.0*
10 cm Snow Temp (^{O}C)	*-11.0*	*-7.0*	*-5.0*	*-4.0*	*-3.0*	*-7.0*
Relative Humidity (%)	*75*	*85*	*95*	*100*	*100*	*65*
Interval (cm) HIN	*0*	*0.1*	*10*	*12*	*4*	*0*
24 hour (HN24)	*0*	*0.1*	*10*	*12*	*15*	*14*
Storm cm (C=cleared) HST	*0*	*0.1*	*10*	*20*	*21*	*19, C*
Snowpack (cm) HS	*223*	*222*	*231*	*239*	*241*	*239*
Mass of new snow (g)	~	~	*33.6*	*42*	*67*	~
Water Equivalent (mm)	~	~	*8*	*10*	*16*	~
Density (kg/m^3)	~	~	*80*	*83*	*110*	~
Rain gauge (mm)	~	~	~	~	*3*	~
Precip gauge (mm)	*60*	*60*	*67*	*77*	*82*	*82*
Foot Pen. (cm)	*40*	*35*	*45*	*50*	*50*	*45*
Surface Form / Size	~	*PP,0.3*	*PP,0.3*	*PP,0.3*	*DF,0.3*	*DF,0.3*
Wind Speed / Dir	*L, E*	*Calm*	*M, SE*	*L, S*	*L, SW*	*M, E*
Blow Snow Extent / Dir	*Nil*	*Nil*	*Nil*	*M, S*	*Nil*	*U*
Barometric Pressure (hPa)	*1033*	*1030*	*1000*	*996*	*1010*	*1026*
Pressure Tendency	↘	↘	↓	→	↗	→
Comments					*Rain*	
					gauge	
					frozen	

Figure 1: Sample field book page for weather observations

1.5 FIELD WEATHER OBSERVATIONS

1.5.1 Objectives, relevant measurements, frequency and location

Avalanche workers in the field often observe local weather conditions during their daily operations. These observations are an important tool in helping evaluate slope-specific snow stability and avalanche hazard to ensure the safety of the party. In addition, when factored together with other field and study plot observations, field weather observations may be incorporated into a stability and hazard analysis and forecast for the operational region.

It is not necessary to measure every variable when undertaking field weather observations. No fixed rule applies about the type and amount of information to be collected. An observer should select the observations that give significant information to achieve the objectives outlined above.

There is no rule regarding the frequency of field weather observations. The number of readings should be adequate to achieve the objectives outlined above. Experienced workers will often make a field weather observation when they first embark on the field trip, when they arrive at a high or a low point for the day, when they change aspect, at midday, or when the weather conditions are changing.

1.5.2 Field procedure guidelines

Record (as outlined in section 1.4):

- Date and time

  Record date and time as outlined in Section 1.4

- Location

  Record the location using latitude and longitude, grid reference, named feature, or a short description of the spot.

- Elevation

  Measure or estimate the elevation in metres

- Sky condition

  Classify the amopunt of cloud cover and measure or estimate the valley fog as outlined in Sections 1.4.3

  If both the bottom and top of the valley fog was observed within a few minutes of each other (during a helicopter flight or while skiing down hill) record both the elevations of the valley fog as well as the sky cover (i.e. valley fog between 1200m and 1750m with scattered clouds above is recorded as SCT VF 1200-1750). If not all of these conditions could be observed, record the ones that were and use a tilde (~) for the others (i.e if the bottom elevation is 1200m but the field teams did not get above the valley fog to observe the top elevation or sky condition, record as ~VF 1200- ~).

- Precipitation type and intensity

  Estimate the type and rate of precipitation as outlined in Section 1.4.4

- Air temperature

  Observe the air temperature in the shade about 1.5m above the snow surface. Use a dry Thermometer, read after about 5 minutes, wait another minute and read again. Record the temperature if there is no change between the two readings. Observe the air temperature to the nearest 0.1 or 0.5 of a degree (C) based on the scale increment (analong or digital) of the thermometer.

- Depth of interval snow (HIN)

  Estimate the amount of snow that has fallen since the most recent field weather observation.

- Depth of storm snow (HST)

- Estimate the amount of snow that has fallen during the period specified in hrs (i.e. 56cm in the past 36hours).

- Total depth of snowpack (HS)

  Estimate the depth of the snowpack. Probing several spots is useful in determining the average depth in the immediate area

- Surface grain form and size

  Record the surface grain form and size either as an estimate or measureed as per Section 1.4.16

- Wind speed and direction

  Estimate wind speed and direction as shown in Section 1.4.17

- Extent of blowing snow

  Estimate the extent and direction of previous and current blowing snow as outlined in Section 1.4.18

- Comments

  Make any addition comments or observations as required, These may include ski and/or foot penetration, intensity of valley fog, etc.

1.6 FIELD WEATHER SUMMARY

1.6.1 Objectives

Field weather summaries are used to create a clear and concise picture of which weather conditions encountered in the field are relevant to creating a stability and/or hazard forecast for an operational region. The objective of such a summary is to filter out data not required for this type of analysis.

Summaries are different from observations in that they are not recorded at a specific location and time but are a general approach to a range of conditions encountered during the field day.

Summaries are generally done once a day, after the field day is completed.

1.6.2 Procedures

Record (as outlined in section 1.4):

- Date
- Time period
- Locations and elevation range
- Percent of area observed
- Sky condition
- Precipitation type and intensity
- High and low temperature
- Field HIN
- Field HST
- Field HS
- Surface form and size
- Wind speed and direction
- Extent of blowing snow
- Comments

1.6.3 Recording

Always record the names (initials are fine) of observers with the primary observer listed first. Use a "~" (tilde, a curved dash) in the field-book when no observation was made. Code as "U" if the observation was attempted but no reliable value could be ascertained (i.e. when blowing snow cannot be observed due to darkness, cloud or fog). Do not leave blanks. Only write "0" when the reading is zero (i.e. when no new snow has accumulated on the H24N board).

1.6.4 New Zealand InfoEx Recordings

Twice daily (0900 and 1500 if possible) ski area, heliski, ski touring and other operations should log in to the Mountain Safety Council website (www.avalanche.net.nz) to record, share and archive weather observations. The format provided on this website is compatible with field-book entries detailed in Figure 1. Help files are available on the website.

2. SNOW OBSERVATIONS

2.1 FULL SNOW PROFILES

A full snow profile is an observation record of the snow cover stratigraphy and the characteristics of the individual layers.

2.1.1 Objectives

The objectives of observing snow profiles in avalanche work are:

- To identify the weak and strong layers that makes up the snowpack.
- To identify weak interfaces between layers and to determine their relative strength and character.
- To observe snow temperatures.
- To monitor and confirm changes in the condition, stratigraphy, temperature and stability of the snowpack.
- To determine the thickness of a potential slab avalanche.
- To determine the state of metamorphism of the snow.

In addition, the information can be used for climatological studies; forecasts of snow melt runoff and studies of the effect of snow on vegetation, wildlife and structures.

2.1.2 Site Selection

Study Plot. Full snow profile observations are carried out at study plots by excavating snow pits progressively in undisturbed snow. Each observation pit should be a distance about equal to the snow depth, but at least 1 metre from the last one. After each observation the location of the extreme edge of the pit should be marked.

The snow profile observation line and area should be selected and marked as early in the season as staffing allows (preferably prior to the first snowfall), and the ground between the marker poles should be clear of vegetation or large rocks.

On Snow. The best information with respect to snow stability is obtained from snow profiles taken at avalanche starting zones. Since starting zones are not always accessible, other slopes should be selected provided that they are undisturbed, safe and representative of the conditions in starting zones. The study slopes may be pre-selected and marked in the same manner as study plots; however, markers on slopes will be tilted by snow creep and may have to be periodically reset. Full snow profiles can be at a specific site selected to satisfy a particular observation objective.

2.1.3 Frequency of Observations

No firm rules can be set on how frequently snow profiles should be observed. The frequency is dependent on the climate, terrain and type of avalanche operation. Usually profiles are observed at regular intervals and, in addition, whenever changes of the snow conditions are suspected.

2.1.4 Equipment

The following equipment is used for snow profile observations:

<u>Recommended equipment:</u>

- Collapsible probe
- Snow shovel
- Snow thermometer
- Ruler (graduated in cm)
- Loupe or magnifying glass (10x -20x magnification)
- Crystal screen
- Snow density cutter and appropriate scale

- Field-book
- Two pencils (soft lead preferred)
- Gloves
- Snow saw
- Inclinometer
- Compass
- Altimeter

<u>Additional useful equipment:</u>

- Spare thermometer
- Camera
- Brush
- GPS receiver
- Calculator
- Safety belay rope (see *The Avalanche Handbook, 3rd Edition)*

The thermometers should be calibrated periodically in a snow-water mixture. Glass thermometers must be checked for breaks in the mercury or alcohol columns before every use.

The field-book should be prepared before the observer goes to the observation site.

2.1.5 Field Procedure

Equipment
Keep all the observation equipment in the shade. Wear gloves when handling the instruments.

Check Snow Depth
Unless the profile is observed on a study plot check the snow depth with a probe before digging the observation pit; make sure the pit is not on top of a boulder, bush or in a depression. Feel the hardness of the snow with the probe and obtain a first indication of weak or stiff stratigraphy.

Digging the Pit
Make the hole wide enough to allow for multiple observations and to allow shovelling at the bottom. In snow deeper than 2 m it is advantageous to dig first to a depth of about 1.5m, to make the observations, then to complete the excavations and observation to the necessary depth. Pile extracted snow such that the disturbed region remains so. Exercise caution in piling debris so it does not reflect solar radiation into the observation pit (particulurly in the latter part of the season). The pit face on which the snow is to be observed must be in the shade. Cut the observation face and an adjacent side vertical and smooth. On inclined terrain it is advantageous to make the observations on a face parallel to fall line.

While the first observer prepares the pit, a second observer begins the observations:

Record: date, time, names of observers, location, elevation, aspect, slope inclination, air temperature, sky condition, precipitation type and rate, wind and surface penetrability. *Observe the air temperature to the nearest 0.5°C in the shade about 1.5 m above the snow surface.*

Date and time
Record the date and time

Location
Record location, elevation, aspect, and slope inclination

Weather obervations
Observe air temperature, sky conditions, precipitation and wind as described in Section 1.5.4

Snowpack Temperature (T)
Observe snow temperatures to the nearest fraction of a degree based on the accuracy of the thermometer.

Note: Digital thermometers are preferred as *__most__* *allow for accuracy of 0.1°C.*

Measure the snow surface temperature by placing the thermometer on the snow surface; shade the thermometer.

Push the thermometer horizontally to its full length parallel to the surface into the snow (use the shaded side wall of the pit on a slope). Wait at least one minute, and then read with the bulb still in the snow. When making measurements within the top 30 cm of the snowpack shade the snow surface above the thermometer in order to reduce influence of radiation.

Measure the first sub-surface snow temperature 10 cm below the surface. The second temperature is observed at the next multiple of 10 cm from the previous measurement and from there in intervals of 10 cm to a depth of 1.4 m below the surface and at 20 cm intervals below 1.4 m. Closer measurements can be made when the temperatures are near to 0°C or when gradients are strong.

Begin the next observation while the snow temperatures are being measured.

Note: Compare the thermometers first when two or more are used simultaneously. Multiple thermometers should be of identlcal style only.

Punch a hole in the snowpack with the metal case or a knife before inserting the thermometer into very hard snow and at the ground surface.

It is important to regularly check (semi-monthly) the accuracy of all thermometers by immersing them in a mixture of water and ice slush, each should read 0 L^{o}C. If possible, recalibrate or note variation from 0^{o}C on the thermometer.

Layer Boundaries
Determine the location of each major layer boundary using a combination of visual and tactile techniques. Determine weak layers or interfaces of layers where a failure might occur. Record in the column "H" of the field book, the layer boundaries by their distance from the ground. *(In glacial terrain or a very deep snowpack, height measurement may be from the snow surface down.)*

Note: When using a brush to highlight layering, it is suggested that a repeatable and reproducible method will provide consistant

Layer Dating
Layers that are significant or used in referencing specific surface conditions or formation can be named by the datethe layer was buried. This is most commmonly done regarding rain crusts or surface hoar.

Snow Hardness (R)
Observe the relative hardness of each layer with the hand test. Record under "R" the object that can be pushed into the snow with moderate effort parallel to the layer boundaries.

Symbol	Hand Test	Term	Symbol
F	Fist in glove	Very low	None
4F	Four fingers in glove	Low	/
1F	One finger in glove	Medium	X
P	Blunt end of pencil	High	//
K	Knife blade	Very high	XX
I	Too hard to insert knife	Ice	-

Note: Fierz and others (2009) suggest a maximum force of 10 to 15 newtons (1 to 1.5kg force) to push the described object into the snow.
Gloves are worn when this test is undertaken.

Slight variations in hand hardness can be recorded using + and – qualifiers, i.e. P+, P, P-. A value of 4F+ is less hard than 1F-.

Grain Form (F)
Appendix E presents the classification scheme that is used in this document. The more detailed sub-class scheme from the classification should, in general, only be used by experienced observers (refer to Appendix E).

Note: Use 10x to 20x lens: lower power does not provide adequate resolution for shape and higher power does not provide adequate field of view for bond identification

Any basic group may be sub-classified into the different forms of solid precipitation according to Appendix E.

Snow layers often contain crystals in different stages of metamorphism. The classification should refer to the predominant type, but may be mixed when different types are present in about equal numbers. A maximum of two grain forms (primary, secondary) may be displayed for any single layer.

In warm weather the crystals may melt and change their shape rapidly on the crystal screen. In this case it is advisable to scrape the pit face back with the crystal card to expose the unmodified crystal form immediately prior to making identification. A quick decision must be made and repeated samples taken from various depths of the same layer.

Note: Snow layers often contain crystals in different stages of metamorphism. The calssification should refer to the predominant type, but may be mixed when different types are present in about equal numbers. A maximum of 2 grain forms, primary and secondary, may be displayed for any single layer with the secondry grain form recorded in parenthesis.

Illustrations of the various types of crystal shapes may be found in the following publications (LaChapelle, 1969; Perla, 1978; Colbeck and others, 1990; McClung and Shaerer, 2006).

Grain Size (D)

Determine the grain size in each layer with the aid of the screen. In doing so disregard the small particles and determine the average greatest extension of the grains that makes up the bulk of the snow. Record the size or the range of sizes in millimetres in the Column "D". Record the size to the nearest 0.5 mm except for fine and very fine grains, which may be recorded as 0.1, 0.3 or 0.5 mm.

Where two distinct grain forms exist in a layer, record the size of the secondary grain form in Parenthesis: e.g., 0.3 (2.5).

Where a range in sizes exist for any single grain form specify the average and maximum size with a hyphen: e.g., 0.5-1.5.

Both notations may be mixed: e.g., 0.5-1.0 (2.5).

The following table contains terms that can be used to describe grain size. These terms should not be used in field notebooks. Always document grain size with digits.

Term	**Size (mm)**
Very fine	< 0.2
Fine	> 0.2 to 0.5
Medium	> 0.5 to 1.0
Coarse	> 1.0 to 2.0
Very coarse	> 2.0 to 5.0
Extreme	> 5.0

Liquid Water Content (θ)
Classify the liquid water content by volume for each layer that has a temperature of 0°C. Gently squeeze a sample of snow and observe the reaction.

Class	Definition	Water Content (by volume)	Data Code	Symbol
Dry	Usually the snow temperature (T) is below 0^{o}C but dry snow can occur at any temperature up to 0^{o}C. Disaggregated snow grains have little tendency to adhere to each other when pressed together, as in making a snowball.	0 %	D	None
Moist	T = 0^{o}C. The water is not visible even at 10 x magnification. When lightly crushed, the snow has a distinct tendency to stick together.	<3 %	M	I
Wet	T = 0^{o}C. The water can be recognized at 10x magnification by its meniscus between adjacent snow grains, but water cannot be pressed out by moderately squeezing the snow in the hands (Pendular regime).	3 - 8 %	W	II
Very Wet	T = 0^{o}C. The water can be pressed out by moderately squeezing the snow in the hands, but there is an appreciable amount of air confined within the pores (Funicular regime).	8 - 15%	V	III
Slush	T = 0^{o}C. The snow is flooded with water and contains a relatively small amount of air.	>15 %	S	IIII

Note: In alpine snow measurable liquid water is present only when the snow temperature is 0^0 C.

Density (ρ)
Measure the density of the snow in layers that are thick enough to allow insertion of the snow density cutter. Accurcy of density measurements reies in part on the orientation of the cutter when it is inserted. Tube- or box-shaped cutters should be used for thin layers in the method described below.

Sample densities from the pit face when working on flat terrain and from the pit sidewall when on an incline.Insert box or large (500cm^3) tube-shaped cutters horizontally. Insert wedge and small (100 cm^3) tube-shaped cutters with the long axis vertical (i.e. the opening of the tube facing down the bottom of the wedge cutter vertical). Do this perpendicular to the layering when on an incline. When incerting a tube shaped cutter vertically, clear the snow from above the sample area and place a flat cutter or crystal screen at the depth equal to the long axis dimension. Trim the ends, remove excess external snow and weight. Volume of thin layers that do not fill the tube cutter can be calculated in the same manner as using a tube for new snow density (area of tube opening, pi times the raduis squared, times the layer thinkness).

Record weight under *Comments* and calculate density. Record cutter volume under *Comments*. Take and appropriate number of samples in thinker layers to provide and average density.

Calculate the density as follows: Divide the weight of the snow sample (measured in grams) by the sample volume (measured in cm^3) and multiply by 1000 to express the result in kg/m^3. Record as a whole number.

$$\rho(kg/m^3) = \frac{\textbf{Mass of snow sample (g)}}{\textbf{Sample Volume}(cm^3)} \times 1000$$

Where:

$$\textbf{Sample Volume } (cm^3) = \left(\frac{\textbf{Diameter of cutter (cm)}}{2}\right)^2 \times \textbf{Length of cutter (cm)} \times 3.14\ (\pi).$$

Note: When multiple samples within one layer are averaged, the resulting value is described as average layer density.

Density measurements that include more than one layer are described as bulk density.

When using a 500 cm^3 density cutter use the following calculation: Multiply net weight of snow in the cutter by 2. Multiply by 5 for a 200cm^3 and 10 for a 100cm^3 cutter.

Strength and Stability Tests
Make rutschblock or other tests of strength and stability as appropriate.

Marking the Site
Fill the pit and place a marker at the extreme edge if you plan to undertake further studies at the site.

2.1.6 Water equivalent of snow cover (HSW) (optional snow profile calculations)

The water equivalent is the vertical depth of the water layer which would form if the snow cover was melted. Information about water equivalent is needed for certain applications.

Water equivalent of the snowpack (mm) can be approximated from the density of the layers as follows:

Multiply the thickness (cm) of each layer by its density (kg/m^3) and sum the products over the full depth of the snow.

$$\textbf{HSW (mm)} = \sum [\textbf{Vertical thickness (cm)} \times \textbf{Density } (kg/m^3)] \times 0.01$$

Where $\sum$ is the sum.

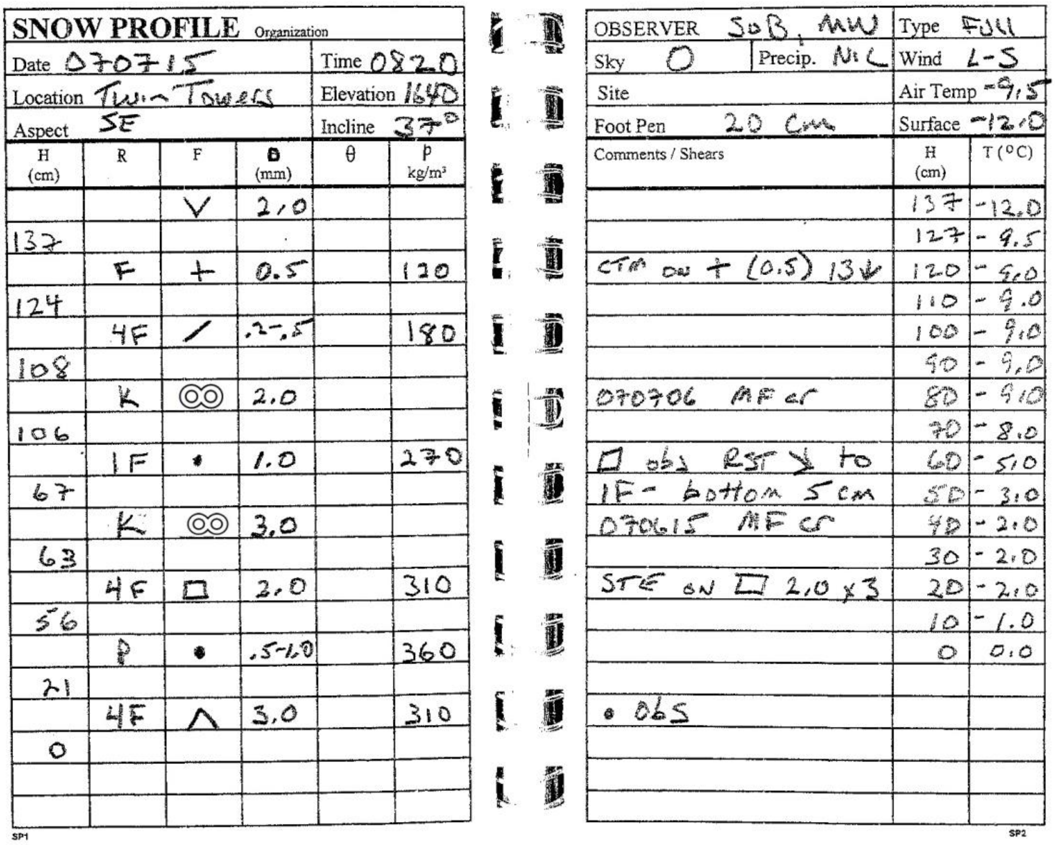
2.1.7 Average bulk density (optional snow profile calculations)

Calculate average bulk density as follow: Divide water equivalent of snow cover (mm) by total snowpack depth (cm) and multiply by 100.

$$\rho = \textbf{Water equivalent of snow cover (mm) / Total snowpack depth (cm)} \times 100$$

2.1.8 Recording

Always record the names (initials are fine) of observers with the primary observer listed first. Use a tilde (~) in the field-book when no observations are made. Code as 'U' if the observation was attempted but no reliable value could be ascertained (i.e. when blowing snow cannot be observed due to darkness, cloud cover or fog). Do not leave blanks. Only write ‘0’ when the reading is zero (i.e. the incline when the profile is performed at a level site).



SNOW PROFILE Organization					
Date 070715			Time 0820		
Location Twin Towers			Elevation 1640		
Aspect SE			Incline 37°		
H (cm)	R	F	E (mm)	θ	ρ kg/m³
		V	2.0		
137					
	F	+	0.5		120
124					
	4F	/	.2-.5		180
108					
	K	◎◎	2.0		
106					
	1F	•	1.0		270
67					
	K	◎◎	3.0		
63					
	4F	□	2.0		310
56					
	P	•	.5-1.0		360
21					
	4F	Λ	3.0		310
0					

SP1

OBSERVER SoB, MW		Type Full
Sky O Precip. NIL		Wind L-S
Site		Air Temp -9.5
Foot Pen 20 cm		Surface -12.0
Comments / Shears	H (cm)	T (°C)
	137	-12.0
	127	-9.5
CTM on + (0.5) 13↓	120	-9.0
	110	-9.0
	100	-9.0
	90	-9.0
070706 MF cr	80	-9.0
	70	-8.0
□ obs RST ↓ to	60	-5.0
1F - bottom 5 cm	50	-3.0
070615 MF cr	40	-2.0
	30	-2.0
STE on □ 2.0 x3	20	-2.0
	10	-1.0
	0	0.0
• obs		

SP2

Figure 2: Sample field-book page

2.1.10 Recording

Record results of a test as follows:

<data code> <fracture character> <reference point> <location in profile> <”on” layer characteristics (form, size, date of burial if known)> <comments>

Example: CTM 17 (SC) down 34 on SH 8.0 080122

Indicate reference point for the fracture position (*down* = from snow surface or *up* = from ground). The snow surface is the default reference point for measuring fracture location. Measure down from the snow surface and record location of fracture in the profile. When location of the fracture is measured up from the ground, record reference point as *up* and indicate this clearly in the comments.

Examples

If multiple tests at the same site produce results on the same layer, record results as follows:

<data code #1> <(fracture character #1)>, <data code #2> <(fracture character #2)>, <data code #3> <(fracture character #3)>, etc. <reference point> < location in profile> <”on” layer characteristics (form, size, date of burial if known)> <comments>

i.e. CTM 14 (SP), 17 (SP), 19 (RP) down 45 on SH 6.0 080212 Comment: SH rounding

Example 1:
Compression test: 36 degree slope, weak layer (SH 3mm) at 45 cm below the surface, buried on 12 January.

Results: Column fractures at 45cm from the surface on 2nd tap from the elbow. The fracture crosses the column suddenly (‘pops’), and block slides off the column.

Recording: CTM 12 (SP) down 45 on SH 3.0 Jan 12

Example 2

Shovel shear test: 25 degree slope, weak layer (DH 6 mm) at 45 cm above the ground

Results: Column fractures at 45cm from the ground with moderate pull applied. The fracture crosses the column suddenly and block collapses into the weak layer.

Recording: STM (SDN) up 45 on DH 6.0 Comment: measured up from ground, HS = 135

2.2 GRAPHICAL SNOW PROFILE REPRESENTATION

The snow profiles can be represented graphically in a standard format for quick reference and permanent record.

a) Plot the snow temperatures; mark the air temperature above the snow surface with a dotted line.

b) Plot the height of the snow layers to scale.

c) Use symbols for the shape of the grains and the liquid water content. Plot a tilde (~) when the liquid water content could not be determined (a blank implies very low (fist) hardness or dry snow respectively).

d) Tabulate the grain size and the density with the values observed in the field.

e) Include written comments where appropriate. If possible, label important layers by their date of burial.

f) Include the results of appropriate strength and stability tests in the comments column. **Document** the grain form and size of the failure layer. Draw an arrow at the height of each observed failure and use a shorthand notation to describe the test.

   e.g., ←STE SH 2.5 (Shovel test, easy shear on 2.5 mm surface hoar)
   ←RB6 FC 1.5 (Rutschblock score six on 1.5 mm faceted crystals)
   ←CTE DH 2.5 (Compression test easy failure on 2.5 mm depth hoar)

g) Plot the results of hand test of snow hardness as a horizontal bar graph from the right side. Use the scale at the bottom of the standard snow profile form.

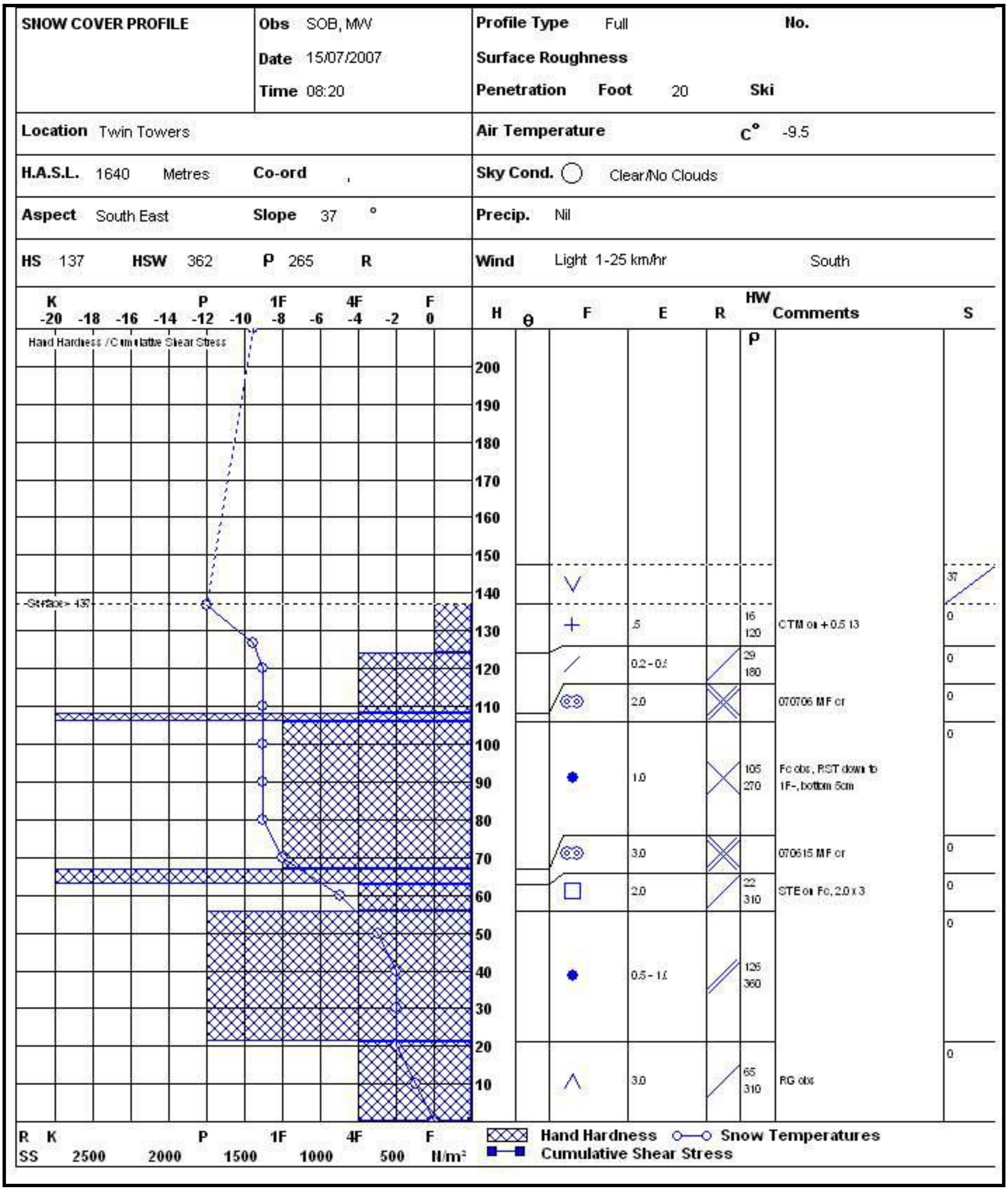


Figure 3: Graphical representation of a snow profile produced by the personal computer programme ‘Snowpro 2006’, Gasman Industries, Vancouver, B.C., Canada.

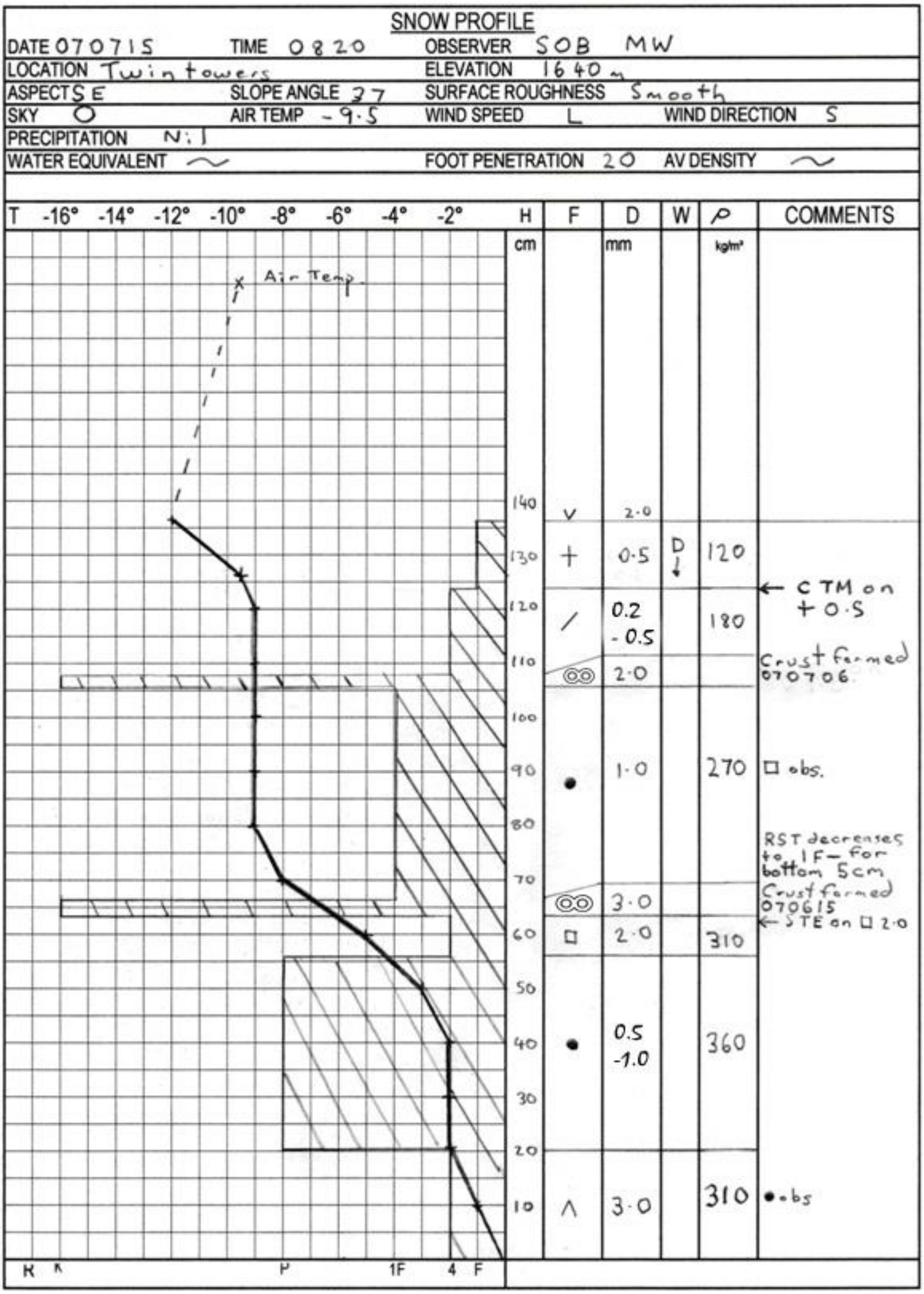


Figure 4: Hand drafted snow profile.

2.3 TEST SNOW PROFILE

Snow profiles that contain only a few key or select observations are referred to as test profiles.

2.3.1 Objective

The prime objective of test snow profiles is to assess snow stability. Test profiles may be used to supplement data from study plots. The variation of snow structure with respect to aspect and elevation is recorded and correlated with conditions observed at study plots. Repetition of test profiles (and most other tests) allows an observer to track changes over space and through time.

2.3.2 Location

Criteria used for site selection depend on the objective of the test profile. Test profiles are often observed where snow conditions are similar to avalanche starting zones. When selecting a site, keep in mind that elevation and exposure to wind and sun are the factors that have the strongest influence on the variations of the snow cover.

Furthermore, profile locations should be at least 5 metres from the tip of tree branches, not be in a depression, nor contain avalanche debris or tracks from skis, vehicles or animals. **Safety considerations are paramount in selecting a site; consider the potential of avalanches from above in addition to the runout below.**

2.3.3 Frequency of Observations

No rule can be set about the frequency of test snow profiles. The number of profiles should be adequate to supplement other observations relating to snow stability.

2.3.4 Relevant Measurements

It is not necessary to measure every variable when undertaking a test snow profile. No fixed rule exists about the type and amount of information that is collected. The observations may concentrate on the identification of weak layers and their relation to other layers, or may contain snow temperatures only (e.g. during snow melt periods), or may have nearly all the information of a full snow profile (e.g. in a shallow snowpack). An observer should select the observations that give significant information about the stability of the snowpack at the specific site and time.

The pit for a test profile needs to be excavated deep enough to observe weak layers and relevant temperatures *typically down to the depth of a previously observed snow layer*. The depth should be known approximately from regularly monitoring the development of the snowpack during the winter, full snow profiles and probing.

Test profiles should be recorded in a format similar to that for snow profiles.

2.3.5 Equipment

Equipment required for a test snow profiles depends on the observations being made. Refer to the previous list for a list of recommendations.

2.3.6 Procedure

a) With a probe or ski pole, determine the approximate location of weak layers, the depth necessary for the pit and the total snow depth.

b) Record date, time, names of observers, location, elevation, aspect, inclination of terrain, sky cover, precipitation and wind.

c) Observe the air temperature in the shade about 1.5 m above the snow surface.

d) Measure foot penetration.

e) Dig the pit and cut a smooth face on the shady side to allow for the identification of layers.

f) Measure the snow temperatures as necessary.

g) Determine the location of significant layers and record the distance from the ground (or from the surface down in glaciated terrain).

h) Observe the hardness, crystal shape, grain size and free water content of significant layers.

i) In a general comment describe any terrain features, vegetation, sun and wind effects on the snowpack and note any evidence of past avalanche activity which may influence the snowpack structure.

Perform strength and stability tests as appropriate.

Always record the names (initials are fine) of observers with the primary observer listed first. Use a tilde (~) in the notebook when no observation was made. Code as “U” if the observation was attempted but no reliable value could be ascertained (i.e. when blowing snow cannot be observed due to darkness, cloud or fog). Do not leave blanks. Only write “0” when the observation is zero (i.e. the incline when the profile is preformed at a level site)

Snow Profile	Organization *Heliguides*	Observer *R S*	Type *Test*
Date *020713*	Time *1245*	Sky ⊕	Wind *Mod, N*
Location *Mt. Aurum*	Elevation *1750*	Precip Nil	Air Temp *- 4.5*
Aspect *SE*	Incline *25°*	Foot Pen 40 cm	Surface *-10.0*

H (cm)	R	F	D (mm)	θ	ρ (kg/m^3)	Comments / shears	H (cm)	T (^{o}C)
0						*surface*	*10*	*-8.0*
	F	~	~				*34*	*-5.0*
6						*Weak bonding between*	*64*	*-3.5*
	P	~	~			*and snow above*		
8								
	4F	/	~					
63								
	~	∨	*2-3*			*ECTP 13 (SP) down 63*		
64						*on SH 3.0*		
	1F	□ •	~					
97								
						Profile location on lee side		
						ridge		

Figure 5: Sample field-book page.

2.4 FRACTURE LINE PROFILES

2.4.1 Objective

Fracture line profiles are observed near the crown or flanks of slab avalanches. Identification of the slab layer(s), weak layer(s) and bed surface(s) are of prime importance. Information is sought on the strength of the weak layer and loading on it from the layers above, grain form and size in the weak layer and snowpack temperatures. Knowledge of the snowpack structure at avalanche sites contributes to a better understanding of the phenomenon.

2.4.2 Location

Safety considerations are paramount when selecting a site for fracture line profiles. Consider the potential for, and consequences of further releases. A pit may be dug back into the flanks or the crown face. If more than a short time has passed since the avalanche, dig into the exposed crown or flank **at least 1.5 metres** in order to trace the bed surface and the failure planes to the profile face.

Observations can be taken at both thick and thin sections of a fracture line. Supplementary information on strength and stability may be obtained away from the fracture line.

Use a sketch to describe the location. Carefully describe the terrain features, vegetation, sun and wind effects on the snowpack. Note any evidence of past avalanche activity which may have influenced the snowpack's structure.

2.4.3 Relevant Measurements

The following should be given special attention for full or test snow profiles:

a) Dig the observation face into undisturbed snow at least 1.5 m back into the crown or flank. Dig down below the depth of the bed surface.

b) Note the location of crystal shape, grain size and temperature in the initial failure plane and bed surface.

c) Measure the height from the surface down if the ground cannot be found by digging or probing.

d) Measure the incline of the terrain with an inclinometer.

e) Record the exact location of the profile with respect to the avalanche fracture geometry.

2.4.4 Recording

Always record the names (initials are fine) of observers with the primary observer listed first. Use a tilde (~) in the field-book when no observations are made. Code as ‘U’ if the observation was attempted but no reliable value could be ascertained (i.e. when blowing snow cannot be observed due to darkness, cloud cover or fog). Do not leave blanks. Only write ‘0’ when the reading is zero (i.e. the incline when the profile is performed at a level site).

2.4.5 Fracture character

(After considerable discussion, the Avalanche Working Group has decided to adopt the CAA standard with regard to quality of shear. Thanks go to the CAA OGRS review committee in general and Bruce Jamieson specifically for allowing MSC to include this section).

Observing fracture character in stability tests can improve interpretation with respect to stability. Experience suggests that fracture character may be observed in shovel shear tests, compression tests, deep tap tests and other tests that load a small column of snow until a fracture appears. Three major classes of fractures are identified: *sudden, resistant and breaks*. The major classes are used to qualify and communicate test results that are significant for avalanche forecasting when test conditions will not allow direct observation of the fracture character subclasses.

2.4.6 Procedure

Fracture character is best observed in tests performed on a small isolated column where the objective is to load the column until a fracture (or no fracture) occurs. Typical small columns are less than 50cm x 50cm in cross-section.

The front face and sidewalls of a test column should be as smooth as possible. The observer should be positioned in such a way that one sidewall and the entire front face of the test column can be observed. Attention should be focused on weak layers or interfaces identified in a profile or previous snowpack tests as likely to fracture.

For tests on low-angled terrain that produce planar fractures, it may be useful to slide the two fracture surfaces across one another by carefully grasping the two sides of the block and pulling while noting the resistance.

2.4.7 Observations

Use the following table to characterise the fracture:

Major class	Data code	Sub class	Data code	Fracture characteristics
Sudden *(pops and drops)*	SDN	Sudden planar *(pop, clean and fast, fracture)*	SP	A thin planar* fracture suddenly crosses column in one loading step AND the block slides easily** on the weak layer.
		Sudden collapse *(drop)*	SC	Fracture crosses the column with a single loading step and is associated with a noticeable collapse of the weak layer.
Resistant *(others)*	RES	Progressive compression (step by step ‘squashing’ of a layer)	PC	A fracture of noticeable thickness (non-planar fractures often greater than 1 cm), which usually crosses the column with a single loading step, followed by step-by-step compression of the layer with subsequent loading steps.
		Resistant planar	RP	Planar or mostly planar fracture that requires more than one loading step to cross column and/or the block does NOT slide easily** on the weak layer.
Break *(others)*	BRK	Non-planar break	BRK	Non-planar, irregular fracture.

*Note: * “Planar” based on straight fracture lines on front and sidewalls of column.*

** Block slides off column on steep slopes. On low-angle slopes, hold sides of the block and note resistance of sliding

2.5 RUTSCHBLOCK TEST

The rutschblock (or glide-block) test is a slope test that was developed in Switzerland in the 1960’s. This section is based on a Swiss analysis of rutschblock tests (Föhn, 1987) and on Canadian research experience (Jamieson and Johnston, 1993).

2.5.1 Objective

The rutschblock test gives a reasonable indication of the stability of a slope where a skier or snowboarder is a likely trigger. It may also allow a qualitative assessment of the likelihood of natural avalanches in an area. Note, however, that it should be interpreted in conjunction with other tests and snowpack and avalanche observations (see section 2.5.7 for limitations).

2.5.2 Site Selection

Test sites should be safe, representative of the avalanche terrain under consideration and undisturbed. For example, to gain information about a wind-loaded slope, find a safe part of a similarly loaded slope for the test. The site should not contain buried ski tracks, avalanche deposits, etc. or be within about 5 m of trees where the buried layers might be disturbed by wind action or by clumps of snow which have fallen from the nearby trees. (In New Zealand this principle may also apply re: rock outcroppings, seracs, etc.) Although Föhn (1987) recommends slope angles of at least 30º, rutschblocks on 25º-30º slopes also give useful information (discussed below). Be aware that near the top of a slope, snowpack layering and hence rutschblock scores may differ from the slope below.

2.5.3 Equipment

Eight metres of 4-7mm cord with overhand knots tied every 20-30cm can be used to cut the upper wall and both sides of the block at the same time(provided no hard crusts are encountered). Long ruschblock-specific snow saws are useful to cut hard crusts.

2.5.4 Procedure

Cutting the Block

After identifying weak layers (and potential slabs) in a snow profile, extend the pit wall until its width is at least 2m mimium across the slope. Do not omit the profile unless the layering is already known.

Mark the width of the block and the length of the side cuts (1.5 m) on the surface of the snow with a ski, ruler, etc. The block should be 2 m wide (see above comment) throughout if the sides of the block are to be dug with a shovel as shown in Figure 7. However, if the side walls are to be cut with a ski, pole, cord or saw, the lower wall should be about 2.1 m across and the top of the side cuts should be about 1.9 m apart. This flaring of the block ensures it is free to slide without binding at the sides. The lower wall should be a smooth vertical surface cut with a shovel.

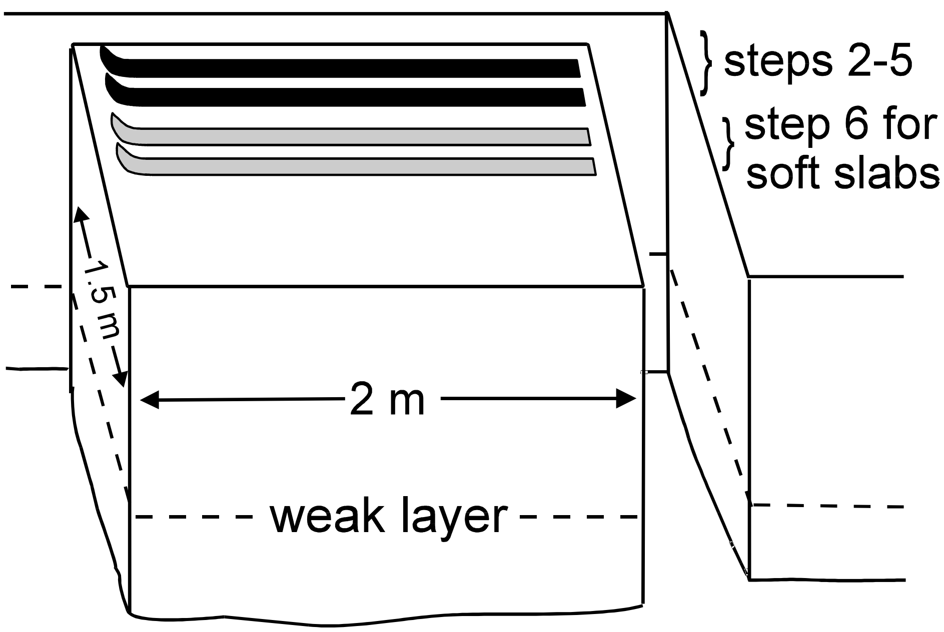


Figure 7: Rutschblock dimensions and ski/snowboard step positions
(Source: B. Jamieson)

Dig or cut the sidewalls and the upper wall deeper than any weak layers that may be active. If the sidewalls are exposed by shovelling, then one rutschblock test may require 20 minutes or more for two people to perform.

Note: If the weak layers of interest are within 60 cm of the surface, time can be saved by cutting both the sides and the upper wall of the block with a ski pole (basket removed) or with the tail of a ski.

If the weak layers are deeper than 60 cm and the overlying snow does not contain any knife-hard crusts, both the sides and upper wall of the block can be sawed with cord, which travels up one side, around ski poles or probes placed at both upper corners of the block and down the other side.

If there are knife hard crusts deeper than 60 cm the block must be isolated either with a shovel or a large rutschblock saw.

2.5.5 Results

The following chart outlines the loading sequence (1-7) in a Rutschblock test:

Field Score	**Loading step that produces a clean shear failure**	**Data Code**
1	The block slides during digging or cutting or any time before the block is completely isolated.	RB1
2	The skier/snowboarder approaches the block from above and gently steps down onto the upper part of the block (within 35 cm of the upper wall).***Snowboarders take the back foot out.***	RB2
3	Without lifting the heels, the skier/snowboarder drops from straight leg to bent knee position, pushing downwards and compacting surface layers.	RB3
4	The skier/snowboarder jumps up and lands in the same compacted spot.	RB4
5	The skier/snowboarder jumps again onto the same compacted spot.	RB5
6	For hard or deep slabs, remove skis/snowboard and jump on the same spot. For soft slabs or thin slabs where jumping without skis/snowboard might penetrate through the slab, keep the gear on, step down another 35 cm, almost to mid-block and push once then jump three times.	RB6
7	None of the loading steps produced a smooth slope-parallel failure.	RB7

Release type

When observing rutschblock tests, observe the amount of the block that releases for each weak layer fracture according to the following table:

Term	**Description**	**Data Code**
Whole block	90 – 100% of block	WB
Most of block	50 – 89% of block	MB
Edge of block	10 – 49% of block releases on a planar surface.	EB

2.5.6 Recording

Rutschblock results should be recorded in a field-book along with pertinent site information.

Record rutschblock score, release type, weak layer properties and comments. The exact percentage of the block which released can be recorded in the comments if relevant

<data code><(release type)><reference point><location in profile><"on" layer characteristics (form, size, date of burial if known)><comments>

Indicate the reference point for the fracture position (*down* = from surface; *up* = from ground). The snow surface is the default reference point for measuring fracture location. Measure down from the snow surface and record location of the fracture in the profile. When location of the fracture is measured up from the ground, record the reference point as *up* and indicate this clearly in the comments.

Example: A rutschblock fractures on the first jump. A planar fracture occurs beneath the skis/snowboard and approximately 60% of the block releases on a layer of 6 mm surface hoar (SH) that is 75cm below the snow surface and was buried 22 January, RB3 down 75 MB SH 6.0 160122.

2.5.7 Limitations

The rutschblock is a good slope test but it is not a one-step stability evaluation. The test does not eliminate the need for snow profiles or careful field observations. Nor does it, in general, replace other slope tests such as ski cutting and explosive tests.

The rutschblock only tests those layers deeper than ski/snowboard penetration. For example, a weak layer 20 cm below the surface is not tested by skis/snowboard which penetrates 20 cm or more. Higher and more variable rutschblock scores are sometimes observed near the top of a slope where the layering may differ from the middle and lower part of the slope (Jamieson and Johnston, 1993). Higher scores may contribute to an incorrect decision.

2.5.8 Effect of Slope Angle

Rutschblock results are easiest to interpret if the tests are done in avalanche starting zones. However, since there is a general tendency for rutschblock scores to increase by 1 for each

10º decrease in slope angle (Jamieson and Johnston, 1993), scores for avalanche slopes can be estimated from safer, less steep slopes (as shallow as 25º).

> *Note: Rutschblocks done on slopes of less than 30º require a smooth lower wall and a second person standing in or near the pit to observe the small displacements (often less than 1 cm) that indicates a shear failure.*

2.6 SHOVEL SHEAR TEST

2.6.1 Objective

The shovel shear test provides information about the location or locations where the snow could fail in shear. The test provides a qualitative assessment of weak layer strength and is best applied for identification of buried weak layers.

Soft snow near the surface is better tested with the shear frame (see section 2.11 "Shear Frame Test"), or the compression test (see section 2.7).

2.6.2 Equipment

The equipment required is that listed for full or test snow profiles. A saw is useful for cutting the block of snow.

2.6.3 Procedure

Select a safe site that has undisturbed snow and is representative of the slopes of interest:

a) Expose a fresh pit wall by cutting back about 0.2 m from the wall of a full snow profile or test profile.

b) Remove any very soft snow (fist hardness) or soft snow (four finger hardness) from the surface of the area where the test is to be carried out.

c) Mark on the snow surface a cross section of the column to be cut, measuring 0.25 m across the slope and 0.35 m upslope.

d) Cut a chimney wide enough to allow the insertion of the saw (or other cutting tool), at one side of the column and a narrow cut at the other side.

e) Make a vertical cut at the back of the column and leave the cutting tool (saw) at the bottom for depth identification. The back cut should be **0.7 m deep at the maximum** and end in medium hard to hard snow if possible. <u>Excavate the back cut behind the column to a sufficient width so that insertion of the shovel does not create a wedging or bending force on the column.</u>

f) Carefully insert the shovel into the back cut. Hold the shovel with both hands and apply a pull force in direction of the slope.

g) When the column breaks in a smooth shear plane above the low end of the backcut, mark the level of the shear plane on the rear (standing) wall of the backcut.

h) After a failure in a smooth shear layer or an irregular surface at the low end of the backcut, or when no failure occurs, remove the column above the bottom of the backcut and repeat steps e) to g) on the remaining column below.

i) Repeat the test on a second column with the edge of the shovel 0.1 m to 0.2 m above the suspected weak layer.

j) If no break occurs, tilt the column and tap. If a break is observed proceed to k).

k) Measure and record the depth of the shear planes if they were equal in both tests. Repeat steps c) to h) if the shear planes were not at the same depth in both tests.

l) Use the following chart to determine the approximate effort necessary to shear the snow as shown; record results:

m) Observe, classify and record the crystal shape and size at the shear planes. (Often a sample of the crystals is obtained best from the underside of the sheared block).

2.6.4 Results

Rate each fracture according to the following table:

Term	Description	Equivalent shear strength (N/m^2)	Data Code
Very easy	Fractures during cutting or insertion of shovel	<100	STV
Easy	Fractures with minimum pressure	> 100 - 1000	STE
Moderate	Fractures with moderate pressure	> 1000 - 2500	STM
Hard	Fractures with firm sustained pressure	> 2500 - 4000	STH
No Shear	no shear fractures observed		STN

Note: Observers are cautioned that identification of the location of weak layers is the primary objective of the shovel shear test. ***The shovel shear test is not a stability test****. While the rating of effort needed to break the snow may assist with a decision concerning snow failure, it is an inaccurate measurement of the snow strength. The ratings of effort are subjective and depend on the strength and stiffness of the slab, on the size, shape, length of the shovel and the length of the shovel handle.*

2.6.5 Recording

Record results according to Section 2.1.10

2.6.6 Limitations

The primary objective of the shovel shear test is to identify weak layers. The ratings of effort are subjective and depend on the strength and stiffness of the slab, on the size, shape, length of the shovel, and the length of the shovel handle.

This test does not usually produce useful results in layers close to the snow surface.

2.6.7 Figures

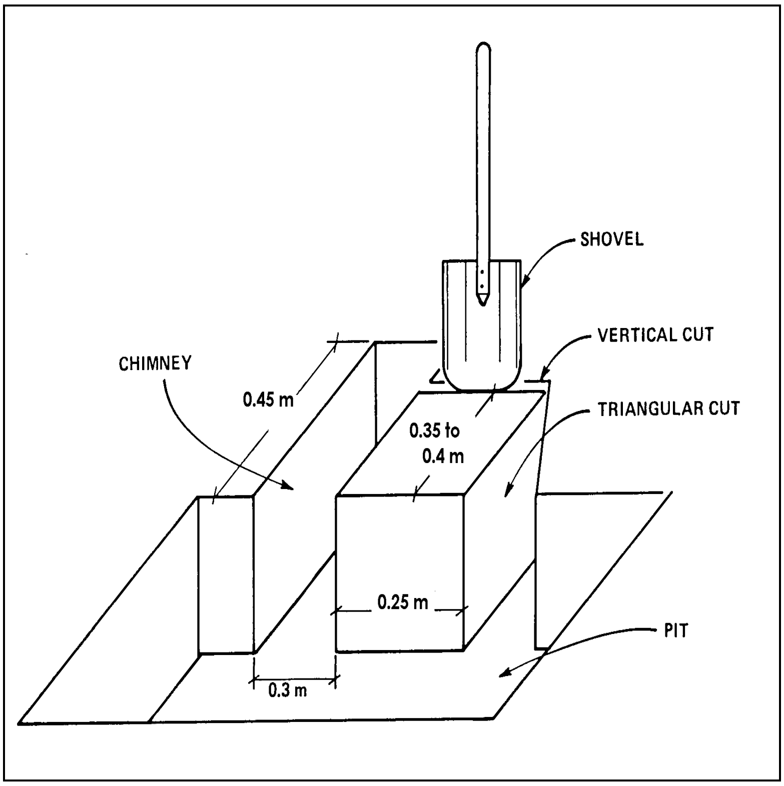


Figure 8: Shovel shear test snow column dimensions.

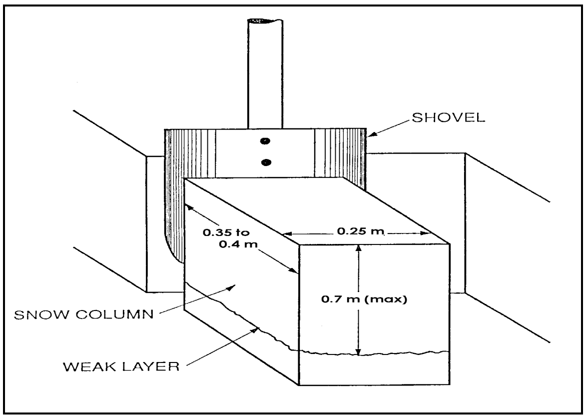


Figure 9: Shovel shear test application

2.7 COMPRESSION TEST

The test as described here was developed by Parks Canada Wardens working in the Canadian Rockies in the 1970s. The following procedure was developed by the University of Calgary avalanche research project in the late 1990's. Similar tests were also developed elsewhere.

This test is commonly used in New Zealand to locate weak layers in the upper snowpack (approx. 1m) and provide an indication of triggering potential on nearby slopes with similar snowpack conditions. This has been found to be useful for identifying new snow instabilities that are quite common in the NZ snowpack.

2.7.1 Objective

The test identifies weak snowpack layers and is most effective at finding weak layers near the snow surface. This test is quite appropriate for soft snow and is considered better than most other stability tests. Manual taps applied to a shovel blade placed on top of a snow column cause weak layers within the column to fail. These failures can be seen on the smooth walls of the column. The test can be performed on level or sloping terrain.

2.7.2 Site selection

Select a safe site that has undisturbed snow and is representative of the slopes of interest.

2.7.3 Equipment

The equipment required is the same for test snow profiles (refer to Section 2.1.4) A snow saw is useful for cutting the test column.

2.7.4 Procedure

a) Isolate a 30 x 30 cm column of snow deep enough to expose potential weak layers on the smooth walls of the column. A depth of 100 – 120 cm is usually sufficient since the test rarely produces failures in deeper weak layers. Also taller columns tend to wobble during tapping, potentially producing misleading results in deep weak layers. Rate any failures that occur while the column is being gently cut as "very easy" (CTV).

b) Place a shovel blade squarely on top of the column.

c) Tap the shovel blade 10 times with your fingertips, moving hand from wrist. Rate any failures as "easy" (CTE).

d) If the snow surface slopes, remove a wedge of snow to level the top of the column.

e) If, during tapping, the upper part of the column slides off or no longer “evenly” supports further tapping on the column, remove the damaged part of the column, level the new top of the column and continue tapping. Do not remove the portion of the column above a failed weak layer, provided that it evenly supports further tapping, since further tapping may cause failures in shallower weak layers. ***(Note: the count of the taps continues whether a failure is observed or not).***

f) Tap 10 times with your fingertips or knuckles moving forearm from the elbow. Rate any failures as “moderate”(CTM). While moderate taps should be harder than easy taps, they should not be as hard as one can reasonably tap with the knuckles.

g) Finally, hit the shovel blade, moving arm from the shoulder 10 times with open hand or closed fist. Rate any failures as "hard" (CTH). If the moderate taps are too hard, the observer will often try to hit the shovel with even more force for the hard taps – and may hurt his or her hand.

h) Rate any identified weak layers that did not fail as no failure (CTN).

i) Record your results as in section 2.1.10

2.7.5 Loading steps and Compression Test Scores

Score each failure according to the following table:

Term	Description	Data Code
Very easy	fails during cutting	CTV
Easy	fails within 10 light taps using finger tips only	CTE
Moderate	fails within 10 moderate taps from elbow using finger tips	CTM
Hard	fails within 10 firm taps from whole arm using palm or fist	CTH
No Failure	does not fail	CTN

Fracture character
Characterise the fracture according to Section 2.1.9

2.7.7 Recording

Record results according to Section 2.1.10

2.7.8 Limitations

The compression test may not produce useful results for weak layers that are very close to the snow surface. Deeper weak layers are generally less sensitive to the taps on the shovel resulting in higher ratings.

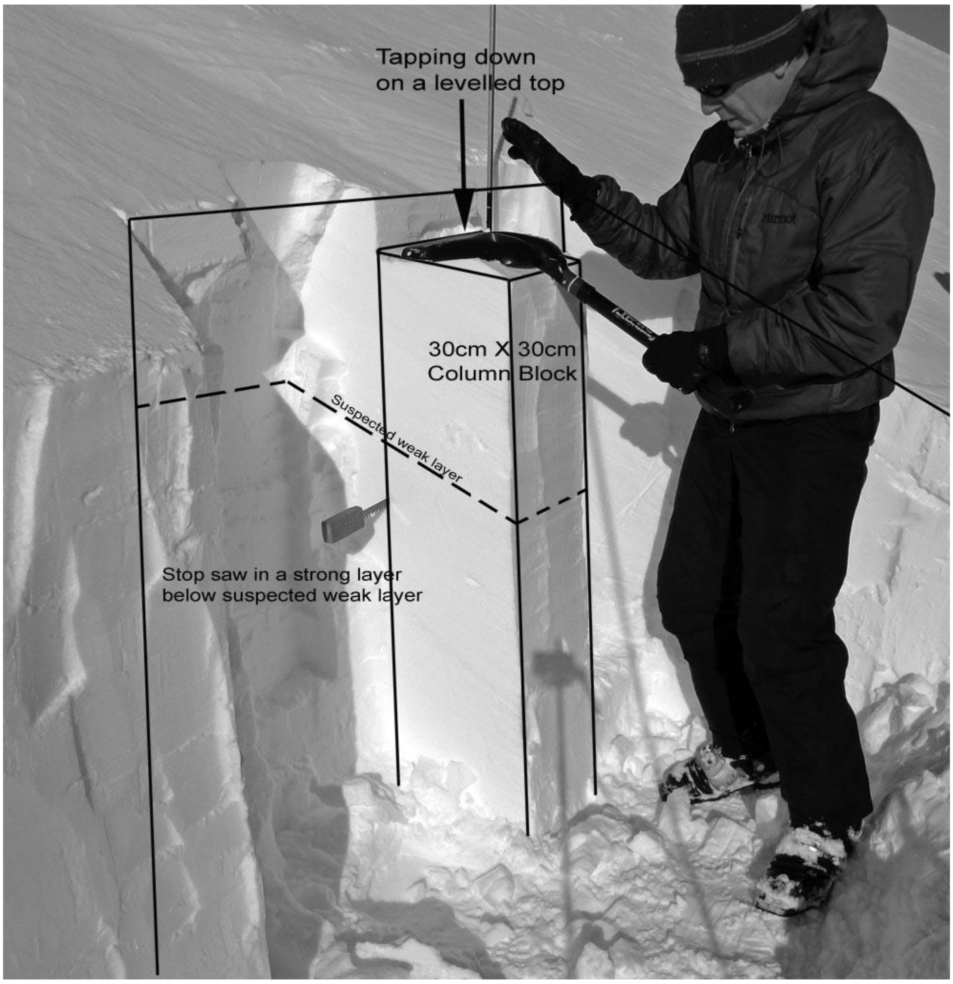


Figure 10: Compression test technique and column dimensions.

2.8 DEEP TAP TEST

2.8.1 Objective

The primary objective of the deep tap test is to determine the fracture character of a weak layer that is too deep to fracture consistently in the compression test. In addition, it is possible to observe the tapping force required for fracture to occur.

2.8.2 Site selection

Select a safe slope or flat area that has undisturbed snow and is representive of the slopes of interest.

2.8.3 Procedure

Select a safe site that has undisturbed snow and is representative of the slopes of interest. The equipment required is the same for full and test snow profiles. A snow saw is useful for cutting the test column:

a) Using a profile or other means, identify a weak snowpack layer that is overlaid by one finger (1F) or harder snow and is too deep to fracture consistently in the compression test.

b) Prepare a 30cm x 30cm column as for a compression test (note that the same column can be used after a compression test of the upper layers, provided the test did not disturb the target weak layer). To reduce the likelihood of fractures in the weak layer below the target layer such as depth hoar at the base of the snowpack, it may be advantageous not to cut the back wall more than a few centimetres below the target weak layer.

c) Remove all but 15cms of snow above the weak layer, measured at the back of the sidewall. This distance should be constant, regardless of slope angle.

d) Place the shovel blade (facing up or down) on top of the column. Apply 10 light, 10 moderate, and then 10 hard tapes as for a compression test.

2.8.4 Results

Score each fracture according to the following table:

Term	Description	Data Code
Very easy	Fractures during cutting	DTV
Easy	Fractures within 10 light taps using finger tips only	DTE
Moderate	Fractures within 10 moderate taps from elbow using finger tips	DTM
Hard	Fractures within 10 firm taps from whole arm using palm or fist	DTH
No Failure	does not fracture	DTN

Fracture character
Characterise the fracture according to Section 2.1.9.

2.8.5 Recording

Record according to Section 2.1.12

2.8.6 Limitations

While very effective for testing deeper weak layers, the number of taps required to initiate failure in the deep tap test has never been correlated with skier-triggering or avalanche activity on adjacent slopes. However, the fracture character observations (van Herwijnen, 2005) may be interpreted as in the compression test.

2.8.7 Figures

Refer to Figure 10 for deep tap test technique and column dimensions.

2.9 EXTENDED COLUMN TEST (ECT)

2.9.1 Objective

The extended column test is a snowpack test that aims to indicate the propersity (tendency) of a slab and weak layer combinations in the upper portion of the snowpack (,1m deep) to propagate a fracture.

2.9.2 Site selection

Select a safe slope or flat area that has undisturbed snow and is representive of the slopes of interest.

2.9.3 Equipment

The equipment required for the ECT includes:

a) A snow shovel.

b) One or two collapsible probes or ski poles, 2 meters of 3-4 mm cord with knots every 20-30 cm or a snow saw with extension.

2.9.4 Procedure

a) Isolate a column of snow 90 cm wide in the cross slope dimension and 30 cm deep in the upslope dimension that is deep enough to expose potential weak layers. Depth should not exceed 100 cm since the loading steps rarely affect deeper layers.

b) Rate any fractures that cross the entire column, while isolating it, as ECTPV.

c) If the snow surface slopes and the surface snow is hard, remove a wedge of snow to level the top of the column at one edge.

d) Place the shovel blade on one side of the column. and apply 10 light, 10 moderate, then 10 hard taps as for the compression test (section 2.7)

2.9.5 Recording and Results

Record the results according to the following:

<data code with ## taps><reference direction><location><"on"layer characteristics><comments>

Indicate the reference direction to locate the fracture position (down= from surface; up =from the ground). Down is the defult direction (i.e. from the snow surface), however, there may be situations where meassuring up from the ground is more convenient.

Example 1: Extended column test fractures across the entire column and the 13th tap. The column releases on a layer of 6 to 10 mm depth hoar that is 35 cm above the ground and was burried on November 22. Record as: ECT 13 up 35 on DH 6.0-10.0 Nov 22

Example 2: During testing a slab fracture occurs, which propagates into the weak layer then across the remainder of the column on the 25th tap. The column releases on a layer of 8mm surface hoar that is 65cm deep and was buried on February 14th. Record as :ECTN25 down 65 on SH 8.0 Feb 14. 14 WL fracture initiated from the slab fracture.

2.9.6 Limitations

The extended column test isnot a good tool to assess weakness in soft (F+ or less) upper layers of the snowpack or in mid-storm shear layers. In these cases the shovel edge tends to cut those soft layers. It is not a good tool to asses fracture propagation propensity on a weak layer deeper then approximately 80-100cm.

Table 2.2: Extended Column Test Scores

Description	**Data Code**
Fracture propagates across the entire column during isolation	ECTPV
Fracture initiates and propagates across the entire column on the ## tap *or* the fracture initiates on the ## tap and propagates across the column on the ## + 1 tap	ECTP##
Fracture observed on the ##tap, but does not propagate across the entire column on either the ## tap or the ##+1 tap.*	ECTN##
No fracture occurs during the test	ECTX

Note: * Fracture either propagates across only part of the column (observed commonly), or it takes more then one additional loading step to propagate across the entire column (observed relatively rarely).

Figure 11: Combined photograph and schematic of Extended Column Test (ECT)

2.10 PROPAGATION SAW TEST

The Propagation Saw Test (PST) was simultaneously developed in Canada (Gauthier and Jamieson, 2007) and in Switzerland (Sigrist, 2006). The PST has been tested in Canada since 2005 - mostly in the Columbia Mountains, in the Swiss Alps and in Colorado's continental snowpack (Birkeland and Simenhois, 2008). The PST has been shown to indicate propagation propensity in persistent weak layers (PWL) buried 30 cm to over 100 cm and occasionally up to 250 cm deep.

2.10.1 Objective

The Propagation Saw Test is a snowpack test that aims to indicate the tendency (propensity) of a pre-identified slab and a PWL combination to propagate a fracture.

Select a safe slope or flat area that has undisturbed snow and is representive of the slopes of interest.

2.10.2 Equipment

The equipment required for the PST includes:
A snow shovel.
A snow saw with a blade at least 30 cm long and approximately 2 mm thick.
For layers much deeper than the saw is long, the following are recommended:
One or two collapsible probes.
Three to five meters of 3-4 mm cord with knots every 20 - 30 cm.

2.10.3 Procedure

The PST procedure involves three main steps (after Gauthier and Jamieson, 2007): Identifying the weak layer of interest within the snowpack, isolating and preparing the test column, performing the test, and noting the results.

a) Select a safe site that has undisturbed snow and is geographically representative of the slope of interest.

b) Isolate a column 30 cm wide across the slope and 100 cm long upslope when the weak layer is less than 100 cm deep. (For layers deeper than the saw is long, two adjacent walls can be cut with a cord between probes.) When the weak layer is >100 cm deep the column length is equal to the weak layer depth in the upslope direction. The column should be isolated to a depth greater than the tested layer's depth.

c) To identify the weak layer clearly, mark the weak layer with a glove, a brush or a crystal card along the exposed column wall.

d) Drag the blunt edge of the saw upslope through the weak layer at a 10-20 cm/s speed until the fracture propagates (jumps) ahead of the saw, at which point the tester stops dragging the saw and marks the spot along the layer where propagation began.

e) After observations are complete, remove the column and check that the saw scored the weak layer in the wall behind the test column. If the saw deviated from the weak layer, the test should be repeated.

2.10.4 Results

Once the fracture propagates ahead of the saw, one of three results can be observed as noted in Table 2.3.

2.10.5 Interpretation

Fracture propagation is considered to be likely only if the fracture propagates to the end of the column, along the same layer and when the length of the saw cut is less then 50% of the column length when propagation begins (Gauthier and Jamieson, 2008). Otherwise, fracture propagation is considered unlikely (i.e. the propagating fracture fails to reach the end of the column or propagation begins when saw cut is greater than 50% of the column length).

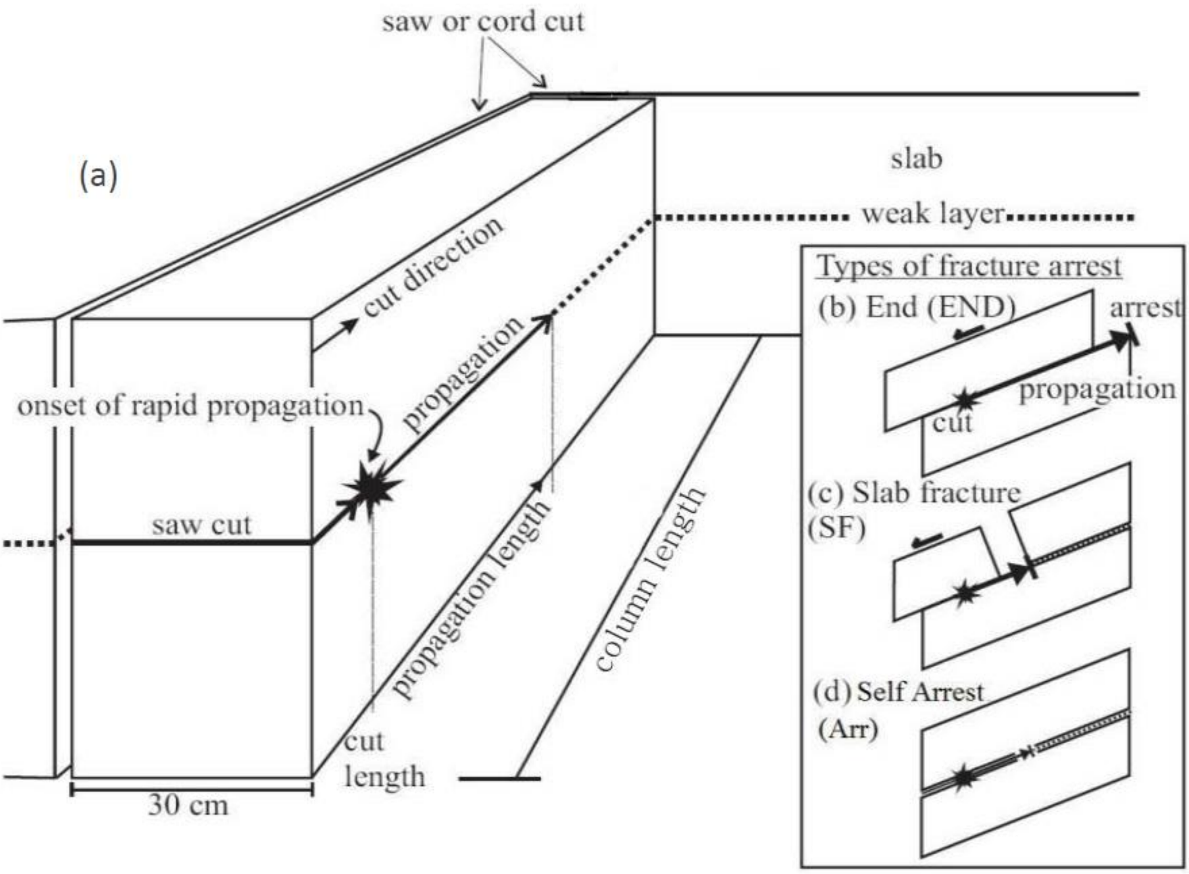


Figure 12: Schematic showing the PST column (a) and the observable results of propagation to end (b), slab fracture (c), and self arrest (d) (after Gauthier and Jamieson, 2007).

Figure 13a: The PST process from above

Figure 13b: Another PST example with result recorded as “PST 45/100 (End) down 42cm on SH 4.0 100724”.

Table 2.3: Propagation Saw Test Description and Data Codes

Term	Description	Data Code
Propagation to the end	The fracture propagates in the weak layer in front of the saw uninterrupted to the end of the column	End
Slab Fracture	The fracture propagates in the weak layer in front of the saw and stops where it meets a fracture through the overlying slab	SF
Self Arrest	The fracture propagates in front of the saw but self-arrests somewhere along the weak layer before reaching the end of the column.	Arr

2.10.6 Recording

The recording standard for the PST is as follows:

<”PST” x/y> <(fracture arrest condition> <reference direction> <location in profile> < “on” layer characteristics> < comments>

Where x is the length of the saw cut when propagation starts, y is the column length up the slope.

Indicate the reference direction to locate the fracture position (down= from surface; up =from the ground). Down is the defult direction (i.e. from the snow surface), however, there may be situations where meassuring up from the ground is more convenient.

Example: a properagtion saw test fractures across the entire column after cutting 23cm. The column releases on a layer of 6-10mm depth hoar that is 135 cm below the surface and was buried on November 22. Record as : PST 23/135 End down 135 on DH 6.0-10.0 Nov 22

2.10.7 Limitations

The propagation saw test tends to give false-stable results for soft shallow slabs and when the weak layer is to diffucult to cut with the saw's blunt edge. Pre-selecting and identifying the layer of concernfor testing can be challenging. The cut distance (x) may depend on the slope angle.

2.11 SHEAR FRAME TEST

2.11.1 Objective

The shear test with tilt board and shear frame is an index observation of the stability of most weak layers including those in new or partially decomposed or fragmented snow.

2.11.2 Location

The shear frame test is performed together with snow and weather observations on a study plot. The observation site must be level and the snow surface undisturbed by wind for meaningful and reproducible test results.

2.11.3 Equipment

The shear frame test requires the following equipment:

- Metal cutting plate about 300 mm x 300 mm
- Shear frame, usually 100 or 250 cm^2 area
- Force gauge, maximum capacity 10 to 25 N (1 to 2.5 kg)
- Snow sampling tube
- Weigh scale
- Ruler
- Tilt board (optional)

2.11.4 Field-book

The shear frame test, as part of the snow and weather observations, may be recorded at the bottom of the field-book page for snow and weather observations, or on a separate page if necessary.

Make a note of the area of the shear frame and the cross section area of the sampling tube.

2.11.5 Procedure

Locating the Weak Layer

There are several ways of finding a weak layer. The method described here is for study plots with tilt boards.

a) Cut a block of undisturbed snow with sides about 0.3 m x 0.3 m and 0.3 m to 0.4 m depth. A second deeper block of similar size must be collected if the suspected failure plane is deeper than 0.4 m.

b) With the cutting plate, lift the snow block onto the horizontal tilt board.

c) Tilt the board to an angle of about 15°. Tap the board gently until a shear failure occurs in the snow.

d) Measure the depth of the failure plane from the surface at the side of the block; record it under "Shear Depth."

e) Collect a sample of snow on the tilt board by inserting the sampling tube perpendicularly to the snow surface to the depth of the failure plane. Weigh the sample and record the net weight under "Shear Weight".

f) Establish the location of the failure plane in the snowpack by measuring the shear depth from the surface.

Applying the Shear Test

a) Remove overlying snow with a cutting plate leaving a few cm of undisturbed snow above the failure plane.

b) Gently push the shear frame, by holding it with thumb and index finger, down through the snow to a few mm above the failure plane.

c) Zero the force gauge then hook it to the frame and pull parallel to the failure plane. Read and record the force required to produce a failure.

d) Repeat the process several times to confirm consistency.

2.11.6 Stability Ratio Calculation

a) Determine the shear strength by dividing the force at failure (measured in g) by the area of the shear frame (measured in cm^2).

b) Determine the weight of snow per unit area by dividing the weight of the snow sample (measured in g) by the cross-sectional area of the sampling tube (measured in cm^2).

Calculate the stability ratio by dividing the shear strength by the weight per unit area:

Stability ratio = Shear strength (g/cm^2) / Weight per unit area (g/cm^2).

2.11.7 Reliability

Experience is required to produce reliable data. The success of the test depends on:

- carefully removing the snow block above without disturbing the layer to be tested;
- inserting the shear frame close to the failure plane and parallel to it without causing a premature failure;
- pulling the shear frame at a constant rate.

Units of Measurement

The stability ratio (previously termed a stability factor) has no units. However it is preferable in its calculation to use SI units rather than other metric units. With SI units the shear force should be expressed in Newtons (N) and the shear frame index in Pascals (1 Pa = 1 Newton per square metre). Because available spring balances may be calibrated in other metric units, gram (g) and gram per square centimetre (g/cm^2) may be used for both the shear force index and weight per unit area.

2.12 SNOWPACK SUMMARY

2.12.1 Objectives
Snowpack summaries provide a clear and concise overview of snowpack conditions to assist stability and hazard analysis and forecasting for the operational region. The objective of such a summary is to organise and reduce data.

Snowpack summary parameters are different from snowpack observation parameters in that they are not recorded at a specific location and time but are a general characterisation of the range of conditions encountered in a broader geographical area during the day. This not only includes average conditions but also potential anomalies and outliers.

2.12.2 Frequency
Summaries are generally done once a day, at the end of the day.

2.12.3 Procedure
The following parameters should be recorded in a snowpack summary:

- Date

  Record date as described in section 1.4.1
- Time period

  The time range during which the snowpack observations were made
- Locations and elevations range
- Locations and elevation where snowpack observtions were made. Many operations will record a drainage as a single location.
- Percent of area observed
- The area observed record as a percentage of the entire operational region.
- Snow profile

  Summarize relevent measurements as described in Section 2.2.4 for a tst profile. This includes slab proberties, weak layers attributes, tempature gradients, etc.
- Stability tests

  Characterize stability test results as described in Section 2
- Comments

  Make any additional comments as required. These may include notes on signs of instabiliy, settlement, and the effects of wind, air temperature and solar radiation.

3. AVALANCHE OBSERVATIONS

3.1 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 have released earlier in the winter, thus snow stability may vary between these sites and 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.
- To further the understanding of avalanche phenomenon through research

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

3.2 IDENTIFICATION OF AVALANCHE PATHS

Avalanche paths should be identified by a key name, number, aspect, or a similar identifier that should be referred to on lists, maps, or photographs. At roads, railway lines and power lines it is convenient to refer to avalanche paths by the running kilometre.

Avalanche starting zones that can produce avalanches independently are often divided into sub zones. Separate targets for explosive control may be identified within each start zone.

Some operators choose to catalogue their paths with a photo.

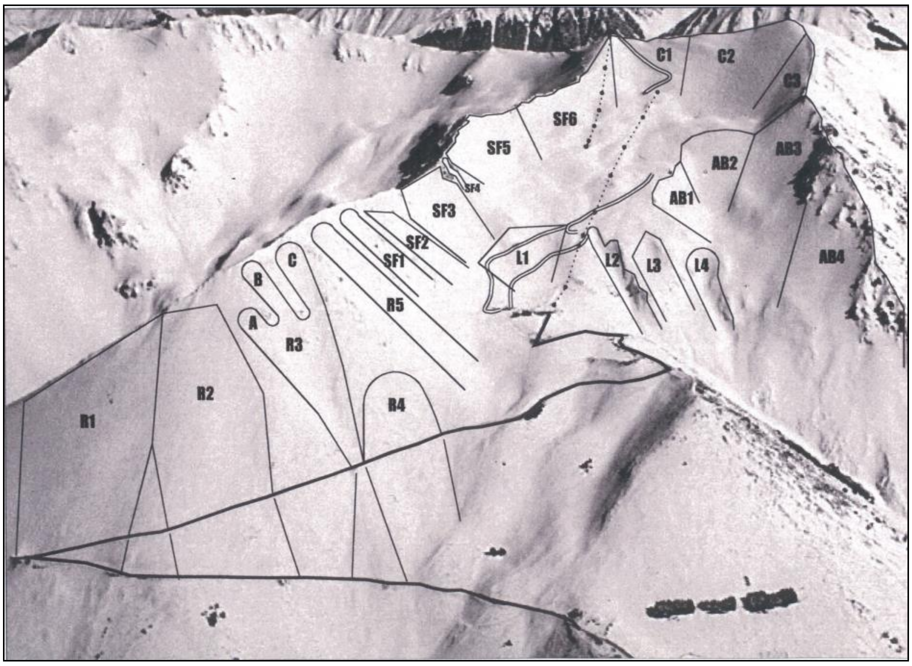


Figure 14, Mt. Cheeseman Avalanche Atlas, 2002.

3.3 OBSERVATIONS OF INDIVIDUAL AVALANCHES

The following section describes techniques used to classify individual avalanches. These guidelines should be followed for all significant events.

Section 3.5 describes a classification system that can be used to report groups of similar events or to summarise the level of avalanche activity in a particular area.

A set of core observations is best recorded on the left-hand page of the field-book (see sample page, Figure 15) or on photographs. The right-hand page may be used for comments and additional observations.

3.3.1 Date

Record year, month and day of the avalanche occurrence. (avoid spaces, commas etc.) e.g., August 1, 2002, is noted as 020801.

3.3.2 Time

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

Estimate and record the age (in hours) of the avalanche.

If the avalanche release was witnessed then the observation time is the time of the occurrence and the age will be 0 hours

Valid entries 0, 0.5, or 1 to 99 hours. Zero indicates that the time is precisely known

Note: +/- 0 is used when the time of occurrence is precisely known.

3.3.3 Area and Path

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

Note: It is not necessary to record the area in every entry of a field-book 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 kilometre. In this case 2 decimal places may be used to identify paths within a whole kilometre.

3.3.4 Aspect

Use eight cardinal points of the compass to specify the avalanche's <u>central</u> aspect in the starting zone.

3.3.5 Elevations

With reference to a contour map record the elevation (in mASL) of the:

* Fracture line or point of failure in the start zone;
* Deposit in the runout zone.

3.3.6 Slope inclination

Record the estimated incline of the starting zone. Add ‘M’ if measured

3.3.7 Size

Estimate the destructive potential of the avalanche from the 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 could have caused.

Size & Data Code	Avalanche Destructive Potential	Typical Mass (t)	Typical path length (m)
1	Relatively harmless to people.	<10	10
2	Could bury, injure, or kill a person.	100	100
3	Could bury and destroy a car, damage a truck, destroy a wood frame house, or break a few trees.	1000	1,000
4	Could destroy a railway car, large truck, several buildings, or a forest area up to 4 hectares (~10 acres).	10,000	2,000
5	Largest snow avalanche known. Could destroy a village or a forest of 40 hectares (~ 100 acres).	100,000	3,000

Note: Size 1 is the minimum size rating. In general, half sizes are not defined, but may be used by experienced practitioners for avalanches that are midway between defined avalanche size classes (e.g. size 2.5).

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 were given by McClung and Schaerer (2006).

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

Another scale used to estimate avalanche size is the **'Relative to Path'** or “**R**” scale. This is used in North America and is gaining traction here in NZ. 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.

When estimating, consider horizontal extent and vertical depth of the fracture, the volume and mass of the debris, and the runout distance of the avalanche.

The classification table is included below and may be recorded alongside the Destructive size to describe the extent of the path that has run and the destructive size of that event. An example would be R3D2 meaning that the avalanche was medium relative to the path and size 2 in its destructive potential. (Use the comments section when recording ‘R’ size into the InfoEx system).

Size & Data Code	Avalanche size - Relative to Path
R1	Very small, relative to path
R2	Small, relative to path
R3	Medium, relative to path.
R4	Large, relative to path
R5	Major or maximum, relative to path

3.3.8 Type of Avalanche

Record the type of avalanche as described in the following table. Use a 'Sub' type where possible but only when evidence is present, otherwise describe using a 'Main' type.

Symbol & Data code		Avalanche type	Description
Main	**Sub**		
S		**Slab**	• Release of a cohesive layer of snow (a slab) evidenced by a remaining crown wall, and blocks of snow in the debris.
	Sst	Storm slab	• Release of a soft cohesive layer (a slab) of new snow which breaks within the storm snow or on the old snow surface. • Storm-slab problems typically last between a few hours and few days. • Storm-slabs that form over a persistent weak layer (surface hoar, depth hoar, or near-surface facets) may be termed Persistent Slabs or may develop into Persistent Slabs.
	Swd	Wind slab	• Release of a cohesive layer of snow (a slab) formed by the wind. • Wind typically transports snow from the upwind sides of terrain features and deposits snow on the downwind side. • Wind slabs are often smooth and rounded and sometimes sound hollow, and can range from soft to hard. • Wind slabs that form over a persistent weak layer (surface hoar, depth hoar, or near-surface facets) may be termed Persistent Slabs or may develop into Persistent Slabs.
	Sp	Persistent slab	• Release of a cohesive layer of soft to hard snow (a slab) in the middle to upper snowpack, when the bond to an underlying persistent weak layer breaks. • Persistent layers include: surface hoar, depth hoar, near-surface facets, or faceted snow. • Persistent weak layers can continue to produce avalanches for days, weeks or even months, making them especially dangerous and tricky. • As additional snow and wind events build a thicker slab on top of the persistent weak layer, this avalanche problem may develop into a Deep Persistent Slab.
	Sdp	Deep persistent slab	• Release of a thick cohesive layer of hard snow (a slab), when the bond breaks between the slab and an underlying persistent weak layer, deep in the snowpack or near the ground. • The most common persistent weak layers involved in deep, persistent slabs are depth hoar, facets surrounding a deeply-buried crust and less commonly deeply-buried surface hoar. • Deep Persistent Slabs are typically hard to trigger, are very destructive and dangerous due to the large mass of snow involved, and can persist for months once developed. • They are often triggered from areas where the snow is shallow and weak, and are particularly difficult to forecast for and manage. • They commonly develop when Persistent Slabs become more deeply-buried over time.
	Swt	Wet slab	• Release of a cohesive layer of snow (a slab) that is generally moist or wet when the flow of liquid water weakens the bond between the slab and the surface below (snow or ground). • They often occur during prolonged warming events and/or rain-on-snow events. Wet slabs can be very destructive.

Symbol & Data code		Avalanche type	Description
Main	**Sub**		
	Sg	Glide slab	• Release of a cohesive layer of snow (a slab or blocks) as a result of gliding over a smooth bed surface, usually the ground or a basal ice layer. • Can be composed of wet, moist, or almost entirely dry snow, and typically occur in very specific paths. • Often preceded by full depth cracks (creep and glide). • Difficult to manage as the timing of release is often highly uncertain.
L		**Loose**	• Release of unconsolidated snow starting from a point entraining snow as they move downhill, forming a fan-shaped avalanche.
	Ld	Loose dry	• Release of dry unconsolidated snow. • These avalanches typically occur within layers of soft snow near the surface of the snowpack. • Loose-dry avalanches start at a point and entrain snow as they move downhill, forming a fan-shaped avalanche. • Other names for loose-dry avalanches include point-release avalanches or sluffs. • Loose-dry avalanches can trigger slab avalanches that break into deeper snow layers.
	Lw	Loose wet	• Release of wet unconsolidated snow or slush. • These avalanches typically occur within layers of wet snow near the surface of the snowpack, but they may quickly gouge into lower snowpack layers. • Like Loose-Dry Avalanches, they start at a point and entrain snow as they move downhill, forming a fan-shaped avalanche. • They generally move slowly, but can contain enough mass to cause significant damage to trees, cars or buildings. • Other names for loose-wet avalanches include point-release avalanches or sluffs. • Loose-wet avalanches can trigger slab avalanches that break into deeper snow layers.
C		**Cornice fall**	• Release of an overhanging mass of snow that forms as the wind moves snow over a sharp terrain feature, such as a ridge, and deposits snow on the down-wind side. • They range from small wind lips of soft snow to large overhangs of hard snow that are 10 meters or more. • They can break off the terrain suddenly and pull back onto the ridge top and catch people by surprise even on the flat ground above the slope. • Even small cornices can have enough mass to be destructive and deadly. • Cornice fall can entrain loose surface snow or trigger slab avalanches.
I		**Ice fall**	• Toppling or collapsing ice masses. • Usually restricted to glaciated areas, but can occur within seasonal ice forms.

Note: In the comments section add "+S" to a recording if a subsequent slab is set in motion, or if the initial slab "steps down" and slides on a deeper weakness. This additional slab could be the more important observation as often a cornice or icefall is more of a trigger mechanism.

Record the slab hardness if observed. Hardness can be measured using the hand hardness test (i.e. 1F, P, etc.) in the starting zone or from the deposit in the runout zone, where the slab is still recognisable.

3.3.9 Liquid Water Content

Liquid Water Content in Start Zone

Determine the liquid water content of the avalanche snow in the starting zone at the time of failure.

Symbol and Data Code	Liquid Water Content in the Avalanche Start Zone
D	Dry snow
M	Moist snow
W	Wet snow

Liquid Water Content of Deposit

Determine the liquid water content of the avalanche snow at the time and location of the deposit.

Symbol and Data Code	Liquid Water Content of Deposit
D	Dry snow
M	Moist snow
W	Wet snow

3.3.10 Terminus

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

Symbol & Data Code	Terminus
SZ	The avalanche stopped in the Start 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 Runout zone
BR	The avalanche stopped in the Bottom part of Runout zone
for short paths	
TP	The avalanche stopped near the Top part 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

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

Operations that have avalanche paths with well defined features may apply additional codes; for example:

Symbol and Data Code	Terminus
1F	Avalanche stopped on the top 1/4 of the fan
2F	Avalanche went halfway down the fan
3F	Avalanche went 3/4 of way down of the fan

3.3.11 Trigger

Indicate the cause of avalanche release with a basic code letter and, where possible, a modifier. Operations may devise other trigger sub classes that apply to their specific conditions.

Symbol and Data Code	Cause of Avalanche Release
N	Natural triggers
X	Explosives
S	Skier etc.
B	Snowboarders
C	Climber, snowshoer, etc
M	Snowmobiles
V	Over-snow Vehicles (snowcat, etc)
U	Unknown trigger
H	Helicopter
O	Other (Specify in comments)

Note: *Avalanches that start when a helicopter or other aircraft flies overhead should be considered to have started naturally.*

A remote event is one occurring at some distance (typically > 5 m) from the probable trigger. The snow at the trigger point does not move. Specify the distance to asympathetic and remote event (in metres).

A more detailed trigger classification system is presented in the following table:

Symbol	Cause of Avalanche Release
Natural Triggers = N:	
Na	Natural (the result of weather events such as snowfall, wind, temperature)
Nc	Cornice fall, natural
Ne	Earthquakes
Ni	Ice falls
Explosives = X:	
Xa	Artillery
Xc	Cornice controlled by explosives
Xe	Hand thrown or hand placed explosive charge (includes road/case charges)
Xg	Gas exploder
Xh	Helicopter bomb
Xl	Avalauncher and other types of launcher
Xp	Pre-placed remotely detonated explosive charge
Xt	Tram or ropeway delivery system
Xr, __m	A remote avalanche occurring at some distance from an explosion
Xy, __m	An avalanche occurring in sympathy with one released by explosives
Skier = S:	
Sa	Skier, accidental
Sc	Skier, controlled (e.g., skier deliberately ski cutting a slope, cornice, etc.)
Sr, __m	A remote avalanche occurring at some distance from a skier
Sy, __m	An avalanche occurring in sympathy with one released by a skier
Snowboarder = B**:**	
Ba	Snowboarder, accidental, etc
Bc	Snowboarder, controlled (e.g., deliberately cutting a slope, cornice, etc.)
Br, __m	A remote avalanche occurring at some distance from a snowboarder
By, __m	An avalanche occurring in sympathy with one released by a snowboarder
Climber = C**:**	
Ca	Climber, snowshoer, tramper or other person on foot, accidental.
Cc	Climber, controlled (e.g., deliberately cutting a slope, cornice, etc.)
Cr, __m	A remote avalanche occurring at some distance from a climber, etc
Cy, __m	An avalanche occurring in sympathy with one released by a climber, etc
Snowmobiles = M:	
Ma	Snowmobile, accidental
Mc	Snowmobile, controlled (e.g., a snowmobiler crossing the top of a slope)
Mr, __m	A remote avalanche occurring at some distance from a snowmobile
My, __m	An avalanche occurring in sympathy with one released by a snowmobile
Over-snow vehicles (other than snowmobiles) = V:	
Va	Over-snow vehicles (snow cats, maintenance equipment, etc.), accidental
Vc	Over-snow vehicles, controlled (deliberate cornice control, etc.)
Vr, __m	A remote avalanche occurring at some distance from a machine
Vy, __m	An avalanche occurring in sympathy with one released by a machine
Helicopters = H:	
Ha	Helicopter, accidental on landing, prop wash when Heli is on the snow, etc
Hc	Helicopter, controlled (e.g., deliberate landing on top of slope, etc.)
Hr, __m	A remote avalanche occurring at some distance from helicopter landing
Hy, __m	An avalanche occurring in sympathy with one released by a helicopter
Artificial triggers (Miscellaneous):	
U	Unknown
O	Other (Specify in Comments)

3.3.12 Comments
Enter information about damage and accidents caused by the avalanche and any other significant information. Describe weather phenomena suspected as the trigger (i.e. rising or falling temperature trend, solar effect, wind loading, wind gust, precipitation intensity)

Avalanche Observations					Observer *B. A.*			
Location *Backcountry, West*						Start Zone		
Date	Time	Area & Path	Asp	Size	Type	Elevation	Term	Comments
020912	*~*	*Kea*	*E*	*2.5*	*S*	*1700*	*MP*	
020912	*1500*	*km 18*	*SE*	*2*	*~*	*1600*	*TR*	
020913	*1500*	*Stoat*	*E*	*4*	*S*	*1850*	*BP*	*Several trees broken*
								in creek, deposit
								up to 10m deep
020914	*1110*	*Dan's*	*NE*	*1.5*	*L*	*1750*	*TR*	

Figure 15: Sample field-book page for basic avalanche observations.

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

For operations that control avalanches by explosives note the:

* Number of explosive charges;
* Type of explosive charge;
* Size of charges (kg);
* Target;
* Location of avalanche starting zone;
* Sliding surface.

When explosives were used but no avalanche resulted or charges misfired note the:

* Number of explosive charges;
* Type of explosive charge;
* Size of charges (kg);
* Target;
* Location of charges.

For highway operations note the:

* Length of road buried;
* Average and maximum depth of snow on the road centreline;
* Distance of the toe of the avalanche from the uphill edge of the road.

For ski areas note the:

* Target;
* Location of avalanche start;
* Failure plane and bed surface (note the date of burial and predominant grain type where possible);
* Width and thickness of slab avalanches at their crown.

3.4.1 Number of Explosive Charges/Number of Detonations
Record the number (1 – 9) of projectiles or explosive charges applied to a target. Record the number (1 – 9) of confirmed detonations.

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

3.4.2 Size of Explosive Charge
Note the amount of explosive per charge.

3.4.3 Location of Avalanche Start
Position in Start Zone

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

Symbol and Data Code	**Location of Start**
T	At the top of the starting zone
M	In the middle of the starting zone
B	At the bottom of the starting zone
U	Unknown

Incline of Start Zone

Record the incline of slope in the avalanche start zone (0 to 90 degrees).

3.4.4 Bed Surface
Level of Bed Surface

Record the level of the bed surface (the layer over which a slab slides) in the snowpack.

Symbol and Data Code	**Bed Surface**
S	The avalanche started sliding within a layer of recent storm snow or at the base of the storm snow on an older snow surface.
O	The avalanche released within the old snow.
G	The avalanche released at the ground.
U	Unknown

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

Form and Age of Failure Plane

Record the predominant grain form observed in the failure plane (refer to Appendix E). Where possible identify the failure plane by its probable date of burial. Use the comments section to note the occurrence of a failure that steps down to other layers.

3.4.5 Slab Width (in meters)
In a slab avalanche, record the width of the slab (in metres) between the flanks near the fracture line. Add "M" when the width was actually measured**.** Observers may wish to use a hip chain to calibrate their estimates.

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

3.4.6 Slab Thickness (in centimetres)
Estimate or measure in a vertical direction, to nearest 10cm, the average thickness of the slab at the fracture line. Add "M" when thickness was actually measured.

3.4.7 Deposit on Road

Record in metres the length of road, ski run, power line, or other facility buried in avalanche snow.

Give average depth at centre line and maximum depth of avalanche snow on the road, etc., in metres and tenths of a metre. Add "M" when length and depth were measured.

3.4.8 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.

3.4.9 Total Deposit Dimensions

Record the average width and length of the deposited avalanche snow in metres.

Record the average deposit depth in metres and tenths of a metre. Add "M" after each value if measured by tape and probing.

3.4.10 Length of Path Run

Some operations may wish to record estimated distance along a slope an avalanche ran.

* Up to a distance of 300 m estimate the distance run to nearest 25m.
* Beyond a distance of 300 m estimate the distance run to nearest 100m.

3.4.11 Road Status

Transportation operations should record the status (open or closed) of any roads at the time when the avalanche occurred.

Avalanche Observations (Road)				Area *MR*		Observer *B.C.*		
Date	*010712*	*010713*						
Time	*0900*	*1320*						
Time ± Hours	*4*	*0*						
Path	*22.3*	*21.5*						
Road open/closed	*Open*	*Closed*						
Size	*2.0*	*2.5*						
Type	*S*	*S*						
Lqd water – deposit	*W*	*W*						
Terminus	*MR*	*BR*						
Trigger	*Na*	*Xh*						
Toe distance mass	*-25*	*10*						
Toe distance dust	*~*	*~*						
Length Rd Buried	*0*	*20*						
Max depth on road	*0*	*3.5*						
Avg depth on road	*0*	*1.2*						
Avg length deposit	*50*	*120*						
Avg width deposit	*35*	*30*						
Avg depth deposit	*4*	*5*						
Damage / Incident	*Nil*	*Nil*						
Comments	*~*	*glide*						
		cracks						
		visible						

Figure 16: Avalanche occurrence field-book page for road operations.

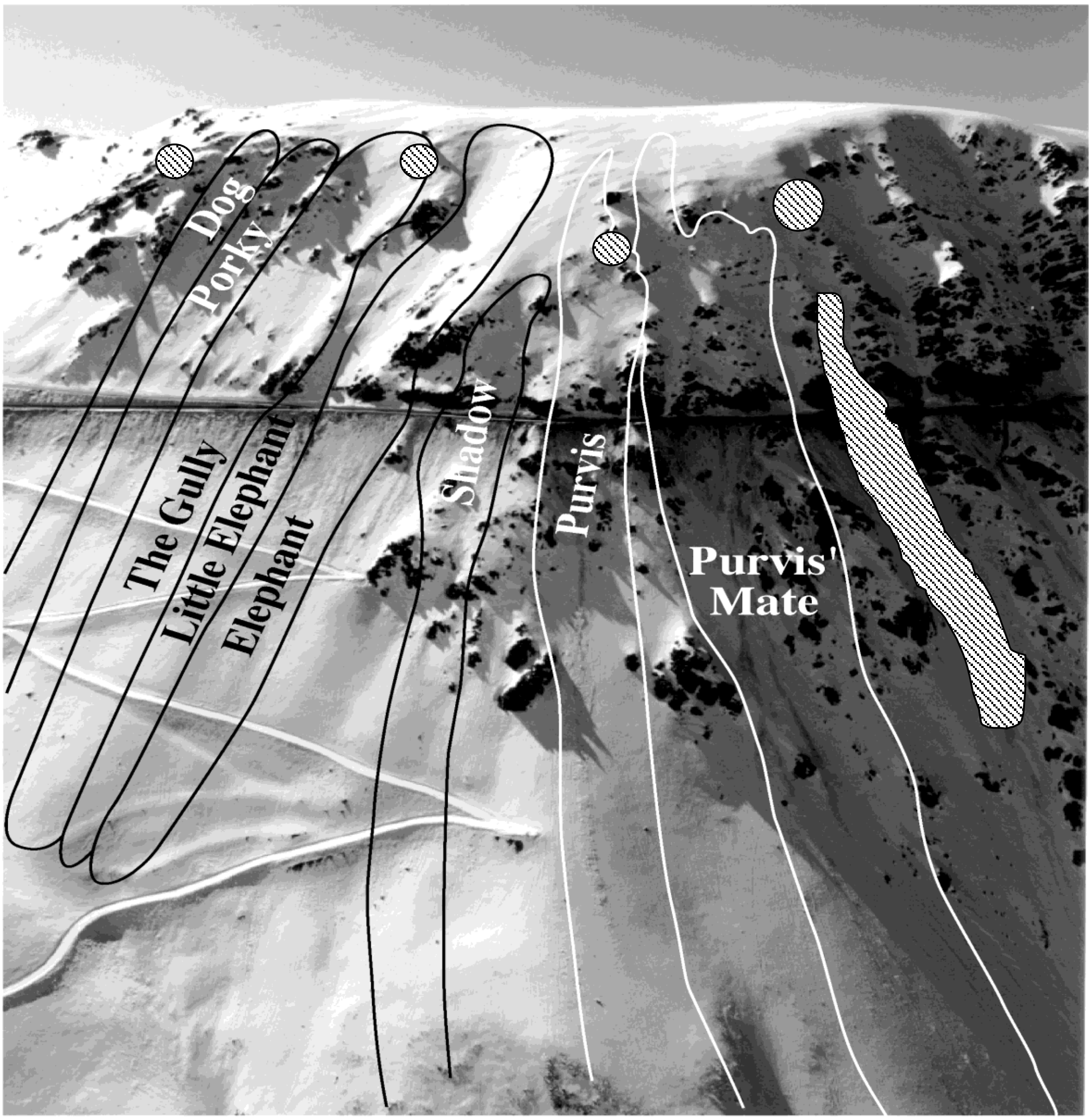
Avalanche Observations (Ski Area)		Location *Totara Hectares*	Observer *J. S.*	
Date	*020811*	*020811*	*020811*	*020811*
Time	*0400*	*0530*	*0820*	*0910*
Time Range ± Hours	*4*	*2*	*0*	*0*
Path	*Black Jack*	*Betty*	*Jim's*	*Granite*
Size	*1.5*	*3.0*	*2.0*	*3.0*
Type	*L*	*S*	*S*	*S*
Lqd water in start zone	*D*	*D*	*D*	*D*
Lqd water in deposit	*D*	*D*	*D*	*D*
Terminus	*TP*	*BP*	*MP*	*BR*
Trigger	*Na*	*Na*	*Xe*	*Sc*
Target	*~*	*~*	*3*	*~*
No. of charges	*~*	*~*	*1*	*~*
Type of Charge	*~*	*~*	*Pgel*	*~*
Charge size	*~*	*~*	*1*	*~*
No of detonations	*~*	*~*	*1*	*~*
Start location	*T*	*T*	*T*	*T*
Level of bed surface	*S*	*S*	*O*	*G*
Grain form fail. pl.	*SH*	*SH*	*SH*	*DH*
Age of failure plane	*020731*	*020731*	*020731*	*020716*
Slab width	*~*	*90*	*60*	*120*
Slab thickness	*~*	*80*	*50*	*160*
Aspect	*NE*	*NE*	*E*	*N*
Elevation	*1900*	*1900*	*1750*	*1800*
Comments		*Stopped at edge*		*Patroller Mark S.*
		of bench		*partially buried*

Figure 17: Sample field-book page for avalanche observations at a ski area with active control.

Note: From 2011, an update to InfoEx allows recording of avalanches as both text, oblique photo overlays, and a 3D GIS application.

Below is an example of a manual oblique photo overlay. This format includes an oblique photo with slide path, maximum runout details, etc. drawn in the relevant part of the photo.

Details of the avalanche can then be recorded, while at the same time the explosive charge position can be drawn by a large dot or "X". The results can also be illustrated by shading the relevant slide path as in the large area on the right.



Location	Number	Time	Aspect	Size	Type	Elev.	Term.	Trig.	Dist
Ogre's Mate	1	1730	SW	2.0	S	1770	MR	Xe	500
Control route, rock shots effective.									

Figure 18: Sample avalanche observation at a ski area with active control, Mt. Hutt Ski Area.

3.5 MULTIPLE AVALANCHE EVENTS

An operation may wish to group large numbers of similar avalanche events into one record or report, especially if that information is to be sent to a central information exchange, such as the NZ Avalanche Information Exchange. The 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 (e.g., natural versus artificially released avalanches).

Parameter	Criteria	Examples
Date	Most probable (median) date for activity as year month day	000911
Time	Digits	0900
Time range	Digits (± 0 to 99 hours)	48
Area (location)	Text (80 characters max.)	"proposed SW recreation area"
Number of occurrences	Digits or keywords acceptable	1 to 99, Several (2 to 9) Numerous (10 or more)
Size	The range of any one report should be limited to 1½ size classes	1.5 - 3.0
Trigger	Key letter (do not mix natural and artificial triggers in this report)	Xe
Type	Key letter (do not mix slab and loose)	S, L
Aspect (of start zone)	Keyword, one or a combination of the eight points of the compass	All, W, SW-NW
Elevation (at fracture)	600 m maximum range	1800 - 2400 m
Incline (at fracture)	20 degree maximum range	32 - 42 degree
Level of bed surface	Key letter (do not mix storm snow, old snow and ground)	S, O, G
Grain form at failure plane	Grain form abbreviation	SH
Age of failure plane	Probable date of burial	000814
Slab width	Range (in m)	60 - 110 m
Slab thickness	Range (in cm)	10 - 30 cm
Length of path's run	Range (in m)	500 - 1500 m
Comments	maximum of 5 lines by 80 characters per line	

Note: Significant avalanches (larger than size 3), events involving incident, damage or injury should not be described in this method. They must be described individually.

3.6 AVALANCHE SUMMARY

3.6.1 Objectives

Avalanche summaries provide a clear and concise overview of avalanche conditions to assist stability and hazard analysis and forecasting for the operational region. The objective of such a summary is to organise and reduce data.

Avalanche summary parameters are different from avalanche observation parameters in that they are not recorded at a specific location and time but are a general characterisation of the range of conditions encountered in a broader geographical area during the day. This not only includes average conditions but also potential anomalies and outliers.

3.6.2 Frequency

Summaries are generally done once a day, after the field day is completed.

3.6.3 Procedure

The following basic avalanche observations should be recorded in an avalanche summary:

- Locations and elevation range

  Locations and elevation where the avalanche observtions were made. Many operations will record a drainage as a single location.

- Percent of area observed

  The area observed record as a percentage of the enture operational region.

- Date of occurrence

  The occurance date as outlined in section 3.3.1. If the actual date is unknown, estimate based on previous weather, conditions of the crown and deposit, etc.

- Time period

  The time range during which the avalanche(s) were observed and the range of the avalanches as outlined in section 3.3.2

- Number

  The number of avalanches of each type and trigger that involved each failure plane amd occurred on each date.

- Size

  The typical size of the avalanche observed and the maximum size observed, as discribed in section 3.3.7 for each type, trigger, failure plane and occurance date.

- Trigger

  Record the cause of avalanche release as outlined in Section 3.3.11

- Type

  Record the type of snow failure as described in Section 3.3.8

- Incline

  The average or range of starting zone inclines for each type, trigger and occurance date

- Aspect

The average or range of starting zone aspects for each type, trigger failure plane and occurance date

- Elevation

  The average or range of starting zone elevation for each type, trigger failure plane and occurance date

- Depth
- The average or range of slab thickness values for the slab, loose snow + slab, cornice fall + slab or ice fall + slab avalanches and for each trigger, failure plane and occurance date.
- Width

  The average or range of slab width values for the slab, loose snow + slab, cornice fall + slab or ice fall + slab avalanches and for each trigger, failure plane and occurance date.
- Length

  The average or range of length of path run values, as described in Section 3.4.11 for each type of trigger, failure plane and occurrence date.
- Failure plane

  Record the predominant grain and level in the snowpack for the failure plane as described in Section 3.4.4.
- Comments

  Make any additional comments as required. These may include notes on whumpfs, factures propagation, slab properties and weak layer attributes

3.6.4 Recording

Always record the names (initials are fine) of observers with the primary observer listed first. Use a tilde (~) in the field-book when no observation was made. Code as 'U' if the observation was attempted but no reliable value could be ascertained (i.e. when an old avalanche is observed and the trigger or type of snow failure cannot be discerned). Do not leave blanks. Only write '0' when the reading is zero (i.e. when the length of road, railway line or ski run buried by the avalanche is zero).

APPENDIX A--WEATHER OBSERVATION SITES AND PROCEDURES

Measurements of precipitation, temperature, wind and the characteristics of the snowpack are dependent on the observation site. Because it is usually impossible to find a place that would both duplicate the conditions in the avalanche starting zones and be safe and accessible for regular, daily observations, one must be satisfied by choosing a site that provides a good correlation between the measurements and snow stability. This means that observational data are only indicative of the conditions in the avalanche paths.

Site selection requires knowledge of the area and skill in meeting contradictory needs. Sometimes parallel observations may have to be carried out in several possible locations for one winter before a permanent site is chosen, or a site may have to be abandoned after yielding unsatisfactory correlations with avalanche occurrences.

Observation sites for precipitation and those for wind speed are incompatible. Data on precipitation, often the most important parameter, should be collected at a location sheltered from the wind, whereas wind observations need an exposed site. For practical reasons, temperature observations usually are carried out together with precipitation measurements, but it is preferable to supplement these data with temperature observations at a wind station.

The following guidelines apply to the selection of observation sites:

A.1 Precipitation, Snowpack and Temperature Study Plots

The observation site should be as close as possible to the avalanche starting zones.

The location should be sheltered from the wind as much as is possible given the nature of the New Zealand environment. Sites that minimize snow drifting should be selected if wind cannot be avoided.

> Note: Precipitation gauges located at windy sites can seriously underestimate the actual precipitation amount. Gauge catch can be improved by up to 20% at such sites by fitting an Alter, or Nipher shield or similar device around the gauge orifice.

Ideal distances from vertical obstructions such as trees and buildings should preferably be about two times the height of the obstruction for precipitation gauges and Stevenson Screens.

In high snowfall areas Stevenson Screens should be fitted to an adjustable tower and kept 1.2 to 1.4 m above the snow surface. The screen door should open to the south to minimise solar radiation effects to the temperature sensors. If electronic sensors are not housed in a Stevenson screen then they must be fitted with radiation shields that allow for good ventilation. A louvered baffle system is commonly used.

The study plot should be on level ground with a smooth surface. The ground should be drained.

The access should be convenient and safe under all weather conditions. Study plots for regular snow and weather observations should be close to the operations headquarters.

A fence and signs should be erected to prevent trespassing. Animal-proof fences might be needed where wildlife might interfere with instrumentation.

A.2 Wind Stations

The main requirement for wind stations is a good correlation between the wind observed at the study plot with wind speeds and direction in the avalanche start zones. It may be advantageous to position a wind station on a ridge lower than the mountain peaks, but close to an avalanche starting zone. *It is useful to identify the potential for snowdrift before placing wind stations.*

Anemometers should be located atop a vibration free tower (10 m). Distance from vertical obstructions such as trees and buildings should preferably be about **ten** times the height for anemometers. Ideally there should be no obstructions within a 100m radius of the anemometer (This may be hard to achieve).

The station must be accessible in the winter either by foot, snowmobile, or helicopter because wind observation equipment needs occasional maintenance. *Rime ice is a common problem.*

A.3 Meteorological Instruments Procedures

(Source: AES Manobs, 1977)

A.3.1 Reading Thermometers

The main steps in reading a thermometer are to:

- Stand as far from the thermometer as is consistent with accurate reading, to prevent body heat from affecting the thermometer.
- Ensure that the line of sight from the eye to the top of the liquid column makes an angle of 90° with the thermometer tube, to avoid an error due to parallax. Read the thermometer to the nearest <u>tenth</u> of a degree.
- Recheck the reading to ensure that it was not misread.
- Care should be taken when reading negative temperatures as the numerical value increases downward towards the end of the bulb.
- The thermometers should be read in the following order:
    - maximum;
    - dry (present);
    - minimum;
    - maximum reset;
    - minimum reset.

A.3.2 Resetting Maximum and Minimum Thermometers

The maximum thermometer shall be reset after each standard observation. To reset, remove the thermometer from its supports, grasp it firmly at the end opposite the bulb and hold it with the bulb down. Allow the mercury to come into contact with the constriction before starting the reset motion. Swing the thermometer, briskly, through an arc that prevents the bulb from rising above the horizontal. This is to prevent damage to the thermometer.

Note: The maximum thermometer is positioned almost horizontally in the Stevenson Screen. Its bulb should be slightly lower than the opposite end.

The minimum thermometer shall be reset after each standard observation. To reset, remove the bulb end from its support and raise it until the index slides down and rests against the meniscus. The bulb end shall then be carefully returned to its support.

Check the maximum and minimum thermometer readings after each reset. Check for the occurrence of breaks or bubbles in the column and ensure that the thermometer readings are representative of the ambient temperature.

Note: Some maximum thermometers may appear to have a short break in the mercury column in the area of the constriction. This break is caused by a small glass rod inside the bore of the thermometer. Do not attempt to re-unite the column in this area after the thermometer has been reset to the ambient air temperature.

A.3.3 Thermograph Procedure and Calibration

Many stations are equipped with thermographs from which a continuous record of temperature against time may be obtained. Although the thermograph is not regarded as a primary standard, it may be used as a reference for temperature data (for maximum and minimum observations). When temperature data are not available from maximum or minimum thermometers, the thermograph may be used to obtain temperatures provided that the following procedures are observed:

- The thermograph shall be housed in a thermometer shelter located no farther than necessary from the one that contains the thermometers. It may be possible in some cases to locate the thermograph and the thermometer in the same shelter.
- At the time of each chart change:
  - Adjust the thermograph so that the temperature indicated by the beginning of the trace on the new chart agrees with the present (ambient) temperature at the time of chart change.
  - Enter the present temperature to the nearest degree just above the end of the temperature trace on the chart just completed.
- At the time of each Standard Observation make a time check mark across the trace by raising and lowering the pen the width of two-printed temperature Intervals.
- Adjust the thermograph promptly if at any time the recorder trace is in error by more than 1.5^{o}C.

A.3.4 Hygrograph Calibration

Calibrate the hygrograph at least twice each winter, at the start of the season and again mid-season. Use a wet and dry bulb psychrometer (either an Assman or sling type) and appropriate tables for the site's elevation to determine the relative humidity. It is preferable to calibrate the hygrograph at a time when the air temperature is close to or above freezing.

Note: Electronic humidity sensors should also be calibrated with a psychrometer. Electronic sensors often suffer long-term degradation and drift.

APPENDIX B- REPORTING AVALANCHE INVOLVEMENTS

B.1 Objective

The objective of reporting avalanche accidents and damage is to collect data about the extent of avalanche problems in New Zealand. Summaries of the reports will draw attention to avalanche dangers and assist in the development of safety measures.

Note: This information is intended for public education and information. It may be summarised and published by MSC. The reporter's name will not be published.

B.2 Reporting Forms

For the past 10 years, two different formats have been available for recording avalanche accidents and damage. The historical practice was to complete a paper form (concise or detailed) and post this to the Mountain Safety Council in Wellington.

The current process is internet based and has been used for some time to produce the 'Annual Summary' published in the Crystal Ball. Operations can complete a concise form from within their InfoEx login, as well as download the detailed form. Public can also submit observations and involvements via the www.avalanche.net.nz web site.

This concise format *does not* replace the detailed report but is a means of sharing details about weather events leading up to an event, the nature of the snowpack, specific details about the avalanche itself, and a short report about the nature of the event's effects. This medium makes the details available to other operations/forecasters in the region.

It is intended that Operations use the concise form for involvements that do not result in any form of burial and/or trauma. It is expected that the detailed form, or a report containing the same information be recorded and sent to NZMSC for any partial, or full burials, as well as any event that causes injury or death.

B.3 Filing of Reports

Completed 'detailed' forms should be returned as quickly as possible to the New Zealand Mountain Safety Council, Wellington. InfoEx data should be entered at the end of each operational day.

Note: Details of how to file a report online are available by selecting the 'Avalanche.net.nz Help Manual' on the website home page.

All reports will be treated confidentially. The summarised data will be made public in the Crystal Ball annually. Interesting cases may be included in publications of avalanche accident case histories should the concerned reporters, people and companies agree. *The reporters' or victims' names are not required.*

B.4 Completion of the Detailed Report

On the form enter the information in the spaces provided or tick off the multiple-choice statements.

Write "N/A" if the information is not available or not applicable; for example, if the starting zone could not be visited.

The definitions of terms are those in Chapter 3: 'Avalanche Observations'.

B.5 Definitions

The following definitions are provided for reporting incidents and accidents with the intent of delineating between different rescue scenarios.

A person is ***caught*** if they are touched and adversely affected by the avalanche. People performing

slope cuts are generally not considered caught in the resulting avalanche unless they are carried down
the slope.

For people who are ***caught***, specify the degree of burial according to the following:

1. A person is ***not buried*** if they are on the surface, their airway is not impaired and they are free to
move when the avalanche stops.
Examples include situations where a person performing a slope cut is carried only a short distance down the slope (caught) but manages to move off of the debris whilst staying on their feet.

2. A person is ***partially buried – not critical*** if part of their body or clothing is visible and their breathing is not impaired by the snow when the avalanche stops. This requires that the person's head is above the snow surface and their airway is not obstructed.

3. A person is ***partially buried – critical*** if part of their body, clothing or attached equipment is visible but their breathing is impaired by the snow when the avalanche stops. Examples include situations where a person's head is buried below the surface, or a person's head is above the surface but their airway is plugged by snow. A person not buried but suffering from impaired breathing (i.e. airway plugged with snow) is also classified ***partially buried – critical***.

4. A person is ***completely buried*** if they are completely beneath the snow surface when the avalanche stops.

For people that were ***completely buried* or *partially buried – critical*** estimate the length of time they were buried and the burial depth measured from the snow surface to their face.

OUTDOOR SAFETY
NEW ZEALAND MOUNTAIN SAFETY COUNCIL

AVALANCHE INVOLVEMENT REPORT

DATE (year, month, date) ______________

TIME (hour, min) ____ : ____ (24 hr clock)

LOCATION Area ____

Slope, avalanche path ____

STARTING ZONE

Elevation (m) _______

Incline (degrees) _______

Aspect (e.g., NW) ______

Ground Cover prior to event (check √)

- ☐ smooth
- ☐ rocky
- ☐ glacier
- ☐ dense forest
- ☐ open forest
- ☐ not known

Avalanche started at (check one√)

- ☐ ridge
- ☐ cornice
- ☐ middle slope
- ☐ middle slope, convex
- ☐ rocks
- ☐ not known

TRACK

Confinement (check one√)

- ☐ Open Slope
- ☐ Channel

Incline (degrees) _____

Aspect (e.g., NW) _____

RUNOUT ZONE

Elevation (m) ________

Incline (degrees) _____

Ground Cover prior to event (check √)

- ☐ smooth
- ☐ dense forest
- ☐ open forest
- ☐ creek bed
- ☐ other
- ☐ not known

START OF AVALANCHE

Failure type (check one√)

☐ Slab (S)	☐ Storm slab(Sst)	☐ Wind slab (Swd)	☐ Persistent slab (Sp)
	☐ Deep persistent slab (Sdp)	☐ Wet slab (Swt)	☐ Glide slab (Sg)
☐ Loose (L)	☐ Loose dry (Ld)		☐ Loose wet (Lw)
☐ Cornice (C)		☐ Ice fall (I)	

Bed surface

Grain form ________

Grain size ________

Date buried (yymmdd) ________

Bed Surface (check one√)

- ☐ new snow
- ☐ old snow
- ☐ ground
- ☐ ice
- ☐ unknown

Fracture dimensions (If failure type is Slab - S):

Thickness, Average (0.1 m) _____• ___ Width (m) _________

Thickness, Maximum (0.1 m) _____• ___ Length (m) _________

MOTION OF AVALANCHE

Motion (check one√)

- ☐ Flowing
- ☐ Powder
- ☐ Mixed
- ☐ Not Known

AVALANCHE SNOW IN DEPOSIT

Density (kg/m^3) __________

Liquid water content (check one√)

- ☐ Dry
- ☐ Moist
- ☐ Wet

Roughness (check one√)

- ☐ Fine, soft
- ☐ Fine, hard packed
- ☐ Rounded lumps
- ☐ Angular blocks

Contamination (check one√)

- ☐ rocks
- ☐ trees / branches
- ☐ debris from facilities / buildings
- ☐ clean

DESTRUCTIVE SIZE OF AVALANCHE

Size (1.0 to 5.0) ___ • ___

RELATIVE SIZE OF AVALANCHE

Size (1.0 to 5.0) ___ • ___

Amount of deposited snow (enter measurements)

Length (m) _________ Average Depth (m) ______ • __

Width (m) _________ Max Depth (m) ______ • __

Volume (m^3) _____________

WEATHER at the time of the avalanche.

Temperature _______ • __

Precipitation ______________________________
(e.g., Nil, S1, RL…)

Sky condition ______________
(e.g., CLR, FEW, SCT, BKN, OVC, X)

Wind direction ________
(e.g., SW)

Wind force ______________
(e.g., Calm, light, moderate, strong)

Weather observations at closest station on days prior to and on the day of the avalanche.

Location ____

Date (yymmdd)	Time (hhmm)	Max. Temp (ºC)	Min Temp (ºC)	Precipitation (mm)	Snowfall (cm)	Snowpack HS (cm)	Wind Speed (km/hr)	Wind Direction

SNOW CONDITIONS

- Note features of the snowpack layering significant for avalanche release.
- Append a snow profile taken closest to the time of the avalanche.
- If possible, append a fracture line profile.

PERSONS INVOLVED

	Not buried	Partially Buried non critical	Partially buried critical	Completely Buried	Injured	Dead	Recovery Method	Time of Recovery (hhmm)	Burial Depth (m)	Position in avalanche
P1	☐	☐	☐	☐	☐	☐				
P2	☐	☐	☐	☐	☐	☐				
P3	☐	☐	☐	☐	☐	☐				
P4	☐	☐	☐	☐	☐	☐				
P5	☐	☐	☐	☐	☐	☐				
P6	☐	☐	☐	☐	☐	☐				

(check where appropriate☑)

Rescue transceiver usage. Note frequency, kHz, digital, brand name.

	None	Digital	Number of aerials	Brand Name
P1	☐	Y / N		
P2	☐	Y / N		
P3	☐	Y / N		
P4	☐	Y / N		
P5	☐	Y / N		
P6	☐	Y / N		

(check where appropriate☑)

Mode of Travel (check one√)
- ☐ Ski
- ☐ On foot
- ☐ Snowmobile
- ☐ Road vehicle
- ☐ Snowboard
- ☐ Other (specify) ___________________

Activity (check one√)
- ☐ Skiing
- ☐ Snowboarding
- ☐ Helicopter skiing
- ☐ Ski touring
- ☐ Mountain climbing
- ☐ Snowmobiling
- ☐ Other recreation
- ☐ Avalanche control
- ☐ Inside building
- ☐ In transit on road

Total number of people in party _______

Total number of people with rescue transceivers _______

VEHICLES INVOLVED Types: Car, Van, Truck, Bus, Snowmobile, Helicopter, Cat, Trailer, Groomer, Other (check where appropriate ☑)

	Type	Trapped	Partially Buried	Buried	Damaged
V1		☐	☐	☐	☐
V2		☐	☐	☐	☐
V3		☐	☐	☐	☐
V4		☐	☐	☐	☐
V5		☐	☐	☐	☐

Estimated total loss from damage to vehicles $ _____ , ____ •00

STRUCTURES INVOLVED

Building Function	Construction Type	Involved	Damaged	Destroyed
B1		☐	☐	☐
B2		☐	☐	☐
B3		☐	☐	☐
B4		☐	☐	☐

(check where appropriate☑)
Choose from: Accommodation, Administration, Cafe, Storage shed, Other

Facility	Type	Number Damaged	Number Destroyed	Length of cable down (m)
Lift Structures				
Bridge				
Tunnel				
Road				
Machinery				
Fuel Tanks				
Other				

(check where appropriate☑)

Utilities	Type	Number Damaged	Number Destroyed	Length of line down (m)
Power line towers				
Telephone poles				
Other				

Estimated total loss from damage to buildings, facilities and utilities: $ _____ , ______ , ______ • 00

FOREST
Area of forest destroyed (ha) ______ • ___
Tree species ____

OTHER DAMAGE ____

____

____

CAUSE OF ACCIDENT
Describe how the people or vehicles came to be involved with the avalanche, i.e. how the accident happened. Add a sketch of the avalanche slope showing location of the people, vehicles and or objects.

____
____
____
____
____

RESCUE

Facilitated by
- ☐ Self rescue
- ☐ Survivors of the party
- ☐ Others in the area
- ☐ Organised rescue

Time when search started ____ : ___
Number of searchers ________

Means of location:
- ☐ Object on surface
- ☐ Transceiver
- ☐ Probing
- ☐ Shovelling
- ☐ Dog
- ☐ Machines
- ☐ Other, Specify

ORGANISED RESCUE

Name of Organisation ....

....

Coordinator (Rescue Leader) ....

Accident Site Commander ....

Name and Address of Reporter ....

....

....

ENCLOSURES

Include additional information that is available, such as, but not limited to:

- Weather observations in greater detail.
- Snow profiles.
- Start zone notes.
- Map with the location of the avalanche.
- Sketch map of the avalanche path showing the location of people, objects and defence structures before and after the avalanche.
- Photographs.
- A copy of the report of the rescue organisation.

Please send to: NZ Mountain Safety Council
PO Box 6027, Wellington
Telephone: (04) 385-7162
Email: info@mountainsafety.org.nz

Note: This information is intended for public education and information. It may be summarised and published by the NZMSC. The reporter's name will not be published.

APPENDIX C- *AUTOMATIC WEATHER STATION DATA FORMAT*

The New Zealand Meteorological Service has a standard which aims to:

- Minimise differences between manual and automatic stations
- Encourage uniformity of measurement
- Establish a common practice for reporting, recording and transmitting data for archiving
- Maintain data quality to meet international standards

The recommended programming system is to:

- Scan sensors once every five seconds, wind speed each second
- Every minute compute the one-minute sensor averages and totals.
- Average/Totalise/Maximise/Minimise sensors' readings over designated time periods.

The recommend reporting frequency is hourly.

C.1 Hourly Outputs

This standard is intended to be used when setting up an automatic weather station. Refer to the "Guidelines for Co-operative Climatological Autostations" for additional details (AES, 1992a and 1992b). Possible hourly outputs are as follows:

Summary	Integration Period	Variable
Averages:	One Minute (minutes 59-60)	Air Temperature Relative Humidity Total Snow depth (acoustic sensor) Atmospheric Pressure Dew Point
	Two Minutes (minutes 58-60)	Wind direction and speed
	Ten Minutes	Wind direction and speed (minutes 50-60)
	One Hour	Air Temperature Relative Humidity Wind direction and speed Soil Temperature

Summary	Integration Period	Variable
Accumulations:	One Hour	Precipitation (Tipping Bucket Gauge) Total Precipitation Radiation 10 minutes with variable total precipitation
Extremes:	Ten Minutes	Peak Wind speed (minutes 50-60) Max. 1 second Wind speed, sample over 3 seconds
	One Hour	Wind speed (max. 1 second gust, over 3 second period) Air Temperature (Maximum and Minimum)

C.2 Twice Daily Summaries

Once daily climate summaries (standard observations) can be generated as follows:

Summary	Integration period	Variable
Extremes:	Period	Air Temperature (Maximum and Minimum) Relative Humidity (Maximum and Minimum)
Accumulations:	Period	Precipitation (Tipping Bucket Gauge) Total Precipitation New snow (acoustic sensor) Radiation Sunshine Hours Windrun (km)
Sample:	End of Period	Snow depth

C.3 Ideal Automatic Weather Stations Hourly Outputs

(Source: AES Guidelines for co-operative climatological Autostations, ver 2.0, 1992, p54). Items marked with an asterisks (*) are recommended for snow safety operations.

*1	Record Identifier	
*2	Year	
*3	Julian Day (or day of year)	
*4	Hour (LST or UTC)	
*5	Station Identifier	
6	Data Availability Diagnostic	- % Ensures data integrity
*7	Station Pressure (kPa)	- On-the-hour (1-min mean)
*8	Air Temperature (C)	- On-the-hour (1-min mean)
*9	Relative Humidity (%)	- On-the-hour (1-min mean)
10	Mean Wind Speed	- Minute 58-60
11	Mean Wind Vector Magnitude	- Minute 58-60
12	Mean Wind Vector Direction	- Minute 58-60
13	Standard Deviation of Wind Direction	- Minute 58-60
14	Wind Speed Standard Dev'n.	- Minute 58-60
*15	Peak 5-second Wind Speed	- Past hour
16	Peak wind speed time	- Past hour
17	Peak wind speed direction	- At peak speed
18	Max. 2-minute wind speed	- Past hour
19	Tipping Bucket Rain Gauge Precipitation (mm)	- Past hour
*20	Snow Depth (cm)	- Minute 59-60
21	Weighing Gauge Precipitation (mm)	- Minute 59-60
22	Weighing Gauge Reading (mm)	- 15 Minutes
23	Weighing Gauge Reading (mm)	- 30 Minutes

24	Weighing Gauge Reading (mm)	- 45 Minutes
*25	Weighing Gauge Reading (mm)	- On the Hour
26	Mean Wind Speed	- Minute 50-60
27	Mean Wind Vector Magnitude	- Minute 50-60
28	Mean Wind Vector Direction	- Minute 50-60
29	Standard Deviation of Wind Direction	- Minute 50-60
30	Peak Wind Speed	- Minute 50-60
31	Max. 10-minute wind speed	- Past hour
32	Temperature (C)	- 1-hour mean
33	Relative Humidity (%)	- 1-hour mean
34	Mean Wind Speed	- 1-hour mean
*35	Mean Wind Speed Vector Magnitude	- 1-hour mean
*36	Mean Wind Vector Direction	- 1-hour mean
*37	Standard Deviation Wind Vector Direction	- 1-hour mean
*38	Maximum Air Temperature	- Past Hour
*39	Minimum Air Temperature	- Past Hour
40	Global Short Wave Solar Radiation	- 1-hour mean
41	Net Radiation (pyrradiometer)	- 1-hour mean
42	Hours of Bright Sunshine	- 1-hour total
43	5 cm Soil Temperature	- 1-hour mean
44	10 cm Soil Temperature	- 1-hour mean
45	20 cm Soil Temperature	- 1-hour mean

*Note: Outputs marked * are recommended. It is unlikely that all of these parameters will be measured but the order should be maintained. 46 to 50 have been reserved for future use by AES.*

Some operations have manually or mechanically reset snow boards positioned below automatic depth sensors. Outputs 51 to 55 are reserved for use with snow boards.

51	New Snow Depth (cm)	- Minute 59-60
52	Standard Snow Depth (cm)	- Minute 59-60
53	Interval Snow Depth (cm)	- Minute 59-60
54	Storm Snow Depth (cm)	- Minute 59-60
55	Snowboard (cm) discretionary use	

Additional outputs should be generated after number 55.

Records should be supplied in comma separated format; Repeated commas imply that parameters are not measured. Use the tilde character (~) to denote a Missing value (i.e. when a sensor has failed.) In the following example the station ID 39123 is specific to British Columbia Ministry of Transportation and Highways. Consult with AES when developing an ID for your area's stations.

```
BC Moth,94,320,1700,39123,,1012.3,,,,,,85,,,,320,,,,450,,,,,,,-12.4,78,,32,275,18,-11.6,-14.2,,,,,,6,18,6,32
```

APPENDIX D- *STANDARD ASCII FILE FORMAT FOR INFORMATION TRANSFER*

A coding system based on a standard abbreviated keyword followed by a colon and then the value is employed. Header and trailer keywords (e.g., SNOWSTART; SNOWEND) bracket the type of information enclosed. Keywords are only included when there are valid data to transfer.

This coding system is based on the proposed AES Climate Message format (CSCN), which will be used for daily, weekly or monthly messages. It is not recommended for hourly reports from electronic data loggers.

Message Control	Keywords
message repeat	**RPT**
message correction	**COR**
missing values	**~**
Message Types	Keywords
	STANDARD
	INTERVAL
	HOURLY
	MORNING
	AFTERNOON
	DAILY
	WEEKLY
	MONTHLY
	INTERMITTENT
Message Issue Time	(generated by the computer system)
Date:	**YYMMDDhhmm**

Note:

- *Compulsory fields are printed here in **BOLD CAPITALS.***
- *Comments and free form text should be enclosed in double quotes (" ").*
- *The use of all capital letters in comments is discouraged as it is more difficult to read then a mix of upper and lower case letters.*
- *Fields that have modifiers should be separated by commas (e.g. 200, M)*

Message Header	Keyword
Location, operation, etc.	**SOURCE:**
Observer	**OBSERVER:**

Weather parameters	
CLIMSTART	
Area or operation name	**CLIMAREA:**
Date and Time of weather observation	**CLIMTIME:**
Station Identifier	**STATIONID:**
Sky Condition	SKYCOND:
Precipitation Type (and Intensity)	PRECIP/RATE:

Air Temperature..PRESTEMP:
Trend in air temperature ....TEMPTREND:
Maximum air temperature...MXTEMP:
Minimum air temperature..MNTEMP:
10 cm Snow Temps...SNOW10TEMP:
Relative Humidity..RH:
Depth of interval snow ....SNOWINT:
Depth of standard obs snow...SNOWSTD:
Depth of new snow (24 hour) ....SNOWHN:
Depth of storm snow (, C = Cleared)...SNOWSTM:
Depth on shoot board (, C = Cleared) ....SNOWSHT:
Total depth of Snowpack ....SNOWHS:
Weight of New Snow ....NSWGHT:
Water Equiv of New Snow ....NSWATER:
Density of New Snow ....NSDEN:
Rain ....RAIN:
Precipitation...TOTPCPN:
Surface Penetration: Foot...PENFOOT:
Surface Penetration: Ram ....PENRAM:
Surface Penetration: Ski..PENSKI:
Form of Surface Snow...SURFFORM:
Size of Surface Snow ....SURFSIZE:
Measured Wind Speed (average) ....WINDSPDAV:
Measured Wind Speed (max gust)...WINDSPDMX:
Estimated Wind speed...WINDSPDEST:
Estimated Wind direction...WINDDIREST:
Measured wind direction (average) ....WINDDIRAV:
Extent of blowing snow ....EXTBLOWSNOW:
Direction of blowing snow..DIRBLOWSNOW:
Barometric pressure at station ....STNPRESS:
Barometric pressure trend...STNPRESSTND:
Relative pressure..PRESSREL:
Abbreviated comments (5 lines x 80 char max) ....................................CLIMCOMMENTS:
CLIMEND

FIELDOBSSTART
Area or operation name...**FIELDAREA:**
Date of field observation..**FIELDDATE:**
Time, or time range, of field observation ....**FIELDTIMES:**
Elevation range of field observation ....**FIELDELEVS:**
Abbreviated comments (5 lines x 80 char max) ....................................FIELDCOMMENTS:
FIELDOBSEND

RUTSTART
Date and Time of rutschblock test...**RUTTIME:**
Area name ....**RUTAREA:**
Site of rutschblock test ....**RUTSITE:**
Field score from rutschblock test...**RUTSCORE:**
Depth of failure ....RUTDEPTH:
Grain form at failure plane ....RUTGFORM:
Grain size at failure plane ....RUTGSIZE:
Tag (date of formation / burial) describing failure plane ....RUTLAYER:
Slope incline at test site...RUTSLOPE:
Aspect at test site ....RUTASPECT:
Elevation at test site ....RUTELEV:
Abbreviated comments (80 char max.) ....RUTCOMMENTS:
RUTSCHEND

SHOVSTART
Date and Time of shovel test..**SHVTIME:**
Area name ....**SHVAREA:**
Site of shovel test ....**SHVSITE:**
Field score from shovel test...**SHVSCORE:**
Depth of failure ....SHVDEPTH:
Grain form at failure plane ....SHVGFORM:
Grain size at failure plane ....SHVGSIZE:
Tag (date of formation / burial) describing failure plane ....SHVLAYER:
Slope incline at test site...SHVSLOPE:
Aspect at test site ....SHVASPECT:
Elevation at test site ....SHVELEV:
Abbreviated comments (80 char max.) ....SHVCOMMENTS:
SHOVEND

COMPSTART
Date and Time of compression test...**CMPTIME:**
Area name ....**CMPAREA:**
Site of compression test ....**CMPSITE:**
Result from compression test..**CMPSCORE:**
Depth of failure ....CMPDEPTH:
Grain form at failure plane ....CMPGFORM:
Grain size at failure plane ....CMPGSIZE:
Tag (date of formation / burial) describing failure plane ....CMPLAYER:
Slope incline at test site...CMPSLOPE:
Aspect at test site ....CMPASPECT:
Elevation at test site ....CMPELEV:
Abbreviated comments (80 char max.) ....CMPCOMMENTS:
COMPEND

Snow profile parameters
SNOWSTART
ASCII files from the "SnowPro for Windows" or similar industry standard programmes will be used to transmit snow profile information. Each data file must specify the programme's name and version number. Refer to the programme's documentation for a file specification.
Additional snowpack comments (5 lines x 80 char max.) .............SNOWCOMMENTS:
SNOWEND

Stability parameters
STABSTART
Avalanche area where path is located ....**STABAREA:**
Alpine stability, trend, comments ....STABALPINE:
Timber line stability, trend, comments...STABTLINE:
Below timber line stability, trend, comments ....STABBELOWTL:
Additional stability comments (5 lines x 80 char max.) .................STABCOMMENTS:
STABEND

Individual avalanche event parameters
AVSTART
Date of avalanche ....**AVDATE:**
Time of avalanche ....**AVTIME:**
Time range (± hours) for avalanche ....AVTIMERNGE:
Avalanche area where path is located ....**AVAREA:**
Avalanche path name or number ....**AVPATH:**
Size of avalanche ....**AVSIZE:**
Type of failure ....AVTYPE:
Liquid water content of snow in start zone ....AVWATERSZ:
Liquid water content of snow in deposit ....AVWATERDP:
Terminus of deposit ....AVTERM:
Trigger (class and optional subclass) ....AVTRIGGER:
Aspect of avalanche within start zone ....AVASPECTSTZ:
Elevation of avalanche at start point ....AVELEVST:
Incline of slope at start point ....AVINCLINEST:
Number of explosive charges applied to target ....AVNUMEXPL:
Number of explosive charges that detonated ....AVEXPLDET:
Size of explosive charge ....AVCHGSIZE:
Location in start zone ....AVLOCSZ:
Level of bed surface ....AVBEDLEV:
Grain form of failure plane ....AVFAILFRM:
Age of failure plane ....AVFAILAGE:
Slab width ....AVSLBWDTH:
Slab thickness ....AVSLBTHCK:
Average depth of deposit on road (, M = measured).......................AVRDAVDPT:
Max. depth of deposit on road (, M = measured) ....AVRDMAXDPT:
Distance from road edge to toe of deposit ....AVTOEDIST:
Length of Deposit ....AVDEPAVLNG:
Width of Deposit ....AVDEPAVWDT:
Depth of Deposit ....AVDEPAVDPT:
Elevation of toe of deposit ....AVELEVTOE:
Length of path run ....AVPATHRUN:
Abbreviated comments (5 lines x 80 char max.) ....AVCOMMENTS:
AVEND

Grouped Avalanche Activity parameters

> Note: This code is used to describe groups of similar avalanches. It is not to be used to describe avalanches larger than size 3. The activity section will be repeated for different groupings of avalanches (e.g. Natural versus artificially triggered. Slab versus loose snow avalanches.)

ACTSTART
Most probable (median) date for activity ....**ACTDATE:**
Most probable (median) time for activity ....ACTTIME:
Range of time (hours) when activity occurred ....ACTTIMERNGE:
Avalanche area where paths are located ....**ACTAREA:**
Number of similar occurrences ....ACTOCCNO:
Range of sizes observed ....ACTSIZES:
Type of failure ....ACTTYPE:
Trigger (basic class) ....ACTTRIGGER:
Range of start zone aspects affected ....ACTASPECTS:
Range of start zone elevations affected ....ACTELEV:
Range of start zone inclines ....ACTINCLINE:

Level of bed surface ....ACTBEDLEV:
Grain form at failure plane ....ACTFAILFORM:
Age of failure plane...ACTFAILAGE:
Range of slab widths observed ....ACTSLBWDTH:
Range of slab thickness observed ....ACTSLBTHCK:
Range of lengths of path run ....ACTPATHRUN:
Abbreviated comments (5 lines x 80 char max.) ....ACTCOMMENTS:
ACTEND

Example of a ski area observation:
SOURCE: WINDY PEAKS SKI RESORT
OBSERVER: "J. SMITH"
TXTIME: 9412150900
CLIMSTART
STANDARD
CLIMTIME: 9412150730
STATIONID: WINDY PEAKS CAR PARK
SKYCOND: -OVC
PRECIP/RATE: S, 4
PRESTEMP: -2.3
TEMPTREND: F
MXTEMP: 2.7
MNTEMP: -3.6
10SNOWTEMP: -5.5
RH: 85
SNOWINT: 14
SNOWSTD: 15
SNOWHN: 20
SNOWSTM: 25, C
HS: 240
SWGHTHN: 43
SNWWATER: 16
SDENHN: 107
RAIN: 0
TOTPCPN: 230
PENFOOT: 25
SURFFORM: NS
SURFSIZE: 0.5
WINDSPDEST: L
WINDDIREST: NW
EXTBLOWSNOW: PREV
DIRBLOWSNOW: W
STNPRESS: 102.85
STNPRESSTND: R
CLIMCOMMENTS: "Precip gauge reset and antifreeze added"
CLIMEND
RUTSTART
RUTTIME: 199412141230
RUTAREA: WINDY PEAKS
RUTSITE: "North Face"
RUTSCORE: 4
RUTDEPTH: 65
RUTGFORM: SH
RUTGSIZE: 6
RUTLAYER: "2 November"

RUTSCOPE: 35
RUTASPECT: NE
RUTELEV: 1750
RUTCOMMENTS: "Clean failure"
RUTEND
STABSTART
STABAREA: WINDY PEAKS
STABALPINE: P, IMPROVING, "Lee slopes, fair elsewhere"
STABTLINE: G, STEADY, "S - NW aspects"
STABBELOWTL: G, DECREASING, "all aspects"
STABCOMMENTS: "Wind transport of snow has ceased, warming at lower elevations"
STABEND
AVSTART
AVDATE: 19941214
AVTIME: 0600
AVTIMERNGE: 3
AVAREA: WINDY PEAKS
AVPATH: "East Slope"
AVSIZE: 3.5
AVTYPE: S
AVWATERSZ: D
AVWATERDP: M
AVTERM: MR
AVTRIGGER: Xe
AVASPECTSZ: S
AVELEVST: 1650
AVINCLINESZ: 36
AVFAILFRM: SH
AVFAILAGE: "2 November"
AVCOMMENTS: "Largest event ever observed on this path"
AVEND
ACTSTART
ACTDATE: 19941214
ACTTIMERNGE: 20
ACTAREA: WINDY PEAKS
ACTOCCNO: NUMEROUS
ACTSIZES: 1.5-2.5
ACTTYPE: S
ACTTRIGGER: N
ACTASPECTS: S - NW
ACTELEVST: 1800 - 2200
ACTINCLINE: 30 - 40
ACTBEDLEV: S
ACTFAILFORM: DH
ACTFAILAGE: "14 January"
ACTSLBWDTH: 30-60
ACTSLBTHCK: 20-40
ACTPATHRUN: 300 - 1600
ACTCOMMENTS: "All in High Alpine"
ACTEND

APPENDIX E- IACS INTERNATIONAL CLASSIFICATION FOR SEASONAL SNOW ON THE GROUND (FIERZ AND OTHERS, 2009)

Morphological classification				*Additional information on physical processes and strength*			
Basic classification	*Subclass*	*Shape*	*Code*	*Place of formation*	*Physical process*	*Dependence on most important parameters*	*Common effect on strength*
Precipitation Particles +			**PP**				
	Columns ▭	Prismatic crystal, solid or hollow	PPco	Cloud; temperature inversion layer (clear sky)	Growth from water vapour at –3 to –8°C and below–30°C		
	Needles ↔	Needle-like, approximately cylindrical	PPnd	Cloud	Growth from water vapour at high super-saturation at –3 to –5°C and below –60°C		
	Plates ⬡	Plate-like, mostly hexagonal	PPpl	Cloud; temperature inversion layer (clear sky)	Growth from water vapour at 0 to –3°C and –8 to –70°C		
	Stellars, Dendrites ∗	Six-fold star-like, planar or spatial	PPsd	Cloud; temperature inversion layer (clear sky)	Growth from water vapour at high supersaturation at 0 to –3°C and at –12 to –16°C		
	Irregular crystals	Clusters of very small crystals	PPir	Cloud	Polycrystals growing in varying environmental conditions		
	Graupel	Heavily rimed particles, spherical, conical, hexagonal or irregular in shape	PPgp	Cloud	Heavy riming of particles by accretion of supercooled water droplets Size: ≤5 mm		
	Hail ▲	Laminar internal structure, translucent or milky glazed surface	PPhl	Cloud	Growth by accretion of supercooled water Size: >5 mm		
	Ice pellets ◬	Transparent, mostly small spheroids	PPip	Cloud	Freezing of raindrops or refreezing of largely melted snow crystals or snowflakes (sleet) Graupel or snow pellets encased in thin ice layer (small hail) Size: both ≤5 mm		
	Rime ∀	Irregular deposits or longer cones and needles pointing into the wind	PPrm	Onto surface as well as on freely exposed objects	Accretion of small, supercooled fog droplets frozen in place. Thin breakable crust forms on snow surface if process continues long enough	Increase with fog density and exposure to wind	

Notes: Diamond dust is a further type of precipitation often observed in polar regions (see Appendix E).
Hard rime is more compact and amorphous than soft rime and may build out as glazed cones or ice feathers (AMS, 2000).
The above subclasses do not cover all types of particles and crystals one may observe in the atmosphere. See the references below for a more comprehensive coverage.
References: Magono & Lee, 1966; Bailey & Hallett, 2004; Dovgaluk & Pershina. 2005; Libbrecht, 2005

Morphological classification				*Additional information xon physical processes and strength*			
Basic classification	*Subclass*	*Shape*	*Code*	*Place of formation*	*Physical process*	*Dependence on most important parameters*	*Common effect on strength*
Machine Made snow			**MM**				
	Round polycrystalline particles	Small spherical particles, often showing protrusions, a result of the freezing process; may be partially hollow	MMrp	Atmosphere, near surface	Machined snow, i.e., freezing of very small water droplets from the surface inward	Liquid water content depends mainly on air temperature and humidity but also on snow density and grain size	In dry conditions, quick sintering results in rapid strength increase
	Crushed ice particles	Ice plates, shard-like	MMci	Ice generators	Machined ice, i.e., production of flake ice, subsequent crushing, and pneumatic distribution	All weather safe	

References: Fauve *et al.*, 2002

Decomposing and Fragmented precipitation particles			**DF**				
	Partly decomposed precipitation particles	Characteristic shapes of precipitation particles still recognizable; often partly rounded.	DFdc	Within the snowpack; recently deposited snow near the surface, usually dry	Decrease of surface area to reduce surface free energy; also fragmentation due to light winds lead to initial break up	Speed of decomposition decreases with decreasing snow temperatures and decreasing temperature gradients	Regains cohesion by sintering after initial strength decreased due to decomposition process
	Wind-broken precipitation particles	Shards or fragments of precipitation particles	DFbk	Surface layer, mostly recently deposited snow	Saltation particles are fragmented and packed by wind, often closely; fragmentation often followed by rounding	Fragmentation and packing increase with wind speed	Quick sintering results in rapid strength increase

Basic classification	Subclass	Shape	Code	Place of formation	Physical process	Dependence on most important parameters	Common effect on strength
	Morphological classification				*Additional information xon physical processes and strength*		
Rounded Grains			**RG**				
	Small rounded particles	Rounded, usually elongated particles of size < 0.25 mm; highly sintered	RGsr	Within the snowpack; dry snow	Decrease of specific surface area by slow decrease of number of grains and increase of mean grain diameter. Small equilibrium growth form	Growth rate increases with increasing temperature; growth slower in high density snow with smaller pores	Strength due to sintering of the snow grains [1]. Strength increases with time, settlement and decreasing grain size
	Large rounded particles	Rounded, usually elongated particles of size $\geq$ 0.25 mm; well sintered	RGlr	Within the snowpack; dry snow	Grain-to-grain vapour diffusion due to low temperature gradients, i.e., mean excess vapour density remains below critical value for kinetic growth. Large equilibrium growth form	Same as above	Same as above
	Wind packed	Small, broken or abraded, closely-packed particles; well sintered	RGwp	Surface layer; dry snow	Packing and fragmentation of wind transported snow particles that round off by interaction with each other in the saltation layer. Evolves into either a hard but usually breakable wind crust or a thicker wind slab. (see notes)	Hardness increases with wind speed, decreasing particle size and moderate temperature	High number of contact points and small size causes rapid strength increase through sintering
	Faceted rounded particles	Rounded, usually elongated particles with developing facets	RGxf	Within the snowpack; dry snow	Growth regime changes if mean excess vapour density is larger than critical value for kinetic growth. Accordingly, this transitional form develops facets as temperature gradient increases	Grains are changing in response to an increasing temperature gradient	Reduction in number of bonds may decrease strength

Notes: Both wind crusts and wind slabs are layers of small, broken or abraded, closely packed and well-sintered particles. The former are thin irregular layers whereas the latter are thicker, often dense layers, usually found on lee slopes. Both types of layers can be represented either as sub-class RGwp or as RGsr along with proper grain size, hardness and/or density.

If the grains are smaller than about 1 mm, an observer will need to consider the process at work to differentiate RGxf from FCxr.

References: [1] Colbeck, 1997

Basic classification	Subclass	Shape	Code	Place of formation	Physical process	Dependence on most important parameters	Common effect on strength
	Morphological classification				*Additional information xon physical processes and strength*		
Faceted Crystals			**FC**		Grain-to-grain vapour diffusion driven by large enough temperature gradient, i.e., excess vapour density is above critical value for kinetic growth		
	Solid faceted particles	Solid faceted crystals; usually hexagonal prisms	FCso	Within the snowpack; dry snow	Solid kinetic growth form, i.e., a solid crystal with sharp edges and corners as well as glassy, smooth faces	Growth rate increases with temperature, increasing temperature gradient, and decreasing density; may not grow to larger grains in high density snow because of small pores	Strength decreases with increasing growth rate and grain size
	Near surface faceted particles	Faceted crystals in surface layer	FCsf	Within the snowpack but right beneath the surface; dry snow	May develop directly from Precipitation Particles (PP) or Decomposing and Fragmented particles (DFdc) due to large, near-surface temperature gradients [1] Solid kinetic growth form (see FCso above) at early stage of development	Temperature gradient may periodically change sign but remains at a high absolute value	Low strength snow
	Rounding faceted particles	Faceted crystals with rounding facets and corners	FCxr	Within the snowpack; dry snow	Trend to a transitional form reducing its specific surface area; corners and edges of the crystals are rounding off	Grains are rounding off in response to a decreasing temperature gradient	

Notes: Once buried, FCsf are hard to distinguish from FCso unless the observer is familiar with the evolution of the snowpack

FCxr can usually be clearly identified for crystals larger than about 1 mm. In case of smaller grains, however, an observer will need to consider the process at work to differentiate FCxr from RGxf.

References: [1] Birkeland, 1998

Morphological classification					Additional information xon physical processes and strength		
Basic classification	*Subclass*	*Shape*	*Code*	*Place of formation*	*Physical process*	*Dependence on most important parameters*	*Common effect on strength*
Depth Hoar ∧			**DH**		Grain-to-grain vapour diffusion driven by large temperature gradient, i.e., excess vapour density is well above critical value for kinetic growth.		
	Hollow cups ∧	Striated, hollow skeleton type crystals; usually cup-shaped	DHcp	Within the snowpack; dry snow	Formation of hollow or partly solid cup-shaped kinetic growth crystals [1]	See FCso.	Usually fragile but strength increases with density
	Hollow prisms ⊓	Prismatic, hollow skeleton type crystals with glassy faces but few striations	DHpr	Within the snowpack; dry snow	Snow has completely recrystallized; high temperature gradient in low density snow, most often prolonged [2]	High recrystallization rate for long period and low density snow facilitates formation	May be very poorly bonded
	Chains of depth hoar ⩕	Hollow skeleton type crystals arranged in chains	DHch	Within the snowpack; dry snow	Snow has completely recrystallized; intergranular arrangement in chains; most of the lateral bonds between columns have disappeared during crystal growth	High recrystallization rate for long period and low density snow facilitates formation	Very fragile snow
	Large striated crystals ⍲	Large, heavily striated crystals; either solid or skeleton type	DHla	Within the snowpack; dry snow	Evolves from earlier stages described above; some bonding occurs as new crystals are initiated [2]	Longer time required than for any other snow crystal; long periods of large temperature gradient in low density snow are needed	Regains strength
	Rounding depth hoar ∩	Hollow skeleton type crystals with rounding of sharp edges, corners, and striations	DHxr	Within the snowpack; dry snow	Trend to a form reducing its specific surface area; corners and edges of the crystals are rounding off; faces may lose their relief, i.e., striations and steps disappear slowly. This process affects all subclasses of depth hoar	Grains are rounding off in response to a decreasing temperature gradient	May regain strength

Notes: DH and FC crystals may also grow in snow with density larger than about 300 kg m^{-3} such as found in polar snowpacks or wind slabs. These may then be termed 'hard' or 'indurated' depth hoar [3].
References: [1] Akitaya, 1974; Marbouty, 1980; Fukuzawa & Akitaya, 1993; Baunach *et al.*, 2001; Sokratov, 2001; [2] Sturm & Benson, 1997; [3] Akitaya, 1974; Benson & Sturm, 1993

	Morphological classification				*Additional information xon physical processes and strength*		
Basic classification	*Subclass*	*Shape*	*Code*	*Place of formation*	*Physical process*	*Dependence on most important parameters*	*Common effect on strength*
Surface Hoar ∨			**SH**				
	Surface hoar crystals ∨	Striated, usually flat crystals; sometimes needle-like	SHsu	Usually on cold snow surface relative to air temperature; sometimes on freely exposed objects above the surface (see notes)	Rapid kinetic growth of crystals at the snow surface by rapid transfer of water vapour from the atmosphere toward the snow surface; snow surface cooled to below ambient temperature by radiative cooling	Both increased cooling of the snow surface below air temperature as well as increasing relative humidity of the air cause growth rate to increase.In high water vapour gradient fields, e.g., near creeks, large feathery crystals may develop	Fragile, extremely low shear strength; strength may remain low for extended periods when buried in cold dry snow
	Cavity or crevasse hoar ∨̂	Striated, planar or hollow skeleton type crystals grown in cavities; orientation often random	SHcv	Cavity hoar is found in large voids in the snow, e.g., in the vicinity of tree trunks, buried bushes [1] Crevasse hoar is found in any large cooled space such as crevasses, cold storage rooms, boreholes, etc.	kinetic growth of crystals forming anywhere where a cavity, i.e., a large cooled space, is formed or present in which water vapour can be deposited under calm, still conditions [2]		
	Rounding surface hoar ∨	Surface hoar crystal with rounding of sharp edges, corners and stria-tions	SHxr	Within the snowpack; dry snow	Trend to a form reducing its specific surface area; corners and edges of the crystals are rounding off; faces may lose their relief, i.e., striations and steps disappear slowly	Grains are rounding off in response to a decreasing temperature gradient	May regain strength

Notes: It may be of interest to note more precisely the shape of hoar crystals, namely plates, cups, scrolls, needles and columns, dendrites, or composite forms [3]. Multi-day growth may also be specified.

Surface hoar may form by advection of nearly saturated air on both freely exposed objects and the snow surface at subfreezing temperatures. This type of hoarfrost deposit makes up a substantial part of accumulation in the inland of Antarctica. It has been termed 'air hoar' (see [2] and [4]).

Crevasse hoar crystals are very similar to depth hoar.

References: [1] Akitaya, 1974; [2] Seligman, 1936; [3] Jamieson & Schweizer, 2000; [4] AMS, 2000

	Morphological classification			*Additional information xon physical processes and strength*			
Basic classification	*Subclass*	*Shape*	*Code*	*Place of formation*	*Physical process*	*Dependence on most important parameters*	*Common effect on strength*
Melt Forms			**MF**				
	Clustered rounded grains	Clustered rounded crystals held by large ice-to-ice bonds; water in internal veins among three crystals or two grain boundaries	MFcl	At the surface or within the snowpack; wet snow	Wet snow at low water content (pendular regime), i.e., holding free liquid water; clusters form to minimize surface free energy	Meltwater can drain; too much water leads to MFsl; first freezing leads to MFpc	Ice-to-ice bonds give strength
	Rounded polycrystals	Individual crystals are frozen into a solid polycrystalline particle, either wet or refrozen	MFpc	At the surface or within the snowpack	Melt-freeze cycles form polycrystals when water in veins freezes; either wet at low water content (pendular regime) or refrozen	Particle size increases with number of melt-freeze cycles; radiation penetration may restore MFcl; excess water leads to MFsl	High strength in the frozen state; lower strength in the wet state; strength increases with number of melt-freeze cycles
	Slush	Separated rounded particles completely immersed in water	MFsl	Water-saturated, soaked snow; found within the snowpack, on land or ice surfaces, but also as a viscous floating mass in water after heavy snowfall.	Wet snow at high liquid water content (funicular regime); poorly bonded, fully rounded single crystals – and polycrystals – form as ice and water are in thermodynamic equilibrium	Water drainage blocked by capillary barrier, impermeable layer or ground; high energy input to the snow-pack by solar radiation, high air temperature or water input (rain)	Little strength due to decaying bonds
	Melt-freeze crust	Crust of recognizable melt-freeze polycrystals	MFcr	At the surface	Crust of melt-freeze polycrystals from a surface layer of wet snow that refroze after having been wetted by melt or rainfall; found either wet or refrozen	Particle size and density increases with number of melt-freeze cycles	Strength increases with number of melt-freeze cycles

Notes: Melt-freeze crusts MFcr form at the surface as layers at most a few centimetres thick, usually on top of a subfreezing snowpack. Rounded polycrystals MFpc will rather form within the snowpack. MFcr usually contain more refrozen water than MFpc and will not return to MFcl.

Both MFcr and MFpc may contain a recognizable minority of other shapes, particularly large kinetic growth form FC and DH. See the guidelines (Appendix C) for examples on the use of the MFcr symbol.

	Morphological classification				*Additional information xon physical processes and strength*		
Basic classification	*Subclass*	*Shape*	*Code*	*Place of formation*	*Physical process*	*Dependence on most important parameters*	*Common effect on strength*
Ice Formations			**IF**				
	Ice layer	Horizontal ice layer	IFil	Within the snowpack	Rain or meltwater from the surface percolates into cold snow where it refreezes along layer-parallel capillary barriers by heat conduction into surrounding subfreezing snow, i.e., snow at T < 0°C; ice layers usually retain some degree of permeability	Depends on timing of percolating water and cycles of melting and refreezing; more likely to occur if a stratification of fine over coarse-grained layers exists	Ice layers are strong but strength decays once snow is completely wetted
	Ice column	Vertical ice body	IFic	Within snowpack layers	Draining water within flow fingers freezes by heat conduction into surrounding subfreezing snow, i.e., snow at T < 0°C	Flow fingers more likely to occur if snow is highly stratified; freezing enhanced if snow is very cold	
	Basal ice	Basal ice layer	IFbi	Base of snowpack	Melt water ponds above substrate and freezes by heat conduction into cold substrate	Formation enhanced if substrate is impermeable and very cold, e.g., permafrost	Weak slush layer may form on top
	Rain crust	Thin, transparent glaze or clear film of ice on the surface	IFrc	At the surface	Results from freezing rain on snow; forms a thin surface glaze	Droplets have to be supercooled but coalesce before freezing	Thin breakable crust
	Sun crust, Firnspiegel	Thin, transparent and shiny glaze or clear film of ice on the surface	IFsc	At the surface	Melt water from a surface snow layer refreezes at the surface due to radiative cooling; decreasing shortwave absorption in the forming glaze enhances greenhouse effect in the underlying snow; additional water vapour may condense below the glaze [1]	Builds during clear weather, air temperatures below freezing and strong solar radiation; not to be confused with melt-freeze crust MFcr	Thin breakable crust

Notes: In ice formations, pores usually do not connect and no individual grains or particles are recognizable, contrary to highly porous snow. Nevertheless, some permeability remains, in particular when wetted, but to much a lesser degree than for porous melt forms.

Most often, rain and solar radiation cause the formation of melt-freeze crusts MFcr.

Discontinuous ice bodies such as ice lenses or refrozen flow fingers can be identified by appropriate remarks (see Appendix C.2).

References: [1] Ozeki & Akitaya, 1998

APPENDIX F- SYMBOLS AND ABBRIVIATIONS

Symbol	Term	Units
D	Grain size	mm
F	Grain form	
H	Vertical co-ordinate (line of plumb)	cm, m
HN24	Height of new snow (24 hours)	cm
H2D	New snow since previous standard observation	cm
H24W	Water equivalent of new snow layer	mm
H2DW	Water equivalent of layer (2D)	mm
HS	Total height of snow pack	cm
HST	Height of storm snow	cm
HIN	Height of interval snow	cm
HSW	Water equivalent of snow pack	mm
HW	Water equivalent of a layer	mm
PF	Depth of foot penetration	cm
PR	Depth of penetration by Swiss ramsonde	cm
PS	Depth of ski penetration	cm
R	Hardness Index (Resistance to penetration)	N
T	Temperature of snow	ºC
Ta	Temperature of air	ºC
Tg	Temperature of ground	ºC
T0	Temperature of snow surface	ºC
T10	Temperature of snow at 10 cm below surface	ºC
Δp	Change in penetration (Delta)	cm
θ	Liquid water content (theta)	% (by volume)
ρ	Density (rho)	kg/m^3
Σ	Summation	
ψ	Inclination (psi)	degrees

USEFUL FORMULAE:

Area of circle:		πr^2
Volume of sampling tube:		$\pi r^2 L$
	Where r is radius	
	L is length of tube	
	π (pi) is constant with value 3.1416	Spreadsheet formula

APPENDIX G- CONVERSION TO STANDARD SI UNITS

G.1 Density

Previous editions of these Guidelines (1989 and earlier) described a measure known as specific gravity. This term is no longer used. Specific gravity of snow was non-dimensional and had a value of less than 1. Old data stored as specific gravity may be converted by multiplying by 1000 as follows:

Density (kg /m^3) = Specific Gravity x 1000

e.g., A Specific Gravity value of .15 = 150 kg/m^3

G.2 Barometric Pressure

Barometric Pressure is to be expressed in hectopascals (hPa).

Use the following multipliers to convert from other units.

Unit	**Multiplier used to convert to hectopascals**
kilopascal	10
millibars	1
millimetres of mercury	1.33
inches of mercury	33.86

G.3 Stress and Strength

The strength of avalanche snow ranges from about 0.1 kPa to an upper limit of 100 kPa.

Unit	**Multiplier used to convert to kilopascals**
Pascal	0.001
Newton / m^2 (N/m^2)	0.001
g/cm^2	0.0981

G.4 Impact Pressures

It is common engineering practice to specify impact pressures in tonnes per square metre. More properly, units are tonnes-force/m^2. Refer to McClung and Schaerer, 2006 for a discussion.

Unit	**Multiplier used to convert to kilopascals**
tonnes/m^2	9.81

G.5 Wind Speed

Wind speed is to be expressed in km/hr.

Use the following multipliers to convert from other units.

Unit	Multiplier used to convert to km per/hour
Metres per second	3.6
knots	1.853
miles per hour	1.609

G.6 Expanded Equations

Several equations are presented in abbreviated form in the text. The expanded versions below are intended to explain how the abbreviated versions were derived.

Section 1.4.11

H2DW (mm) = Mass (g) / Area(cm^2) x 10;

Expanded –

H2DW(mm) = Mass(g) / Area(cm^2) x 1(cm^2) / 100(mm^2) x 1(cm^3 H_2O) / 1(g H_2O) x 1000(mm^3) / 1(cm^3)

Section 1.4.13, first equation

ρ(kg/m^3) = Mass of snow sample (g) / Sample volume (cm^3) x 1000

Expanded –

ρ(kg/m^3) = Mass of snow sample (g) / Sample volume (cm^3) x 1,000,000(cm^3) / 1(m^3) x 1(kg) / 1000(g)

Section 1.4.12, second equation

ρ(kg/m^3) = H_2O equivalent of snow sample (mm) / Height of snow sample (cm) x 100

Expanded –

ρ(kg/m^3) = H_2O equivalent of snow sample (mm) / Height of snow sample (cm) x 1(cm) / 10(mm) x 1(g H_2O) / 1(cm^3 H_2O) x 1(kg) / 1000(g) x 1,000,000(cm^3) / 1(m^3)

Section 2.1.5

ρ(kg/m^3) = Mass of snow sample (g) / Sample volume(cm^3) x 1000

Expanded –

ρ (kg/m^3) = Mass of snow sample (g) / Sample volume(cm^3) x 1 (kg) / 1000(g) x 1,000,000(cm^3) / 1(m^3)

Section 2.1.6

HSW (mm) = 0.01 x $\Sigma(\Delta H \times \rho)$

Expanded –

HSW (mm) = 1(cm^3 H_20) / 1(g H_20) x 1000(g) / 1(kg) x 1(m^3) / 1,000,000(cm^3) x $\Sigma\{\Delta H$ (cm) x ρ(kg/m^3)}

Section 2.1.7

$\overline{\rho}$ (kg/m^3) = HSW (mm) / HS(cm) x 100

Expanded –

$\overline{\rho}$ (kg/m^3) = HSW (mm) / HS(cm) x 1(cm) / 10(mm) x 1(kg) / 1000(g) x 1(g H_2O) / 1(cm^3 H_2O) x 1,000,000(cm^3) / 1(m^3)

APPENDIX H- STANDARD ABBREVIATIONS FORMAT FOR INFORMATION TRANSFER

Note: some abbreviations can mean different things - the distinction is usually obvious in context.

Alpine	ALP	No observations	n/o or ~
Artillery	Art / Xa	North	N
Aspect	Asp	Numerous	num
Avalanche	Aval	Observations, observed	obs
Below treeline	BTL	One finger	1F
Compression test - very easy, easy, moderate, hard	CTV (E,M,H)	Partly decomposed	PD
Conditions	Cond	Pencil	P
Considerable	Consid	Precipitation	precip
Consolidated	consol	Precipitation particle	PP
Crust	CR	Previous, previously	prev
Crown	Crwn	Propagation saw test	PST
Cubic metre	M3	Radiation	radn
Decomposing fragments	DF	Recoilless Rifle	RR
Degrees	Deg	Redeposited, redeposition	redep
Density	Dens	Relative humidity	RH
Depth hoar	DH	Rounds	RG
Deteriorating	deter'g	Rutschblock	RB
East	E	Several	sev
Easy	E	Shovel test - very easy, easy, moderate, hard	STV (E,M,H)
Elevation	Elev		
Explosive-control	Expl	Significant	signif
Extended column test	ECT	Size	sz
Facets	FC	Skiable terrain	skiable
Fist	F	Skier-controlled	Sc
Foot penetration	FP	Skier-remote include (metres away)	Sr_
Four finger	4F	Ski penetration	ski-pen
Freezing level	FL	Slab	S
Hand charge	Xe	Snowpack	snpk
Hard	H	Soft slab	SSL
Hard slab	HSL	South	S
Height of new snow	H24N, H2DW	Stability	stab
Height of snowpack	HS	Start zone	SZ
Helicopter-triggered	heli-trig	Storm snow	HST
Highway	Hwy	Surface	sfce
Incline	Incl	Subalpine	subalp
Instability	Instab	Surface hoar	SH
In the afternoon	PM	Temperature	temp
Hn the morning	AM	Temperature gradient	temp grad
Isolated	Isol	Trace	Tr - .01
Knife	K	Transport	transp
Loose	L	Treeline	TL
Moderate	Mod / M	Unskiable terrain	unskbl
Maximum	Max	Water equiv of new snow	HNW
Melt-freeze	MF	Weather	Wx
Minimum	min	West	W

Natural trigger	Na	widespread	wdspr
		wind slab	windsl

APPENDIX I- SNOW STABILITY RATING SYSTEM

Stability Rating	**Comment on** Snow Stability	**Natural Avalanches** *(excluding avalanches triggered by icefall, cornice fall or rockfall)*	**Triggered Avalanches** *(including avalanches triggered by human action, icefall, cornice fall, rockfall or wildlife)*	**Expected Results of Stability Tests**	**Expected Fracture Character**
Very Good (VG)	Snowpack is stable	No natural avalanches expected	Very heavy loads such as large cornice falls or loads in isolated terrain features	Generally little or no results	No fracture or non-planar break fractures
Good (G)	Snowpack is mostly stable	No natural avalanches expected	Avalanches may be triggered by heavy loads in isolated terrain features	Generally moderate to hard results	Generally resistant or non-planar break fractures
Fair (F)	Snowpack stability varies considerably with terrain, often resulting in locally unstable areas	Isolated natural avalanches on specific terrain features	Avalanches may be triggered by light loads in areas with specific terrain features or certain snowpack characteristics	Generally easy to moderate results	Resistant or sudden fractures
Poor (P)	Snowpack is mostly unstable	Natural avalanches in areas with specific terrain features or certain snowpack characteristics	Avalanches may be triggered by light loads in many areas with sufficiently steep slopes	Generally easy results	Generally sudden fractures

Very Poor (VP)	Snowpack is very unstable	Widespread natural avalanches	Widespread triggering of avalanches by light loads *(direct and remote)*	Very easy to easy results	Sudden fractures

Note: Statements about avalanche activity take precedence over results of stability tests. For regional and larger forecast areas isolated natural avalanches may occur even when stability for the area as a whole is good.

Definitions / examples:

- **Natural avalanches**: avalanches triggered by weather events such as snowfall, rain, wind, and temperature changes.
- **Heavy load**: a cornice fall, a compact group of skiers, a snowmobile or explosives.
- **Light load**: a single person or small cornice fall.
- **Isolated terrain features**: extreme terrain; steep convex rolls, localised dispersed areas (pockets) without readily specifiable characteristics.
- **Specific terrain features**: lee slopes, sun-exposed aspects.
- **Certain snowpack characteristics**: shallow snowpack with faceted grains, persistent weaknesses, identified weaknesses.

Specify the forecast area and stability for three elevation bands if relevant:

- High Alpine (approx > 2000 metres).
- Alpine (approx > 1000 and < 2000 metres).
- Sub Alpine (approx < 1000 metres),

Where possible give the expected stability trend for the next 12 to 24 hours. Use the terms: improving, steady and decreasing to describe the trend.

Specify a confidence level in the ratings when appropriate.

Experienced observers may qualify the rating based on:

- Topography (aspect, slope angle, etc.)
- Spatial extent (localised or widespread)
- Time of day
- Level of the unstable layer in the snow pack e.g., near surface, mid-level, deep.

Stability
The chance that avalanches do not initiate. Stability is analysed in space and time relative to a given triggering level.

Hazard
The potential for avalanches to cause death, injury or loss to people, things of value and the environment.

Danger (to backcountry recreationists)
The potential for avalanches to cause death or injury to backcountry recreationists.

Risk
The probability or chance of death, injury or losses, including adverse effects on health, property and the environment. Avalanche risk can be analysed in terms of the probability of the avalanche, the exposure of the element-at-risk (people, property or environment) and the consequences of the avalanche on the exposed elements.

APPENDIX J- BACKCOUNTRY AVALANCHE ADVISORIES AND THE NEW ZEALAND DANGER SCALE

J.1 Objective

The purpose of a "Danger" scale is to provide a means of informing the public about the current avalanche threat. In reality, there is no standard method of ranking avalanche danger.

Avalanche centres tailor their "Danger" rating to local needs. The Snow & Avalanche Committee of the Mountain Safety Council uses the "Danger Scale" (refer to section J.3) to inform backcountry users of the probability of avalanches occurring and to recommend appropriate travel precautions.

J.2 Requirements for a Danger Advisory

A danger advisory requires:

- Knowledge of recent weather
  Danger advisories by their nature are regionally based. Given this, understanding of weather at not just one location but several within a given region is crucial. Details of these observations can be obtained by daily review of the InfoEx data.

- Knowledge of Snowpack
  Snowpack observations are conducted daily by several operations within each geographic region in New Zealand. These observations are recorded regularly on www.avalanche.net.nz. Awareness of these observations is important but must be supplemented by direct observation. Direct observations should begin with the first snow of each season and continue throughout the winter so as to identify significant layers that may be reactive over time.

- Knowledge of recent avalanche activity
  The most important piece of information in order to express an accurate danger rating is knowledge of recent avalanche activity. Details are recorded on the InfoEx by individual observers. This should be supplemented by direct observation.

- Knowledge of recent avalanche accidents

J.3 New Zealand Danger Scale

This 5 level danger scale is recommended for use at ski areas (signs at heavily used backcountry access points), on the Internet (www.avalanche.net.nz), on road signs and when using the print and broadcast media to relay current conditions.

J.3.1 New Zealand Danger scale for backcountry recreation

New Zealand Avalanche Danger Scale

Avalanche danger is determined by the likelihood, size and distribution of avalanches.

Danger Level		Travel Advice	Likelihood of Avalanches	Avalanche Size and Distribution
5 Extreme	4 5	Avoid all avalanche terrain.	Natural and human-triggered avalanches certain.	Large to very large avalanches in many areas.
4 High	4 5	Very dangerous avalanche conditions. Travel in avalanche terrain not recommended.	Natural avalanches likely; human-triggered avalanches very likely.	Large avalanches in many areas; or very large avalanches in specific areas.
3 Considerable	3	Dangerous avalanche conditions. Careful snowpack evaluation, cautious route-finding and conservative decision-making essential.	Natural avalanches possible; human-triggered avalanches likely.	Small avalanches in many areas; or large avalanches in specific areas; or very large avalanches in isolated areas.
2 Moderate	2	Heightened avalanche conditions on specific terrain features. Evaluate snow and terrain carefully; identify features of concern.	Natural avalanches unlikely; human-triggered avalanches possible.	Small avalanches in specific areas; or large avalanches in isolated areas.
1 Low	1	Generally safe avalanche conditions. Watch for unstable snow on isolated terrain features.	Natural and human-triggered avalanches unlikely.	Small avalanches in isolated areas or extreme terrain.

Safe backcountry travel requires training and experience. You control your own risk by choosing where, when and how you travel.

No Rating	?	Insufficient information to establish avalanche danger rating. Check zone forecast for local information.

Note: *The theory behind a 5 level scale for backcountry recreationists is to provide a means of relaying the danger quickly.*

J.4 Public Avalanche Danger Advisories

Daily advisories are produced on the MSC's website www.avalanche.net.nz when avalanche conditions exist. This work is primarily focused during the winter season but certain parts of New Zealand may produce an advisory when unusual weather patterns at higher elevations create potential avalanche activity.

Advisories include a specific danger rating for each of the three elevations bands. Information is given as text, and graphics which include graduated icons using numbers and colours. More detailed information is also included for users who have more understanding of avalanche character. These concerns are described using text as well as icons showing estimated size, location, timing, and likelihood of avalanche activity.

Summaries of weather Snowpack and recent avalanche conditions are provided and a Travel Advisory is also issued.

Glossary

Use "Size" instead of "Class" when talking about the size of an avalanche.

Use Metric measurements instead of imperial.
Use Density (kg/m^3) instead of specific gravity.

Instead of "avalanche control (AC)" specify type of control e.g. "hand charge (Xe)", "artillery (Xa)", "skier controlled (Sc)", etc.

AGE HARDENING The strengthening of snow after mechanical compacting (e.g., boot packing and ski packing).

ARTIFICIAL AVALANCHE Triggered by an animal, human or their equipment.

BED SURFACE The main sliding surface of the slab, usually quite smoothed and compacted by the sliding blocks.

BOOT PACKING Trampling the snow by boot to densify and strengthen the snow in avalanche starting zones.

BRIDGING The ability of a relatively stiff slab to spread a person's weight over a wider area, making that person less likely to trigger an avalanche.

CALORIE The quantity of heat needed to raise the temperature of one gram of water one degree centigrade. (1 BTU = 252 calories; 1 Joule = 0.2388 calorie)

CLIMAX AVALANCHE Avalanche that involves layers of older snow.

COARSE GRAINED OLD SNOW Old snow, which is at or near the end product of the rounding metamorphism process plus melt metamorphism.

COHESION The condition where individual particles are united or stuck together to form a coherent unit.

CONCAVE Curved like a segment of the interior of a circle or hollow sphere.

CONVEX Having a surface that is curved or rounded outward.

CREEP Viscous deformation, which takes place within the snow cover under the influence of gravity.

CREEP TENSION Tensile stress in snow caused by variations in creep velocity.

CROWN The snow that remains on the slope above the crown surface.

CROWN WALL The top fracture surface of the slab, usually a smooth clean cut, 90 degrees to the bed surface.

CRYSTAL Any domain of ice or snow, which has a common orientation of the orderly array of molecules, which makes up the solid structure.
DELAYED ACTION AVALANCHES Avalanches, which occur other than during or immediately after a storm.

DENSITY Mass per volume, in scientific units, kg/m^3 (kilograms per cubic meter). The density of water is 1000 kg/m^3.

DEPOSITION The direct formation of ice from the vapour phase.

DEPTH HOAR Large-grained, faceted, cup-shaped crystals near the ground.

DIRECT ACTION AVALANCHES Avalanches, which occur during or immediately after a storm.

DUST CLOUD Mixture of air and snow particles accompanying an avalanche.

ELASTIC In the case of snow, capable of returning, to some limited extent, to original shape after being deformed.

ELASTIC DEFORMATION The temporary change in shape produced in an elastic substance by a stress that is less than the elastic limit of the substance.

EVALUATION Assessment of current snow stability.

FACETED SNOW angular, large-grained snow with poor bonding created by large temperature gradients within the snowpack.

FINE GRAINED OLD SNOW Snow in middle to advanced stages of rounding processes resulting from weak temperature gradients in the snowpack.

FIRNSPIEGEL Thin layer of clear ice on the surface, which permits sunlight to pass through to cause, melt in the subsurface layers. A highly reflective, mirror-like surface.

FLANK The side boundary of a slab.

FORECAST To predict the occurrence of an avalanche event(s).

FRACTURE Cracking of snow under stress.

FRONT A discontinuity between air masses.

GLIDE The slow, downhill movement of the entire snow cover over the ground surface.

GRAIN A mechanically separate particle in the snow cover which may consist of several crystals.

GRAUPEL Rimed precipitation particles that looks like little Styrofoam balls.

GROUND AVALANCHE A slab avalanche in which the ground is the bed surface.

GROUND SURFACE Bottom boundary of the snowpack.

HAZARD The risk of avalanche accident when humans or their works are exposed to snow avalanches.

HEAT OF FUSION The amount of heat needed to melt a unit mass of a substance at its normal melting point. For ice = (MJ/kg; 334 J/g at 0^0C).

HEAT OF VAPORIZATION The heat required to vaporize a unit mass of a substance (e.g., water). For water = (MJ/kg; 2501 J/g at 0^0C).

HOMOGENEOUS Similar throughout (referring to the snowpack).

INVERSION Cold air near the ground with warmer air above.

ISOTHERMAL Same temperature throughout – usually referring to 0^{0}C for a melting snowpack.

LEE The side of a mountain protected from the wind.

MELT Change of state from a solid to a liquid.

METAMORPHISM Changes in the snow texture caused by vapour pressure and temperature conditions.

NORWESTER Warm dry wind caused by descending air flowing down the lee side of a mountain range. (Föhn in Europe, Chinook in North America).

OROGRAPHIC LIFTING Forcing of air up and over terrain barriers.

POINT RELEASE A loose avalanche originating at a point and spreading out as it descends. The snow structure involved is cohesionless.

POSITIVE RADIATION BALANCE The snow absorbs more radiant heat than is lost to space.

PRECIPITATION INTENSITY Rate of precipitation measured in amount of water per unit time.

RADIATION Heat that is emitted as electromagnetic radiation from any body not at absolute zero.

RADIATION BALANCE Algebraic sum of all the radiant heat inputs and losses at a surface (e.g., a snow surface).

RADIATION RECRYSTALISATION Recrystalised snow on or near the snow surface caused by an extreme temperature gradient induced by radiation processes.

RAIN CRUST A clear layer of ice formed from rain on the snow surface, which later freezes.

RELATIVE HUMIDITY Ratio (in percent) of actual amount of water vapour in a body of air to the maximum amount that body can hold at a given temperature. Relative humidity varies with temperature for a given amount of water vapour.

RIME Accretion of frozen super cooled water droplets on a snow crystal or any exposed surface.

SATURATION A parcel of air at a given temperature is said to be saturated with water vapour at that temperature when the addition of any more water (or a decrease in the temperature) will lead to condensation.

SATURATION VAPOUR PRESSURE Water vapour pressure in the atmosphere at which saturation is achieved for a given temperature.

SETTLEMENT The decrease in thickness of a snow layer due to gravity and metamorphism.

SINTERING The process of vapour diffusion, which joins individual snow grains together forming an ice skeleton of connected grains. The eventual effect is a stronger snow layer.

SLAB A cohesive layer or layers of snow.

SLAB AVALANCHE An avalanche involving a discrete, cohesive layer of snow. The presence of a crown surface, or fracture line, is the key indicator.

SNOW BOARD Flat square board which lies on the snow with a measuring stick fastened vertically. Used to measure increments of new snow falling on an old snow surface.

SNOW FLAKE Aggregation of several snow crystals.

SNOW SLIDE Synonymous with avalanche.

SNOW SURFACE Top boundary of the snowpack.

STABLE A snow slope, which is well anchored and possesses sufficient internal strength so as not to be susceptible to avalanching.

STARTING ZONE The area near the top of an avalanche path.

STAUCHWALL The downslope boundary of the slab, often difficult to identify since it is ploughed over by the sliding blocks.

STRESS The physical pressure, pull, or other force exerted on a substance.

STRAIN Mechanical deformation within a material as the result of stress.

STUDY PLOT Flat, sheltered clearing used for gathering snow and weather data.

SUBLIMATION To pass directly from the solid to the gaseous state.

SUBSTRATUM Layer or surface of snow within the snow pack.

SUN CRUST A thin, clear layer of ice formed by radiation from the sun followed by refreezing.

SUPERCOOLED Water that is cooled below the normal freezing point but remains liquid.

SUPERSATURATION Amount of water vapour in excess of saturation.

SUNBALLS (Rollerballs) Balls of wet or damp snow, which roll down a snow slope.

SURFACE AVALANCHE An avalanche involving the surface layer or layers of the snowpack.

SURFACE HOAR Deposition of water vapour from the air as ice crystals on to a cold surface (e.g., a snow surface).

TEMPERATURE GRADIENT The change of temperature over a certain distance within the snowpack.

THRESHOLD The amount of snow depth required in a start zone, relative to the terrain anchoring features, for avalanching to occur."

TRIGGER A force or event that initiates an avalanche.

VISCOSITY The internal friction of a fluid. Snow is, in part, a viscous substance.

WHUMPF or WHUMPFING refers to the sound or feeling associated with fracture propagation due to a skier's weight, a.k.a. rapid settlement.

WIND BLAST The air pressure wave that may precede (or accompany) an avalanche.

WINDWARD The side of a mountain exposed to a wind.

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SNOW PROFILE

Organization:	Location:	
Observer:	Date:	Time:
Slope Incline:	Slope Aspect:	Elevation:
Wind:	Sky:	Precipitation:
Foot Penetration:	Water Equiv:	Avg Density:

T	-16°	-14°	-12°	-10°	-8°	-6°	-4°	-2°	H (cm)	θ	F	D (mm)	ρ	
I	K				P	1F	4F	F						

LIKELIHOOD OF TRIGGER EVALUATION CHECKLIST

DATE: year-month-day YYMMDD	TIME: 24hr clock to nearest 15 mins
FORECASTER: Initial & Surname	LOCATION: Ski Area, Region or Mountain Range

EVALUATION FACTORS	INFLUENCE / TREND LIKELY UNLIKELY
AVALANCHES RUNNING AND PAST AVALANCHES: Observations of any natural avalanche activity for the region. Date, time, number of avalanches, size, aspect, altitude, trigger. The closer to today, the more significant.	☐ . . ☐
SLOPE TESTING: Observations of skiing in start zone, bombing results, Rutschblock scores, cornice falls, all with date, size, aspect, altitude	☐ . . ☐
CRACKING OR SLOPE SETTLEMENT: Observations of cracking in the surface snow, and/or whoomphing sounds, snowballing, glide cracks. Include date, size, aspect, altitude	☐ . . ☐
SNOW STRUCTURE: Observations from snow profiles, assessment of the snowpack structure including results of compression tests & shovel shear tests, all with date, aspect, altitude. Any significant weaknesses	☐ . . ☐
SNOW DEPTH: Field observations of which slopes are above threshold, with qualifiers, altitude & aspect	☐ . . ☐
SNOW TEMPERATURES: Observations from snow profiles of the temperature gradient, isothermal, TG high (greater than 1 degC /10 cm), TG low (lower than 1 degC /10cm), closeness to 0 degC	☐ . . ☐
SNOW DRIFTING: Field & weather observations of wind loading, qualify with the particular wind direction (eg lee to westerly quarter last 24 hrs significant snow drifting)	☐ . . ☐
PENETRABILITY: Foot pen at weather plots, indicates snow available for transport by wind. Also consider snow surface conditions and size of fetch area.	☐ . . ☐
SNOW SETTLEMENT: Field & weather observations. 15% settlement is considered a stabilizing trend, very little or too rapid settlement are a destabilizing trends. Measured off storm board, HS, and field observations	☐ . . ☐
SLOPE USE / COMPACTION: Field observations, have surface layers been broken down by skiing, is the new snow/wind loading falling onto an uneven surface?	☐ . . ☐
SNOW SURFACE CONDITIONS: Is there any new snow fall, what will the old snow surface be? Critical conditions include surface hoar, facets, graupel, crusts, frozen wet grains. Crystal type & size, surface roughness	☐ . . ☐
PRECIPITATION: When snowpack is stable & no wind, instability may develop with storm precipitation greater than 25mm (30cm snow) or precipitation intensity greater than 2mm/hr (2cm snow). I.e. S3 or greater, RM and RH are unstable. Rain introduces warmth & adds weight to Snowpack	☐ . . ☐
WIND: The most recent wind speed and direction. Free air or ridge top wind is a better indicator to the loading trend than localized winds. Use the term "lee" to a particular wind, from a "1/4 or ½"	☐ . . ☐
HUMIDITY: High humidity (80% +) in combination with wind transported snow often aids the formation of stiff, hard slabs. Low humidity (60% or less) in combination with wind transported snow often results in sublimation back into the atmosphere.	☐ . . ☐
SOLAR RADIATION: Low early season solar radiation on shady aspects aids high TG (faceting). Heat from the sun aids stability on sunny aspects in the early winter (rounding) but destabilizes these aspects in spring (wet slides). Incoming radiation is greatest when the slopes are at right angles to the sun.	☐ . . ☐
AIR TEMPERATURES: Affect the snow temperature which in turn influences snow strength & metamorphism. Low temps may cause high TG and faceting, no freeze for three nights may cause wet slides in spring. Note changes of temperature, especially rapid changes & near zero degC are significant	☐ . . ☐

LIKELIHOOD OH TRIGGER EVALUATION: Your call for the current snow stability is? Write the least stable areas first. Use qualifiers of altitude, aspect, lee to a particular wind. Use the snow stability rating system, consider carefully the expected loading required to initiate an avalanche (light/heavy load), terrain features & snowpack characteristics. Be as accurate as you can!
WEATHER FORECAST: Write the weather forecast for the time period you are going to make the stability forecast, preferably at least 12-24hrs ahead. I should include wind speed & direction, cloud cover, precipitation type & intensity and significant changes to these that are forecast to occur within the forecasted time frame.
STABILITY FORECAST: Where possible give the expected stability trend for the next 12-24 hrs. Use the terms improving, steady and decreasing/deteriorating to describe the trend. Predicted rating, elevation and aspect.