AVALANCHE RISK MANAGEMENT AT WHISTLER MOUNTAIN UTILIZING STRATEGIC MINDSET AND DE-BIASING STRATEGIES

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Timothy R. Haggerty[1]*, Darren Saul[1], and Nicole Koshure[2]

1 Whistler Mountain Avalanche Forecaster, Whistler BC, Canada
2 Blackcomb Mountain Avalanche Forecaster, Whistler BC, Canada

ABSTRACT: With over two million annual skier visits, and an operational season that runs from November to May and switches to an industrial forecasting program in the off-season; Whistler Mountain has one of the largest ski resort avalanche risk management and mitigation programs in North America. High level expectations of avalanche safety within the ski resort while operating in constantly changing complex alpine terrain due to glacial recession and subsequent large rockfalls has created a new operational challenge, due to the reduced relevance of historical avalanche observations. This coupled with the increased frequency of extreme weather events producing large storm cycles with heavy precipitation, fluctuating freezing levels, and strong-to-extreme winds, adds to the creation of persistent weak layers (PWL), often resulting in large avalanches within the ski resort. Further to changing terrain and weather patterns, large turnover in operational staff has created constraints on the program and has influenced timely lift access, the availability of avalanche mitigation resources and influenced avalanche technician experience. As a result, the program has had to significantly adapt to continue to provide safety for staff and guests while maximizing operational efficiencies. Despite these challenges, risk management strategies at Whistler Mountain are constantly evolving, and the program continues to adapt to this dynamic environment through changes in policies and procedures. This paper aims to illustrate one such adaptation, the inclusion of the strategic mindset in daily forecasts which uses inflection points to help de-bias this large avalanche program. This coupled with a daily reflection and debriefing process has helped to improve communication, strengthen mentorship, and create consistency within our large and ever-changing program.

KEYWORDS: Ski resort avalanche forecasting, risk management, strategic mindset, de-biasing, reflection, mentorship

1. INTRODUCTION

The Whistler Mountain Avalanche Program has a very aggressive approach to conducting avalanche control with the goal of limiting terrain closures due to avalanche hazard as much as possible. This approach enables us to meet operational needs and provide our guests with alpine terrain as efficiently and safely as possible while still maintaining a low level of residual risk (Horvath, et al., 2019).

1.1 Location

Whistler Mountain is located approximately 135km north of the city of Vancouver, within the South Coast Mountains in the Fitzsimmons Range. Its climate is primarily maritime and is subject to strong Pacific frontal systems often associated with high winds, generous amounts of precipitation, and temperatures that are moderated by its proximity to the ocean. The average snowfall at 1650 m during the winter season (November to April) is 1020cm.

* *Corresponding author address:*
Timothy R. Haggerty, Whistler Avalanche Program,
8140 Crazy Canuck Dr Whistler, BC V8E0G8;
tel: +1 604 902 6722;
email: thaggerty@vailresorts.com

1.2 Terrain

Whistler Mountain provides up to 4,757 acres of skiable terrain with a lift capacity of 36,000 skiers per hour using 20 lifts. It encompasses all three elevation bands and has a base elevation of 675m, with the top of our resort at 2,185m.

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Whistler has 8 alpine bowls with two glaciers and smooth shale start zones in many of the 130 paths in alpine terrain. Each winter cornices develop along 6.5km of broad ridge lines and require constant control work, as the majority of our alpine skiing is in the lee of these ridge lines. We have 47 tree line start zones and 23 below tree line start zones that are spread over all aspects of our skiable terrain.

2. Weather

Located on the edge of the transitional zone between Coastal rainforest and the drier climate of the Caribou-Chilcotin, Whistler's weather predominately arrives in the form of Pacific frontal storm systems, which can deliver significant precipitation rates and strong to extreme south-easterly winds to alpine elevations. These storms rapidly load our alpine bowls and promote large cornice development.

Temperatures fluctuate wildly through the season and are dependent on the predominant upper air flow. For example, a south westerly flow can bring warmer air along with 1800-2100m freezing levels, while a north westerly flow results in much cooler temperatures and light accumulations of snowfall.

Cold northerly outflow conditions develop a few times a year, bringing Arctic temperatures and strong outflow winds with wind chills down to -40degC. These colder events tend to follow warmer weather, which often results in a melt-freeze crust (MFcr) and facet (FC) combination at the surface that can develop into a persistent weak layer (PWL).

With such variable and rapidly changing weather patterns the snow conditions are constantly changing too and recognizing these sometimes-subtle changes is a large part of the avalanche risk management process.

3. WHISTLER AVALANCHE PROGRAM

Whistler Mountain opened to skiing in 1966 with skiing to 2000m. Over the years the mountain tenure has expanded from Creekside to include the T-Bars to the north side in 1970. The original Peak chair was installed in 1986, Harmony Chair in 1994 and the Symphony chair in 2006 along with an expansion into the Symphony zone. In 2010 we hosted the Winter Olympics which put us on the world stage as a year-round tourism destination resort.

The avalanche program started after the winter of 1972 when a group of four skiers traveling outside the ski area boundary were caught and killed in an avalanche. The original program was set up by Norman Wilson from Alpine Meadows, California. The first Avalanche Safety Plan (ASP) was developed by Stethem and Associates in 1980 and is constantly evolving.

Avalanche Forecasters at Whistler Mountain assess hazards using the Conceptual Model of Avalanche Hazard (CMAH) and manage risks based on the mountain's Avalanche Safety Plan (ASP). The program is supervised and executed by two full-time forecasters.

3.1 Responsibilities

Forecasters are supported by a team of CAA Level 2 graduates and each day one is designated to act as the assistant forecaster. Responsibilities include, but are not limited to, the following:

- Gathering and maintaining weather and snowpack data
- Daily weather, snowpack and avalanche control (AC) meetings
- Daily AM/PM hazard analysis/Infoex workflows
- Avalanche clearances for public and staff (24 hours a day)
- Planning and executing all avalanche mitigation and control measures
- Explosives – delivery, storage and use
- Avalanche safety training – pre-season and ongoing
- Backcountry avalanche responses and out of bounds rescues/searches
- Maintenance of records
- CAA Level 2 mentorship, training and selection of new candidates.

3.2 Elements at Risk

2.2.1 Staff

Several departments on Whistler Mountain have staff that are exposed to avalanche hazard during their regular working shift and their safety is one of our main responsibilities. Travel through avalanche terrain is closely controlled by the avalanche Forecaster and is communicated via daily meetings/briefings and over the radio to outside departments. Staff are categorized as either non-avalanche or avalanche workers, as set out in the ASP.

Non-avalanche workers, such as groomers, lift operations and Senior Leadership Team (SLT), are neither trained nor equipped to deal with avalanche terrain and therefore our risk tolerance to these workers is zero.

Avalanche workers consist of ski patrol staff who are under the supervision of the Forecaster. They are responsible for all active avalanche control mitigation measures.

2.2.2 Guests

During daily operations the primary element at risk on Whistler are the guests, which are challenging to manage due to the wide range of abilities and experience. Following significant snowfall events, increased demand for fresh snow often results in long queues, impatient crowds and individuals who ignore avalanche closure protocols. Operational risk tolerance for all guests is maintained at a minimal level, as even small avalanches can pose substantial risks, especially to vulnerable groups traveling through areas with minor overhead hazard.

2.2.3 Backcountry Users

Since the Spearhead Hut opened east of our boundary in 2019, we have had operational challenges during active control work with guests entering the boundary from this hut. Consequently, several additional layers of safety have been implemented and now include a live map (found at https://whistlerblackcombterrainmap.com) that informs users when it is safe to enter the boundary.

2.3.4 Infrastructure

Most permanent facilities, such as buildings and lift towers, have very limited exposure to avalanches as they are not in avalanche terrain. The following exposed towers and drive stations are subject to full path events only:

- Peak Chair Load Station and Towers 6 and 7.
- Harmony Chair Towers 14 and 15.
- Symphony Chair Towers 20 and 21.

4. PROGRAM CHALLENGES

An average day at Whistler Blackcomb sees up to 25,000 skier visits with the busiest days around 34,000. The pressure to open as much of our 4500 acres of terrain as efficiently and effectively as possible presents unique challenges to the snow safety team.

In order to manage these guest visit numbers our operation runs 24 hours a day, with grooming and lift maintenance staff working two shifts around the clock.

One of our main travel routes affected by avalanche hazard is Pika's Traverse, which connects the lower mountain at 1,850m to the upper mountain at 2,000m. Along its length it is exposed to ten avalanche paths, some of which can produce up to Size 3 avalanches. The entire operation hinges on accessibility along this route, such that if the travel route is closed for avalanche hazard there is no access for grooming or lift maintenance into our alpine terrain.

Whistler also has multiple paths that can produce up to size 4 avalanches and when powerful coastal storms bring significant precipitation in a short amount of time, maintaining access to these start zones in order to

complete avalanche control work to manage the building hazard becomes a critical element of the program's risk management process.

Regular control of access routes and large avalanche paths during storms reduces the opportunity for weak layers to get buried and linger, therefore reducing the amount of uncertainty when exposing our avalanche technicians to this terrain to conduct control work and eventually when opening this terrain to the public. Conversely, being "shut out" of the alpine and unable to actively mitigate the hazard increases uncertainty and may result in several days of alpine closures.

Changing terrain due to melting glaciers has added start zones and made access to some control routes increasingly challenging. In 2023 a ladder was added to one control route affected by an 80 foot drop in the depth of ice in Whistler Bowl.

Another unique challenge to the avalanche program is easy access to the 6.5 km of cornice lines that run adjacent to beginner and intermediate ridge runs. Many incidents have occurred over the years with unsuspecting guests and a few ski patrollers taking nature's elevator to the bottom floor, resulting in injury or lost equipment.

5. BIAS AND UTILIZING DE-BIASING STRATEGIES

Biases can cause avalanche practitioners and professionals to ignore critical danger signs in the environment resulting in potentially fatal accidents in familiar terrain (McCammon, 2002; McClung, 2002; Hetland et al., 2025).

Motivation produces the main bias that influences decision making and it is the ski patrol's purpose to open terrain and keep it open for as long as possible.

Familiarity bias also plays an important role in avalanche forecasting. Whilst an intimate familiarity of terrain is required by the forecasting team, terrain changes such as glacial recession can lead to subtle changes in avalanche paths, which can go unnoticed. This can lead to a mentality that can catch snow safety technicians off-guard, because "this never goes".

Sunk-cost effects can also keep us moving towards a goal solely based on the time, effort or money that we have already invested into trying to achieve said goal. Once we commit to the plan for the day or have brought staff in early, we will tend to push towards completing that plan. This can compound both our motivational and familiarity bias' (Arkes and Blumer, 1985). De-biasing strategies are safeguards utilized to match the intuitive thought process to the rational processes (Kahneman and Klein, 2009). Some processes we use are laid out in our daily AM and PM hazard analysis/Infoex workflows.

5.1 Strategic Mindset

Strategic mindset was brought forth by Roger Atkins in his ISSW paper from Banff 2014 "Yin, Yang and You". In this paper Roger introduces us to mindset and how we consciously and unconsciously weight the potential risks and rewards in avalanche terrain with our desired outcomes which can influence our decisions and perception of terrain and conditions (Atkins 2014). It is important to recognize not just the desires, but the possible outcomes of those desires be them good or bad.

The mindset becomes strategic when consciously put it into workflows and used to communicate the operational plan for the day. Atkins named and characterized a list of mindsets in his 2014 paper, since 2018, the Whistler Avalanche Program has adopted them and defined them in a way that works best for the ski area operation (Haggerty and Horvath, 2018).

Table 1: Whistler Mountain Strategic Mindset – Definitions and Strategies

Mindset	***Definition/Strategy***
Assessment	-Early season or after big storm cycles, confidence low to moderate, more info needed -Active control to open terrain, passive control if informational gaps persist
Stepping out	-Hazard rating decreasing, confidence increasing -Active limited control work
Status Quo	-Same as yesterday, could be during a storm cycle, but still planning on opening all terrain -Active, passive or no control needed
Maintenance	-A possible PWL is about to be or has just been buried within our tenure -Active control, Sc or Xe to disturb layer so it doesn't develop into a widespread PWL in future -Opening the terrain to promote compaction of the possible PWL
Stepping Back	-Hazard rating increasing or closing operational terrain due to building hazard or partial re-assessment of conditions needed before opening terrain -Active and sometimes passive control through the day may be required
Entrenchment	-PWL buried, unpredictable results occurring during control work, continued assessments needed -Active and passive control, operational terrain limited, often only time or big warm storm systems will heal or clean out the PWL -Can happen in spring when we have long warm periods and an active PWL in the region
Spring Diurnal	-Open season to stepping back through day with warming -Passive control with closure
Open Season	-Willing to ski anything (including permanent closures), 1/1/1 -this goes hand in hand with surface conditions not just avalanche hazard

In the AM Hazard workflow, we are "forecasting" the hazard that we expect to see each day and ratings are made for an unmodified snowpack. In addition, a free form page takes each compacted zone into account and a separate rating is given to each zone highlighting individual concerns for those areas. On this page notable changes and uncertainties for the day are discussed. Before the workflow is submitted two simple questions must be answered and justified:

i. Do the avalanche problems (bubbles) reflect the hazard of the day and why?

ii. Is our operational plan on par with our strategic mindset and why?

These questions are designed to add reflection into the forecasting process, our own biases and to promote collaborative thinking by initiating a discussion on what is appropriate for the day, including required risk mitigation measures, given the strength and weight of the avalanche hazard data collected for the operational period.

Each morning in the Snow Safety office the initial mindset is determined during the hazard assessment process. Once any field observations and mitigation measures (if required) are completed, then a reassessment of our mindset can be made. Typically to step up a level during the operational period significant evidence is required to prove that the initial assessment is too conservative. In this case the snow safety team and patrol supervisor of the day would have a discussion to determine if the change of plans is in line with other operational objectives.

5.2 Inflection Points

Inflection points build on our strategic mindset for the day and assist the forecasting team in assessing a myriad of factors that may impact the operation. Simple assessments are made of the most influential factors with estimates of possible outcomes.

The term “inflection point” is built into the daily workflow and lists elements that may cause a step back or decision to not open certain terrain. The following are some of the factors and their effect on the opening/closing of terrain that are discussed:

i. Environmental – Temperature/Freezing level, Wind and precipitation types/amount, rapid changes.
ii. Avalanche Conditions – changing problems/character, building hazard, deep instabilities, PWL, wet slab and location of problems
iii. External Factors – staffing, transport, lifts

Each factor is assessed throughout the day and the risk management strategy is adjusted when the evidence of one or more factors has sufficient strength and weight to promote a re-assessment. For example, one single factor, such as extreme wind speeds, can cause us to step back during avalanche mitigation, whereas a combination of smaller factors and their effects can make it an unsafe environment to continue with the planned program.

Grit and perseverance are often associated with the patrol team and “quitting" is often looked on as a negative attribute. But if “quitting” criteria can be rebranded and built into your operational plan it can help in recognizing when efforts persevere for too long, especially when it has become unsafe to do so (Gollwitzer, 1999).

Annie Duke refers to “kill criteria” in her book “Quit”, she states “we already know that we’re not particularly good at responding rationally in the moment to signals that tell us that we ought to quit (Duke 2022) In fact, we tend to react to bad news by increasing our commitment rather than cutting our losses. If we can identify in advance what the signals are that we should pay attention to and make a plan for how we will react to them, we can increase the chances that we’ll “cut our losses when we ought to” (Duke 2022).

Inflection points attempt to address the above biases and establish “quitting” criteria to avoid “pushing too hard” to open and stay open when the evidence suggests otherwise.

5.3 Confidence and Uncertainty

Confidence and uncertainty should be reflected in the mindset of the day. Low confidence and high uncertainty leans towards Assessment, Stepping Back or Entrenchment mindsets while higher confidence and low uncertainty leads towards Status Quo, Maintenance, and Stepping Out mindsets. Open season should be reserved for the highest certainty in avalanche and surface conditions.

Confidence and uncertainty are clearly communicated each day, through daily meetings and the AM Infoex Workflow. To manage our uncertainty and confidence we use both direct and indirect methods of risk treatment.

5.3.1 Sources of uncertainty

A scarcity of high-quality information can result in high levels of uncertainty, such as when no results are observed during early season storm cycles with basal instabilities and there is little in the way of skier compaction. As the season progresses and if PWL’s are absent, explosive testing and skier compaction reduces uncertainty. Conversely, snowpack conditions, unexpected mitigation results, PWL’s and Wet Slabs contribute to high levels of uncertainty (McClung, 2002).

In addition, a lack of quality observations increases uncertainty. In the mornings, forecasters are often only able to extrapolate the problems based on telemetry, as it is not possible to obtain direct observations due to darkness, weather or access. One solution to this problem is technology, such as implementing the use of automated avalanche detection systems (AADS) as an effective way to obtain continual avalanche observations in avalanche terrain in order to reduce uncertainty.

5.3.2 Managing uncertainty

During storm cycles where only surface instabilities are expected we can maintain operations through ski cutting until certain thresholds are met, depending on the vulnerability of the element at risk. If we are unable to keep avalanche terrain open due to rapid loading with direct methods, then we will manage the risks using indirect methods such as closing lifts and avalanche sign lines.

5.4 Hazard and Risk Analysis

The operational hazard analysis at Whistler follows the Conceptual Model of Avalanche Hazard (CMAH) (Statham et al. 2017) and involves twice-daily evaluations based on weather, snowpack conditions, avalanche observations and potential problems.

Hazard ratings are continuously monitored and refined through observations, risk treatments and patroller input. Hazard assessment is communicated via several means: a live Google Sheet, regular patrol meetings and the InfoEx. Reflection discussions at the end of the day help improve forecasting accuracy and operational practices (Tannenbaum and Cerasoli, 2013).

5.5 Communication

The risk treatment plan starts with the daily hazard evaluation and InfoEx reporting and is communicated within the ski patrol and to other departments on the hill. The Forecasting team often communicates directly with the mountain manager, patrol and lift supervisors. Each afternoon a one on one meeting with maintenance and grooming staff is held with weather, travel clearances and go/no go parameters established when outside of regular operating hours.

Information is disseminated to the ski patrol during daily morning meetings and detailed avalanche briefings before control work commences. Key messages include morning weather observations, avalanche problems including expected spatial distribution and sensitivity, previous avalanche observations and snow profile data, nearest neighbor data, mitigation measures and whether ski cutting can be employed as a control measure safely. During these briefings, we also recognize previous human behaviors (fatigue, stress and bias), as well as any other previously noted material from our PM hazard form reflections.

5.6 Reflection and Debriefing

The PM InfoEx workflow is a “nowcast” and is a reflection of the day, the assigned hazard ratings from the morning and elaborates on data/evidence collected throughout the operational period.

This is a more elaborate workflow as the team has time to discuss the day and it has become one stop shopping for all the daily events related to the snow safety team. The morning hypothesis is assessed, based on the evidence collected from any applied risk treatments. Confidence in the assessment is rated and we reflect on mitigation measures implemented on each route, notable changes through the day, notable occurrences from our neighbors, and any inconsistencies from the AM hazard and weather forecast.

Most importantly, this free form page creates discussion and reflection while debriefing topics such as:

- Did we encounter any human biases and behaviors through the day?
- Was our mindset accurate?
- Did we employ a proper operational plan for the day to be effective, efficient and safe for staff and guests?

Reflecting on all experiences, good and bad, is the key to developing intuition. Picking apart decisions with honesty and humility is essential for seeing weaknesses in the decisions that have been made, even when direct evidence and feedback is not observed (Kahneman and Klein, 2009; Tannenbaum and Cerasoli, 2013).

6. FUTURE WORK - SUCCESSION PLANNING

Mentorship and development of the next generation of forecasters and snow safety technicians is an ongoing process. Currently the forecasters are mentoring patrollers through their CAA level 2 course and CAA Professional Memberships. In order to fulfil the role as an Avalanche Forecaster in British Columbia, WorkSafe BC requires CAA Professional Membership. With continued training, mentorship and professional development, resilience and redundancy is built into the program along with career opportunities, succession planning and personal growth.

7. CONCLUSION

Grit, perseverance and optimism need to be contained in certain situations before failure is achieved (Duke 2022). We discussed de-biasing strategies as part of the procedures that keep us within our operational risk band. The unconscious is always picking up on patterns and cues from our environment to keep us safe. Understanding that our own desires play a huge role in our decision-making allows us to recognize the noise associated with our roles.

Structured daily meetings and clear communication are essential components for continued success when directing a team that performs at a high level in a dynamic and often austere environment. Inflection points go hand in hand with the Strategic Mindset and the CMAH and it allows forecasters to further define their concerns for the day. As a result, communication to the team is improved, uncertainties are recognized, and safety margins increased.

The Whistler Avalanche Program continues to create a culture of reflection, honesty and humility and as the team continues to evolve and adapt to new challenges we must not forget: “The problem with experts, they don’t know, what they don’t know” (Talib, 2007)

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