A COMPARISON OF AVALANCHE HAZARD METHODOLOGIES

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ABSTRACT: Large, active avalanche paths in the Casper Bowl and Crags areas of the Jackson Hole Mountain Resort are situated above open ski runs. The hazard from these paths has been mitigated by two different methodologies. For 23 seasons, from 1966 to 1997, the starting zones of these avalanche paths were closed to skiers, and artillery was used to reduce the hazard. During the past 17 seasons, the hazard has been mitigated by running hand charge routes in combination with the use of bomb trolleys and an avalauncher. “Hiking only” access has been provided to this terrain during this period. This study reviewed and analyzed 40 seasons of avalanche activity for the slide paths in the Casper and Crags areas. Observations indicate that the occurrence of both artificially and naturally triggered large avalanches (destructive size class III and larger) was significantly reduced during the latter period.

KEYWORDS: ski compaction, artillery, avalanche hazard mitigation

1. INTRODUCTION

Avalanche hazard mitigation efforts have been conducted at the Jackson Hole Mountain Resort, which is located in the Bridger-Teton National Forest in western Wyoming, since the resort began operations in 1965. The methods employed to mitigate the avalanche hazard at the resort have evolved over 48 seasons of operation. Early efforts relied heavily upon artillery, and impacts to the snow pack from skier use were limited and localized. Modern age efforts rely upon the extensive use of hand charges, bomb trolleys, avalaunchers and GazEx units. Impacts to the structure of the snowpack from skiers have become more significant and widespread.

This study investigates the impact of two different avalanche hazard mitigation approaches in a small section of the resort where distinct changes in avalanche hazard mitigation methodology occurred over a relatively short time period.

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2. STUDY DETAILS

2.1 Study area

The study area is comprised of two adjacent portions of the resort that are known as Casper Bowl and the Crags. These areas have seven large avalanche paths with active starting zones that are situated above lift served terrain.

Avalanches that originate from starting zones in these areas run onto popular groomed ski runs.

Large events in these avalanche paths can run several kilometers with an elevation drop of 300 to 700 meters. The starting zones of these avalanche paths are situated at an elevation of 2,800 meters, and are comprised of complex terrain includes cliffs, hanging snowfields and mountaineering hazards.

2.2 *Avalanche hazard mitigation history in the study area*

The upper boundary of lift served terrain in the resort has always been located part way down the Crags and Casper Bowl avalanche paths.

From 1966 until the Casper Chairlift was constructed in 1974, the inbounds area beneath these slide paths was only accessible by traverses from other lift accessed areas of the resort. The Casper Chairlift provides access to ski runs located directly below these avalanche starting zones.

Artillery was used to mitigate the avalanche hazard in the study area during the 31 winter seasons from 1966 to 1997. This methodology employed avalanche forecasters who monitored conditions, and gunners who used military weapons to address the hazard when conditions dictated. During this period, no access was allowed to skiers in the upper portions of these avalanche paths.

The objective of the hazard mitigation program in this era was to keep large avalanches from running down onto ski runs. Artillery missions were conducted when forecasters expected that resultant avalanches would run far enough to impact the public.

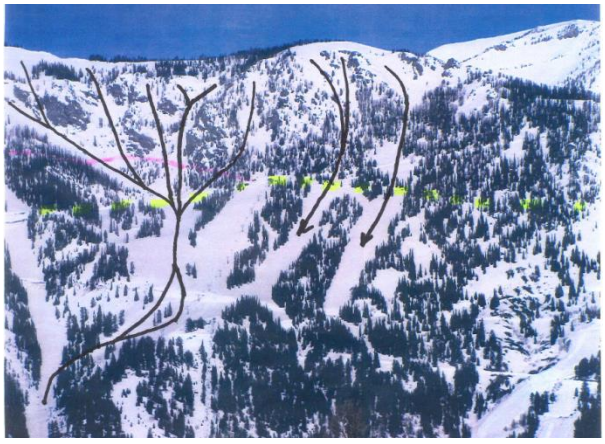

Figure 1: Photograph of the study area. The Casper Bowl slide paths are visible on the left. The Crags are in the center. The lower dashed line (yellow) represents the upper boundary of skier accessible terrain before the construction of the Bridger Gondola. The higher dashed line (pink) represents the upper boundary of lift served access after construction of the Bridger Gondola.

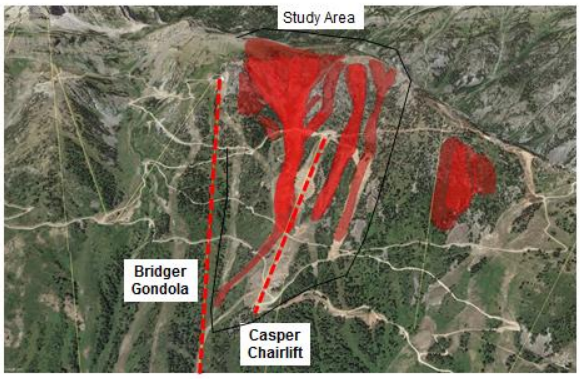

Figure 2: The study area is located in the center portion of this image. The maximum limits of the slide paths in the Crags and Casper Bowl areas are delineated using geographical information system technology, and are superimposed upon a base layer derived from aerial photographs. The locations of the Bridger and Casper lifts are represented by dashed lines.

In 1997, the Bridger Gondola was constructed in terrain adjacent to the study area. Two changes in skier access to the study terrain occurred when this new lift opened. First, the operational boundary of the resort was moved uphill in the Casper Bowl portion of the study area. Skiers leaving the top terminal of the new lift now had access to open terrain higher up in the Casper Bowl area slide paths.

Second, when conditions permitted, resort skiers and snowboarders were allowed hiking access from the top of the new lift to the top of the study area. This change enabled skiers and riders to access starting zones which had never before experience skier traffic.

The objectives of the avalanche hazard mitigation program in the study area changed with the opening of this new lift. The new goals became to reduce the avalanche hazard in the entire study area to the extent that even small avalanches would not occur and harm the public when this area was open, and to keep avalanches from running past the new higher operational boundary when the area above that boundary was closed.

Due to the mountaineering hazards in the study area, this terrain does not open to uphill hiking during periods of bad visibility. In this terrain, very small slides can sweep a skier over a cliff, and people can ski or ride off cliffs by mistake.

New tools and procedures were adopted to address the new avalanche hazard mitigation goals and objectives. These included the continued use of artillery but in a more limited manner, the use of an avalauncher in Casper Bowl, the construction of several bomb trolleys and establishment of four hand control routes in the Crags and Casper Bowl areas.

These new hand charge routes required resort ski patrollers to hike to the top of the study area from the Bridger Gondola. Due to manpower and operational constraints, these routes are not run every day. On days when these routes are not run the avalanche hazard is mitigated by the use of the avalaunchers and/or artillery in combination with terrain closures.

Skier impacts to the study area are significant during extended periods of fair weather. In contrast, skier access and hand charge route access can be non-existent during extended storm cycles.

In summary, the avalanche hazard reduction goals and methods changed in 1997 after the construction of the Bridger Gondola. Prior to 1997, the goal was to keep avalanches from running into open terrain beneath the Crags and the Casper Bowl slide paths. Hazard mitigation efforts after 1997 had a dual purpose. They included preventing skiers and riders from triggering slides in the entire study area, and mitigating the potential for slides to run into open terrain during periods when the study area was closed

2.3 Avalanche observations in the study area

Daily records of avalanche activity at the resort have been kept since 1974. The only avalanche events in the study the area that were entered into this historical record before 1997 were ones that ran past the operational boundary onto the ski slopes. These events were considered to be large (Class III, IV or V) on both the relative and destructive size scales.

After 1997, avalanches of all sizes that have been observed in the study area have been entered into this historical database.

2.4 Analysis of avalanche observations

For this study, a list of avalanche events that occurred in the Crags and Casper Bowl areas that were noted to be Class III sized or bigger, were selected from the historical record and reviewed. Particular attention was given to events that were noted to have run past the pre 1997 operational boundary onto main ski runs. The frequency of artificially and naturally released avalanches that ran that far during the 23 year period from 1974 to 1996 was compared to the 17 year period from 1997 to 2014.

3. STUDY RESULTS

A total of 134 Class III or larger avalanche events were retrieved from the historical records for the avalanche paths in the study area during the 40 year period from 1974 to 2014. Nine of these events were recorded as Class IV in size and there were no Class V sized events.

A Class V event from the Casper Bowl area is known to have occurred prior to 1974, but records for the period from 1966 to 1974 are incomplete and were therefor not included in this study.

Eight of the nine Class IV sized avalanches that occurred in the study area happened during the 23 year period from 1974 to 1997 when the avalanche hazard mitigation program was limited to the use of artillery. During this period, 22 slides crossed the boundary onto the main ski runs of the resort. Eight of these were natural events.

During the 17 seasons from 1997 to present, one Class IV size slide occurred in the study area, and only one slide ran onto a main ski run of the resort. There were no naturally released avalanches that ran onto main ski area runs during this period.

In summary, the frequency of avalanches running onto main ski runs from the study area was once per year (22 in 23 seasons) during the period from 1974 to 1996, and once in 17 seasons during the period from 1997 to 2014.

During the early period, the frequency of natural avalanches running onto the open runs from the study area was once every three years (8 in 23 seasons). No natural avalanche events were observed to have run onto the ski runs during the latter 17 year period.

The frequency of Class IV sized avalanches in the study area was once every three years (8 in 23 seasons) from 1974 to 1996. There was one Class IV sized avalanche recorded from 1997 to 2014 (17 years). That avalanche was triggered by artillery on December 28, 1998 during a period

when the management of this terrain was transforming from the old hazard mitigation methodology to the new methodology. No Class IV sized avalanches have been observed in this terrain since that event in 1998. A summary of these avalanche observations is provided in Table1.

Table.1: Avalanche frequency in the study area

	Frequency	
	1974-1996	*1997-2014*
Artificially triggered onto main ski runs	1/year	1/17 years
Naturally triggered onto main ski runs	1/3 years	0/17 years
Class IV size avalanche	1/3 years	1/17 years

4. DISCUSSION OF RESULTS

The avalanche observations reviewed indicate there has been a significant decrease in the frequency of large avalanches in the study area, which corresponds chronologically with a change in the methodology of avalanche hazard mitigation and skier use.

Avalanche hazard mitigation efforts were employed more frequently and in a more robust manner during the past 17 seasons compared to the previous 23 seasons, and therefore these results are not unexpected.

Large avalanches are certainly possible in the study area in the future, but are expected to continue to occur on a less frequent basis if avalanche mitigation methods and skier access remain unchanged.

Red flag conditions for large avalanche events include but are not limited to:

1) Conditions when a persistent weak layer exists that is unaffected by ski compaction
2) Extreme storm cycles or weather conditions
3) Rain on snow events and sudden prolonged thaws

5. STUDY LIMITATIONS

This study presents a review and analyses of information obtained regarding avalanche activity and avalanche mitigation techniques used at the Jackson Hole Mountain Resort. Conclusions based on this information are limited by the methods used to collect and review that data.

6. ACKNOWLEDGMENTS

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