AVALANCHE HAZARD
ASSESSMENT & MITIGATION REPORT

SYLVAN PASS,
YELLOWSTONE NATIONAL PARK

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1.0 Executive Summary

The East Entrance Road through Sylvan Pass in Yellowstone National Park has a long history of impacts from avalanches. The purpose of this study has been to identify the hazards from avalanches associated with travel through the pass, identify safety concerns associated with the hazard management program and to present hazard mitigation strategy options.

The efforts conducted have determined that snow avalanches large enough to violently sweep vehicles off of the road and cause serious injury or death to the occupants are a hazard to snowmobiles, snow coaches and snow surface grooming equipment in the winter and wheeled vehicles including cars, trucks and snowplows in the fall and spring.

A program to assess and mitigate the hazard on Sylvan Pass has been operational since the 1970's. For over 30 years this program has relied upon artillery to assess the stability of the snow and reduce the hazard for the purpose of quickly reopening the road to travel. In North America artillery has a long history as an effective and safe tool for mitigating avalanche hazards to roads, railways and ski areas. The National Park Service (NPS) recently replaced the tasks conducted by artillery with a specialized contract crew that deploys explosive charges into avalanche target zones from a helicopter.

Highway avalanche hazard mitigation programs are based on the premise that experienced and well-trained avalanche specialist can determine when conditions are potentially dangerous, temporarily close the road, use explosives to test the stability of the snow and reduce the hazard by creating small avalanches in a controlled environment.

Avalanche hazard mitigation programs can greatly decreases the potential for a traveler to be seriously injured on killed in an avalanche but may not completely eliminate this possibility. The complete elimination of all hazards to a road from avalanches can be expensive and may not be feasible. Schaerer (1988) suggest that an acceptable risk from avalanches to a road would lie somewhere between the risk from other natural hazards and from traffic accidents.

This report provides an overview of the past and current operations. Safety concerns to the public and NPS employees are identified and discussed. Alternate hazard mitigation strategies exist and are presented.

2.0 Introduction

The East Entrance Road in Yellowstone National Park is one of five major arteries for vehicle traffic into the park. This road crosses over the Absaroka Mountain Range through Sylvan Pass. Sylvan Pass is the location of active avalanche paths that impact the roadway.

The goal of this study has been to identify the hazards from avalanches associated with travel on the East Entrance Road and to review alternative mitigation strategies. To accomplish this task the avalanche hazard has been characterized and a review of the existing avalanche mitigation program has been conducted. These efforts included a review of available records, interviews with personnel familiar with winter operations, and a visit to the pass in winter conditions.

Section 3.0 of this report identifies hazards to the public and personnel involved in the management of these hazards. Section 4.0 presents hazard mitigation alternatives. References are provided in Section 5.0 and Section 6.0 provides a biography of this reports chief contributor. The work performed for this study is provided in response to the National Park Service (NPS) Request For Quotation No. Q1571060030. The authorization for this work to commence was provided in an Order For Supplies Or Services issued on August 25, 2006.

This study only evaluates the hazard to travelers on the road and to NPS personnel responsible for the management of that hazard. It is based on the sources of information referenced.

3.0 Avalanche Hazard Assessment

3.1 Background Information

This section provides information regarding the location and setting on Sylvan Pass that pertains to the avalanche hazard and a history of the pass with respect to the management of winter travel and avalanche hazards. A summary of avalanche fatalities that have occurred in the park is also included.

Location/Setting

The East Entrance Road runs from the east boundary of the park to a junction with other interior park roads near Fishing Bridge and Lake Village. At Sylvan Pass the East Entrance Road crosses over the height of the land at an elevation of 8,555 feet between the steep slopes of Top Notch Peak (10,238 feet) to the south, and Hoyt (10,506 feet) and Avalanche Peak to the north. The road is 28 miles in length. Sylvan Pass is 7 miles from the east entrance of the park and 21 miles from NPS facilities at Lake Village. It is 63 miles to Cody, Wyoming from the east entrance of the park. The location of the East

Entrance Road is shown on Figure 1. The layout of the road is shown on Figure 2. The road, avalanche paths that impact it, and the location of a gun mount for artillery is provided on Figure 3. This figure also shows the location of a service road that provides summer access to the gun mount. The locations of smaller avalanche paths in the vicinity of the gun mount and the service road are also shown. A list of the physical attributes of the avalanche paths that impact the East Entrance Road is provided in Table 1.

The Sylvan Pass area receives a great deal of snow (an estimated 350 inches or more per season) and is extremely windy. At these elevations snow can fall during all months of the year. Snow begins to accumulate in September and can reach depths of five to fifteen feet deep during the winter. Seasonal accumulations can linger into July.

During the winter season (typically from the third weekend in December through the second Monday in March) the road is machine groomed and open to the public for over-snow vehicle use. During the summer season (typically from the first Monday in May to the first Monday in November) the road is open to the public for wheeled vehicle use. During the shoulder seasons the road is closed to public vehicle travel and is subject to administrative and maintenance vehicle travel. If conditions permit snowplows keep the road open for this use until the first Monday after Thanksgiving. Snow removal equipment is mobilized in April for the purpose of reopening the road to public wheeled vehicle traffic in early May. During the snow season the highway to Cody is plowed to the park boundary, which is about one mile east of the East Entrance Ranger Station.

Sylvan Pass History

Before the East Entrance Road was constructed in the early 1900's, Indians and early travelers in the area used trails through Sylvan Pass and other passes in the area to cross over the Absaroka Mountain Range. Initially the road was open for summer travel only. Later on, maintenance crews shoveled through the last remaining snow in June to get the pass open earlier.

In the 1960's the NPS desired to improve public winter access to the interior of the park. Snowmobiles and snow coaches were introduced to attain this goal and were allowed seasonal access to the park roads. Snow grooming equipment was necessary to prepare the snow surface of the park roads for this type of travel.

The hazard to the East Entrance Road from avalanches was well known. Early on, before Yellowstone became a national park, soldiers were ordered not to ski over the pass due to avalanche hazards. In the early 1970's an avalanche hazard mitigation program was instituted to protect the snow grooming personnel and the public. By the end of the 1990's snowmobile use became so popular that environmental concerns arose. A temporary management plan currently requires visitors on snowmachines to be accompanied by a guide, limits the number of snowmobiles allowed in the park, and permits commercial snow coaches as an alternative winter transportation option.

Park records indicate 4,183 visitors passed through the east entrance during the 2001 winter season on 3,494 snowmobiles. During the 2005/06-winter season these records indicate 947 visitors passed through the east entrance via 635 snowmobiles and 23 snow coaches.

Avalanche Fatalities in Yellowstone National Park

There have been six avalanche fatalities in Yellowstone. Three of these occurred prior to 1917 in the northwestern portion of the park. Two of these were soldiers and the other was a person riding in a horse drawn sleigh between Mammoth Hot Springs and Gardiner, Montana (Lee 1995).

The other three fatalities occurred after 1991. On February 22, 1992 Gregory Felzien died while tracking mountain lions in the Lamar Valley. On March 3, 1997 Yellowstone Park research geologist Rick Hutchinson and Diane Dustman, a visiting seismic geologist, died on Factory Hill near Mount Sheridan in the Heart Lake area.

No avalanche fatalities are known to have occurred in the Sylvan Pass area.

3.2 Avalanche Hazard Characterization

Avalanches have been a safety concern to travelers on the East Entrance Road since it was opened to motorized winter travel in the 1970's. Avalanche hazard is defined as the expected frequency of damage and loss as the result of an interaction between an avalanche and objects and persons (Schaerer 1988). There are two components to this hazard. One is the frequency of an encounter in a given period of time, the other is the nature and magnitude of the resulting damage which in turn is a function of the nature of the avalanche.

An idealized classification system based on an avalanches effect to travel exists (Schaerer 1988). This scheme classifies dry snow avalanches as powder snow, slough, light snow, deep snow or plunging snow events. An abbreviated version of this scheme follows.

Powder snow events deposit less than 3.5 inches of snow on a roadway. These events produce conditions similar to those encountered from blowing snow. Poor visibility may cause drivers to collide with a snowbank or another vehicle. In most cases only minor damages occur.

Sloughs are slow moving flows of snow that typically originate from short steep slopes. Deep snow can be deposited on one shoulder of the road. Deposits that cross the road are generally less than 11 inches deep. Drivers are usually able to go around the deposition.

Light Snow events deposit 12 to 37 inches of snow on the roadway. These events can push cars off of the road but are not likely to bury them. A vehicle pushed over a steep slope can incur severe damage.

Deep snow events cross the roadway and deposit over 37 inches of debris. These events sweep vehicles off the road. Severe damage and death from trauma or burial in the snow is possible.

Plunging events involve high-speed avalanches that have fallen over long steep slopes and cliffs. These events are extremely destructive.

To assess the avalanche hazard to this roadway this study has reviewed available information regarding the nature of the avalanches involved in this setting and the potential for these avalanches to interact with winter travelers. The primary resources used to characterize the avalanche hazard on Sylvan Pass were topographic maps, aerial photographs, historic records and interviews with personnel knowledgeable with the existing avalanche mitigation program. This effort included a visit to the Sylvan Pass area by an avalanche specialist who is familiar with avalanche assessment and mitigation programs in North America, Europe and New Zealand. The results of this analysis are summarized as follows.

The East Entrance Road runs through Sylvan Pass in an east-west direction. A 5,000-foot long segment of the road at Sylvan Pass crosses through terrain that is known to produce powder, light and deep snow avalanche events that impact the road. This terrain does not produce plunging events. The remaining portion of the road to the East Entrance and Lake Village has a few steep hillsides, banks, and road cuts that can slough minor deposits of snow onto the roadway during unstable conditions.

Figure 3 shows the Sylvan Pass segment of the road and avalanche paths of concern. Avalanches that impact the roadway initiate from starting zones situated above the road. After release, they flow down gullies between rocky outcrops towards, to, and sometimes over, the roadway. The size and length of these avalanches varies depending on the volume of moving snow involved and conditions at the time of release.

The exact location of the road through the pass has changed over the years, however its course has been confined to a narrow passageway that goes up and down the drainages that flow east and west from the top of the pass. Over the years there have been massive earthworks conducted in this passageway. A huge volume of material has been excavated and used for road building purposes. These earthworks have repeatedly changed the detailed topography of the roadway and may have removed vegetation in portions of the avalanche paths that can provide insight into the frequency and size of historical avalanche events.

To assess the hazard from avalanches to travelers on the East Entrance Road the topographical attributes of the avalanche paths of concern have been investigated. All of the avalanche paths that have historically impacted the road originate from starting zones on the north side of the road. The starting zones of these avalanche paths are numbered according to artillery target designations. Other dangerous avalanche paths on both sides of the road in Sylvan Pass exist. This assessment does not evaluate the hazard associated with avalanche paths that are not known to impact the road or the gun mount area.

Outlines of avalanche starting zones, artillery targets (numbered) and outlines of the estimated extent of a large avalanche initiated from these target areas are shown on Figure 3. During periods of severe widespread instability some of these paths may overlap and release simultaneously. In extreme or unusual circumstances, areas between the delineated slide paths (areas between paths 16 & 17 and paths 17 & 18) could also fail and potentially impact the road.

Avalanche paths are comprised of starting zones, tracks and runout zones. The starting zones are located in the upper portion of a path. Snow accumulates in starting zones and under certain conditions can collapse or fail and flow down the track of the avalanche path. Some avalanche paths have multiple starting zones. The runout zone is located in the lower portion of the track where the slope becomes less steep and the avalanche stops. The majority of the snow entrained in a flowing avalanche is typically deposited in the runout zone.

To characterize the hazard presented by these paths to the road the physical attributes of the portions of the avalanche path above and to the road have been investigated. The delineation and characterization of the portions of the paths below the road that do not impact any other features of concern was not considered to be a goal of this study.

Avalanche Path Attributes

The physical attributes of the terrain where avalanches occur can provide insight into the magnitude and frequency of resultant avalanches. An understanding of the attributes of the avalanche starting zones can help forecasters to anticipate when snow in these paths may become unstable. Knowledge of the physical attributes of a slide path at its intersection with the road can be an important consideration in the selection of potential mitigation options. Selected physical attributes were determined for each of the slide paths that are known to have historically impacted the East Entrance Road and are listed in Table 1. A discussion of these attributes follows.

Starting Zone Elevations

The average elevation of the starting zone of the avalanche paths that impact the road is 9,096 feet above sea level. All of these starting zones are located between an elevation 8,692 and 9,363 feet. The range of elevations of these starting zones is 671 feet. The elevations of these starting zones are similar. Avalanche paths with similar elevations tend to become unstable during similar conditions.

Starting Zone Aspects

The aspect of the starting zone is defined as the compass direction that the starting zone slope faces. The average aspect of the avalanche starting zones that impact the road is 205 degrees (south-southwest). The aspect of these starting zones is distributed across a range of 46 degrees from 184 to 230 degrees (south to southwest). The aspects of these starting zones are similar. Avalanche paths with similar aspects tend to become unstable during similar conditions. In general weaknesses associated with buried faceted snow tend to persist longer on northerly aspects than southerly aspects. Southerly aspects are favorable areas for the development of sun and radiation re-crystallization crusts. These crusts can become sliding layers and can also provide strength to a snowpack.

Starting Zone Slope Angles

Most avalanches initiate on a 30 to 45 degree slope. A slope angle of 38 degrees is an ideal slope angle for avalanche initiation. The average slope angle of these starting zones is 38 degrees. The mean maximum slope angle of these starting zones is 47 degrees. The mean minimum slope angle of these starting zones is 33 degrees. Avalanche paths with similar slope angles tend to become unstable under similar conditions.

Length of Avalanche Tracks Above the Road

The distance from the starting zone of each path to the road was determined. The average distance from the starting zone to the roadway along the avalanche tracks was 1,160 feet. These distances ranged from 1,646 feet to 518 feet. Paths 1, 8C, 17, 18 and 18B have shorter track lengths above the road than the others. The length of these tracks above the road ranges from 518 to 739 feet. The length of the remaining tracks range from 925 to 1646 feet.

Elevation Difference between the Avalanche Starting Zones and the Road

The difference in the elevation (vertical drop) between avalanche starting zones and the road was determined. The average vertical drop was 613 feet. The vertical drop ranged from 337 to 901 feet. Paths 1, 8C, 17, 18 and 18B have shorter vertical drops than the other paths. The vertical drop of these tracks ranges from 337 to 406 feet. The vertical drop of the remaining tracks ranges from 505 to 901 feet.

Avalanche Track Angle above the Road

The slope angle of the avalanche track from the starting zone to its intersection with the road was calculated. The average angle of the track above the road was 32 degrees. This angle ranges from 27 to 41 degrees.

Width of Avalanche Track at the Road

The width of the avalanche tracks at the road varies depending on the volume of snow in each avalanche event on a specific avalanche path. A maximum width for a large sized avalanche relative to the size of a specific track was estimated based on the topography of the track and vegetation patterns observed along the parameter of the track. The average maximum width for these avalanche paths at the road is 243 feet. The width of the tracks at the road ranged from 89 to 600 feet.

Runout Zones

The runout zone of an avalanche path is defined as the portion of the avalanche track or path where the steepness of the slope along the track lessens to the point where the mass of the snow in the avalanche begins to slow down and is deposited.

The extent of the area of the runout zone where the avalanche debris is deposited varies depending on the volume of snow incorporated in each avalanche event. Small avalanches with low volumes of snow run only short distances and in many cases would not run far enough along a track to reach the road. Medium sized avalanches could run to the road and would likely impact a portion of the road less than the maximum width determined for larger events. Large avalanches would cross the road and could impact the maximum width of the road estimated for each slide path. The delineation of the extent of runout zones below the road if they did not have potential to impact the area of the gun mount was not considered to be essential to the purpose of this study.

Avalanche Path Attributes Discussion

The physical attributes of the avalanche starting zones that impact the East Entrance Road are similar with respect to elevation, aspect and starting zone slope angle. These starting zones are also close to each other with respect to distance and therefore weather conditions that create unstable conditions likely occur in these starting zones at the same time. The starting zone slope angles of these avalanche paths are favorable for artificial and natural avalanche initiation.

The length and slope angle of these avalanche tracks above the road are sufficient to produce powder, light, and deep snow avalanches. These events could obscure visibility, push a vehicle off the road, or violently sweep a vehicle from the road and severely damage or bury a vehicle. In addition steep slopes exist on the downhill side of the road. The consequences to a vehicle being hit by a large fast moving avalanche on one of these paths are severe. Serious injury, death by trauma, or suffocation could occur to the occupants of a vehicle.

Avalanche Frequency

Knowledge of the return period or frequency of avalanche events is an essential component of an avalanche hazard assessment.

A trigger is necessary to start an avalanche in motion. Snowfall, rainfall, drifting snow, sunshine and rapid rises in temperatures are examples of natural triggers that can initiate the failure of an unstable slope and cause an avalanche. Explosive charges, artillery or the weight of a skier, snowmobile, snow groomer or other winter traveler are artificial triggers that can release avalanches.

The NPS has an existing avalanche hazard mitigation program for Sylvan Pass. This program monitors avalanche conditions and closes the pass when conditions are suspected to be unstable. When conditions warrant explosives are deployed into avalanche starting zones to test the stability of the snow. If unstable conditions exist avalanches occur and the hazard is reduced. By conducting numerous missions expertly timed with periods of instability skilled specialist can trigger frequent small avalanches as opposed to occasional large avalanches. This methodology of monitory conditions and triggering small avalanches during periods of instability is a standard practice for mitigating avalanche hazards on highways and at ski resorts in North America.

The crews on Sylvan Pass have been triggering avalanches with artillery for over 30 years. In the 1970's hazard reduction missions were infrequent and were only conducted after big storms or in the spring before plowing operations began. With this mode of operation large avalanches were triggered when conditions were favorable.

As traffic increased, hazard reduction missions became more frequent. A former employee, who participated in this program for 22 years, reported that there was a large variation in the number of avalanches artificially triggered on a year-by-year basis (Lounsbury 2006). He estimated 120 to 130 slides were triggered by artillery during a season with a lot of avalanches and 60 to 80 were triggered during seasons with minimal avalanche activity.

This former program leader estimated 20 to 30 significant natural events occur during an active season. He reported that the occurrence of naturally triggered avalanches decreased significantly when hazard reduction mission were conducted more frequently. It is generally accepted that the use of explosives as a mitigation strategy can reduce the occurrence of natural occurring avalanches by as much as 90% (Schaerer 1988).

Mission records from the last eight seasons were available and reviewed. No records of avalanche activity prior to 1999 were reported to exist. These records provide some vague information with respect to the number of avalanches triggered and if the slides crossed the road. The notes on these records indicate approximately 300 avalanches were triggered by these missions. Approximately sixty-eight of these avalanches are believed to have run to or across the road. Some references to observed natural avalanche activity are included on these mission records.

Avalanche Hazard Index

The Avalanche Hazard Index (AHI) is a numerical expression of damage and loss caused by the interaction between snow avalanches and vehicles on a road (Schaerer 1988). The index is determined by multiplying the frequencies of moving and waiting vehicles being hit by various types of avalanches (slough, powder, light, deep, and plunging) by a weighting that reflects the severity of the consequences. Its calculation is based on estimates of the types of avalanches, their widths on the road, frequencies of occurrence and the relation of timing with respect to avalanches in adjacent avalanche paths.

The formula to calculate an avalanche hazard index on Sylvan Pass could be modified for over snow vehicle traffic, however an essential component of the calculation is the frequency of natural avalanche activity for the different types of avalanche events that impact the roadway at each known path. In the case of Sylvan Pass an avalanche mitigation program that routinely artificially triggers avalanches has been in place for over 30 years. Appropriate data regarding the frequency of natural avalanche occurrences on these paths is not available. Without natural avalanche frequency data this calculation would not be valid.

Schaerer states that elimination of all hazards to a road from avalanches can be expensive and may not be feasible. He suggests that an acceptable risk from avalanches to a road would lie somewhere between the risk from other natural disasters and from traffic accidents. Using his calculations an avalanche hazard index of 1 is considered to be acceptable.

Schaerer reports that the section of the Trans-Canadian Highway that crosses the Selkirk Mountains through Rogers Pass in British Columbia has the highest avalanche hazard of all roads in Canada. He calculated an AHI of 1004 without a mitigation program. He further reports that mitigation efforts employed reduce the AHI for this section of highway to 0.8.

Gun Mount Access

Large dangerous avalanche paths also exist on the south side of the pass**,** however none of these paths have been reported to have historically impacted the East Entrance Road. The gun mount for artillery is located on the south side of the East Entrance Road at a location that is shown on Figure 3. There are several small avalanche paths in the vicinity of this service road. These paths are a several hundred feet long and slide infrequently, however they are capable of producing avalanches that could injure, bury, or kill a person. Their estimated locations are outlined on Figure 3.

Wet Snow Avalanches

Assessment efforts conducted above relate to hazards associated with dry snow avalanches. Wet snow avalanches occur when temperatures are warm enough for at least a portion of the snow entrained in the avalanche to be damp. Wet snow avalanches typically occur during rain on snow events or when the snow surface is exposed to intense sunshine, a rapid rise in temperature, or during an extended period with air temperatures above freezing. Wet slides can occur during the period of winter use but are more likely to occur at the onset or during the melting season. A wet snow avalanche on a path with these attributes could sweep a vehicle off the road and bury and kill or injure the occupants. Wet snow avalanches can be problematic compared to dry snow avalanches with respect to hazard forecasting and mitigation and should be considered to be a serious threat to oversnow and wheeled vehicle traffic on Sylvan Pass.

Spring & Fall Avalanche Hazards

The threat of snow avalanches to the East Entrance Road is not limited to the winter season. Spring snow removal operations occur in April when snow depths are typically near their maximum depths. In the past the author of this report has skied on the avalanche paths of concern during May after the road had been plowed and opened to the public for wheeled vehicle traffic. At this time it was observed that these paths had sufficient snow cover for dangerous avalanches to occur.

The attributes of these slide paths, their geographical relationship to the roadway and the climate of this area indicate dry and wet snow avalanches should be considered to be a potential hazard when these paths are snow covered (typically November through May and possibly in October or June). An avalanche hazard assessment and mitigation program is necessary to protect the public, administrative travelers and NPS workers during the entire snow season.

3.3 Mitigation Program Overview

The need for an avalanche hazard mitigation program was apparent before grooming operations for snowmobile travel began in the 1970's. For over 30 years a specialized team has used hazard evaluation skills and artillery to mitigate the avalanche hazard. Operations are based out of facilities located in Lake Village and at the East Entrance to the park.

The primary purpose of the mitigation team has been to monitor conditions and close the road to all forms of traffic when dangerous conditions occur. When conditions are determined to be appropriate, the team uses explosives to assess and reduce the hazard and potentially reopen the road.

The program has relied upon military weapons (recoilless rifles or howitzers) since it started. These weapons fire explosive rounds into avalanche starting zones from a gun mount located on the south side of the pass. The artillery enables the crew to test the stability of the snow and attempts to reduce the hazard by triggering frequent small avalanches. This methodology is common among crews who manage highways and ski areas in avalanche prone areas. In 2004 a helicopter was introduced as a method to deploy explosives to avalanche starting zones.

3.3.1 Program History

A former member of the mitigation team for 22 years, who also had some previous knowledge of the program, provided insight into the historical operations of the Sylvan Pass avalanche program (Lounsbury 2006). He reported that a 105 mm recoilless rifle was used in the early 1970's. It was mounted on a steel platform close to the location of the present gun mount. After one or two seasons this weapon was replaced with a 75 mm recoilless rifle. A 102 105mm Howitzer replaced the recoilless rifle in January 1997.

In the 1970's there were few artillery missions. The artillery was used only after large storms or when the road was to be plowed in the spring. Avalanches typically occurred during storm cycles and periods with high winds. As traffic increased grooming occurred at night and the number of missions increased. Early crews were inexperienced and untrained. Formal military weapons operations training and avalanche rescue equipment were introduced to the program in the 1980's.

Helicopter missions became part of the program during winter 2004/2005 and played a substantial role in the 2005/2006 season. The mitigation team has been directed that all explosives deployment be conducted by helicopter except in the case of an emergency during the 2006/2007season.

Snowmobile traffic through the east entrance increased during the 1980's to an estimated volume of 100 machines per day (Lounsbury 2006). Since 2000 the use of snowmobiles in this area has decreased and snow coaches have been introduced. For the past two seasons snowmobiles were required to be accompanied by guides and numbers were limited at the east entrance station to a daily maximum of 40 snowmobiles. Winter traffic through the east entrance was estimated to be 12 snowmobiles per day last season and 1 snowcoach every 3 to 4 days.

3.3.2 Current Operations

A review of program operating procedures was conducted with NPS personnel during a site visit on November 8th and 9th. Operational Profiles, Forecasting Guidelines, a Howitzer Operation Plan, Helicopter Operations Plan, program records, daily operations, mission specific topics, training and education policies were reviewed and discussed. Copies of these profiles, guidelines and operation plans are provided in the Appendix of this report.

The forecasting and mitigation crew is comprised of a core group of highly experienced employees. Every day from November to May depending on snow conditions members of the crew review data and information from available resources and make an assessment of the hazard to travelers on the road. Helicopter missions are conducted to test conditions and mitigate the hazard. Conditions are continually monitored and hazards reassessed.

The resources used to assess the hazard include meteorological observations made by NPS program personnel at the Lake and East Entrance facilities. They also include daily reviews of the weather forecast provided by the National Weather Service and other sources. Other resources include Backcountry Avalanche Forecasts issued by the Bridger-Teton National Forest, and the Gallatin National Forest Avalanche Centers and data from a remote National Resources Conservation Service (NRCS) snow survey station (Snotel site) located near Sylvan Lake on the west side of Sylvan Pass.

The Sylvan Pass Snotel site provides air temperature and precipitation data that is used by the NRCS to forecast and manage water supplies. These resources do not include any real time data for wind speeds and direction from the Sylvan Pass area. Wind speed and direction are critical parameters associated with the assessment of avalanche hazards.

This program currently does not operate specialized weather stations in the vicinity of the avalanche paths. This practice would greatly enhance the ability of this program to assess the hazard. The use of specialized weather stations to provide real time data regarding wind direction, wind speed, temperatures, snow depths and precipitation rates from the area of concern is a standard practice for similar programs in North America and Europe.

Remote weather stations should be installed and equipped with instrumentation that will operate in the severe conditions that exist on Sylvan Pass and provide data that is specific to the needs of this NPS avalanche hazard assessment and mitigation program.

Guidelines for the use of remote weather stations and for generally gathering avalanche data can be found in the American Avalanche Association/Forest Service National Avalanche Center Snow, Weather, and Avalanches: Observational Guidelines for Avalanche Programs in the United States.

3.3.3 Comparison to Other Programs

Other programs that assess and mitigate avalanche hazard to transportation corridors and ski areas exist in North America. These programs are similar in that they rely upon highly trained personnel to monitor conditions and manage the hazard from avalanches. The primary mitigation practice is to close access when conditions dictate. In most cases economic needs typically call for quick action to address the hazard and abate economic impacts. Explosives are clearly the industry standard to accomplish this task.

The Sylvan Pass program differs from other programs in that it is conducted for the purpose of addressing the avalanche hazard to over snow vehicle use in a recreational setting in a National Park. Other programs used for comparison assess and mitigate the hazard to plowed roads, railways or ski areas. Automobile and truck traffic volumes for some of these other programs were reported to range from 400 to 22,000 vehicles per day. Current winter traffic volumes for Sylvan Pass have been reported to be in the order of 8 to 12 vehicles per day.

Artillery has historically been a tool of choice for explosive delivery in North America. Recent innovations include non-military devices to deliver explosive projectiles and fixed place explosive delivery devices. In ski areas hand charge delivery by ski patrollers is prevalent. In the majority of mitigation programs the helicopter delivery of explosives is a supplementary role. A brief overview of other programs in North America follows. Explanations of some of the mitigation methods and devices referenced below are provided in Section 4.0 Avalanche Hazard Mitigation Strategies of this report.

The following programs were used for comparision: Alaska Department of Transportation (AKDOT), California Department of Transportation (CADOT), Colorado Department of Transportation (CODOT), Utah Department of Transportation (UDOT); Washington State Department of Transportation (WADOT), the Wyoming Department of Transportation (WYDOT) and the highway department of British Columbia in Canada.

In Alaska the DOT uses Howitzers to protect roadways over Thompson Pass and near Juneau. A recoilless rifle is used on Atigun Pass. The portion of this program that addresses the Seward Highway averages about 12 to 15 artillery missions per year. An estimated 300 artillery rounds are fired during these missions. Helicopter bombing missions and hand placed explosives supplement the artillery program. This program also uses earthworks as a mitigation method. The traffic volume on the Seward Highway was estimated to be 6,000 vehicles per day.

The Washington Department of Transportation conducts an estimated 32 avalanche hazard reduction missions per year to protect highways over Stevens and Snoqualamie Passes. Their program uses four recoilless rifles, one Howitzer, four M60A3 Battle Tanks, one Avalanche Guard (a fixed place solid propellant explosive delivery system), fixed place aerial explosive delivery cables, hand charge routes supported by tracked oversnow vehicles and occasional helicopter missions. The Avalanche Program Coordinator estimated they fired an average of 150 artillery rounds per year. The traffic volume over Snoqualamie Pass was estimated to be 27,000 vehicles per hour.

The Wyoming DOT uses a Howitzer to mitigate avalanche hazard on Teton Pass and in Hoback Canyon. This program uses two Avalanche Guards and four Gazex (fixed position explosive detonating devices) on the Glory Bowl and Twin Slide avalanche paths. This program is using infrasonic sensors to detect natural occurring avalanches that impact the highway as they occur. These sensors also detect small avalanches that occur naturally or are initiated by mitigation efforts. Near real time knowledge of these events are useful in the decision making process associated with managing the avalanche hazard to this highway. These sensors can also remotely confirm the detonation of explosive charges during storm conditions. The WYDOT program uses snow sails to disrupt snow deposition in an avalanche-starting zone as a method to mitigate impacts to a highway south of Jackson, Wyoming.

The Utah DOT uses artillery and avalaunchers (a non-military explosive projectile delivery device) to mitigate the threat of avalanches to busy highways. Infrasonic sensors have been recently installed to research the potential to detect spontaneously released avalanches that impact the highway in Little Cottonwood Canyon.

The Colorado DOT uses six howitzers, at least five avalaunchers and helicopter missions to reduce the avalanche hazard on numerous passes and transportation corridors in the state. The California DOT uses one avalauncher, two Gazex devices, hand charge routes, two LoCats (infrequently) and on rare occasions helicopter missions.

The province of British Columbia in Canada has an extensive avalanche mitigation program for its highways. The section of the Trans-Canada Highway that passes through Rogers Pass has the highest avalanche hazard of all roads in Canada (Schaerer 1988). Sixty-five avalanche paths threaten this section of highway. It had a winter traffic volume of 1700 vehicles per day in 1987. Schaerer calculated that without an avalanche hazard mitigation program this section of highway would have an AHI of 1004. Engineering designs including snow sheds, retaining barriers in starting zones, earth dikes and earth mounds were used to reduce the AHI to 235. An extensive artillery program was used to further reduce the AHI to 27. Frequent road patrols that keep the exposure time of waiting vehicles to less than one hour and signage that attempts to keep waiting vehicles from stopping in avalanche paths and road closures were used to address the residual hazard. Schaerer reported in 1988 that on average two uncontrolled light-snow avalanches were observed to impact the road per year (that resulted in an AHI of 0.8).

Railroads in Alaska, Montana and Canada have avalanche hazard mitigation programs. The Alaska and Canadian programs use artillery. Alaska Railroads uses a Howitzer on the Seward Railroad Transportation corridor and has two other Howitzers mounted on railcars that are used on other rail lines. The Burlington Northern-Santa Fe railroad has recently proposed using artillery in Glacier National Park, although the NPS opposes this proposal.

Many ski resorts in North American also have avalanche mitigation programs. The programs at Alyeska in Alaska; Alta and Snowbird in Utah; Bridger Bowl in Montana Alpine Meadows and Mammoth Mountain in California; Las Vegas Resort in Nevada, Taos in New Mexico and Jackson Hole in Wyoming all have historically used artillery as a avalanche hazard reduction tool. Many of these resorts also use avalaunchers and run routes where ski patrollers deploy hand charges. Helicopters are occasionally used in ski area applications

In Wyoming, Montana, Utah and Idaho over 10,000 miles of trails and unplowed roads are machine groomed for oversnow vehicle travel. Snowmobilers, cross-country skiers, walkers, dogsledders, snow coaches and snowshoers use these trails. Although best efforts have been made to avoid avalanche hazards, sections of these trails pass through avalanche prone terrain and are impacted by natural and human triggered avalanches during periods of instability. Recreational users and workers who maintain these trails are exposed to avalanche hazards. None of these routes are known to have active avalanche hazard assessment and mitigation programs. Educational efforts are being developed to raise the avalanche awareness of this hazard to the public.

3.3.4 Mitigation Program Hazards

Avalanche forecasters and mitigation crews are exposed to hazards as they perform their jobs. In this section hazards associated with the Sylvan Pass program are presented and discussed.

Reconnaissance Patrols

NPS employees on snowmobiles conduct daily patrols for the purposes of assessing conditions on the Pass. These patrols originate from the East Entrance Ranger Station and Lake Village. Prior to each patrol, the Sylvan Pass team conducts an in-depth assessment of the expected hazard. If this assessment or observations made during the patrol indicate the potential for significant danger the pass is closed and hazard mitigation efforts are considered. Real time weather data from the pass would greatly increase the accuracy of this hazard assessment.

A NPS service ranger died on a reconnaissance patrol on Sylvan Pass in January 1994 when he drove his snowmobile off the road during whiteout conditions. Whiteout conditions occur when strong winds blow snow or during periods of intense snowfall. Weather instrumentation could provide data that would indicate whiteout conditions are possible. Travel during whiteout conditions should be avoided. Snowmobile safety and training courses and annual refresher courses are required for all park employees who use snowmobiles.

The interior of Yellowstone National Park experiences some of the coldest temperatures in the continental United States. Sylvan Pass is very windy. Very cold temperatures and windy conditions can combine to create extreme wind chill conditions. Frostbite, hypothermia and cold exposure are serious hazards to workers in this environment. A heated enclosed shelter exists at the gun mount. The Howitzer can operate in temperatures as low as 40 degrees below zero, however the use of this weapon in the severe cold environment of Sylvan Pass has resulted in occasional equipment failure. The Sylvan Pass team has developed procedures to address these challenges.

Artillery Missions

The use of artillery is widespread in the military. The safe operation of military weapons and storage and handling of explosive rounds requires weapon specific training and practice. Training and practice regarding the use of artillery in the Sylvan Pass program has been and continues to be a high priority. Since 1996 the Sylvan Pass program has contracted experts to provide a three-day weapon specific training course to the Sylvan Pass crew. This training includes a review of weapon operation and maintenance procedures, bore-sighting procedures, direct and indirect (blind) sighting procedures and a live-fire mission on Sylvan Pass. Personnel from outside programs that use artillery attend these training sessions.

The Sylvan Pass mitigation team members belong to the Avalanche Artillery Users of North America Committee (AAUNAC), a group that represents the non-military artillery users of North America. Participation in this organization helps keep the mitigation team abreast of the latest developments in artillery use. All members of AAUNAC adhere to standard operating procedures (SOPs) that have been developed over the past 50 years by the US Army, the USDA Forest Service, the NPS, various state departments of transportation, Forest Service permitted ski areas, and other entities, organizations and individuals. These SOPs have evolved over time and are described in detail in The AAUNAC Training Manuals: Gunnery Fundamentals.

Avalanche artillery programs have safety considerations that are inherent to all snow avalanche hazard programs and safety considerations that are specific to the setting of each program. For the Sylvan Pass program these hazards have been identified, assessed and managed for over 30 years. The hazards specific to this program include threats to the gun crew as they approach the gun mount and threats to the crew while they occupy the gun mount.

To get from Lake Village to the Howitzer, the NPS gunners must pass through the runout zone of avalanches that initiate from starting zones 1 through 8 on the north side of the road (Figure 3). These starting zones are known to produce light and deep snow avalanches that can impact the road. Consequences could be severe if an avalanche struck a team member. Members of the gun crew from the East Entrance Station do not travel across the pass before artillery missions are conducted when significant hazards from avalanches are anticipated.

The decision to conduct a reconnaissance patrol, travel to the gun mount or open the pass to the public is a reasonable and calculated risk based on the information available and the knowledge and experience of the members of the avalanche hazard assessment and mitigation program. Risk based decisions are made by NPS personnel who fight fires and perform technical climbing rescues. The safety of team members and the public is dependant on the resources available to make this assessment and the skill and experience of the professional involved.

Travel through the lower end of avalanche paths before avalanche reduction efforts are conducted is to be avoided in an ideal situation. Avalanche mitigation programs attempt to locate gun mounts in locations that are not threatened by avalanches, with an access route that is not threatened by avalanches. However, this ideal situation is not always possible. This scenario is not unique to this program. In Jackson, Wyoming a school campus has been recently constructed in avalanche terrain. Gun mounts and other structures at some ski resorts are located in avalanche paths. In the populated alpine valleys of the European Alps humans reside in the runout zones of major avalanche paths. In these instances conditions are monitored, experts continually assess the situation and contingency plans exist to mange the hazard. These are a few examples of mitigation strategies that relay upon avalanche hazard assessment efforts to determine when it is safe for to occupy avalanche runout zones.

Most artillery missions at Sylvan Pass involve precision targeting of unstable wind drifts high in the avalanche starting zones. In many scenarios it is reasonable to travel to the gun mount. There are certainly other scenarios when the crew, based on its assessment of the hazard would not approach the gun mount until conditions change. Safe travel procedures dictate that travelers passing through avalanche terrain are well spaced when they cross these paths and are properly equipped and well trained in avalanche rescue techniques. Similar strategies are used in numerous other avalanche mitigation programs.

Section 4.0 Avalanche Hazard Mitigation Strategies of this report presents supplemental mitigation alternatives that could further mitigate this hazard.

There are avalanche paths on the south side of the pass that can cross the summer access road to the gun mount. Compared to their counterparts on the north side of the highway these paths are small in area and have short running lengths in the order of several hundred feet.

Although these paths are relatively small they are big enough to catch and bury a person with potentially fatal consequences. These paths have been the location of at least one near miss. Due to their limited extent and infrequent activity the hazard associated with these paths may have been underestimated prior to this event. The gun mount can be approached without crossing through these paths.

The exact location of the gun mount has been moved several times since the 1970's in an effort protect it from avalanche hazards. Reloaction of the gun mount has also occurred as a result of massive earthworks conducted, associated with road maintenance projects. Even through the detailed topography of the location has been changed, the gun mount position is understood to have remained in the same general area for the life of the program.

One potential hazard to the gun mount is for an avalanche to release from avalanche starting zone 8C and flow across the East Entrance Road towards the mount. The attributes of this path are provided in Table 1. This table lists the slope of this path as 27 degrees. This path is less steep than any of the other paths that impact the road. This path also has one of the shorter track distances from the starting zone to the road (739 feet) and a short vertical drop (342 feet). The topography on the south side of the road flattens almost immediately on the downhill side of the road, and then goes uphill to the gun mount.

This path has been observed to produce slides that have crossed the East Entrance Road. In over thirty years of operation none of the events witnessed on this path, either naturally or artificially triggered, were reported to have run to or close to the present gun mount (Loundsbury 2006, Keator 2006). Earthworks designed to deflect or retard the advancement of an avalanche could be constructed between the road and the gun mount, however the thirty plus year record of events indicate this effort may not be necessary. The results of daily avalanche hazard assessment efforts can be used to determine when an extreme event is possible and this mount should not be approached or occupied.

Steep cliffs are located to the south (behind) of the gun mount. Snow cornices develop on the ridgeline along the top of these cliffs. In the past, on a mission when the recoilless rifle was in use, a section of cornice fell from this ridgeline. The cornice triggered a small avalanche on the slope above the gun mount. Debris from this avalanche partially buried government snowmobiles and a portion of the gun mount ammunition magazine.

Recoilless rifles produce a destructive back blast that can kill a human or damage equipment in a defined area behind the weapon. Firing procedures address this hazard. A recoilless rifle has not been used at this site since the early 1990's. The Howitzer in use since 1997 does not emit a back blast.

To mitigate the hazard from the above instance the location of the gun mount has been moved. A rock berm reinforced with a spine of concrete Jersey Barricades has also been constructed behind the mount and cornice development is monitored. The decision to occupy this gun mount should include an evaluation of the potential hazard from a cornice drop. Cornice drops typically occur during a period of rapid warming, during an extended period of above freezing temperatures or during or following a blowing snow event. Knowledge of on-site meteorological conditions is an essential component of this evaluation process. Recent or occurring cornice drops along the ridge above the gun mount or along similar ridges are key indicators of the potential hazard. In unusual situations a contract helicopter crew may be able to land near the cornice and place hand charges to test its stability and potentially trigger the cornice under controlled conditions.

Rocks have been observed to fall from this steep cliff and bounce or roll towards the mount. The most likely time for this to occur is when temperatures are above freezing. None of this falling material is understood to have damaged any of the permanent structures located at the mount. To mitigate this hazard a rock berm reinforced with a spine of concrete Jersey Barricades has been constructed above the gun mount. The decision to occupy this gun mount should include an evaluation of the potential for rock fall to occur. Above freezing temperatures, rapid warming, evidence of recent or occurring rock fall activity at this site or other similar locations are key indicators that can be used in this evaluation process. The installation of netting or other engineered solution to address this hazard could be researched. The enclosure of the gun mount in a protective building has also been suggested.

The explosive projectiles used by the Howitzer are anti-personnel warheads that are designed to produce flying metal fragments (shrapnel) when they explode. All AAUNAC members adhere to the Army 105 Howitzer shrapnel fly distance of 464 meters, which is based on army research data (Weingart 1994, Hendrickson 1994). A team of British researchers conducted studies that indicate the fly distance of shrapnel from anti-personnel rounds is projected sideways and forward from the shell's axis and that almost nothing goes backward. The distance from the gun mount to starting zone 8C may be close to or less than 464 meters. A site survey could be conducted to determine this actual distance and the distance to starting zones 8, 8B, 9, 9B and 10.

Unexploded ordnance, commonly referred to as duds, is a consequence of avalanche artillery programs. From the 1970's to the early 1990's many programs used 75 mm recoilless rifles. This weapon and its ammunition had not been in production for many years. As this ammunition aged, increased dud rates resulted and the amount of ammunition remaining became a concern. In the 1990's YNP and many other programs retired their 75 mm recoilless rifles.

Unexploded ordnance has the potential to explode. Unexploded duds should not be handled and are a potential threat to the public. Areas where duds may exist are closed and signs are posted to alert and educate the public regarding this hazard. The occurrence and location of a dud is required to be noted on mission records. It is also a requirement for the NPS to conduct a search for these duds at a later date. When duds are found their location is marked and specialist from the military are deployed to destroy them. These procedures are customary practice for avalanche artillery programs.

A former program manager estimated there was an average of five to six duds every year in the early 1980's (Lounsbury 2006). He estimated that at the end of the life of the 75mm recoilless rifle there were 15 to 18 duds per season. Records detailing how many duds occurred prior to the replacement of the recoilless rifle with the Howitzer and how many were located and destroyed were not available. Since the Howitzer replaced the recoilless rifle in 1997 there have been 8 duds. Two of these were found and destroyed.

The dud rate for the Howitzer at Sylvan Pass is 0.5%. Dud rates for the Alaska DOT artillery program were reported to be 0.25%. The Washington State DOT reported no duds from the artillery program in the last nine years. The standard practice is to record as duds any rounds whose detonations cannot be confirmed by sound or sight. There is some anecdotal evidence that many of these rounds recorded as duds detonate deep in the snowpack and are not seen or heard. The only fuse authorized by the Army for avalanche work has a delay element that should function if the impact portion does not. In deep snow, this detonation may not be audible or visible. Thus the dud rate may be substantially lower than reported.

At Sylvan Pass the steep angle of the slide paths above the road creates the potential for duds to roll downhill onto the road. This scenario has occurred in the past and presents a hazard to road travelers and the maintenance crews that plow the road. In the past a motorist on the East Entrance Road is reported to have picked up an unexploded round and transported it to the Fishing Bridge Visitor Center. A similar event occurred near Teton Pass in the Bridger-Teton National Forest in Wyoming when a hiker picked up an unexploded round above Teton Pass and brought it home. It is currently procedure for NPS personnel to search the road with a metal detector before spring snowplow operations begin.

Motorized winter travelers are currently required to be accompanied by guides. Guides could be educated with respect to the potential for duds to be encountered. Park visitors on roadways pass through entrance stations to get into the park. At these points they receive printed and verbal information. These entrance stations are an excellent venue for the NPS to provide these visitors with educational information regarding the potential hazards associated with unexploded ordnance in the Sylvan Pass area and other areas of the park where artillery and/or explosives have been historically used for avalanche mitigation purposes. This material could include a map depicting closed areas, pictures of duds and instructions on what to do if a dud is encountered.

Another potential concern with the use of artillery is the potential for an overshoot. An improperly directed shot could miss its intended target and travel as far as seven miles from its point of origin. No overshoots were reported to have occurred at Sylvan Pass with the existing Howitzer. The Utah DOT recently had an overshoot that landed in a residential neighborhood. There were no injuries associated with this event. An investigation of this incident determined that failure to follow standard operating procedures created the potential for this incident to occur. This investigation did not result in the termination of the use of artillery for this program; however the employee responsible for the failure was fired. Strict adherence to standard operating procedures is necessary to prevent an overshoot. Overshoot bars restrict the barrel of a weapon from pointing in a direction that could result in an overshoot. Because the Howitzer ammunition has a variable charge further analysis would be necessary to determine if an overshoot bar would be beneficial for the Sylvan Pass Howitzer.

Helicopter Missions

The use of helicopters to deploy explosive charges for the purpose of avalanche hazard reduction is not uncommon, however the majority of helicopter use associated with highway programs is as a supplement to other explosive delivery methods. Safe operations rely upon trained personnel familiar with the handling of explosives and pilots with experience in mountainous terrain. These missions require the helicopter to fly close to the ground surface in steep rugged terrain and can become dangerous during periods of increasing wind and/or decreasing visibility. They are not possible during periods of limited visibility or high winds. The helicopter contracted for the Sylvan Pass program operates out of Bozeman, Montana. Bozeman is approximately 90 air miles from Sylvan Pass.

Hand charges deployed from a helicopter can also fail to detonate. These hand charges are tagged with specialized chips that enable them to be located with a detection device. Located hand charges are destroyed according to the explosives manufacturer’s protocols. During the 2005/2006 season there were two duds deployed by helicopter. Both were recovered and destroyed. During the 2006/2007season there have been three helicopter-deployed duds to date. At this time these duds have not been recovered. The dud rate for the Sylvan Pass helicopter program is 1.7%.

3.5 Avalanche Hazard Assessment Findings

A 5,000-foot long section of the East Entrance Road through Sylvan Pass has a well-documented history of impacts from snow avalanches. Avalanches that impact the road originate from starting zones on steep slopes on the north side of the road. The destructive forces associated with these avalanches could sweep vehicles from the road and severely injure or kill its occupants. This hazard is a threat to oversnow traffic during the winter season, wheeled traffic in the late spring and fall, snowplow drivers and maintenance personnel who plow the road and administrative travelers on the road in the shoulder seasons.

A small group of highly trained and experienced NPS personnel based in Lake Village and the East Entrance Station have successfully managed this hazard for over 30 years. The success of this and other similar programs in North American are based on the premise that experienced and well-trained specialists can determine when conditions are unstable and take appropriate action. These actions include closing the road to all traffic when necessary and using explosives to test the stability. Programs that actively use explosives are accepted to be very effective in reducing the number of large natural avalanches by triggering frequent small events in a controlled environment. This program has a significant history of accomplishing this goal.

This crew has performed this task without the benefit of real time meteorological data from the area of concern. Continual real time information regarding wind speeds and direction, air temperatures and snowfall are essential for this type of program.

The lack of essential meteorological instrumentation is a safety concern. To be useful this equipment must be properly sited, reliable in a severe environment and produce data essential to the decision making process. Data interpretation is a skill that can be enhanced by specialized training and experience.

A key component of the program has involved the use of artillery to test slope stability and reduce the hazard by triggering avalanches when unstable conditions exist. In North America the use of artillery has proven to be an effective and safe method for the mitigation of avalanche threats to roads, railways and ski areas.

Previous efforts by the NPS identified safety concerns associated with the artillery program. These concerns included threats to the public and the team that manages this hazard. Threats to the public included natural occurring avalanche events, unexplored ordnance and overshoots. Safety concerns for the NPS mitigation team included threats from rock fall, cornice drops, avalanches, shrapnel and a severe winter environment.
To address these concerns the NPS replaced the tasks previously conducted by the artillery program with a specialized contract crew that drops explosive charges from a helicopter.

Avalanche hazard mitgation programs strive to prevent large volumes of snow from building up on unstable snow covered slopes that could result in large dangerous avalanches. This is accomplished by using explosives to trigger numerous small avalanches when conditions are unstable. The most effective time to trigger these small avalanches is during a storm when these slopes are being rapidly loaded with new snow. The inability of helicopters to fly during periods of poor visibility and or gusty or high winds limits the ability of helicopters to trigger avalanches during storm periods.

This change in management approach is likely to result in an increase in the amount of time the road is closed due to avalanche hazards. In addition the inability of helicopter missions to be conducted during storm conditions could result in an increase in the number of large and natural released avalanches that impact the road.

The majority of programs that use helicopters for road mitigation programs use them as a supplement to artillery or other devices that can reliably deliver explosives during storm conditions. The option to use a helicopter is a good resource for the Sylvan Pass mitigation team when conditions are believed to be too dangerous to approach or occupy the gun mount, for deployment of charges in starting zone 8C if an extreme event is a concern and on occasion to better target starting zones 17, 18 and 18B, which are more oblique to the gun, mount than the other starting zones. Multiple mitigation options have benefits.

The results of this assessment indicate that travelers on this road could be threatened during the snow season (October through June depending on conditions). To protect travelers an active avalanche hazard assessment and management program is suggested to be operational during this period.

Alternative mitigation strategies for the management of the avalanche hazard on Sylvan exist and are presented in the next section of this report. Mitigation alternatives that allow traffic over the pass when the avalanche paths of concern are snow covered may not completely eliminate the hazard to travelers from avalanches. Uncontrolled avalanches can occur and persons traveling on the road in the path of one of these avalanches could die or be seriously injured. In general avalanche hazard assessment and mitigation programs greatly decrease the chance that someone will be caught on the road but may not completely eliminate this possibility.

Mitigation programs that include the storage and handling of explosives are subject to security concerns and Bureau of Alcohol, Tobacco and Firearms and Department of Homeland Security compliance requirements.

The use of artillery and the deployment of explosives from helicopters have resulted in the presence of unattended ordnance and explosive hand charges in the Sylvan Pass area. These duds pose a threat to the public and NPS personnel. The Sylvan Pass program and other artillery programs in North America replaced recoilless rifles with Howitzers in the 1990's to address high dud rates. Helicopter deployed explosives are equipped with chips that can be located with a searching device. These actions have significantly reduced the artillery dud rate and should increase the potential to recover helicopter deployed charges, however duds continue to occur and present a threat to winter travelers, snowplow drivers, summer travelers and backcountry users.

At the time of this report three helicopter deployed charges and blasting caps are unaccounted for from this season's effort. In addition there have been six non-recovered artillery duds since the Howitzer replaced the recoilless rifle in 1997. Previous use of artillery has resulted in an unknown number of unexploded ordnance.

To address this hazard, the area where duds may be located have been closed to travel and signs are posted to alert the public to this hazard. Additional options exist to help mitigate this hazard. Motorized travelers in the park pass through entrance gates. These gates are excellent venues to disseminate information regarding the hazard from duds and avalanches. Information provided could include maps of the areas of concern, pictures of duds and instructions on how to proceed if a dud is encountered. Information regarding safe travel techniques, such as not stopping in avalanche paths, would benefit all travelers on the road.

Winter motorized travelers are currently required to be accompanied by guides. These guides also present an excellent venue to disseminate dud and avalanche hazard awareness information to the public. Daily communications and an exchange of information regarding avalanche conditions between the guides and the NPS mitigation team is a mitigation management option that would greatly increase the safety to winter pass users.

Alternative dud detection methods could be explored such as specially trained dogs from the military or the Department of Homeland Security.

A review of historic avalanche fatalities in the park identified three that occurred before 1918 and three that have occurred since 1991. The recent fatalities were all field scientists, two of which died near Mount Sheridan in the Heart Lake area and one who died in the Lamar Valley area. Two of the earlier fatalities were soldiers and the third was a person riding in a horse drawn sled between Mammoth Hot Springs and Gardiner, Montana.

It is likely that other park personnel are exposed to avalanche hazards in the backcountry and avalanche hazards exist on other park roads. The level of avalanche expertise processed by the personnel in the Sylvan Pass avalanche program is sophisticated and a tremendous asset to the park. The expertise of the Sylvan Pass program would be useful to other park employees who work in avalanche prone terrain.

The NPS employees who manage the Sylvan Pass avalanche program have 30 years of accumulated knowledge specific to the assessment and mitigation of the avalanche hazard to the East Entrance Road. The loss of this knowledge and experience would severely impact the safety of this program.

4.0 Avalanche Hazard Mitigation Strategies

Sylvan Pass has an existing avalanche hazard assessment and mitigation program. This section of the report presents and discusses mitigation strategies that could replace, or supplement the existing program. The use of multiple mitigation strategies can help overcome inherent shortcomings in single strategy programs. Topics covered include road management alternatives, explosive delivery options and engineering designs. Wilderness values and engineering considerations may preclude some of the alternatives discussed. Feasibility studies are likely to be necessary if any of these alternatives are to be considered.

Hazard Management Alternatives

Alternative road management options are available to address the hazard from avalanches to the East Entrance Road.

To completely eliminate the avalanche hazard the East Entrance Road would be required to be closed during the period when there is snow in the avalanche paths that can impact the road. Depending on conditions this period could extend from early fall to late spring.

An alternative is to use avalanche hazard forecasting expertise to only open the road during the snow season when there is a high level of confidence that avalanches are very unlikely to be a threat. This alternative would require constant monitoring of conditions by trained professional but would not employ active avalanche hazard reduction efforts. This alternative would not completely eliminate the hazard to travelers from avalanches as avalanche hazard forecasting techniques have limitations and unexpected rapid changes in conditions can quickly destabilize the snow. Without the use of explosives to test snow stability a conservation management approach would be necessary. This alternative would result in significantly longer road closures then are now experienced.

The current management program uses avalanche hazard forecasting expertise to close the road when hazardous conditions are expected and includes the use of explosives to test the stability and reduce the hazard for the purpose of reopening the road.

Explosives are a proven method used to test stability and reduce the hazard by triggering avalanches in a controlled environment. The use of explosives is not effective if the timing of detonations does not coincide with periods of instability. Spontaneous released avalanches can occur after explosives have been used and a road is reopened if conditions change and create instability that was not present at the time the explosives were deployed. Therefore avalanche hazard forecasting expertise is fundamental to the effective use of explosives to mitigate avalanche hazards. Specialized remote weather stations are essential for roadway avalanche mitigation programs.

Another possible resource to the program is available in emerging technology that uses infrasonic sensors to monitor avalanche activity. Avalanches and explosives emit distinctive infrasonic (sub-audible) sound signatures that can be detected in near real time by remote instrumentation (Scott et al 2006). This technology has the ability to detect avalanches as they occur and can remotely confirm the detonation of explosive charges during inclement weather (limited visibility and high winds). This tool could immediately alert road managers to the occurrence of an unexpected avalanche event that had either impacted the road or may indicate that conditions have rapidly become unstable and the road should be closed. This tool can also tell program personnel if avalanche mitigation efforts are producing small avalanches that don't run to the road during periods of poor visibility. This knowledge has been found to be useful to managers in the hazard reassessment and decision making process used by the Wyoming DOT on Teton Pass.

Avalanche awareness & safe travel techniques are information that would be beneficial to road travelers. NPS personnel should be trained, equipped and prepared to assess the hazard and perform effective rescues.

Avalanche Hazard Reduction – Explosive Delivery Alternatives

The avalanches that impact the East Entrance Road are similar with respect to the elevation, aspect and slope angle of their starting zones. The steepness of the starting zones of these avalanche paths is conducive for artificial triggering by explosives. Mitigation strategies using explosives are likely to be efficient because similar conditions with respect to instability are likely to be encountered at the same time in all of the starting zones. Varieties of mechanisms exist to deliver explosives to unstable slopes and are discussed below.

Artillery is proven to be an effective and safe explosive delivery method for the mitigation of avalanche hazards to roads and railways in North America. The precise targeting necessary to address the buildup of unstable snow in the starting zones of the Sylvan Pass avalanche paths and the similar attributes of these starting zones makes artillery the preferred mitigation option from an avalanche hazard reduction perspective. Unexploded rounds, overshoots, shrapnel and threats to the gunners from avalanches, cornice drops and rock fall are safety issues that have been identified by this study. Mitigation actions to address these concerns have been discussed in previous sections of this report. Some supplemental mitigation strategies to further protect NPS personnel in the artillery program are available and are included in the following text.

The helicopter deployment of explosives is a method that was introduced during the 2004/05 season. Helicopter missions played a substantial role during the 2005/2006season and have been used exclusively to date during the 2006/2007season. The ability to perform helicopter missions during storm conditions is at times limited. The consequences of this limitation are longer road closure periods and a potential increase in the frequency of natural avalanches and the size of avalanches both natural and artificially triggered. Helicopter missions provide the advantages of increasing the probability of retrieving duds and increase the ability of the program to better target a few of the starting zones (Nos. 17, 18 & 18B). It also provides an alternative to the existing program when conditions are too hazardous to get to the gun mount. Helicopter missions are considered to be a viable explosive delivery method and a good supplement to the artillery program.

Avalaunchers

Avalaunchers are commercially available non-military devices that use compressed gas to propel explosives projectiles into avalanche starting zones in a manner similar to artillery. Avalaunchers are widely used in the ski industry and by highway programs. The charges used can be equipped with a chip that can be located with a search device in the event the charge does not detonate. The avalauncher projectiles are propelled at lower velocities than artillery rounds and precise targeting can be difficult especially in high wind conditions. Precise targeting is essential for most Sylvan Pass missions. This use of an avalauncher at Sylvan Pass is considered to be a viable explosive delivery method. The feasibility of using an avalauncher from a new gun mount on the west side of the pass to address starting zones 1-8B could be researched.

Hand Charge Routes

The delivery of hand charges by personnel on skis is a common practice at ski areas and a method that is used by some highway programs and has been used by the NPS at other locations in Yellowstone National Park. The methodology requires the personnel involved to have good skiing skills and explosive handling training and experience. Hand charges can also be fitted with chips to enhance dud recovery efforts. It is understood that NPS employees are no longer allowed to handle hand charges.

The topography of the terrain on the north side of the East Entrance Road is appropriate for hand charge routes. A safe hand charge route could originate from the woods on the west side of the pass and access the ridge above the starting zones. The incorporation of an aerial cable delivery system with hand charge routes would likely increase the effectiveness, decrease manpower requirements and increase the safety of this alternative.

A reduced version of this alternative could result in the safe and effective delivery of explosives to starting zones 1 through 8B that threaten access to the gun mount. These starting zones are approximately 400 to 800 feet above the elevation of the road. The deployment of hand charges in these starting zones would provide stability information and reduce the hazard from crossing beneath these avalanche paths on the way to the gun mount.

A change in park policy and proper training could enable NPS personnel to safely deploy hand charges to starting zones 1 through 8B before they cross beneath these avalanche paths on the way to the gun mount. Hand charges could also be used to mitigate the hazard from smaller avalanche paths in the vicinity of the gun mount and starting zones 17, 18, and 18B (from the east), and at other road locations in the park.

Aerial Cable Delivery Systems

Elaborate systems that use cable suspended from towers to deliver explosives are widely used in the Alps. Less elaborate systems are used at ski areas in North America. These systems are considered to be effective and safe. The installation of a cable delivery system on Sylvan Pass is considered to be a viable explosive delivery method. These systems require a minimal amount of manpower to operate. A tower and cable system would present visual impacts. A less elaborate system could be used in conjunction with hand charge routes.

A reduced version of this alternative could safely and effectively address staring zones 1 through 8B and reduce the hazard associated with passing beneath these starting zones to access the gun mount.

Gazex

Gazex is a commercially available fixed location product that uses a mixture of combustible gases to create remotely triggered explosions. This alternative requires the installation of explosion chambers and gas storage and delivery structures in or near the avalanche starting zones. Controls are used to remotely transfer stored gases into the combustion chamber and detonate a mixture of these gases with an ignition source. Over 1,500 Gazex exploders have been installed in 15 countries. This alternative would present visual impacts but is considered to be an effective and safe alternative. A helicopter is typically used to install and re-supply these devices.

The installation of one or more of these devices near starting zone 1 through 8B would effectively and safely address these staring zones and reduce the hazard associated with passing beneath these starting zones to access the gun mount. Multiple Gazex devices would be necessary to address all avalanche starting zones that impact the road.

Avalanche Guard

The Avalanche Guard and similar products produced by other manufactures is a commercially available product that is used by the Wyoming DOT on Teton Pass, by the Washington State DOT and ski areas. It is also a fixed location product. It uses solid propellant to deliver explosive charges to avalanche starting zones. The explosive charges are stored in a secure magazine that is mounted on a pole near the avalanche starting zones. Controls are used to remotely open the magazine and fire the charges into the starting zones. This alternative would present visual impacts but is considered to be an effective and safe explosive delivery method. Similar products by different manufacturers have been developed and are used in the Alps. A helicopter is typically used to install and re-supply these devices.

The installation of one or more of these devices near starting zones 1 through 8B would effectively and safely address these staring zones and reduce the hazard associated with passing beneath these starting zones to access the gun mount.

LoCat

LoCat is a commercial non-military explosive delivery system similar to artillery and avalaunchers that is used on an infrequent basis by the California DOT. A LoCat tested at the Jackson Hole Mountain Resort in the 1990's was reported to have performed poorly in cold conditions. As this test was conducted approximately 10 years ago the potential may exist that improvements have been made that could make LoCat a viable option for Sylvan Pass.

Engineering Designs

Any construction effort associated with engineering designs or previously discussed devices will need to consider the environment of Sylvan Pass. These considerations likely include but are not limited to construction on talus slopes in areas with potentially incompetent bedrock, buried ice or permafrost; extreme weather conditions and the environmental sensitive nature of this setting. Proven designs exist in similar environments in North America and Europe and are therefore worthy of discussion.

Deflection Berms & Mounds

This mitigation option involves the construction of structures or features to deflect the flow of avalanches away from areas of concern or to disrupt the flow and retard the forward advance of an avalanche. Deflection berms and avalanche track mounds are proven effective alternatives. The berms redirect the avalanches away from the structures of concern and the mounds are successful in decreasing the running length of an avalanche. These alternatives typically are constructed in the runout zone of an avalanche path.

A berm has been constructed uphill of the gun mount in an effort to provide protection to the mount occupants from the potential for small but dangerous avalanches and rockfall to impact this area. An engineering study could evaluate the potential effectiveness of the existing berm or investigate the possibility of other earthworks or constructing a protective building for the gun mount.

A deflection structure or mounds are also a potential mitigation option to protect the gun mount from a large avalanche descending from starting zone 8C. There appears to be space and sufficient material between the East Entrance Road and the gun mount to accomplish this task.

Avalanche paths that cross the road from the other staring zones on the north side of the road are steep at their intersection with the road. Based on the attributes of these paths it is believed that it is unlikely that deflection berms or mounds would be effective mitigation alternatives for these paths. An engineering study could determine the feasibility of engineering designs and provide construction specifications and estimated costs.

Wind Sails

This mitigation option involves the construction of specially designed sails or wind fences that disrupt the pattern of snow deposition by wind in avalanche starting zones. This mitigation alternative has been used on an avalanche path that impacts a highway south of Jackson, Wyoming. At this location the starting zone is in critical game habitat. This passive mitigation option has likely decreased the necessity for explosives use at this location. This alternative can be effective in reducing the frequency of avalanche events, but may not be effective in eliminating large natural avalanches.

Snow Fencing

This mitigation option involves the construction of specialized fencing in multiple parallel lines along elevation contours in avalanche starting zones. The fencing retains the snow in the starting zones and prevents it from moving downhill in unstable conditions. Snow fences are common in the Alps and have proven to be an effective and safe mitigation alternative. Snow fencing is expensive and presents visual impacts. From an avalanche hazard mitigation perspective snow fences are considered to be an excellent mitigation alternative. The Swiss and other European countries have extensive experience constructing avalanche snow fences in difficult environments.

Snow Sheds

Snow sheds are enclosed structures that cover the roadway and are designed to allow avalanches to flow over the top of the structure while protecting the vehicles within the sheds from the destructive forces of avalanches. Snow sheds are expensive. Properly designed show sheds would be an excellent mitigation alternative on Sylvan Pass. This option could eliminate the avalanche hazard along the 5,000 feet area of identified impacts. A reduced version of this strategy could involve construction of a snow shed beneath starting zones 1 through 8B to provide safe access to the gun mount. Providing a snow surface in the snow sheds for over snow vehicle travel would be a unique challenge.

Tunnel

The construction of a tunnel to bypass the 5,000-foot section of impacted road would eliminate the avalanche hazard. In addition a tunnel would address summer road maintenance problems (mudflows, rockfalls, slumping road bed, etc.) that have resulted in road closings and repairs. Providing a snow surface in the tunnel for over snow vehicle travel would be a unique challenge.

Rerouting the Road

An alternative route for the road over Jones or Cold Creek Passes is a mitigation alternative that may provide a travel corridor over the Absaroka Mountain Range that is not exposed to avalanche hazards or has less or more easily managed hazards. Both Jones and Cold Creek Passes are in designated wilderness and may not be viable alternative due to wilderness value concerns.

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6.0 Chief Contributor Biography

Bob Comey has over 28 years of avalanche assessment and mitigation experience. This experience includes 19 years of conducting daily avalanche mitigation efforts at the Jackson Hole Mountain Resort, 15 years of avalanche forecasting for the resort and the Bridger-Teton National Forest Avalanche Center (BTAC) and 10 years of being the lead avalanche forecaster at the resort and lead avalanche forecaster and director of the BTAC.

His responsibilities include the operation and interpretation of data from a state-of-the-art network of automated avalanche weather stations. The data from these stations and daily visits to historic snow study plots is essential to the resort avalanche hazard assessment and mitigation program and the US Forest Service backcountry avalanche forecasting program in Western Wyoming. A project developed and managed by Bob to expand the extent of this forecast received a national award in 2004 from the Coalition of Recreational Trails in recognition of its outstanding use of Recreational Trails Program grant funds.

Bob's job responsibilities have involved the use of explosive hand charges, avalaunchers, artillery (including a 105 mm Howitzer, 105 mm recoilless rifle and 75 mm recoilless rifle), large explosive charges, aerial cable explosive delivery systems and helicopter explosive deployment. His interaction with highway department avalanche mitigation programs has given him insight into the use of fixed location explosive delivery systems (Gazex and Avalanche Guard), engineering designs and passive mitigation methods.

Bobs efforts have included working with colleagues to pioneer the use of geographical information systems to assess avalanche hazards and researching the potential benefits of using infrasonic technology to assist transportation managers mitigate the threat of avalanches to roadways.

Bob attended the University of Maine where he received a degree in geology and took graduate level snow science courses. Bob is a professional member of the American Avalanche Association and a Wyoming Professional Geologist. He has previously attended the annual artillery training session in Yellowstone National Park and has skied in the avalanche paths that impact the highway on Sylvan Pass.

Bob has been afforded a tour of many ski area and highway mitigation programs in North America and spent several years performing avalanche hazard and mitigation efforts in New Zealand and for oil and gas exploration crews in the Rocky Mountains. In 2006 Bob was chosen by the US Forest Service National Avalanche Center to participate in an international avalanche forecaster exchange with the Swiss Federal Institute of Snow and Avalanche Research in Davos, Switzerland.

Table 1. Sylvan Pass Avalanche Path Attributes

Sylvan Pass Avalanche Hazard Assessment

	Starting Zone Attributes			Track Attributes			
Name	Aspect (°)	Elevation (ft)	Slope (°)	Length (ft)	Verticle Drop (ft)	Mean Slope (°)	Width (ft)
1	196	8913	33	722	406	34	207
2	190	9007	38	925	505	33	108
3	192	9074	38	986	539	33	89
4	204	9154	38	1189	636	32	161
5	214	9194	38	1278	680	32	144
6	214	9217	37	1314	699	32	164
7	207	9218	38	1304	661	30	144
8	230	9226	37	1367	687	30	417
8B	227	9363	38	1584	813	30	417
8C	206	8852	38	739	342	27	600
9	199	9127	34	1146	NA	NA	210
9B	205	9265	37	1377	NA	NA	253
10	199	9140	37	1332	663	29	266
11	190	9148	38	1351	665	29	308
12	199	9185	40	1366	711	31	213
13	202	9216	40	1394	787	34	249
14	210	9197	39	1354	750	33	200
15	199	9222	36	1484	771	31	344
15B	184	9322	33	1646	901	33	344
16	211	8982	40	1100	570	31	200
17	216	8798	47	687	406	36	240
18	208	8694	43	525	337	39	190
18B	219	8692	37	518	346	41	118
Mean	205	9096	38	1160	613	32	243
Max	230	9363	47	1646	901	41	600
Min	184	8692	33	518	337	27	89
Range	46	671	14	1128	564	14	512

Notes: The avalanche track attributes for length, vertical drop and mean slope have been derived for the portion of the track from the starting zone to its intersection with the road. The width attribute is the distance along the road expected to be impacted by a large avalanche.

Figure 1 Location of the East Entrance Road
Yellowstone National Park

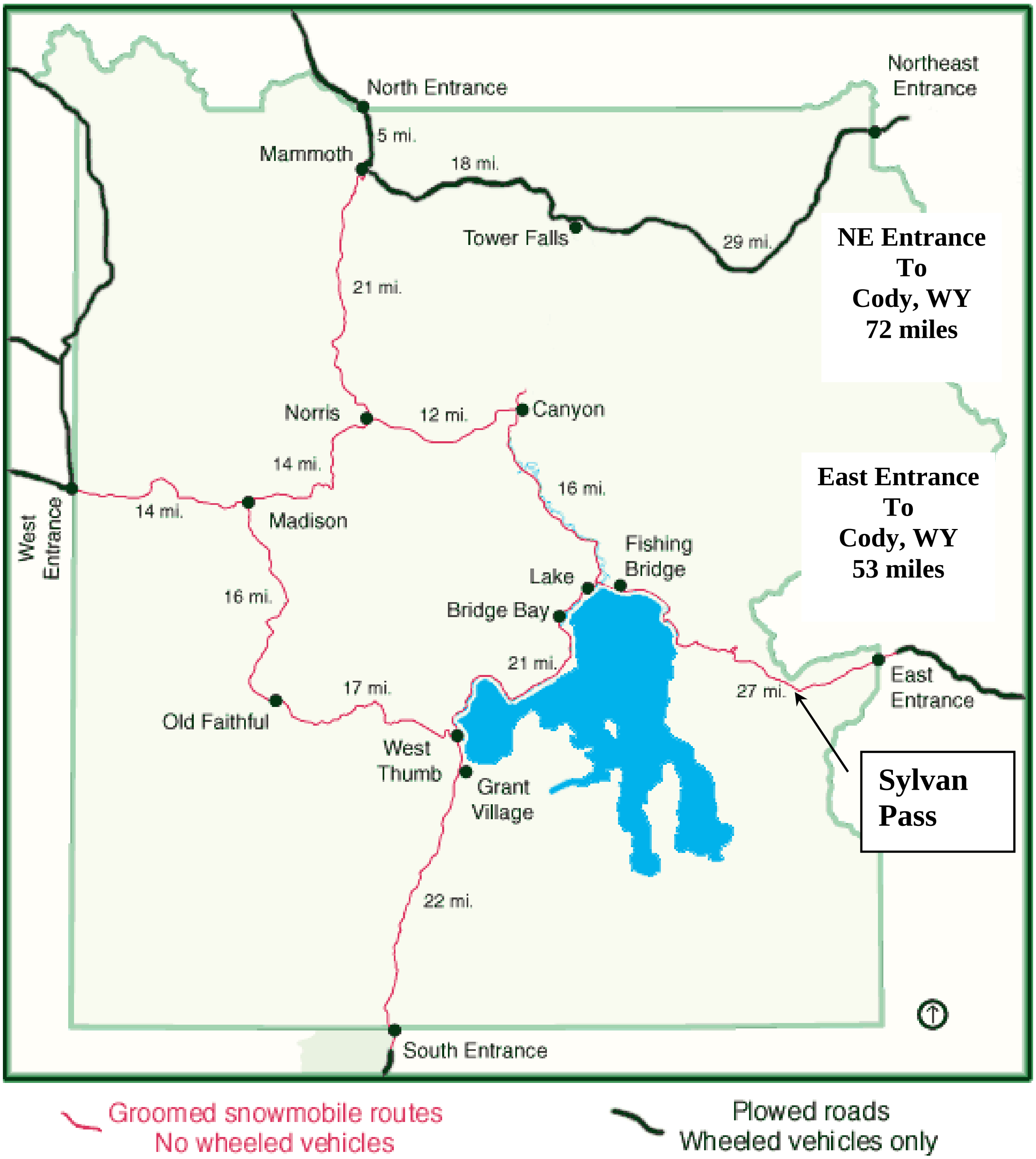
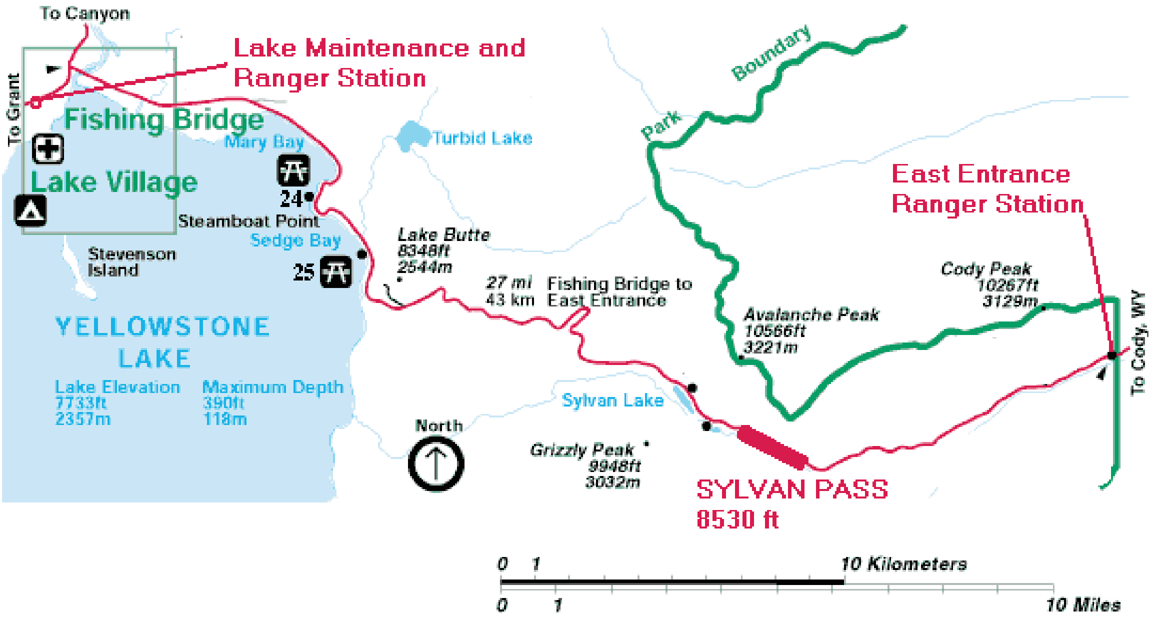


Figure 2 Layout of the East Entrance Road Yellowstone National Park



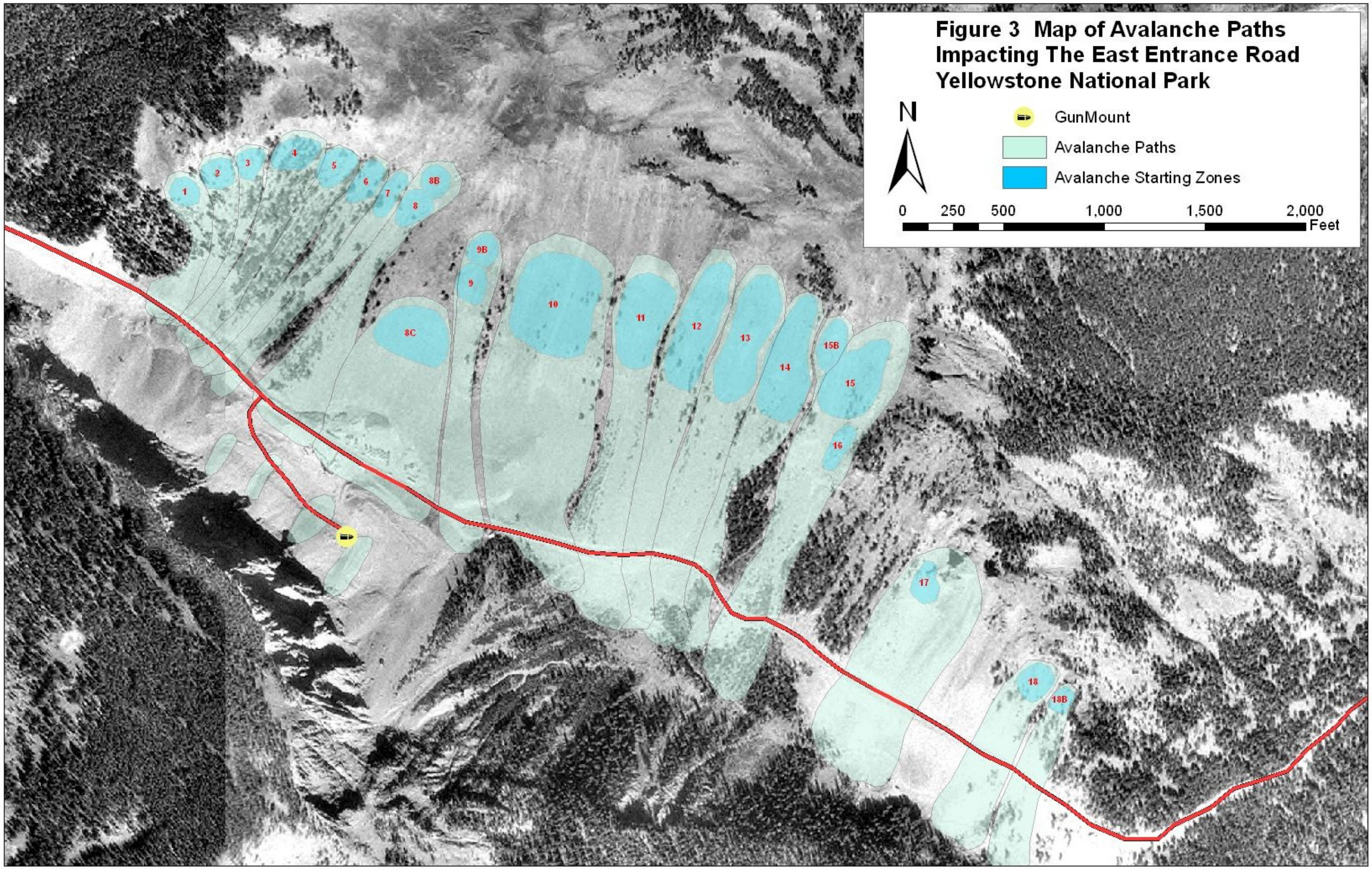


Figure 3 Map of Avalanche Paths
Impacting The East Entrance Road
Yellowstone National Park
N
GunMount
Avalanche Paths
Avalanche Starting Zones
0 250 500 1,000 1,500 2,000
Feet
1
2
3
4
5
6
7
8
8B
8C
9
9B
10
11
12
13
14
15
15B
16
17
18
18B

APPENDIX CONTENTS

GOALS AND OBJECTIVES

Intent

- Is to provide the Winter Use Planning Team with objective information that will assist them with formulating "Alternatives" for the EIS on Winter Use.

Goal

- Present to the Winter Use Planning Team by February 14, 2006 "Operational Profiles" associated with avalanche control on Sylvan Pass that identify the following:
    - Grooming
    - Forecasting
    - Helicopter Dispensed Explosives
    - Artillery Dispensed Explosives

Objectives

- Present the information in an easy to follow, straight forward format.
- Identify key components to each operation profile.
- Present objective statements that will assist the Winter Use Planning Team with understanding the key components of each operational profile.
- Understand that this is the first phase of a multi-phase exercise. The following will be presented at a later date as requested by the Winter Use Planning Team:
    - Cost of each operation
    - Operational limitations and how they may or may not be mitigated
    - Safety concerns and how they may or may not be mitigated
    - Recommendation of which components of avalanche control will be necessary to meet the intent of identified "Alternatives" and/or the "Preferred Alternative".
        - Present infrastructure improvements and costs to implement an "Alternative"

- Infrastructure improvements will be based on avalanche control and forecasting standards currently in place for highway, ski resort and railroad protection.

FORECASTING

Regional forecasting identifies an avalanche hazard as it pertains to a standard definitions and is not site specific ie. Extreme, Considerable, High, Moderate, Low. Avalanche forecasting for Sylvan Pass is site specific and specifically identifies whether the road is safe for visitors to travel without being caught in an avalanche.

Training

- Support continued training anticipating that forecasters may leave for other positions.
    - It may take one to two years to train a forecaster
    - Professional forecasters typically have years of training and experience
- Lake District Winter Staff – American Avalanche Association or comparable
    - Individuals checking the road and first year forecasters
    - Necessary to decide whether you should travel into Sylvan Pass to check current conditions
    - Essential for collecting snow pit data
    - Transceiver operation and rescue
- Forecaster – Phase I and II of the National Avalanche Foundation, National Avalanche School
    - Necessary to collect and interpret data to forecast for public safety
    - May take one to two seasons before independent forecasting is possible
    - Training is continues and on going
- International Snow Science Workshop (ISSW) every two years
    - Two forecasters attend

Operation

- November 15^{th} to May 15^{th} depending on snow levels
- Daily review and interpretation of data
    - Regional avalanche advisories for Gallatin and Bridger-Teton National Forest
    - Data from Sylvan Lake Snotel site

        - Temperature
        - Precipitation
        - New snow
    - Weather forecasts
        - Regional and Western United States satellite images
    - Visual observations of current weather conditions on Sylvan Pass
        - Morning and evening inspections
        - Record observations
    - Data acquired from digging snow pits on Sylvan Pass
        - Snow pits should be dug at the same elevation, aspect and slope angle of the starting zone. The majority of starting zones and surrounding areas cannot be safely accessed.
- Record all natural and control released avalanches
    - Helps identify areas that haven't slid and remain suspect
    - Provides historical data set

Control

- Not all starting zones release during control missions
- The most effective time to control avalanches is immediately after the storm cycle
- Sylvan Pass and snow science is complex
    - Hazards may exist after control missions and may be subject to natural release
    - Natural avalanches occur and may cross the road when open to the public

Equipment

- Site specific forecasting for highways and ski areas have automated weather stations
    - There is no weather station at Sylvan Pass due to lack of funding
    - Nearest weather station is Sylvan Lake Snotel
        - Does not have an anemometer
        - Is not site specific
            - Elevation and aspect

- Specific forecasting instruments have been purchased and require periodic replacement
    - Used for digging, collecting and interpreting data from snow pits

Personnel

- Senior forecaster
- Two to four staff forecasters for seasonal coverage
    - Includes one or two forecaster in training

GROOMING OPERATIONS

Training

- Commercial driver's license required to operate the groomer
- Avalanche Hazard Awareness
    - Transceiver and rescue operations
    - Identification of observed hazards
        - Assess whether to enter Sylvan Pass and to make informed decisions once on site
- Operation of the groomer and techniques of grooming
- Groomer operators are generally cross trained for howitzer positions ie. gunner, assistant gunner and loader

Operations

- Fishing Bridge Junction to Pahaska
    - 29 miles
    - 8 to 10 hours to groom
        - 12+ hours when grooming coincides with an avalanche control mission
            - depends on weather and avalanche debris clean-up
        - 3 hours from Fishing Bridge to Sylvan Pass
- Frequency
    - As needed for quality of the road and/or drifting on Sylvan Pass
        - Frequency has increased to accommodate snowcoaches on Sylvan Pass
            - 50% of grooming runs occur to clean-up drifting when the snowcoach is scheduled to enter the park even though the rest of the road doesn't necessarily require grooming
- Control Missions
    - Helicopter
        - Clean up avalanche debris that crosses the road
        - West side road guard

- Howitzer
    - Clean up avalanche debris that crosses the road
    - Clean out the “catch berm” at the howitzer platform and around the howitzer
    - West side road guard

Equipment

- Snow Cat Grooming Equipment
  - Owned by NPS
    - Potential for leasing
  - This type of equipment is the only type that can accomplish the grooming needs associated with avalanche control and clean-up

Personnel

- One individual to operate the equipment
- Three individuals to provide seven day a week coverage
  - Includes duties as a member of the howitzer team
- Independent spotter when hazards dictate or requested by groomer operator

ARTILLERY DISPENSED EXPLOSIVES
M101 HOWITZER

The US Army has identified the M101 Howitzer as the "avalanche gun" and is currently the most frequently used military weapon for avalanche control in the United States – ski areas, highways and railroads. There has not been a malfunction/explosive accident with a M101 howitzer during avalanche control operations.

Training

- Mandatory recertification every three years, refresher every year
  - Conducted by a private contractor and approved by Avalanche Artillery Users of North America Committee (AAUNAC)
- Key operational positions
  - Gunner in Charge
  - Gunner
  - Assistant Gunner
  - Loader
- Each position requires a training and experience component
- Depending on the number of missions it may take three to five years to go from a Loader to a Gunner
  - Significant number of missions and/or training to reach a gunner
  - Need to focus on continuing education and experience to maintain key operational positions
- Several years of experience are required to oversee the program
  - Oversees the training and certification of personnel
  - Experienced with approved maintenance and servicing of the weapon
- Attend the annual Avalanche Artillery Users of North America Committee (AAUNAC) meeting
  - Two to three individuals each year

Operation

- Missions can be conducted on the same day an avalanche hazard is identified

  - Crew assembled from Lake and East Entrance
- Weather
  - Crew is trained to conduct indirect fire missions to pre-established targets
    - Poor visibility does not affect the ability to conduct a mission
  - Severe weather can affect the crews ability to perform the mission
    - The weapon is not affected by strong winds or cold temperatures
- Prior to accessing the howitzer platform
  - Conditions are assessed
    - Forecast for the current weather event
    - Follow safe travel practices
  - Crew members cross the bottom of four avalanche runout zones en route to the platform
  - Crew members cross two additional avalanche paths if they use the access road to the platform
    - Crew members can walk up the "nose of the platform" to bypass these two paths
    - Groomer must drive up the access road to clean out the catch berm
      - Catch berm is designed to catch rock or cornice debris if it falls from the cliffs behind the platform
      - Groomer crosses a total of six avalanche runout zones if the catch berm is full of snow and needs to be cleaned out
  - The platform has the potential to be affected by avalanche debris during "50 - 100 year weather/avalanche cycles"
- Howitzer Ammunition
  - A magazine for howitzer rounds and another for fuzes are stored at the platform
    - ATF mandated weekly inspections and monthly inventories
    - Magazine meets ATF regulation of 300' from public highway
  - 100 to 300 rounds and fuzes are typically stored on site
  - During missions each round is assembled exposed to current weather conditions

- Fuzes have a three stage arming mechanism for safety
    - Rounds are considered not armed while being handled by personnel
- Unexploded Ordnance
    - Dud rate is less than 1%
    - Can be an intact projectile considered “armed”
    - Preferred that military personnel and/or private contractor locate and destroy projectiles in place
    - Vast majority of unexploded ordnance is from the 75mm howitzer
- Explosives
    - 105mm HE, Comp-B
- Environmental concerns should be studied

Equipment - M101 Howitzer

- Classified as a Loan Agreement with the US Military
    - Military has the authority to remove the weapon from service at any time
    - Pay an annual fee for administering the Loan Agreement
- NPS pays for maintenance
    - Required bore inspections
    - Major repairs if necessary
- Howitzer is stored at the Lake Maintenance Area during the summer months

NPS Personnel

- East Road Guard
- West Road Guard
- Groomer and operator for debris clean-up
    - Groomer operator and West Road Guard may function as one
- Howitzer Operations – minimum number of trained participants
    - Gunner/Gunner in Charge
    - Assistant Gunner
    - Loader

HELICOPTER DISPENSED EXPLOSIVES

Helicopter dispensed explosives are typically used in dual programs with an avalauncher, howitzer and/or hand charges. Helicopters are also used for avalanche control during spring plowing operations when a section of highway has been closed for the winter season.

Training

- One Contracting Officer Representative is require to monitor the contract
    - Forty hour class with a forty hour refresher every two years
    - Approve and submit payment of invoices
    - Guidance and oversight of contract inspectors

- Contract Inspector
    - Aviation Safety training with a yearly refresher
    - Training for executing and oversight of control missions
- Artillery Avalanche Users of North America Committee – (AAUNAC)
    - Annual meeting

Operation

- Requires twenty-four hour notice prior to conducting a control mission
- Ability to conduct a mission is influenced by:
    - Flight weather
        - Visibility, wind and temperature
            - Flight to Sylvan Pass
            - Conducting the control mission
    - Additional contracts
        - US Forest Service contract "Call When Needed" certification and check rides
    - Scheduled maintenance
        - One-hundred hour service – one to two days to complete
        - FAA check rides/certification

    - Other commitments to guarantee sustainability of his helicopter business (has some flexibility)
        - Filming/photo
        - Search and Rescue
        - Charter and sightseeing
        - Mining and Seismic Support
        - Utility work and Exploration
- Flies from Bozeman Montana to Sylvan Pass – approximately 45 minutes
    - Transports unarmed explosives
        - 20 - 5 lb boosters
        - 40 blasting caps with 90 second fuses
    - Personnel – blaster, controller and explosives permitee
        - Certified Blaster
        - Controller, certified blaster
        - Explosives Permitee – ATF explosives credentials, certified blaster
- Control Mission
    - Lands at Sylvan Pass
        - Assembles explosives
        - Crew and project inspector briefing
    - Conducts the mission in approximately sixty minutes
        - Each booster is ignited with a pull mechanism and has a 90 second fuse
        - Boosters are dropped into starting zones
    - Debriefs and returns to Bozeman Montana
- Explosives
    - 5 pound Trojan-25 Booster, two blasting caps and 90 sec fuse
            - Contractor's discretion on the type of explosive
- Unexploded ordnance
    - Dud rate is less than 1%
    - Can be tracked with a RECCO chip and located at a later date

    - Unexploded booster can be handled after 30 minutes of expected detonation
    - Will break apart with freezing and thawing
        - Breaks apart into small pieces upon impact with hard objects
    - Contractor is responsible for dud mitigation
- Environmental concerns should be studied

Equipment - B-III Bell Helicopter

- Contract with guaranteed five paid mission per season
- Paid full mission price if he launches from Bozeman and cannot reach Sylvan Pass because of poor flight weather
- End – Use Contract
    - No NPS personnel can fly
    - Minimal direction on how the control mission is conducted
- Explosives are stored in Bozeman, Montana and are the responsibility of the contractor

NPS Personnel

- East Road Guard
- West Road Guard
- Project Inspector
- Groomer and operator for debris clean-up
    - Groomer operator and West Road Guard may function as one
- Aviation oversight by Yellowstone Fire Cache
    - General aviation safety
    - Flight following within the boundary of Yellowstone NP

Sylvan Pass Avalanche Hazard Forecasting Guidelines

Objectives:

- Identify resources available that will build the package for your forecast
- Identify Human Factors that have the potential to influence your forecast/decision
- Establish a communication link between forecasters

There is no single indicator that will give you the answer to your forecasting decision (unless you wake up and find three feet of snow has fallen over night). Forecasting is based on past, present and future weather that has, is or will affect the stability of the snowpack. This being said, daily observations are extremely important for your forecasting and personal safety.

This is considered a fluid document. Items listed are not the only source of information. We will evaluate these guidelines at anyone's request and at the end of the season and make any necessary adjustments to improve forecasting and safety.

Resource List: during storm cycles and/or returning from lieu days, all or part of these sites should be checked daily.

- Bridger Teton NF Avalanche Center – Togwotee Pass http://www.jhavalanche.org
    - Historically has been fairly representative of Sylvan Pass weather
    - Has good weather data – Max and current temp. average wind speed @ 10,400', new 24 hr. snow total, snowfall/precipitation
- Gallatin NF Avalanche Center – http://www.mtavlanche.com
    - This report is more regional – Cooke City, Bridger, Madison and Lionshead MT. ranges
    - Has good educational information on snowpack development and specific layers

- Sylvan Lake Snotel Site http://www.met.utah.edu/cgi-bin/roman/meso_base.cgi?stn=SYLW4
    - No wind indicator
    - Precipitation in tenths of inches – good to track weight added to the slope during a storm cycle
    - New snow – only slightly accurate for overnight accumulation due to settling
        - Wind could add 5 to 10 times the amount to the road and/or starting zones
- Snow Pit Data – http://www.snowpilot.org
    - Sylvan Pass Pits
    - Regional pits from Gallatin NF Avalanche Center
        - Compare their pit data to the appropriate avalanche forecast
            - Assists with forecasting the hazard level
    - Pits should be evaluated for how past, present and future weather affected or will affect the snowpack stability

- NOAA - http://www.crh.noaa.gov/forecasts
    - Yellowstone NP weather forecast
        - Five day forecast
        - Hazardous weather outlook
            - will identify areas across the state
            - posts regional Snotel sites when appropriate
                - track the storm and amount of snow
        - Links to more weather data and predictions
        - Satellite images
- Visual Observations
    - Are current weather conditions increasing the avalanche hazard
        - Wind transport of snow during and after storms
            - Have crown faces been filled in since the last control missions

            - Development of "pillows" in specific locations
        - Temperatures
        - Sun, wind, rain or rime crust development
        - Natural avalanche activity on similar slopes and/or other aspects
            - Slopes from East Entrance to Six-Mile Corner
            - Avalanche Peak and Top Notch
            - Other small slopes while traveling to Sylvan Pass
- Mountain Weather - http://www.mountainweather.com/
    - Has all the weather information and links
    - Sat & Radar Link – Future weather
        - US/PAC WV Loop – water vapor image of the pacific and western US & Wyoming
        - West WV Loop Link – Current Weather
            - Idaho, Wyoming and Montana
- Avalanche.Org - http://www.avalanche.org/av-reports/index.html
    - Regional avalanche fatalities and close calls
        - Reports available
        - Tragically, helps identify and/or confirm regional instability on specific aspects and at what elevation
        - Links to educational information

Human Factors: If you don't travel into, across or below avalanche terrain then you will never be killed or injured in an avalanche.

- Go – No Go
        - Terrain - You will be traveling across and/or below 20+ avalanche paths on Sylvan Pass. East Entrance to Six-Mile

Corner has several small slopes that have avalanched on the road with potentially catastrophic consequences.

- These avalanche paths are steep enough to slide, can be extremely sunny during the spring, typically get wind loaded and can be affected by other weather disturbances ie. rime, rain, wind, sun

- Snowpack - from the above resource list you should be able to determine the following
  - Slab Configuration – is a slab forming – new snow + wind, depth and distribution
    - Visual observations
      - Are the starting zones loading and/or filling in crown faces?
      - What intensity
    - BTNF and GNF Avalanche Forecast
      - Check wind speed, direction and new snow
    - Sylvan Lake Snotel
      - Overnight snow depths
      - Storm cycle precipitation – this is more important than new snow
    - Weather Forecasts
      - Check forecasted wind speed, direction and new snow
      - How will the forecast affect the snowpack
  - Bonding ability – weak layer and bed surfaces identified in
    - snow pits
    - hasty pits
    - avalanche reports
  - Sensitivity – shear tests identified in
    - snow pits

      - hasty pits with “tap test”
- Weather – will the current weather or future weather contribute to instability?
  - Precipitation – type, amount, intensity as it pertains to *added weight!*
    - *Visual observations*
    - Sylvan Lake Snotel Site
  - Wind – amount and rate of transported snow, is snow available for transport?
    - Visual observations
    - BTNF Togwotte Pass Avalanche Forecast
  - Temperature – changes or trends during a storm cycle, gradient and crystal formation within the snowpack?, developing surface hoar?
    - Visual observations
    - Sylvan Lake Snotel Site
    - Area weather station logs
    - Weather forecasts
- Human Factor – what are your alternatives and their possible consequences as it pertains to your personal safety
  - Attitude – towards life, risk, goals and assumptions?
    - I will return home each evening to my family
    - I will work within and develop my decisions based on my experience/training
    - The National Park Service and your supervisor will support your decision to forecast avalanche hazards and/or close the road for public and personal safety without the worry of repercussions.
    - Visitor convenience or inconvenience is not part of avalanche hazard forecasting

            - After the road is closed, we will make every attempt to safely eliminate the hazard through control and/or grooming within a safe and reasonable period of time.
    - Technical Skill Level – traveling, evaluating avalanche hazards
        - Decisions are only as good as your training and experience
        - Continued education and field observations will be a priority
            - Daily review of formation in the resource list
            - Communicating with other forecasters
            - Local knowledge of the forecasting area
            - Ground truth your suspicions and concerns
    - Strength – ability and equipment to snowmobile over Sylvan Pass during poor conditions or increasing avalanche danger
        - Call Lake Rangers to meet and/or evaluation from the west side of the pass
        - The ability to identify your skill level and work within it

Communication: Open communication between forecasters, groomers etc. will increase our overall knowledge and safety during a storm cycle and throughout the avalanche season.

- Hazard Forecasting
    - Discuss all your findings from the resource list, visual observations and snow pits.
    - Discuss how past present and future weather forecasts will affect the snowpack
    - Complete daily observation form for Sylvan Pass
- Lieu Days or other periods of absence

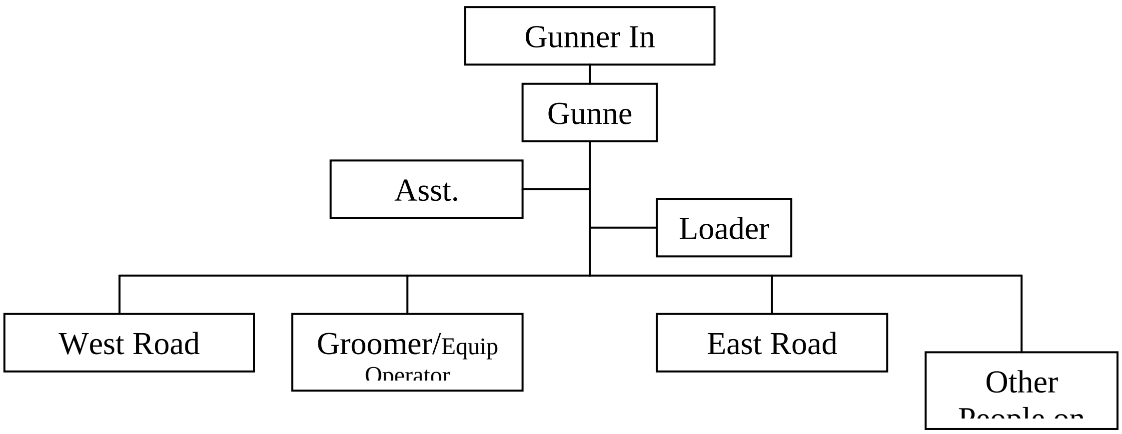
    - Update your knowledge prior to traveling up to Sylvan Pass, especially if a storm system is or has been over the area
        - Check BTNF Avalanche Center
        - Sylvan Lake Snotel
        - Weather Forecast
        - Forecasters working during your absence
            - East rangers may need to leave a brief summary for the next individual coming on duty
- Increasing Hazard
    - Consider having forecasters from Lake check the pass from the west side prior to crossing Six Mile Corner and Brown Drift
    - Consider using Lake Rangers for 10-47 or to meet you on the pass
    - Lake Rangers should confirm that East Rangers are aware of increasing hazards
        - Formulate a plan for the morning inspection of Sylvan Pass
            - Develop a plan the night before
            - East stays at Six Mile Corner while Lake checks the pass from the west side.
    - East and Lake rangers should make every effort to communicate
        - Phone
        - Dig and evaluate snow pit findings together
        - Meet on the pass to discuss visual observations
        - Discuss the total forecasting package
            - What is the hazard level
            - What is contributing to instability
            - Is the stability increasing or decreasing
            - How will the forecast affect the stability
            - What will it take to reach the closure point
                - Is it a closure for public safety
                - Is it a maintenance control closure

DRAFT

HOWITZER OPERATION PLAN

SYLVAN PASS

ROLES AND RESPONSIBILITIES



- Gunner in Charge: ***Assumes overall responsibility for the mission from beginning to end (Incident Commander)***. Assures that each operation is completed, and that it is completed by qualified personnel (proper training and experience for role being completed).
- Gunner: Performs the roles of the *gunner* (specific duties are contained later this document). 2nd in Command for the mission. Directs the operations of the mission and fires the weapon.
- Assistant Gunner: Performs the roles of the *assistant* (specific duties are contained later this document). 3rd in Command. Assistant to the gunner.
- Loader: Performs the roles of the (specific duties are contained later this document).

- Road Guards: Perform the roles of the *road guards* (specific duties are contained later this document)
- Groomer/Equipment Operator: Gains access to the platform. Prepares the road corridor for safe travel after control work is complete. Responsible for radio communications between the crew and the Communications Center.
- Other People on Scene: This includes additional help, observers, etc. They need to be approved by the *gunner in charge* in order to be allowed on the platform.

GENERAL RULES

Only trained and experienced individuals may participate in Howitzer firing missions

- Clearly designate “Gunner in charge” who will have absolute responsibility
- No smoking during any portion of the operation
- Anyone can call “CEASE FIRE” during any portion of the mission
- Ensure that all individuals are aware of their roles and responsibilities
- Go slow and communicate your intentions

EQUIPMENT TO BE BROUGHT FROM LAKE

- Gunners pack containing keys, firing pin, logbook, extra transceiver, spare transceiver batteries
- Batteries for operation of the winch
- Avalanche transceivers (Worn by each person involved in the mission before entering the avalanche zone)
- Shovels, and probe poles will be on each snowmobile operated by a member of the crew
- Avalanche Forecasting Kit
- Satellite phone in pelican case with spare battery

GUN MOUNT ACCESS PROCEDURES

- Groomer (snow crew equipment in spring) stages at the west side avalanche sign until “spotters” arrive.

- A minimum of 2 spotters are required before the groomer proceeds into the avalanche zone
- Before the groomer enters the avalanche zone
    - Confirm radio communication plan/channel
    - A transceiver check will be performed
    - Close any open windows in the groomer
- Spotters will observe the groomer from the west side avalanche sign until the groomer has reached the gun-mount access road. At least 1 spotter will then relocate to a safe position at the top of the Pass while the other spotter stays in place. If a safe position cannot be achieved at the top of the Pass, spotters will observe from the west side avalanche sign.
- After the groomer has gained access to the gun mount, he will tell the rest of the team to come up one at a time and monitor their progress

AREA SET UP

- **Keys to the work shed are never left inside. They should remain in the lead gunner's pocket. The door has a tendency to lock unexpectedly.**
- **Start the generator to begin warming up the recoil mechanism *first*. Warming will occur for at least 1.5 hours**
- Light the propane heater in the work shed.
- Gain access to the magazines
- Shovel snow off of the platform
- Put in place rubber anti-slip mats as appropriate
- Attach the winch to the howitzer trailing arms. Run the cable through the barrel
- Pull out rounds and fuzes and set up the round assembly area
- After warming is completed exercise the recoil mechanism with the winch
    - Check for ice build-up on the front of recoil mechanism
- Gunner installs the firing pin
- Punch the bore with a dry brush (may punch it wet if needed)

COMMUNICATIONS

- Communications between members of the crew will occur on “South” Direct Channel. If an alternate channel is needed, it will be a direct channel.
- Radio numbers will not be used by members of the mission crew. Members will be identified by their role when using the radio (examples include “Gunner,” “West Guard,” “East Guard,” “Groomer”).
- The Gunner will generally be in charge of communication on the platform to eliminate “the middle man” (do to direct control over the weapon). However, the Gunner does have the discretion to assign this responsibility to another member of the platform personnel.

ONSITE SAFETY MEETING AND ASSIGNEMENTS

- Assign road guards and their responsibilities
  - Insure visitor safety
  - Constant communications with Gunner on “South” direct
  - Road Guards will monitor
    - Sweep the road through the control area if the road is open
    - or insure no tracks are going into the control area if the pass has been closed
  - When directed, stop all traffic until notified to resume traffic flow
  - Gunner will get confirmation from Road Guards that the control zone is free of traffic
  - Broadcast “Cease Fire” if intruder enters the closed area
- Gunner in Charge, Gunner, Assistant Gunner, Loader personnel identified
- At anytime anyone involved has the right and responsibility to call “CEASE FIRE” in the event of a safety hazard or during firing sequence
- Watch for wildlife, aircraft and people within the avalanche control zones and firing area Once firing has commenced no traffic will be allowed to enter the area until avalanche control is complete

- Any personnel on scene not AAUNAC certified will stand well clear during firing operations in a designated location.

FIRING COMMANDS

- **At no time will a crew of less than 3 people fire the weapon.**
- Consistency in procedures and commands are a must. Consistency is the key to safety.

Before Firing Sequence Begins

- Remove cardboard or plastic insert
- **Loader** inserts fuze in projectile.
- Insure supplementary charge is in place
- Install fuze and tighten with appropriate tool
- Insure action is set to “super-quick”
- Wait for command from gunner before mating projectile with shell casing

- COMMAND: State that the mission is ready to begin (ex. Action live fire).
- PROCEDURES: Gunner and assistant gunner determine the target to be fired. Gunner and assistant gunner lay weapon on target in a coordinated manner using the direct fire method. Gunner opens breech and inspects chamber and bore to assure they are clear and free of obstructions.
- COMMAND: Ready to load, charge 5 hang 2 (charge to be fired and increments to be cut).
- PROCEDURES:
    - Loader acknowledges the command
    - loader removes increments to be cut and mates projectile with shell casing
    - loader pulls downward on string of increments hanging outside shell, cutting from shell.

- Loader displays cut increments to gunner and repeats request “charge five hang two”
- Gunner validates the increments
- Loader stores cut increments in a safe location while maintaining physical control of the round
- Loader sweeps the bottom of the round to ensure felt pad is not present
- Loader cradles the round in his/her arms with the super-quick action facing up
- Loader then carries the round to the gun and hands the round to the assistant gunner

- assistant gunner will verbalize that he/she has control of the round before the loader releases control of the round
- Assistant gunner will verbally confirm with the gunner that the fuze is set at super-quick
- Assistant gunner will verbally confirm with the gunner that the bore is clear, then place the round into the breech opening.
- Gunner will acknowledge that the bore is clear.
- Ram round into bore (with closed fist to avoid injuring hand)**. Be careful when handling live rounds to avoid striking *fuze* or *primer***
- When round is seated, assistant gunner remains holding the round in the chamber with a closed fist until the gunner closes the breech, thus pushing the hand up and out of the way

- COMMAND: Gunner makes sure breech locks in place, announces, “Loaded.” Assistant gunner repeats gunner’s announcement, “Loaded.”
- PROCEDURES: Gunner makes sure the breech is locked, ready to fire. Gunner keeps hands off of the lanyard until the assistant gunner is outside of the trails.

    - COMMAND: Gunner, “Clear to the front.” **Assistant gunner**, “Clear to the rear.”
    - PROCEDURES: Gunner: has confirmed on target and fire fan is clear of personnel, objects that may be in danger of injury or death resulting from exploding rounds or resulting snow slides. Assistant gunner: confirms on target, recoil area clear of personnel, obstructions, and he/she is prepared for firing.
    - COMMAND: Gunner: “Ready to fire…. Fire.”
    - PROCEDURE: By saying ready to fire, has confirmed he/she is in agreement with assistant gunner. This cadence prepares crewmember for weapon discharge. The second fire should not be heard because weapon is discharging at this time. When firing, gunner should apply a gradual, steady pull to the lanyard. Jerking may cause firing assembly to malfunction. Don’t release lanyard during firing. If released, the knob may lodge between breech assembly and carriage.

TERMINATION OF AVALANCHE CONTROL

- Notify Comm Center that avalanche control is complete
- Notify road guards that avalanche control is complete
    - Traffic may enter the area after avalanche debris has been cleared and road is passable
- Remove firing pin from breech
- Punch the bore with a wet brush (preferably Break Free). Repeat this process several times.
- Punch the bore with dry cloth, using the bell ram. Leave bore dry except for the last control mission of the year.
- Put away all equipment
- **Gunner in Charge**
    - Perform a complete inventory of both round and fuzes
    - ensure that magazines and warming hut are locked and secure
    - Perform a post control debriefing

- Ensure firing pin is properly stored and locked back at Lake

DOCUMENTATION

- Complete avalanche control form
- Record inventory results in inventory log book
- Update gun cards

Sylvan Pass Avalanche Control
Helicopter Dispensed Operating Plan
V1.4 Updated 04/24/06

- **Notifications to occur the day before each mission** (if possible):
  - Carisch Helicopters W 406-586-4300 or C 406-579-5498
    - Carisch will notify the Bomber and Explosives Permitee
    - Carisch will order all explosives
  - Minuteman Aviation Inc. W1-800-926-7481 or 406-728-9363
    Fax 406-728-6981
    - Pilot – Mark Mamuzich C 406-544-2630
    - Minuteman will notify the Bomber and Explosives Permitee
    - Minuteman will order all explosives
    - Minuteman acts as a subcontractor for Carisch Helicopters.
  - Fire Cache 344-2181 or 344-2188 or Perkins
    344-2180
  - Lake Rangers
    - Keator 242-2401
    - Ross/Vandzura 242-2403
  - East Entrance Personnel (307)587-2682
    - Kurt Speers 527-9487
  - Communications Center 344-2645
  - Lake Interpretation
    - Warming Hut 242-2452
    - Supervisor 242-2451
  - Lake Maintenance
    - Bruce Sefton 242-2430
    - Shop 242-2432
- **Project Inspectors:**
  - Michael Keator – Contracting Officer Representative

- Kurt Speers
- Boone Vandzura
- Brad Ross

- **Communication Plan**
  - Flight Follow with Yellowstone Fire Cache when entering the Park
    - Fire Cache Operations TX 172.5000 Tone 103.5 / RX 172.5000 Tone 103.5
  - Landing at Sylvan Pass
    - South Direct TX 165.5875 Tone 110.9 / RX 165.5875 Tone 110.9
  - Satellite Phone 254-204-2873
- **Day of the mission:**
  - Notify appropriate individuals mentioned above
    - Fire Cache or Communication Center must be notified that a mission will be conducted
    - Confirm which dispatch center will be conducting flight following
  - Determine the approximate helicopter time of arrival.
  - Ensure that road guards are on the pass prior to the arrival of the helicopter.
  - Secure the landing zone and install a wind indicator.
    - Flagging or wind sock
  - Call the warming hut after the helicopter lands so they can begin holding traffic.
    - Brief on *approximate* time Sylvan Pass will be closed
    - During control operations the road is open to Lake Butte Overlook
  - Helicopter arrives. **Sylvan Pass N44 28.089 / W110 08.134, Elevation 8500 ft.**
    - **Contact Project Manager on South Direct 165.5875 Tone 110.9 TX/RX for status of helispot and permission to land**

        - Project Inspector Notifies the Fire Cache that the helicopter has landed at Sylvan Pass and that the Project Inspector will conduct flight following during the mission.
        - Build explosives and attach two RECCO reflector patches to each charge. This is carried out by the helicopter crew—*no involvement of NPS personnel!*
    - NPS personnel are responsible for traffic control around the helicopter while it is on the ground
    - Project Inspector performs a mission briefing with the pilot and helicopter crew, and both road guards (when it is possible for both road guards to be there). The briefing should review the following topics and procedures:
        - Determine radio channel for flight operation
            - South Direct 165.5875 Tone 110.9 TX/RX
        - Establish communication with East and West Road Guards
        - Ensure everyone knows that anyone can call "Cease Fire" when a hazard is identified or perceived
        - Fly over of control area and roadway
            - Determine that the road is clear
            - Look for skiers, wildlife etc in starting zones and/or runout zones
            - Communicate with the East Road Guard
                - West Road Guard may be the Project Inspector, groomer or a designated individual
        - When area is determined to be clear the Pilot radios the Project Inspector that the area is clear
        - Project Inspector will then give approval to begin control operations
        - Identify any hazards and give a predicted weather forecast for the day
        - Review any avalanche hazards that have been identified in snow pits, regional forecasts and area observations

        - Call the Project Inspector whenever the helicopter is in bound to the helispot
    - Road guards get in place and hold all traffic. Verbalize completion to Project Inspector.
    - Project Inspector notifies the Fire Cache or Communication Center that control operations are commencing
    - Helicopter then flies over the control area, including the road to determine that all is clear. Verbalize completion to Project Inspector. Project Inspector gives approval to begin control operations
    - Carry out the control work.
        - Transmit over the radio which "shot" is being controlled
        - If avalanche activity is observed transmit it to the Project Inspector
    - Verbalize completion of the control work so the helispot can be secured.
    - Project Inspector notifies the Fire Cache or Communication Center that control operations have been completed
    - Helicopter will land and pick up equipment.
    - Debrief the mission.
        - Avalanche activity
        - Flight weather
        - Lessons Learned
        - Get Explosives invoice from Explosives Permitee
        - Inform pilot that he will need to flight follow with the Fire Cache from Sylvan Pass to Gardiner
        - Remind pilot to fax invoice to Lake Rangers
    - Inform the Fire Cache or Communication Center when the helicopter is off Sylvan Pass enroute to Gardiner
    - Groomer begins clean-up of the road.
    - Call the warming hut with an estimated time that the road will be open.
- **Communication during the mission:**

- ALL RADIO COMMUNICATION BETWEEN MEMBERS OF THE CONTROL MISSION WILL OCCUR ON A DIRECT CHANNEL FREQUENCY!
  - Helicopter will use the call sign 7CH. Personnel on the ground will use the title of their position (ie, Project Inspector, East Guard, West Guard, Groomer).
  - Helicopter will flight follow with the Fire Cache or Comm. Center (Fire Cache Ops 172.5000 Tone 103.5 TX/RX) while in transit.
  - Helicopter will flight follow with the Project Inspector while completing the control mission.
  - Project Inspector will notify the Fire Cache (or Comm. Center when Fire Cache is unavailable) of both the start and finish of the control mission flight. If the Project Inspector is unable to make contact with the dispatcher, then the pilot will conduct this notification from the air (this will allow them to hit a repeater channel).
  - “CEASE FIRE” can be verbalized by any member of the mission at any time!
- **Un-detonated Explosive Charge:**
  - Immediate retrieval
    - Proximity to East Entrance Road
    - Hazard to grooming/plowing operations
    - Hazard to personnel
    - Close Sylvan Pass to all travel if safety concerns dictate
  - Delayed Retrieval
    - Charge is located in an identified avalanche starting zone
    - Safety issues preclude immediate retrieval
    - Subsequent avalanches that cross the East Entrance Road initiating from the identified starting zone will be scanned with the RECCO Detector prior to grooming/plowing operations.
  - When retrieval is initiated Carisch Helicopter will conduct the retrieval operation

        - Carisch Helicopter will be paid for flight hours
        - Intermountain Energy or a certified explosive handler will dispose of the charge within established industry standards and will be paid for their services independent of the helicopter contract
            - DI-1 stating the emergent situation
            - Account # from YNP Safety Officer
- **Documentation:**
    - Complete and email the Helicopter Avalanche Control Form to:
        - Phil Perkins, Laura Dooley, Brandon Gauthier, Kurt Speers
        - File copy in the Helicopter Avalanche Control Operations binder
    - Receive faxed invoice from Carisch Helicopters
        - Review invoice, Write "Approved, sign and date"
            - Fax to Tina Holland in Procurement 344-2079
            - Send a copy Brandon Gauthier
    - Explosives Invoice:
        - Review Invoice faxed from Intermountain West Energy (406-287-3229)
        - Write "Approved, sign and date" Fax to Rose Gallagher 344-2626
        - Send copy of invoice to Brandon Gauthier, file copy in binder
        - Account # 1571-0300-HZY
    - Un-detonated Explosive Charge:
        - Document on a Case Incident form
            - Location – Shot #
            - Photograph location and identify location
            - Type of charge and size of charge, number of blasting caps
            - Condition of charge
            - Proximity to the East Entrance Road

Contact Information:

- Carisch Helicopters
    - 406-586-4300 W
    - 406-582-8446 H

- 406-579-5498 C
- Allen Torgersen – Explosives Permitee
    - 406-287-7838
- Intermountain West Energy – Gil Price
    - 406-287-3229
- Jeff Frink Bomber
    - 406 490 8558
- Jason Lyon Bomber
- Shawn Jackson – Bomber
    - 406-855-2066
    - actionjackson1963@hotmail.com
- Mark Rickbeil – Bomber
    - 406-446-2610 x130 Redlodge Ski Patrol
    - 406-670-7253 C
    - rarkbeil@aol.com
    - patrol@redlodgemountain.com