National Park Service
U.S. Department of the Interior
Intermountain Region

Sylvan Pass Operational Risk Management Assessment

Final Report of Results and Initial Interpretation August 6-8, 2007 Workshop in Gardiner, Montana Yellowstone National Park

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II. Purpose, Participants & History

Introduction & Purpose

On August 6, 7 and 8, 2007, sixteen internal NPS and external avalanche control experts and observers undertook a detailed, systematic review of agency winter operations on Yellowstone National Park's Sylvan Pass, called an Operational Risk Management Assessment (ORMA). With a charge from National Park Service (NPS) Intermountain Regional Director Mike Snyder, the panel of experts evaluated the risks to employee and visitor safety as well as the potential gains (for visitor access, agency cost, resource protection, and effectiveness of avalanche control) of several different potential avalanche control options, with the operation's mission being to avoid negative avalanche-human contact.

The process was co-led by Billy Shott, NPS Branch Chief, Law Enforcement and Ranger Activities in the Intermountain Region, and Chief Rodney Slade of the U.S. Coast Guard. The group also had a charge to consider, as they conducted the assessment, how Sylvan Pass operations compare and contrast to NPS winter operations at Talus Slope on the South Entrance Road. Figures 1 and 2 illustrate the location and avalanche paths on Sylvan Pass; Figure 3 shows photographs contrasting Talus Slope and Sylvan Pass (under the Talus Slope discussion below).

The primary audience for this report is Mike Snyder and Yellowstone Superintendent Suzanne Lewis, two of the winter use decision-makers. With a recommendation from Suzanne Lewis and Grand Teton Superintendent Mary Gibson Scott, Snyder will sign the Record of Decision (ROD) that summarizes the Park's winter use management decision later this fall.

The important secondary audience for this report is the community of Cody and the State of Wyoming because of their intense interest in finding a way to keep Sylvan Pass open to motorized oversnow traffic (snowmobiles and snowcoaches) in the winter season.

Figure 1: Location of Sylvan Pass, Yellowstone National Park.

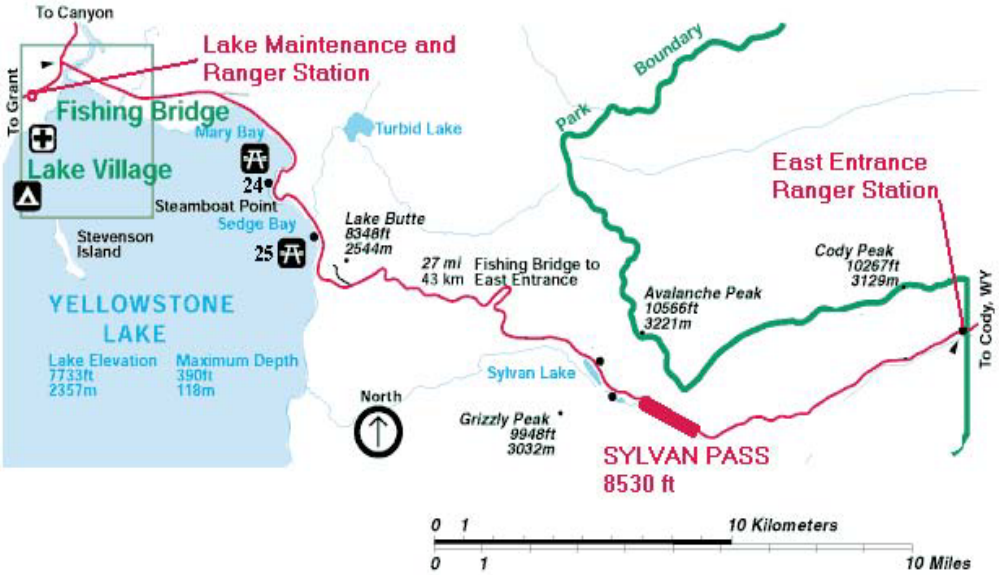
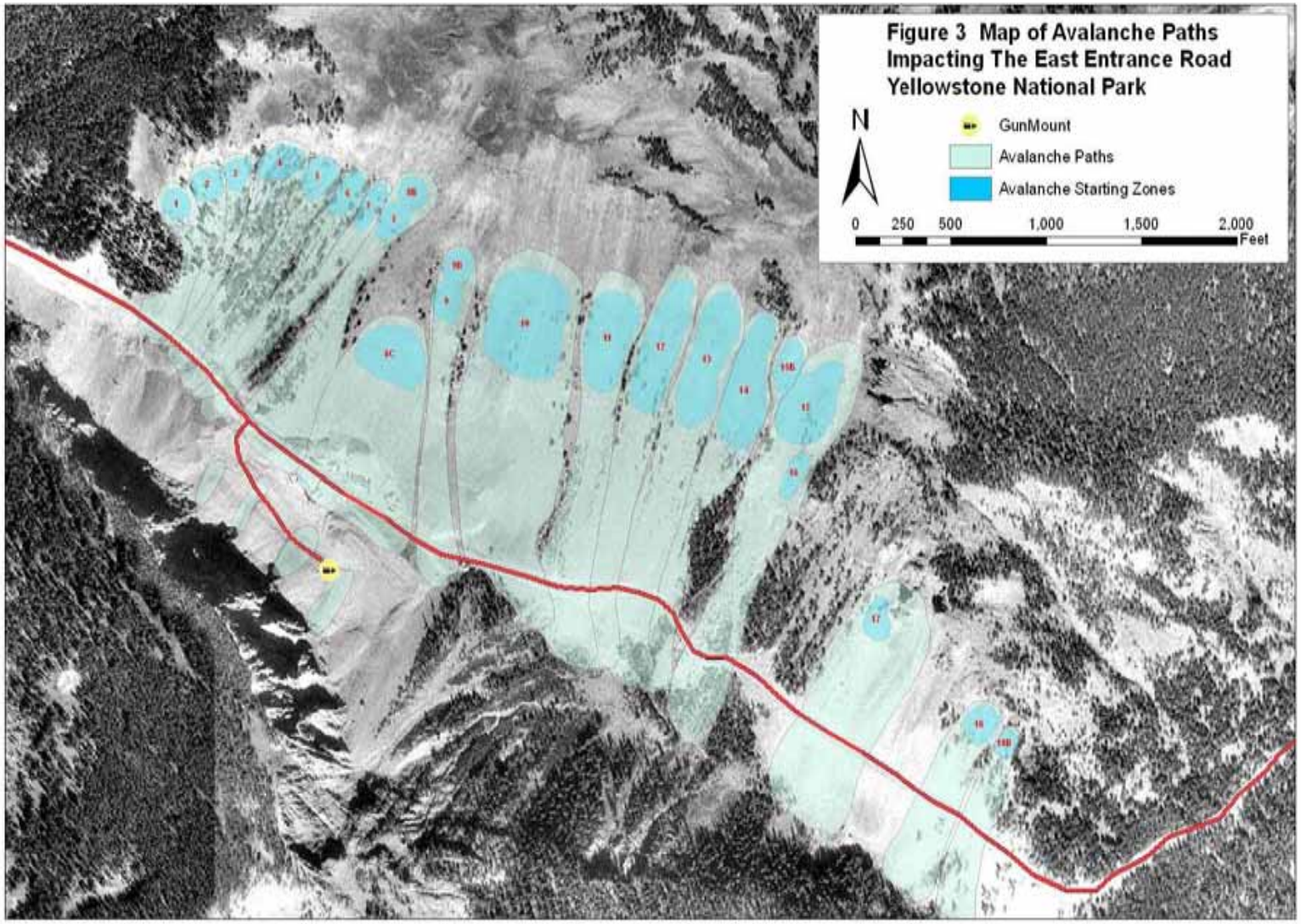


Figure 2: Avalanche paths at Sylvan Pass (taken from Comey 2007).



Note that access to the howitzer platform can occur along two routes from the west (see Figure 2– the yellow dot is the howitzer platform). Both routes initially cross 8 avalanche paths (1-8a and b on the map). Then one route, used historically, uses the summer access road to reach the platform. In the winter, this road was formerly groomed for snowmobile access to the platform. The road crosses an additional 4 chutes (not numbered on the map). In recent winters, instead of using the summer access route, the gun crew has continued east on the East Entrance Road to a point directly north of the gun platform, where they leave their snowmobiles and proceed on foot to the platform. This alternate approach puts the crew on foot in deep snow in an additional avalanche path (8c), but avoids the four short avalanche paths on the side road and is in keeping with a recommendation by the Occupational Safety and Health Administration (OSHA). There are no other routes of access to the howitzer platform available; clearly, both of these routes entail traveling below uncontrolled avalanche chutes.

Who Was There and Why

The Operational Risk Management Assessment took place from August 6–8, 2007. It was an open meeting with invitations sent by NPS to particular interested parties based on their expertise. Those who attended are listed in Table 1 below. Others who were invited but were unable to attend included Doug Abromeit of the U.S. Forest Service, Ryan Lance from the Wyoming Governor's Office, and Jamie Yount from the State of Wyoming Department of Transportation.

Table 1: ORMA Participants

Name		Role & location	Why Present
Bachman	Don	Environmental consultant (land use policy, advocacy, snow safety, and avalanche control), Bozeman, MT	Expert panelist with many years of specialized knowledge of corridor avalanche forecasting and control operations. Currently consulting for Glacier Park regarding avalanche mitigation issues connected to Burlington Northern operations in Glacier Park.
Birkeland	Karl	Snow Scientist, U.S. Forest Service National Avalanche Center, Bozeman, MT	Expert panelist with many years of specialized knowledge and experience in avalanche forecasting and avalanche control operations. Specialized experience on the Gallatin National Forest.
Campbell	Colin	NPS Deputy Superintendent, Yellowstone National Park	Observer.
Chandler	Nedra	Cadence, Helena, MT	Independent facilitator for agency and public participation in winter use planning and decision making. Has no stake in the outcome(s)—sole role is to facilitate communications.
Comey	Bob	Geologist and avalanche specialist, Jackson, WY	Expert panelist. Wrote report: Avalanche Hazard Assessment and Mitigation Report: Sylvan Pass, Yellowstone National Park for NPS, March 2007. Director of the Bridger-Teton Avalanche Center. Lead avalanche forecaster for the Jackson Hole Mountain Resort. Has expertise in avalanche assessment and mitigation in North America, Switzerland, and New Zealand, including a long-time familiarity with the operations of the Sylvan Pass avalanche program.

French	Tim	Park County Commission, Cody, WY	Observer. Elected commissioner from Cody and cooperating agency representative for Park County for NPS winter use EIS. Has key interest in maximizing "openness" of Sylvan Pass in the winter, and continued acceptability of oversnow vehicles using the East Entrance to keep growing Cody's economic and community vitality.
Keator	Michael	Lake District Ranger, Yellowstone National Park (NP)	Expert panelist. More than 15 years of specialized knowledge of Sylvan operations—supervises east side operations.
Meyer	Ken	Safety Manager, Yellowstone NP	Expert panelist. Twelve years of safety and risk management experience in private industry and government, including OSHA.
Obernesser	Rick	Chief Ranger, Yellowstone NP	Observer.
Pochelon	Remy	Ecosystem Research Group, Missoula, MT, contractor to the State of Wyoming Office of the Governor, Cheyenne, WY	Wyoming State Governors Office Consultant/Observer.
Sacklin	John	National Park Service, Yellowstone National Park; Management Assistant to Superintendent Lewis	Observer. Winter use team leader since mid 1990s.
Sefton	Bruce	NPS Maintenance Supervisor, Lake District, Yellowstone NP	Expert panelist. Supervisor, road operations in Lake District and Sylvan Pass. More than 15 years of specialized knowledge of Sylvan operations.
Shott	Billy	Chief, Branch of Law Enforcement and Ranger Activities Intermountain Region, NPS	Operational Risk Management Leader, invited by NPS Intermountain Regional Director Mike Snyder and Yellowstone Superintendent Suzanne Lewis to lead the objective, collaborative look at risk to employees and visitors related to Sylvan Pass operations.
Slade	Rodney	Chief, U.S. Coast Guard	Operational Risk Management Leader, brought in to provide an outside expert perspective on ORM process and results from a sister federal agency that, unlike NPS, has been doing this type of assessment for the past 20 years.
Swanke	Denice	Outdoor Recreation Planner, Yellowstone NP	Observer. NPS winter use team member, one of the co-authors of winter use EIS document.
Swanke	Steve	Deputy Chief Ranger, Yellowstone NP	Expert panelist. Supervisor. Manages ranger operations throughout the park and supervised Sylvan Pass Operations as Lake District Ranger.

Selected Context—Past and Present

Table 2 below is a chronology that highlights some of the key events since 1932 that have helped shape the context for winter use decision-making in general and Sylvan Pass winter operations specifically.

This chronology was adapted from a more detailed version, Appendix B: History and Timeline, of the March 2007 Winter Use Plans Draft Environmental Impact Statement for Yellowstone and Grand Teton Parks and John D. Rockefeller, Jr. Memorial Parkway.

Table 2: Winter Use Chronology

Date	Description
1932-1989	In 1932, interested people in Cody requested that the NPS plow Yellowstone roads to allow year-round access. Park authorities turned down the requests, citing poor roads, severe winter conditions, un-winterized buildings, and lack of rotary plows. In 1938, NPS began plowing Mammoth to Cooke City year-round. Two years later, Cody asked again to look at feasibility of plowing Park roads year-round and the Park declined again. Requests for Park plowing continued to roll in over the next decade from Cody and other local communities. With additional concerns about wildlife getting trapped in road corridors due to snow piled high on the roadsides, the NPS continued to turn down such requests, while soon accommodating a new form of winter tourism, oversnow motorized vehicles. In 1955 several West Yellowstone people began offering the first snowcoach tours of Yellowstone and several thousand people tried them the next several winters. In 1956, local communities again asked the agency to consider plowing park roads. In response, an NPS committee concluded it was feasible but not practical due to poor roads, severe weather, estimates of low traffic volumes, and cost of necessary developments and road improvements. In 1963, the first modern snowmobiles entered Yellowstone. In 1972, President Nixon issued Executive Order 11644, establishing a federal policy on off-road vehicle use in relation to resource issues. Yellowstone's Superintendent Jack Anderson responded by designating all the park's interior roads for snowmobile use. In 1973, NPS began conducting avalanche control operations on Sylvan Pass to provide a safe travel corridor for visitors. By 1981, winter use had increased to 105,000 visitors annually (parkwide). In the 1980s the NPS closed Dunraven Pass in Yellowstone due to avalanche concerns there; current management there is backcountry use.
1989-1996	Winter use visitation continued to increase. Regarding Sylvan Pass operations during this period, Ranger Bob Mahn died in a 1994 accident while on patrol en route to Sylvan Pass to assess the avalanche danger there.
1997-2005	See details in the EIS Appendix to review the succession of planning and lawsuits regarding winter use during this period. Regarding the Sylvan Pass aspects of the analyses, note that both the first EIS (2000) and Supplemental EIS (2003) examined avalanche control at Sylvan Pass, acknowledging that there was considerable risk in operating an avalanche control program there. Also in 2001 and 2004 respectively, the Occupational Safety and Health Administration (*Sylvan Pass: Yellowstone National Park*) and the State of Montana Department of Military Affairs (*Potential Environmental and Safety Impacts Associated with the Use of Ordnance for Avalanche Control at Sylvan Pass, Yellowstone National Park, Wyoming*) identified hazards related to job tasks in the Sylvan Pass avalanche control program.
June 2005	Scoping began on a new winter use EIS.
Fall 2005	Winter use team members met with Cody interests twice and held a conference call to discuss which scenarios would be modeled—this was the first time the possibility of closing Sylvan to

	oversnow vehicles was raised by NPS in the current EIS process.
January 2006	NPS and 10 cooperating agency representatives (the three states, five counties, EPA, and the Forest Service) signed the information-sharing Memorandum of Understanding (MOU) for this (3rd) EIS process.
March/April 2006	NPS held information-sharing meetings in Bozeman, Montana and Jackson, Wyoming to roll out preliminary scenarios for managing recreational winter use in the parks. These open meetings invited agencies and public participants together to look at six scenarios for managing winter use in the parks. Several of these scenarios contemplated closing Sylvan Pass to motorized oversnow vehicle use. Cooperating agencies met in Idaho Falls to review what NPS had heard from public and audience commentors.
Summer 2006	Superintendent Suzanne Lewis visited Cody interests to inform them of what she was learning about risks inherent in avalanche control on Sylvan Pass, in anticipation of continued study of those alternatives that would cease avalanche control and grooming on the pass during winter.
November 2006	NPS released a preliminary Draft Environmental Impact Statement for Cooperating Agency review. The agency preferred alternative called for closing Sylvan Pass to motorized travel beginning in 2008-09 while leaving it open for ski and snowshoe access (and skier/snowshoe drop off) to a point about six miles west of the entrance. Three of the other five alternatives also called for the pass to be closed to motorized vehicles.
December 2006	NPS met with cooperating agencies and others in Cody to explain the reasoning behind the approaches shown in the preliminary draft. NPS also held an information fair for members of the public. Now that the possibility of ceasing avalanche control on the pass and closing it to oversnow vehicle use had become much more real, State of Wyoming and Park County interests stated their strong interest that the East Entrance remain open for snowmobile and snowcoach travel. They noted how much they felt the community and economic health of Cody and the broader city region depended on that access for motorized travel in the winter. NPS committed to developing options for keeping the pass open, but did not commit to changing course on the preferred alternative. In the Cody area, a grassroots community group called *Shut Out of Yellowstone* formed, for the purpose of working to keep Sylvan Pass open to motorized oversnow vehicle use in the winter.
January 2007	*Shut Out of Yellowstone* hosted a community forum with about 500 participants and invited panelists, including Superintendent Lewis, to discuss the Sylvan Pass aspects of the preliminary Draft EIS (the official Draft EIS was not yet out for formal public review).
February-March 2007	NPS contracted with Robert Comey to produce the "Avalanche Hazard Assessment & Mitigation Report, Sylvan Pass, Yellowstone National Park."
Spring 2007	Superintendent Lewis continued to meet with Cody-based interests to seek clarity and a common base of understanding about the Park's approach to risk management on Sylvan Pass. While Cody interests expressed appreciation for the working relationship they had with the Park, they reported surprise about ceasing avalanche control in the preferred alternative. Other issues connected to Cody-Park communications were raised again, especially regarding internal and external communications about weather and conditions and when the East Entrance was open or closed in the winter. In their gateway community role, Cody interests felt that the lower numbers entering the East Entrance were a self-fulfilling prophecy related to a pattern of ratcheting down the winter opportunities there over time. Participants also continually emphasized they would value stability of winter use park policy so Cody can better plan for and build their socioeconomic opportunities related to their proximity and access to the Park. The winter use team emphasized that no decision was yet made and that because of risk there is/was limited room to move, but that they were willing to keep listening and exploring options until the time when they have to have a decision and rule in place in order to have a winter season in the parks.

	NPS emphasized their significant investments roads on Yellowstone's east side and in the Canyon visitor center, illustrating that NPS is not "trying to shut the east gate down." Superintendent Lewis explained differences between the NPS approach to risks and hazards in front country and non-maintained backcountry—especially as it relates to the howitzer gun (for avalanche control), helicopter-discharged avalanches, and trying to keep the road open in the winter. She emphasized NPS attention to risks regarding avalanche control on Sylvan is not new and not an expedient way to justify the preferred alternative.
March 2007	The Draft Environmental Impact Statement (DEIS) was released for the 60-day public comment period, with the preferred alternative continuing to propose ceasing avalanche control activities on Sylvan and closing it to motorized oversnow vehicle use in the winter season.
May 2007	NPS convened four public comment meetings for the DEIS in Cody, Wyoming; West Yellowstone, Montana; St. Paul, Minnesota; and Lakewood, Colorado. Wyoming Senators Thomas and Enzi and Representative Barbara Cubin delivered a letter to the winter use team emphasizing their primary concern with the Draft EIS was the possible closure of the East Entrance to motorized oversnow vehicles. They urged the NPS to reconsider their preferred alternative.
June 2007	Regional Director Mike Snyder and Superintendent Suzanne Lewis met with Cody interests to discuss the range of concerns. One result of that meeting was Snyder's request for an Operational Risk Management Assessment to be conducted to objectively assess the hazards and risks associated with techniques currently used by NPS staff and to review potential strategies that could be used by NPS staff to control avalanche threats on Sylvan Pass. The charge was to use process and procedures of *Operational Risk Management (ORM),* developed by the United States Coast Guard to systematically and methodically assess each mitigation option and quantify the risk exposure to both employees and visitors.
August 2007	Operational Risk Management Assessment conducted with a panel of seven NPS internal and external/independent avalanche experts (representatives from the Park, Cody, and the State of Wyoming served as additional observers of the work).
Now: Next Steps	At the time of the assessment, the panel understood that the winter use team planned to publish the Final EIS this fall and that no further public comment was called for under the National Environmental Policy Act at that stage. The results of the ORMA will be integrated into the avalanche control appendices of the EIS and will help inform NPS decision makers as they finalize the Record of Decision (ROD) and the Final Rule implementing the ROD. The ROD will be signed by Intermountain Regional Director Mike Snyder with recommendations from Yellowstone Superintendent Suzanne Lewis and Grand Teton Superintendent Mary Gibson Scott. In any case, whether the NPS decision is to go forward with some version of the current preferred alternative or to modify the preferred alternative regarding Sylvan Pass winter operations, no closure to oversnow vehicles will occur in the 2007-08 season.

Additional Historical Considerations of Visitor and Employee Safety

Yellowstone has been conducting avalanche control operations at Sylvan Pass since 1973. The 2000 EIS, the 2003 Supplemental Environmental Impact Statement (SEIS), and the Temporary Winter Use Environmental Assessment (EA) of 2004 acknowledged that there is a considerable risk in operating an avalanche control program at Sylvan Pass. The 2000 EIS considered closing Sylvan Pass and the Temporary EA introduced helicopter operations as another mitigation technique.

The NPS formerly allowed motorized oversnow travel between Canyon and Tower Fall over Dunraven Pass in Yellowstone. Growing concerns over avalanche danger there prompted the park to close Dunraven to oversnow vehicle travel in the 1980s.

Yellowstone has stepped up its commitment to visitor and employee safety in recent years in all facets of park operations. Outside agencies including the Occupational Safety and Health Administration (2001) and the State of Montana Department of Military Affairs (2004) have looked at the risk of avalanche control on Sylvan Pass.

During this current winter use planning effort, NPS conducted new evaluations on a variety of options to manage avalanches and improve safety. The preferred alternative in the 2007 FEIS would close Sylvan Pass to all motorized oversnow travel because of unacceptable risks to visitor and employee safety.

Trained, experienced NPS rangers run the avalanche control program at Sylvan Pass. The program has been successful to date preventing "negative avalanche-human contact,[1] yet, because of the magnitude and complexity of Sylvan Pass, it is understood as dangerous work.[2] One person has died as a result of these winter operations on Sylvan, Ranger Bob Mahn, who died in a 1994 accident while on patrol en route to Sylvan to assess the avalanche danger there. Over the years there have been several instances when park employees or visitors had close calls or near misses with avalanche mitigation-associated operations.

During historic use, the peak number of people who traveled through Sylvan Pass was less than 5,000 people (visitation there averaged about 4,500 per winter in the early 1990s). That is about the same number of visitors that travel through Sylvan Pass on a single peak day in the summer.

(Original source of text adapted above: National Park Service, Winter Use Plans Final EIS, Yellowstone and Grand Teton National Parks, John D. Rockefeller, Jr. Memorial Parkway; NPS, Newsletter March 2007; and descriptive comments offered by expert panelists in August 2007.)

III. ORMA Process

This section contains the ORM instructional materials and group work products from the three-day workshop itself (August 6–8, 2007). These are cataloged here to provide a brief record of the steps the group followed—how they moved through each Operational Risk Management Assessment task. The

[1] This was the short-hand phrase the expert panelists kept in mind as the goal as they conducted the ORMA.

[2] The East Entrance road crosses 20 avalanche paths through Sylvan Pass (see Figure 2). Rangers must travel through nine uncontrolled avalanche zones to reach the howitzer, which has been used historically for avalanche control. In addition, sometimes the munitions used for avalanche control do not explode, leaving hazardous unexploded ordnance that can later reach the road corridor, where they pose a threat to visitors and employees. For these reasons, the Park began to use helicopters for avalanche control starting in the winter of 2004-2005 and then switched completely to the use of helicopters for avalanche control during the winter of 2006-2007. Rangers lack a weather station that would allow consistent forecasting. In addition they contend with extreme conditions, including arctic cold temperatures, extreme tendency to wind loading, and a "moving" mountain of unconsolidated materials under the snow (unlike Talus Slope, an area with potential avalanche danger on the South Entrance Road also evaluated in this report; the substrate is more stable there than at Sylvan Pass). Rangers have performed this avalanche hazard mitigation to keep the pass open for oversnow vehicle, recreational use (not interstate commerce). The expert panelists knew of no other place where NPS rangers or others are doing this kind of avalanche control.

material is divided into two main parts; foundations (for the work), and products (of the group). The subsections below roughly follow the order in which the group moved through each part.

Foundations

The group began with self-introductions and confirmed the substantive, procedural, and relational results they were seeking, as well as the workshop objectives.

Substantive Outcomes Desired

1) Define Sylvan Pass avalanche control mission systematically and methodically; identify hazards, assess risk, identify options, and evaluate risk versus gain ratio.
2) Deliver Operational Risk Management Report to Mike Snyder and Suzanne Lewis by end of August, 2007.

Procedural Outcomes Desired

3) Assist park managers toward informed risk decision(s) regarding avalanche control activities for Sylvan Pass.
4) Continue clarity and honesty about who has what kind of influence in the winter use decision, implementation steps, and schedule.
5) Post/share results with anyone interested.

Relational Outcomes Desired

6) Fully engage expert panelists as raters to get to the substantive results above.
7) Continue to invest in collaborative working relationships for the long term.

Workshop Objectives.

- **Demonstrate:** A thorough understanding of the Operational Risk Management (ORM) process.
  - Participants will efficiently be able to use the process and apply the principles in their role of providing objective expertise.
  - Observers will understand the systematic and procedural methods involved in assessing risk profiles of avalanche control activities.
- **Do:** Use the ORM process to complete a systematic and methodical review and assessment.
  - Participants will gather meaningful data specific to Sylvan Pass without regard to subjective interferences.
  - Participants will provide a detailed report of employee and public safety risks associated with avalanche control operation decisions on Sylvan Pass.

Background on ORM

U.S. Coast Guard Chief Rodney Slade and NPS Law Enforcement Branch Chief Billy Shott described the origins, benefits, and process of ORM. The U.S. Coast Guard developed it approximately 20 years ago after a major mishap, which resulted in the loss of lives (the Sea King rescue). The National Transportation Safety Board charged the Coast Guard with making system changes and ORM was born. Chief Rodney Slade pointed out that one of the reasons the Coast Guard shone in the Hurricane Katrina situation is because the agency consistently applies ORM.

Billy Shott further described how and where the National Park Service is making it a priority to integrate ORM into NPS safety culture (where culture can be defined as “how we do things around here”). The

Intermountain Region is implementing ORM in all aspects of their ranger activities branch; doing so is influencing the way the agency functions from the inside out. A key feature is that ***Operational Risk Management does NOT tell you what to do, it gives you an accurate assessment of ALL risks and asks the question: "What is acceptable to you?"***

Four Core Principles

There are four core principles of ORM that facilitate the critical thinking necessary to objectively complete this assessment:

1. Accept no unnecessary risk
2. Accept risk when benefits outweigh the cost
3. Anticipate and manage risk by planning
4. Make risk decisions at the right level.

Seven Key Steps of ORM

The group reviewed the seven key steps of ORM and understood that this workshop would only address steps 1-5:

1. Define mission
2. Identify hazards
3. Assess risks
4. Identify Options
5. Evaluate Risk vs. Gain
6. Execute Decisions
7. Supervise (watch for changes).

The group noted that they would have to develop a "mission" definition that could potentially apply to any avalanche control option conceived.

Green-Amber-Red—The "GAR"

Shott and Slade instructed the group on use of the "GAR," something Chief Slade called a "living, breathing animal." GAR is a fluid tool, not a static exercise. Users can use it to continually adjust operations to minimize risk and maximize gains. GAR stands for Green, Amber, Red as depicted in the simple rating scale in Table 3 below. The GAR is a model and tool that is ideally used to evaluate an individual rotation of a field operation and is also used to assess operations programmatically (the typical conditions of a recurring operation). Numbers correlate with the colors to serve as a guideline measurement, but should not be considered a steadfast definition of risk or hazard. ORM recognizes that different organizations and workgroups within organizations have different levels of acceptable risk (i.e. the training division of an organization typically has a lower tolerance for risk than the operational division, the military typically has a higher tolerance of risk than a civilian organization, and/or the military has a higher tolerance of risk when at war than during peaceful periods). It is up to an organization's leadership to define what levels of risk are appropriate.

Table 3. GAR Scale. Numbers on the scale are derived from the Coast Guard scale as modified for NPS application. The numbers and colors are intended to serve as a qualitative and quantitative indication of risk. Charts 1 and 2 below apply this scale to the identified options for avalanche risk reduction at Sylvan Pass.

RED (High Risk)	80
AMBER (Caution)	60
GREEN (Low Risk)	35
	0

Risk Calculation Worksheets

Shott and Slade further instructed the group in the use of the risk calculation worksheets they would be using to rate activities or options for avalanche control at Sylvan Pass. The worksheet looks like that in Table 4 below. Expert panelists rate the avalanche control options on a scale of 1 to 10, with 10 being most risky. Panelists do this individually, but always check each other's assumptions and learn more through dialogue. For example, the question, "who put more than 6 on supervision?" could lead to discussion in which participants may or may not reconsider their rating in light of more information from peers or other panelists.

Table 4. Risk Calculation Worksheet; operational components are defined and discussed in more detail below.

Operational Components	Rating
SUPERVISION	
PLANNING	
CONTINGENCY RESOURCES	
COMMUNICATION	
TEAM SELECTION	
TEAM FITNESS	
ENVIRONMENT	
INCIDENT COMPLEXITY	
TOTAL	

Working Definitions of GAR Elements

The working definitions of the eight operational components in the Risk Calculation Worksheet were important to review as a group so that all panelists were operating from the same framework. The group reviewed and discussed each in turn.

The experts were asked to look at each component with the assumption of current park resources (staffing levels and expertise) as they existed in the 2006-2007 winter. For new options that do not exist (i.e. fixed gas), the panelist were to assume that current resources would be augmented with the funding to implement and operate the option. If "current resources" change (for example, employee turnover that brings more or less expertise), then the relevant scores might also change.

Supervision

Supervisory control should consider both how qualified the supervisor is and also whether supervision is actually taking place. Even if a team member is qualified to perform a task, supervision acts as a control to further minimize risk. This may simply be someone checking what is being done to ensure it is correct. The higher the risk, the more the supervisor needs to be focused on observing and checking. A supervisor who is actively involved in performing a task at hand rather than observing employee performance and checking for safe compliance with procedures can be easily distracted and should not be considered an effective safety observer in moderate to high-risk situations.

Planning

Planning and preparation should consider how much information one has, how clear it is, and how much time one has to plan the incident or evaluate the situation. Planning includes the use of pre-defined plans and on-site incident plans.

Contingency Resources

Contingency resources should include those pre-defined resources that will be called upon in an overwhelming incident. Items to consider include:

- Who is the team member going to call?
- Can he or she make the call?
- Are the contingency resources available and aware that they are such a resource?
- What is their capability for the incident?
- What is the response time for any given location?

Communications

Communications need to ensure the clear and accurate sending and acknowledging of information, instructions, and commands; and provision of useful feedback. Items to consider are not only interpersonal communications but also the physical communication equipment.

Team Selection

Team selection should consider the qualifications and experience level of the individuals used for the specific incident or operation. Individuals may need to be replaced during the incident or in the operation. The same concerns apply to the contingency resources. Also, teams should have an adequate number of members from which to choose for any single mission.

Team Fitness

Team fitness should consider the physical and mental state of the team. This is a function of the amount and quality of rest a team member has had. Quality of rest should consider conditions slept in, potential sleep length, and any interruptions. Fatigue normally becomes a factor after 18 hours without rest; however, lack of quality sleep builds a deficit that worsens the effects of fatigue. Other factors to consider are physical preparedness and personal life factors that may impede the outcome of the operation.

Environment

Environment should consider factors affecting personnel performance and factors affecting the performance of equipment, vehicles, vessels, or aircraft. This includes, but is not limited to, time of day, wind exposure, temperature, humidity, precipitation, elevation, isolation, vertical exposure, proximity to aerial/navigational hazards and other exposures (e.g. oxygen deficiency, toxic chemicals, and/or injury from falls and sharp objects).

Incident Complexity

Incident complexity should consider both the required time and the situation. The longer exposed to a hazard, the greater the risks. Factors considered include how long the environmental conditions will remain stable and the complexity of the work.

The Severity, Probability and Exposure Model

The panel was also introduced to the Severity-Probability-Exposure (SPE) risk model, where a different measurement of risk is obtained from the formula: Risk = Severity x Probability x Exposure. This is a model used to take a closer look at specific operations and is helpful to consider when planning ongoing operations. In this ORM, the panel relied primarily upon the GAR model, but used the SPE model to illustrate the risks from three options, as discussed below.

The definitions of the SPE components are:

- **Severity:** the potential loss or consequences of a mishap (Risk Control such as protective devices, engineering controls, and personal protective equipment are used to control Severity.)
- **Probability:** the likelihood that given a certain exposure, the projected consequences will occur. (Risk Control--training, awareness, attitude change, etc.)
- **Exposure:** the amount of time, number of cycles, number of people involved, and/or amount of equipment involved (Risk Control--reducing the number of people involved, the number of events, cycles, evolutions, etc.).

To rate the Risk of an option under the SPE model, panelists would rate severity on a scale of 1 to 5 (5 being worst), probability on the same scale (5 being highest probability), and exposure on a scale of 1 to 4 (4 being worst) and then multiply the ratings to achieve an overall score. Table 5, below, illustrates how those multiples would be considered qualitatively.

Table 5. SPE Worksheet

Values*	Risk Level	Action
80-100	Very High	Discontinue
60-79	High	Immediate Correction
40-59	Substantial	Correction Required
20-39	Possible	Attention Needed
1-19	Slight	Possibly Acceptable

*These values are separate from and not related to the GAR values in Table 3.

To use the SPE model, the panel would compute the risk levels for each hazard identified. Then, those hazards can be rank ordered from the highest to the lowest risk, allowing such a panel to focus on the areas of most concern first under conditions of current resources.

Universal Risk Considerations

Finally, the group was exposed to the concept of "Universal Risk Considerations," broader factors that managers must consider when implementing an operation. For example, managers must consider impacts upon other facets of park operations when implementing a specific project. Some Universal Risk Considerations include injury, occupational illness or death; equipment damage and fiscal resources; adverse or positive public impacts; reduced morale; adverse administrative and/or disciplinary actions. The group noted that many of these considerations will be applied to this process; however, the priority of this workgroup was to focus on the risk associated to employees and public. (Further discussion of universal risk considerations occurs in the Risk vs. (Factual) Gain section below).

Operational Risk Assessment

Upon completion of the ORM orientation the group conducted ORM steps 1-5 (see "Seven Key Steps of ORM" above) in the allotted time (3 days), but modified the order of the steps. The group took the foundations from the morning's orientation and began doing the assessment itself, as described below.

Mission: Keep Snow Off People

The group accepted the working description of the mission: "**keep snow off people**" or, more specifically, "**avoid negative avalanche-human contact**."

The group discussed that any option is potentially feasible to achieve that mission—an open mind is part of the process. Remaining open-minded keeps the steps honest and methodical, rather than value-laden and assuming at this stage. Also, the group agreed not to discuss financial costs of options until the very end of day 3 in order to evaluate all options objectively.

Options to Achieve the Mission

The basis of this review is to evaluate operational risk in any and all potential avalanche control options at Sylvan Pass. The group was tasked with identifying avalanche control options that could be applied there.

The group began making a list of all the options they could think of to achieve the mission, stated as simply as possible "to keep snow off people" on Sylvan Pass. The options were named and re-named and

defined a few times during the three days, but the end list of what the panel analyzed by the GAR method and what the group meant by each option is described below. These are in alphabetical order only, but there is a second list below Table 6 that shows the group's sorting of the options on day 2, moving from most to least effective.

Table 6: Avalanche Control Options/Activities

Option	**Description/Working Definition**
Access	NPS staff travel, during winter conditions, usually by snowmobile and often as a single person from the NPS facilities at Lake Village (21 miles) and the East Entrance (7 miles) to Sylvan Pass for the express and non-discretionary purposes of conducting avalanche hazard assessment and mitigation efforts.
Artillery (a 101 or 102 model howitzer that uses a 105 mm. shell)	Military weapons such as a howitzer, recoilless rifle, or battle tank that shoot high velocity explosive projectiles are used to test snow stability and trigger avalanches in a controlled environment. This option includes avalanche risk reduction as done historically in Yellowstone, before many of the recommendations by OSHA were implemented.
Avalauncher/LOCAT	Non-military devices that use compressed gas to shoot low velocity explosive projectiles are used to test snow stability and trigger avalanches in a controlled environment.
Backcountry Standards	Pass is left open to non-motorized travel without active mitigation techniques. NPS conducts general forecasting of avalanche hazards. The public is left to assess the hazard and act accordingly on their own.
Berms, Deflectors, Catchment Basins	Engineered structures that retard the forward advance of avalanches or deflect the flow of avalanches away from structures or areas or concern are constructed.
Closure + Helicopter Hybrid	The pass closes to the public and administrative travel in the fall when the avalanche paths of concern begin to accumulate snow and remains closed until designated date in early May. Helicopter deployed explosives would be used to assess and mitigate the avalanche hazard for pre-public road opening snow removal efforts in spring and to address avalanche hazards that occur after the road is opened.
Fixed Gas + Helicopter Hybrid	Explosions originating from fixed installations located near the avalanche starting zones and from hand charges dropped from a helicopter are used to test snow stability and trigger avalanches in a controlled environment.
Fixed Gas Systems	Mixtures of explosive gases are remotely detonated from fixtures installed near the avalanche starting zones to test the stability of the snow and release avalanches in a controlled environment.
Full Forecasting	Experienced personnel use resources including specialized remote automated weather stations to monitor conditions, assess the avalanche hazard, and open the pass during the winter season when conditions are safe with respect to potential impacts from avalanches. There would be no use of explosives to test snow stability or trigger avalanches. No public or administrative oversnow travel would occur during closed periods.
Hand Charges	Workers on skis deploy explosive hand charges into avalanche starting zones to test snow stability and trigger avalanches in a controlled environment. Although NPS prohibits the use of avalauncher, they were

	considered for this assessment in the spirit of considering all potential options.
Helicopter	Helicopters are used to drop explosives into avalanche starting zones to test snow stability and trigger avalanches in a controlled environment
Helicopter-Avalhex	Helium-exploding balloons suspended from a helicopter are used to discharge avalanches.
Helicopter + Howitzer Hybrid	Military weapons and a helicopter are used to deploy explosive charges into avalanche starting zones to test snow stability and trigger avalanches in a controlled environment.
Howitzer + Access Mitigation Hybrid	Military weapons are used to test snow stability and trigger avalanches in a controlled environment in the majority of the avalanche paths. Alternative methods (trolleys, fixed gas system, hand charge routes, sheds or start zone support structures) are used to mitigate the hazard in the avalanche paths that impact the approach to the gun mount.
Pre-placed explosive charges	Remotely-discharged explosives are placed in avalanche start zones prior to winter.
Re-route main road	The main road is rerouted to a nearby pass not as subject to avalanches.
Snow Sails	Specially designed sails or wind fences are installed perpendicular to elevation contours along the windward side of avalanche starting zones. These structures can disrupt the pattern of snow deposition in avalanche starting zones and may decrease the frequency of avalanche occurrences.
Support Structures in Start Zones	Engineered structures (specialized fencing in multiple parallel lines along elevation contours) are permanently installed in avalanche stating zones. These structures keep unstable snow from moving downhill and causing an avalanche.
Total Closure (“Snowflake to snowflake” when the first falls and last melts.)	No access is allowed when there is snow in the avalanche paths that can potentially impact the East Entrance Road on Sylvan Pass. All public and administrative travel, whether motorized or non-, would be prohibited.
Trolleys	Explosive charges are delivered to avalanche starting zones via a system of permanently installed cable and towers to test snow stability and trigger avalanches in a controlled environment.
Tunnel/Snowshed	The East Entrance Road would be re-routed though a tunnel to avoid the area of avalanche hazard on Sylvan Pass, or a snow shed would be built over the road in the area on Sylvan Pass that is threatened by snow avalanches. Avalanches would flow over the road on top of this protective shed with no impacts to travelers.
Window Closure (Similar to “total closure” above but reduces the window of time the pass is closed in each shoulder season fall and spring.)	Employees with avalanche expertise and local knowledge would monitor conditions with the objective of closing the pass when conditions dictate in the fall and reopen it when conditions permit in the spring. All public and administrative travel, whether motorized or non-, would be prohibited during the closed period.

Very, Moderately, and Least Effective

After developing the options shown in table 6, the group began to sort and group them into the three general categories of very, moderately, and least effective for Sylvan Pass, provided below. The group then focused its discussions and GAR evaluations on those methods deemed to be very and moderately effective, but returned to some of the methods initially thought to be least effective later in the process. As part of this discussion the panel also worked to compare and contrast effectiveness of measures on Sylvan Pass versus Talus Slope (see the *Talus Slope Comparisons* section below).

Very Effective

- Total closure
- Tunnel/snowshed
- Re-route main road; discarded because there is no viable alternate route.
- Snow fencing (support structures in start zone)

Moderately Effective

- All other closures (Window Closure, Closure with Helicopter, Backcountry Standards, and Full Forecasting)
- Helicopter
- Artillery
- Fixed gas system—Gazex/Avalhex
- Hand charges
- Pre-placed explosive charges; discarded due to public safety hazards
- Avalguard
- Trolleys

Least Effective

- Berms, Deflectors, and Catchment basins
- Snow sails
- Avalauncher/LOCAT
- Heli Avalhex; discarded because this system seemed to be little different from helicopter-dropped explosives and has not been tried in the U.S.

Of special note, the panel significantly changed this initial categorization of effectiveness during the final day of the review, when they were asked to rate numerically the effectiveness of the options (see risk vs. gain scores, Appendix B). One potential reason for this change is that the panel better understood the current operation and resources as it relates to the specific demands of Sylvan Pass (refer to Appendix B, Risk vs. Gain data, for final group concurrence on effectiveness).

Unique or Notable Qualities of Sylvan Pass

It was important for everyone to know the specific attributes of Sylvan Pass so that: a) all potential hazards could be identified, b) panelists all had a better understanding of how individual options could be applied, and c) they could all better compare Sylvan Pass to other road corridor areas that require avalanche control work. The panel identified the following unique or notable qualities of Sylvan Pass.

Table 7: Unique/Notable Qualities of Sylvan Pass

Notable Quality	Notes/comments from Panelists (including direct, unattributed quotes)
Access	Howitzer cannot be moved from current location without sacrificing its ability to reach all avalanche start zones.
Vulnerability to the platform	Cornices, rockfall, and natural hazards can all affect the platform.
"Long return" avalanche could roar down targeted avalanche paths on south face of Hoyt Peak	These are extremely large avalanches with the potential to sweep part way up the opposite slope.
Cold climate—extreme arctic conditions	Wind, very low temperatures, and other climactic conditions make Sylvan a challenging place to work.
Start zones within proposed or recommended or existing Wilderness	This situation may not be all that unique—e.g., Glacier National Park, Cascade National Park, Mt. Rainer, and Little Cottonwood Canyon, among other locations, have this quality.
Start zones are similar in aspect, slope and elevation. Spatially too, results of avalanches are similar and contained.	Note that the egress to the gun mount is different. This area of start zones constitutes a "nice little scary, but contained, package…"
Doing avalanche control for recreational use	Sylvan is the only discretionary travel corridor known to this panel where explosives are used for avalanche control. It is neither a highway open for interstate commerce (such as an interstate highway like Snoqualmie Pass in Washington or Teton Pass in Wyoming) nor a busy railroad corridor (such as Marias Pass in Montana). Nor is it a ski area. Rather, it is a road corridor open only for recreational use.
Uniquely controversial	The context for winter use decision making is controversial with litigation, "the world's first National Park," intensely interested gateway communities, and so on.
Intermittent control—"where else do we have rangers doing this kind of avalanche control?"	With regard to avalanche risk, NPS's full attention is not there, and consistent attention is not possible. This situation is not up to "industry practices."
Type of traffic	Skiers, oversnow vehicle, or bicycles would be in potential slide path longer than vehicles in other controlled corridors.
Guided situation	NPS has the opportunity to use commercial guides to help decrease the risk with respect to hazard. NPS can use its entrance stations to give education and information materials to visitors to help. NPS also has control over administrative travel.
Availability of others—contingency resources	Distance, availability, and mode of travel for these are different than they are for other controlled corridors.
Logistics are unique: timing, distance, our targets change, and we have to maintain with a groomer. We also have to heat the barrel on	NPS must get to the fixed mount gun with OSV (snowmobiles only)—a unique situation that is also slower and less environmentally friendly. Rangers have a 20 mile distance to travel—Sylvan is remote. Also, the groomer takes 3 hours to get there while others heat the barrel.

the howitzer.	
Federal Highway Administration says Sylvan is unique with its unconsolidated material	Sylvan Pass has "no bedrock, the mountain is moving…" This condition may limit any option that requires permanent foundations.
Interaction of excessive number of unexploded ordnances in the vicinity with mudflow	Group's note to itself: duds will show up as hazard, but the additional situation of unconsolidated material makes it notable here.
Wind	Sylvan Pass has lots of wind loading. NPS staff have to use precision targeting with its explosives.
Unique Equipment	Regarding the howitzer, NPS has a 102 (Vietnam era howitzers that are less reliable in cold weather conditions; in cold weather use, the barrel of this model must be preheated); everyone else has 101's (Korean era howitzers that are older but more reliable in cold weather conditions and which have a wider turning radius).
Proximity of road to slope	East Entrance Road is directly below slope of descent. There is no room to relocate road within corridor to avoid this.
Angle of fire—projectile	It is very difficult to precision hit extreme sides of avalanche slopes, so the effectiveness of "hit or impact" decreases. Also, the howitzer cannot be moved from its current location without sacrificing its ability to reach all avalanche zones.

Talus Slope Comparisons

The Talus Slope is an area on Yellowstone's South Entrance Road that may, under rare circumstances, experience avalanche activity. After the group identified unique or notable qualities about Sylvan Pass, several qualities of Talus slope were noted for comparison and contrast to Sylvan Pass. The list of such qualities follows Figure 3, which has comparative photographs of the two areas.

Figure 3: Comparison Photographs of Talus Slope (left) and Sylvan Pass (right). Note that photos are at different scales; heights of the trees in the photographs may be used for general scale.

Abbreviated comments from panel discussion include:

- There are big “magnitude and duration” differences between Sylvan and Talus.
- Talus has about a 3-400 hundred foot run on it and is not extremely wind loaded (as Sylvan is).
- There is standard deposition at Talus (unlike the loose, unconsolidated material on Sylvan).
- Big boulder fields provide good anchor points on Talus.
- Talus was subjected to 1988 fires, with a substantial growth of “doghair” lodgepole in fetch area that prevents wind transport, inhibiting the likelihood of a slide.
- Slides hit the road below Talus maybe once every 10 or 15 years, leaving only about 2 feet of snow on the road. You’d have to be lying down to get covered, or have a heavy pack on and fall.
- There is never a day in the winter the Talus slope is not ski-able (this could be one good way to control it).
- Talus is a non-issue based on its history and size.
- Talus is a place where if you put up a traffic sign that says, “no stopping,” that would be good enough.
- Berms and catchment basins that were seen as least effective on Sylvan may be most effective on Talus.
- Forecasting is so much more effective for Talus because the physical attributes are so different and the magnitude of the events so much less at Talus.
- The complexity of Sylvan is huge next to Talus (which is not complex).
- On Sylvan, avalanche hazard usually begins in November where on Talus there may not be hazard until January or even no hazard the entire season (depending in part on snowfall).

Hazards

The group then identified hazards associated with access to the Sylvan Pass staging area, as well as those related to avalanche mitigation-related tasks; these hazards are listed in Table 8 below. The panel noted there are hazards associated with the 20-mile approach by snowmobile to the avalanche zones from Lake, and the approximately 6-mile approach from the east side to “Brown Drifts” (a local name for the point about 6 miles west of the East Entrance, at the edge of the Sylvan Pass avalanche zone), so there are hazards getting to the site and other hazards once there.

Table 8. Hazards Associated with Site Access*

Category/Type of Hazard	Notes/Comments from Panelists**
Snowmobile accident	Ergonomics of driving snowmobile is hazardous. Cold, injuries, driving off the road or other accident.
Collision	Hit stationary object or wildlife.
Ungroomed road	
Stuck snowmobile	
Visibility	
Extreme conditions	Potential for slough to come down on road.
Mechanical failure	There is a hazard of exposure to weather when you get a failure.
Places where there is no guard rail coming from east side	More of a hazard coming from east side.
Low staffing, dark	Staffing comes from Lake at 7 a.m., but staff coming from East Entrance cannot leave until daylight (about 7 a.m.). Now there are no groomers up there at night. By the time road groomer works to Pahaska Teepee, avalanche staff are returning under the slide paths at dark. East road guard people check the pass every day prior to opening. A team of two travels up from East (last year one came from East, one from Lake) and they would pass below the paths. Seventeen employees have been killed in history of Yellowstone Park, more than a handful in the winter. There are also about six property damage or personal injury accidents with snowmobiles a year. Snowmobiling is inherently unsafe. We chose in the 1960s to do it, now we're trying to make it work.

* While such risks are present in oversnow vehicle travel elsewhere in Yellowstone, the largely recreational or discretionary nature of such travel (whether administrative or visitor) means that these access risks do not have to be present in such travel. By contrast, the non-discretionary nature of travel to Sylvan Pass for avalanche control makes these risks unavoidable and therefore cumulative to the other risks unique to Sylvan Pass avalanche control.
** These are comments, notes, and paraphrases from the panelists themselves.

Because of the significant hazards associated with just accessing the staging area of Sylvan Pass, the panel decided that "access" should be considered its own independent activity. Therefore, it was evaluated independently through the GAR model. There is further discussion of "access" later in this report.

GAR Scores

Next, the group individually scored, discussed, and assessed each of the options identified in Table 6 in turn. The raw scores off these worksheets are compiled for reference in Appendix A of this report. Each panelist had his (all were men) own worksheet to score the eight operational components on the GAR (the eight categories of potential risk presented in Table 4 and discussed thereafter). Also, Chart 2 compiles the average scores for each option.

Severity Probability Exposure Assessment

The group then applied the severity, probability and exposure (SPE) model (see the Severity, Probability, Exposure Model section above) to a few of the options as examples. Using worksheets, they individually

assessed the SPE for the options that have been used most recently (use of the helicopter and howitzer), as well as conducting an SPE as a comparison between Talus Slope and Sylvan Pass. Results are presented in the Severity, Probability, Exposure Comparison section below.

Quantifying "Factual" Gain

At the end of Day 3, the group built a matrix to jointly assess factual gains, which are quantifiable benefits derived from implementation of an alternative. For this exercise the group of experts invited the observers to participate in the discussion of the rating scales and the four primary measures of gain that can be quantitatively rated: 1) Effectiveness of the option to meet the objective of "avoiding negative human/snow contact," 2) Amount of time Sylvan Pass remains open, 3) Amount of impact to surrounding environment, and 4) the general cost of implementing option. The group gave a numeric score (0 to 6) to these consequences or outcomes of each option. The four factual gain scores for each option were then summed to produce an overall factual gain score. This information can then be compared to risk profile scores as a way to begin assessing the risk vs. gain ratio of each option. See Appendix B for a compilation of the factual gain scores.

Final Group Discussion

The workshop concluded with a review and discussion of the raw data and those findings easily identified. Some inconsistencies were noted (and discussed later in this report) but the panel generally felt that the assessments appeared accurate and realistic. Notable points shared by the panelists include the understandings that a weather station would lower risk, as would forecasting, an adequate number of dedicated personnel to the mission, and local knowledge/experience. Before turning to these results (in Section IV, Risk Model Findings, starting on the next page) it is useful to mention three other subjects discussed by the panel.

Spring Snow Conditions

Forecasting is more difficult with wet slabs (which occur mainly in spring conditions), altering the effectiveness of any option. This weakness is important when considering options that either do or do not include other active mitigation methods (i.e. artillery, fixed gas, etc.) or options that require clearing Sylvan Pass by a fixed date in the spring.

Weakening of a loaded snow slab is very poorly understood, even by the avalanche control community. The implications are significant and not intuitive when assessing risk in avalanche control activities. All active mitigation methods are much less effective in wet slab situations. Forecasting when wet snow conditions exist is more difficult, and hazards are more likely to change day to day and even hour to hour due to temperatures, exposure, moisture content, etc. Adding the difficulties of forecasting to the expected timelines of opening the pass compounds the chance of potential avalanche accidents.

The panel generally thought that opening and closing the pass with only forecasting as a tool was hazardous unless done extremely conservatively, in part due to the difficulty of predicting spring snow conditions. Those same conditions would also make repetitive openings and closings likely at that time of year.

Comparisons with Past Risk Assessment

In 2006, NPS staff in Yellowstone conducted a risk assessment using a private sector model with 11 people providing input. When asked to compare that assessment to the one discussed in this report, panelists noted the following:

- Some were surprised that the 2007 results are not a little more similar to those of the earlier assessment. Some felt this difference was because they went deeper in this assessment; there is no doubt they analyzed significantly more mitigation strategies. Conversely, they considered property damage in 2006 and not this time.
- Last time they focused on employee safety, and this time they looked at safety of both employees and visitors.
- Environmental protection was considered more in 2006.
- The first assessment used a 25 year time frame while this assessment considered the risk for one operational period.

Selected Parting Comments

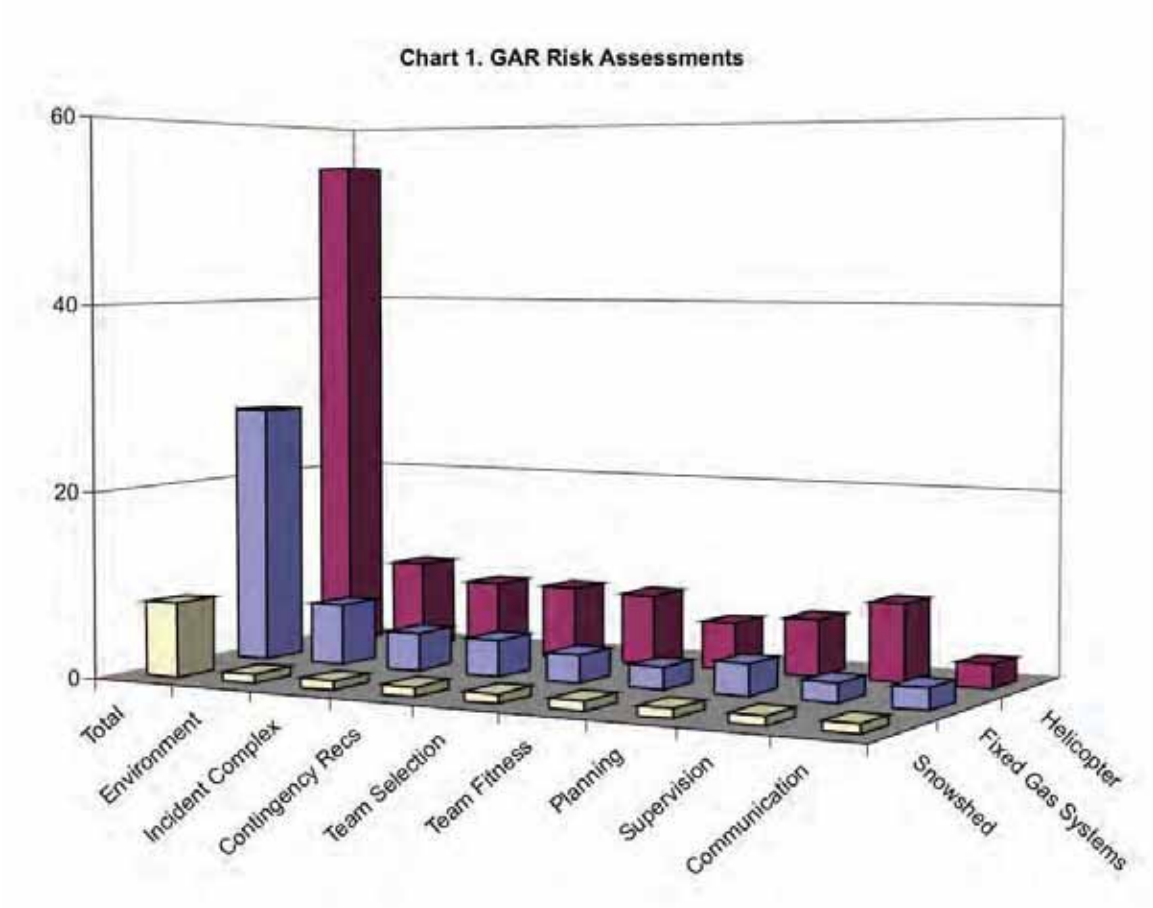
Below are responses to one of the four evaluation questions posed to workshop participants and observers. In response to the question "what was most useful to you in this process?", participants gave the following responses, a mix of both support and caution:

- "The entire session was very useful in observing the interactions and input into going through the ORMA process."
- "The positive, professional give and take among the panel members and the respectful participation of the observers resulted in really good information."
- "Participation by operational personnel, especially Lake District Ranger and Maintenance Foreman."
- "Opportunity for dialogue; relationship building."
- "The exposure to this method of evaluating risk was very useful to me. Also very useful to me was the opportunity to participate in this very important process."
- "The ORM appears to be an excellent tool to characterize risk. Its strength appears to be as a living document that can manage risk associated with specific tasks. I am not sure of the validity of this application with respect to the selection of management alternatives for Sylvan Pass. The results of this work could be taken out of context or misapplied."

IV. Risk Model Findings

Individual GAR Assessments

Following (Chart 1) are the GAR assessments (Green-Amber-Red; see the section of the same name above) for a passive mitigation option (snow shed), the most recent mitigation option (use of contract helicopter), and an active automated option (fixed gas system) (three examples chosen to illustrate the breadth of potential findings). The chart illustrates how different activities affect risk profiles. As indicated, the helicopter option has a higher risk profile across all components than the other two options, due primarily to human presence at the pass during avalanche hazard mitigation (fixed gas systems can be remotely activated, such as from Lake Village). Appendix A shows all the rating summaries for all of the options considered by the expert panel.



Other points of interest, discussed more in detail below, include:

- All operational components known to affect risk to personnel under each option were assessed and combined for a total risk score, given on the far left for each of the three options. It is this total score that represents the option's total risk score, or GAR risk assessment.
- Employee and public risk are both considered in the assessment.

GAR Assessment Discussion

Each of the risk categories (the operational components shown on the X axis above, such as environment, incident complex, etc.) is known to influence the overall risk of an operation. Some components (such as team selection and fitness) can be changed by NPS personnel where others may depend on the situation. For example, *Planning* may or may not be sufficient for an incident depending upon whether the incident is emergent (occurring at the moment) or not. If the incident is recurring and static, pre-planning may suffice.

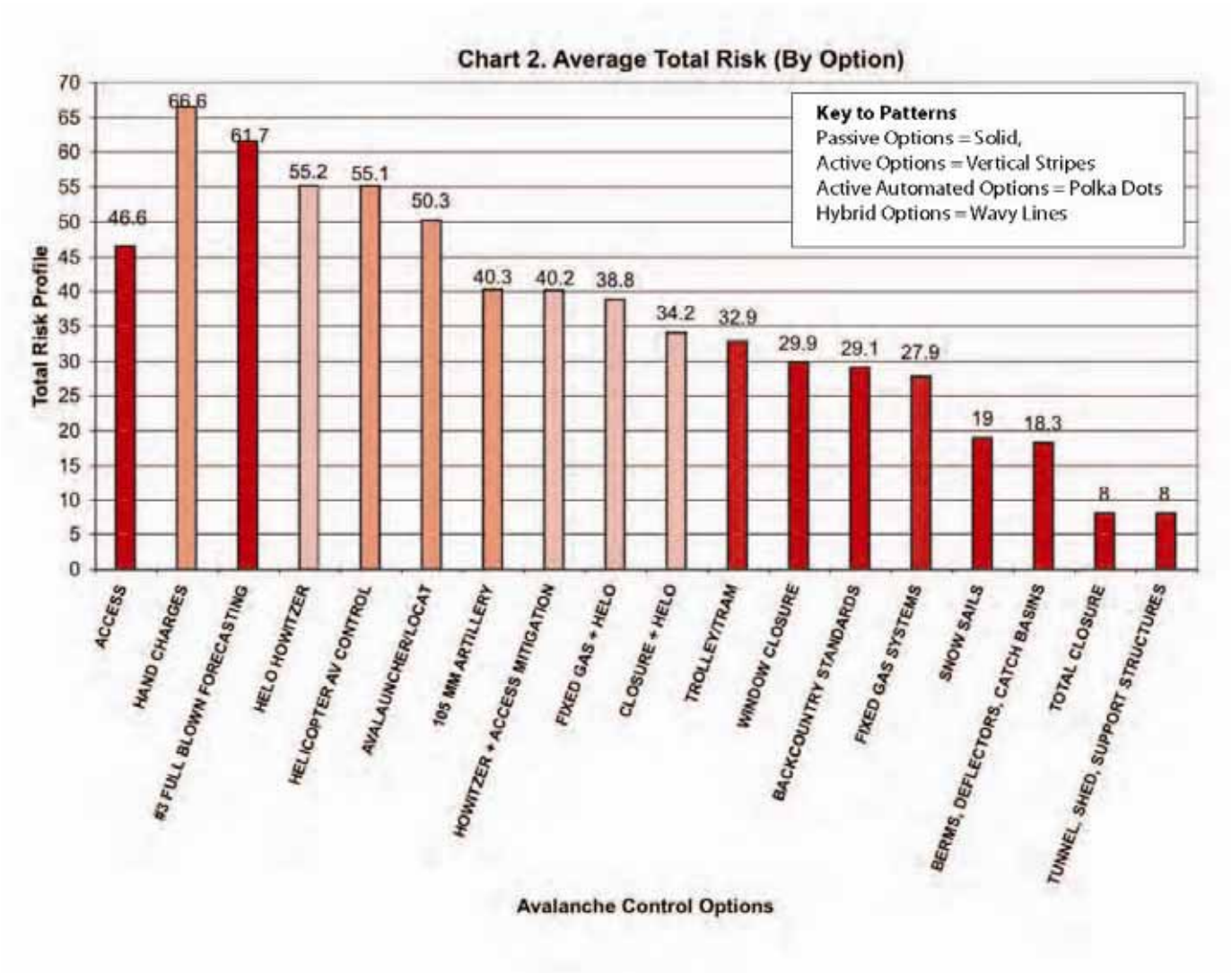
The relationship between components is important to understand. While many activities may be inherently hazardous with several moderately rated components, one component rating especially low may keep the activity within an acceptable risk level. In that situation, the total risk profile is dependent on a single element and could be considered fragile (where this single element affects the overall activity risk disproportionately). A better scenario is an activity that has more equal levels of risk and remains acceptable since it is an inherently more stable (less fragile, more balanced) profile. In the unbalanced

example, conditions only have to change the risk level of the single vulnerable component to alter the risk profile of the entire activity.

Conversely, recognizing an activity where one or two operational components rate high is also important as it represents a potential to lower an overall risk profile by making only a few changes to the operation.

GAR Risk Profiles Compared

Chart 2 below illustrates total risk scores (GAR scores) for all avalanche control options discussed in the workshop.



Other points of interest include (and are discussed in more detail below):

- *Access* is considered its own activity and receives its own risk score due to its own inherent hazards.
- The risk exposure of *Access* must be considered along with that of those activities that require personnel to travel to the pass.

- With some exceptions, risk increases consistently from passive to active automated to active mitigation techniques. Exceptions to the above include the use of *Full Forecasting* and to some degree *Backcountry Standards* and *Window Closure.*
- There are some inconsistencies, discussed below.

Risk Profile Discussion

To obtain the summary values for each option in Table 6 and Chart 2, the subject matter experts rated the risk inherent within each operational component (i.e. each risk category, such as supervision, planning, etc.). They were asked to assume programmatic conditions, that is, average or typical conditions; for example, that staff members responsible for avalanche control would be operating in typical weather with normal communication and normal park operations. By contrast, the typical ORM process, when assessing a single operational mission just prior to its start, rates components as they are at that moment so that the team can apply guidelines and mandates on what actions need to occur based on that particular mission's risk profile.

In so doing, the panel noted a seeming inconsistency (mentioned above), which is that the use of *howitzer* and *howitzer with access mitigation* risk profiles did not change; they were nearly identical. One would expect that mitigation of the access risks would remove some risk from the overall howitzer operations. It is doubtful that the panel misunderstood what activities the typical mission involved; rather, the intrinsic risks of using the artillery likely overshadow the recognized risk of accessing the platform.

Access (referring to the travel from the Ranger Station or East Entrance to the staging area on Sylvan Pass) is identified as being an independent hazardous activity. This is relevant because access to the staging area is required for many of the mitigation options and so increases the overall risk profile of those options (including *Full Forecasting, Helicopter, Trolleys, Hand Charges, Artillery, Avalauncher/LOCAT,* and all of the hybrid combinations) beyond their rated risk levels. In other words, all options that require travel to Sylvan Pass effectively have a minimum risk level of 46.6—the rating for *Access* alone—because *Access* has its own, non-discretionary risks. *Access* does not comprise the only risk, however; each option has other, separate and identified, risks.

Access has an elevated risk profile compared to typical oversnow vehicle travel in Yellowstone due to the non-discretionary nature of this travel to determine on-site conditions (it must be done or the pass is not opened for the day), Sylvan Pass's severe environment, the lack of contingency resources available, the general remoteness and difficulty marshalling assistance, and low supervision. Other factors that differentiate this activity from other winter motorized travel include a potential sense of urgency in such travel, decreased flexibility in planning (given its non-discretionary nature), and higher potential for poor weather conditions when combined with some mitigation options.

Some passive mitigation options such as *Tunnels, Snow-sheds, Start Zone Structures,* and *Full Closure* have consistently low risk profiles because of their high effectiveness of eliminating avalanche/human contact with little or no need to use personnel. The more an activity exposes personnel and introduces human error into an operation, the higher its risk profile. The use of *Sails* and *Berms* also show low risk profiles; however, they were assessed by the group later as likely to have poor effectiveness in controlling avalanches at Sylvan.

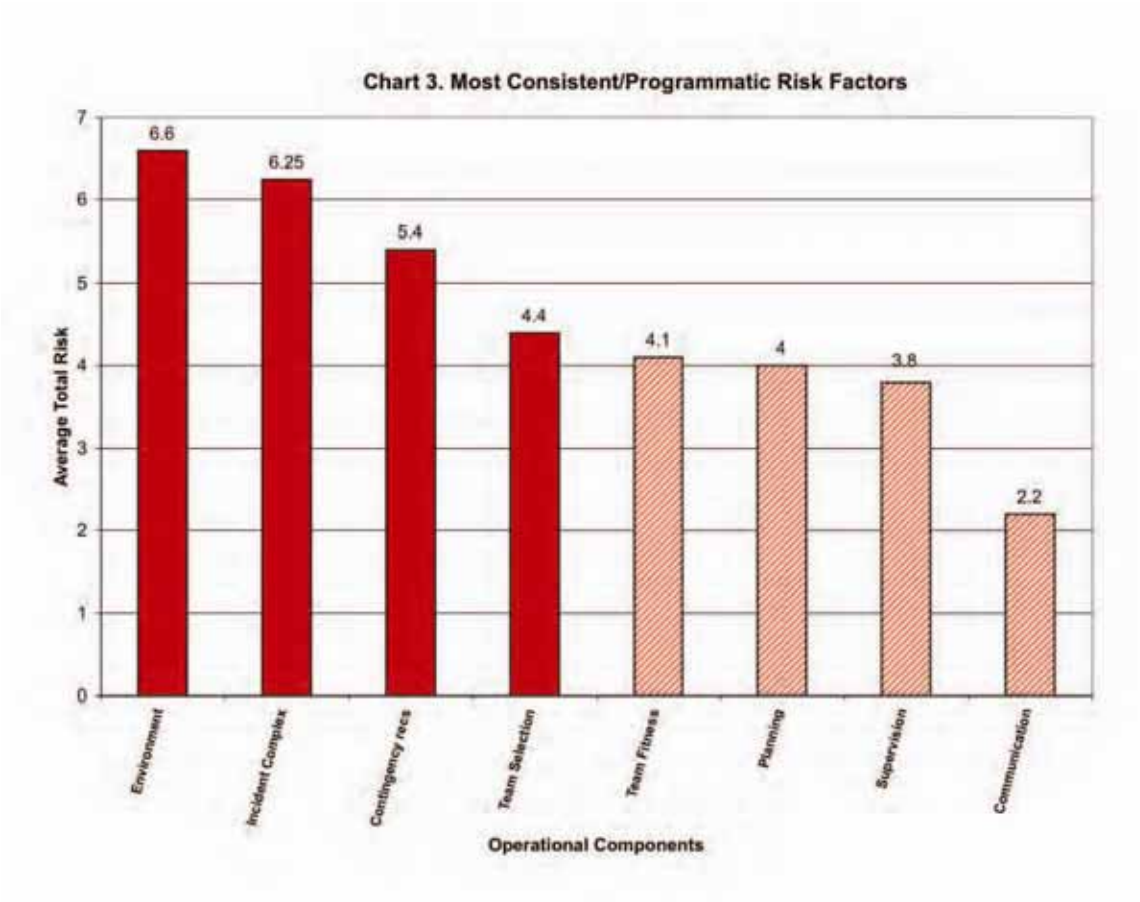
Most of the risk associated with *Backcountry Standards* and *Window Closure* represent potential hazards to the public (as opposed to hazards to park employees) because a) *Backcountry Standards* warn the public of avalanche hazards but allows full access in any conditions, and b) with *Window Closure* there is the potential for having to re-close and open the pass in spring due to unexpected late season storms and

the extra uncertainty that exists with spring snow and wet slab conditions, increasing the odds of human error.

Full Forecasting is the highest rated (i.e. highest risk) passive option due to the difficulty in forecasting without additional tools and the inability to "move snow" with other mitigation tools under that option. With current resources and without other active techniques, predicting when to open and close Sylvan Pass is difficult and potentially inaccurate. This difficulty increases the odds of having unexpected natural release avalanches involving staff and/or public. This limitation is represented in the high ratings of incident complexity, environment, and team components for that option. It was also noted that this option might be the most susceptible to the negative influences of external pressures to "forecast" Sylvan Pass as safe to keep it open.

GAR Operational Component Scores Compared

Chart 3 below illustrates how operational components affect risk profiles consistently and programmatically, as averaged across all options. Note that environment averaged 6.6, making it the most significant contributor of risk to all options. By contrast, communication averaged only 2.2, meaning that communication is ordinarily the strongest operational component and provides the largest measure of safety.



Other points of interest include (and are discussed in more detail below):

- Environmental Factors, Incident Complexity, and Contingency Resources consistently rate high.
- Communication consistently rates low.
- There are some inconsistencies when compared between option categories and personnel influences (passive, active, active automated, and hybrids).
- When considering strategies to lower risk profiles, these three trends should be considered.

GAR Operational Component Score Discussion

The environmental factors that affect personnel performance (and equipment) are significant in almost all options. These hazards include extreme temperatures, wind, elevation, precipitation, navigational hazards, and vertical exposure. It is impossible to eliminate all of these hazards, but NPS has attempted to mitigate them by installing a warming hut at the artillery platform (pursuant to OSHA's recommendation and requirement). The panel noted that team selection and team fitness currently offsets some of these hazards because the current team happens to be exceptionally experienced as well as acclimatized to the weather conditions, but that will change over time as staff experiences turnover.

The complexity of Sylvan Pass avalanche control work increases the likelihood of accidents. The complexity of actual work (including forecasting), constantly changing conditions, and typical length of exposure are all prominent factors. This complexity and inherent risk is reflected in the overall profile of *Full Closure* as compared to the profiles for *Avalauncher/LOCAT, Hand Charges,* and *Hybrid Helicopter/Artillery,* as shown in Chart 2. The latter three have substantially higher overall risk profiles largely due to the higher complexity they entail as compared to *Full Closure*. Such complexity is often intrinsic to tasks and environments but can be managed by improved planning (contingency) and communication (better information) as well as increased staffing.

Contingency Resources risk components score high in all non-passive options. One factor that substantially contributes to this high hazard is the distance from the nearest resources to Sylvan Pass (approximately 20 miles from Lake to the initial avalanche paths, approximately 6 miles from the East Entrance to "Brown Drifts," and approximately 60 miles from Sylvan Pass to Cody, the location of the nearest hospital or outside respondent) and consequently the amount of time it takes resources to respond. A second complicating factor is hazardous emergency transit, as resources would have to contend with the same *Access* issues in addition to possibly being cut off by existing avalanche paths. Still another factor that contributes is the availability of staff; scheduling, weather, and other normal operational logistics mean that there are not always adequate staff available. There is no system in place to ensure that resources exist where they would be expected, which further compounds the problem. When utilizing a helicopter, the Contingency Resources component is again compounded due to the fact that a helicopter travels not only over roads, but also over backcountry areas and extreme terrain; should the helicopter have trouble, emergency response times could be substantial.

Communication is a single component that is low in all options. Good radio infrastructure, ability to work face to face, and some structured established commands (as in *artillery*) facilitate operational communication. Because communication is consistently low it represents in some options the only component that offers any margin of error. (Options with helicopter use appear to depend on good communication to lower an already moderate risk profile).

One relative inconsistency in these profiles, and thus a caution, is the overall mid to low rating of team fitness and team selection. Considering that most control options (especially active options) require up to three personnel and that the total available pool of qualified personnel is only four, it seems that these logistical restraints should have more of an impact to operations. The applied risk may be "captured"

elsewhere in the panel's assessments but it should be noted that the operational categories of team fitness/selection are other potential areas for improvement.

These findings are useful to consider when managing risk in an operation. Programmatic mitigation strategies that could potentially apply to several options include 1) use of different vehicles to provide environmental protection during access, 2) Use of control tactics that limit exposure to environment, 3) Use of localized weather/forecasting data to improve quality of information, 4) Dedicated forecasters to increase accuracy and decrease complexity, 5) Use of additional staff in operation for purpose of increasing contingency options, and 6) Use of engineering to eliminate human risk and error.

Sylvan Pass: Talus Slope SPE Comparison

As a way to quantify the differences in avalanche control risks on Sylvan Pass and Talus Slope, the panel conducted a SPE assessment on both locations. The panel was asked to assess the SPE components for both sites in the context of what they thought could occur over a five-year period. Considerations include historical knowledge, visitation or traffic patterns, and the unique qualities of both slopes and their specific hazards. Panelists rated severity on a scale of 1 to 5 (5 being worst), probability on the same scale, and exposure on a scale of 1 to 4 (4 being worst) and multiplied the ratings to achieve an overall score. The panel was also asked to consider risks to employees and visitors.

The assessments were consistent in recognizing a higher risk at Sylvan (Rating of 20.3) than at Talus (Rating of 2.1). Of the three components, Severity consistently rated higher at Sylvan (all panelists rated the maximum score of 5) compared to Talus (average score of 1). Panelists assessed the probability of a negative event occurring nearly twice as high at Sylvan than at Talus (average 2.9 vs. 1.5). Of special note all panelists assessed exposure (including amount of time, number of people involved, repetitions) average or below average for both Sylvan and Talus.

Risk vs. (Factual) Gain Analysis

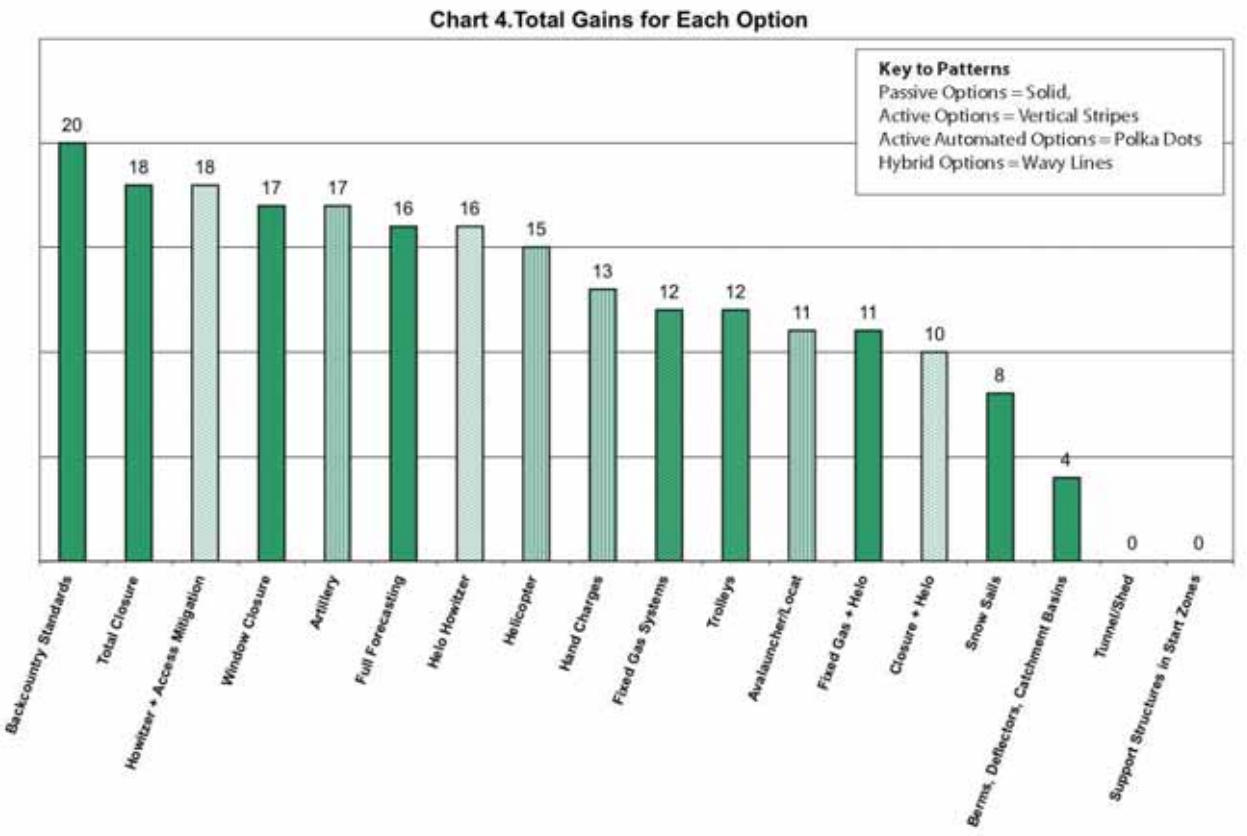
Assessing risk vs. gain is an important part of risk management and one of the primary principles of the ORM process. Individual missions identify gain as a single mission objective, while programmatic gain (gain for the whole program of avalanche risk reduction, whatever that may be) is measured in several areas considered to be *Universal Risk Considerations* (discussed previously), of which only some are based in fact. The expertise contained in the working panel could only evaluate those potential gains related to the avalanche control options that were quantifiable (based on facts), as opposed to those potential gains based on organizational values (i.e. if the organization places a higher intrinsic value on fiscal resources, the "cost" component of measured gain would change the overall gain profile). The primary consideration for this assessment is the safety of personnel; therefore, the risk (measured and quantified by the GAR risk profile score—so a high score = high risk) should be compared to the overall gains. The factual gains assessed include:

- **Effectiveness**. An assessment of how well the avalanche control option performs its objective of eliminating negative avalanche/people contact (high score = highly effective).
- **Pass Access**. An assessment of how well the avalanche control option keeps Sylvan Pass open to human travel, whether motorized or non-. A numeric score of 2 is equivalent to 18 days open (only). Only days between December 15th and March 15th were considered (high score = fewer closures).
- **Natural Resource avoidance**. An assessment of how well the avalanche control option avoids structures and other impacts to the designated or recommended wilderness surrounding Sylvan

pass (high score = low impact). Such resources as wildlife, vegetation, soils, sound, and T&E Species were implicit in this category.

- **Cost**. An assessment of how much the avalanche option would cost to implement. The cost estimates included only the one-time, up-front costs of implementing an option. They are not intended to be construction estimates, nor do they include an operational component (either an increase or a decrease in operating costs). However, they especially help inform the discussion as to the relative cost of each option. In addition, the cost estimates are not amortized over time, nor do they include the annual cost of maintaining the option. Therefore, with an option like snowsheds, which may have a very long service life, the cost can be amortized over decades, and the annual maintenance needs may be low (at least initially). Thus the annual costs, spread over 50 years, of a snowshed may also be lower than some of the other options. Note that the group used a general scale dividing the range of costs from $100 million to $0. Tunnel, snow-sheds and starting zone structures costs were out of scale (over $100 million) and noted (high score = low cost). Note too that cost information was not provided to panelists until the last day, to enable consideration of all options without regard to their costs.

Chart 4 illustrates the panel's quantification of gain from highest to lowest. Values are the sum of the gain factors in Table B-1, and are a measure of the overall factual gain (organizational values are not included) of implementing each option. Gain values were derived in a manner similar to that for risk values as explained above, except that the lowest value for gains was 0 instead of 1. This does not mean that gains are worth less than risk; rather, the comparison between the gain values for the various options is the important consideration here.



Other points to consider (and discussed in greater detail below) include:

- It is important to consider ratios of gain.
- Organizational Values and Universal Risk Considerations must both be applied or considered.
- How would these "gains" change with operational changes implemented to decrease risk?

Discussion of Total Gains

Tunnels and support structures possess the highest percentage of gain *except* for "cost" which is nearly ten times as much as the next highest option (fixed gas). For consistency the gain is considered zero for these options.

There was no attempt to apply values, either personal or organizational, to this risk vs. gain assessment. The ratings given to each of these "factual" categories was based on technical and objective information.

Chart 4 only shows the total factual gain measures for each mitigation option and is valuable for seeing trends in options (ratios of gain components—the individual values for risk, effectiveness, access, and natural resource avoidance that sum to the total factual gain measure—are illustrated in Chart 5 below). Unlike the risk profile data, the relationship between passive, active automated, and active avalanche control options does not exist, confirming that even without organizational values attached to factual gains, some option categories do not provide viable solutions.

As the gain scores are based solely on operational facts, it may be important to place organizational values on each of the "gain" categories to further measure the benefits. For example, NPS has professed a commitment to employee and visitor safety, so those options that have the highest "effectiveness" gains would receive greater consideration by the agency—but those gains must be weighed against both access risks and the risks of the avalanche control option(s).

The Universal Risk Considerations of fiscal resource impacts and mission success are represented by quantifying Cost, Pass Access, Effectiveness, and Natural Resource Avoidance in this assessment; these gains are included in the gain measurements in Chart 4. Other universal risk considerations (whether potential gains or liabilities) are not; for example, the considerations of morale, adverse or positive publicity, and administrative and/or disciplinary impacts could not be evaluated by this work group (because these are outside the scope of this group of experts).

This assessment is a static snapshot of these avalanche control options with current and available resources. If operational changes (assuming improvements) were made, the ratio of gain to risk could also improve. For example, *Full Forecasting*, *Window Closure*, *Backcountry Standards*, and *Hybrid Closure with Helicopter* are options in which, if changes were implemented to lower the total risk profile, those changes would also increase factual gain measurements (in effectiveness and pass access). However, in most situations, as operational mitigation changes are made, gain measurements drop. For example, it is not uncommon for a mitigation to involve a new expense, which then lowers the financial gain. Similarly, a common mitigation is to add staff, but this measure increases exposure.

The elements of Chart 5 illustrate the relationship and ratio of risk vs. gain within individual avalanche control options. They are a visual illustration of the information in Appendix A and Appendix B. The risk pie chart captures the average total risk profile and the contribution (in percent) of each element to the overall risk. For example, the 105 mm artillery has a average total risk profile of 40.3 (see Appendix A), and the "environment" element contributes 22% to the total. Similarly, the gain pie chart shows the total

gain (17 for the 105 mm artillery from Appendix B) and the contribution of the different gain factors. As an example, effectiveness contributes 29% of the gain for the 105 mm artillery.

The bar charts allow the reader to get a snapshot of risk versus gain. The risk bar chart puts use of the 105 mm artillery into relative comparison to the option with the highest risk profile (hand charges, which were assigned a score of 100). Use of the 105 mm artillery would score about a 60 (on the 100 scale). Similarly for gain, the bar chart shows the gain from use of the 105 mm artillery as compared to the option with the highest gain (backcountry). Thus the 105 mm artillery has a gain of about 80 as compared to the 100 for backcountry.

Chart 5: Risk vs. Gain Ratios of most avalanche control options identified in Table 6.

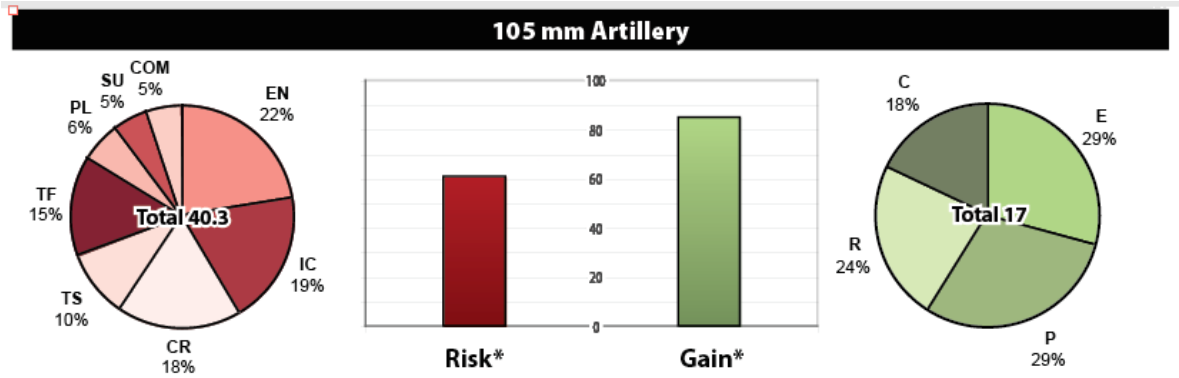
KEY TO ABBREVIATIONS

EN	Environment	**TF**	Team Fitness
IC	Incident Complex	**PL**	Planning
CR	Contingency Recs	**SU**	Supervision
TS	Team Selection	**COM**	Communication

KEY

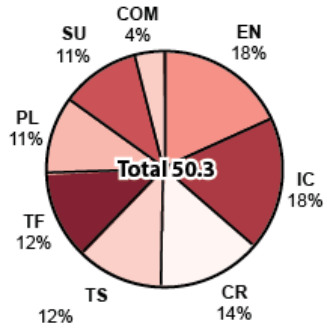
E	Effectiveness
P	Pass
R	Resources
C	Cost

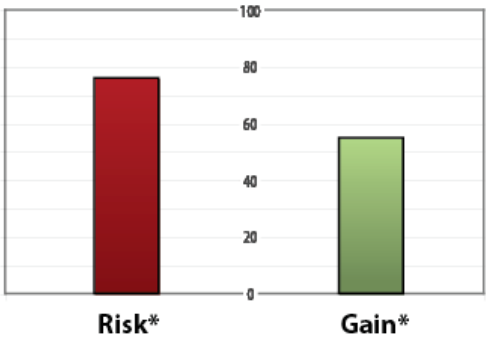
* The options with the highest Risk and highest Gain are calibrated as equal to 100. Thus Hand Charges Risk = 100 and Backcountry Gain = 100. All other options correspond to these calibrations.

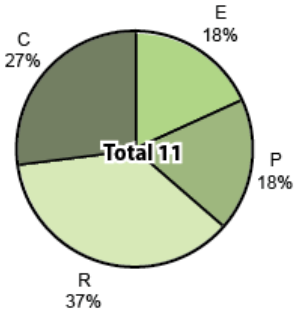


Note: since this review, the cost for this option was estimated at $150,000, not the $250,000 that panelists understood would be the cost. Therefore, if the panel were to reevaluate the gains for this option, the cost would be less and the gains possibly greater.

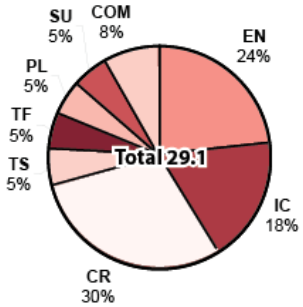
Avalauncher/Locat

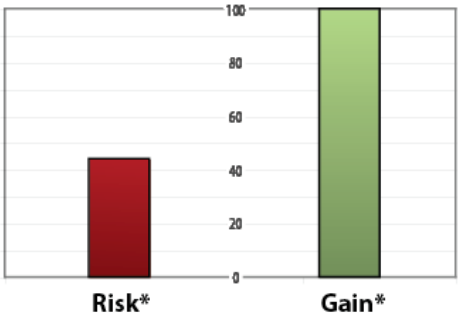


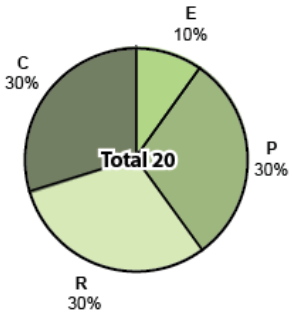




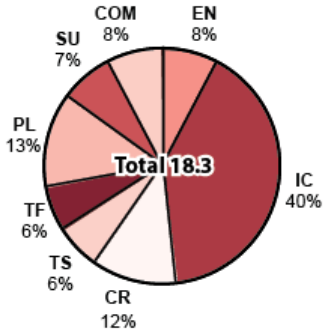
Backcountry Standards

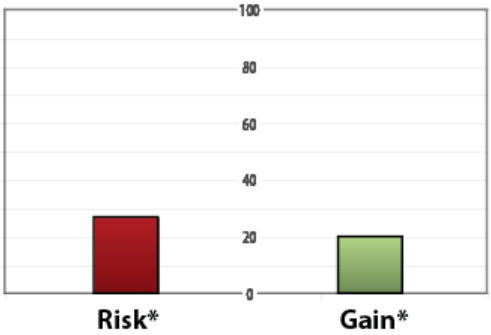


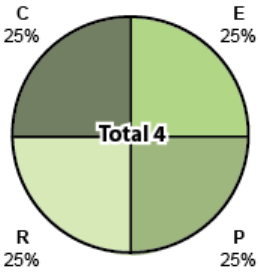




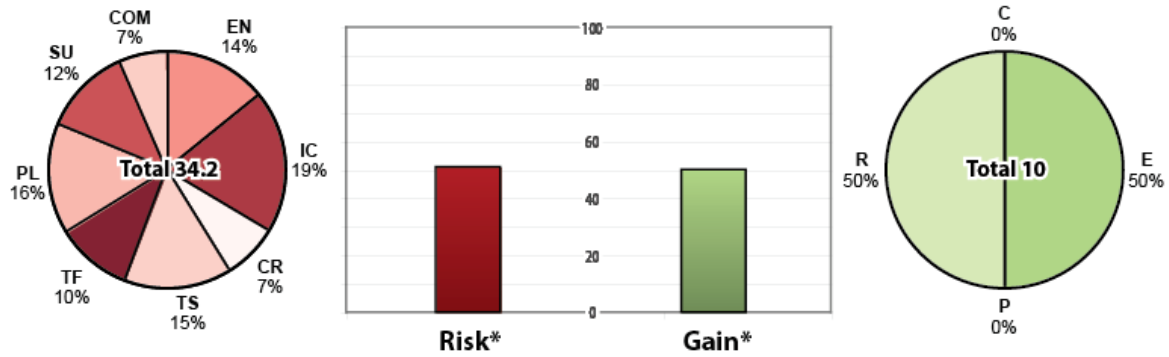
Berms, Deflectors, Catchment Basins



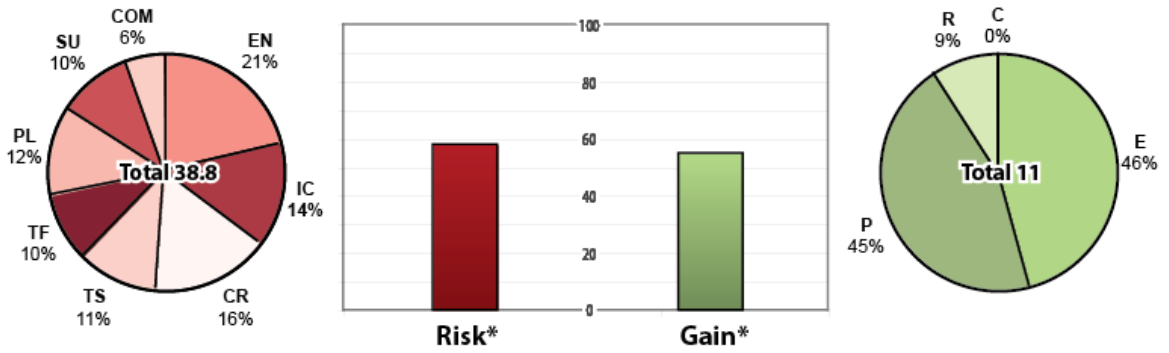




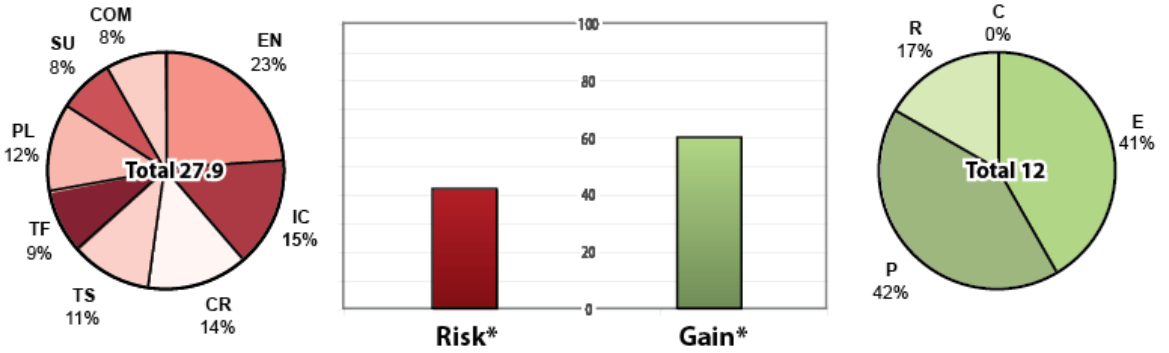
Closure + Helo



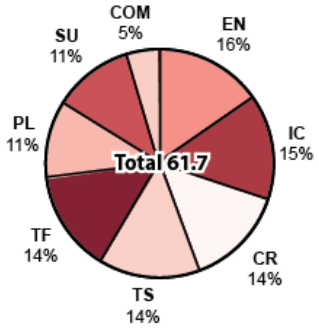
Fixed Gas + Helo

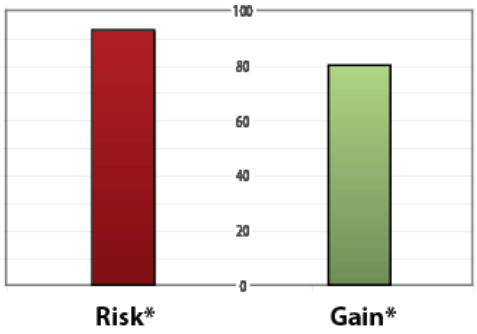


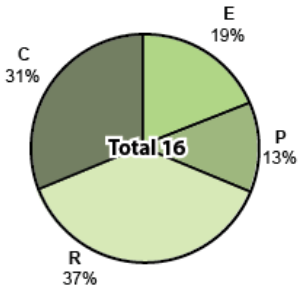
Fixed Gas Systems



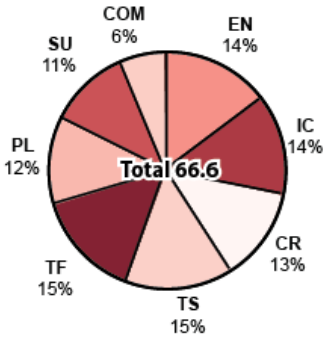
Full Forecasting

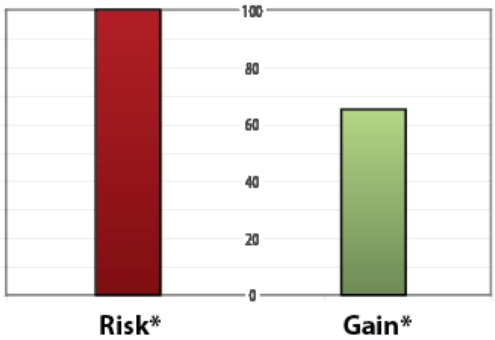


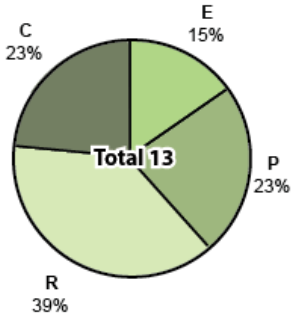




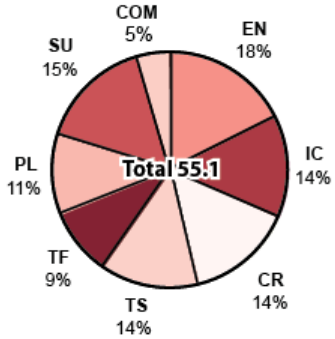
Hand Charges

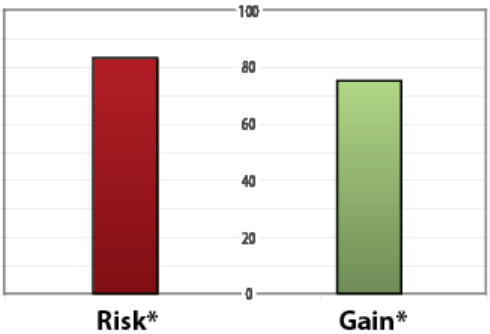


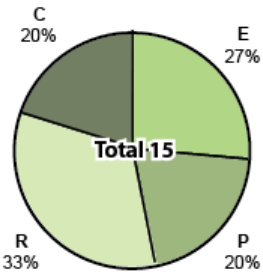




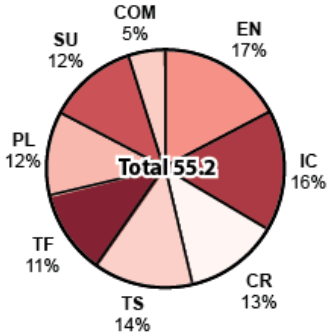
Helicopter

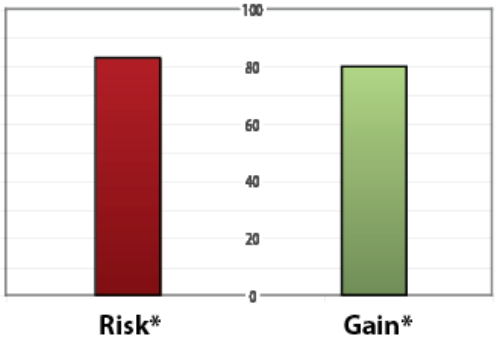


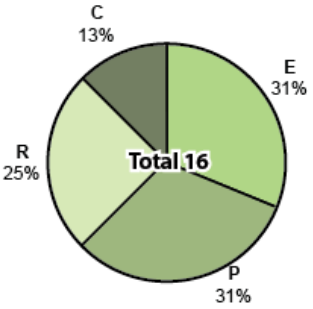




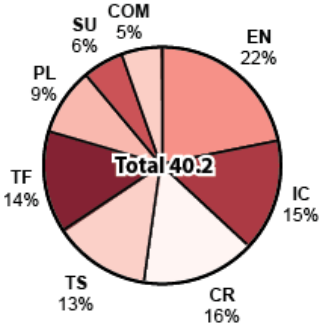
Helo Howitzer

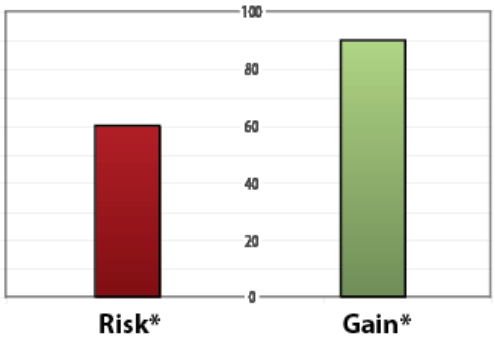


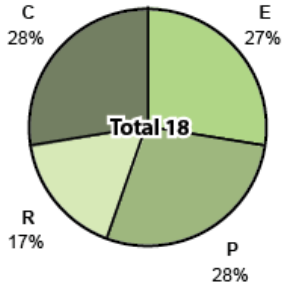




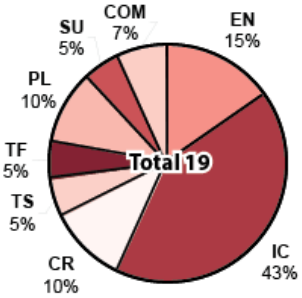
Howitzer + Access Mitigation

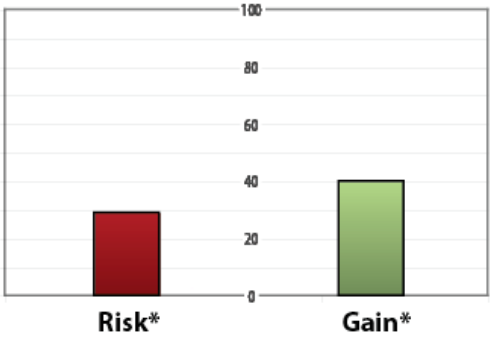


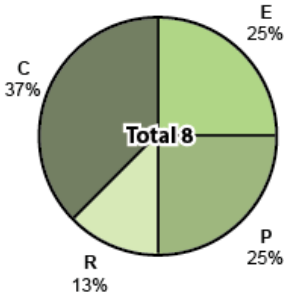




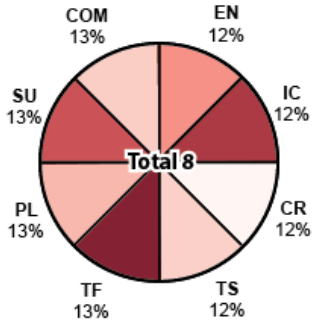
Snow Sails

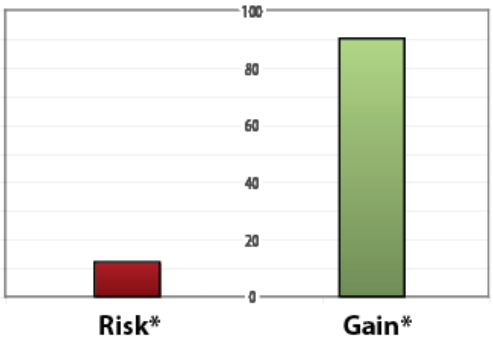


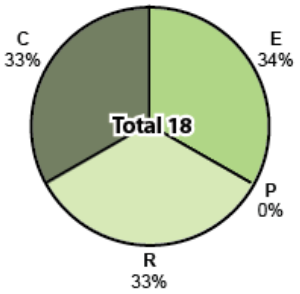




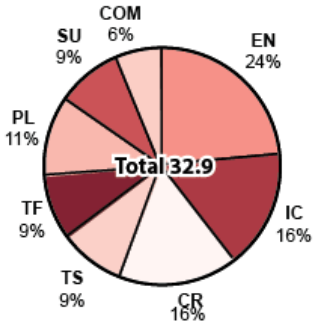
Total Closure

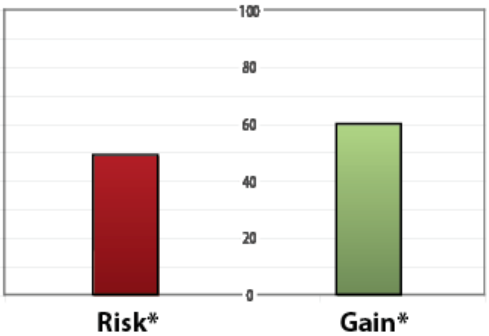


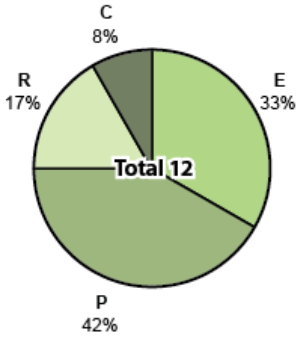




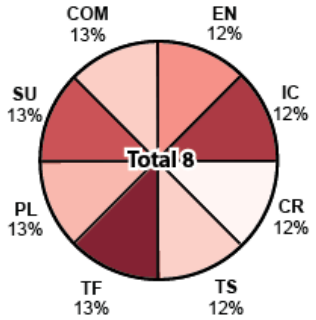
Trolley/Tram

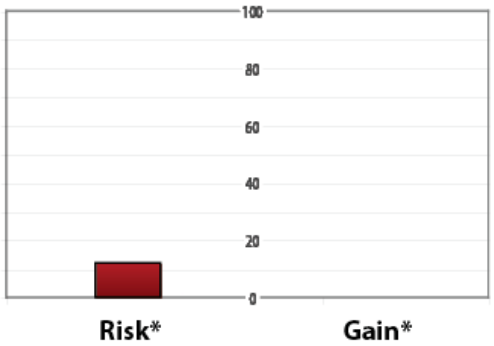


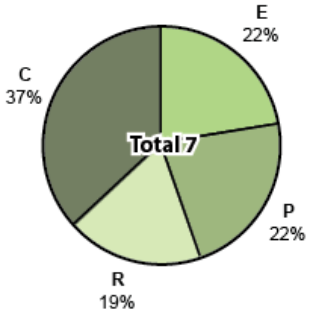




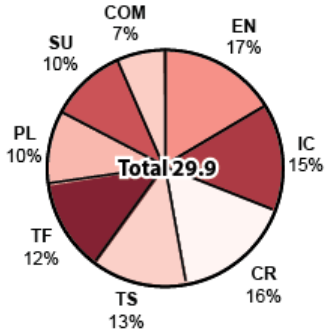
Tunnel/Shed

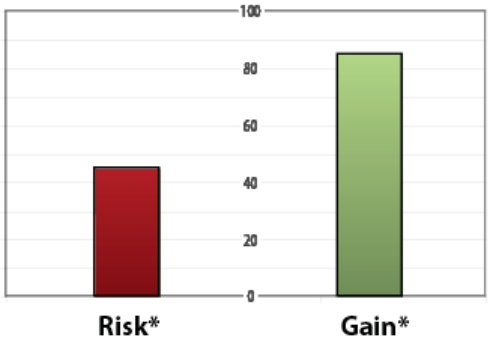


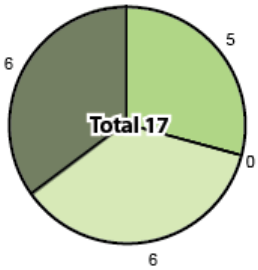




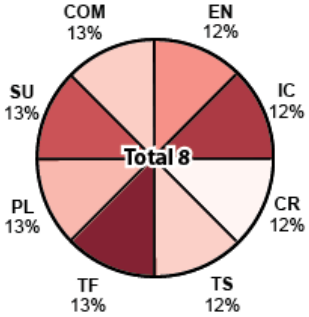
Window Closure

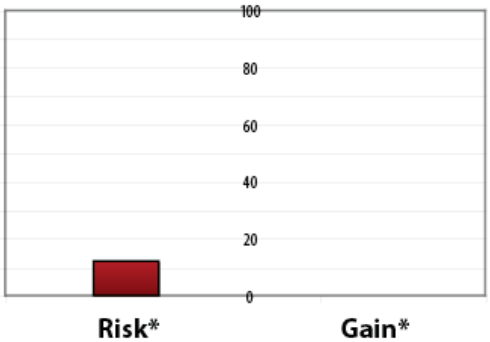


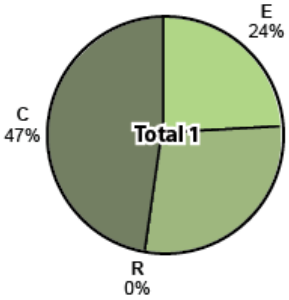




Support Structures in Start Zone







KEY TO ABBREVIATIONS

EN	Environment	**TF**	Team Fitness
IC	Incident Complex	**PL**	Planning
CR	Contingency Recs	**SU**	Supervision
TS	Team Selection	**COM**	Communication

KEY

E	Effectiveness
P	Pass
R	Resources
C	Cost

* The options with the highest Risk and highest Gain are calibrated as equal to 100. Thus Hand Charges Risk = 100 and Backcountry Gain = 100. All other options correspond to these calibrations.

Other points to consider include (these are discussed in more detail below):

- Consider which components of both risk and gain make up the total profile as compared to each other.
- Consider which risk components can be mitigated and which gain components carry more value (however, gain value should not drive risk acceptance).
- Review consistent and programmatic operational components and identify where these influence profile ratios (Environmental Factors, Incident Complexity, and Contingency Resources).

Discussion of Risk vs. Gain Ratios

The ideal ratio of risk to gain is a low risk/high gain model. As the data in this report are based on current operations, one has to look further inside each score to consider operational improvements.

If the organization can place more value on any of the gain components, that potential change should be noted as it affects total ratio (i.e. if cost has a high organizational value, an increase in gain ratio should be expressed for those options showing a larger cost component (lower cost, as defined above)). Conversely, gain should not drive the risk (i.e. if cost is a high organizational value, changes should not be made to strengthen the cost-gain component as it will negatively affect risk).

In reviewing what operational components present consistently high risk in a program, one should first identify which ratios can most easily be improved. For example, if Environmental Factors, Incident Complexity, and Contingency Resources components were improved throughout the operation (lowering the risk profile across most options), more viable options may be available.

V. Continuing the Process: Considerations in Using this Assessment

The primary objective of this assessment is to provide an accurate and general measurement of the risk contained in both current and potential Sylvan Pass avalanche control operations. To meet this objective several models have been used to study the intrinsic risk. This report describes and illustrates:

- Those factors specific to Sylvan Pass that provide hazards and affect risk to personnel.
- Those hazards specific to all Sylvan Pass winter road corridor operations.
- Those operational components that affect risk to personnel in avalanche control activities.
- A measurement of personnel risk involved in past Sylvan Pass operations.
- A measurement of personnel risk involved in current Sylvan Pass operations.
- A measurement of risk to personnel involved in other potential avalanche control options.
- A comparison of risk measurements of combined avalanche control options.
- Risk trends in individual avalanche control options.
- Programmatic risk trends found in most control options.
- A measurement of factual gains directly related to each avalanche control option.

- A ratio measurement of risk vs. gain for each avalanche control option.

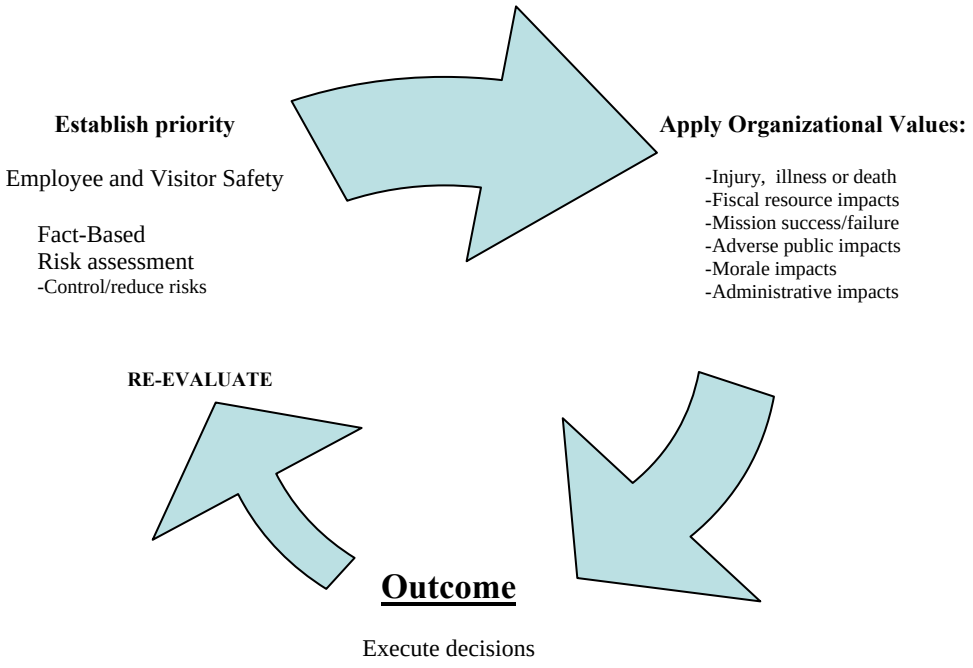
A weakness of this report is that it cannot provide an exact and precise assessment of any one single mission. All of the operational components can change from day to day, depending on which individuals are on duty, weather conditions that day, and many other dynamic factors. The principles and models used for this assessment can and should be used prior to personnel leaving their duty station en route to perform avalanche control on Sylvan Pass. It is only by doing so that a precise risk profile can be established for any one mission.

Another weakness of this report is that of evaluating potential operations in whose technical aspects the panel had expert knowledge but not experiential knowledge of how those aspects would specifically apply to Sylvan Pass and the work group that would conduct the operations. Some assumptions had to be made by the panel in quantifying those operational components.

This report also offers risk mitigation models as well as some suggestions that can apply to many of the avalanche control options. There are improvements that can be made to lower risk profiles for some of the options, improvements that will also affect risk vs. gain ratios. What the report leaves to the reader and ultimately the Sylvan Pass operational staff are the assessments of operational risk after (potential) mitigations techniques have been implemented. As the decision to lower risk and by which mitigation techniques is an organizational one (based on value factors), this report and the panel that participated can only articulate that these options exist and should be considered. The assessments reported give an accurate representation of risk profiles for each control option and will accurately lead the reader to those options that can gain from operational changes.

Continued Process: Applying Values and Priorities

When assessing operational components and applying numeric scores, there is limited opportunity to apply subjective reasoning. As experts in avalanche control and Sylvan Pass operations, the panel was asked to base their assessments on what was realistic and based on fact. The next step in applying the operational risk management process is for management to apply organizational or agency values.



It should be common for an organization's priority to be its employees' safety but it is rare for it to be the *only* priority. Other considerations that also contain risk must be assessed, often times with values attached. Financial risks, local and long-term repercussions to the organization's mission, external opinion and relationships, and internal staffing concerns all possess different ratios of risk and gain.

Sample Decision Trees

The following tables (9, 10, and 11) are decision trees that display different ways of using the information from the Operational Risk Assessment. First, those options that are below a certain risk profile number are included. For illustration purposes, the risk profile of 36 was chosen based on the quantity and severity of hazards involved in the options that fell above and below that risk profile level. This professional judgment also accounts for the amount of mitigation techniques available within each option. The options that fall at or below a 36 score recognize that there are some risks but that none of the GAR elements are unacceptable, or they are appropriately addressed. Considering only those options with a risk profile less than 36 is consistent with the scale in Table 3, where a score of 35 separates green options from amber.

In Table 9, only those options with a risk profile less than 36 were considered (those appearing in the first column on the left). This, the first priority, is personnel safety. Then the effectiveness of the options was considered (second priority and second column from left). Only those with a perceived effectiveness on the upper half of the scale were considered. Those options that were less effective received a "NA" (not acceptable). As third priority (third column from left), the cost of implementing the options was considered; only those options whose cost was on the lower half of the scale were considered. The result

is that only total closure, backcountry standards, window closures, and closures with helicopters utilized for spring opening were viable (and are shown in the last column, that on the far right).

In Table 10, the same risk profile (36) was used, but second priority was the amount of time Sylvan Pass would be open and the third priority was effectiveness. The results indicate that tunnel/snowsheds, support structures in start zones, backcountry standards, fixed gas system, and trolleys were the viable options.

In Table 11, a higher personnel risk profile of 47 was assumed for illustration purposes, as was a fourth criterion. This does not mean that 47 is a safe operational risk profile. Park management must determine what an acceptable risk profile is for this or any operation. As noted earlier in the report in the discussion of Table 3 (GAR scale), different organizations have different levels of acceptable risk. If a higher risk profile is assumed and an open pass, effectiveness, and resource impacts (as the fourth priority) are considered, then Table 11 indicates tunnel/showshed, backcountry standards, and artillery are viable options. Again, this is not intended to imply that use of artillery is acceptable to park management or that the risks can be mitigated reasonably.

What is most illustrative of the viable options among the three decision trees is that only backcountry standards remains consistent in all three. No other options are viable across all different considerations.

Table 9. Control Options with < 36 Total Risk Profile, Effectiveness

Options	Effectiveness > ½ scale	Cost > ½ scale	Viable Options
Total closure	Total closure	Total Closure	Total Closure
Tunnel/snowshed	Tunnel/snowshed	NA	
Support in start zones	Support in start zones	NA	
Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards
Window closure	Window closure	Window closure	Window closure
Fixed gas system	Fixed gas system	NA	
Trolleys	Trolleys	NA	
Berms/deflectors/basins	NA	NA	
Snow sails	NA	NA	
Closure w/ helo. to open	Closure w/ helo.	Closure w/ helo.	Closure w/ helo.

Table 10. Control Options with < 36 Total Risk Profile, Open Pass

Options	Open Pass > ½ scale	Effectiveness>½ scale	Viable Options
Total closure	NA	Total Closure	
Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed
Support Structures in start zones	Support Structures in start zones	Support Structures in start zones	Support Structures in start zones
Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards
Window closure	NA	Window closure	
Fixed gas system	Fixed gas system	Fixed gas system	Fixed gas system
Trolleys	Trolleys	Trolleys	Trolleys
Berms/deflectors/basins	NA	NA	
Snow sails	NA	NA	
Closure w/ helo. to open	NA	Closure w/ helo. to open	

If an organization is willing to accept a higher risk profile (either with the assumption that it can mitigate some of the inherent risk or that the potential gain makes the additional risk worthwhile) while adding a fourth priority of resource impact, it has more initial options, as shown in Table 11.

Table 11. Control Options with < 47 Total Risk Profile, 4 Priority Model

Option	Open Pass	Effectiveness	Res. impact>½ scale	Viable Options
Total closure	NA	NA	Total Closure	
Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed
Support in start zones	Support in start zones	Support in start zones	NA	
Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards
Window Closure	NA	Window Closure	Window Closure	
Fixed gas system	Fixed gas system	Fixed gas system	NA	
Trolleys	Trolleys	Trolleys	NA	
Berms/deflectors/basins	NA	NA	NA	
Snow sails	NA	NA	NA	
Closure w/ helo. to open	NA	Closure w/ helo. to open	Closure w/ helo. to open	
Artillery	Artillery	Artillery	Artillery	Artillery
Artillery + Access mit.	Artillery + Access mit.	Artillery + Access mit.	NA	
Fixed Gas + helo	Fixed Gas + helo	Fixed Gas + helo	NA	

As an organization better understands what hazards and risks threaten an operation, new options become viable and other options become unacceptable. These decision trees, when used with the organization's other risk considerations and the associated values, are useful in designing durable operations and unassailable decisions. The final step is an ongoing commitment to re-assess and re-evaluate, always beginning first with those risks that affect personnel safety.

Reducing the Risk on Sylvan Pass

When faced with managing a hazardous operation, an organization can choose to spread out, share, trade, accept, or reduce the risk. The identified risk involved with the Sylvan Pass avalanche control operation cannot be spread out as the weather and environment dictate frequency and volume of work. The ability to share or trade the risk involved is limited secondary to the management responsibilities of the NPS. Therefore, with the first three options effectively eliminated, the NPS is left with either accepting or reducing the risk. Prior to accepting any of the inherent risk of Sylvan Pass avalanche control, the NPS should make efforts to reduce the risk and hazard exposure to the field personnel performing the task.

The four basic steps of risk reduction or mitigation include:

1) Identify operational components that can or should be improved
2) Identify hazards associated with components
3) Identify actions to take (in order of and per mitigation methods, specified below) to decrease hazards
4) Implement and supervise.

The first two steps of mitigating risk as it relates to the utilization of artillery to perform avalanche risk reduction at Sylvan Pass are outlined below. Each step gives examples of content but is not absolute in identifying hazards or mitigation options.

Step 1: Operational Components to Improve	***Step 2: Associated Hazards (examples)***
Environment	exposure to weather, snowmobile accidents, exposure to avalanche/rock fall, etc.
Incident Complexity	increased exposure to all environmental factors, human errors related to multiple steps of firing howitzer.
Contingency Resources	incapacitated solo employee, 45 minute to hour + response time, unavailable/unscheduled help, nearest assistance required to pass under avalanche/rockfall.

Moving to the third step, the five common methods of mitigating risk, in declining order of effectiveness, are:

- Avoidance- Not engaging in the activity, as it is unnecessary or the risk outweighs the gain.
- Substitution- Choosing another method (presumably lower in risk) to achieve the same or similar outcome.
- Engineering- Changing the condition of the operation, typically through physical alterations/additions that eliminate human performance factors.
- Policy/Procedure- Changing the behavior of personnel and the process used to complete a task through internal policy and guidelines.

- Personal Protection- Using personal protective equipment (PPE) to lessen the negative outcome of exposure to a hazard.

With operational components and hazards of the Sylvan Pass howitzer operation identified, the next step in mitigating those hazards is to identify actions to take in that direction. Although this workshop identified some such options, it did not prioritize them. Table 12 below illustrates one such POSSIBLE prioritizing; it is NOT the outcome of this workshop and should not be construed as a recommendation. Rather, it is intended to illustrate what the next possible step of risk reduction at Sylvan Pass COULD look like.

Table 12. Potential actions to mitigate hazards of howitzer operation at Sylvan Pass. Note that this table is not the outcome of this workshop but rather one possible example of how the workshop's process can be continued to reduce the hazards of this operation.

Hazards	Avoid	Substitute	Engineer	Policy	P.P.E.
Exposure to weather, severe and arctic conditions	No	Other options	Use of snowcoach	Parameters on what weather conditions warrant a "no go"	Environmental specific clothing
Snowmobile accidents	No	Use of snowcoach or safer vehicle	Speed governor, better groomed access, etc.	Parameters on operation, increased supervision	Helmets, snowmobile clothing and padding
Exposure to avalanche/rock fall, crossing 6 to 8 avalanche slopes to access platform, rock fall behind platform.	No- unable to change route	Other options	Use of automated system for access to platform, bunker/barrier behind platform site, etc.	Parameters on "no go" conditions based on forecasting	Use of transceivers, other avalanche tech., helmets, etc.
Increased exposure to environmental factors (time)	No	Other options	Automate all forecasting, use of different gun that has fewer steps, increased staffing to simplify	Parameters on what weather conditions warrant a "no go"	Environmental specific clothing
Human error accidents	No	Other options	Use of different gun, increased staffing	Parameters on what weather conditions warrant a "no go"	Environmental specific clothing
Incapacitated solo employee	Yes, see policy	Other options	Automated sensors, GPS technology, PLBs, etc.	Prohibit solo missions	Use of safer vehicle, environmental specific clothing
Long response time/unavailable or unscheduled help	Yes	No	Automated closures	Require minimum personnel, involve contingency resources in planning, weather based guidelines, EMS training requirement	Environmental specific clothing, warming hut
Hazardous approach for contingency resources	Yes	No	Use of other options	Require approach only from west side	Environmental specific clothing

VI. Conclusions

None of the avalanche control options identified in this workshop are without risk. Even those options with the lowest risk profile to personnel have significant impacts to NPS resources. Also, as with any field operation, the corollary requirements reach far into other park operations, affecting them in differing ways. Regardless of which option the NPS determines to be the best solution, there will be impacts, not evaluated in this report, to other work groups, including those responsible for snow grooming, road maintenance, facility management, emergency services, concessions, and park management.

As there appears to be no simple solution to reducing avalanche risk at Sylvan Pass, it is extremely important to consider the common themes that this workshop and consequent report have identified.

1) **Sylvan Pass is unique.** Geographic, logistical, atmospheric, and managerial issues that are specific to Sylvan Pass significantly affect the risk profiles and overall effectiveness associated with mitigation options. These qualities must be considered when deliberating avalanche control options. Solutions to Sylvan Pass' avalanche hazards cannot be viewed in the same manner as they would be on other travel corridors**.**

2) **There are elements in the NPS Sylvan Pass operation that positively and negatively affect the safety of our employees and visitors.** It is important to understand all of these elements as they relate to current operations and potential future operations rather than relying on common knowledge of what has worked in the past. Safety records do not speak for themselves and there are other factors specific to the NPS that are not evaluated in this report but that do affect personnel safety.

3) **All risk involved in avalanche control on Sylvan Pass can be mitigated, but some mitigations may not be reasonable.** The options identified in this report, ranging from passive options such as closure or snowsheds to active options such as howitzer control or fixed gas systems, can reduce the avalanche hazards at Sylvan Pass. What this report does not assess is the feasibility of implementing these control options or mitigation techniques. Again, the exceptional nature of Sylvan Pass requires further research as well as management input to truly establish whether any of the identified options are achievable.

4) **This assessment is a process.** If this assessment is of any value in making operational decisions, it is urged, even assumed, that this process, now that it has been started, will be continued. This assessment has focused almost exclusively on facts related to employee and visitor safety. The report outlines the next steps: attaching additional (but lesser) priorities and values in reaching an outcome.

Appendix A

Risk Model Data

Table A-1. Risk Model Data

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
ACCESS								
Supervision	8	7	7	7	7	5	8	7
Planning	4	3	4	6	5	6	6	4.857142857
Contingency Recs	7	3	8	6	8	9	8	7
Communication	2	2	2	2	2	2	2	2
Team Selection	8	3	8	5	6	7	8	6.428571429
Team Fitness	4	5	5	3	3	9	4	4.714285714
Environment	9	10	8	8	8	8	10	8.714285714
Incident Complex	4	3	6	6	4	8	10	5.857142857
Total	46	36	48	43	43	54	56	46.57142857
HELICOPTER AV CONTROL								
Supervision	9	7	9	9	9	8	8	8.428571429
Planning	7	4	7	8	7	3	7	6.142857143
Contingency Recs	7	5	9	8	9	8	9	7.857142857
Communication	2	3	2	3	3	2	3	2.571428571
Team Selection	8	5	8	9	8	6	9	7.571428571
Team Fitness	7	4	8	5	6	3	3	5.142857143
Environment	10	10	9	9	9	10	10	9.571428571
Incident Complex	8	4	9	8	8	8	10	7.857142857
Total	58	42	61	59	59	48	59	55.14285714
FIXED GAS SYSTEMS								
Supervision	2	2	2	2	2	3	2	2.142857143
Planning	2	4	2	6	4	4	2	3.428571429

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Contingency Recs	3	3	4	3	3	4	7	3.857142857
Communication	2	2	2	2	2	3	3	2.285714286
Team Selection	3	3	3	3	2	4	3	3
Team Fitness	2	2	2	3	2	3	3	2.428571429
Environment	8	10	3	5	7	3	10	6.571428571
Incident Complex	5	3	3	5	6	3	4	4.142857143
Total	27	29	21	29	28	27	34	27.85714286
TROLLEY/TRAM								
Supervision	3	2	2	2	2	6	3	2.857142857
Planning	3	4	3	4	4	6	2	3.714285714
Contingency Recs	4	3	4	4	7	7	9	5.428571429
Communication	2	2	2	2	2	2	3	2.142857143
Team Selection	3	3	3	2	3	3	3	2.857142857
Team Fitness	2	2	3	2	3	5	3	2.857142857
Environment	9	10	4	7	7	7	10	7.714285714
Incident Complex	7	5	5	5	5	3	7	5.285714286
Total	33	31	26	28	33	39	40	32.85714286
HAND CHARGES								
Supervision	8	7	7	7	7	8	8	7.428571429
Planning	9	7	8	7	8	8	9	8
Contingency Recs	8	8	8	9	8	9	9	8.428571429
Communication	4	3	4	3	4	7	5	4.285714286
Team Selection	10	10	10	8	10	10	10	9.714285714
Team Fitness	10	10	10	9	10	10	10	9.857142857

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Environment	10	10	9	10	9	10	10	9.714285714
Incident Complex	9	8	9	10	9	9	10	9.142857143
Total	68	63	65	63	65	71	71	66.57142857
FULL BLOWN FORECASTING								
Supervision	8	5	8	9	8	6	6	7.142857143
Planning	8	8	8	9	7	6	2	6.857142857
Contingency Recs	8	8	8	10	9	8	9	8.571428571
Communication	3	3	4	2	2	3	3	2.857142857
Team Selection	9	8	9	8	10	9	9	8.857142857
Team Fitness	9	8	9	8	10	8	9	8.714285714
Environment	9	10	8	10	9	10	10	9.428571429
Incident Complex	8	10	9	10	9	10	9	9.285714286
Total	62	60	63	66	64	60	57	61.71428571
BACKCOUNTRY STANDARDS								
Supervision	1	2	2	2	1	2	1	1.571428571
Planning	1	2	2	1	1	2	1	1.428571429
Contingency Recs	9	9	5	8	10	10	9	8.571428571
Communication	2	3	2	2	4	2	2	2.428571429
Team Selection	2	2	1	2	2	1	1	1.571428571
Team Fitness	2	2	1	2	2	1	1	1.571428571
Environment	9	10	5	8	8	2	5	6.714285714
Incident Complex	5	4	9	2	10	2	5	5.285714286
Total	31	34	27	27	38	22	25	29.14285714

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
TOTAL CLOSURE								
Supervision	1	1	1	1	1	1	1	1
Planning	1	1	1	1	1	1	1	1
Contingency Recs	1	1	1	1	1	1	1	1
Communication	1	1	1	1	1	1	1	1
Team Selection	1	1	1	1	1	1	1	1
Team Fitness	1	1	1	1	1	1	1	1
Environment	1	1	1	1	1	1	1	1
Incident Complex	1	1	1	1	1	1	1	1
Total	8	8	8	8	8	8	8	8
WINDOW CLOSURE								
Supervision	2	3	3	2	2	7	3	3.142857143
Planning	2	4	3	2	2	7	2	3.142857143
Contingency Recs	5	3	4	2	4	6	9	4.714285714
Communication	2	3	2	2	1	2	2	2
Team Selection	2	4	3	4	5	7	2	3.857142857
Team Fitness	2	4	3	2	5	8	2	3.714285714
Environment	5	6	3	2	6	5	7	4.857142857
Incident Complex	7	3	5	4	4	4	4	4.428571429
Total	27	30	26	20	29	46	31	29.85714286
105 MM ARTILLERY								
Supervision	2	2	2	2	2	2	2	2
Planning	2	4	3	2	2	2	2	2.428571429
Contingency Recs	7	4	7	8	7	9	9	7.285714286

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Communication	2	2	2	2	2	2	3	2.142857143
Team Selection	4	3	2	7	2	4	5	3.857142857
Team Fitness	7	6	8	7	3	5	5	5.857142857
Environment	10	10	9	10	8	6	10	9
Incident Complex	9	6	7	9	8	6	9	7.714285714
Total	43	37	40	47	34	36	45	40.28571429
BERMS, DEFLECTORS, CATCH BASINS								
Supervision	1	1	1	1	1	3	1	1.285714286
Planning	1	1	1	6	5	2	1	2.428571429
Contingency Recs	1	1	1	6	3	2	1	2.142857143
Communication	1	3	1	1	1	2	1	1.428571429
Team Selection	1	1	1	1	1	2	1	1.142857143
Team Fitness	1	1	1	1	1	2	1	1.142857143
Environment	1	1	1	1	2	3	1	1.428571429
Incident Complex	9	8	9	10	5	3	7	7.285714286
Total	16	17	16	27	19	19	14	18.28571429
SNOW SAILS								
Supervision	1	1	1	1	1	1	1	1
Planning	1	1	1	6	2	1	1	1.857142857
Contingency Recs	1	1	1	8	1	1	1	2
Communication	1	3	1	1	1	1	1	1.285714286
Team Selection	1	1	1	1	1	1	1	1
Team Fitness	1	1	1	1	1	1	1	1
Environment	1	1	1	10	5	1	1	2.857142857

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Incident Complex	9	8	9	10	6	7	7	8
Total	16	17	16	38	18	14	14	19
AVALAUNCHER/LOCAT								
Supervision	7	2	7	6	6	8	2	5.428571429
Planning	3	4	5	9	7	8	2	5.428571429
Contingency Recs	5	4	7	8	8	9	9	7.142857143
Communication	2	2	2	2	2	2	3	2.142857143
Team Selection	7	3	8	6	5	7	5	5.857142857
Team Fitness	7	6	8	4	5	7	5	6
Environment	9	10	7	10	10	8	10	9.142857143
Incident Complex	10	8	9	10	9	8	10	9.142857143
Total	50	39	53	55	52	57	46	50.28571429
TUNNEL, SHED, SUPPORT STRUCTURES								
Supervision	1	1	1	1	1	1	1	1
Planning	1	1	1	1	1	1	1	1
Contingency Recs	1	1	1	1	1	1	1	1
Communication	1	1	1	1	1	1	1	1
Team Selection	1	1	1	1	1	1	1	1
Team Fitness	1	1	1	1	1	1	1	1
Environment	1	1	1	1	1	1	1	1
Incident Complex	1	1	1	1	1	1	1	1
Total	8	8	8	8	8	8	8	8
HELO HOWITZER								
Supervision		6	6	6	8	7	7	6.666666667

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Planning		6	7	6	6	7	7	6.5
Contingency Recs		5	7	5	8	8	9	7
Communication		3	3	3	3	2	3	2.833333333
Team Selection		5	8	8	8	7	9	7.5
Team Fitness		6	8	6	5	8	4	6.166666667
Environment		10	9	10	10	8	10	9.5
Incident Complex		10	8	9	8	9	10	9
Total		51	56	53	56	56	59	55.16666667
HOWITZER + ACCESS MITIGATION								
Supervision		3	2	3	2	2	2	2.333333333
Planning		5	3	5	2	5	2	3.666666667
Contingency Recs		3	6	5	6	9	9	6.333333333
Communication		2	2	2	2	2	3	2.166666667
Team Selection		3	5	7	4	7	5	5.166666667
Team Fitness		6	6	6	4	7	5	5.666666667
Environment		10	9	9	6	8	10	8.666666667
Incident Complex		5	7	6	5	5	9	6.166666667
Total		37	40	43	31	45	45	40.16666667
FIXED GAS + HELO								
Supervision		3	4	4	3	7	3	4
Planning		4	4	6	4	7	4	4.833333333
Contingency Recs		3	7	6	5	8	9	6.333333333
Communication		2	2	2	2	2	3	2.166666667
Team Selection		3	4	5	5	4	4	4.166666667

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Team Fitness		2	4	4	4	4	4	3.666666667
Environment		10	8	7	7	7	10	8.166666667
Incident Complex		4	5	6	6	7	5	5.5
Total		31	38	40	36	46	42	38.83333333
CLOSURE + HELO								
Supervision		4	6	2	5	3	4	4
Planning		6	7	6	6	3	4	5.333333333
Contingency Recs		2	3	3	4	1	2	2.5
Communication		3	2	2	2	2	3	2.333333333
Team Selection		5	7	5	6	2	5	5
Team Fitness		4	5	3	5	1	3	3.5
Environment		4	7	6	6	2	4	4.833333333
Incident Complex		7	8	9	9	2	5	6.666666667
Total		35	45	36	43	16	30	34.16666667

Appendix B

Risk Versus Gain Data

Table B-1. Risk-Gain Comparison.

The potential gain was accomplished as a group exercise, with the expert panelists as well as the observers contributing information to cost, resources, and pass being open.

Effectiveness refers to how effective the option will be in keeping snow off of people. It is a relative scale, with those perceived to be most effective receiving a 6 and those that are not effective receiving a 0. As noted in the body of the report, the expert panelists' perception of option "effectiveness" changed from the beginning of the workshop to the end. Thus the values in this table do not match the "Very, Middle and Least Effective" categories earlier in report.

Pass refers to pass being open, with a 6 denoting the pass is open for the most days. A 2 would mean the pass is open about 18 days (only). A zero would mean the pass is closed.

Resources refer to impacts on resource, with those that are most impacting receiving a 0 and the least getting a 6.

Cost takes the general estimates (estimates were general, not specific) of the one-time costs of implementing an option, and puts those costs on a scale of 0 to 6, according to this scale:

6 is about 0–$100K
5 is about $100K to $250K
4 is about $250K–$500K
3 is about $500K–$1.5 million
2 is about $1.5 million–$5 million
1 is about $5 million–$10 million, and
0 is about $10 million–$100 million.
X represents costs off this scale (greater than $100 million).

Option	**Risk**	**Effectiveness** (where 6 is very, 0 is not)	**Pass** (where 6 is most open, 0 is most closed 90 day period)	**Resources** (where 6 is low impact, 0 is high)	**Cost** (where 6 is low cost, 0 is high)
Access	46.6				
Total Closure	8	6	0	6	6
Tunnel/Shed	8	6	6	5	X
Support Structures in Start Zones		5	6	0	X
Full Forecasting	62	3	2	6	5
Helicopter	55.1	4	3	5	4
Backcountry Standards	29.1	2	6	6	6
Window Closure	29.9	5	0	6	6
Fixed Gas Systems	27.9	5	5	2	2
Hand Charges	66.6	2	3	5	3
Trolleys	32.9	4	5	2	2
Artillery	40.3	5	5	4	4
Berms, Deflectors, Catchment Basins	18.3	1	1	1	1
Snow Sails	19	2	2	1	2
Avalauncher/LOCAT	50.3	2	2	4	3
Helo Howitzer	55.1	5	5	4	2
Howitzer + Access Mitigation	40.1	5	5	3	3
Closure + Helo	34.1	5	0	5	6
Fixed Gas + Helo	38	5	5	1	2