ENVIROMENTAL IMPLICATIONS FOR EXPLOSIVES BASED RISK MITIGATION: A CASE STUDY FROM THE BNSF RAILWAY AVALANCHE SAFETY PROGRAM ESSEX, MONTANA, USA.

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ABSTRACT: On January 28th, 2004, numerous avalanches released above the BNSF Railway tracks located in John F. Stevens Canyon, Montana. In particular, three avalanches occurred in a short period of time and close proximity, resulting in 15 freight cars derailed, an Amtrak train narrowly missed, two workers nearly buried, and the rail shut down for 29 hours. This avalanche event prompted BNSF Railway to initiate an in-house Avalanche Safety Program. The resulting program has derived an Avalanche Atlas and an Avalanche Safety Plan while providing education for railway workers, site specific avalanche forecasting, and proposed explosives based risk mitigation. Environmental and safety concerns regarding use of explosives/ artillery for avalanche hazard mitigation have been voiced and documented by governing land agencies that include the National Park Service, the United States Forest Service, and Montana Department of Transportation. Future direction of the BNSF Avalanche Safety Program and application of explosives for avalanche hazard mitigation is currently being determined by an Environmental Impact Statement (EIS) analyzed by Glacier National Park officials and funded, in part by BNSF and Glacier National Park.

Keywords: BNSF, railroad, snowsheds, avalanche forecasting, avalanche hazard, explosives, artillery

1. INTRODUCTION

1.1 Railroad Setting

The railway through John F. Stevens Canyon (canyon), named after John F. Stevens who located Marias Pass for the railroad, has been in existence since 1890. The creation of the railroad predates the formation of both the United States Forest Service (1905) and Glacier National Park (1910). The railway was owned and operated by Great Northern Railway until 1970 and then merged with three other railroad companies to form Burlington Northern Railroad. The railroad is now owned and operated by BNSF Railway, formally Burlington Northern Santa Fe Railway.

BNSF Railway is currently running an average of 30 freight trains daily through the canyon with an average freight train length of 2424 meters (Agnew, 2006, pers. comm.). In addition, two passenger trains averaging 280 meters in length the rail twice daily. BNSF rail traffic frequency and train lengths are at all-time record levels.

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Railroad infrastructure in the canyon is surrounded by government lands, designated Wilderness or GNP “recommended Wilderness”, and consists of two sets of railroad tracks, Main 1 and Main 2. Both tracks convey east or west bound trains and allow trains to run simultaneously in different directions.

The section of the canyon presenting avalanche hazard to the rail is located in Flathead County, approximately 7.2 kilometers in length and 1303 meters above sea level (a.s.l.). The Canyon is narrow and predominantly oriented east-west with ridgeline elevations on both sides of the Canyon averaging 2100 meters a.s.l.

Also in the canyon is US Highway 2 (Highway), managed by the Montana Department of Transportation (MDT). The highway runs parallel to the rail but at a lower elevation along the canyon floor. The highway currently averages 1000 commercial and non-commercial vehicles per day (*Great Falls Tribune*, Jan 30th, 2004).

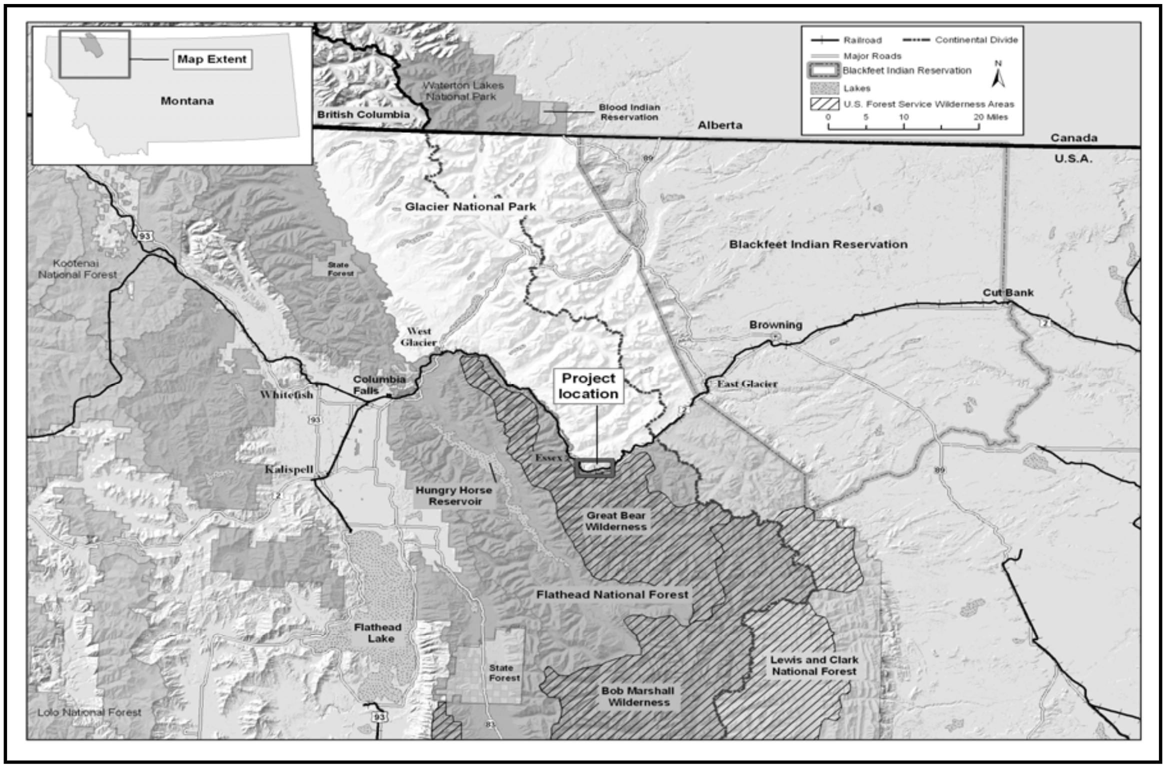

Figure 1. Graphic overview of BNSF Avalanche Program location, government lands, and designated Wilderness. Map provided by Glacier National Park.

Current ownership and management of land in the Canyon is divided between the United States Forest Service (USFS) and Glacier National Park (GNP) (**Figure 1**). The USFS assumed ownership of the land on and near the floor of the canyon as well as its northerly aspects upon its formation in 1905. Upon its formation, the USFS inherited a right of way agreement established in 1891 between the US federal government and James Hill, owner of the Great Northern Railway. As such, today's railroad operations take place on USFS land that is managed by Flathead National Forest (FNF) and fall under the guidance of the 1891 right of way agreement. A similar right of way is in place for U.S. Highway 2. (Burren, 2006 pers. comm.).

Wildlife in the canyon is prevalent and even with infrastructure development, the canyon serves as a major wildlife corridor as well as providing wildlife wintering range along its southerly slopes.

Wildlife species known to exist in the canyon during the winter include deer, elk, mountain goat, and moose. Wildlife species listed as threatened and endangered under the Endangered Species Act are also in the area and include grizzly bear, Canada lynx, bull trout, and the gray wolf.

There are currently 26 identified and active avalanche starting zones feeding 15 paths that pose a potential avalanche hazard to wintertime rail operations in the canyon (**Figure 2**). The vertical fall from starting zone to the rail ranges from 254 m. to 984m. (Hamre 2004).

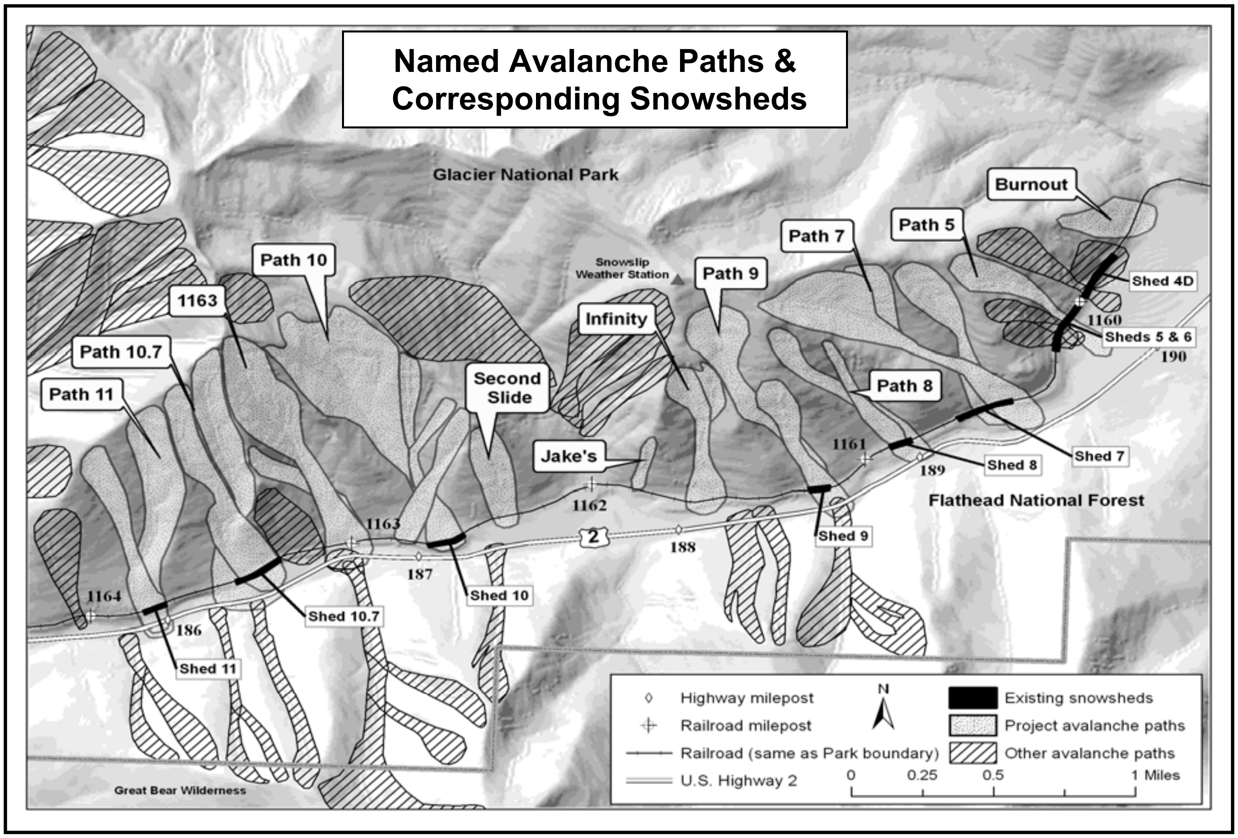

Figure 2. Named Avalanche Paths and corresponding Railway snowsheds. Map provided by Glacier National Park.

1.2. <u>Avalanche History</u>

Throughout the history of the railroad in the canyon there have been numerous encounters with avalanches that include near misses, fatalities, infrastructure destruction, and rail closures. Historical documents of avalanche accidents and near misses in the canyon date back to 1910 and include three documented avalanche fatalities on March 4th 1929. These fatalities occurred as a result of a large magnitude avalanche that hit a Great Northern Railway west bound express mail train, derailed it, and ultimately killed the three workers (*Kalispell Weekly News*, 1979).

Large magnitude avalanches have occurred on both the north and south aspects of the canyon with rail operations only being affected by avalanches initiating from the canyon's southerly aspects. The existing historic record indicates a majority of avalanche events occurring between the months of January and March with several outlier events in December and April.

To defend against avalanche activity, the Great Northern Railway built large timber snowsheds (defense structures) that date back to at least 1910. Since that time, snowsheds have been added onto, rebuilt, maintained, and destroyed. Today, a total of 9 snowsheds are maintained and provide continued protection against avalanches for a total of 1794 meters of rail in the canyon **(Figure 2).**

Based on current research of the canyon's historic record, it appears rail road and highway operations combined have been impacted by between 98 and 100 avalanche events (Reardon, 2006, pers. comm.). However, this number accounts for incidents in avalanche prone terrain in the entire length of John F. Stevens Canyon and involves events outside the geographic area focused on in this paper.

1.3. Recent Avalanche Events

Avalanche events affecting rail operations since the year 2000 have occurred sporadically over time and space and, similar to the existing historic record, there are some seasons where no avalanche activity was reported at all. In the winters of 2002, 2003, and 2004 several large magnitude avalanche cycles occurred. In each of these years, the highway was closed due to avalanche activity and the railroad reported avalanche debris on the rail. In March of 2003 a widespread avalanche cycle forced the railroad to close passenger rail service in the canyon and limit freight traffic to Main 1 (the inside line of the rail) as a safety precaution.

1.4. 2004 Avalanche Event

The winter of 2004 began as many have in recent years with below average snowpack and colder temperatures than normal. A well established storm cycle finally locked into the region in late January and had started out under the influence of an arctic air mass. Abundant moisture was being pumped into the region under the influence of a moisture laden westerly flow from the Pacific. Snow that fell during the onset of the storm was cold and dry.

As happened so many years in the past, the jet stream shifted to the south and a warming air mass with copious amounts of moisture continued to climb into the region and override the artic air mass. Heavy snow fall, very strong shifting winds from northeast to southwest at ridgetop levels, blizzard conditions along the canyon floor, and moderating air temperatures that climbed rapidly from the depths of negative digits (-32^0 C) to above freezing.

Local BNSF officials knew these conditions were historically reminiscent of previous avalanche cycles and with the intensifying storm conditions had closed Main 2 to rail traffic in case of an avalanche.

On January 28th, 2004 at 11:47 AM a dry slab avalanche released in a well established, unprotected, and historically notorious avalanche path named “1163.” The resulting avalanche hit an east bound grain train on Main 1 derailing seven (7) empty grain cars from the rail. The resulting derailment displaced the cars, not tipping them over but disabling the train so it could not move. A secondary avalanche released a moderate elevation starting zone of an avalanche prone area now appropriately named “Second Slide and derailed an additional eight (8) cars **(Figure 3**).

Figure 3. 2004 BNSF freight train derailment caused by a natural avalanche initiated in “Second Slide” avalanche path. Photo Credit: BNSF Railway.

In all, 15 grain cars were derailed from the track and both main lines were closed for 29 hours. Following standard protocol, BNSF closed the rail and additional railroad crews were dispatched to address the derailment. Initially, additional assistance included two local BNSF management officials who began an on-site assessment of the derailment.

One of the officials walked a complete loop of the train from the rear to the head end. It was a matter of thirty (30) minutes when this official returned to the rear of the train. In the time it had taken him to complete his walk-around, an additional avalanche had released from 1163, impacted the already derailed cars, and packed approximately four meters (4 m) of avalanche debris on the high side of the train where he had been just minutes before. Both officials came to the unnerving realization that if this secondary avalanche had caught anyone, they would be completely buried in avalanche debris and potentially killed or seriously injured. Additionally, an eastbound Amtrack passenger train with 147 people on board had been missed by only 71 minutes.

Following the secondary release in 1163, BNSF officials deemed the avalanche hazard too great to continue clean-up operations and all railroad operations were closed in the canyon until the following morning.

As there was no site specific avalanche forecast or safety protocol established for this type of situation, BNSF contacted local avalanche professionals for assistance in assessing the hazard. They also contacted Dave Hamre of the Alaska Railroad to assist as a consultant for the Railway. After assessing the situation the following morning, he informed BNSF that their only viable options for mitigating the avalanche hazard was to utilize explosives to artificially trigger the remaining slabs or wait until snowpack conditions improved naturally.

BNSF contacted GNP officials and formally requested the use of explosives in GNP to mitigate avalanche hazard above the rail. The request was originally denied, but after some discussions an Emergency Special Use Permit (ESUP) for the use of explosives was granted by GNP. Continued storms delayed usage of that permit, and when the weather cleared, the snowpack had warmed and re-cooled, reducing the avalanche hazard significantly to where explosives were no longer needed.

By the time the snowpack had naturally stabilized and the railroad was cleared, the rail had been closed for 29 hours and the effects of the avalanche cycle began to surface. Passenger rail service had been shut down three (3) days, freight trains were backed up across the northern region of the United States, and international shipments from Asia to Europe were stalled in the Port of Seattle.

The resulting derailment, the secondary near miss avalanche incident with the BNSF officials, and the glaring fact that the east bound Amtrak passenger train had been narrowly missed prompted BNSF Railway to pursue further consultation to improve avalanche safety on the rail in the canyon.

1.5. Railway Avalanche Atlas

The first consultant recommendation to BNSF Railway management was that an avalanche atlas be created for the canyon. The atlas would define specific avalanche paths, each path's terrain characteristics, and each path's respective hazard to rail operations. The atlas, titled "Avalanche Risk Analysis John Stevens Canyon Essex, Montana" (Atlas), was completed in December of 2004 and consists of detailed avalanche path photos, a technical and narrative description for each of the avalanche path, statistical information related to the rail's existing avalanche hazard, avalanche hazard reduction recommendations, and a table of historically documented avalanche occurrences in the canyon. Of note in the Atlas is the computed Avalanche Hazard Index of 110, which is a high enough hazard index to warrant significant actions (Hamre 2004).

2. AVALANCHE SAFETY PROGRAM

2.1 Avalanche Program Organization

On January 12th, 2005 BNSF hosted a meeting in Whitefish, MT. in which the consultant presented the Atlas to BNSF management officials. Also attending the meeting were representatives from GNP, USFS, MDT, USGS, GCAC Inc., and officials from Flathead County as well as Montana Fish Wildlife and Parks. The consultant verbally recommended that an avalanche safety program be implemented immediately. A BNSF Management Official verbally accepted this recommendation and committed to beginning the process of establishing a formal avalanche safety program.

Although this was the first formal avalanche safety program instituted by the railroad, impromptu and informal consultation regarding avalanche safety and forecasting in the canyon dates back to at least the late 1970s. Consultation has been provided to BNSF and MDT by representatives from the USFS, USGS, and Glacier Country Avalanche Center Incorporated (GCAC Inc.). During the remainder of 2005, the newly established BNSF Avalanche Safety Program (Program) consisted of a single avalanche specialist and an avalanche safety consultant available on an as needed basis. The Program focused on providing quasi functional avalanche forecasting operations while developing an industry standard avalanche training, forecasting, and explosives program.

For the 2005-06 season, the Program was expanded to include an additional part-time avalanche specialist which allowed expanded and more consistent field work at avalanche starting zone elevations.

2.2 *Explosives Based Mitigation*

The crux of Program development and current operations has been working with GNP, USFS, and to some extent MDT in establishing explosives use for avalanche hazard mitigation.

Land and transportation manager concerns to the use of explosives for avalanche hazard mitigation continues to be based on the area's recommended Wilderness status, environmental sensitivity, the potential for damaging Highway infrastructure and/or creating extended Highway transportation interruptions, and the presence of sensitive species.

GNP officials have explained during meetings with BNSF management that due to the recommended Wilderness status of GNP lands above the rail, naturally triggered avalanches in this area are regarded as natural processes that the agency is mandated to protect. Artificially triggered avalanches in the canyon by use of explosives are not condoned as they are initiated by artificial means and may create excessive and unjustified impact on the canyon's natural aesthetics, terrain, flora and fauna. The consensus of land and highway officials during these meetings is that BNSF Railway should construct additional snowsheds and continue to adjust or shut down rail operations based on the forecasted avalanche hazard. It has also been conveyed by land managers that although the BNSF Railway operates on USFS lands, and avalanche starting zones are located on GNP lands, mitigating the Railway's avalanche hazard is the sole responsibility of BNSF Railway. (Ross, L., 2006 pers. comm.).

The position of BNSF Railway management is that without the option to utilize explosives and/or artillery as active avalanche hazard mitigation tool(s) that even with the Program in place, the railroad will continue to be jeopardized by avalanche hazard as it has been in the past. Further, rail closures are costly and the unexpected down time alone has been estimated to cost the railroad in the neighborhood of U.S. $337,000 for a 29 hour rail closure (Ross, L., 2006, pers. comm.).

In addressing the recommendation of constructing additional snowsheds, which totals 1527 lineal meters, the estimated capitol cost alone is U.S. $100,782,000 with an estimated ten (10) year construction time frame (Burns, B, 2006, pers. comm.)

After the 2004 events, GNP agreed to extend the ESUP option to BNSF for the use of explosives only until a GNP Environmental Impact Study (EIS) regarding the use of explosives/ artillery in the Canyon is completed. However, before issuance of the ESUP, GNP officials required the BNSF Railway establish a Snow Blasting Plan inclusive of an explosives operation "Decision Making Tree" that acts as a flow chart for land managing Agencies in the canyon to either concur or disagree with a BNSF proposed explosives operation. In addition, details of the new ESUP required that BNSF Railway:

- Allow a minimum 24 hour window before application of explosives to allow for agency ramp up and public notification.
- Submit an operations plan to GNP for each explosives operation at least eight (8) hours prior to any explosives operation.
- Confirm with GNP officials within the 24 hour window that avalanche hazard conditions are continuing to pose an imminent threat to life and property on the rail.

By the end of the 2004/05 season, BNSF Avalanche Safety had received necessary permitting for explosive storage and handling and acquired explosive magazines, cast primer explosives, and an avalauncher to assist in avalanche hazard mitigation if needed.
At the start of the 2005/06 season, all GNP requirements for issuance of an ESUP had been met by BNSF Avalanche Safety and issuance of an ESUP was expected in early December of 2005. This target date was not reached because of the necessity of negotiating an agreement with MDT for this activity, which was complicated by the terms offered for this agreement.

2.3 *Explosives Based Operation*
At 2330 on February 23rd, 2006 the BNSF Avalanche Safety Team posted an "Avalanche Watch" for rail operations in the canyon. An Avalanche Watch means that: "Weather and snowpack conditions are favorable for avalanche activity. Avalanches that do occur MAY POSSIBLY reach the Railroad Tracks posing a threat to human life, rail vehicles, and infrastructure." At this time a Memorandum of Understanding had not been reached between BNSF Railway and MDT regarding explosive use, although this hurdle was overcome on a temporary basis.

Since 1500 intense snowfall and strong/ variable winds, and blizzard conditions had been occurring in the canyon. At 1600 a moderate sized dry slab (SS-N-R2-D2) was observed by BNSF Avalanche Safety. The avalanche had released from the starting zone of "Infinity," an avalanche path without a snowshed, and had run two-thirds path to the rail.

Previous to the onset of the storm, an artic air mass had dominated the area, which included frigid air (-30^{0}C) and wind chill temperatures in the canyon. Snowpack profiles conducted during this time indicated a large temperature gradient in the near surface snow pack deposited on a previous melt-freeze crust.

The storm abated in the canyon at approximately 0500 on February 24th with a storm total snow water equivalent (SWE) of 1.9" and a 24 hour SWE of 1.5." New snowfall densities and temperatures had increased during the storm and winds had averaged 48 km/hr with gusts to 161 km/ hr. The immediate forecast called for clearing skies, calm winds, and temperatures remaining below freezing. The extended forecast was for rapidly rising temperatures and significant rainfall to at least 1500 meters a.s.l beginning on February 27th, 2006.

In retrospect, the forecasted February 27th storm arrived as anticipated with temperatures exceeding three degrees Celsius (3^o C) and over twelve millimeters (12 mm) of liquid precipitation recorded at the Pike Creek SNOTEL site located east of the canyon at 1798 meters a.s.l. BNSF Avalanche Safety observed and documented widespread natural avalanche activity associated with the storm.

At 0730 on February 24th canyon based field observations conducted by the BNSF Avalanche Safety Team indicated extensive hard slab formation on east, northeast exposures in the upper elevation starting zones of Path "1163," "Infinity," "Shed 8," and "Shed 7."

With current and forecasted weather conditions in mind, BNSF Avalanche Safety made the recommendation at 0830 to BNSF management that explosives be implemented to assist with avalanche hazard mitigation above the rail. The request was soon submitted to GNP and an ESUP obtained at 1300. An 8 hour track closure window was created on the rail, explosives would be delivered into starting zones of concern via helicopter, and the anticipated time for the operation was three (3) hours. An Operations Plan detailing explosive delivery procedures, highway closure and sweep procedures, debris clean-up procedures, and emergency procedures was sent to GNP at 0020 on February 25th.

The helicopter delivery operation began at roughly 1200 on February 26th. Ten (10) double armed charges with RECCO chips were delivered to the starting zones of Shed 8, 1163, Shed 7, and Infinity. In total, five (5) four kilogram (4 kg) Avalanche Guard rounds and five (5) two kilogram (2 kg) rounds were deployed. Explosive initiation triggered a moderate hard slab in the starting zone of Shed 8 (HS-AE-R3-D3) (**Figure 4**) and two smaller soft slabs in the starting zone of 1163 (SS-AE-R2-D2). There were no results in the starting zones of Shed 7 or Infinity.

Figure 4. Shed 8 avalanche debris and powder cloud from BNSF Railway explosives operation. Photo Credit: Blase Reardon, USGS.

2.4 *Explosives Operation Overview*
The explosives helicopter delivery operation lasted approximately two (2) hours and the highway was closed for just over two (2) hours. Rail traffic was closed for 8 hours with no train delays. A debriefing followed the operation in which BNSF management and Agency representatives had the opportunity to comment and suggest future improvements on the operation.

The explosives based avalanche hazard mitigation operation on February 25th was the first of its kind in the history of railroad operations in the canyon and the first time a private entity was permitted to utilize explosives in GNP for operations outside the Park.

At the end of the 2006 season, a Memorandum of Understanding was agreed upon and signed between BNSF Railway and MDT. The BNSF Avalanche Safety Program is scheduled for operating during the winter of 2006/07 and the status of explosive use for the season is yet to be determined.

3. AGENCY AUTHORIZATION AND PERMITS

Continued and improved avalanche hazard mitigation alternatives anticipated for the Program include the construction of permanent snowsheds, installation of on-mountain facilities, and use of explosives and potential use of artillery. Each of these can be construed as a “major” activity which might affect the environment. Given that the Program occurs on federal lands, this in turn triggers the need for an analysis under the National Environmental Policy Act (NEPA)

Different federal agencies create their own internal rules for NEPA compliance which are approved by the Council of Environmental Quality and published in the Federal Register. All are bound by guidelines that affect the level of analysis required. The most basic level is a Categorical Exclusion (CE). This is generally accomplished for projects on a list of actions that are expected to have no significant impacts on the environment. The next higher level of review is an Environmental Assessment or “EA”. These are typically accomplished for projects that are not on an approved list of CE actions, but are determined through analysis to have no significant impacts. EA analysis are commonly tested in court over the issue of significance and found to be incomplete. The third level of analysis, the Environmental Impact Statement or “EIS” is reserved for those projects that the effects are not known or are expected to have significant impacts and/or are controversial and set precedents. NEPA regulations may allow those impacts to occur as long as they are identified in an EIS and mitigated to the maximum extent possible, although different agencies mandates vary in the amount of protection required. The EIS processes can take up to 3-4 years depending on the depth of analysis required.

Once the level of review is decided, the agency establishes a proposed timeline for completion of their analysis, and sends out notifications to interested parties containing information on the project. This “scoping” phase is intended to identify the potential issues involved. The range of issues generally guides the level and type of analysis required. The entire process can take one to two years or more to complete, during which no proposed activities can take place that might degrade the environment. For that reason, the Program is currently limited to providing avalanche training, forecasted rail restrictions/ closures, and explosives application only in emergency situations.

All affected parties agreed to conduct an EIS level review for the Programs future use of explosives and artillery. Following the "Record of Decision" established by the EIS, and depending on the decision reached, a permit may be issued for explosives use.

4. EXPECTED EIS ISSUES

Any approved alternative must address both environmental impacts and potential risks. Project scoping identified a range of potential impacts for analysis.

Potential impacts to wildlife were prominent in scoping comment, including the potential for endangered species such as grizzly bears to be displaced by explosives use. These impacts may include disruptions to winter habitat. Intrusions into proposed wilderness areas is identified as an issue. There are also potentially negative impacts to highway traffic from increased closure periods as well as the benefit of a more managed avalanche situation to the public. Increased closures might also affect business and commercial interests in a number of ways. Recreational visitor closures are expected with any explosives based mitigation as well. The natural soundscape will change if explosives are used.

Proposed solutions may be prohibitive from a cost/benefit perspective. Not acting on the documented risk also has potentially adverse environmental impacts because of the increased potential for a human related avalanche incident and/or incident involving rail cars carrying hazardous materials.

5. IMPLICATIONS FOR OTHER PROGRAMS

The current proposed explosives based Program, and proposed artillery usage as part of this Program, has triggered what is likely the first EIS conducted on an avalanche program in the United States. Findings from the EIS may have an affect or be cited in future environmental analysis on other federal lands. Accordingly, other operators of avalanche programs in the U.S. may want to consider some future issues.

There is a high certainty level that environmental scrutiny will increase over time. Programs currently operating may be subject to increased levels of scrutiny during permit renewal processes. For this reason, there is a need for users to get more knowledgeable about the environmental review process. This can help greatly in affecting the outcome of any required reviews.

Another significant benefit may be derived by anticipating potential environmental issues, and deriving appropriate strategies for addressing these issues. Many environmental decisions are made by agencies in a conservative manner because they lack the science or understanding of the resource to make more informed decisions.

Entities might consider funding baseline analysis on critical issues over long periods of time. As an example, when the issue of populations of golden eagles comes up, a baseline analysis may show that population densities are increasing despite ongoing avalanche mitigation efforts. In this case there would be no need for restrictions on explosives use. Conversely, it is possible that impacts from explosives use could be affecting wildlife in a way that would require program modifications in order to assist a recovery program.

As the environmental review process unfolds, it is critical to stay up on process timeline and provide comments and input at appropriate times.
The outcome of the review process is somewhat dependent on the input provided. Better science almost always results in better decision making. An agency mandated with the environmental review process doesn't necessarily have access to the same information the user does. Providing good science that supports a particular program's position may assist in a favorable outcome in the review process. Consider supporting regulatory agencies in their quest for better information on which to base decisions. This support might extend to political levels in the form of lobbying for

increased funding for particular studies or analysis needed in establishing baselines for species of concern.

6. CONCLUSIONS

Since its inception in January of 2005, the BNSF Avalanche Safety Program has improved avalanche safety on the rail and perhaps, indirectly for the Highway too. However, establishing the Program has also revealed bureaucratic complexities of operating a newly developed explosive based avalanche safety program in an area that is environmentally sensitive and consists of U.S. government owned lands.

In regards to explosives use and proposed artillery use as part of the BNSF Avalanche Safety Program, the level of environmental scrutiny has been unprecedented in the United States. For that reason the required EIS analysis will be more thorough than what has previously appeared. Implications regarding this analysis to other programs may be significant.

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