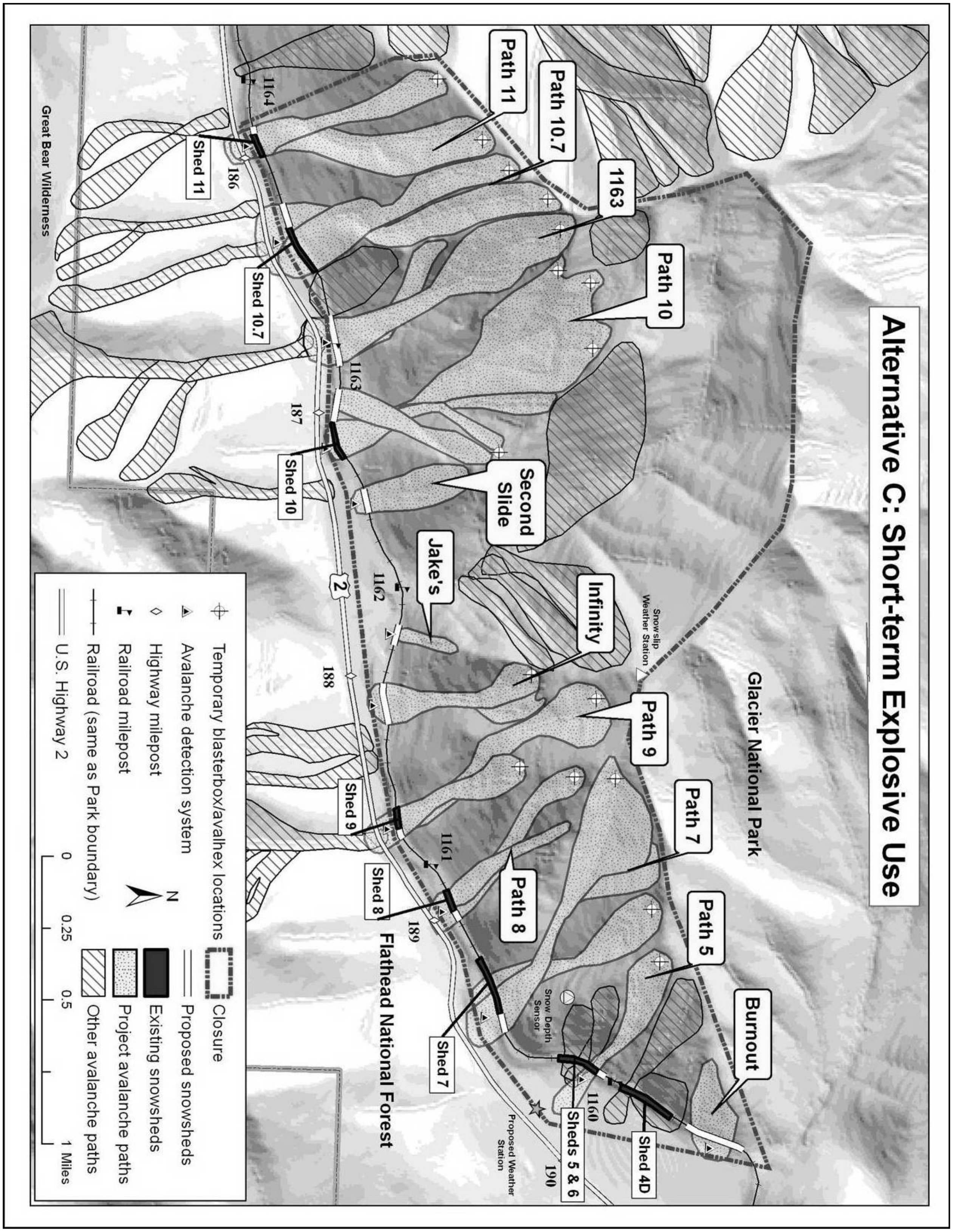


Map 2-3. Actions under Alternative C.

Snowsheds

BNSF would build new snowsheds or lengthen existing snowsheds on the railroad right-of-way. Snowsheds would be constructed or modified in the same priority and manner as in Alternative B. BNSF would commit to build extensions on snowsheds 7 (100 feet) and 9 (150 feet) as the avalanche risk is greatest in these two paths. BNSF may determine that some avalanche path risk is low enough to reduce by other means such as snow removal from the tops of snowsheds (avalanche debris may build up, diverting future slides around the snowshed), avalanche signal technology, traffic restrictions, or snowshed construction in other paths.

Resource Monitoring and Assessment

An extensive resource monitoring program is the foundation of Alternative C. The use of explosives is expected to have many impacts on the resources in the project area as discussed in Chapter 4, but the quantitative impacts are unknown. Under this alternative, BNSF would fund a 15 year monitoring program of wildlife, noise, water, soils, vegetation, and natural avalanche processes. The construction of new snowsheds or extensions would be thoroughly documented to record impacts to the existing historic snowsheds.

An inter-agency technical team would be established to develop monitoring thresholds and a protocol for the project area after the EIS process is complete. Once developed, the monitoring thresholds would guide annual permitting and conditions of explosive use.

Adaptive management in the NPS (516 Department Manual 4.16) is a process of management practices based on identified resource thresholds; monitoring to determine when and if thresholds are reached; and if they are, implementing changes in the action. Under this proposal, resource thresholds would be determined for the project area and changes would occur to the BNSF Special Use Permit if the thresholds were reached. BNSF would fund an annual newsletter produced by the cooperating agencies to brief the public on the explosive use program and the resource monitoring results. Years of no explosive use are important for comparison with years of multiple cycles of explosive use. If the resource thresholds were not reached, there would be little or no change to the explosive use program over the 10-year period.

An infrasonic avalanche detection system would be installed by BNSF for avalanche monitoring and would used to determine the efficiency of explosive use and the presence of natural avalanche activity. The infrasonic system detects low frequency sound waves under the snowpack with a temporary array of 6-inch square metal boxes affixed to lengths of hose placed on the ground before snowfall. This system involves a solar or regular electric source and a computer data processing unit. All of the equipment would be on the ROW or in the runout zones on NFS lands. This equipment would allow cooperating agencies to monitor natural avalanche processes. The system would detect the magnitude, frequency and direction of avalanches in the project area. It would also detect explosive use effectiveness and avalanches undetectable by ground crews. The system would provide valuable information concerning dud explosives, successful avalanche triggering, distance and location of the slide. It would provide specialists and agency staff with information concerning natural and explosive use avalanche frequency and magnitude. This infrasonic system is in the experimental stage currently, however, the data from use at Teton Pass shows a promising technology. There may be matching funding for this technology, which would reduce costs of the system for the railroad. The system would be an integral component of the adaptive management program, as it would demonstrate the accuracy and success of explosives for each avalanche cycle.

Avalanche Detection System

Avalanche detection systems would be maintained or installed in the same location and manner as in Alternative B. BNSF would continue to use signal wire or another avalanche detection system in addition to snowsheds. BNSF would continue to maintain the existing signal wire detection system, although technology is rapidly advancing in avalanche detection. Current detection technology would not provide enough time for a train to stop before hitting the avalanche even if the equipment were placed in starting zones. Detection technology would be used in combination with forecasting to determine avalanche risk and hazard along the length of track in the project area by warning BNSF personnel when avalanche debris hits the tracks. The technology below would provide additional avalanche safety for the railroad.

Infrasonic detection systems as described under the monitoring section above could also be used by the railroad for avalanche detection. Doppler radar, and/or geophone avalanche detection technology could also be installed under this alternative. Doppler radar would require fixed equipment just outside of the runout zone on ROW land. The Doppler radar sensor, solar panel, and remote transmitter would be fixed on a 15-20 foot tower. Geophone vibration sensing technology would require fixed structures on BNSF ROW land. The geophone instruments would be set in the ground in a two-foot square area along the edge of the avalanche path on the right-of-way. The geophones would be connected to the Doppler radar tower for power and radio transmission. This equipment would employ a remote system to activate alarms in BNSF vehicles and trains if avalanche activity is detected or debris crosses the tracks. This equipment would only detect avalanches in those paths where it was installed. Currently, geophones cannot be used in an environment that has vibration noise from a non-avalanche source such as trains. If the technology improves to allow use of this device with trains, the instruments may be installed. Remote cameras or continuous video may be installed along the ROW to differentiate false alarms from actual avalanche activity. Visual devices would only be effective during daylight hours.

Avalanche Forecasting

Avalanche forecasting would be the same as described in Alternative B. Avalanche forecasting would be an integral part of this alternative as instability leading to explosive use would be dependent on detailed avalanche forecasting techniques.

BNSF avalanche forecasters would continue to provide specific, local avalanche hazard information for the railroad. Weather patterns would be observed and risk assessed during predictable pre-avalanche conditions. Conditions observed would include type and amount of snow precipitation, temperature, wind, snow water equivalent, relative humidity, barometric pressure, and weather trends. Snowpack analysis for weak layers may be used to determine fracture zones. *Rutschblock* tests, ski cutting, collapse tests, tilt board tests, shear frame tests, stuff block tests, and shovel shear tests are non-explosive stability testing techniques that would be employed by avalanche forecasters to determine unstable snow layers. Weather data, snowpack stability and avalanche information would be continuously recorded into BNSF logs. BNSF would monitor avalanche paths through direct observation and record natural avalanche activity, and other weather events such as wind scour and deposition patterns.

The USGS weather station on Snowslip Mountain and the Pike Creek Snotel site would continue to provide continuous local weather data to forecasters. This information would be used to help determine current snow conditions and avalanche hazard levels. A weather station at a lower elevation (4600 feet) would be installed at reference post 189.8 along US Highway 2 on NFS land. The weather station would be a tripod structure with 6-inch square feet. Weather station stability would be reinforced with rebar lengths driven into the ground. The weather station would be non-obtrusive and painted a natural color to blend into the surroundings. A snow depth sensor would be placed on NPS land at elevation 5600 on the ridge between Shed 6 and Shed 7. While the sensor is temporary, it would be permitted to stay in the project area while avalanche forecasting is conducted. The sensor would be a fixed pipe with a perpendicular arm located above the snowpack. The arm has a sonic sensor that measures the snow depth from above the snowpack. The snow depth sensor would have a radio transmitter to send information to forecasters. The snowdepth sensor and the Snowslip weather station would be removed after the permitted explosive use period.

The ASD would be responsible for BNSF avalanche safety training for railroad crews and would be present for crew exposure to avalanches. Railroad workers exposed to avalanche conditions would continue to undergo avalanche awareness, safety, and rescue training as part of their duties. Workers in these situations would be equipped with shovels, probes, and avalanche transceivers. Watchers and rescue personnel would be available to reduce the chance of worker fatality due to avalanche.

Explosive Avalanche Hazard Reduction

The NPS would permit explosive avalanche hazard reduction during daylight hours in John F. Stevens Canyon for up to 10-years. Explosive delivery methods permitted under this alternative would be hand charges, helicopter delivery, Avalauncher, blaster boxes, and Avalhex type systems. Explosive use methods are compared in Table 2-5. Explosive use would only be permitted during daylight hours to mitigate wildlife impacts and direct mortality. The Avalanche Safety Director (ASD) would initiate explosive avalanche hazard reduction procedures defined in an *Avalanche Operations Plan* to be developed by BNSF. A final *Avalanche Operations Plan* would include explosive use weather conditions (defined in Table 2-2) and the explosive use program protocol. On-going monitoring of the avalanche program would require BNSF to maintain a “state-of-the-art” system and to reduce resource impacts when possible. BNSF would maintain changes and updates to the *Avalanche Operations Plan*. This plan would be approved by the NPS, USFS, and MDT. The *Avalanche Operations Plan* would be a working document that may change with emerging conditions, documented resource impacts, or unforeseen concerns. If changes were proposed that had not been analyzed in the EIS, another NEPA analysis may be required. BNSF would maintain the *Avalanche Operations Plan* and all accept all liability associated with explosive use, weather thresholds, and implementation. Explosives would be stored on a private property site in a secure manner in compliance with the Bureau of Alcohol, Tobacco, and Firearms standards for explosive storage. Non-explosive stability testing would be permitted at any time to determine snowpack stability. Following non-explosive stability testing, weather condition assessment and snowpack analysis the decision would be made whether to use explosives for hazard mitigation in avalanche prone areas.

Avalanche hazard conditions result from a combination of these weather and snowpack conditions typically occurring between December and April. Explosive use would be permitted when these conditions (Table 2-2) create high avalanche hazard in the defined avalanche paths. These conditions are derived from the *Draft BNSF Snow Blasting Operations Plan* prepared by Ted Steiner, BNSF Avalanche Safety Director (ASD). The conditions are indicative of potential avalanche hazard; however, they do not necessarily indicate instability or require the use of explosives for hazard reduction. While this table establishes conditions under which explosives may be warranted for avalanche hazard reduction, it is not a decision making tool. It would be the responsibility of the BNSF Avalanche Safety Director to determine when conditions exist that warrant the use of explosives and to describe those conditions, in writing, when making a request for explosives use. The NPS does not have the expertise to determine when unsafe conditions exist along the railroad tracks, nor should the NPS, for liability reasons, be responsible for deciding when the railroad tracks are safe to use.

Table 2-2. Weather and snowpack conditions under which explosive use may be warranted.

Explosive Use Conditions
If a combination of the following conditions exist or develop and weather forecast conditions are anticipated to continue or increase the avalanche hazard, explosive use may be considered. Not all conditions below must be present for explosives to be considered.
Snowpack • Evidence of natural avalanche activity • 9 inches of snow water equivalent (SWE) at Pike Creek Snotel site • Snow cover over 2/3 of vegetative and rock anchors in avalanche paths above the tracks
Stability Tests • Starting zone snowpack stability tests resulting in Easy to Moderate failures using Compression Test or Rutschblock Test • Stability test failures resulting in Q-1 or Q-2 shear quality
Starting Zone Profile Snowpack Structure • Stability test shear plane having 1 step or greater hand hardness difference between layers • Grain size difference in stability test fracture plane ≥ 1.0 millimeters • Presence of persistent weak layers (surface hoar/ facets/ depth hoar) • Weak layer thickness ≤ 10 centimeters
Forecasted Weather **Precipitation** • 1.5 inches SWE or greater gain or predicted gain at Pike Creek Snotel Site in 24 hours • 2.5 inches of SWE or greater gain or predicted gain at Pike Creek Snotel Site in 72 hours • 0.25 inches of measurable rain recorded or predicted at Pike Creek Snotel Site in 24 hours **Wind** • 24 hour average windspeed of or forecast to be 12-15 miles per hour or greater **Temperature** • Temperatures rising or forecast to rise rapidly from negative to positive Fahrenheit digits

Figure 2-1 Handcharge
Photo Steve Abrocrombie/The Daily

Hand delivered charges would be thrown into a starting zone by trained personnel. The hand charges would be delivered by people who ski along an avalanche path and drop a charge into a start zone. Time constraints, avalanche safety concerns, and energy expenditure are limitations of hand charge delivery. Hand charge delivery personnel would have to determine a travel path to the starting zone that does not disturb wildlife.

The Avalauncher is a pneumatic cannon that would propels 1 kg cast primer explosives into low and mid-elevation (<~5500 feet) avalanche start zones. The Avalauncher is a portable device that would be transported and shot from US Highway 2. Wind can greatly affect the accuracy and range of the propelled charge. The Avalauncher cannot be shot from the railroad right-of-way, as the angle of fire is too high. Firing from the highway would provide avalanche personnel a lower trajectory allowing for more successful targeting of low and mid-elevation start zones.

High elevation start zones over 5500 feet could only be treated by three methods under this alternative; helicopter delivery, blaster box delivery, and Avalhex system explosions. Helicopter explosive delivery involves flying low over starting zones while personnel drop a 1, 2, 3 or 4 kg cast primer hand charge on a targeted starting zone. A helicopter would be used for avalanche hazard mitigation. Cast primer explosives would be used for helicopter delivery and blaster box delivery. Ammonium nitrate and fuel oil (ANFO), an inexpensive explosive mixture of fertilizer and fuel oil, would not be permitted due to the possibility of unexploded ANFO attracting bears or other wildlife. Helicopter flight paths would be a minimum of 50 feet elevation above the start zones for explosive work. Procedurally, the helicopter would monitor the effectiveness of the explosives from a considerable distance and would avoid hovering over adjacent forested areas that may contain sheltering wildlife. Helicopter delivery is limited by inclement weather, which often accompanies typical avalanche cycles. When the use of a helicopter is required for explosive work, a flight path to and from the project area would be as direct as possible avoiding known and active raptor nesting areas.

Figure 2-2 Blaster Box
Photo Avalanche Guard

Blaster boxes may be used for avalanche hazard reduction in high elevation start zones. This equipment would be placed in predetermined start zone locations before the winter months. The blaster box explosive delivery system would involve the fixed installation of 20-25 foot high metal towers with metal boxes that house explosives. The tower would be bolted to a 5-foot square concrete pad poured on flat bedrock. These towers and pads would be removed from the starting zones after the 10-year period of explosive use. The blaster box delivers 3 kg, biodegradable cast primer charges. The boxes would be remotely activated with radio signals. BNSF personnel would preload the blaster boxes with explosives in the fall before the avalanche season (November or December) and the unused explosives would be removed from the towers after the avalanche season is over (April or May). BNSF personnel would hike into accessible blaster box locations. If the blaster box tower were in an inaccessible start zone, helicopter use would be permitted by the NPS. Explosive contractors estimate that 3-6 helicopter trips per year are required for loading and maintenance of the blaster boxes. Blaster boxes would have to be secured according to the Bureau of Alcohol, Tobacco and Firearms explosive storage standards. When staff loads explosives into the blaster boxes, the boxes would be sighted on the appropriate fixed target in the starting zone for remote explosive delivery. The blaster box remote control explosive delivery would be initiated by the ASD to hit predetermined start zones. Blaster boxes could be placed to hit starting zones of paths Shed 5, Shed 7, Shed 8, Shed 9, Infinity, Shed 10, Path 1163, Shed 10.7 and Shed 11.

Figure 2-3 Avalhex
Photo Mountain Management

Avalhex type systems could be used for avalanche hazard reduction in high elevation start zones. The Avalhex is a 20-25 foot tower with hydrogen canisters. The ASD would control the explosion by a remote radio link. A mixture of hydrogen gas and air are combined in a balloon and an ignition squib creates an explosion atop the tower. The Avalhex is the only explosive device that does not require the use of explosive charges. Hydrogen gas is non-polluting and the latex balloon fragments are biodegradable (Mountain Management, 2005). Both the blaster box and Avalhex type systems would be flown into the start zones by helicopter and bolted to a 5 by 5 foot concrete pad. The concrete pads would be poured by a special device that transports concrete by helicopter and pours the pad by a funnel hose. The Avalhex towers are removable and would be taken out of the project area after the 10-year period of explosive use is completed. The towers would be painted with natural colored paint to blend into the natural surroundings.

Both the blaster box and Avalhex type systems would require placement on concrete for optimal efficiency of blast effects. The Avalhex-type systems would require approximately 14-21 towers for the project area depending on the combination of other avalanche hazard reduction methods. There would be approximately 13 blaster boxes installed in start zones to cover the project area. Blaster boxes have had occasional technical problems and Avalhex type systems have not been used in the United States. Both systems have security issues related to explosives and would have to be secured against vandalism. While these systems have not been fully proven, they are being included in this analysis to provide more options for BNSF.

Hand, Avalauncher, and helicopter delivery methods use 1-4 kg cast primer charges equipped with reflector chip locator (RECCO) technology, for unexploded ordnance recovery. Blaster boxes use biodegradable 3-4 kg cast primer charges with RECCO technology. BNSF avalanche safety staff can recover duds with RECCO technology tracking devices. Unexploded charges may remain in the explosive use area until spring as snow conditions and depth may be too hazardous for immediate dud recovery. Every effort would be made to recover unexploded charges as quickly as possible. The Avalhex type systems do not produce duds.

Explosive use would follow a safety plan that would be prepared by the BNSF Avalanche Safety Director (ASD) following the EIS process. Detailed reports and logs concerning explosive use would be kept by the ASD according to the safety plan. Information in these logs would be provided to the NPS, USFS, and MDT. All dud charges would be recorded and removed by BNSF personnel. The area would be signed and closed to public use until the dud was recovered. Table C-1 in Appendix C displays the number of anticipated explosive use charges that would be used per avalanche cycle in the project in this alternative. The amount of explosives that could be used is based on avalanche history and the number of times avalanche cycles may have occurred over the last 29 years. The amount of avalanche cycles has an historic average of 2-3 times a year with the most being 5 avalanche cycles per year (Blase Reardon, USGS personal communication). According to this information, explosive use could range from no explosives during years of little avalanche activity, 110-165 explosives on average, and up to 275 explosives during a winter having the greatest amount of historic avalanche activity (See Appendix B).

The Avalauncher and blaster boxes would require the use of practice rounds and start zone target sighting prior to formal emergency use as the range, accuracy, and explosive charge delivery depend on initial testing and operator familiarity with the specific unit. This type of testing would be permitted in avalanche paths within the Park. Training for how to use specific equipment would occur outside the Park and the Forest.

It is important to note that the success of explosives is dependent on snow instability throughout the avalanche path and explosive use timing. A degree of uncertainty occurs with explosive use. Snow in the starting zones may not be as unstable as lower elevation snow. Dry, brittle snow that is triggered in starting zones may mix with wet snow lower in the avalanche path and slow, creating a small magnitude avalanche. Wet snow conditions in the start zones may be difficult to trigger with explosives if the snow cohesion is strong. The ideal condition for personnel to conduct avalanche hazard reduction is unstable, brittle snow in the start zones that fractures easily when explosives are used. This type of avalanche entrains snow in the avalanche track and debris runs into the runout zone removing snow along the entire path effectively removing the avalanche hazard. The success of explosive use depends on snow stability assessment. There is a measure of fallibility with explosive use in hazard reduction. Equipment can malfunction and snow can have different degrees of instability.

Under this alternative, explosive use would only be permitted for a period of up to 10-years. The projected use of explosives would be decreased each year as BNSF completes snowshed construction. NPS personnel would directly monitor the use of explosives and determine the success of the avalanche hazard reduction program.

Railroad and Highway Travel Delays

Trains would be delayed until the avalanche risk is reduced and/or until avalanche debris is removed. According to BNSF, railroad closures would occur when avalanche danger is high, explosive triggering is underway, or avalanche debris is across the tracks. High avalanche danger is defined by snow instability, natural avalanche activity, and weather conditions causing instability and natural avalanche activity. Amtrak passengers would be bussed around John F. Stevens Canyon if necessary. MDT would pre-approve a BNSF plan concerning the cooperative closure of US Highway 2. US Highway 2 would be closed during periods of BNSF explosive use over the permitted 10 years. The highway would be closed from reference post 185-191 and swept for motorists prior to explosive use. MDT would maintain control over highway closures and would oversee all operations along the highway. BNSF would be responsible for clearing any avalanche debris that crosses the highway due to explosive use. BNSF would also be responsible for repairing damage caused by artificially triggered avalanches on US Highway 2. The US Highway 2 closure would prevent recreational use of the area during closure periods. A recreational closure of the immediate project area from the highway to the ridgeline would be in effect during explosive use. If a dud resulted the closure would be extended it could be removed. Highway and railroad delays may last up to 48 hours at a time depending on explosive methods used and the frequency could be up to five times or more per year with an average number of two. Blaster box or Avalhex type system use may substantially decrease the amount of time the highway is closed as avalanches could be triggered remotely in different paths in a very short amount of time. Helicopter use would allow many paths to be treated over a short period, although inclement weather that typically coincides with avalanche activity may hinder helicopter use.

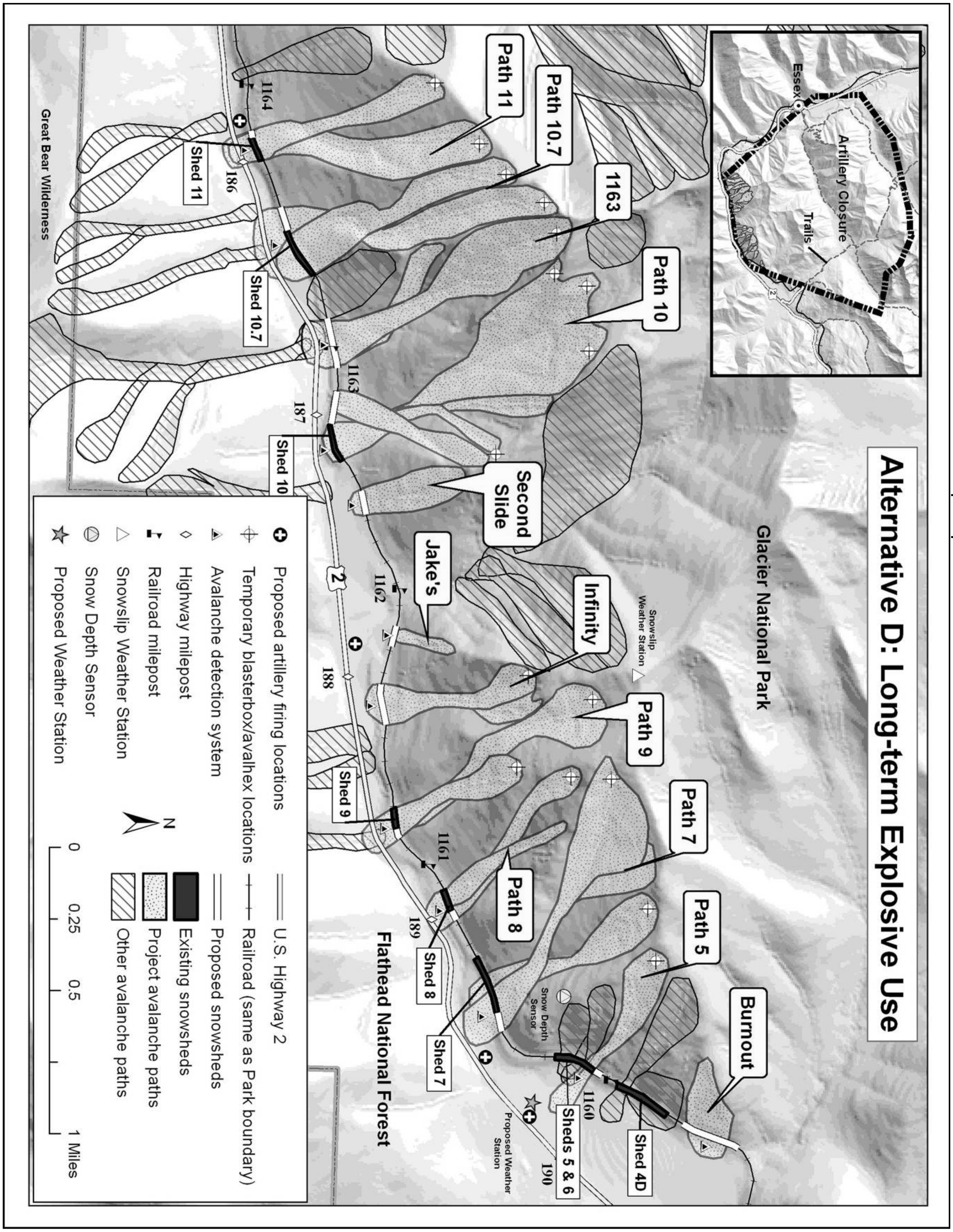
ALTERNATIVE D (BNSF PROPOSAL)

The NPS would issue a special use permit to BNSF for an ongoing explosive avalanche hazard reduction program. BNSF would continue avalanche monitoring, forecasting, and detection system use.

This alternative is the proposal submitted by BNSF. Some elements of it have been added by the NPS because they were not addressed in the submitted BNSF proposal. Alternative D would permit an annual, on-going avalanche hazard reduction program using several types of explosive methods. The annual limit of explosive use would be for three avalanche hazard events. BNSF may request additional permission from the NPS to use explosives if weather conditions require mitigation more than three times in one year. The methods of explosive delivery permitted would be hand, helicopter, Avalauncher, blaster boxes, Avalhex type systems, and military artillery. This alternative would lower the avalanche risk in the area (Hamre and Overcast, 2004). Permanent structures that would be permitted under this alternative are detection systems, weather station, 4 asphalt artillery firing pads, construction of 700 feet of artillery pad access roads, snow depth sensor, Avalhex type systems and/or blaster boxes. Blaster boxes, Avalhex type systems, and the snow depth sensor would be permanent structures on GNP lands. The weather station would be a permanent structure on NFS land. The avalanche hazard reduction program would be coordinated between the NPS, USFS, MDT and BNSF and would be monitored and rated annually for effectiveness and resource impacts. BNSF would be responsible for funding all infrastructure, monitoring, and explosive use operations. Map 2-4 depicts the action items of Alternative D. BNSF would reimburse agencies for all operational costs associated with the program.

Tables 2-1, 2-3, and 2-4 provide a comparative explanation of action items for each alternative. The following avalanche hazard mitigation methods would be used under this alternative:

- BNSF would be issued a permit to use military artillery, hand charges, Avalauncher, helicopter delivery, blaster boxes, and/or Avalhex type systems for a permanent annual program of avalanche hazard reduction in all 12 of the avalanche paths.



Map 2-4. Actions under Alternative D.

- BNSF would be issued a permit to use all of the above methods up to 3 times per year as snow and weather conditions reach the thresholds defined in Table 2-1. BNSF may request permission to use explosives more than 3 times if additional avalanche hazards arise.
- BNSF would seek a permit from MDT to construct up to 4 asphalt artillery firing pads off the US Highway 2 ROW for artillery use. Access roads for these firing pads would be approximately 700 feet long in total.
- BNSF would be permitted to conduct practice sighting and firing of military artillery, blaster boxes, and Avalauncher on park lands.
- Avalanche signal wire would continue to be used in avalanche paths without snowsheds or in snowshed bypass areas.
- BNSF would build extensions on Shed 7 (150 feet) and Shed 9 (100 feet).
- Avalanche detection systems such as infrasonic sensors, geophones and/or Doppler radar could be installed on BNSF right-of-way land.
- BNSF avalanche forecasters would monitor avalanche conditions and make specific action recommendations depending on hazards in specific avalanche paths.
- BNSF avalanche forecasters would monitor and report on the effectiveness of explosive control during the program. The monitoring would be conducted according to the standardized guidelines published by the American Avalanche Association in *Snow, Weather, Avalanches: Observational guidelines for avalanche programs in the United States*.
- A new weather station at elevation 4,600 feet would be installed at milepost 189.8 on NFS land.
- A snow depth sensor would be installed on NPS land at elevation 5600 feet on the ridge between Shed 7 and Shed 6 avalanche paths.
- Snowslip Weather Station and Pike Creek Snotel would be used for forecasting and avalanche hazard determination. The Snowslip Weather Station would become permanent.
- BNSF would temporarily stop or delay train traffic in the John F. Stevens Canyon area when avalanche danger is high, explosives are used, or avalanche debris crosses the tracks
- The NPS, USFS, and BNSF would review the avalanche program annually to discuss effectiveness and new environmental concerns from explosive use.
- US Highway 2 would be temporarily closed during explosive use to prevent vehicles from being hit by triggered avalanches. High avalanche danger is defined by snow instability, natural avalanche activity, and weather conditions causing instability and natural avalanche activity.
- The project area and a buffer zone of 7 miles from the highway north (Map 2-4), including Ole Creek, Fielding Creek and Autumn Creek would be closed to recreational use during from mid-December through March for pre-season practice with of explosive equipment. The restrictive closure would be in effect during the whole season because of the potential for unexploded ordinance to be in the area until located and removed.

Snowsheds

BNSF would build extensions on Shed 7 (150 feet) and Shed 9 (100 feet) as recommended in the *Avalanche Risk Analysis John F. Stevens Canyon, Essex, Montana* (Hamre and Overcast 2004). Shed 7 would be built as it has the highest avalanche risk. Shed 9 would be built as the high elevation start zones are difficult to reach with artillery, although the blaster boxes or Avalhex type systems may be placed in Shed 9 avalanche path instead of snowshed extension construction.

Avalanche Detection System

Avalanche detection systems could be maintained or installed in the same location and manner as in Alternative B. BNSF could continue to maintain the existing signal wire detection system, although technology is rapidly advancing in avalanche detection. Current detection technology would not provide enough time for a train to stop before hitting the avalanche even if the equipment were placed in starting zones. Detection technology would be used in combination with forecasting to determine avalanche risk and hazard along the length of track in the project area by warning BNSF personnel when avalanche debris hits the tracks. The technology below would provide additional avalanche safety for the railroad.

BNSF could install and use more advanced infrasonic detection system, Doppler radar, and/or geophone avalanche detection technology. The infrasonic system detects infrasonic sound waves under the snowpack with a temporary array of small metal boxes affixed to lengths of hose placed on the ground before snowfall. This system would involve a solar or regular electric source and a computer data processing unit. All of the equipment would be on the ROW or in the runout zones on NFS lands. Doppler radar would require fixed equipment just outside of the runout zone on ROW land. The Doppler radar sensor, solar panel, and remote transmitter would be fixed on a 15-20 foot tower. Geophone vibration sensing technology would require fixed structures on BNSF ROW land. The geophone instruments would be set in the ground in a two-foot square area along the edge of the avalanche path on the right-of-way. The geophones would be connected to the Doppler radar tower for power and radio transmission. This equipment would employ a remote system to activate alarms in BNSF vehicles and trains. Currently, geophones cannot be used in an environment that has vibration noise from a non-avalanche source such as trains. If the technology improves to allow use of this device with trains, the instruments may be installed. This equipment would only detect avalanches in those paths where it was installed. Remote cameras or continuous video may be installed along the ROW to differentiate false alarms from actual avalanche activity. Visual devices would only be effective during daylight hours.

Avalanche Forecasting

Avalanche forecasting would be the same as described in Alternative B. Avalanche forecasting would be an integral part of this alternative as instability leading to explosive use would be dependent on detailed avalanche forecasting techniques.

BNSF avalanche forecasters would continue to provide specific, local avalanche hazard information for the railroad. Weather patterns would be observed and risk assessed during predictable pre-avalanche conditions. Conditions observed would include type and amount of snow precipitation, temperature, wind, snow water equivalent, relative humidity, barometric pressure, and weather trends. Snowpack analysis for weak layers may be used to determine failure planes within the snowpack. *Rutschblock* tests, ski cutting, compression tests, tilt board tests, shear frame tests, stuff block tests, and shovel shear tests are non-explosive stability testing techniques. Weather data, snowpack stability and avalanche information would be continuously recorded into BNSF logs. BNSF would monitor avalanche paths through direct observation and record natural avalanche activity, and other weather events such as wind scour and deposition patterns.

The USGS weather station on Snowslip Mountain and the Pike Creek Snotel site would continue to provide continuous local weather data to forecasters. This information would be used to determine current snow conditions and avalanche hazard levels. A weather station at a lower elevation (4600 feet) would be installed at reference post 189.8 along US Highway 2 on NFS land. The weather station would be removed during the May to December period. The weather station would be a tripod structure with 6-inch square feet. Weather station stability would be reinforced with rebar lengths driven into the ground. The weather station would be non-obtrusive and painted a natural color to blend into the surroundings. A snow depth sensor would be placed on NPS land at elevation 5600 on the ridge between Shed 6 and Shed 7. The sensor would be a fixed pipe with a perpendicular arm located above the snowpack. The arm has a sonic sensor that measures the snow depth from above the snowpack. The snow depth sensor would have a radio transmitter to send information to forecasters.

The ASD would be responsible for BNSF avalanche safety training for railroad crews and would be present for crew exposure to avalanches. Railroad workers exposed to avalanche conditions would continue to undergo avalanche awareness, safety, and rescue training as part of their duties. Workers in these situations would be equipped with shovels, probes, and avalanche transceivers. Watchers and rescue personnel would be available to reduce the chance of worker injury or fatality due to avalanche.

Explosive Avalanche Hazard Reduction

Under this alternative, the NPS would issue a permit for an on-going program of avalanche hazard reduction using explosive devices up to 3 times per year on Park lands adjacent to the Railroad ROW between US Highway 2 reference posts 185 and 191. Explosive use would only be permitted during daylight hours to mitigate wildlife impacts and direct mortality. If BNSF determined that avalanche hazard was present more than 3 times in a given year, they would request permission of the NPS for additional use of explosives. The NPS would deny or grant the request based on resource impacts. Some of the methods permitted to deliver explosives involve the use of permanent structures on GNP lands. These would be blaster boxes and/or Avalhex type systems located in avalanche starting zones. Other explosive delivery methods that would not involve placing structures on GNP land would include hand charges, helicopter delivery, Avalauncher, and military artillery. Explosive use methods are compared in Table 2-5. The NPS, USFS, MDT and BNSF would cooperate in monitoring the success and efficiency of the avalanche program.

Figure 2-4 105 mm Howitzer
Photo Doug Abromeit

The Avalauncher, hand charges, blaster boxes, Avalhex type systems, and helicopter would be used for avalanche hazard reduction as described in Alternative C. The use of military artillery (105mm howitzer) would be an additional tool for avalanche hazard mitigation. Military ammunition used in artillery leaves shrapnel and unexploded ordnance that is difficult to find. Shrapnel and ammunition may affect Avalhex or blaster box systems if these systems are used in conjunction with artillery. Placement of fixed blaster box or Avalhex structures should be taken into consideration if artillery is used with fixed explosive devices. Both the Avalauncher and 105mm howitzer would be transported by trailer along US Highway 2 and shot from predetermined locations. The Avalauncher and howitzer along with ammunition and explosives would be stored in secure private property locations under guidelines defined by the military and the Bureau of Alcohol, Tobacco, and Firearms. BNSF would construct up to 4 asphalt artillery firing pads, resembling vehicle turnouts, along US Highway 2. The pads would measure approximately 14 feet by 14 feet. A fixed pipe and concrete curbing on the pad would enable BNSF to place the Howitzer in a fixed location to shoot at one or multiple targets. BNSF would be required to shoot into snow and to avoid shooting geological features with military ammunition. Military artillery ammunition does not have dud tracking technology, however, BNSF would be required to make every effort to recover unexploded ordnance as soon as possible after firing. Duds may be in the area for several days, weeks, or months while snow stabilizes or melts enough for the ASD to find them. A closure of the area would remain in effect until the unexploded ordnance was found.

Avalhex type systems could be installed in the starting zones of Shed 5, Shed 7, Shed 8, Shed 9, Infinity, Shed 10, 1163, Shed 10.7, and Shed 11. Blaster boxes may be installed in the starting zones of Shed 7, Shed 8, Shed 9, Infinity, Shed 10, 1163, Shed 10.7, and Shed 11. Blaster boxes and Avalhex type systems may be used separately or together in combination. Military artillery, Avalauncher, or helicopter delivery use may be phased out depending on the success, maintenance, and environmental effects of the Avalhex and/or blaster boxes.

The description of other explosive methods for this alternative is the same as in Alternative C. The estimated frequency of explosive use for this alternative is listed in Appendix C, Table C-1. Military ammunition is used with military artillery. The Avalauncher, hand charges, and blaster box charges are composed of cast primer explosives. The Avalhex explosive mechanism is composed of hydrogen gas and air in a balloon ignited by a detonator.

Railroad and Public Delays

Railroad and public delays would occur under the same conditions as in Alternative C. Under this alternative, MDT may close US Highway approximately 2 to 3 times a year based on historic avalanche hazard frequency. Avalanche hazards reached threshold levels up to 5 times per year once in the past 29 years (Reardon, personal communication 2005). While this level of avalanche hazard is infrequent, it is the worst-case scenario for highway and railroad delays. Under this alternative, the road closures would continue annually whenever the avalanche hazard reached threshold levels. The use of military artillery and Avalauncher could make road and railroad delays longer as the transport, equipment setup, daylight shooting restrictions, and multiple targets may take up to two days.

Table 2-3. In-depth comparison of alternative actions.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Snowsheds	BNSF would maintain 5920 feet of snowsheds.	NPS, USFS and MDT would recommend that BNSF construct 5 new snowsheds (3540 feet total). NPS, USFS and MDT would recommend that BNSF lengthen 7 snowsheds (1500 feet total longer).	BNSF would commit to construct 5 new snowsheds (3540 feet total) and lengthen 7 snowsheds (1500 feet total longer). BNSF commitment to snowshed construction would determine period of permitted explosive use.	BNSF would lengthen 2 snowsheds -Shed 7 (100 feet) and Shed 9 (150 feet).
Avalanche Detection System	BNSF would maintain 4580 feet of avalanche signal wire	BNSF would use 4580 feet of existing signal wire until snowsheds are built then remove unnecessary wire BNSF may install Doppler Radar or Geophones for avalanche detection on right-of-way land.	BNSF would use 4580 feet of existing signal wire until snowsheds are built then remove unnecessary wire BNSF may install Doppler Radar or Geophones for avalanche detection on right-of-way land. BNSF would install the Avalanche Sentry system for avalanche program assessment.	BNSF would remove 100 feet of signal wire from Shed 7 BNSF would use 4480 feet of existing signal wire BNSF may install infrasonic detection systems, Doppler Radar or Geophones for avalanche detection on right-of-way land.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Resource Monitoring Program	No monitoring or assessment program.	No monitoring or assessment program.	Extensive resource monitoring and assessment program with changes in explosive use if monitoring shows impact levels beyond the EIS. Resources monitored would include wildlife, noise, water, soils, vegetation, and avalanche processes. Inter-agency team would be established for monitoring and assessment.	Extensive resource monitoring program initiated. If resource impacts are causing impairment program may be modified, restricted, or stopped.
Avalanche Forecasting	The BNSF Avalanche Safety Director would use weather data from Snowslip weather station and Pike Creek Snotel and non-explosive stability testing to determine avalanche danger	The BNSF Avalanche Safety Director would use weather data from Snowslip weather station and Pike Creek Snotel and non-explosive stability testing to determine avalanche danger BNSF would construct a new weather station at milepost 189.8 on NFS land. BNSF would install a precipitation gauge on NPS land at elevation 5600 feet.	The BNSF Avalanche Safety Director would use weather data from Snowslip weather station and Pike Creek Snotel and non-explosive stability testing to determine avalanche danger BNSF would construct a new weather station at milepost 189.8 on NFS land. BNSF would install a precipitation gauge on NPS land at elevation 5600 feet.	The BNSF Avalanche Safety Director would use weather data from Snowslip weather station and Pike Creek Snotel and non-explosive stability testing to determine avalanche danger BNSF would construct a new weather station at milepost 189.8 on NFS land. BNSF would install a precipitation gauge on NPS land at elevation 5600 feet.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Explosive Avalanche Hazard Reduction	The NPS would not permit explosive use in the Park.	The NPS would not permit explosive use in the Park.	BNSF would be permitted to use hand charges, helicopter delivery, and the Avalauncher on Burn Out, Jakes, and Second Slide. BNSF would be permitted to use Avalhex systems, blaster boxes, or helicopter delivery for stability testing and avalanche hazard reduction in Shed 5, Shed 7, Shed 8, Shed 9, Infinity, Shed 10, Path 1163, Shed 10.7 and Shed 11. BNSF would only be able to use explosives for avalanche hazard reduction for up to a 10-year period BNSF would develop an avalanche safety operations plan. NPS and USFS would review and monitor program.	BNSF would be permitted to use multiple explosive delivery methods (hand charges, Avalauncher, blaster boxes, Avalhex systems, helicopter, and military artillery) for stability testing and avalanche hazard mitigation in 12 avalanche paths. BNSF would be permitted to use explosives for up to three events per year. If a more than 3 avalanche cycles occur in a year, BNSF may request additional approval for more explosive use. A continuous program of explosive avalanche hazard reduction would be permitted by the NPS. BNSF would develop an avalanche safety operations plans. NPS and USFS would review and monitor program.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Closures/Delays	BNSF would delay trains during high avalanche hazard periods (may be days). Amtrak passengers would be bussed around John F. Stevens Canyon during delay periods.	After snowsheds are constructed, delays are not expected to occur BNSF would delay trains during high avalanche hazard periods (delay may be up to 96 hours for natural stability to occur) until snowsheds are built. Amtrak passengers would be bussed around John F. Stevens Canyon during delay periods until snowsheds are built.	BNSF would delay trains during high avalanche hazard periods (closure may be up to 48 hours per cycle) until snowsheds are built. Up to 5 avalanche cycles per year may occur with an average of 2 cycles per year. After snowshed construction, delays are not expected to occur. BNSF would delay trains during explosive use (delays may be up to 36 hours for one avalanche cycle). Explosive use would be permitted for up to 10-years. Amtrak passengers would be bussed around John F. Stevens Canyon until snowsheds are built during delay periods. After snowsheds are constructed, rerouting Amtrak passengers is not expected to occur. MDT would close US Highway 2 during explosive use during the 10-year period for up to 48 hours at a time. The area would be closed to recreation during explosive use.	BNSF would delay trains during high avalanche hazard, explosive use, or until debris is cleared from track and risk is reduced (each delay period would be up to 36 hours). Amtrak passengers would be bussed around John F. Stevens Canyon during delay periods until railroad opens again. MDT would close US Highway 2 during explosive use and avalanche debris cleanup (each closure period may be up to 36 hours). The area and a 7-mile buffer zone of recreational trail use north of the area would be closed during explosive use.

Table 2-4. Avalanche path treatment comparison by alternative.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Burn Out (4C) **Frequency 2 years**	No snowshed.	BNSF could build a new 900-foot snowshed. BNSF could install Doppler Radar and Geophone infrasonic detection system. BNSF could install infrasonic detection type systems, Doppler radar and/or geophone avalanche detection systems.	BNSF would build a new 900-foot snowshed. BNSF would use: Hand charges Helicopter delivery Avalauncher (for up to 10-years or until snowshed is built). BNSF would install infrasonic detection type systems, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Hand charges Helicopter delivery Avalauncher BNSF could install infrasonic detection type systems, Doppler radar and/or geophone avalanche detection systems.
Shed 5 **Frequency 20 years**	BNSF would maintain 380-foot snowshed.	BNSF could lengthen snowshed 100 feet. BNSF could install infrasonic detection type system, Doppler Radar and/or geophone avalanche detection system.	BNSF would lengthen snowshed 100 feet. BNSF would use: Helicopter delivery Avalauncher Avalhex Blaster Box (for up to 10 years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Avalauncher Helicopter delivery Avalauncher Avalhex Blaster Box Military Artillery BNSF could install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Shed 7 **Frequency 3 years**	BNSF would maintain 1000-foot snowshed.	BNSF could lengthen snowshed 150 feet. BNSF could install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would lengthen snowshed 150 feet. BNSF would use: Helicopter delivery Avalhex Blaster box (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection system.	BNSF would lengthen snowshed 150 feet. BNSF would use: (until snowshed is lengthened) Helicopter delivery Avalhex Blaster box Military Artillery BNSF could install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.
Shed 8 **Frequency 20 years**	BNSF would maintain 650-foot snowshed.	BNSF could lengthen snowshed 100 feet. BNSF could install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would lengthen snowshed 100 feet. BNSF would use: Helicopter delivery Avalhex Blaster box (for up to 10 years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Helicopter delivery Avalhex Blaster box Military artillery BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Shed 9 **Frequency 10-years**	BNSF would maintain 400-foot snowshed.	BNSF could lengthen snowshed 100 feet. BNSF could install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would lengthen snowshed 100 feet. BNSF would use: Helicopter delivery Avalhex Blaster box (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would lengthen snowshed 100 feet. BNSF would use: Military Artillery Helicopter delivery Avalhex Blaster box BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.
Infinity **Frequency 10-years**	No snowshed.	BNSF would build new 400-foot snowshed. BNSF would install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would build new 400-foot snowshed. BNSF would use: Helicopter delivery Avalauncher Avalhex Blaster box (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Military Artillery Helicopter delivery Avalauncher Avalhex Blaster box BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Jakes **Frequency 3 years**	No snowshed.	BNSF would build new 600-foot snowshed. BNSF would install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would build new 600-foot snowshed. BNSF could use: Hand Charges Helicopter delivery Avalauncher (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Hand charges Helicopter Delivery Avalauncher Military artillery BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.
Second Slide **Frequency 3 years**	No snowshed	BNSF would build new 440-foot snowshed. BNSF would install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF could build new 440-foot snowshed. BNSF could use: Hand charges Helicopter delivery Avalauncher (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Hand charges Helicopter delivery Avalauncher Military artillery BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Shed 10 **Frequency 10-years**	BNSF would maintain 500 foot snowshed	BNSF would lengthen snowshed 350 feet. BNSF would install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would lengthen snowshed 350 feet. BNSF would use: Helicopter delivery Avalauncher Avalhex Blaster box (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Military Artillery Avalauncher Helicopter delivery Avalhex Blaster box BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.
1163 **Frequency 5 years**	No snowshed	BNSF would build new 1200-foot snowshed. BNSF would install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would build new 1200-foot snowshed. BNSF would use: Helicopter delivery Avalhex Blaster box (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Military Artillery Helicopter delivery Avalhex Blaster box BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.

	Alternative A: No action	Alternative B: Snowshed construction w/ no explosive use (Preferred)	Alternative C: Up to 10-Year, limited use of explosives	Alternative D: Continuous explosive avalanche control program (BNSF Proposal)
Shed 10.7 **Frequency 10-years**	BNSF would maintain 670-foot snowshed.	BNSF would lengthen snowshed 550 feet. BNSF would install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would lengthen snowshed 550 feet BNSF would use: Helicopter delivery Avalauncher Avalhex Blaster Box (for up to 10-years or until snowshed is built BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Military artillery Helicopter delivery Avalhex Blaster boxes BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.
Shed 11 **Frequency 20 years**	BNSF would maintain 400-foot snowshed.	BNSF would lengthen snowshed 150 feet. BNSF would install infrasonic detection type system, Doppler Radar and/or Geophone Avalanche Detection System.	BNSF would lengthen snowshed 150 feet. BNSF would use: Helicopter delivery Avalauncher Avalhex Blaster box (for up to 10-years or until snowshed is built) BNSF would install infrasonic detection type system, and they could install Doppler radar and/or geophone avalanche detection systems.	BNSF would use: Military Artillery Helicopter delivery Avalauncher Avalhexes Blaster box BNSF would install infrasonic detection type system, Doppler radar and/or geophone avalanche detection systems.

Table 2-5. Alternative C and D explosive use method comparison.

Explosive Delivery Method	Type of Explosive	Decibel Level (dBC) Range	Limitations /Issues	Benefits
Hand Charges	1 Kg cast primer explosive	250’ distance= 65dBC 1000’=143dBC	▪ Not a method that can be used in high elevation or mid-elevation start zones. ▪ Safety issues with employees skiing into avalanche zones ▪ Not practical in most instances with avalanche hazard and time constraints ▪ Small amount of residue from explosives ▪ Duds possible- need RECCO chip for retrieval ▪ Dud retrieval may be necessary	▪ No explosive delivery method needed except willing and trained skiers ▪ Mostly used on low start zones ▪ One starting zone detonation ▪ Explosive delivery person can see target and resulting slides

Explosive Delivery Method	Type of Explosive	Decibel Level (dBC) Range	Limitations /Issues	Benefits
Avalauncher	1 Kg cast primer explosive	250' distance= 65 dBC 1000' distance=143.0 dBC	▪ Will not reach high elevation start zones ▪ Wind affects trajectory ▪ Targets are difficult to reach during inclement weather affecting charge aerodynamics ▪ Small amount of residue from explosives ▪ If visibility is poor it is difficult to see results of explosive use ▪ If the charge does not hit head on, the resulting dud can remain armed and will need to be destroyed in place ▪ Duds possible- need RECCO chip for retrieval	▪ Pneumatic gun without a propellant explosion ▪ Portable and able to hit most starting zones from the railroad ▪ Charge cases are mostly consumed by the explosion, except for plastic tailfin assemblies and backing plate. ▪ Can hit low to mid range starting zones ▪ One explosion in starting zone
Helicopter Delivery	3 kg cast primer explosives	250' distance= 97 dB	▪ Helicopter noise (70dB at 500 feet above ground), movement, and visibility disturbs wildlife over the whole flight path ▪ Weather and visibility limited- not able to fly in bad weather ▪ Small amount of residue from explosives ▪ Duds possible- need RECCO chip ▪ Dud retrieval may be necessary	▪ Can fly between high elevation start zones and perform explosive drops quickly ▪ Can observe avalanche activity and success from the air ▪ One explosion in starting zone

Explosive Delivery Method	Type of Explosive	Decibel Level (dBC) Range	Limitations /Issues	Benefits
Avalhex	Hydrogen/Oxygen explosion	260’= 146.07 dBC 518’= 140.0 dBC 1,036’= 134.0 dBC	▪ Fixed towers within recommended wilderness ▪ May harden snow around base of tower, causing the unit to be ineffective in immediate start zone ▪ Helicopter trips necessary for maintenance and installation ▪ If visibility is poor it is difficult to see results of explosive use ▪ Not proven technology ▪ Explosive squib not certified by Bureau of Alcohol, Tobacco and Firearms ▪ Can only target one start zone per tower	▪ High elevation start zone can be targeted ▪ Can be controlled remotely and impact start zones multiple times. ▪ No explosive residue- balloons are biodegradable ▪ No duds ▪ One explosion in starting zone ▪ Can be used in poor visibility/weather

Explosive Delivery Method	Type of Explosive	Decibel Level (dBC) Range	Limitations /Issues	Benefits
Blaster Box	3 kg cast primer explosives	250' distance= 97 dB	▪ Fixed towers within recommended wilderness. ▪ Two explosions in start zones (propellant charge and detonation of explosive) ▪ Problems with remote door opening after ice riming ▪ Users say it is 60% effective ▪ Needs helicopter servicing several times a year ▪ Charges are unsecured in a start zone ▪ If visibility is poor it is difficult to see results of explosive use ▪ Small amount of residue from explosives ▪ Duds are possible- need RECCO chip ▪ Dud retrieval may be necessary ▪ Avalanche personnel may not know the charge did not explode if triggered remotely.	▪ Can be used in high altitude start zones ▪ Can be controlled remotely ▪ Can impact several starting zones with multiple directional shots from one tower ▪ Charge cases are biodegradable ▪ Can be used in poor visibility/weather

Explosive Delivery Method	Type of Explosive	Decibel Level (dBC) Range	Limitations /Issues	Benefits
105 Howitzer (Alternative D only)	Ammunition for 105 (2.8 kg explosive)	Detonation from 250' distance= 92 dBC 1000'=130.5 dBC Firing propellant from 1200' distance= 90 dBC	▪ Storage, transfer and use of artillery and ammunition regulated with security issues ▪ Ammunition duds and retrieval, by military demolition team. ▪ Pre-season target sighting necessary (one time should be sufficient) ▪ Permanent recreational/public use closure of area (could be seasonal, but if duds are noted, then year round) ▪ If visibility is poor it is difficult to see results of explosive use ▪ Artillery pads and access roads must be constructed off main highway on USFS lands ▪ Two noise events, one from firing and the second from detonation in target area- explosion at firing pad and explosion in starting zone. ▪ Ammunition is anti-personnel and leaves shrapnel in start zones after explosion occurs- shrapnel is comprised of small pieces of metal scattered over a large area from detonation ▪ Potential for overshoot.	▪ Quickly targets high elevation start zones as unit is portable ▪ Would eliminate need for most of the other methods except on Burnout Path ▪ Can be used in poor visibility/weather

ALTERNATIVES CONSIDERED BUT ELIMINATED FROM FURTHER ANALYSIS

A variety of concepts and specific ideas for avalanche hazard reduction were examined during the preparation of this document. Most of these solutions are or have been employed in mountainous areas in Europe, Canada and to a lesser extent in the United States. The following actions were dismissed from further detailed analysis for the reasons given below. These ideas and concepts arose during research for this project and from scoping.

PASSIVE STRUCTURES

Passive structures installed in the starting zones, avalanche path, and runout zones are designed to reduce the frequency and magnitude of avalanches. The passive structures discussed below were considered for avalanche hazard reduction in the project area. The small reduction in the overall avalanche hazard index would not justify the amount of impact that installation of the structures would have on Park and Forest resources.

Snow Fences, Vortex Generators, and Jet Roofs/Blower Fences

Snowfences are installed upwind of ridges and points that have windloading and cornice buildup. They change the wind flow and redistribute snow upwind of a ridgeline in areas where the prevailing winds are consistent. Snowfences do not work where winds are generated from varying directions or on steep ridges where snow cannot build up behind the fence.

Vortex generators, jet roofs, and blower fences are large, angled roofs that increase wind velocity on ridges and redistribute snow. These structures are used for preventing the formation of cornices in starting zones.

Data from the USFS Snowslip weather station show remarkably consistent wind direction throughout the winter. Winds blow almost entirely from the SW-W except during arctic outbreaks, when wind direction switches to the east. Wind speeds during these arctic events are quite low. The consistent wind direction means that snow fences etc could be effective; however, they would do little to reduce the hazards from avalanches in this area. The conditions in the canyon are heavy snowfall followed by rapid warming or rains, no wind slabs, which typically result in the avalanche events that disrupt train traffic in the corridor. Though wind loading can add to the amount of snow in the start zones, the principal factor is precipitation. When a primarily wind slab-related hazard exists, it is generally localized and does not typically result in widespread disruptions to traffic in the corridor. (Pers. Comm. Blase Reardon June 16, 2006)

Terraces

Terraces were considered for starting zones within the Park. Horizontal terraces are constructed parallel to the slope in a stair-step fashion along a mountainside. The theory behind horizontal terracing is the flat terrace acts to disperse avalanche energy by retarding initial avalanche release and/or slowing and eventually stopping the flow of an avalanche within the track. Horizontal terracing of the starting zones is only effective under specific conditions. The starting zones must have a slope angle of less than 35 degrees for these structures to be effective and mitigate avalanche hazard. Only two of the 12 avalanche paths have a starting zone angle less than 35 degrees. Overall snow depth must be less than 5 feet deep for the terraces to be effective. The average snow depth in starting zones in the canyon is greater than 5 feet. This method would not effectively reduce the risk of avalanche hazard because snow depths on average, are deeper than 5 feet. In addition, long-term impacts to vegetation, wildlife movements, viewscapes, and wilderness values would also be considerable.

Supporting Structures/Flow Retarders

These structures were considered for installation on steep mountainsides within the Park. Steel frame structures with nets or steel braces are fixed to the slope providing an anchor and stop avalanches from gaining momentum. These structures are installed in groups of long, continuous lines across the full width and length of the starting zone. The structures need to be taller than the maximum expected snow depth to be effective. Limitations for the success of these structures include high cost, deep snow, steep terrain, and unstable soils. These structures would not appreciably reduce the risk of avalanche hazard and impacts to vegetation, wildlife movements, viewscapes, and wilderness values would be considerable.

Deflector Berms, Dikes, Walls

The installation of these structures were considered on Park, Forest, and ROW lands in avalanche paths and runout zones. These structures are designed to intercept snow and redirect the avalanche flow into a desired channel. The height of the deflection structure is a function of structure, flow depth of a model avalanche, and speed of a model avalanche. Average heights are from 19 to 39 feet high with a maximum height of 66 feet. The structure should reinforce the physical terrain. The channel on the avalanche side of the deflector should be free of obstacles such as vegetation, rocks, and earth barriers. The structures are built of reinforced earth berms, rock, concrete or steel. These structures would be effective for wet avalanches in the project area; however, powder avalanches could overrun the barrier. Deflector berms, dikes, or walls could be placed above snowsheds to make avalanches run over the snowshed; however, this would only be effective at reducing avalanche hazard to the railroad during wet avalanche events. This method would not effectively mitigate avalanche hazard, as it does not address dry avalanche cycles. Long-term impacts from construction and permanent presence of these structures to vegetation, wildlife movements, viewscapes, and wilderness values would also be considerable.

Mounds/Retarders

The structures would be placed in runout zones on both Park and Forest lands and would cover a large area. A series of large earthen or rock mounds are placed at the head of the runout zone to disperse the energy of avalanches and decrease the runout zone distance. Mounds work best when avalanches are wet and slow moving. Dry avalanches can flow over the structures. The mounds must be tall enough to collect the debris of two or more avalanches. In some avalanche paths, the amount of snow would cause the mounds to be extremely large (over 26 feet). The number of mounds would be determined by modeled magnitude and speed of avalanches in a path and is often difficult to determine. This method would only be applicable to 2 avalanche paths and would not effectively mitigate avalanche hazard over the whole project area. Long-term impacts to vegetation, wildlife habitat, viewscapes, and wilderness values would also be substantial.

Catchment Dams/Containment Walls/Trenches

These structures are constructed perpendicular to avalanche flow in avalanche runout zones on Park and Forest lands. Height and storage capacity limit the effectiveness of these structures. The catchment dams must be large enough to store the debris of 2 or more avalanches over the course of a winter. These structures are successful for small, slow (<10m/s) avalanches or in the runout zones of large avalanches. Most of the avalanches in the project area are large avalanches that travel at high speeds due to starting zone and path steepness. In many of the avalanche paths, the containment structure would have to be on the downhill side of the railroad tracks. The structures would only partially mitigate avalanche hazard and long-term impacts from construction and permanent presence of these structures to vegetation, wildlife movements, viewscapes, and wilderness values would be considerable.

Revegetation

Revegetation in avalanche paths on both FNF and GNP lands is a common and cyclic occurrence. Revegetation is a method for restoration of natural anchor points on a slope. Vegetation increases surface friction allowing slides to occur less frequently. The project area has been burned by natural forest fires and the resulting natural revegetation of avalanche paths has decreased the avalanche hazard in several avalanche paths. The revegetation of avalanche paths is a slow process that is thwarted by natural avalanche processes and Forest fires. Often vegetation is removed by avalanches before it can become effectively established. The extended timeframe of a decade or more for vegetation establishment does not appreciably mitigate avalanche hazard.

Tunnel

One public comment letter suggested that a tunnel alternative be considered. The tunnel would run approximately 7 miles to avoid the hazard area. The tunnel was rejected as an alternative due to high cost, environmental impacts, and ventilation concerns.

The tunnel would have to be bored through Glacier National Park lands. The current NFS right-of-way would be abandoned. The BNSF Railway cost estimate for a twin track, twin bore tunnel would be approximately $2 billion dollars. There would be two cross-connected tunnels for the double track. Test holes to determine the composition and stability of underlying strata would have to be excavated on Park lands. The tunnel would be built with a combination of a boring machine and explosives. Approximately 2.1 million cubic yards of material would be removed from the tunnel and would have to be disposed of in a manner consistent with state and federal regulations. According to BNSF, a complex ventilation system would be required that would involve air intakes along the length of the tunnel and utilize large amounts of energy. Air and escape routes would need to be accessible from any location along the length of the tunnel. A 7-mile long tunnel would take approximately 4 years to build.

The construction of a tunnel under NPS lands would have several direct environmental impacts. The removal of millions of cubic yards of material would result in the exposure of subsurface geology and soils to mineral leaching from water inside the tunnel. Large amounts of explosives for tunnel excavation and boring equipment would temporarily affect sound, water, and air quality. Air intakes for the ventilation system would be permanent structures above the tunnel on Park land that would have to be tall enough to reach above deep snow and would be visible from outside the tunnel. While a tunnel alternative would be the most complete avalanche protection of any of the alternatives, the natural resource impacts and economic costs do not justify further consideration of this option. The recommended snowshed construction would serve the same purpose as a tunnel, use the existing tracks and ROW, and not have the adverse environmental impacts of tunnel construction.

Passive Structure Conclusion

Passive structures are not visually appealing, are extremely expensive, prevent access within the avalanche path, and are inflexible when conditions change. The success of these structures depends largely on the physical characteristics of the installation area. If these physical characteristics change, the structures may not function effectively. The effectiveness of most of these structures is difficult to determine as each avalanche path has unique characteristics that would require different strategies for avalanche hazard reduction. The avalanche paths were examined to determine the possibility of a combination of the passive structures. Each path had limitations that made the use of most of the structures inappropriate.

EXPLOSIVE DELIVERY METHODS

Ropeway Trams

Ropeway trams were considered that would be installed along mountainsides and ridgetops in the Park. These structures operate like chairlifts and incorporate towers and machinery to move the explosive charges up the mountainside to the starting zone. This method of explosive delivery is expensive and has a large associated infrastructure. The distance limit of this type of explosive delivery mechanism is about 3.7 miles. This method of explosive delivery does not reduce the avalanche hazard any more than the methods of delivery in Alternative C and D and the tram would have a greater impact on vegetation, visual resources, and visitor experience than the other explosive methods. The permanent structures would need to be longer than 3.7 miles long and would not effectively mitigate avalanche hazard.

Preplaced Charges

Preplaced charges were considered and would have to be placed before snowfall in the avalanche start zones within the Park. The explosives have a remote triggering device with coded radio signals that can be activated from a distance. The explosions are set off under the snowpack, which is not effective with a deep snowpack. It is difficult to determine how much explosive material is necessary for a given location and varying snow conditions. The charges are subject to tampering or wildlife interference. The charges are subject to the Bureau of Alcohol, Tobacco and Firearms regulations and would not be permitted in an unsecured environment.

Gas Exploders/ GasEx

GasEx type systems are common in Europe, but very few are used in the United States. The systems are fixed in place within starting zones and a large chamber would have to be installed on GNP lands. Gas exploders combine fuel and an oxidant to create a concussive explosion within the chamber. The equipment does not have flexibility in targeting different starting zones for avalanche hazard mitigation. These structures are large, require regular maintenance and are visually intrusive. Specialists have determined that the explosive methods discussed in Alternatives C and D are as effective and more flexible than gas exploders.

Explosive Delivery Conclusion

The explosive delivery methods listed above are not as efficient or user friendly as the explosive methods that are listed in the alternatives. Fixed explosives are not flexible for use in other starting zones. Preplaced charges are subject to explosive storage regulations and would not be permitted in the project area. Gas exploders and rope tramways include large, expensive infrastructure. The explosive delivery methods described in the alternatives provide both flexibility and efficiency compared to the above methods.

ENVIRONMENTALLY PREFERRED ALTERNATIVE

The environmentally preferred alternative is determined by applying the criteria in the National Environmental Policy Act of 1969 (NEPA), which is guided by the Council on Environmental Quality (CEQ). The CEQ provided direction that the environmentally preferable alternative is the alternative that will promote the national environmental policy as expressed in NEPA Section 101:

1. Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
2. Assure for all generations safe, healthful, productive, aesthetically and culturally pleasing surroundings;
3. Attain the widest range of beneficial uses of the environment without degradation, risk of health or safety, or other undesirable and unintended consequences;
4. Preserve important historic, cultural and natural aspects of our nation's heritage and maintain, wherever possible, an environment that supports diversity and variety of individual choice;
5. Achieve a balance between population and resource use that will permit high standards of living and a wide sharing of life's amenities; and
6. Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

The environmentally preferred alternative is based on these national environmental policy goals. A discussion of how each alternative meets or does not meet these goals follows.

Alternative A: No Action

Alternative A fulfills criteria 1, 2, 3, 4, 5 and 6 if the railroad takes precautions and institutes delays during periods of high avalanche activity. A derailment of hazardous materials due to avalanche would cause this alternative to fall short of meeting all of the above criteria. Safety of train passengers and employees would be at risk if no delay action is taken and the railroad remains open during all conditions. If a derailment occurred due to avalanche, the impact to resources and human safety would be major. With this alternative, the criteria may be met inside Glacier National Park; however, the criteria would not be met on the Flathead National Forest where most of the effects from a derailment would occur. The potential for derailments under this alternative is long-term. The integrity of existing historic snowsheds would be maintained achieving criteria 4 under this alternative.

Alternative B: (Environmentally Preferred and Preferred Alternative) Snowsheds with No Explosive Avalanche Hazard Reduction

Alternative B fulfills criteria 1, 2, 3, 5, and 6 during and after snowsheds are modified and new sheds are constructed. This alternative would achieve criteria 4 only if the integrity of historic snowsheds is maintained with snowshed extensions. Once snowsheds are built or modified under this alternative, the tracks would be fully protected through the most dangerous avalanche paths significantly improving safety along the railroad. Human health and safety criteria would be met more efficiently if BNSF begins construction immediately on those snowsheds that have the highest avalanche risk. Human health and safety criteria would improve as more sheds are constructed. This alternative would achieve all of the criteria on Glacier National Park land and Flathead National Forest land because it conserves the park and forest resources for successive generations, assures a safe, healthful, productive, esthetically and culturally pleasing surroundings, and attains the widest range of beneficial uses by protecting BNSF equipment, personnel and freight without causing undesirable or unintended consequences to park and forest resources. It achieves a balance between population and resource use by providing the highest protection of park and forest resources while ultimately protecting BNSF property.

Alternative C: Snowsheds with Temporary Use of Explosives for Avalanche Hazard Reduction

Alternative C eventually achieves criteria 1, 2, 3, 5, and 6 once the snowsheds are constructed. This alternative would achieve criteria 4 only if the integrity of historic snowsheds is maintained. The impacts of explosive use may affect resources over several generations. Human health and safety criteria would be met more efficiently if BNSF prioritizes construction on those snowsheds that have the highest avalanche risk. This alternative would eventually achieve the criteria on Glacier National Park or Flathead National Forest properties once the recommended snowsheds are built and extended. Human health and safety would improve with an interim program of explosive use while snowsheds are built.

Alternative D: Continuous Avalanche Control Program

Alternative D does not achieve any of the criteria. The impacts of a permanent explosive use program would affect park resources over several generations. Avalanche hazard would be lessened and human health and safety criteria improved from the no action alternative. This alternative would not achieve any of the criteria on Glacier National Park or Flathead National Forest lands. It would not fulfill the responsibilities as a trustee of the environment for successive generations due to resource impacts that would occur, it would not assure for all generations a safe, healthful, productive, and esthetically and culturally pleasing surroundings from the reduced winter recreational use of the area and impacts on resources that visitors to the park and forest enjoy. It would not attain the widest range of beneficial uses of the environment because degradation would occur. It would not preserve important historic, cultural and natural aspects of our natural heritage. BNSF would likely allow the sheds to fall into disrepair and eventually remove them. No balance would be achieved between resource use and populations as the park resources would be significantly impacted and would not recover under a permanent explosive use program by BNSF. This alternative would neither achieve or not achieve criteria 6.

COST OF ALTERNATIVES

The following estimates (Table 2-6) include costs that BNSF would incur with each alternative for avalanche hazard mitigation. This information was derived from a socioeconomic analysis performed by the University of Montana, Cooperative Park Studies Unit.

Table 2-6 Comparative annual cost estimate of each alternative. (See Chapter 4- Socioeconomic Section for detailed costs)

	Annual Cost
Alternative A: No Action	$1,039,000-$1,978,000
Alternative B: Snowshed modification and construction	$1,019,000-$5,739,000
Alternative C: 10-year explosive program w/ snowshed modification and construction	$2,543,500-$8,139,200 (first 10 years) $631,000-$5,739,000 (After 10-year period- amortized cost of sheds)
Alternative D: Continuous avalanche hazard mitigation program	$1,304,000-$2,287,400

SUMMARY OF IMPACTS

Table 2-7. Summary of impacts from each alternative on resource topics.

Impact Topic	Alternative A: No Action	Alternative B: Snowshed Construction (Preferred)	Alternative C: 10-Year Use of Explosives	Alternative D: Long-term Explosives Use (BNSF Proposal)
Avalanche Processes	No effect	Negligible, beneficial, site-specific, long-term impact	Major, adverse, site-specific, long-term impact	Major, adverse, long-term, site-specific, impact
Water Resources	Negligible, adverse, site-specific, long-term impact	Minor, adverse, site-specific, long-term impact	Minor, adverse, site-specific, long-term impact	Minor, adverse, site-specific, long-term impact
Aquatic Resources	No effect	Minor, beneficial, localized, long-term impact	Negligible, beneficial, site-specific, long term impact	Negligible, beneficial, site-specific, long term impact

Impact Topic	Alternative A: No Action	Alternative B: Snowshed Construction (Preferred)	Alternative C: 10-Year Use of Explosives	Alternative D: Long-term Explosives Use (BNSF Proposal)
Geology/Soils	No effect	Minor, adverse, site-specific, long-term impact	Minor, adverse, site-specific, long-term impact	Minor to moderate, adverse, site-specific, long-term impact
Vegetation	Minor to moderate, beneficial, localized, and long-term impact	Minor to moderate, adverse, site-specific, short and long-term impact	Minor to moderate, adverse, localized, short and long-term impact	Moderate to major, adverse, localized, short and long-term impact
Wildlife	No effect	Minor to moderate, adverse, site-specific, and short-term to long-term impact	Minor to major, adverse, adverse, site-specific to widespread, and short-term to long-term impact *Significant impact*	Moderate to major, adverse, adverse, site-specific to widespread, and short-term to long-term impact *Significant Impact*
Threatened and Endangered Species	No effect	Negligible to moderate, adverse, site-specific, and short-term to long-term impact	Minor to major, significant, adverse, site-specific to localized, and short-term to long-term impact *Significant impact*	Minor to major, adverse, site-specific to localized, and short-term to long-term impact *Significant Impact*
Air Quality	Negligible, adverse, localized, and long-term impacts	Negligible to major, adverse, site-specific, short-term impact	Negligible to major, adverse, site-specific, short-term impact	Negligible to major, adverse, site-specific, short-term impact
Natural Sound	No effect	Minor, beneficial, site-specific, long-term impact	Major, adverse, short-term, site-specific to localized impact	Major, adverse, long-term, site-specific to localized impact
Historic Buildings and Structures	No effect	Moderate, adverse, long-term, site-specific impact	Moderate, adverse, long-term, site-specific impact	Moderate, adverse, long-term, site-specific impact

Impact Topic	Alternative A: No Action	Alternative B: Snowshed Construction (Preferred)	Alternative C: 10-Year Use of Explosives	Alternative D: Long-term Explosives Use (BNSF Proposal)
Socioeconomics	Minor, adverse, BNSF-specific, and long-term impact	Minor to moderate, adverse, long-term, BNSF-specific impact	Minor to moderate, adverse, BNSF-specific long-term impact	Minor, adverse, BNSF-specific long-term impact
Health and Safety	Negligible to major, adverse or beneficial, site-specific to regional, and short-term or long-term impact	Negligible to major, adverse or beneficial, site-specific to regional and short-term or long-term impact during 10 years of snowshed construction. Beneficial impacts after 10 years.	Negligible to major, adverse or beneficial, site-specific to regional, and short-term or long-term impact during 10 years of snowshed construction. Beneficial impacts after 10 years.	Negligible to major, adverse or beneficial, site-specific to regional, and short-term or long-term impact
Wilderness	No effect	Minor, beneficial, localized long-term impact	Moderate, adverse, localized, and long-term impact	Major, adverse, localized, and long-term impact
Visual Resources	No effect	Moderate, adverse, site-specific, long-term impact	Moderate, adverse, site-specific, long-term impact	Minor, adverse, site-specific, long-term impact
Public Use and Experience	No effect	Negligible, adverse, site-specific, and long-term impact.	Minor to moderate adverse, localized, and long-term impact. Once snowsheds are built, negligible, adverse, site-specific, long-term impact.	Moderate, adverse, localized, and long-term impact

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