control work is carried out through closure and military artillery, supplemented at times with helicopter control. Of concern to the military artillery program is the problem of firing over inhabited structures, and the possibility of firing into avalanche starting zones when backcountry skiers may be in the area. Of all the areas in the canyon, this section presents the greatest number of problems, and the greatest risk of disastrous consequences. This situation makes the Town of Alta a unique community.

As stated earlier in this report, the Alta Bypass Road was constructed to allow travel into and out of the Town of Alta while avoiding the Hellgate and Superior avalanche areas. Except for the largest avalanche events from these areas, there is little or no effect on this section of the road, and consequently, it serves as a "life-line" to the Town of Alta during the avalanche season. It is, however, not entirely free of avalanche concerns. The Blackjack Cliffs can pose a significant threat to safe travel on the Bypass Road, as do portions of the west facing slope that divides Collins and Peruvian Gulch. The northwesterly aspect of the starting zones of these two paths allow for snowpack structure to play an important role in the development of the avalanche hazard in this area, and a hazard may develop in this section when no threat is posed to other sections of the canyon road.

Although these avalanche starting zones lay within the permitted area of the Snowbird Ski Resort, little or no skier compaction takes place in this complex and rugged terrain, therefore the stabilization that occurs in other more accessible portions of the ski area does not occur here. Control work is carried out with closure and hand thrown explosives (much of the area can be reached from lift-served terrain in Alta and Snowbird), with some of the areas controlled with military artillery. In spite of the rather low frequency with which the Bypass Road is over-run by avalanches, an aggressive explosives control program is carried out in these areas. This is due to the accessibility by hand-charge teams, and to the fact that travel, including emergency services, between the Town of Alta and the Village of Snowbird is often limited to this corridor during the winter months.

Overview of the Avalanche Hazard Index

The Avalanche Hazard Index (AHI) assesses the avalanche risk to traffic. It is a numerical expression of the avalanche hazard on a road. The index is determined by calculating the probability of moving and waiting vehicles being hit by various types of avalanches and multiplying the probability with a weight according to the severity of damage. Calculation of the AHI considers several factors, including:

- Average daily traffic
- Traffic speeds
- Average length of avalanche debris on the roadway centerline
- Vehicle braking
- Avalanche frequency

Waiting vehicles are more likely to be hit by avalanches than moving vehicles. This occurs where an avalanche blocks the road ahead, vehicles line up waiting for the traffic to clear and a second avalanche hits the waiting traffic. Drivers wait in the vehicles due to poor weather and difficulty or inability to turn around (e.g. large vehicles). Usually they will wait until maintenance staff come along and clear the vehicles or at least the drivers from the hazard area.

This method has been applied on most highways in the United States, Canada and New Zealand to quantify the avalanche hazard for roads. The AHI has the following applications:

1. Comparison of the avalanche hazard between different roads and the level of control that is applied and acceptable;
2. Identification of the avalanche paths that contribute most strongly to the hazard of a road and consequently the paths that should be given priority for control measures;
3. Evaluation of the effect of alternative control measures, including cost benefit analysis;
4. Calculation of the hazard for future traffic volumes to allow orderly planning of control measures.

Highways are categorized with respect to the AHI as described in Table 2-4.

Table 2-4: Category of Hazard

Hazard Category	*Avalanche Hazard Index*
Very Low	<1
Low	1 to 10
Moderate	10 to 40
High	40 to 150
Very High	>150

North American practices in highway operations are summarized in Table 2-5 with respect to the Avalanche Hazard Index. Agencies utilizing these strategies include several state departments of transportation (Alaska, California, Colorado, Washington, and Wyoming), as well as the British Columbia Ministry of Transportation and Parks Canada.

Table 2-5: North American Practices in Highway Operations

Category	*Personnel*	*Explosives -*	*Structures*	*Data*	*Closures*
Very High	Full-and- part time personnel in forecasting and control operations	Active control with multiple fixed & mobile explosive systems	Snowsheds & earthworks (mounds, diversion berms, benches, dams)	Multiple remote alpine weather stations & alpine snow plot observers	Short control closures with occasional preventative closure
High	Full-or part time personnel in forecasting and control operations	Active control operations at all accessible sites	Earthworks & wide road ditching	Remote alpine weather stations	Short control closures with occasional preventative closures
Moderate	Part time personnel in forecasting and control operations	Mobile or fixed explosive control at key sites	Wide road ditching & occasional earthworks at key sites	Remote alpine weather stations	Preventative closures
Low	Maintenance staff, with periodic site visits by avalanche technicians	Occasional heli-bombing	Wide road ditching	Some remote weather stations or shared data	Preventative closures
Very Low	Maintenance staff				Preventative closures in exceptional circumstances

Source: Stetham et al, 1994

Methodology for Calculation of the AHI for SR-210

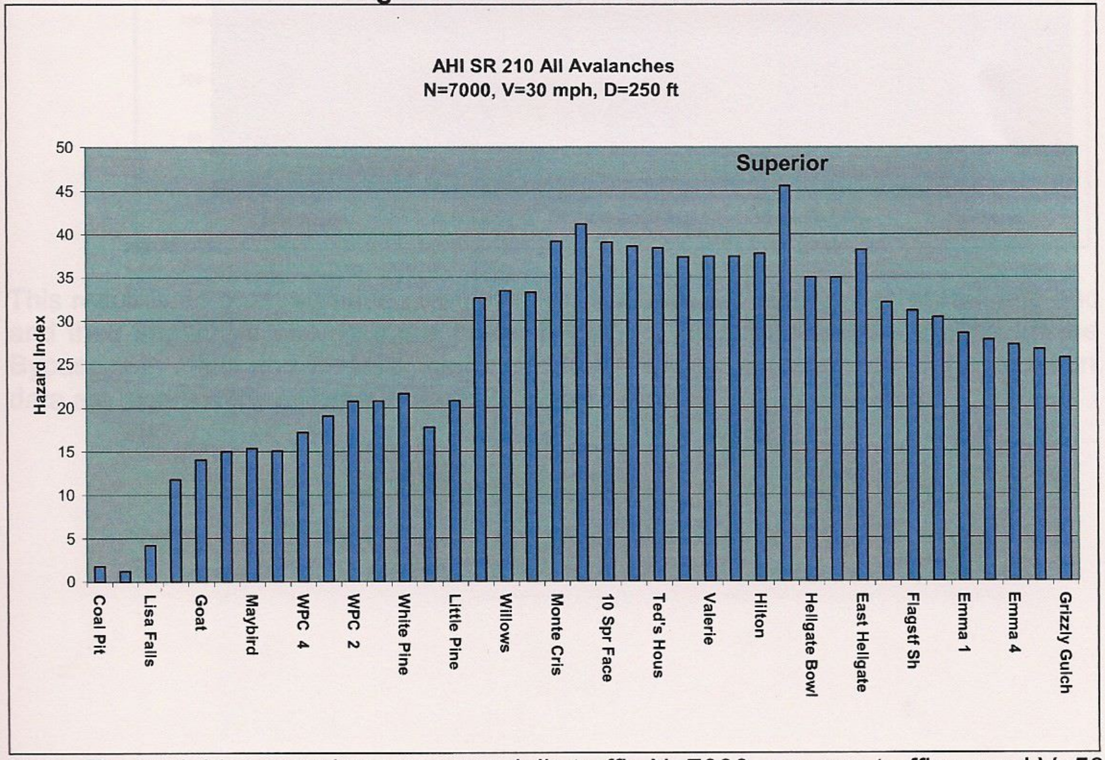
The inputs for the current analysis have been based on the historic record of avalanche occurrences accumulated for SR-210. Avalanche occurrence data have been compiled by UDOT for the period from 1972 to 2005. Additional historic data have been gleaned from the Highway Safety Plan (UDOT 2002) and interviews with key personnel.

We have separated the avalanche data into light snow avalanches (≤ 3 ft deposit on the road) and deep snow (>3 ft. deposit on the road) in accordance with the method of the AHI. Where more than one avalanche path runs out to the road in the same runout zone we have combined the data for these paths under one name (e.g. Superior or Little Pine East). The widths on the road are the actual averages from the light and deep snow deposits recorded in the database. The safe distance between paths is estimated from the minimum distance between paths plus 10% of the widths of the two adjacent paths. This is due to the fact that avalanches do not usually cover the full width of the path.

The Avalanche Hazard Index for SR-210

The baseline AHI for SR210 for an average winter daily traffic (WADT) of 7000 vehicles is 1045, in the Very High category. This includes all avalanches and assumes no control measures and free flowing traffic. The indices for the individual paths are illustrated in Figure 2-6.

Figure 2-6: AHI SR-210 All Avalanches

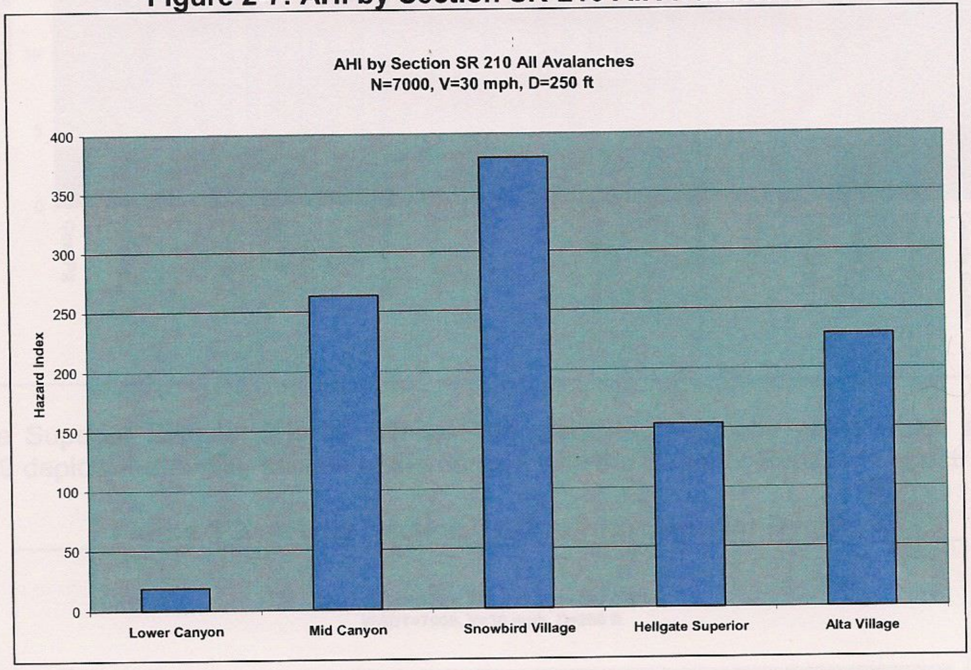


Note: The variables are winter average daily traffic N=7000, average traffic speed V=50 km/h (30 mph) and the stopping distance D=75 m (250 ft).

The index values for the road indicate a severe hazard spread through a large number of relatively high frequency and closely spaced avalanche paths. An important factor in this is the high traffic volume (7000 vehicles) and the resultant long queue of waiting traffic if an avalanche blocks the road (2188 m or 1.3 miles for a waiting period of 1 hour). The highest hazard is encountered at the Superior path.

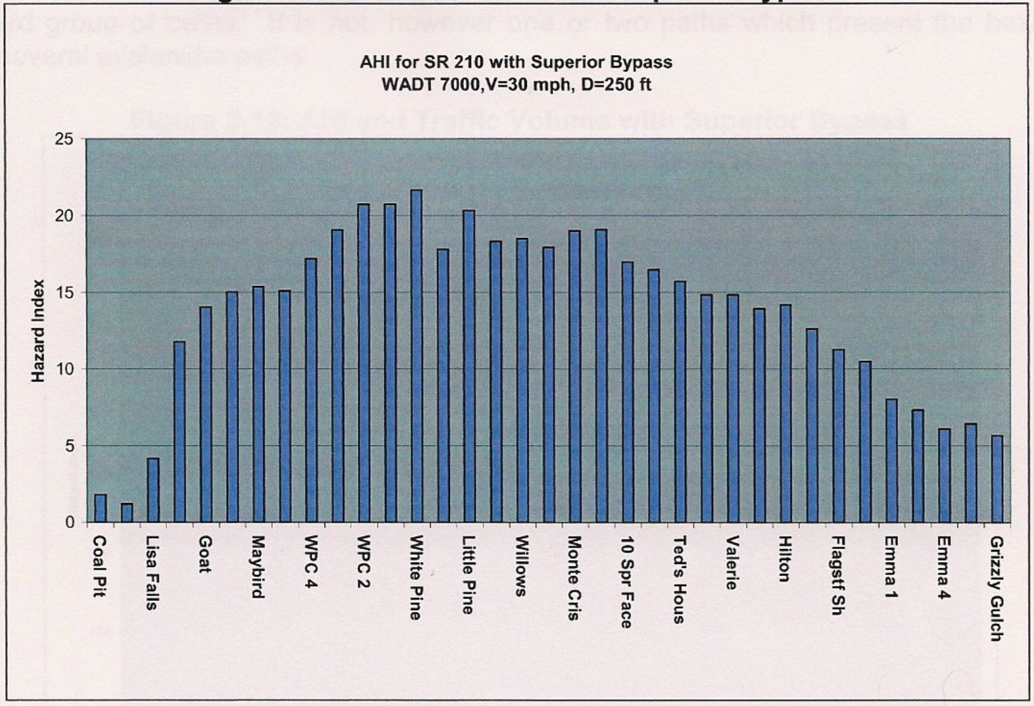
Figure 2-7 shows how the indices from Figure 2-6 combine to form AHI rankings for each of the six canyon sections. For each canyon section, the AHI for individual avalanche paths in that section are added together to determine a cumulative canyon section AHI.

Figure 2-7: AHI by Section SR-210 All Avalanches



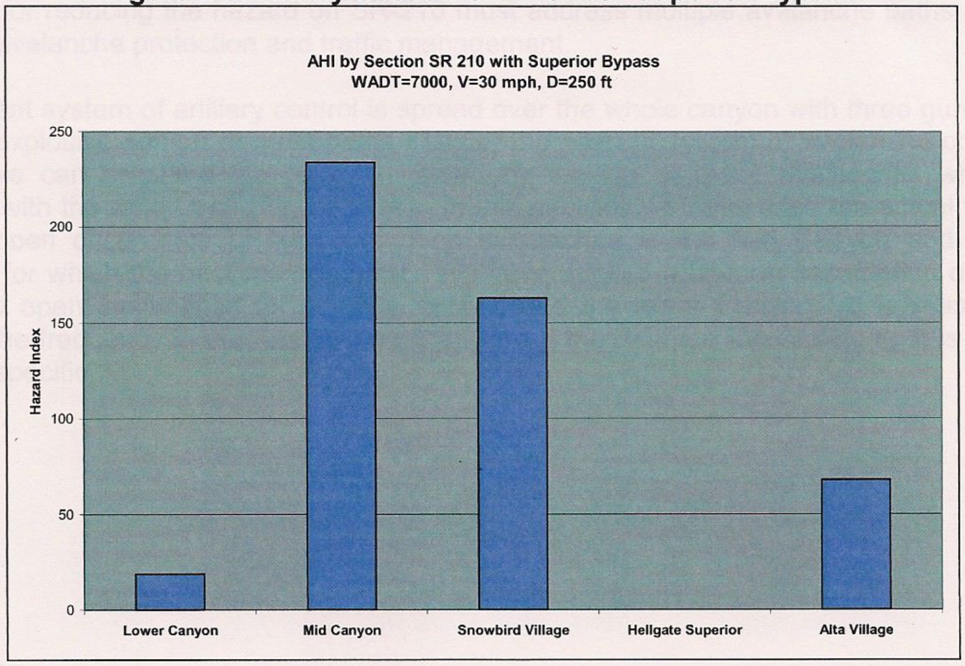
This result is no great surprise given the high frequency of avalanches at Hellgate and Superior and their impact on waiting traffic in the Snowbird, Superior and Alta groups. If the Superior Bypass is in effect and we take the hazard from Hellgate-Superior out of the equation, then the data are significantly different (Figure 2-8).

Figure 2-8: AHI for SR-210 with Superior Bypass



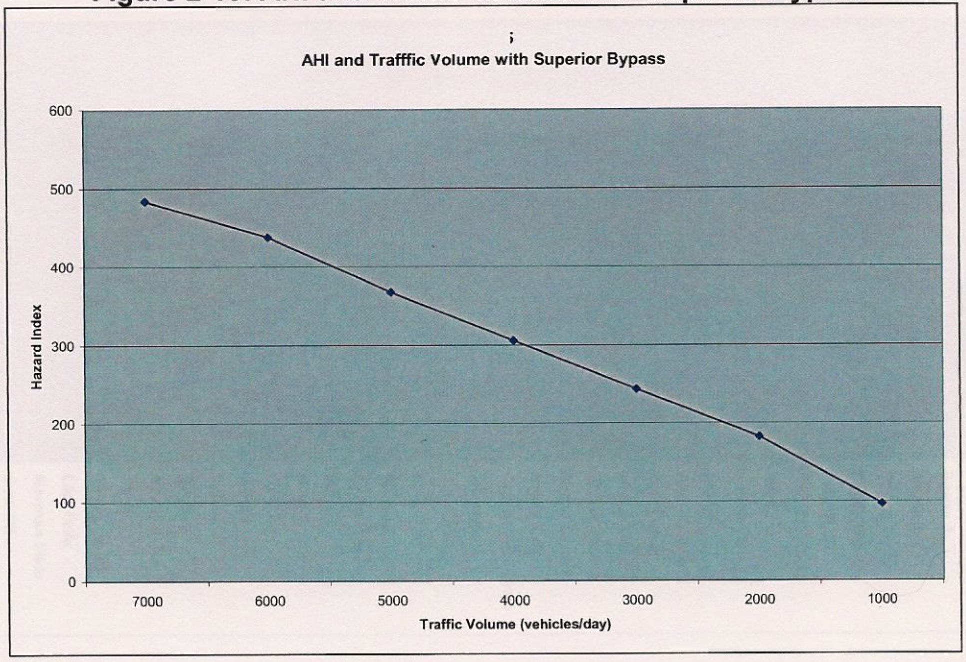
Given the Superior Bypass, it is the White Pine group of avalanche paths which stand out. Figure 2-9 depicts the AHI by section of the canyon with the Superior Bypass in effect.

Figure 2-9: AHI by Section SR-210 with Superior Bypass



With the Superior Bypass in effect, the Mid-Canyon becomes the priority followed by the Snowbird group of paths. It is not, however one or two paths which present the hazard but rather several avalanche paths.

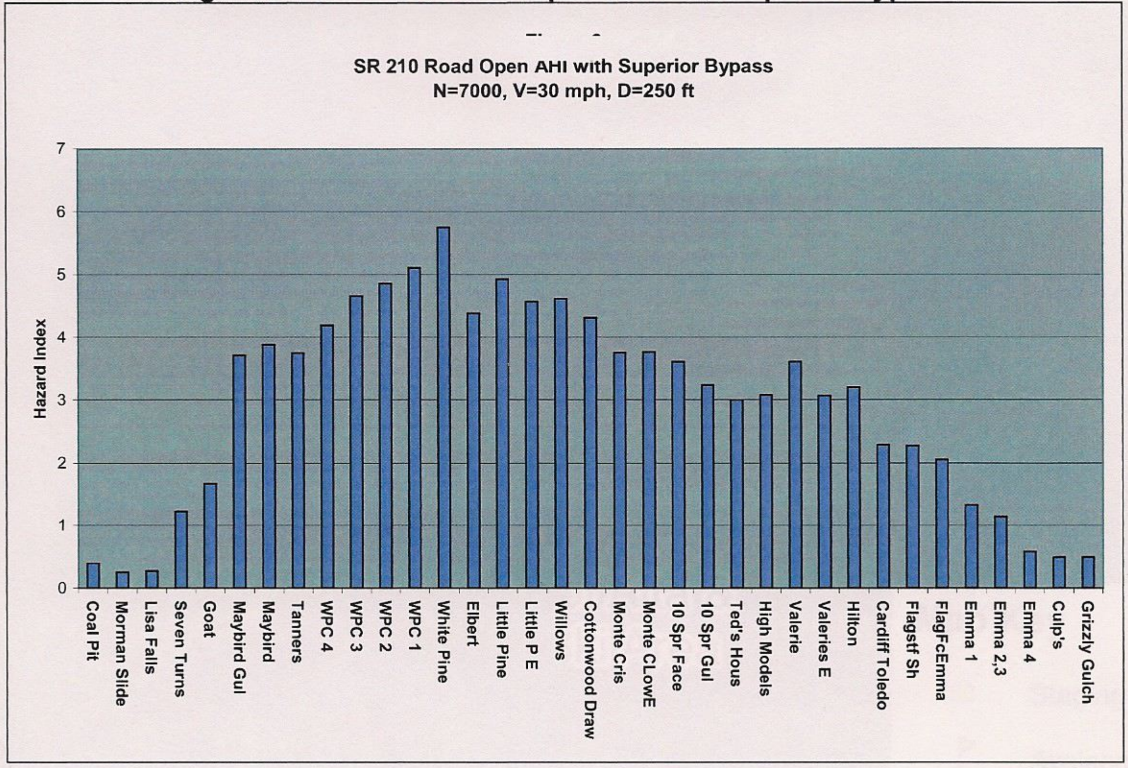
Figure 2-10: AHI and Traffic Volume with Superior Bypass



The effect of traffic volume with the Superior Bypass in place is illustrated in Figure 2-10. The solutions for reducing the hazard on SR-210 must address multiple avalanche paths and could combine avalanche protection and traffic management.

The present system of artillery control is spread over the whole canyon with three gun positions allowing explosive control at most paths. Under the present system of avalanche control with artillery we can calculate the residual hazard by looking at those avalanches which have occurred with the road open (Figure 2-11). In this analysis we have used the actual frequency of road open occurrence of light and deep avalanches in the Mid Canyon and Snowbird sections, for which the best records exist. We have applied a uniform assumption of 1 in 100 year road open avalanches for the Alta section and the lower Canyon. It is reasonable to assume the frequency in the Alta section is lower but the data are incomplete so it is difficult to be more specific.

Figure 2-11: SR-210 Road Open AHI with Superior Bypass



The highway open AHI hazard for SR-210 with the Superior Bypass in place is 103 or a high hazard. This is a very significant risk for an open road and solutions should be explored to reduce this to at least a moderate hazard (<40). At Rogers Pass, British Columbia, a combination of structural control measures and active artillery control has been used to reduce a very high hazard route to a current road open hazard of moderate. On SR-210, the greatest contributor to the road open risk is White Pine; however the risk is spread over a number of paths in the Mid-Canyon and Snowbird groups. This underlines the need for measures which will address the hazard at several avalanche paths in each of the Mid-Canyon and Snowbird areas.

Canyon Section Priority

While each of the canyon sections discussed above have unique characteristics and avalanche risks, some sections are more hazardous than others. The Town of Alta section is essentially one continuous runout zone, and represents the greatest avalanche threat to occupied buildings. The Snowbird Village section also has a considerable avalanche hazard risk to structures and occupied areas. However, the Bypass Road enables traffic to avoid both of these sections. Since the focus of this study is to reduce avalanche hazard to vehicles (rather than reducing hazard to structures), most of the future alternatives and solution packages will focus on the Mid-Canyon section of SR-210.