Southeast Alaska Mid-Region Access
Preliminary Snow Avalanche Assessment Technical Memorandum

Prepared for

Federal Highway Administration

Prepared by

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List of Acronyms and Abbreviations

ACP	Aaron Creek Pass
ACT	Aaron Creek Tunnel
B.C.	British Columbia
IRV	Iskut River Valley
pdf	probability density function
MRA	mid-region access
SR	Stikine River

EXECUTIVE SUMMARY

This technical memorandum contains the results of a preliminary assessment of snow avalanche risk along the proposed Southeast Alaska Mid-Region Access (MRA) Project road systems in coastal Alaska and northwest British Columbia.

The study area is classified as a maritime snow climate, characterized by heavy snowfall, long winter seasons, and fluctuating winter temperatures, which can result in rain at low elevations any time during the winter. This combination of factors means that snowfall amounts can increase sharply with elevation and vary considerably from year to year.

The proposed road system is mostly along the valley floor; however, the avalanche start zone elevations vary from about 500 feet to more than 5,000 feet above the road system. This indicates that that there will likely be winters without snow for some of the lower start zones, but abundant snow in those paths with high, alpine start zones every winter. This important characteristic is well documented at nearby Highway 37a (Stewart Highway), approximately 60 miles south of the MRA road alignments and subject to similar snow climate conditions. Also important is that Highway 37a is within the front rank in relation to avalanche control challenges, compared to about 70 different avalanche areas in British Columbia.

From the perspective of avalanche control, the proposed road system presents significant and probably expensive challenges. In this study, more than 200 possible avalanche paths are identified spread over the MRA alignments. For comparison, there are 134 controlled avalanche paths along 40 miles of the Rogers Pass highway, and this is generally considered one of the world's largest avalanche control programs. In addition, the MRA avalanche control program would likely be more complex and expensive than Rogers Pass for four reasons:

1. The paths are spread over a greater area.
2. There are a greater number of avalanche paths.
3. The areas are much more remote, whereas Rogers Pass is on the Trans-Canada Highway with good access to transportation and facilities.
4. The snow climate at Rogers Pass in the interior of British Columbia has less variability than a maritime snow climate.

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1 STUDY OBJECTIVES

The proposed Southeast Alaska Mid-Region Access (MRA) road system traverses mountainous fjordlands in coastal Alaska and northwest British Columbia (B.C.), as shown on Figure 1. The objective of this type of work is to identify and quantify snow avalanche paths and associated risk and then develop a plan for mitigation strategies and implementation. For the Southeast Alaska MRA Project, this objective was limited to a preliminary assessment only, along with recommendations for the additional work to complete the above objective.

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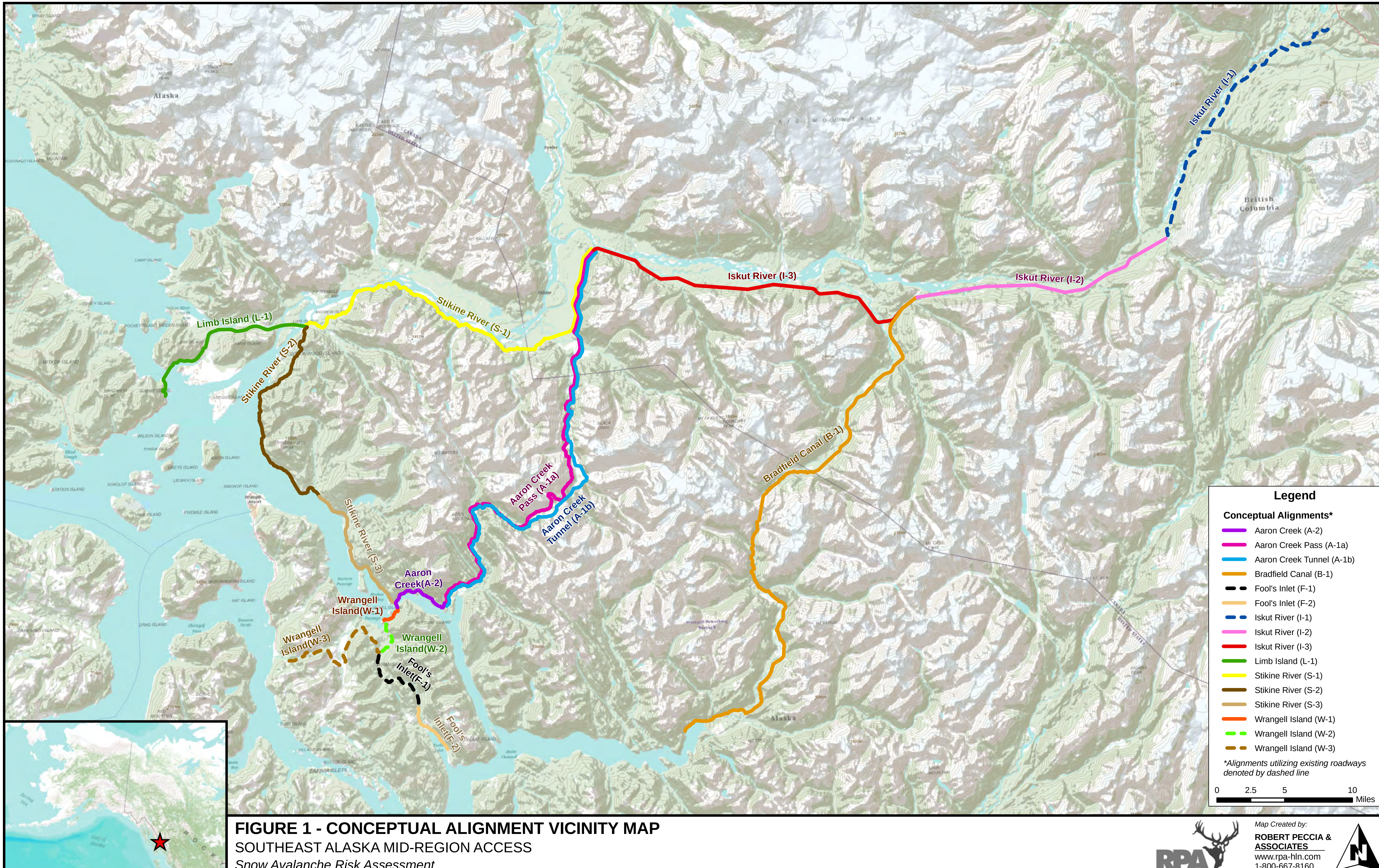

FIGURE 1 - CONCEPTUAL ALIGNMENT VICINITY MAP

SOUTHEAST ALASKA MID-REGION ACCESS

Snow Avalanche Risk Assessment

Map Created by:
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2 STUDY METHODS

The information compiled in this study is done by a risk-based method from terrain assessments using visual information provided by Robert Peccia and Associates. In general, risk for avalanche hazards is contained within the product of avalanche frequency, avalanche magnitude, and spatial exposure at the level of the proposed road system. The method used in this study is based on the paper of McClung (2003)[1]. In that paper, magnitude and frequency of avalanches measured along B.C. highways (including Bear Pass) are related to terrain parameters and forest cover.

For this study, the magnitude was estimated using the five-part destructive avalanche size classification, which is accepted in both the United States and Canada. For this, the principal variables are as follows:

1. The total vertical elevation drop from the top of start zone to the runout zone. This is the proposed road elevation in nearly all cases.
2. The snow supply to start zones was assessed using a five-part wind index with values from 1 to 5 (McClung and Schaerer (2006): The Avalanche Handbook, p. 112).
3. The frequency was estimated by the character of vegetation (or lack thereof) in the runout zone.
4. The exposure was estimated by the total width of the avalanche path at the road level.

The imagery available for this assessment was of two kinds:

1. Google Earth™ images with the road and mile markers
2. Air photos with the road mile markers (stations) inserted

Of these, the Google Earth™ images, when of good quality, enabled estimates of all three risk parameters: magnitude, frequency, and exposure. For many sections, the Google Earth™ images were not of sufficient quality to be used. For those sections, only the frequency and exposure could be extracted from the air photos and used in the risk assessment.

In all cases, the risk was calculated in a relative sense as the product of the available factors. The relative weighting of the factors in the product was determined by other studies for which there was good control on the magnitude and frequency, as in McClung (2003) and other studies on transport routes in B.C. where the same or similar methods have been used. For those areas where Google Earth™ images were of good quality, relative risk was calculated from the product of frequency,

[1] McClung, D.M. 2003. Magnitude and frequency of avalanches in relation to terrain and forest cover variables. Journal of Arctic and Alpine Research: 35 (1): 82 – 90.

magnitude, and exposure. For areas where only air photos had to be used, relative risk was calculated by the product of frequency and exposure. Because the information from air photos is less complete, there is less confidence in the assessment of these results than for the areas with Google Earth™ images.

For all cases, Poisson arrivals (rare, discrete, independent events) were assumed for the avalanches. The frequency was input to calculate the encounter probability: that is, the probability of at least one event on an annual (meaning winter season) basis. As an example, if the frequency is estimated as one event per year, the encounter probability is 0.63.

The only variable used in calculating exposure is the width of the avalanche path at the road. This assumption is also compatible with Poisson arrival of traffic. On an annual basis, the Poisson parameter is the width divided by the speed of traffic. Assuming constant average traffic speed, then the Poisson parameter is proportional to the width. For the values concerned, the Poisson encounter probability is given simply by the ratio of path length along the road to traffic speed, so the exposure encounter probability is directly proportional to the length exposed for any constant average traffic speed.

Once the relative risk was calculated for all the paths, the values were fit to a probability density function (pdf) for the two populations of avalanche paths:

1. For those assessed with Google Earth™ imagery, the best fit for relative risk was found to follow a Type II extreme value (also called Frêchet) distribution.
2. For those assessed with air photos, the best fit for relative risk was found to follow a log-normal pdf.

The distributions are similar, being skewed to the right. Both gave very good fits to the estimates on the low risk side of the pdfs where it is important. The estimates showed some lack of fit on the right tails of the pdfs, but this is not important, since the high values will be high risk with little doubt.

From the pdfs, lower and upper limits on the relative risk were subjectively assigned for low risk and high risk levels of relative risk. In between those limits, the avalanche paths were classed as moderate risk. The division between low and moderate risk was taken as the mode of the distributions since this was compatible with experience.

In summary, 89 paths were assessed as low risk, 50 as moderate risk, and 62 as high risk for a total of 201 paths.

3 AVALANCHE ASSESSMENT

Results are broken down by route segments: Wrangell Island, Limb Island, Fools Inlet, Bradfield Canal, Stikine River, Iskut River, Aaron Creek Tunnel, and Aaron Creek Pass. Summaries for each are included below.

1. Wrangell Island: Nominal risk for avalanches exists; nothing of concern was found.

2. Limb Island: Nominal risk for avalanches exists; nothing of concern was found.

3. Fools Inlet: Nominal risk for avalanches exists; nothing of concern was found.

4. Bradfield Canal: Stations 10 to 85: Nominal risk for avalanches exists; nothing of concern was found.

   Stations: 85 to 2085: Google Earth™ image poor and not usable.

   Stations 2085 to 2405: Nominal risk for avalanches, nothing of concern was found. The route joins the Iskut River at station 2405.

   For Bradfield Canal, no useable air photos were available. Thus, with available resources, most of Bradfield Canal could not be assessed.

5. Stikine River Segment 1: Google Earth™ image was unusable until station 3430. Google Earth™ was used from stations 3437 to 4212. Over this section, quantitative risk maps are possible. From stations 3437 to 4212, 23 avalanche-prone areas were found, and risk parameters were gathered.

   From stations 2550 to 3385, air photos were used. With the air photos alone, it is not possible to make a quantitative risk map since there is no information about path scale and character of the starting zone. In such cases, a descriptive, judgmental assessment will have to be made accounting for frequency (from vegetation), path width at the road, and position of the road in relation to the avalanche path track and runout zone as seen in the air photos. For this section, 47 avalanche-prone areas were found.

   Stikine River Segments 2 and 3: Nominal risk for avalanches exists; nothing of concern was found.

   Summary: There are approximately 70 avalanche-prone areas along Stikine River Segment 1. Of these, 23 were assessed by Google Earth™ and 47 were assessed by air photos.

6. Iskut River: For this route, the Google Earth™ image was good from station 5000 to 6465, making quantitative risk mapping possible. Beyond station 6465, the Google Earth™ image was poor, and no air photos were available with the route marked on them. However, the portion from station 5000 to 6465 is the critical section since the Iskut River route crosses an existing road at station 6293, and the route is coming out of the high mountains into more open terrain. The route intersects with Bradfield Canal at station 6322.

   From station 5000 to 6465, approximately 51 avalanche-prone areas were found, all of which could be assessed risk using Google Earth™.

7. Aaron Creek Tunnel: Stations 1005 to 3390: Aaron Creek Tunnel and Aaron Creek Pass are subject to fairly severe avalanche risk, much more so than Iskut River and Stikine River. Numerous high-risk paths are found along both routes. There are also proposed bridges, which will need avalanche impact pressure estimates.

   For stations 2800 to 3390, Google Earth™ could be used, so quantitative risk mapping is possible. From stations 2800 to 3390, nine avalanche areas were found.

   For Aaron Creek Tunnel, air photos had to be used from stations 1005 to 2800. For stations 1005 to 1870, the route was deemed to have nominal risk. For stations 1870 to 2755, 42 avalanche-prone areas were found.

   The Aaron Creek Tunnel route includes numerous places of high risk. The proposed road crosses many of the paths high enough to be in the avalanche tracks (instead of the runout zone) where very high avalanche speeds are usually found. In addition, the avalanche frequency appears to be quite high at such locations.

8. Aaron Creek Pass. Much of the route is the same as Aaron Creek Tunnel, so only the section deviating from Aaron Creek Tunnel was assessed. For Aaron Creek Pass, air photos had to be used since the Google Earth™ image is poor. For Aaron Creek Pass from stations 2093 to 2736, 26 avalanche-prone areas were found. However, a number of these include multiple avalanche paths and large sections of the proposed roadway.

4 SUMMARY OF RESULTS

For Stikine River, approximately 70 avalanche-prone areas were found. Most of the paths appear to be in the low to moderate risk range.

For Iskut River, approximately 51 avalanche-prone areas were found with most paths in the low to moderate risk range.

For Aaron Creek Tunnel and Aaron Creek Pass, approximately 76 avalanche-prone areas were found. For this sector, the risk is much higher than for Stikine River or Iskut River. This is due to the proposed road crossing large sections of big avalanche paths or groups of avalanche paths. For some of the route, the proposed road crosses above the runout zone and into the track where expected speeds are high, and avalanche frequency increases. The high risk for either the Aaron Creek Tunnel or the Aaron Creek Pass route suggests that either this is a summer route only (closed from approximately November 1 until May 1), or it would be very expensive to protect if open during winter.

The detailed tables of results are given in Tables 1 and 2 in Appendix A, and are summarized in the tables below:

Table 4-1. Summary of relative risk results from Stikine River (SR), Aaron Creek Tunnel (ACT), and Aaron Creek Pass (ACP) given as number of paths. The table shows assessment from air photos.

Area	Low	Moderate	High
SR	30	11	6
ACT	17	7	18
ACP	10	3	13

Table 4-2. Summary of relative risk results from SR, ACT, and Iskut River Valley (IRV) given as number of paths. The table shows analysis from Google Earth™.

Area	Low	Moderate	High
SR	11	8	4
ACT	2	3	4
IRV	20	14	17

In total, approximately 200 avalanche-prone areas are expected. The scale of the paths ranges from about a 400-foot vertical drop to about a 5,900-foot vertical drop with many over a 3,000-foot vertical drop.

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5 RISK ASSESSMENT LIMITATIONS

This study can only be used as a rough guide for expected avalanche conditions along the routes checked. There are no avalanche records for the areas, and the assessment is done only with terrain parameters. There is a high degree of uncertainty when assessing avalanche frequency from air photos or Google Earth™ images. A site visit would probably eliminate some of the paths, such as narrow gullies, and would provide a better idea of avalanche frequency and the overall avalanche risk. There are certainly debris flow hazards along the route, and some of the fans assessed could be more the result of these hazards than snow avalanches.

In this study, the two levels of risk assessment (Google Earth™ and air photos) mean that there may not be a direct one-to-one correspondence between the low-, moderate-, and high-risk categories between the two groups.

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6 AVALANCHE RISK MITIGATION OPTIONS

There are a number of options for dealing with the problems along the proposed routes. These are listed below in order of likelihood.

6.1 Road Realignment

There are some places where the road could be realigned slightly to reduce or eliminate the hazards. However, from scanning the images, there are very few of these opportunities since the avalanche paths, in most cases, reach the valley bottoms.

6.2 Forecast and Control

In regard to the vast areas involved, the most practical method, overall, would be a program of avalanche forecasting, closures, and explosive control. As a minimum, such a program would have to be in place from approximately November 1 to May 1. Of the latter, the most likely option would be helicopter bombing due to the remoteness and large geographical area involved. A disadvantage of this method is that it is weather-dependent and cannot be done in storms when most avalanches occur.

Another option for explosive control would be to set up a series of gun towers and use explosive shells. This method is not very suitable for the vast terrain which must be considered. The best weapon in the past has probably been the 105 mm recoilless rifle, but ammunition is not readily obtainable any more.

The cost for an avalanche forecasting and control program in this remote area would be in the range $350,000 to $400,000 per winter season. Because of the International Boundary, it may be necessary to establish two separate programs, one in B.C. and one in Alaska; therefore, the costs could double.

6.3 Structural Protection

Structural protection, including earthen deflection berms and dams, might be used in some cases to eliminate smaller avalanches. However, this would have to be in addition to an avalanche forecasting and control program. It would not be acceptable to guarantee safety to the travelling public with earthen structures alone.

For the present proposed road system, snow sheds would have to be used in some places. For the Aaron Creek Tunnel and Aaron Creek Pass routes, there are places where the proposed road alignment crosses above the runout zone in portions of the path, called the track, where avalanche speeds are near maximum. Without such protection, the risk to the travelling public would be unacceptable under winter conditions. This can be very expensive, since snow shed costs can range from $10,000 to $20,000 per yard of exposure.

6.4 Winter Road Closures

Finally, an option may be to designate some or all the routes as summer only. Due to the large number of avalanche paths, this would still involve snow clearing to open the roads in the spring. Avalanche debris persists long after snow is gone from low elevations due to the depths it piles up.

7 RECOMMENDATIONS

This study has provided a preliminary assessment of the snow avalanche hazards and risk assessment for the Southeast Alaska MRA Project. Normally, the next step would be to conduct field investigations to more accurately define the terrain parameters, and obtain any available historical information on observations of avalanche activity.

For this area, field visits are considered to be essential and are best conducted in the early springtime. At that time, most avalanches would be down, without too much melting of the deposits. The winter of 2009/2010 is an El Niño winter, resulting in highly variable snow cover for the area and, therefore, even more useful in assessing snow conditions.

A concerted effort should be made to compile any observations of past snow avalanche activity along the Southeast Alaska MRA road alignments. This would involve contacting avalanche professionals in the area, as well as personnel working on the various mining projects in the area, pilots having flown the area, and any other sources.

Once the above steps are underway, cost estimating for the various mitigation strategies can be undertaken.

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APPENDIX A

Risk Rating Tables

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Table 1. Risk ratings based on air photo analysis of avalanche paths. The first column contains the road mileage station numbers. If it is one single number rather than a range, it is usually a narrow gully. In some places, there is more than one path feeding in and the station numbers represent the regime in aggregate.

Road Mileage	Risk Rating	Area of Avalanche Path
2093-95	Low	Aaron Creek Pass
2096-2102	Low	Aaron Creek Pass
2122-33	High	Aaron Creek Pass
2136-38	Low	Aaron Creek Pass
2140-62	High	Aaron Creek Pass
2165-75	High	Aaron Creek Pass
2176-87	High	Aaron Creek Pass
2195-2200	Low	Aaron Creek Pass
2202-15	High	Aaron Creek Pass
2215-2350	High	Aaron Creek Pass
2350-2480	High	Aaron Creek Pass
2480-94	High	Aaron Creek Pass
2505-07	Medium	Aaron Creek Pass
2514-24	High	Aaron Creek Pass
2552-55	Low	Aaron Creek Pass
2558-72	High	Aaron Creek Pass
2595-2633	High	Aaron Creek Pass
2637-55	High	Aaron Creek Pass
2664-80	High	Aaron Creek Pass
2683-84	Low	Aaron Creek Pass
2686-88	Low	Aaron Creek Pass
2994	Low	Aaron Creek Pass
2696	Low	Aaron Creek Pass
2704-05	Low	Aaron Creek Pass
2713-15	Medium	Aaron Creek Pass
2732-36	Medium	Aaron Creek Pass
1870-76	Low	Aaron Creek Tunnel
1885-92	Medium	Aaron Creek Tunnel
1995-2002	Low	Aaron Creek Tunnel
2020-24	Low	Aaron Creek Tunnel
2027-30	Low	Aaron Creek Tunnel
2037	Low	Aaron Creek Tunnel
2052-57	Medium	Aaron Creek Tunnel
2067-77	High	Aaron Creek Tunnel
2077-82	Low	Aaron Creek Tunnel
2102-25	High	Aaron Creek Tunnel
2130-50	High	Aaron Creek Tunnel
2153-2200	High	Aaron Creek Tunnel
2202-25	High	Aaron Creek Tunnel
2300-12	High	Aaron Creek Tunnel
2321-38	High	Aaron Creek Tunnel
2344-53	High	Aaron Creek Tunnel
2355-57	Medium	Aaron Creek Tunnel
2358-61	Medium	Aaron Creek Tunnel
2363-67	Low	Aaron Creek Tunnel
2370-71	Low	Aaron Creek Tunnel
2377-78	Low	Aaron Creek Tunnel
2393-97	Medium	Aaron Creek Tunnel
2407.5-17	Low	Aaron Creek Tunnel
2417-45	High	Aaron Creek Tunnel
2445-60	High	Aaron Creek Tunnel
2460-80	High	Aaron Creek Tunnel
2480-95	Low	Aaron Creek Tunnel
2496-99	Low	Aaron Creek Tunnel
2499-2520	High	Aaron Creek Tunnel
2520-25	Low	Aaron Creek Tunnel
2525-48	High	Aaron Creek Tunnel
2560-65	Low	Aaron Creek Tunnel

Table 1. Risk ratings based on air photo analysis of avalanche paths. The first column contains the road mileage station numbers. If it is one single number rather than a range, it is usually a narrow gully. In some places, there is more than one path feeding in and the station numbers represent the regime in aggregate.

Road Mileage	Risk Rating	Area of Avalanche Path
2571-87	High	Aaron Creek Tunnel
2587-2601	High	Aaron Creek Tunnel
2607-22	High	Aaron Creek Tunnel
2624-26	Low	Aaron Creek Tunnel
2632-48	High	Aaron Creek Tunnel
2652-80	High	Aaron Creek Tunnel
2682-87	Medium	Aaron Creek Tunnel
2700-05	Medium	Aaron Creek Tunnel
2709	Low	Aaron Creek Tunnel
2755	Low	Aaron Creek Tunnel
2754-57	Medium	South Stikine
2760	Low	South Stikine
2767-69	Medium	South Stikine
2770-82	High	South Stikine
2765-2770	Medium	South Stikine
2700-2705	Medium	South Stikine
2665-2700	High	South Stikine
2795-2802	High	South Stikine
2802-37	High	South Stikine
2847-52	Medium	South Stikine
2867-70	Low	South Stikine
2879	Low	South Stikine
2872-78	Low	South Stikine
2901-03	Low	South Stikine
2916-23	Medium	South Stikine
2923-27	Low	South Stikine
2970-77	Low	South Stikine
2977-85	High	South Stikine
3000-06	Low	South Stikine
3012-17	Medium	South Stikine
2947-50	Low	South Stikine
3015-18	Medium	South Stikine
3019-27	Low	South Stikine
3037-40	Low	South Stikine
3062-67	Low	South Stikine
3067-72	Low	South Stikine
3079	Low	South Stikine
3115-19	Low	South Stikine
3130	Low	South Stikine
3136-38	Low	South Stikine
3141-45	Low	South Stikine
3327	Low	South Stikine
3247	Low	South Stikine
3283-86	Medium	South Stikine
3306	Low	South Stikine
3355-58	Medium	South Stikine
3365-69	Medium	South Stikine
3250-85	High	South Stikine
3286	Low	South Stikine
3327	Low	South Stikine
3385	Low	South Stikine
3437	Low	South Stikine
3490	Low	South Stikine
3554.5-56	Low	South Stikine
3576-79	Low	South Stikine
3595	Low	South Stikine
3599-3603	Low	South Stikine

Table 2. Risk ratings based on Google Earth© analysis of avalanche paths. The first column contains the road mileage station numbers. If it is one single number rather than a range, it is usually a narrow gully. In some places, there is more than one path feeding in and the station numbers represent the regime in aggregate.

Road Mileage	Risk Rating	Area of Avalanche Path
2834-55	High	Aaron Creek Tunnel
3081-90	High	Aaron Creek Tunnel
3094-3106	High	Aaron Creek Tunnel
3135-65	Medium	Aaron Creek Tunnel
3172-74	Low	Aaron Creek Tunnel
3178-81	Low	Aaron Creek Tunnel
3185-90	Medium	Aaron Creek Tunnel
3266	Medium	Aaron Creek Tunnel
3295	Medium	Aaron Creek Tunnel
3437	Low	South Stikine
3490	Medium	South Stikine
3554-56	Low	South Stikine
3576-79	Medium	South Stikine
3595	Low	South Stikine
3599-3603	Medium	South Stikine
3655-75	High	South Stikine
3721	Low	South Stikine
3748-3749	Low	South Stikine
3763-65	Low	South Stikine
3759	Low	South Stikine
3907-11	Medium	South Stikine
3916-25	High	South Stikine
3930-40	High	South Stikine
3941-44	Medium	South Stikine
4007-10	Low	South Stikine
4013-17	Low	South Stikine
4020-25	Medium	South Stikine
4032-38	Low	South Stikine
4078-83	Low	South Stikine
4095-99	Medium	South Stikine
4099-4117	Medium	South Stikine
4200-12	High	South Stikine
5019-27	High	Iskut River Valley
5042-45	Medium	Iskut River Valley
5070	Low	Iskut River Valley
5080-81	Low	Iskut River Valley
5129-5130	Medium	Iskut River Valley
5199-5202	Medium	Iskut River Valley
5242-44	Low	Iskut River Valley
5277-5300	High	Iskut River Valley
5405-21	High	Iskut River Valley
5433-35	Medium	Iskut River Valley
5440-41	Low	Iskut River Valley
5458-60	Medium	Iskut River Valley
5458-92	High	Iskut River Valley
5542	Low	Iskut River Valley
5534	Low	Iskut River Valley
5564-70	High	Iskut River Valley

Table 2. Risk ratings based on Google Earth© analysis of avalanche paths. The first column contains the road mileage station numbers. If it is one single number rather than a range, it is usually a narrow gully. In some places, there is more than one path feeding in and the station numbers represent the regime in aggregate.

Road Mileage	Risk Rating	Area of Avalanche Path
5583-93	High	Iskut River Valley
5594-97	Low	Iskut River Valley
5613-15	Low	Iskut River Valley
5620-28	High	Iskut River Valley
5650	Low	Iskut River Valley
5659-60	Low	Iskut River Valley
5677-82	Low	Iskut River Valley
5680-82	Low	Iskut River Valley
5677-80	Low	Iskut River Valley
5687-90	Medium	Iskut River Valley
5708-13	High	Iskut River Valley
5794-98	High	Iskut River Valley
5800-41	Medium	Iskut River Valley
5850-58	High	Iskut River Valley
5859-5864.5	High	Iskut River Valley
5870-74	Medium	Iskut River Valley
5878-82	Low	Iskut River Valley
5884.5-5886	Low	Iskut River Valley
5909	High	Iskut River Valley
5910-30	High	Iskut River Valley
5930-43	High	Iskut River Valley
5943-60	High	Iskut River Valley
5976-5977	Medium	Iskut River Valley
5977-5882	Low	Iskut River Valley
5987-97	Medium	Iskut River Valley
6018-21	Low	Iskut River Valley
6045-50	Low	Iskut River Valley
6050-53	Low	Iskut River Valley
6050-53	Low	Iskut River Valley
6057-69	Medium	Iskut River Valley
6078-86	Medium	Iskut River Valley
6154-61	High	Iskut River Valley
6130-40	Medium	Iskut River Valley
6186-92	Medium	Iskut River Valley
6209-20	High	Iskut River Valley