July 8, 2009

CG25309.B

Alberta Transportation
2nd Floor, 803 Manning Road NE
Calgary, AB T2E 7M8

Attn: Mr. Ross Dickson

Re: Southern Region Geohazard Assessment Program
Highway 742:02 Avalanche Areas
2009 Annual Inspection Report

This letter documents the 2009 annual site inspection of the avalanche areas along Highway 742:02, southbound of Canmore, AB.

AMEC Earth & Environmental (AMEC), a division of AMEC Americas Limited, performed this inspection in partial fulfillment of the scope of work for the supply of geotechnical services for Alberta Transportation's (AT's) Southern Region (AT Consulting Services Agreement CE061/08).

The site inspection was performed on June 11, 2009 by Mr. Andrew Bidwell, P.Eng. and Mr. Bryan Bale, EIT of AMEC in the company of Mr. Ross Dickson and Mr. Neil Kjelland, P.Eng. of AT along with Mr. George Field, Public Safety Specialist for Kananaskis Country with the Parks Division of Alberta Tourism, Parks and Recreation.

BACKGROUND

During the 2007/2008 geohazards review of the Highway 742 corridor three areas signed as "Avalanche Area, No Stopping" were noted along the highway:

- "East End Of Rundle" avalanche area, approximately 4.8 to 6.0 km southbound from the junction between Highway 742 and Three Sisters Parkway in Canmore, AB. This area was referred to as the "Km 4.8 to Km 6.0 Snow Avalanche Area" in the corridor review report.

- "Back Of Big Sister" avalanche area, a short distance southbound of the Three Sisters Dam. This area was referred to as the "Snow Avalanche Area South Of Three Sisters Dam – Km 16.3 To 17.4" in the corridor review report.

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- "Buller Corner" avalanche area, approximately 28.9 to 32.1 km southbound from the junction between Highway 742 and Three Sisters Parkway in Canmore, AB.

Figure 1, attached, illustrates the location of these areas along the Highway 742 corridor.

Figures 2 to 4, attached, show oblique aerial views of each site with the approximate location of the avalanche source and runout zones relative to the highway.

Please refer to the report on the Highway 742 corridor review[1] for background information on each site.

JUNE 2009 FIELD REVIEW OF AVALANCHE AREAS

The June 11, 2009 field review of the avalanche areas was performed as follows:

- The AT and AMEC personnel met with Mr. George Field (Parks Division) at the parking lot of the Canmore Nordic Centre at the north end of Highway 742 to discuss:
    - The avalanche conditions at the sites and the impacts to the highway corridor over the past couple of decades.
    - The scope, logistics and typical costs of the avalanche control work performed in recent years by the Parks Division.
    - The advantages and disadvantages of other possible avalanche control measures for these sites.
- The East End Of Rundle and Back Of Big Sister avalanche areas were visually reviewed from the highway after the meeting, with further discussion and exchange of information between AT, AMEC and the Parks Division.

The following subsections summarize the information discussed regarding each of the avalanche areas.

[1] AMEC report "Geohazards Review, Highway 742 and Highway 940 Corridors, Southwestern Alberta", submitted to AT on April 8, 2009, AT Consulting Services Agreement CE044/04, AMEC project number CG25262.

General Information

Parks Division personnel assess the avalanche conditions in these three areas as an extension of their avalanche forecasting and control work for the Kananaskis Country. The training and experience of the Parks Division team in avalanche forecasting, mapping and control work generally exceeds the requirements for managing avalanche safety programs for highway operations as listed for the Qualified Avalanche Planner (QAP) designation proposed by the Canadian Avalanche Association (CAA). However, it is understood that the more junior members of the Parks Division team would require formal training for specific items listed in the requirements for the QAP designation if their previous training and ongoing experience working under the supervision and direction of more experienced personnel cannot be recognized relative to the QAP designation.

"East End Of Rundle" Avalanche Area

- There is an avalanche hazard along the highway from the steep slopes on the east end of Mount Rundle. Of note, this area was also the site of the February 1991 incident where a vehicle parked within the signed avalanche hazard area was swept from the highway by a naturally occurring avalanche (please refer to the April 2009 Highway 742 corridor geohazard review report for further details).

- The approximate location of the avalanche source zones and runout paths above the highway are shown on Figure 2, attached.

- The Parks Division personnel assess the avalanche hazard in this area based on visual reviews of the snowpack conditions on the slopes above the highway, supplemented with temperature and wind data from a weather station near the summit of the east end of Mount Rundle that is operated by the Parks Division. It was noted that this weather station does not have the capability to measure snowfall, but that the addition of a precipitation/snowfall gauge to the existing weather station would almost certainly not provide representative data for the avalanche source areas that are subject to highly localized wind-borne snow accumulation.

- When judged necessary to reduce the avalanche hazard to the highway, the Parks Division has performed avalanche control work in this area as follows:

    - Contact the highway maintenance contractor to:
        - Arrange for equipment to clear snow from the highway. When possible, the snow clearing equipment is pre-positioned at the Whiteman's Gap (uphill) end of the highway through the avalanche area so that it can work in a downhill direction to more efficiently clear avalanche deposits from the road.

- Temporarily close this segment of Highway 742 using the gates at the Grassi Lakes turnoff a short distance northbound of the Canmore Nordic Centre and North Whiteman's Dam.
- Tow any parked vehicles from the closed segment of the highway prior to avalanche control work.

- Parks Division personnel use a contracted helicopter to "heli-bomb" the avalanche source zones, i.e. fly over the avalanche source zones and drop explosive charges in order to trigger avalanches.

- The location and extent of runout from the triggered avalanches and the remaining snowpack in the source zones are visually reviewed in order to determine if conditions are safe for snow clearing equipment to work along the highway.

- Avalanche deposits on the highway are cleared and any guardrail damage is repaired, prior to the highway reopening to traffic.

- It has been found that the time required before reopening the highway after heli-bombing varies widely, from less than an hour for situations where the runout from triggered avalanches does not extend onto the highway to most of a day when significant amounts of snow and debris are deposited on the highway and need to be cleared. There is sometimes also guardrail damage that needs to be repaired.

- On rare occasions this segment of the highway is closed for up to two days or longer because extremely strong, gusty winds and/or visibility conditions have prevented helicopter overflights and heli-bombing of the avalanche source zones during times when the avalanche hazard is considered too high for the highway to remain open without avalanche control work being performed. This is understood to have occurred on two occasions in the past 25 years.

- The southern end of Highway 742 can be accessed via Highway 40 when this segment of the highway is closed due to the avalanche hazard. The Parks Division personnel report that traffic on the highway is generally from outdoor recreational users, industrial users (e.g. TransAlta Corporation, to access their dam sites and facilities in the Spray Reservoir area) and commercial users (e.g. guides and outfitters). It is understood from the Parks Division personnel that the users of the highway have generally been tolerant of the frequency and duration of temporary highway closures in recent years, with the exception of a single, Canmore based commercial user of the highway that objects strongly to closures lasting more than one day.

- From 2001 to 2009, the number of heli-bombing missions per avalanche season has varied from zero to four, depending on the snow conditions during any given season. Please refer to the attached "Yearly Costs Of Helicopter Control Missions 2001-09" provided by the Parks Division for a summary.

- The ballpark cost for each heli-bombing trip is roughly $3,000, based on typical hourly rates for the contracted helicopter and the cost of the explosive charges that are used. The annual cost depends on the number of missions required during each avalanche season, and from 2001 to 2009 the annual costs varied from $0 to approximately $13,000. Please refer to the attached "Yearly Costs Of Helicopter Control Missions 2001-09" provided by the Parks Division for further details. These costs are borne by the Parks Division, along with their personnel time and CAA training/certification for the personnel. There are also ongoing costs incurred by the Parks Division for the licensing, operation and maintenance of a secure storage facility for the explosive charges.

- The Parks Division personnel have noted that an additional 1 to 2 heli-bombing missions per year in order to perform "pre-avalanche control" work would typically have been appropriate in recent years. These missions would have triggered avalanches earlier in the natural avalanche cycle that would stop above the highway. This would reduce snow buildup prior to the development of an unstable snowpack that could later release avalanches that would reach the highway. This would maintain a relatively lower avalanche hazard throughout each avalanche cycle and also reduce the number of temporary closures required if avalanche control work was only performed later in each avalanche cycle, resulting in larger triggered avalanches reaching the highway and require clearing.

- The Parks Division personnel reported that members of the public have speculated that the use of explosive charges in the avalanche control work will lead to an increased number and magnitude of rockfalls from the upper slopes above the highway over time. Few rockfalls from the upper slopes appear to reach the highway, however on one occasion in 2006 a rockfall originating from the uppermost slopes above the highway deposited numerous boulder-sized rocks onto the highway. Please refer to the inspection report with respect to rockfall along this segment of Highway 742 for further information regarding the rockfall hazard[2].

[2] Upcoming AMEC report "Southern Region Geohazard Assessment Program, Highway 742:02 Rockfall Areas, Between ~Km 4.8 and 6.1, June 2009 Inspection Report", AT Consulting Services Agreement CE061/08, AMEC project number CG25309.B.

"Back Of Big Sister" Avalanche Area

There is an avalanche hazard along the highway from the steep lower slopes on the west/southwest side of the "Big Sister" mountain, a short distance southbound from the Three Sisters Dam. The approximate location of the avalanche source zones and runout paths above the highway are shown on Figure 3, attached.

It is understood from the Parks Division that the avalanche hazard at this site is relatively low for most of each winter season because there is typically relatively little snow accumulation in the avalanche source zones in the treed area upslope of the highway. However, under certain conditions more significant and unstable snowpacks can develop and the avalanche hazard increases correspondingly. This can occur as a result of moist snowfalls that "stick" to the slope rather than more typical drier winter snow that is prone to being blown off the slope by the prevailing winds in this area. Suitably moist snowfalls with winds favourable for snowpack accumulation in the source zones can occur during upslope storm events and/or in the spring of each year. As a result, the segment of the highway below the avalanche runout zones has been temporarily closed on occasion every few years but typically not every year. The frequency and duration of closures varies depending on weather and snowpack conditions. The avalanche hazard conditions are evaluated daily during each season by the Parks Division personnel.

As described in the April 2009 Highway 742 corridor geohazard review report, the runout from an avalanche at this site is known to have crossed the highway on at least one occasion in recent years. Furthermore, it is understood that heli-bombing avalanche control measures have been applied at this site on one occasion in the past.

"Buller Corner" Avalanche Area

There is an avalanche hazard to the highway from the west/northwest slopes of Mount Buller. The approximate location of the avalanche source zones and runout paths above the highway are shown on Figure 4, attached.

This site was not reviewed in the field on June 11, 2009.

It is understood from the Parks Division that this area typically produces avalanches throughout each winter season, and in the last approximately 20 years avalanche runout has come close to the highway on occasion but has not reached the road surface. However, the potential for future avalanche runout to reach the highway cannot be entirely ruled out. It is also understood that heli-bombing avalanche control measures have been applied at this site on one occasion in the past.

ASSESSMENT

General

There is an avalanche hazard to the highway at all three of the sites. The risk to motorists is only partially mitigated by the "Avalanche Area – Do Not Stop" signage in place along the highway at each site. However, it is known that motorists do stop and park in these areas at times during avalanche season. This has been illustrated by the February 1991 incident where a parked vehicle was swept from the highway in the "East End Of Rundle" avalanche area. Furthermore, the Parks Division reports that they occasionally note vehicles parked in the signed avalanche hazard areas.

"East End Of Rundle" Avalanche Area

This area is by far the most active of the three avalanche areas and poses the greatest hazard to the highway. The Parks Division performs avalanche control work in this area as described in the previous section. The heli-bombing avalanche control work is practical for this site provided that the temporary closures of the highway are acceptable to AT. Other avalanche control options for this site include:

- "Gaz-EX" style remotely operated avalanche triggering devices installed throughout the avalanche source zones. These devices explode an oxygen/propane gas mixture in tubes that direct the explosive force onto the snowpack surface in the source zones, thus triggering avalanches without the need for a helicopter overflight to drop explosive charges[3]. Aside from annual refilling of the gas storage tanks installed above the avalanche source zones along with annual inspection/maintenance of the equipment (this can be done during the summer months), the "Gaz-EX" devices can be operated remotely during any weather and daylight conditions. This option could be effective at this site if the devices could be installed close enough to the avalanche source zones, however such installations and subsequent maintenance would be technically challenging and expensive due to the steep rocky terrain that would require helicopter access. Furthermore, the installations would likely be visible from Canmore, AB and be considered unsightly.

- "Daisybell" style compressed gas device to trigger avalanches[4]. These devices are essentially helicopter borne versions of "Gaz-EX" devices, carried below the helicopter on a long sling-line and triggered from the helicopter cockpit while hovering over the

[3] Please refer to the manufacturer's website, http://tas.groupemnd.com/en/gazex/gazex.html, for further information regarding this product.
[4] Please refer to the manufacturer's website, http://tas.groupemnd.com/en/daisybell/daisybell.html, for further information regarding this product.

avalanche source zone. These devices offer the advantage of not having to establish and maintain permanent "Gaz-EX" installations around the avalanche source zones. However, their use is subject to the ability of a helicopter to safely hover over the avalanche source zones with a long sling-line used to carry the "Daisybell". Given the high, gusty winds often encountered at this site, this would be even more challenging that heli-bombing and likely impractical to unsafe for the helicopter at times.

- Explosive charges delivered via permanently installed winch lines between the highway and the avalanche source zones – high installation and maintenance costs given that the source zones are up to roughly 700 vertical metres above the highway. These installations would likely also be visually unappealing to residents in Canmore.

- Explosive charges delivered via an artillery device installed in the valley below the avalanche source areas. This could be an effective way around the limitations of helicopter overflights for heli-bombing. However, because the upper avalanche source zones are only a short distance below the summit ridgeline of the east end of Mount Rundle, shells fired from the valley below could very easily overshoot the summit and land on the far side of Mound Rundle or even the Goat Creek/Spray River valley further beyond.

- Passive avalanche control measures to deter the accumulation of an unstable snowpack in the avalanche source zones. Such measures would consist of snow redistribution structures (avalanche snow bridges). The installation and maintenance of such structures would be very expensive given the locations of the source zones in the very steep, rock slope terrain across the upper slopes of Mount Rundle. Furthermore, the permanent installations would likely also be considered unsightly by residents of Canmore.

- Snow nets installed along the avalanche paths upslope of the highway to retain avalanches and prevent them from reaching the highway. Such nets are essentially dynamic rockfall barrier nets similar to the one installed along Highway 3 at Crowsnest Lake but configured to retain avalanching snow. Considering the length of runout path and the expected volume and velocity of avalanche runout that would impact the highway, such nets are judged impractical for this area. Even if they were practical, the snow accumulated behind the nets would need to be cleaned after each avalanche event in order to maintain their capacity, which would be far more difficult, time consuming and costly to do than plowing the highway after avalanches are triggered by heli-bombing.

- Avalanche sheds – the avalanche risk to the highway could be virtually eliminated by constructing and maintaining avalanche sheds at locations where avalanche paths cross the highway. However, this would not be a cost-effective use of resources unless

performed as part of an overall upgrade of the existing highway to a two lane design standard.

The heli-bombing avalanche control work is judged to be the most suitable option for this site. It is also considered to be by far the most cost-effective, given that the ballpark cost per season has been in the order of $13,000 per year or less from 2001 to 2009 (not including the associated cost for the maintenance contractor to plow the highway after avalanches are triggered).

Another item to consider is that the potential for avalanche runout onto the highway below the point-release avalanche area on the treed slope at the south end of the overall area may increase in the future if the tree cover is reduced due to pine beetle infestation, forest fire or other issues. The heli-bombing avalanche control may need to be extended into this area if this occurs and/or passive avalanche control measures (e.g. avalanche snow bridges) may become worthwhile in this area in the future. This can be assessed in future years.

"Back Of Big Sister" Avalanche Area

This avalanche area is reported to be the least active of the three avalanche areas posing a hazard to the highway. However, monitoring of the snowpack conditions in this area by the Parks Division personnel along with heli-bombing avalanche control if required is warranted in this area. Alternative avalanche control measures are not considered worthwhile.

If the tree cover on this slope is reduced due to pine beetle infestation, forest fire or other issues, then the potential for avalanche runout onto the highway may increase. This may increase the need for avalanche control measures in this area. This can be assessed in future years.

"Buller Corner" Avalanche Area

This area is reported to be the second-most active avalanche area among the three sites, typically producing avalanches throughout each winter season but with the avalanche runout rarely reaching the highway.

If the tree cover on this slope is reduced due to pine beetle infestation, forest fire or other issues, then the potential for avalanche runout onto the highway may increase. This may increase the need for avalanche control measures in this area. This can be assessed in future years.

RISK LEVEL

"East End Of Rundle" Avalanche Area

The recommended Risk Level with respect to avalanches along this segment of the highway, based on AT's snow avalanche risk matrix (copy attached), is described below.

- Probability Factor of 13 because it appears that multiple avalanches occur in a typical year. This does not consider the artificial triggering of avalanches during the control work, i.e. it is judged that multiple avalanches would occur naturally if the avalanche control work were not performed. A Probability Factor of 13 is judged appropriate, being between a value of 11 (corresponding to "one or two" avalanches each year) and 15 (corresponding to "frequent" avalanches each year). This is the same value of Probability Factor that was recommended in the April 2009 corridor geohazard review report.

- Consequence Factor of 2 contingent upon effective, timely avalanche control work along this segment of the highway. This value of Consequence Factor corresponds to "negligible, if any, snow deposited on the road surface by avalanches. Can be cleared during routine snowplowing of the road", i.e. it relies on the avalanche control work to prevent natural avalanches from running out across the road while the highway is open to traffic.

Therefore, the recommended Risk Level for this site is 26, contingent upon the continuation of effective, timely avalanche control work along this segment of the highway. If this cannot be relied upon, then the Consequence Factor would be increased to 6, and therefore a Risk Level of 78, because naturally occurring and artificially triggered avalanches are known to run across the road and vehicles struck by such avalanches could be fully buried and possibly swept off the road (as illustrated by the February 1991 incident).

"Back Of Big Sister" Avalanche Area

The recommended Risk Level for this segment of the highway, based on AT's snow avalanche risk matrix, is as follows:

- Probability Factor of 7 because there is a record of an avalanche extending across the highway on at least one occasion, however such avalanches are not probable each year based on the available information. As noted earlier, there is usually relatively little snow accumulation in the avalanche source zones at this site and the avalanche hazard is correspondingly low, however at times during each winter a larger, unstable snowpack does accumulate.

- Consequence Factor of 2 contingent upon continued assessment of the avalanche conditions by the Parks Division and proactive road closure as required. This value of Consequence Factor corresponds to "negligible, if any, snow deposited on the road surface by avalanches. Can be cleared during routine snowplowing of the road".

Therefore, the recommended Risk Level for this site is 14, contingent upon continued assessment of the avalanche conditions by the Parks Division and proactive road closure as required. If this cannot be relied upon, then the Consequence Factor would be increased to 6, and therefore a Risk Level of 42, because naturally occurring avalanches are known to have run across the highway on at least one occasion in recent years and vehicles struck by such avalanches could be fully buried and possibly swept off the road.

"Buller Corner" Avalanche Area

The recommended Risk Level for this segment of the highway, based on AT's snow avalanche risk matrix, is as follows:

- Probability Factor of 7 because the avalanche paths extending across the highway are not active each year but at least one avalanche has reached the ditch in recent years.

- Consequence Factor of 3, which is likely slightly conservative based on the single report of an avalanche reaching the upslope highway ditch but not spilling onto the road surface. This value for the Consequence Factor is intermediate between:

    - A value of 2 that would be associated with negligible amounts of snow deposited on the road, and

    - A value of 4 that would be associated with closure of the road while heavy equipment clears snow from the road surface and also the possibility for vehicles on the highway to be at least partially buried but likely not swept off the highway.

Therefore, the recommended Risk Level for this site is 21. This Risk Level does not account for any mitigative measures, such as temporary road closure when judged to be warranted due to avalanche conditions or heli-bombing to trigger avalanching of an unstable snow pack. It is understood that such measures are not routinely applied at this site (aside from one heli-bombing occasion in the past).

RECOMMENDATIONS

The following is recommended for these avalanche areas:

1. **It is recommended that the Parks Division continue with the monitoring of avalanche conditions and avalanche control work as required for these three areas.** The use of other avalanche control measures to supplement or replace the heli-bombing avalanche control work is not recommended. As described in the "Assessment" section, the other possible avalanche control measures are assessed to be less practical and/or less cost-effective than continuing with the heli-bombing by the Parks Division as required, provided that AT can accept the consequence of temporary closures of the highway through the "East End Of Rundle" area pending heli-bombing and snow clearing from the road.

   This approach would also continue to draw upon the Parks Division personnel's avalanche control expertise and long-standing first-hand experience with these sites, which would be significantly more cost-effective than contracting out the avalanche forecasting and control work to an outside consultant.

2. As discussed during the meeting on June 11, 2009, it is understood that the costs for the avalanche control work at the "East End Of Rundle" area are currently borne by the Parks Division. However, because this work is not officially within the scope of the Parks Division these expenditures create pressure on their annual budget and as a result the heli-bombing is occasionally not performed as frequently as would be likely be assessed as necessary under the CAA recommendations for managing avalanche safety for highway operations. **Therefore, as discussed during the meeting on June 11, 2009, if AT is able to commit annual funding towards the avalanche control work that would be a significant supplement towards the total annual costs for the avalanche control work.** For example, approximately $10,000 per season would be sufficient for approximately 2 to 3 additional heli-bombing missions to perform "pre-avalanche control" work in order to maintain a lower risk to the highway and reduce the number of temporary closures per season. t is judged that this would be a very cost-effective use of resources to manage the avalanche risk to the highway and to minimize the frequency and duration of temporary highway closures due to the avalanche hazard. This does not take into account the costs for the maintenance contractor to clear the snow from the highway (along with guardrail repairs if necessary) after avalanche control work. It is understood that these costs are covered within the existing highway maintenance contract, but the particulars of this are not known to AMEC.

3. **Project site data binders should be established for the three avalanche areas.** This would be consistent with other sites that are monitored as part of AT's Geohazard Risk Management Program (GRMP) and would collect all of the documentation on the geohazard assessment and control work for each site.

4. **The annual site inspections by AT and AMEC personnel should be discontinued and replaced with an annual report (either by the Parks Division or AT with input from the Parks Division) documenting and summarizing the previous winter's avalanche control work.** This report should be prepared by the Parks Division or AT with input from the Parks Division. Such reports would allow for evaluation of the costs and cost-effectiveness of the control work relative to other avalanche control options in the future.

5. **The potential for increased rockfall from the upper slopes above the highway due to the use of explosive charges in the avalanche control work and the associated risk to the highway should be assessed.** This could be done with measurements of the vibrations induced into the underlying rock slopes by the explosive charges and some form of assessment of associated "loosening" of the rock slope beyond naturally occurring erosion and weathering.

Upgrading the existing weather station near the avalanche source zones at the "East End Of Rundle" or installing a new weather station closer to the source zones to measure snowfall/precipitation is not recommended. The cost to install and maintain the equipment in this helicopter-accessible area would not be worth the value of the data, i.e. such data is not expected to provide a basis to modify the timing or frequency of heli-bombing.

CLOSURE

This report has been prepared for the exclusive use of Alberta Transportation for the specific project described herein. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it are the responsibility of such third parties. AMEC Earth & Environmental, a division of AMEC Americas Limited, cannot accept responsibility for such damages, if any, suffered by any third party as a result of decisions made or actions based on this report. This report has been prepared in accordance with accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

We trust that this meets your needs at this time. Please contact the undersigned if you have any questions or require any further information.

Respectfully Submitted,

AMEC Earth & Environmental,
a division of AMEC Americas Limited

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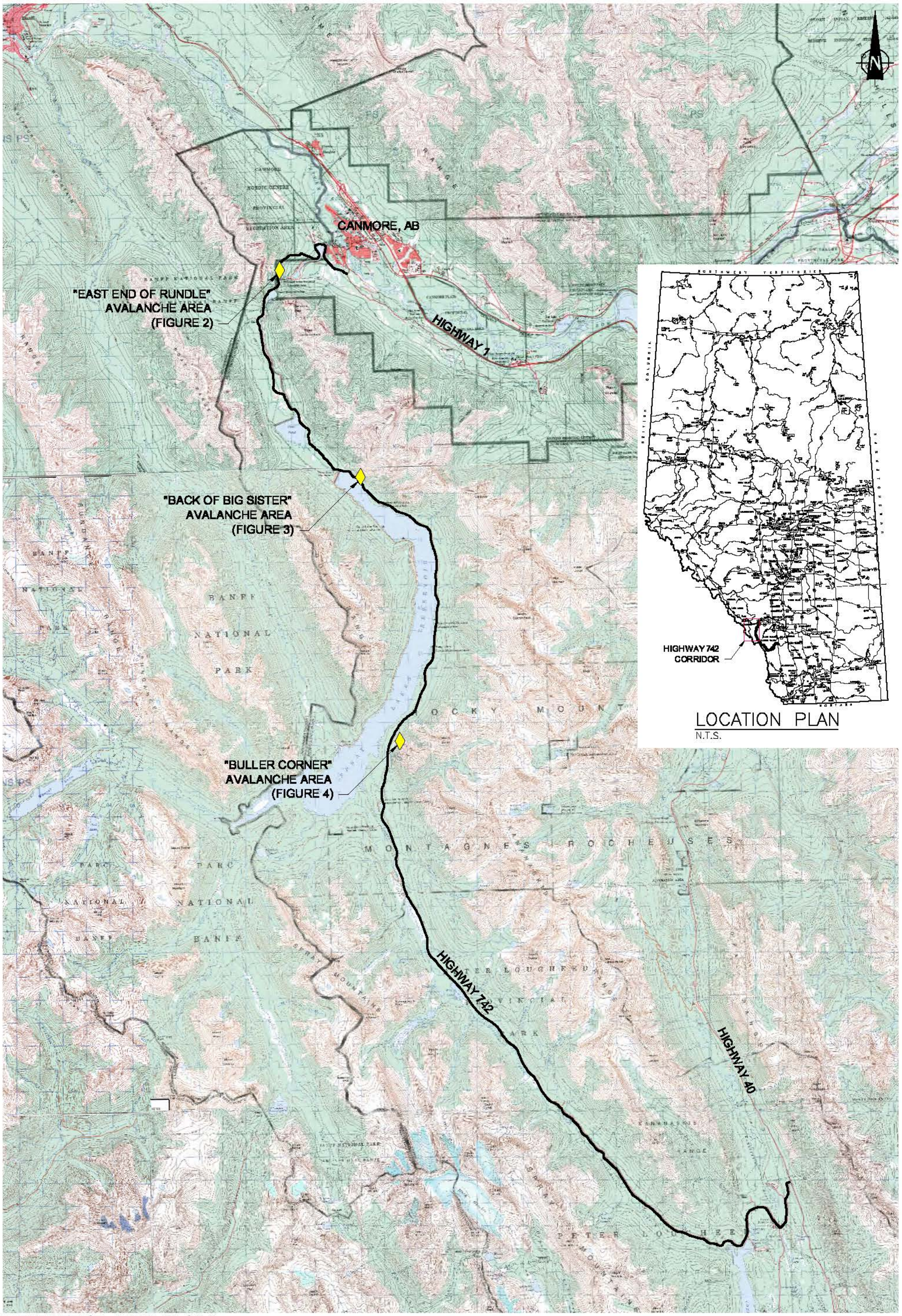
Associate Geological Engineer

APEGGA Permit to Practice No. P-04546

Reviewed by:

Pete Barlow, M.Sc., P.Eng.
Principal Geotechnical Engineer

Attachments: Figures 1 to 4
"Yearly Costs Of Helicopter Control Missions 2001-09"
AT Snow Avalanche Risk Matrix



LOCATION PLAN
N.T.S.

MAP REFERENCE: 1:50 000, 82-J/10,11, 14, 82-O/3 (ETOPO)

SCALE
1:150 000
0 1 2 3 km

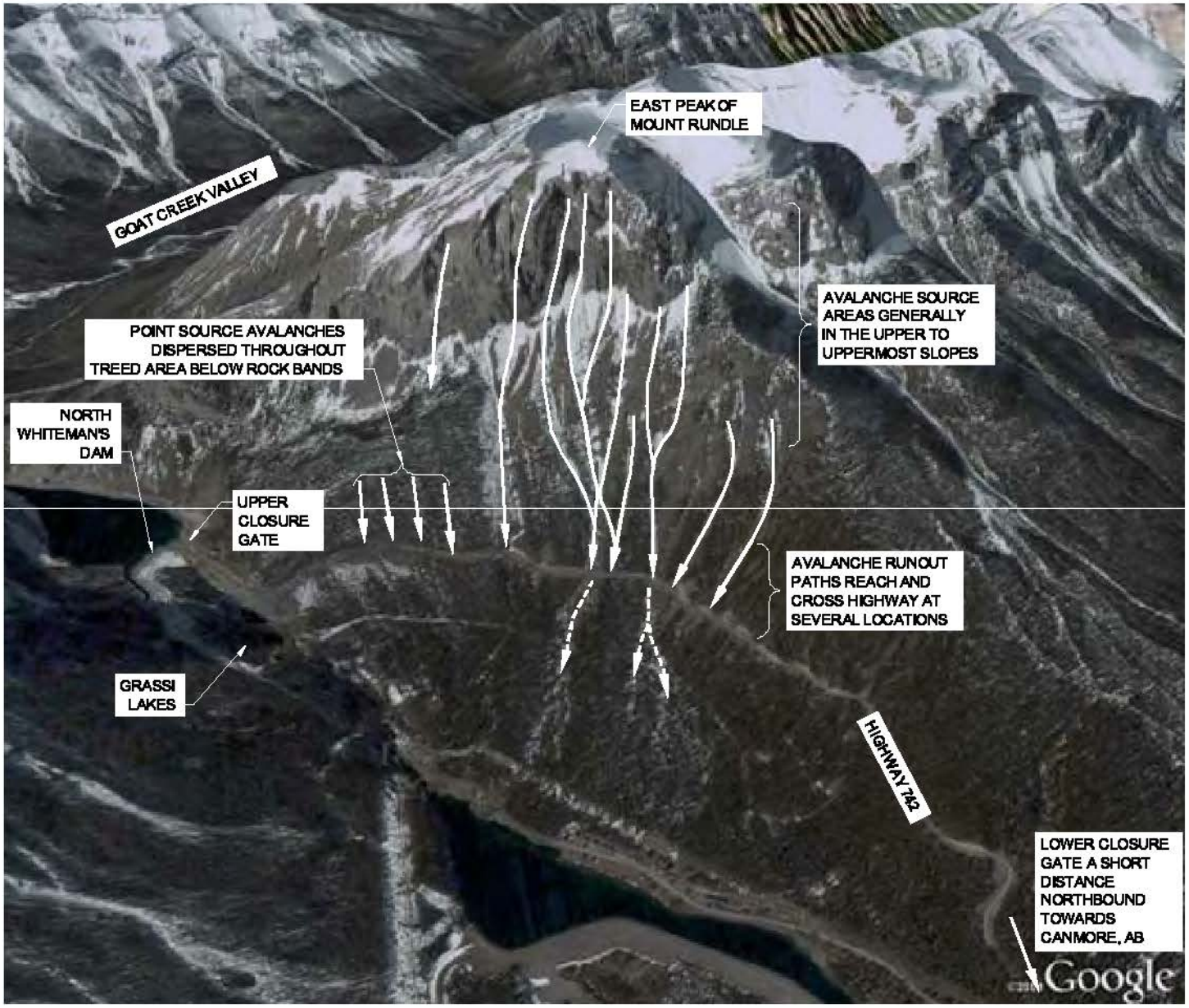
amec Earth & Environmental

CLIENT: Alberta Transportation

PROJECT: SOUTHERN REGION GEOHAZARD ASSESSMENT

TITLE: HIGHWAY 742 CORRIDOR SNOW AVALANCHE AREAS

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
JUNE 2009	CG25309.B	25309N14.dwg	FIGURE 1	A



NOTES:

1. IMAGE FROM GOOGLE EARTH.
2. FACING WEST.
3. AVALANCHE PATHS AS SHOWN ARE APPROXIMATE. ACTUAL LOCATIONS DEPEND ON SNOWPACK CONDITIONS THROUGHOUT EACH WINTER SEASON.

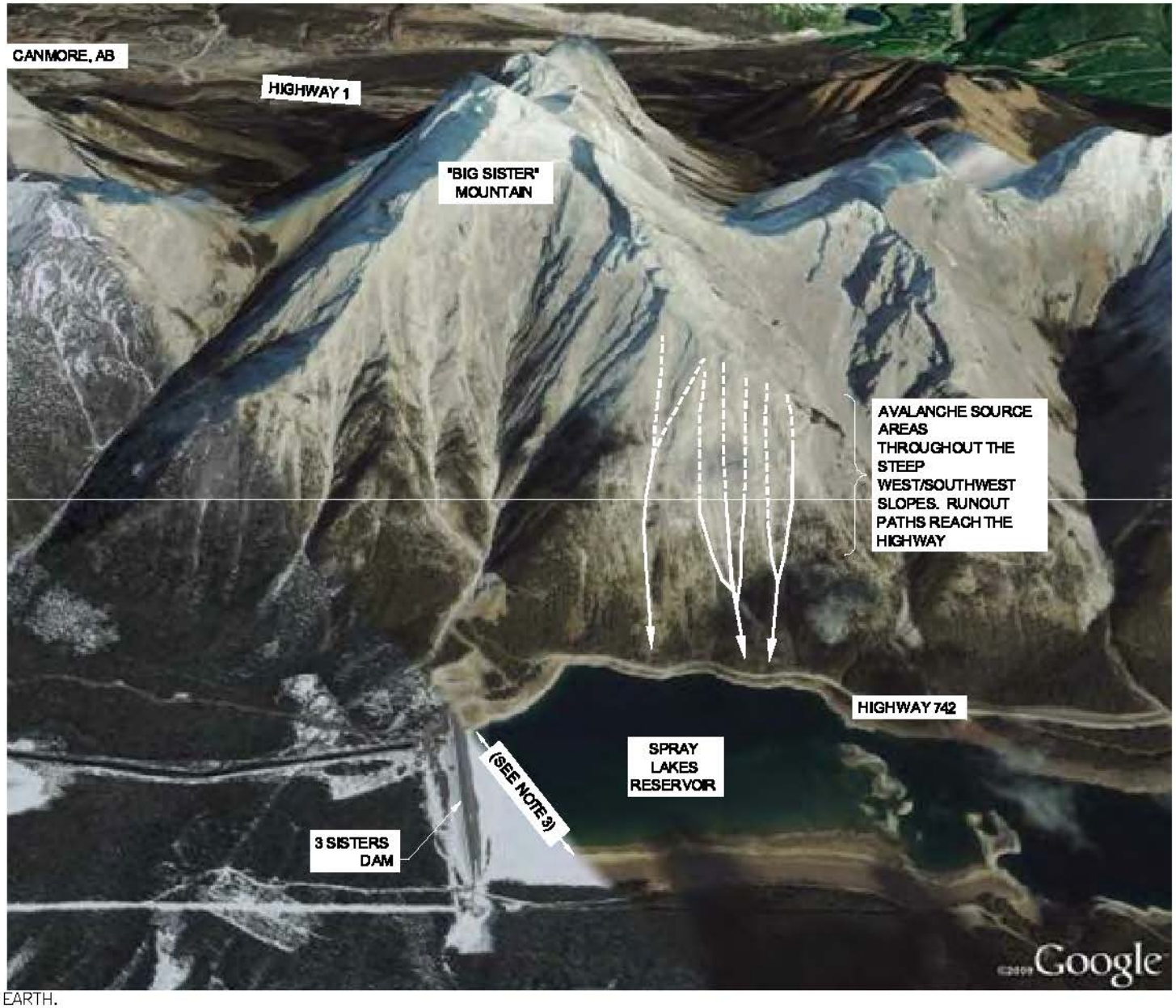
amec Earth & Environmental

CLIENT: Alberta Transportation

PROJECT: SOUTHERN REGION GEOHAZARD ASSESSMENT

TITLE: "EAST END OF RUNDLE" AVALANCHE AREA OBLIQUE VIEW SHOWING AVALANCHE PATHS

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
JUNE 2009	CG25309.B	25309N15.dwg	FIGURE 2	A



NOTES:

1. IMAGE FROM GOOGLE EARTH.
2. FACING NORTHEAST.
3. APPARENT STRAIGHT BOUNDARY BETWEEN SNOW COVERED AND NON-SNOW COVERED AREAS DUE TO COMPILATION OF SATELLITE PHOTOS FROM DIFFERENT DATES.
4. AVALANCHE PATHS AS SHOWN ARE APPROXIMATE. ACTUAL LOCATIONS DEPEND ON SNOWPACK CONDITIONS THROUGHOUT EACH WINTER SEASON.

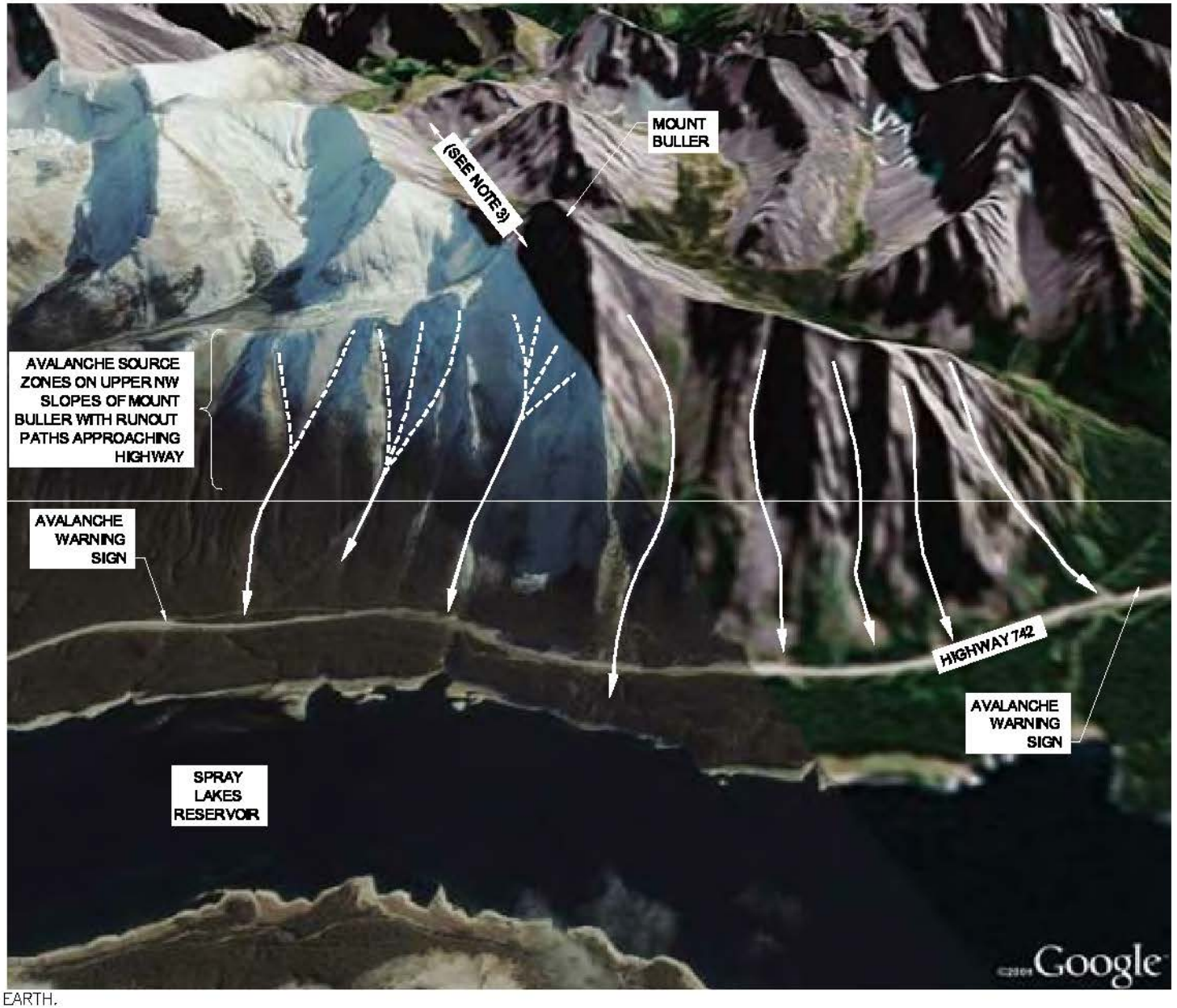
amec Earth & Environmental

CLIENT: Alberta Transportation

PROJECT: SOUTHERN REGION GEOHAZARD ASSESSMENT

TITLE: "BACK OF BIG SISTER" AVALANCHE AREA
OBLIQUE VIEW SHOWING AVALANCHE PATHS

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
JUNE 2009	CG25309.B	25309N15.dwg	FIGURE 3	A



NOTES:

1. IMAGE FROM GOOGLE EARTH.
2. FACING EAST.
3. APPARENT STRAIGHT BOUNDARY BETWEEN SNOW COVERED AND NON-SNOW COVERED AREAS DUE TO COMPILATION OF SATELLITE PHOTOS FROM DIFFERENT DATES.
4. AVALANCHE PATHS AS SHOWN ARE APPROXIMATE. ACTUAL LOCATIONS DEPEND ON SNOWPACK CONDITIONS THROUGHOUT EACH WINTER SEASON.

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CLIENT: Alberta Transportation

PROJECT: SOUTHERN REGION GEOHAZARD ASSESSMENT

TITLE: "BULLER CORNER" AVALANCHE AREA
OBLIQUE VIEW SHOWING AVALANCHE PATHS

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
JUNE 2009	CG25309.B	25309N15.dwg	FIGURE 4	A

~Km 4.8 to ~Km 6.0 Snow Avalanche Area

Site Observations

The segment of the highway between approximately Km 4.8 and Km 6.0 is signed as "Avalanche Area, No Stopping".

There are several avalanche paths along drainage draws on the east slope of Mount Rundle that extend across the highway right-of-way. These paths are visible on the oblique aerial view on Figure A5 in Appendix A.

Case History – 1991 Avalanche

There is a case history reported in Jamieson and Geldsetzer (1996) of a February 1, 1991 avalanche that struck a pickup truck that was parked on the highway a short distance southbound from the "Avalanche Area, No Stopping" sign around Km 4.8. The truck was swept off the road and the guardrail along the downslope side of the road was destroyed. The three occupants of the parked truck were not injured because they sighted the oncoming avalanche and fled on foot before the avalanche impacted the truck. However, there was the potential for the truck occupants to be seriously injured if not killed had they been in the truck. Photos 742-18 and 742-19, attached (from Jamieson and Geldsetzer (1996)) show views of the site from shortly after the avalanche.

Avalanche Control Work

Public Safety Officers from Alberta Tourism, Recreation and Parks (Parks Division, Kananaskis Country) perform avalanche control work for this segment of the highway and have provided the following information:

- The avalanche control work is funded by the Parks Division and is performed by the Public Safety Officers working with the Kananaskis Country avalanche forecast team. They report that at times in recent years "control work was less frequent than was ideal" due to resource availability. Wind and visibility conditions also limit the ability to use a helicopter to safely perform the control work at certain times.

- The control work has consisted of dropping explosive charges into avalanche source zones above the highway from a helicopter (and on occasion landing and hand-throwing charges into one specific target zone) in order to artificially trigger avalanches. A number of bowls across the upper portions of the slope above the highway have been targeted at various times along with selected locations further downslope (but still above the highway).

- This segment of the highway is closed to traffic during the control work because the avalanches triggered by the charges often, but not always, reach the highway. The triggered avalanches have on occasion destroyed segments of the guardrail as they cross the highway. The duration of the closures varies depending how many of the avalanche paths have slides that reach the highway and how much snow is deposited on the highway at each location. The average closure duration is around two to three hours, however during some control work in March 2009 the highway was closed for only approximately 35 minutes because none of the triggered avalanches reached the highway.

- The frequency of avalanche control work varies from year to year, depending on snowpack conditions, as follows:

    - Winter 2008/2009 – at the time of writing in March 2009, control work has been performed at three times during the winter of 2008/2009 and it is considered likely that another occasion will be required prior to the end of the avalanche season.

    - Winter 2007/2008 – two occasions.

    - Winters 2004/2005, 2005/2006 and 2006/2007 – no control work performed.

Furthermore, AMEC understands from AT that:

- Road closures are required at other times when maintenance contractor personnel find avalanche debris on the highway while checking the road or when the RCMP reports such conditions to the maintenance contractor.

- There are no established criteria for a proactive road closure during snowstorms or times when the avalanche hazard is considered to be relatively high.

Assessment

Motorists traveling this segment of the highway are at risk from snow avalanches. To date, the avalanche control work described above has been performed to reduce the risk to the highway. However, it has been reported that the control work is sometimes not performed as often as intended due to the availability of resources for the work and cannot be done at certain times when the wind and visibility conditions make it unsafe for the helicopter to fly over the site.

The current avalanche control work is effective in triggering avalanches and clearing the subsequent snow deposits from the highway while the road is temporarily closed. However, the frequency and timing of the control work is limited at times and it should

therefore not be relied upon to maintain a sufficiently low risk along the highway at all times. For example, a high intensity snowfall under certain weather conditions could rapidly increase the avalanche risk to the point where avalanche control measures would be applied but cannot be done promptly due to high wind and/or poor visibility conditions. There would be a risk to the highway unless it were closed to traffic until avalanche control work could be done. Proactive blasting of the preceding, stable snowpack would not be beneficial.

It would be worthwhile to assess the advantages and disadvantages along with the cost effectiveness of the current avalanche control procedures relative to other options that could supplement the current avalanche control work and further or more reliably reduce the avalanche risk to the highway.

The posted warning signs that warn motorists not to stop along the highway within the avalanche area also help to reduce the risk. However, the February 1991 incident shows that they may be ignored at key times.

Risk Level

The recommended Risk Level with respect to avalanches along this segment of the highway, based on AT's snow avalanche risk matrix, is described below.

Please note that the recommended Risk Level conservatively disregards the benefit of the avalanche control work which, in reality, reduces the Consequence Factor before an unstable snowpack re-accumulates in the avalanche source zones above the highway. The recommended Consequence Factor can be revised to reflect the avalanche control work after the recommended assessment of the avalanche conditions at this site along with the effectiveness of the current avalanche control work and possible additional measures to increase the effectiveness and reliability of the avalanche control work.

- Probability Factor of 13 because it appears that multiple avalanches occur in a typical year. This does not consider the artificial triggering of avalanches during the control work, i.e. it is judged that multiple avalanches would occur naturally if the avalanche control work were not performed. A Probability Factor of 13 is judged appropriate, being between a value of 11 (corresponding to "one or two" avalanches each year) and 15 (corresponding to "frequent" avalanches each year).

- Consequence Factor of 6 because naturally occurring avalanches would result in road closure while heavy equipment clears snow from the road surface. In addition, vehicles struck by avalanches could be fully buried and possibly swept off the road. This rating is supported by the need for such work after triggering avalanches, the reported occasional guardrail damage and the February 1991 incident.

Therefore, the recommended Risk Level for this site is 78.

Recommendations

Maintenance and Short Term Actions

- Maintain the warning signage posted along the highway.
- Continue the current avalanche forecasting and control work by the Parks Division.

Medium To Long Term Actions

- Assess the avalanche conditions along this segment of the highway along with the effectiveness of the current avalanche control work given the available resources and occasional limitations of helicopter use due to wind and visibility conditions.
    - This assessment should meet the Canadian Avalanche Association's recommended standard of practice for avalanche hazard identification and management for resource and transportation industries. It should be done collaboratively between AT and the personnel performing the current avalanche control work.
    - The participation of a specialist consultant with suitable training and experience in assessing avalanche conditions will likely also be required. The training and experience requirements for managing avalanche safety programs for highway operations as listed for the Qualified Avalanche Planner designation proposed by the Canadian Avalanche Association would provide guidance on this.
    - As part of this assessment, consider supplementary measures that may cost effectively increase the reliability of avalanche control work each season. Please refer to the "*Options For Avalanche Control Measures*" below for some initial thoughts on this.
    - One of the conclusions of the assessment may be that temporary, proactive road closures are warranted at certain times until avalanche control can be performed to trigger avalanches and clear the snow from the road.
- Establish a maximum vehicle length permitted on this segment of the highway so that the vehicles on the narrow road will have sufficient maneuverability to avoid

avalanche debris on the road or turn around if necessary. Long vehicles and tows should be directed to alternate routes.

Options For Avalanche Control Measures

Avalanche control measures to reduce both the Probability Factor for avalanches and also the Consequence Factor for any avalanches that do occur include:

1. Active measures – the artificial triggering of relatively smaller avalanches to prevent snowpack buildup to the point where larger, higher consequence avalanches occur naturally. The avalanches are triggered either with explosives or manually, as described below:

    a. Explosives – there are several options for delivering the explosives into the avalanche initiation zone above the highway:

        i. Aerially ("heli-bombing") – thrown from a helicopter hovering over the target location. The main advantage of this option is that the charges can be targeted to specific locations as required and does not require permanent infrastructure for the control work. The main disadvantage of this options is that it is cannot be performed during poor weather or darkness when a helicopter is unable to safely fly over the slope. The current avalanche control work at this site uses this option.

        ii. Hand placed – by personnel accessing the slopes above the avalanche initiation zone (by traversing up from the road via a safe travel route or via helicopter drop-off) and then throwing an explosive package into the snowpack in the initiation zone. This option offers the greatest flexibility in where to attempt to trigger an avalanche provided that the area can be safely accessed. However, it is limited by the need for worker safety and is relatively labour-intensive. It is understood that this option has been used on occasion at this site.

        iii. Via winch line – a permanent winch line is suspended between a tower constructed near the highway and an anchor point upslope of the avalanche source area. An explosive package is suspended from the line, winched over the target zone on the slope and released by remote signal to drop into the snowpack. The explosives are triggered with a timer device or via remote signal after being dropped. This option is applicable to recurring avalanche initiation zones. The main advantage of this option is that it can be done by personnel working from the highway, in any weather and during darkness if necessary. The main disadvantage is that it can only be applied to locations beneath the winch line.

iv. Shelling – explosive shells are fired into the avalanche initiation zone from an artillery piece near the highway. The main advantage of this option is that it can be done by personnel working from the highway and it can be applied to multiple locations from a single firing location set up near the highway. Furthermore, it can be performed in low visibility weather or in darkness if the target locations are known and pre-sighted.

b. Manually triggering avalanches, typically by trained personnel "ski-cutting" the uppermost portions of an avalanche initiation zone in order to trigger avalanches further downslope (i.e. without the personnel being caught in the avalanche). This option can be effective and avoids the use of explosives, but is limited by the availability of trained and qualified personnel and whether or not they are able to safely perform the work without getting entrained into the triggered avalanche.

2. Passive measures – to deter the accumulation of an unstable snowpack in avalanche source zones or mitigate the consequences of naturally occurring avalanches. The main advantage of passive avalanche control measures is that they are effective at all times and require relatively little maintenance. Furthermore, most of any necessary maintenance (aside from clearing avalanche debris from snow nets) can be done safely during the summers. Options for passive measures include:

   a. Snow redistribution structures (avalanche snow bridges) – installed in the initiation zone of avalanches to disrupt the formation of thick and unstable snowpacks in avalanche initiation zones. These structures are similar to snow fences, however they are permanent structures that are inclined or horizontal, rather than vertical as a snow fence would be. Photo 742-20 shows an example of a snow redistribution structure from a site in Europe.

   b. Avalanche deflection or catchment dams – constructed in the flatter portions of the avalanche run-out path in order to deflect or retain avalanches and prevent them from reaching the highway. Not applicable at this site because the segments of the avalanche paths just above the highway are too steep and the dams would likely be overtopped by any avalanches that are capable of reaching the highway.

   c. Tree cover – establishing tree cover through the avalanche initiation zone would serve to prevent the buildup of a continuous, unstable snowpack in the same way that snow redistribution structures do. This option is not considered applicable for the slopes above the highway because they are largely exposed rock with a discontinuous cover of loose, rocky soil and colluvium.

d. Snow nets – installed along the avalanche path upslope of the highway can be used to retain avalanches and prevent them from reaching the highway. The nets are essentially dynamic rockall barrier nets similar to the net installed at the Highway 3 rockfall site at Crowsnest Lake but configured to retain avalanching snow. They can be effective, however if they are filled by an avalanche they require prompt cleanout to restore their capacity. The volume of snow to be retained by avalanches at this site may exceed the practical capacity of snow nets (see Photo 742-19).

3. Avalanche sheds – the avalanche risk to the highway could be virtually eliminated by constructing and maintaining avalanche sheds at locations where avalanche paths cross the highway. However, this would likely not be a cost-effective use of resources unless performed as part of an overall upgrade of the existing highway to a two lane design standard.

4. Proactive road closures – this segment of the highway could be closed to traffic when the avalanche hazard is judged to be sufficiently high and the weather/daylight conditions are such that it is not possible for a helicopter to safely fly over the slope to drop explosive charges and trigger avalanches. This option could be used to supplement the current avalanche control work at this site.

The best option or combination of options should be determined as part of the recommended assessment of the avalanche hazard at this site. The best path forward may be to continue the heli-bombing during times that the avalanche hazard above the highway is judged to be sufficiently high and possibly supplemented with proactive road closures and/or the installation of a winch line or artillery piece to deliver explosive charges into annually recurring avalanche source areas during poor weather conditions. A trial application of snow redistribution structures may also be worthwhile, however the size of the source areas and difficult site access for construction would make their cost-effectiveness for this site questionable.

~Km 4.8 to ~Km 6.0 Avalanche Area

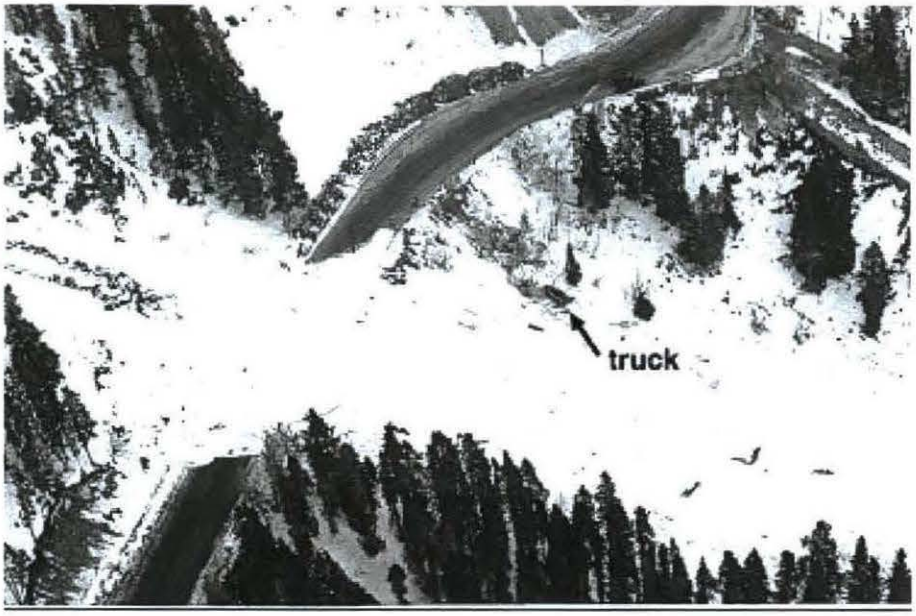

Photo 742-18 (top)
(Figure 7.4 from Jamieson and Geldsetzer (1996))

February 1, 1991 photo of avalanche across Highway 742, apparently a short distance southbound from the warning sign at Km 4.8. The location of the truck that was swept from the highway is shown.

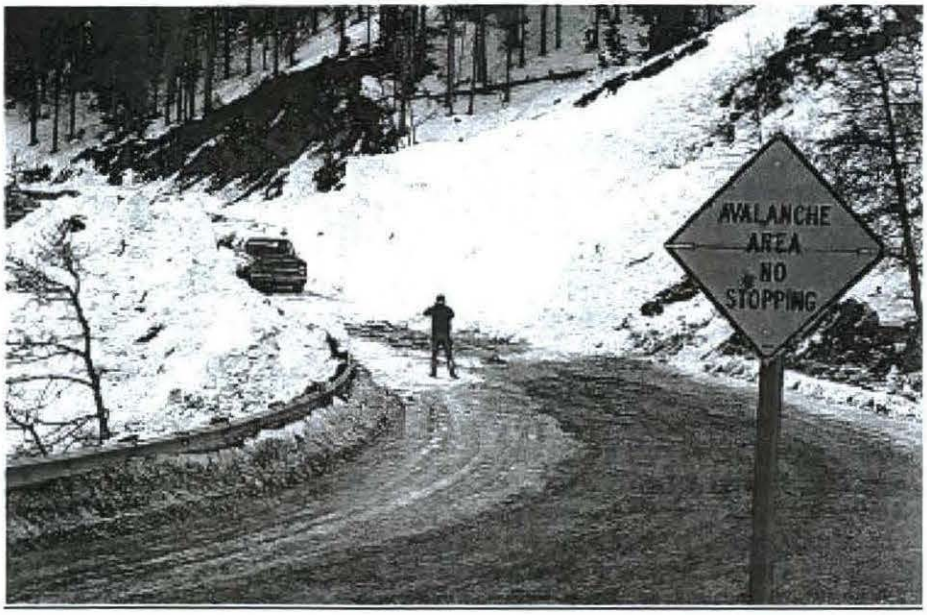

Photo 742-19 (bottom)
(Figure 7.5 from Jamieson and Geldsetzer (1996))

February 1, 1991 photo facing southbound from the warning sign around Km 4.8, with the recently-cleared snow deposit across the highway visible in the background.

~Km 4.8 to ~Km 6.0 Avalanche Area

Photo 742-20 – example of a snow redistribution structure installed at a ski resort in Austria to deter the accumulation of an unstable snowpack in an avalanche source area.
(Photo from http://en.wikipedia.org/wiki/Avalanche_control, accessed on March 12, 2009.)