COUGAR CREEK LONG-TERM MITIGATION

OPTION ANALYSIS SUMMARY REPORT

Town of Canmore

Engineering Department

January 13, 2015

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INTRODUCTION

For creek hazards, Canadian practice has been to estimate the discharge of a 100-year or 200-year return period flood and design protection to defend against the associated flood stage. This hazard-based method, while based on sound principals, does not account for severity of consequences to assets at risk. As such, international best-practices have generally moved towards a risk-based approach that explicitly and systematically evaluates the consequences of any flooding. This approach facilitates an objective determination of the optimal approach to risk reduction, allows a transparent and repeatable evaluation of potential flood mitigation alternatives, allows comparison of flood risk to other risks faced by society, and helps define thresholds for the tolerance of flood risk. Risk tolerance criteria have been internationally and nationally established and should be adopted soon in provincial guidelines for Alberta.

The floods of 2013 demonstrated the limitations of hazard based mitigation for protecting Canmore from debris flows and debris floods generated by our steep mountain creeks. Lacking adequate mitigation for the magnitude of this event, tens of millions in losses were experienced, highways and the railway were severed, and the public and emergency response teams were put at risk.

In the past year, the Town, with the support of the Province, and along with an experienced international team of consultants and specialist advisors, has undertaken a detailed hazard and risk assessment for Cougar Creek. The hazard assessment was reviewed in detail by Specialist Advisor, Dr. Michael Church; the hazard and risk reports were reviewed by Specialist Advisor, Dr. Norbert Morgenstern; and the mitigation strategies developed by Alpinfra were reviewed by Specialist Advisor Dr. Johannes Hübl. Both, Dr. Church and Dr. Morgenstern have provided a letter summarizing their involvement with the project. These letters are included in Appendix C.

The study shows that the risk on Cougar Creek is unacceptable in its current state. Safety risk, expressed by the annual probability of death of an individual (PDI), exceeds the threshold of 1:10,000 on 190 parcels of the Cougar Creek fan. This number is comparable to the probability of dying in a car accident. Estimated group safety risk also fell in the “unacceptable” range. Estimated direct building damage has an annualized damage cost of $700k. This does not include damage to contents or inventory, cost of cleanup and recovery, indirect costs due to business interruption, loss of power transmission, or highway or railway interruption. For reference, revenues of all businesses on Cougar Creek Fan correspond to about $168 M/year.

Based on this detailed study, and the advice of our specialist advisors, administration recommended a study be undertaken to identify options for risk reduction. On March 18th, 2014 Council approved a capital project to undertake this work.

Option Analysis Consultant Selection

The Town undertook an intensive process to select a qualified specialist consultant to develop options for mitigation. A request for proposal was issued through Alberta Purchasing Connection as part of the short-term mitigation work to identify North American specialists in the design and construction of mitigation infrastructure. That process yielded in a number of qualified consultants that successfully delivered four short-term projects. Due to the limited amount of infrastructure in Canada, there were very few examples of sediment retention structures designed by Canadian firms, and no examples of projects similar to Cougar Creek. That meant that we needed to find specialists from outside Canada that had this expertise.

Austria is home to a robust research and education program for mountain risk engineering. This research and education informs design standards, engineering and construction for around $400,000,000 CAD in avalanche and torrent control mitigation each year. As a result of this intensive effort, Austria is home to some of the worlds most advanced understanding in managing and mitigating steep creek hazards.

The project team has established an advisory relationship with Dr. Johannes Hübl, head of the Institute of Mountain Risk Engineering at the University of Natural Resources and Life Sciences (BOKU) in Vienna, Austria. We asked Dr. Hübl to support us in our search for consulting expertise by recommending Austrian firms that have appropriate experience and are respected in this field. Dr. Hübl recommended two firms for shortlisting.

Lead designers for both firms visited Canada to gain a better understanding of the Creek site and the project in general. This gave us an opportunity to interview the proponents in person and to gain a better understanding of the capabilities of their firms. Both firms were provided a Request for Proposal document and, in turn, submitted proposals for the work. The Town employed our standard quality based selection process to determine a highest ranked proponent. Alpinfra Engineering of Salzburg, Austria, stood out as the highest ranked proponent based on their project team's extensive experience dealing with similar hazards in the Alps. Alpinfra specializes in mitigating geotechnical hazards, including snow avalanches, rock falls, landslides, debris flows and debris floods.

Option Development

The first step in establishing design parameters for any mitigation option was to determine the level of protection desired for the creek. The Hazard and Risk Assessments prepared by BGC Engineering indicated that individual risk of loss of life and group risk of loss of life are very high and outside of generally accepted thresholds. Based on this assessment we provided Alpinfra with the following goals:

- Reduce the annual risk of individual loss of life (PDI) to less than 1:10,000 years for each of the 190 properties that exceeded this threshold. The 1:10,000 years threshold is established by draft provincial guidelines for existing development;
- Reduce risk of group loss of life into the as-low-as-reasonably-practicable (ALARP) zone. This group risk threshold is also established by draft provincial guidelines for existing development.

Alpinfra was asked to give consideration to the physical location of options, as well as the hazard and risk, to come up with mitigation strategies. They were not asked to give consideration to social, economic, or environmental impacts as those would be considered and mitigated separately as part of the evaluation process.

Based on this direction, Alpinfra developed three mitigation options.

PROPOSED OPTIONS

The following options were presented as conceptual designs that considered the function, positioning, geometry, materiality and size. This level of detail allowed for evaluation of options and estimation of costs.

The first proposed option (Option A) consists of a debris flood retention structure at the site of the existing debris net. The structure is 30m high at the spillway and spans across the 45m wide bedrock confined channel. At its highest point the structure is approximately 100m wide. The basin the structure would create during extreme events would hold back up to 650,000 cubic meters of water and debris. A rendering of the structure is shown below, looking upstream.

Figure 1: Rendering Option A

The second proposed option (Option B) consists of a debris flood retention structure at the 'Kame Terrace' site. This site is located slightly upstream of the last houses along Eagle Landing. The structure is 20m high at the spillway and approximately 350m wide. This structure is also designed to hold back up to 650,000 cubic meters of water and debris during a large event. A rendering of the structure is shown below, looking upstream.

Figure 2: Rendering Option B

The final proposed option (Option C) consists of a debris retention structure at the Kame Terrace site. It is 12m high and approximately 200m wide. This structure is designed to only retain sediment, up to a maximum of 120,000 cubic meters. The water and finer sediment passes through large rake covered openings mostly unimpeded. A rendering of the structure is shown below, looking upstream.

Figure 3: Rendering Option C

For a more thorough presentation of the options, refer to Alpinfra Mountain Creek Hazard Mitigation – Design of Mitigation Measures, Interim Report 03, R00 (rev.4 FINAL, January 13, 2015).

Stakeholder Input

Engagement with provincial stakeholders has been ongoing since August 2013. On June 25th, 2014, the conceptual options were presented to a large group of stakeholders including AESRD, Alberta Transportation, and Alberta Tourism, Parks and Recreation. A number of land, environmental, cost, social, technical, and political concerns, as well as several items to address were raised in the meetings.

Based on the feedback received during engagement, the project team established draft criteria for evaluating options. Feedback has also been used to address a number of questions through further investigation. The project team then further refined options, undertook geotechnical work, and considered pedestrian, wildlife, and maintenance access. Planned schedules were adjusted for the options to account for permitting requirements.

The project team organized engagement for the option analysis, to select a preferred option, with the larger stakeholder group on September 23, and 24th, 2014. Prior to the option selection workshop, stakeholders were encouraged to review pertinent background information and provide feedback that was to be incorporated into the process.

Because of the sensitive nature of the hazard and risk assessments, the public had not been directly engaged prior to the option analysis. However two focus groups were engaged in September with a limited number of affected and non-affected residents. The focus groups were provided with general flood information and asked specific questions to determine preferences and sensitivities. The results were used as inputs for the decision making process, to improve the overall communication strategy, and to help guide the format and content of the two public information sessions.

Subsequent to the option analysis workshop in September, two public open houses were held for the community. A newsletter has also been published and studies have been posted to the website.

Option Analysis and Option Selection

On the recommendation of our specialist advisor, Dr. Norbert Morgenstern, the project team retained Kepner Tregoe (KT) to facilitate the decision making process. The methodology developed and tested by KT over 50 years provided a structured and effective process for selecting the preferred option. It is a methodology that is well respected in both private and public organizations.

The KT method is based on the premise that the end goal of any decision is to make the "best possible" choice. The goal is not to make the perfect choice, or the choice that has no risks, but to make the best choice possible. An important feature of the KT method is that it helps evaluate and mitigate the risks of the decision taken.

KT Preparation Workshop

On August 29th, the project team held a preparation workshop with KT. The goal was to understand the overall KT decision making process, to develop a decision statement, define some basic assumptions, establish draft objectives and weightings, and determine what further information would be required prior to the option selection workshop. The following people were present at the meeting: Julia Eisl, Mountain Risk Specialist, Town of Canmore; Andy Esarte, Manager of Engineering, Town of Canmore; Felix Camire, Project Engineer, Town of Canmore; Rob Copeland, Project Manager, ISL Engineering; Troy Letwin, Bridge Design Manager, ISL Engineering; Heinrich Heinz, Managing Director – Geotechnical Engineer, Thurber Engineering; Eric Vanice, Consultant, Kepner Tregoe.

In the preparation workshop, the participants worked out drafts for the decision statement, the basic assumptions and the objectives to prepare the information required for the final workshop. The list of the defined objectives and weightings was not meant to be exclusive or final. Moreover it was a basis for discussion with the stakeholder group.

Draft decision statement: **The goal of the decision-making process is to recommend a debris flood mitigation concept for Cougar Creek.**

Six basic assumptions were identified to set the basic boundary conditions guiding the analysis. They are:

- ✓ No existing property will have a residual life safety risk exceeding 1:10,000
- ✓ Group loss of life shall be reduced to the “as low as reasonably practicable” (ALARP) zone
- ✓ None of the options pose significant negative impacts to downstream communities
- ✓ Funding for the selected mitigation option will be available
- ✓ Mitigating flood damage through infrastructure can be accomplished for less cost than that of moving people out of harm’s way
- ✓ The province will provide regulatory approvals for selected option.

These assumptions were necessary to be able to focus on what was important for the selection analysis. As an example, if the project budget had been capped at a fixed level, some option(s) might not have been considered, even though one of them could have been the best to attain the objectives. Most importantly, all options had to meet the risk reduction criteria proposed in the first place, since the aim of the long-term mitigation work in Cougar Creek is to reduce risk to acceptable levels.

Finally, the following draft objectives and relative weights were developed:

Weight	Objective
10	Minimize damage to public and private property
10	Potential for blocked evacuation routes is minimized
10	Minimize downtime of major transportation links including Trans-Canada Highway, Highway 1A and CP Rail.
9	Maximize protection of major utilities including power, gas, and communication
9	Eliminate need for emergency equipment involvement during flood event
8	Minimize ecological impacts
7	Minimize annual maintenance costs including: Sediment removal, post-flood re-vegetation, infrastructure inspection
6	Minimize construction costs.
4	Minimize social and recreational impacts
3	Minimize construction duration with a goal of two or less construction seasons.

Following this preparation workshop with KT several other technical and stakeholder meetings took place. Some of them were to refine the cost estimates, to discuss potential permitting issues, to discuss environmental concerns, to refine some of the complex concepts, and to complete an ACRP application for funding.

Option Analysis Workshop

The option analysis workshop took place over two days, on September 23rd and 24th, 2014. The following people participated: Julia Eisl, Mountain Risk Specialist, Town of Canmore; Felix Camire, Project Engineer, Town of Canmore; Andy Esarte, Manager of Engineering, Town of Canmore; Lorrie O'Brien, General Manager of Municipal Services, Town of Canmore; John Sobkowicz, Principal – Senior Geotechnical Engineer, Thurber Engineering; Calvin McClary, Calgary Office Manager – Senior Engineer, ISL Engineering; Eugene Yaremko, Principal - Senior Engineer, Northwest Hydraulic Consultant; Matthias Jacob, Senior Geoscientist, BGC Engineering; Melanie Percy, Senior Park Ecologist, ESRD Parks Division; Dave Hannah, Kananaskis Area Manager, ESRD Parks Division; Jim Choles, River Hydraulics Engineer, ESRD; Brian Allen, Lands Officer, ESRD; Dan Adams, Land – Operations Unit Lead, ESRD; Pauline

Scoffield, Water Approvals Technologist, ESRD; Cathy Maniego, Executive Director, Resilience and Mitigation, ESRD (day 1 only); Robert Wolf, Environmental Specialist, ESRD; Roger Skirrow, Director of Geotechnical and Materials Section, Alberta Transportation.

The decision making process was explained and facilitated by Eric Vanice of KT so that all participants would understand the objectives of the two days and how the decision making process would unfold.

Time was dedicated to refine the draft objectives and their weights. Some objectives were re-worded or split out. The objective “Minimize ecological impacts” was separated into two different objectives, namely “Minimize impact on regional corridor” and “Minimize habitat fragmentation”. The objective “Minimize social and recreational impacts” was replaced with “Minimize impact to park users’ experience” and “Provide access to recreation and natural areas”. Finally, “Minimize impacts related to resident’s view and sight lines” was created as a new objective. This revised list of thirteen objectives provided a better balance between safety, economic and environmental objectives.

Table 1: Final list of revised objectives and their respective weight

Weight	Objective
10	Minimize damage to public and private property
10	Minimize potential for blocked evacuation routes
10	Maintain safe passage of goods and services on major transportation links including Trans-Canada Highway, Highway 1A and CP Rail.
9	Maximize protection of major utilities including power, gas, and communication
9	Minimize need for operation of heavy equipment involvement during flood event
9	Minimize impact on regional corridor
8	Minimize habitat fragmentation
7	Minimize annual maintenance costs including: Sediment removal, post-flood re-vegetation, infrastructure inspection
6	Minimize construction costs
4	Provide access to recreation and natural areas
3	Minimize impacts related to resident’s view and sight lines
3	Minimize impact to park users’ experience
3	Minimize construction duration with a goal of two or less construction seasons.

The three proposed mitigation options were then scored on a scale of 1 to 10, 10 being the best. Also, the option of not doing any further mitigation work was evaluated and compared to the proposed strategies. The exercise of evaluating the do-nothing-further approach assists with testing project rationale and further develops project justification.

The Option A, a 30m high debris flood retention structure at the debris net site, scored the highest overall and ranked number 1 in all key objectives. The overall score of the next best option was significantly lower than Option A. The option of not doing any further mitigation work scored poorly in all key objectives as well as in the overall ranking.

The decision making matrix with the ranking for the different options is displayed in Table 2.

Table 2: Decision making matrix with ranking of each option. The best option, per objective, is highlighted in green.

Wt	OBJECTIVE	Option A	Option B	Option C	No Further Mitigation
10	Minimize damage to public and private property	1	1	3	4
10	Minimize potential for blocked evacuation routes	1	1	3	4
10	Maintain safe passage of goods and services on major transportation links including Trans- Canada Highway, Highway 1A and CP Rail.	1	1	3	4
9	Maximize protection of major utilities including power, gas, and communication	1	1	3	4
9	Minimize need for operation of heavy equipment involvement during flood event	1	1	3	4
9	Minimize impact on regional wildlife corridors	1	4	2	2
8	Minimize habitat fragmentation	4	3	2	1
7	Minimize annual maintenance costs including: Sediment removal, post-flood re-vegetation, infrastructure inspection.	2	3	1	4
6	Minimize construction costs	2	3	4	1
4	Provides access to recreation and natural areas	2	4	2	1

3	Minimize impacts related to residents' view and sight lines	2	4	3	1
3	Minimize impact to park users' experience.	4	3	2	1
3	Minimize construction duration with a goal of two or less construction seasons	2	2	4	1

The complete decision matrix, including all evaluation criteria for all options, can be found in Appendix A – KT Workshop Decision Matrix.

Risks associated with the project

Following the option selection, several risks associated with recommending Option A as a long-term mitigation concept for Cougar Creek were identified. Political, community, safety, design, construction, permitting and maintenance risks were assessed. Most of the risks identified were common to all three options. All the risks identified during the session will be taken into account and mitigated throughout the project. Risk management is of utmost importance in the delivery of this project and many of those risks were already identified prior to the KT workshop. Some of the important risks are discussed below.

The permitting aspect of the project is one of the biggest risks. The location of the mitigation structure is within the Bow Valley Wildland Provincial Park. Several activities are regulated and some are restricted in a provincial Wildland Park. The construction of a dam and a road is a restricted activity. The Town of Canmore currently has a land disposition at the Debris Net site. It is believed that this disposition will be amended and used for the debris flood retention structure. However, there is currently no mechanism in the Parks Act to allow the construction of a road within a Wildland Park. The road is essential during the construction of the structure. It will also be needed to annually maintain the structure and to remove the debris accumulated upstream of the structure after large events. Alberta Parks has been seeking legal advice on this matter to find a solution. Other options are possible but would necessitate a change in the Park boundary or a change to the Parks Act. These would take several years to complete.

The ground and geotechnical conditions could be different or worse than expected. These could delay the project and increase its cost significantly. Geotechnical investigation prior to detailed design is therefore a very important aspect of the work pre-construction.

There is also a risk of flood events during construction. This could significantly disrupt the construction schedule and an increase in cost would ensue for the clean-up and re-establishment of lost work. A flood mitigation strategy will have to be developed and implemented during construction phases.

Appropriate maintenance must be performed on the structure on an annual basis. There is a risk that the Town of Canmore will not be able to maintain appropriate level of funding for long-term maintenance. This could result in reduced performance or degradation of the structure. An appropriate funding strategy will have to be put in place to provide funds necessary throughout the years.

There are several social and environmental risks that will need to be mitigated. It is expected that the Environmental Impact Assessment (EIA) will cover all of those risks, and more. The EIA will become the backbone of our environmental and social risks management strategy.

The complete risk matrix that was developed during the workshop can be found in Appendix B – KT Workshop Risk Matrix.

Summary of Recommended Option A

The recommended option is a Debris Flood Retention Structure at the current site of the Debris Net. In the conceptual design stage, it is designed as a 34m high dam. It only retains water during a large event. In a normal spring run-off, the water flow will be allowed to go through the retention structure mostly unimpeded. The associated gravel will also pass through the structure to eventually be able to reach the Bow River.

Benefits of recommended option

The Debris Net site presents better geotechnical conditions than the Kame Terrace site for building a large retention structure. The rock walls on both sides of the canyon at the Debris Net are well suited to buttress such a structure. The Kame Terrace site would represent a much bigger challenge to prevent unwanted water seepage around and under the structure.

The structure will barely be visible from Elk Run Boulevard and the adjoining properties on Canyon Close and Eagle Landing. Visual disruption will be minimal with this option.

Option A provides the highest risk reduction of all three options. For more information on risk reduction, refer to BGC Engineering's Cougar Creek Debris Floods: Risk Reduction Optimization, Draft / September 19, 2014.

The East-West movement of wildlife through the Regional Wildlife Corridor will not be affected by the structure (Figure 4 below shows the wildlife movement in the area). On the contrary, the Corridor can be improved once the structure is in place. After the floods of 2013, the creek bed is very wide and is devoid of vegetation. Wildlife needs vegetation cover to feel safe while crossing such areas. Future damage to the wildlife corridor due to floods will be minimized due to the lower maximum flow of water that will pass-through the structure. Working closely with Alberta Parks and ESRD, it will be possible to revegetate the corridor to improve its current state as shown in Figure 5.

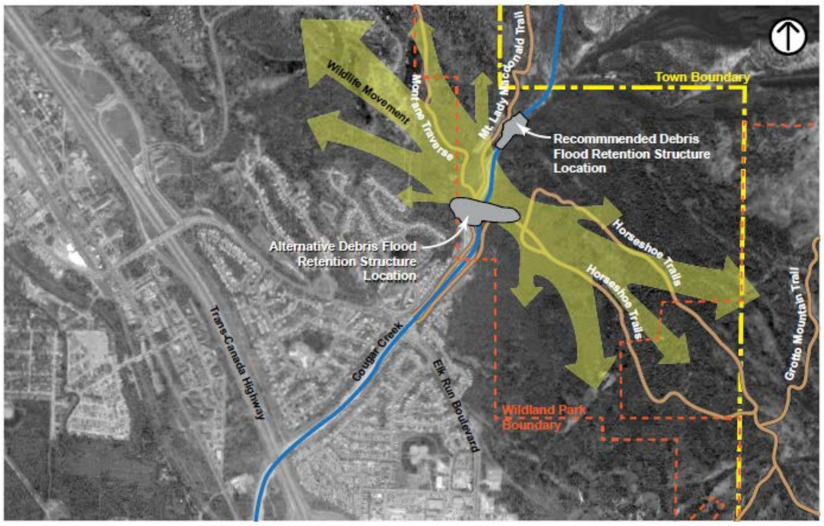

Figure 4: Debris Flood Retention Structures in relation to wildlife movement and park boundaries

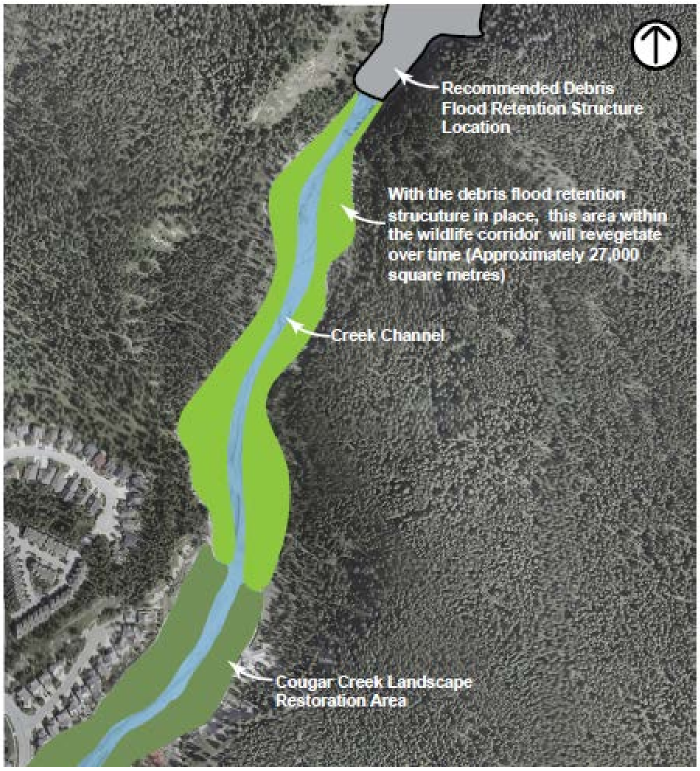

Figure 5: Option A with additional wildlife corridor improvement and landscaping

IMPACTS OF RECOMMENDED OPTION

A large man-made structure will be built in the Bow Valley Wildland Park. Some disruption to the natural environment will occur: trees will need to be removed; construction equipment will be driving through the Park during construction, and later on for maintenance; water will be diverted within the channel, during construction; offsite material will be needed to construct the structure;

The retention structure is located at the location where the channel flanks are steep and rocky. The structure will be impeding the movement of wildlife up and down Cougar Creek by creating a 30m high barrier.

CLOSURE

This report presents the steps taken to select the preferred option strategy for the long-term mitigation of Cougar Creek. It also discusses challenges, issues and risks associated with such a project, as well as benefits that the selected option will provide. The next phases of work will include additional geotechnical work, design and value engineering of the selected option, application for permits, supplemental stakeholder and community engagement, and tender and construction of the infrastructure.

Appendices

Appendix A - KT Workshop Decision Matrix

Town of Canmore, Cougar Creek Flood Mitigation Decision Analysis. Sept 23, 2014

Decision Statement: Recommend a debris flood mitigation option for Cougar Creek

OBJECTIVES			Alternative 1			Alternative 2			Alternative 3			Alternative 4		
No.	**Wt**	**Description**	**Dam @ Debris Net/ Option A**	**Score**	**Total**	**Dam @ Terrace / Option B**	**Score**	**Total**	**Debris Retention / Option C**	**Score**	**Total**	**No Further Mitigation**	**Score**	**Total**
1	10	Minimize damage to public and private property; a.m.b - average annual loss in dollars	$1K/Yr	10	100	$1K/yr	10	100	$30K/Yr	9	90	$700K /Yr	1	10
2	10	Minimize potential for blocked evacuation routes; a.m.b - the number of routes that can be kept open.	Can keep 3 routes open: Hwy 1, 1A & Elk Run, for all events up to a 1 in 1,000 event	10	100	Can keep 3 routes open: Hwy 1, 1A & Elk Run, for all events up to a 1 in 1,000 event	10	100	Can keep 1 route, Elk Run, open for all events up to 1 in 3,000 and 3 routes up to 1 in 100 event	7	70	1 Route, Elk Run, open up to a 1 in 300 event	3	30
3	10	Maintain safe passage of goods and services on major transportation links including Trans Canada Highway, Highway 1A and CP Rail.	Hwy 1 & 1A open up to 1 in 1,000 year event, CP rail open up to 1 in 30 year event	10	100	Hwy 1 & 1A open up to 1 in 1,000 year event, CP rail open up to 1 in 30 year event	10	100	Hwy 1 & 1A open up to 1 in 100 year event & CP rail open up to 1 in 30 year event	6	60	Hwy 1 & 1A open up to 1 in 30 year event & CP rail open up to 1 in 30 year event	1	10
4	9	Maximize protection of major utilities including power, gas, and communication; a.m.b - minimizing bank and streambed erosion.	A 1 in 1000 year event would likely damage gas & communication utilities with no intervention	10	90	A 1 in 1000 year event would likely damage gas & communication utilities with no intervention	10	90	A 1 in 300 year event would likely damage gas & communication utilities with no intervention	7	63	A 1 in 100 year event would likely damage gas & communication utilities with no intervention	4	36
5	9	Minimize need for operation of heavy equipment involvement during flood event; a.m.b – minimizing bank erosion and culverts blockage.	No need for heavy equip intervention up to 1 in 1,000 year event. CP to initiate own intervention at 1 in 5 event.	10	90	No need for heavy equip intervention up to 1 in 1,000 year event. CP to initiate own intervention at 1 in 5 event.	10	90	No need for equip at Hwy 1 & 1A for 1 in 100 event, possible need from 1 in 100 to a 1 in 300 event, Very likely need above 1 in 300. CP to initiate own intervention over 1 in 5.	7	63	For Hwy 1 & 1A, no need for equip up 1 in 30 event. Do need equip above 1 in 30. Elk Run would need equip at 1 in 100. CP to initiate own action every 1 in 5.	1	9
6	9	Minimize impact on regional (cross) wildlife corridors; a.m.b. - extent of cover and amount of undisturbed area.	Negative impact on up corridor, potential positive impact on cross corridor. Needs new 6 m wide maintenance access road for sediment clean out.	10	90	Negative impact on both up and cross corridors. Has road but of lesser extent than option A.	2	18	Has least impact on up corridor and less negative impact on cross corridor than option B. Least impact on corridor from road.	7	63	Has least additional negative impact to current state.	7	63
7	8	Minimize habitat fragmentation; a.m.b- minimal additional fragmentation resulting from construction.	Two lines of fragmentation: Has longest maintenance access road. Moderate footprint of dam structure. Has moderate impact of flood impound footprint.	5	40	Two lines of fragmentation: Has moderate length maintenance access road. Largest footprint of dam structure. Has high impact of flood impound footprint.	6	48	Two lines of fragmentation: Shortest access road. Smallest dam structure footprint. Smallest flood impound footprint.	9	72	Minimal fragmentation. No road. No flood impound footprint.	10	80

8	7	Minimize annual maintenance costs including: Sediment removal, post-flood re-vegetation, infrastructure inspection.	$170,000	9	63	$210,000	7	49	$150,000	10	70	$250,000	5	35
9	6	Minimize construction costs; a.m.b estimated project cost.	$40M	6	36	$60M	4	24	$80M	2	12	$0	10	60
10	4	Provides access to recreation and natural areas; a.m.b - extent of approved access available	Minor impact to 1 of 3 routes: Can hike up and over 30 meter dam. Current downstream access maintained.	9	36	Minor impact to 2 out of 3 access routes.(has 24 meter climb)	8	32	Minor impact to 2 out of 3 access routes. (has 10 meter climb)	9	36	Minor impact on 1 of 3 routes.	10	40
11	3	Minimize impacts related to residents' view and sight lines; a.d.b. community input on options.	Minimal visibility from few homes. A large structure in a natural area.	9	27	Visible from several homes. Largest and most visible structure. Can be seen from Elk Run. Large structure in a natural area.	2	6	Similar to B but smaller impact.	5	15	No structure visible from homes. Small structure in natural area.	10	30
12	3	Minimize impact to park users' experience.	Large manmade structure in park	3	9	Large manmade structure in park	6	18	Moderate manmade structure in park	8	24	Small manmade structre in park	10	30
13	3	Minimize construction duration with a goal of two or less construction seasons	2 Years for dam const. +6 mos. to complete landscaping, most complex permitting.	6	18	2 Years for dam const.+1 year to complete landscaping, moderate complexity in permitting.	6	18	3 years for dam const, +3 mos to complete landscaping, moderately complex permitting.	3	9	2 years to complete landscaping	10	30
			Total		**799**	**Total**		**693**	**Total**		**647**	**Total**		**463**

Notes:
a.m.b. means "as measured by"
a.d.b. means "as demonstrated by"

Appendix B – KT Workshop Risk Matrix

Town of Canmore, Cougar Creek Flood Mitigation Decision Analysis
Decision Statement: Recommend a debris flood mitigation option for Cougar Creek
Risks Common to Options A, B C
Permitting
If permitting process including first nations consultations take longer than anticipated,
Then project start is delayed 1 to 2 years (or more)
If permitting is denied,
Then protracted delays result during redesign and review.
Design and Construction
For risk of dam failure refer to Canadian Dam Safety Guidelines table 2.1
If geotechnical conditions are worse than anticipated,
Then costs may be 10 to 20% for seepage mitigation.
If ground conditions are significantly different than expected,
Then Schedule and costs could be 50% or more than expected and,.
Then (if drastically different) may need to relocate footprint of design or reevaluate options.
If abnormal weather occurs,
Then delays and cost increases can occur
If ground conditions differ than expected,
Then delays and cost increases can occur
If common construction management risks such as material or labor shortages, contractor's performance, & etc occur,
Then cost increases and delays occur.
If cost escalation occurs between recommendation and date of approval to proceed is significant,
Then budget impacted accordingly
Maintenance
If appropriate annual maintenance (and budget therefor) is not completed,
Then capacity, on average, is lost at 3% per cycle; usefulness reduced.
If structure is blocked by debris or sediment prematurely,
Then performance of structure is reduced resulting in possible increased maintenance costs.
If infrastructure maintenance costs unexpectedly spike,
Then alternate funding sources will be needed.
Safety
If people are trapped above dam during flooding,
Then loss of life can occur
If safety and security measures around site are not adequate,
Then people can get hurt or be die and,
Then Infrastructure can be damaged.
Environmental
If downstream sediment decreases,
Then downstream ecological impacts are possible in Cougar Creek & Bow River.
If renaturalization efforts are not successful,
Then wildlife movement will be permanently reduced
If wildlife movement routes are not successful,
Then wildlife movement will be permanently reduced.
If inundation of areas occur,
Then habitat loss will occur and,
Then shift in ecological habitats will occur
If more people visit area,
Then corridor becomes less effective for wildlife.

Environmental
Road use by maintenance or other heavy equipment,
May result in in wildlife mortality.
If construction phase's wildlife accommodations are inadequate or fail,
Then habitat abandonment may occur in short term and, possible on long-term
If hazardous material spills occur
Then contamination of downstream environment must be mitigated resulting in delays and costs incur
Community
If protests occur (or vandalism) over construction,
Then project delays occur and,
Then possible lack of confidence in decision makers.
If construction activities (traffic, noise, vibration, etc) disturb community,
Then community complaints will need to be address possibly impacting schedule and costs and,
Then temporary reduction in housing value may occur.
If restricted site access during construction causes unacceptable conditions for some,
Then public enjoyment of area is lost, possible economic impact on businesses and,
Then people may create illegal trails adding to increased habitat fragmentation
If project is not executed, or is only after significant delay,
Then community will not feel safe and,
Then likely impacts on property values and,
Then possible additional flood damage.
If some members of community strongly oppose project,
Then a decrease in public confidence may decrease
If the purpose and execuition of project is not communicatied properly,
Then media may not report accurately and,
Then community may misunderstand purpose and intent of project and,
Then lose community, political, budgetary support.
If community support for project is divisive,
Then may have appeals EAB resulting in possible delays from a month to years.
If financial institutions are uncomfortable with risks,
Then may not provide mortgages or insurance.
If construction delays occur,
Then people's stress levels will increase.
If people perceive this mitigation system to be intended to permanently hold back water,
Then people will be concern about dam failure.
Political
If funding agreements are delayed,
Then project could be delayed indefinitely.
If project loses political support,
Then project and funding approvals may be impacted.
If community support for local funding is lacking,
Then political support by council may flag.
If project cost overruns begin to significantly impact costs,
Then taxes could be impacted.

Appendix C – Letters of support

Norbert R. Morgenstern Consulting Ltd.
106 Laurier Drive
Edmonton, Alberta, T5R 5P6

December 2, 2014

Mr. A. Esarte, P.Eng.
Manager of Engineering
Town of Canmore
Canmore, Alberta

Re: <u>Cougar Creek Debris Flood Risk Management</u>

As your advisor with respect to debris flood risk management on Cougar Creek, I am writing to re-affirm my support for the direction that you and the Town of Canmore (Canmore) are taking to mitigate the effects of future flooding on Canmore Creek.

Following the June 19 and 20, 2013 event, Canmore retained Consultants (BGC) to assess flood hazards and options for future flood risk management. Canmore had retained Consultants in the past to evaluate flood risk, but until BGC were brought into the picture, none had either recognized or adequately articulated the central challenge of debris management in future safety concerns associated with development on the mountain creek fans. The Province had not recognized the issue and flood management had relied on traditional prescriptive floods for the design of protective works.

It was an outstanding achievement on the part of BGC to decipher the past and to develop a Magnitude – Return Period relationship for these past events. This recognizes that larger events than the June 2013 debris flood can occur with even greater intensity. This awareness cannot be set aside.

There is experience in Canada to totally deny development on a debris fan if events causing multiple deaths with a Return Period of 5-10,000 years were conceivable. The Village of Garibaldi in British Columbia was such an example. The Village was denied planning permission to grow and ultimately prior land owners were obliged to sell back to the Crown when the wished to give up use of their properties. This is not an option for Canmore, which must find its way to manage its risk in a feasible fair and affordable manner. Not to do so would, in my mind, be unconscionable.

In order to frame options BGC have proposed that Canmore adopt group risk tolerance criteria to help it evaluate its choices. I have been involved in the development of these criteria when acting as a Consultant to the Government of Hong Kong and have supported BGC in promoting the adoption of these criteria by the City of North Vancouver, and elsewhere. They are entirely appropriate for use by Canmore. Modelling debris flow scenarios consistent with the Cougar Creek geomorphological history indicates that the outcomes, the societal risk, are unacceptable. There is both a moral and a practical obligation to reduce risk to the broadly acceptable range.

With this as an objective, I regard it as up to the community to establish its own risk tolerance and preferred option(s) to meet its risk targets. Canmore has done this in an open and transparent manner. Other jurisdictions are looking on with great interest and respect for the leadership provided by Canmore on this issue.

I urge Council to support the proposed way forward. The science is right; the logic of risk assessment and management is right; and the public policy leadership is right. As a home-owner in Canmore I look forward to expressing my appreciation to the professional staff and elected officials who bring this positive outcome, as proposed, to fruition.

Sincerely yours,

N.R. Morgenstern, CM, AOE, FRSC, Ph.D., P.Eng.
Consultant and
Distinguished University Professor Emeritus
University of Alberta

NRM/sp

Department of Geography
The University of British Columbia
Vancouver, British Columbia, V6T 1Z2

22 November, 2014

Mr. Andy Esarte
Manager of Engineering
Town of Canmore, AB T1W 1K8

Dear Mr. Esarte

This letter is in reply to your request that I provide a comment on the work of BGC Engineering, Ltd. to analyze and recommend remedies for hazards presented in your community by the mountain creeks. I begin by indicating that I have acted as an independent reviewer of BGC's reports. I was, however, nominated for this role by BGC (a usual practice in review of engineering work) and I have been for many years a professional colleague of their senior consultant in this work, Dr. Matthias Jakob. Your request asks me to summarize the reviews completed, how my questions and comments have been addressed, and my satisfaction with the final reports and their conclusions.

I have reviewed the following documents:

Cougar Creek Debris Flood Hazard Assessment, Final Report 24 June, 2014

Cougar Creek Forensic Analysis: Hydroclimatic Analysis of the June, 2013, Storm, Final Report 1 Aug., 2014

Echo Canyon Creek Forensic Analysis and Long-term Debris Flow Mitigation Concepts, Draft Report 10 Oct., 2013

Pigeon Creek Forensic Analysis and Short-term Debris Flow mitigation, Final Draft Report 1 Oct., 2013.

Stone Creek Debris Flow Hazard Assessment, Draft Report 20 Aug., 2014.

Stoneworks Creek Forensic Analysis and Short-term Debris Flood Mitigation, Draft Report 8 Oct., 2013.

Three Sisters Creek Forensic Analysis and Short-term Debris Flood Mitigation, Final Draft Report, 1 Oct., 2013,

Three Sisters Creek Debris Flood Hazard Assessment, Final Draft Report 1 Aug., 2014.

Three Sisters Creek Debris Flood Hazard and Risk Assessment. Draft Report 7 March, 2014.

X, Y and Z Creeks Forensic Analyis and Debris Flow Mitigation Concepts, Draft Report 28 Oct., 2013.

In cases annotated 'final report' I have also seen one or more draft versions.

I made many comments on the reports, some of editorial character, some to improve clarity, and some to suggest substantive changes. BGC responded to all my comments. In particular, they changed the organization of some of the earlier reports to respond to my opinion that the draft presentation was not organized to facilitate reading by non-experts (such as Councillors) – that the main issues were not directly and straightforwardly presented. I judge that this has changed the overall accessibility and usefulness of the reports. We have also had detailed discussions over the construction and presentation of the critical magnitude-frequency analyses for debris floods/flows to achieve the most appropriate presentation of the limited historical data and prehistoric reconstructions.

Two aspects of BGC's analyses stand out in my mind. The first is the separation of hazard and risk in appraising the potential problems presented by the mountain creeks. BGC, and particularly Dr. Jakob, have been pioneers in Canada in advocating this approach to the appraisal and management of natural hazards. It is particularly important in a situation such as that faced in Canmore where varying degrees of development on different alluvial fans, and different hazards (debris flood versus debris flow) should lead to different degrees of mitigation as the most cost-effective way to ensure public safety at different sites, and whereby the necessary mitigative costs of proposed future developments can be rationally assessed.

The second aspect is BGC's insistence that, in order to plan appropriate mitigation, geophysical processes in the upstream drainage basin must be properly understood. It is lack of understanding of this requirement that resulted in earlier engineering assessments of the 'flood' potential of the mountain creeks to be grossly underestimated. BGC's explorations of the upstream sources of potential sedimentation hazards represent exemplary problem analysis.

Beyond these important initiatives, I have found BGC's work consistently to be of the high scientific and professional standard. They have, in particular, brought to bear advanced methods of dating and stratigraphical analysis in attempts to appraise the magnitude and frequency of hazardous flows in the subject streams, and they have given due consideration to the likelihood for changes in event frequency under the influence of a changed future climate. These analyses do not yield perfect clarity simply because the complete record of past events is not available to recover. In this respect, I have questioned the strategy of using the compilation of recent events in different places as a substitute for the possible historical record of events on one stream through time (a strategy sometimes used in environmental reconstruction but, in this case, of doubtful validity). BGC personnel engaged this matter in a professional manner, as I expected, and have qualified their analyses accordingly.

Because of his European origin, Dr. Jakob is very aware of the more extensive experience in the European Alps of hazards presented by mountain streams. The engagement of Austrian experts and some of their techniques toward resolving the potential problems at Canmore is a further advantage that BGC has brought to their work for you.

Altogether, then, I believe that BGC Engineering, bringing a combination of geological, hydrological and engineering expertise to the task, has served your needs as well as any consultancy could and that their advice points to viable resolution of the mountain stream hazards present in your community. I trust that my engagement in the work has also been helpful.

Yours sincerely

Michael Church, D.Sc., FRSC, P.Geol.(BC), FGC, FEC(Hon.)

(transmitted by e-mail)