BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

SQUAMISH-LILLOOET REGIONAL DISTRICT

SETON PORTAGE AREA INTEGRATED HYDROGEOMORPHIC RISK ASSESSMENT

FINAL

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April 6, 2018
Project No: 1358005

Ryan Wainwright
Emergency Program Manager
Squamish-Lillooet Regional District as agent for Emergency Management BC
Box 219
Pemberton, BC V0N 2L0

Dear Mr. Wainwright,

Re: Seton Portage Area Integrated Hydrogeomorphic Risk Assessment – FINAL

Please find enclosed a copy of our above referenced final report. This version of the document incorporates comments and suggestions from the steering committee on a draft of the report issued on January 10, 2018. This final version of the report also supersedes the January 10, 2018 draft. Should you have any questions or comments please do not hesitate to contact the undersigned.

We appreciate the opportunity to work on this most interesting project.

Yours sincerely,

BGC ENGINEERING INC.
per:

Matthias Jakob, Ph.D., P.Geo.
Principal Geoscientist

EXECUTIVE SUMMARY

BGC Engineering Inc. (BGC) was retained by the Squamish-Lillooet Regional District (SLRD) as agent for Emergency Management BC (EMBC) to assess hydrogeomorphic hazards and risks at Seton Portage, British Columbia. Hydrogeomorphic hazards are defined herein as hazards stemming from Bear/Pete's, Whitecap and Spider creeks and include floods, debris floods, debris flows and bank erosion. Other hydro-geomorphic hazards such as landslide-generated waves may exist, but were not included in this assessment. BGC's scope also included snow avalanches whose hazard was reviewed. Lastly, hazards were assessed that could indirectly affect steep creek processes such as deep seated landslides.

The key objectives were to assess hydrogeomorphic hazards, assess risk and propose conceptual mitigation measures for risks that are considered unacceptable by the key stakeholders.

Hazards

BGC assessed debris flow hazard at Bear and Pete's creeks (which share a common fan), and debris flood hazard at Whitecap and Spider creeks. Flood hazard was also assessed at a cursory level at Portage River (also known locally as Portage Creek). Debris floods on Whitecap Creek and debris flows on Bear Creek can impact, dam and deflect Portage River into Seton Portage. The tributary events were modeled, but not the outbreak floods on Portage River that could result from such damming events given the very substantial uncertainties related to such processes and the high likelihood of human interference (engineered breaching of a landslide dam). Return period scenarios considered in this study ranged from 10 to 3000 years. Debris flows and debris floods were numerically simulated for each scenario, which led to development of hazard maps that identify areas that may be impacted during future hydrogeomorphic flood events.

Table E-1 summarizes the estimated sediment volumes transported past the fan apex and peak discharges for each return period class and study creek.

Table E-1. Frequency-magnitude estimates for the three creeks studied.

	Bear Creek		Whitecap Creek		Spider Creek	
Return Period (T) (years)	Sed. Volume Estimate (m^3)	Peak Discharge (m^3/s)	Sed. Volume Estimate (m^3)	Peak Discharge (m^3/s)	Sed. Volume Estimate (m^3)	Peak Discharge (m^3/s)
10 to 30	11,000	30	30,000	60	13,000	25
30 to 100	70,000	220	38,000	130	17,000	55
100 to 300	150,000	480	46,000	275	20,000	140
300 to 1000	240,000	760	59,000	410	24,000	280
1000 to 3000	320,000	1000	66,000	600	28,000	up to 1000

Table E-1 shows that estimated sediment volumes transported past the fan apex at Bear Creek can be up to 5 times higher than those estimated for Whitecap Creek for higher return period classes and up to 11 times higher than at Spider Creek. The difference for peak discharges is less. In the case of Whitecap Creek and Spider Creek, peak discharges of return periods in excess of 300 years are likely governed by landslide dam outbreak floods (LDOFs). Lesser return periods are likely to be floods that exceed a critical threshold for significant sediment mobilization.

Bank erosion was estimated for Whitecap and Spider creeks. Bank erosion was not expected to be significant for Bear/Pete's creek as debris flows are less likely to erode their banks.

Snow avalanche hazards formed part of BGC's scope and were thus reviewed. BGC concluded that snow avalanches are very unlikely to reach developed areas under current conditions. Large scale deforestation by fires, logging or landslides may require a review of current avalanche hazards.

While not within BGC's scope, it is worthwhile highlighting that landslide-generated tsunamis from Anderson Lake or Seton Lake could impact Seton Portage. The risk associated with this process has not been quantified.

Risks

The risk assessment considered safety and economic risk, including estimating the probability that hazardous events will: impact dwellings; cause loss of life or economic damage; or impact roads, bridges or the railway. For the risk assessment, BGC assumed that evacuation of residents only occurs for bank erosion scenarios on Whitecap Creek, but that areas impacted directly by Whitecap Creek debris floods or Bear Creek debris flows would not be evacuated due to the expected lack of response time.

Two different safety risk metrics were considered: individual risk and group risk. Individual risk evaluates the chance that a specific individual (the person judged to be most at risk) will be affected by the hazard. Group risk, also known as societal risk, evaluates the potential number of fatalities that could be caused by a hazard scenario.

BGC's safety risk estimates are summarized in Table E-2, and economic risk estimates are summarized in Table E-3. Results were compared to quantitative risk tolerance criteria to help identify areas where mitigation measures are warranted. Risks associated with hazard scenarios with greater than 3000-year return periods have not been quantified. Those exist and are in addition to those reported in Table E-2 and E-3.

Ultimately, the decision of which creeks require mitigation will be made by the stakeholders and be informed by the risk ratings in this report, but also by the available funds and comparison of other funding priorities at Seton Portage.

Table E-2. Individual and group safety risk.

Creek	No. of Buildings that Exceed Tolerable Individual Safety Risk	Group Risk	Mitigation Priority
Bear and Pete's Creek	59	unacceptable	High
Whitecap Creek	1	tolerable	Low
Spider Creek	0	acceptable	None

Table E-3. Maximum and annualized economic damage of the creeks studied. All figures are rounded.

Creek	No. of Buildings Affected	Maximum Economic Damage	Annualized Economic Damage	Businesses Affected
Bear and Pete's Creek	134	$ 8,000,000	$ 140,000	6
Whitecap Creek	5	$640,000	$ 8,000	3
Spider Creek	1	$70,000	$ 70	0

Mitigation

Table E-2 and Table E-3 demonstrate that debris flow risks from Bear and Pete's creeks are much higher than risks from other creeks at Seton Portage. These findings suggest that mitigation efforts and funds should be focused on Bear and Pete's creeks. Mitigation measures for Spider Creek have not been proposed because risks at Spider Creek are interpreted to be acceptable when compared to risk tolerance standards developed and applied elsewhere.

Tables E-4 summarizes three mitigation options and estimated conceptual costs for Bear and Pete's creeks. The measures have been sized for the largest magnitude event considered in this study with the objective of reducing risks to levels typically considered 'acceptable'. During the pre-design phase mitigation can be optimized to achieve tolerable risk targets if adopted by the stakeholders. The mitigation concepts listed also reduce economic and outage risk for a broad spectrum of other elements at risk including roads, railway, utilities, and power transmission, although this risk reduction was not quantified. Non-structural mitigation measures, for example education of residents about hydrogeomorphic hazards and development of emergency response plans, should be implemented along with any structural measures that are selected.

Table E-4. Mitigation options and costs for Bear and Pete's creeks to control risk up to the 3000-year return period event.

Proposed Mitigation Option	Description	Cost
1 – Basin and Anderson Lake conveyance	Attenuate flows with a basin at the fan apex; convey attenuated flows and remaining debris to Anderson Lake through the gap between the Whitecap Development and Necait.	$8.0 million
2 – Basin and diversion to eastern fan	Attenuate flows with a basin at the apex; divert attenuated flow and remaining debris to the northeast; retain debris on the eastern fan.	$8.0 million
3 – Basin and distal berms	Attenuate flows with a basin at the apex; build local berms on the distal fan to protect elements at risk.	$7.3 million

The three proposed options appear to be technically feasible and have a similar cost. Stakeholder input will be needed to select the option for final design. BGC prefers Option 3 because the potential for risk transfer is lowest, and measures could be upgraded if a limited mitigation budget were available at a later date.

Table E-5 summarizes mitigation options and estimated conceptual costs for Whitecap Creek. The design intent is to reduce the likelihood and duration of Anderson Lake road closure. The 30 to 100-year event was initially selected as the design event, similar to the size of both the 2015 and 2016 events. BGC understands that the 100 Anderson Lake Road[1] residence, which is currently exposed to intolerable safety risk, is planned to be moved in the spring of 2018. Safety risk is tolerable at other buildings on Whitecap Creek fan. After relocation of the 100 Anderson Lake Road residence, risk reduction would thus focus to reduce economic losses only. No risk reduction measures were proposed to avoid Portage River from being diverted into Seton Portage as the cost of such measures would likely grossly exceed the expected losses from such floods and would be difficult to justify.

Table E-5. Mitigation options and costs for Whitecap Creek (assuming 100 Anderson Lake Road residence is relocated).

Proposed Mitigation Option	Description	Construction Cost
1 – Short berm	Berm along Anderson Lake Road to protect the road.	$290,000
2 – Long berm	Berm along the creek to prevent avulsions from the existing channel. This is similar to the NHC concept presented after the 2015 event.	$1,070,000
3 – Event response	Prepare an emergency management plan and restore the road and Portage River channel as quickly as possible following each flood and debris-flood event.	$0

[1] Civic address provided by Cliff Casper, Tsal'alh Housing and Infrastructure Manager.

Bank erosion mitigation (Options 1 and 2) at Whitecap Creek would likely cost substantially more than the value of any damage that they would prevent. As such, BGC prefers Option 3, assuming the main design objective is to prevent closure of Anderson Lake Road. Anticipating that budget to reduce the risk of the various geohazard examined is limited, BGC recommends that the majority of the available budget be spent on reducing risk from Bear and Pete's Creek.

Several steps are required before the chosen mitigation measure can be implemented. BGC recommends that at the next design stage, mitigation measures be refined to optimize risk reduction given the available budget. Residual risk, should it still be deemed intolerable, could be addressed through land-use zoning and local protection of buildings. Recommendations for future work are provided in Section 8, including a description of studies and work sequence to support structural mitigation implementation, and guidance for policies that could be adopted to manage current and future development in the Seton Portage area.

It is important to note that at this stage of study, no attempt was made to optimize mitigation measures to reduce risk to 'tolerable' rather than 'acceptable' limits. The distinction between 'tolerable' and 'acceptable' is subtle but noteworthy: A tolerable risk level is one that is generally tolerated by society, but ought to be reduced where practical and where funding allows. An 'acceptable' risk is one that requires no further risk reduction. Once a decision has been made as to the risk tolerance considered acceptable by the SLRD and other stakeholders, such optimization should be achieved at the pre-design stage.