BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

SQUAMISH-LILLOOET REGIONAL DISTRICT

MOUNT CURRIE LANDSLIDE RISK ASSESSMENT

FINAL

PROJECT NO.: 1358004 DATE: January 16, 2018

EXECUTIVE SUMMARY

Squamish-Lillooet Regional District (SLRD) retained BGC Engineering Inc. (BGC) to assess landslide and associated flood risk of the north face of Mount Currie. The project was initiated by SLRD following a series of rock fall events towards the top of the mountain occurring in 2015 and 2016. The rock fall events raised concerns about the risk to the public in the area around Pemberton and near the hamlet of Mount Currie.

The types of geohazards within the study area that were considered by BGC are: rock avalanches, rock falls, debris flows, rock slides / debris slides, landslide damming and associated flooding.

Study Area Description

Mount Currie is located immediately south of the village of Pemberton and the hamlet of Mount Currie, which lie in the floodplain of the Lillooet River upstream of Lillooet Lake. The mountain range is delimited to the north by the Lillooet River Valley, to the west and northwest by Green River Valley, and to the southeast by Gravell Creek. Mount Currie's rugged topography and geology contribute to the occurrence of landsliding. The area receives substantial precipitation in the form of rain and snow.

The main rock type in the study area is a fine- to medium-grained diorite, a rock type similar to granite. The diorite has a well-developed steeply dipping foliation (alignment of the minerals that form the rock). Volcanic rocks prevail at the eastern end of Mount Currie ridge. Two northwest-southeast trending faults have been previously mapped along Mount Currie ridge.

Geohazard Analysis

BGC undertook the following work to characterize landslide geohazards:

- Desktop analysis
- Geomorphic mapping
- Fieldwork including seismic survey
- Rock avalanche probability of occurrence estimate and runout modelling
- Landslide damming and flood modelling
- Debris flow magnitude-frequency analysis.

The desktop analysis reviewed and interpreted the literature, geotechnical reports, Google Earth and Bing imagery, available historical aerial photographs, and LiDAR data.

The Mount Currie ridge was traversed by foot to check the geomorphic mapping, and to characterize the rock mass. Temperature was measured in tension cracks to investigate the possible presence of frozen ground. While no sub-zero temperatures were encountered, the strong temperature gradient, and the elevation and aspect of the Mount Currie ridge, indicates that permafrost may prevail at depth.

Select locations on the Green and Lillooet rivers floodplain were inspected for evidence of pre-historic rock avalanche debris deposits. A geophysical investigation program was conducted in the valley bottom to search for buried rock avalanche deposits. Neither the ground inspection nor geophysical survey found evidence of buried rock avalanche deposits.

The results of the geohazard assessment found that based on the desktop analysis and fieldwork observations, the area impacted by past rock falls, rock slides, debris avalanches and debris flows is confined to the south side of Green River and, as such, are not considered to represent significant hazards to infrastructure and residents below Mount Currie.

Through geomorphic mapping, BGC documented the distribution and orientation of “lineaments”, which are distinct linear features in the rock mass and may represent significant geological structures. The distribution of these lineaments and other geomorphic features allowed the identification of 19 potential rock avalanche source zones.

The review of the potential rock avalanche sources identified four main sources based on a qualitative ranking of the hazard. The qualitative ranking was based on activity level (evidence of recent deformation), kinematics (orientation of joints in consideration of slope stability), and volume estimate.

Computer models were used to estimate the potential rock avalanche travel distance and the associated flooding due to potential landslide blocking of the Green and Lillooet rivers. The numerical models of the rock avalanches runout and flooding associated with the damming of Green and Lillooet River showed that two of the four potential rock avalanche sources have the potential to affect areas on the north side of Green River.

The estimated annual probability of the modeled rock avalanche scenario 1 (from potential source identified near Currie NE3 Peak) is approximately 1 in 5,000, or a 0.02% chance of occurrence in any given year. The estimated annual probability of the modelled rock avalanche scenario 2 (from potential source identified along ridge east of Currie NE3 Peak) is approximately 1 in 11,000 or 0.009% chance of occurrence in any given year, under current conditions (including weathering/erosion rates). These probability estimates are subject to uncertainty, and could be adjusted up or down based on the results of further assessment and/or monitoring data.

Projected climate change is expected to further deteriorate rock slope stability, but how this might increase rock avalanche probability in the future cannot be reliably quantified due to the unknown distribution of permafrost and strength reduction associated with loss of ice cohesion in the rock mass. A subjective two-fold and ten-fold increase in the annual rock avalanche probability as a consequence of climate change was used to test the sensitivity of rock avalanche hazard to climate change. These two rock avalanche scenarios were carried forward in the geohazard risk assessment.

Geohazard Risk Assessment

The first step of the risk assessment identified and characterized the elements which could potentially be exposed to the geohazard scenarios considered in the risk analysis. These included persons, buildings, critical facilities, business activities, power and communication lines.

Risk was assessed for direct impact of a rock avalanche and vulnerability was assessed for flooding associated with the potential damming of the Green and Lillooet rivers.

On Mount Currie, rock avalanches are expected to travel at over 100 km/hr and involve volumes up to approximately 8 Million m^3 of material. This would likely lead to total destruction of everything in their path. The two rock avalanche scenarios with the longest runout (greatest damage potential) were included in the risk assessment. The risk was calculated for an individual person and for groups of people and compared to risk tolerance criteria developed elsewhere. Occupants in up to 15 parcels could be exposed to risks that exceed individual risk tolerance criteria. For the group risk, depending on the rock avalanche scenario and the climate sensitivity analysis, the results indicated the risk could range from tolerable to unacceptable.

For the flooding hazard, the water depth as a result of a landslide dam is expected to increase over minutes to hours allowing for people to respond to the hazard. This response is difficult to quantify as it varies in different sections of the valley (due to different road networks providing exit routes) and it varies in time (whether the flooding occurs during the day or night, summer or winter). Furthermore, the timing and location of a breach of a landslide dam would impact the flood hazard and risk, but are extremely difficult to quantify. Approximately 160 buildings were identified as being potentially impacted by flooding associated with one of the rock avalanche scenarios, however the probability of flood-related losses has not been quantified.

Preliminary economic loss estimates were provided in association with direct impact and flooding for building damage (between $1.6 million and $16 million depending on the rock avalanche scenario) and business activity (between $2 million and $31.5 million depending on the rock avalanche scenario). Critical infrastructure and lifelines potentially affected by rock avalanche direct impact or flooding include the waste water treatment plan and various water and sewer infrastructure (i.e. mains and lift stations), Pemberton search & rescue base, and Ministry of Forest fire base.

Although there is considerable uncertainty in the risk estimates, the results of the study indicate that rock avalanche hazards from Mount Currie pose risks that likely exceed individual and group risk tolerance criteria. Given the uncertainties and potential risks, additional investigation, analysis, and implementation of a monitoring system likely represent the most practical and cost-effective approach to risk management. This would also allow future refinements or revisions of the current hazard and risk estimates.

SLRD might consider restricting land use in parts or all of the areas within modeled rock avalanche runout zones as any increase in development density in these areas would further increase the risk estimates.