Cheekeye River Fan Geohazards, risks and residential development

July 15, 2014, Squamish
Outline

• Background and Process
• Objectives
• Glacial history and fan evolution
• Rock Avalanche Modeling
• Frequency – Magnitude Analysis
• Mitigation Concepts
• Summary
Objectives

• Establish a reliable frequency-magnitude relationship of debris flows
• Estimate/model the hazard intensity on the fan
• Estimate the existing risk for loss of life on the fan
• Can portions of the fan be safely occupied? If so, what type and scale of mitigation is needed?
• What can be done to improve current resident’s safety and reduce hazard of future development to tolerable levels?
• In absence of legislated levels of risk tolerance, what levels are deemed tolerable by the DoS/the province?
## Current Elements at Risk

<table>
<thead>
<tr>
<th>Elements at Risk</th>
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<tbody>
<tr>
<td>First Nations Reserves</td>
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<tr>
<td>Don Ross Secondary School</td>
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<tr>
<td>Brackendale Elementary School</td>
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<tr>
<td>Brackendale Residential</td>
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<tr>
<td>Highway 99 Users</td>
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<tr>
<td>Cheekeye Bridge</td>
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<tr>
<td>BC Railway</td>
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<tr>
<td>Squamish Airport</td>
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<td>DOS Infrastructure</td>
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<tr>
<td>BC Hydro Substation and Transmission Line</td>
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<tr>
<td>Ross Road</td>
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<tr>
<td>Saw Mill</td>
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<td>Squamish Valley Road</td>
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<td>Cheekeye Development</td>
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</tbody>
</table>
Brakendale
First Nation IRs
Cheekeye Subdivision
Schools
BC Hydro Transmission Line
First Nation IRs
Possible Development Area
Hwy. 99
Airport
BC Rail
Brakendale
Elements at Risk
The Steps

Steps completed to date:

- Hazard Recognition
- Frequency-Magnitude Analysis
- Hazard Intensity Mapping
- Consequence Determination
- Risk Calculations
- Risk Evaluation
- **Risk Reduction Development**

Not completed
Glacial History
Fan Evolution

12,000 - 10,200 yrs

10,200 - 6,900 yrs

6,900 yrs

6,000 to 2,000 yrs

present

A: 12 - 10.2 ka
B: 10.2 - 6.9 ka
C: 0.9 ka

D: 6 - 2 ka
E: Present

Terrain Units
- Uplands
- Middle fan
- Lower fan
- Floodplain
- Debris flow units
- Chronozone (cal yr BP)

Fan Features
- Scarp
- IC Incised channel
- A Apex
- IP Intersection point

Evolutionary Stages
I Rock slides, debris flows, and floods
II Debris flows and floods
III Debris flows, floods, incised channels
Squamish River and Cheakamus River damming potential

Legend
- Alluvial Fans
- Cheekye Fan
- Floodplain
- Water Features

*Solid colours are used to convey local physiography and distance

Fath, 2014
Dendrochronology
• ~60 wedges, cores, discs sampled along channel
• Cross-sections reconstituted along confined reaches
• Discharge back-calculated
Test Trenching Program

Objectives:
- Determine size of Garbage Dump debris flow
- Update frequency-magnitude analysis
Test Trenching Program

- Southern part of airport
- Fluvial Gravels (5 m)
- Northern part of airport
- Garbage Dump event (1 m)
- Fluvial Gravels

BGC
Stump Lake Sediment Coring

Debris flow deposits

~ 6900 yrs BP
~ 11,600 yrs BP

Stump Lake
Cheekeye River
Garbage Dump Debris Flow ~ 900 years ago

Cheakamus R.

BC Hydro Sub

Hwy. 99

Airport

2.1 M m³ = 175,000 dump truck loads
Debris Flow Volume

Return Period (years) vs. Total Debris Flow Volume (m$^3$)

- $V_{\text{rock avalanche}}$ generated debris flows
- $V_{\text{rainfall}}$ generated debris flows
- $V_{\text{rock avalanche}}$ generated debris flow ($V_{\text{max}}$)

- 10,000 yr $\approx 5.5 \text{ Mm}^3$
- 2500 yr $\approx 2.8 \text{ Mm}^3$
- 500 yr $\approx 1.4 \text{ Mm}^3$
- 200 yr $= 0.8 \text{ Mm}^3$
- 100 yr $= 0.6 \text{ Mm}^3$
- 50 yr $= 0.4 \text{ Mm}^3$
- 20 yr $= 0.2 \text{ Mm}^3$

- 100 yr $= 0.6 \text{ Mm}^3$
- 50 yr $= 1.4 \text{ Mm}^3$
- 2500 yr $= 2.8 \text{ Mm}^3$
- 10,000 yr $= 5.5 \text{ Mm}^3$
The July 2010 rock avalanche and debris flow at Capricorn Creek, Mount Meager

Photos: courtesy Prof. John Clague, SFU
Rock Avalanche Modeling

(a) Atwell Peak (4 Mm$^3$)

(b) Dalton Dome (57 Mm$^3$)

(c) Cheekye Ridge (25 Mm$^3$)

(d) Brohm Ridge (32 Mm$^3$)

Maximum Velocity (m/s)

- >100
- 100
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
- 10
- 0
Debris Flow Modelling

Scenario 1: Existing Conditions
(7 million m³, volume 15,000 m³/s discharge)
20-year return period event, unmitigated
100-year return period event, unmitigated
2500-year return period event, unmitigated
10,000-year return period event, unmitigated (subject to further revision)
Preliminary mitigation concepts (subject to further revision)

~ 35 m high barrier

Sedimentation basin
What does $5.5 \text{ M m}^3$ debris mean?

5.5 million cubic metres is roughly twice the volume of BC Place Stadium.

Images from www.bcplacestadium.com
Main Barrier
(preliminary design concept)

Downstream view

Squamish River
Vision of Post-Mitigation Design (conceptual)

- Dike improvements
- Sedimentation basin
- Principal retention basin
- 5.5 Mm³ debris
- Dewatering culverts
- Brackendale
- Cat Lake
- Alice Lake
- BC Hydro Sub
- I.R. 11

Model Input Parameters
- Volume = 300,000 m³
- Peak discharge = 1,100 m³/s
- Low viscosity

Debris Flow Velocity (m/s)
- > 10
- 0 - 10
- 0 - 5
- 0 - 2
Conclusions

• Risk is currently deemed unacceptable as compared to standards, for example, used by DNV and requires mitigation irrespective of future developments
• Significant economic loss would result in case of moderate size and large debris flows
• The expert review panel suggested the structure(s) be designed for a 10,000-year return period event with a volume of 5.5 Mm$^3$
• The lay of the land lends itself well to mitigation works which would protect, amongst other elements at risk, the villages and people of the Squamish nation.
• Preliminary mitigation concept to provide two primary would be based on two structures with auxiliary risk reduction measures and monitoring