Pierre A. Friele, MSc, PGeo
P.O. Box 612
1021 Raven Drive
Squamish, BC
V8B-0A5
Ph. (604) 898-4770

Malcolm Schulz, RPF
Sea to Sky District
Ministry of Forests, Lands and Natural Resource Operations

August 30, 2013

Re: Catalina Creek debris flow, August 30, 2013.

Introduction

At about 1:30 am August 30, 2013 a debris flow occurred on Catalina Creek, affecting the Lillooet Lake FSR (Fig. 1). An emergency assessment was conducted by Pierre Friele (Cordilleran) and Malcolm Schulz (MoFLNRO) between 8am to 11am, August 30 2013 by low level helicopter overview flight and foot traverse. This report presents findings and recommendations from that assessment. Safety protocols to follow during reopening of the FSR were provided verbally to Lizzie Bay staff, and subsequently work commenced about 11am.

Figure 1. Approximate outline of the August 30 2013 debris flow, Catalina Creek.

Event Description (see Fig. 1 & Annotated Photos 1-7)
On reaching the apex of the debris cone, the debris flow remained confined along the ~900 m length of channel downstream to the debris basin just upslope of the FSR crossing, perhaps depositing 7-15 m^3/m along this length (6000-14000 m^3); it filled the debris basin (1000 m^3); deposited 4-5 m of debris on the FSR (300-500 m^3); then carried on down the channel depositing a large lobe (750-1000 m^3) on the south bank, plugging the channel at a footbridge crossing; and avulsed north, overrunning the boat launch and reaching the beach. The north lobe swept over the driveway of the A-frame house, pushed a small pickup truck into the lake, and destroyed a boat rack full of boats. In the deposition zone of the north lobe, the debris is on average 1-2 m thick along the margins and <1 m thick along the centre of the track, with a volume of perhaps 2000-6000 m^3.

Based on these observations, the total debris deposition below the apex could be on the order of 10,000-25,000 m^3 in volume, a Class 4 debris flow (Table 1). The material was a bouldery slurry, with a 30-40% clast content of cobble to medium boulder, with maximum clast size up to 2-3 m b-axis.

Table 1. Landslide size classification and potential consequences by class (Jakob 2005).

Class	Volume (m^3)	Peak discharge (m^3/s)	Potential consequences
1	$<10^2$	<5	Very localized damage, known to have killed forestry workers in small gullies and damaged small buildings.
2	10^2-10^3	5-30	Bury cars, destroy small wooden buildings, break trees, block culverts, and damage heavy machinery.
3	10^3-10^4	30-200	Destroy larger buildings, damage concrete structures, damage roads and pipelines, and block creeks.
4	10^4-10^5	200-1500	Destroy camps, destroy sections of infrastructure corridor, damage bridges and block creeks.
5	10^5-10^6	1500-12,000	Destroy camps and forest up to 2km^2 in area, block creeks and small rivers.

Debris Flow Initiation Zone and Other Debris Sources
The helicopter overview flight revealed that the debris flow initiation site was located in the upper part of the watershed in an eastern bedrock gully system (Fig. 2). This is the same gully system that produced a debris flow in 2010 (Cordilleran 2010). The headscarp was in a debris blanket overlying smooth bedrock (WP 677, Photo 8). As the debris travelled downslope more debris was entrained by channel erosion (WP 676). At the crest of slope an area of tension cracking in bedrock was noted, and this is a potential rockfall source area (WP 678, Photo 9). This area was identified in 2010 (Cordilleran 2010).

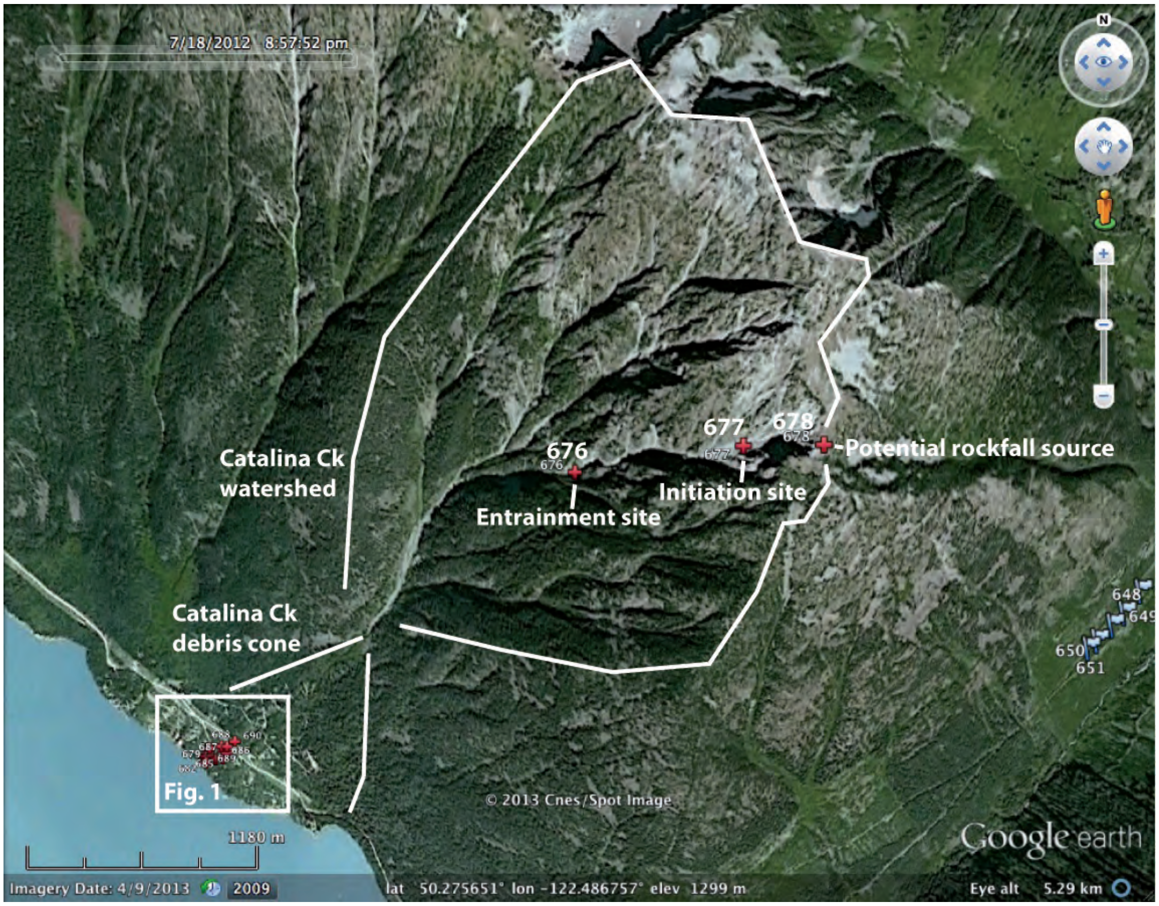

Figure 2. Catalina Creek watershed showing the initiation site of the August 30, 2013 debris flow. WP numbers and debris source locations are cited in the text.

Climate Trigger

The event was triggered by a short, but intense rainfall event resulting from thunderstorm activity. A special weather summary for coastal British Columbia was issued by Environment Canada at 9:56 am PDT on August 30, 2013. A strong Pacific frontal system spread heavy rain into the South Coast on August 29, 2013. Unofficial 24 hour rainfall totals for August 29 are reported below (Table 2).

Table 2. Daily precipitation, August 29, 2013 for various locations SW BC.

Station	Daily precip. (mm)
Vancouver international airport	31
Downtown Vancouver	46
West Vancouver	51
Kitsilano	28
Squamish Airport	79
Downtown Squamish	97
Powell River	20
North Courtenay	29
Pemberton Fire base	12
Meager Creek	19

In addition, a strong line of thunderstorms moved across the region late on the evening of August 29, bringing heavy downpours to the area. One hour (11pm-12am) rainfall totals from last evening's thunderstorm are presented below (Table 3).

Table 3. One hour rainfall intensities, 11pm-12 midnight, August 29, 2013.

Station	1-hour precip. (mm)
Downtown Vancouver	17
West Vancouver	16
Point Atkinson	18
Kitsilano	14
Burns bog	13
Pemberton Fire base	2
Meager Creek	5

The data presented above indicate considerable spatial variation in rainfall over the region and they also indicate orographic effects, with higher daily totals and 1-hr intensities in areas closer to, or in the mountains. Overall, the Pemberton and Meager rainfall data do not show significantly high values. The timing of the Catalina Creek debris flow suggests it was triggered by the evening thunderstorm activity, and in this instance the Pemberton and Meager climate stations may not be representative of Catalina Creek.

FSR Cleanup & Operational Safety Plan

With respect to operational safety during the FSR cleanup, since the event was triggered by intense rain, it was judged that a similar rainfall would be required to trigger a recurrence (see email from Hardy Bartle to Malcolm Schulz, August 30, 2013 1:58 PM). The weather is reported to be improving somewhat (http://weather.gc.ca/city/pages/bc-16_metric_e.html), and under these conditions it was judged that cleanup work could begin under the following operational safety plan.

The operational safety plan entailed a watcher posted near the apex who would visually monitor stream flow (volume and colour), and listen for loud rumbling, and if anything was detected they would radio the machine operator who had a radio in the hoe with him and was directed to run to away from the crossing if alerted. Secondly, a rain gauge was to be placed onsite and the BCTS operational shutdown guidelines for sites with unstable ground conditions upslope were to be followed (In grey, Table 4).

Table 4. BCTS (2010) wet weather safety shutdown guidelines (rainfall and snowmelt).

Zone	Shift end	24 hour	48 hour	72 hour
Very wet	50 mm	100 mm	150 mm	200 mm
Wet	45 mm	80 mm	130 mm	170 mm
Drier	30 mm	50 mm	80 mm	110 mm
Ustable conditions upslope	10 mm	20 mm	30 mm	40 mm

(http://www.for.gov.bc.ca/ftp/tch/external/!publish/EMS2/Supplements/Wet_Weather_Shutdown_Guidelines.pdf)

The FSR bridge was inspected (Photo 5). Only a portion of the deck and abutment wingwalls were visible on the downstream side of the bridge. The bridge opening was plugged, the deck overtopped, the guard rails destroyed and the wingwalls appeared somewhat undermined. Despite this impact, the bridge appeared not to have shifted.

As of 11 am debris was being cleared off the road alignment, and spoil was to be endhauled to a site campside where material was stored during the previous cleanup in 2010 and 2012. Apparently as of late this afternoon, one-lane traffic had been restored (Photo 10).

Once the channel upstream and downstream of the bridge opening, and the opening itself, are fully cleared of debris, a proper engineering inspection of the bridge will be required prior to allowing regular traffic, especially larger vehicles, to resume.

Residual Risk & Longer Term Remediation

Cordilleran (2010) reviewed the history of past events and indicated that the potential for future events was high. Based on the helicopter overview conducted after the 2013 event, it is clear that significant volumes of channel debris and rockfall sources remain in the headwaters.

Based on the history of past events, the volume of material stored in channel and available for entrainment, the presence of potential rockfall sources, and the expected increase in precipitation frequency, amount and intensity with anthropogenic climate change, the future debris flow hazard remains high (1/20-1/100 per annum) to very high (>1/20 per annum). Regionally, landslide frequency is expected to increase with anthropogenic climate change (Jakob and Lambert 2009).

KWL (2012) developed and supervised the post-2010 debris flow channel remediation work on behalf of Squamish Lillooet Regional District. This work cost approximately $200,000.00. Assuming PEP funding is available to restore the site to pre-event condition, then the channel between the lake and the apex will need to be cleaned again, and the catchment basin above the FSR reconstructed. The works below the road need to be better thought out as they were clearly insufficient in capacity to handle the debris that overflowed the catchment basin.

Given the density of settlement at Lillooet Lake Estates, and the history of recent debris flow in 2004, 2010 and 2013, it is suprising that no significant residential property damage has occurred, nor loss of life or limb. This most recent debris flow highlights the existing and future landslide risk at this site. If compared to existing hazard/risk standards such as Cave (1993), MoTI (2009) or those adopted recently by the District of North Vancouver (BGC 2006), the landslide risk facing residences at Lillooet Lake Estates would likely be judged to be unacceptable. Under existing conditions, it is judged that it is only a matter of time before there is a fatality at Lillooet Lake Estates.

It is strongly recommended that a proper Quantiative Landslide Risk Assessment (APEGBC, 2010; Wise et al 2006) be conducted for Lillooet Lake Estates, and that based on the findings of such an analysis a Landslide Risk Mitigation Plan be developed and executed.

References

APEGBC, 2010. Guidelines for legislated landslide assessments for proposed residential development in British Columbia. APEGBC, Burnaby, BC.

BGC Engineering Inc., 2006. Berkley Landslide Risk Management, Phase 1 Risk Assessment, District of North Vancouver.

Cave, 1993. Hazard acceptability thresholds for development approvals by local government, British Columbia. British Columbia Geological Survey Branch, Open File 1992-15.

Cordilleran Geoscience, 2010. Emergency assessment for the September 28, 2010 Catalina Creek debris flow. For Ministry of Forests and Range, Squamish BC.

Jakob, M. 2005. A size classification for debris flows. Engineering Geology, 79: 151-161.

Jakob, M., and Lambert, S. 2009. Climate change effects on landslides along the southwest coast of British Columbia. Geomorphology 107: 275–284.

KWL, 2012. Lillooet Lake Estates – Cataline Creek Debris Flow Remediation Construction Completion Report – Final. Report to Squamish Lillooet Regional District, Pemberton, BC.

Ministry of Transportation and Infrastructure, 2009. Hazard/Risk Tolerance Guidelines for Subdivision in British Columbia. Unpublished document.

Wise. M., Moore, G., and Vandine, D., 2004. Landslide risk case studies in forest development planning and operations. Land Management Handbook 56. MoF, Victoria.

Closure

This report was prepared for use by Ministry of Forests, Lands and Natural Resource Operations, including distribution as required for purposes for which the report was commissioned. The work has been carried out in accordance with generally accepted geoscience practice. Judgment has been applied in developing the conclusions stated herein. No other warranty is made, either expressed or implied to our clients, third parties, and any regulatory agencies affected by the conclusions.

Should you have any questions please call.

PROFESSIONAL PROVINCE OF P.A.M. FRIELE BRITISH COLUMBIA GEOSCIENTIST

Pierre Friele
Geoscientist

Annotated Photos

Photos 1 & 2. Aerial oblique NE views of the deposition zone below Lillooet Lake FSR. Note the southern lobe that triggered the northerly avulsion. The avulsing lobe missed the A-frame house by only a few metres. A pickup truck in the driveway was destroyed by the event and is likely in Lillooet Lake.

Photo 3. Aerial oblique SW view showing the proximity of the avulsed lobe to the A-frame house (left) and the lobe on the subdivision road near the white car.

Photo 4. View SE from campside to woodside at the 4-5 m of debris on Lillooet Lake FSR.

Photo 5. View NW at the downstream edge of the FSR bridge before cleanup. Seija Halonen photo.

Photo 6. Aerial oblique SW view of filled debris basin upstream of the FSR.

Photo 7. Aerial oblique SW view of channel upstream of FSR. In this area the debris flow remained confined.

Photo 8. WP 677. The debris initiation point is visible as a series of spoon shaped scallops on the lower edge of the debris blanket where it overlaps bedrock.

Photo 9. WP678. Area of tension cracking in bedrock. This site identified in 2010 represents a potential rockfall source area. Rockfall onto the debris blanket downslope could entrain significant volumes of additional debris.

Photo 10. The FSR as of late afternoon, August 30 2013. Seija Halonen photo.