Post-Wildfire Risk Analysis, Fire N70261, 2015, Sitkum-Duhamel

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Introduction and methods

This memo gives further information on post-wildfire natural hazards in the Sitkum-Duhamel fire, to accompany the preliminary report dated 26 August 2015.

The Sitkum-Duhamel fire burned about 777 ha on the ridge between Sitkum and Duhamel Creeks. It began on 4 July, and was 90% contained by July 27. The largest area of high burn severity is in the drainage of Airey Creek, which has an alluvial fan bordering Kootenay Lake about halfway between Sitkum and Duhamel Creeks. On July 15 I did a reconnaissance flight over the fire, and on July 17 I did a field inspection of the Airey Creek fan. Because it was apparent that much of the Airey Creek watershed was severely burned, and the creek might be subject to debris flows, the Regional District of Central Kootenay issued a preliminary alert to residents of the area, advising them of the possible hazard.

On August 12-14, a team consisting of myself, Steve Thompson, P.Ag., and field assistants did mapping work in the burned area. This consisted of ground traverses throughout the accessible parts of the fire, and soil tests at a number of plots. On August 19 I did a further field trip to inspect the channel of Airey Creek.

Several types of imagery were obtained for the fire to assist in mapping. LIDAR data was provided by the forest licensee, Kalesnikoff Lumber. On July 30 I took oblique aerial photographs to use in preparing a preliminary burn severity map. A high-resolution (0.5 m) satellite image was acquired on August 22 and 23. In early September, a BARC (burned area reflectance classification) map was prepared from pre-fire and post-fire Landsat satellite imagery. (Separate file, N70261_BARC_11x17_final.pdf.)

Watershed conditions

Watershed boundaries were drawn by hand on a topographic map, using detailed contours from the LIDAR data. Watersheds are shown on the BARC map. For the Duhamel and Sitkum gullies, the point of interest (POI, which defines the bottom of the watershed) was located a short distance above the mouth, where it appears on air photos that debris flow deposition is likely to start. For Airey Creek, it was arbitrarily located at the top of the private land, about 300 m (horizontal) above the fan apex and highest known water intakes. The face unit boundaries (slopes between the watersheds) were arbitrarily located along the power line on the southeast side, and on the west side by the discontinuous bench above Duhamel Creek.

<u>Airey Creek</u>

Airey Creek has unusual geological conditions in its watershed, which makes it difficult to assess the likely effect of the fire on erosion and sedimentation, and on debris flow hazard. It appears to be spring-fed, as it had quite a high flow this August, higher than would be expected in a drought year. The channel was inspected to about 1000 m elevation to try to find the spring, but could not proceed further due to dangerous conditions from fallen trees in the burn. From aerial and field inspections of the upper gully, there is no indication of flow or a channel above 1200 m, so the spring source must be between about 1000 and 1200 m.

The area of the fire is underlain by granite of the Nelson Batholith. On the logging road (Five Gables road), there are many outcrops of granite with saprolitic weathering, which produces a crumbly, sandy material which is easily eroded, and which may provide a pathway for groundwater infiltration. On the LIDAR images, there is a prominent set of NNW trending joints on the slope above Duhamel Creek, which extends into the Airey Creek drainage, and there are also some features trending east-west which appear to be ancient slump scarps. A possible interpretation of these features is that when the glaciers retreated about 12,000 years ago, there was a small amount of movement on the over-steepened west-facing slope above Duhamel Creek, which created the prominent linear features which follow the joint sets. In Airey Creek, there was possibly a large landslide, or else many small rockfall or debris slide events, in the weak saprolitic rocks. The debris from these failures was carried to the mouth of the creek by many debris flows, which built the large alluvial fan of Airey Creek. This fan has a slope of 15 to 20%, which is typical of coarse-textured debris flow fans, and it has a steeper escarpment along its lower edge, which indicates that it was built into a higher level of Kootenay Lake (similar to many other raised fans and terraces along the lake, which were deposited during deglaciation). The lower channel and upper fan of Airey Creek has some recent debris flow deposits (discussed below), which indicates that it still carries occasional, relatively small, debris flows. It is likely that rainfall and snowmelt in the upper watershed (and possibly further northwest) infiltrates into the joints and weathered bedrock, and emerges as a spring in the lower channel.

Duhamel Creek

The very steep gullies above Duhamel Creek are subject to frequent, small, rockfall-fed debris flows, which reach the creek occasionally. Some of the gullies are also subject to snow avalanches.

Sitkum Creek

On the east side of the ridge above Sitkum Creek, the slope is gentler, but it steepens below into a series of gullies which enter the creek. These gullies are also subject to debris flows, but less frequent than on the Duhamel Creek side. They are probably triggered by high runoff events from the gentler contributing area above. These upper slopes have an unusual amount of year-round seepage.

Burned area observations

The attached map shows the burn severity or BARC (burned area reflectance classification), derived from Landsat 8 satellite images taken before and after the fire. The definitions of high, moderate, and low vegetation burn severity (VBS) are given in Hope et al. (2015) and Parsons et al. (2010), as well as the procedure for preparing a BARC map. Briefly, the burn severity categories are:

High – trees dead, needles, twigs, and understory consumed
Moderate – trees dead, scorched needles remain on trees, understory burned
Low – canopy mostly unburned, understory lightly burned.

Soil burn severity (SBS) is similarly classified as high, moderate, or low, and is based on the extent of consumption of the forest floor and fuels on the ground.

During field work, 29 plots were located, and VBS and SBS were described, mostly in the high and moderate VBS areas. These observations were used to calibrate the BARC map. SBS was generally somewhat higher than VBS in the Airey Creek watershed (that is, high SBS was often observed in areas of moderate VBS). Strong water repellency was observed in many areas of high SBS. The high SBS and extensive water repellency are probably due to the very dry soil conditions that were prevalent this summer.

Table 1 gives the BARC burn severity classes for each watershed. Airey Creek, the D3 gully, and the S1 gully are the most significantly affected watersheds, with 76%, 71%, and 53% respectively burned at high or moderate severity. In Airey Creek and S1 the high burn severity areas are concentrated in upper elevations of the watersheds, where they are likely to have the greatest hydrologic impact.

Debris flow and flood hazards

Debris flows and floods following wildfires can occur in summer as a result of high-intensity rainfall on severely burned and/or water-repellent soils (for example, the 2004 Kuskonook Creek debris flow which followed the 2003 fire). This hazard is greatest in the one to two years after the fire. Debris flows and floods can also occur during spring runoff as a result of rapid snowmelt in burned areas (for example, the debris flows in Middle Van Tuyl, South Van Tuyl, and Memphis Creeks which occurred in 2008, 2009, and 2010, following the 2007 Springer fire). They can also occur, although less commonly, during fall or early winter rain-on-snow events (for example, several large debris flows occurred in October 2005 in the 2003 Ingersoll fire near Burton). These hazards are due to increased snow accumulation, more rapid snowmelt, and higher groundwater levels in burned areas, and can persist for many years until revegetation occurs.

Analysis of 36 debris flow and flood events which followed the 2003 and 2007 wildfires (Jordan, 2012) identified several risk factors, including “gentle-over-steep” topography (gentler slopes or plateau draining into a steeper channel below), and high burn severity concentrated in the upper part of a watershed. Both these risk factors are present in the Airey Creek and S1 watersheds.

Airey Creek

The debris flow hazard is most significant in the Airey Creek watershed, due to the very large extent of high SBS and VBS in the upper part of the watershed. Water repellency is also extensive; although it is not the most important factor in runoff generation (loss of forest floor is more significant), it adds to the hazard during high-intensity rainfall, especially in the first year after the fire.

Although Airey Creek and its fan have been subject to previous debris flows, the frequency (or likelihood of occurrence) of debris flow events is low, based on the apparent age of the deposits. There are obvious debris flow deposits in a wide portion of the lower channel, between about 750 and 900 m elevation. They are covered with mature forest, but lack a well-developed soil profile, indicating they are probably between several hundred and several thousand years old. On the upper top part of the fan, in the vicinity of several water intakes, there are deposits of one or several debris flows, which may be from the same events. Further down the fan, below the power line, there are features visible on the LIDAR images which appear to be older debris flow deposits. These deposits indicate that debris flows occasionally occur under modern climate conditions, maybe or maybe not associated with wildfire. If a debris flow were to occur, it is likely that much of it, in the order of 10,000 m^3, would be stored in the channel above the fan. To reach the lower part of the fan, a debris flow would probably have to be about 20,000 m^3 in volume (about the same size as the 2004 Kuskonook Creek debris flow). The upper part of the gully is very likely dry year-round, which makes it difficult for a debris flow to be initiated. For this to happen, about 6000 m^3 of water (about 1/3 the volume of the debris flow) would need to be generated from overland flow during a rainstorm, or from rapid snowmelt, which could then mix with the debris in the dry upper gully. This would require 20 mm over 30 ha (half the total area of high severity burn) – a very large amount of overland flow, but not impossible. The length of the upper channel in which colluvial debris has accumulated is about 2 km, implying that about 10 m^3/m of channel erosion would need to occur – a high yield rate compared with other debris flow events in the region, but possible, considering the large accumulations of debris observed in the upper channel.

The above discussion gives order-of-magnitude estimates only, but it is based on observations in the watershed and channel, and comparisons with locations in the southern interior of BC where post-wildfire debris flows have occurred. The conclusion is that a large debris flow in Airey Creek is unlikely, but possible – a hazard that is considered "moderate" according to criteria given by Wise et al. (2004) and Hope et al. (2015).

Sitkum Creek

Of the gullies draining into Sitkum Creek, S1 has the greatest hazard of a post-fire debris flow, due to its gentle-over-steep topography, and the large area of high burn severity. To have an effect on the Sitkum Creek fan, a debris flow would have to be large enough to create a substantial blockage of the channel, or to send a wave of sediment downstream to the water intake. The gully appears on the air photos to have had a recent debris flow, and it enters Sitkum Creek in a confined reach, 2 km above the water intake and fan apex. If a debris flow were to block the channel, a flood wave could reach the fan apex. It is worth noting that in the 2007 Sitkum Creek fire, the watersheds of ten similar gullies were burned to the same or greater extent, and none of them experienced debris flow events. However, in the nearby Springer fire, three somewhat similar gullies (gentle-over-steep, burned headwaters, but with steeper, more active, channels) had debris flows.

Duhamel Creek

In the Duhamel Creek gullies, most of the high severity burn is low in the watersheds, or on rocky ridges between the gullies. It is less likely that the fire will affect the debris flow likelihood in these watersheds.

Potential Water Quality Impacts

In Airey Creek, water quality impacts due to soil erosion in the burned area are unlikely, because of the low connectivity with the lower channel. Above 1200 meters, there is no evidence of seasonal flow in the dry gully channels. In Sitkum and Duhamel Creeks, water quality impacts are unlikely due to the large size of the watersheds; however, brief high turbidity periods are possible if a debris flow or erosion event occurs.

Risk analysis

In simplest terms, *risk* is the combination of *hazard* and *consequence*. For the purpose of post-wildfire risk analyses, only *partial risk* is considered; this is the probability that a hazardous event (e.g. a debris flow) will occur and that it will reach or affect the site of the element at risk (e.g. a house or water intake). Other components of risk, such as spatial and temporal probability, and value or vulnerability of the elements at risk, are not considered. Subjective terms (low, moderate, high) are used to describe hazard and risk, based on generally accepted definitions used in British Columbia in other risk analysis studies and mapping projects. The hazards and risks are summarized in Table 2, and the qualitative risk matrix used are shown in Table 3.

Airey Creek

The debris flow hazard in Airey Creek is moderate, but if an event were to reach the fan, the likelihood of it affecting some value at risk is high. Therefore the risk is considered high. There are about 45 houses on the fan (including those on the lakeshore). Because all the houses are on the lower part of the fan, the likelihood of a debris flow directly impacting any of them is low. However, debris flow runout deposits (fine sediment or muddy water) would probably reach the highway, and affect some houses. The path that a debris flow or runout deposits would take on the fan is unpredictable. The creek was diverted many years ago from its original course on the west part of the fan, to its present location crossing Bodard Drive. The diversion structure could easily be destroyed by even a small flood or discharge of sediment, which would cause the creek to flow back towards its original course, or somewhere else on the fan.

Sitkum Creek

In Sitkum Creek, the community water intake at the fan apex is considered vulnerable if a large debris flow upstream caused an outburst flood or debris flood. It is also possible that the creek could overtop its banks at the highway bridge. However, it is also possible that a debris flow could enter the creek without causing significant downstream effects. The likelihood of a debris flow in the S1 gully, and the downstream consequence, are both considered to be moderate.

Duhamel Creek

Similarly, if a large debris flow in any of the Duhamel Creek gullies were to enter the creek, the water intake and/or the stability of the creek on the fan could be impacted. Duhamel Creek has a large watershed, and it is likely that small debris flows could enter the creek without much downstream effect. The hazard of a debris flow in the D3 gully, and the downstream consequence, are both rated as moderate. Debris flow events in the other gullies are also possible, but the effects of the fire on the hazard are less.

Mitigation of risks

There are several risk reduction methods which might be considered for the Airey Creek watershed. Mitigation measures for post-wildfire debris flow risk fall into three general categories: broadcast treatments such as mulching; engineering treatments in the watershed (mainly deactivation of old roads, trails, and landings); and defensive structures such as deflection berms or catch basins on the fan.

Mulching with straw or wood chips is a common post-wildfire treatment in the western United States. In BC, such treatments are less commonly used; however, straw mulch was applied on parts of the 2007 Sitkum and Springer fires. Recent research and operational experience in BC has shown that mulching is very effective at reducing soil erosion in severely burned areas, but is less effective at reducing runoff from rainstorms, and has little benefit during spring snowmelt. Grass seeding is generally of little benefit in the first year, when it is needed most, although fall rye may be of some use in establishing an early cover crop. Mulching is generally not needed in moderate VBS areas, as fallen needles provide an effective natural mulch. Tree planting in burned areas can be beneficial in encouraging earlier hydrologic greenup.

Airey Creek has very little past logging; there is one short spur road and some old selective logging that covers a small area in the uppermost part of the watershed, and there are several switchbacks on the watershed divide. These do not at present contribute significantly to debris flow or flood hazards in the watershed, although care must be taken to avoid accidental diversions of water off the switchbacks.

Recommendations

1. Residents of the Airey Creek fan should be informed of the risks of possible debris flows and diversion of the creek.

2. Residents should be alert to changes in streamflow or sediment in the creek. If high levels of turbidity are observed in the creek during heavy rains or snowmelt, or if the supply of water from a water intake is interrupted, this could indicate that a debris flow may occur. Unusual stream behaviour, such as surging or pulsing flow, or a sudden drop in streamflow, could indicate that a debris flow is imminent.

3. The feasibility of mitigation treatments in the Airey Creek watershed, and/or on the fan, should be investigated.

4. Further field investigation should take place on the Airey Creek, to identify the potential runout pathways of a debris flow.

5. Rehabilitation of roads used in firefighting should be especially careful in the watersheds of Airey Creek and the S1 gully, to reduce the hazard of accidental drainage diversions.

6. Salvage logging should not take place in low and moderate burn severity stands above elevations of 1230 m in Airey Creek watershed, or above 1520 m in the S1 watershed, as this would increase the already very high ECA (equivalent clearcut area). (These are the approximate

H60 elevations in these watersheds.) Any salvage logging proposals in the burned area should be subject to review by a professionally qualified hydrologist.

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Table 1. Vegetation burn severity from BARC map, by watershed.

	Areas in hectares:					By % of area:		
Watershed	Total Area	High	Moderate	Low	Unburned	High	Moderate	Low
Airey Creek	140.9	61.7	45.8	14.8	18.5	44	33	10
Heddle-Airey Face	159.3	1.4	11.3	22.2	124.5	1	7	14
Sitkum-Airey Face	264.4	0.7	14.3	15.0	234.4	0	5	6
D1	34.3	0.0	0.6	7.5	26.2	0	2	22
D2	60.7	4.8	14.1	25.1	16.7	8	23	41
D3	49.1	12.2	22.6	7.4	6.9	25	46	15
D4	40.2	2.9	21.9	10.0	5.5	7	54	25
D5	33.8	0.5	7.5	21.3	4.4	2	22	63
D6	64.7	1.4	8.3	20.9	34.1	2	13	32
D7	62.2	0.0	6.4	12.6	43.2	0	10	20
Duhamel Residual	311.0	21.0	45.8	70.4	173.9	7	15	23
S1	116.6	22.9	39.1	20.3	34.4	20	33	17
S2	48.2	2.1	10.2	5.4	30.6	4	21	11
S3	60.4	0.0	0.0	0.2	60.2	0	0	0
S4	70.9	0.0	0.0	1.0	69.9	0	0	1
Sitkum Residual	214.3	0.9	6.5	1.1	205.8	0	3	1

Table 2. Summary of risks by watershed.

Watershed	Hazard	Consequence	Risk
Airey Creek (debris flow)	M	H	H
Airey Creek (water intakes, creek diversion)	H	H	H
Heddle-Airey Face	VL	M	L
Sitkum-Airey Face	VL	L	L
D1, D7	VL	M	L
D2, D4, D5, D6	L	M	L
D3	M	M	M
Duhamel Residual	L	M	L
S1	M	M	M
S2	L	M	L
S3, S4	VL	M	L
Sitkum Residual	VL	M	L

Table 3. Examples of risk rating definitions, from Hope et al. (2015).

TABLE 1 *Qualitative descriptions of hazard ratings (or the likelihood of occurrence of a natural hazard), adapted from Wise et al. (2004)*

Descriptor of hazard	Description
Very high	A specific post-wildfire hazardous event[a] is very likely or would occur soon after the wildfire.
High	A specific post-wildfire hazardous event is probable (likely) within the short term.
Moderate	A specific post-wildfire hazardous event is not likely but possible within the short term.
Low	A specific post-wildfire hazardous event is a remote possibility (unlikely) within the short term.
Very low	A specific post-wildfire hazardous event is a very remote possibility within the short term.

[a] An event is most likely to occur under adverse weather conditions, such as high-intensity rainfall or rapid snowmelt.

TABLE 6 *Qualitative risk matrix for determining partial risk with three levels of risk (adapted from Wise et al. 2004)*

Likelihood of occurrence of natural hazard	Risk			
	Likelihood that natural hazard will affect element:	High	Moderate	Low
High		High	High	Moderate
Moderate		High	Moderate	Low
Low		Moderate	Low	Low

TABLE 7 *Example of the implications of qualitative risk ratings (adapted from Wise et al. 2004)*

Risk rating[a]	Example implications for evaluation[b]
VH Very high risk	The extensive detailed investigation and implementation of mitigation treatments essential for reducing risk to acceptable levels may be very expensive or not practical.
H High risk	Detailed investigation, planning, and implementation of mitigation treatments are required to reduce risk to acceptable levels.
M Moderate risk	Tolerable, provided the treatment plan is implemented to maintain or reduce risks. May be accepted. May require investigation and planning of treatment options.
L Low risk	Usually accepted. Treatment requirements and responsibility to be defined to maintain or reduce risk.
VL Very low risk	Acceptable. Manage by normal slope maintenance procedures.

a Use of dual descriptors for likelihood, consequence, and risk reflect uncertainty of the estimate, and may be appropriate in some cases.
b Implications for a particular situation are to be determined by all stakeholders; these are examples only.

Photo 1. Overview of Fire N70261. Airey Cr watershed in foreground, Sitkum Cr on right.

Photo 2. Duhamel Creek gullies.

Photo 3. High burn severity site, Airey Creek watershed.

Photo 4. Moderate burn severity site, Airey Creek watershed.