Morley Creek Post-Fire Debris Flood August 2019

October 10, 2019

Introduction

Early in the morning on August 11, 2019 a debris flood occurred on Morley Creek. Debris blocked the highway culvert, overflowing onto the highway and causing damage to several properties downslope of the highway. The headwaters of Morley Creek were burned in 2017. A post-fire natural hazard assessment identified an elevated debris flow and flood hazard due to the fire impacts on the vegetation and soil.

A site investigation of the fan and lower channel was undertaken the day of the debris flood event, followed by aerial surveys on August 11 and August 12. The author also traversed the headwaters area on August 14 and August 27 to inspect the post-fire soil impacts and vegetation regrowth conditions.

Description of the Event

In the early hours of Sunday morning at some time between 1:00 and 3:00 am, a debris flood occurred in Morley Creek. The timing of this event corresponds with a rain event in the area. The flood deposited fine sediment, gravel, cobbles and wood debris on the fan and plugged the culvert. The sediment-laden water ran west along the highway, spilling down to the lake side of the road at numerous locations and causing property damage. The maintenance contractor estimates that the volume of debris removed from the highway area was approximately 100 m^3. See Figure 1 for photos of the channel upstream of the highway. A water licence diversion structure on the fan of Morley Creek retained numerous cobbles and several boulders behind a small dam.

Upper Channel Observations and Debris Flood Initiation

The debris flood initiated at an elevation of 1580 m in the middle headwater channel of Morley Creek. Most of the upper watershed area in Morley Creek is of moderate gradient (~ 35-40%). At around 1600 m elevation, the terrain steepens to 60% with gully sideslopes of up to 80%. Minor channel erosion was observed in the channel below where the terrain steepens (see debris flow initiation point on the map in Figure 2). The channel at this location is less than 1 m wide and the water flow on August 27 was less than 1 litre per second. Only a short distance downstream, there was evidence of cobble movement of up to 20 cm. After several other side channels enter the main gully channel from the east, the debris flood appears to have become larger, causing increasing erosion of the bed and banks. The channel was eroded down to bedrock in many locations. Photos of the progressive bulking of the debris flood in the headwater gully channel are shown in Figure 3.

The helicopter overview flights on August 11 and 12 were hampered by cloud cover; however, the channel further downslope from the initiation zone appears to have been widely eroded down to bedrock (Figure 4).

Evidence of overland flow (bent over grass and areas of fine sediment erosion) was observed on the steep (>60%) hillslopes adjacent to the gully initiation zone, which suggests that high runoff from the upper watershed was a major contributing factor to the debris flood initiation. There was no evidence of any slope failure or temporary channel blockage that may been a factor in this event.

Precipitation Summary

After two and a half weeks of very hot and dry weather, bands of subtropical moisture approached from the south bringing showers to the West Kootenays from August 10 through 11. On the afternoon of Saturday August 10 regional precipitation records recorded 1-12 mm of rain. The nearest hourly precipitation gauges to Morley Creek are 8 km east in the Redfish Creek watershed. These gauges recorded 4-7 mm of rain with maximum 30 minute precipitation intensities of 4-9 mm/h.

In the early hours of Sunday August 11, another storm came through the region, which triggered the debris flood in Morley Creek. Between midnight and three am PST, the Redfish Creek gauges recorded 8-14 mm of rain with maximum 30 minute precipitation intensities of 6-12 mm/h. It is likely that the storm was more intense further east at Morley Creek, as the Nelson NE Environment Canada station (4 km south of Morley Creek headwaters) recorded 18 mm of rain overnight and the historical radar (while not necessarily accurate in this region) does show an isolated area of more intense precipitation around Morley Creek. Other regional weather stations documented 5-11 m of total precipitation for this same storm.

Burned Area Observations

The Morley Creek watershed was burned in 2017 (see burn severity mapping in Figure 2) and a post-fire assessment was completed by the author of this report (Crookshanks 2017). The burned area covered 38% of the watershed. Of the burned area within the watershed, 47% was high burn severity and 33% was moderate burn severity. All duff and organic matter were consumed in high burn severity areas, leaving grey ash and mineral soil exposed. Strongly water repellent soils were widespread, even where moderate vegetation burn severity was observed. Rilling and surface erosion of the ash and surface material were observed at numerous sites in the fire area due to the rainstorm that helped to extinguish the fire. The Selkirk District opted to seed the Morley Creek fire area with a grass seed mixture in the fall of 2017.

In August 2019, vegetation regrowth was highly variable throughout the fire area (see photo examples in Figure 5). Along the upper perimeter of the fire in the moderate burn severity area, fireweed was dominant, providing up to 50% ground cover. Within the high burn severity area, significant grass growth from the aerial seeding was present in some areas, while only limited vegetation (<10% coverage) had re-established in other areas.

Water repellency was observed throughout the fire area in 2019, although it was more widespread in some areas and patchier elsewhere (Figure 6). The most notable area of strong water repellency (and limited vegetation regrowth) was in the headwater area above the middle channel of Morley Creek. Traversing from near the top of the watershed to where the slope steepens above the gully where the debris flood began, water repellency was observed at all points sampled (approximately every 25 m). Where the slope steepens, more vegetation was growing and water repellency was patchier, possibly because of a) a decrease in soil burn severity (this zone is at the transition between high and moderate burn severities); b) increased moisture availability (due to subsurface seepage at the slope transition); and/or c) vegetation growth breaking down the water repellency.

In the moderately sloped headwater areas with limited vegetation, the soil surface had developed a crust. There was evidence of surface erosion and rilling; however, it was unclear how much of the erosion was recent. Rilling was also observed immediately after the fire, but no quantitative data was collected to compare rill extent and depth. At least some of the eroded sediment had been deposited locally on the hillside immediately below areas of erosion. More obvious signs of recent surface erosion of fine sediments were observed further downslope where the slope steepens to 60%.

Across the fire area, vegetation (whether natural or seeded) appeared to be more established where the burn severity was more moderate and where there would be expected be higher soil moisture (e.g. on the sideslopes of the gullies). Further investigation is required to determine whether seeding was useful in mitigating the post-fire soil impact and evaluate the impacts of seeding and vegetation regrowth on water repellency and post-fire soil properties.

Discussion and Conclusions

So why did the relatively small, low intensity rainstorm on the morning of August 11 cause a debris flood event on Morley Creek? The few documented post-fire debris floods and flows in BC with nearby rainfall data have generally been triggered by rainfall events that were much more intense than the Morley Creek rainstorm (Jordan 2016). The exceptions include two small debris flows from the Springer Creek Fire occurred that occurred in August 2007 and September 2009 in response to small, low intensity rain showers. The Springer Creek fire was also located in ‘gentle-over-steep’ topography, where gently sloping terrain drains into a steep channel or gully. In his synthesis of post-wildfire debris flows in southern British Columbia, Jordan (2016) observed that this type of watershed morphology appears to present a greater hazard than steeper, concave-up topography if the upper watershed is severely burned.

The precipitation event on Saturday afternoon that came before the Morley Creek debris flood could have also influenced the runoff response to the storm event on Sunday morning. The Saturday rain shower was smaller than the Sunday event, and some of the water was likely stored in the soil, which could have ‘primed’ the soil for a larger runoff response the following day.

Observed increases in post-fire runoff and sediment yields after high-severity fires have been attributed to loss of surface cover, soil structural changes (e.g. soil sealing), and soil water repellency. The lack of surface cover (vegetation, organic matter and duff layers in the soil) was almost certainly a contributing factor in the case of Morley Creek, as the vegetation and soil organic layers were both almost entirely removed, and there has been only moderate and patchy vegetation regrowth since. Soil sealing refers to the development of a thin, dense soil layer at the mineral soil surface that has a much lower infiltration rate than the underlying soil. This seal or crust can form in response to structural factors (e.g. raindrop impact) or the deposition of fine particles carried by runoff. Therefore, soil sealing may have developed over the past two years and could have also been a factor in increasing runoff to Morley Creek on August 11. Water repellency was also present over a widespread area in the headwaters of the middle channel where the debris flood initiated.

Of course, it is nearly impossible in hindsight to understand the relative contribution of surface cover, soil structure, and water repellency on the debris flood initiation in Morley Creek. Surface cover has not been present in the fire area for the past two years, yet other high-intensity spring and late fall rainstorms have occurred since the fire, which would suggest that this was not the main factor in generating this debris flood. The timing of the debris flood (i.e. after 2.5 weeks of hot and dry weather) and relatively low rainfall intensities, could indicate that water repellency was an important factor in the debris flood generation.

The 2017 fire was initiated by lightning on August 12, and essentially extinguished by two rainstorms on the morning and evening of August 13. The total precipitation for these two storms was 7.8 mm (morning) and 14.2 mm (evening), with maximum 30 minute precipitation intensities of 4 mm/h and 18 mm/h, respectively. This same rainstorm caused rilling and erosion through the fire zone, some channel erosion in the westernmost headwater channel of Morley Creek, and transported fine black sediment down to the fan area. For the rest of 2017 and throughout 2018, there was no rainstorm that: a) exceeded the debris-flood triggering precipitation event of August 11, 2019 in terms of the total or precipitation intensity; ***and*** b) was preceded by an extended hot and dry period (to allow for the re-establishment of the strong water repellency). In spring and early summer of 2018 and 2019, there were several rainstorms that substantially exceeded the rainfall thresholds of the August 2019 storm. There were also several intense, large storms in mid-September 2018; however, these were preceded by multiple days of small precipitation events that may have broken up the strong water repellency.

Others have questioned the importance of soil water repellency in post fire runoff and erosion. For example, studies of fires in Colorado have shown that high post-fire sediment yields tend to last longer than post-fire soil water repellency, which breaks down within a couple years (Larsen et al. 2009). Water repellency is also highly variable in both time and space. Spatial heterogeneity suggests that if any runoff is generated by point-scale soil water repellency, it could quickly infiltrate further downslope. In 2019, patches of strong water repellency were observed throughout the fire area, with particularly widespread repellency in the headwater area above the debris flood initiation channel; however, it is entirely possible that the water repellency was in fact more highly spatially variable than point-sampling could document. Despite these uncertainties, given the timing of the debris flood event and the prevalence of water repellency in the headwaters, it is difficult to dismiss the role that the soil water repellency in the Morley Creek watershed may have played in the large runoff generation from a relatively low intensity storm.

The post-fire soil impacts, including water repellency, will likely remain for the next year or two, and may be more of a factor in runoff response after an extended hot and dry period in the summer. While debris floods and debris flows are natural occurrences on Morley Creek, post-fire soil and vegetation impacts do increase the hazard of a debris flood or flow reaching the fan area; however, the hazard has not increased because of the August 11 event. Because the primary debris source for this debris flood was from the channel and it appears that the debris flood has eroded the channel down to bedrock for much of its length, it is unlikely that an event of similar magnitude will occur in Morley Creek. Smaller debris flood events remain a moderate likelihood for the next few years. With the vegetation likely to continue to re-establish over the fire area, the water repellency and other post-fire soil impacts are expected to be a diminishing factor in runoff response as additional time passes.

(Original Signed and Sealed by:)

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References

Crookshanks, Sarah. 2017. Post-Wildfire Natural Hazards Risk Analysis, Fire N71691, Morley Creek. Available at https://rdck.ca/assets/Services/Emergency~Management/Morley%20Creek%20N71691%20Post-Wildfire%20Risk%20Analysis.pdf.

Jordan, P. 2016. Post-wildfire debris flows in southern British Columbia, Canada. International Journal of Wildland Fire 25: 322-336.

Larsen, I., MacDonald, L.H., Rough, D., Welsh, M.J., Pietraszek, J.H., Libohova, Z., Benavides-Solorio, J., and Schaffrath, K. 2009. Causes of Post-Fire Runoff and Erosion: Water Repellency, Cover, or Soil Sealing? Soil Science Society of America Journal 73: 1393-1407.

Figure 1. Photos of the Morley Creek Channel upstream of the highway showing debris flood deposits from August 11.

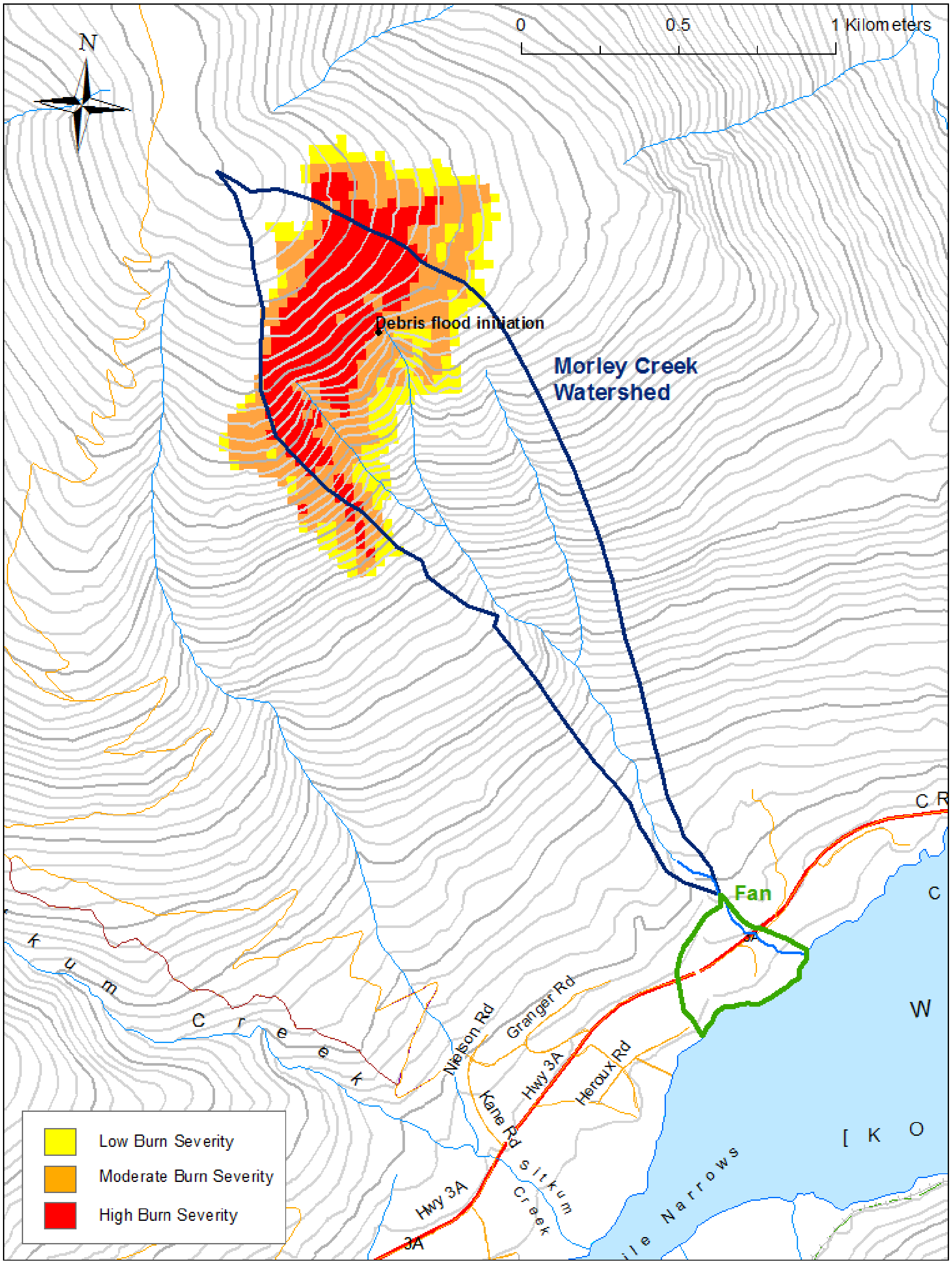

Figure 2. Burned Area Reflectance Classification map of the Morley Creek fire showing the estimated burn severity as derived from Sentinel 2 satellite images taken before and after the fire. The location where the debris flood initiated is also shown.

Figure 3. Photographs showing the initiation of the Morley Creek debris flood and its progressive bulking through channel erosion (upstream to downstream locations from top left to bottom right).

Figure 4. Aerial photograph of Morley Creek channel at approximately 1150 m elevation showing channel erosion down to bedrock.

Figure 5. Photographs from August 22, 2017 (upper left and lower left) and photographs at the same locations from August 14, 2019 (upper right and lower right) showing varying rates of vegetation regrowth.

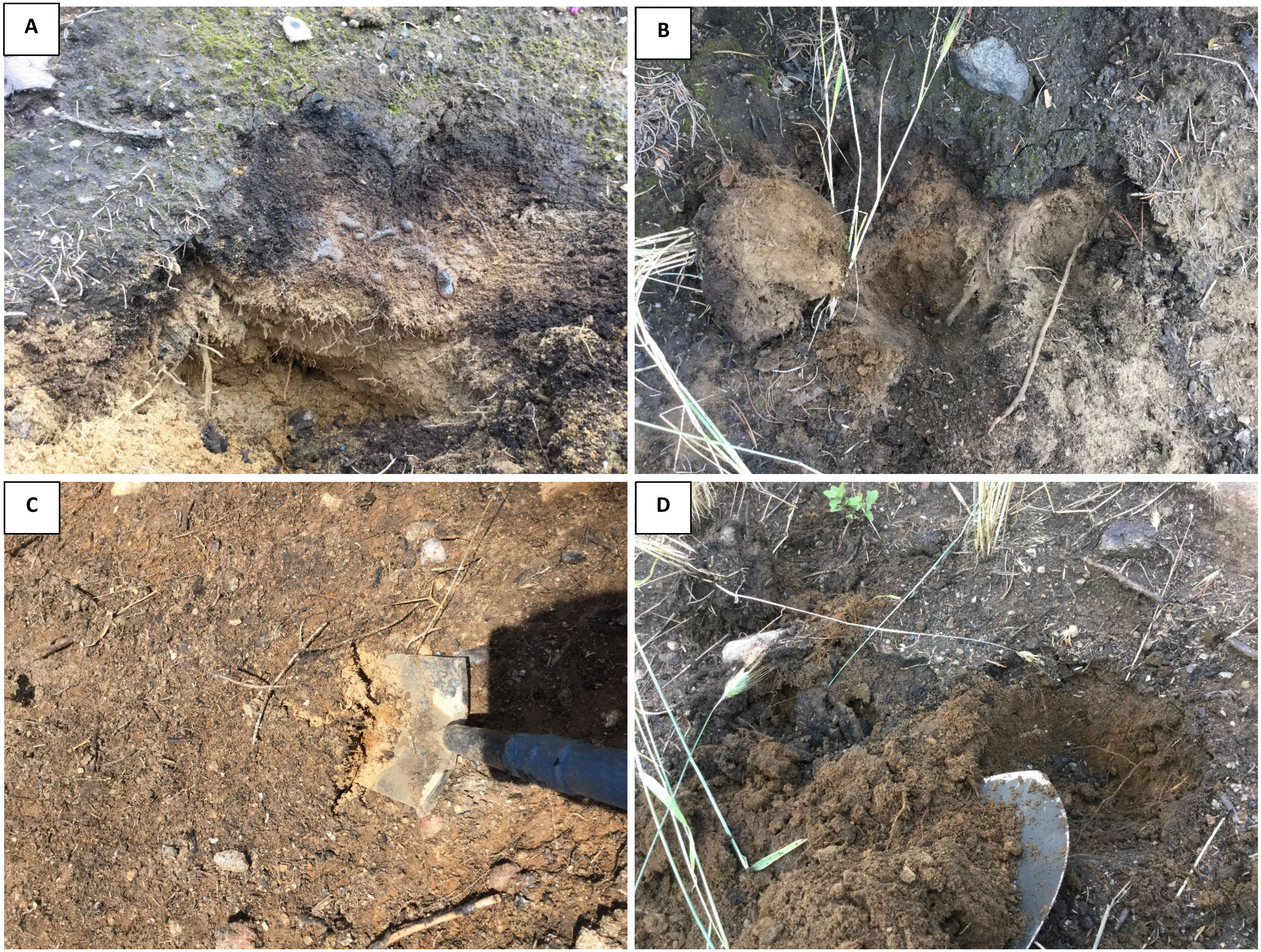

Figure 6. Visual observations of water repellency (or the lack thereof) on August 14, 2019 at four different sites in the Morley Creek fire area: A) At this site, the top two cm of darker material was wet and overlying dry mineral soil. Water drops were not able to infiltrate the dry soil; B) Spatial variability of water repellency is apparent here, where the left hole has damp soil throughout the soil profile and the right hole has dry mineral soil below a wet upper layer; C) At this site, a 0.5 cm layer of wet soil overlies dry mineral soil; and D) No water repellency was observed at this site, and the entire soil column was damp.