

Post-Wildfire Debris Flows in Southern British Columbia

Abstract of paper presented at AGU Chapman Conference on Post-wildfire Runoff and Erosion Response, Estes Park, Colorado, 25-31 August 2013

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A number of post-wildfire debris flows and other landslides occurred after the extreme wildfire season of 2003 in the southern interior of British Columbia. Such events had not been previously reported in Canada. Because of the concerns generated by these events, the BC Forest Service developed a risk analysis procedure for post-wildfire natural hazards in interface areas. As part of this work, we conducted a research project on areas burned by four large wildfires in 2007 and 2009, to examine runoff, erosion, and mass movement processes following wildfire.

Three of the research sites are in the Columbia Mountains, part of the “inland rainforest”, which is characterized by high relief, dense coniferous forest (cedar, hemlock, spruce, fir), and a snowmelt-dominated hydrologic regime. One of the sites is in Douglas-fir and lodgepole pine forest of the drier Okanagan valley. These areas resemble parts of the western Rocky Mountain and intermontane plateau regions of the northwestern United States, although they typically have a longer winter, greater snowfall, and less intense summer rainfall. The 2-year, 30-minute rainfall intensity in the region ranges from 12 to 18 mm/hr. The historical natural fire regime varies across the region, ranging from 100-200 year stand replacement fires in the wetter Columbia Mountains, to 0-35 year low severity fires in the drier valleys. The region experiences hot, dry summers in some years, which can result in high-severity wildfires in those years. Most forest soils are derived from glacial deposits, and although soil erodibility has not been systematically measured, it may be lower than in environments characterized by residual soils.

Post-wildfire landslides observed in the study included debris slides (which may occur on open slopes, and are typically infiltration-triggered), and debris flows (saturated slurries which flow in steep, confined channels, and are typically runoff-triggered). Debris floods (sediment-laden floods with less than 50% sediment by volume, typically occurring in channels not sufficiently steep to support debris flows) were also observed. Although they are not landslides, they were included in the inventory as they form a continuum with debris flows, and the two can be difficult to distinguish on initial inspection. Rockfall is common following fire on steep slopes, but in this study, no individual rockfalls large enough to be termed landslides occurred.

In the four years following the 2007 and 2009 wildfires under study, eleven significant debris flow events occurred, one of which caused a fatality, as well as three debris slides. We have documented a total of 36 debris flows, debris slides, and debris floods following the 2003, 2007 and 2009 wildfires. Our observations on the causes of these events have improved our ability to assess the risks of post-wildfire landslides which can threaten public safety and infrastructure.

Post-wildfire landslides occurred in three seasons: spring, summer, and fall. Three types of weather event have triggered the landslides: spring snowmelt, high-intensity summer rainstorms, and long-duration, low-intensity fall rainstorms. Drainage diversion or concentration by old

logging roads was a significant factor in some events. Debris flows were by far the most common type of landslide, and the most common initiating mechanism was high peak flow in channels. Most sediment in these events was derived from the channels, not from erosion in burned areas. A variety of hydrologic changes contributed to the initiation of post-wildfire landslides, including increased snow accumulation, more rapid snowmelt, loss of forest floor, and water-repellent soils.

Estimates of debris flow volumes and surveys of source areas were made after events in accessible locations, for the 2007 and 2009 wildfires under detailed study. Nearby hillslope silt fence plots yielded 0.001 to 10 Mg/ha in the three years after the wildfires. Debris flow volumes ranged from a few hundred to 5000 m³, which if averaged over the contributing drainage areas, represent yields of about 50 to 500 Mg/ha. Clearly defined initiation points were observed in the channels of most debris flows, which combined with measured yields, demonstrate that most sediment originated in the channels, and that there was minimal contribution from eroded soil in burned areas. Some of the debris flows following the 2003 wildfires were much larger, up to 30,000 m³. Although their source areas were not studied in detail, aerial observations indicated that most of the events originated at discrete points in the channel, and that most sediment was derived from channel erosion.

The maximum 30-minute rainfall intensities observed in the three years after the 2007 and 2009 wildfires ranged from 16 to 24 mm/hr. Some debris flow events occurred during moderate rainfalls, but most occurred in the spring in response to high rates of snowmelt. Increased snow accumulation and higher peak snowmelt rates were the most significant post-wildfire hydrologic impacts observed in the study, with respect to the likelihood of debris flows and other mass movement events. Following the 2003 wildfires, there were anecdotal reports of locally high (but unmeasured) rainfall intensities, which may have been responsible for some debris flow and flood events. Extensive water repellency was observed in several of the 2003 wildfires, and was believed to be an important factor in at least four events. However, strong water repellency was not common in the 2007 and 2009 wildfires, although soil burn severity was severe over much of the burned area as indicated by other measures.

The events following several recent severe wildfire seasons in southern British Columbia demonstrate that the likelihood of debris flows and other mass movement events in susceptible channels is significantly increased following severe wildfire in this northerly, snow-dominated environment. However, in most watersheds not affected by such events, only minimal increases in sediment yield have been observed.