Burned Area Emergency Response (BAER)

Jolly Mountain Fire

Geology: Landslides

Okanogan-Wenatchee National Forest, Washington

Contributors: Stephen Slaughter – DNR Washington Geological Survey, Landslide Hazards Geologist
Trevor Contreras – DNR Washington Geological Survey, Landslide Hazards Geologist

Contents

Introduction

A rapid Burned Area Emergency Response (BAER) assessment was conducted to evaluate the public hazard from landslides and debris flows from the Jolly Mountain Fire. Hazards assessed include landslides, debris flows, and flooding that may adversely impact public safety and (or) infrastructure. Of these potential hazards, debris flows and flash flooding pose the greatest risk to public safety and infrastructure. Wildfire can significantly change the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous flash floods and debris flows. Areas downstream of slopes burned by fire were assessed for historic evidence of debris flow impacts using field reconnaissance, GIS interpretation of lidar (when available), and informed by local knowledge of past post-fire erosional events. Field observations were performed to evaluate the characteristics of surficial deposits, hillslope conditions, and channel bed material, gradient, and confinement. This is a qualitative assessment based on our professional judgement and experience and was performed as part of the emergency response efforts of the U.S. Forest Service.

Geologic observations, interpretations, and recommendation are summarized herein. The focus of this assessment is to the fire’s overall effect across all ownerships and to the potential downstream impacts of debris flows. The objectives of this report are to:

1. Identify debris flow hazards potential affected by the fire.
2. Identify both emergency and long-term actions that could mitigate potential hazards.

Background

A lightning strike started the Jolly Mountain Fire on August 11, 2017. The fire burned in the Cle Elum Ranger District of the Okanogan-Wenatchee National Forest and on or near land managed by the Washington Department of National Resources and The Nature Conservancy. At the time of the completion of this report, the fire was reported to be nearly 37,000 acres and 50 percent contains. It is anticipated the fire will continue to burn until a season-ending weather event occurs.

Methods

Assessment of past evidence of debris flows and the potential impacts from debris flows at locations intersecting infrastructure and public safety were reliant upon observations in the field, lidar (where available) interpretation, unsupervised Burned Area Reflectance Classification (BARC) mapping, and ortho imagery. Field assessments were performed on October 3, 4, and 7, 2017 and focused exclusively on impacts to areas outside of the fire perimeter. Observations were focused on areas downstream of the fires where a channelized debris flow may travel and intersect campgrounds, highways, buildings and structures, and other areas where public safety is a concern. Our observations were compared to the USGS website Emergency Assessment of Post-Fire Debris-Flow Hazards[1] mapping to further evaluate where debris flows may be a concern. Though in some areas we briefly discuss flooding and soils, a detailed description of fire effect on soils and hydrology can be found in the related narratives in the final BAER report.

Hillslope Processes

Soils impacted by fire, especially those on steep slopes and in areas of high burn severity, are prone to surface erosion by water and wind when bare of a protective vegetative cover. Hydrophobic (water

---

[1] https://landslides.usgs.gov/hazards/postfire_debrisflow/index.php

repellant) soil conditions from fire can increase water runoff potential by repelling water from infiltrating into the subsurface, thus intensify the amount and rate of runoff produced during a storm event. When effective ground cover has been denuded after intense fire, soils are exposed to erosive forces such as raindrop impact, runoff can become rapid and erosion accelerated, and overland flow can result in rills and gullies that signify an accelerated rate of surface erosion. The steepest slopes are most prone, particularly where soils are shallow, are somewhat hydrophobic, or where there is a restrictive subsurface layer such as bedrock. Soils that have developed in volcanic ash and glacial till are easily detachable, having low cohesion and structure, and relatively low amounts of organics and moderately thin topsoil horizons.

On the steepest of slopes, the risk of debris flows can be high when runoff is channelized. Shallow soils on steep slopes in first- and second-order (Strahler stream order) headwater drainages are most prone to debris flows. The probability of debris flows is typically relative to hillslope gradient, channel convergence, available fine sediments, severity of hydrophobic soil conditions, the removal of a protective canopy and diminished root strength by fire, and the occurrence of a notable storm or precipitation event(s). Weather events that generate heavy precipitation and runoff in the area typically are associated with seasonal convective thunderstorms. Culmination of debris flows are usually associated with steep drainages and channels where sediment is routed downslope. If a debris flow does initiate, it will likely transform to a flash flood due to decreasing channel gradient, less convergent channel, or entraining sufficient water – all effectively decreasing the amount of sediment within the moving mass and changing the physical attributes of the debris flow.

Debris flows and flash floods

Debris flows have a specific, geologic definition that is often misused by media, the public, and scientists. Most observed "debris flows" are actually debris-laden flash floods or "hyperconcentrated flows." In the following sections, we attempt to explain the differences between a debris flow and a sediment-laden flash flood.

Flash floods, especially those that originate from recently burned areas, are often described as "debris flows" due to the appearance of sediment-laden water transporting woody and vegetative debris, trash, and carrying gravel, cobbles, and occasionally boulders. Though "debris flow" may be an observer's description of the event, a true debris flow has specific properties, behaviors, and characteristics that significantly differentiate them from flash floods. What are often describe as a "debris flow" are actually a sediment-rich flash flood called a hyperconcentrated flow (HCF). A HCF is the transition between a flash flood and debris flow. One way geologists differentiate the three is by the percent of sediment (by volume) carried by the flowing water, so a flood contains less than 5 percent sediment by volume, a HCF is around 5 to 60 percent sediment by volume, and a debris flow exceeds 50 percent sediment by volume.

Debris flows are often described as appearing similar to flowing, wet concrete and travel quickly in steep, convergent channels. Debris flow speed may exceed that of the water flowing in the same channel. A moving debris flow can be very loud because they can buoy cobbles, boulders, and debris to the front and sides of the moving debris flow. The sound is often described as similar to that of a freight train and may cause the ground to vibrate. In the post-fire situation, a debris flow may start as a flash flood surge that entrains (picks up) sufficient sediment to transform into a HCF and, if conditions are suitable, (typically very steep and convergent slopes with significant, unconsolidated sediments) can transform into a debris flow.

Evidence of debris flow deposits tend to be distinct and include channel-adjacent levees of gravel, cobbles, and boulders; channel-adjacent trees display upslope damage such as scarring to bark from rock or debris impact; mud and gravel may be splashed onto trees and other channel adjacent objects; and (or) debris flow deposits that display coarse gravel, cobbles, and boulders “suspended” in fine-grained sediments (sand and finer).

The USGS provided models of post-fire debris-flow likelihood, volume, and hazard for the fire and this data can be downloaded or viewed on the USGS website Emergency Assessment of Post-Fire Debris-Flow Hazards[2]. The modeling calculates debris flow hazards with a range of precipitation storm scenarios and we opted to analyze the 15 minute, 24 millimeters (0.94 inches) storm intensity, the same storm event that the USGS displays on their webpage.

Debris flow and flooding hazards

Because of the ability of a debris flow to buoy cobbles, boulders, and woody debris to the front of the moving mass, debris flows are extremely dangerous to public safety and infrastructure. The hazard is typically limited to first and second order channels, so exposure by the public may be limited in wilderness areas and forestlands. The hazard of HCF and flash floods should not be discounted because they are not debris flows. Both flash floods and HCF can mobilize large volumes of woody debris and HCF can transport large volumes of coarse sediment. Both flash floods and HCF can inundate areas not typically wetted by regular flows, so channel-adjacent roads, trails, building, and other infrastructure can still be damaged by impact from debris, sedimentation, water erosion, and (or) water inundation.

Alluvial Fans

Alluvial fans are low-gradient, cone-shaped deposits built by deposition of sediment and debris that accumulate immediately below a significant change in channel gradient and (or) valley confinement, such as a canyon or steep channel that drains from mountainous terrain and emerges onto a low gradient area such as a flood plain. Sediment on the alluvial fan is deposited by streams, floods, HCF, and (or) debris flows and are typically sourced from a single channel. Over time the alluvial fan stream will migrate across the fan surface to occupy many areas. The migrating stream commonly form distributary channels that branch across the surface and do not rejoin as water flows down the fan. On varying time scales, the channel(s) will change location on the fan, seeking a lower elevation away from where it has most recently been depositing sediment. Due to the low gradient of alluvial fans, the capacity of the channel to move sediment is reduced and channels will fill with sediment, forcing the channel to change direction. In extreme events these changes in channel can occur quickly, during a single storm. Over time, this gradual accumulation of sediment and channel migration builds and maintains the characteristic shape of a fan or cone.

Alluvial fans are attractive locations to build cabins and homes due to the slight elevation above river flood plains and (or) the occasion to have a view of the flood plain (Figure 1). However, alluvial fans are there because they are active depositional areas that accumulate sediment over time. The sediment can be deposited both slowly, such as during a spring melt when high streamflow during spring runoff transports and deposits fine sediment on the fan or quickly, when a flash flood, HCF, or debris flow transports sediment and debris to the fan. As stated above, both flash floods and HCF can inundate areas not typically wetted by regular streamflow, so channel-adjacent roads, trails, building, and other infrastructure can still be damaged by impact from debris, sedimentation, water erosion, and (or) water inundation. In addition, a debris flow can be very destructive due to the ability of a debris flow to buoy

---

[2] https://landslides.usgs.gov/hazards/postfire_debrisflow/index.php

cobbles, boulders, and woody debris at the front of the moving mass, debris flows are extremely dangerous to public safety and infrastructure.

Observations and Interpretations

Teanaway River Watershed

DNR-managed campgrounds

Indian Camp

Indian Camp is on the Middle Fork (MF) Teanaway River (Figure 2) and the upper portion of the basin northeast of the camp experienced high burn severity and soils displayed hydrophobic conditions to depths of 2 cm. The basin revealed no evidence of past debris flows; however, the concern in this basin is flash flood and (or) HCF that could impact Indian Camp. The camp is on a small alluvial fan with several sites potentially exposed to a flash flood. Particularly exposed is the horse camp adjacent to the creek (east of the T5000 road) where a flash flood would likely inundate the camp site. In addition, camp 3 in the main portion of the campground is on a low terrace of the Middle Fork Teanaway River, near the current mouth of the creek, and may be impacted by flooding. It is recommended that the campground remain closed to allow for recovery of herbaceous growth and breakdown of hydrophobic soil conditions in the upper basin. The USGS combined relative debris flow hazard model indicated the basin above Indian Camp has a “moderate” rating during a 12mm (0.47in) in 15-minute storm event. This is the only DNR-managed campground close enough to the wildfire perimeter to have USGS modeling.

A secondary flooding hazard at this campground is a flash flood in the MF Teanaway River. Campsite 3 on the low terrace is at the greatest risk and depending on the magnitude of the flood, other campsites may be at risk, too. A detailed description of fire effect on hydrology can be found in final BAER report.

29 Pines Campground

Though outside of the burn area and debris flow hazards, the campground (Figure 2) may see impacts from the Jolly Mountain Fire. The campground is on a river terrace and due to the proximity to the North Fork (NF) Teanaway River there is an increased likelihood of flash flooding and (or) HCF. Intense precipitation in upstream areas burned by the fire could produce significant runoff that may impact areas outside of the burn. At 29 Pines Campground, there are approximately a dozen campsites on a lower terrace that may be impacted by a flash flood. The remaining campsites are on a higher terrace would need further hydrologic analysis to determine the flooding hazard to those sites. Also of significance at the campground is an intake for a WDFW fish hatchery that may be at risk from sedimentation, debris damage, turbid flood waters and (or) flash flooding. At the time of the field visit, the intake was protected from debris with a plywood structure; however, sedimentation and debris may be an ongoing issue and should be considered by operators of the hatchery.

Teanaway Campground

Though outside of the burn area, the campground (Figure 2) may see impacts from the Jolly Mountain Fire. The campground is on a river terrace and is not at risk of a debris flow; however, due to the proximity to the West Fork (WF) Teanaway River there is an increased likelihood of flash flooding and (or) HCF. Intense precipitation in upstream areas burned by the fire could produce significant runoff that may impact areas outside of the burn. At the Teanaway Campground, a significant flooding hazard area is the dispersed camping (which isn't allowed, but does occur) on the forested gravel bar adjacent to the river. Numerous signs should be posted to describe the hazard and discourage camping on the gravel bar. The designated campsites are on a river terrace that would need further hydrologic analysis to determine the flooding hazard.

Overall, all stream-adjacent campgrounds described above should be analyzed for post-wildfire flooding hazards and considered for temporary closure. Both flash floods and HCF can inundate areas not typically wetted by regular flows, so channel-adjacent campsites can still be damaged by impact from debris, sedimentation, water erosion, and (or) water inundation. To determine the post-wildfire downstream flooding hazards to campgrounds, further hydrologic analysis is recommended.

Houses, cabins, and structures

There are numerous structures built in the Teanaway River watershed and many are adjacent to the various forks of the Teanaway River, including the Wagon Wheel development (Figure 2) at Lick Creek. There is an extremely low likelihood of a debris flow from the burn area directly impacting any of the structures along the three forks of the Teanaway River. Flooding is likely the most significant post-wildfire hazard and both flash floods and HCF can mobilize large volumes of woody debris and HCF can transport large volumes of coarse sediment. Both flash floods and HCF can inundate areas not typically wetted by regular flows, so channel-adjacent roads, trails, building, and other infrastructure can still be damaged by impact from debris, sedimentation, water erosion, and (or) water inundation. To determine the post-wildfire downstream flooding hazards to cabins along the river, further hydrologic analysis is recommended.

Cle Elum Reservoir

Morgan Creek

There was no obvious evidence of historic debris flow(s) at the mouth of Morgan Creek at the Salmon La Sac Road (Figure 2). The stream channel shows evidence of flooding and transport of gravel and cobbles. The alluvial fan at the mouth of the creek suggests a history of sediment transport and deposition from the above basin. Flooding is likely the most significant post-wildfire hazard and both flash floods and HCF can mobilize large volumes of woody debris and HCF can transport large volumes of coarse sediment and impact the Salmon La Sac Road. In addition, when Cle Elum Reservoir is low, dispersed camping is common on the Morgan Creek alluvial fan and this location should be assessed for potential flood hazards and possible closures.

Despite there being no evidence of debris flows in this basin, the USGS combined relative debris flow hazard model indicated Morgan Creek basin has a “moderate” rating during a 12mm (0.47in) in 15-minute storm event. This basin is modeled with a higher combined hazard rating than many other basins along Salmon La Sac Road.

Areas of additional concern are in the Morgan Creek Homeowners Association and includes two culverts on the community access road. Both culverts have the potential to become blocked by debris. We recommend that the existing culverts are maintained and potential woody debris that could block the culverts be removed. A blocked culvert can stop stream flow and redirect flood water to flow over the road and diverting flow into a different channel and (or) damaging or destroying the road. Culverts should be inspected before and after storm events to check for blockage and debris.

An area of additional concern are dry channels that have been filled for driveways and developing level ground for a house and (or) yard. If these fills have undersized drainage (such as small diameter culvert or coarse fill), the dry channel upslope of the fill could impound flood water and may lead to failure of the fill, potentially leading to a flood or debris flow to areas downslope.

Dry Creek

There was no evidence of historic debris flow(s) at the mouth of Dry Creek at the Salmon La Sac Road (Figure 2). The stream channel shows evidence of flooding and transport of gravel and cobbles. The alluvial fan at the mouth of the creek suggests a history of sediment transport and deposition from the above basin. The Dry Creek drainage basin was primarily low burn severity and unburned, reducing the likelihood of post-wildfire flooding. However, during low reservoir levels, there is dispersed camping on the Dry Creek alluvial fan and this location should be assessed for potential flood hazards.

Bell Creek

There was no evidence of historic debris flow(s) at the mouth of Bell Creek at the Salmon La Sac Road (Figure 2). A WDFW boat launch site at the mouth of Bell Creek (Annabelle or Bell Creek Water Access?) contains a vault toilet and is day-use only. If there is a flood in Bell Creek and the culvert under Salmon la Sac Road is blocked or overwhelmed, flood water will likely flow south in the Salmon la Sac Road ditch to a culvert that drains into the boat launch site. If flood water were to flow to this culvert, the assets at risk is Salmon La Sac Road and the WDFW access road to the site. We do not believe that the vault toilet is at risk of impact by flooding. Also, much of the Bell Creek drainage basin wasn’t burned or experience primarily low burn severity, reducing the likelihood of post-wildfire flooding.

Limitations

This report was written as part of emergency operations of the Burned Area Emergency Response (BAER) assessment to quickly assess and identify geological hazards associated with the Jolly Mountain Fire. It is intended to help the land managers focus efforts and make decisions regarding post-wildfire geological hazards. Limited fieldwork was done to assess hazards presented by landslides, and not all areas were evaluated, and we did not assess flooding issues. Hydrological professionals with the USFS provided that analysis and their report should be consulted. We encourage the DNR, USFS, WSDOT, Federal Highways, landowners and others to consult licensed professionals for site specific analysis of geological hazards and flood risk due to the wildfires.

We presented limited results of the USGS preliminary assessment of post-fire debris-flow hazard modeling, choosing to present the 12mm in 15-minute storm models. There is additional modeling of

24mm and 40mm in 15-minute storm interval that models more extreme precipitation events. The modeling can be accessed at:
https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=149

2699
Stephen Slaughter

2687
TREVOR A. CONTRERAS

Stephen Slaughter
Licensed Engineering Geologist #2699
Washington Geologic Survey
Washington State Dept. of Natural Resources
Olympia, WA
Office: 360-902-1498
Cell: 360-742-9103
Email: stephen.slaughter@dnr.wa.gov

Trevor Contreras
Licensed Engineering Geologist #2687
Washington Geologic Survey
Washington State Dept. of Natural Resources
Olympia, WA
Office: 360-902-1553
Cell: 360-810-0005
Email: trevor.contreras@dnr.wa.gov

Appendix

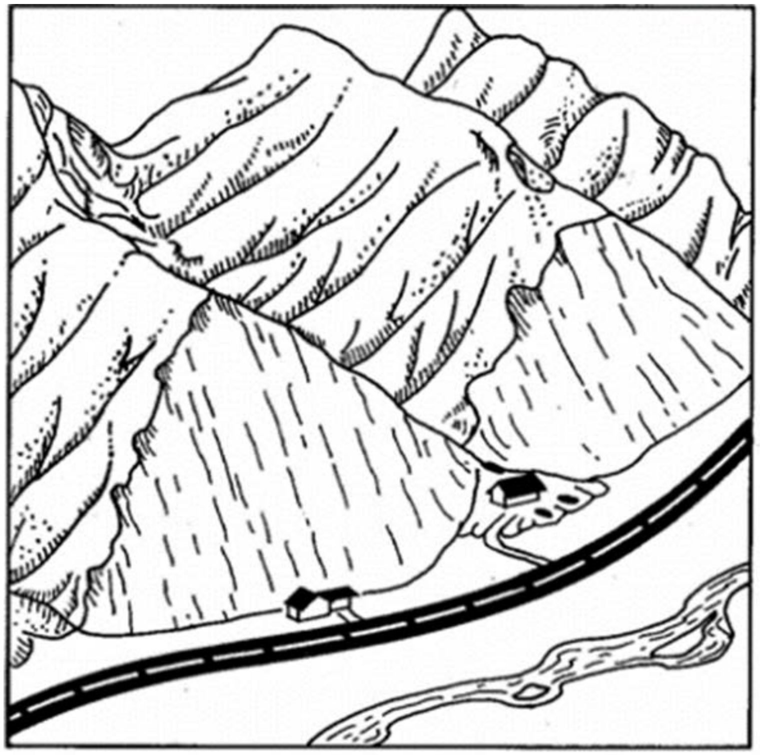

Figure 1. Homes and road in debris flow-prone locations on alluvial fans. Courtesy of Oregon Dept. of Forestry.

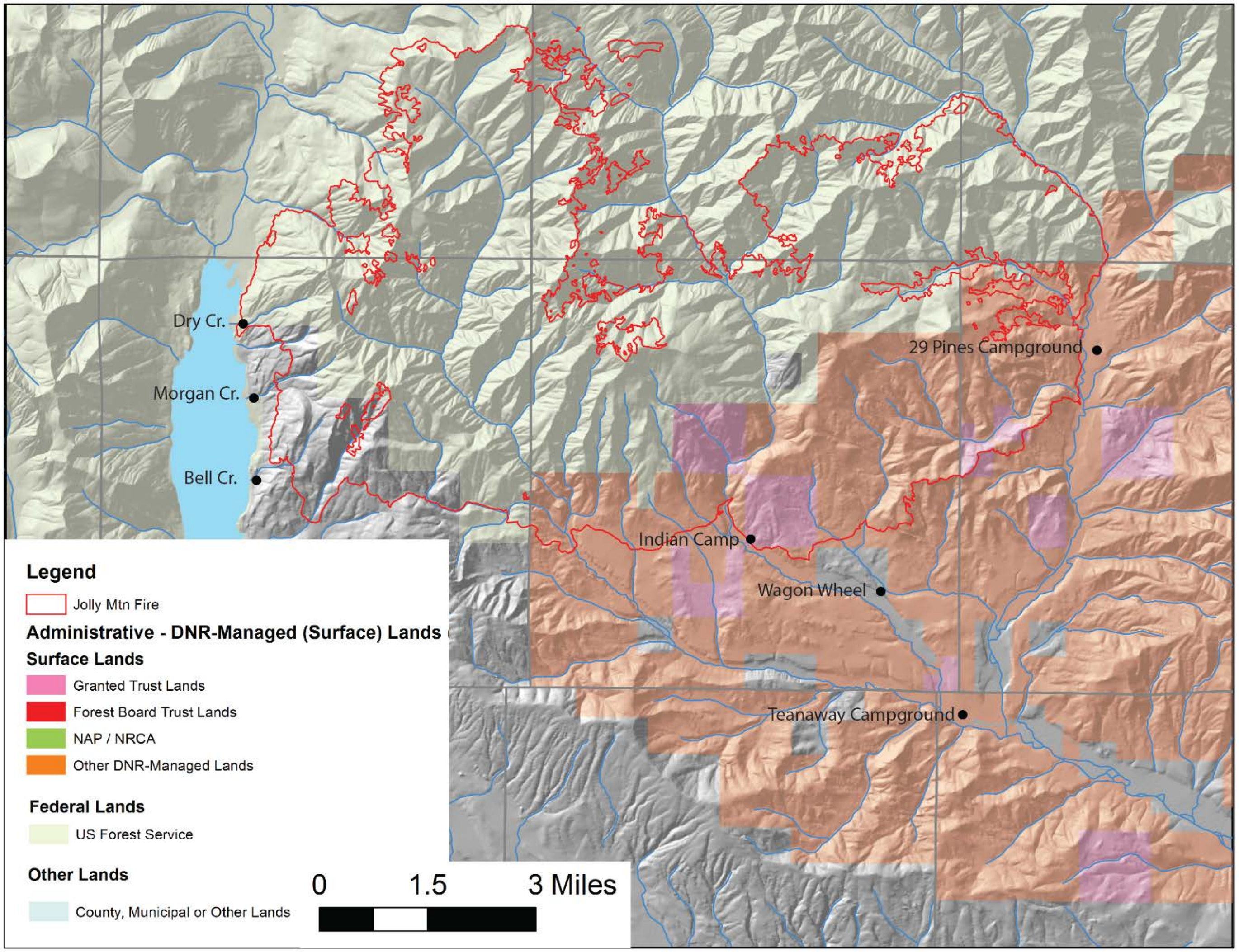

Figure 2. Map showing the extent of the Jolly Mountain Fire (in red) and locations discussed in the report.