Burned Area Emergency Response (BAER)

Cougar Creek Fire

Geology: Entiat River Road Debris Flow Evaluation

Okanogan-Wenatchee Ranger District, Washington

Boulders at the apex of Gray Canyon

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

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Introduction

This report is a rapid geologic assessment evaluating hazards from post-wildfire landslides and debris flows from the Cougar Creek Fire and along the Entiat River Road. Hazards assessed in the field include landslides, debris flows, and flooding that may adversely impact public safety and (or) infrastructure. Wildfire can significantly change the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous flash flooding and (or) debris flows. Areas downstream of slopes burned by wildfire 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-wildfire events. Field observations evaluated 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 in cooperation with the emergency response efforts of the U.S. Forest Service (USFS) Burned Area Emergency Response (BAER) team. The assessment is for areas adjacent to lands managed by the USFS and outside of the jurisdiction of the federal agency.

Summarized in the report are geologic observations, interpretations, and recommendations. The focus of this assessment is to the wildfire's effect across all ownerships and to identify downstream areas susceptible to impacts from a post-wildfire debris flows.

Background

The Cougar Creek fire was ignited by lightning on July 29, 2018, in the Okanogan-Wenatchee National Forest (OWNF) and located approximately 10 miles northwest of Entiat, WA. As of September 13, 2018, the fire was 42,712 acres and 79 percent contained.

The Entiat River valley has experienced floods and debris flows following wildfires and during notable storm or precipitation events. For example, debris flows in the spring and summer of 1972 impacted several fan in the Entiat River valley killing four people on Preston Creek [1]on June 10th. This fan is approximately 2 miles northeast of the current fire perimeter, near river mile 23.

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 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

[1] Klock, G.O.; Helvey, J.D., 1976, Debris Flows Following Wildfire in North Central Washington: Federal Intra-Agency Sedimentation Conference, 3rd, Proceedings, p. 1.91-1.98.

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 can transform back to a flash flood due to a number of physical variables including decreasing channel gradient, a widening channel, and (or) entraining additional water. These variables effectively decrease the amount of sediment within the moving mass and change 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 (sediment)-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. It is important to distinguish between these events because debris flows can be much more hazardous than floods.

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 described 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: 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 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

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

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.

Fans

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 floodplain. Sediment on the fan is deposited by streams, floods, HCF, and (or) debris flows and are typically sourced from a single channel. Over time, the 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 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.

Fans are attractive locations to build cabins and homes due to the slight elevation above river floodplains and (or) the occasion to have a view of the floodplain (Figure 1). However, 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 previously, 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 cobbles, boulders, and woody debris at the front of the moving mass. Debris flows are extremely dangerous to public safety and infrastructure.

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 orthoimagery. A rapid field assessment was performed by the authors on September 11, 2018 and focused exclusively on impacts to areas along the Entiat River Road between river mile 14 and Gray

Canyon. Field assessments focused on areas downstream of the fire where a channelized debris flow may travel and intersect roads, buildings and structures, and other areas where public safety is a concern. We prioritized site visits along the Entiat River Road to fans with watersheds impacted by the Cougar Creek Fire and where houses are built on those fans. In addition, we accessed sites only where property owners granted permission. Our field observations are compared to the USGS Emergency Assessment of Post-Fire Debris-Flow Hazards mapping to further assess where debris flows may be a concern. Though in some areas we briefly discuss flooding and soils, a detailed description of wildfire effects on soils and hydrology can be found in the related narratives in the final BAER report.

Observations and Interpretations

This section includes field observations and interpretations augmented by remote sensing. Remote sensing is performed in a GIS and include 1 foot lidar digital elevation model, historic orthoimagery, and geologic mapping. We also compare our field observations to the outputs of the USGS combined hazard debris flow model.

Entiat River Valley

Fans along the Entiat River

Appendix A depicts fan mapping along the Entiat River between river miles 13 to 19. This mapping was performed in a geographic information system (GIS) using 1-foot grid LIDAR digital elevation data. The mapping shows fans where tributary drainages enter the Entiat River valley. Many of the larger fans appear to have pushed the Entiat River to the opposite side of the valley with repeated fan building events. Some of these fans were clearly impacted during a 2006 flooding event (discussed in the next section) and in the absence of a preceding wildfire.

2006 Flooding Event

Orthoimagery from the summer of 2006 show evidence of a notable weather event that impacted many fans in the Entiat River valley between approximately river miles 12 and 19. Fans and stream channels, especially on the east side of the valley, show evidence of sediment erosion and deposition. This includes fans with residences built on them. Many of the watersheds that feed the Entiat River contain steep valley walls that reveal hundreds of bare soil stripes tracking downslope to stream channels. Some channels transported the sediment to fans. This process of fan building is expected and is a model example of how fans are built over time.

Fans on west side of the Entiat River

We did not visit fans on the west side of the Entiat River unless residences were built on a fan. There is local concern of landslides blocking the Entiat River from debris shed from fire burned areas west of the river. We did not observe evidence of past landslides that may have blocked the Entiat River; however, fans have built onto the floodplain of the river and it is possible that additional debris mobilized during notable storm or precipitation events could build fans, shifting the Entiat River away from the fan. Predicting the impacts of flooding and channel migration is outside the scope to this reconnaissance report.

Potato Creek

Potato Creek enters the Entiat River upstream of river mile 15. The Potato Creek watershed is approximately 6,300 acres and flows onto a 33 acre fan. Six structures and 650 feet of the Entiat River Road are built on the fan. Approximately 20 percent of the watershed nearest the fan was impacted by the fire. The channel was dry at the time of our field visit.

The lower watershed is characterized by a broad, low gradient valley floor. At the fan apex, the valley floor is over 400 feet wide. Upstream, over a distance of 1800 feet, the valley floor narrows to about 100 feet wide. The broad and low gradient valley floor is not conducive to debris flow mobilization, so the likely hazard on the fan is a flash flood or HCF. The USGS combined hazard debris flow model ranks the main channel of Potato Creek above the fan as “low” for a debris flow from a storm intensity of 24mm (0.94in) in 15 minutes.

The watershed appears to have been impacted by the storm event in summer of 2006. Orthoimagery clearly show dozens of shallow debris flows and (or) debris slides from the slopes above the main channel. The main channel appears to have been impacted by the event, though it is unclear if the fan was impacted. However, given the amount of visible mass wasting in the watershed, it is very likely that the fan experienced overbank flooding and (or) sediment deposition during this storm event.

An additional observation is an extensive berm on the fan and paralleling USFS-managed lands. A 1,000 foot long berm confines Potato Creek to USFS lands and the east side of the fan (Figure 2). This berm would likely confine flood waters to the east side of the fan and places two structures and a portion of the Entiat River Road at the greatest likelihood of impact from a flooding event. Damage includes debris, sedimentation, water erosion, and (or) water inundation.

Decker Canyon

Decker Canyon Creek enters the Entiat River slightly upstream of river mile 16. The watershed is approximately 540 acres and flows onto a 40 acre fan. Over 14 structures and 1600 feet of the Entiat River Road are built on the fan (Figure 3). The fire impacted the entire watershed, with the exception of a small portion near private residences on the fan. The active channel was dry at the time of our field visit and a resident stated the channel is dry much of the year.

Upstream of the fan, the floor of Decker Canyon is broad, ranges in width between 10 to 30 feet wide, and has an approximately 18 to 24 inch wide active channel incised into the canyon floor. A resident of the fan stated that the canyon was once used to transport lumber downslope by steel-wheeled trucks and tractors. The material in the canyon floor are primarily fines with occasional cobbles and a few boulders. Approximately 500 feet upstream of the canyon mouth, immediately below a historic grade that crosses the canyon, the canyon floor widens to about 30 feet. In this area, several small lobes of clast-supported debris are evident, suggesting a very small HCF or debris flow may have deposited at this location. Downstream of this location, we saw no evidence of conveyance of this event. We also did not observe field evidence on the fan to indicate the presence of historic debris flows. The USGS combined hazard debris flow model identified Decker Canyon Creek as “moderate” for a 24mm (0.94in) in 15-minute storm event.

Based on observations from 2006 orthoimagery, this watershed does not appear to have been impacted by the storm event.

An additional observation is at the apex of the fan and the mouth of Decker Canyon, an approximately 150 foot long earthen berm, up to 6 feet high and 30 to 40 feet wide, directs the active channel to the north side of the fan. The berm continues downslope an additional 300 feet; however, it is significantly smaller and is as tall as 3 feet. The smaller berm is armored in places with cobbles and some boulders. The berms appear to be of various vintages and design and also directs the water to the north away from a private structure. The channel goes into a sub-18 inch culvert that passes under Entiat River Road.

Gray Canyon

The Gray Canyon fan is on the east side of the Entiat River downstream of river mile 17. Approximately 15 structures and 1300 feet of Entiat River Road are on the fan. Gray Canyon watershed is approximately 1205 acres and flows onto an approximately 19 acre fan. About 30 percent of the lower watershed was impacted by the fire. The channel was flowing water at the time of our field visit.

Above the fan, Gray Canyon creek is unconfined and the channel gradient is low. There are abundant fines in the channel and it lacks evidence of debris flows. About 1200 feet upstream of the fan, Gray Canyon creek incises into glacial deposits that consist of a mixture of boulders and fines. The incised channel creates steep side slopes exceeding 38 degrees and slope heights up to 60 feet. Channel gradient is approximately 12 degrees (measured from LIDAR). The steep side slopes show evidence of pre-fire raveling into the creek below. We also observed pea-sized float of subrounded pumice at the surface in the upper watershed near the confluence of the north and south forks.

Near the confluence of the north and south forks, the active channel leaves the incised glacial deposits and flows on the valley floor. At the north fork, the channel gradient is about 2 degrees and the active channel is approximately 4 feet wide and deep. The channel is dry at this location. The channel contains historic evidence of flooding, including the washout of a culvert leading to a fenced orchard. The wide upland valley for both the north and south forks are wide, low gradient and unlikely to transmit debris flows. If a debris flow were to initiate in the steep uplands, upon reaching the wide valley floor, the debris flow would likely deposit sufficient sediment and transform into a flash flood.

On the fan, the creek flows on the south side in an excavated channel. According to a resident of the fan, the main creek channel was modified to flow from the northern channel to the south many years previous. Abandoned, distributary channels and low areas are apparent below the apex of the fan. In this same area, cobbles and boulders up to 4 feet diameter protrude from the ground and some have been excavated by landowners (see photo on front of report). The cobble/boulder deposits and fan gradient suggest that debris flows may have impacted this fan in the past. The date of the debris flow(s) is unknown and could predate historic occupation of the valley and (or) be associated with post-glacial erosion of the glacial deposits in the lower watershed.

A resident of the fan reported that in June 2007 a storm event caused the creek to jump from the southern channel and flood a property on the north side of the fan (12950 Entiat River Road), resulting in approximately 7 inches of mud and debris that impacted structures. We were not able to verify the date of this event; however, orthoimagery 6/23/2006 (Figure 5) suggest that this event may have occurred between 7/31/2005 and 6/23/2006. The 2006 air photo clearly shows dozens of shallow debris slides in the watershed and the main channel was impacted by debris. Both the southern and northern channels of the fan received sediment from this event.

In the field, we did not observe conditions that suggest debris flows are common to the Gray Canyon fan; however, the fan has experienced historic flooding events and boulders on the fan body suggest that debris flow events are possible.

The USGS combined hazard debris flow model identified the drainages above the Gray Canyon fan “low” for a 24mm (0.94in) in 15-minute storm event. While it is unlikely that debris flows would reach the fan, existing channels on the fan could convey debris and flood water, impacting residences and Entiat River Road.

An additional observation is immediately upstream from the fan is a channel spanning structure approximately 8 feet high and 100 feet long (Figure 4). It appears armored with boulders on the downstream side and the upstream side is filled with sediment. We are unsure when the structure was constructed and the purpose of the structure.

Fan at Tyee Ridge Spring No.1

The fan on the west side of the Entiat River near river mile 14 has at least 7 structures on it. The watershed above is approximately 350 acres and the fan is 19 acres. All of the watershed was impacted by the fire. A private bridge crosses the Entiat River near where the fan channel enters the river. Utility lines appear to be hanging from the bridge. The stream was dry during our field visit.

This fan has a well-defined channel on the main body of the fan; however, near the apex of the fan, the channel disappears for 300 feet before reappearing again. This area is near a home and according to a resident near the river, the creek on the fan rarely flows and water in the upper valley typically goes subterranean prior to the apex of the fan. The resident also stated that a 1994 storm event manifested as “a little water in the channel” and stated that typically the channel is dry. Orthoimagery from 2006 show sediment deposition to the fan both by the main creek and from a small watershed to the north. The deposits appear as light colored lines on the pasture suggesting sediment and water came down the fan (Figure 6).

We found no field evidence of debris flow deposits on the body of the fan. At the apex, deposits of white ash and sand dominate with occasional cobbles and boulders, suggesting no major fan building events in the historic past. Some minor flooding and sedimentation may occur depending on future storm events and the burn severity of the watershed above.

The USGS combined hazard debris flow model identified the drainages above the Tyee Ridge Spring No. 1 fan as “moderate” for a 24mm (0.94in) in 15-minute storm event.

Recommendations

The primary depositional process we observed suggest that flooding and hyperconcentrated flows (HCF) are the most-likely hazards that may impact the areas evaluated in the field. The reduced likelihood of debris flows are primarily due to either the areas being adjacent to higher order (third) streams where debris flows are unlikely or in areas where the watershed experience low burn severity and a lower likelihood of hydrophobic soil conditions that can drive debris flow initiation.

The most significant potential impact at all visited sites is flash flooding and associated damaged by impact from debris, sedimentation, water erosion, and (or) water inundation. Owners and residents of homes and other structures built on fans and (or) adjacent to streams flowing from burned areas should be informed of potential post-fire flooding hazards. Cascadia Conservation District may assist local landowners to find resources to help mitigate potential flooding problems. Chelan County public works should be reminded of the increased likelihood of sediment transport, sediment deposition, and (or) erosion to roads, as well as potential issues with blocked culverts. Many of the culverts we observed are small and could be plugged and overwhelmed with debris if a notable precipitation event occurs. We suggest reminding transposition network managers that before and after notable storm or precipitation events to inspect culverts and bridges where channels drain areas impacted by the fires.

Areas of specific concern include:

- All fans of the Entiat River Valley pose flooding and sedimentation issues to residents living on these features, regardless of the burn severity in the watershed. Imagery from 2006 shows the majority of the fans mapped in Appendix A had some sediment deposition. It is important for residents to recognize fans, understand the process that builds them, and plan and mitigate for future flooding and sedimentation events.
- The channel-spanning berm in Gray Canyon should be evaluated for potential future treatments. If it was constructed as a sediment retention structure, it has exceeded capacity and should be evaluated for hazards related to capacity and future events that deliver sediment onto the fan.
- Near the confluence of the north and south forks of Gray Canyon Creek, a forest road passes over the south fork and an 18 to 24 inch plastic culvert was burned on both ends. This culvert should be evaluated and potentially replaced due to the potential for a blockage and subsequent failure of the four foot fill above the culvert. It is not on the OWNF lands.
- The home at the apex of the Tyee Ridge Spring No.1 fan, 11125 Entiat River Road, may need to consider improving drainage in the dry creek channel to accommodate potential future flooding.
- An evaluation of the fan channel morphology and berm design could help property owners in preparations for additional sediment and flooding from the Decker Canyon watershed.

Limitations

This report was written in support of emergency operations of the Burned Area Emergency Response (BAER) assessment to quickly assess and identify geological hazards associated with the Cougar Creek Fire. It is intended to help the USFS, Chelan County, conservation districts, and others focus efforts and make decisions regarding post-wildfire geological hazards. Limited fieldwork was accomplished to assess hazards presented by landslides, and not all areas or hazards 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 USFS, Chelan County, landowners and others to consult qualified professionals for site specific analysis of geological hazards and flood risk due to the wildfires.

We presented limited results of the USGS Emergency Assessment of Post-Fire Debris-Flow Hazards modeling, choosing to present the 24mm (0.94in) in 15-minute storm intensity as the USGS provides on their website. There is additional modeling of higher and lower storm intensities that can be accessed at: ftp://ftpext.usgs.gov/pub/cr/co/golden/Staley/cug2018/

Resources:

Here are a few resources about debris flows and flooding preparedness:

- https://pubs.usgs.gov/fs/fs-176-97/fs-176-97.pdf
- https://www.wrh.noaa.gov/lox/hydrology/files/DebrisFlowSurvivalGuide.pdf
- https://www.lacounty.gov/wp-content/uploads/2016/12/LANDSLIDE_MUDSLIDE_Safety_phbs_2012.pdf

Stephen Slaughter
Licensed Engineering Geologist #2699
Washington Geological 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 Geological Survey
Washington State Dept. of Natural Resources
Olympia, WA
Office: 360-902-1553
Cell: 360-810-0005
Email: trevor.contreras@dnr.wa.gov

Figures

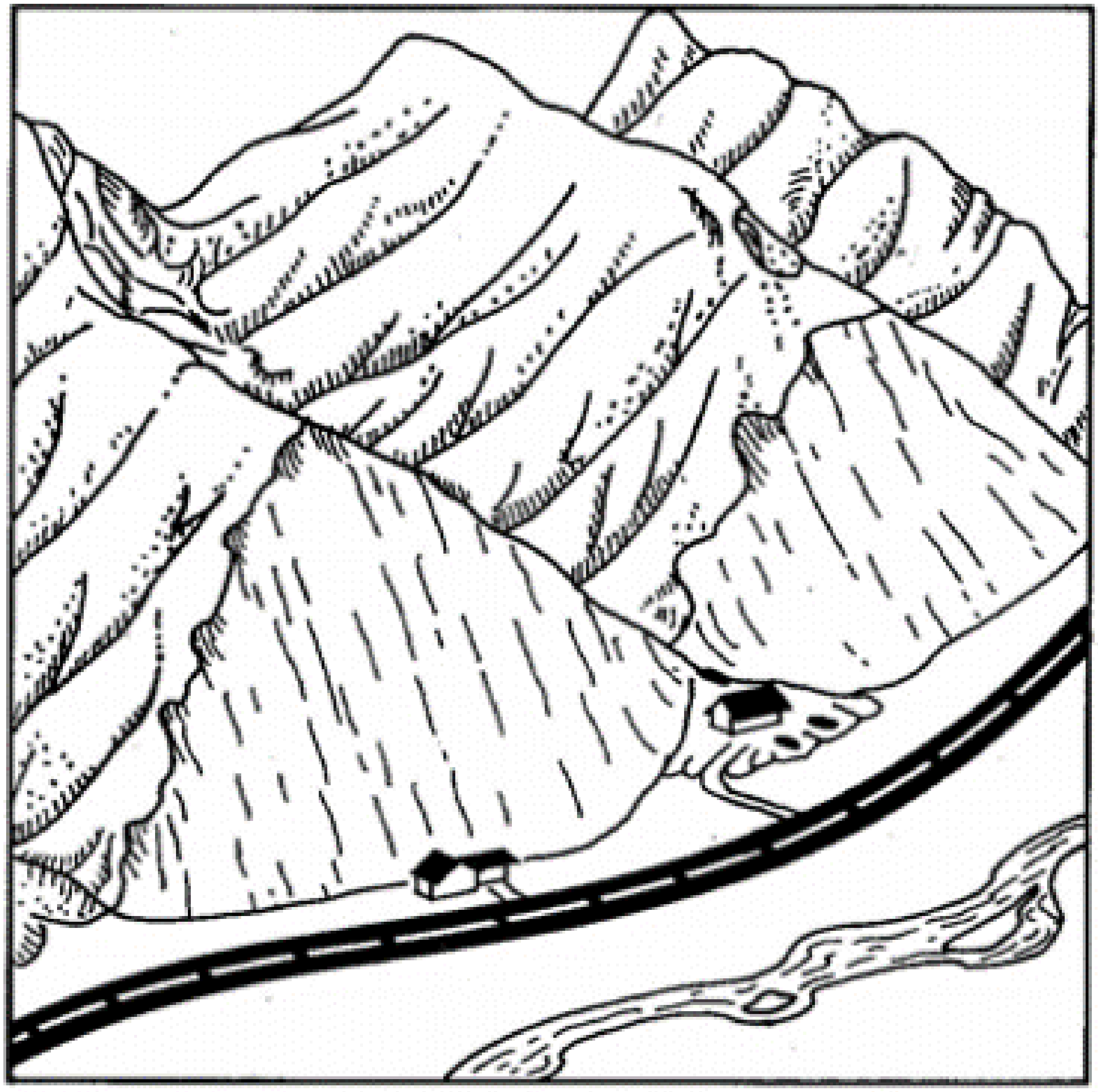

Figure 1. Homes and road in debris flow-prone locations on fans. Courtesy of Oregon Dept. of Forestry.

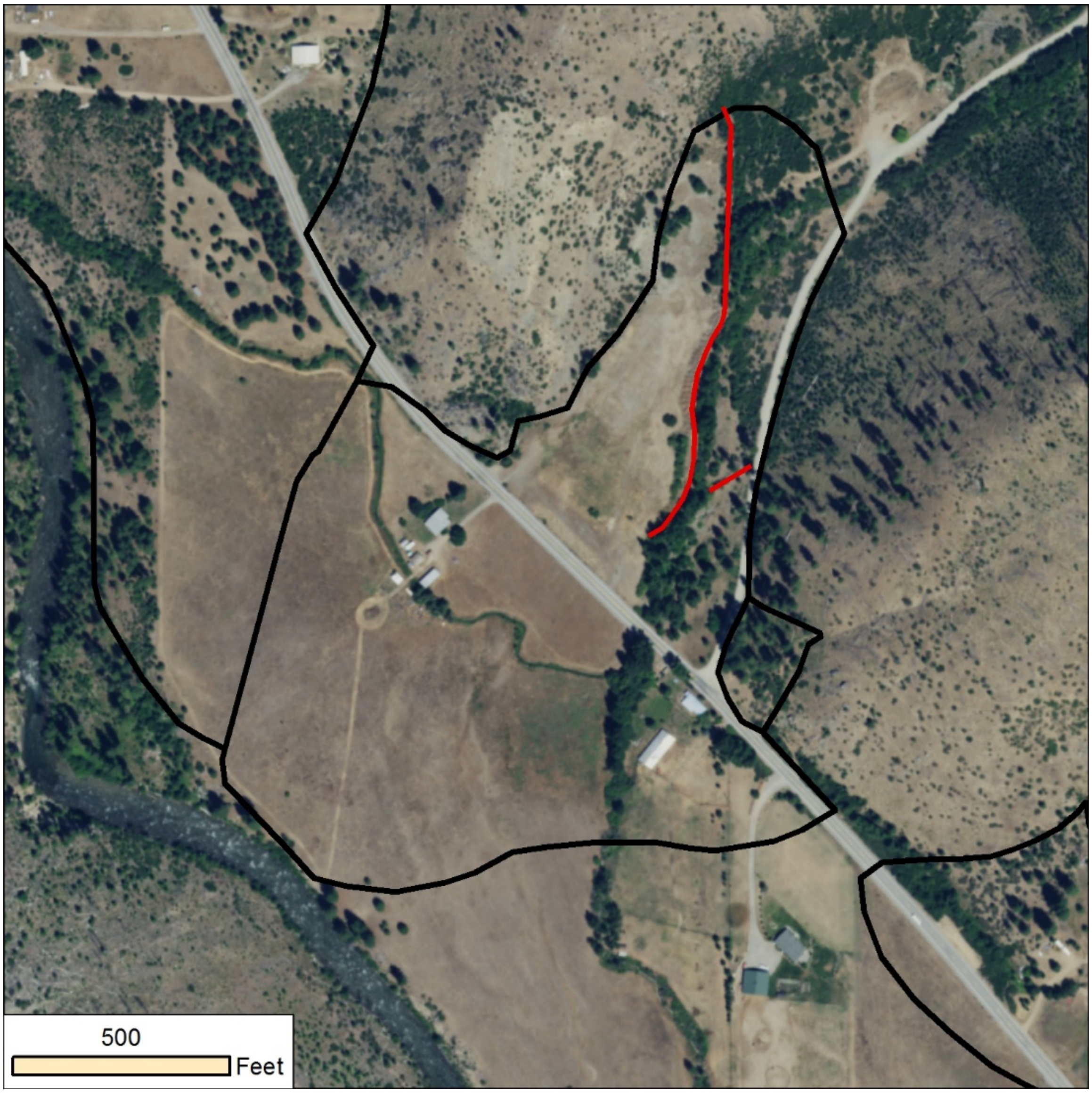

Figure 2. Potato Creek fan and modifications to the channel. Black lines delineate fans and the red lines are berms observed in the field and mapped in a GIS using 1-foot resolution lidar digital elevation model. The berm confines Potato Creek to the east side of the fan. Imagery is from 2017.

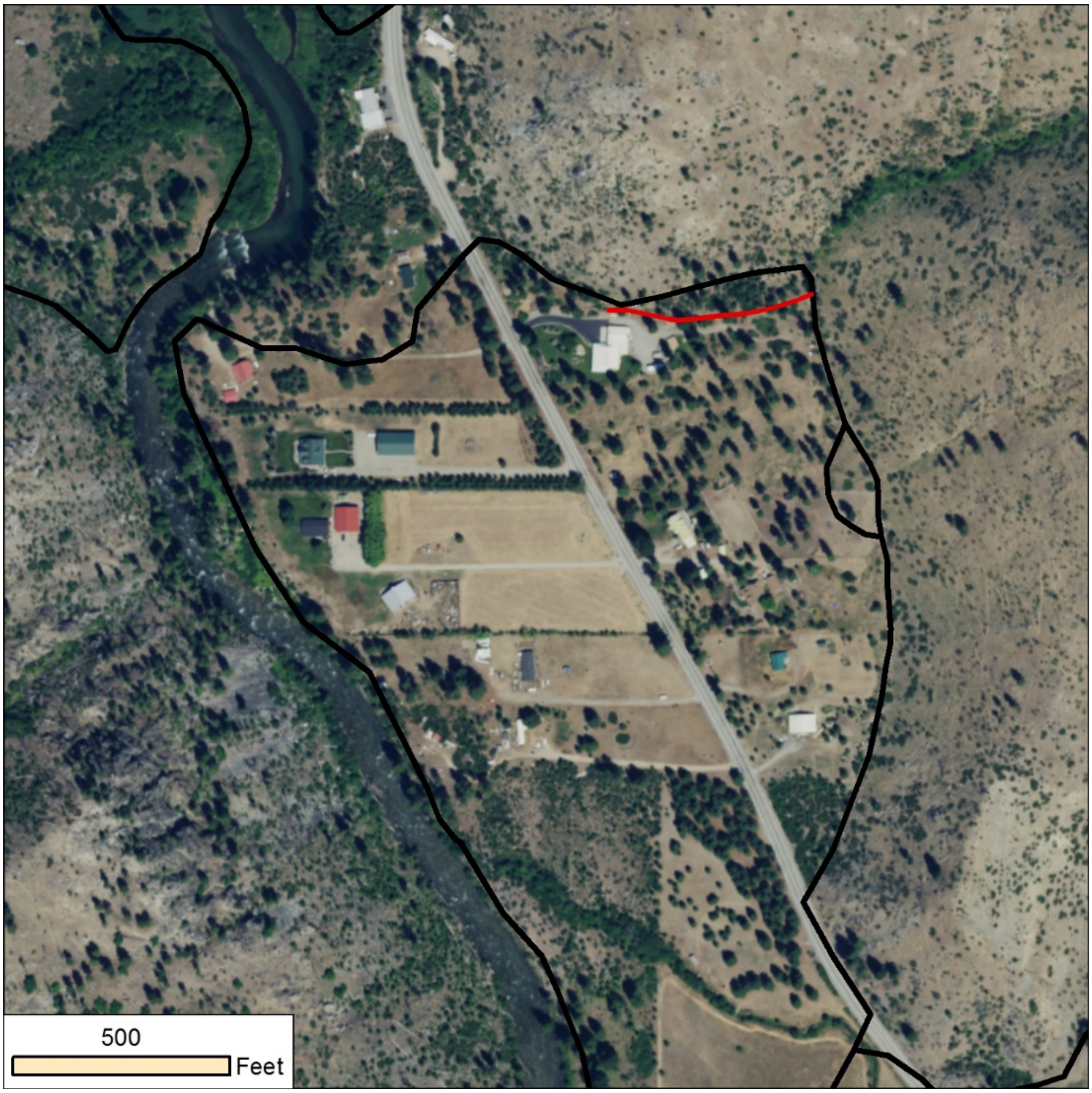

Figure 3. Decker Canyon Creek fan and modifications to the channel. Black lines delineate fans and the red lines are berms observed in the field and mapped in a GIS using 1-foot resolution lidar digital elevation model. The berm confines Decker Canyon Creek to the north side of the fan. Imagery is from 2017.

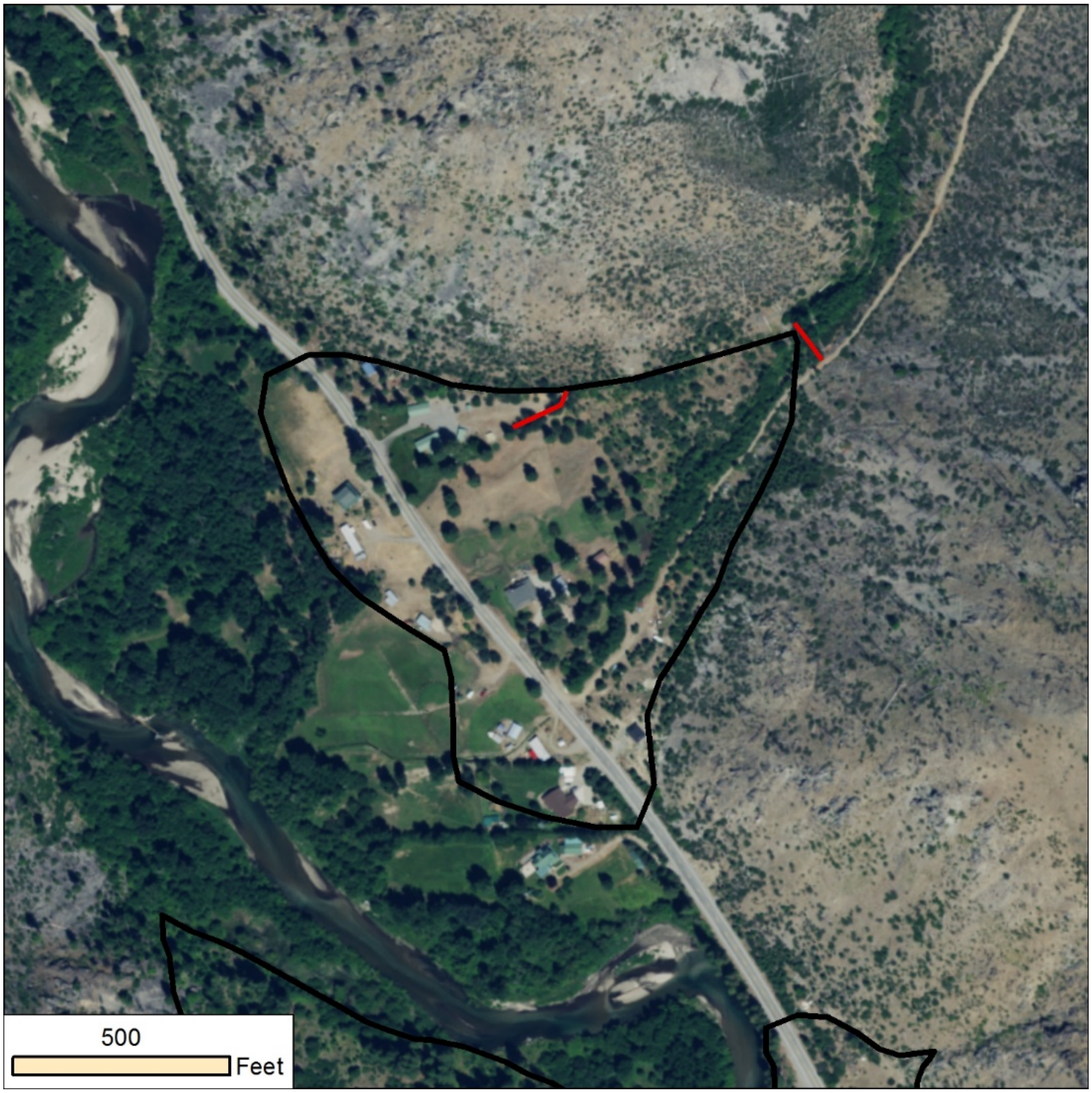

Figure 4. Gray Canyon Creek fan and modifications to the channel. Black lines delineate fans and the red lines are berms observed in the field and mapped in a GIS using 1-foot resolution lidar digital elevation model. The berm on the upper right (northeast) at the apex of the fan, is approximately 8 feet high and crosses the span of the channel. The upstream side is filled with sediment. Human modification confines Grays Creek to the south side of the fan. Imagery is from 2017.

Figure 5. 2006 USDA photo of Gray Canyon Creek fan showing impact from sediment onto the fan, both on the northwest and southwest lobes. The southwest lobe shows sediment beyond the mapped fan. Note the channel above the fan apex on the northeast corner is light in color suggesting that vegetation in the channel was impacted.

Figure 6. 2006 USDA photo of Tyee Ridge Spring No. 1 fan and unnamed fan to the east showing impact from sediment onto the fans, from the 2006 event. This is obvious from light colored lobes on the fans.

Appendix A