NATURAL RESOURCES

WILDFIRE-ASSOCIATED LANDSLIDE EMERGENCY RESPONSE TEAM REPORT

Red Apple Fire

Burch Mountain, Chelan County, Washington

by Trevor Contreras and Emilie Richard

WASHINGTON
GEOLOGICAL SURVEY
WALERT Report
August 11, 2021

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Hilary S. Franz—*Commissioner of Public Lands*

WASHINGTON GEOLOGICAL SURVEY

Casey R. Hanell—*State Geologist*
Jessica L. Czajkowski—*Assistant State Geologist*
Ana Shafer—*Assistant State Geologist*

WASHINGTON GEOLOGICAL SURVEY

Mailing Address:
MS 47007
Olympia, WA 98504-7007

Street Address:
Natural Resources Bldg, Rm 148
1111 Washington St SE
Olympia, WA 98501

Phone: 360-902-1450; *Fax:* 360-902-1785
E-mail: geology@dnr.wa.gov
Website: http://www.dnr.wa.gov/geology

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Wildfire-Associated Landslide Emergency Response Team Report for the Red Apple Fire

by Trevor Contreras[1] and Emilie Richard[1]

[1] Washington Geological Survey
MS 47007
Olympia, WA 98504-7007

INTRODUCTION

A Wildfire-Associated Landslide Emergency Response Team (WALERT) assessment was conducted to evaluate the potential risk posed by landslides and debris flows from the Red Apple Fire. Wildfires can significantly change the hydrologic response of a watershed so that even modest rainstorms can produce dangerous flash floods and debris flows.

In coordination with the Cascadia Conservation District and the U.S. Forest Service (USFS), WALERT assessed soil burn severity and areas downstream of slopes burned by wildfire to determine whether debris flows or flooding could impact roads, structures, irrigation infrastructure, or other areas where public safety is a concern. Further information about these hazards is provided in Appendix A.

WALERT looked for historical evidence of debris flows using field reconnaissance, lidar interpretation, Burned Area Reflectance Classification (BARC) maps, and orthoimagery. The team's assessment was also informed by knowledge of past flooding provided by Chelan County and USFS hydrologists. The USFS Burned Area Emergency Response (BAER) team finalized a soil burn severity map based on satellite data, which was provided to partners and is posted online (http://www.centralwashingtonfirerecovery.info/)

This report is primarily a qualitative assessment of post-wildfire landslide hazards based on our professional judgment and experience. The assessment was performed as part of emergency response with the intent to produce a rapid report for decision-makers, land managers, landowners, and other stakeholders.

WILDFIRE OVERVIEW

The Red Apple Fire started on July 13, 2021 near Wenatchee, Washington, above the community of Sunnyslope (Plate 1). The fire burned 12,280 acres, including Warm Springs Canyon, up to Eagle Rock, and portions of the Swakane State Wildlife Area. Much of the land is privately owned, with a patchwork of land managed by the Washington Department of Fish and Wildlife (WDFW), the Bureau of Land Management (BLM), the Washington State Department of Natural Resources (DNR), and the USFS. The burned extent utilized in this assessment was obtained from the National Incident Feature Service on July 18, 2021 (https://data-nifc.opendata.arcgis.com/datasets/wildfire-perimeters). Most of the vegetation that burned was mixed grasses and shrub. However, the unnamed drainage west of Rocky Reach Dam up to the radio tower had considerable forest land that was lightly burned in a patchy manner.

The majority of the land that burned is privately owned (40.8% of the total burned area) or managed by the WDFW. See Table 1 for land ownership information.

Table 1. Ownership distribution of burned area.

Land Owner/Manager	Acres	Percent of burned area
Private ownership	4,990	40.8
Washington Dept. of Fish and Wildlife (WDFW)	3,959	32.4
Bureau of Land Management (BLM)	1,821	14.9
US Forest Service (USFS)	792	6.5
Washington Dept. of Natural Resources (DNR)	564	4.6
Chelan County	88	0.7
Washington State Dept. of Transportation (WSDOT)	2	<0.02
Total	12,216,[1]	99.9

[1] This value does not match the acres burned reported above. An unknown error left 64 acres unaccounted for, approximately 0.5 percent.

OBSERVATIONS AND INTERPRETATIONS

Field assessments were performed July 21 and 22 while mop-up operations were occurring. The work focused on areas where wildfire effects on watershed hydrology could put life and property at risk along portions of U.S. Route 97 Alternate (US 97A) and the neighborhoods along the southern portion of the fire, including the neighborhoods of Sunnyslope and Monitor. The field work also assessed a limited portion of soil burn severity within the fire perimeter. We specifically focused on the wooded upland on the north side of the fire that drains to US 97A near Rocky Reach Dam and locations where drainages could impact the irrigation canal along the southwest and southern portion of the fire perimeter.

Soil burn severity and Burned Area Reflectance Classification (BARC) data and flooding

OBSERVATIONS

The soil burn severity was assessed by the USFS BAER team using Burned Area Reflectance Classification (BARC) data provided by USFS. The BARC data was field-checked using guidance from the report of Parson and others (2010), and was calibrated and posted online (http://www.centralwashingtonfirerecovery.info), along with a short report. In their report the BAER team outlines burn severity in acres by ownership and the various levels of soil burn severity (low, medium and high). We provide an overview of that information in Tables 2 to 5 for property owners, state agencies, and the Cascadia Conservation District, who may work on post-fire restoration efforts. We encourage interested parties to consult the USFS report and maps for further information. If you need assistance accessing or analyzing the data, please contact us and we can provide support.

The Red Apple Fire burned mostly light fuels of grasses and shrubs on the eastern and central portions of the burned area. According to the USFS BAER report, 65 percent of the area affected by the fire was either unburned or had low soil burn severity. The 105 acres (1%) that were marked as high burn severity are predominantly restricted to the riparian corridor of Warm Springs Creek, and the more heavily vegetated areas above an elevation of 3,600 feet. For the most part these are isolated patches with slopes under 30 degrees.

To categorize the soil burn severity by basin, we used basin areas provided by the USGS debris flow modeling that were clipped to fire perimeter. They may not exactly match the true basin area and are approximate.

INTERPRETATIONS

There were canyons along the eastern portion of the fire where vegetation did not burn, or only burned lightly such that soils may not have been altered dramatically. These are the steep drainages that drain east to US 97A where vegetation was sparse. Some additional rockfall may occur along the highway corridor of US 97A, but likely not beyond what the Washington State Department of Transportation (WSDOT) is accustomed to dealing with along this section of highway.

Low soil burn severity occurred throughout the burned area and was likely the result of sparse vegetation (grasses and lighter fuels) and the plants and roots were not subjected to intense heat by the fire. If precipitation and snow pack allow it, the vegetation will likely reestablish in these areas.

Moderate soil burn severity affected the western and central portions of the burned area with isolated pockets primarily in drainages and the uplands where vegetation was denser. Areas with moderate and high burn severity may need additional mitigation to get vegetation reestablished depending on the long-term goals of the land owners and managers.

A few drainages had some high soil burn severity on steeper slopes. These include Warm Springs Canyon and the unnamed drainage along the northeastern portion of the fire that drains to US 97A and Rocky Reach Dam, referred to on Plate 1 and in this report as “Drainage west of Rocky Reach Dam”.

Erosion is expected in the steeper portions of these drainages where the fire burned the vegetation and where soil burn severity is higher. Sedimentation may occur in the valley bottom downslope of these channels.

Warm Springs Canyon

Warm Springs Canyon had 45.8 percent of its basin burned with moderate and high soil burn severity. It is the largest basin within the fire perimeter, and it has at least one home and some barns downslope (Location 16). The irrigation canal is piped through a siphon through the valley but the stream channel is constricted where the stream channel passes the pipe (Location 17 on Plate 1). The pipe should be inspected to evaluate if it might be impacted by debris flows and flooding. The residents should be warned of the potential for future flooding due to the extensive moderate and high soil burn severity in the basin. See Table 2 for additional data on soil burn severity for the basin.

Table 2. Distribution of soil burn severity for Warm Springs Canyon basin.

Soil burn severity	Acres	Percent of burned area
High	63	2.0
Moderate	1359	43.7
Low	1648	53.0
Unburned soil	39	1.3
Total	3109	100

Drainage above Burch Hollow Lane

For the most part the basin above Burch Hollow Lane burned with low soil burn severity, covering approximately 446 acres. However, about 130 acres burned with moderate and high soil burn severity, which is about 21.7 percent of the basin. We advise evaluating the culverts at Burch Hollow and Rolling Hills Lanes and discussing potential flooding with the neighborhood residents. See Table 3 for additional data on soil burn severity for the basin.

Table 3. Distribution of soil burn severity above Burch Hollow Lane.

Soil burn severity	Acres	Percent of burned area
High	1	0.2
Moderate	129	21.5
Low	446	74.2
Unburned soil	25	4.2
Total	601	100

Unnamed drainage above Red Apple and Kenoyer Roads

The unnamed drainage above Red Apple and Kenoyer Roads (Location 4 on Plate 1; Fig. 1) had 773 acres burned with moderate and high soil burn severity. The drainage is steep and is modeled with a High hazard (see section *U.S. Geological Survey post-fire debris flow hazard assessment* below) of debris flows. The irrigation canal is elevated where it crosses the drainage in a flume but could be impacted if enough debris were to pass through the drainage and undermine the canal. See Table 4 for additional data on soil burn severity for the basin.

Table 4. Distribution of soil burn severity for the basin above Red Apple and Kenoyer Roads.

Soil burn severity	Acres	Percent of burned area
High	3	0.3
Moderate	770	72.6
Low	285	26.9
Unburned soil	3	0.3
Total	1,061	100

Unnamed drainage west of Rocky Reach Dam

The drainage west of Rocky Reach Dam had 78.6 percent of its 1,893 acres burn with low soil burn severity. Otherwise 21.4 percent of the drainage burned with moderate and high soil burn severity. A home exists on the alluvial fan where the channel becomes unconfined (Location 21 on Plate 1). The residents should be made aware of post-fire flooding and the possibility of debris flows to the fan. The current channel also crosses US 97A to the parking lot of Rocky Reach Dam (Location 22). See Table 5 for additional data on soil burn severity for the basin.

Table 5. Distribution of soil burn severity for the basin west of Rocky Reach Dam.

Soil burn severity	Acres	Percent of burned area
High	36	1.9
Moderate	370	19.5
Low	1124	59.4
Unburned soil	363	19.2
Total	1,893	100

U.S. Geological Survey (USGS) post-fire debris flow hazard assessment

MODELING RESULTS

The USGS provided a debris flow assessment for the Red Apple Fire based on the field-validated soil burn severity data provided by the USFS. The data can be viewed directly at their website (https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=360).

There are various outputs and ways to view the data using the website. Here we'll discuss the combined relative debris flow hazard, which uses both probability and volume from the USGS model to provide three different hazard ratings: Low, Moderate, and High.

INTERPRETATIONS

The USGS modeling suggests that there is Low, Moderate, and High debris flow hazard in drainages throughout the burned area. This is based on a modeled storm event with a peak rainfall intensity of approximately one quarter of an inch of rain in a 15-minute period.

Only one of the basins has a combined High debris flow hazard: the unnamed drainage on the west side of the fire above Red Apple and Kenoyer Roads above Location 4 (Plate 1). The irrigation canal at this location is elevated across this drainage but the footings and support structure of the canal likely weren't designed to take the impact of a debris flow, should one occur. If a debris flow occurs, this area of the canal could be vurnerable and undermined. There are other small drainages along the west side of the fire that are shown as having a Moderate debris flow hazard but have a higher probability of debris flow generation than other drainages in the burn area. These can be viewed on the USGS website by toggling on the *Basin Probability* data layer. We've noted these drainages as Locations 5 to 10 on Plate 1 for additional review of infrastrure and potential armoring in preparation for potential debris flows.

During heavy precipitation events these drainages could suffer from flooding, erosion and sedimentation, and (or) debris flows. This would most likely occur as a result of thunderstorms in the spring or summer within the next few years following the fire, or until vegetation is reestablished.

Warm Springs Canyon

Much of the Warm Springs Canyon was modeled as having Moderate hazard for debris flows. The channels could transport debris flow materials in stretches that might deposit where the channel becomes unconfined and where stream gradients flatten out. Thus it is unlikely that debris flows would transport through the entire stretch of the stream. However, flash floods and sediment could impact the water impoundment, the home, barns, and siphon, and should be evaluated (Location 15–17, Plate 1).

One home and two barns are downstream of the impoundment, and it's unclear where floodwaters might affect them (Location 16). The basin also constricts downstream of the home and barns where the irrigation canal is piped (Location 17).

Drainage above Burch Hollow Lane

An alluvial fan exists just west of Burch Mountain Road, between Rolling Hills Lane and Burch Hollow Lane (Location 18 on Plate 1). This was the only alluvial fan on that south side of the fire where we observed large boulders, suggesting previous debris flow activity. We were unable to determine the age of the activity, but it likely happened more than 70 years ago because evidence of a debris flow is not observed in the 1949 aerial photos available from Central Washington University's Historical Aerial Photograph Project (https://www.gis.cwu.edu/geog/historical_airphotos/). There is a hint of exposed soil in the 1949 aerial photo in the upper reaches of the watershed, suggesting debris could have failed in some hollows where springs likely exist perennially.

This drainage has a Moderate combined debris flow hazard rating for the modeled storm. Based on evidence of past debris flows and the Moderate debris flow hazard, nearby residents should be alerted to the hazard, and stormwater conveyance should be evaluated in case there are vulnerabilities to the irrigation canal (Location 20 on Plate 1; Fig. 2).

Unnamed drainage west of Rocky Reach Dam

The unnamed drainage west of Rocky Reach Dam has a Moderate combined hazard for the modeled storm. The channel appears confined until just before it reaches US 97A and a private residence (Location 21 on Plate 1) before going under the highway at the Rocky Reach Dam near the parking lot at Location 22. There are isolated portions of the drainage with high soil burn severity that could have contributed sediment to the alluvial fan below and be a hazard. A similar steep drainage approximately 3.5 miles to the northeast of the Red Apple Fire suffered debris flow activity after the 2010 Swakane Fire at Tenas Gorge. The Tenas Gorge fan was also the site of eight fatalities resulting from debris flows in 1942.

Given that this area includes a residence, highway US 97A, the Rocky Reach Dam parking lot, and that the channel is confined to the alluvial fan, residents should be alerted to the debris flow potential during intense rainstorms in the basin above, and WSDOT and dam operators should evaluate the risk to the public.

Unnamed drainages along the west side of the fire

There are several smaller unnamed drainages along the western portion of the burned area (Locations 5 to 10 on Plate 1) that have a Moderate debris flow hazard but a higher probability of debris flow generation than other drainages. We show these locations on the map (Plate 1) and list them in Appendix B.

Given that there are homes and the irrigation system near these small drainages with higher probability for debris flows, residents and irrigation managers should evaluate their exposure to these hazards.

RECOMMENDATIONS

Landowners and managers may choose to take action to prevent excessive soil erosion, reduce flooding, and promote revegetation to meet their management and economic goals. Utilizing the soil burn severity map provided by the USFS as a tool to find areas of high and moderate burn severity should assist in this evaluation.

At locations downstream of the burned area, residents should be prepared for additional flooding during periods of intense precipitation. Managers of local infrastructure, including the irrigation canal, should evaluate their infrastructure for flooding risks during heavy rainstorms and come up with contingency plans in case they are impacted during irrigation season.

Our assessment suggests that flash flooding is the hazard most likely to impact the areas evaluated downstream of the burned area. However, there are drainages where high and moderate debris flow hazards exist, and during periods of intense precipitation (approximately one quarter of an inch of rain in a 15-minute period), these drainages may have debris flow activity.

Residents of homes built on alluvial fans and (or) adjacent to streams flowing from burned areas should be informed of potential post-fire flash flood hazards. Managers of transportation networks should be reminded of the increased likelihood of sediment transport, sediment deposition, and (or) erosion to highways and roads, as well as potential issues with blocked culverts. We suggest reminding transportation network managers to inspect culverts from channels draining areas impacted by the fires both before and after storm events, otherwise culverts could be blocked, causing additional flooding and damage.

Irrigation district managers should closely inspect storm water conveyance above the irrigation canal along the west and southern perimeter where drainages cross the canal. These crossings could be vulnerable to additional sedimentation, and if the irrigation water is running, additional damage to the system could occur. We made an attempt to highlight locations where issues might occur but not all areas were visited during this reconnaissance survey. These locations are described in Appendix B and marked on Plate 1.

REFERENCES

Parsons, Annette; Robichaud, P. R.; Lewis, S. A.; Napper, Carolyn; Clark, J. T., 2010, Field guide for mapping post-fire soil burn severity: U.S. Department of Agriculture General Technical Report RMRS-GTR-243, 49 p. [https://www.fs.fed.us/rm/pubs/rmrs_gtr243.pdf]

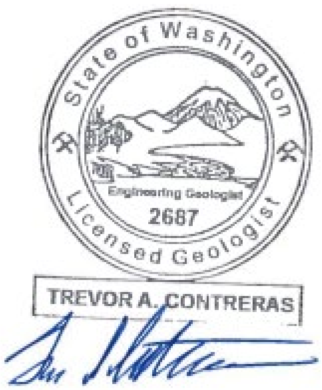
LIMITATIONS

WALERT aims to quickly identify and assess geologic hazards associated with wildfires in order to inform decision making and to help focus the efforts of local officials and residents who may be impacted by post-wildfire hazards.

All observations and interpretations are based on empirical evidence and local knowledge. Not all areas or hazards were evaluated. We encourage landowners, land managers, and those potentially at risk from post-wildfire hazards to consult qualified professionals for site-specific analysis of geological hazards and flood risk and prepare accordingly.

ACKNOWLEDGMENTS

WALERT thanks our partners, especially Greg Kuyumjian (USFS retired) and Molly Hanson, who provided the soil burn severity mapping and provided some hydrological analysis and consultation. We also thank Jon Riley of the Chelan County Fire District #1 and Patrick Haggerty of the Cascadia Conservation District for coordinating access to the burned area and assisting with reviewing soil burn severity sites.



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

Emilie Richard
Geologist-in-Training
Washington Geological Survey
Washington State Dept. of Natural Resources
Olympia, WA
Cell: 360-529-7984
Email: emilie.richard@dnr.wa.gov

APPENDIX A: GEOLOGICAL BACKGROUND

Hillslope processes

A variety of factors contribute to the probability of debris flows occurring in burned areas. These include hillslope gradient, channel convergence, availability of fine sediments, severity of hydrophobic (water repellant) soil conditions, burn severity, and the removal of a protective canopy and diminished root strength caused by fire.

Hydrophobic soil conditions in burned areas can increase water runoff potential on hillslopes during a storm by preventing water from infiltrating into the subsurface. Overland flow can result in rills and gullies that further channel water downhill.

When effective ground cover has been denuded after intense fire, soils are also exposed to erosive forces such as raindrop impact and wind. The steepest slopes are most prone to erosion, particularly where soils are shallow 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 contain relatively low amounts of organics, resulting in moderately thin topsoil horizons.

Flash floods and debris flows

Debris flows have a specific geologic definition that is often misused by the media, the public, and scientists. Most observed "debris flows" are actually sediment-laden flash floods known as hyperconcentrated flows (HCFs). In the following sections, we explain the differences between these two types of flows.

FLASH FLOODS

Flash floods, especially those that originate from recently burned areas, are often described as "debris flows" due to the sediment-laden water transporting woody and vegetative debris, trash, 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 differentiate it from a flash flood. An HCF is the transition between a flash flood and a 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, an HCF carries around 5 to 60 percent sediment by volume, and a debris flow exceeds 50 percent sediment by volume.

DEBRIS FLOWS

Debris flows are often described as having the appearance of flowing, wet concrete. These flows travel quickly in steep, convergent channels. A moving debris flow can be very loud because it can buoy cobbles, boulders, and debris to the front and sides of the flow. The sound is often compared to that of a freight train and may cause the ground to vibrate. In a post-fire situation, a debris flow may start as a flash flood surge that picks up sufficient sediment to transform into an HCF and, if soil and slope conditions are suitable, can transform into a debris flow.

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 on bark from rock or debris impact. Mud and gravel may be splashed onto trees and other channel-adjacent objects. Because of the ability of a debris flow to buoy these materials to the front of the moving mass, debris flows are extremely dangerous to public safety and infrastructure.

Alluvial fans

Alluvial fans are low-gradient, cone-shaped deposits that consist of sediment and debris. These features often accumulate immediately below a significant change in channel gradient and (or) valley confinement. This might occur at the mouth of 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, HCFs, and (or) debris flows and is typically sourced from a single channel.

Alluvial fans are attractive locations to build cabins and homes due to the slight elevation above the flood plain. However, alluvial fans 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 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.

An information flyer about alluvial fan hazards is available on our website in both English (https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf) and Spanish (https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans_esp.pdf).

APPENDIX B: LOCATIONS MENTIONED IN THIS REPORT

There are multiple locations surrounding the burned area that may need additional review and potential mitigation to protect from debris flows or sedimentation, particularly into the irrigation canal. Places mentioned in this report are listed in the table below along with a short description of the site and its predicted debris flow hazard. The percentages indicate the predicted probability of debris flows occurring during the modeled storm and were taken from the USGS *Basin Probability* percentages.

Table B1. Description of locations mentioned in this report.

Location number	Concern
1	Culvert with 77% debris flow predicteded above
2	Culvert with 77% debris flow predicted above
3	Elevated canal with 77% debris flow predicted above
4	Elevated canal with 65% debris flow predicted above
5	Irrigation canal with 52% debris flow predicted above
6	Irrigation with 38% debris flow predicted above
7	Irrigation canal with 76% debris flow predicted above
8	Irrigation infrastructure with 51% debris flow predicted above
9	Drainage with 77% debris flow predicted above
10	Home with 49% debris flow predicted above
11	Hwy with 29% debris flow predicted above
12	Power substation with 37% debris flow predicted above
13	Structures with 39% debris flow predicted above
14	Irrigation siphon with 46% debris flow predicted above
15	Warm Springs impoundment with moderate debris flow hazard above
16	Warm Springs home with moderate debris flow hazard above
17	Irrigation pipe where channel is confined
18	Burch Hollow Lane alluvial fan with 27% debris flow predicted above
19	Culvert at Rolling Hills Dr. with 27% debris flow predicted above
20	Culvert over irrigation canal with 27% debris flow predicted above
21	Home on alluvial fan with 26% debris flow predicted above
22	Alluvial fan at Rocky Reach with 26% debris flow predicted above

Figure 1. Photo taken where irrigation canal crosses unnamed drainage in a flume with high combined hazard for debris flows. This location is above the intersection of Kenoyer and Red Apple Roads (Location 4 on Plate 1).

Figure 2. Photo taken downstream of Burch Hollow Lane, near 3510 Burchvale Rd (Location 20 on Plate 1). Depending on the amount of sediment that travels through the larger metal culvert, the smaller corrugated culverts could be clogged resulting in sediment in the canal.

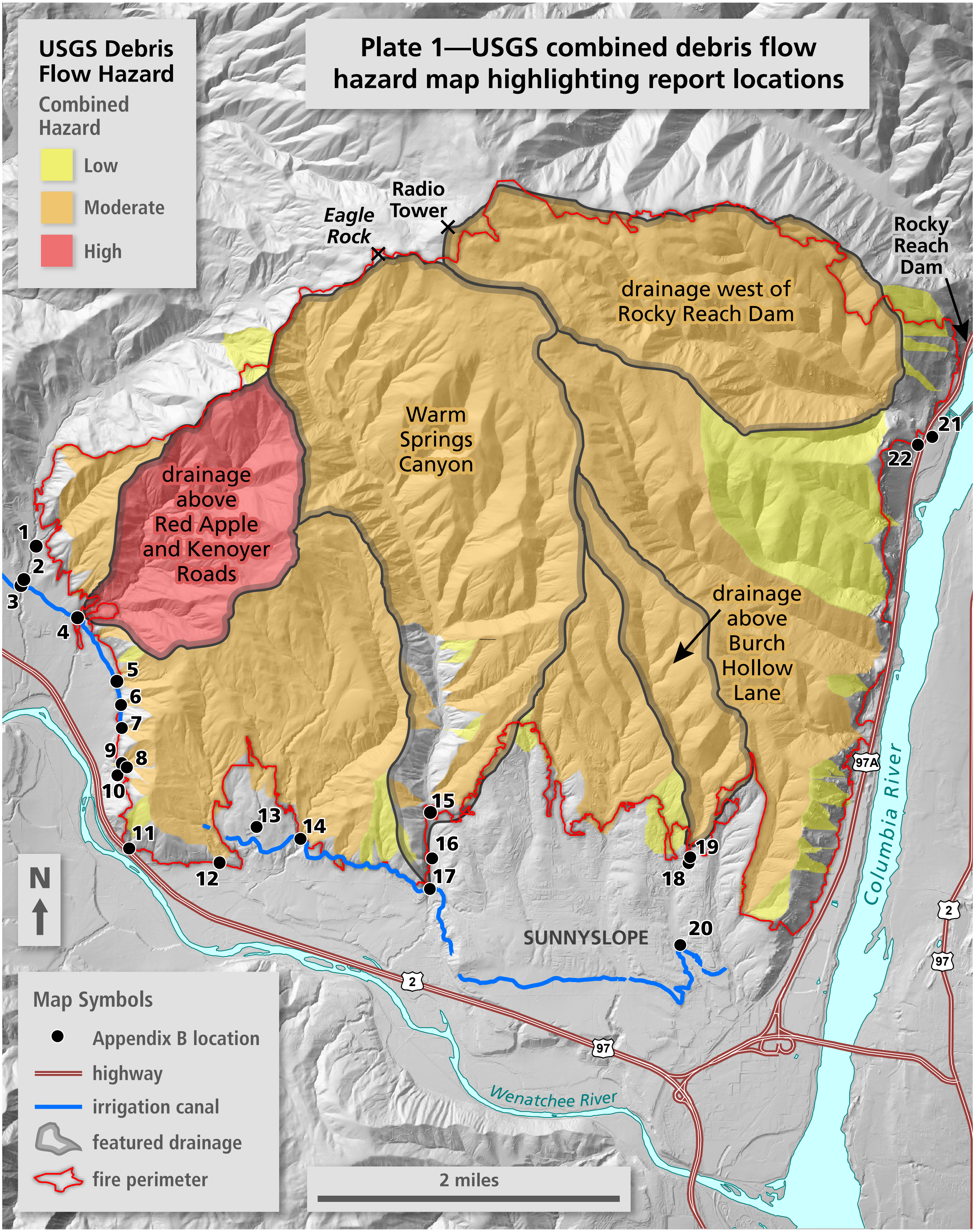


Plate 1—USGS combined debris flow hazard map highlighting report locations
USGS Debris Flow Hazard
Combined Hazard
Low
Moderate
High
Radio Tower
Eagle Rock
Rocky Reach Dam
drainage west of Rocky Reach Dam
Warm Springs Canyon
drainage above Red Apple and Kenoyer Roads
drainage above Burch Hollow Lane
SUNNYSLOPE
Columbia River
Wenatchee River
97A
2
97
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
N
Map Symbols
Appendix B location
highway
irrigation canal
featured drainage
fire perimeter
2 miles