N A T U R A L   R E S O U R C E S

WILDFIRE-ASSOCIATED LANDSLIDE EMERGENCY RESPONSE TEAM REPORT

Retreat Fire

Yakima County, Washington

by Kate Mickelson, Emilie Richard, and Kara Fisher

WASHINGTON
GEOLOGICAL SURVEY
WALERT Report
September 2024

WASHINGTON STATE DEPARTMENT OF
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(Plates are located at the end of this document)

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INTRODUCTION

A Wildfire-Associated Landslide Emergency Response Team (WALERT) assessment was conducted to evaluate the potential risk posed by flash floods and debris flows from the Retreat Fire in Yakima County, Washington. Wildfires can significantly change the hydrologic response of a watershed so that even modest amounts of rainfall can produce dangerous flash floods and debris flows. Increased runoff, flash floods, and debris flow hazards may remain elevated for several years after the fire.

WALERT assessed areas downstream of slopes burned by the wildfire to determine whether debris flows or flooding could impact infrastructure, structures, and 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, and orthoimagery. We also mapped alluvial fans within and downstream of the burn area using lidar data and terrain models generated from digital aerial photogrammetry.

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 partners.

WILDFIRE OVERVIEW

The Retreat Fire started on July 23, 2024. The fire burned 45,601 acres along State Route (SR) 12 between milepost markers 169 and 184, about 14 miles west of the town of Naches, WA (INCI Web, 2024). Most of the burn area is on Federal and State lands, with a small percentage on private land. United States Forest Service (USFS) land comprises all the federal lands that were burned, while state owned lands are owned by the Department of Fish and Wildlife (DFW) or the Washington Department of Natural Resources (DNR). The fire burned a mix of sage/grassland, oak/mixed conifer and sub-alpine fir forest. Mop-up operations were wrapping up and post-wildfire recovery efforts were underway at the time of this assessment.

OBSERVATIONS AND INTERPRETATIONS

WALERT conducted a field assessment August 20–22, 2024. We specifically focused on areas where wildfire effects on watershed hydrology could put life and property at risk. These areas included slopes along Oak Creek Road and the Tieton River corridor, which includes slopes that may direct hazards toward SR-12 (Plate 1).

Soil burn severity data

OBSERVATIONS

The Burned Area Reflectance Classification (BARC) data, a satellite-derived data layer of changes between pre- and post-fire vegetation conditions, were provided and field validated by the U.S. Forest Service to generate a Soil Burn Severity (SBS) map. If you need assistance accessing or analyzing these data, please contact us and we can provide some support.

The SBS mapping shows that roughly 11,400 acres, or 25 percent of the area affected by the Retreat Fire, were either unburned or had very low soil burn severity. Approximately 23,973 acres (53%) experienced low soil burn severity, 8,390 acres (18%) were moderate in severity, and 1,703 acres (4%) were shown to have experienced high burn severity.

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

MODELING RESULTS

The USGS provided a debris flow modeling assessment for the Retreat Fire that incorporates the SBS data provided by the U.S. Forest Service. The modeling data are typically available on their website within a few weeks of being generated (https://landslides.usgs.gov/hazards/postfire_debrisflow/). However, if access is needed prior to these data being made available please contact us and we can provide some support.

There are various outputs and ways to view these data. Here we will discuss the combined relative debris flow hazard for hydrologic basins, which combines both probability and volume from the USGS model to provide three different hazard ratings: Low, Moderate, and High. The USGS also models the combined relative debris flow hazard for stream channel segments within basins using the same hazard ratings. We focus our assessment on locations where public safety and infrastructure could be impacted. If you need assistance accessing or analyzing the debris flow assessment data, please contact us and we can provide support.

The USGS debris flow modeling is based on a modeled storm event with a peak rainfall intensity of approximately 0.25 inches of rain in a 15-minute period or 1 inch of rain in a 60-minute period (6 mm/15 minutes or 24 mm/hour, respectively). Of note, this model does not consider the effect of rain-on-snow or rapid snowmelt events in a recently burned area. Debris flows and flash floods may occur during rain-on-snow events that do not meet the predicted rainfall threshold.

INTERPRETATIONS

The USGS modeling indicates that there are Low, Moderate, and High debris flow hazards in drainages throughout the burned area. Remote and field observations revealed that some alluvial fans have experienced debris flows and flooding in the past. Accumulated cobbles and boulders, subtle debris levees, and apparent avulsion channels on several fans suggest historic debris flow activity.

The steep mountain corridor along the Tieton River that burned in the Retreat Fire has several alluvial fans that display signs of past debris flow activity. Even in areas without historical evidence for debris flows, the fire likely impacted the basin’s hydrologic response to future storm events. Increased runoff and the potential for flash floods may remain elevated for several years after the fire. The steep cliffs also pose a rock fall hazard in the coming years, especially as the tree roots that hold the rocks decompose.

We mapped alluvial fans that show evidence of possible debris flow or flooding hazards but did not do an exhaustive assessment of all the post-fire hazards in the area. In this report we focus on alluvial fans along the irrigation canal, SR-12, and Oak Creek Road (FS 1400). Note that not all alluvial fans that intersect this infrastructure are called out in this report. Any area where the irrigation canal, SR-12, and Oak Creek Road (FS 1400) cross an alluvial fan may be at elevated risk after the fire. See Plate 1 for locations mentioned in the text and alluvial fan mapping. We can provide additional alluvial fan maps at appropriate scale for emergency managers and communities planning for post-fire flooding and debris flows. Below we outline areas where flash flooding or debris flows could impact the property and infrastructure that we reviewed during this assessment.

Yakima-Tieton Irrigation Canal

The Yakima-Tieton Irrigation Canal is a 12-mile-long canal that serves roughly 28,000 acres of orchards in the Naches and Yakima areas. The canal was constructed along the southern hillside of the Tieton River from 1903–1907 and is managed by the Yakima Tieton Irrigation District (YTID). In addition to being steep and rocky, the southern hillside experienced high to moderate soil burn severity, increasing the risk of flooding and debris flows (Plate 2).

Cabin Creek Alluvial Fan (Point 1 on Plate 2)

The USGS modeling indicates a Moderate debris flow hazard for this drainage basin. A debris flow from this basin has the potential to deliver fine sediments and larger debris to the Tieton River, increasing turbidity. This flux of sediment could have implications for the irrigation canal intake diversion system located down-river from the Cabin Creek alluvial fan.

Unnamed Alluvial Fan (Point 2 on Plate 2)
The modeling indicates a High debris flow hazard for this drainage basin. Where the irrigation canal crosses this channel, there are roughly 3 feet of clearance between the channel bed and the canal. Based on the size of material on the alluvial fan and in the channel, we believe the crossing would allow flood water to run underneath the canal flooding, but the canal could still be damaged by large boulders or woody debris from a debris flow.

Unnamed Alluvial Fan (Point 3 on Plate 2)
This basin was too small to be captured in the modeling. However, we observed steep topography and Moderate burn severity. No culvert is present to route flow below the canal crossing. During heavy precipitation storms there is potential for damage or burial of the canal at this junction.

Unnamed Alluvial Fan (Point 4 on Plate 2)
The modeling indicates this basin as having a Low debris flow hazard. We observed no culvert at the canal crossing and a burnt retaining structure that would not support the canal if undermined by debris flows or floods.

Unnamed Alluvial Fan (Point 5 on Plate 2)
The modeling indicates that this basin has a High debris flow hazard. Large (2–3 ft diameter) boulders on this alluvial fan indicate past debris flow activity. The 3-ft culvert is undersized for the material that would mobilize during a debris flow event, which could potentially bury or damage the canal.

Unnamed Alluvial Fan (Point 6 on Plate 2)
The modeling indicates this basin as having a Moderate debris flow hazard. Boulders observed in the channel and on the alluvial fan indicate past debris flow activity. At this crossing, the canal is covered and does not have a culvert. Flash flooding and debris flows could impact this section of the canal.

Unnamed Alluvial Fan (Point 7 on Plate 2)
The modeling indicates this basin as having a Moderate debris flow hazard. A recent thunderstorm (accumulating up to 0.5 inches of water) produced a small flow of mud that delivered material to and crossed over the canal. Multiple distributary channels, abundant large cobbles and boulders, and this recent event on the alluvial fan suggest flooding and debris flows could impact the canal, powerline corridor and structures on the alluvial fan. There are several private residences along Sentinel Creek Lane at the distal portion of the alluvial fan that could be at increased risk for flooding and debris flows.

Sentinel Creek Alluvial Fan (Point 8 on Plate 2)
The modeling indicates this basin as having a High debris flow hazard. The canal crossing has 2–5 feet of clearance between the channel and the base of the canal pipe. Large boulders (up to 4 ft in diameter) were observed on the alluvial fan from past debris flow activity. Roads and power lines also cross the lower section of the alluvial fan and could be minimally impacted.

Unnamed Alluvial Fan (Point 9 on Plate 2)
Where the canal crosses this modeled High debris flow hazard basin, there are roughly 10–12 ft of clearance above the channel. While most flows could pass under the canal, damage to the structure from debris impacts is possible.

Unnamed Alluvial Fans (Points 10–13 on Plate 2)
The basins above these fans all represent a Moderate debris flow hazard based on the modeling. The presence of cobbles to large boulders on the alluvial fans suggest past debris flow activity. Rockfall is also a concern across these basins where rocks are either scattered across the hillside or accumulated as talus below steep basalt outcrops. The canal crossing at point 10 is elevated and should accommodate flooding or debris flows in the channel. The canal crossing at point 11 has been covered to prevent sediment from entering the system but could still be at risk of damage or burial during a debris flow. There is a larger bridge structure providing 15–20 ft of clearance above the channel at point 12 that would allow flows to pass under the canal, though damage to the concrete structure from debris impacts is still possible. The canal crossing at point 13 is elevated with roughly 10–15 ft of clearance above the drainage and we observed a culvert beneath routing flow under the access path. Flash flooding or debris flows

could plug the culvert and impact the access road as well as the FS 415 road that cuts along the base of the alluvial fan.

Unnamed Alluvial Fan (Point 14 on Plate 2)
Modeling indicates a low debris flow hazard for the basin above this alluvial fan. We observed historic activity of an event that partially buried the covered canal with mud and debris that is now growing young vegetation. While the modeling shows low debris flow hazard, evidence of a past event suggests that flooding or debris flows could impact this area.

Unnamed Alluvial Fan (Point 15 on Plate 2)
The modeling indicates this basin has a Moderate debris flow hazard. We observed large boulders on the surface of the alluvial fan, which indicates past debris flow activity. Flash flooding and debris flows could impact the FS 415 road that cuts along the base of the alluvial fan. We did not observe the canal crossing at this drainage.

Unnamed Alluvial Fan (Point 16 on Plate 2)
Modeling indicates a High debris flow hazard for the basin above this small, steep alluvial fan. We observed abundant large cobbles and boulders on the surface of the alluvial fan from past debris flow activity. Flash flooding and debris flows could impact the FS 415 road where it intersects the base of the fan. We did not observe the canal crossing at this drainage.

Unnamed Alluvial Fan (Point 17 on Plate 2)
The modeling indicates this basin has a Moderate debris flow hazard. Review of the lidar reveals several landslides at the headwaters of the drainage basin. We did not visit the canal crossing but based on photos from the USFS there is evidence of past debris flow activity and a culvert at the crossing where the canal pipe is slightly elevated. Based on the debris flow modeling, remote observations, and field reconnaissance, the canal and FS 415 road could be impacted by flash flooding and debris flows on the alluvial fan.

State Route 12 Corridor

Unnamed Alluvial Fan at Mile Post 172 (Point 18 on Plate 2)
Modeling indicates a Moderate debris flow hazard for this basin. Hummocky topography and large boulders were observed in the main channel and on the alluvial fan during field reconnaissance, suggesting past debris flow activity. SR-12 and a powerline corridor cross the alluvial fan. Mobilization of debris during storm events can plug culverts and potentially lead to public safety threats, washouts of the roadway, or increased flooding impacts.

Unnamed Alluvial Fan at Mile Post 172.5 (Point 19 on Plate 2)
Modeling indicates a Moderate debris flow hazard for this basin. We did not visit this alluvial fan during our field reconnaissance; however, the alluvial fan is evident in the lidar. Where SR-12 crosses the alluvial fan's apex, flash flooding and debris flows could impact the powerline corridor and roadway along SR-12.

Unnamed Alluvial Fan at Rainbow Rock Lane (Point 20 on Plate 2)
The unnamed basin above the Rainbow Rock Lane alluvial fan is modeled as Moderate debris flow hazard. Hummocky topography and boulders greater than 5 feet in diameter were observed on the alluvial fan's surface. Private property, residential structures, Rainbow Rock Lane, and SR-12 are all located within the mapped extent of this alluvial fan. SR-12 has also excavated into portions of the alluvial fan. Based on the modeling and field reconnaissance, flash flooding and debris flows during heavy precipitation could impact structures, the powerline corridor and SR-12.

Unnamed Alluvial Fans between Mile Posts 173.8 and 173.9 (Points 21 and 22 on Plate 2)
Modeling indicates a Moderate debris flow hazard for the basins upstream of these alluvial fans. Abundant large boulders were observed on the alluvial fan surfaces from past debris flow activity. SR-12 crosses the toes of these alluvial fans and could be impacted by flash flooding and debris flows.

Unnamed Alluvial Fan at Mile Post 174 (Point 23 on Plate 2)
This unnamed basin is modeled as Moderate debris flow hazard. Hummocky topography, numerous small boulders, and several boulders greater than 5 feet in diameter were observed on the surface of the alluvial fan. The stream channel exits directly to SR-12. Debris flows and flooding could impact the highway at this location.

Unnamed Alluvial Fan at Mile Post 174.2 (Point 24 on Plate 2)
This unnamed basin is modeled as Moderate debris flow hazard. Hummocky topography, abundant small boulders, and several boulders greater than 7 feet in diameter were observed on the alluvial fan's surface. SR-12 crosscuts the middle of the alluvial fan, providing clear exposure of the alluvial fan's composition. Observations of the material in this excavated section along the roadway further support the remote lidar-based review and the field observations that flooding and debris flows have historically posed a hazard here, even prior to the fire. Based on the debris flow modeling, lidar-based observations, and field reconnaissance, flash flooding and debris flows could impact this section of SR-12.

Stream Outlet at Mile Post 174.7 (Point 25 on Plate 2)
The unnamed basin above the alluvial fan is modeled as Moderate debris flow hazard. SR-12 and the Tieton River have removed any evidence of an alluvial fan at this location. Based on basin characteristics and similar adjacent basins with alluvial fans, however, we believe that there is a potential for flash floods and debris flows to impact SR-12 at this location.

Bear Canyon Alluvial Fan at Mile Post 179 (Point 26 on Plate 1)
The two basins above Bear Canyon alluvial fan are modeled as Moderate and Low debris flow hazard. The FS 1301 road, which leads to Bear Canyon trailhead, traverses this alluvial fan and SR-12 crosses the distal edge of the alluvial fan. Bear Canyon trail continues up Bear Canyon, which is modeled as Moderate debris flow hazard. Field reconnaissance observed large boulders, distributary channels, and boulder levees indicating past debris flow and flooding activity. Debris flows and flooding could impact the trail and roads at this location.

Oak Creek Road (FS 1400)

Two Unnamed Alluvial Fans, NPK Canyon Alluvial Fan, and Clint Canyon Alluvial Fans (Points 27-30 on Plate 3)
The unnamed basins above these alluvial fans are modeled as Low debris flow hazard. Hummocky topography and cobbles and boulders 1–2 feet in diameter were observed on the alluvial fan's surface. Oak Creek Road (FS 1400) crosses over these alluvial fans. Increased runoff, flooding, and debris flows could impact the road.

Pine Tree Canyon Alluvial Fan (Point 31 on Plate 3)
Pine Tree Canyon is modeled as Moderate debris flow hazard. Cobbles and 1–2-feet-in-diameter boulders suggest past debris flow activity. A 6–10 ft wide channel intersects the road and leads directly to a dispersed campsite. A second dispersed campsite exists on the western side of the alluvial fan. Based on debris flow modeling, remote observations, and field reconnaissance, flash flooding and debris flows could impact the road and dispersed camping areas.

Unnamed Alluvial Fan (Point 32 on Plate 3)
The unnamed basin above the alluvial fans is modeled as Low debris flow hazard. Hummocky topography, cobbles, and boulders (2-3 feet in diameter) were observed on the alluvial fan's surface. Increased runoff, flooding, and debris flows could impact the roadway where it crosses the alluvial fan.

Hoover Canyon Alluvial Fan (Point 33 on Plate 3)
Hoover Canyon is modeled as Moderate debris flow hazard. Cobbles, 1–2-feet-in-diameter boulders, and evidence of more recent water movement in the channel suggest past debris flow and flooding activity. Oak Creek Road (FS 1400) crosses over the alluvial fans and two dispersed campsites are present on the western and eastern sides of the alluvial fan. Based on debris flow modeling, lidar-based observations, and field reconnaissance, flash flooding and debris flows could impact the road and dispersed camping areas.

Unnamed Alluvial Fans (Points 34-35 on Plate 3)
The unnamed basins above these alluvial fans are modeled as Low and Moderate debris flow hazard. Hummocky topography, cobbles, and boulders 1–2 feet in diameter were observed on the alluvial fan's surface. Increased runoff, flooding, and debris flows could impact Oak Creek Road (FS 1400) where it crosses over these alluvial fans.

Indian Creek Alluvial Fan (Point 36 on Plate 3)
Indian Creek basin is modeled as Moderate debris flow hazard. Hummocky topography, boulders 1–3 feet in diameter, and numerous cobbles, and boulder levees were observed on the alluvial fan's surface, suggesting past debris flow activity. Oak Creek Road (FS 1400) crosses over the alluvial fan, and a dispersed campsite is present on the western edge of the alluvial fan. Based on debris flow modeling, lidar-based observations, and field reconnaissance, flash flooding and debris flows could impact the road and dispersed camping areas.

North Fork Oak Creek Alluvial Fan (Point 37 on Plate 3)
North Fork Oak Creek basin is modeled as Moderate debris flow hazard. The channel is flanked by large deep-seated landslides for 1.5 miles upstream of the alluvial fan, possibly conveying ample unconsolidated rock and debris into the channels. Increased runoff, flooding, and debris flows could impact Oak Creek Road (FS 1400) where it crosses over the apex of the alluvial fan.

Unnamed Alluvial Fan (Point 38 on Plate 1)
This unnamed basin is modeled as Moderate debris flow hazard. The lidar shows hummocky topography and multiple distributary channels. Upstream of the alluvial fan, a large deep-seated landslide exists, possibly conveying unconsolidated rock and debris into the channels. FS 1400 and FS 235 roads cross over the alluvial fan and a dispersed campsite was noted on the alluvial fan by the USFS BAER team. Based on debris flow modeling, remote observations, and field reconnaissance, flash flooding and debris flows could impact the roads and dispersed camping areas.

RECOMMENDATIONS

Our assessment indicates that flash flooding and debris flow hazards have existed in this area prior to the fire and will likely occur in future storm events within the burn area. In this report we identify locations where these hazards intersect with property or infrastructure and attempt to explain what issues might occur at the sites. Most but not all sites were visited by our team during this reconnaissance survey, and we rely on remote GIS review for those sites that we were not able to visit. The areas we discussed are at elevated risk for debris flows and flash flooding from increased runoff during periods of intense precipitation (approximately 0.25 inches of rain in a 15-minute period or 1 inch of rain in a 60-minute period), rain-on-snow, or rapid snowmelt. These hazards may remain elevated for several years after the fire.

Landowners and land managers may choose to take action to prevent excessive soil erosion and promote revegetation to help mitigate flooding and meet their management and economic goals. The soil burn severity map created and field-validated by the USFS BAER team can be a useful tool to evaluate areas for re-planting. We are willing to help direct users to this map product or provide the data in various formats as needed.

Residents of homes built on alluvial fans and (or) adjacent to streams flowing from burned areas should be informed about potential post-fire flash flood and debris flow hazards. Residents should seek appropriate professional consulting services for site-specific evaluations of the potential threats to their life, safety, and property. For more information on how to stay safe when at risk from debris flows, please consult our Floods After Fire pamphlet and the USGS's fact sheet with safety tips relating to post-fire debris flows (links in the footnote at the bottom of this page).[1]

[1] The Washington Geological Survey's Floods After Fire pamphlet:
https://www.dnr.wa.gov/publications/ger_fs_alluvial_fans.pdf
The USGS's fact sheet on post-fire debris flows safety:
https://pubs.usgs.gov/fs/2022/3078/fs20223078.pdf

Managers of transportation networks and private landowners should be reminded of the increased likelihood of sediment transport, sediment deposition, and (or) erosion impacts to roads following wildfires, as well as potential issues with blocked culverts. We recommend inspecting any culverts within channels draining areas impacted by the fire both before and after storm events, specifically along SR-12 and Oak Creek Road. Blocked culverts can cause additional flooding and exacerbate damages by increasing the amount of erosion during an event. The damage to roads and infrastructure can be minimized by proactively clearing these culverts prior to storms or seasonal snowmelt. We recommend additional site-specific evaluations of the alluvial fans along SR-12 to identify potential life safety threats and impacts to infrastructure.

The Yakima Tieton Irrigation District may need additional support to protect and maintain the irrigation canal and should closely inspect areas where this critical infrastructure crosses drainages. These crossings could be vulnerable to additional sedimentation from ash and mud runoff that could cause additional damage to pumping systems while the canal is active. The canal is at risk of burial from mud and debris at many of these crossing where it is not elevated above the stream channel. In a large debris flow event, catastrophic failure of the canal could occur from impact damage by fast-moving boulders or woody debris. The Irrigation District may choose to seek outside support from engineering or geologic consultants to protect and maintain critical infrastructure.

Land managers responsible for the dispersed camping areas adjacent to Oak Creek Road and Bear Canyon trail should consider the placement of signs to warn the public of flash flood and debris flow hazards that could occur post-fire. Elevated rockfall hazards may be present in locations where the Retreat Fire perimeter is adjacent to steep slopes along the Tieton River Corridor. These areas (particularly known recreation sites) need signs to warn the public of the elevated rockfall, flooding, and debris flow risks that could occur post-fire.

REFERENCES

INCI Web, 2024, Retreat [webpage]. INCI Web. [accessed August 23, 2024 at https://inciweb.wildfire.gov/incident-information/wases-retreat].

LIMITATIONS

WALERT aims to quickly identify and assess geologic hazards associated with wildfires to inform decision making and 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.

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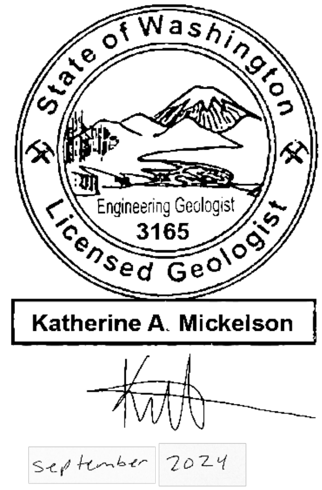

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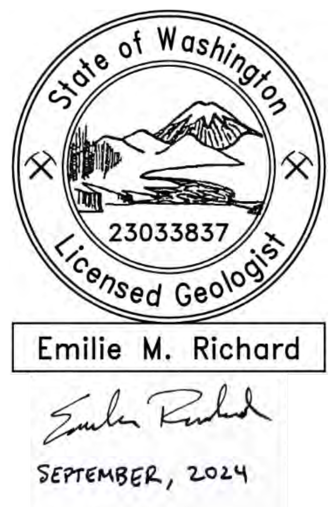

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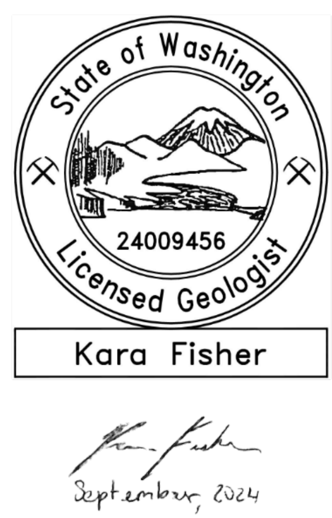

APPENDIX A: GEOLOGICAL BACKGROUND

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 alluvial fan, or quickly, when a flash flood, HCF, or debris flow transports sediment and debris to the alluvial 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).

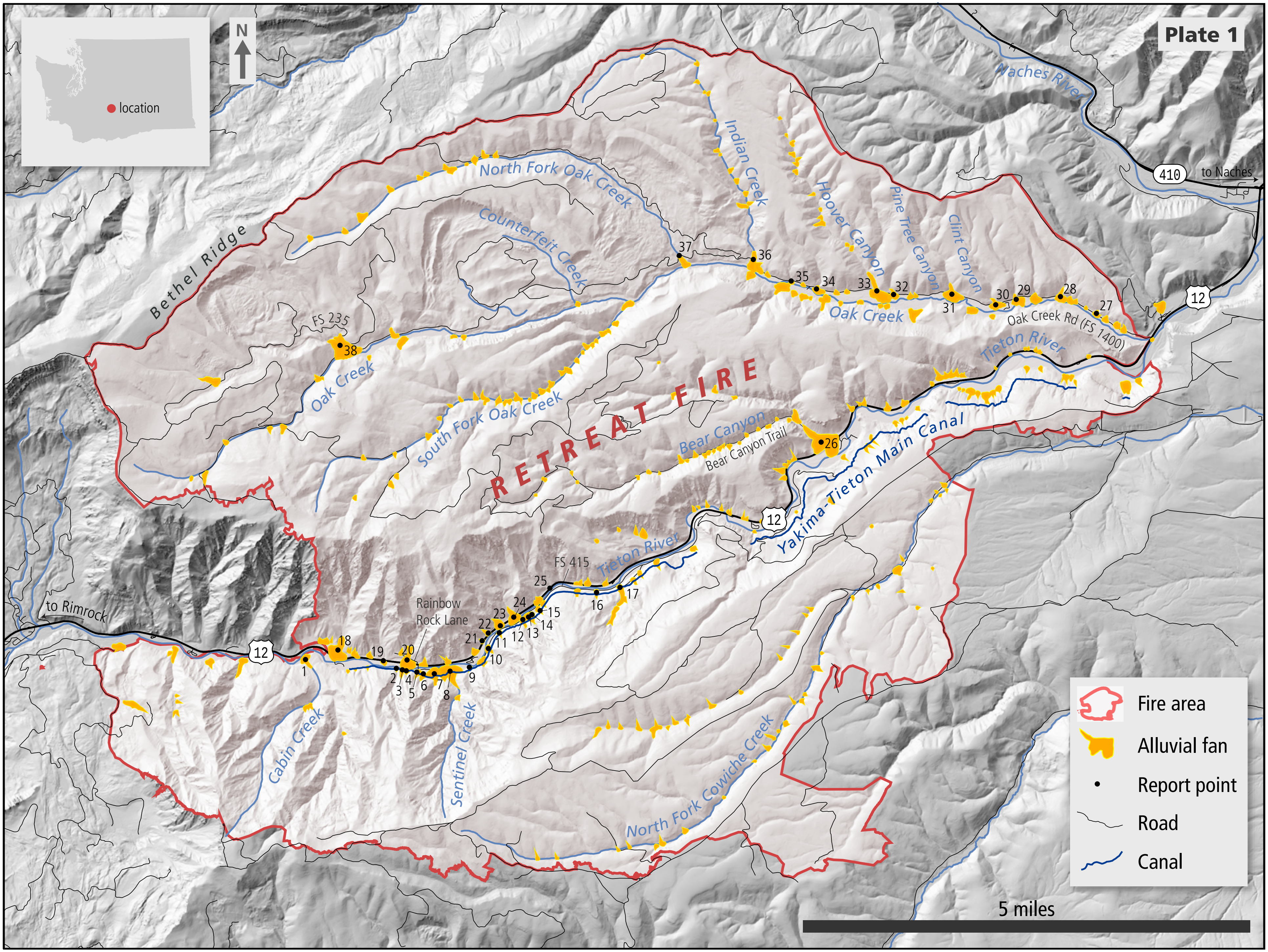

Plate 1
N
location
RETREAT FIRE
Bethel Ridge
North Fork Oak Creek
Counterfeit Creek
Indian Creek
Hoover Canyon
Pine Tree Canyon
Clint Canyon
Naches River
410
to Naches
12
Oak Creek
Oak Creek Rd (FS 1400)
Tieton River
FS 235
South Fork Oak Creek
Bear Canyon
Bear Canyon Trail
Yakima-Tieton Main Canal
FS 415
to Rimrock
Rainbow Rock Lane
Cabin Creek
Sentinel Creek
North Fork Cowiche Creek
Fire area
Alluvial fan
Report point
Road
Canal
5 miles

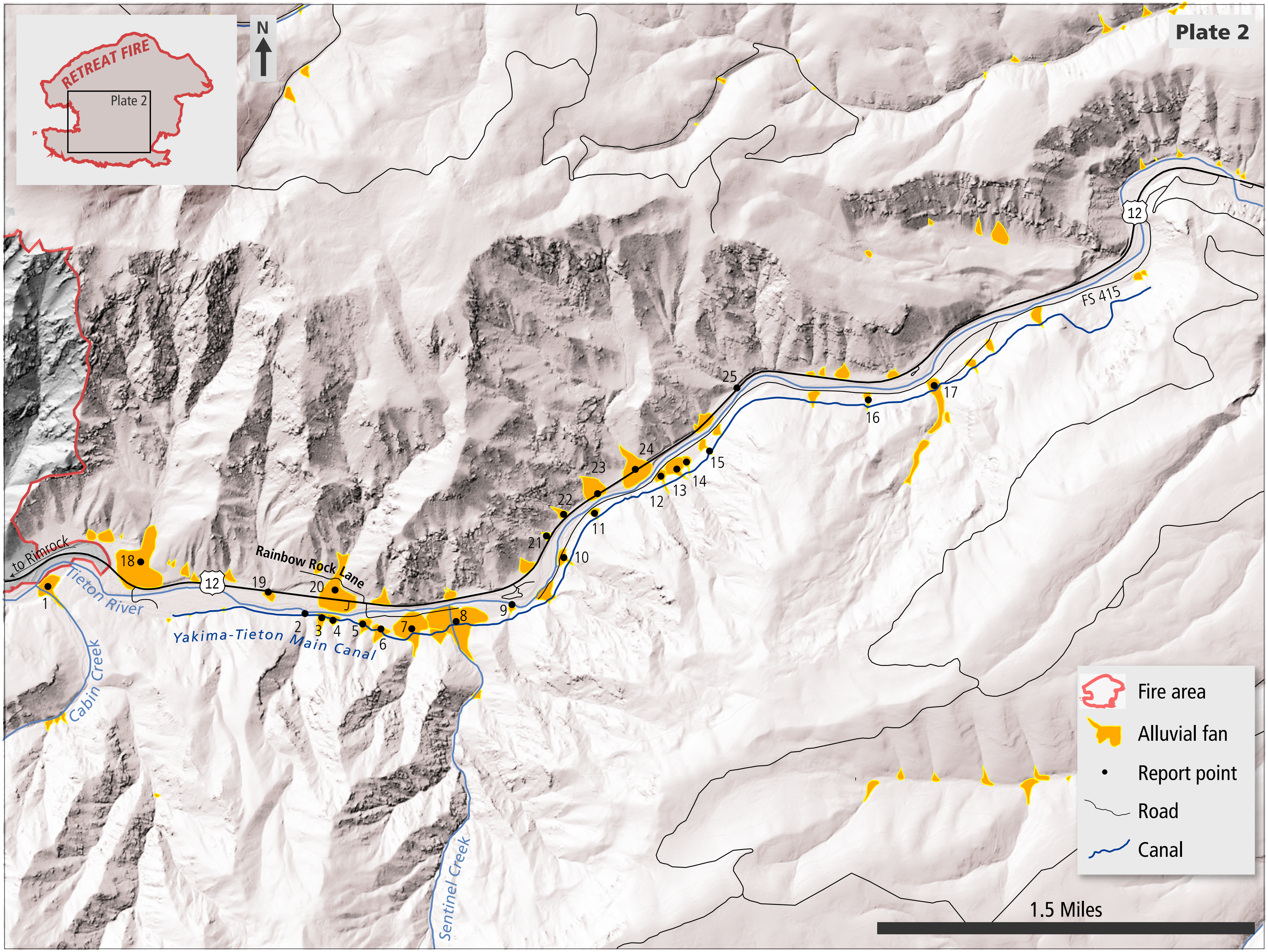
Plate 2
RETREAT FIRE
Plate 2
N
to Rimrock
Tieton River
Cabin Creek
Yakima-Tieton Main Canal
Rainbow Rock Lane
Sentinel Creek
FS 415
12
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Fire area
Alluvial fan
Report point
Road
Canal
1.5 Miles

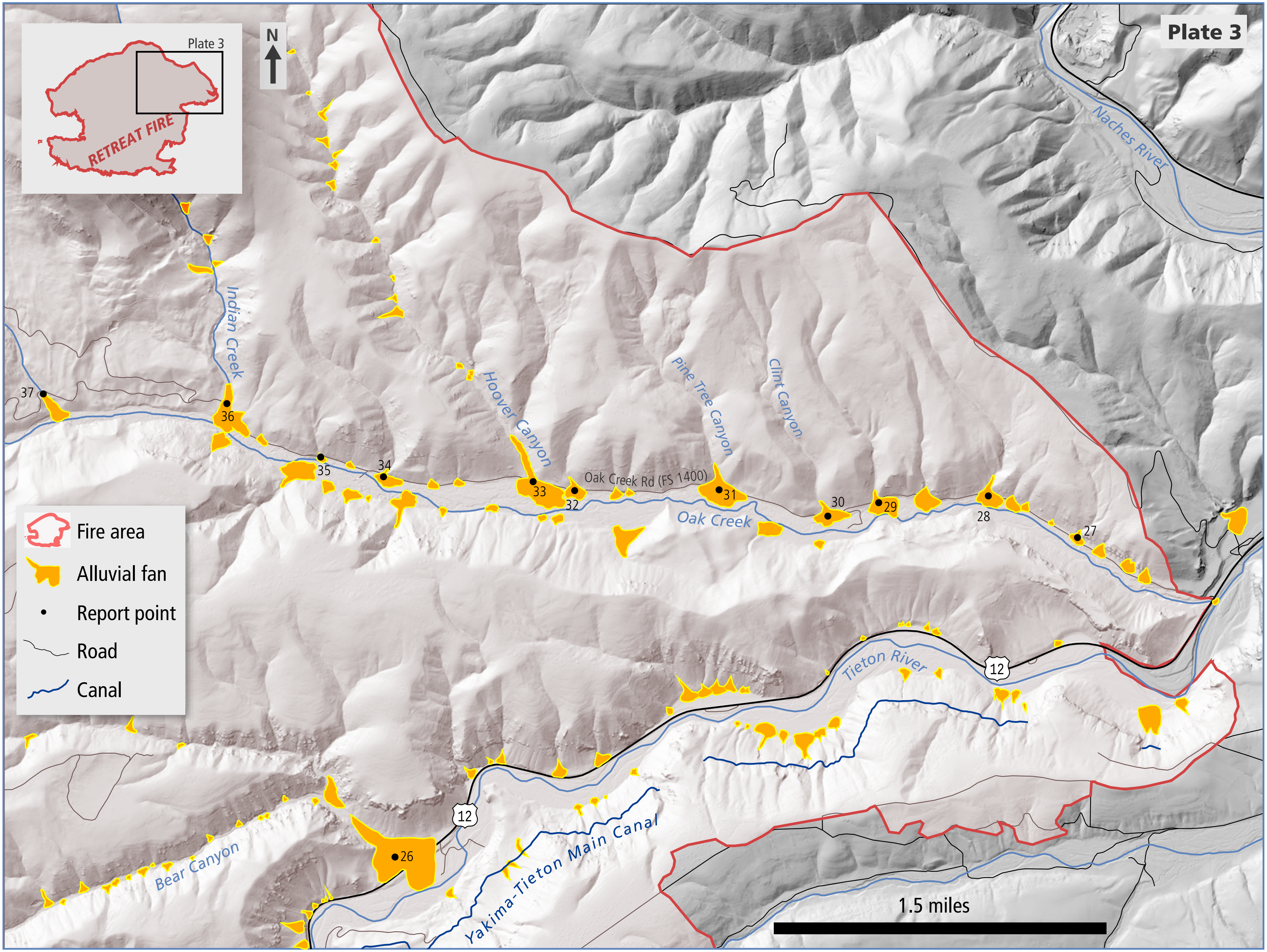
Plate 3
Plate 3
RETREAT FIRE
N
Fire area
Alluvial fan
Report point
Road
Canal
Naches River
Indian Creek
Hoover Canyon
Pine Tree Canyon
Clint Canyon
Oak Creek Rd (FS 1400)
Oak Creek
Tieton River
Bear Canyon
Yakima-Tieton Main Canal
12
12
26
27
28
29
30
31
32
33
34
35
36
37
1.5 miles