LIST OF FIGURES

Figure 1. Location and ownership map of the Glass Fire...........................................3

Figure 2. Physical processes and landforms associated with potential hazards in a post-fire setting. ........................................................................................................5

Figure 3. Shaded relief map for the Glass Fire. ..........................................................6

Figure 4. Fire history map for the Glass Fire and surrounding area...........................8

Figure 5. Map showing the Glass Fire in relation to other recent fires in the general area. .....................................................................................................................9

Figure 6. Annual peak flow discharges for the Napa River near St. Helena, CA gaging station, representative of the fire area..............................................................12

Figure 7. Geologic map and legend for the Glass Fire. .............................................15

Figure 8. Landslide map for the Glass Fire...............................................................16

Figure 9. Mineral hazards map for the Glass Fire......................................................18

Figure 10. Soil burn severity map for the Glass Fire..................................................20

Figure 11. Glass Fire pour point watersheds, with soil burn severity categories......24

Figure 12. The combined debris flow hazard classification as a function of predicted debris flow probability and debris volume production.................................25

Figure 13. USGS debris flow model results for the Glass Fire.................................27

Figure 14. Glass Fire predicted surface erosion rates for the 2-year storm event using the Erosion Risk Management Tool (ERMiT). .......................................................30

Figure 15. Boundaries used to define areas for more detailed descriptions of Values-at-Risk. .............................................................................................................32

LIST OF TABLES

Table 1. Proportion of the Glass Fire burned areas by ownership group. .......................2

Table 2. Glass Fire WERT members. .........................................................................2

Table 3. Recurrence intervals (RI) for 15-minute rainfall intensities by location. ........7

Table 4. Glass Fire soil burn severity. ........................................................................19

Table 5. Glass Fire pour point watershed and soil burn severity percentages. ........22

Table 6. Estimated bulked post-fire flow multipliers and flow increases for the pour point watersheds. ..............................................................................................23

Table 7. ERMiT surface erosion rates for 2-year and 5-year recurrence interval storm events, first and second years following the Glass Fire...............................29
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAER</td>
<td>Burned Area Emergency Response</td>
</tr>
<tr>
<td>BARC</td>
<td>Burned Area Reflectance Classification</td>
</tr>
<tr>
<td>CAL FIRE</td>
<td>California Department of Forestry and Fire Protection</td>
</tr>
<tr>
<td>Cal OES</td>
<td>California Office of Emergency Services</td>
</tr>
<tr>
<td>Caltrans</td>
<td>California Department of Transportation</td>
</tr>
<tr>
<td>CAM-17</td>
<td>California Administrative Manual Title-22 Metals</td>
</tr>
<tr>
<td>CEG</td>
<td>Certified Engineering Geologist</td>
</tr>
<tr>
<td>CFM</td>
<td>Certified Floodplain Manager</td>
</tr>
<tr>
<td>cfs</td>
<td>Cubic Feet per Second</td>
</tr>
<tr>
<td>CGS</td>
<td>California Geological Survey</td>
</tr>
<tr>
<td>CPESC</td>
<td>Certified Professional in Erosion and Sediment Control</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>DOC</td>
<td>California Department of Conservation</td>
</tr>
<tr>
<td>DWR</td>
<td>California Department of Water Resources</td>
</tr>
<tr>
<td>EAS</td>
<td>Emergency Alert System</td>
</tr>
<tr>
<td>EPM</td>
<td>Emergency Protection Measure</td>
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<td>ERMIT</td>
<td>Erosion Risk Management Tool</td>
</tr>
<tr>
<td>FCC</td>
<td>Federal Communications Commission</td>
</tr>
<tr>
<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GISP</td>
<td>GIS Professional certification from the GIS Certification Institute</td>
</tr>
<tr>
<td>GIT</td>
<td>Geologist-in-Training</td>
</tr>
<tr>
<td>HEC-HMS</td>
<td>Hydrologic Engineering Center—Hydrologic Modeling System</td>
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<tr>
<td>HEC-RAS</td>
<td>Hydrologic Engineering Center—River Analysis System</td>
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<tr>
<td>IPAWS</td>
<td>Integrated Public Alert and Warning System</td>
</tr>
<tr>
<td>LiDAR</td>
<td>Light Detection and Ranging</td>
</tr>
<tr>
<td>LNU</td>
<td>CAL FIRE Sonoma-Lake-Napa Unit</td>
</tr>
<tr>
<td>NCRWQCB</td>
<td>North Coast Regional Water Quality Control Board</td>
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<tr>
<td>NOAA</td>
<td>National Oceanographic and Atmospheric Administration</td>
</tr>
<tr>
<td>NRCS</td>
<td>USDA Natural Resources Conservation Service</td>
</tr>
<tr>
<td>NWS</td>
<td>NOAA National Weather Service</td>
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<tr>
<td>OES</td>
<td>Office of Emergency Services</td>
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<tr>
<td>PG</td>
<td>Professional Geologist</td>
</tr>
<tr>
<td>PH</td>
<td>Professional Hydrologist cert. from the American Institute of Hydrology</td>
</tr>
<tr>
<td>RPF</td>
<td>Registered Professional Forester</td>
</tr>
<tr>
<td>SBS</td>
<td>Soil Burn Severity</td>
</tr>
<tr>
<td>SCS</td>
<td>Soil Conservation Service (renamed NRCS in 1994)</td>
</tr>
<tr>
<td>SFBRWQCB</td>
<td>San Francisco Bay Regional Water Quality Control Board</td>
</tr>
<tr>
<td>SR</td>
<td>State Route</td>
</tr>
<tr>
<td>TMDL</td>
<td>Total Maximum Daily Load</td>
</tr>
<tr>
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<td>United States Army Corps of Engineers</td>
</tr>
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<td>United States Department of Agriculture</td>
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<td>Values-at-Risk</td>
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<td>Wireless Emergency Alerts</td>
</tr>
<tr>
<td>WERT</td>
<td>Watershed Emergency Response Team</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

State of California
Watershed Emergency Response Team (WERT)

GLASS FIRE – WERT ASSESSMENT EXECUTIVE SUMMARY

CA-LNU-015947 WERT Evaluation

Mission Statement: The California Watershed Emergency Response Team (WERT) helps communities prepare after wildfire by rapidly documenting and communicating post-fire risks to life and property posed by debris flow, flood, and rockfall hazards.

It should be noted that the findings included in this report are not intended to be fully comprehensive or conclusive, but rather to serve as a preliminary tool to assist the counties of Napa and Sonoma – and their local department of emergency services, various agencies within each respective county; Caltrans; Sonoma Water; the California Governor’s Office of Emergency Services; the USDA Natural Resource Conservation Service; the Cities of Santa Rosa, Calistoga, and St. Helena; utility companies; and other responsible agencies in the development of more detailed post-fire emergency response plans. It is intended that the agencies/entities identified above will use the information presented in this report as a preliminary guide to complete their own more detailed evaluations, and to develop detailed emergency response plans and mitigations. This report should also be made available to local districts, residents, businesses, and property managers so that they may understand their proximity to hazard areas, and to guide their planning for precautionary measures as recommended and detailed in this document.

The Glass Fire started on September 27, 2020 near Glass Mountain Road in Napa County and eventually burned to Santa Rosa in Sonoma County. A total of 1,555 residential and commercial structures were destroyed, and an additional 282 structures were damaged in both counties. Approximately 650 homes and 31 wineries were either destroyed or damaged. The fire burned 67,484 acres, with full containment obtained on October 20, 2020.

At the request of the CAL FIRE Sonoma-Lake-Napa Unit Chief, a WERT composed of staff from the California Department of Forestry and Fire Protection (CAL FIRE) and California Department of Conservation-California Geological Survey (CGS) was deployed to the fire on October 16, 2020, with field work completed on October 22nd.
Summary of the Key WERT Findings

- Twenty (20) percent of the fire burned at moderate to high soil burn severity, whereas the remaining portion of the fire (80%) burned at low or very low/unburned soil burn severity.
- Post-fire runoff is expected to significantly increase within and downstream of the burned area for the basins with higher levels of moderate and high soil burn severity. Specifically, estimated post-fire bulked runoff for the 2-year recurrence interval storm event is expected to increase from 10 to 100 percent, with the greatest increases expected to occur in the Simmons Canyon and Santa Rosa Creek watersheds.
- The ERMIIT post-fire surface erosion model predicts mostly a minimal to moderate increase in the rate of surface erosion across the burned area due to the preponderance of low and very low soil burn severity.
- Compared to other areas in California, the USGS debris flow model indicates that there is generally a low to moderate hazard. The model results for the Glass Fire show that with a 15-minute rainfall intensity of 36 mm hr⁻¹ (1.42 in hr⁻¹), 197 of 422 basins (approximately 47 percent) have a likelihood of 40-60 percent or greater to produce debris flows. This threshold represents a 50 percent chance that debris flows may initiate within approximately 50 percent of the modeled basins.
- Based on the debris flow model, basins within the Mark West Creek, Santa Rosa Creek, Sulphur Creek, and Simmons Canyon have the highest probability of triggering a debris flow with this 2 to 5-year recurrence interval rainfall intensity.
- Thirty-three (33) Values-at-Risk (VARs) were identified within and downslope/downstream of the fire. Twenty-five (25) of the VARs are located in Napa County, with the remaining 8 VARs located in Sonoma County. Eighteen (18) of the VARs are polygons that encompass several individual structures or extended alignments of road. The majority of VARs are likely to be subject to localized flooding and/or localized potential for debris flows.
- Two (2) VARs were identified as subject to high life-safety threat. Twenty-three (23) VARs were identified as subject to moderate life-safety threat.
- The majority of the VARs identified (26) relate to either houses or house pads in close proximity to stream channels subject to inundation from sediment-laden flows or debris flows.

General Recommendations

The WERT’s objectives for the burned area were to quickly identify potential post-fire life-safety and property threats, including those from debris flows, flooding, rockfall, and erosion. General recommendations include:

- Utilize early warning systems available to homeowners, particularly those located in debris flow and flood-prone areas. The WERT recommends the use of Napa and Sonoma county emergency alert notification systems. See the following websites:

  Napa County
  https://www.countyofnapa.org/353/Emergency-Services
- Clearly communicate the potential and risk of post-fire watershed hazards to the agencies responsible for emergency planning and response.
- Develop emergency response and evacuation plans based upon the identified post-fire hazards.
- Increase the situational awareness of affected residents and the communities regarding the hazards and risks associated with living downstream/downslope of burned areas.
- Perform monitoring and maintenance of road drainage and storm drain infrastructure. Drainage facilities were noted to be undersized for larger storm events in many locations, and the post-fire environment can create conditions that quickly overwhelm even drainage facilities normally considered to be adequately sized.
- Utilize temporary flood control and structure protection (sandbags, K-rails, Muscle Wall) where appropriate.
- Place temporary signage and consider road closure in areas of potential post-fire rockfall, debris flow, and flooding hazards.
- Until more detailed evaluation of the level of increased risk can be determined, close recreational areas (i.e., campgrounds, parks, trails) that are low-lying or located below the mouths of steep debris flow canyons prior to and during predicted large rain events.
- While the majority of the Bell Creek watershed was unburned or burned at low to very low severity, the City of St. Helena should consider conducting a hydrologic evaluation of the potential post-fire impacts to Bell Canyon Reservoir, including evaluating possible mitigation measures designed to minimize the potential for debris and ash to impact the water supply.
1. Introduction

This report presents the results of a rapid evaluation of post-fire geologic and hydrologic hazards to life-safety and property (i.e., collectively known as “Values-at-Risk”, or VARs) for private lands, state lands, and non-profit ownerships affected by the 2020 Glass Fire in Napa and Sonoma counties, California. Wildfire can have profound effects on watershed processes. A primary concern for burned watersheds is the increased potential for damaging flood flows, debris flow occurrence, rockfall from steep slopes, and hillslope erosion. As winter approaches, it is critical that people who live in and downstream from large wildfires implement emergency protection measures (EPMs) where appropriate, remain alert of weather conditions, and be ready to evacuate if necessary during large and high intensity storms.

Watershed Emergency Response Teams (WERTs) identify life-safety and property hazards associated with the post-fire environment, determine preliminary mitigative and/or protective measures, and rapidly communicate these findings to responsible agencies and affected parties. This document summarizes downslope/downstream VARs and makes general recommendations to reduce life-safety and property exposure to post-fire hazards on non-federal lands.

Area and proportion of the Glass Fire by ownership group are shown in Figure 1 and Table 1. Ownership within the Glass Fire is composed of private lands (75% percent), park lands (10%), non-profit conservancies and trusts (7%), local government lands (5%), and other state and federal lands (3%).

WERT products associated with this report include GIS data in the form of shapefiles and raster files. Clear communication of life-safety and property hazards is an objective of the WERT process, and the use of these spatial data is a critical component for communicating hazards in a planning and operational context. These data have been shared with federal, state, and local responsible agencies.

Background

The Glass Fire started early on the morning of September 27, 2020 near Glass Mountain Road in Napa County (Figure 1). A total of 1,555 residential and commercial structures were destroyed, and an additional 282 structures were damaged in both Napa and Sonoma counties. Approximately 650 homes and 31 wineries were either destroyed or damaged. No injuries or deaths were reported. The fire burned 67,484 acres, with full containment obtained on October 20, 2020.

A WERT was deployed on October 16th following a request from the CAL FIRE Sonoma-Lake-Napa Unit Chief. Field observations were made from October 16 to October 22 (see photos in Appendix E). Team members and their positions are listed in Table 2.
Table 1. Proportion of the Glass Fire burned areas by ownership group.

<table>
<thead>
<tr>
<th>Glass Fire Ownership</th>
<th>Acres</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bureau of Land Management</td>
<td>137</td>
<td>0.2</td>
</tr>
<tr>
<td>CA Dept. of Parks and Recreation</td>
<td>7,050</td>
<td>10.4</td>
</tr>
<tr>
<td>Local Government</td>
<td>3,258</td>
<td>4.8</td>
</tr>
<tr>
<td>Non-Profit Conservancies and Trusts</td>
<td>4,545</td>
<td>6.7</td>
</tr>
<tr>
<td>Other State Lands</td>
<td>2,237</td>
<td>3.3</td>
</tr>
<tr>
<td>Private Lands</td>
<td>50,257</td>
<td>74.5</td>
</tr>
<tr>
<td>Total</td>
<td>67,484</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 2. Glass Fire WERT members.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Agency</th>
<th>Expertise-Position</th>
</tr>
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<tbody>
<tr>
<td><strong>Main Team</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pete Cafferata</td>
<td>Team Leader</td>
<td>CAL FIRE</td>
<td>Hydrology/Forestry</td>
</tr>
<tr>
<td>PH No. 1676, RPF No. 2174, CPESC No. 417</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kevin Doherty</td>
<td>Team Co-Leader</td>
<td>CGS</td>
<td>Engineering Geology</td>
</tr>
<tr>
<td>PG No. 7824; CEG No. 2666</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Adjunct Team</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pete Roffers</td>
<td>Adjunct Member</td>
<td>CGS</td>
<td>Engineering Geology/GIS</td>
</tr>
<tr>
<td>PG No. 9100; GISP 91498</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sol McCrea</td>
<td>Adjunct Member</td>
<td>CGS</td>
<td>GIS</td>
</tr>
<tr>
<td>CFM No. 3527, GISP 90957</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Francesca Rohr</td>
<td>Adjunct Member</td>
<td>CAL FIRE</td>
<td>GIS</td>
</tr>
<tr>
<td>Stefani Lukashov</td>
<td>Adjunct Member</td>
<td>CGS</td>
<td>GIS</td>
</tr>
<tr>
<td>GIT No. 898</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Figure 1. Location and ownership map of the Glass Fire.
Objectives and Scope

The two primary objectives of the Glass Fire WERT were (1) to identify types and locations of on-site and downstream threats to life-safety or property from debris flows, rockfall, landslides, flooding, erosion, road hazards, and other post fire-related problems (Figure 2), and (2) to develop preliminary general emergency protection measures needed to avoid potential life-safety and property threats.

The scope of work performed included the following:

- Compiling geology map layers, and reviewing the general distribution and relationships between geology and past occurrence of debris flows and landslides in the burned area.
- Reviewing aerial photography, including Google Earth images.
- Reviewing local topography, including high resolution digital elevation models (DEMs).
- Reviewing available satellite imagery and creating a soil burn severity map.
- Reviewing USGS generated debris flow model results.
- Producing and reviewing Batch ERMiT soil erosion model results.
- Estimating post-fire flood flows for selected watersheds with the highest threat to public safety and property.
- Contacting local government agencies to discuss potential post-fire impacts to life-safety, property, and infrastructure.
- Performing field reconnaissance to identify potential hydrologic and geologic hazards, as well as potential VAR sites.
- Developing a list of preliminary recommendations to mitigate possible post-fire hazards as they pertain to identified VAR sites.
- Holding a closeout meeting coordinated by Cal OES for local agencies.
- Drafting a final report documenting data, findings and recommendations.

It is important to emphasize that the WERT performs a rapid evaluation of post-fire hazards and risk. A complete characterization of post-fire hazards and/or in-depth design of protection measures is beyond the scope of the WERT evaluation. However, findings from the WERT evaluation can potentially be used to leverage emergency funds for emergency treatment implementation and more detailed site investigation and/or treatment design.
2. Physical Setting

Topography, Climate, and Vegetation

The Glass Fire is located in the Mayacamas Mountains, part of the northern California Coast Ranges (CGS 2002). The fire burned primarily in tributaries of the Russian River, including the Santa Rosa Creek and Mark West Creek drainages; the Sonoma Creek drainage that drains to San Pablo Bay; basins that drain to the Napa River; and tributaries of Putah Creek, that drain into Lake Berryessa. The cities of Santa Rosa, Calistoga, and St. Helena are adjacent to the burned area.

Elevations range from approximately 240 feet above mean sea level near St. Helena to 2,988 feet at Sugarloaf Mountain, located northeast of Calistoga. Slopes within the fire perimeter range from gentle (<20%) to steep (>65%), with an average slope gradient of approximately 40% (USGS StreamStats). Steeper slopes are located in the Palisades; the upper parts of the Santa Rosa Creek, Sulphur Creek, Simmons Creek, Dutch Henry Creek, and Swartz Creek watersheds; and along Adobe Canyon Road in the upper Sonoma Creek basin. More gentle slopes are present in the Deer Park and Bear Valley areas, and within valley bottoms at lower elevations. Figure 3 provides a slope map within the fire perimeter and surrounding areas.
Figure 3. Shaded relief map for the Glass Fire.
The burned area has a typical Mediterranean climate with warm dry summers and cool wet winters. Average annual rainfall in the fire area ranges from 37 inches in St. Helena and 38 inches in Santa Rosa and Calistoga, to an average of approximately 45 inches within the burned watersheds (USGS StreamStats). Most of the rain falls from November through April. Precipitation occurs almost entirely as rain, with rare occurrences of snow at the highest elevations. The 1-, 2-, 5-, and 10-year recurrence intervals for 15-minute rainfall intensities are displayed in Table 3.

Table 3. Recurrence intervals (RI) for 15-minute rainfall intensities by location (inches per hour and mm per hour). Data from NOAA Atlas 14 (http://hdsc.nws.noaa.gov/hdsc/pfds/).

<table>
<thead>
<tr>
<th>Location</th>
<th>1-yr RI</th>
<th>2-yr RI</th>
<th>5-yr RI</th>
<th>10-yr RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Bell Creek watershed</td>
<td>1.05 (27 mm)</td>
<td>1.26 (32 mm)</td>
<td>1.56 (40 mm)</td>
<td>1.81 (46 mm)</td>
</tr>
<tr>
<td>Bell Canyon Reservoir</td>
<td>0.96 (24 mm)</td>
<td>1.15 (29 mm)</td>
<td>1.42 (36 mm)</td>
<td>1.65 (42 mm)</td>
</tr>
<tr>
<td>Upper Santa Rosa Creek watershed</td>
<td>1.20 (31 mm)</td>
<td>1.44 (37 mm)</td>
<td>1.75 (44 mm)</td>
<td>2.00 (51 mm)</td>
</tr>
<tr>
<td>Santa Rosa Creek at Hwy 12</td>
<td>1.14 (29 mm)</td>
<td>1.36 (35 mm)</td>
<td>1.67 (42 mm)</td>
<td>1.92 (49 mm)</td>
</tr>
<tr>
<td>Sonoma Creek at west end of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugarloaf Ridge State Park</td>
<td>1.17 (30 mm)</td>
<td>1.41 (36 mm)</td>
<td>1.72 (44 mm)</td>
<td>1.98 (50 mm)</td>
</tr>
</tbody>
</table>

Vegetation in the burned area is largely comprised of coastal oak woodland, mixed hardwood/conifer forest, mixed chaparral, grassland, and vineyards. Douglas-fir and coast redwood are common conifer species found throughout large parts of the fire. Additionally, there are scattered areas of knobcone pine and cypress in the upper parts of the burned area near Hood Mountain. Annual grasslands and vineyards also comprise a significant portion of the vegetated area within the fire perimeter.

**Fire History and Recent Post-Fire Monitoring**

Fire history can be a useful metric for fuel loading and the energy expenditure for fire. The areas with the least frequent fire theoretically correspond with the highest potential unit area biomass, indicating that sufficient fuels may exist to increase potential soil damage.

Figure 4 indicates that most of the north part of the northern section of the Glass Fire last burned in the 1964 Hanly Fire. Most of the southern lobe of the Glass Fire had not burned in recent history, with two exceptions. Approximately 9% of the Glass Fire previously burned in the 2017 Nuns Fire, and a small part of the southern lobe burned in the 1994 PG&E #24 Fire. The northeastern portion of the Glass Fire abuts the westernmost margin of the 2020 Hennessey Fire (part of the LNU Lightning Complex Fire).

Figure 4. Fire history map for the Glass Fire and surrounding area.
Figure 5. Map showing the Glass Fire in relation to other recent fires in the general area.
Considerable monitoring work has taken place following the 2017 North Bay wildfires which is useful for understanding possible impacts from the 2020 Glass Fire. Longstreth (2019) reported that the mean basin rainfall thresholds for debris flows established were exceeded (24 mm hr$^{-1}$ or 0.94 in hr$^{-1}$ at the 15-min intensity) at two monitoring sites located at Hood Mountain Regional Park and Sugarloaf Ridge State Park in the 2017 Nuns Fire, but no debris flows occurred the first two winters. Peak 15-minute rainfall intensity recorded during the monitoring period was approximately 39 mm hr$^{-1}$. This dataset indicates that higher rainfall intensities are necessary for debris flow initiation in the Mayacamas Mountains.1

Diaz (2019) reported on rainfall and runoff data for the first two winters following the 2017 Nuns and Tubbs fires in Sonoma and Napa counties. There were no large storm events the first winter after the fires, and the Central Sonoma Watershed Project built in the 1960’s for flood control in Santa Rosa handled the storm runoff well. A 5 to 10-year recurrence interval flow event occurred in February 2019 (second winter), but it also did not cause flooding. Rainfall intensities for both winters were below National Weather Service (NWS)-established debris flow thresholds. Monitoring upstream in the Mark West Creek watershed for geomorphic stability and debris jams did not reveal significant channel changes. Perkins et al. (2020) also quantified watershed response in the Tubbs and Nuns fires. Their preliminary results show that (1) the heavily burned monitored areas experienced the greatest reductions in saturated hydraulic conductivity (Ksat), and (2) dry ravel data show an order of magnitude less ravel for a given slope compared to ravel yield for the 2009 Station Fire in the San Gabriel Mountains in southern California.

Concern was raised after the 2017 North Bay fires regarding potential toxic runoff generated from burned structures that could impact domestic water supplies. Monitoring by the San Francisco Bay Regional Water Quality Control Board did not show that water quality in the Napa River watershed had been significantly impacted by the Nuns, Atlas, or Tubbs fires after the first winter (SFBRWQCB 2018). Similarly, fire-related pollutants were only minimally detected for the Tubbs and Nuns fires below the urban dominated burn in Russian River watershed tributaries after the first winter (NCRWQCB 2018). Larger and more intense storms during the second post-fire winter caused widespread deposition of fire-related residues and elevated streambed metal concentrations. This suggested that the increased precipitation and associated erosion was much greater during the storms of water year 2018-2019, however these residues were not at levels that caused aquatic toxicity or threats to human health (NCRWQCB 2020).

**Hydrology/Flood History**

Flooding events occur in the northern part of the California Coast Ranges when atmospheric rivers tap into tropical moisture creating warm, long duration storm events with periods of intense rainfall. Flood history for the affected watersheds was determined from several sources—local knowledge, stream gaging records, technical reports, and newspaper accounts. The flood of record for the USGS Napa River near St. Helena gage between 1929

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1 Observations and monitoring conducted to date for the 2017 North Bay wildfires have shown limited significant impacts from flooding or debris flows (Oakley and Lancaster 2018) due to generally low rainfall intensities and burn severity. A shallow landslide that mobilized as a debris flow during a January 2018 storm event did, however, deliver rocks and debris that resulted in a fatality on State Highway 121 in Napa County within the perimeter of the Atlas Fire in an area with low soil burn severity (Cafferata et al. in review).
and 2016 took place in December 2005; the second highest peak flow occurred in February 1986 (Figure 6). Similarly, the flood of record for the USGS Sonoma Creek at Agua Caliente gage is December 2005, but the flow record is missing for water years 1982 through 2001. Other significant flood events occurred in Sonoma and Napa counties in 1955, 1982, and 1995.

Portions of lower Sonoma Creek have frequently flooded during relatively small winter storm events that cause flows to overtop the channel banks, particularly from upstream of Highway 121 to San Pablo Bay (ESA PWA 2012). Significant portions of lower Sonoma Creek, Napa River, and Laguna de Santa Rosa are mapped as within the 100-year floodplain by FEMA (FEMA 2008), or mapped by DWR as within Awareness Floodplains.

Implementation of the Central Sonoma Watershed Work Plan (Santa Rosa SCD and Sonoma County FCWCD District 1958) during the 1960’s included construction of 25 miles of flood control channels, four flood-retarding structures and two diversion structures. The facilities were designed to provide protection for a flood that would have 1% chance of recurring in a given year (i.e., a 100-year flood). The Central Sonoma Watershed Project has successfully alleviated most of the flooding for the City of Santa Rosa (Santa Rosa Public Works Department 2006; C. Diaz, Sonoma Water, per. communication).

The majority of the flooding within Napa County occurs within the Napa Valley floor. The City of Napa and those areas surrounding the Napa-Sonoma Marshes are the most heavily affected, although Yountville, St. Helena, American Canyon, and Calistoga all have flooding from the 100-year event within their boundaries. There are approximately 2,500 properties in the floodplain and over 60 have made more than one flood damage claim to FEMA (Napa County 2007). In addition, the Napa County hazard mitigation plan states that there remains a significant threat of flooding along the many feeder streams in the Napa River watershed, even with reservoirs such as Lake Hennessy in place (Napa County 2018).

**Soils**

Numerous soil series are found within the Glass Fire perimeter. Soils on slopes above 30 percent are generally shallow (<10 inches to approximately 35 inches). They are derived from several types of weathered bedrock, including rhyolite, metavolcanics, and sedimentary rocks, generally sandstone and shale (USFS-SCS 1972). Upland soils can generally be classified as gravelly, very gravelly, or stony loams or clay loams, or rock outcrops (USFS-SCS 1972, SCS 1978). They are considered as moderately well drained to excessively drained. Common soils include Henneke, Montara, rock outcrop-Kidd, Forward, Goulding, Yorkville, Boomer, Aiken, Felton, Hugo, Felta, Sobrante, and Josephine. The distribution of mapped soil units generally corresponds to their underlying geologic parent materials.
Geology and Landslides

Regional geologic mapping (Graymer et al. 2007) indicates that the Glass Fire burned area is located within the southern portion of the northern California Coast Ranges geomorphic province (CGS 2002). The Coast Ranges geomorphic province is a series of steep, northwest-trending mountain ranges and valleys extending from the Oregon border to the north, Transverse Ranges to the south, and the Great Valley province to the east. The western edge of the province along the Pacific Ocean is uplifted, terraced and wave-cut. The Coast Ranges run subparallel to the active San Andreas Fault, which runs approximately 600-miles from Point Arena to the Gulf of California. The province is divided into northern and southern sections separated by a depression containing the San Francisco Bay. Within the northern portion of the geomorphic province, the bedrock is generally comprised of Mesozoic and Cenozoic-era (65 million years to 250 million years) sedimentary rocks which are overlain in areas by Tertiary-age (1.6 million years to 65 million years) volcanic rocks (e.g., Sonoma Volcanics).

Bedrock underlying the Glass Fire burned area is comprised of the Jurassic to Cretaceous-age Central Belt Franciscan Complex, Jurassic to Cretaceous-age Great Valley Sequence, Miocene to Pleistocene-age volcanic rocks (Sonoma Volcanics), and Pliocene and Pleistocene-age fluvial sedimentary rocks. Cretaceous and Jurassic-age marine and
ultramafic rocks associated with the Franciscan Complex are mapped within the southwestern Glass Fire boundary. Sandstone, shale, and mudstone of the Great Valley Sequence underlie the northeastern corner of the Glass Fire burned area. The Franciscan Complex is described as generally massive to distinctly bedded, green to gray lithic wacke and dark-gray or black siltstone, shale, and slate (Graymer et al. 2007). A small portion of the Franciscan Formation is described as a mélange, consisting of blocks and lenses of graywacke, chert, metachert, greenstone, serpentinite, silica-carbonate rock, blueschist, eclogite, amphibolite, limestone, and quartz-mica schist. The Great Valley Sequence is described as marine mudstone, siltstone, sandstone, and conglomerate (Graymer et al. 2007). Pliocene to Pleistocene-age fluvial deposits of the Huichica and Glen Ellen Formations are mapped as underlying the southwestern Glass Fire burned area. The fluvial deposits are described as massive yellow siltstone, well-sorted quartz-lithic sandstone and poorly consolidated gravel (Graymer et al. 2007).

Miocene to Pleistocene-age Sonoma Volcanics, which unconformably overlie the Franciscan Complex and Great Valley Sequence, are mapped as underlying the majority of the Glass Fire burned area. The volcanic rocks are described as consisting of basalt, andesite, rhyolite, tuff, and other pyroclastic rocks (Graymer et al. 2007), which appear to be ridge formers within the Glass Fire burned area at Hood Mountain, Diamond Mountain, Sugarloaf Mountain, and the Palisades. Mapped bedrock is mantled by Quaternary-age fluvial, alluvial fan, alluvial terrace, and landslide deposits which overlie the older bedrock within elevated valleys, the mouths of tributary drainages, and wide fluvial valleys.

Regional geologic landslide mapping (Clahan et al. 2005; Delattre et al. 2007; Wagner and Gutierrez 2010; Delattre and Gutierrez 2013) identifies areas of deep-seated landsliding within the Glass Fire burned area. The regionally mapped landslides represent a portion of the mapped large, deep-seated landslides within the burned areas. Additional sources are compiled within the California Geological Survey online landslide inventory (Wills et al. 2011) and included on the attached landslide map (Figure 8). The inventory includes regional mapping by Dwyer et al. (1976) and Huffman and Armstrong (1980). As part of our evaluation of the burned area, we did not validate the landslide mapping but used it as a tool to help guide our evaluation of the burned area and focus on areas of potential hazard. Generally based on field observations and review of available LiDAR imagery, landsliding appears to be prevalent across the burned area, primarily as shallow debris flows or complex deep-seated landslides. Extreme short-term and long-term rainfall events are a primary trigger for initiating both shallow and deep-seated landslides, respectively, in the area, while ground shaking from nearby active faults is an important process in preparing slopes for landsliding and initiating landslides (Keefer 1984). These landslide prone materials can add to the increased slope hazards (e.g., rockfall, shallow landslides), erosion, and runoff expected because of post-fire soil hydrology changes.

There are numerous active earthquake fault systems within and adjacent to the Glass Fire burned area. Northwest-trending folds and faults run through the burned area and are associated with the southern extent of the Maacama Fault Zone (Jennings and Bryant 2010). Mapped faults within the Glass Fire burned area generally exhibit Quaternary and late Quaternary-age fault movement. The main trace of the Maacama fault is capable of generating a Maximum Moment Magnitude 7.1 earthquake with a recurrence interval of 220 years (Peterson et al. 1996). High ground acceleration associated with fault rupture along the Maacama Fault Zone is likely a contributing factor for movement of deep-seated landslides in
Napa and Sonoma counties. There are numerous other regional seismic sources that are capable of producing strong ground motions in the burned area, including the Rodgers Creek Fault Zone located approximately 3-miles southwest of the southwestern Glass Fire boundary. Earthquakes and subsequent landsliding during the typical 3- to 5-year recovery period that burned slopes are susceptible to post-fire response flood flows can be further increased by bulking with sediment and debris delivered to the channel networks by coseismic landsliding. The material delivered to streams can also be mobilized in sediment laden flood and debris flow events increasing their magnitude and destructive power.

**Hazardous Minerals**

Hazardous minerals in the Coast Ranges province are often associated asbestos, mercury, and other heavy metals. Regional geologic mapping (Graymer et al. 2007) identifies serpentinite and other ultramafic rock units within and downstream of the southwestern and northeastern portions of the Glass Fire burned area that may contain asbestiform minerals. Asbestos is classified as a known human carcinogen by state, federal and international agencies and is regulated under Title 8 Section 1529 of the California Code of Regulations. State and federal health officials consider all types of asbestos to be hazardous. There is no agreed-upon “safe” level of asbestos exposure because there is insufficient scientific information to support the identification of an exposure level at which there would be zero risk of cancer. Asbestos can be entrained with increased runoff and brought into areas that when disturbed could cause potential hazards. Based on our field observations, outcrops and road cuts of serpentinite were observed within the burned area.

Figure 7 shows the distribution of the Jurassic to Tertiary-age Central Belt Franciscan Formation that has the potential for locally elevated levels of CAM-17 metals. These hazardous minerals, including silver, mercury, copper, chromium, and manganese, may be entrained with increased surface runoff and impair water quality downslope. There are numerous historic mining operations, including the Calistoga mining district and Mayacamas mining district, within and adjacent to the Glass Fire burned area that may contain potentially harmful concentrations of heavy metals. Primary and secondary mined minerals contain silver, mercury, copper, chromium, and manganese (https://www.mindat.org/). Mine tailings and mine waste may contain minerals with harmful concentrations of hazardous elements, including arsenic, cadmium, lead, zinc, mercury, silver, and other CA Title-22 (CAM-17) metals. These hazardous minerals may be entrained with increased surface runoff and impair water quality downslope, notably to Santa Rosa Creek, and the Napa River and its tributaries. The locations of potential mineralogical hazards, including the CAM-17 mines and ultramafic minerals, are shown in the Mineral Hazard Map (Figure 9).
Figure 7. Geologic map for the Glass Fire.
Figure 8. Landslide map for the Glass Fire.
The historic Aetna Mining District is a series of former mercury and manganese mines located along the flanks of Oat Hill within and downstream of the northeast Glass Fire burned area. Operations within the mining district are located upslope of James Creek, a tributary to Pope Creek. Pope Creek drains to Lake Berryessa, which provides drinking water to residents in Solano and Napa counties. Mining operations are no longer ongoing, but tailings, equipment and open adits remain. According to information provided by Napa County, methylmercury levels in Lake Berryessa have resulted in state warnings recommending limits of fish consumption. Increased runoff associated with moderate and high soil burn severities observed within the headwaters of James Creek and Pope Creek, particularly along Swartz Creek and Bateman Creek, may result in higher flows within the drainages, potentially increasing runoff or inundating the mine areas during large rain events, increasing the potential for mercury delivery to Lake Berryessa.

Geothermal wells are mapped within and downstream of the northern portion of the Glass Fire burned area, particularly near the City of Calistoga. Very little infrastructure associated with the geothermal wells was observed within the fire boundary during our field review, as much of the area was difficult to access due to locked gates and poor roads. Our field evaluations were conducted over a relatively short period and should not be considered comprehensive and/or conclusive. Moderate and high soil burn severities observed within the northern Glass Fire boundary will likely result in increased runoff into the mapped drainages. Geothermal well infrastructure located within the drainages may be at risk of inundation from higher flows in the drainages during large storm events.

Information regarding the hazardous minerals discussed above can be found at the California Office of Environmental Health Hazard Assessment (https://oehha.ca.gov/chemicals/).

For additional information, see:
http://pubs.usgs.gov/fs/2005/3014/
http://www.who.int/mediacentre/factsheets/fs361/en/
https://ww2.arb.ca.gov/resources/documents/naturally-occurring-asbestos-publications-maps
https://www.conservation.ca.gov/cgs/mineral-hazards/asbestos
Sonoma County Mining
https://www.mindat.org/loc-22971.html

Napa County Mining
https://www.mindat.org/loc-3512.html

Department of Conservation Well Finder
https://www.conservation.ca.gov/calgem/Pages/WellFinder.aspx
Figure 9. Mineral hazards map for the Glass Fire.
3. Modeling results

Soil Burn Severity

The degree to which fire affects soil properties, along with other controlling factors, is important for predicting the potential for increased runoff and sedimentation (Keeley 2009). Soil burn severity mapping reflects the spatial distribution of the fire’s effects on the ground surface and soil conditions, and is needed in order to rapidly assess fire effects, identify potential Values-at-Risk, and prioritize field assessment (Parsons et al. 2010). Initial soil burn severity was determined using a Landsat satellite imagery-derived Burned Area Reflectance Classification (BARC) map, followed by field verification work. (https://www.fs.fed.us/eng/rsac/baer/barc.html). There was some active fire and smoke in limited areas of the north and east portions of the fire that affected the burn severity values. The BARC map was produced by the USGS Earth Resources Observation and Science Center in Sioux Falls, SD.

The Glass Fire BARC map was field verified using methodology developed by Parsons et al. (2010). These methods included assessments of ground cover, fine root condition, soil structure alteration, ash color and depth, as well as soil hydrophobicity testing. Field verification occurred over two days at 18 sites. Soil structure was generally unaltered and fine roots in the surface inch were rarely consumed or heavily charred. In general, the WERT found that the BARC map overestimated soil burn severity and the thresholds for moderate and high soil burn severity were reduced for the final field verified map. Overall, the Glass Fire burned area is characterized by a high proportion of very low to low soil burn severity. Two (2) percent of the burned area was classified as high soil burn severity, 18 percent as moderate, 64 percent as low, and 16 percent as unburned/very low (Table 4, Figure 10). These values are very similar to those reported for the 2017 Nuns Fire, which had 81 percent low and unburned/very low soil burn severity. The soil burn severity map was finalized on October 17th and sent to the USGS for post-fire debris flow modeling. It was also used for the post-fire peak flow modeling, and the ERMiT surface erosion modeling.

Table 4. Glass Fire soil burn severity.

<table>
<thead>
<tr>
<th>Glass Fire Soil Burn Severity</th>
<th>Percent of the Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unburned/Very Low</td>
<td>16</td>
</tr>
<tr>
<td>Low</td>
<td>64</td>
</tr>
<tr>
<td>Moderate</td>
<td>18</td>
</tr>
<tr>
<td>High</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure 10. Soil burn severity map for the Glass Fire.
**Post-Fire Hydrology**

Nine watersheds, or “pour points”, were selected to estimate potential post-fire peak flow increases to Values-at-Risk from flooding and sediment-laden flood hazards (Figure 11). Not all watersheds in the burned area are modeled for post-fire peak flow. Pour point locations are selected based on field and office observations to better understand post-fire flood response in areas that may have higher flood hazards to life-safety, property, and infrastructure. Additional pour points can be modeled using the equations and methods in the 2020 WERT Draft Procedural Guide (CAL FIRE and CGS 2020). Due to modeling uncertainties, absolute changes in flow volumes or peak magnitude from the Glass Fire are not provided; rather an estimate of peak flow response is provided to make a more informed determination of flood hazards. Relative increases in peak flows from one drainage basin to another were judged to be most important for this rapid assessment, not estimated absolute values of the peak flows.

Pre-fire peak flow estimates were first produced for the nine pour point watersheds by using the North Coast USGS Regional Regression Equation for a range of recurrence interval discharges (USGS StreamStats; Gotvald et al. 2012). Post-fire estimates were generated using a flow modifier method (Foltz et al. 2009). The modifier assumes a 100% flow increase (doubling of flows) for high and moderate soil burn severity and no change for low and very low/unburned soil burn severity (Table 5). The modifier was then multiplied by a sediment bulking factor that is proportional to soil burn severity (Gusman 2011) to produce a combined flow modifier for that pour point watershed. The combined post-fire modifier was then multiplied by the pre-fire 2- and 10-year recurrence interval discharges and compared with a range of pre-fire flows using the USGS Regional Regression Equation (i.e., 2, 5, 10, 25, 50, 100, 200, 500 recurrence intervals) to determine the predicted recurrence interval during a post-fire storm event (Table 6). The Foltz et al. (2009) and Gusman (2011) methods are described in greater detail in the 2020 WERT Draft Procedural Guide.²

Generation of post-fire flow modifiers for the Glass Fire ranged from 1.1 to 2.0 (increase of 10% to 100%). The watersheds with the highest increases were Simmons Canyon and Santa Rosa Creek, with modifiers calculated at 2.0 for each (increase of 100%). These watersheds have the highest percentage of moderate and high soil burn severity at 48% and 47%, respectively (Table 5). It is estimated that a post-fire 10-year event in the Simmons Canyon and Santa Rosa Creek watersheds would be equivalent to a 100 to 200-year pre-fire peak flow. The watershed with the lowest increase is upper Sonoma Creek where it crosses Highway 12. The flow modifier was calculated at 1.1 (10% increase) for Sonoma Creek. The upper Sonoma Creek watershed has only 3% moderate and high soil burn severity and 66% of the watershed was burned at low or very low/unburned soil burn severity within the fire perimeter (an additional 31% of the watershed is outside the fire perimeter).

Predictions of post-fire flood recurrence interval should be viewed in a relative sense, as the predicted recurrence interval may be underestimated and/or overestimated due to the use of

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² Although the flood flow model used suggests low to moderate levels of risk, uncertainties within the models don’t preclude the threat of increased debris-laden floods and hyperconcentrated flows from impacting the built environment. This condition is pronounced during periods of high-intensity, short-duration (30 to 60 minute) storms that are not included in the post-fire hydrology model applied. Post-fire peak flows were correlated with rainfall intensity at Boggs Mountain Demonstration State Forest after the 2015 Valley Fire (Wagenbrenner et al. 2019).
the USGS Regional Regression Equations rather than local hydrologic analysis.\textsuperscript{3} In general, all post-fire peak flow predictions are subject to considerable uncertainty due the limited data available for post-fire hydrology at the watershed scale. These estimates are intended for emergency response planning purposes only and are not to be used for design. Moreover, they are most appropriately applied to flows within the first year following the fire, or until ground cover within the burned area is well established.

Table 5. Glass Fire pour point watershed and soil burn severity percentages.

<table>
<thead>
<tr>
<th>Pour Point No.</th>
<th>Pour Point Watershed Name</th>
<th>Drainage Area (acres)</th>
<th>Percent Burned</th>
<th>Low, Unburned/Very Low SBS (%)</th>
<th>Moderate SBS (%)</th>
<th>High SBS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sonoma Creek @ Hwy12</td>
<td>5,324</td>
<td>69.4</td>
<td>96.9</td>
<td>3.0</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>Santa Rosa Creek</td>
<td>7,997</td>
<td>99.6</td>
<td>52.6</td>
<td>39.9</td>
<td>7.5</td>
</tr>
<tr>
<td>3</td>
<td>Ducker Creek</td>
<td>358</td>
<td>96.5</td>
<td>86.1</td>
<td>13.4</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>Mark West Creek</td>
<td>5,480</td>
<td>98.4</td>
<td>60.6</td>
<td>32.5</td>
<td>6.9</td>
</tr>
<tr>
<td>5</td>
<td>Sulphur Creek</td>
<td>2,921</td>
<td>99.3</td>
<td>66.6</td>
<td>31.6</td>
<td>1.8</td>
</tr>
<tr>
<td>6</td>
<td>York Creek</td>
<td>1,724</td>
<td>99.9</td>
<td>80.6</td>
<td>18.5</td>
<td>0.9</td>
</tr>
<tr>
<td>7</td>
<td>Bell Creek</td>
<td>3,146</td>
<td>81.3</td>
<td>97.3</td>
<td>2.7</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>Dutch Henry Creek</td>
<td>1,965</td>
<td>99.9</td>
<td>76.3</td>
<td>23.5</td>
<td>0.2</td>
</tr>
<tr>
<td>9</td>
<td>Simmons Canyon</td>
<td>1,465</td>
<td>99.9</td>
<td>52.2</td>
<td>47.7</td>
<td>0.1</td>
</tr>
</tbody>
</table>

\textsuperscript{3} Detailed USACE HEC-HMS and HEC-RAS modeling previously conducted by the Sonoma County Water Agency for Santa Rosa Creek and Sonoma Creek can be used to supplement this rapid analysis.
Table 6. Estimated bulked post-fire flow multipliers and flow increases for the pour point watersheds.

<table>
<thead>
<tr>
<th>Pour Point No.</th>
<th>Pour Point Watershed Name</th>
<th>Post-Fire Modifier</th>
<th>Post-Fire Combined Bulked Modifier</th>
<th>Percent Flow Increase</th>
<th>Predicted 2-Year Recurrence Interval Flow</th>
<th>Predicted 10-Year Recurrence Interval Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sonoma Creek @ Hwy 12</td>
<td>1.0</td>
<td>1.1</td>
<td>10</td>
<td>2-5</td>
<td>10-25</td>
</tr>
<tr>
<td>2</td>
<td>Santa Rosa Creek</td>
<td>1.5</td>
<td>2.0</td>
<td>100</td>
<td>5-10</td>
<td>100-200</td>
</tr>
<tr>
<td>3</td>
<td>Ducker Creek</td>
<td>1.1</td>
<td>1.4</td>
<td>40</td>
<td>2-5</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>Mark West Creek</td>
<td>1.4</td>
<td>1.8</td>
<td>80</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>Sulphur Creek</td>
<td>1.3</td>
<td>1.7</td>
<td>70</td>
<td>2-5</td>
<td>50-100</td>
</tr>
<tr>
<td>6</td>
<td>York Creek</td>
<td>1.2</td>
<td>1.5</td>
<td>50</td>
<td>2-5</td>
<td>25-50</td>
</tr>
<tr>
<td>7</td>
<td>Bell Creek</td>
<td>1.0</td>
<td>1.2</td>
<td>20</td>
<td>2-5</td>
<td>10-25</td>
</tr>
<tr>
<td>8</td>
<td>Dutch Henry Creek</td>
<td>1.2</td>
<td>1.6</td>
<td>60</td>
<td>2-5</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>Simmons Canyon</td>
<td>1.5</td>
<td>2.0</td>
<td>100</td>
<td>5</td>
<td>100-200</td>
</tr>
</tbody>
</table>
Figure 11. Glass Fire pour point watersheds with soil burn severity categories.
USGS Post-Fire Debris Flow Combined Probability Model

The USGS post-fire debris flow hazard model estimates the likelihood, potential volume, and combined hazard of debris flows at both the drainage basin scale and along stream segments within each basin. The combined hazard reflects the potential likelihood of a debris flow occurring as well as the volumetric yield of the debris flow. This concept is illustrated in Figure 12, which shows how the likelihood of a debris flow and the predicted debris flow volume are used to assign an ordinal combined hazard ranking of either low, moderate, or high.

![Figure 12. The combined debris flow hazard classification as a function of predicted debris flow probability and debris volume production. Colors in yellow, orange, and red represent a combined debris flow hazard of low, moderate, and high, respectively.](https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html)

<table>
<thead>
<tr>
<th>Combined Hazard Matrix</th>
<th>Debris Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20%</td>
<td>Low</td>
</tr>
<tr>
<td>20-40%</td>
<td>Moderate</td>
</tr>
<tr>
<td>40-60%</td>
<td></td>
</tr>
<tr>
<td>60-80%</td>
<td></td>
</tr>
<tr>
<td>80-100%</td>
<td>High</td>
</tr>
</tbody>
</table>

The model estimates the 15-minute threshold rainfall intensity for triggering post-fire debris flows for the Glass Fire to be 38 mm hr⁻¹ (1.50 in hr⁻¹) at the basin scale. This threshold represents the median rainfall intensity at which there is a 50 percent probability of debris flow initiation. For reporting purposes, we utilized model outputs from a 15-minute rainfall intensity of 36 mm hr⁻¹ (1.42 in hr⁻¹) because model outputs for an intensity of 38 mm hr⁻¹ were not provided. For the Glass Fire, the 36 mm hr⁻¹ storm generally represents a 2-year to 5-year recurrence interval 15-minute storm event using NOAA Atlas 14 website (https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html) (see Table 3).

Figure 13 shows the estimated combined debris flow probability and volume hazard for the 36 mm hr⁻¹ (1.42 in hr⁻¹) storm. This map indicates that the combined debris flow hazard is primarily moderate to high for the selected rainfall intensity. The VAR maps in Appendix C show combined debris flow hazard in response to the 36 mm hr⁻¹ (1.42 in hr⁻¹) storm event.

The USGS post-fire debris flow hazard model (Staley et al. 2016) was employed for the Glass Fire to assist in the WERT’s assessment of locations where hazards to life and property may exist. This modeling defined the presence of 422 basins within the burned area. The debris flow model results indicate that with a 36 mm hr⁻¹ (1.42 in hr⁻¹) precipitation event, 197 of 422 basins (approximately 47 percent) have a likelihood of 40-60 percent or greater to produce debris flows. Based on the model, basins within the Mark West Creek, Santa Rosa Creek, Sulphur Creek, and Simmons Canyon have the highest probability of triggering a debris flow with a 15-minute rainfall intensity of 36 mm hr⁻¹.
For catchments burned in the Glass Fire, these results give an indication of potential post-fire watershed response. It is important to note that the USGS probability and volume models provide debris flow hazards results for a single precipitation event. However, an additional hazard to be considered is the coupled result from several small debris flow or sediment-laden runoff events that load channel networks, followed by one large intense precipitation event that mobilizes this sediment as a large debris flow. The USGS model results do not constitute a site-specific analysis of debris flow hazards. Additional on-the-ground evaluation should be conducted by qualified and licensed professionals where necessary and appropriate. The model results are also limited in that they do not show hazards for basins that are less than 0.02 km² (~5 acres) in area, and do not specifically identify hazards in areas where one or more tributaries may contribute flood and debris flows (watch segments). The hazards in burned areas that do not show a modeled result are therefore undefined by the model, but may be present. Similarly, for areas not shown as having a segment debris flow hazard associated with a drainage network, a hazard may still be present, yet undefined because the segment model results are limited based on the resolution of the input digital elevation model (DEM). Additionally, other hillslope processes such as rockfalls and debris slides are not included in the model results.

Post-Fire Surface Erosion and Water Quality Concerns

Pre-fire sedimentation rates were investigated using bathymetric data from Bell Canyon Reservoir (Appendix E, Photo 1). The Napa River Sediment Total Maximum Daily Load (TMDL) Technical Report (Napolitano et al. 2009) states that there was an average of 334 t/mi²/yr (0.5 t/ac/yr) of reservoir sedimentation from 1959 to 2001. This sedimentation rate is approximately half of Minear and Kondolf’s (2009) mean estimated sediment yield for reservoirs found in the California coastal region of 1.1 t/ac/yr.

Post-fire erosion rates for the Glass Fire area were estimated using the Erosion Risk Management Tool (ERMiT) (Robichaud et al. 2011). The ERMiT model predicts primarily low to moderate post-fire surface erosion rates for the 50-percent exceedance (2-year) probability storm event during the first wet season following the fire for the majority of the burned area (Figure 14). Localized high surface erosion rates generally consist of hillslopes with steeper slopes and/or areas burned at moderate to high soil burn severity.

Based on the ERMiT modeling, the estimated mean post-fire erosion rate is 5.2 t/ac for the first winter, assuming a 2-year storm event, and 9.7 t/ac assuming a 5-year storm (Table 7). Estimated mean erosion rates drop to 3.1 and 7.0 t/ac for 2- and 5-year storms the second winter. Based on the Bell Canyon Reservoir sedimentation rates, first year post-fire erosion rates for the Glass Fire burned area are estimated to be approximately an order of magnitude (10 times) higher than pre-fire rates.
Figure 13. USGS debris flow model results for the Glass Fire.
A post-fire sediment study conducted on Boggs Mountain Demonstration State Forest, approximately 20 miles to the north of the Glass Fire, following the 2015 Valley Fire provides monitoring data to compare to these estimates. Measured sediment rates the first winter were 0.3 t/ac for low soil burn severity, 0.9 t/ac for moderate soil burn severity, and 6.2 t/ac for high soil burn severity for first order catchments in volcanic-derived soils (Olsen 2016). Rates were higher the second year, but the relative differences between soil burn severities remained the same. For small plots (800 ft²) burned at high severity, a geometric mean of 6 t/ac was measured with a 2-year recurrence interval storm event, and rates were higher the second year with a 2 to 5-year RI recurrence interval (RI) maximum intensity storm (Cole et al. 2020). Based on these results, the ERMiT estimates for the Glass Fire seem reasonable.

Other post-fire studies in the California Coast Ranges also suggest a considerable level of increased sedimentation for watersheds burned at higher severities. For example, Ritter and Brown (1972) reported that sediment yields increased significantly in Williams Reservoir following a 1961 wildfire that burned in the Los Gatos Creek watershed. Warrick et al. (2015) state that average sediment yields can increase by an order of magnitude within watersheds the first year following a wildfire in the Santa Ynez Mountain region, located to the southern Coast Ranges.

Concerns regarding post-fire impacts to water quality and its effect on water treatment facilities are best addressed by further specific analysis by the responsible entity. Potential post-fire impacts to Bell Canyon Reservoir could include elevated sediment and debris loading and turbidity, and increased concentrations in nitrates, phosphates, organic carbon, and trace metals that could place an added demand on water treatment systems. Data from the 1981 Atlas Peak Fire and its effect on water quality on the Milliken Reservoir water system (Cohen 1982) found that turbidity increased by more than a factor of twenty (20) when discharge in upper Milliken Creek increased from approximately 100 to 700 cfs. Data from the thesis also indicated that turbidity in Milliken Reservoir and the reservoir outlet remained elevated, even after upper Milliken Creek turbidity recovered. This basic pattern was consistent for other water quality constituents, such as nitrate and nitrite (Cohen 1982). Due to the low level of moderate and high soil burn severity in the Bell Creek watershed, the water quality impacts to Bell Canyon Reservoir are expected to be lower than those documented in Milliken Reservoir.

More recently, Uzun et al. (2020) reported that the watersheds burned in the 2015 Rocky and Wragg fires (located to the north and south of the Glass Fire, respectively) showed rapid water quality degradation from elevated levels of turbidity, color, and suspended solids, with greater degradation in the more extensively burned watershed. During the first year’s initial flushes, concentrations of dissolved organic carbon (DOC), dissolved organic nitrogen (DON), ammonium (NH₄/NH₃), and specific ultraviolet absorbance (SUVA₂₅⁴) were significantly higher in the more extensively burned watershed compared to the reference watershed. These elevated values gradually declined and finally returned to levels similar to the reference watershed in the second year. Similar water quality impacts could occur for the more heavily burned watersheds in the Glass Fire.
<table>
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<th>5-Year RI Event, 1st year following fire</th>
<th>2-Year RI Event, 2nd year following fire</th>
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<td>30.5</td>
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* Based on Bell Canyon Reservoir sedimentation rates, first year post-fire erosion rates for the Glass Fire burned area are estimated to be approximately an order of magnitude (10 times) higher than pre-fire rates.
Figure 14. Glass Fire predicted surface erosion rates for the 2-year storm event using the Erosion Risk Management Tool (ERMiT).
4. VAR Area Observations and Recommendations

Potential Values-at-Risk (VARs) are grouped into four (4) areas defined by geographical communities, watershed boundaries, and facilities and critical infrastructure (Figure 15). General observations and recommendations for each of these areas are provided below. More detailed observations are provided in the VAR summary table (Appendix B) and VAR locations are displayed in Appendix C. VAR-specific maps and information are provided on information sheets in Appendix D. Furthermore, spatial data for VARs are available upon request.

This evaluation is not intended to be comprehensive and/or conclusive, and additional VARs may be identified through more detailed evaluation by responsible agencies. Several limitations include:

- Pre-existing flood hazard mapping (i.e., FEMA, DWR Awareness Floodplains) was not complete or non-existent in several areas.
- Roadway culverts and bridges in and adjacent to the burned area were generally not evaluated.
- Some potential VARs were not evaluated, or evaluated from a distance, because of the lack of access.
- Hazards on alluvial fans could not be represented as single-points given the potential for avulsion and flow-path uncertainty. Alluvial fan VARs are generally presented as polygons or included in FEMA and DWR floodplain and awareness zones. FEMA and DWR flood maps do not exist for all drainages or alluvial fans.
- VAR evaluation was not conducted within all mapped flood hazard areas that are downstream of the burn perimeter. Risk of flooding in these areas is pre-existing and is anticipated to be increased by post-fire runoff. As such, local agencies should consider these mapped hazard areas in addition to the VARs identified in this report.

This report serves as a preliminary tool to assist emergency responding agencies (e.g., Sonoma and Napa counties; Cities of Calistoga, St. Helena, and Santa Rosa; local fire departments; Caltrans; Office of Emergency Services; Sonoma Water; Napa County Flood Control and Water Conservation District, utility companies; and other responsible agencies) in the development of more detailed post-fire emergency response plans and assessments.

It is intended that the responsible agencies will use the information presented in this report as a preliminary guide to complete their own more detailed evaluations and develop detailed emergency response plans and mitigations. These agencies may identify additional VARs through their more detailed evaluations.
Figure 15. Boundaries used to define areas for more detailed descriptions of Values-at-Risk.
Observations

The area downslope of the Glass Fire burned area within Santa Rosa and Kenwood along State Route 12 (SR 12) and Calistoga Road between the Porter Creek and Sonoma Creek drainages is a source of potential hazards to downslope residents, property, and infrastructure. South, southeast and southwest-facing slopes within the burned area upstream of the developed areas are primarily burned at low soil burn severity, with sizeable patches of moderate and high soil burn severity along the ridges and in the headwaters of steep drainages. The three main catchments, Mark West Creek, Santa Rosa Creek, and Adobe Canyon (Sonoma Creek), and numerous small catchments drain the burned area to the west and southwest through residential, commercial, agricultural, and recreational development areas. All of the drainages are tributary to the Russian River, except Sonoma Creek which drains south to San Pablo Bay. Drainage infrastructure (culverts, bridges, stormwater drains/channels, basins) were observed at locations along the drainages adjacent to and upstream of residential and commercial developments. These structures are designed to convey floodwaters and reduce the potential for downstream flooding. Much of the residential development downslope of the burned area is located on alluvial deposits adjacent to the canyon mouth of the catchments or along narrow alluvial fans downslope. Many of the fan surfaces are graded and developed, making it difficult to discern the fan surfaces in the field. Developments within and downslope of the Russian River portion of the burn are accessed from SR 12 via Calistoga Road, St. Helena Road, Los Alamos Road, Adobe Canyon Road, and numerous local side streets.

Many of the residential, commercial, and agricultural developments are constructed on fluvial, alluvial fan, and alluvial terrace deposits and may experience a higher risk of flooding because of their location. Where extensive grading has occurred, the drainages disappear and reappear as they extend through the built environment on alluvial deposits. Review of LiDAR imagery shows what appear to be areas of shallow- and deep-seated landsliding throughout and downslope of the Russian River and Sonoma Creek burned area, which confirm active hillslope processes. These processes can provide material to stream channels that can be mobilized by subsequent flood flows, hyperconcentrated flows, and debris flows.

USGS debris flow modeling on the slopes within the Russian River and Sonoma Creek portion of the burned area indicates that 107 of 172 modeled drainage basins exhibit debris flow probabilities between 40 to 60-percent or greater (using a threshold of a 15-minute duration at 36 mm hr⁻¹ rainfall rate) within the burned portions of these drainages (Figure 13).

Portions of regional and state managed public parks, including Trione-Annadel State Park, Sugarloaf Ridge State Park and Hood Mountain Regional Park, are located within the Russian River and Sonoma Creek portion of the burned area. The parks contain low-lying day-use picnic areas, trails, infrastructure, and campgrounds (Sugarloaf Ridge SP) below and directly adjacent to steep burned drainages. Material observed within the channels, ranging from fine sediment to 1- to 5-foot diameter boulders, suggest the drainages may be subject to high flows during intense or large storm events. The steep slopes upstream of the parks were burned at generally very low to low soil burn severity, with patches of moderate soil burn severity near the ridgelines, suggesting that the drainages could experience higher flows than normal during large rain events, particularly Santa Rosa Creek (Appendix E, Photo 2). The burned catchments drain through the parks to residential, commercial and agricultural structures along the SR 12 corridor and numerous residential side streets.
picnic areas, and trails within the parks located low in the watershed or crossing steep burned drainages could pose a risk to public safety resulting from inundation by post-fire debris flows and flooding. Additionally, low-lying roads and trails that cross steep burned drainages that are susceptible to post-fire inundation may pose a risk to public safety when accessing the park infrastructure.

Portions of the residential and commercial developments downstream of the southwestern Glass Fire burned area, particularly along Calistoga Road, Sharp Road, St. Helena Road, Pythian Road, and Adobe Canyon Road and local side streets, are designated as Zone AE-Special Flood Hazard Areas by FEMA and as Awareness Floodplains by the California Department of Water Resources (DWR). Residences and structures located within these areas are subject to inundation by the 1-percent annual chance flood event. Commercial, residential, agricultural and recreational structures located within these areas may be subject to increased potential for inundation because of the post-fire soil effects of the moderate and high burn severity in the Porter Creek, Mark West Creek, Hood Creek, and Sonoma Creek watersheds. Residential, commercial, agricultural, and recreational areas at potential risk of localized flood and debris flows include, but are not limited to, rural portions of Santa Rosa, Kenwood, and residential and commercial developments along SR 12, Calistoga Road, St. Helena Road, Sharp Road, Pythian Road, Adobe Canyon Road, and connecting side streets. Flood flow along drainages within the Rincon Valley, Skyhawk, Melita, and Oakmont neighborhoods of Santa Rosa, including Santa Rosa Creek and Ducker Creek, is regulated by the Central Sonoma Watershed Project facilities, including flood control channels, flood-retarding structures and diversion structures, which have generally been adequate to address flood flows (Appendix E, Photo 3). The magnitude of the hillslope response will be increased by the post-fire changes to hydrology and soil properties. The potential for localized post-fire flood and debris flow hazards within these neighborhoods should be further evaluated.

Portions of the headwaters of the Santa Rosa Creek and Mark West watersheds were burned at moderate and high soil burn severity (Appendix E, Photo 4), suggesting flood flows within Santa Rosa Creek, Mark West Creek and tributary drainages may be significantly increased. What appear to be undersized, plugged, failing, and/or non-existing culverts observed at tributary crossings along Los Alamos Road and St. Helena Road may be overwhelmed by the increased flood flows and debris flows during large rain events limiting resident and emergency responder access. The crossings should be evaluated and mitigation measures developed to ensure that Los Alamos Road and St. Helena Road remain passable for Santa Rosa Creek and Mark West Creek residents and emergency responders.

Portions of the residential, commercial, and agricultural development downslope of the burned area are located on stream alluvium, stream terrace, and alluvial fan deposits within the catchments or along wide gently sloping alluvial fans downslope. Alluvial fans are gently sloping and convex radial depositional landforms located below the mouths of confined canyons. A channel avulsion is the process by which flow is diverted out of an established channel into a new course on the alluvial surface. Many of the fan surfaces observed within the Glass Fire boundary are graded and developed with vineyards, partly disguising the shape of the fan surfaces and making the evaluation of potential avulsion paths unpredictable. This includes areas outside of active channel network delineated by FEMA and DWR 100-year flood zones. Debris flows, hyperconcentrated flows, and flood flows originating in watersheds upslope of residential and agricultural areas can flow downslope across roads and through the communities to impact the low-lying residential, commercial,
and agricultural areas as sediment and debris-laden floods. Unmaintained drainage structures, including low bridges, culverts, debris basins, confined constructed channels and at-grade, low water road crossings, can become overwhelmed and trigger in-channel avulsion (i.e., the rapid shifting of channel location) and overbank flooding during storm events.

Residential communities and infrastructure observed downslope of the steep slopes and debris flow drainages were identified as Values-at-Risk (Appendix E, Photo 5). A total of 8 VARs (VARs 26 through 33) were found within and downslope of the southern burned area within and downstream of the Russian River and Sonoma Creek portion of the burned area, including polygons encompassing several individual structures and public park infrastructure. Generally, all of the VARs observed within and downslope of the southern burned area are identified as subject to moderate risk to public safety, and/or property, or both. The identified risk is due to the location of residential, commercial, agricultural, and recreational structures downstream of the mouths of debris and flood flow-prone catchments.

**Recommendations**

- Cleanout and maintain culverts, basins, drainage structures, and debris racks prior to, during, and after large rain events where they cross residential streets.
- Perform storm infrastructure monitoring during large rain events to ensure drainage structures and debris racks are functioning along commercial and residential roads, including but not limited to SR 12, Calistoga Road, St. Helena Road, Los Alamos Road, Adobe Canyon Road, and residential side streets.
- Utilize existing early warning systems, linked to up-to-date storm information. Since portions of Sonoma Water’s flood control infrastructure, including the Central Sonoma Watershed Project facilities, are located on low-lying alluvium below the mouths of steep drainages and emergency responder access may be limited, consider evacuation of crews and equipment from low-lying areas and confined debris flow drainages prior to predicted large rain events.
- Consider closure of public parks and campgrounds, particularly Trione-Annadel State Park, Sugarloaf Ridge State Park, and Hood Mountain Regional Park and low-lying public parks located within identified flood zones by FEMA, prior to and during predicted intense storms where they are located within or where trails cross flood prone areas, and at the base of steep canyons and steep side slopes that may be subject to hyperconcentrated or debris flows, floods and/or rockfall hazards.
- Evaluate the potential for installing stormwater control structures, including sandbags and/or concrete K-rails, along stream banks and around at-risk residences when high flood flows and debris flows are predicted along drainages.
- Consider the applicability of constructing diversion structures where debris and flood flow channels may adversely impact residential development or restrict residential access roads where flooding is anticipated during predicted high intensity rain events. Site specific mitigations and containment and diversion structures should be designed by licensed professionals specializing in geotechnical engineering, soil erosion, and engineering geology.
- Consider the use of appropriate professionals to review and design additional engineered mitigations not provided in this report.
• Consider signage for low-lying areas subject to flooding, and structures located within or below the mouths of burned steep drainages at risk from flood flows, hyperconcentrated flows, and debris flows.
• Consider signage in areas subject to rockfall, such as St. Helena Road, Los Alamos Road, and Adobe Canyon Road.

**Napa River-West Drainages**

*Observations*
The area downslope of the Glass Fire burned area within Calistoga and St. Helena along State Route 29 (SR 29) between the Nash Creek and Heath Canyon drainages is a source of potential hazards to downslope residents, property, and infrastructure. North, northeast and east-facing slopes within the burned area upstream of the developed areas are primarily burned at low soil burn severity, with patches of moderate and high soil burn severity along the ridges and in the headwaters of steep drainages. The four main catchments, Ritchie Creek, Mill Creek, York Creek, and Sulphur Creek, and numerous small catchments drain the burned area to the east and northeast through residential, commercial, agricultural, and recreational development areas. All of the drainages are tributary to the Napa River.

Drainage infrastructure (culverts, bridges, stormwater drains/channels, basins) were observed at locations along the drainages adjacent to and upstream of residential and commercial developments. These structures are designed to convey floodwaters and reduce the potential for downstream flooding. Much of the residential development downslope of the burned area is located on alluvial deposits adjacent to the canyon mouth of the catchments or along narrow alluvial fans downslope. Many of the fan surfaces are graded and developed, making it difficult to discern the fan surfaces in the field. Developments within and downslope of the Napa River-West portion of the burn are accessed from SR 29 via Spring Mountain Road, White Sulphur Springs Road, and numerous local side streets.

Many of the residential, commercial, and agricultural developments are constructed on fluvial, alluvial fan, and alluvial terrace deposits and may experience a higher risk of flooding because of their location. Where extensive grading has occurred, the drainages disappear and reappear as they extend through the built environment on alluvial deposits. Review of LiDAR imagery shows what appear to be areas of shallow- and deep-seated landsliding throughout and downslope of the Napa River-West burned area, which confirm active hillslope processes. These processes can provide material to stream channels that can be mobilized by subsequent flood flows, hyperconcentrated flows, and debris flows.

USGS debris flow modeling on the slopes within the Napa River-West portion of the burned area indicates that 34 of 66 modeled drainage basins exhibit debris flow probabilities between 40 to 60-percent or greater (using a threshold of a 15-minute duration at 36 mm hr\(^{-1}\) rainfall rate) within the burned portions of these drainages (Figure 13).

Bothe-Napa Valley State Park is located within and downslope of the Napa River-West portion of the burned area. The park contains low-lying day-use picnic areas, trails, infrastructure, and a campground (VAR 024) below and directly adjacent to Ritchie Creek and Mill Creek (Appendix E, Photo 6). Material observed within the channels, ranging from fine sediment to 1 to 3-foot diameter boulders, suggest the drainages may be subject to high flows during intense or large storm events. The steep slopes upstream of the park were burned at generally very low to low soil burn severity, with patches of moderate and high soil
burn severity along the northern ridgeline and in the Ritchie Creek headwaters, suggesting that the drainages could experience higher flows than normal during large rain events. The burned catchments drain through the park to residential, commercial, and agricultural structures along the SR 29 corridor to the confluence with the Napa River. Campground, picnic areas, and trails within the park located low in the watershed or crossing steep burned drainages could pose a risk to public safety resulting from inundation by post-fire debris flows and flooding. Additionally, low-lying roads and trails that cross steep burned drainages that are susceptible to post-fire inundation may pose a risk to public safety when accessing the park infrastructure. Historic infrastructure of the Bale Grist Mill State Historic Park is located within Bothe-Napa Valley State Park in the mouth of the Mill Creek drainage. The historic infrastructure is located along a terrace high above the active incised Mill Creek channel and likely not at risk.

Portions of the residential and commercial developments downstream of the southeastern Glass Fire burned area, particularly along State Route 29, White Sulphur Springs Road, Spring Mountain Road, Diamond Mountain Road, and local side streets, are designated as Zone A and AE-Special Flood Hazard Areas by FEMA and as Awareness Floodplains by DWR. Residences and structures located within these areas are subject to inundation by the 1-percent annual chance flood event. Commercial, residential, agricultural, and recreational structures located within these areas may be subject to increased potential for inundation because of the post-fire soil effects of the moderate and high burn severity in the Sulphur Creek, York Creek, Mill Creek, Ritchie Creek, and Kortum Canyon Creek watersheds. Residential, commercial agricultural and recreational areas at potential risk of localized flood and debris flows include, but are not limited to, portions of Calistoga, St. Helena, and residential, agricultural, and commercial developments along SR 29, White Sulphur Canyon Road, Spring Street, Palmer Drive, Spring Mountain Road, Diamond Mountain Road, Dean York Lane, Charter Oak Avenue, and connecting side streets. The magnitude of the hillslope response will be increased by the post-fire changes to hydrology and soil properties. The potential for localized post-fire flood and debris flow hazards within these neighborhoods should be further evaluated.

Portions of the residential, commercial, and agricultural development downslope of the burned area are located on stream alluvium, stream terrace, and alluvial fan deposits within the catchments or along wide gently sloping alluvial fans downslope. Alluvial fans are gently sloping and convex radial depositional landforms located below the mouths of confined canyons. A channel avulsion is the process by which flow is diverted out of an established channel into a new course on the alluvial surface. Many of the fan surfaces observed within and downstream of the Glass Fire boundary are graded and developed with vineyards, partly disguising the shape of the fan surfaces and making the evaluation of potential avulsion paths unpredictable. This includes areas outside of the active channel network delineated by FEMA and DWR 100-year flood zones. Debris flows, hyperconcentrated flows, and flood flows originating in watersheds upslope of residential and agricultural areas can flow downslope across roads and through the communities and impact the low-lying residential, commercial, and agricultural areas as sediment and debris laden floods. Unmaintained drainage structures, including low bridges, culverts, debris basins, confined constructed channels and at-grade, low water road crossings, can become overwhelmed and trigger in-channel avulsion (i.e., the rapid shifting of channel location) and overbank flooding during storm events.
Residential communities and infrastructure observed downslope of the steep slopes and debris flow drainages were identified as Values-at-Risk (Appendix E, Photos 7 and 8). A total of 11 VARs (VARs 15 through 25) were found along and below the northeast and east-facing slopes within and downstream of the Napa River-West portion of the burned area. This includes polygons encompassing several individual structures and public park infrastructure. Two VARs, observed as residential structures located downstream of the mouths of debris and flood flow-prone catchments within and downslope of the southern burned area, were identified as high risk to public safety (VAR 022), and/or property (VAR 020).

**Recommendations**

- Cleanout and maintain culverts, basins, drainage structures, and debris racks prior to, during, and after large rain events where they cross residential streets.
- Perform storm infrastructure monitoring during large rain events to ensure drainage structures and debris racks are functioning along commercial and residential roads, including but not limited to SR 29, Spring Street, Spring Mountain Road, Diamond Mountain Road, and residential side streets.
- Utilize existing early warning systems, linked to up-to-date storm information.
- Consider closure of public parks and campgrounds, particularly Bothe-Napa Valley State Park and low-lying public parks located within identified flood zones by FEMA, prior to and during predicted intense storms where they are located within or where trails cross flood prone areas, and at the base of steep canyons and steep side slopes that may be subject to hyperconcentrated or debris flows, floods, and/or rockfall hazards.
- Evaluate the potential for installing stormwater control structures, including sandbags and/or concrete K-rails, along stream banks and around at-risk residences where high flood flows and debris flows are predicted along drainages.
- Consider the necessity for constructed diversion structures where debris and flood flow channels may adversely impact residential development or restrict residential access roads. Site-specific mitigations, and containment and diversion structures, should be designed by licensed professionals specializing in geotechnical engineering, soil erosion, and engineering geology.
- Consider the use of appropriate professionals to review and design additional engineered mitigations not provided in this report.
- Consider signage for low-lying areas subject to flooding, and structures located within or below the mouths of burned steep drainages at risk of flood flows, hyperconcentrated flows, and debris flows.
- Consider signage in areas subject to rockfall, including Diamond Mountain Road, Spring Mountain Road, and White Sulfur Springs Road.

**Napa River-East Drainages**

**Observations**
The area downslope of the Glass Fire from Calistoga to St. Helena along State Route 29 (SR 29) and the Silverado Trail, and between the Garnett Creek drainage and Howell Mountain is a source of potential hazards to downslope residents, property, and infrastructure. Southwest-facing slopes within the burned area upstream of the developed areas are primarily burned at low soil burn severity, with patches of moderate and high soil burn severity along the ridges and in the headwaters of steep drainages (Appendix E, Photo 9),
particularly within Simmons Canyon and Dutch Henry Canyon. The five main catchments, Garnett Creek, Simmons Canyon, Dutch Henry Canyon, Biter Creek, and Canon Creek, and numerous small catchments drain the burned area to the southwest through residential, commercial, agricultural, and recreational development areas. All of the drainages are tributary to the Napa River. Drainage infrastructure (culverts, bridges, stormwater drains/channels, basins) were observed at locations along the drainages adjacent to and upstream of residential and commercial developments. These structures are designed to convey floodwaters and reduce the potential for downstream flooding. Much of the residential development downslope of the burned area is located on alluvial deposits adjacent to the canyon mouth of the catchments or along narrow alluvial fans downslope. Many of the fan surfaces are graded and developed, making them difficult to discern in the field (Appendix E, Photo 10). Developments within and downslope of the Napa River-East portion of the burn are accessed from SR 29 via Silverado Trail, Pickett Road, Deer Park Road, Glass Mountain Road, Howell Mountain Road, and numerous local side streets.

Many of the residential, commercial and agricultural developments are constructed on fluvial, alluvial fan, and alluvial terrace deposits and may experience a higher risk of flooding because of their location. Where extensive grading has occurred, the drainages disappear and reappear as they extend through the built environment on alluvial deposits. Review of LiDAR imagery shows what appear to be areas of shallow- and deep-seated landsliding throughout and downslope of the Napa River-East burned area, particularly the northwestern portion, which confirm active hillslope processes. These processes can provide material to stream channels that can be mobilized by subsequent flood flows, hyperconcentrated flows, and debris flows.

USGS debris flow modeling on the slopes within the Napa River-East portion of the burned area indicates that 40 of 131 modeled drainage basins exhibit debris flow probabilities between 40 to 60-percent or greater (using a threshold of a 15-minute duration at 36 mm hr\(^{-1}\) rainfall rate) within the burned portions of these drainages (Figure 13).

Portions of Robert Louis Stevenson State Park are located within the Napa River-East part of the burned area. Much of the park within the Glass Fire burned area contains trails along Table Rock and the Palisades, a northwest-southeast trending ridgeline upstream of Garnett Creek, Garnett Creek-East Fork, and Hoisting Works Canyon, and is likely not at significant risk. The Oat Hill Trail, within the southern extent of Robert Louis Stevenson State Park, appears to cross steep burned south and southwest-draining catchments that drain to Calistoga. Material observed within the channels, ranging from fine sediment to moderately sized boulders, suggest the drainages may be subject to high flows during intense or large storm events. The steep slopes crossed by the Oat Hill Trail were burned at generally very low to low soil burn severity, with patches of moderate and high soil burn severity, suggesting that the drainages could experience higher flows than normal during large rain events. The burned catchments drain through the park to residential, commercial, and agricultural structures along State Route 29 and Silverado Trail to the confluence with the Napa River. The trails within the park located low in the watershed or crossing steep burned drainages could pose a risk to public safety due to inundation by post-fire debris flows and flooding.

Critical infrastructure, including Bell Canyon Reservoir (Appendix E, Photo 1), St. Helena Hospital, sewage treatment ponds in Pratt Valley, and the Cedar Flat Landfill, are located within the Glass Fire burned area. The Cedar Flat Landfill and St. Helena Hospital are elevated along ridgelines in a manner that does not appear to be at risk of inundation from
post-fire flood flows. Bell Canyon Reservoir was formed by the damming of Bell Creek at the mouth of Bell Canyon. The resulting lake supplies water to residents in the City of St. Helena. Bell Canyon and short modeled debris flow drainages drain to the reservoir from the north and east. A large portion of the Bell Canyon Reservoir watershed is burned (Appendix E, Photo 11). Based on the low to very low soil burn severities within the headwaters, it is likely that Bell Canyon Reservoir will experience only minor increased flows during large rain events (Table 6), but water quality impacts may still occur. Material observed near the inlet of the structure generally appears fine-grained, suggesting that larger material drops out and the area is more likely to experience hyperconcentrated and sediment laden flood flows than debris flows. The Pratt Valley sewage treatment facility is located downstream of Bell Canyon Reservoir at the confluence of Bell Creek and Canon Creek. Flow along Bell Creek is mostly regulated by the Bell Canyon Reservoir approximately 1.5-miles upstream and is not expected to significantly increase as a result of the burn. Based on the low and moderate soil burn severities mapped within the Canon Creek watershed, it appears the potential exists for increased flood flows during large rain events. Further evaluation of the sewage treatment ponds is warranted.

A portion of State Route 29 (SR 29) is located along the northwestern Glass Fire boundary. While the majority of the highway alignment is setback or located upslope of the burned area, a short segment just south of Robert Louis Stevenson State Park appears to be located below locally steep, south-facing burned slopes. Although generally low soil burn severities are mapped upslope of SR 29, patches of moderate and high soil burn severity observed upslope of SR 29 suggest the potential exists for increased flood flows at highway crossings. Fractured bedrock exposed in the SR 29 cut bank and rock fragments observed along the inner edge of SR 29 suggest that rockfall onto the road running surface is a preexisting hazard and may be exacerbated by the loss of vegetation and increased runoff along the burned slopes.

Portions of the residential and commercial developments downstream of the Napa River-East section of the Glass Fire burned area, particularly along State Route 29, Silverado Trail, Palisades Road, Pickett Road, Larkmead Road, Glass Mountain Road, Crystal Springs Road, Deer Park Road, and local side streets, are designated as Zone A and AE-Special Flood Hazard Areas by FEMA and as Awareness Floodplains by DWR. Residences and structures located within these areas are subject to inundation by the 1-percent annual chance flood event. Commercial, residential, agricultural, and recreational structures located within these areas may be subject to increased potential for inundation due to moderate and high burn severity in the Garnett Creek, East Fork Garnett Creek, Simmons Canyon, Dutch Henry Canyon (Appendix E, Photo 12), and Canon Creek watersheds. Residential, commercial, agricultural, and recreational areas at potential risk of localized flood and debris flows include, but are not limited to, portions of Calistoga, St. Helena, and residential, agricultural, and commercial developments along SR 29, Silverado Trail, Palisades Road, Pickett Road, Larkmead Road, Glass Mountain Road, Crystal Springs Road, Deer Park Road, and connecting side streets. The magnitude of the hillslope response will be increased by the post-fire changes to hydrology and soil properties. The potential for localized post-fire flood and debris flow hazards within these neighborhoods should be further evaluated.

Portions of the residential, commercial, and agricultural development downslope of the burned area are located on stream alluvium, stream terrace, and alluvial fan deposits within the catchments or along wide gently sloping alluvial fans downslope. Alluvial fans are gently
sloping and convex radial depositional landforms located below the mouths of confined canyons. A channel avulsion is the process by which flow is diverted out of an established channel into a new course on the alluvial surface. Many of the fan surfaces observed within and downstream of the Glass Fire boundary are graded and developed with vineyards, partly disguising the shape of the fan surfaces and making the evaluation of potential avulsion paths unpredictable. This includes areas outside of the active channel network delineated by FEMA and DWR 100-year flood zones. Debris flows and hyperconcentrated flows originating in watersheds upslope of residential and agricultural areas can flow downslope across roads and through the communities to impact low-lying residential, commercial, and agricultural areas as sediment and debris-laden floods. Unmaintained drainage structures, including low bridges, culverts, debris basins, confined constructed channels and at-grade, low-water road crossings, can become overwhelmed and trigger in-channel avulsion (i.e., the rapid shifting of channel location) and overbank flooding during storm events.

Residential communities and infrastructure observed downslope of the steep slopes and debris flow drainages were identified as Values-at-Risk (Appendix E, Photos 13 and 14). A total of 14 VARs (VARs 1 through 14) were found along and below of the southwest-facing slopes within and downstream of the Napa River-East portion of the burned area, including polygons encompassing several individual structures and public park infrastructure. One VAR, observed as residential structures located downstream of the mouth of a debris and flood flow-prone catchment within and downslope of the Glass Fire burned area, was identified as high risk to life-safety and property (VAR 003).

**Recommendations**

- Cleanout and maintain culverts, basins, drainage structures, and debris racks prior to, during, and after large rain events where they cross residential streets.
- Perform storm infrastructure monitoring during large rain events to ensure drainage structures and debris racks are functioning along commercial and residential roads, including but not limited to SR 29, Silverado Trail, Glass Mountain Road, Deer Park Road, and residential side streets.
- Utilize existing early warning systems, linked to current storm information. Since some critical infrastructure, including the Platt Valley sewage treatment ponds, are located on low-lying alluvium below the mouths of steep drainages, and emergency responder access may be limited, consider evacuation of crews and equipment from low-lying areas and confined debris flow drainages prior to predicted large rain events.
- Consider closure of public parks, particularly the Oat Hill Trail in Robert Louis Stevenson State Park, and low-lying public parks located within identified flood zones by FEMA, prior to predicted intense storms where they are located within or where trails cross flood prone areas, as well as along and at the base of steep canyons and steep side slopes that may be subject to hyperconcentrated or debris flows, floods, and/or rockfall hazards.
- Evaluate the potential for installing stormwater control structures, including sandbags and/or concrete K-rails, along stream banks and around at-risk residences when high flood flows and debris flows are predicted along drainages.
- Consider the necessity for constructed diversion structures where debris and flood flow channels may adversely impact residential development or restrict residential access roads during predicted high intensity rain events. Site-specific mitigations and
containment and diversion structures should be designed by licensed professionals specializing in geotechnical engineering, soil erosion, and engineering geology.

- Consider the use of appropriate professionals to review and design additional engineered mitigations not provided in this report.
- Consider signage for low-lying areas subject to flooding, and structures located within or below the mouths of burned steep drainages at risk from flood flows, hyperconcentrated flows, and debris flows.
- Consider signage in areas subject to rockfall, including State Route 29 and the Silverado Trail.

**Putah Creek Drainages**

**Observations**

The area downslope of the Glass Fire along Pope Valley Road and Aetna Springs Road, and between the James Creek drainage and Howell Mountain is a source of potential hazards to downslope residents, property, and infrastructure. North, southeast and northeast-facing slopes within the burned area upstream of the developed areas are primarily burned at low soil burn severity, with patches of moderate and high soil burn severity along the ridges and in the headwaters of steep drainages. The two main catchments, Van Ness Creek and Swartz Creek (Appendix E, Photo 15), and numerous small catchments drain the burned area to the north, southeast, and northeast through residential and agricultural development areas. All of the drainages are tributary to Putah Creek, except Conn Creek which drains south to Lake Hennessey and ultimately the Napa River. Approximately 260-acres of the 7,296-acre Conn Creek watershed (planning watershed #2206.500305) are located within the Glass Fire boundary.\(^4\) Drainage infrastructure (culverts, bridges, stormwater drains/channels, basins, inside ditches) were observed at locations along the drainages adjacent to and upstream of residential, commercial, and agricultural developments. These structures are designed to convey floodwaters and reduce the potential for downstream flooding. Much of the residential development downslope of the burned area is located on alluvial deposits adjacent to the canyon mouth of the catchments or along narrow alluvial fans downslope. Many of the fan surfaces are graded and developed, making them difficult to discern in the field. Developments within and downslope of the Putah Creek portion of the burn are accessed from SR 29 via Deer Park Road, Pickett Road, Howell Mountain Road, Pope Valley Road, and numerous local side streets.

Residential, commercial, and agricultural developments located within Pope Valley downstream of the Glass Fire burned area are constructed on fluvial, alluvial fan, and alluvial terrace deposits and may experience a higher risk of flooding because of their location. Where extensive grading has occurred, the drainages disappear and reappear as they extend through the built environment on alluvial deposits. Review of LiDAR imagery shows what appear to be areas of shallow- and deep-seated landsliding throughout and downslope of the Putah Creek burned area, which confirm active hillslope processes. These processes can provide material to stream channels that can be mobilized by subsequent flood flows, hyperconcentrated flows, and debris flows.

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\(^4\) Impacts to Lake Hennessey from the 2020 Hennessey Fire are expected to be minimal, since less than 30 percent of the watershed upstream of the reservoir was burned, and the Conn Creek watershed was unburned in that fire (WERT 2020).
USGS debris flow modeling on the slopes within the Putah Creek drainages portion of the burned area indicates that 12 of 43 modeled drainage basins exhibit debris flow probabilities between 40 to 60-percent or greater (using a threshold of a 15-minute duration at 36 mm hr$^{-1}$ rainfall rate) within the burned portions of these drainages (Figure 13).

The Friesen Lakes consist of several dammed water supply reservoirs within the Conn Creek drainage, including Lake Henne, Lake Orville, and Lake Newton, that provide drinking water to the Town of Angwin. Critical water supply infrastructure, including tanks, piping, and associated structures, was observed in aerial photography. Several of the lakes are within the eastern Glass Fire boundary and are located downstream of several small drainages. The headwaters of the water supply reservoirs generally burned at low soil burn severity, suggesting significant post-fire increases in flood flows into the lakes is not likely. However, sediment and debris may negatively impact water quality in these reservoirs.

The historic Aetna Mining District is a series of former mercury and manganese mines located downstream of the northeastern Glass Fire burned area, within an area recently burned by the Hennessey Fire. Operations within the mining district are located upslope of James Creek, a tributary to Pope Creek. Pope Creek drains to Lake Berryessa, which provides drinking water to residents in Solano and Napa counties. Mining operations are no longer ongoing, but tailings, equipment, and open adits remain. According to information provided by Napa County, methylmercury levels in Lake Berryessa have resulted in state warnings recommending limits of fish consumption. Increased runoff associated with the low and moderate soil burn severities observed within the headwaters of Bateman Creek and Cedar Canyon, both tributaries to James Creek, may result in higher flows within the James Creek watershed, potentially increasing runoff and inundating low-lying mine areas during large rain events. This could result in greater potential for delivery of mercury and other mining-related metals to Lake Berryessa.

Portions of the residential, agricultural, and commercial developments downstream of the Putah Creek section of the Glass Fire burned area, particularly along SR 29, Pope Valley Road, Aetna Springs Road, Butts Canyon Road, and local side streets, are designated as Zone A-Special Flood Hazard Areas by FEMA and as Awareness Floodplains by DWR. Residences and structures located within these areas are subject to inundation by the 1-percent annual chance flood event. Commercial, residential, agricultural, and recreational structures located within these areas may be subject to increased potential for inundation because of the post-fire soil effects of the moderate and high burn severity in the Swartz Creek, Bateman Creek, and Van Ness Creek watersheds. Residential, commercial, and agricultural areas at potential risk of localized flood and debris flows include, but are not limited to, rural portions of Napa County within Pope Valley, and residential, agricultural, and commercial developments along SR 29, Aetna Springs Road, Pope Valley Road, Butts Canyon Road, and connecting side streets. The magnitude of the hillslope response will be increased by the post-fire changes to hydrology and soil properties. The potential for localized post-fire flood and debris flow hazards within these neighborhoods should be further evaluated.

Residential, commercial, and agricultural development within Pope Valley downslope of the burned area are located on stream alluvium, stream terrace, and alluvial fan deposits within the catchments or along wide gently sloping alluvial fans downslope. Alluvial fans are gently sloping and convex radial depositional landforms located below the mouths of confined canyons. A channel avulsion is the process by which flow is diverted out of an established
channel into a new course on the alluvial surface. Many of the fan surfaces observed within and downstream of the Glass Fire boundary are graded and developed with vineyards, partly disguising the shape of the fan surfaces and making the evaluation of potential avulsion paths unpredictable. This includes areas outside of the active channel network delineated by FEMA and DWR 100-year flood zones. Debris flows and hyperconcentrated flows originating in watersheds upslope of residential and agricultural areas can flow downslope across roads and through the communities and impact the low-lying residential, commercial, and agricultural areas as sediment and debris laden floods. Unmaintained drainage structures, including low bridges, culverts, debris basins, confined constructed channels and at-grade, low water road crossings, can become overwhelmed and trigger in-channel avulsion (i.e., the rapid shifting of channel location) and overbank flooding during storm events.

No Values-at-Risk were identified within and downslope of the Putah Creek burned area; however, structures located within or near mapped DWR Awareness Floodplains and FEMA Special Flood Hazard Areas may be at increased flood risk. Given the generally low soil burn severities in the Putah Creek burned area, though, we anticipate relatively low increases to rockfall and post-fire flood flows due to the fire.

**Recommendations**

- Cleanout and maintain culverts, basins, drainage structures, and debris racks prior to, during, and after large rain events where they cross residential streets.
- Perform storm infrastructure monitoring during large rain events to ensure drainage structures and debris racks are functioning along commercial and residential roads, including but not limited to SR 29, Aetna Springs Road, Pope Valley Road, Butts Canyon Road, Ink Grade Road, and residential side streets.
- Utilize existing early warning systems, linked to up-to-date storm information. Residents of structures located within and directly adjacent to delineated FEMA Flood Zones and DWR Awareness Floodplains should be notified prior to large rain events to expect an increased potential for inundation, including along SR 29, Aetna Springs Road, Pope Valley Road, Butts Canyon Road, and local side streets.
- Evaluate the potential for installing stormwater control structures, including sandbags and/or concrete K-rails, along stream banks and around at-risk residences when high flood flows and debris flows are predicted along drainages.
- Consider the necessity for constructed diversion structures where debris and flood flow channels may adversely impact residential development or restrict residential access roads during predicted high intensity rain events. Site specific mitigations and containment and diversion structures should be designed by licensed professionals specializing in geotechnical engineering, soil erosion, and engineering geology.
- Consider the use of appropriate professionals to review and design additional engineered mitigations not provided in this report.
- Evaluate potential mitigation measures at historic mining sites within the Aetna Mining District to minimize the potential for increased post-fire flows to inundate the mine areas and deliver sediment and contaminants to James Creek.
- Consider signage for low-lying areas subject to flooding, and structures located within or below the mouths of burned steep drainages at risk from hyperconcentrated flows and debris flows.
- Consider signage in areas subject to rockfall, including Aetna Springs Road.
5. General Recommendations

Early Warning Systems

Existing early warning systems should be used and improved such that residents can be alerted to incoming storms, allowing enough time to safely vacate hazard areas. In areas where cellular reception is poor or non-existent, methods should be developed to effectively contact residents. For example, installation of temporary mobile cellular towers should be considered. Early warning systems should take advantage of the following services:

Emergency alert notification systems for Napa and Sonoma counties are found at the following websites:

Napa County:
https://www.countyofnapa.org/2481/Emergency-Alerts

Sonoma County:
https://socoemergency.org/emergency/current-socoalerts/

National Weather Service Forecasting

Flash flood and debris flow warnings with practical lead times of several hours must come from a combination of weather forecasts, rainfall measurements of approaching storms, and knowledge of triggering thresholds. The following information is from the National Weather Service (NWS); they provide flash flood and post-fire debris flow “watch” and “warning” notifications in burned areas:

The NWS provides 24/7 information on watches, warnings and advisories for California. For additional information, see:

NWS – San Francisco Bay Area Forecast Office: https://www.weather.gov/mtr/

NWS - Post-wildfire flash flood and debris flow guide:

Nixle

Nixle is a community information service dedicated to helping residents stay connected with alerts and advisories from local law enforcement and all agencies within an affected zip code. Resident can sign up by texting their zip code to 888777, or by signing up online at:
https://local.nixle.com/accounts/login/

General information regarding Nixle is found at:
https://www.nixle.com/

Wireless Emergency Alerts (WEA)

WEA is an alert system originated by the NWS that can inform residents and businesses of flash flood warnings and other potential hazards. WEA alerts are emergency messages sent by authorized government alerting authorities through mobile carriers. Government partners include local and state public safety agencies, FEMA, the FCC, the Department of Homeland
Security, and the National Weather Service. No signup is required, and alerts are automatically sent to WEA-capable phones during an emergency. Residents and businesses interested in this function must turn on the emergency alert setting for their phone.

https://www.weather.gov/wrn/wea

Emergency Alert System (EAS)

EAS is a national public warning system that may also be used by state and local authorities to delivery important emergency information, such as weather information, to targeted specific areas.

https://www.fcc.gov/emergency-alert-system

Integrated Public Alert and Warning System (IPAWS)

IPAWs is a FEMA-originated system that integrates federal, state, and local emergency warning systems (e.g., WEA, EAS) into a single interface.

https://www.fema.gov/integrated-public-alert-warning-system

Education for Residents, Park Personnel, Businesses and the General Public

The following information should be conveyed to residents, park personnel, businesses, and the general public that can be affected by post-fire runoff and erosion associated within the Glass Fire: First and foremost, it is critical that residents heed evacuation warnings from local officials. In the absence of an official notice, residents should pay attention to evolving conditions around their homes.

Suzanne Perry, disaster scientist from the USGS, suggests the following talking points:

- Be ready for debris flows for 2-5 years after a wildfire. Don’t worry about every storm, as it takes more intense rain (typically about ½ inch per hour – like being in a thunderstorm) on a recently burned slope to trigger a debris flow.
- Follow all evacuation orders. Debris flows can destroy everything in their path.
- Pay attention to official weather forecasts. The National Weather Service will issue a Flash Flood “Watch” or “Warning” for your area when rainfall is anticipated to be intense. Also – and this is important - the rain back in the mountains can be different than where you are. It’s the rain in the mountains that will start the debris flow.
- Don’t rely on what you’ve seen in past floods or debris flows. Debris flows and floods can hit new areas or return to previous areas; they might be smaller - or larger - the next time. Whatever happened before, the next time could be different.
- If you must shelter in place, choose your spot in advance and stay alert. Find the highest point nearby (such as a 2nd story or roof) and be ready to get there with a moment’s notice. Listen and watch for rushing water, mud, unusual sounds. Survivors describe sounds of cracking, breaking, roaring, or a freight train.
- Never underestimate a debris flow. Unlike other landslides, debris flows can start in places they’ve never been before. They can leave stream channels and plow through neighborhoods. When a debris flow is small, people can control it with walls, K-rails, and sandbags. When a debris flow is big enough, nothing can stop it.
• Expect other flood dangers. Storms that can cause debris flows can also cause more common flooding dangers.
• Turn Around, Don’t Drown!® Never drive, walk, or bicycle through a flooded road or path. Even a few inches of water can hide currents that can sweep you away. Also, the water level can rise before you finish crossing.

For an easy to understand summary of what a debris flow is see Geology.com, What is a Debris Flow.

Debris Basins

Clean (if necessary), monitor, and maintain all debris basins downstream of burned areas. Particular emphasis should be placed on monitoring and maintaining debris basins upstream of residential and commercial developments.

Burned Debris, Structures, Vehicles, Temporary and Replacement Housing

Before burned structures are replaced with temporary housing or rebuilt they should be specifically evaluated for site-specific post-fire hazards such as rockfall, flooding, debris flow, and excessive sedimentation. These evaluations should be conducted by qualified licensed professionals, such as licensed civil/geotechnical engineers and licensed geologists.

Increased Flood Flows, Erosion and Sedimentation

Estimated hydrologic response for watersheds of concern (i.e., pour points) indicate that a 2-year recurrence interval storm could potentially cause a flood flow up to that of the 5- to 10-year event (Table 6). Post-fire erosion modeling predicts that erosion, and therefore sedimentation, rates will be low to moderate following the wildfire, but more than in unburned conditions. Depending on the size of the storm event, sedimentation in some portions of the burned area may be increased through bulking or erosional response from debris flow processes. Therefore, emergency actions, maintenance, and storm response activities should be developed with these conditions in mind.

Stormwater Control

It is expected that runoff from the burned area will contain chemical contaminants, in addition to ash and fire-related sediment and debris, that may pose adverse environmental impacts (Uzun et al. 2020). Additional study of potential impacts to downstream receptors, including Bell Canyon Reservoir, should be considered to ensure that stormwater and/or treatment systems are equipped to address potential fire-derived sediment, ash, and chemical contaminants. Additional study should include the monitoring of stream flow and sedimentation rates within the burned drainages prior to, during and after large rain events to
evaluate post-fire impacts to water quality and promote the development of appropriate mitigation measures.\(^5\)

**Hazardous Trees**

Burned and damaged trees may be present adjacent to homes, infrastructure, and roadways, and should be felled to ensure safety of residents, workers, and the traveling public. Considerable road right-of-way tree felling was actively occurring during the WERT’s field inspections.

**Debris Flow Runout**

No tools are currently available to rapidly predict post-fire debris flow runout. WERT geologists rely partially on geomorphic evidence to estimate the downstream extent of debris flow inundation. However, many of the at-risk sites are within built environments where geomorphic evidence has been altered or destroyed through grading and/or construction. Also, geomorphic evidence may not be sufficient to predict the downstream extent of debris flows under these post-fire conditions. In areas below large, severely burned drainages (e.g., Santa Rosa Creek and tributaries), the areal extent of debris flow inundation is highly uncertain. The WERT strongly recommends more detailed analysis to further refine the identification of downstream debris flow inundation areas.

**Increased Rockfall**

Rockfall hazards were identified during field evaluations, particularly along Adobe Canyon Road.\(^6\) However, due to the rapid nature of the evaluation, a comprehensive evaluation of rockfall hazard was not possible. DeGraff and Gallegos (2012) provide an overview of rockfall hazard following wildfire, along with suggested approaches for identifying these hazards. The WERT strongly recommends more detailed analysis to further refine the identification of rockfall hazard areas.

**Road Drainage Systems, Storm Monitoring, and Storm Maintenance**

The residential and business communities within and downstream of the burned area are serviced via a network of roads and highways. Caltrans, Napa and Sonoma counties, and various cities and municipalities maintain numerous roads within and downstream of the burned area. Due to observed moderate and high soil burn severities in some locations, increased flows on slopes and onto the road system and into storm drain systems can be expected (e.g., Los Alamos Road in Sonoma County). Loose and erodible soils that mantle the slopes could wash down, inundate, and plug these drainage systems. Flows could be diverted down roads and cause erosion and possible blockage, and/or loss of portions of the

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6 A CAL FIRE vehicle was damaged by rockfall along Adobe Canyon Road during fire suppression for the Glass Fire.
road infrastructure and structures along roads. The WERT did not evaluate the potential for rockfall, sedimentation, flooding or debris flow hazards at all roads or watercourse crossings along federal, state, county, municipal or private roads. Additionally, not all burned plastic culverts were inventoried by the WERT. Existing road drainage systems should be inspected by the appropriate controlling agency to evaluate potential impacts from floods, hyperconcentrated floods, debris torrents, debris flows, and sedimentation resulting from storm events. Spatial data generated by the USGS, and the WERT (e.g., USGS debris flow model, ERMiT erosion model, and flood flow predictions) can be used to screen potential at-risk areas.

**Storm Drains**

Storm drains will be subject to increased flooding, sediment, and debris. In addition, flooding below debris flow prone areas is difficult, if not impossible to predict. It was beyond the scope of this evaluation to examine every storm drain. The WERT recommends further evaluation of the storm drain systems so that appropriate protective measures are put into place.

**Signage**

Temporary signage should be placed in areas of potential post-fire rockfall and flooding hazards. Place signage along roads, bridges, and other types of crossings identified at risk of flooding, rockfalls and debris flows. The WERT suggests responsible agencies consider installing gates, warning signs, or other measures to alert and keep people out of areas of identified risk.

**Regional Parks, Campgrounds, and Trailer Parks**

There are public parks, campgrounds, day use areas and open space areas located within and downstream of the Glass Fire burned area that may be at risk from post-fire debris flows and flooding. Not all of the public areas were visited during our review due to time and access constraints. All of the public areas, including, but not limited to Trione-Annadel State Park, Sugarloaf Ridge State Park, Hood Mountain Regional Park, Bothe-Napa Valley State Park, and Robert Lewis Stephenson State Park, appear to contain structures and/or infrastructure that are low-lying or located along steep slopes, and below the mouths of steep debris flow drainages. Further evaluation of the public recreation areas should be undertaken to evaluate the increased potential for hazards to public safety and property from increased rockfall, debris flows, hyperconcentrated flows, and flooding. Additionally, until the level of increased risk can be determined, recreational areas that are low-lying or located below the mouths of steep debris flow canyons should be closed prior to and during predicted large rain events.

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7 The City of Santa Rosa has already installed weighted straw wattles above storm drains subject to post-fire storm runoff.
6. Acknowledgements

We thank Dr. Dennis Staley, Jaime Kostelnik, and Dr. Jason Kean with the USGS Landslide Hazards Program, who provided the debris flow modeling and provided insight into appropriate rainfall thresholds for the burned areas. We express our appreciation to Shana Jones, CAL FIRE Sonoma-Lake-Napa Unit Chief; Jay Jasperse and Carlos Diaz, Sonoma Water; John Kessel, Sonoma County; and Patrick Ryan, Napa County, for their assistance with this evaluation. A list of contacts is provided in Appendix A.

7. References


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Santa Rosa SCD (Soil Conservation District) and Sonoma County FCWCD (Flood Control and Water Conservation District). 1958. Central Sonoma watershed work plan. Sonoma County, CA. 93 p. plus maps and drawings.


Wills, C.J., Perez, F.G., and Gutierrez, C.I., 2011; Susceptibility to Deep-Seated Landslides in California: California Geological Survey, Map Sheet 58, landslide inventory available online at https://maps.conservation.ca.gov/cgs/lsl/app/
## APPENDIX A: GLASS FIRE CONTACTS

<table>
<thead>
<tr>
<th>Name</th>
<th>Agency</th>
<th>email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
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APPENDIX B: VALUES-AT-RISK TABLE
## Glass Fire

### Values-at-Risk Table

<table>
<thead>
<tr>
<th>Site</th>
<th>Community / Local area</th>
<th>Potential hazard to life</th>
<th>Potential hazard to property</th>
<th>Potential hazard / Field observation</th>
<th>Hazard Category</th>
<th>Specific at-risk feature</th>
<th>Feature Category</th>
<th>Preliminary EMP</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLS-001</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>moderate</td>
<td>Houses built on fan near confluence of two drainages.</td>
<td>debris flow / flood</td>
<td>Houses</td>
<td>home</td>
<td>Early Warning</td>
<td></td>
<td></td>
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<tr>
<td>GLS-002</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>moderate</td>
<td>House built within axis of drainage. Drainage appears to be slightly diverted and confined. Resident (geologist) says channel produces 100 cfs.</td>
<td>debris flow / flood</td>
<td>House and barn</td>
<td>home</td>
<td>Early Warning</td>
<td>38.60030</td>
<td>-122.58282</td>
</tr>
<tr>
<td>GLS-003</td>
<td>Napa River-East</td>
<td>high</td>
<td>high</td>
<td>House built within mouth of drainage. Watercourse appears diverted slightly around house.</td>
<td>debris flow / flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning</td>
<td>38.59168</td>
<td>-122.56903</td>
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<tr>
<td>GLS-004</td>
<td>Napa River-East</td>
<td>low</td>
<td>moderate</td>
<td>Winery structure within mouth of drainage.</td>
<td>debris flow / flood</td>
<td>Winery structure</td>
<td>business</td>
<td>Early Warning; Close the structure and restrict access during predicted large rain events</td>
<td></td>
<td></td>
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<tr>
<td>GLS-005</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>moderate</td>
<td>Winery structures within mouth of drainage</td>
<td>debris flow / flood</td>
<td>Winery structures</td>
<td>business</td>
<td>Early Warning; Close access to structures during predicted large rain events</td>
<td>38.57547</td>
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<td>GLS-006</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>low</td>
<td>Burned out plastic culvert. Appears to extend at least 30-feet under Silverado Trail (highly travelled public road).</td>
<td>other</td>
<td>Public road</td>
<td>drainage structure</td>
<td>Clear and maintain culvert; Evaluate mitigation measures including culvert replacement</td>
<td>38.57647</td>
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<td>GLS-007</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>low</td>
<td>Burned house and trailer within mouth of drainage.</td>
<td>debris flow / flood</td>
<td>House and trailer</td>
<td>home</td>
<td>Early Warning; Consider moving trailer prior to predicted large rain events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-008</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>low</td>
<td>Burned winery structure on fan below mouth of drainage.</td>
<td>debris flow / flood</td>
<td>Winery structure</td>
<td>business</td>
<td>Early Warning; Consider closing winery during predicted large rain events</td>
<td>38.57708</td>
<td>-122.52570</td>
</tr>
<tr>
<td>GLS-009</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>low</td>
<td>Burned resort structures/cabins within mouth of drainage. Drainage is directed under building via culvert.</td>
<td>debris flow / flood</td>
<td>Burned resort structures/ca bins</td>
<td>recreational</td>
<td>Early Warning; Consider closing this section of the resort during predicted large rain events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-010</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>low</td>
<td>Burned resort structures along low terrace. Overflow and levee for pond above is scoured. Bedrock is exposed at several locations. Channel and chute are full of large boulders. Numerous burned structures appear low-lying downstream.</td>
<td>debris flow / flood</td>
<td>Burned resort structures</td>
<td>recreational</td>
<td>Early Warning; Consider closing this section of the resort; Evaluate structural integrity of pond and levee; Evaluate location of existing structures downstream</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site</td>
<td>Community / Local area</td>
<td>Potential hazard to life</td>
<td>Potential hazard to property</td>
<td>Potential hazard / Field observation</td>
<td>Hazard Category</td>
<td>Specific at-risk feature</td>
<td>Feature Category</td>
<td>Preliminary EMP</td>
<td>Latitude</td>
<td>Longitude</td>
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</tr>
<tr>
<td>GLS-01</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>moderate</td>
<td>Burned house built within mouth of drainage. Channel is diverted around house, loose earthen levee is constructed upstream of the house. Levee appears inadequate to contain large flow.</td>
<td>debris flow / flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning; Evaluate the existing levee</td>
<td>38.57499</td>
<td>-122.51666</td>
</tr>
<tr>
<td>GLS-02</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>moderate</td>
<td>Houses and inn structures within mouth of drainage. Drainage is shallow and constrained between the houses.</td>
<td>debris flow / flood</td>
<td>Houses and inn structures</td>
<td>multiple</td>
<td>Early Warning; Close inn during predicted large rain events; Consider evacuation of house during predicted high intensity rain events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-03</td>
<td>Napa River-East</td>
<td>moderate</td>
<td>moderate</td>
<td>Houses built at mouth of drainage. Road is built in drainage. Drainage is diverted into small constructed channel. A large flow would likely overwhelm diversion.</td>
<td>debris flow / flood</td>
<td>House and barn/garage</td>
<td>home</td>
<td>Early Warning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-04</td>
<td>Napa River-East</td>
<td>low</td>
<td>moderate</td>
<td>Winery structure built in mouth of drainage. Drainage is modified and constricted. Winery manager says channel was full during large rain event 2 years prior.</td>
<td>debris flow / flood</td>
<td>Winery structure</td>
<td>business</td>
<td>Early Warning; Close structure during predicted large rain events</td>
<td>38.51719</td>
<td>-122.45526</td>
</tr>
<tr>
<td>GLS-05</td>
<td>Napa River-West</td>
<td>low</td>
<td>moderate</td>
<td>House built on island bar terrace above creek. Evidence of shallow landsliding upstream. Earthen levee along upper edge of terrace. Terrace is armored and check dams in creek suggest active erosive processes. House built in potential overflow channel.</td>
<td>debris flow / flood</td>
<td>House and grounds</td>
<td>home</td>
<td>Early Warning; Evaluate existing levee</td>
<td>38.49006</td>
<td>-122.50703</td>
</tr>
<tr>
<td>GLS-06</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>moderate</td>
<td>Resort structures built low near drainage. At least 3 tributaries enter drainage at resort. Channel past resort is modified, diverted and confined.</td>
<td>debris flow / flood</td>
<td>Resort structures</td>
<td>business</td>
<td>Early Warning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-07</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>moderate</td>
<td>House built on pad in channel.</td>
<td>debris flow / flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning</td>
<td>38.48977</td>
<td>-122.49385</td>
</tr>
<tr>
<td>GLS-08</td>
<td>Napa River-West</td>
<td>low</td>
<td>moderate</td>
<td>House built below diverted and confined drainage. Homeowner says creek has overtopped in the past. Lived there 57 years. Neighbors have placed sandbags to protect structure.</td>
<td>flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning; Sandbags</td>
<td>38.50410</td>
<td>-122.48814</td>
</tr>
<tr>
<td>GLS-09</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>moderate</td>
<td>House built low adjacent to creek. Neighbor says big flows have been a problem. Culvert under driveway is likely avulsion point</td>
<td>debris flow / flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning</td>
<td>38.52474</td>
<td>-122.50068</td>
</tr>
</tbody>
</table>
## Glass Fire
### Values-at-Risk Table

<table>
<thead>
<tr>
<th>Site</th>
<th>Community / Local area</th>
<th>Potential hazard to life</th>
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<th>Potential hazard / Field observation</th>
<th>Hazard Category</th>
<th>Specific at-risk feature</th>
<th>Feature Category</th>
<th>Preliminary EMP</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLS-020</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>high</td>
<td>Modular homes within drainage. Creek is directed into small drop inlet and under playground and houses. Resident says house has flooded before.</td>
<td>debris flow / flood</td>
<td>Houses and playground</td>
<td>home</td>
<td>Early Warning; Close playground during predicted large rain events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-021</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>moderate</td>
<td>Winery cabin and adjacent neighbors house are built adjacent to drainage. Cabin appears to be inhabited. Drainage is diverted at picnic area above winery structures. Boulders in channel. Cabin and house are low lying.</td>
<td>debris flow / flood</td>
<td>House and cabin</td>
<td>home</td>
<td>Early Warning; Consider closing picnic area above winery structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-022</td>
<td>Napa River-West</td>
<td>high</td>
<td>moderate</td>
<td>Houses at mouth of drainage on fan. Channel is diverted, constricted and becomes smaller/shallower near houses. Undersized culvert at diversion is possible avulsion point. Channel is full of rocks, fallen trees, vegetation. Residents say it has overtopped</td>
<td>debris flow / flood</td>
<td>Houses</td>
<td>home</td>
<td>Early Warning; Clear and maintain channel of debris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-023</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>low</td>
<td>Burned houses built at confluence of two drainages. Houses are low lying. Channel is modified. Potential for trailer placement.</td>
<td>debris flow / flood</td>
<td>Burned houses</td>
<td>home</td>
<td>Early Warning; Placement of temporary housing (trailers) should be evaluated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-024</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>low</td>
<td>Campground and trails adjacent to large drainage. Small drainage through campground.</td>
<td>debris flow / flood</td>
<td>Campground structure and trails</td>
<td>recreational</td>
<td>Early Warning; Consider closing campground and trails during predicted large rain events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-025</td>
<td>Napa River-West</td>
<td>moderate</td>
<td>moderate</td>
<td>Houses built adjacent to drainage. Houses are low lying. Boulders in creek. Watershed is large and burned moderate to high SBS.</td>
<td>debris flow / flood</td>
<td>Houses</td>
<td>home</td>
<td>Early Warning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLS-026</td>
<td>Russian River</td>
<td>moderate</td>
<td>moderate</td>
<td>House built in drainage.</td>
<td>debris flow / flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning</td>
<td>38.52166</td>
<td>-122.59652</td>
</tr>
<tr>
<td>GLS-027</td>
<td>Russian River</td>
<td>moderate</td>
<td>low</td>
<td>Burned house within mouth of drainage. St Helena road crosses drainage above via small (36&quot;) culvert. Culvert inlet is inset and appears inadequate to receive high flow. Potential to cross road to house. Spot on house pad for temporary trailer.</td>
<td>debris flow / flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning; Clear and maintain culvert</td>
<td>38.51931</td>
<td>-122.60884</td>
</tr>
</tbody>
</table>
## Glass Fire
### Values-at-Risk Table

<table>
<thead>
<tr>
<th>Site</th>
<th>Community / Local area</th>
<th>Potential hazard to life</th>
<th>Potential hazard to property</th>
<th>Potential hazard / Field observation</th>
<th>Hazard Category</th>
<th>Specific at-risk feature</th>
<th>Feature Category</th>
<th>Preliminary EMP</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLS-028</td>
<td>Russian River</td>
<td>low</td>
<td>moderate</td>
<td>Private road crossing of Ducker Creek, 60 inch plastic pipe burned completely, potential for scour and fill collapse. Average of 5 feet of fill above pipe. Channel appears active. Within 150 feet of a public road.</td>
<td>flood</td>
<td>Road</td>
<td>drainage structure</td>
<td>Clear and maintain culvert; Replace culvert</td>
<td>38.48251</td>
<td>-122.65187</td>
</tr>
<tr>
<td>GLS-029</td>
<td>Russian River</td>
<td>moderate</td>
<td>moderate</td>
<td>Houses built on low terrace in Santa Rosa Creek. Large boulders in creek, but gradient is low. Potential flooding issue.</td>
<td>flood</td>
<td>Houses</td>
<td>home</td>
<td>Early Warning; Deflection structure; Any potential diversion structures should be evaluated by licensed professional</td>
<td>38.45544</td>
<td>-122.61970</td>
</tr>
<tr>
<td>GLS-030</td>
<td>Russian River</td>
<td>low</td>
<td>moderate</td>
<td>House built low adjacent to channel. Homeowner says channel has overtopped in the past.</td>
<td>flood</td>
<td>House</td>
<td>home</td>
<td>Early Warning; Sandbags</td>
<td>38.45544</td>
<td>-122.61970</td>
</tr>
<tr>
<td>GLS-031</td>
<td>Russian River</td>
<td>low</td>
<td>moderate</td>
<td>Houses built on low lying fan. Evidence of debris flows in channel upstream.</td>
<td>flood</td>
<td>Houses</td>
<td>home</td>
<td>Early Warning</td>
<td>38.45544</td>
<td>-122.61970</td>
</tr>
<tr>
<td>GLS-032</td>
<td>Russian River</td>
<td>low</td>
<td>moderate</td>
<td>Houses built low adjacent to drainage. Box culvert between houses is partially plugged. Debris at the top of the crossing suggests large flows in the channel.</td>
<td>flood</td>
<td>Houses</td>
<td>home</td>
<td>Early Warning; Sandbags</td>
<td>38.45544</td>
<td>-122.61970</td>
</tr>
<tr>
<td>GLS-033</td>
<td>Russian River</td>
<td>moderate</td>
<td>moderate</td>
<td>Houses built low along Sonoma Creek and in the mouths of tributaries. VARs were identified after the Nuns Fire in 2017. Glass Fire soil burn severity is lower than the Nuns Fire.</td>
<td>debris flow / flood</td>
<td>Houses</td>
<td>home</td>
<td>Early Warning</td>
<td>38.45544</td>
<td>-122.61970</td>
</tr>
</tbody>
</table>

### General Recommendations (see discussion in report)

1. Utilize early warning systems available to residents:
   - Use Napa and Sonoma county-recommended emergency alert notification systems.
2. Develop emergency response and evacuation plans based on the identified hazards.
3. Monitor and maintain road drainage and storm drain infrastructure.
4. Utilize temporary flood control and structure protection (sandbags, K-rails) where appropriate.
5. Place temporary signage and consider road closure in areas of potential post-fire flooding, debris flow, and rockfall hazards.
6. Consider conducting more hydrologic evaluations of potential impacts to water supply reservoirs, including Bell Canyon Reservoir.
7. Evaluate temporary housing sites for site-specific hazards including debris flow, flooding, and rockfall.
8. Until more detailed evaluations are conducted, close recreational areas (i.e., campgrounds, parks, trails) that are low-lying or located below the mouths of steep debris flow canyons prior to and during predicted large rain events.
APPENDIX C: VAR MAPS
Incident: CA-LNU-015947 Glass Fire

Value at Risk (Point)
Potential hazard to life
- Low
- Moderate
- High

Value at Risk (Polygon)
Potential hazard to life
- Low
- Moderate
- High

Segment Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Basin Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Legend:
- USGS Watchstream
- FEMA/DWR Floodplain
- Fire Perimeters

Scale: 1:26,000

Date Saved: 10/28/2020 12:36 PM
Incident: CA-LNU-015947 Glass Fire

Value at Risk (Point)
Potential hazard to life
- Low
- Moderate
- High

Value at Risk (Polygon)
Potential hazard to life
- Low
- Moderate
- High

Segment Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Basin Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Legend:
- USGS Watchstream
- FEMA/DWR Floodplain
- Fire Perimeters

Date Saved: 10/28/2020 12:36 PM
Scale: 1:26,000
Incident: CA-LNU-015947 Glass Fire

Value at Risk (Point)  
Potential hazard to life
- Low
- Moderate
- High

Value at Risk (Polygon)  
Potential hazard to life
- Low
- Moderate
- High

Segment Combined Hazard  
15 min 36 mm/hr  
- Low
- Moderate
- High

Basin Combined Hazard  
15 min 36 mm/hr  
- Low
- Moderate
- High

Legend:
- USGS Watchstream
- FEMA/DWR Floodplain
- Fire Perimeters

Scale: 1:26,000

Date Saved: 10/28/2020 12:36 PM
Incident: CA-LNU-015947 Glass Fire

Value at Risk (Point)
Potential hazard to life
- Low
- Moderate
- High

Values at Risk (Polygon)
Potential hazard to life
- Low
- Moderate
- High

Segment Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Basin Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Date Saved: 10/28/2020 12:36 PM
Incident: CA-LNU-015947 Glass Fire

Value at Risk (Point)
Potential hazard to life
- Low
- Moderate
- High

Values at Risk (Polygon)
Potential hazard to life
- Low
- Moderate
- High

Segment Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Basin Combined Hazard
15 min 36 mm/hr
- Low
- Moderate
- High

Legend:
- USGS Watchstream
- FEMA/DWR Floodplain
- Fire Perimeters

Scale: 1:26,000

Date Saved: 10/28/2020 12:36 PM
APPENDIX D: VAR SITE INFORMATION SHEETS
**Incident: Glass Fire**  
*Incident Number: CA-LNU-015947*

**Community:** Napa River east  
**Site Number:** GLS-001  
**Feature:** Houses  
**Feature Category:** home

**Field Observation or Potential Hazard:** Houses built on fan near confluence of two drainages

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** NA  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

*Map showing values at risk, potential hazard, and emergency measures.*

*Photo of the area affected by the incident.*

*Scale: 1:8,000*
**Incident: Glass Fire**

*Community:* Napa River east  
*Site Number:* GLS-002  
*Feature:* House and barn  
*Feature Category:* home

**Field Observation or Potential Hazard:**
House built within axis of drainage. Drainage appears to be slightly diverted and confined. Resident (geologist) says channel produces 100 cfs

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** Early Warning  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA  
**Preliminary Emergency Protective Measures (4):** NA

**Location and Photo**

*Latitude:* 38.6003  
*Longitude:* -122.582824
**Location and Photo**

- **Incident**: Glass Fire
- **Incident Number**: CA-LNU-015947
- **Community**: Napa River east
- **Site Number**: GLS-003
- **Feature**: House
  - **Feature Category**: home

**Field Observation or Potential Hazard**: House built within mouth of drainage. Watercourse appears diverted slightly around house.

**Potential Hazard to Life**: high

**Potential Hazard to Property**: high

**Preliminary Emergency Protective Measures (1)**: Early Warning

**Preliminary Emergency Protective Measures (2)**: NA

**Preliminary Emergency Protective Measures (3)**: NA

**Preliminary Emergency Protective Measures (4)**: NA

**Description**: NA

---

**Location and Photo**

- **Latitude**: 38.591676
- **Longitude**: -122.569033

![Map and Photo](image-url)
Incident: Glass Fire  Incident Number: CA-LNU-015947

Community: Napa River east
Site Number: GLS-004
Feature: Winery structure
Feature Category: business

Field Observation: Winery Structure within mouth of drainage

Potential Hazard to Life: low  Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): NA
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA

Description: NA
**Incident:** Glass Fire  
**Incident Number:** CA-LNU-015947

**Community:** Napa River east  
**Site Number:** GLS-005  
**Feature:** Winery structures  
**Feature Category:** business

**Field Observation:** Winery structures within mouth of drainage

---

**Value at Risk**

- **Latitude:** 38.575474  
- **Longitude:** -122.549434

---

**LOCATION AND PHOTO**

---

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** Early Warning

**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA  
**Preliminary Emergency Protective Measures (4):** NA

**Description:** Close access to structures during predicted large rain events
**Incident: Glass Fire**

**Community:** Napa River east

**Site Number:** GLS-006

**Feature:** public road

**Feature Category:** drainage structure

**Field Observation or Potential Hazard:** Burned out plastic culvert. Appears to extend approximately 30-feet under Silverado Trail (highly travelled public road)

**Potential Hazard to Life:** moderate

**Potential Hazard to Property:** low

**Preliminary Emergency Protective Measures (1):** Clear and maintain culvert

**Preliminary Emergency Protective Measures (2):** NA

**Preliminary Emergency Protective Measures (3):** NA

**Preliminary Emergency Protective Measures (4):** NA

**Description:** Evaluate mitigation measures including culvert replacement

---

**LOCATION AND PHOTO**

[Map and photo of the location with markers for value at risk, combined hazard, and fire perimeter.]

**Latitude:** 38.576467  
**Longitude:** -122.540293
Incident: Glass Fire

Community: Napa River east
Site Number: GLS-007
Feature: House and trailer
Feature Category: home

Field Observation: Burned house and trailer within mouth of drainage.

Potential Hazard to Life: moderate
Potential Hazard to Property: low

Preliminary Emergency Protective Measures (1): NA
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA

Description: NA

LOCATION AND PHOTO
**Incident: Glass Fire**

**Incident Number:** CA-LNU-015947

**Community:** Napa River east

**Site Number:** GLS-008

**Feature:** Winery structure

**Feature Category:** business

**Field Observation:** Burned winery structure on fan below mouth of drainage

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** low

**Preliminary Emergency Protective Measures (1):** Early Warning

**Preliminary Emergency Protective Measures (2):** NA

**Preliminary Emergency Protective Measures (3):** NA

**Preliminary Emergency Protective Measures (4):** NA

**Description:** Consider closing winery during predicted large rain events

---

**LOCATION AND PHOTO**

![Map and Photo](image-url)

**Latitude:** 38.577082  
**Longitude:** -122.525695
**Incident: Glass Fire**

**Incident Number:** CA-LNU-015947

**Community:** Napa River east

**Site Number:** GLS-009

**Feature:** Burned resort structures/cabins

**Feature Category:** recreational

**Field Observation or Potential Hazard:** Burned resort structures/cabins within mouth of drainage. Drainage is directed under building via culvert.

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** low

**Preliminary Emergency Protective Measures (1):** NA  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

---

[Map and photo showing the location and value at risk polygons]
**Incident: Glass Fire**  
**Incident Number: CA-LNU-015947**

**Community:** Napa River east  
**Site Number:** GLS-010  
**Feature:** Burned resort structures  
**Feature Category:** recreational

**Field Observation or Potential Hazard:** Burned resort structures along low terrace. Overflow and levee for pond above is scoured. Bedrock is exposed at several locations. Channel and chute are full of large boulders. Numerous burned structures appear low-lying downstream.

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** low

**Preliminary Emergency Protective Measures (1):** NA  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

**LOCATION AND PHOTO**

![Map and photo of the area affected by the Glass Fire incident.](image-url)
**Incident: Glass Fire**  
**Incident Number:** CA-LNU-015947

**Community:** Napa River east  
**Site Number:** GLS-011  
**Feature:** House  
**Feature Category:** home

**Field Observation or Potential Hazard:** Burned house built within mouth of drainage. Channel is diverted around house, loose earthen levee is constructed upstream of the house. Levee appears inadequate to contain large flow.

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** Early Warning  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA  
**Preliminary Emergency Protective Measures (4):** NA

**Description:** Evaluate the existing levee

---

**LOCATION AND PHOTO**

![Map and Photo](image-url)
**Incident: Glass Fire**  
*Incident Number: CA-LNU-015947*

**Community:** Napa River east  
**Site Number:** GLS-012  
**Feature:** Houses and Inn structures  
**Feature Category:** multiple

**Field Observation or Potential Hazard:** Houses and inn structures within mouth of drainage. Drainage is shallow and constrained between the houses.

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** NA  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

![Map and photo of the incident area](image-url)

- Value at Risk (Point)  
- Values at Risk (Polygon)  
- Values at Risk (Polygon) (Focused)  
- Fire Perimeter  
- FEMA/DWR Floodplain  
- Segment Combined Hazard  
  - 15 min 36 mm/hr  
  - Low  
  - Moderate  
  - High

Scale: 1:1,000
**Incident: Glass Fire**

**Incident Number:** CA-LNU-015947

**Community:** Napa River east

**Site Number:** GLS-013

**Feature:** House and barn/garage

**Feature Category:** home

**Field Observation or Potential Hazard:** Houses built at mouth of drainage. Road is built in drainage. Drainage is diverted in small constructed channel. A large flow would overwhelm.

**Potential Hazard to Life:** moderate

**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** NA

**Preliminary Emergency Protective Measures (2):** NA

**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

[Map and image of the incident area]
Incident: Glass Fire

Community: Napa River east
Site Number: GLS-014
Feature: Winery structure
Feature Category: business

Field Observation or Potential Hazard:
Winery structure built in mouth of drainage. Drainage is modified and constricted. Winery manager says channel was full during large rain event 2 years prior.

Potential Hazard to Life: low
Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): Early Warning
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA
Preliminary Emergency Protective Measures (4): NA

Description: Close structure during predicted large rain events.

LOCATION AND PHOTO

Latitude: 38.517194  Longitude: -122.455258
Incident: Glass Fire

Community: Napa River west

Site Number: GLS-015

Feature: House and grounds

Feature Category: home

Field Observation or Potential Hazard: House built on island bar terrace above creek. Two drainages above evidence shallow landsliding. Earthen levee along upper edge of terrace. Terrace is armored and check dams in creek suggest active erosive processes. House built in potential overflow ch

Potential Hazard to Life: low
Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): Early Warning
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA
Preliminary Emergency Protective Measures (4): NA

Description: Consider Evaluating levee

Latitude: 38.490062
Longitude: -122.507032
Incident: Glass Fire  Incident Number: CA-LNU-015947

Community: Napa River west  Site Number: GLS-016
Feature: Resort structures  Feature Category: business

Field Observation or Potential Hazard: Resort structures built low near drainage. At least 3 tributaries enter drainage at resort. Channel past resort is modified, diverted and confined.

Potential Hazard to Life: moderate  Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): NA
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA

Description: NA

LOCATION AND PHOTO

[Map and photo of the location and photo of the incident]
Incident: Glass Fire

Community: Napa River west
Site Number: GLS-017
Feature: House
Feature Category: home
Field Observation: House built on pad in channel.

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): Early Warning
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA
Preliminary Emergency Protective Measures (4): NA
Description: NA

LOCATION AND PHOTO

Latitude: 38.489775    Longitude: -122.493849
**Incident: Glass Fire**

*Community:* Napa River west

*Site Number:* GLS-018

*Feature:* House

*Feature Category:* home

*Field Observation or Potential Hazard:* House built below diverted and confined drainage. Homeowner says creek has overtopped in the past. Lived there 57 years. Neighbors placed sandbags.

*Potential Hazard to Life:* low

*Potential Hazard to Property:* moderate

**Preliminary Emergency Protective Measures (1):** Early Warning

**Preliminary Emergency Protective Measures (2):** Sandbags

**Preliminary Emergency Protective Measures (3):** NA

**Preliminary Emergency Protective Measures (4):** NA

*Description:* NA

---

**LOCATION AND PHOTO**

![Map and Photo](image-url)
**Incident: Glass Fire**  
**Incident Number:** CA-LNU-015947

**Community:** Napa River west  
**Site Number:** GLS-019  
**Feature:** House  
**Feature Category:** home

**Field Observation or Potential Hazard:** House built low adjacent to creek. Neighbor says big flows have been a problem. Culvert under driveway is likely avulsion point

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** Early Warning  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA  
**Preliminary Emergency Protective Measures (4):** NA  
**Description:** NA

---

**LOCATION AND PHOTO**

- **Latitude:** 38.52474  
- **Longitude:** -122.500679

---

**Value at Risk (Point)**  
**Value at Risk (Point) (Focused)**  
**Values at Risk (Polygon)**  
**Fire Perimeter**

**Segment Combined Hazard**
- 15 min 36 mm/hr
  - Low
  - Moderate
  - High

**FEMA/DWR Floodplain**
Incident: Glass Fire  
Incident Number: CA-LNU-015947

Community: Napa River west
Site Number: GLS-020
Feature: Houses and playground
Feature Category: home

Field Observation or Potential Hazard: Modular homes within drainage. Creek is directed into small drop inlet and under playground and houses. Resident says house has flooded before.

Potential Hazard to Life: moderate  
Potential Hazard to Property: high

Preliminary Emergency Protective Measures (1): NA
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA

Description: NA

LOCATION AND PHOTO
Incident: Glass Fire

Community: Napa River west

Site Number: GLS-021

Feature: House and cabin

Feature Category: home

Field Observation or Potential Hazard:
Winery cabin and adjacent neighbors house are built adjacent to drainage. Cabin appears to be inhabited. Drainage is diverted at picnic area above winery structures. Boulders in channel. Cabin and house are low lying.

Potential Hazard to Life: moderate

Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): NA

Preliminary Emergency Protective Measures (2): NA

Preliminary Emergency Protective Measures (3): NA

Description: NA

LOCATION AND PHOTO

Scale: 1:1,000
Incident: Glass Fire  
Incident Number: CA-LNU-015947

Community: Napa River west
Site Number: GLS-022
Feature: Houses
Feature Category: home

Field Observation or Potential Hazard: Houses at mouth of drainage on fan. Channel is diverted, constricted and becomes smaller/shallower near houses. Undersized culvert at diversion is possible avulsion point. Channel is full of rocks, fallen trees and vegetation. Resident says has overtopped

Potential Hazard to Life: high  
Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): NA
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA
Description: NA

LOCATION AND PHOTO
**Incident: Glass Fire**  
**Incident Number: CA-LNU-015947**

**Community:** Napa River west  
**Site Number:** GLS-023  
**Feature:** Burned houses  
**Feature Category:** home

*Field Observation or Potential Hazard:* Burned houses built at confluence of two drainages. Houses are low lying. Channel is modified. Potential for trailer placement.

**Potential Hazard to Life:** moderate  
**Potential Hazard to Property:** low

**Preliminary Emergency Protective Measures (1):** NA  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

![Map and photo of the incident location]
Incident: Glass Fire  
Incident Number: CA-LNU-015947

Community: Napa River west
Site Number: GLS-024
Feature: Campground structure and trails
Feature Category: recreational

Field Observation or Potential Hazard: Campground and trails adjacent to large drainage. Small drainage through campground.

Potential Hazard to Life: moderate  
Potential Hazard to Property: low

Preliminary Emergency Protective Measures (1): NA
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA

Description: NA
Incident: Glass Fire

Community: Napa River west

Site Number: GLS-025

Feature: Houses

Field Observation or Potential Hazard: Houses built adjacent to drainage. Houses are low lying. Boulders in creek. Watershed is large and burned moderate to high sbs.

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): NA
Preliminary Emergency Protective Measures (2): NA
Preliminary Emergency Protective Measures (3): NA

Description: NA

LOCATION AND PHOTO
**Incident:** Glass Fire  
**Incident Number:** CA-LNU-015947  

**Community:** Russian River & Sonoma Creek  
**Site Number:** GLS-026  
**Feature:** House  
**Feature Category:** home  
**Field Observation:** House built in drainage

<table>
<thead>
<tr>
<th>Potential Hazard to Life:</th>
<th>Potential Hazard to Property:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>moderate</strong></td>
<td><strong>moderate</strong></td>
</tr>
</tbody>
</table>

**Early Warning**

**Preliminary Emergency Protective Measures (1):** Early Warning

**Preliminary Emergency Protective Measures (2):** NA

**Preliminary Emergency Protective Measures (3):** NA

**Preliminary Emergency Protective Measures (4):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

- **Latitude:** 38.521661  
- **Longitude:** -122.59652

Map showing the location and risk values with various symbols and colors indicating floodplains, hazard segments, and risk levels.
Incident: Glass Fire  
Incident Number: CA-LNU-015947

Community: Russian River & Sonoma Creek  
Site Number: GLS-027  
Feature: House  
Feature Category: home

Field Observation or Potential Hazard: Burned house within mouth of drainage. St ahekena road crosses drainage above via small (36”?) culvert. Culvert inlet is set down and appears difficult to receive high flow. Potential to cross road to house. Spot for temp trailer.

Potential Hazard to Life: moderate  
Potential Hazard to Property: low

Preliminary Emergency Protective Measures (1): Early Warning  
Preliminary Emergency Protective Measures (2): Clear and maintain culvert  
Preliminary Emergency Protective Measures (3): NA  
Preliminary Emergency Protective Measures (4): NA

Description: NA

LOCATION AND PHOTO

Latitude: 38.519309  
Longitude: -122.608838
Incident: Glass Fire  
Incident Number: CA-LNU-015947

Community: Russian River & Sonoma Creek
Site Number: GLS-028
Feature: Road
Feature Category: drainage structure

Field Observation or Potential Hazard: Road crossing of Ducker Creek, 60 inch plastic pipe burned completely, potential for scour and fill collapse. Average of 5 feet of fill above pipe. Channel appears active.

Potential Hazard to Life: low  
Potential Hazard to Property: moderate

Preliminary Emergency Protective Measures (1): Clear and maintain culvert
Preliminary Emergency Protective Measures (2): Signage
Preliminary Emergency Protective Measures (3): NA
Preliminary Emergency Protective Measures (4): NA

Description: Replace culvert.

LOCATION AND PHOTO

Latitude: 38.482512  
Longitude: -122.65187
**Incident: Glass Fire**

**Incident Number:** CA-LNU-015947

**Community:** Russian River & Sonoma Creek

**Site Number:** GLS-029

**Feature:** Houses

**Feature Category:** home

**Field Observation or Potential Hazard:** Houses built on low terrace in Santa Rosa Creek. Large boulders in creek, but gradient is low. Potential flooding issue.

**Potential Hazard to Life:** moderate

**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** NA

**Preliminary Emergency Protective Measures (2):** NA

**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

![Map and Photo](image-url)

Scale: 1:2,000
### INCIDENT: Glass Fire

**Incident Number:** CA-LNU-015947

**Community:** Russian River & Sonoma Creek

**Site Number:** GLS-030

**Feature:** House

**Feature Category:** home

### Field Observation

House built low adjacent to channel. Homeowner says channel has overtopped before.

### Potential Hazard

<table>
<thead>
<tr>
<th>Potential Hazard to Life:</th>
<th>Potential Hazard to Property:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>moderate</td>
</tr>
</tbody>
</table>

### Preliminary Emergency Protective Measures

1. **Early Warning**
2. **Sandbags**
3. **NA**
4. **NA**

**Description:** NA

### LOCATION AND PHOTO

- **Latitude:** 38.455443
- **Longitude:** -122.619705
**Incident: Glass Fire**

**Incident Number:** CA-LNU-015947

**Community:** Russian River & Sonoma Creek

**Site Number:** GLS-031

**Feature:** Houses

**Feature Category:** home

**Field Observation or Potential Hazard:**
Houses built on low lying fan. Evidence of debris flows in channel upstream.

**Potential Hazard to Life:** low

**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** NA

**Preliminary Emergency Protective Measures (2):** NA

**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

**LOCATION AND PHOTO**
**Incident: Glass Fire**  
**Incident Number:** CA-LNU-015947

**Community:** Russian River & Sonoma Creek  
**Site Number:** GLS-032  
**Feature:** Houses  
**Feature Category:** home

**Field Observation or Potential Hazard:** Houses built low adjacent to drainage. Box culvert between houses is partially plugged. Debris at the top of the crossing suggests large flows in the channel.

**Potential Hazard to Life:** low  
**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** NA  
**Preliminary Emergency Protective Measures (2):** NA  
**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

![Map and photo of the incident area with symbols for Value at Risk, FEMA/DWR Floodplain, and Fire Perimeter, along with a legend for Combined Hazard levels.]
**Incident: Glass Fire**

**Incident Number:** CA-LNU-015947

**Community:** Russian River & Sonoma Creek

**Site Number:** GLS-033

**Feature:** Houses

**Feature Category:** home

**Field Observation or Potential Hazard:** Houses built low along Sonoma Creek and in the mouths of tributaries. VARs were identified after the Nuns Fire in 2017. Glass Fire soil burn severity is lower than the Nuns Fire.

**Potential Hazard to Life:** moderate

**Potential Hazard to Property:** moderate

**Preliminary Emergency Protective Measures (1):** NA

**Preliminary Emergency Protective Measures (2):** NA

**Preliminary Emergency Protective Measures (3):** NA

**Description:** NA

---

**LOCATION AND PHOTO**

![Map Diagram](image1.png)

![Photo](image2.jpg)

Scale: 1:22,000
APPENDIX E: GLASS FIRE PHOTOGRAPHS

Photo 1. Bell Canyon Reservoir on October 17, 2020.

Photo 2. Steep burned slopes in upper Santa Rosa Creek watershed.

Photo 4. Santa Rosa Creek watershed near Hood Mountain Regional State Park, below Timberline Drive.
Photo 5. House near channel in the upper Mark West Creek drainage (VAR 026).

Photo 6. Ritchie Creek near trails and campground in Bothe-Napa Valley State Park.
**Photo 7.** House near channel outside of St. Helena (VAR 018).

**Photo 8.** House near channel in the Sulphur Creek watershed (VAR 017).
Photo 9. View of the patchy nature of the Glass Fire from State Route 29, looking northeast.

Photo 10. Vineyards planted on an alluvial fan surface coming out of Hoisting Works Canyon, Napa Valley-East.
Photo 11. Burned slope in the Bell Creek watershed above Bell Canyon Reservoir.

Photo 12. Burned hillslope in Dutch Henry Canyon.
Photo 13. House and outbuilding adjacent to channel near Calistoga (VAR 002).

Photo 14. Winery structure and tanks adjacent to channel near St. Helena (VAR 014).
Photo 15. Swartz Creek watershed above Aetna Springs.