CAMP FIRE

Watershed Emergency Response Team

Final Report

CA-BTU-016737

November 29, 2018

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 rock fall hazards.

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List of Acronyms

BAER	USFS Burned Area Emergency Response
BARC	Burned Area Reflectance Classification
BOF	California State Board of Forestry and Fire Protection
CAL FIRE	California Department of Forestry and Fire Protection
Cal OES	California Office of Emergency Services
CalVeg	Classification and Assessment with Landsat of Visible Ecological Groupings
Caltrans	California Department of Transportation
CEG	Certified Engineering Geologist
CFS	Cubic Feet per Second
CGS	California Geological Survey
DEM	Digital Elevation Model
DFW	California Department of Fish and Wildlife
DWR	California Department of Water Resources
EHR	Erosion Hazard Rating
ERMiT	Erosion Risk Management Tool
EROS	Earth Resources Observation Systems
FEMA	Federal Emergency Management Agency
FT	Flow Transference Method
GIS	Geographic Information System
GPS	Global Positioning System
HUC	Hydrologic Unit Code
NOA	Naturally Occurring Asbestos
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PE	Professional Engineer
PG	Professional Geologist
PH	Professional Hydrologist (AIH)
RPF	Registered Professional Forester
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VARs	Values-at-risk
WERT	Watershed Emergency Response Team

State of California

Watershed Emergency Response Team (WERT)

CAMP POST-FIRE WERT ASSESSMENT EXECUTIVE SUMMARY

CA-BTU-016737 - WERT Evaluation

The Camp Fire started on November 8, 2018 on Pulga Road and Camp Creek Road near Jarbo Gap and has burned a total of 153,336 acres (about 240 square miles). A total of 13,972 single, multiple, and mixed commercial residences, 528 commercial and 4,293 other buildings were destroyed. To date, 85 civilian fatalities have been recorded. As a result, the Camp Fire has been designated the most destructive and deadliest California wildfire to date. Acting Governor Newsom issued a State of Emergency Proclamation for Butte County on November 8. A Presidential Major Disaster Declaration followed on November 12, and included the fires burning in Los Angeles and Ventura Counties. Local and state responsibility areas accounted for approximately 85 percent of the burn area, with the remaining 15 percent under federal responsibility area.

Due to the large proportion of private land impacted by the Camp Fire, the burned area was evaluated by an interagency Watershed Emergency Response Team (WERT) comprised of engineering geologists, hydrologists, foresters, engineers, and GIS specialists. The WERT rapidly evaluated post-fire watershed conditions, identified potential values-at-risk related to human life-safety and property, and evaluated the potential for increased post-fire flooding and debris flows. The team also recommended potential emergency protection measures to help reduce the risks to those values.

Summary of the WERT Key Findings

- Approximately 19 percent of the fire is low/unburned soil burn severity, 63 percent of the fire is low soil burn severity, 16 percent of the fire is moderate soil burn severity, and 2 percent of the fire is high soil burn severity.
- 1,416 watershed basins were evaluated for post-fire debris flow hazards. Using a design storm with a peak 15-minute intensity of 1.6 inches/hour (40 mm/hr), 420 of the 1,416 basins (approximately 30 percent) have a likelihood of 60 percent or greater probability of debris flows. The majority of these basins are located along steep slopes that flank the North Fork Feather River and the West Branch of the Feather River upstream of Lake Oroville.
- Twelve sub-watersheds (i.e., pour points) were specifically analyzed for increased post-fire sediment-laden flood hazards, including sub-watersheds identified as having resources at risk within identified FEMA 100-year flood zones, DWR awareness floodplains, and USGS designated Watch Streams. Post-fire peak flows for return periods ≤ 10 years were estimated to increase between 10% and 70% over pre-fire flows, with the highest increases occurring at the inlet to the Concow Reservoir.

- ERMiT post-fire erosion model predictions suggest an area averaged sediment production rate for a 2-year recurrence storm event to be approximately 6 tons per acre, or approximately 4 times more sediment production relative to unburned sites. Areas that show elevated increased erosion potential (between 20 to 25 tons per acre) included the very steep soils along the upper reaches of Butte Creek, Dry Creek, Clear Creek, and other smaller drainages to Butte Valley and along the West Branch Feather River.

Identified Values-at-Risk and Hazards, and Emergency Conditions

The WERT's objectives for the burned area were to quickly identify potential post-fire life-safety threats, including those from debris flows, flooding, rock fall, and erosion. The WERT identified values-at-risk (VARs) resulting from increased post-fire debris flow hazard, rock fall hazards, flood flows, and increased erosion and sediment delivery. A total of 58 VARs were identified, including 36 VAR points, generally associated with individual structures and/or drainage structures, and 22 VAR polygons, generally associated with road segments and flood prone areas. One (1) VAR was classified as having a high hazard to life and safety. Five (5) point VARs and two (2) polygon VARs are classified as having moderate hazard to life and safety. The remaining VARS are classified as having a relatively low hazard to life and safety, but this does not equate to an absence of risk. Furthermore, some VARs were identified in association with burned residences, with the assumption that temporary housing might be placed onsite during the rebuilding phase.

Key areas of concern are:

- Flooding and debris flow impacts to structures in the town of Pulga.
- Flooding and debris flow impacts to segments of State Highway 70 and Union Pacific Railroad within the Feather River Canyon and local access roads, such as Honey Run Road and Jordan Hill Road with moderate to high risk of debris flow.
- Flooding and debris jams within designated FEMA 100-year flood zones, DWR awareness floodplains, and/or USGS modelled Watch Streams in Butte Valley and Butte Creek Canyon east of Chico.
- Rock fall hazards downslope of steep rocky slopes, particularly along the Highway 70 and Union Pacific Railroad corridors.
- Impacts to water quality within local reservoirs (e.g. Lake Oroville and Concow Reservoir) used for municipal water supply.
- Debris flow and flood impacts to drainage diversion structures located on Little Butte Creek and Little Chico Creek.

General Recommendations

General recommendations to mitigate fire-related impacts to identified VARs include:

- Increasing affected resident and the community situational awareness about the hazards and risks associated with living downstream/downslope of a burned area.

- Utilizing early warning systems available to homeowners, particularly those located in debris flow and flood prone areas.
- Performing storm patrols and monitoring and clearing road drainage infrastructure, particularly along State Highway 70.
- Properly locating temporary and permanent housing when rebuilding.
- Placing temporary signage in areas of potential post-fire rockfall, debris flow, and flooding hazards.
- Monitoring and/or removing accumulated debris from within channels that are subject to post-fire flooding, where there is an elevated risk to life and property.
- The burned debris from structures and vehicles should either be properly disposed of, or mitigations put in place to prevent runoff from burned sites from entering watercourses. Areas with the highest density of burned structures near watercourses or with storm drainage systems that drain directly to watercourses should be the priority.

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 Butte County Office of Emergency Services, local first responders, Butte County Department of Public Works, City of Chico, City of Paradise, City of Oroville, Caltrans, the California Governor's Office of Emergency Services, the United States Department of Agriculture Natural Resource Conservation Service, utility companies, and other responsible agencies in the development of more detailed post-fire emergency response plans. It is intended that the agencies identified above 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.

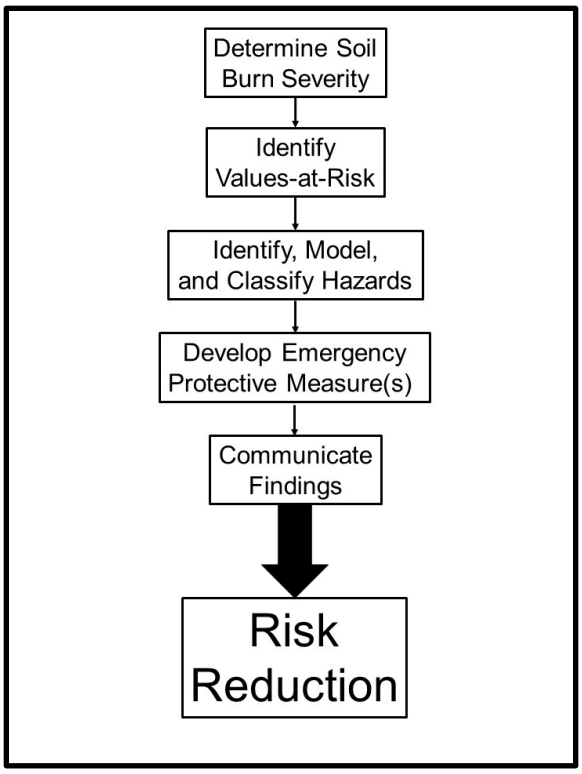
1 INTRODUCTION, PHYSICAL SETTING, AND METHODS

This report presents the results of a rapid assessment of post-fire geologic and hydrologic hazards to life, safety, and property (i.e., collectively known as “Values-at-Risk”) on private lands affected by the 2018 Camp Fire in Butte County, California. Wildfire can have profound effects on watershed processes. Wildfire-induced loss of surface cover and enhancement of soil water repellency from wildfire can increase runoff generation and the erosive power of overland flow, resulting in accelerated erosion of material from hillslopes. Increased runoff can also erode significant volumes of material stored within channels. A primary concern for burned watersheds is the increased potential for damaging flood flows and increased probability for debris flow occurrence. Other hazards include rockfall from steep slopes and hillslope erosion that can impact roadways, drainage features, and water supplies.

Debris flows are among the most hazardous consequences of rainfall on burned hillslopes. Debris flows pose a hazard distinct from other sediment-laden flows because of their unique destructive power. Debris flows can occur with little warning and can exert great impactive loads on objects in their paths. Even small debris flows can strip vegetation, block drainage ways, damage structures, and endanger human life. Additionally, sediment delivery from debris flows can “bulk” the volume of flood flows, creating an even greater downstream flooding hazard. As winter approaches, it is critical that people who live in and downstream from large wildfires implement emergency protection measures where appropriate, remain vigilant and alert of weather conditions, and be ready to evacuate if necessary during large storms.

When wildfire-induced threats to life and safety are present, a state team of foresters, hydrologists, and geographic information systems specialists from the California Department of Forestry and Fire Protection (CAL FIRE), engineering geologists from the California Geological Survey (CGS) and Regional Water Quality Control Boards (RWQCB), and civil engineers from the Department of Water Resources (DWR), can be assembled into a Watershed Emergency Response Team (WERT) to assess potential life-safety hazards from post-fire debris flows, hyper-concentrated flows, and flood flows. CAL FIRE Incident Commanders from Incident Management Team 4, determined that a WERT was needed for the Camp Fire.

Clear communication of life, safety, and property hazards is an objective of the WERT process, and the use of spatial data is a critical component for communicating these hazards in a planning and operational context. WERT specialists were deployed to the Camp Fire burn area to identify and collect spatial data of potential life-safety hazards. These data have been shared with Federal, state, and local responsible agencies and distributed to a FEMA file sharing site for use by responsible agencies.



Finally, the WERT's primary goal is to avoid and/or minimize risk to potential life-safety and property values from post-fire watershed hazards (Figure 1). A comprehensive evaluation of potential resource impacts following wildfire is beyond the scope of this document. However, the same tools used to determine hazard to life-safety and property values (i.e., model outputs; spatial data) can also be used to determine hazards to ecosystem services (e.g., water resources and aquatic habitat). We urge local government, responsible agencies, and private landowners to utilize the tools and data presented herein to aid in informed decision-making when seeking to minimize impacts to resource values (e.g., water quality).

Figure 1. WERT goals and objectives.

1.1 BACKGROUND

The Camp Incident burned in private, local agency, and federal land ownership. Due to the private and local agency land affected by the fire (Figure 2) and the risk to life and safety, a WERT comprised of individuals with expertise in engineering geology, engineering, geomorphology, hydrology, forestry, and GIS was assembled for the Camp Fire. WERT members and their qualifications are summarized in Table 1.

Post-fire soil burn severity assessment was conducted by soil scientists from the United States Forest Service (USFS) and WERT members from November 18 to 20, 2018. The Soil Burn Severity (SBS) map was finalized on November 20, 2018. The USGS Debris Flow Model results were generated on November 20, 2018. WERT members identified VARs and performed hazard evaluations from November 18 through November 25, 2018.

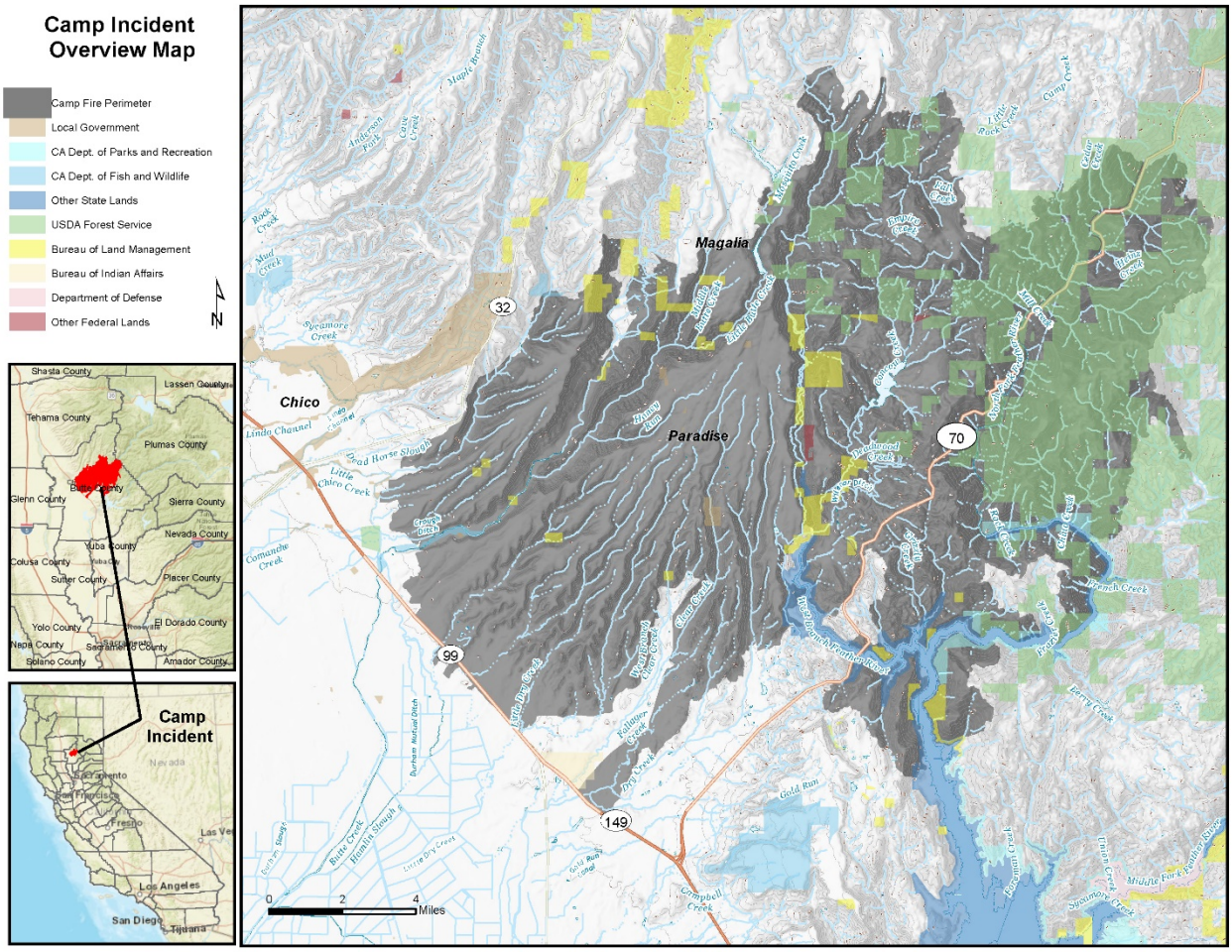


Figure 2. Camp Incident Overview Map.

Table 1. Camp Fire WERT members and qualifications.

Camp Fire Team			
Name	Position	Agency	Expertise-Position
Jon Woessner; RPF No. 2571	Team Leader	CAL FIRE	Forestry
Jacob Lee; CEG No. 2633, PG No. 8865	Co-Lead	CGS	Engineering Geology
Chris Gryszan; CEG No. 2640, PG No. 9142	Team Member	CGS	Engineering Geology
Justin LaNier	Team Member	CVRWQCB	Water Quality
Ivan Houser; RPF No. 2649	Team Member	CAL FIRE	Forestry
Trevor Morgan; PE No. 79967	Team Member	DWR	Civil Engineering
Scott Kennedy, PE No. 63801	Team Member	DWR	Civil Engineering
Brad Rust	Team Member	USFS	Soil Science
Eric Nicita	Team Member	USFS	Soil Science - ERMiT
Remote Adjunct Team			

Pete Roffers; PG No. 9100; GISP No. 91498	Team Member	CGS	GIS/Geology
Sol McCrea; CFM No. 3527; GISP No. 90957	Team Member	CGS	GIS/Hydrology
Stacy Stanish; RPF No. 3000	Team Member	CAL FIRE	GIS/Biology

1.2 OBJECTIVES

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 rock fall hazards.

Primary objectives for the WERT are to conduct a rapid preliminary assessment to:

- Identify types and locations of on-site and downstream threats to public health or safety from landsliding, debris flows, flooding, erosion, road hazards, and other fire-related problems.
- Develop preliminary emergency protection measures needed to avoid life-safety threats.

2 PHYSICAL SETTING

2.1 CAMP FIRE SUMMARY

The Camp fire began on November 8, 2018 near Jarbo Gap, at Pulga Road and at Camp Creek Road in Butte County, California. The fire was fully contained on November 25, 2018 at approximately 153,336 acres. Ongoing dry weather, strong northeast winds, very low live fuel moistures and heavy fuel loading resulted in extreme fire behavior. At one point the fire grew from 18,000 acres on November 8, 2018 to over 90,000 acres by the evening of November 9, 2018. By 10:00 A.M. November 9, the fire was reported to have burned through the communities of Concow and Paradise and had crossed State Highway 70 near Pulga, threatening the Yankee Hill area. This extreme rapid rate of spread resulted in over 153,000 acres burned by November 23, 2018. Acting Governor Gavin Newsom proclaimed a state of emergency in Butte County on November 8, 2018 and President Trump approved California's Major Disaster Declaration on Monday November 12, 2018.

During the Camp Fire, evacuation orders were in effect throughout the incident with 52,000 residents evacuated by November 9, 2018. Evacuations orders initially were for the areas of Paradise, Magalia, Concow, Butte Creek Canyon, and Butte Valley. Forest Ranch, Chico, Yankee Hill, Stirling City and Berry Creek were added to the list by the second day. Other locations were added as wind direction shifted or fire growth necessitated. As of November 25, 2018, the fire has resulted in the destruction of at least 13,972 residences, 528 commercial buildings, and 4,293 other minor structures.

To date, 88 civilian fatalities have been recorded. As a result, the Camp Fire has been designated the most destructive and deadliest California wildfire to date.

Table 2. Acreage and proportion of burn area by Ownership Group.

Ownership Group	Percent
Federal Responsibility Areas	15 %
State Responsibility Areas	77 %
Local Responsibility Areas	8 %
Total	100 %

2.2 REGIONAL FIRE HISTORY

Much of the Camp Fire area has been burned previously between the 1960's and through to the past 2017 fire season (Figure 4), except for Paradise and Magalia. Specifically, 70% of the current fire area in acres burned has seen fire in the last 58 years (since 1960), approximately 92,000 acres (60% of the current area) have been impacted by fire in the last 30 years (since 1987). The fires that burned the largest acreage *within* the 2018 Camp Fire perimeter include the 2008 BTU Lightning Complex, totaling 28,465 acres and the associated Humboldt Fire, also of 2008 for 22,583 acres. The larger notable fires occurring in the Camp Fire perimeter are included in Table 3.

Table 3. Regional Fire History within the Camp Fire area.

Fire Name	Year	Acres within the Camp Fire
Hamlin Canyon	1983	2,459
Burton	1992	5,888
Doe Mill	1999	9,502
Bloomer	1999	1,861
Concow	2000	1,823
Highway 70	2001	1,692
Poe	2001	7,379
BTU Lightning Complex	2008	28,465
Humboldt	2008	22,583

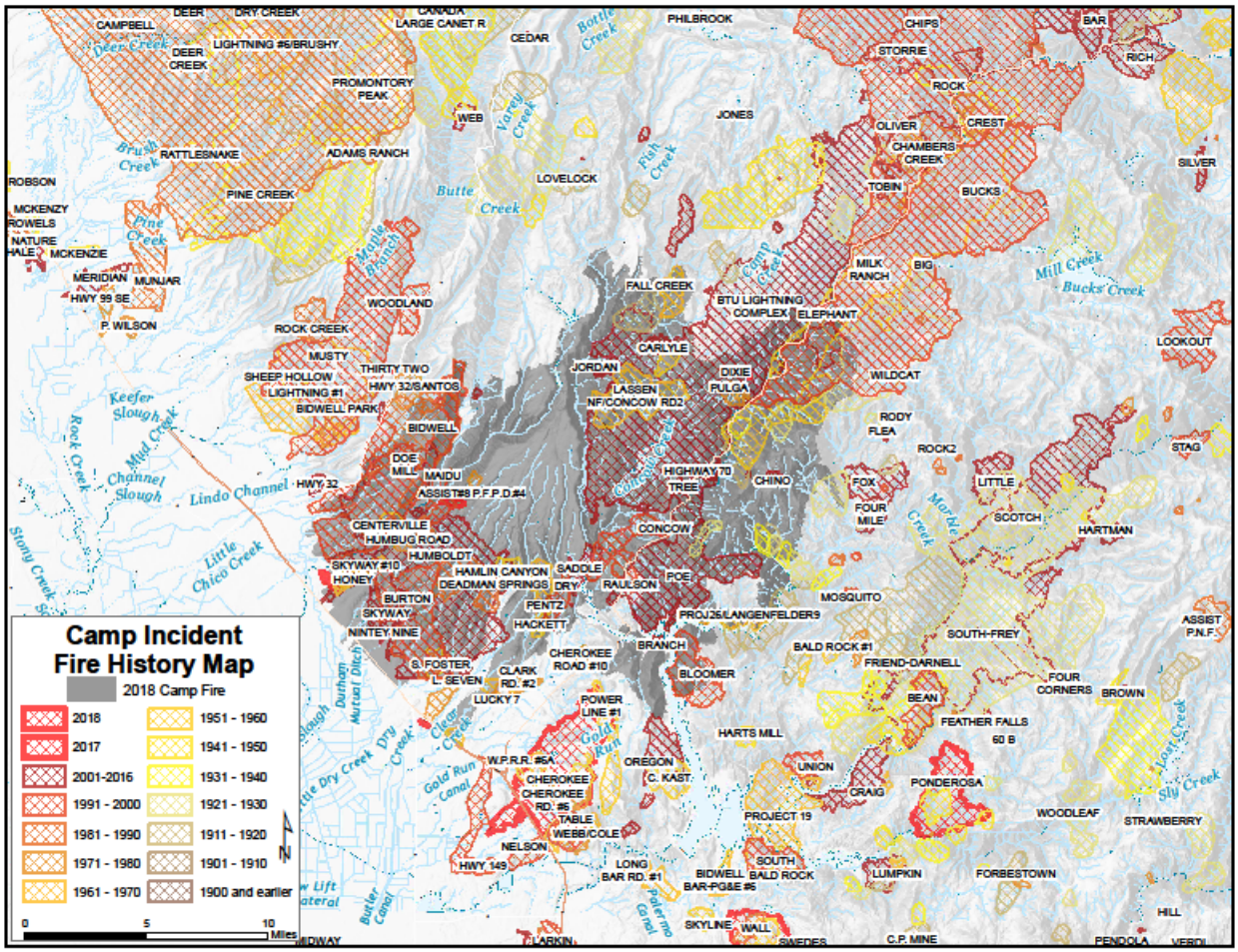


Figure 3. Fire history map of the Camp Fire burn area.

2.3 TOPOGRAPHY, RAINFALL, AND CLIMATE

Topography within the Camp Fire burn area ranges from gentle to very steep. Elevations range from about 200 feet above mean sea level (amsl) along the western margin of the fire near CA State Highway 99 and the town of Durham to about 5,100 feet near Bear Ranch Ridge, east of CA Highway 70 on the Northeastern portion of the burn area.

Figure 5 is a map showing the distribution of slope steepness classes in the burn area. The majority of the slopes within the burn area occupy broad, gentle- to moderate- sloping (0 to 40 percent) ridge tops that are flanked by steep to precipitous (>40 percent) slopes that descend to local creeks and rivers, including Little Chico Creek, Butte Creek and the Feather River. The burn area drains from northeast to southwest; the portion east of Paradise drains to the Feather River and Lake Oroville, and the western portion drains to Butte Creek, Little Chico Creek, and tributaries of Butte Valley (Dry Creek, and Clear Creek, and their tributaries).

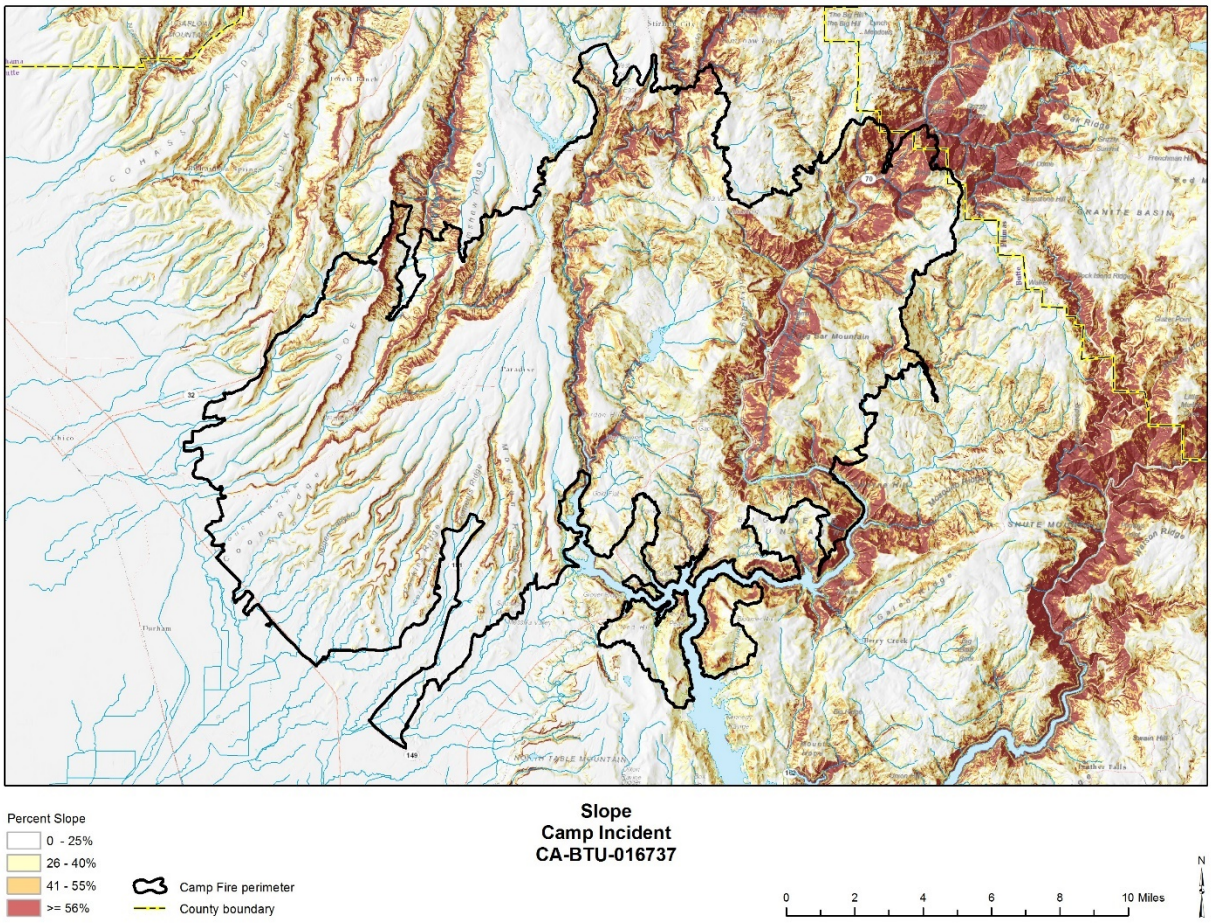


Figure 4. Slope map of the Camp Fire burn area.

Precipitation varies within the burn area primarily due to orographic effects. Average annual rainfall ranges from 25 inches per year in the lower elevations near the City of Chico to about 71 inches per year in the upper elevations east of the burn area. In the town of Paradise, average annual rainfall is about 55 inches per year. The highest recorded annual precipitation in the town of Paradise is 100 inches in 1995 and the lowest recorded annual precipitation was 18.5 inches in 1976 (https://wrcc.dri.edu/summary/Climsmnca.html).

The one-year, 10-year, and 25-year recurrence interval for the 15-minute rainfall magnitude within the City of Paradise is 0.4, 0.7, and 0.8 inches, respectively (http://hdsc.nws.noaa.gov/hdsc/pfds/).

The burn area has a typical Mediterranean climate with hot dry summers and cool wet winters. Precipitation occurs almost entirely as rain, with rare occurrences of snow in the lower elevations of the burn area and light annual winter snowfall accumulation in the high elevations. Only a small fraction of the fire (0.2 percent) is within the rain-on-

snow elevation range (Kattelmann, 1997). Post-fire conditions are therefore not anticipated to result in significant rain-on-snow flooding effects.

2.4 HYDROLOGY AND FLOOD HISTORY

USGS gaging station 11390000 located on Butte Creek near Honey Run Road is one of the only gages that is in the burn area and has an 87-year record of peak flows. The Butte Creek gage has a 148-square mile watershed of which 15% was burned from the Camp Fire. The flood record for the Butte Creek gage between the years 1931 – 2017 took place in January 1997. The January 1997 flood recorded a peak flow of 35,600 cfs. USGS software PeakFQ was used to generate a flood frequency analysis on the Butte Creek gage. See Figure 6 for the flood frequency curve of the Butte Creek gage. The January 1997 flood event is estimated to be between a 200- and 500-year recurrence interval flood event. Based on the annual peak flow frequency analysis generated by PeakFQ for the years of 1931 - 2017, the 2-year, 5-year, and 10-year recurrence interval flows are 5,646 cfs, 10,420 cfs, and 14,180 cfs, respectively. Pour point #4 is located just upstream of the Butte Creek gage, see Table 6 for pour point results on Butte Creek.

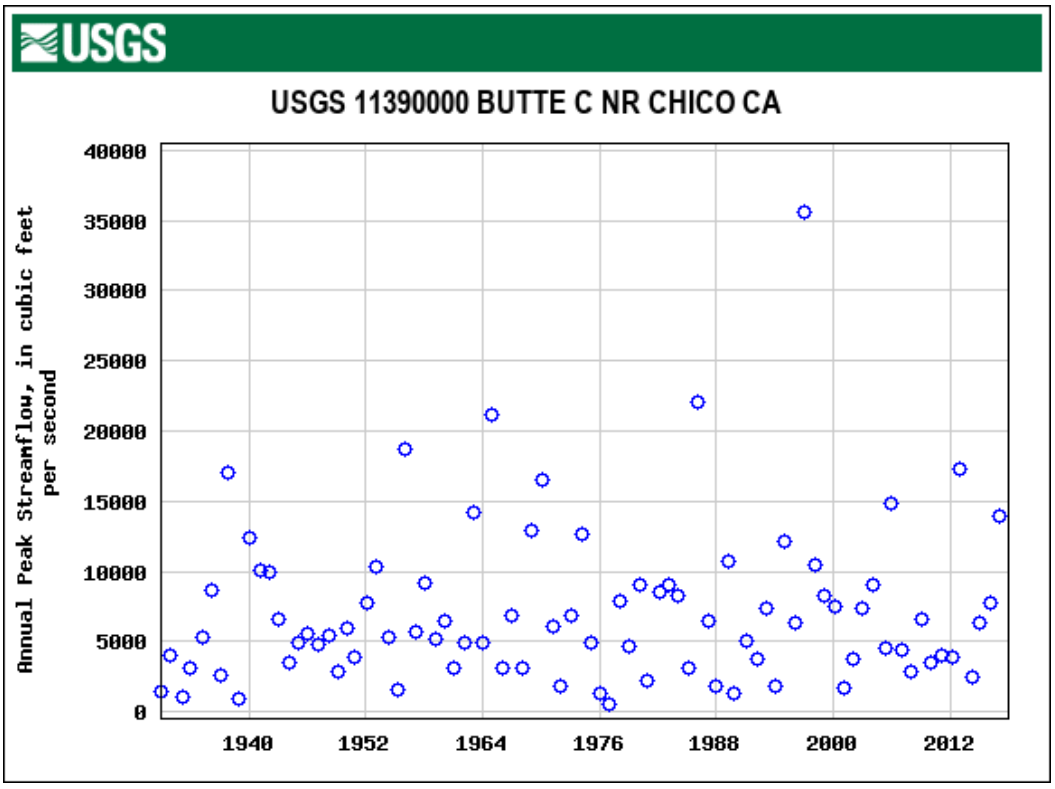


Figure 5. Annual peak flow for Butte Creek from 1931-2017.

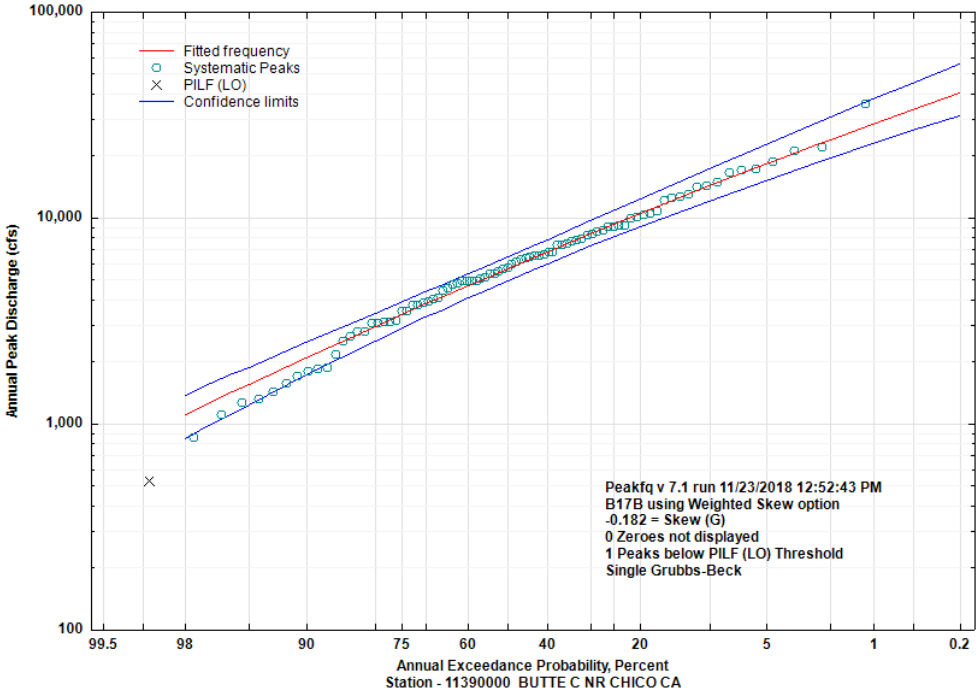


Figure 6. Flood Frequency Curve for Butte Creek.

2.5 VEGETATION

The California Wildlife Habitat Relationship (CWHR) system was used to identify pre-fire vegetation types within the Camp Fire perimeter, of which there are fourteen (14), (Table 4). This diversity of vegetation types is characteristic of the Sierra Nevada Region in which the Camp Fire perimeter is located, due to variables such as elevation, slope, aspect, soil moisture and including past disturbance regimes from landslide and fire. Past disturbance from fire was noted during field evaluation and is discussed in fire history. It was observed that several areas pre-fire, were in early seral development represented by Mixed Chaparral or Montane Chaparral. These could also be described as brush fields having in some instances, a significant amount of large downed woody debris from past fires. Relative abundance of any one vegetation type however, is directly related to location within the fire perimeter. There is also mixing or transition between vegetation types to consider. Additional species were observed but that are not included specifically in the CWHR description for a given habitat type such as poison oak and to a lesser extent, bay laurel.

Ponderosa Pine, Montane Hardwood Conifer, Blue Oak Woodland, Blue Oak Foothill Pine, Mixed Chaparral and Annual Grassland comprise approximately 60% of the representative vegetation types encountered and are relatively equally present. Sierran Mixed Conifer, Douglas Fir, Montane Hardwood, Valley Oak Woodland, Montane Riparian, Valley Foothill Riparian, Montane Chaparral and Urban (Grass Lawns,

Ornamental Trees and Hedges) combined, represent the remaining 40% of the fire area. Many species within the Camp Fire perimeter are representative of plants having fire tolerant or fire-dependent mechanisms. For example, seed that requires fire to sprout or oaks that re-sprout from the root collar. These species will likely re-sprout within a year, where present pre-fire, and begin to reclaim the landscape. Annual grasses for example were already noted to be sprouting in some areas where water was present in the soil. Other areas were noted within the fire perimeter however that experienced higher-severity heat and intense wind resulting in loss of some of the uppermost soil layer. Soils in the moderate to high burn severities were heated deeply enough to kill fine roots and likely destroyed many of the surface and some of the buried seed in these areas.

Table 4. Vegetation Types found within the Camp Fire perimeter.

CWHR TYPE	Estimated Percentage
Sierran Mixed Conifer (SMC)	5%
Douglas Fir (DFR)	5%
Ponderosa Pine (PPN)	10%
Montane Hardwood Conifer (MHC)	10%
Montane Hardwood (MHW)	5%
Blue Oak Woodland (BOW)	10%
Valley Oak Woodland (VOW)	5%
Blue Oak Foothill Pine (BOP)	10%
Montane Riparian (MRI)	5%
Valley Foothill Riparian (VRI)	5%
Montane Chaparral (MCP)	5%
Mixed Chaparral (MCH)	10%
Annual Grassland (AGS)	10%
Urban (URB)	5%
TOTAL	100%

2.6 GEOLOGIC SETTING

Regional geologic mapping at 1:250,000 scale by Saucedo and Wagner (1992) indicated that the Camp Fire burn occurred within the foothills of the Sierra Nevada Geomorphic Province (CGS, 2002). The Sierra Nevada is an approximate 400-mile-long tilted block with a gentle western slope and a high, steep eastern face. Within the geomorphic province, the bedrock is generally comprised of the metamorphosed Paleozoic era (200 million to 540 million years) sedimentary and volcanic rocks, Mesozoic era (65 million years to 250 million years) metasedimentary and metavolcanic

rocks, Mesozoic era granitic batholith/plutons and Cenozoic era (present to 65 million years) volcanic and sedimentary rocks.

Generally speaking, the portion of the burn area east of the West Branch Feather River is underlain by Paleozoic metasedimentary and metavolcanic rocks and the lower-lying portions of the burn area west of the West Branch Feather River are underlain by Cenozoic era volcanic and sedimentary rocks. The geologic units underlying the burn area is shown in Table 5, below.

The Camp Fire burn area is bisected by the Long Ravine, Big Bend, Magalia and Chico Monocline faults. Only the Chico Monocline shows evidence of recent fault displacement (i.e. within the past 1.6 million years) within the burn area (Jennings and Bryant, 2010).

Table 5. Description of Geologic Units underlying the Camp Fire area.

Geologic Unit	Age	Description
Dredge or Mine Tailings (t)	Holocene	Mixtures of sands, gravels and cobbles
Landslide Deposits (Qls)	Pleistocene-Holocene	Chaotic mixtures of sands, gravel and boulders
Modesto Formation (Qm)	Pleistocene	Alluvial terrace and fan deposits
Tuscan Formation (Ptu)	Pliocene	Interbedded lahars, volcanic conglomerate, volcanic sandstone, siltstone and pumiceous tuff
Volcanic Rock (Pv[b])	Pliocene	Basalt
Channel Deposits (MPc)	Miocene-Pliocene	Interbedded fluvial conglomerates and sandstone
Love Joy Basalt (Mlb)	Miocene	Black, fine-grained olivine basalt, highly fractured
Volcanic Rocks of the Smartville Complex (Mv)	Oligocene-Miocene	Pyroclastic and volcaniclastic rocks; pillow lavas, breccias and massive flows
Ione Formation (Ei)	Oligocene	Quartzose sandstone, claystone and conglomerate, mostly non-marine
Chico Formation (Kc)	Cretaceous	Sandstone, conglomerate and siltstone, marine
Quartz Diorite (KJqd)	Cretaceous-Jurassic	Quartz diorite, tonalite, trondhjemite, quartz monzonite
Monte De Oro Formation (Jmo)	Jurassic	Sandstone, conglomerate, slate and siltstone; minor volcanic rocks, marine
Jurassic Volcanic Rocks (Jv)	Jurassic	Pyroclastic rocks and flows
Gabbroic Rocks (gb)	Jurassic	Locally includes diorite and gabbro
Ultramafic Rocks (MzPz um)	Paleozoic to Mesozoic	Peridotite, serpentinite, and metaserpentinite, includes serpentinite-matrix mélange and locally talc and chlorite schists
Metasedimentary Rocks (MzPz mv)	Paleozoic-Mesozoic	Mafic to felsic flows, tuffs, breccias, and volcaniclastic rocks
Metavolcanic Rock (MzPz ms)	Paleozoic-Mesozoic	Argillite, phyllite, chert, conglomerate, and breccia; some quartzite, and volcaniclastic rocks; includes argillite-matrix melange

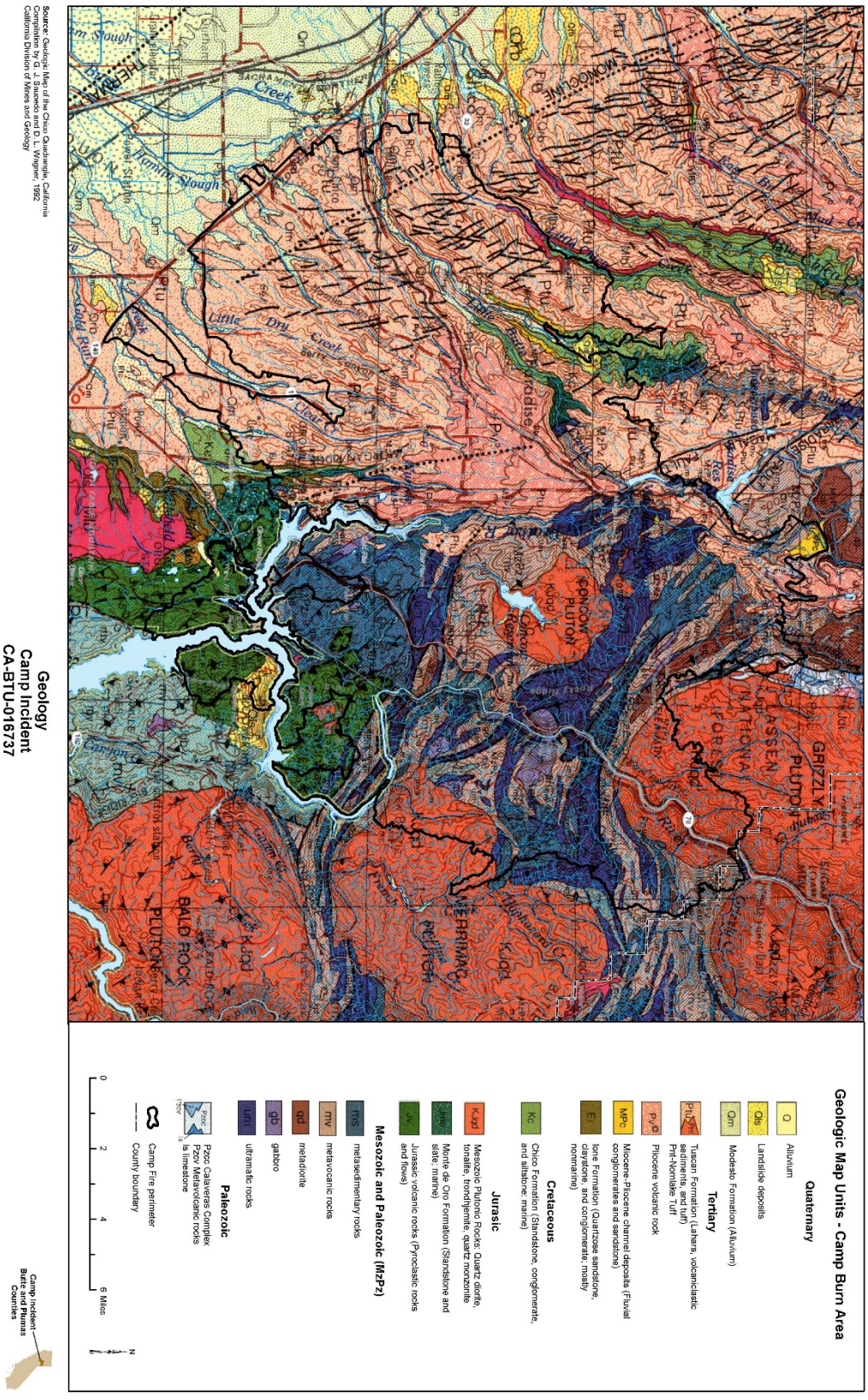


Figure 7. Geologic map for the Camp Fire burn area.

2.7 SOILS

Soils in the burn area range from clay loams to gravelly clay loams that generally correspond to their geologic parent materials (see Section 2.6). As stated above, the west half of the fire is underlain by weathered volcanics whereas the east half of the fire are generally underlain metavolcanic, metasedimentary, and igneous rocks. Soils are generally thin (less than two feet thickness) to moderate thickness (two to five feet thick) on the steeper slopes of the eastern half of the burn area and moderate to thick (Greater than five feet in thickness) in the lower lying areas within the western half of the fire. A more detailed description of soil types is included in the attached Soils Report (Appendix E).

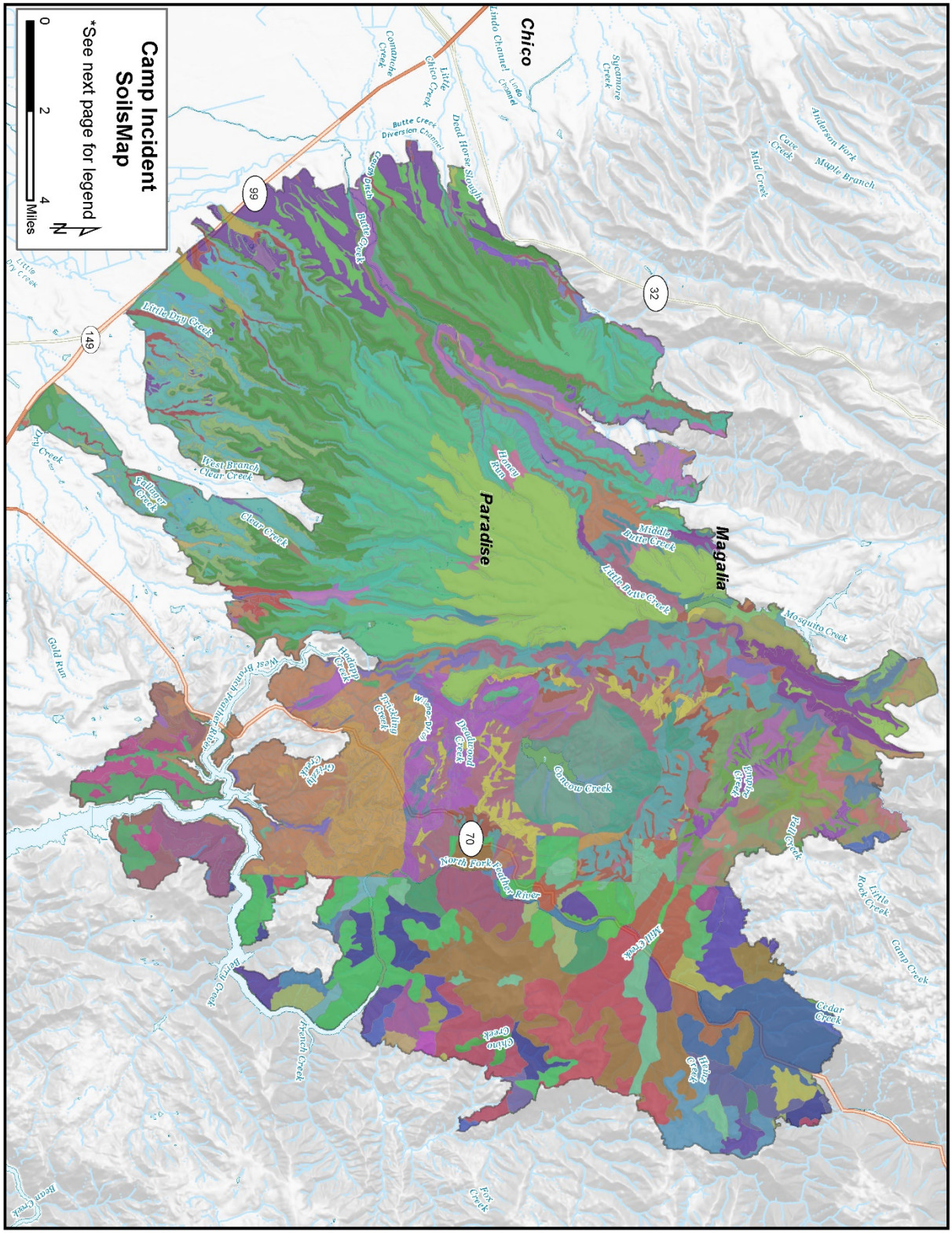


Figure 8. Soils map for the Camp Fire burn area.

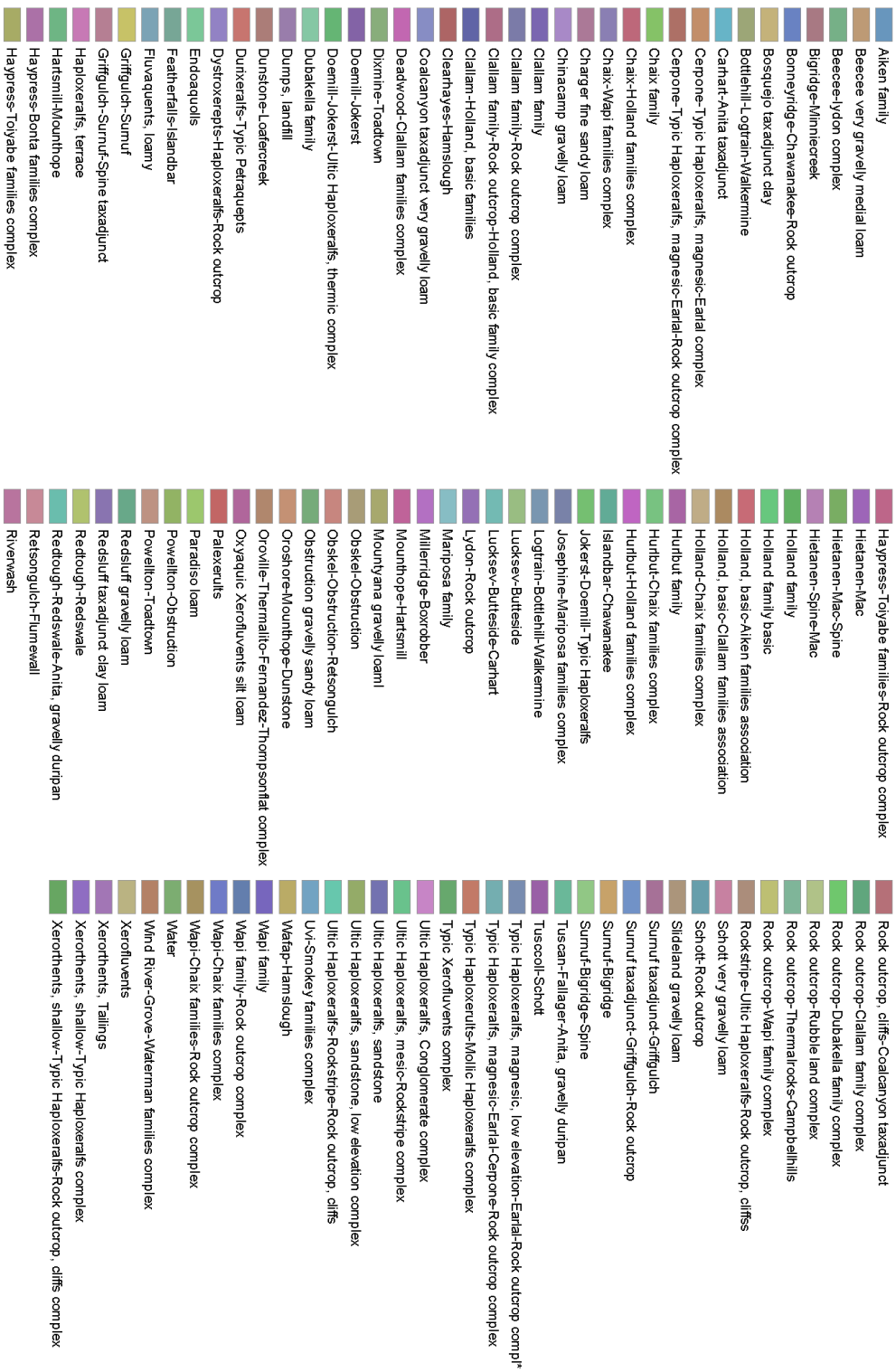


Figure 8A. Soils map Legend for the Camp Fire burn area.

2.8 LANDSLIDES

Published regional geologic mapping identifies multiple landslides within the Camp Fire Burn area (Saucedo and Wagner, 1992, CDWR, 2016). These features are primarily located within the area of Bloomer Hill, along steep (greater than 65 percent) planar to convergent slopes above Lake Oroville. These features may be susceptible to an increased potential for debris flow and rockfall hazards as a result of the Camp Fire.

Oversteepened slopes that flank incised channels are present within the burn area, particularly along Little Butte Creek and Dry Creek, among others. These slopes appear to predominantly be the result of extensive historic hydraulic mining that occurred regionally during the mid- to late-1800s. The effects of historic hydraulic mining often leave hummocky, highly-dissected landscapes adjacent to present day watercourses, as is evident throughout the Camp Fire burn area. Due to the irregular topographic expression of these hydraulic mining landscapes, they are often interpreted to be the result of naturally-induced landsliding. However, in many areas, these landscapes have supported steep slopes over long periods without evidence of significant mass wasting.

Alluvial fans can pose a significant hazard to life and property on and adjacent to the fan surfaces because of the inherent unpredictable flow paths of water, sediment, and debris. Significant evidence of alluvial fan activity was not observed within the burn area.

2.9 HAZARDOUS MINERALS

Hazardous minerals in the Sierra Nevada province are often associated with asbestos, mercury, and other heavy minerals. Based on our limited review of regional geologic maps (Saucedo and Wagner, 1992) and our field observations, partially serpentinized ultramafic rock units are present within the burn area that may contain asbestiform minerals. Asbestos is classified as a known carcinogen by state, federal and international agencies. 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.

Naturally occurring asbestos, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, silver, and zinc are known metals found in metamorphic rocks of the Sierra Nevadas. These rocks mostly underlay most of the eastern half of the burn area. Contributions of metals to the North Fork and West Branch Feather River within the burn area can be anticipated.

The burn area contains numerous historic mines with associated mine tailings and mine waste that may contain potentially harmful concentrations of heavy minerals. The use of mercury was common practice to enhance gold recovery in all the various types of mining operations since 1850.

The locations of potential mineralogical hazards, including ultramafic rocks and known mine locations are shown below in the Mineral Hazard Map (Figure 9).

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

We recommend consultation with the Butte County Air Quality Management District (https://bcaqmd.org/resources-education/asbestos/) to develop mitigations that are centered on limiting dust generation and exposure.

For general review information on hazardous minerals, see:

http://www.conservation.ca.gov/cgs/geologic_hazards/hazardous_minerals/Pages/Index.aspx

https://www.arb.ca.gov/toxics/asbestos/geninfo.htm

For additional mineral hazards information, see:

https://pubs.usgs.gov/fs/2005/3014/

http://www.mindat.org/loc-25791.html

http://www.who.int/mediacentre/factsheets/fs361/en/

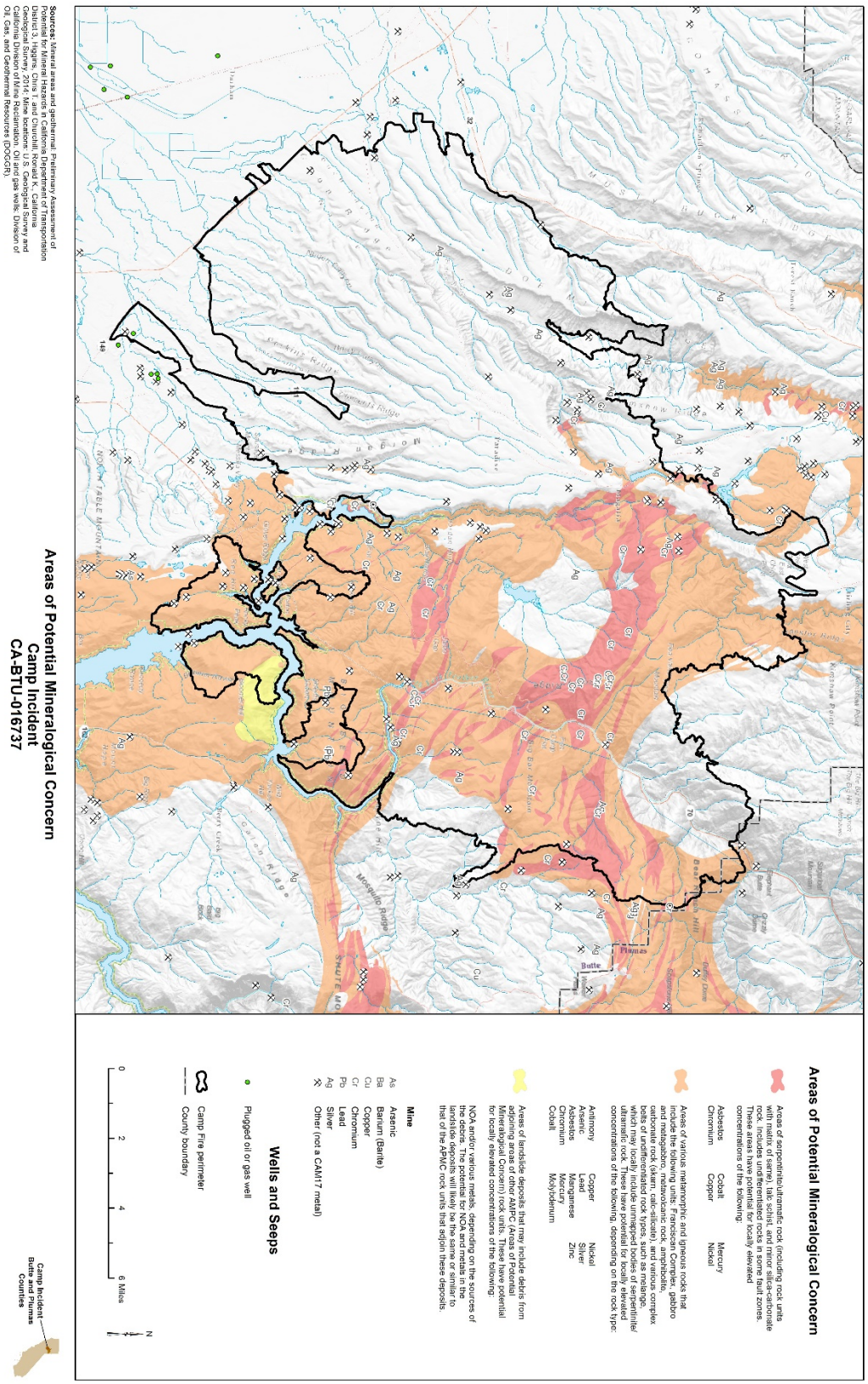


Figure 9. Map of hazardous minerals within or adjacent to the Camp Fire area.

3 METHODS

3.1 VALUES-AT-RISK

A fundamental step in the WERT process is the identification and characterization of Values-at-Risk (VARs). VARs are the values or resources at risk of damage or loss by post-wildfire geologic and/or hydrologic hazards (Calkin et al., 2007). The WERT process utilizes a qualitative approach for evaluating risk to these values, and relies on a combination of modeling and best professional judgement to guide risk determination. Potential VARs may be identified during the initial phases of reconnaissance and/or through consultation with local agency personnel and stakeholders. However, these VARs may be found to have little risk associated with them following further evaluation and analysis.

3.2 OFFICE METHODS

To validate the Burn Area Reflectance Classification (BARC) map (see Section 3.3.1) and to collect values-at-risk points and associated information, a mobile mapping application was used. The application, an Esri product called "Collector for ArcGIS[1]", allowed field observers to use mobile devices (tablets and smart phones) to view and use for reference the following information:

- Fire perimeter
- BARC layer
- USGS debris flow model for design storm with a peak 15-minute intensity of 1.6 inches/hour (40 mm/hr),
- Watershed boundaries (HUC-12)
- FEMA Special Flood Hazard Areas
- DWR Awareness Floodplains
- Hydrography
- Structures
- Ownership
- Roads
- Soils
- Geology
- Slope gradient
- Topographic hillshade

The Collector mobile application was useful for navigation and it provided drop-down

[1] http://doc.arcgis.com/en/collector/

menus that allowed field observers to capture locations (as points or polygons), attributes, and georeferenced photos of the following features:

- Soil burn severity (for field verification of the BARC map)
- Values-at-risk
- General observations

The data recorded in Collector was uploaded nightly to a secure cloud service (ArcGIS Online), allowing it to be quickly viewed by team members in different locations or downloaded into desktop GIS software for preparation of custom maps. To provide data redundancy, one member of each team served as a backup data recorder, recording field observations and photos using a different device.

3.3 MODELLING METHODS

3.3.1 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 (SBS) 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 VARs, and prioritize field assessment (Parsons et al., 2010). A SBS map was created by USFS soil scientists using a combination of Sentinel 2 Burned Area Reflectance Classification (BARC) imagery taken on November 18, 2018, with modifications based on actual field assessments of SBS (Appendix E).

3.3.2 USGS POST-FIRE DEBRIS FLOW MODEL

The USGS assessment uses results of the soil burn severity map along with empirical models to estimate the likelihood and potential volume of debris flows for selected basins in response to a design storm. The empirical models are based upon historical debris flow occurrence and magnitude data, storm rainfall conditions, terrain and soils information, and burn severity data from recently burned areas (Staley et al., 2016).

Postfire debris flow likelihood, volume, and combined hazards are estimated at both the drainage basin scale and in a spatially distributed manner along the drainage network within each basin. These are described as **basin** and **segment**, respectively. The characteristics of basins affected by the fire were calculated using a geographic information system (GIS) with a minimum area of 0.02 km² (approximately 5 ac) and a maximum area of 8.0 km² (1977 ac). Debris-flow likelihood, volume, and combined hazard were estimated for each basin outlet, as well as along the upstream drainage networks.

Basins with drainage areas greater than 8.0 km^2 were not explicitly modeled for debris flow probability, but were designated as **"**watch streams**"**, which may consist of a combination of flood and debris flow hazards.

The USFS assessment predicts the total volumetric yield for debris flow and/or sediment laden flows. In the context of this evaluation, volumetric yield is a surrogate of debris flow magnitude. Volumetric predictions were estimated using Equation 3 from Cannon and others (2010):

$$\text{Ln } V = 4.22 + (0.39 \times \sqrt{i15}) + (0.36 \times \ln(Bmh)) + (0.13 \times \sqrt{R})$$

where,

V = volume of sediment (m^3)
i15 = the peak rainfall intensity over a 15-minute period (mm hr^{-1})
Bmh = the watershed area burned at moderate and high SBS (km^2)
R = watershed relief (m)

Minimum and maximum volumes were also estimated as upper and lower bounds using +/- one standard error.

The comprehensive US Geological Survey (USGS) preliminary hazard assessment of the Camp Fire can be accessed at: https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=250.

3.3.3 FLOOD FLOW MODELING

To analyze projected peak flow changes within the burn area, 14 "pour points" were selected at points where FEMA and DWR mapping identify flood hazard zones or where post-fire flood hazards were identified for Values-at-Risk (Figure 11 and Appendix C).

While it is beyond the scope of this report to predict absolute changes in flow volumes or peak magnitude from the Camp Fire, a relative estimate of peak flow response is necessary to make a more informed determination on flood hazard. To this end, estimated post-fire flow multipliers were calculated for each pour point by multiplying "clear water" runoff increase modifiers by the proportion of the pour point watershed area in the moderate and high Soil Burn Severity class (Kinoshita et al., 2014), and assuming additional sediment bulking proportional to SBS (West Consultants, Inc, 2011).

In order to project the clear water changes in post-fire peak flows, the percent area burned at moderate and high severity within each pour point sub-watershed was

determined (Table 6). Based on an equation from Foltz et al. (2009), the post-fire flow modifiers were predicted:

$$M = 1 + \left[\frac{Percent\ Runoff\ Increase}{100\%} \times \frac{(A_{h+m})}{A_T}\right]$$

where,

A_{h+m} = Area burned at high and moderate severity (acres)

A_T = Total watershed area (acres)

M = Clear water flow multiplier

For the "Percent Runoff Increase", an assumption of 100% flow increase (doubling of flows) for high and moderate burn severity areas was used in most cases, which is typical of flow increases used by U.S. Forest Service BAER teams (Foltz et al., 2009; Story et al., 2006).

Once the clear water multiplier is calculated, it is necessary to further adjust the flow for increased post-fire sediment through the use of a sediment bulking factor. The sediment bulking factor assumes that flow is bulked 70, 50, and 20 percent for areas in high, moderate, and low SBS, respectively. Hence, a watershed completely burned at moderate SBS (i.e., 100%) will have a maximum bulked peak flow increase of 150 percent, or a multiplier of 2.5. These multipliers can be used to calculate an absolute post-fire flow by multiplying the pre-fire storm flow by the multiplier as follows:

A bulked post-fire multiplier was generated by adjusting the post-fire clear water multiplier with a bulking factor for sediment:

BF = 1 + %HighSBS*0.7 + %ModerateSBS*0.5 + %LowSBS*0.2

where,

BF = Bulking factor

%HighSBS = Proportion of the watershed with high SBS

%ModerateSBS = Proportion of the watershed with moderate SBS

%LowSBS = Proportion of the watershed with low SBS

Finally, a bulked post-fire multiplier is calculated using the following equation:

Bulked Post-Fire Multiplier = M x BF

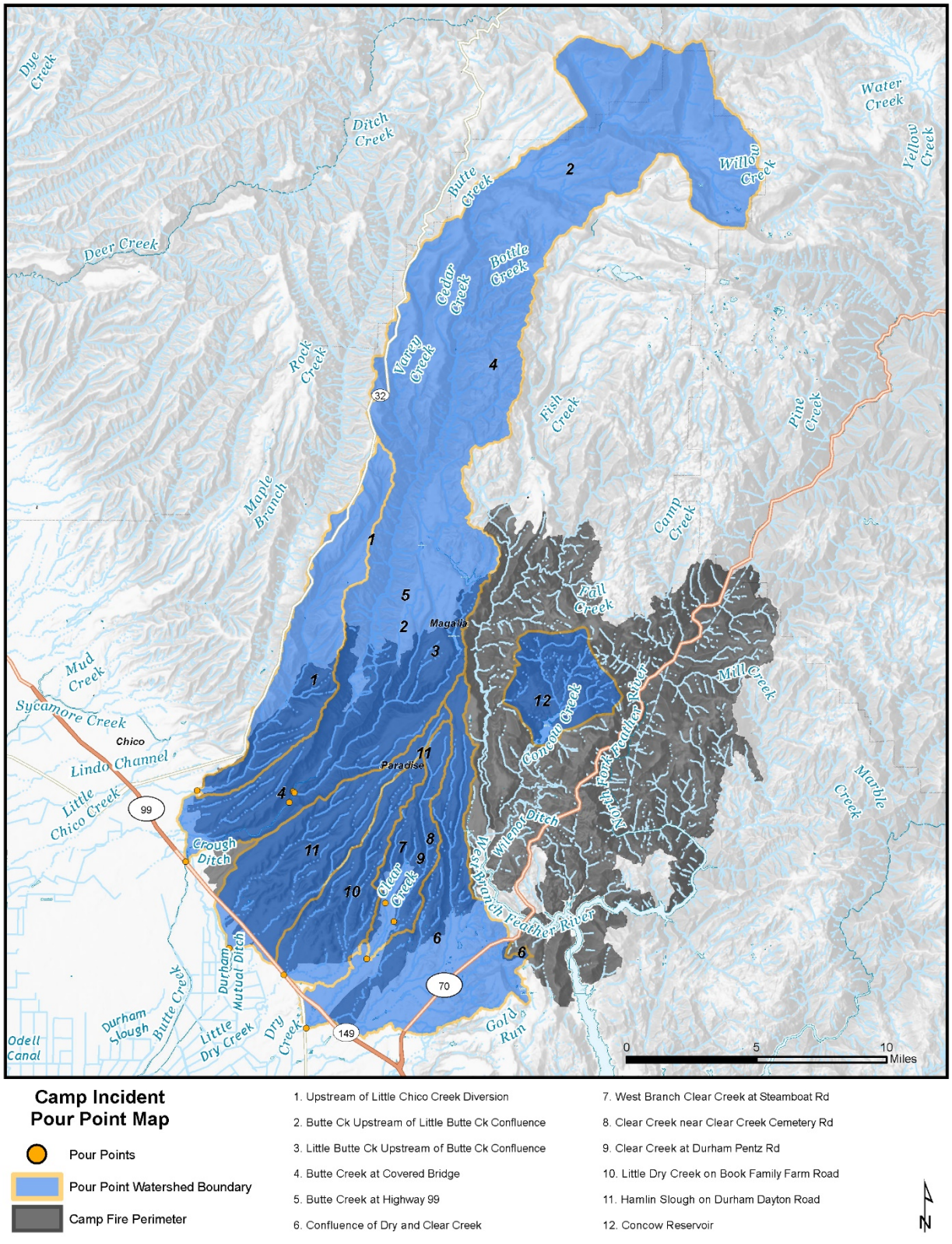


Figure 10. Pour points used in the flood flow analysis for the Camp Fire.

3.3.4 PRE- AND POST-FIRE EROSION AND SEDIMENTATION MODELING

Pre-fire sedimentation rates were calculated using sedimentation data from Oroville Dam Reservoirs at about 1.5 tons per acre (CDWR, 2014). Volumetric rates were converted to tons per acre by assuming a bulk density of 60 pounds per cubic foot (Minear and Kondolf, 2009).

Post-fire erosion rates for the fire area were calculated for the 10- and 50-percent exceedance (10- and 2-year) probability using Batch ERMiT (Erosion Risk Management Tool). ERMiT is a web-based tool developed to predict surface erosion from pre- and post-fire hillslopes, and to evaluate the potential effectiveness of various erosion mitigation practices (Robichaud et al. 2011). ERMiT requires input for climate parameters based on location, vegetation type (forest, range, chaparral), soil type (clay loam, silt loam, sandy loam, loam and rock content), topography (slope length and gradient), and soil burn severity class (low, moderate, high). This model provides probabilistic estimates of single-storm post-fire hillslope erosion by incorporating variability in rainfall characteristics, soil burn severity, and soil characteristics into each prediction (Robichaud et al. 2011). A more detailed discussion on the ERMiT model is included in Appendix E.

3.3.5 FIELD OBSERVATIONS OF VALUES-AT-RISK

The WERT conducted a site-specific evaluation of Values-at-Risk (VARs). Areas where there were concentrations of residential homes, campgrounds, and public infrastructure received the greatest attention. Field observations were conducted from November 16 to November 21, 2018. Road-related features, such as culverts and bridges, were surveyed at major drainage crossings. **Some potential VARs could not be evaluated due to locked gates.**

The VARs evaluated by the WERT include possible loss of life and property due to an elevated potential for increased stream flows, hyper concentrated flows, debris torrents, debris flows, rock fall, and associated slope movement as a result of the fire (Figure 12). VARs were evaluated using the USGS post-fire debris flow modeling data for the 40 mm hr^{-1} 15-minute rainfall intensity (probability hazard), FEMA 100-year floodplain mapping, soil burn severity data, topography, aerial imagery, hillshade, slope, watershed boundaries (HUC-12), DWR awareness floodplains, and roads. Team members confirmed hazards based on site-specific observations and interpretation of present geomorphic processes and landforms. When appropriate, team members noted preliminary or possible emergency protection measures. **It should be noted that the observations included in this report are not intended to be fully comprehensive and/or conclusive**, but rather to serve as a preliminary tool to assist emergency responding agencies (e.g., CAL FIRE, Butte County, Caltrans, local first responders,

City of Redding, California Office of Emergency Services, Natural Resource Conservation Service, utility companies, and other responsible agencies) in the development of more detailed post-fire emergency response plans.

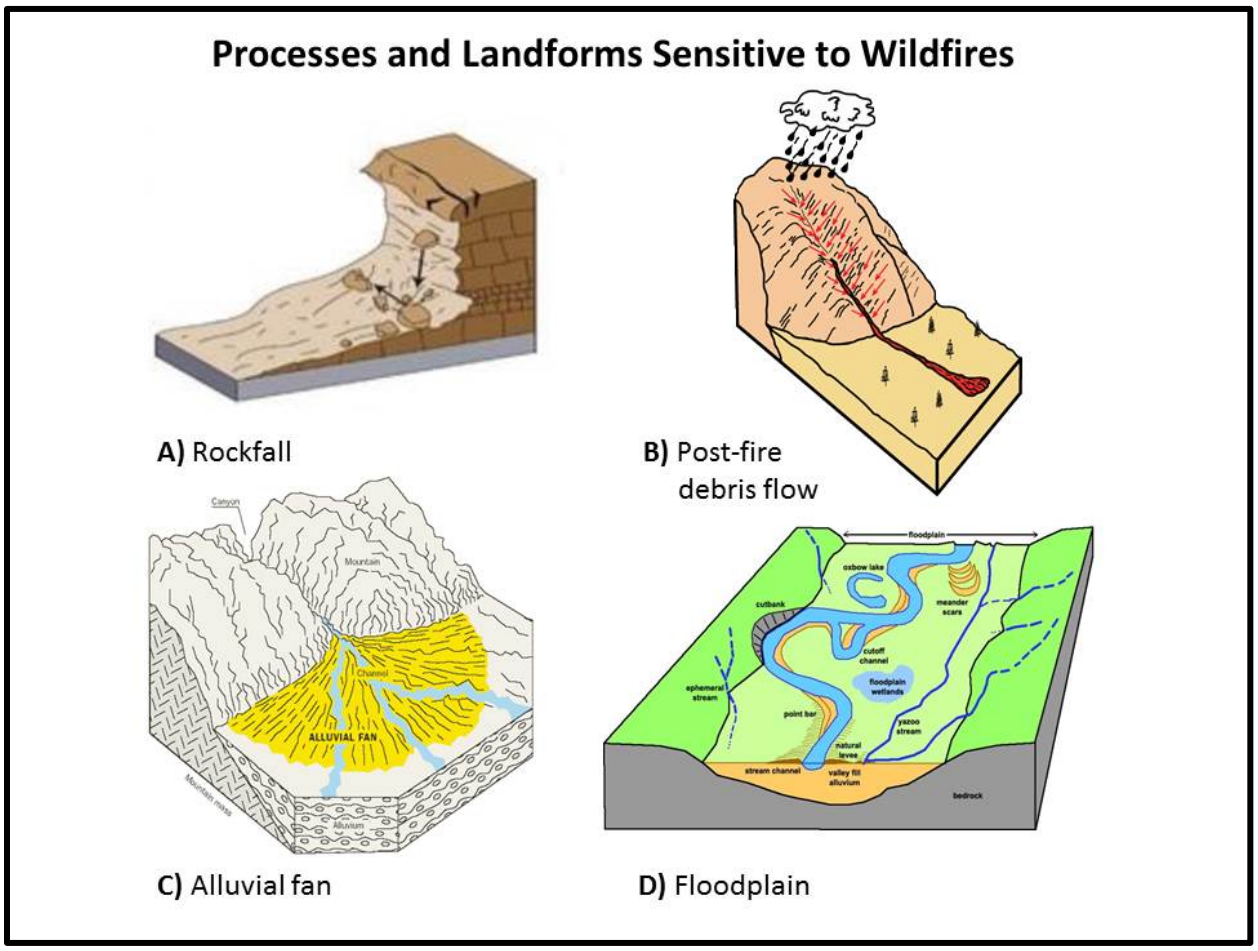


Figure 11. Geomorphic processes and landforms considered by WERT personnel to verify and assess hazards for VARs on the Camp Fire. VARs potentially subject to these geomorphic processes or located within or adjacent to these landforms were generally assigned a higher risk.

4 RESULTS AND OBSERVATIONS

4.1 SOIL BURN SEVERITY

In general, the WERT found the Camp Fire BARC map was reflective of our field observations on better than 90 percent of the field verification sites (Appendix E). The final Soil Burn Severity (SBS) of the fire area can be classified as follows:

- **19** percent unburned to very low SBS;
- **63** percent low SBS;

- **16** percent moderate SBS; and
- **2** percent high SBS.

Figure 12 is a map of SBS and shows the spatial pattern of SBS throughout the burn area.

The map exemplifies that the burn area is dominated by very low to low SBS. Areas of high SBS are most common in the areas around Concow, Jordan Hill, Yankee Hill, and upslope of Pulga.

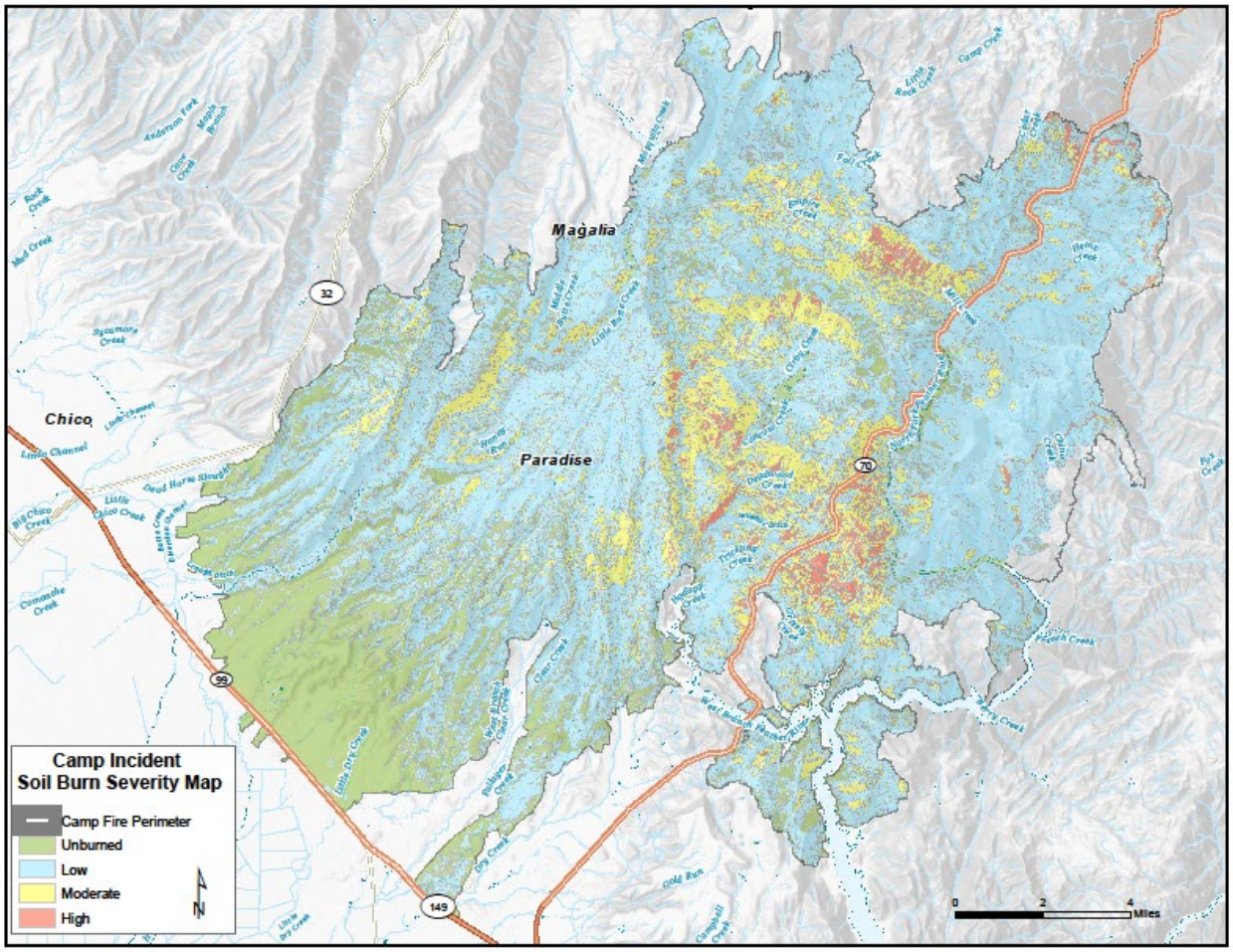


Figure 12. Soil Burn Severity Map of the Camp Fire burn area.

4.2 POST-FIRE FLOOD FLOW MODEL RESULTS

Watersheds, or “pour points”, were selected to estimate potential post-fire peak flow increases to Values-at-Risk from flooding and sediment-laden flood hazard. Figure 10 shows the pour point locations. These pour points represent the highest potential for life-safety related flood hazard and/or sediment. Table 6 shows the basin characteristics of the pour point watersheds and calculated bulking factor multiplier.

Generation of post-fire flow multipliers indicates a 10 to 20 percent potential peak flow increase in the Butte Creek watershed with the highest increase located on Little Butte Creek. A 10 percent potential increase in the Little Chico Creek Watershed was calculated at the diversion structure. Post-fire flow multipliers indicate a 20 to 40 percent increase in the Butte Valley area. Concow reservoir is predicted to have a potential increase of 70 percent due to the high proportion of drainage areas in high and moderate SBS. Generation of post-fire flow multipliers for the West Branch and North Fork of the Feather River indicates a 30 percent and 3 percent potential peak flow increase, respectively. **The post-fire multipliers in Table 6 should only be applied to return period flows of ten years or less. Additionally, these multipliers are most appropriately applied within the first 1-2 years following the fire, or until ground cover within the burn area is well established.**

Table 6. Estimated bulked post-fire flow multipliers for the fourteen pour points shown in Figure 10. Post-fire multipliers should not be applied beyond the 10-year recurrence interval/return period.

Pour Point ID	Pour Point Number	Drainage Area (mi^2)	Low SBS (%)	Moderate SBS (%)	High SBS (%)	Bulked Post-Fire Multiplier
Upstream of Little Chico Creek Diversion	1	25.4	18.8	3.1	0.0	1.1
Butte Creek Upstream of Little Butte Creek Confluence	2	117.4	5.5	0.6	0.0	1.0
Little Butte Creek Upstream of Butte Creek Confluence	3	30.2	39.9	9.8	0.2	1.2
Butte Creek at Covered Bridge	4	147.9	12.6	2.5	0.0	1.1
Butte Creek at Highway 99	5	157.9	14.8	2.6	0.0	1.1
Confluence of Dry and Clear Creek	6	49.3	35.5	5.8	0.0	1.2
West Branch Clear Creek at Steamboat Rd	7	3.6	58.8	5.2	0.0	1.2
Clear Creek near Clear Creek Cemetery Rd	8	5.9	76.0	12.4	0.0	1.4
Clear Creek at Durham Pentz Rd	9	11.7	60.1	7.8	0.0	1.2
Little Dry Creek on Book Family Farm Road	10	16.3	44.2	2.9	0.0	1.1
Hamlin Slough on Durham Dayton Road	11	23.3	37.4	4.9	0.0	1.2
Concow Reservoir	12	13.3	55.2	32.5	1.9	1.7
West Branch Feather River at Fire Perimeter	13	144.7	22.2	11.3	1.4	1.3
North Fork Feather River at Fire Perimeter	14	620.8	6.0	1.1	0.3	1.0

4.3 DEBRIS FLOW MODEL RESULTS

The debris flow likelihood maps based design storm with a peak 15-minute intensity of 1.6 inches/hour (40 mm/hr) design rainfall are presented in Figure 13 and Appendix D, and illustrate the likelihood of debris flows occurring in response to a 1- to 2-year annual

precipitation event. Based on the results, 420 of the 1,416 basins was (approximately 30 percent) have a likelihood of 60 percent or greater to debris flows.

For watersheds burned in the Camp Fire, these results give a general 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.

USGS Watch Stream Segments were used to indicate the presence of drainages within and below the burn area that can be impacted by the combined effects of debris flows and floods generated from one or more tributary basin. These are areas where a combination of runoff hazards may be present, and where flood hazard analyses should consider bulking factors for modeling the increase in runoff volume due to the contribution of sediment and debris.

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. 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), as discussed above. The hazards in burn 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 rock falls and debris slides are not included in the model results.

It is important to note that the dataset used to develop the USGS model contains little data from northern California. Despite the fact that the model has not been formally validated for northern California, WERT geologists have found the model to be very helpful in concentrating field evaluation efforts.

Based on our experience and field observations on past WERT assignments, it appears that the debris flow model results generally tend to overpredict the probability of debris flows in the region. As stated above, the majority of slopes within the Camp Fire burn area are gentle to moderate (less than 40 percent slopes) with rolling topography and do not appear conducive to the production of debris flows (see Figure 4, Slope Map).

Generally, steeper slopes within the burn area were interpreted by the model as having a high probability of producing debris flows. The dissected steep slopes observed along Butte Creek and in other areas within the burn area were interpreted by the model as debris flow producing basins. As stated above, the slopes along Butte Creek appear to have been modified by historical hydraulic mining and these landscapes have supported steep slopes over long periods and multiple fires without evidence of significant mass wasting. Along the West Branch and North Fork Feather River, bedrock is generally competent, supports moderate to steep slopes, and is mostly mantled by shallow, gravel-rich soils. While these steep slopes within the burn area are likely to produce additional erosion and rock fall as a result of post-fire effects, no obvious visible geomorphic evidence of substantial historic debris flows were observed in these areas.

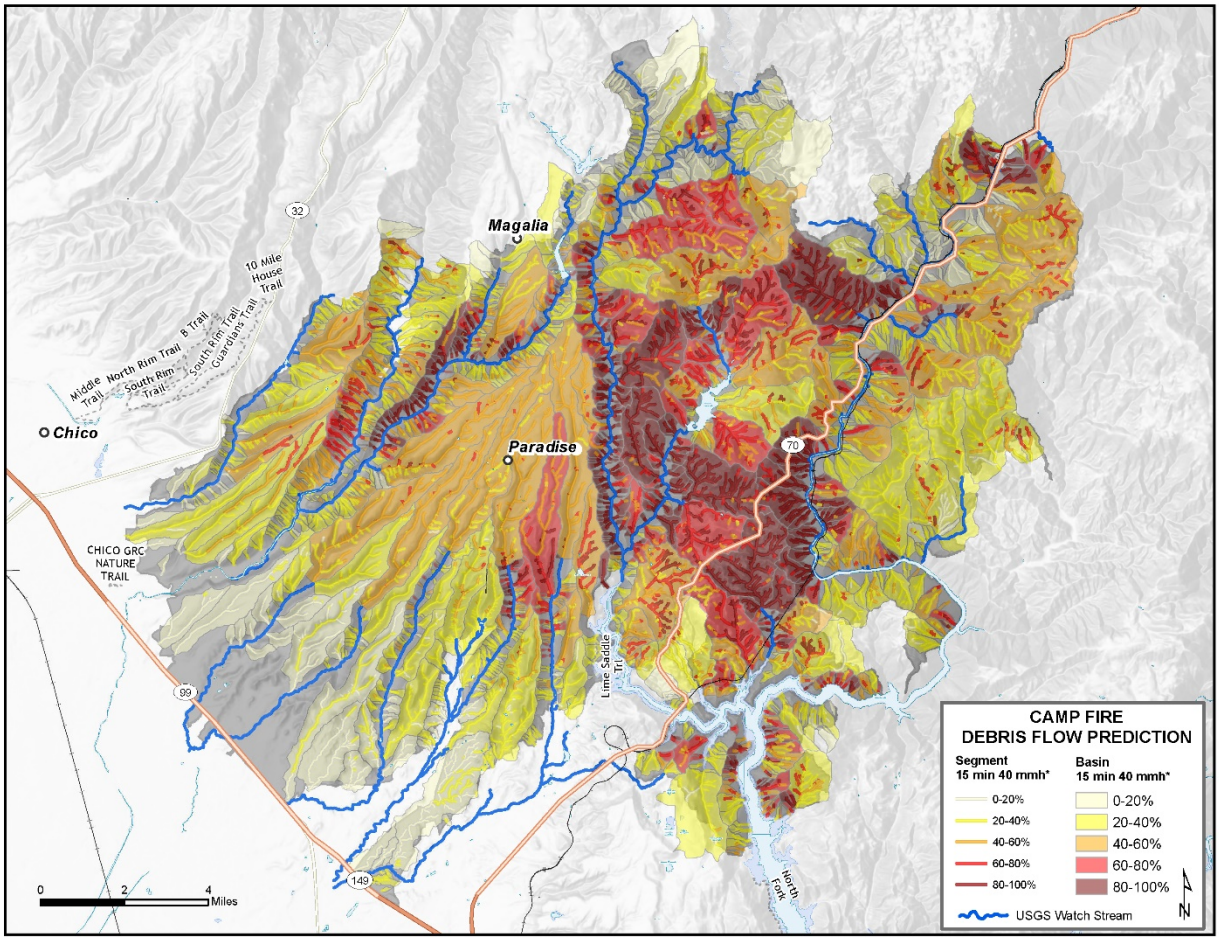


Figure 13. Combined basin and stream segment debris flow hazard for a 15-minute, 1.6 in hr^{-1} (40 mm hr^{-1}) storm event.

4.4 PRE- AND POST-FIRE EROSION AND SEDIMENTATION RESULTS

Batch ERMiT model results indicate average post-fire sediment production rates up to 25 tons per acre with an overall average of 5.89 tons per acre over the burn area for a 2-

year recurrence interval storm (Figure 14). Areas that show elevated increased erosion potential (between 20 to 25 tons per acre) included the very steep soils along the upper reaches of Butte Creek, Dry Creek, Clear Creek, and other smaller drainages to Butte Valley and along the West Branch Feather River.

The average rate of modelled post-fire sediment erosion is approximately 4 times higher than the decadal scale sedimentation rates estimated from data from Oroville Dam (see Section 3.3.4).

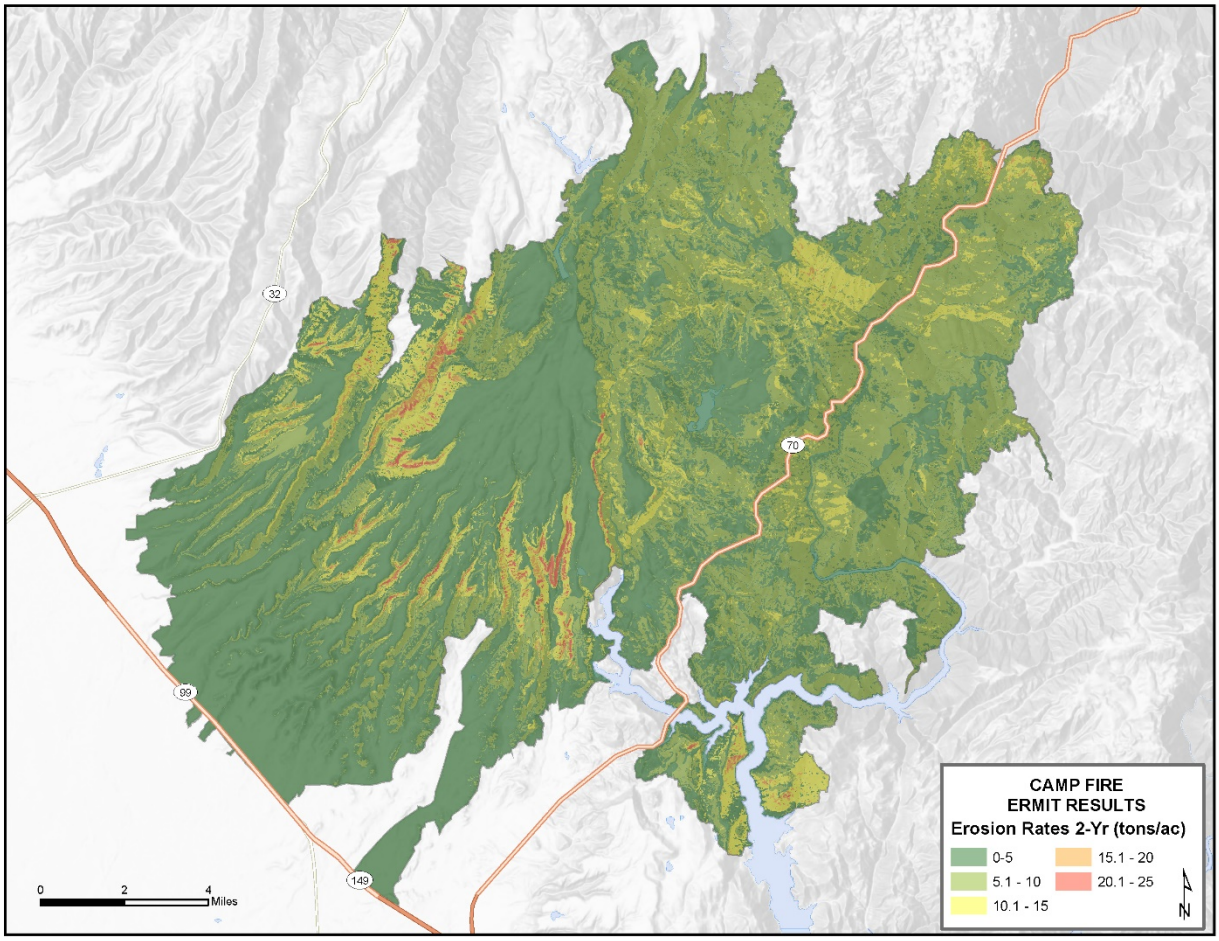


Figure 14. ERMiT Results Map showing Erosion Rates for a 2-year storm event.

4.5 EMERGENCY DETERMINATION - EXIGENCIES

No exigencies were observed or identified during the WERT evaluation of the Camp Fire.

Locations of known moderate risk were identified in areas of increased likelihood of rockfall and debris flows along the Highway 70 and Union Pacific Railroad corridors within the eastern portion of the burn area, within the Feather River Canyon. It is

understood that Caltrans and the Union Pacific Railroad (UPRR) are responsible for further evaluation of the Highway 70 and railroad corridors, respectively.

The Town of Pulga, located within the northeastern portion of the burn area west of Highway 70 was observed as an area at high risk due to debris flows and flooding. This portion of the burn area is located at the base of Flea Canyon, a steep drainage basin that exhibits moderate to high burn severities.

WERT field observations confirmed a low to moderate potential risk to property due to flooding along Little Butte Creek, Little Chico Creek, Clear Creek, Dry Creek, Little Dry Creek, and the Feather River. These areas are located in previously mapped flood hazard zones as identified by FEMA and DWR, and are at an elevated flood risk regardless of the Camp Fire effects.

4.6 DEVELOPMENT AND KEY INFRASTRUCTURE

Development in the assessment area is generally low density except around the Towns of Paradise and Magalia and on the outskirts of the City of Chico. Outside of these areas, concentrations of residential development are located around Concow, Yankee Hill, and Butte Valley. Residential development is generally on flatter topography along ridgetops and/or away from debris flow and/or flood prone areas. Public roads (county, state Highways 99 and 70) and railroads occur throughout the assessment area. Highways 70 and 99 are the major access connecting the north and south portions of the county.

A significant portion of the burn area is located immediately upstream of Lake Oroville, a reservoir that is formed by the Oroville Dam impounding the Feather River. Lake Oroville is the largest impoundment of the California State Water Project and provides hydroelectric power, drinking and agricultural water, and flood control to the Northern Sacramento Valley Region.

4.7 OBSERVATIONS AND RECOMMENDATIONS

4.7.1 TOWN OF PULGA (VAR 1)

The Town of Pulga is located in the northern portion of the burn area at the mouth of Flea Valley Creek just west of State Highway 70. The Flea Valley Creek drainage basin immediately upslope of the Town of Pulga is characterized by moderate to steep convergent slopes that show evidence of active to dormant-historic landslide activity. The majority of the canyon slopes were observed to exhibit moderate to high burn severities.

The Town of Pulga appears to consist of a series of around 20 historic buildings and vacation cabins, all of which appear to have been constructed within the apparent flood or runout area of Flea Valley Creek. The facilities are primarily occupied for summer

group rentals and the landowner is the only permanent year-round occupant. According to the landowner, heavy flows and occasional flooding are common along Flea Valley Creek through the town.

An existing concrete arch culvert was observed across Flea Valley Creek above the majority of the town buildings. The crossing appeared to have been installed at approximately 30 to 40 degrees off of the natural stream course. Post-fire sediment and debris could result in the crossing being overtopped, further exacerbating the potential for flooding and debris flow impacts to the structures below.

Based on our field observations, the entire Town of Pulga was identified as polygon VAR (VAR 1). Our observations and the potential high risk to life and property due to post-fire effects were conveyed to the landowner in the field, who informed us that she resides in the Pulga schoolhouse during the winter months. The schoolhouse was observed to be located on a convex slope about 300 feet southeast and 50 feet higher in elevation from identified hazard area.

Recommendations

- Consider specific recommendations for VARs provided in Appendix C.
- Develop or utilize early warning systems, tied to prediction of incoming storm events.
- Perform storm patrols and monitor road drainage infrastructure.
- Consider vegetation and debris removal within channels, particularly at watercourse crossings.
- Utilize experts in civil, geotechnical, and hydrologic engineering, soil erosion, hydrology and engineering geology to develop site-specific recommendations and mitigation activities.
- The Town of Pulga within the floodplain of Flea Valley should not be occupied during storm warnings.

4.7.2 HIGHWAY 70 CORRIDOR (VARS 2-7)

The Highway 70 corridor assessment area includes the North Fork Feather River canyon and the area to the eastern most margin of the burn area, excluding the Flea Canyon above Pulga area (see VAR #1). Elevations range from 1,100 feet near Lake Oroville to 5,200 feet amsl near Bear Ranch Ridge. The slopes east of the Highway 70 corridor are mountainous and drain to the Feather River exhibit evidence of regular rockfall slope failures. Highway 70 and the Union Pacific Railroad run along opposite sides of the canyon in the burned area and are constructed below steep and bowl-shaped slopes. The Cresta powerhouse, a Caltrans maintenance yard, and rest area also lie within this area.

The Feather River Canyon's walls are generally steeper along its eastern margin. South of the town of Pulga, Highway 70 is located on the west side of the canyon, while the railroad is on the east side. The railroad and highway both cross the Feather River just south of Pulga where they run along the opposite sides of the canyon; Highway 70 to the east and the railroad on the west. Soil exhibits moderate to high burn severities along the west side of the Feather River canyon from China Gulch to Bardees Bar, and the east side across from Jarbo Gap. Highway 70 runs along the upper portions of the western slopes; however, the railroad runs along the bottom of the slopes.

A total of six VARs (2-7) were identified within the Highway 70 assessment area. The primary VAR polygon is the Highway 70 and the Union Pacific Railroad corridors that traverse both sides of the Feather River canyon (VAR#2) and was assessed as low risk to life and high risk to property due to the high debris flow hazards associated with the steep slopes within the canyon. VAR #3 is the Pulga maintenance yard, owned by Caltrans, and was identified as a site that may be potentially impacted by debris flows and/or flooding. VAR #4 is a UPRR-owned wooden trestle bridge at the UPRR maintenance yard at Pulga and was assessed because of the high probability of flooding and debris flows from Flea Valley Creek (see VAR #1). VAR #5 is the Shady Rest Picnic Area and rest stop along Highway 70 and assessed as low risk to life and property from potential flooding of the Feather River. VAR #6 is the Cresta Powerhouse and penstocks, which could be impacted by flooding and debris flow impacts but were assessed to be of low risk to life and property. VAR #7 is a privately-owned historical homesite along Highway 70, which could be impacted by flooding of a nearby culvert. It was assessed to be relatively low risk to life and moderate risk to property because of its proximity to a watercourse crossing.

Recommendations

- Consider specific recommendations for VARs provided in Appendix C.
- Develop or utilize early warning systems, tied to prediction of incoming storm events.
- Perform storm patrols and monitor road drainage infrastructure.
- Consider vegetation and debris removal within channels, particularly at watercourse crossings.
- Close Shady Rest Picnic Area during winter storm warnings.
- Utilize experts in civil, geotechnical, and hydrologic engineering, soil erosion, hydrology and engineering geology to develop site-specific recommendations and mitigation activities.

4.7.3 CONCOW AREA (VARS 8-19)

The Concow assessment area includes burned areas draining to Concow Creek and West Branch Feather River, and those areas north of Lake Oroville. This area includes the sparsely populated communities of Concow, Deadwood, Jordan Hill, and Yankee Hill. This area consists of rural single-family homes and ranches, as well as federally- and privately-owned timberlands.

The Concow area is characterized by gentle to moderate rounded slopes. Slopes within the Concow area appear modified as a result of historic mining practices and residential grading. Residential structures within the Concow portion of the burn area are built atop gentle rolling hills. The majority of the steep slopes in this area are located along watercourses, such as the West Branch Feather River.

Generally, soils in this investigation area exhibited moderate to high burn severity except near Concow Reservoir, the lower elevation areas near Lake Oroville, Big Bend, along Oakway Road, and the northern portion of West Branch Feather River canyon. Of the properties within floodplains, only a few of them had structures located in the floodplain itself.

A total of twelve VARs (8-19) were identified within the Concow assessment area. Most of the identified VARs (8, 9, 11, 12, 16, 17, & 19) were structures or homesites found to be located within the FEMA flood hazard awareness areas. Other VARs (14, 15, & 18) include watercourse crossings showing signs of compromised functionality. VAR #13 is Concow Reservoir and is at risk of increased sediment delivery from wildfires, but is assessed as a low risk to property. The watershed draining into the reservoir was estimated to have a 70% increase in flows as compared to pre-fire conditions. These VARs may be impacted by sediment-laden runoff, flooding, elevated erosion, and, to a lesser extent, debris flows. VAR #10 is a road segment on Jordan Hill Road a steep slope showing signs of slope failures.

Recommendations

- Consider specific recommendations for VARs provided in Appendix C.
- Develop or utilize early warning systems, tied to prediction of incoming storm events.
- Perform storm patrols and monitor road drainage infrastructure.
- Consider vegetation and debris removal within channels, particularly at watercourse crossings.
- Utilize experts in civil, geotechnical, and hydrologic engineering, soil erosion, hydrology and engineering geology to develop site-specific recommendations and mitigation activities.

4.7.4 PARADISE PLATEAU AREA (VARS 20 AND 55-58)

The Paradise Plateau assessment area contains the ridge top communities of Paradise and Magalia. The area is comprised of urban and rural residential development on primarily gentle slopes on the ridge tops above the West Branch Feather River, Butte Valley and Butte Creek. Most the structure loss occurred in this assessment area. Soil burn severity in the assessment area is primarily low with small pockets of unburned and moderate.

Five VAR's (#20, 55-58) were identified within the assessment area. VAR #20 is a residential structure immediately downstream of a watercourse crossing on Oakmont Road. A portion of the structures foot print may be impacted if the crossing fails during rainfall events. VAR's 55-58 are also residential structures that may be impacted by flood flows. Because the area has significant amount of road and development infrastructure, drainage patterns may alter the anticipated flow paths.

Recommendations

- Consider specific recommendations for VARs provided in Appendix C.
- Develop or utilize early warning systems, tied to prediction of incoming storm events.
- Perform storm patrols and monitor road drainage infrastructure.
- Consider vegetation and debris removal within channels, particularly at watercourse crossings.
- Utilize experts in civil, geotechnical, and hydrologic engineering, soil erosion, hydrology and engineering geology to develop site-specific recommendations and mitigation activities.

4.7.5 BUTTE VALLEY AREA (VARS 21-38)

The Butte Valley assessment area includes the low-lying areas of the southern portion of the burn area below Paradise including the drainages of Clear Creek, Dry Creek, Hamlin, Berry, and Nugen Canyons, and areas near Cherokee, and Bloomer Hill near Lake Oroville. The area is generally sparsely populated, and consists of single-family homes and ranches, and Butte College's main campus which is 928 acres and includes low-lying areas of West-branch Clear Creek. Of the properties within floodplains, only a few structures were located in the floodplain itself.

The drainages within Butte Valley exhibit relatively gentle slopes, except within the moderately steep walls in the canyons, that descend to gentle rolling hills and transition to flat valleys. The slopes have been modified in some of the canyons through historic mining practices that bored under the prominent lava caps typical of this area as well as minor amounts of residential and agricultural grading. Soils in this area generally exhibit

low and very-low burn severity. Exceptions include the burned areas near Cherokee and Bloomer Hill near Lake Oroville where some moderate soil burn severity is mapped.

Eighteen VARs (21-38) were identified within the Butte Valley area. Most of the VARs identified were homes or structures within the floodplain or flood prone areas or watch streams (VARs 22-27, 30-33, & 36). VAR 21 is a bridge and maintenance buildings on Butte College property. VARs 28, 34, & 35 are bridges below flood level. VAR 34 is a power substation with gasoline tanks stored nearby, both located in a floodplain. VAR 37 is a historic water impoundment in a tributary to Dry Creek, portions of which were damaged by fire. The water impoundment appears to have a low risk of overtopping and exacerbating any potential flood impacts in Dry Creek and damaging any life or property. VAR 38 is a single-family home located on steep convergent slopes of an apparent dormant landslide. Accordingly, these VARs may be impacted by sediment-laden runoff, flooding, elevated erosion, and, to a lesser extent, debris flows.

Recommendations

- Consider specific recommendations for VARs provided in Appendix C.
- Develop or utilize early warning systems, tied to prediction of incoming storm events.
- Perform storm patrols and monitor road drainage infrastructure.
- Consider vegetation and debris removal within channels, particularly at watercourse crossings.
- Utilize experts in civil, geotechnical, and hydrologic engineering, soil erosion, hydrology and engineering geology to develop site-specific recommendations and mitigation activities.

4.7.6 BUTTE CANYON AREA (VARS 38-54)

The Butte Canyon assessment area includes the watersheds of Butte Creek and Little Chico Creek. Tributaries to Butte Creek include Little Butte Creek and Honey Run. The area is comprised of gentle slopes on the ridge tops and adjacent to the main stem watercourse and steep slopes immediately below the ridge tops. The area is comprised of rural residential development, mainly adjacent to the main stem watercourses. Some rural residential development is also located on the gentle slope ridge tops. Evidence of historic mining (tailings) also occur in the watershed. Soil burn severity in the assessment area is mainly unburned to low with small amounts of moderate, typically associated with the steeper slopes.

A total of 15 VAR's were identified in the assessment area. VAR's 40-44 were identified for flooding, primarily because they are within the FEMA flood hazard awareness areas. VARS 45-47, 50 and 51 were identified as hazards from debris

flows. VAR's 48, 52 and 54 were identified as bridges with limited free board and may be subject to debris racking, overtopping or failure during flood events. VAR 53 is a fish ladder that may be impacted by flooding and debris racking. VAR 49 is the remains of the covered bridge in the channel at Honey Run. The county is currently in the process of removing the debris from the channel.

Recommendations

- Consider specific recommendations for VARs provided in Appendix C.
- Develop or utilize early warning systems, tied to prediction of incoming storm events.
- Perform storm patrols and monitor road drainage infrastructure.
- Consider vegetation and debris removal within channels, particularly at watercourse crossings.
- Utilize experts in civil, geotechnical, and hydrologic engineering, soil erosion, hydrology and engineering geology to develop site-specific recommendations and mitigation activities.

4.8 GENERAL RECOMMENDATIONS

Education for Residents and General Public

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, and be aware of the following (Suzanne Perry, USGS, Disaster Scientist, Personal Communication).

- Be ready for debris flows or floods for 2-5 years after a wildfire. Do not 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, 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 have seen in past debris flows or floods. Debris flows 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 second 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 have 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.

Increased Flood Flows, Erosion and Sedimentation

Hydrologic modeling predicts that in addition to post-fire debris flows, post-fire runoff will increase by a bulking factor of 1.1 to 1.7 relative to unburned areas. Post-fire erosion modeling predicts that erosion, and therefore sedimentation, rates will increase more than an order of magnitude above background rates. The USGS debris flow model and ERMiT model results can be used to predict relative impacts to critical infrastructure such as municipal drinking water facilities (Figure 13). Therefore, emergency actions, maintenance and storm response activities should be developed with these conditions in mind. Additionally, the ERMiT model can be used to help identify areas that can be expected to generate the most hillslope sediment so that transportation and public works agencies can prioritize road maintenance crews prior to and during storm events.

The NRCS offers technical assistance and produces a number of post-fire mitigation pamphlets that may be useful for local agencies and residents. These can be accessed at the following website:

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ca/newsroom/features/?cid=nrcseprd1289661

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.

Emergency-response and public-safety agencies are often faced with making decisions and deploying resources both well in advance of strong winter storm events and during the storms themselves. Information and methodology critical to this process is provided for by the USGS Open File Report OF10-1039 that can be accessed at: http://pubs.usgs.gov/of/2010/1039/pdf/OF10-1039.pdf.

For post-fire debris flow hazards, warnings with practical lead times of several hours must come from a combination of weather forecasts, rainfall measurements of approaching storms, and debris-flow triggering thresholds. The USGS has worked together with the NWS to provide guidance for post-fire debris flow thresholds that may be used by the NWS for “watch” and “warning” notifications:

https://landslides.usgs.gov/hazards/warningsys.php

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 burn areas:

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

NWS – Northern California Region (Sacramento): http://www.weather.gov/sto/

NWS - Post-wildfire flash flood and debris flow guide

http://www.wrh.noaa.gov/lox/hydrology/files/DebrisFlowSurvivalGuide.pdf

Homes Located in or near the FEMA 100-Year Floodplain, DWR Awareness Floodplain, or USGS Watchstream

The WERT noted several areas of homes and infrastructure that are located within or in close proximity to the FEMA 100-year floodplain, DWR Awareness Floodplain or USGS Watchstream (Appendix B). An early warning system should be used to notify home

owners and/or communities prior to onset of large storm events. Information and methodology critical to this process is provided above and by the USGS Open File Report OF10-1039 that can be accessed at: http://pubs.usgs.gov/of/2010/1039/pdf/OF10-1039.pdf.

Homes located in or near the FEMA 100-Year Floodplain, DWR Awareness Floodplain, or USGS Watchstream downstream of the burn area should be made aware of the increased risk of flooding.

Temporary/Permanent Housing

When there is need for temporary and permanent housing or new building construction for residents displaced by the fire, site-specific evaluation of hazards for temporary housing should be conducted by a qualified professional and in accordance with the local lead agency. In addition to assessing post-fire flood hazards, the following factors should be considered as part of the evaluation.

On hillslopes above potential temporary housing and building sites:

- Could runoff from the hillslope concentrate in swales and small drainages and flow onto the site, and flood or otherwise damage the proposed structure, or present a life-safety hazard?
- Is the hillslope behind the structure steep and erodible, where rilling, gullying, or shallow failures could deliver a sufficient volume of sediment and debris to damage the proposed structure or pose a life-safety hazard?
- Are large rocks, boulders, or other material present on the slope that pose a rock or debris fall hazard that could impact the proposed structure, or present a life-safety hazard?
- Is there evidence of recent or impending erosion or mass wasting that could damage the proposed structure or pose a life/safety hazard (e.g., debris torrents/flows, deep-seated slides or slumps)?

On hillslopes below potential temporary housing and building sites:

- Is there evidence of recent or impending fill slope landslide-type failures that indicate an elevated risk of building pad failure?
- Is the building pad located above a watercourse where normal or flood flows could potentially erode the toe of the slope and trigger failure?

If any of these conditions are present, then mitigations need to be implemented, or alternative sites need to be identified and evaluated. Technical experts such as licensed engineers and/or geologists may be needed to support the evaluation.

Road Drainage Systems and Storm Patrols

The residential communities within and downstream of the Camp Fire burn area are serviced via a network of roads and highways. Caltrans maintains Highway 70 and Butte County, City of Chico, City of Oroville, and the City of Paradise control the municipal road system. The WERT did not evaluate the potential for rockfall, sedimentation, flooding or debris flow hazards at all crossings along the highway or municipal road corridors.

The WERT contacted the responsible road management agencies and advised them of the availability of this report. Many of the roads are located near or cross the drainages that flow within or downstream of the fire area. The road system includes numerous culverts and bridges that discharge into natural and man-made drainage swales. Many of the roads are insloped and carry water to culverts with inside ditches. Because water repellent soils developed from the fire and vegetation has been burned, increased flows on slopes and onto the road system can be expected. Loose and erodible soils that mantle the slopes could wash down, inundate, and plug the drainage structures. Flows could be diverted down roads and cause erosion and possible blockage and/or loss of portions of the road infrastructure and structures along roads. Rockfalls can occur where slopes are steep and larger rocks or rock outcrops are present, this is exacerbated in areas where the fire has damaged or consumed supporting vegetation. Responsible agencies can utilize the ERMiT results to assist in evaluating areas of increased erosion, additionally areas of steep slopes adjacent to roadways can be noted to assist in evaluating areas that may be subject to rockfall.

The WERT did not evaluate every culvert, bridge or other type of crossing within or downstream of the burn area. Only observed areas that appeared at risk to obvious debris flow impact or flooding were evaluated. The observations documented in this report are intended to be used as a preliminary indication of some of the most obvious areas of potential concern for follow-up work and more detailed evaluations. The observations are not intended to be comprehensive and conclusive, but rather to serve as a preliminary tool to assist emergency response agencies (for example Shasta County, City of Redding, Caltrans, Office of Emergency Services, Natural Resource Conservation Service, Central Valley Regional Water Quality Control Board, utility companies, and other responsible agencies) in development of more detailed post-fire emergency response plans.

Along bridges and other types of crossings identified as a risk to flooding and hyper-concentrated (bulked) flows, the WERT suggests responsible agencies consider installing gates, warning signs, or other measures (such as evacuation warnings) to control traffic and keep people out of identified risk areas during large storm events. It will be very important to utilize scheduled storm patrols during large, intense storm

events to ensure that identified high risk watercourse crossings are functioning properly. Existing road drainage systems should be inspected by the appropriate controlling agency to evaluate potential impacts from floods, hyper-concentrated floods, debris torrents, debris flows and sedimentation resulting from storm events.

Signage

Place temporary signage 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.

Hazardous Minerals

Portions of the Camp Fire burn area may be underlain by naturally occurring hazardous minerals (particularly naturally occurring asbestos (NOA)). Rock and associated soil in these areas may contain naturally occurring asbestos. Information regarding these hazardous minerals can be found at the Bay Area Air Quality Management District (http://www.baaqmd.gov/in-your-community/napa-county), Butte County Air Quality Management District (https://bcaqmd.org/resources-education/asbestos/) and Cal EPA Air Resources Board (http://www.arb.ca.gov/toxics/asbestos/geninfo.htm). We recommend consultation with the appropriate District to develop mitigations that are centered on limiting dust generation and limiting dust exposure consistent with NOA.

Historic and Active Mine Sites

Owing to the extreme relief and potential access limitations following significant rain events, it may be difficult to access known mine sites. See Mineral Hazards map (Figure 9) for a map of mining sites that the WERT is aware of. Additional recommendations are as follows:

- Expect higher erosion and sedimentation rates, as well as increased runoff from these mining sites. Take appropriate actions to reduce the potential for these processes to further impact infrastructure and the environment.
- Regularly inspect drainage culverts at road crossings for debris blockage before and after a weather event.
- Maintain channels free of debris upstream of structures; improve routing of drainage; consult with qualified professionals to review natural drainage and conveyance structures.
- Manage surficial storm runoff to divert around waste containment ponds, fill caps, and other environmental cleanup infrastructure.

- Consider evacuation of active mine sites prior to a predicted high intensity storm event**.**
- Manage and patrol roads that are prone to rockfall and erosion prior to and following rain events.
- Regularly monitor environmental cleanup infrastructure before, during, and after forecasted storm events.

Municipal Water Supplies.

The majority of the burn area drains into watersheds above domestic water intakes in the Sacramento Valley and Lake Oroville. Other portions of the burn area may drain to other domestic water supplies (including private domestic water). It is expected that runoff from the burn area will contain chemical contaminants in addition to ash and fire-related sediment and debris that may pose adverse impacts to the water supply and water supply systems. Additional study of impacts to downstream water supplies should be undertaken. Water supply agencies should be notified of this potential threat.

Water Impoundments

Many rural properties contain small ponds/reservoirs created by impounding streams behind earthen dams. We did not evaluate earthen dams. Where vegetation growing on these earthen dams has burned, landowners should contact the appropriate licensed professional to inspect the integrity of the dam.

Signage

Place temporary signage 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.

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APPENDIX A – LIST OF CONTACTS

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Cindi Dunsmoor	Butte County EOC	CDunsmoor@buttecounty.net>	
Ed Fortner	Paradise Irrigation District		530-518-6696
Dana Hendrix	CalTrans	Dana.hendrix@dot.ca.gov	
Chris Heindel	Thermalito Water and Sewer	cheindell@twsd.info	
Alexander Hoon	National Weather Service	Alexander.hoon@noaa.gov	
Mark Mattoxs	City of Paradise	mmattox@townofparadise.com	
Radley Ott	Butte County Public Works	ROtt@buttecounty.net	
Eric See	DWR-Orrville Dam		530-990-8804
	Union Pacific Railroad		888-877-7267
Betsy Ann Cowley	Town of Pulga Landowner	townofpulga@gmail.com	530-534-1096

Site Number	Community / Local area	Latitude	Longitude	Potential hazard / Field observation	Hazard Category	Specific at-risk feature	Feature Category	Potential hazard to life?	Potential hazard to property?	Preliminary Emergency Management Practice
48	Butte Canyon	39.73616	-121.68901	.Bridge does not appear to have adequate freeboard for woody debris passage	other	Bridge, residential access	drainage structure	low	high	Storm patrol
52	Butte Canyon	39.74451	-121.67737	Bridges that provide residential access does not appear to have adequate freeboard for woody debris passage. Bridge may detach during high flows and impact several bridges downstream.	flood	Bridge, residential access	drainage structure	low	high	Early warning system
45	Butte Canyon	39.76988	-121.67288	Residence located at the bottom of steep slopes. Based on a review of topographic maps residence is located near the outlet of channel, possible debris flow deposits observed upslope of residence.	debris flow	Residence	home	low	low	Early warning system
46	Butte Canyon	39.76860	-121.67350	Residence located at the bottom of steep slopes. Based on a review of topographic maps residence is located near the outlet of channel, possible debris flow deposits observed upslope of residence.	debris flow	Residence	home	low	low	Early warning system
47	Butte Canyon	39.76843	-121.67354	Residence located at the bottom of steep slopes. Possible debris flow deposits observed upslope of residence.	debris flow	Residence	home	low	low	Early warning system
50	Butte Canyon	39.73338	-121.69111	Debris flow plugging culvert and flowing toward downslope residence.	debris flow	Residence	home	low	low	Early warning system
39	Butte Canyon			Multiple residences located at the confluence of several stream channels. Possible debris flow deposits located in the area.	debris flow/flood	Residences	home	low	low	Early warning system
43	Butte Canyon			Residential structures located in mapped flood hazard area.	flood	Homes and structures	multiple	low	low	Early warning system
41	Butte Canyon			Houses within mapped DWR floodplain awareness area. Butte Creek identified as USGS Watch Stream.	flood	Residences	home	low	moderate	Early warning system and storm patrol
42	Butte Canyon			Residential structures located in mapped flood hazard area.	flood	Homes	home	low	moderate	Early warning system
44	Butte Canyon	39.75552	-121.73037	Residence located within floodplain.	flood	Residence	home	moderate	moderate	Early warning system
49	Butte Canyon	39.72857	-121.70390	Honey Run Bridge. County removed bridge debris. Support pylons remain in channel.	other	Downstream infrastructure	drainage structure	moderate	moderate	Storm patrol

Note: These results were based upon a rapid review so that as much time as possible was allowed for emergency measures to be put into place before storm events. This table is part of a broader document and should be used in conjunction with that document to ensure proper implementation of recommendations provided.

Sites shaded in gray indicate VARs with a polygon. Latitudes and longitudes are not provided.

Site Number	Community / Local area	Latitude	Longitude	Potential hazard / Field observation	Hazard Category	Specific at-risk feature	Feature Category	Potential hazard to life?	Potential hazard to property?	Preliminary Emergency Management Practice
51	Butte Canyon	39.73984	-121.67959	Debris flow plugging culvert and flowing towards Butte Creek Mobile Home Park.	debris flow	Butte Creek Mobile Home Park	home	moderate	moderate	Early warning system
40	Butte Canyon			Residences located within 100-year floodplain	flood	Residences	home	moderate	moderate	Early warning system
53	Butte Canyon	39.70978	-121.75087	Flooding, debris racking, and sedimentation.	flood	Fish ladder and screen	other	no	low	Monitor
54	Butte Creek	39.76725	-121.67344	Bridge, privately owned, could be compromised by high flows.	flood	Bridge	drainage structure	low	moderate	Early warning system and storm patrol
32	Butte Valley	39.68452	-121.62803	Two garages located adjacent to channel. Structures could be at risk of flooding.	flood	House	home	low	low	Early warning system
33	Butte Valley	39.66257	-121.66214	House mapped within flood zone. Channel is scoured below house.	flood	House	home	low	low	Early warning system
34	Butte Valley	39.64214	-121.64553	Sediment and debris could back up against bridge supports. Gas line observed across upslope side of bridge.	debris flow / flood	West Clear Creek Bridge	drainage structure	low	low	Storm patrol
35	Butte Valley	39.65255	-121.58856	Sediment and debris could back up against bridge supports.	debris flow / flood	Dry Creek Bridge	drainage structure	low	low	Storm patrol
36	Butte Valley	39.68716	-121.58734	Burned houses located within flood zone, including burned bridge crossing.	flood	House foundation	home	low	low	Early warning system
37	Butte Valley	39.70199	-121.58787	Historic water impoundment located near top of Dry Creek. Breach in dam may exacerbate flooding downstream. Impoundment is located on a low potential debris flow segment.	flood	Historic dam	drainage structure	low	low	Early warning system
38	Butte Valley	39.67588	-121.56971	House located on steep concave slopes and atop dormant landslide.	debris flow	House	home	low	low	Early warning system
21	Butte Valley			Footbridge and maintenance facilities located within mapped flood risk zone. Channel shows evidence of scour.	flood	Bridge and maintenance buildings	other	low	low	Early warning system
23	Butte Valley			Houses located within mapped FEMA flood hazard area. Structures appear to be located on terraces.	flood	Houses and outbuildings	home	low	low	Early warning system
24	Butte Valley			Houses located within mapped flood zone. Locked gate.	flood	Houses and outbuildings	home	low	low	Early warning system
25	Butte Valley			Houses located within mapped flood zone. Structures appear to be located on terraces. Private bridges within the flood zone may be prone to failure.	flood	Houses and outbuildings	home	low	low	Early warning system

Note: These results were based upon a rapid review so that as much time as possible was allowed for emergency measures to be put into place before storm events. This table is part of a broader document and should be used in conjunction with that document to ensure proper implementation of recommendations provided.

Sites shaded in gray indicate VARs with a polygon. Latitudes and longitudes are not provided.

Site Number	Community / Local area	Latitude	Longitude	Potential hazard / Field observation	Hazard Category	Specific at-risk feature	Feature Category	Potential hazard to life?	Potential hazard to property?	Preliminary Emergency Management Practice
26	Butte Valley			Houses located within mapped flood zone. Structures appear to be located on terraces.	flood	Houses and outbuildings	home	low	low	Early warning system
27	Butte Valley			Homes located within and adjacent to mapped flood hazard area.	flood	Homes	home	low	low	Early Warning System
28	Butte Valley			Bridge and Road located in mapped flood hazard area.	flood	Bridge and Road	drainage structure	low	low	Early Warning System
29	Butte Valley	39.65442	-121.63534	Electrical substation located within flood plain.	flood	Clark Road Substation	utilities	low	moderate	Early warning system. Notify PG&E .
31	Butte Valley	39.68269	-121.62838	House mapped within flood zone. Channel is scoured below house.	debris flow / flood	House	home	low	moderate	Early warning system
22	Butte Valley			Several homes located within mapped FEMA flood hazard area. Several small private bridges located along creek may be at risk of failure.	flood	Houses located in flood zone	home	low	moderate	Early warning system
30	Butte Valley	39.66584	-121.62598	House mapped within flood zone	flood	House	home	moderate	moderate	Early warning system
16	Concow	39.70500	-121.54831	Barn located adjacent to DWR floodplain awareness zone. Evidence of overland surface flow within the area.	flood	Barn	other	low	low	Early warning system
17	Concow	39.72165	-121.54223	Garage shed and butane tank located within channel zone. Channel appears highly modified.	flood	Shed and gas tank	home	low	low	Early warning system
10	Concow			Unpaved road on steep slope with multiple fillslope failures.	debris flow / flood	Road	other	low	low	Early warning system
18	Concow	39.78132	-121.50545	Crossing overtopping, undersized bridge. Bridge previously identified as VAR in 2008 SEAT Report.	flood	Bridge	drainage structure	low	moderate	Storm patrol
19	Concow	39.78181	-121.50562	House appears to be located within flood plain of tributary to Concow Reservoir.	flood	Residence	home	moderate	moderate	Early warning system, storm patrol
8	Concow			Burned house and other outbuildings located in channel zone, could be impacted by debris and/or flood. Site is located on moderate probability debris flow segment.	debris flow / flood	House and outbuildings	home	moderate	moderate	Early warning sytem
12	Concow	39.74525	-121.53729	Burned house located adjacent to stream in mapped flood hazard area. Stream is identified as USGS watch stream.	flood	House foundation	home	low	low	Early warning system

Note: These results were based upon a rapid review so that as much time as possible was allowed for emergency measures to be put into place before storm events. This table is part of a broader document and should be used in conjunction with that document to ensure proper implementation of recommendations provided.

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Site Number	Community / Local area	Latitude	Longitude	Potential hazard / Field observation	Hazard Category	Specific at-risk feature	Feature Category	Potential hazard to life?	Potential hazard to property?	Preliminary Emergency Management Practice
11	Concow	39.74587	-121.53883	Existing bridge downstream of Concow Reservoir. Concrete supports within thalweg of channel could block debris and accumulate upstream of crossing.	debris flow / flood	Bridge	drainage structure	low	moderate	Storm patrol
14	Concow	39.78940	-121.50754	Existing box culvert bridge at risk of plugging. The crossing shows evidence of past failure.	debris flow / flood	Box culvert bridge	drainage structure	low	moderate	Storm patrol
15	Concow	39.74110	-121.52022	Wood bridge on deadwood creek. The channel is identified as a moderate debris flow risk.	debris flow / flood	Bridge	drainage structure	low	moderate	Storm patrol
9	Concow			House and outbuildings built on alluvial fan deposits. Ditch constructed upslope to divert water around house.	debris flow / flood	House	home	low	moderate	Early warning system
13	Concow	39.77322	-121.51953	Increased sediment from wildfire may impact reservoir	debris flow / flood	Reservoir	utilities	no	low	Notify local water district
4	Highway 70	39.80250	-121.44761	Railroad trestle bridge crossing on Flea Creek at risk of debris flow. Observed apparent utility line across upstream side of bridge.	debris flow / flood	Railroad bridge crossing	drainage structure	low	high	Storm patrol
5	Highway 70	39.84787	-121.39382	Shady Rest Picnic area and public toilet located in mapped flood plain.	flood	Gazebo and toilets	recreational	low	low	Early warning system. Close facility during heavy storms.
6	Highway 70	39.82621	-121.40889	Cresta Powerhouse located within mapped Flood Hazard Area. Potential for debris flow impacts to powerhouse and penstocks.	debris flow / flood	Cresta Powerhouse and penstocks	utilities	low	low	Early warning system. Notify PG&E.
7	Highway 70	39.78891	-121.45326	Historical foundation / homesite located at mouth of steep concave hill slope. Culvert crossing located upslope of pad. Observed building foundation adjacent to culvert. Site appears unoccupied	debris flow / flood	Homesite	home	low	moderate	Early warning system
3	Highway 70			Caltrans Pulga Maintenance Station located at mouth of Mill Creek. It appears Mill Creek has been rerouted around the maintenance facility. Mill Creek is identified as a USGS Watch Stream	debris flow / flood	Caltrans maintenance buildings	utilities	low	moderate	Early warning system, notify Caltrans
2	Highway 70			Debris flow potential on highway 70 and Railroad may clog crossings and restrict transportation corridor.	debris flow / flood	Highway and railroad	other	low	moderate	Early warning system. Storm patrol, notify CalTrans and Union Pacific Railroad

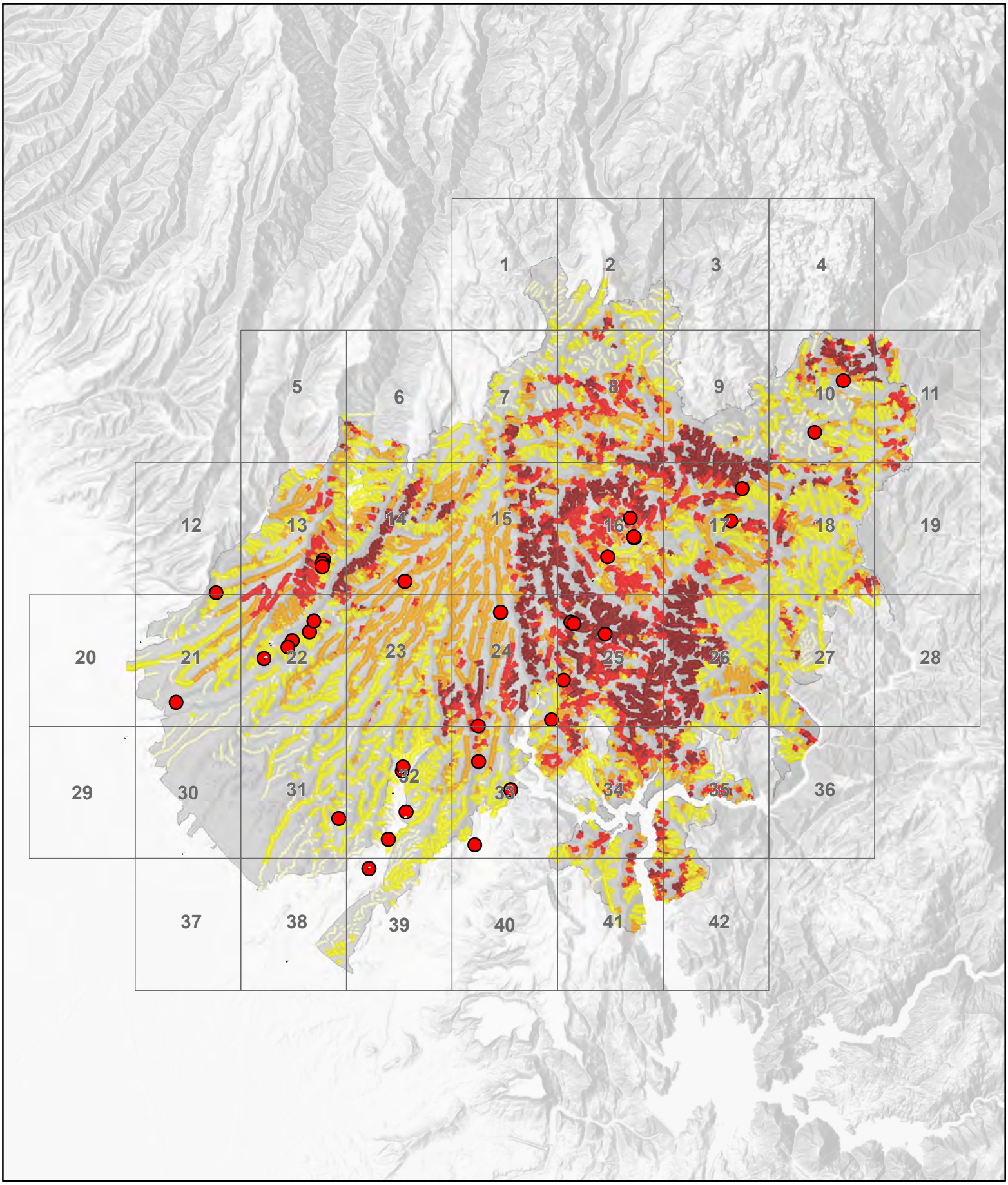
Note: These results were based upon a rapid review so that as much time as possible was allowed for emergency measures to be put into place before storm events. This table is part of a broader document and should be used in conjunction with that document to ensure proper implementation of recommendations provided.

Sites shaded in gray indicate VARs with a polygon. Latitudes and longitudes are not provided.

Site Number	Community / Local area	Latitude	Longitude	Potential hazard / Field observation	Hazard Category	Specific at-risk feature	Feature Category	Potential hazard to life?	Potential hazard to property?	Preliminary Emergency Management Practice
20	Paradise	39.76162	-121.62868	Culvert could plug and divert towards downstream residence	flood	Residence, burned down	home	low	low	Storm patrol
55	Paradise			Several homsites adjacent to watercourse along with box culvert at risk of plugging and diversion.	flood	Several homesites along creek	home	low	low	Storm patrol and Early warning system
57	Paradise			Several homesites adjacent to creek. Several in channel structures, crossings and bank reinforcement that may reduce channel capacity.	flood	Homesite, watercrouse crossings	home	low	low	Early warning and storm patrol.
56	Paradise	39.74948	-121.57684	Homesite in creek bottom/ flood risk. Evidence of erosion mitigations on lot adjacent to creek.	flood	Homesite	home	low	moderate	Early warning
58	Paradise			Homes in close proximity of Clear Creek and tributaries. Watercourse observed running through homesite, unsure if it is by design.	flood	Homes	home	low	moderate	Early warning system.
1	Pulga			Several cabins and houses located in flood plain of Flea Creek. Owner reported past flooding and debris flow on property. Bridge crossing on Pulga Road is off alignment could restrict passage of debris.	debris flow / flood	Numerous structures and crossing	home	high	high	Early warning system and storm patrol

Note: These results were based upon a rapid review so that as much time as possible was allowed for emergency measures to be put into place before storm events. This table is part of a broader document and should be used in conjunction with that document to ensure proper implementation of recommendations provided.

Sites shaded in gray indicate VARs with a polygon. Latitudes and longitudes are not provided.



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 0

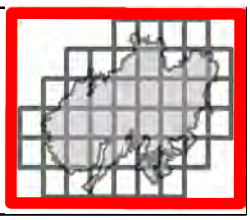
0 2 4 Miles

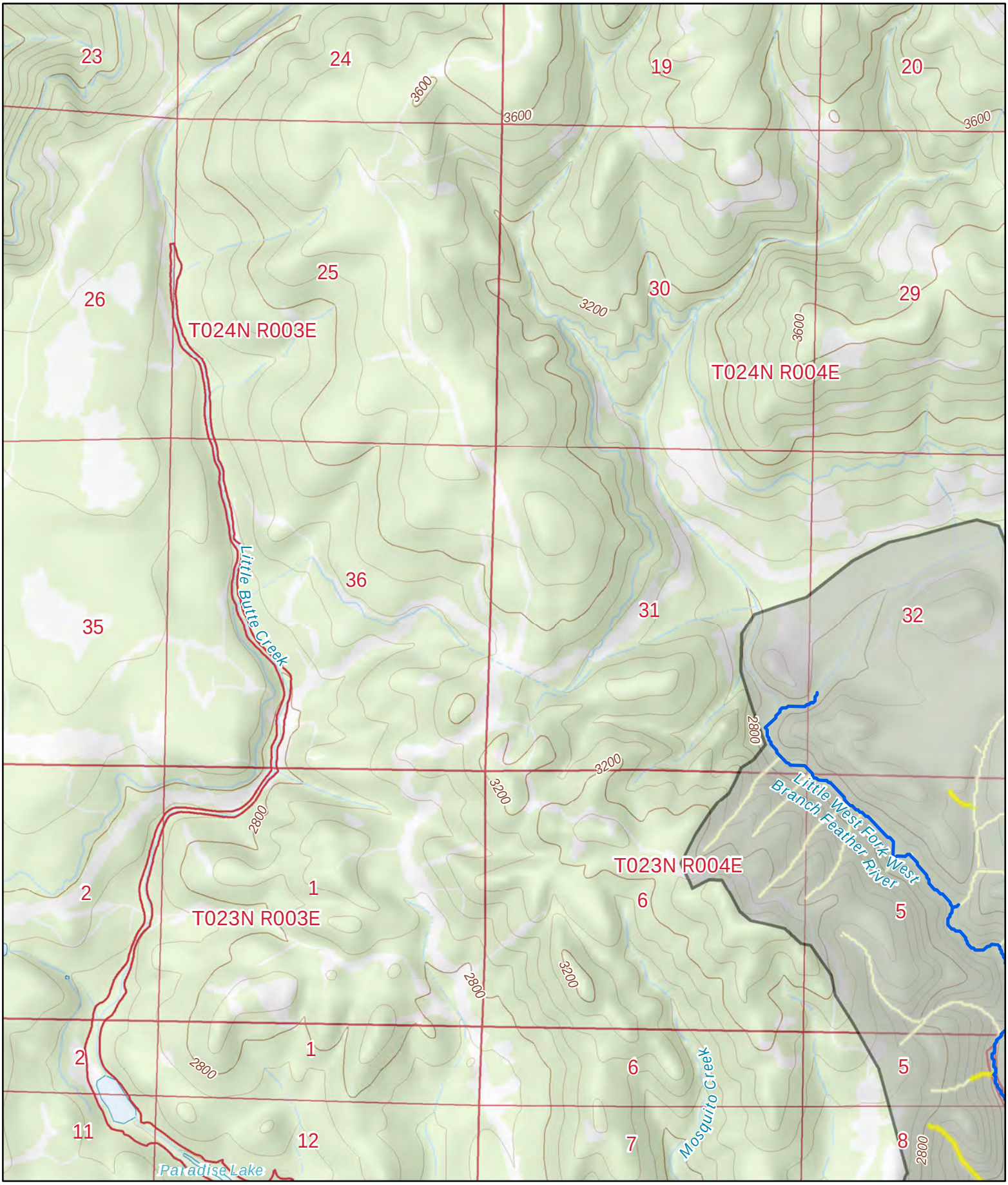
- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour





USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 1

N

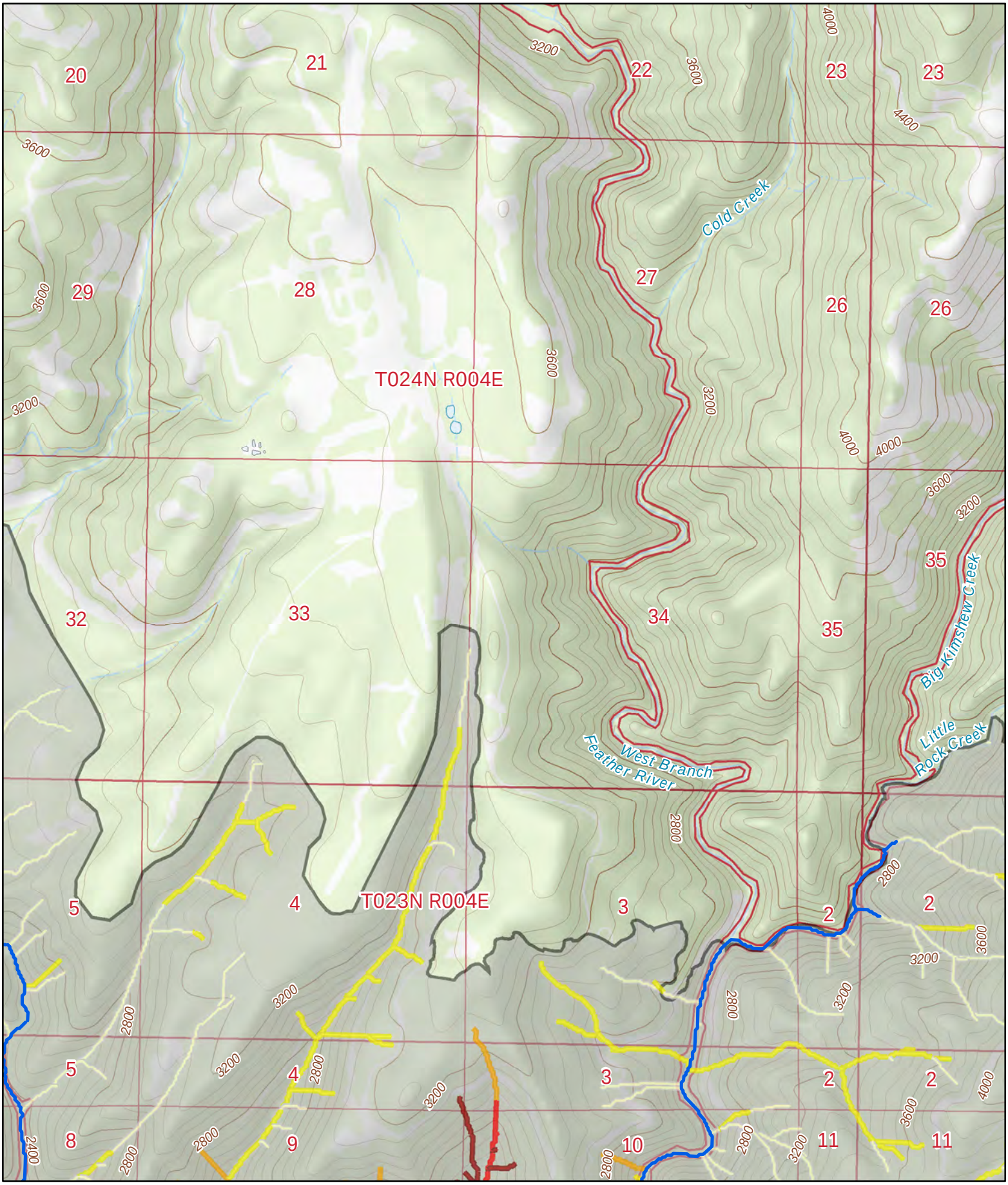
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 2

N

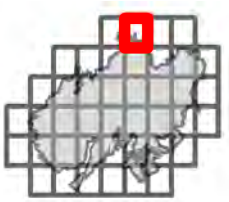
0 0.2 0.4 Miles

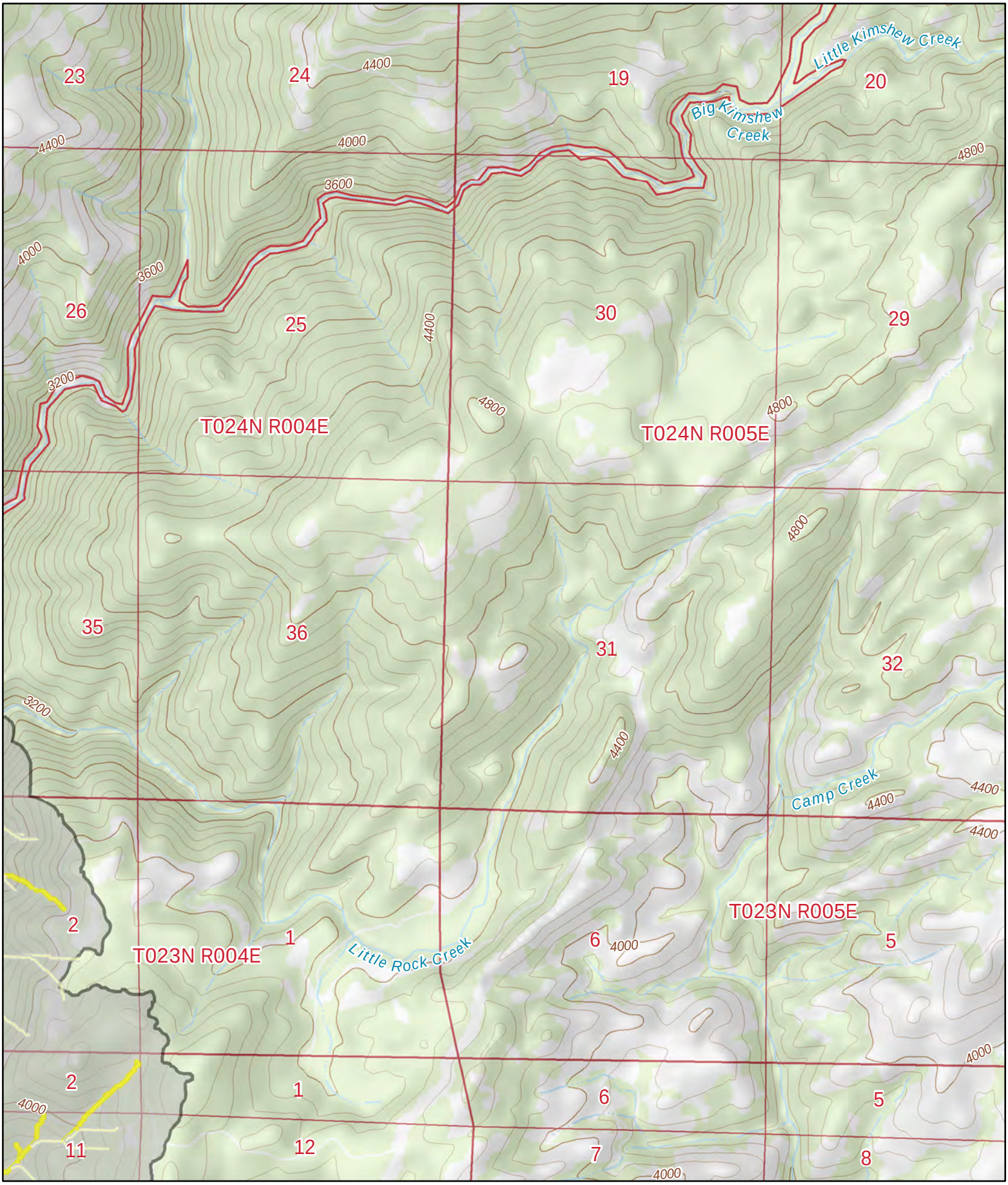
- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour





USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 3

N

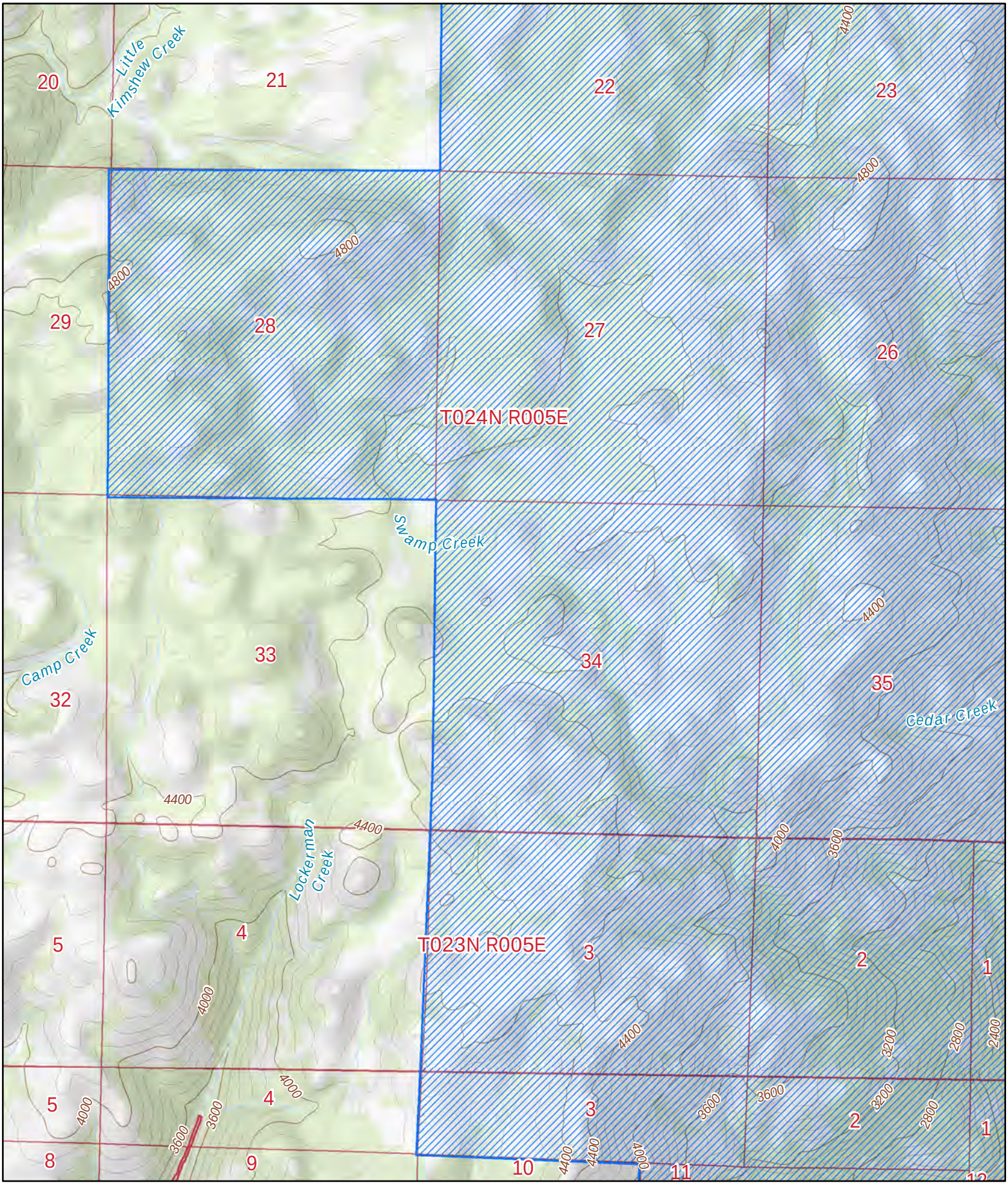
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 4

N

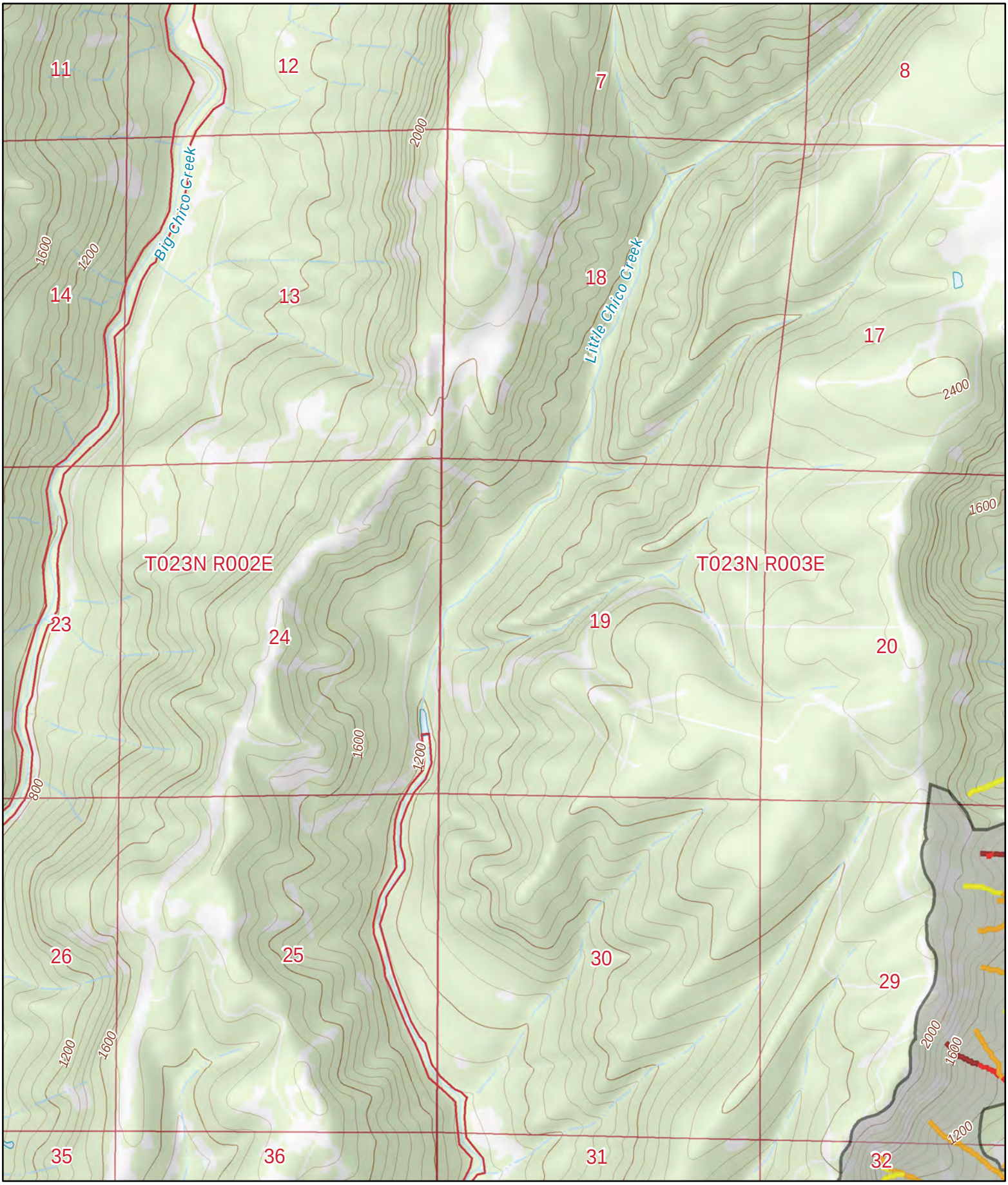
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 5

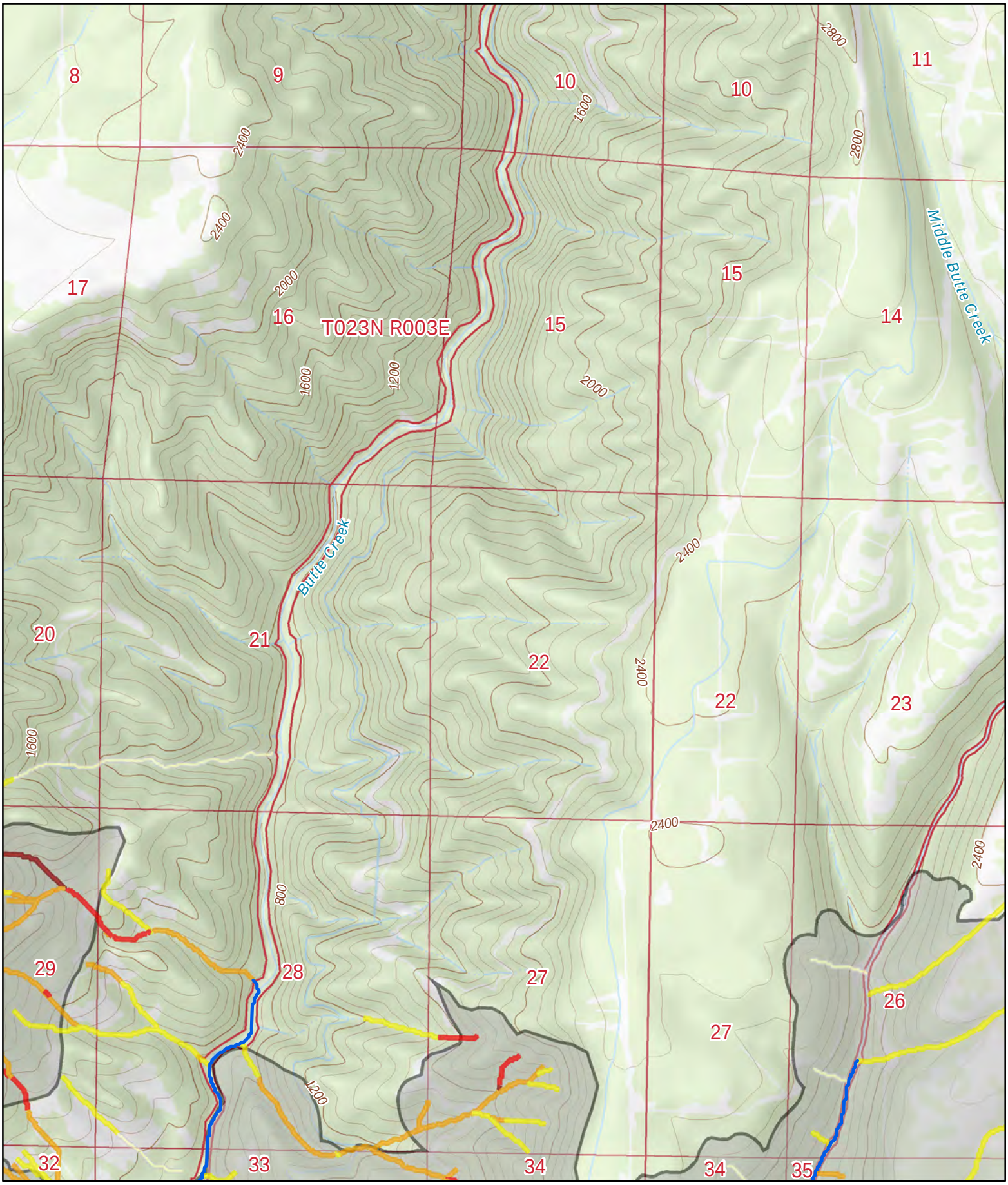
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 6

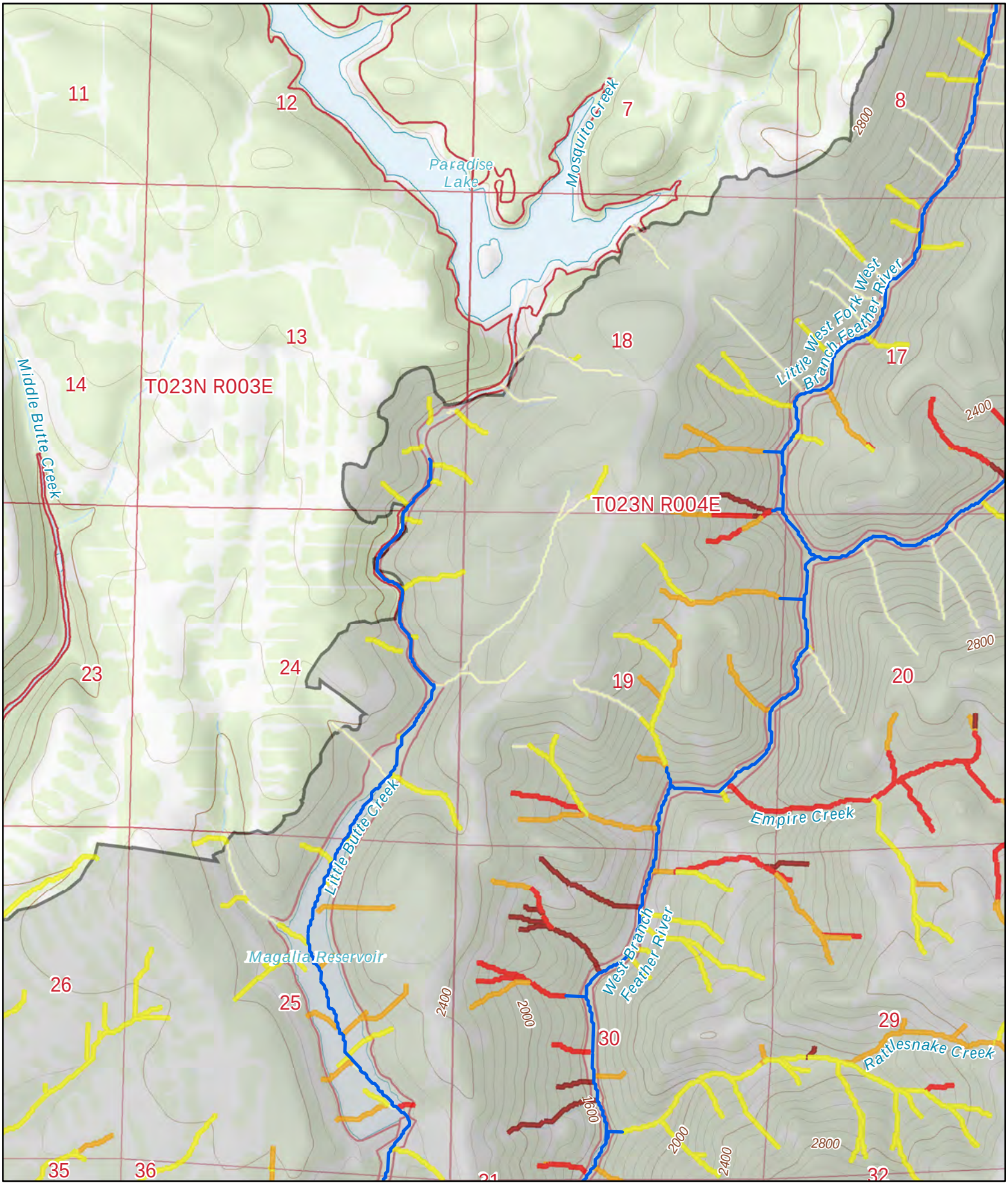
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 7

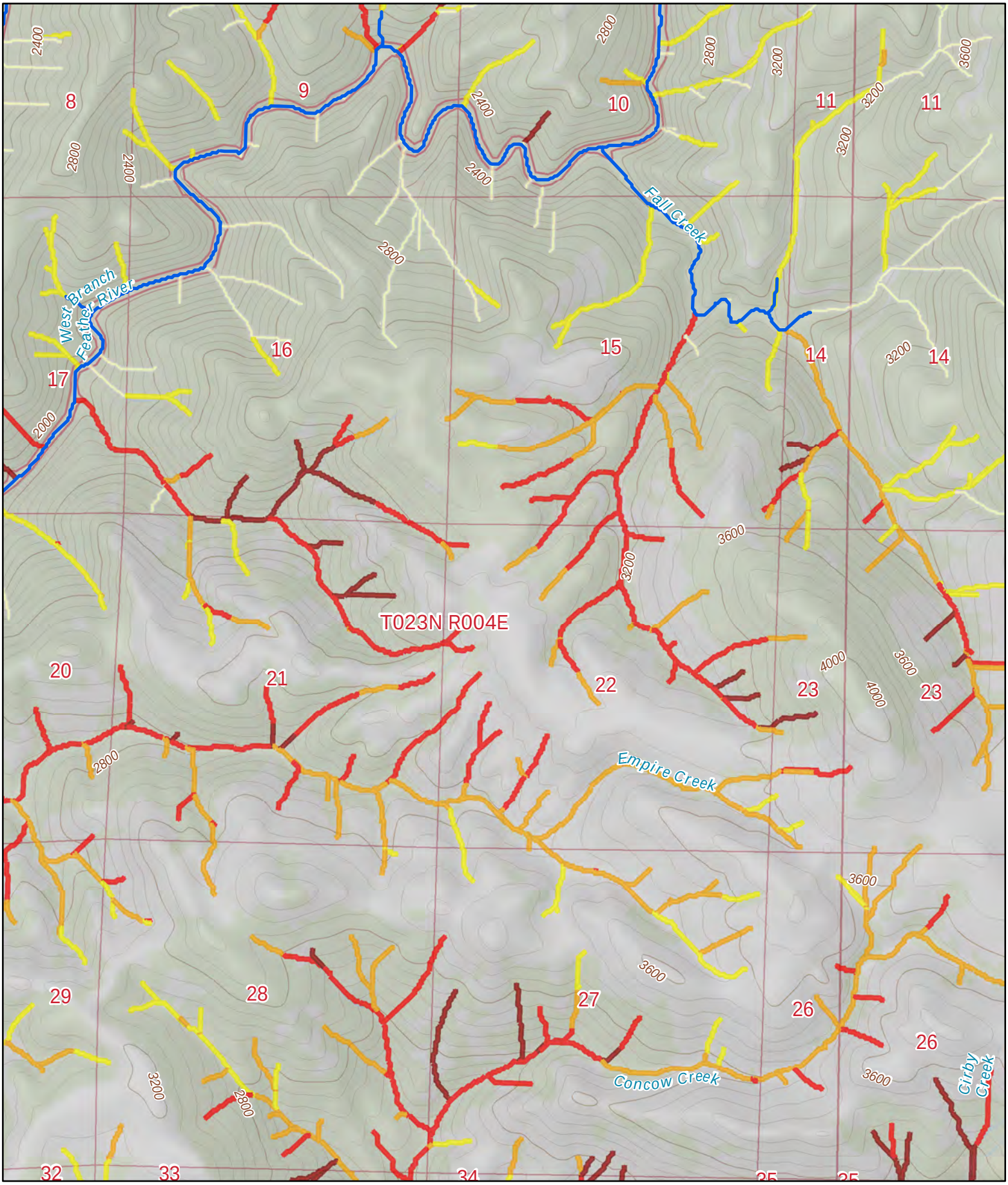
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 8

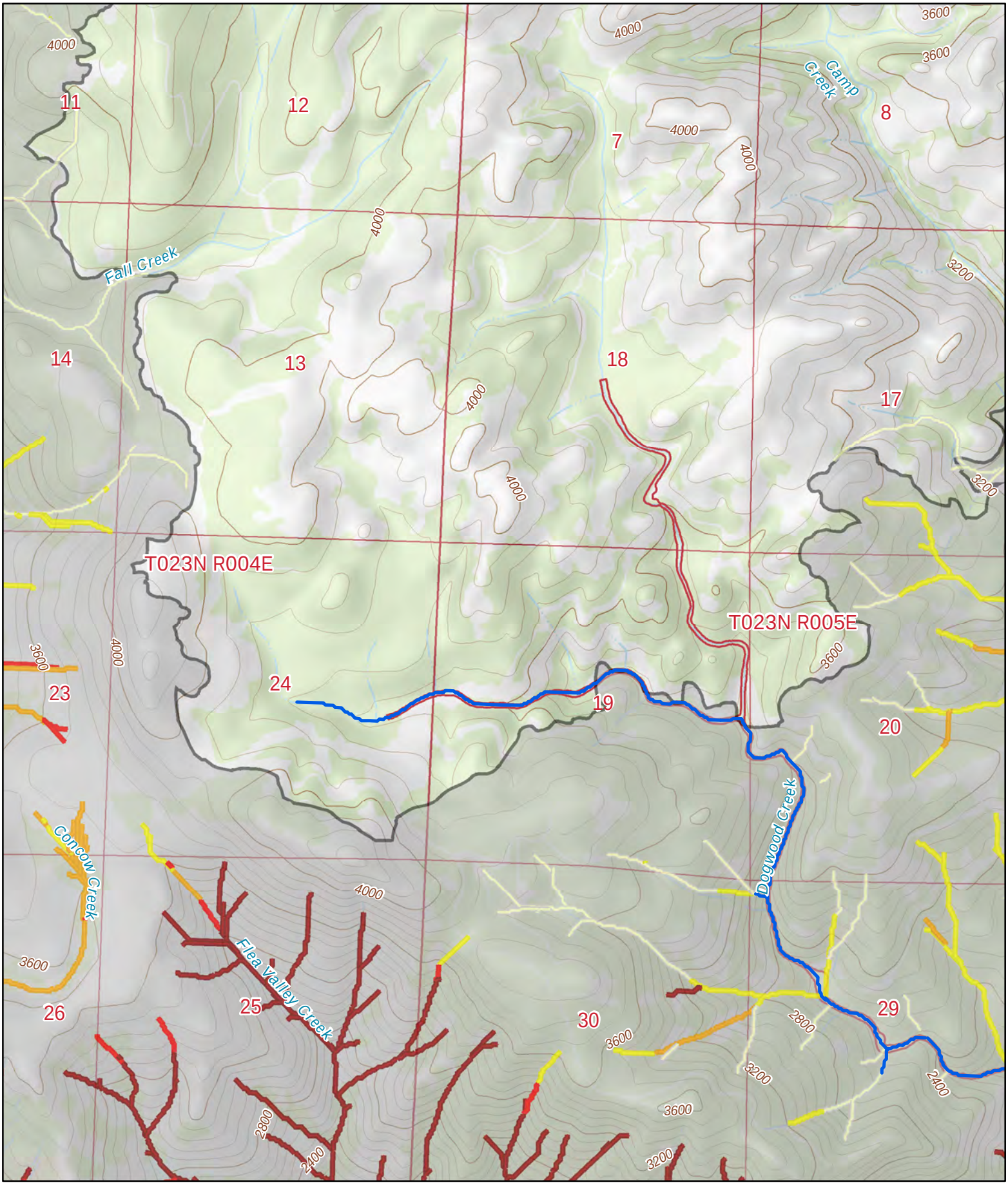
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 9

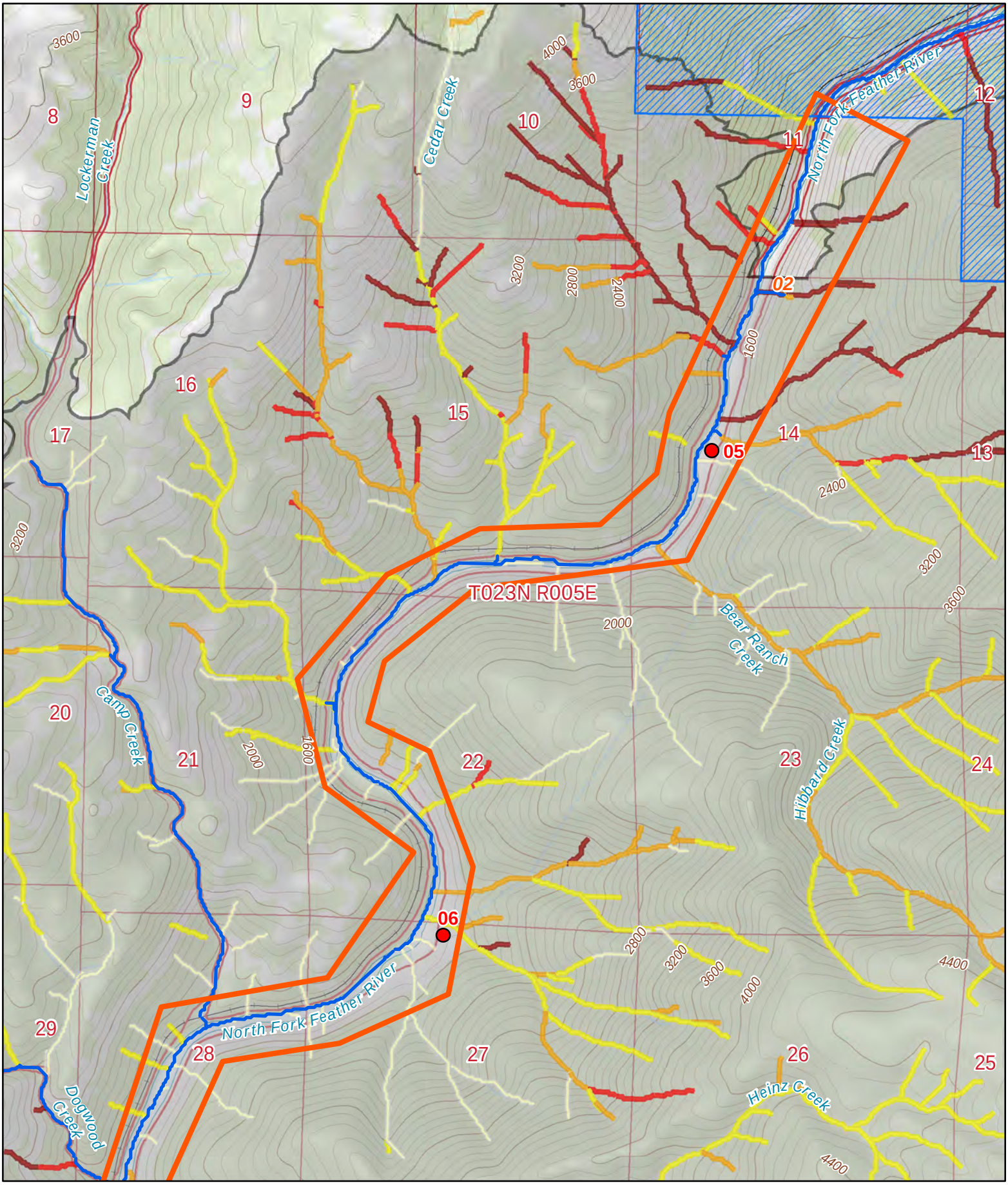
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 10

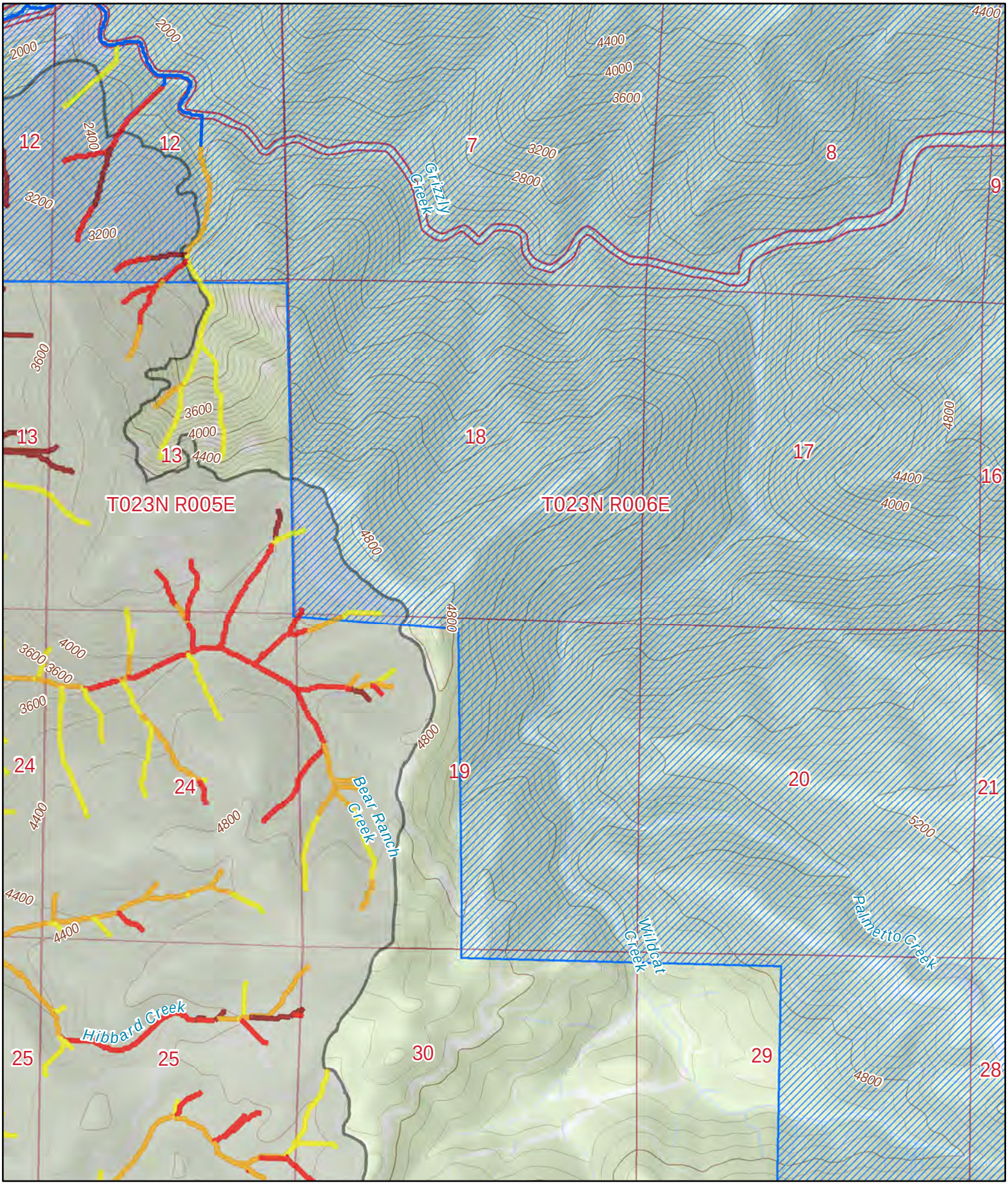
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 11

N

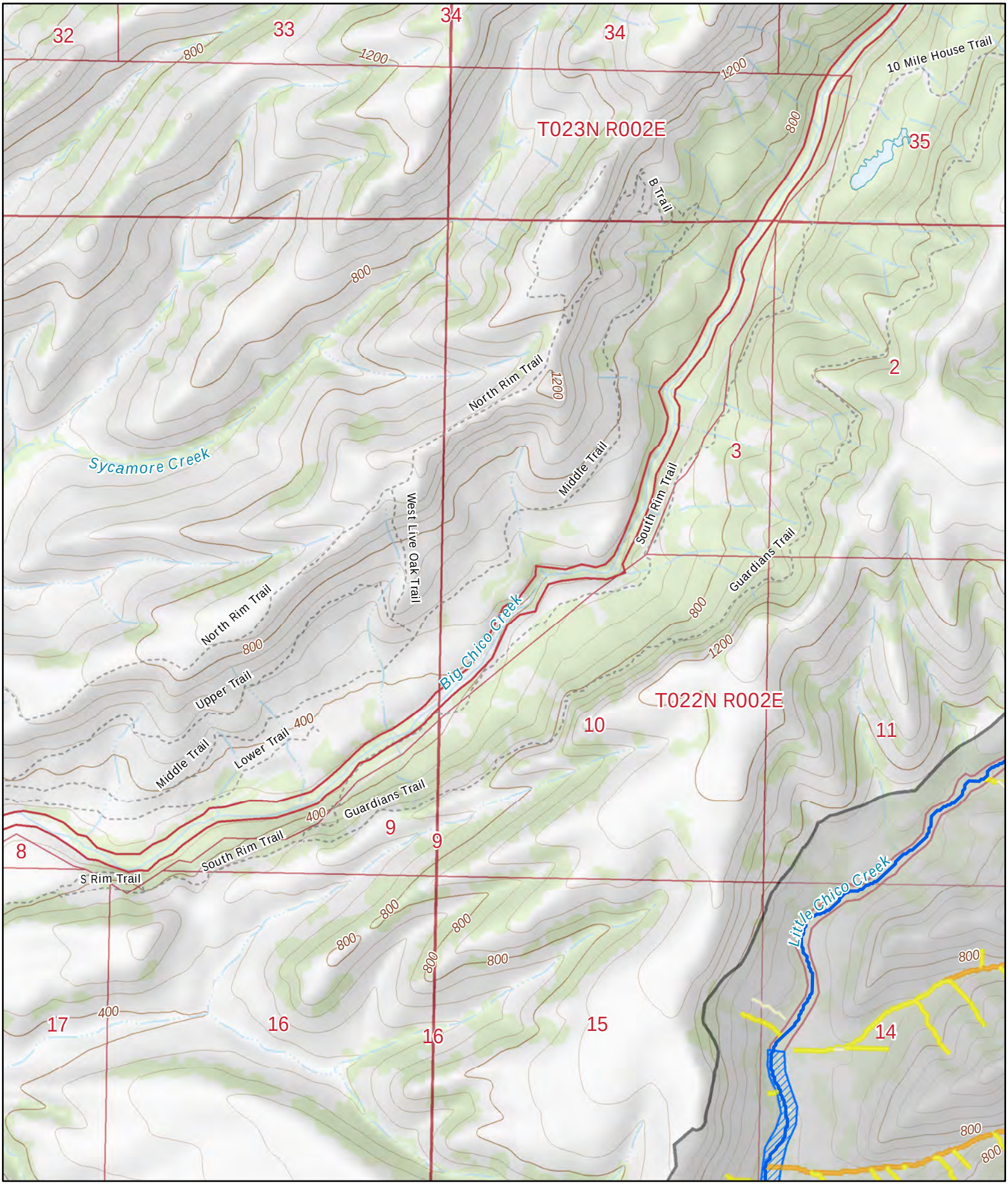
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 12

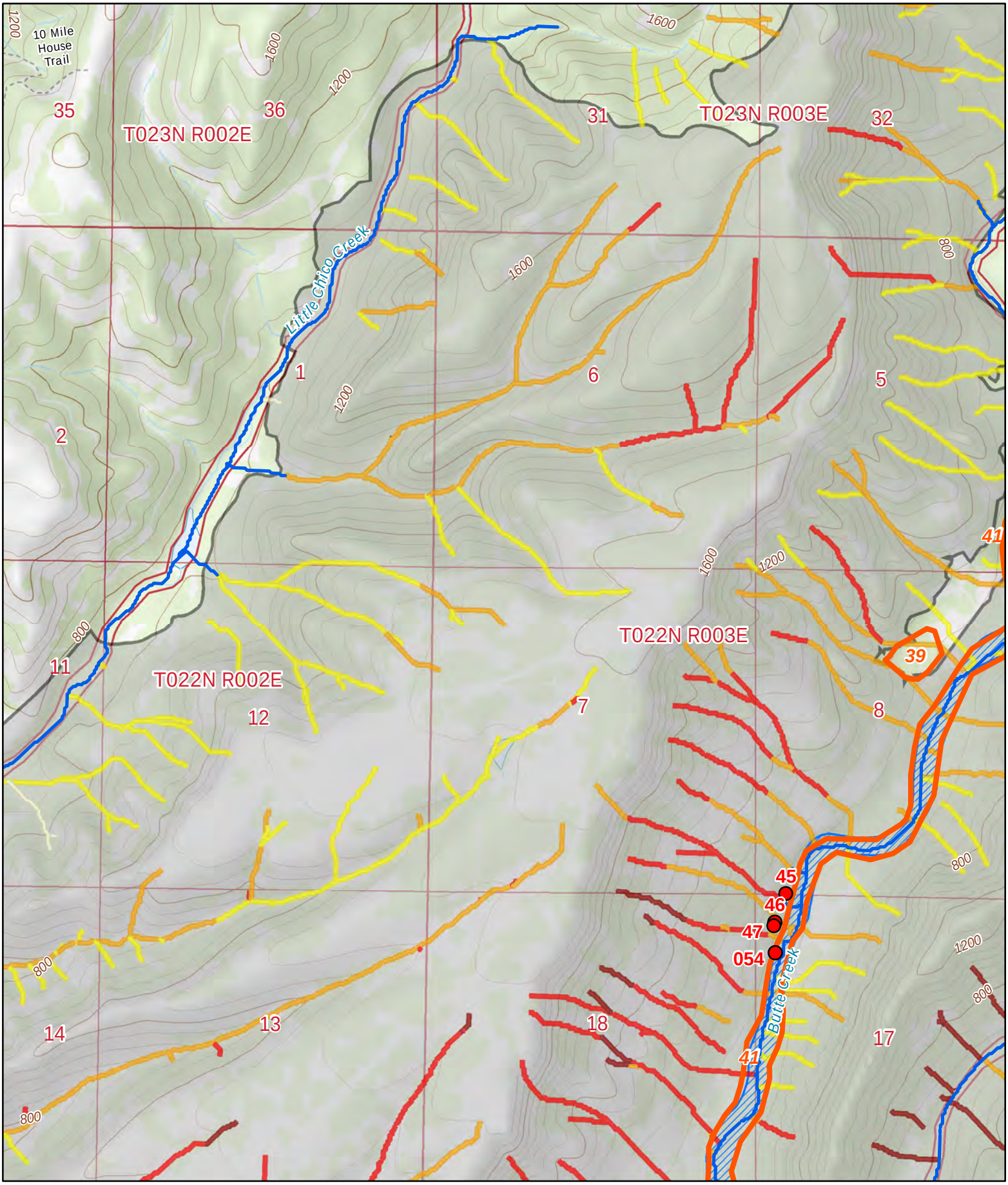
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 13

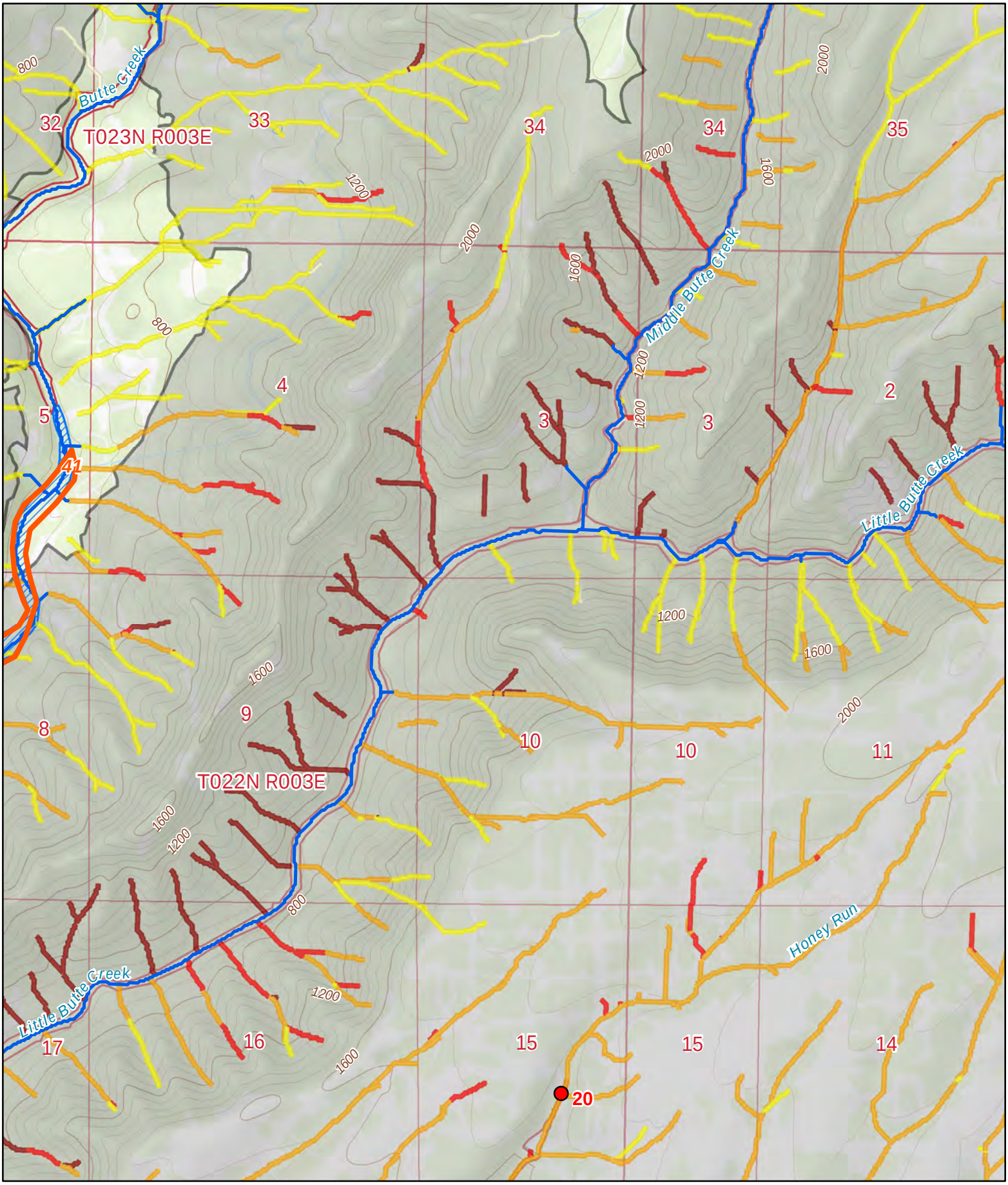
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 14

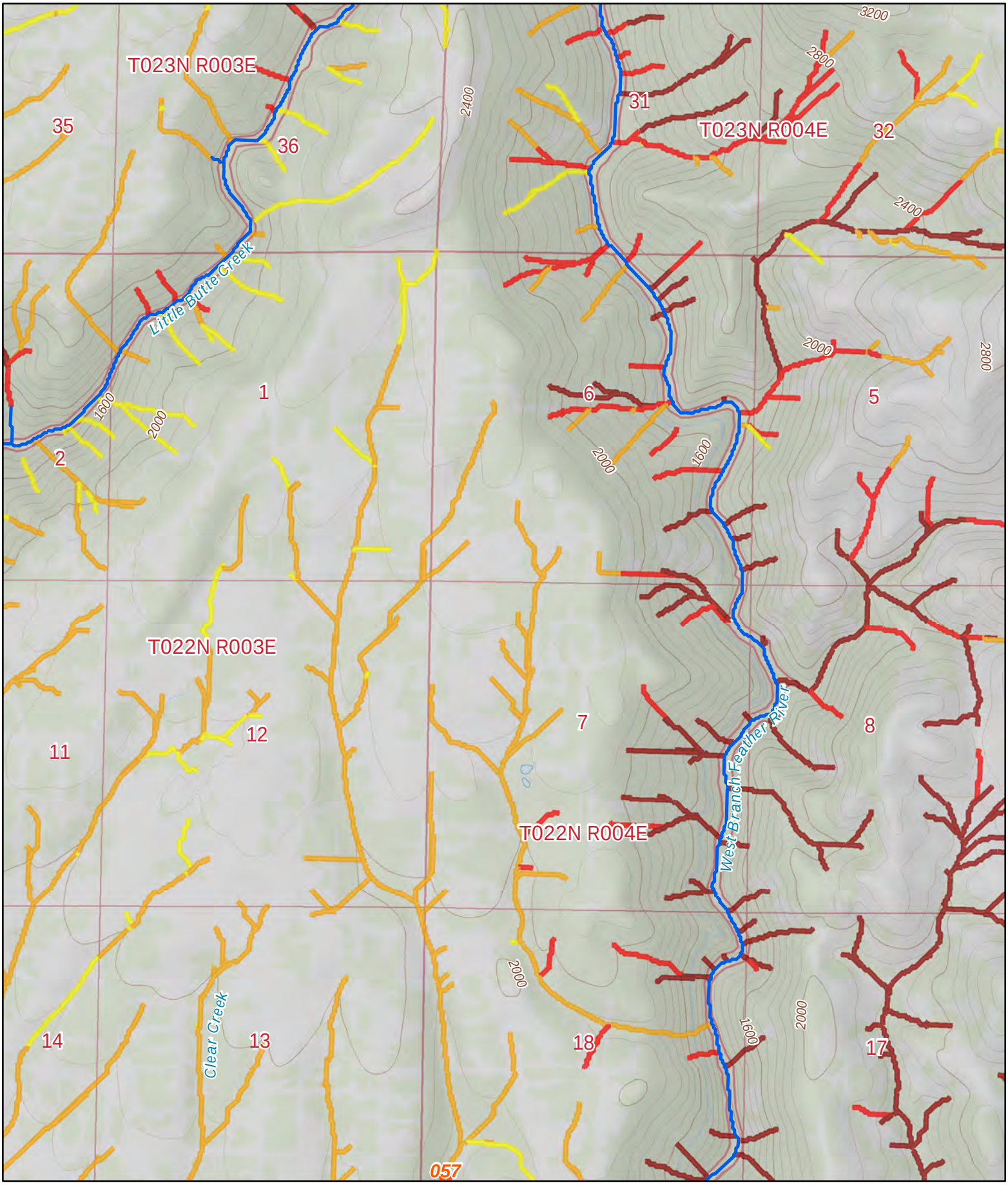
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 15

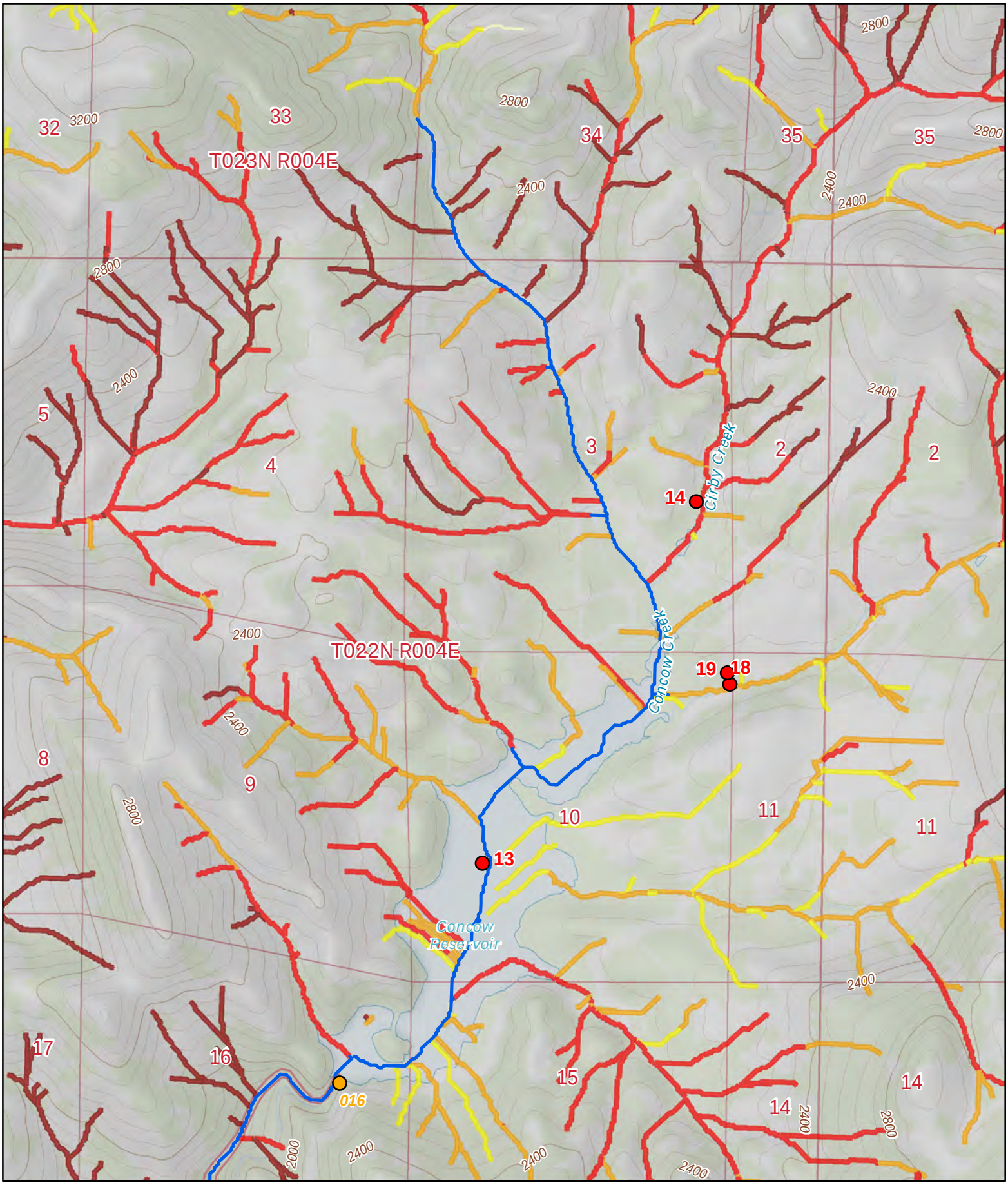
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 16

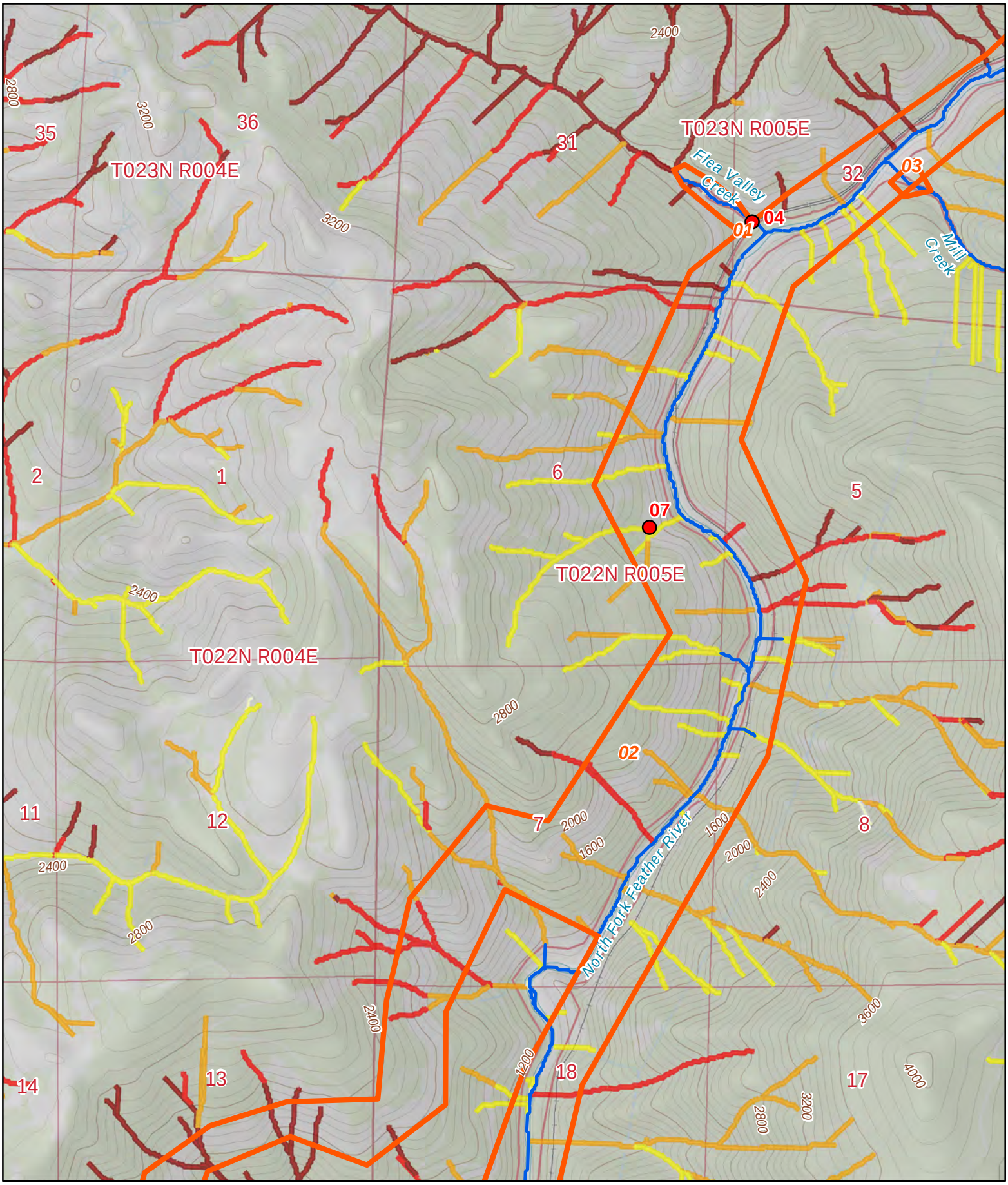
- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

0 0.2 0.4 Miles

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 17

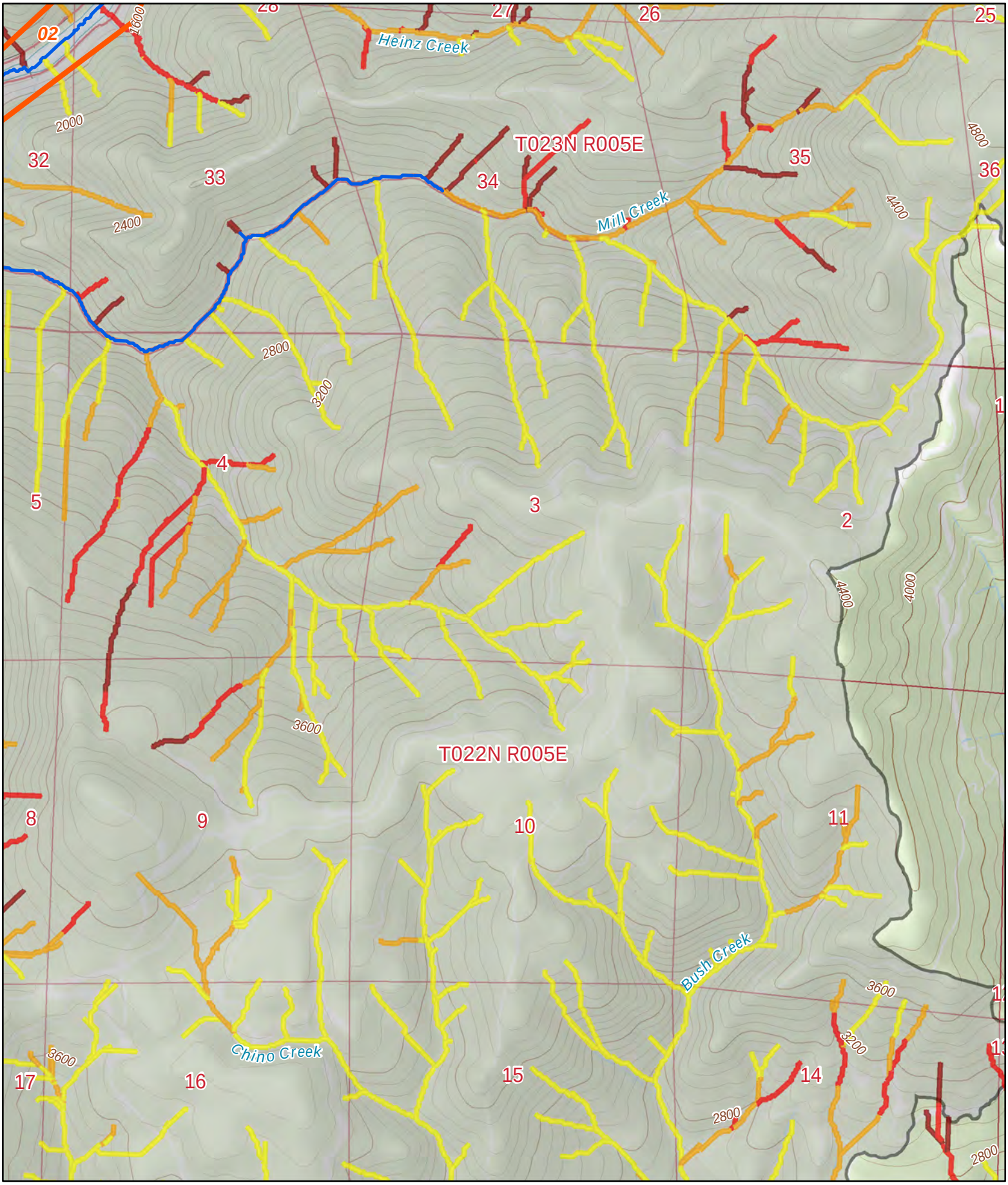
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 18

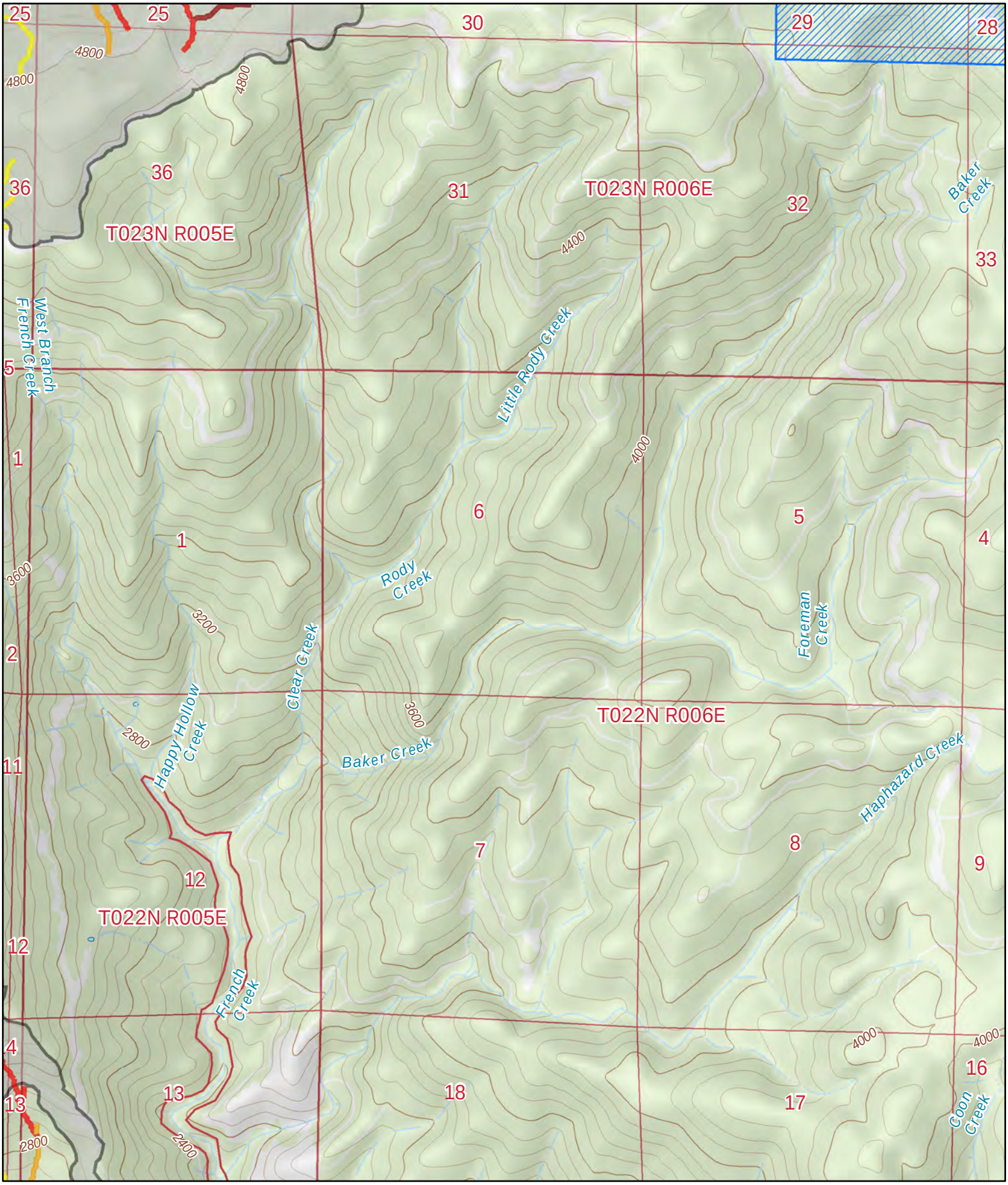
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 19

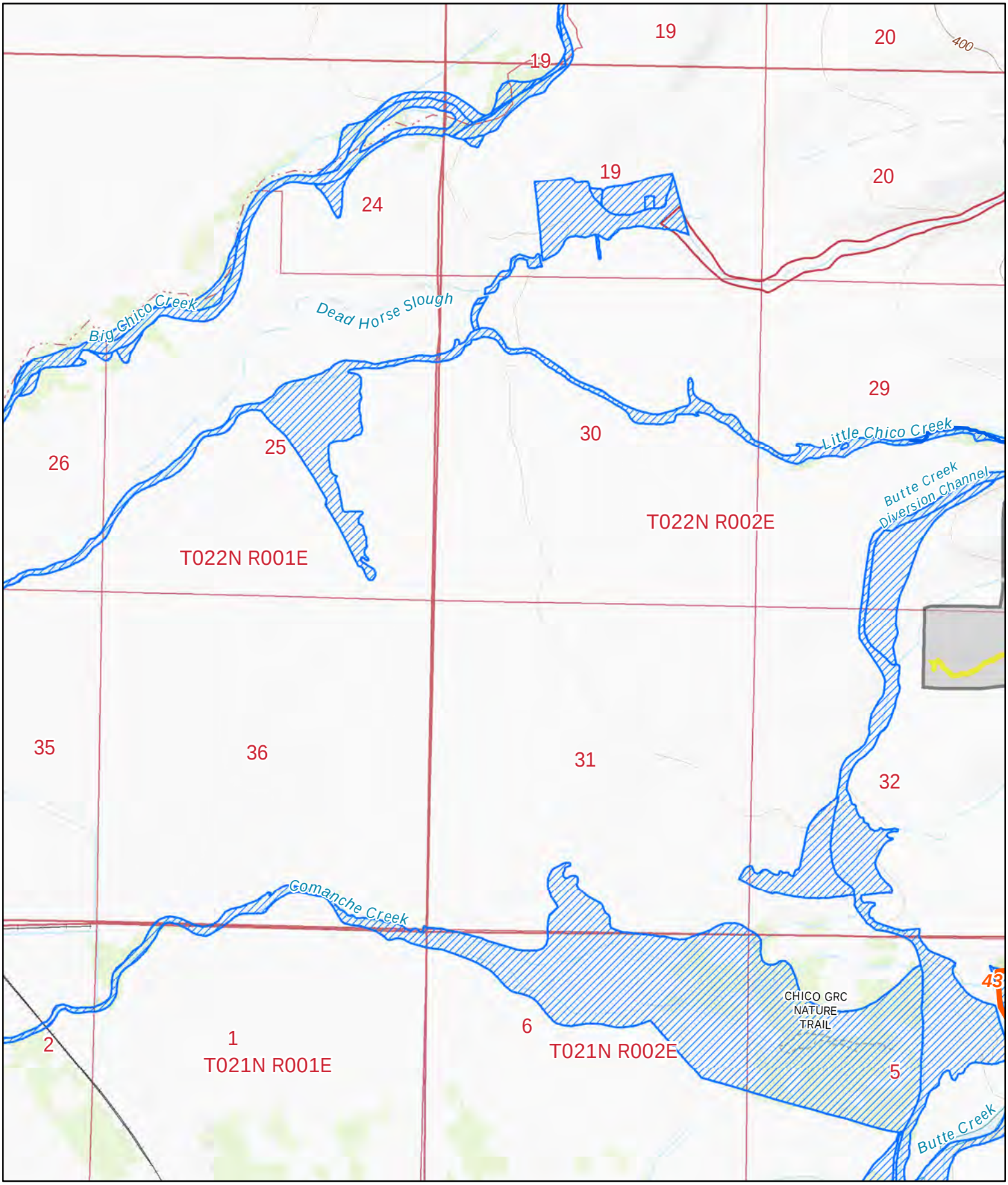
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 20

N

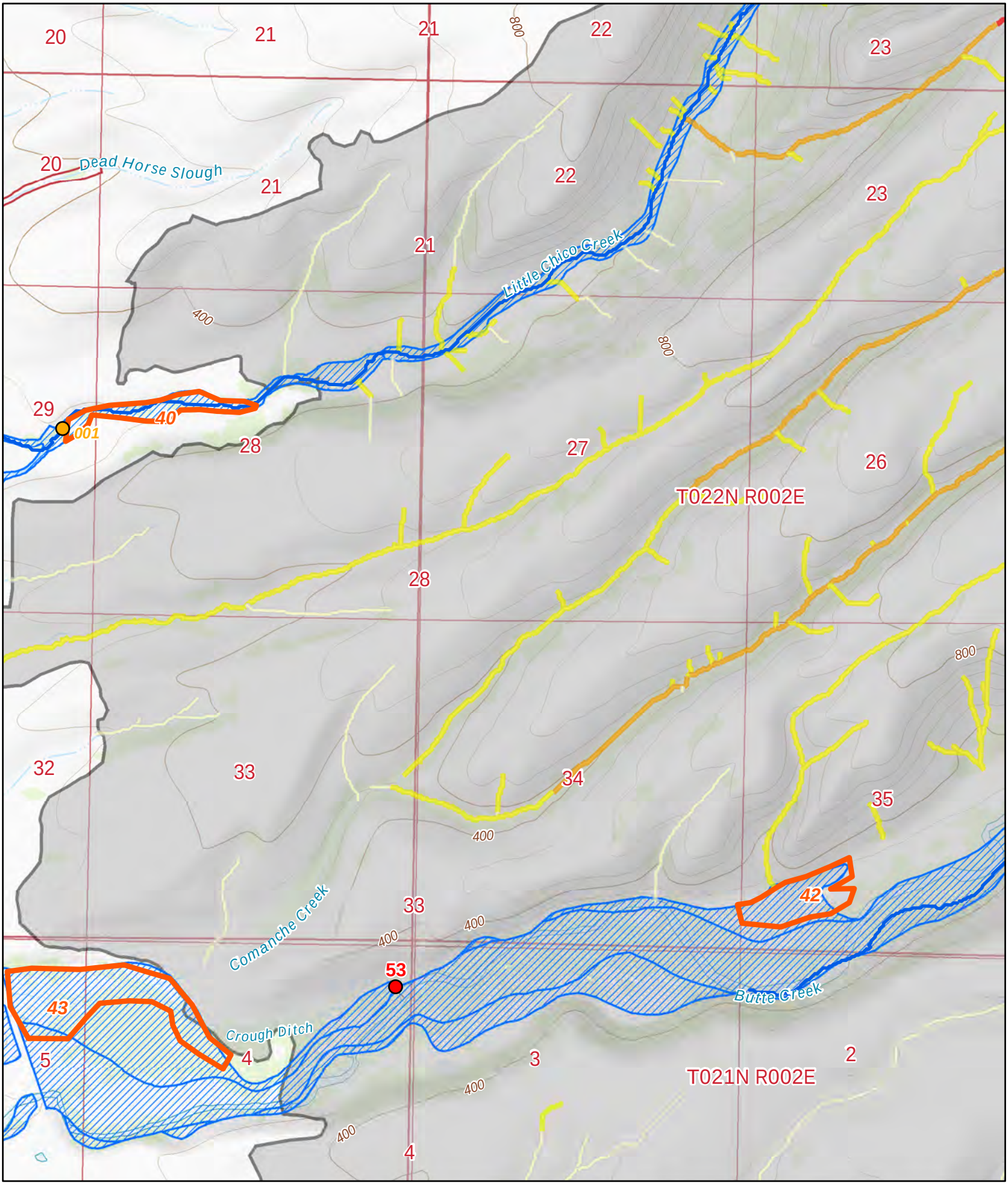
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 21

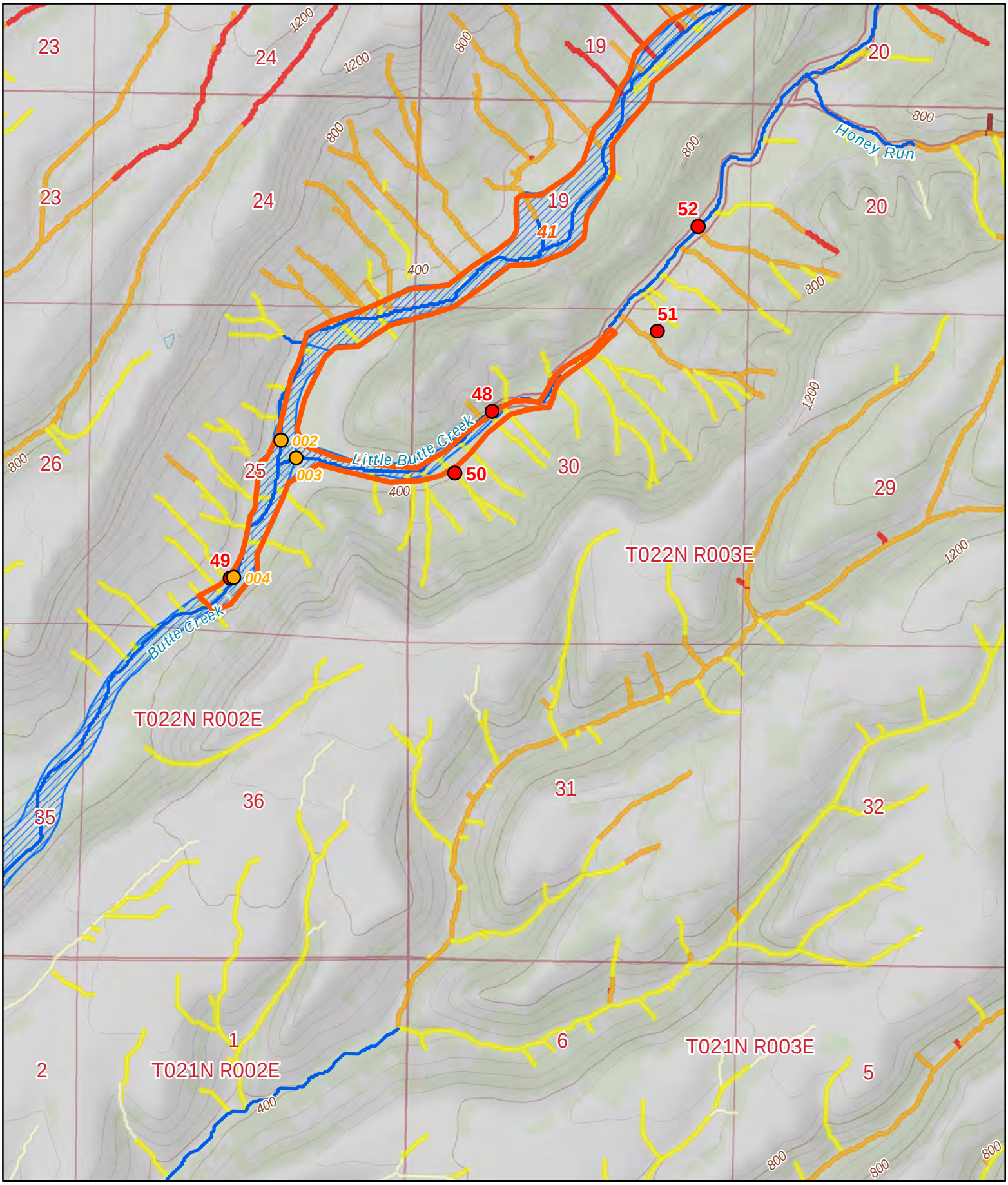
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 22

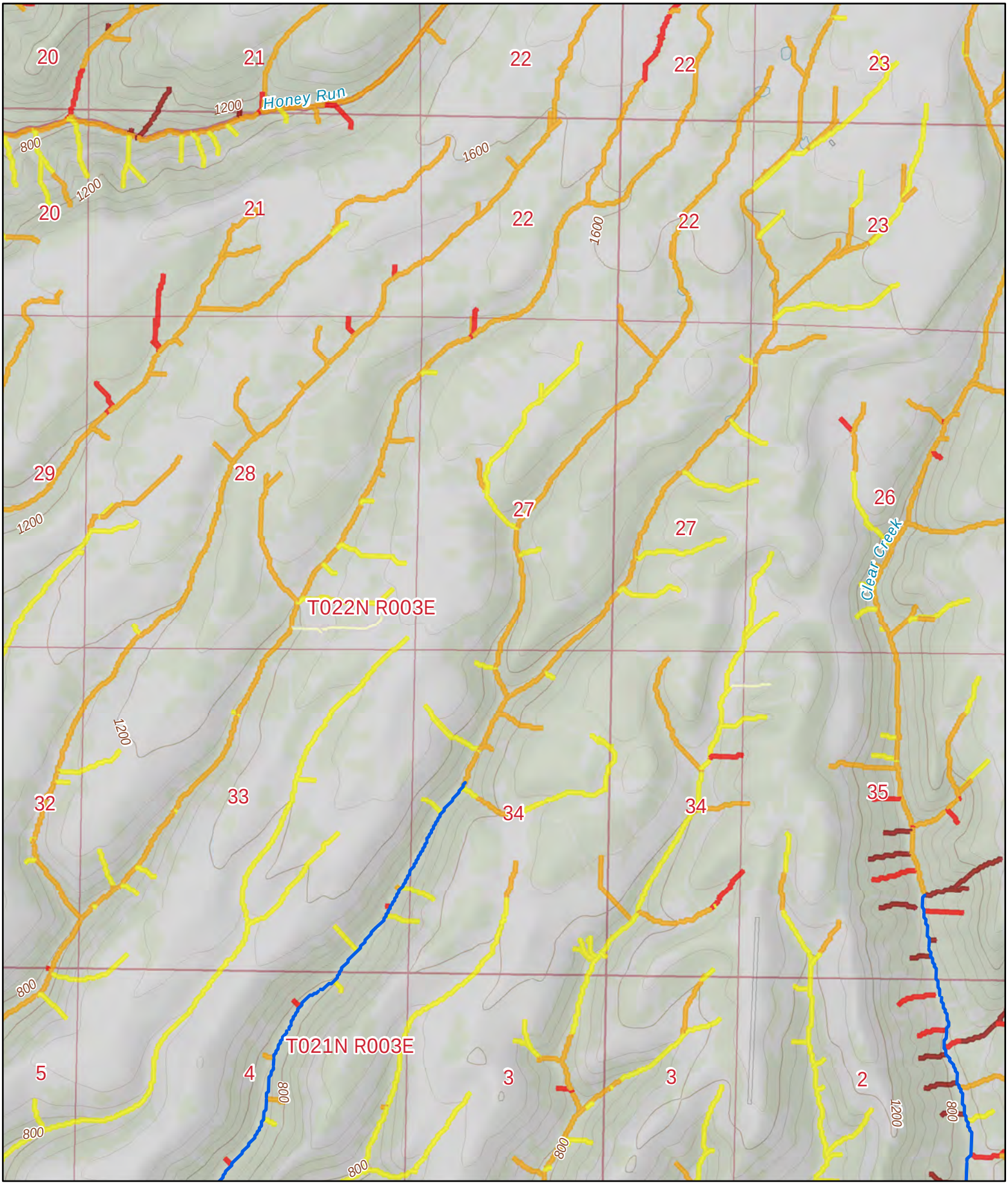
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 23

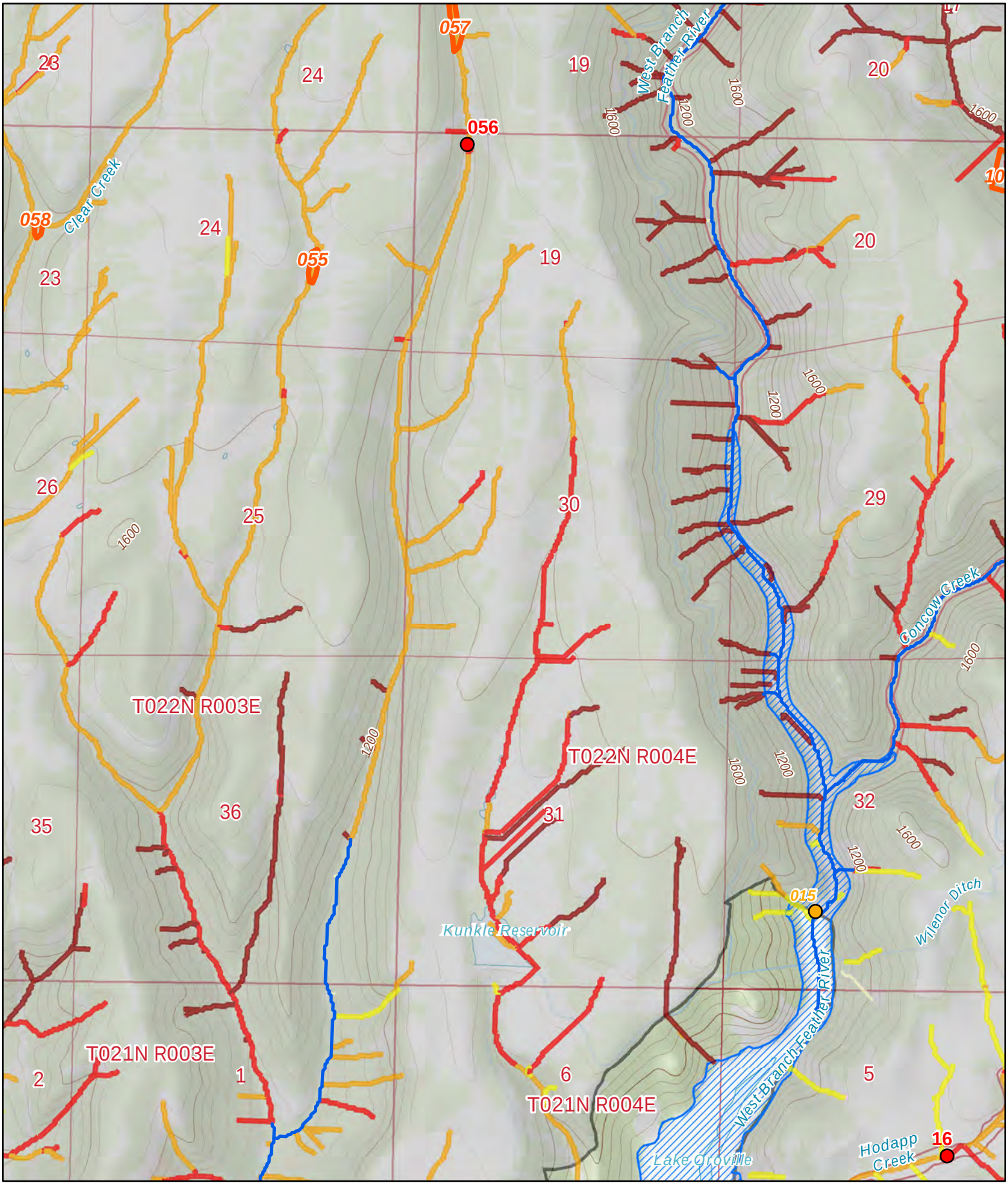
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 24

0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour

USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 25

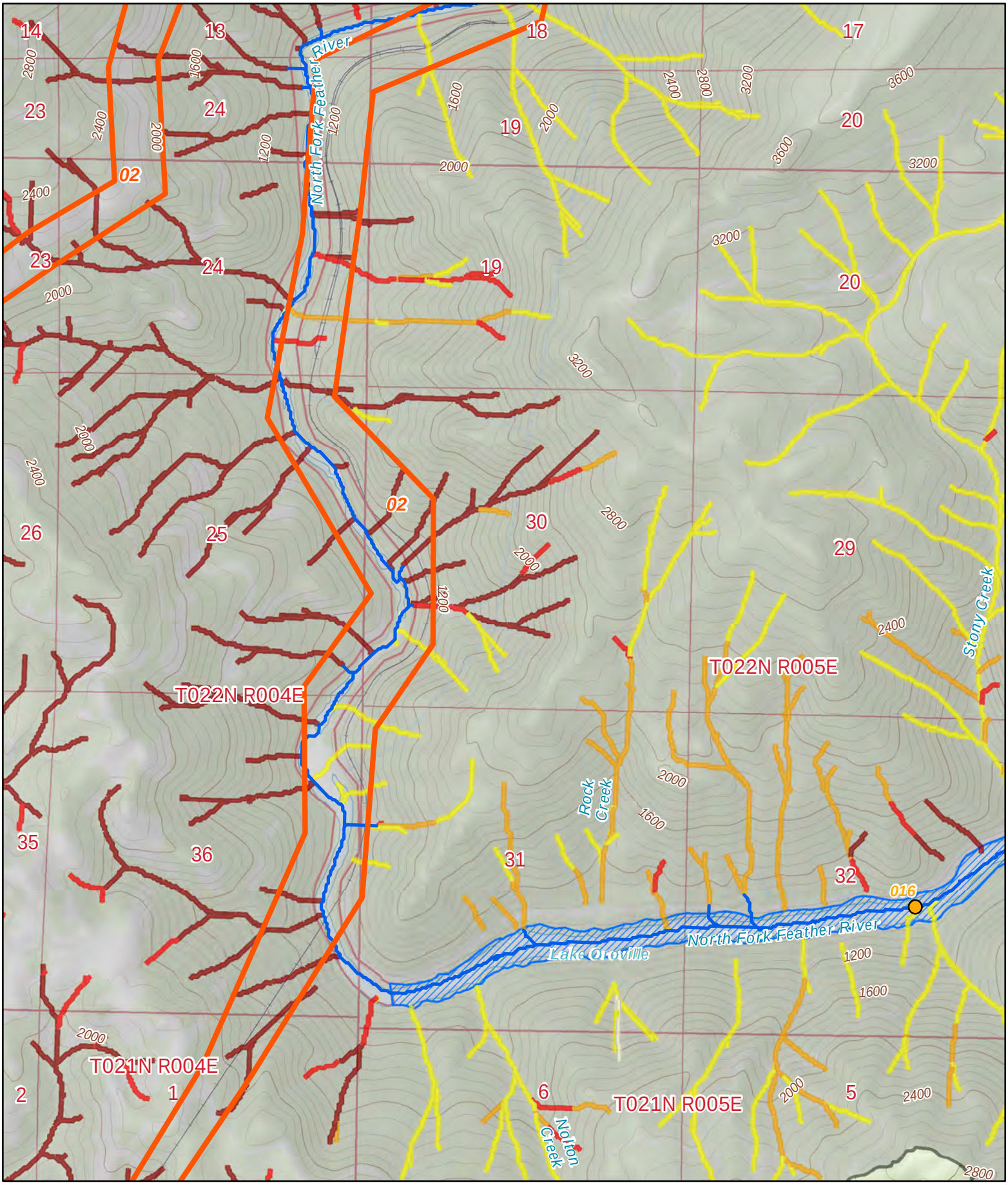
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 26

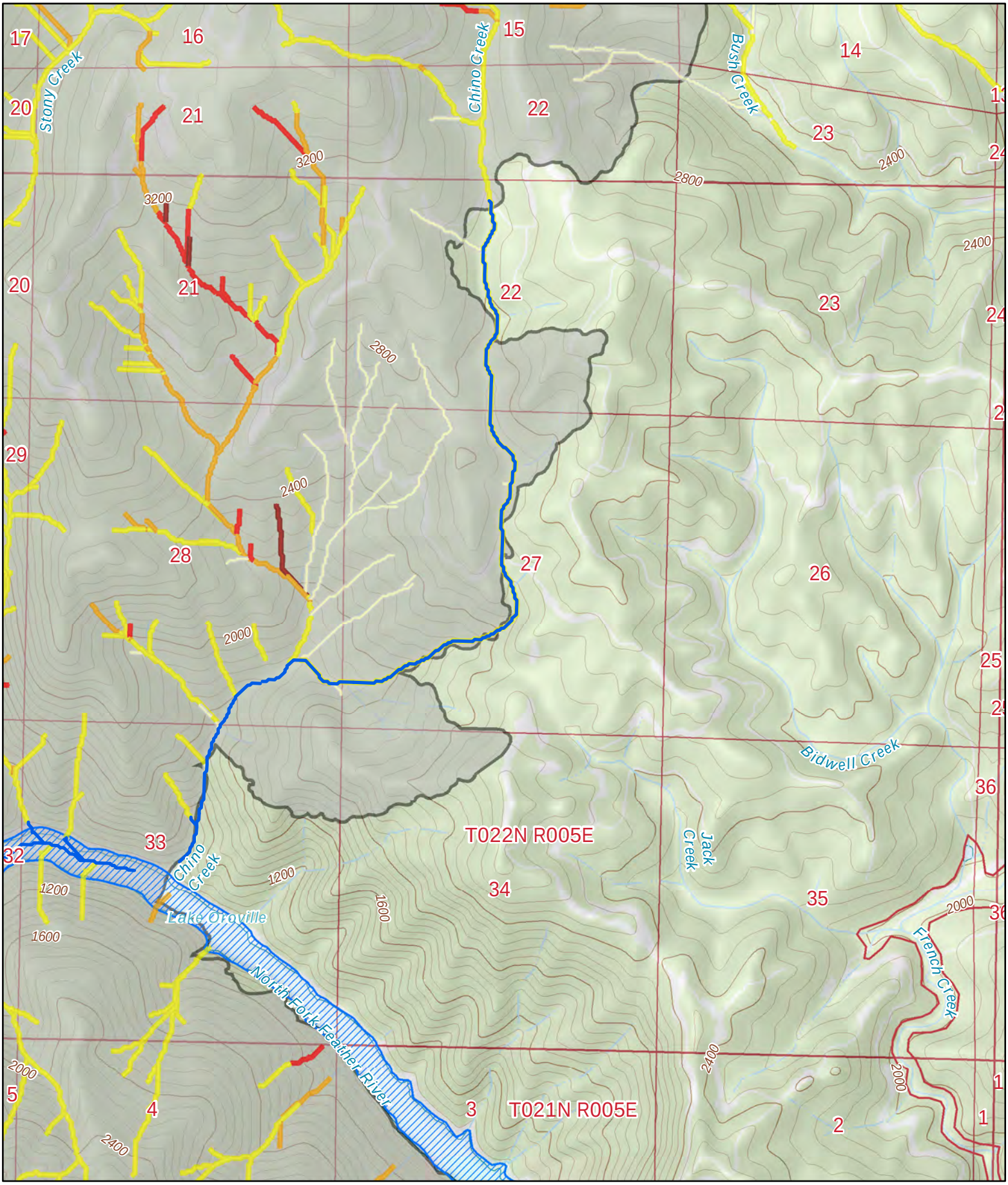
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 27

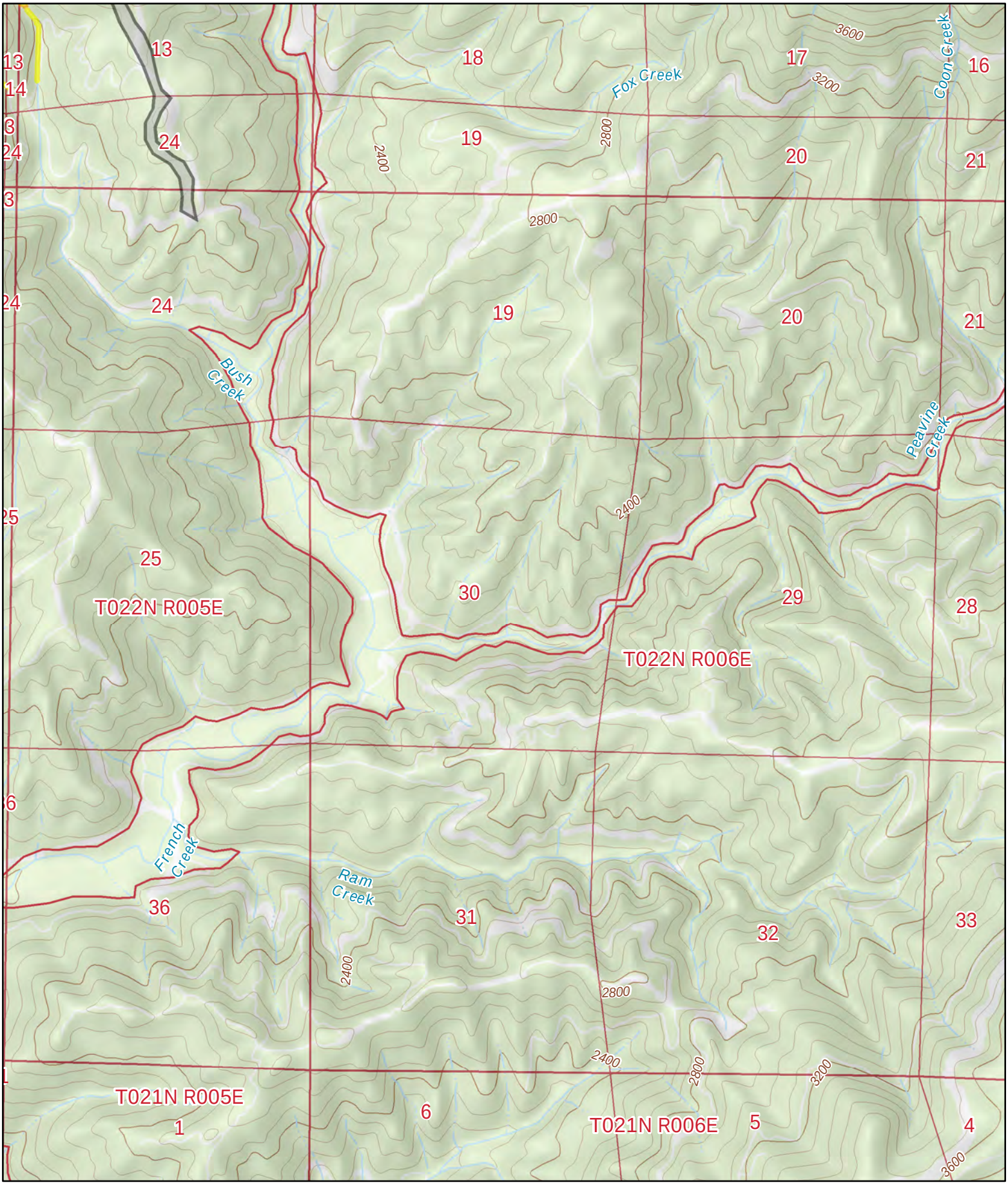
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 28

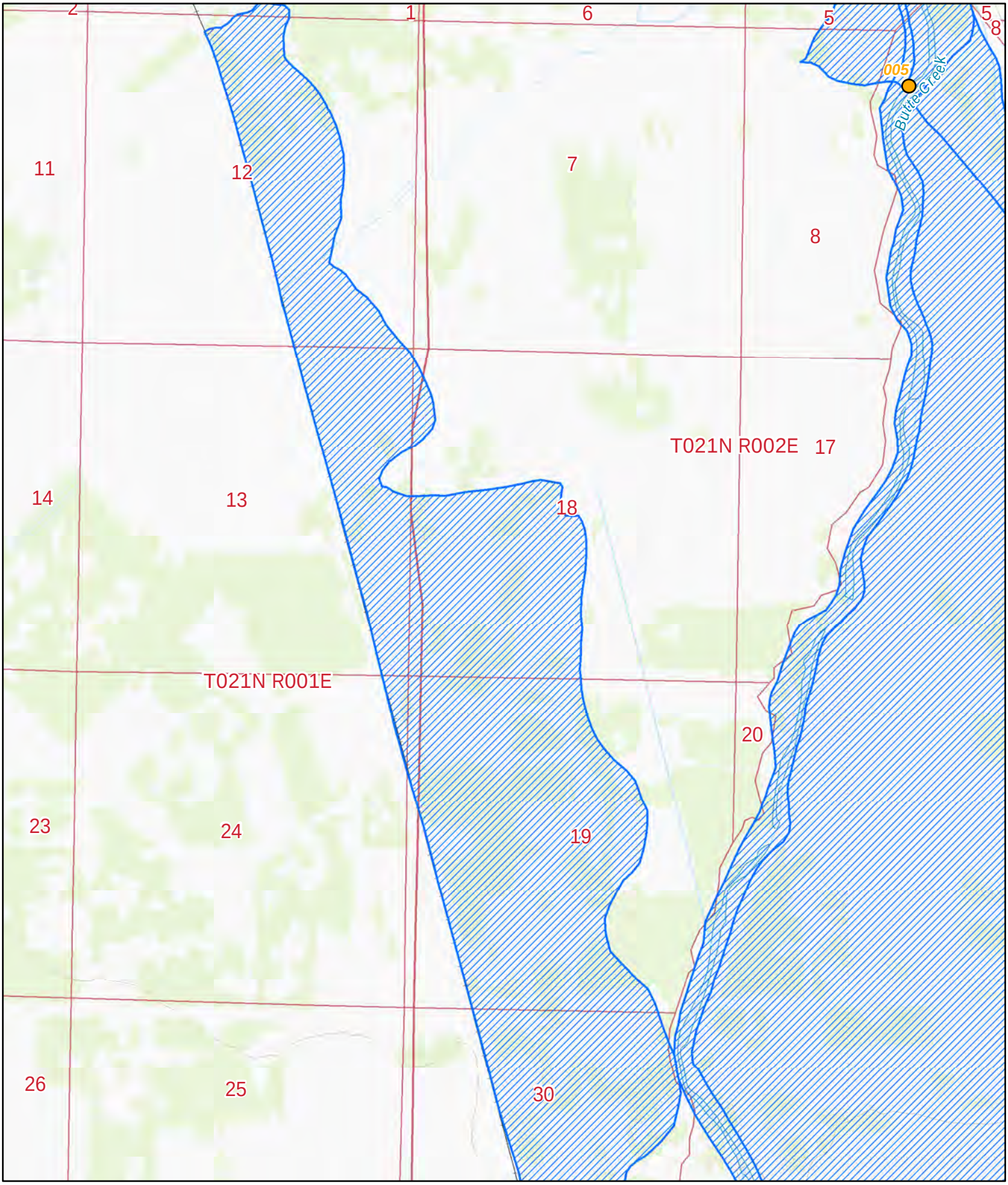
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 29

N

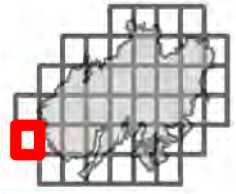
0 0.2 0.4 Miles

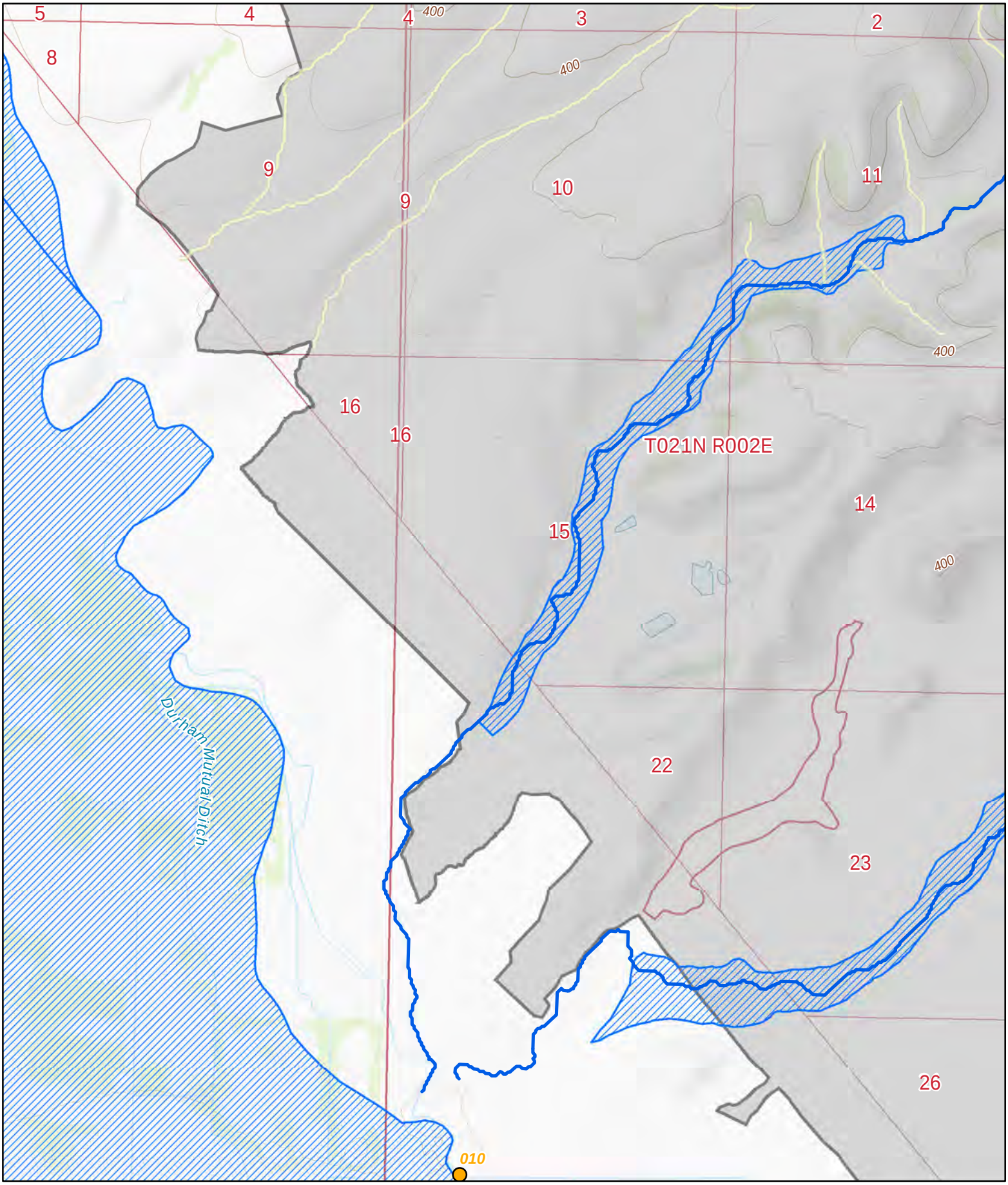
- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour





USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 30

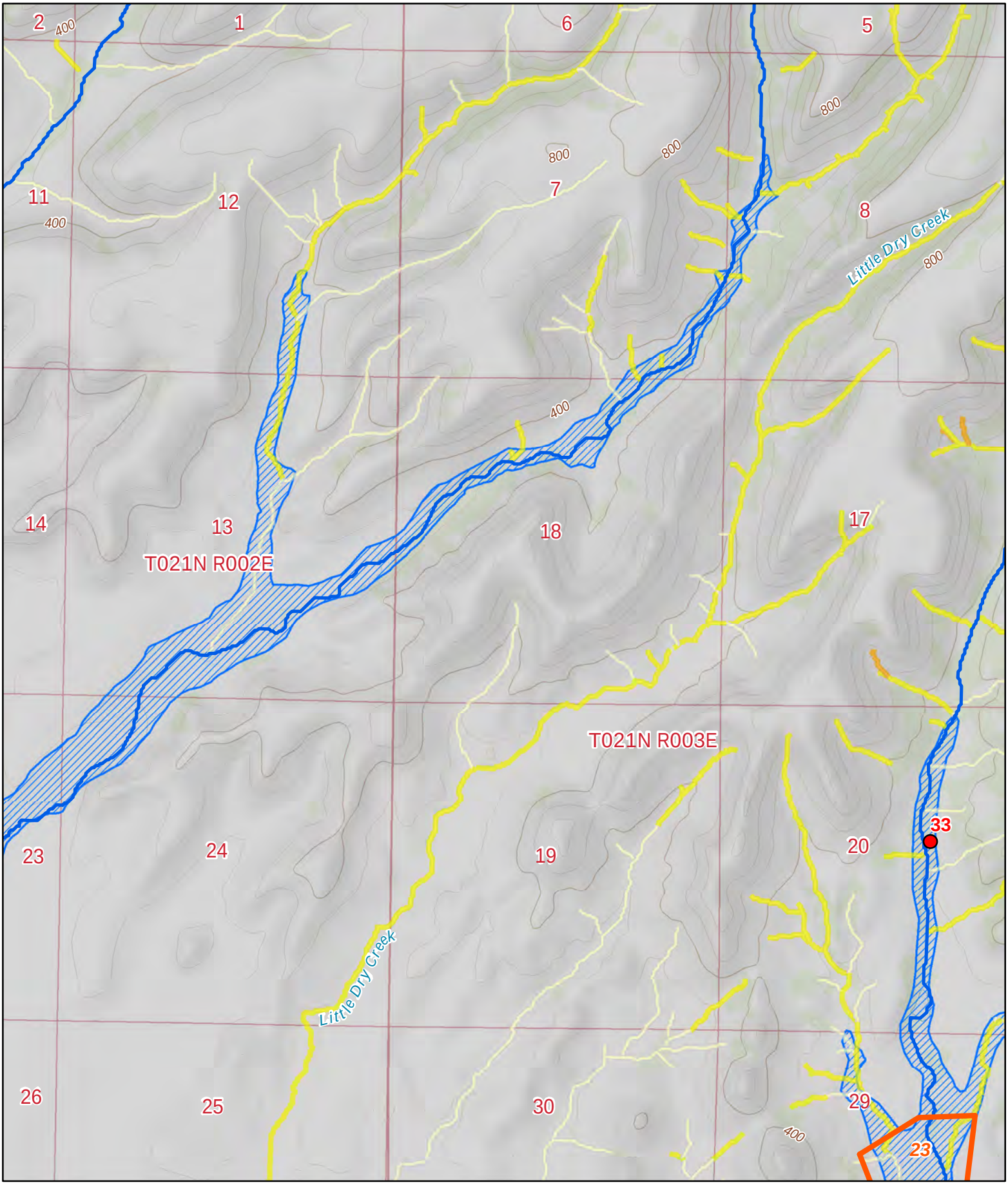
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 31

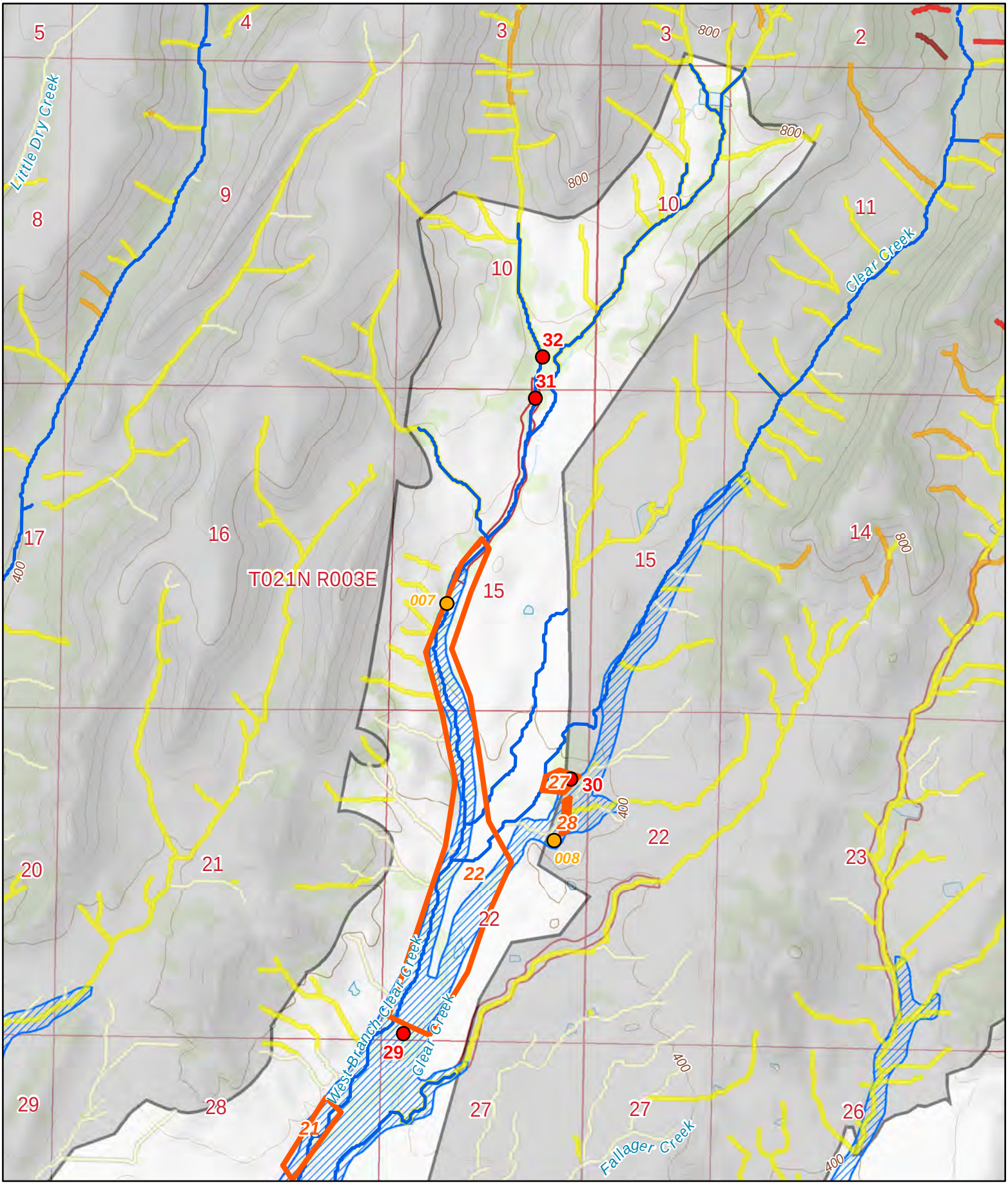
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 32

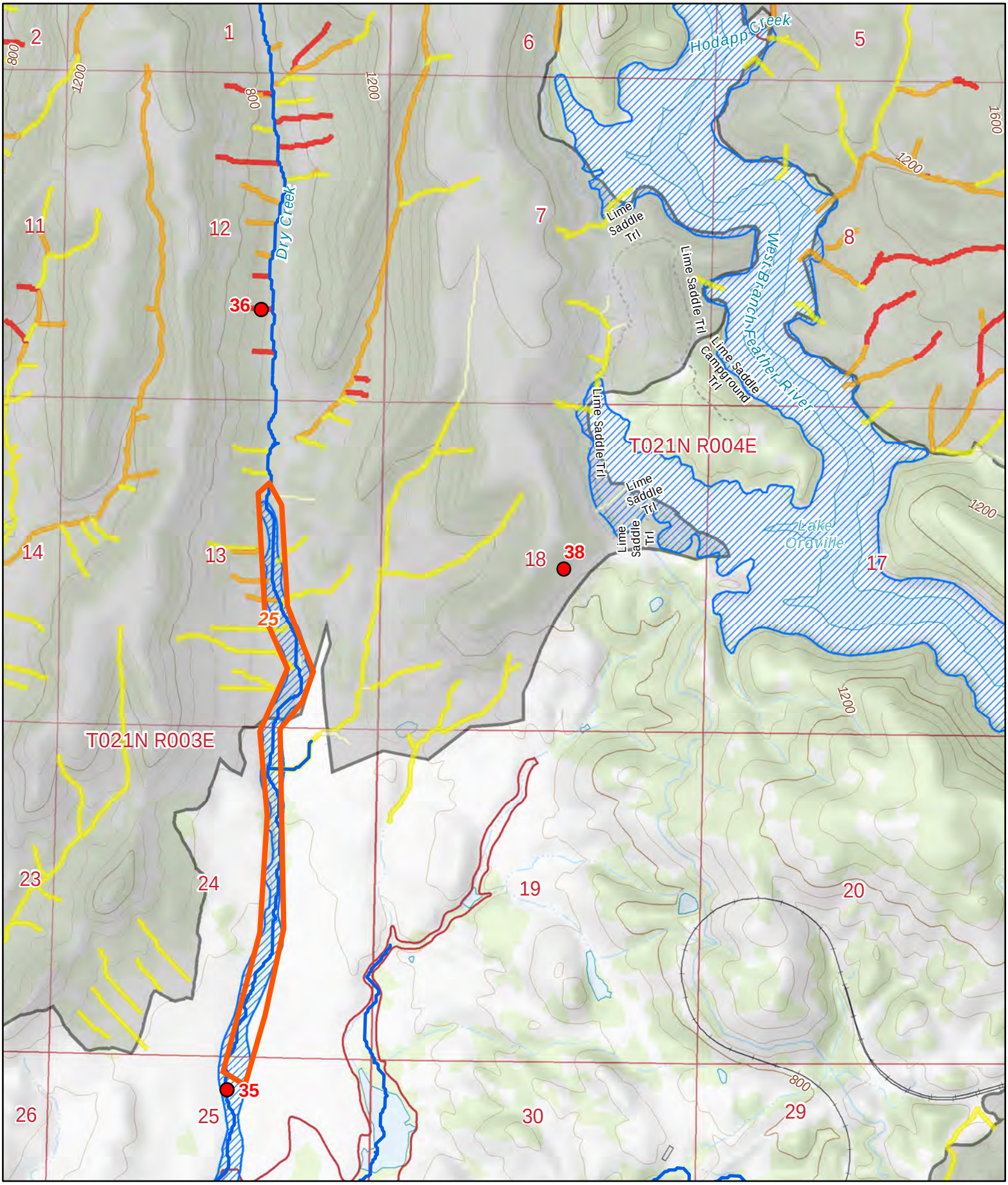
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 33

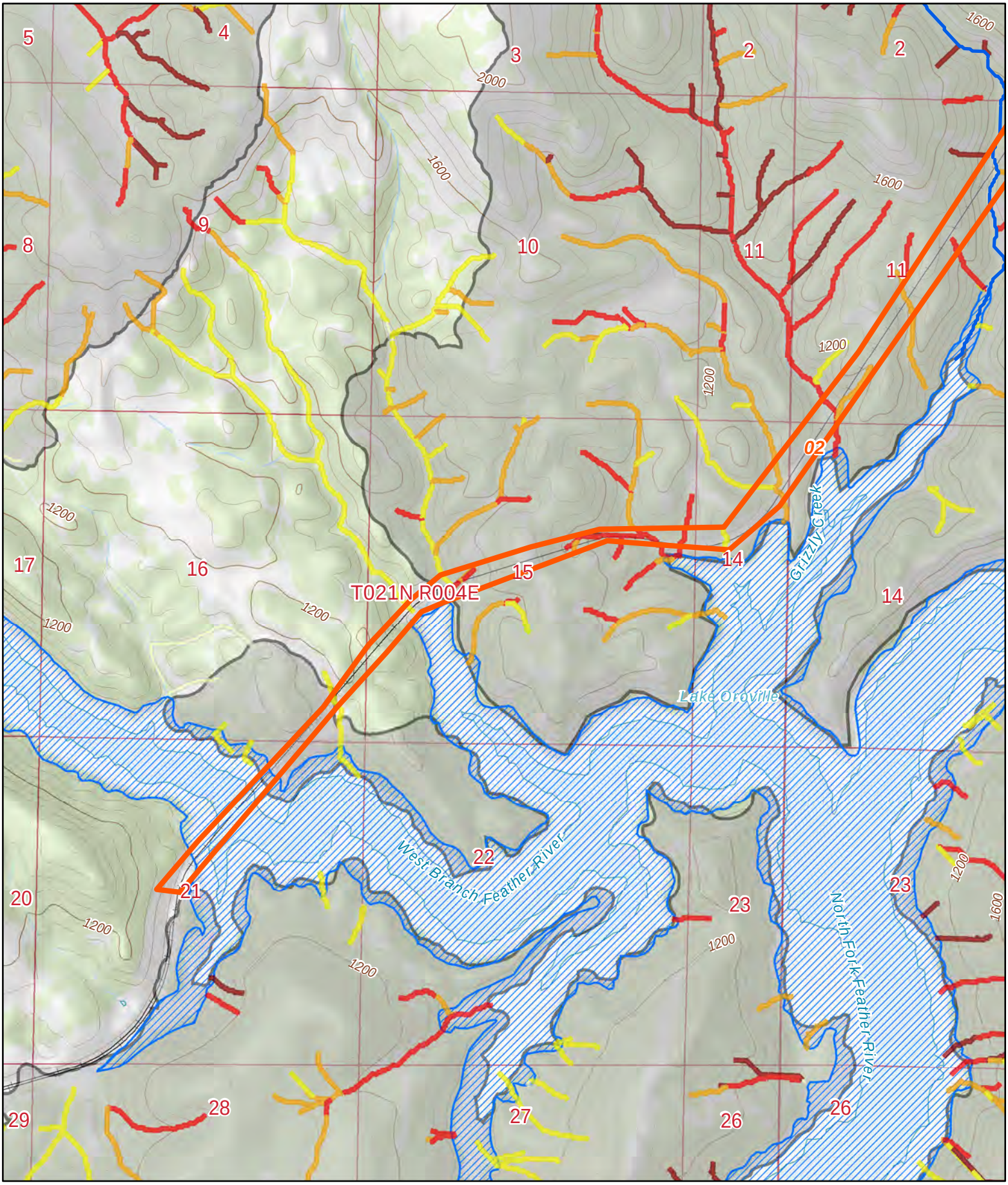
- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

0 0.2 0.4 Miles

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 34

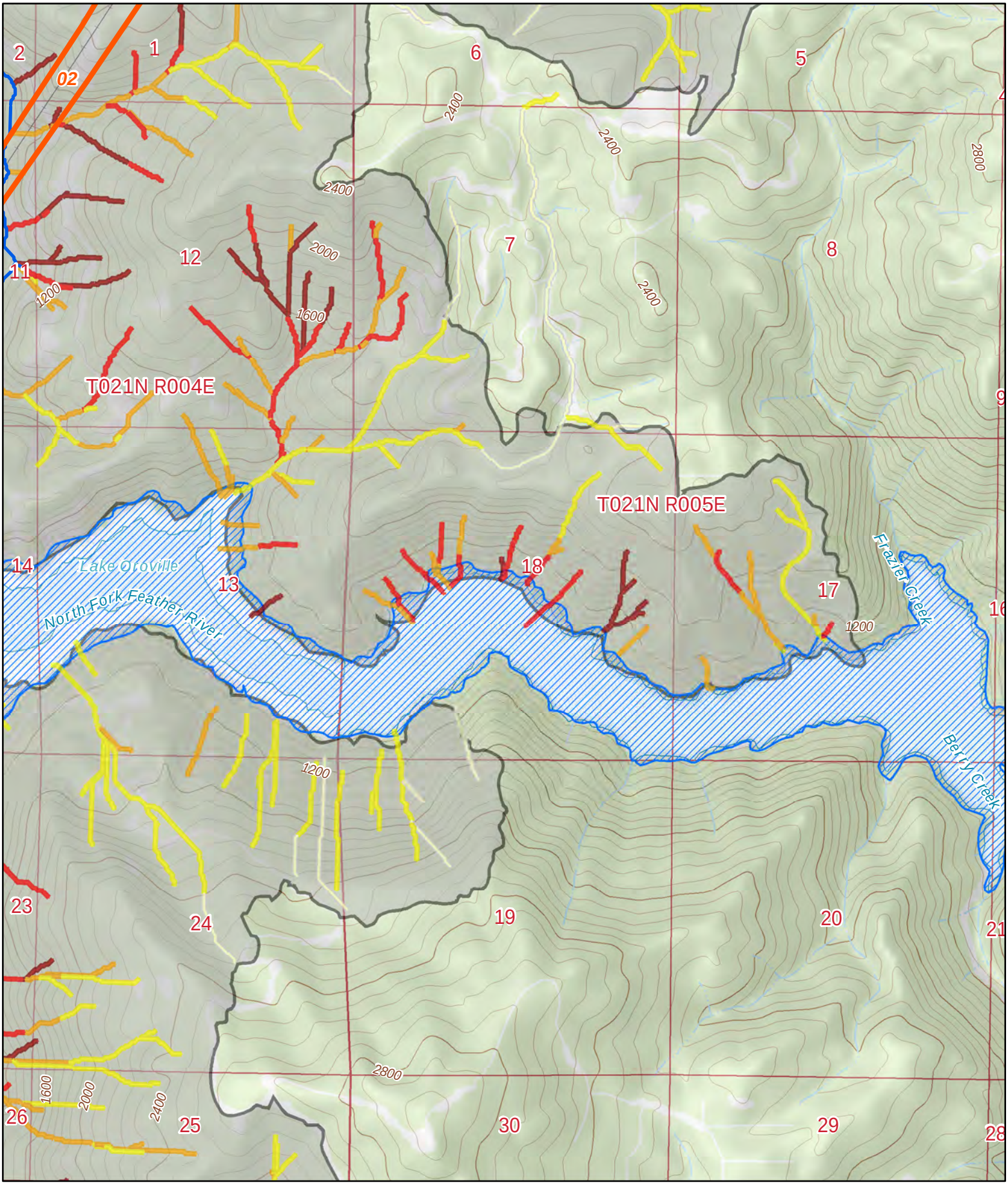
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 35

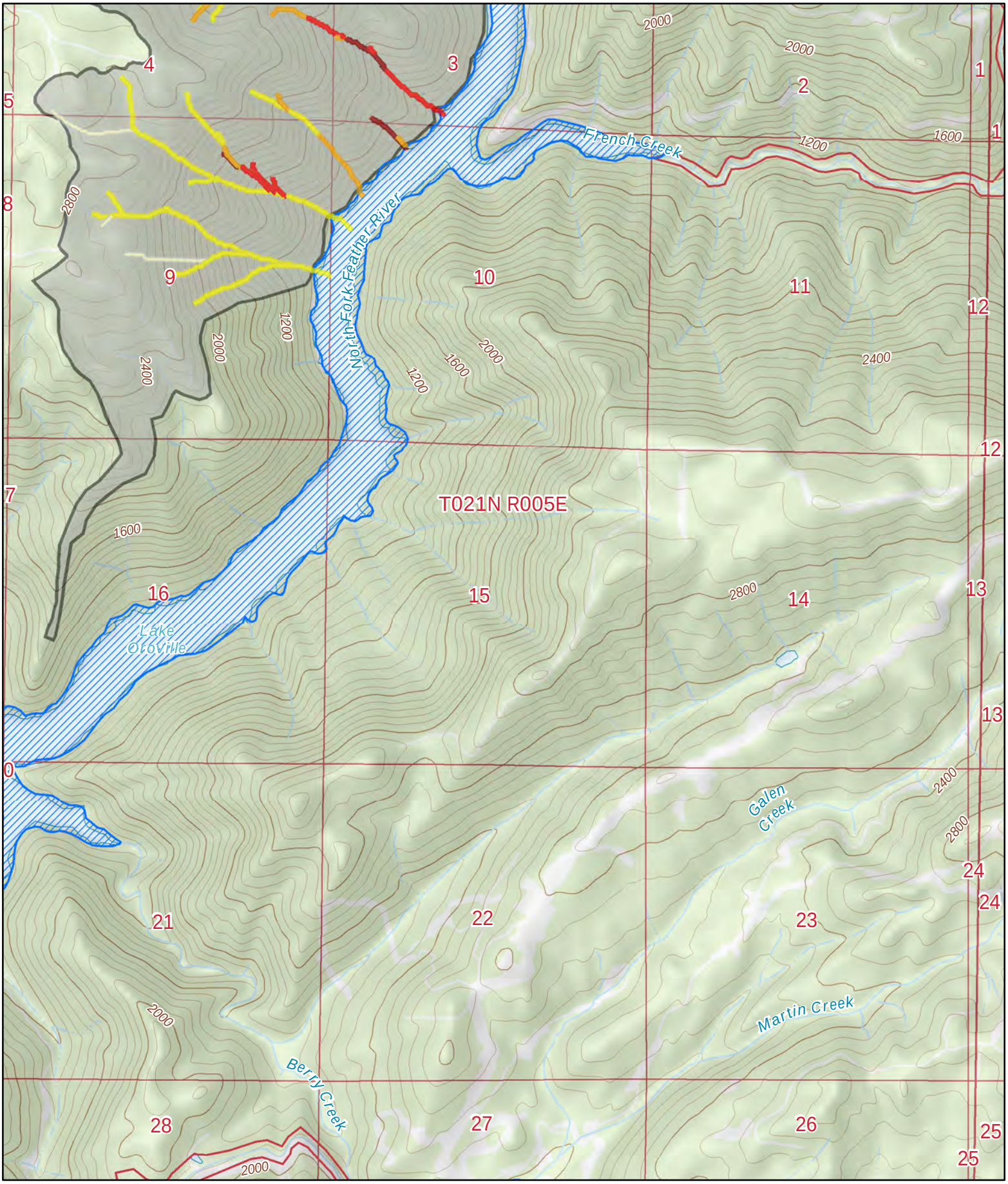
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 36

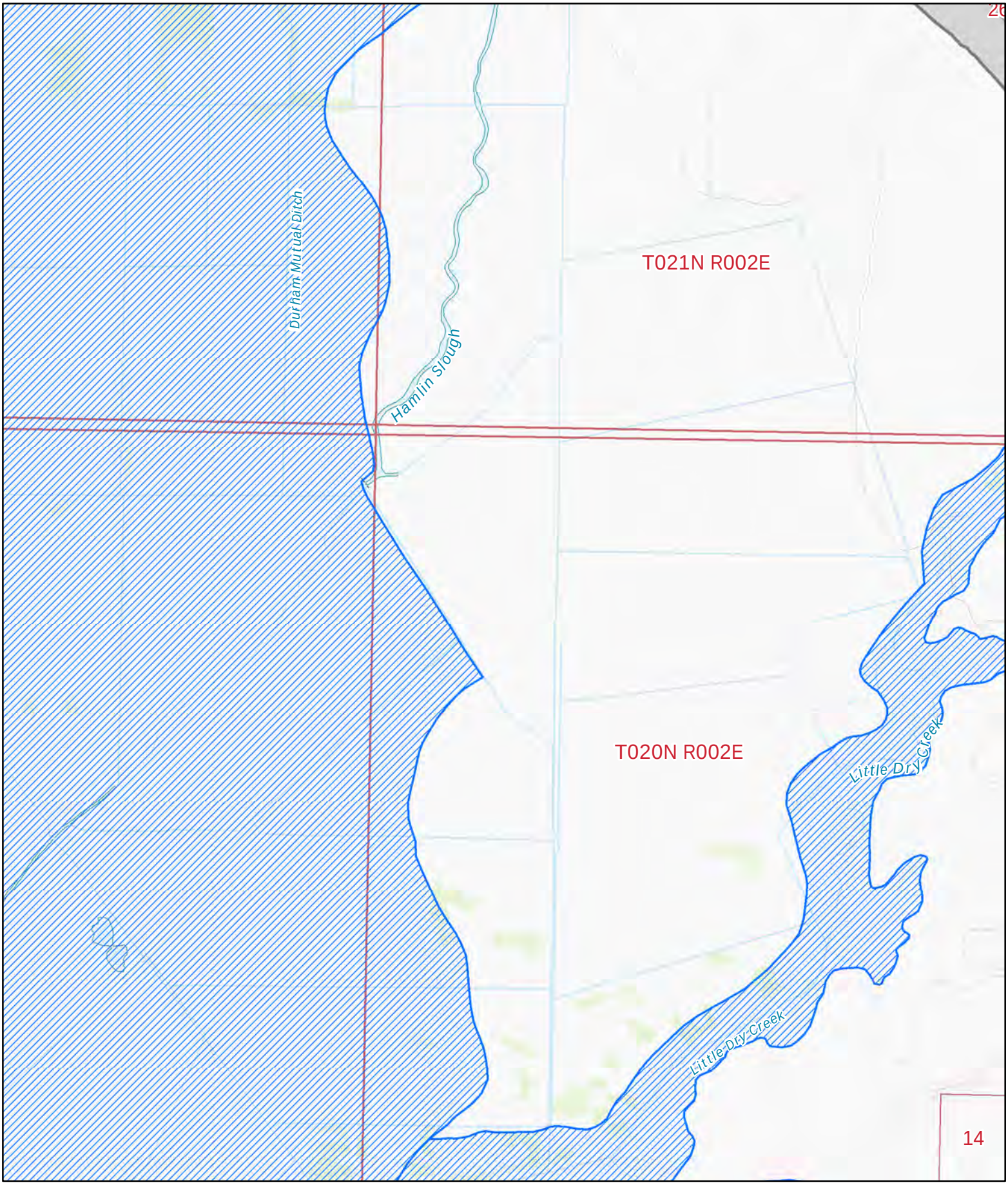
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 37

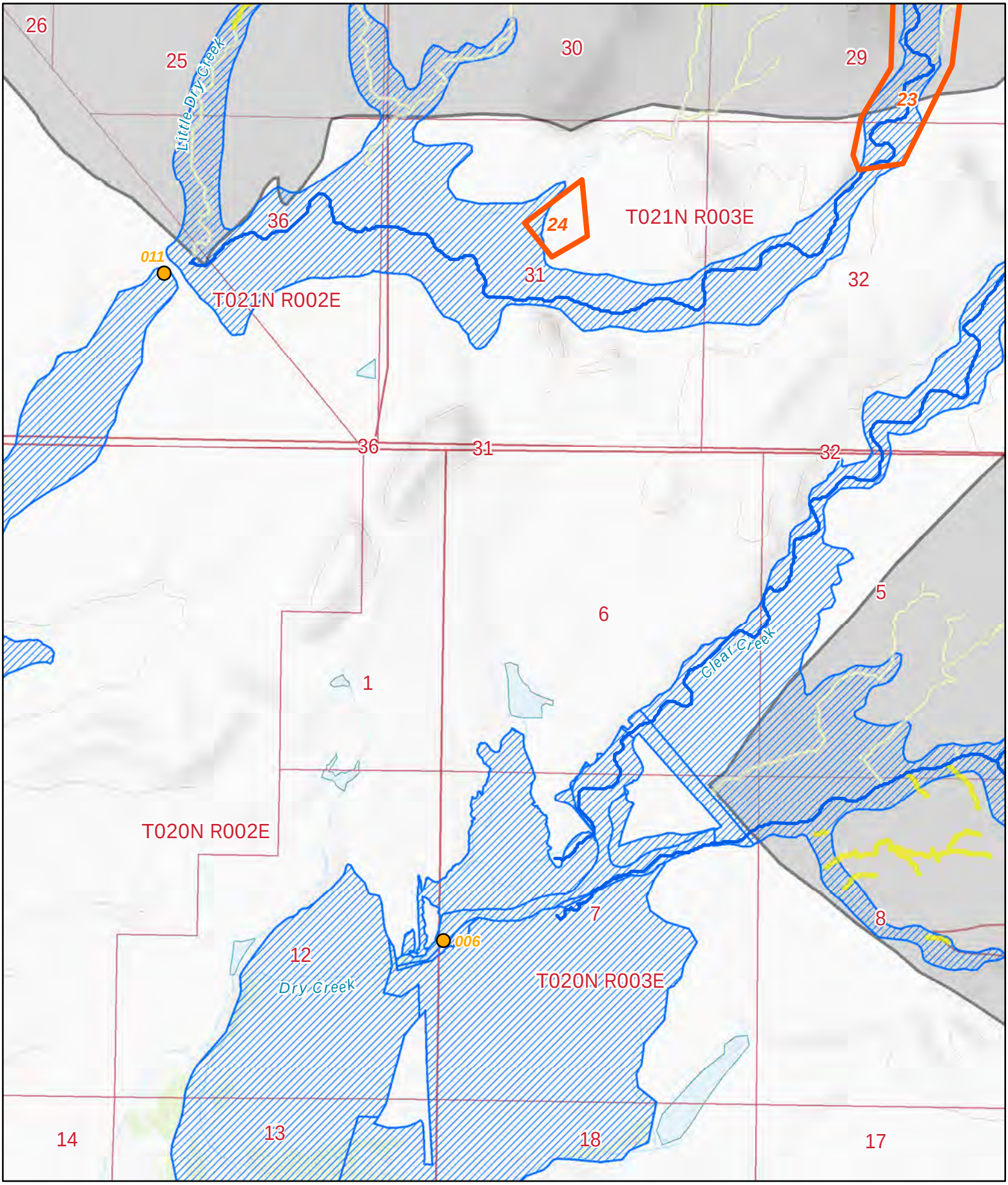
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 38

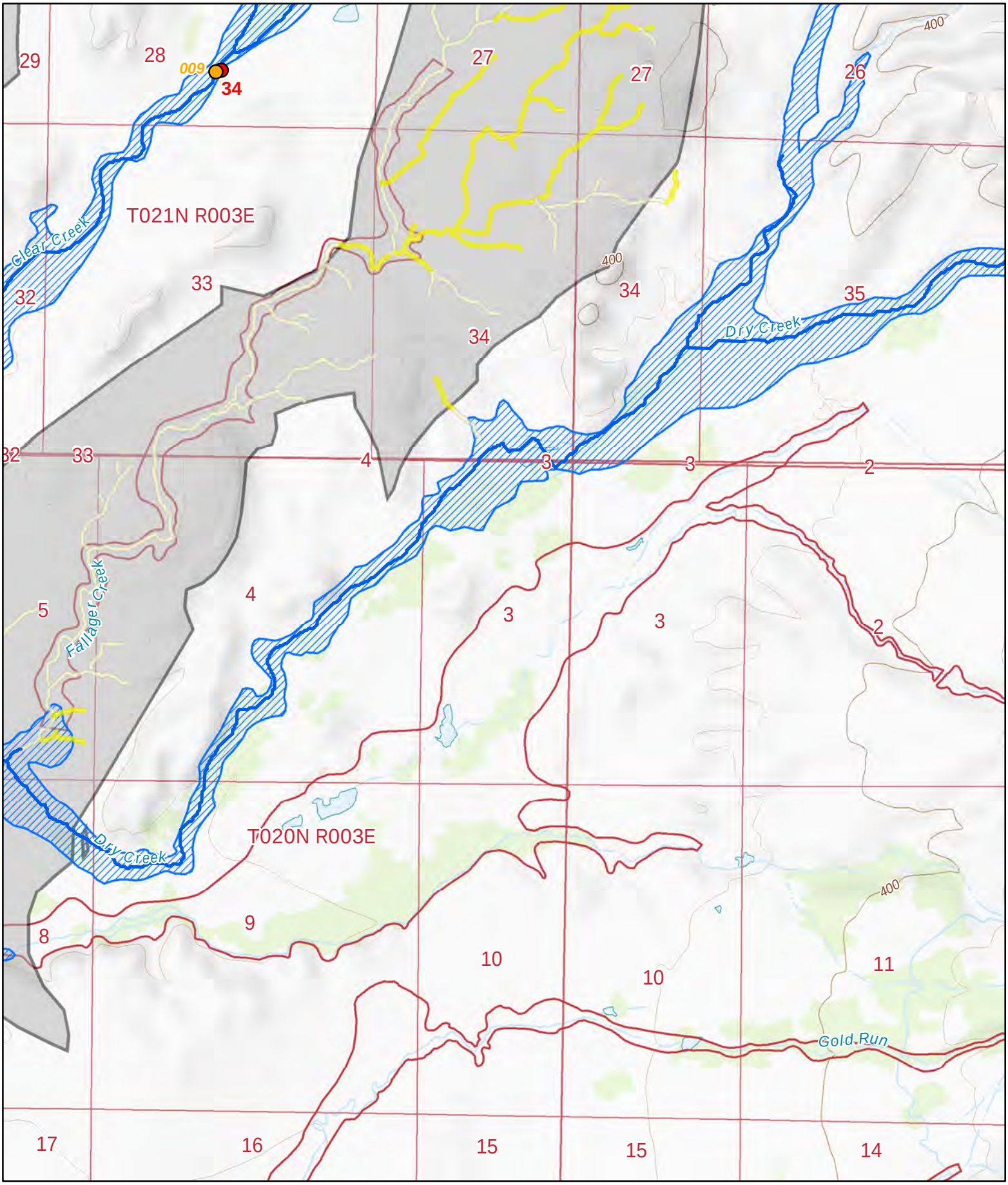
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 39

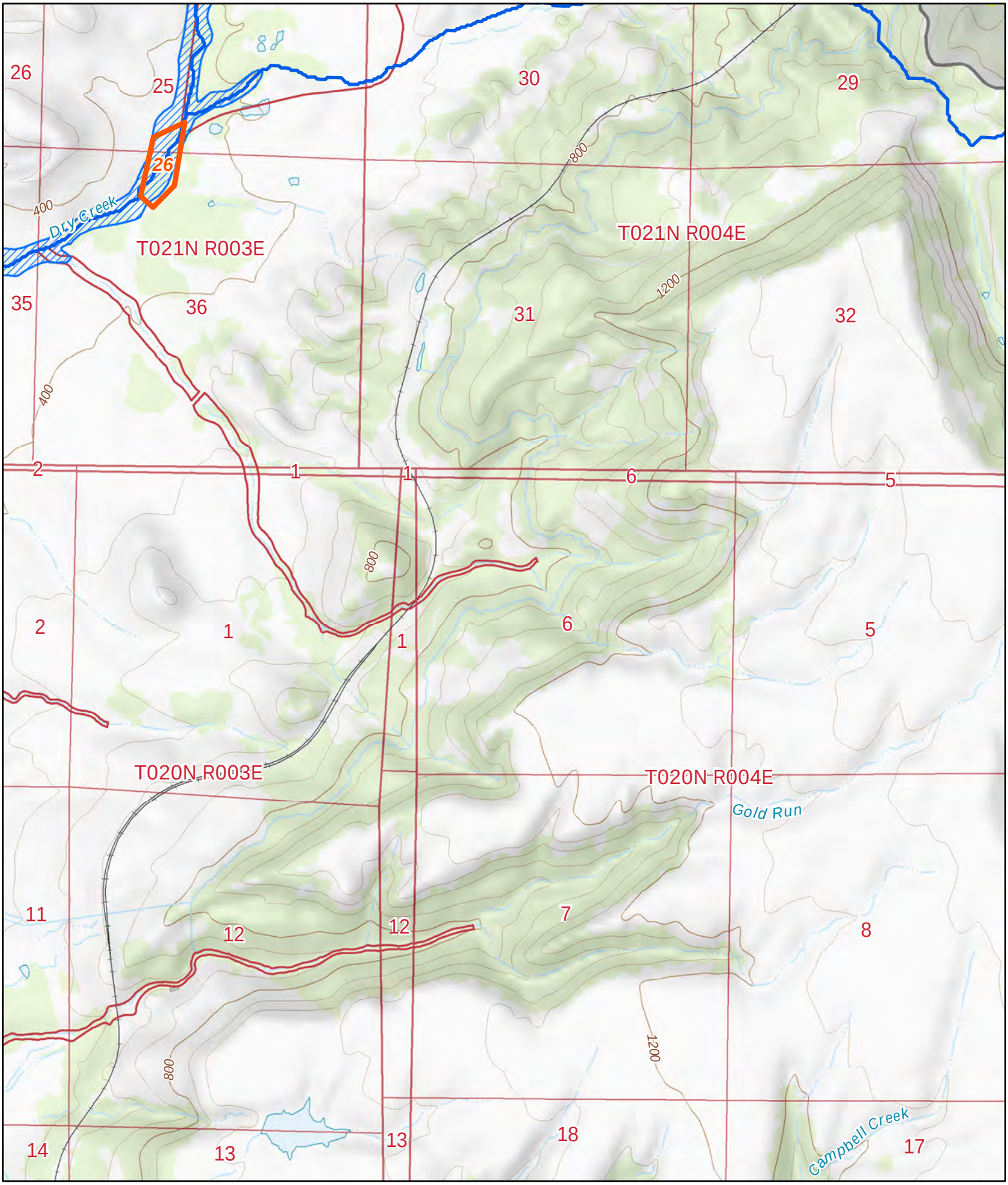
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 40

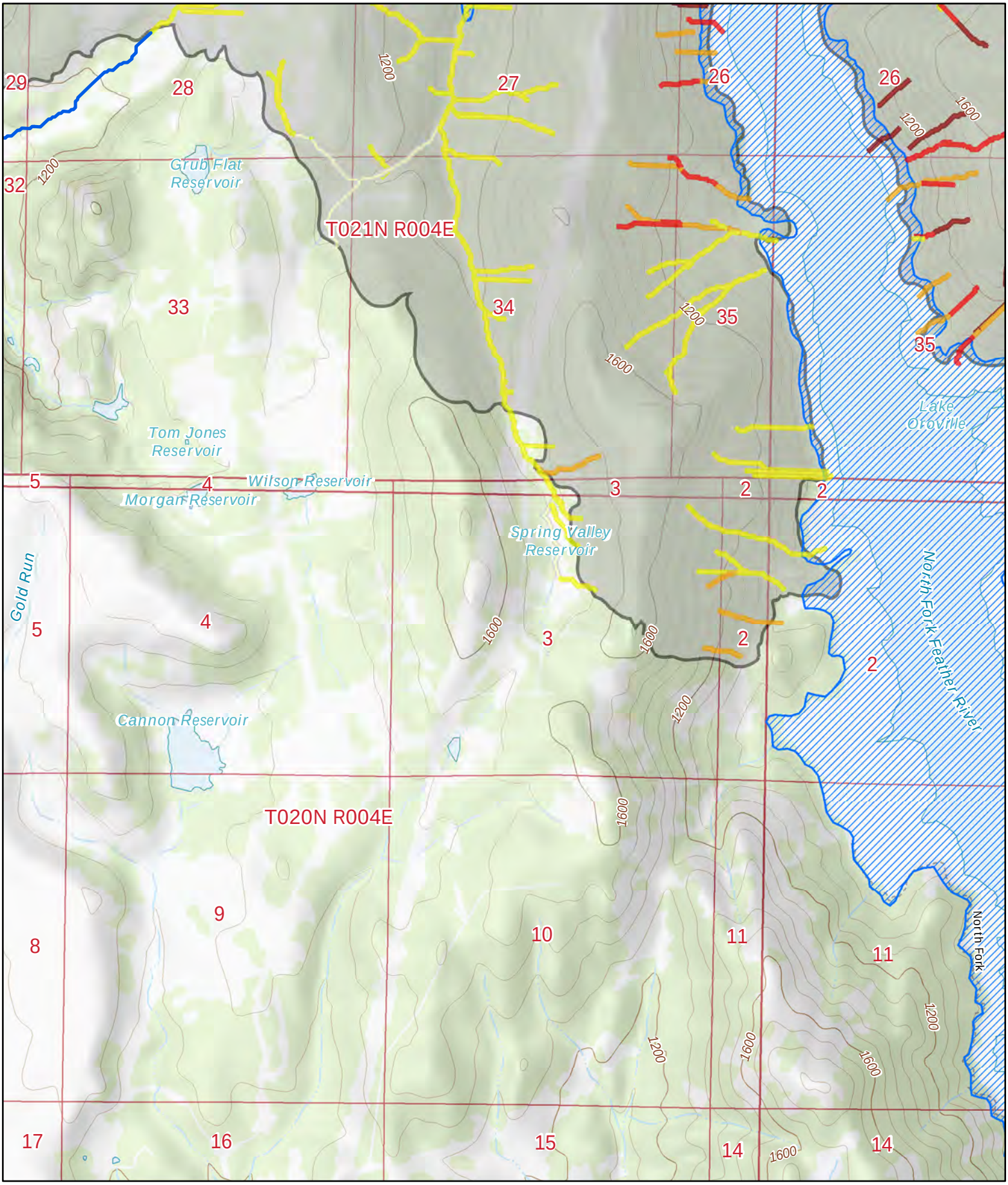
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 41

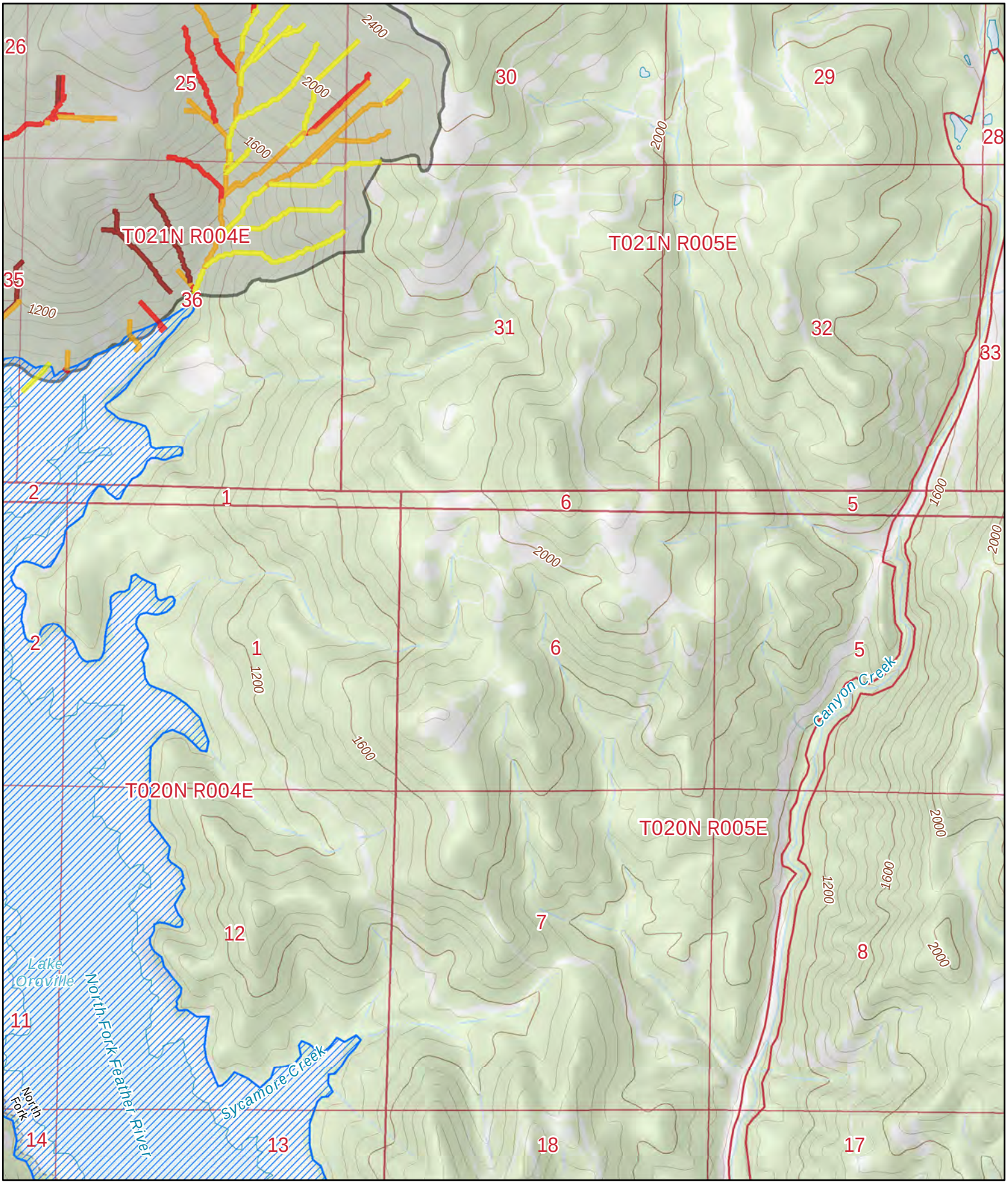
0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour



USGS Post-Fire Debris Flow Model Results
Camp Fire
Page 42

0 0.2 0.4 Miles

- Value at Risk - Point
- Value at Risk - Polygon
- Pour Point
- FEMA Floodzone and DWR Awareness Floodplain
- USGS Watch Stream
- Camp Fire Perimeter

Segment Debris Flow Prediction
15 min 40 mm/h*

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

* Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 40 mm per hour

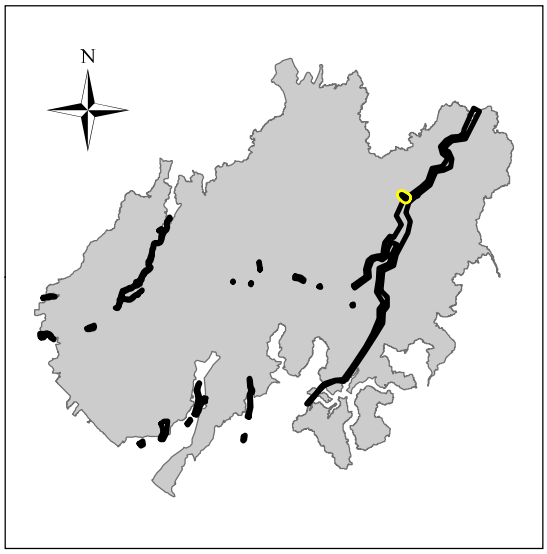
VALUE AT RISK DETAIL

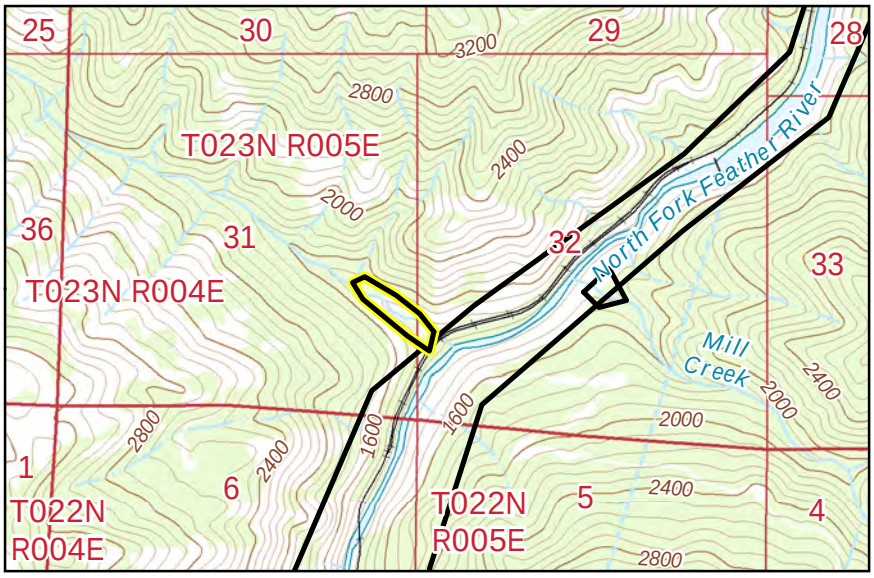
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Pulga**
Site Number: 01
Feature: Numerous structures and crossing
Feature Category: debris flow / flood
Field Observation: Several cabins and houses located in flood plain of Flea Creek. Owner reported past flooding and debris flow on property. Bridge crossing on Pulga Road is off alignment could restrict passage of debris.

Potential Hazard to Life: high
Potential Hazard to Property: high
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system and storm patrol
Protective Measures

Location





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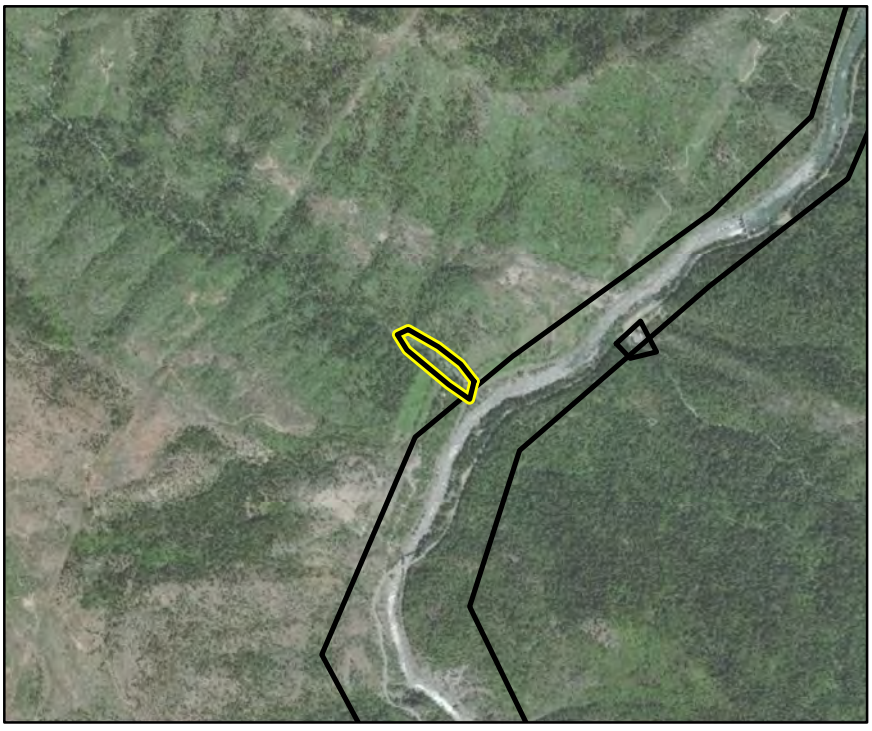


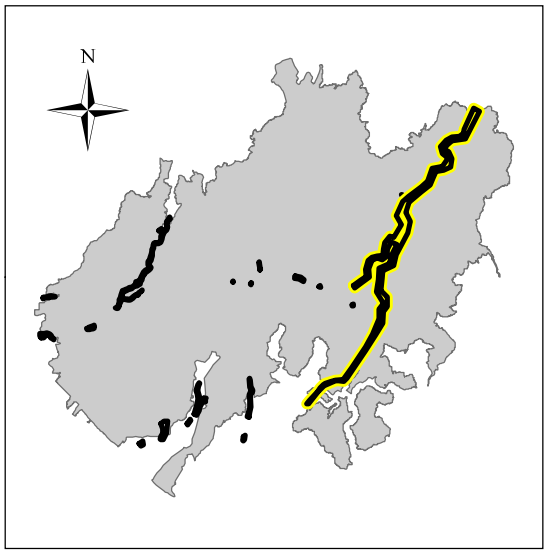
VALUE AT RISK DETAIL

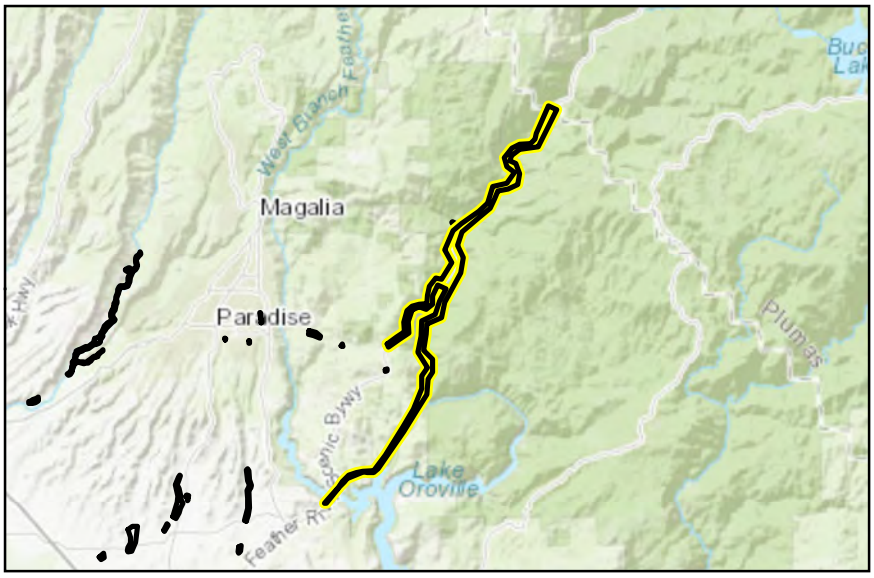
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Highway 70**
Site Number: 02
Feature: Highway and railroad
Feature Category: debris flow / flood
Field Observation: Debris flow potential on highway 70 and Railroad may clog crossings and restrict transportation corridor.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system
Protective Measures

Location





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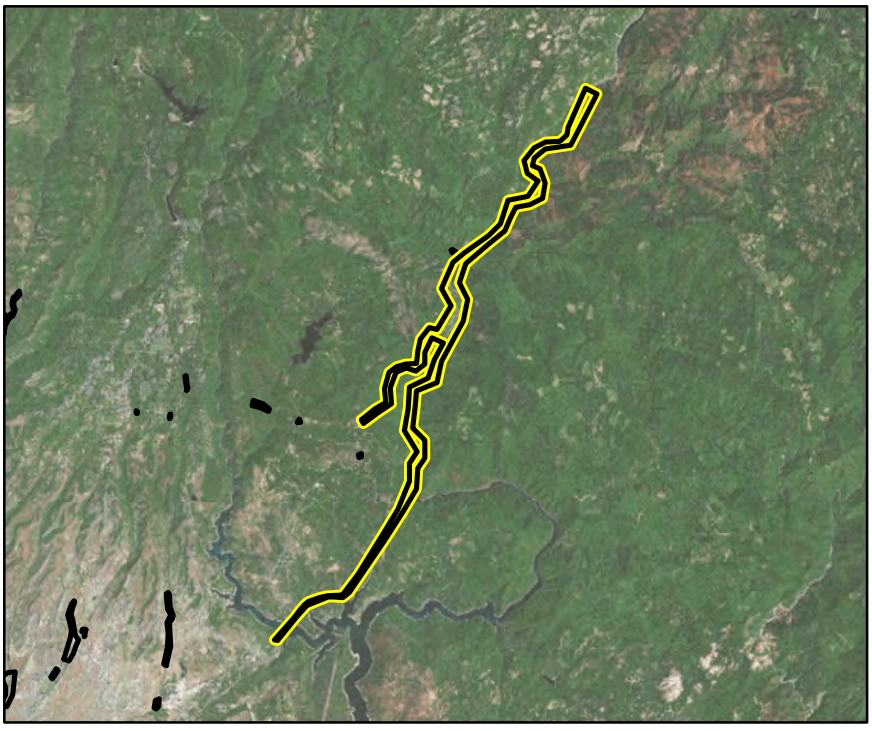


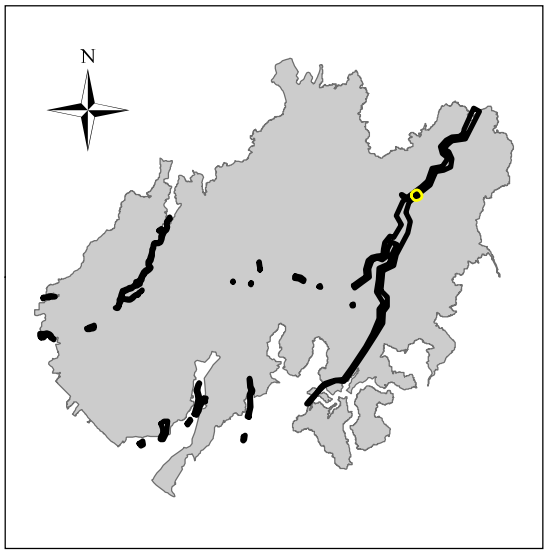
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Highway 70**
Site Number: 03
Feature: Caltrans maintenance buildings
Feature Category: debris flow / flood
Field Observation: Caltrans Pulga Maintenance Station located at mouth of Mill Creek. It appears Mill Creek has been rerouted around the maintenance facility. Mill Creek is identified as a USGS Watch Stream

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency Protective Measures: Early warning system, notify Caltrans

Location



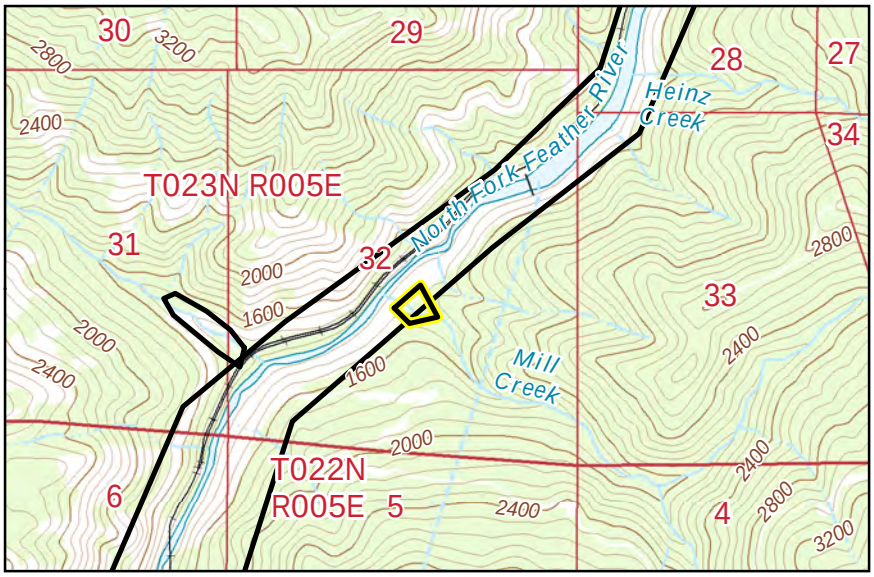


Photo ID:

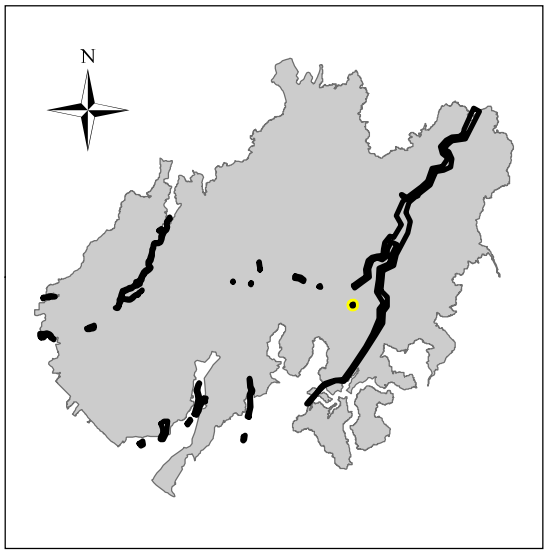
VALUE AT RISK DETAIL

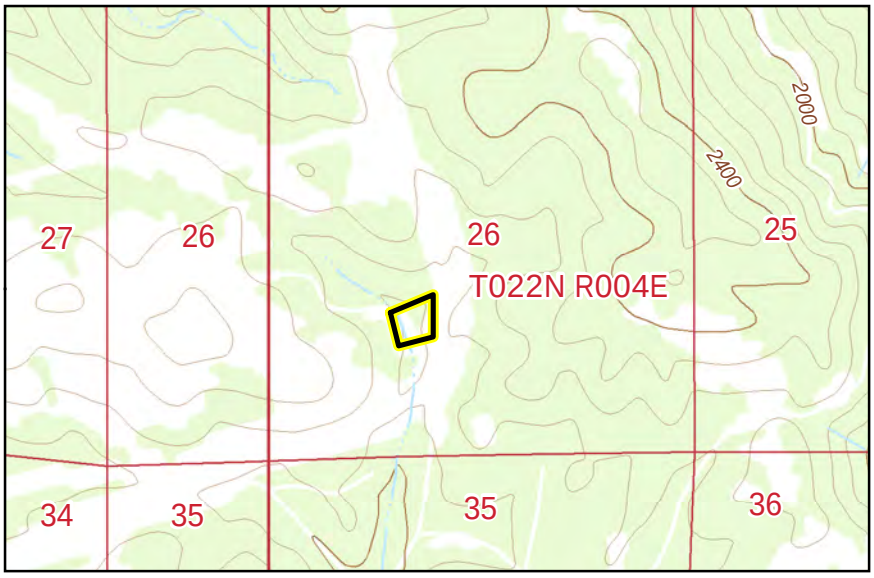
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 08
Feature: House and outbuildings
Feature Category: debris flow / flood
Field Observation: Burned house and other outbuildings located in channel zones, could be impacted by debris and/or flood. Site is located on moderate probability debris flow segment.

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: No
Preliminary Emergency: Early warning sytem
Protective Measures

Location





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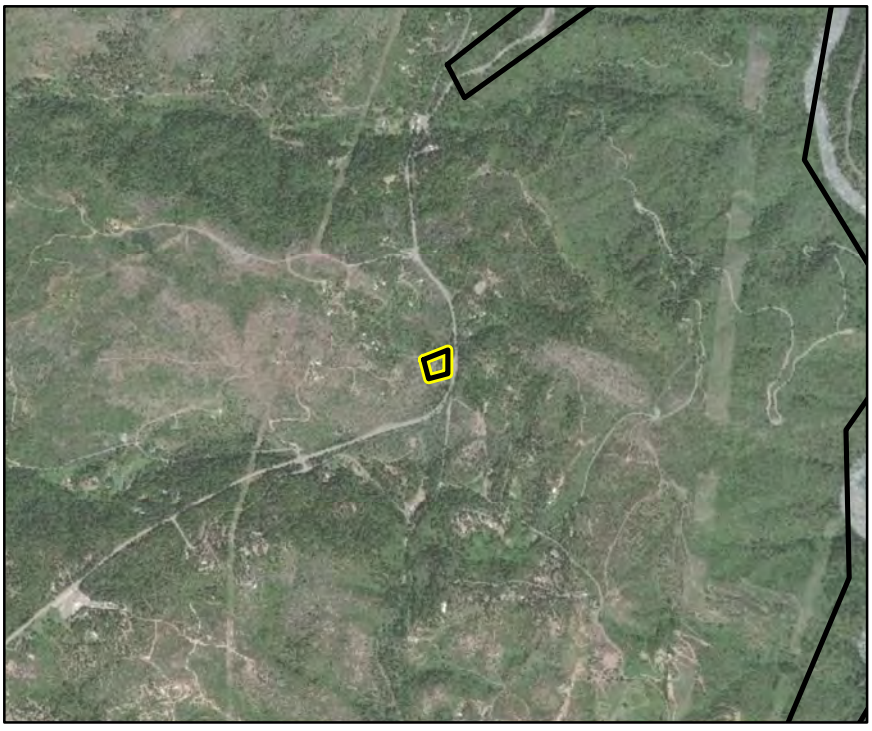


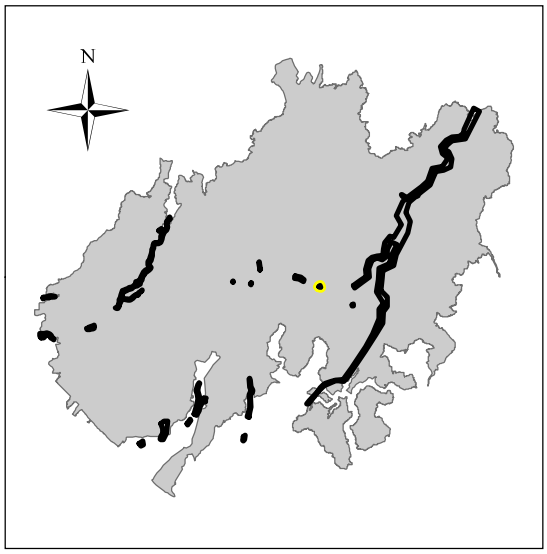
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 09
Feature: House
Feature Category: debris flow / flood
Field Observation: House and outbuildings built on alluvial fan deposits. Ditch constructed upslope to divert water around house.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: No
Preliminary Emergency: Early warning system
Protective Measures

Location



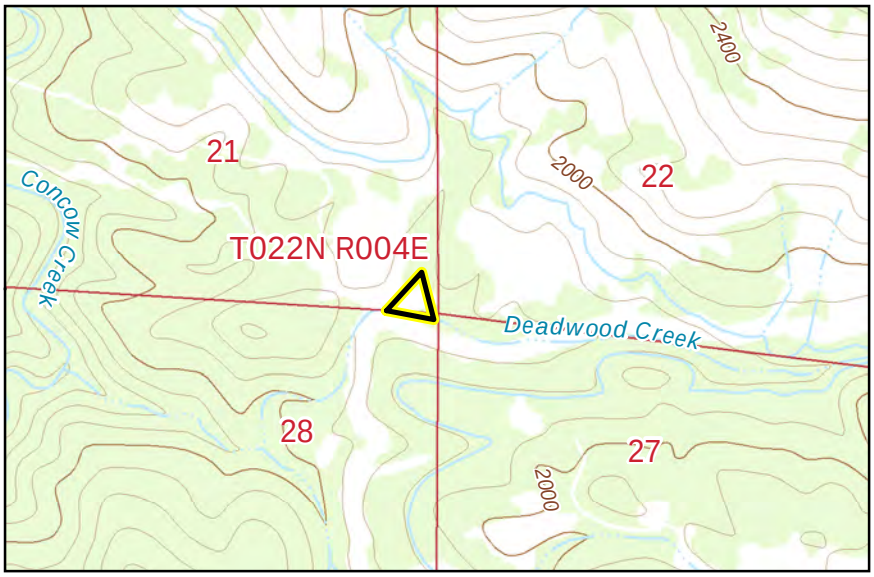


Photo ID:

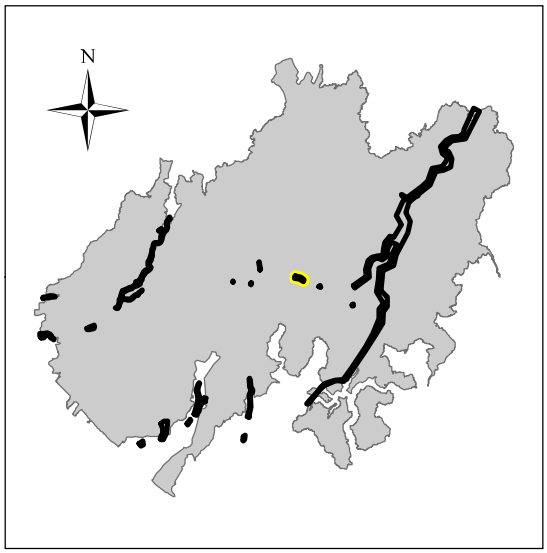
VALUE AT RISK DETAIL

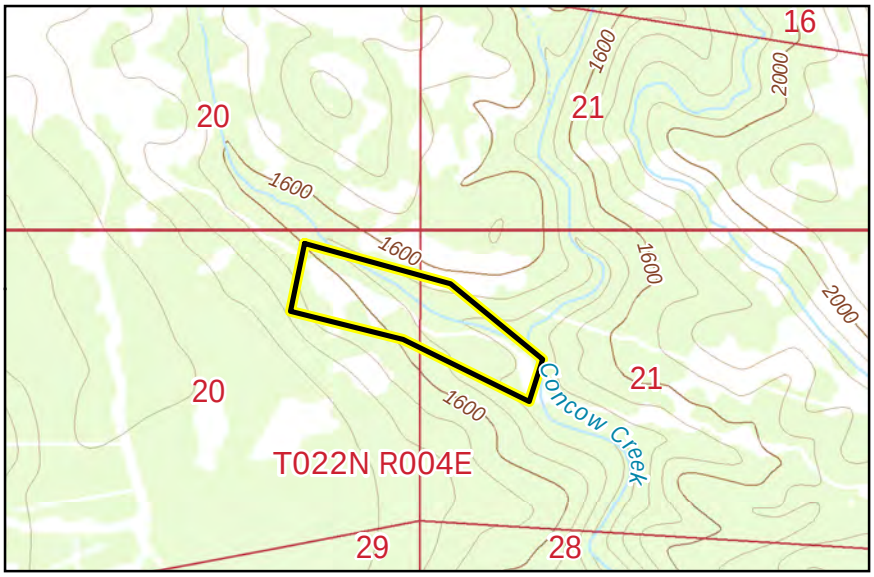
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 10
Feature: Road
Feature Category: debris flow / flood
Field Observation: Unpaved road on steep slope with multiple fillslope failures.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency Protective Measures: Early warning system

Location





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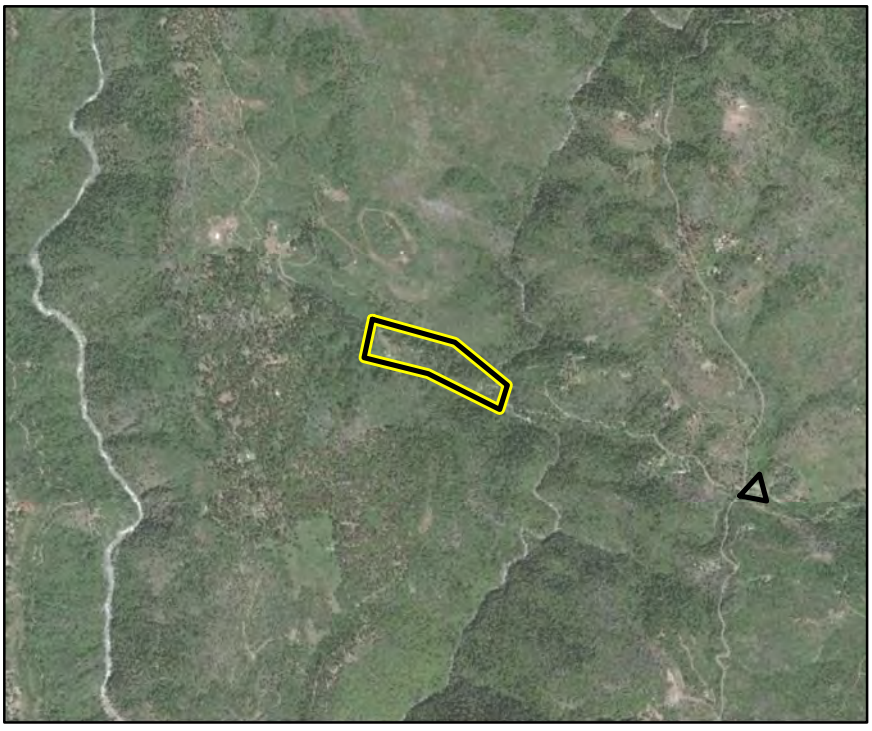


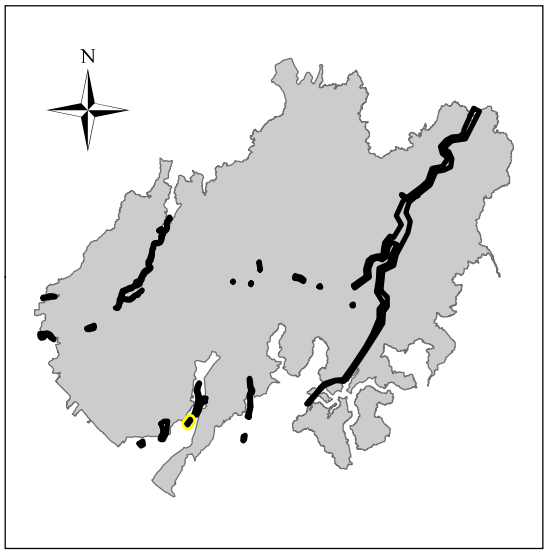
VALUE AT RISK DETAIL

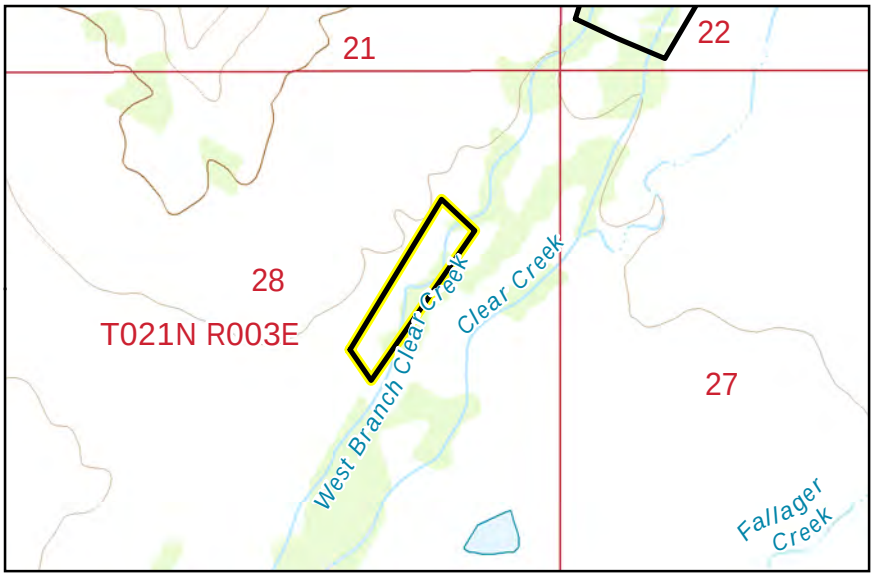
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 21
Feature: Bridge and maintenance buildings
Feature Category: flood
Field Observation: Footbridge and maintenance facilities located within mapped flood risk zone. Channel shows evidence of scour.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency Protective Measures: Early warning system

Location





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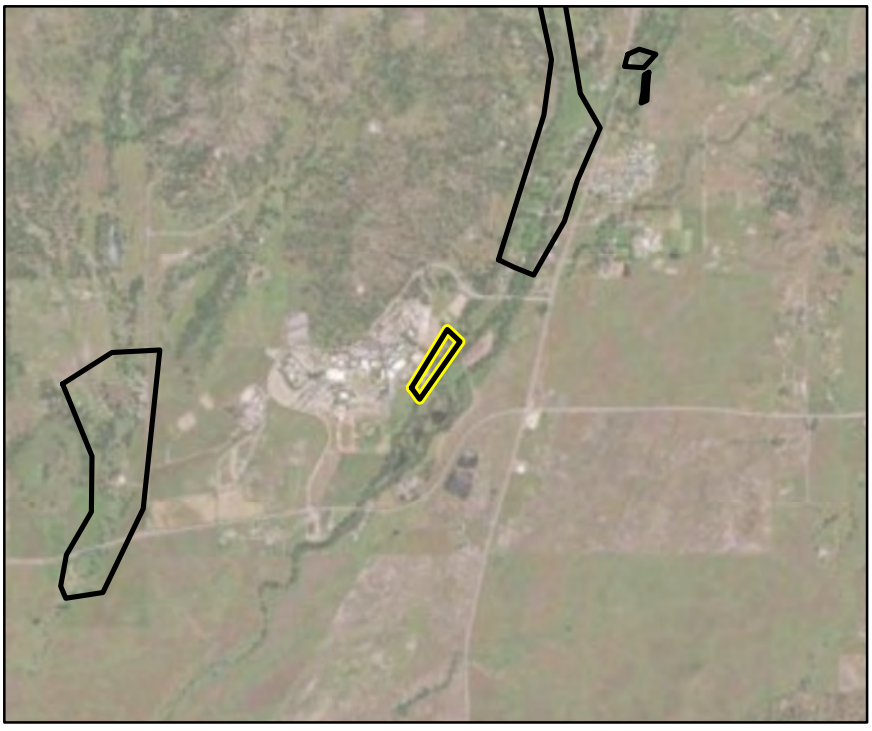


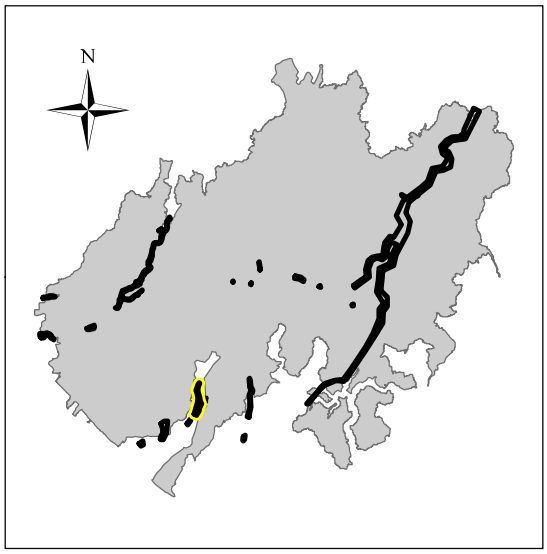
VALUE AT RISK DETAIL

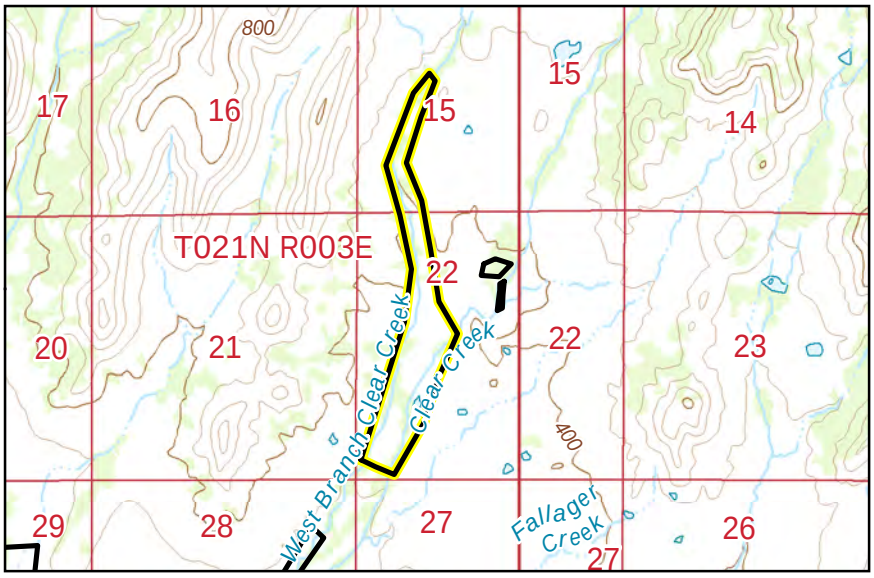
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 22
Feature: Houses located in flood zone
Feature Category: flood
Field Observation: Several homes located within mapped FEMA flood hazard area. Several small private bridges located along creek may be at risk of failure.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency Protective Measures: Early warning system

Location





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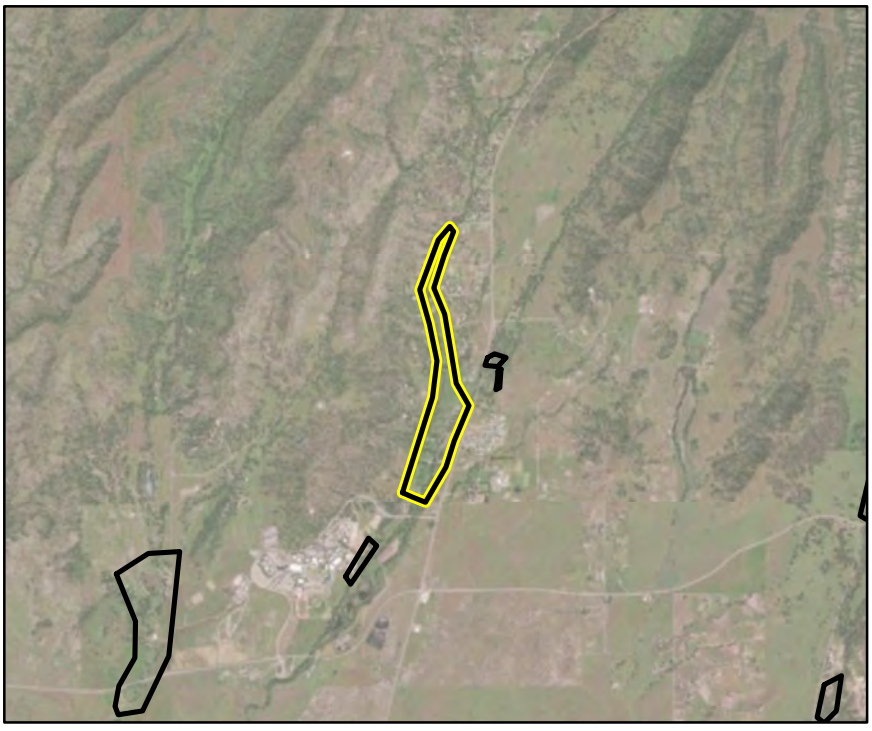


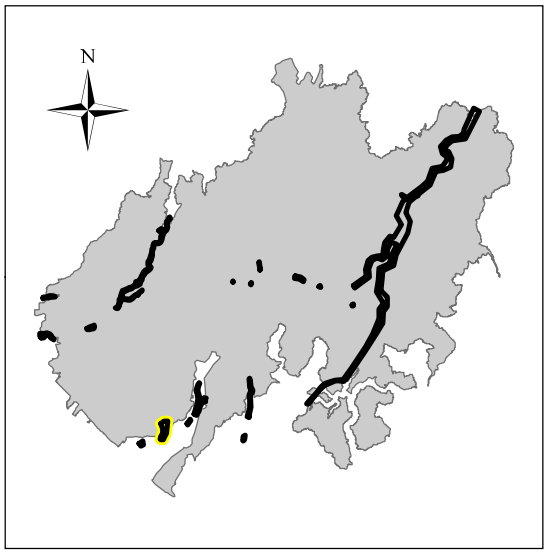
VALUE AT RISK DETAIL

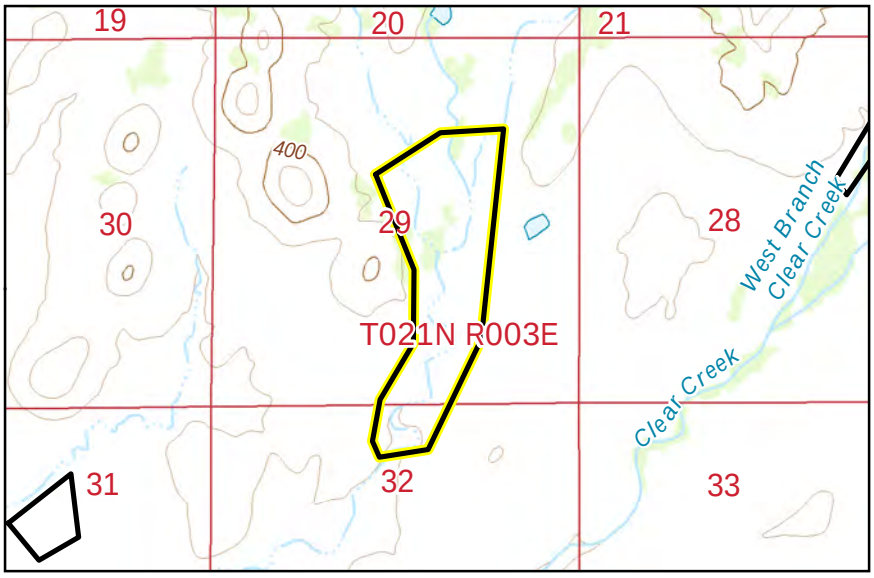
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 23
Feature: Houses and outbuildings
Feature Category: flood
Field Observation: Houses located within mapped FEMA flood hazard area. Structures appear to be located on terraces

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency Protective Measures: Early warning system

Location





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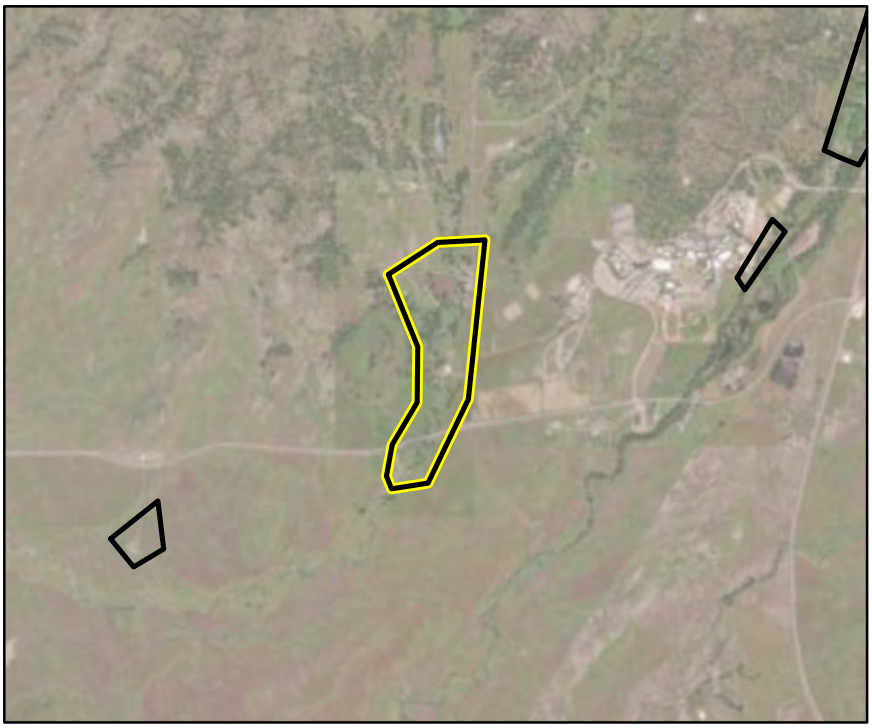


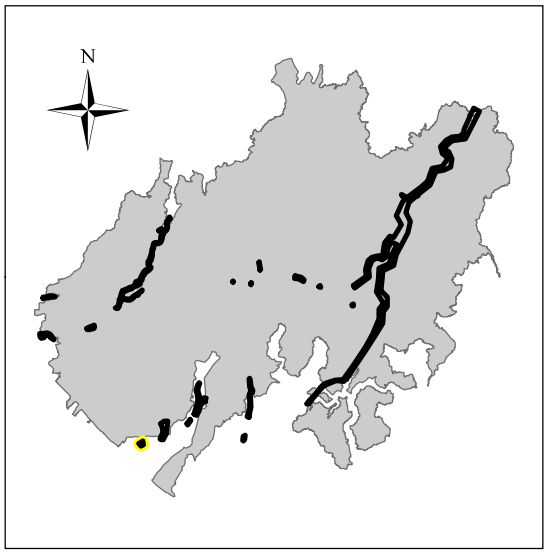
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 24
Feature: Houses and outbuildings
Feature Category: flood
Field Observation: Houses located within mapped flood zone. Locked gate

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system
Protective Measures

Location



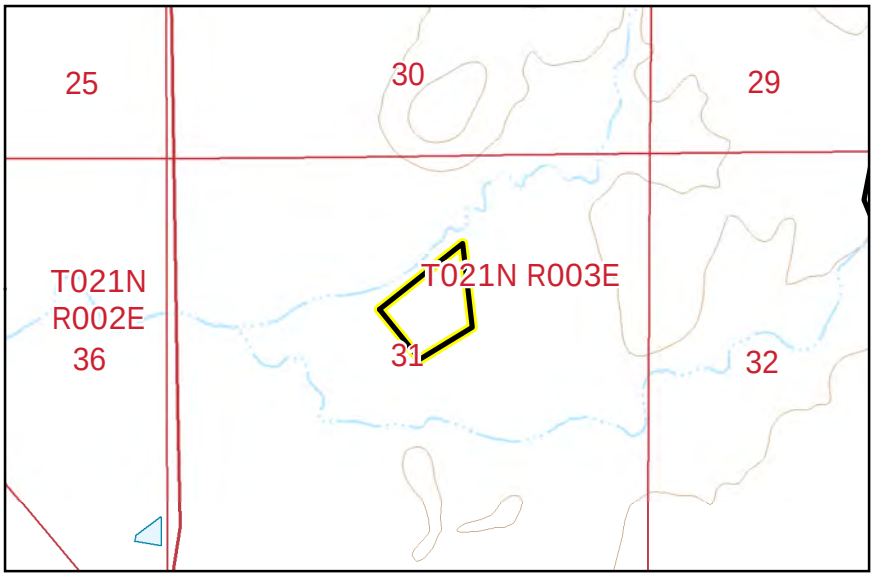


Photo ID:

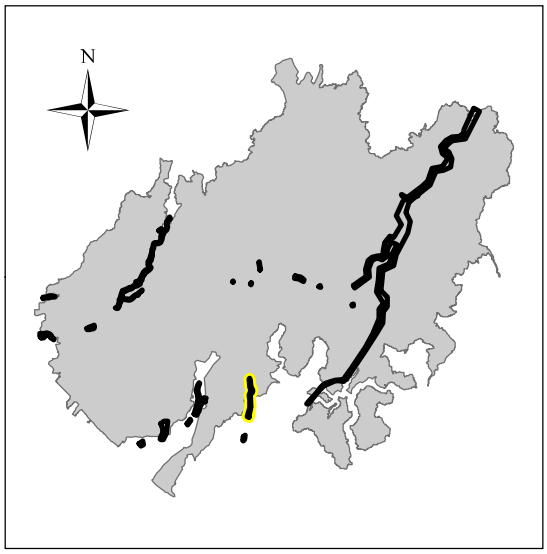
VALUE AT RISK DETAIL

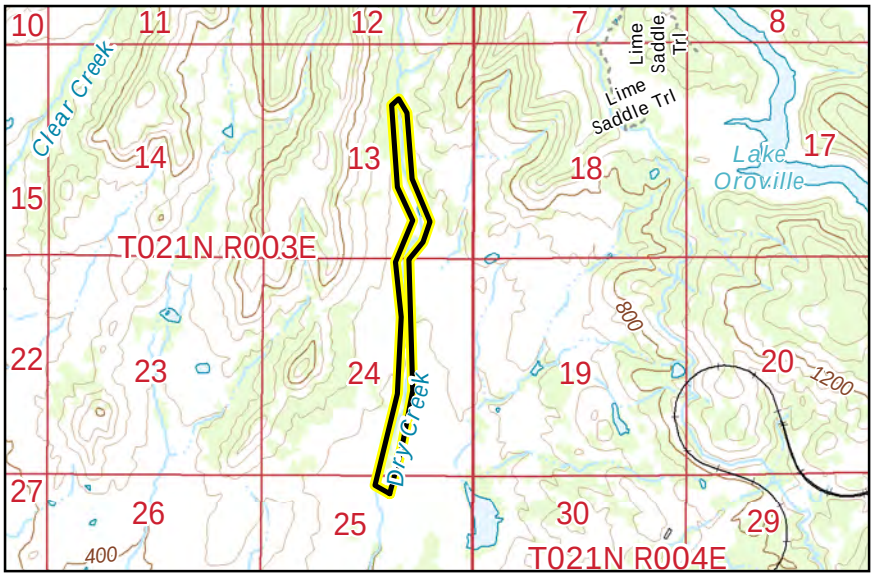
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 25
Feature: Houses and outbuildings
Feature Category: flood
Field Observation: Houses located within mapped flood zone. Structures appear to be located on terraces. Private bridges within the flood zone may be prone to failure.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency Protective Measures: Early warning system

Location





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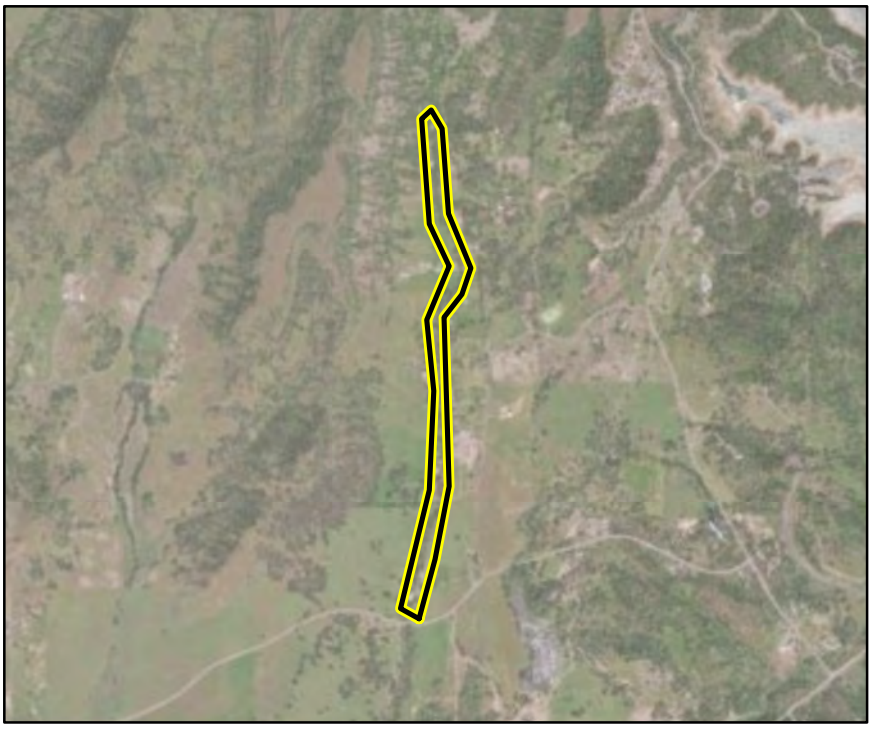


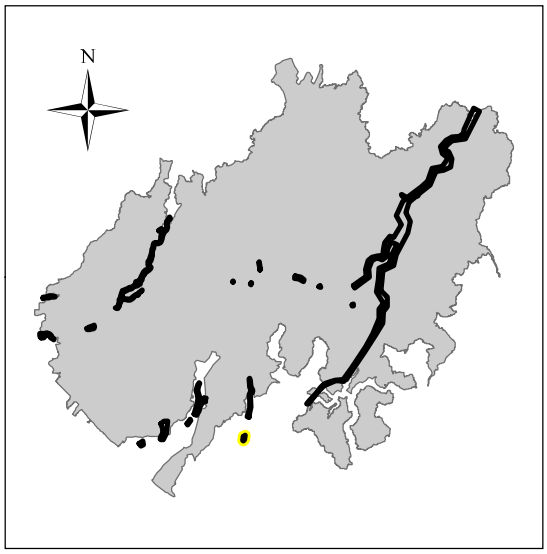
VALUE AT RISK DETAIL

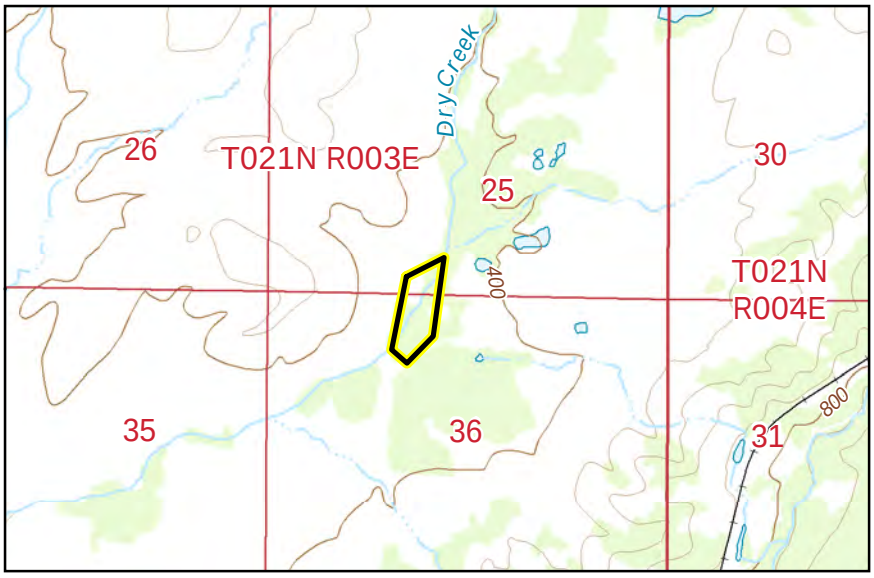
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 26
Feature: Houses and outbuildings
Feature Category: flood
Field Observation: Houses located within mapped flood zone. Structures appear to be located on terraces.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system
Protective Measures

Location





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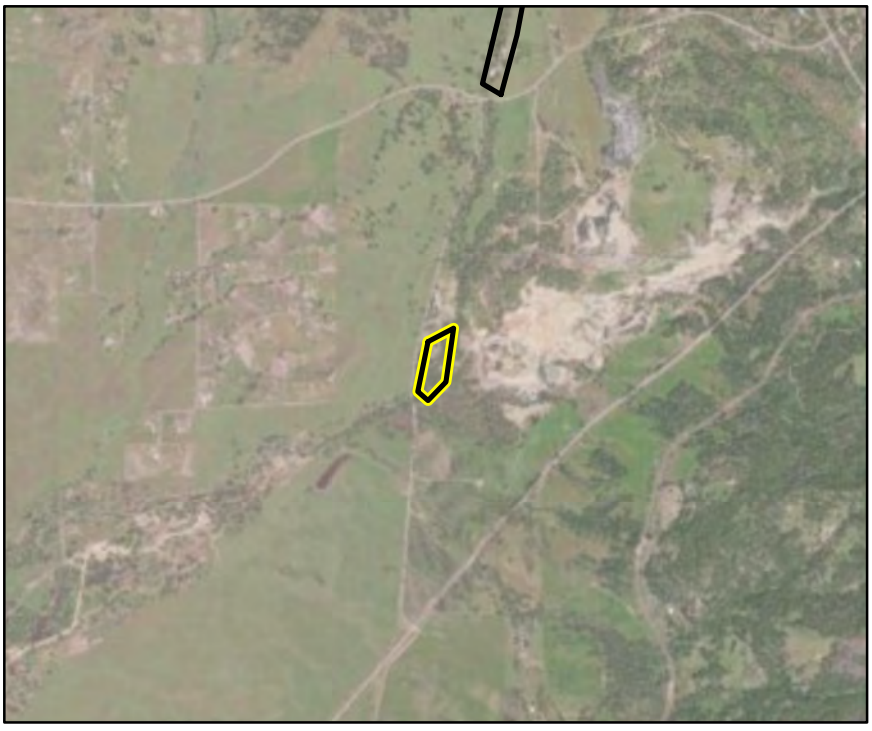


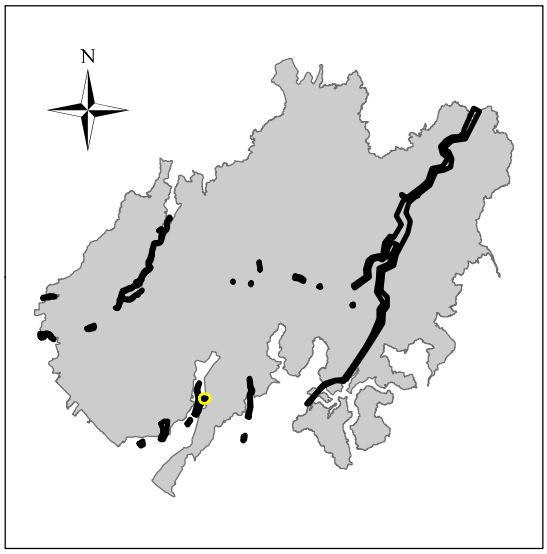
VALUE AT RISK DETAIL

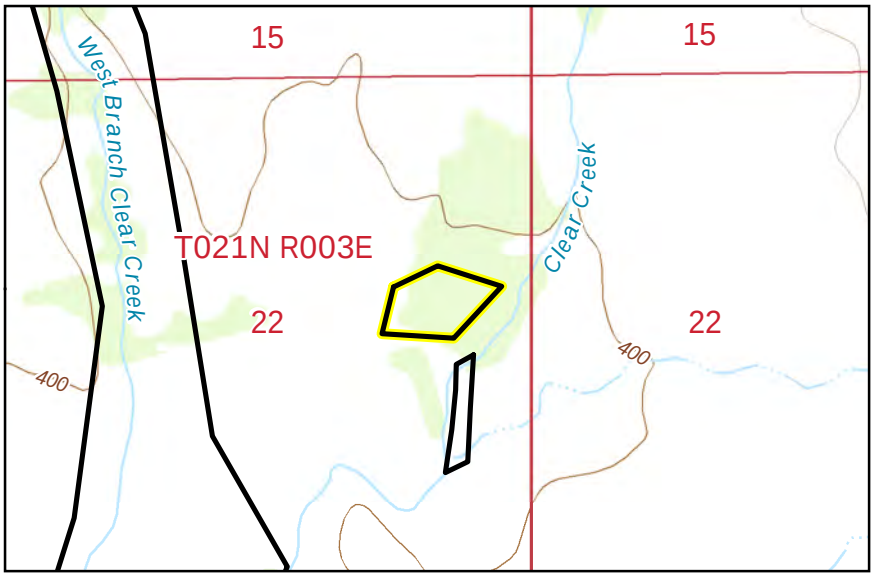
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 27
Feature: Homes
Feature Category: flood
Field Observation: Homes located within and adjacent to mapped flood hazard area.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early Warning System
Protective Measures

Location





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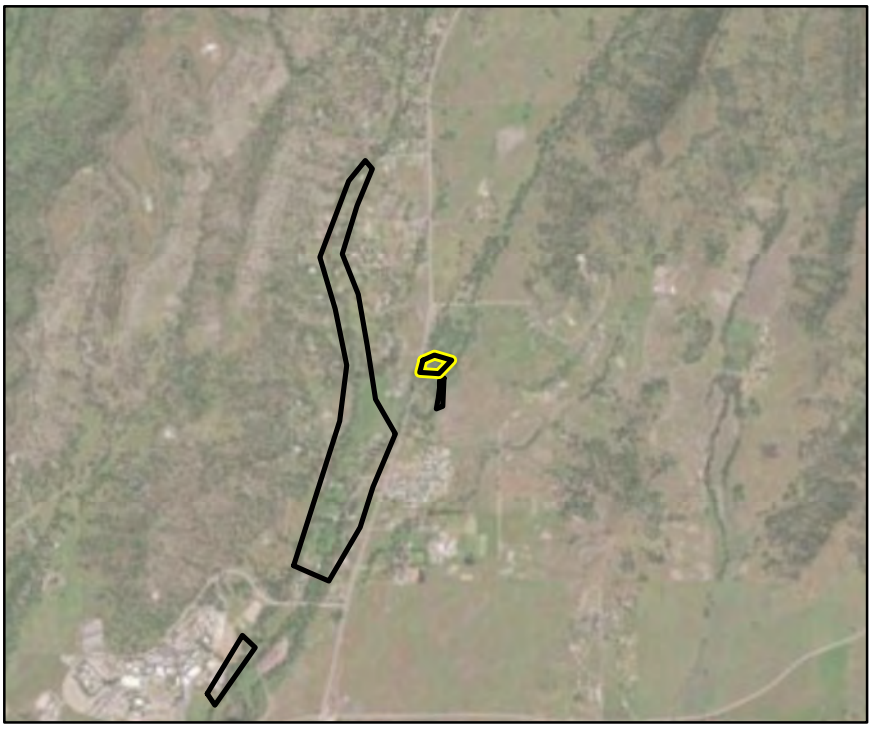


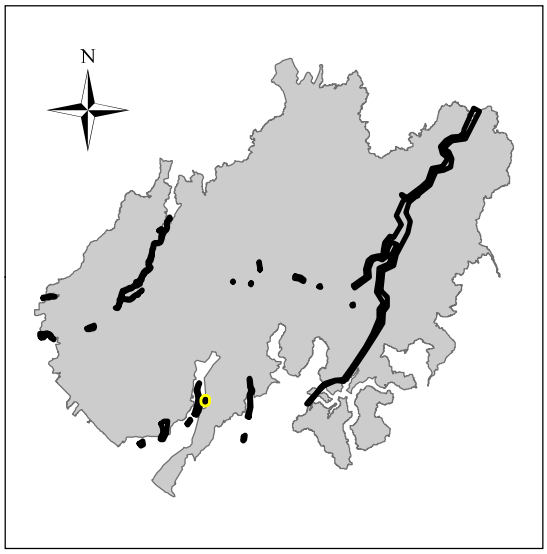
VALUE AT RISK DETAIL

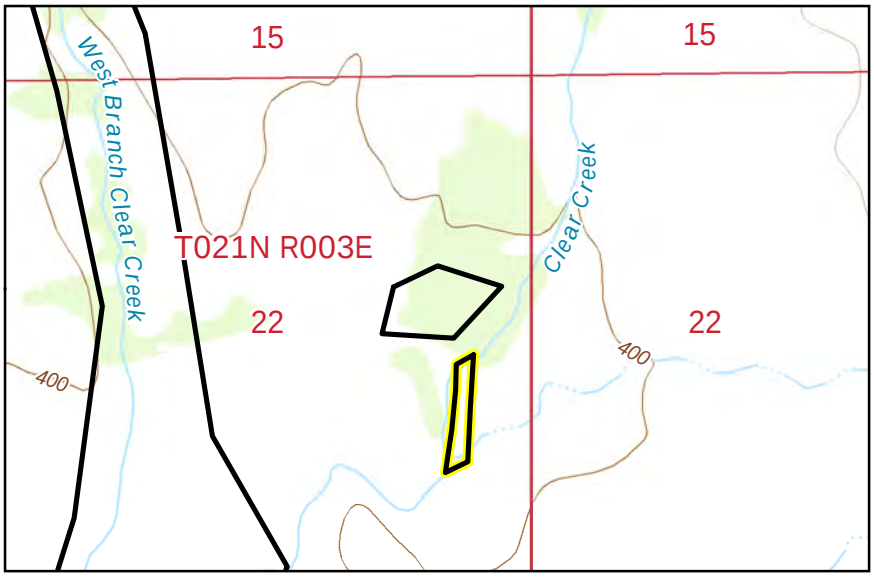
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 28
Feature: Bridge and Road
Feature Category: flood
Field Observation: Bridge and Road located in mapped flood hazard area

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early Warning System
Protective Measures

Location





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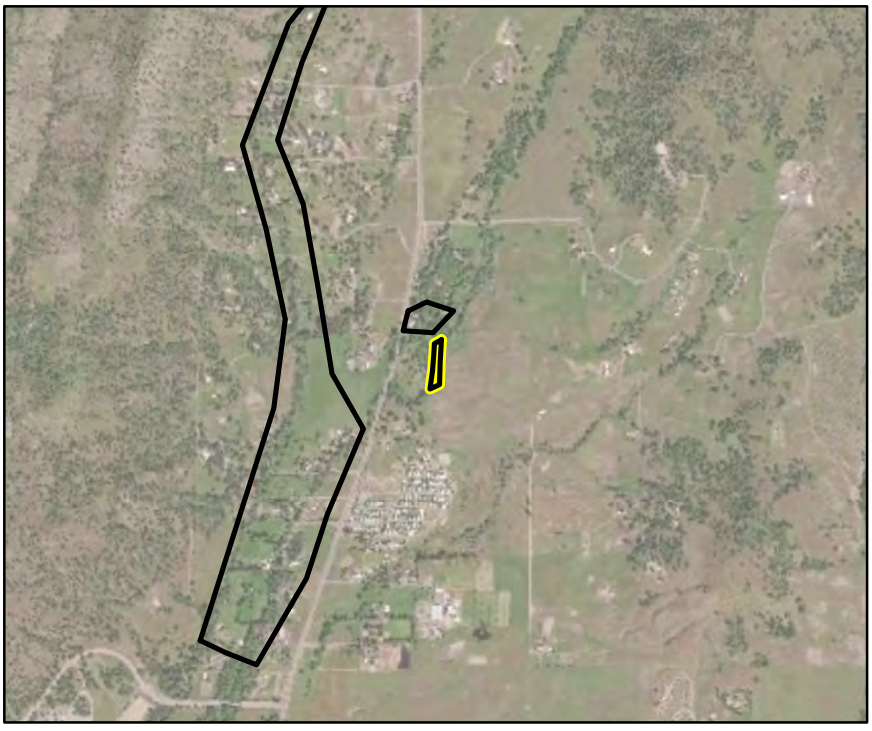


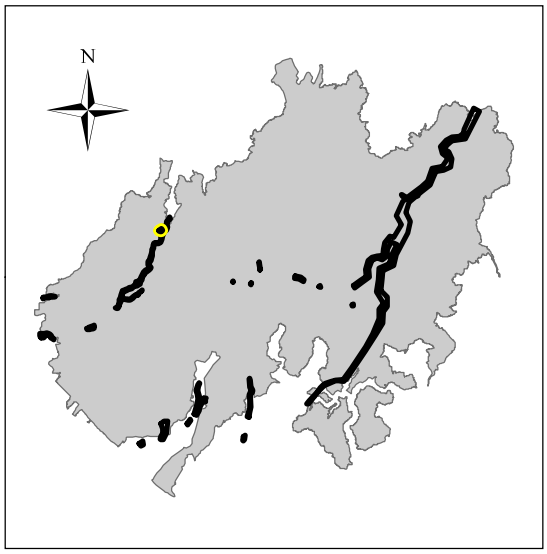
VALUE AT RISK DETAIL

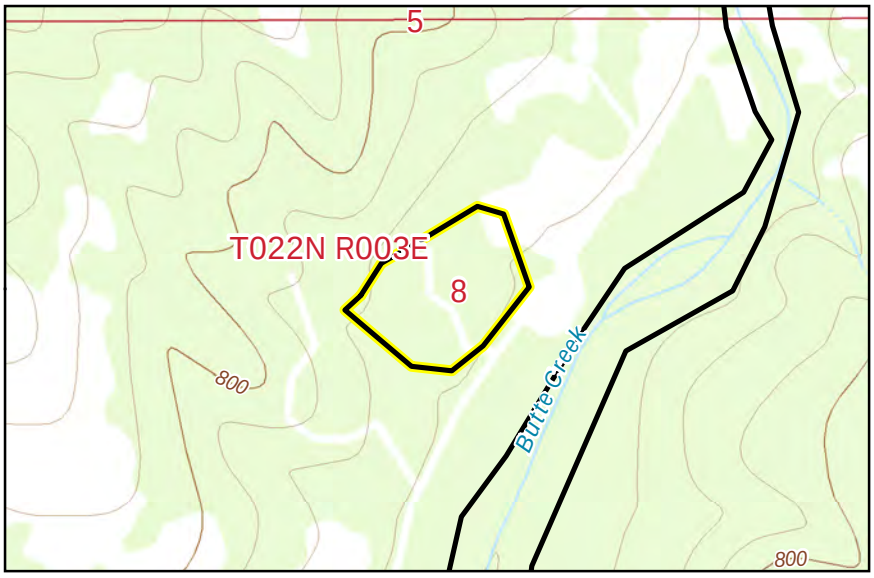
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 39
Feature: Residences
Feature Category: debris flow/flood
Field Observation: Multiple residences located at the confluence of several stream channels. Possible debris flow deposits located in the area

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: No
Preliminary Emergency Protective Measures: Early warning system

Location





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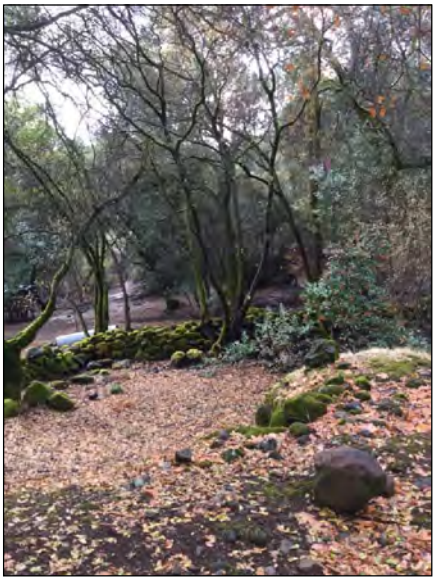


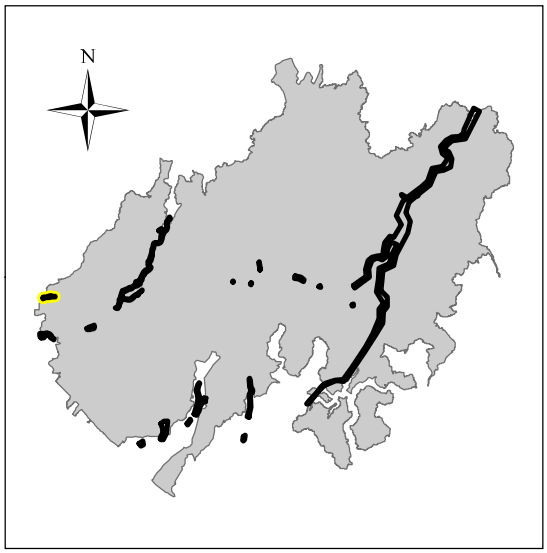
VALUE AT RISK DETAIL

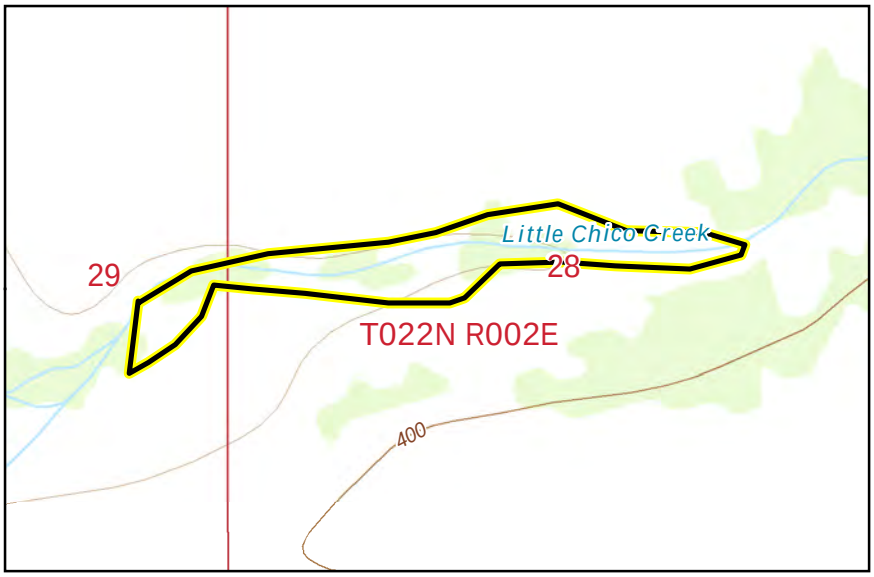
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 40
Feature: Residences
Feature Category: flood
Field Observation: Residences located within 100-year floodplain

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system
Protective Measures

Location





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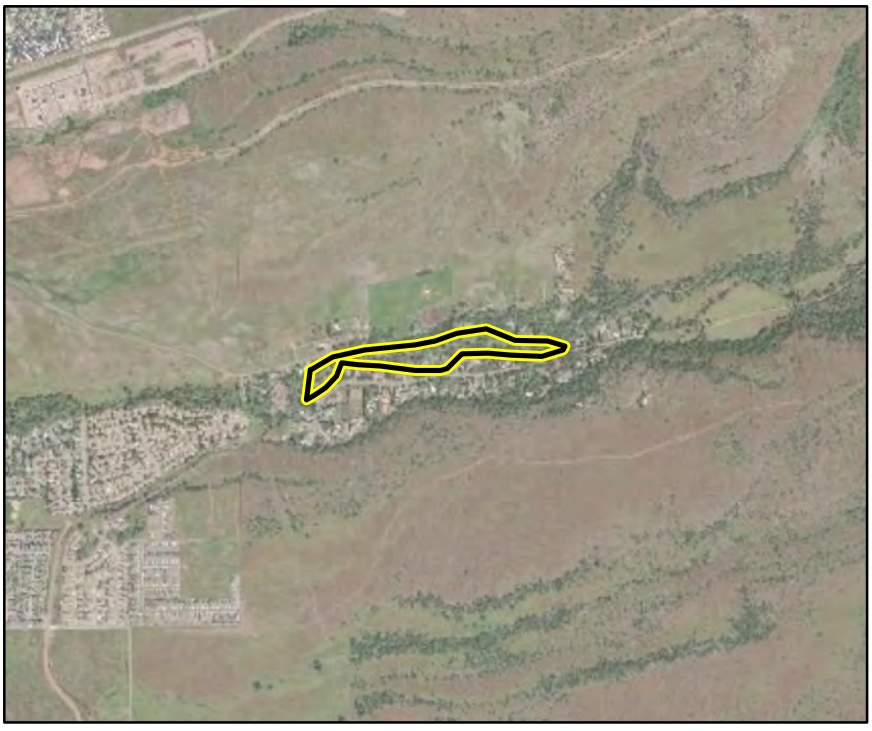


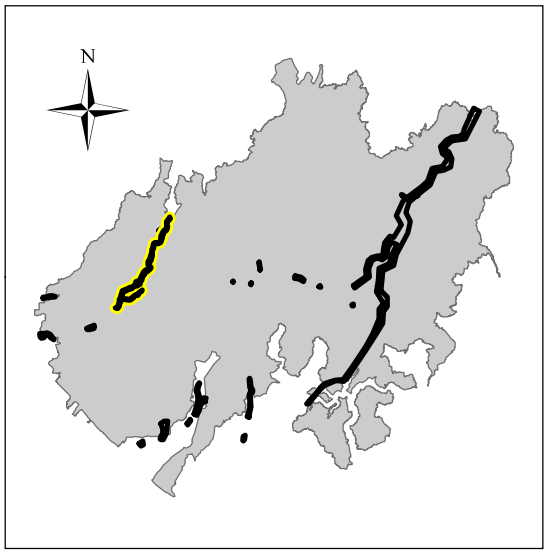
VALUE AT RISK DETAIL

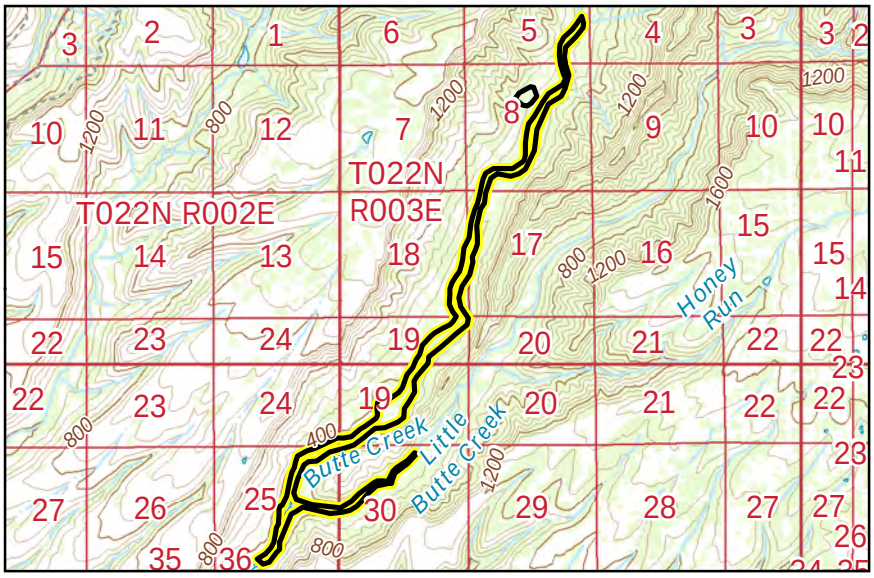
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 41
Feature: Residences
Feature Category: flood
Field Observation: Houses within mapped DWR floodplain awareness area. Butte Creek identified as USGS Watch Stream.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system and storm patrol
Protective Measures

Location





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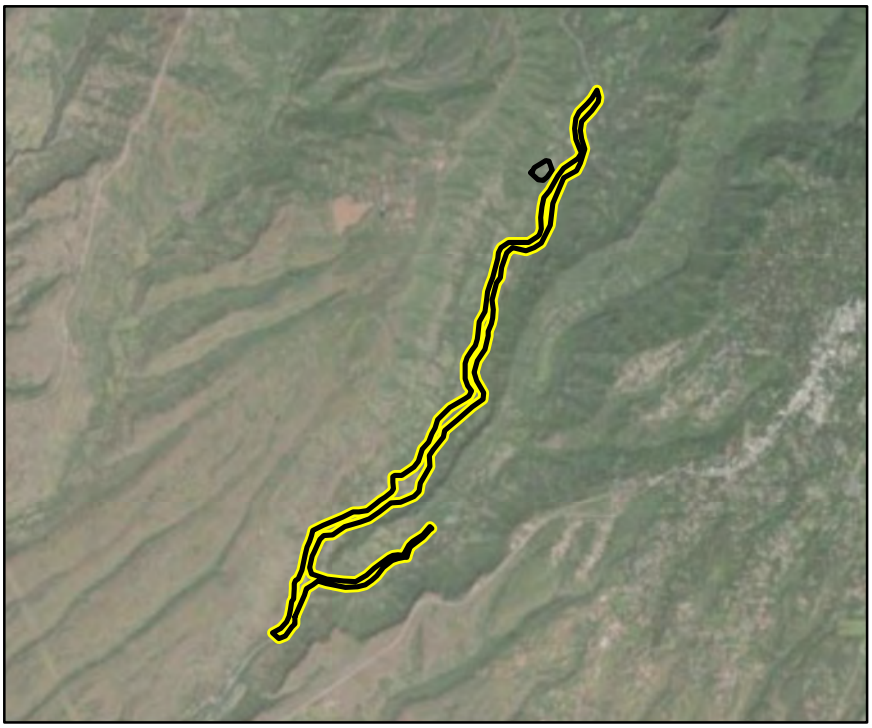


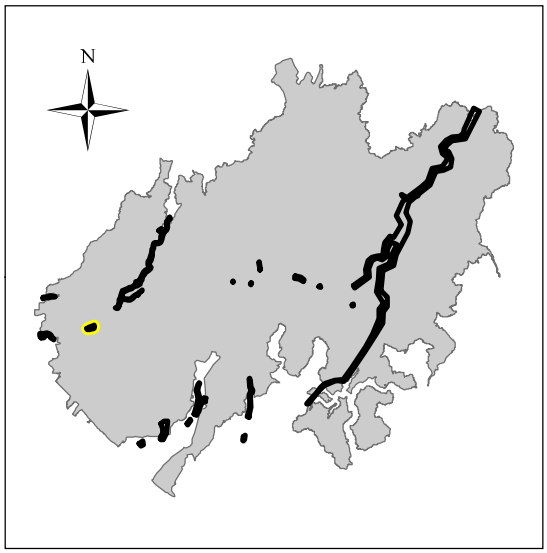
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 42
Feature: Homes
Feature Category: flood
Field Observation: Residential structures located in mapped flood hazard area.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system
Protective Measures

Location



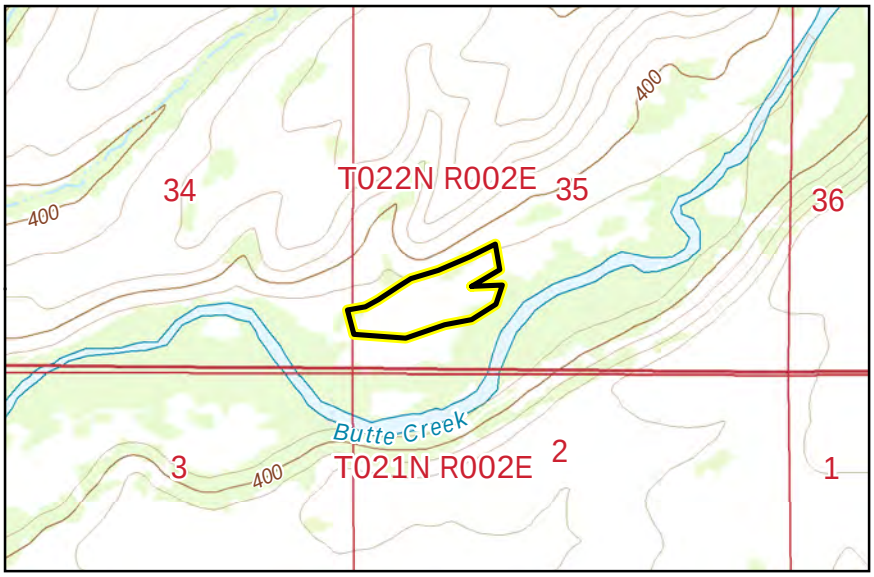


Photo ID:

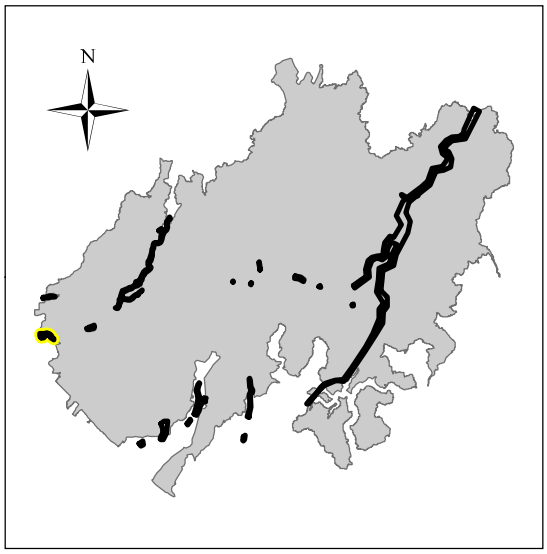
VALUE AT RISK DETAIL

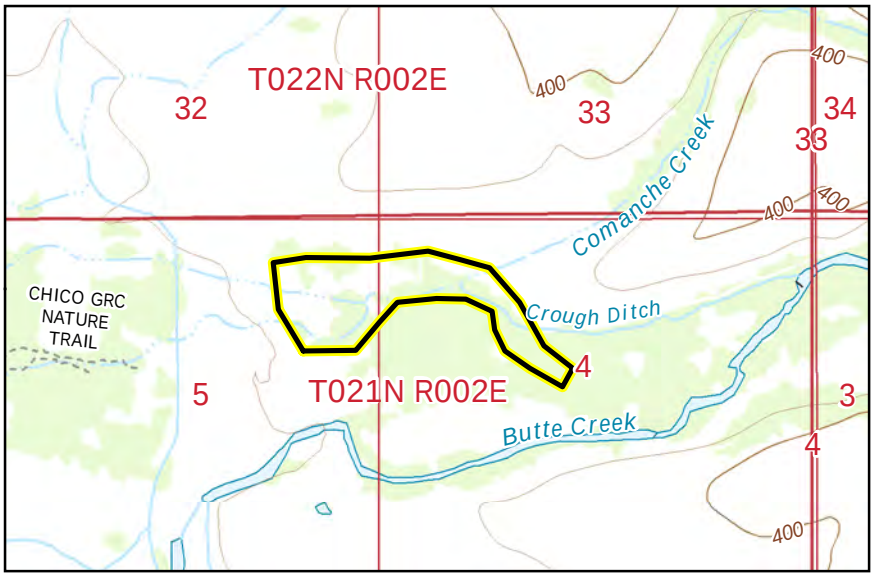
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 43
Feature: Homes and structures
Feature Category: flood
Field Observation: Residential structures located in mapped flood hazard area.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: Yes
Preliminary Emergency: Early warning system
Protective Measures

Location





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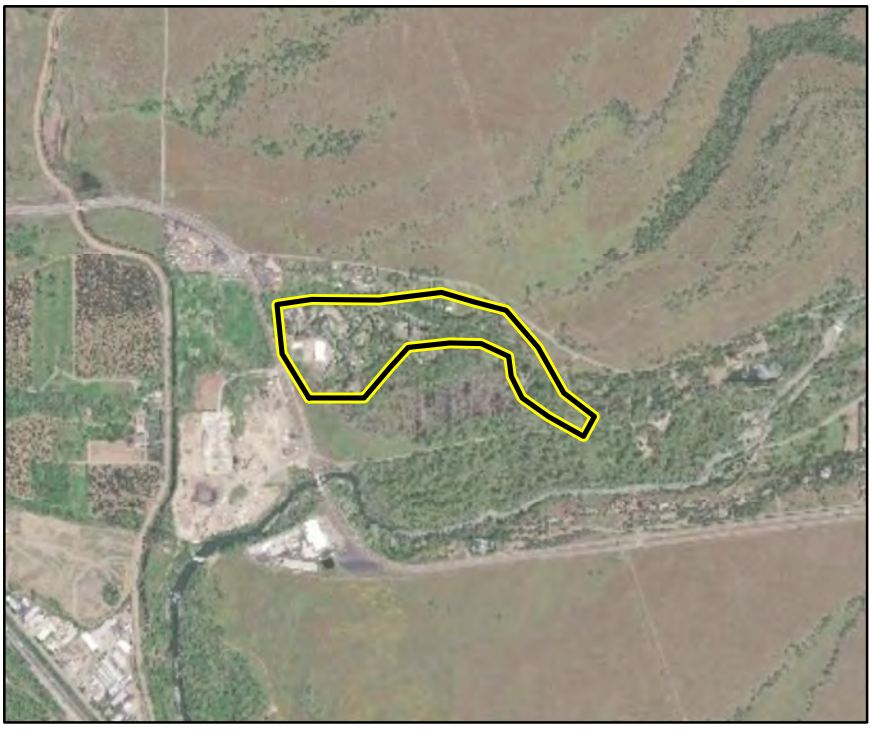


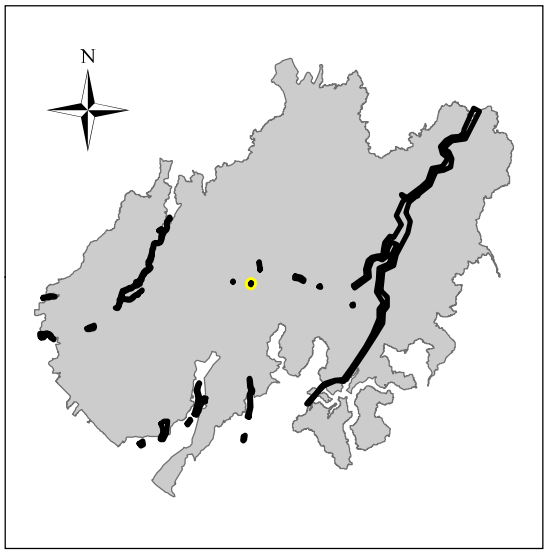
VALUE AT RISK DETAIL

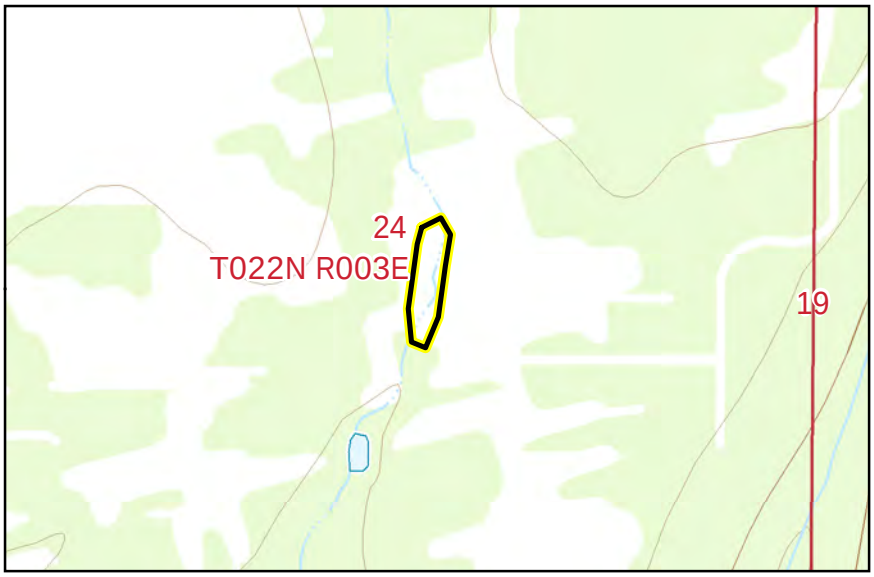
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Paradise**
Site Number: 055
Feature: Several homesites along creek
Feature Category: flood
Field Observation: Several homsites adjacent to watercourse along with box culvert at risk of plugging and diversion.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: No
Preliminary Emergency Protective Measures: Storm patrol and Early warning system

Location





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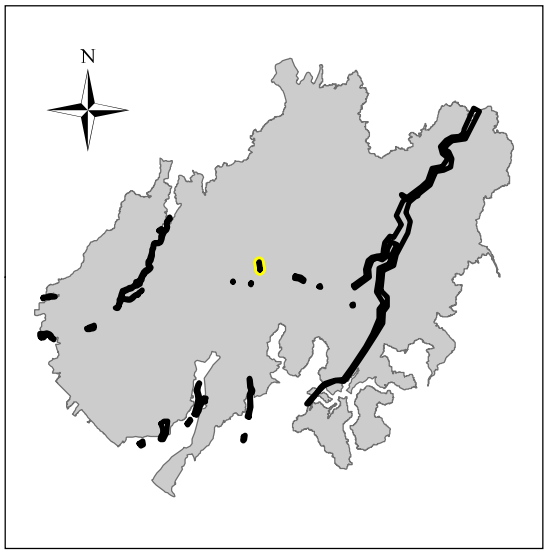
VALUE AT RISK DETAIL

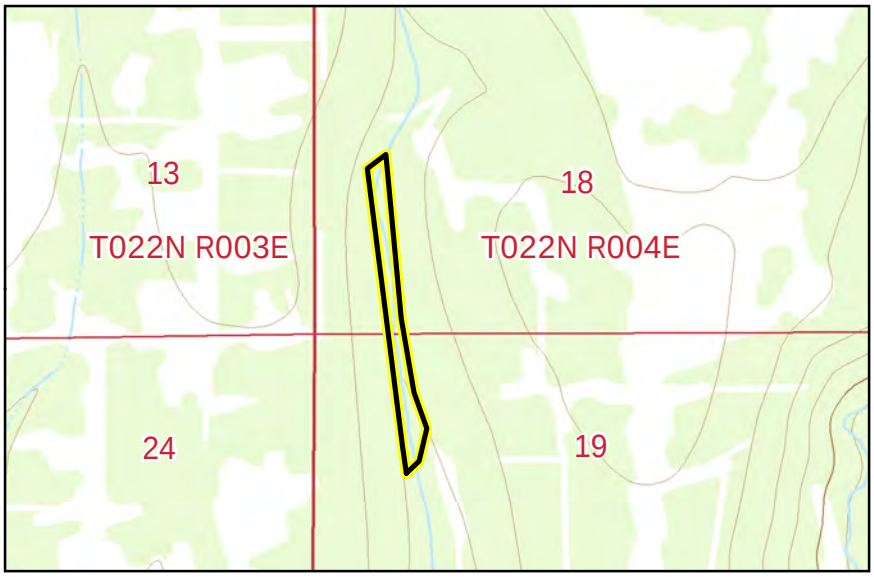
Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Paradise**
Site Number: 057
Feature: Homesite, watercrouse crossings
Feature Category: flood
Field Observation: Several homesites adjacent to creek. Several in channel structures, crossings and bank reinforcement that may reduce channel capacity.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: No
Preliminary Emergency Protective Measures: Early warning and storm patrol.

Location





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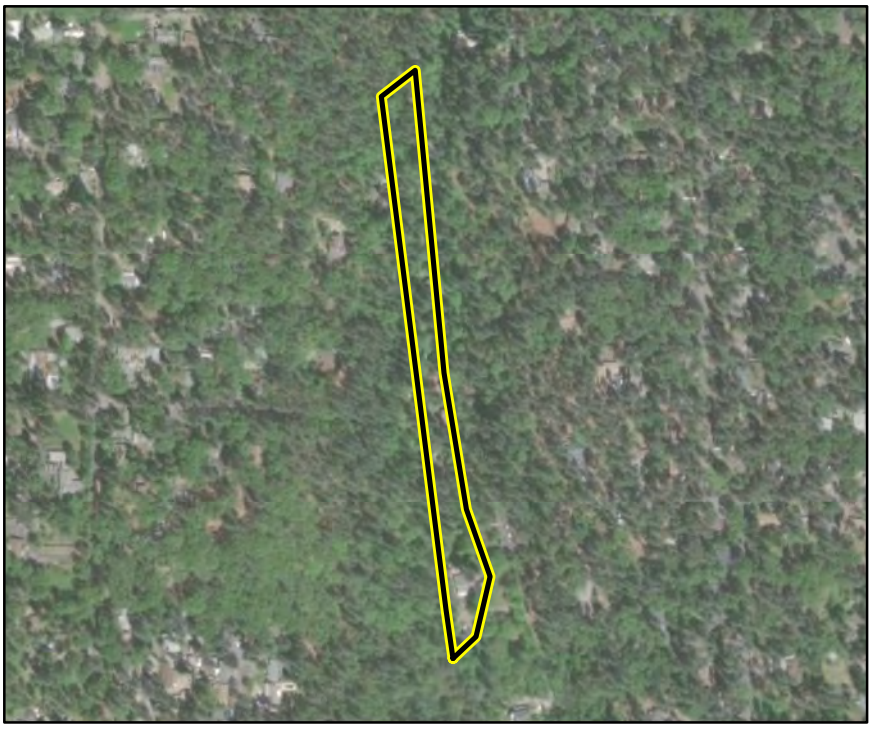


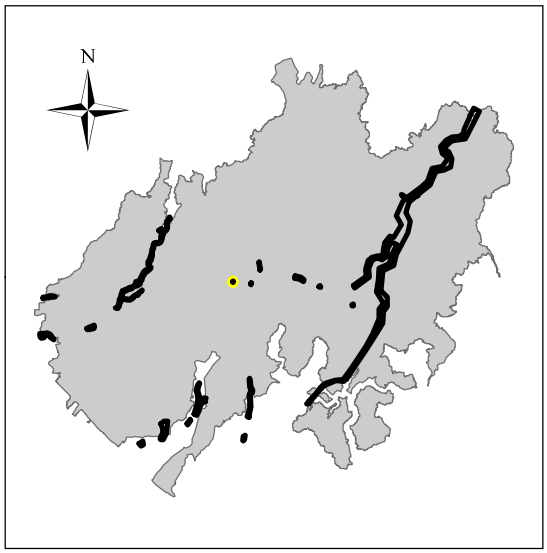
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Paradise**
Site Number: 058
Feature: Homes
Feature Category: flood
Field Observation: Homes in close proximity of Clear Creek and tributaries. Watercourse observed running through homesite, unsure if it is by design.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: No
Preliminary Emergency Protective Measures: Early warning system.

Location



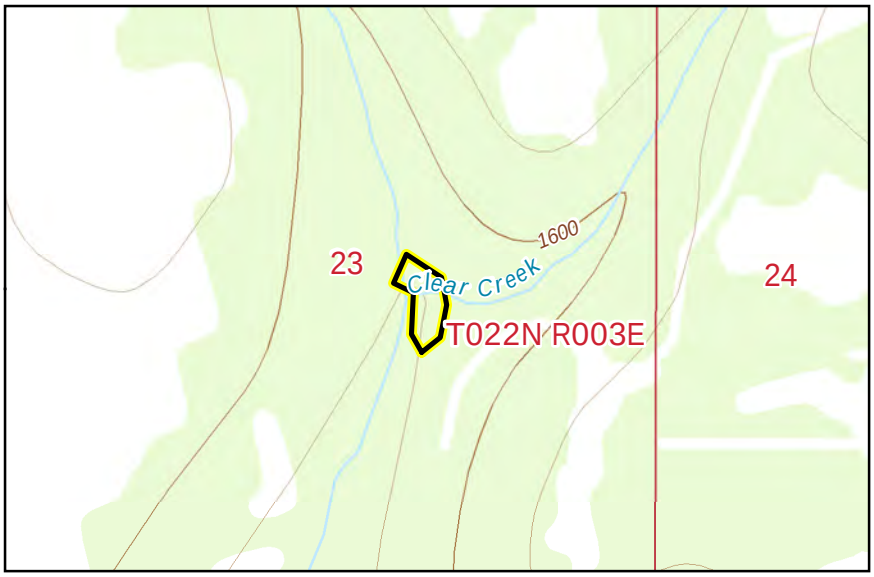


Photo ID:

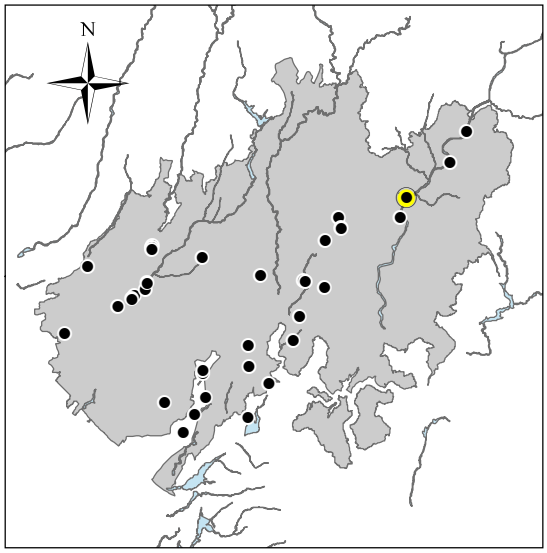
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Highway 70**
Site Number: 04
Feature: Railroad bridge crossing
Feature Category: debris flow / flood
Field Observation: Railroad trestle bridge crossing on Flea Creek at risk of debris flow. Observed apparent utility line across upstream side of bridge.

Potential Hazard to Life: low
Potential Hazard to Property: high
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Storm patrol
Protective Measures

Location



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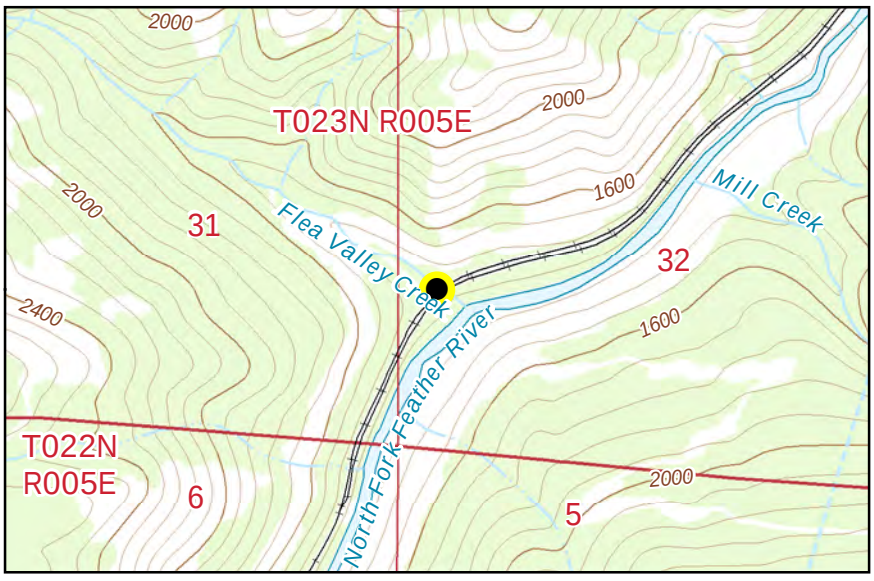


Value at Risk - Point

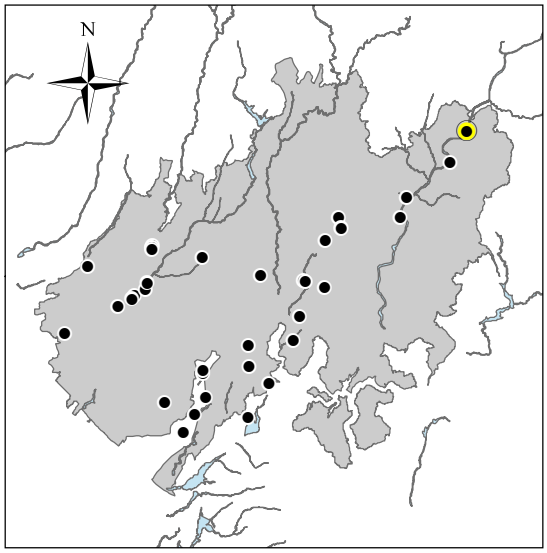
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Highway 70**
Site Number: 05
Feature: Gazebo and toilets
Feature Category: flood
Field Observation: Shady Rest Picnic area and public toilet located in mapped flood plain.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency Protective Measures: Early warning system. Close facility during heavy storms.

Location



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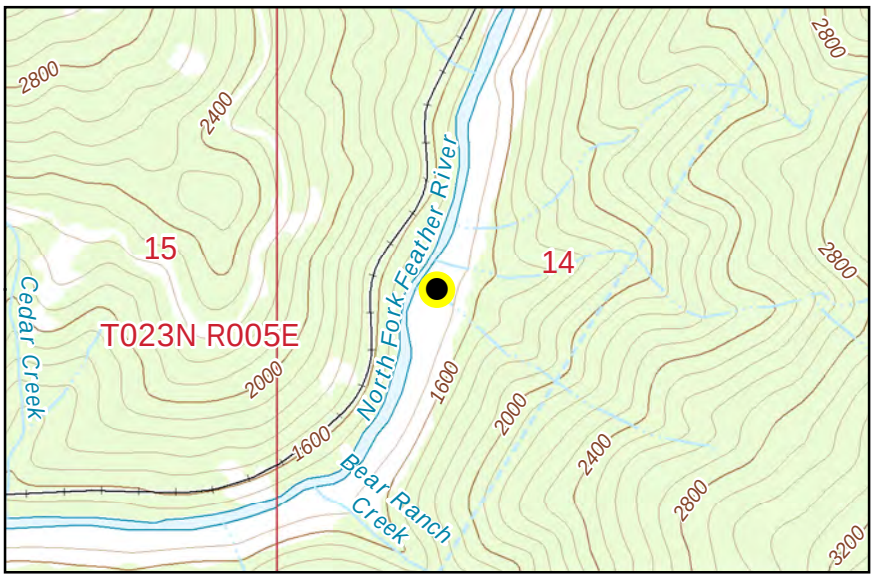


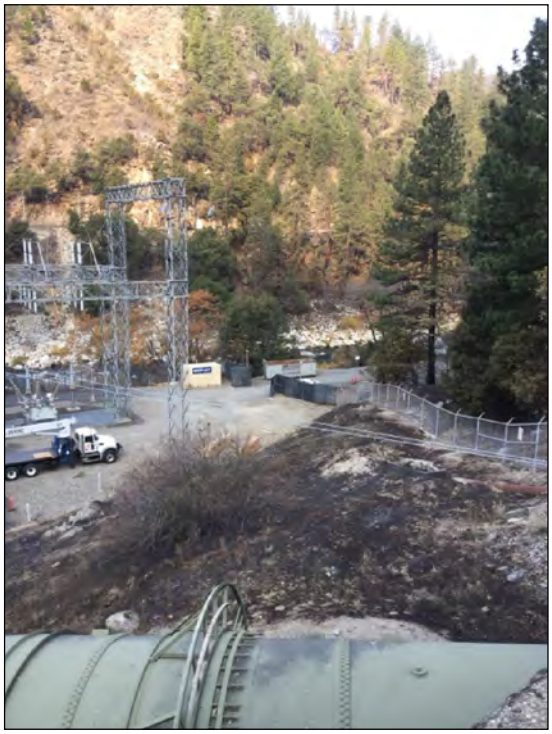
Value at Risk - Point

VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Highway 70**
Site Number: 06
Feature: Cresta Powerhouse and penstocks
Feature Category: debris flow / flood
Field Observation: Cresta Powerhouse located within mapped Flood Hazard Area. Potential for debris flow impacts to powerhouse and penstocks.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency Protective Measures: Early warning system. Notify PG&E.



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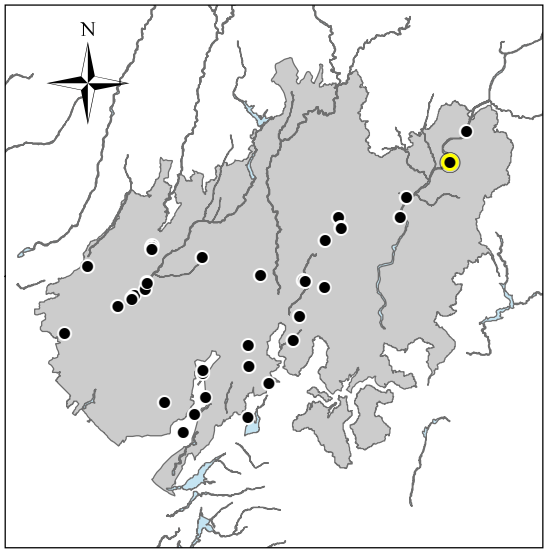
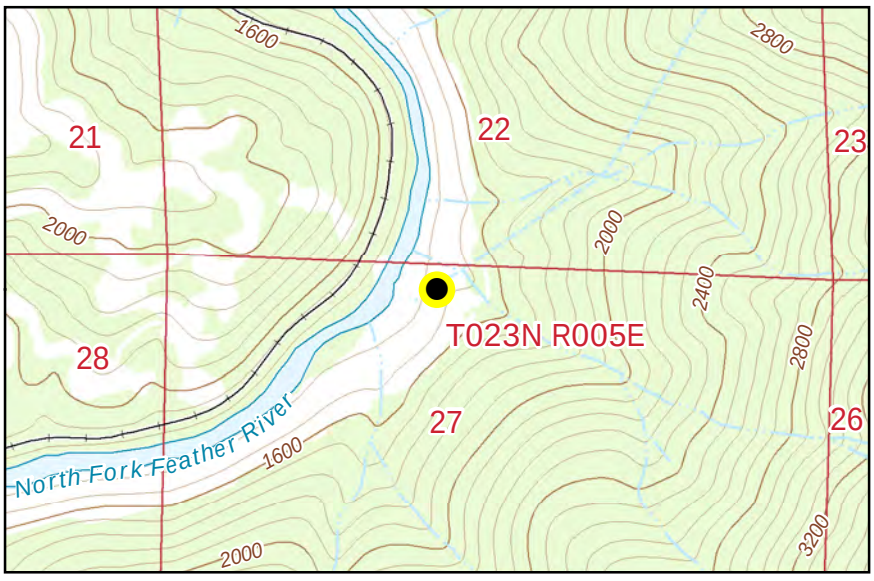




Value at Risk - Point

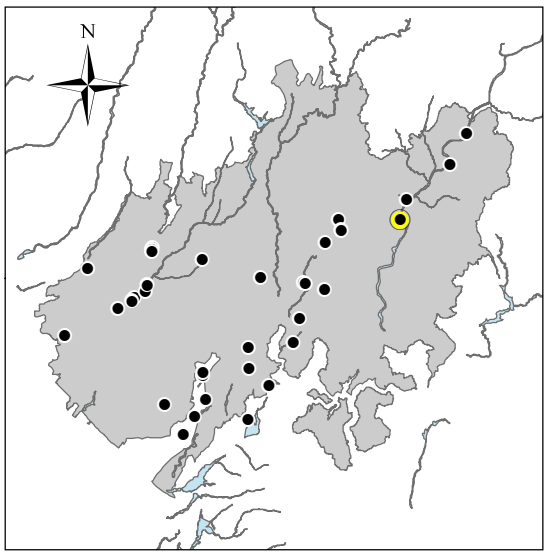
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Highway 70**
Site Number: 07
Feature: Homesite
Feature Category: debris flow / flood
Field Observation: Historical foundation / homesite located at mouth of steep concave hill slope. Culvert crossing located upslope of pad. Observed building foundation adjacent to culvert. Site appears unoccupied

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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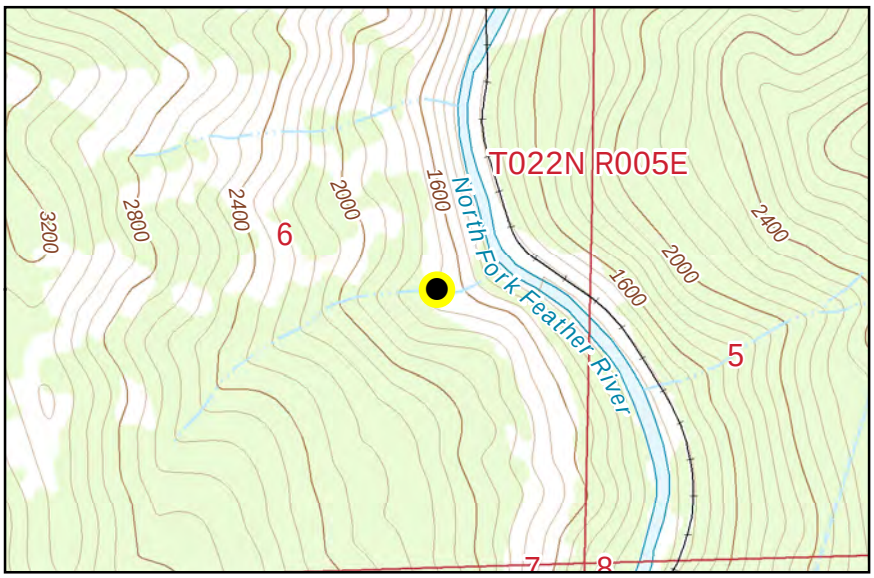


Value at Risk - Point

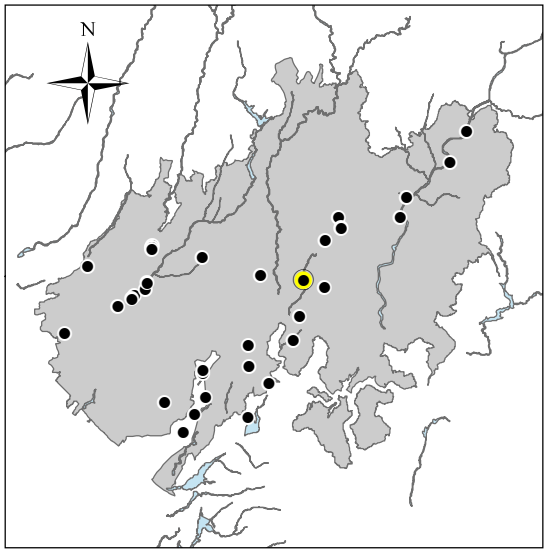
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 11
Feature: Bridge
Feature Category: debris flow / flood
Field Observation: Existing bridge downstream of Concow Reservoir. Concrete supports within thalweg of channel could block debris and accumulate upstream of crossing.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Storm patrol
Protective Measures

Location



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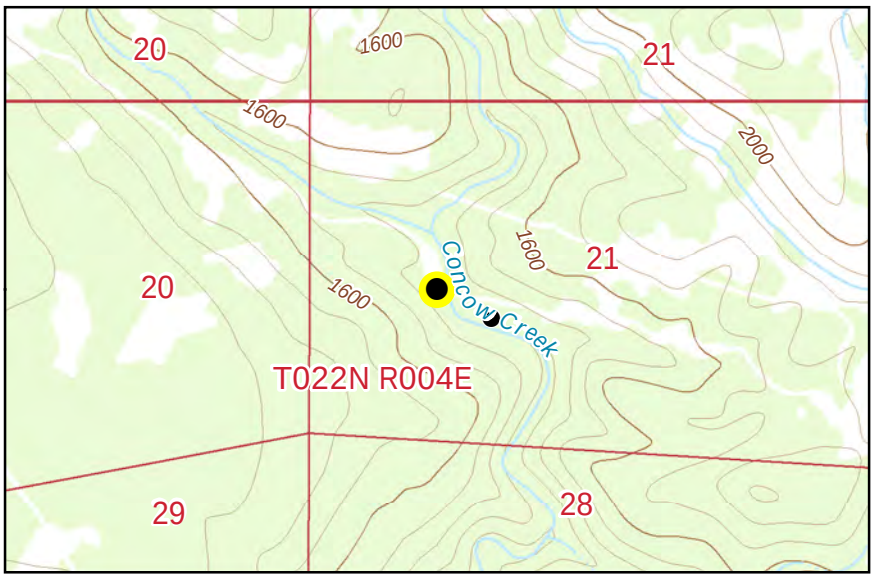


Value at Risk - Point

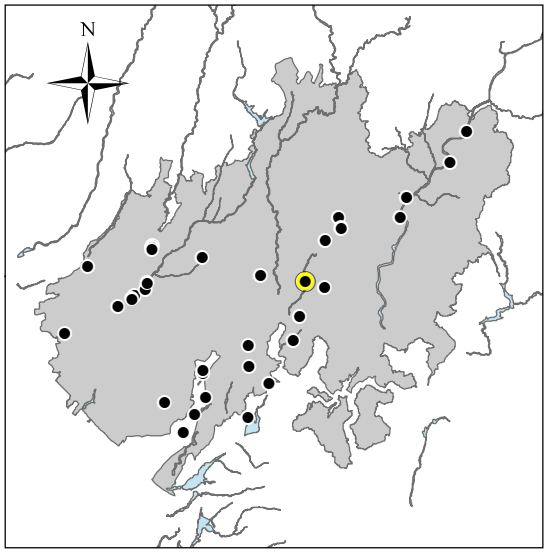
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 12
Feature: House foundation
Feature Category: flood
Field Observation: Burned house located adjacent to stream in mapped flood hazard area. Stream is identified as USGS watch stream.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system
Protective Measures

Location



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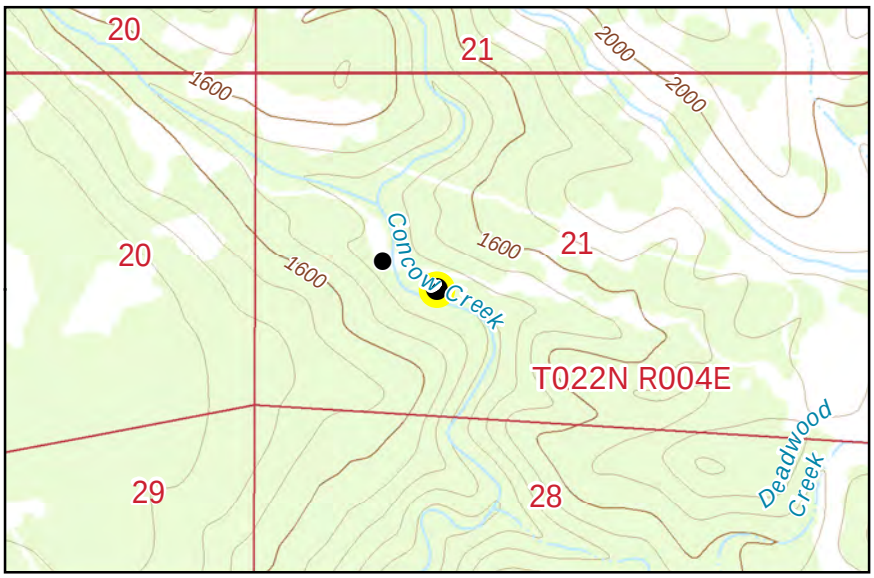


Value at Risk - Point

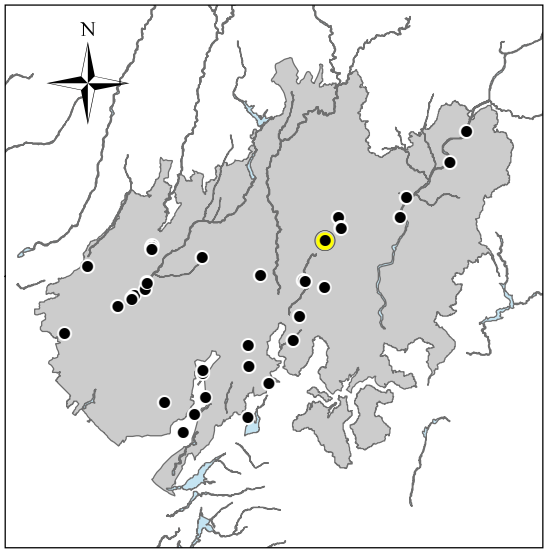
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 13
Feature: Reservoir
Feature Category: debris flow / flood
Field Observation: Increased sediment from wildfire may impact reservoir

Potential Hazard to Life: no
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Notify local water district
Protective Measures

Location



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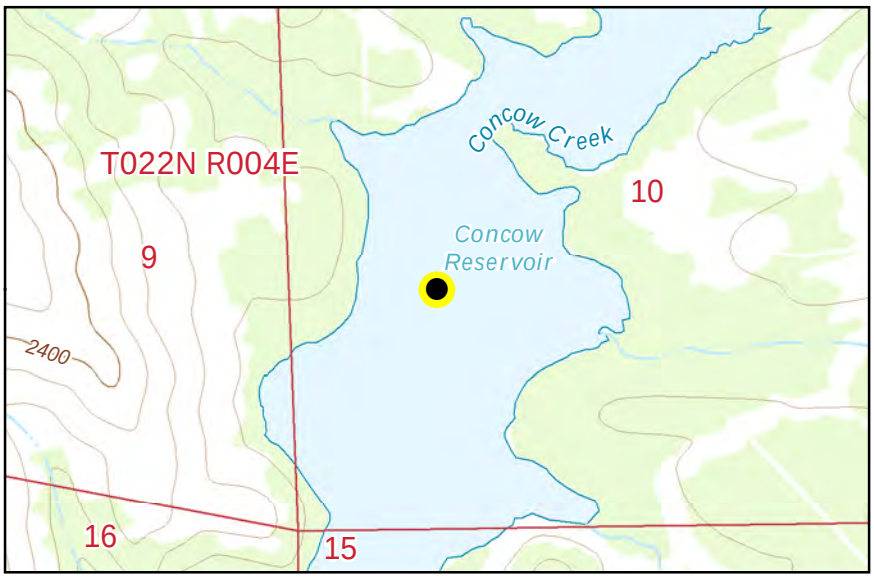


Value at Risk - Point

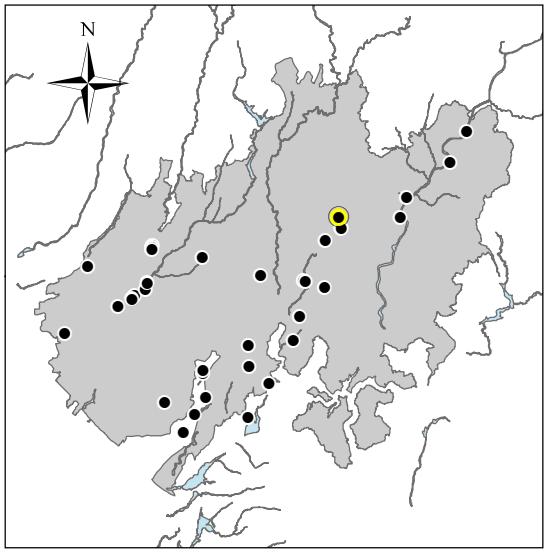
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 14
Feature: Box culvert bridge
Feature Category: debris flow / flood
Field Observation: Existing box culvert bridge at risk of plugging. The crossing shows evidence of past failure.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Storm patrol
Protective Measures

Location



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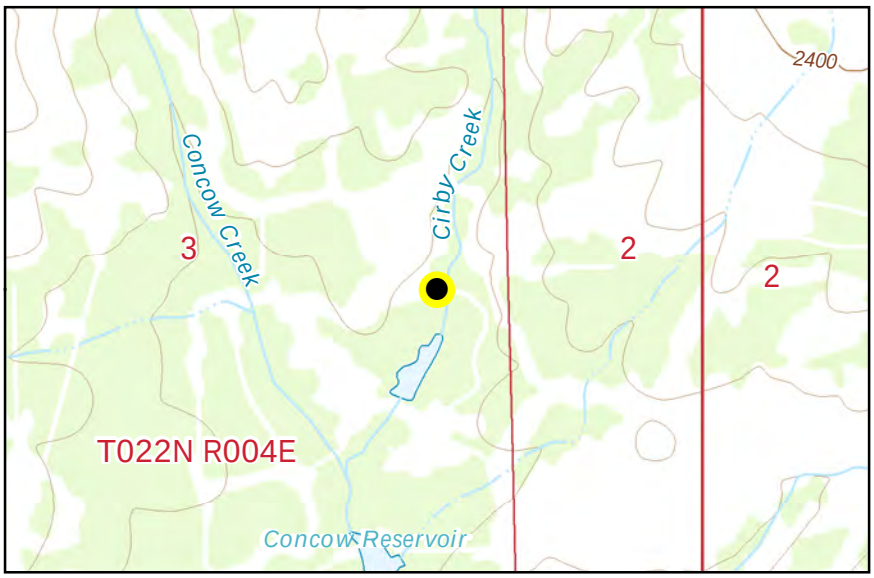


Value at Risk - Point

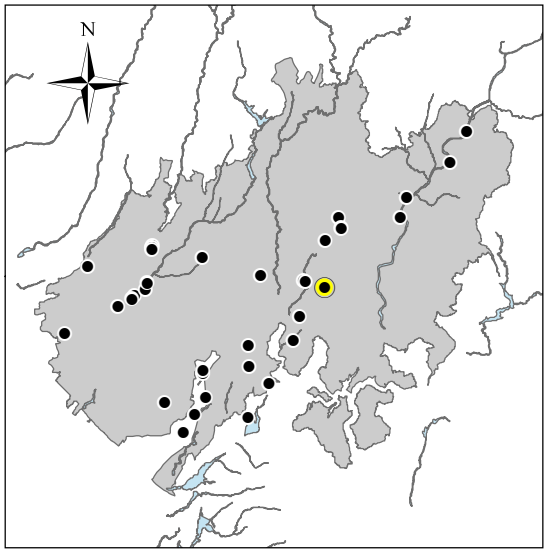
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 15
Feature: Bridge
Feature Category: debris flow / flood
Field Observation: Wood bridge on deadwood creek. The channel is identified as a moderate debris flow risk.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Storm patrol
Protective Measures

Location



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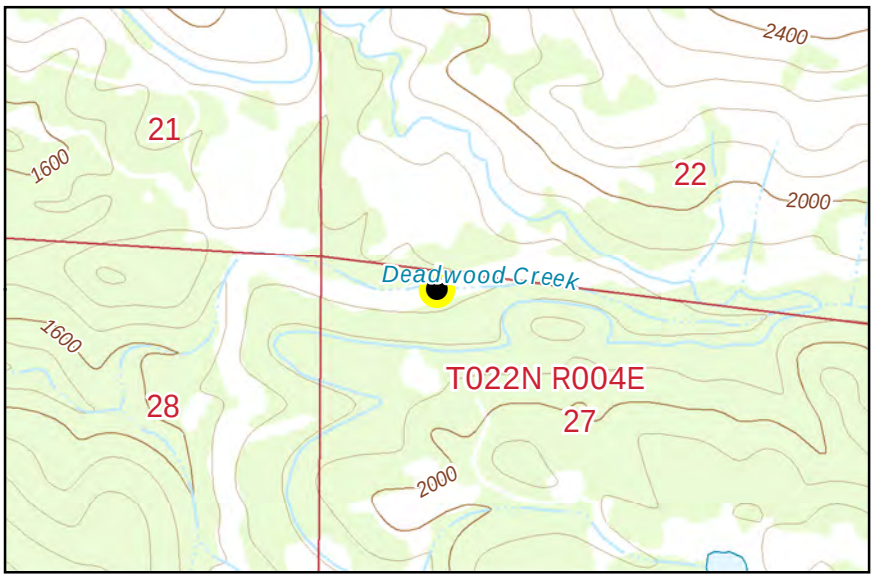


Value at Risk - Point

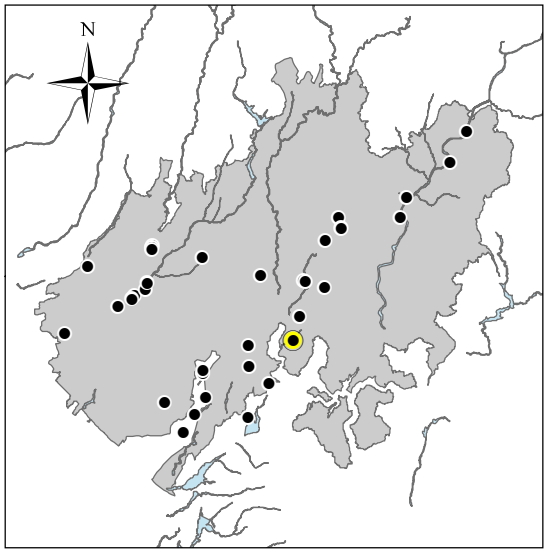
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 16
Feature: Barn
Feature Category: flood
Field Observation: Barn located adjacent to DWR floodplain awareness zone. Evidence of overland surface flow within the area.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system
Protective Measures

Location



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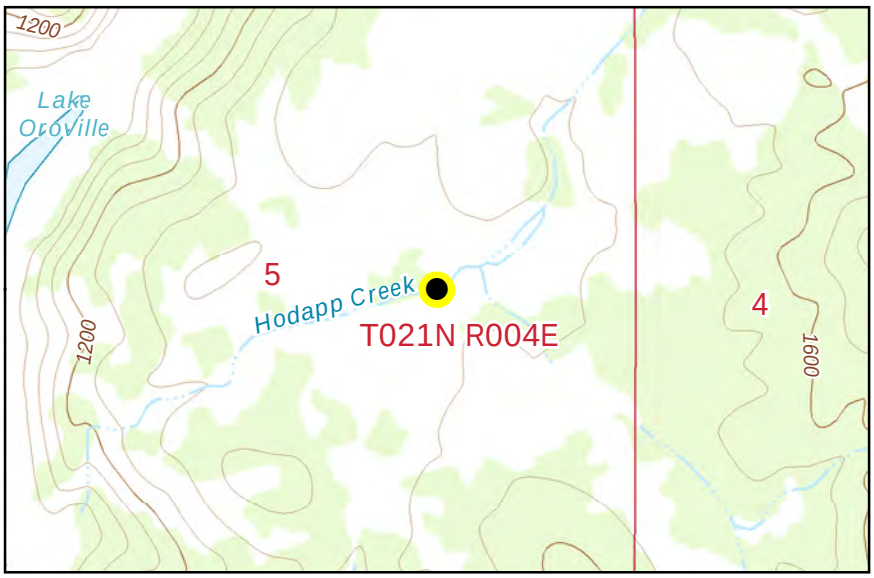


Value at Risk - Point

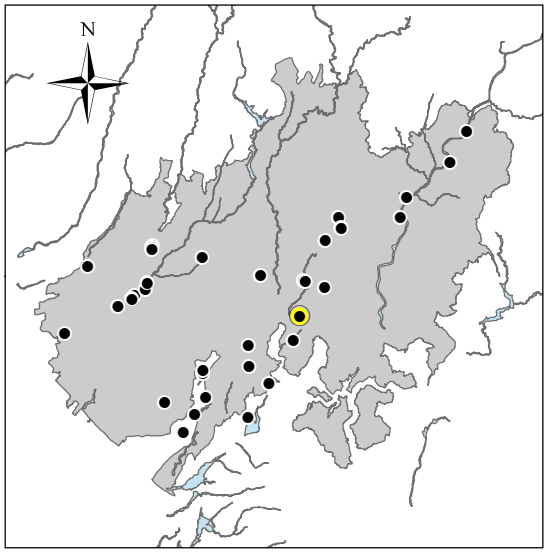
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 17
Feature: Shed and gas tank
Feature Category: flood
Field Observation: Garage shed and butane tank located within channel zones. Channel appears highly modified.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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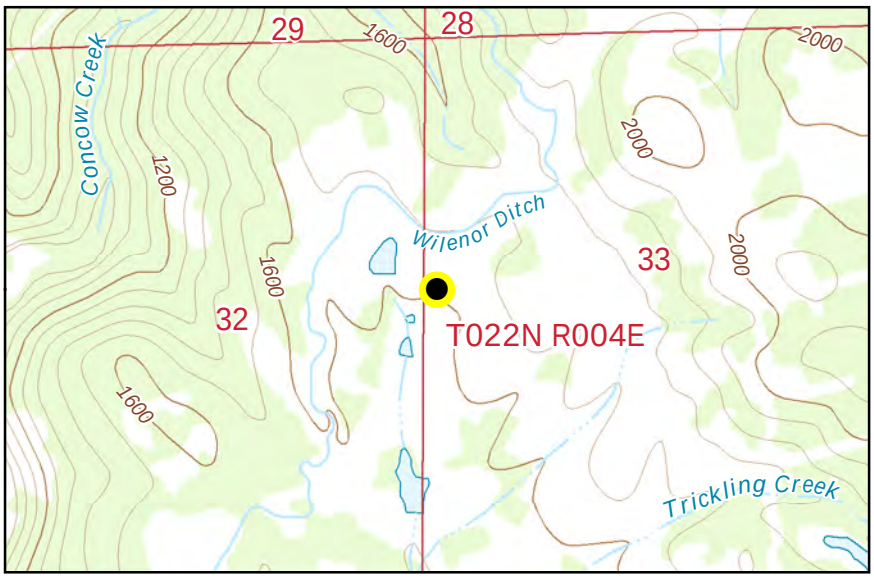


Value at Risk - Point

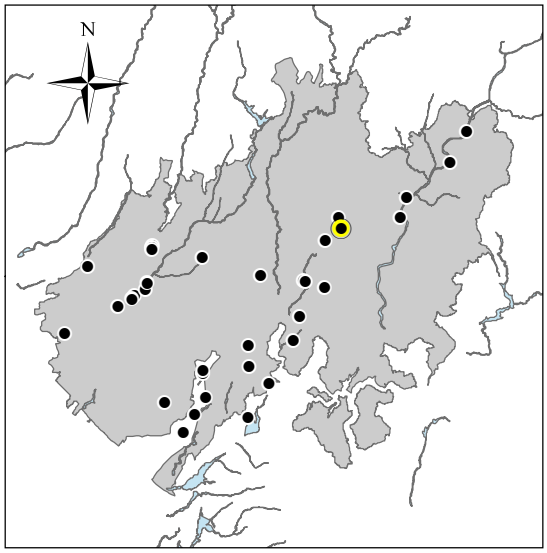
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 18
Feature: Bridge
Feature Category: flood
Field Observation: Crossing overtopping, undersized bridge. Bridge previously identified as VAR in 2008 SEAT Report.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Storm patrol
Protective Measures

Location



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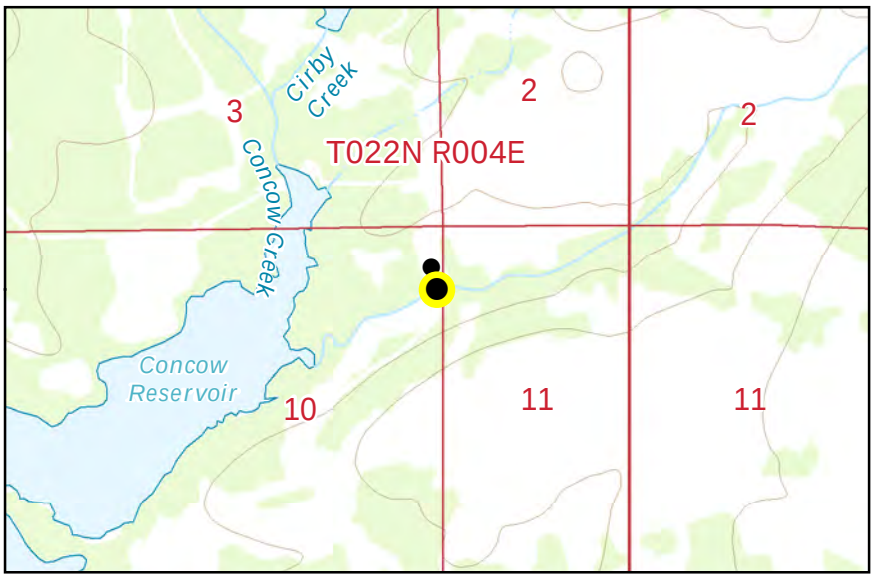


Value at Risk - Point

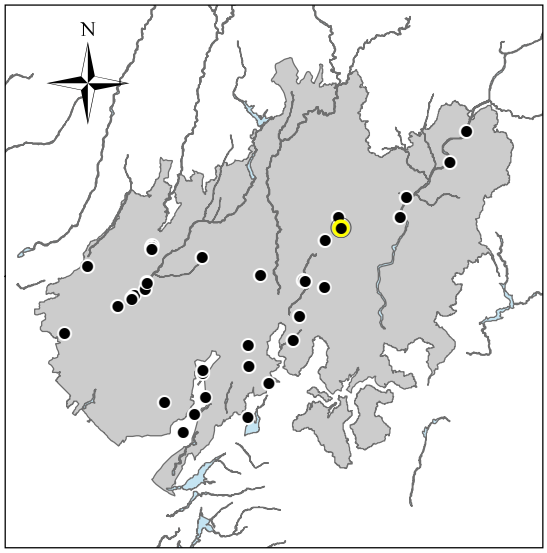
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Concow**
Site Number: 19
Feature: Residence
Feature Category: flood
Field Observation: House appears to be located within flood plain of tributary to Concow Reservoir.

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system, storm patrol
Protective Measures

Location



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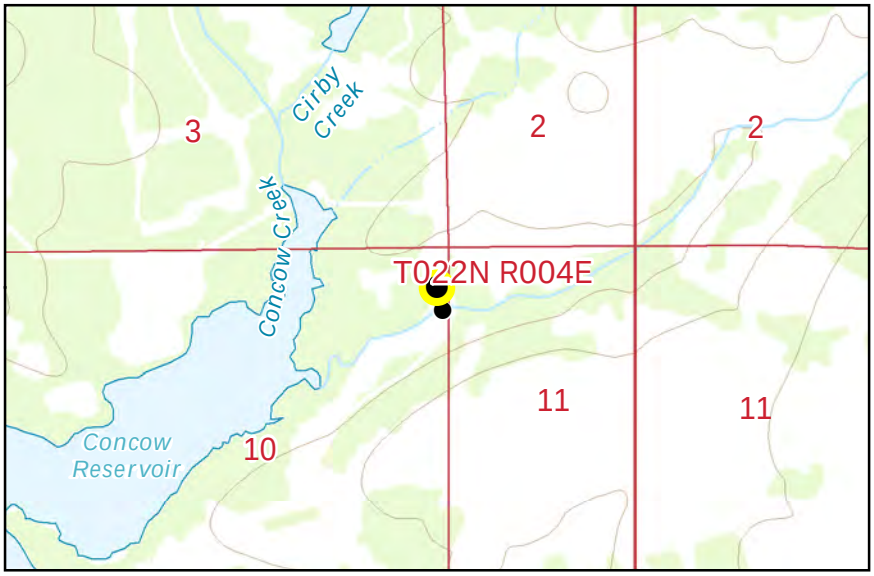


Value at Risk - Point

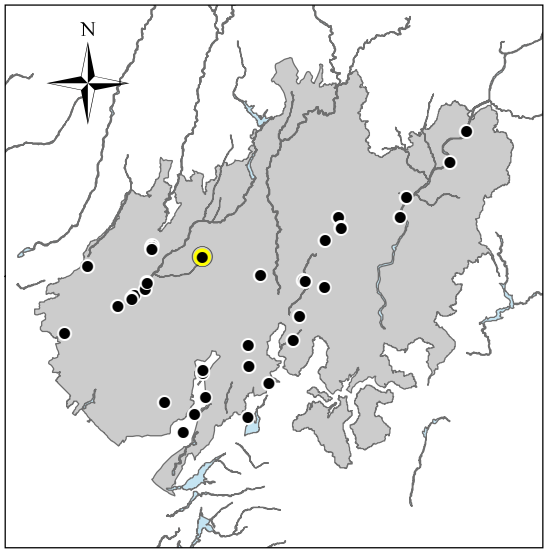
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Paradise**
Site Number: 20
Feature: Residence, burned down
Feature Category: flood
Field Observation: Culvert could plug and divert towards downstream residence

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Storm patrol
Protective Measures

Location



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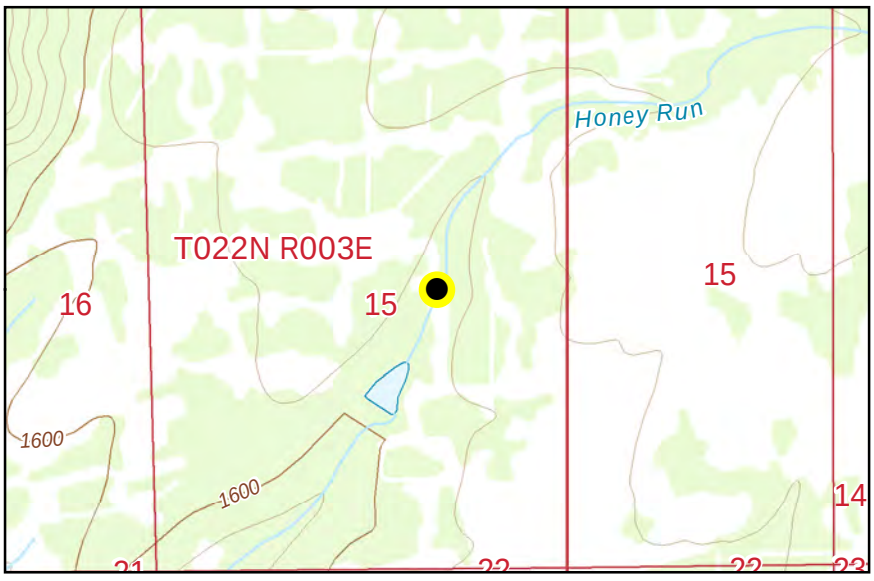


Value at Risk - Point

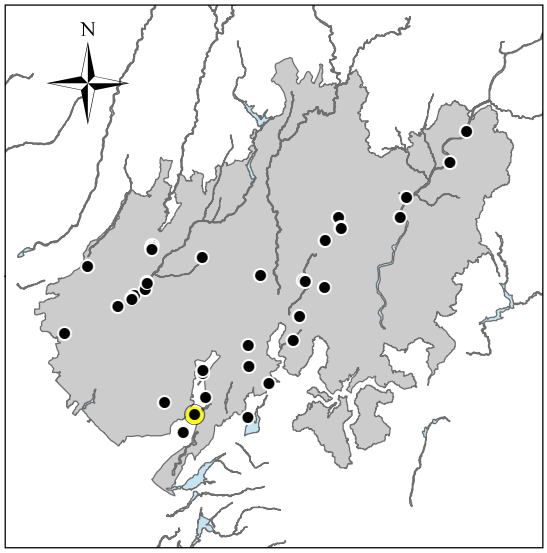
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 29
Feature: Clark Road Substation
Feature Category: flood
Field Observation: Electrical substation located within flood plain

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system
Protective Measures

Location



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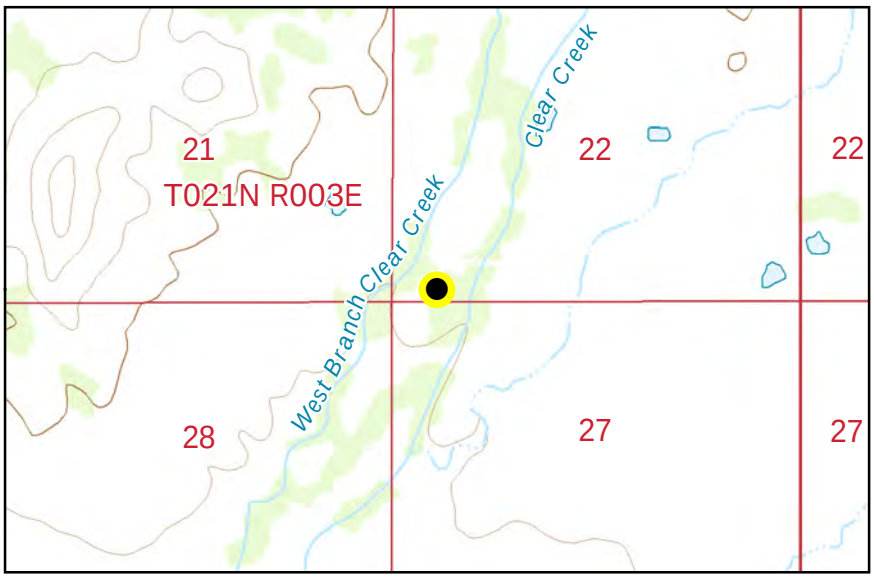


Value at Risk - Point

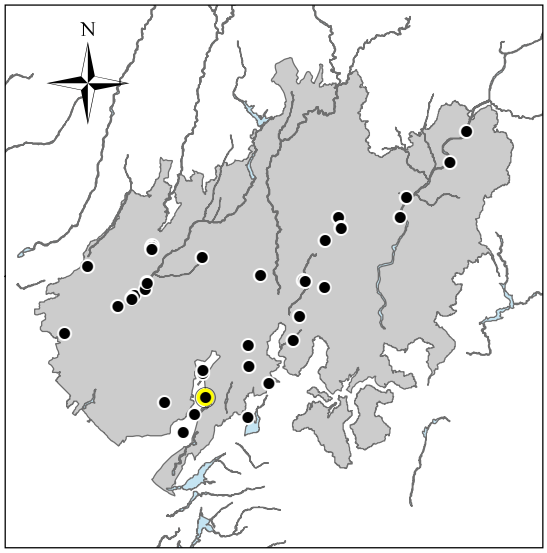
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 30
Feature: House
Feature Category: flood
Field Observation: House mapped within flood zone

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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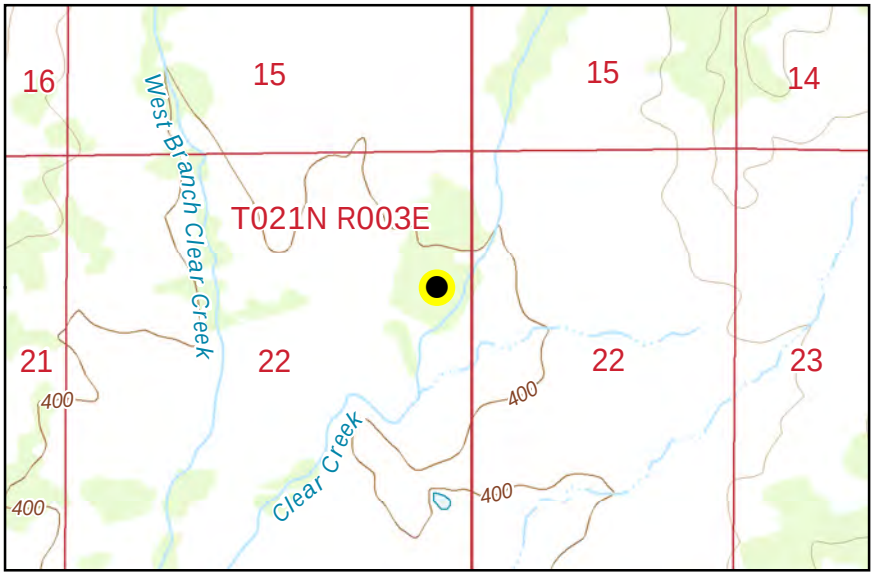


Value at Risk - Point

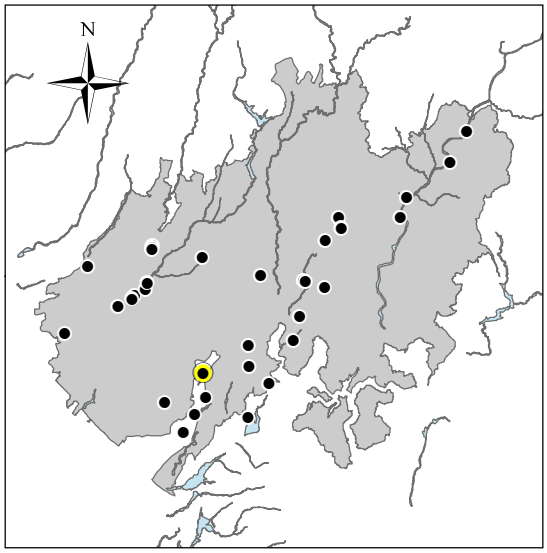
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 31
Feature: House
Feature Category: debris flow / flood
Field Observation: House mapped within flood zone. Channel is scoured below house.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system
Protective Measures

Location



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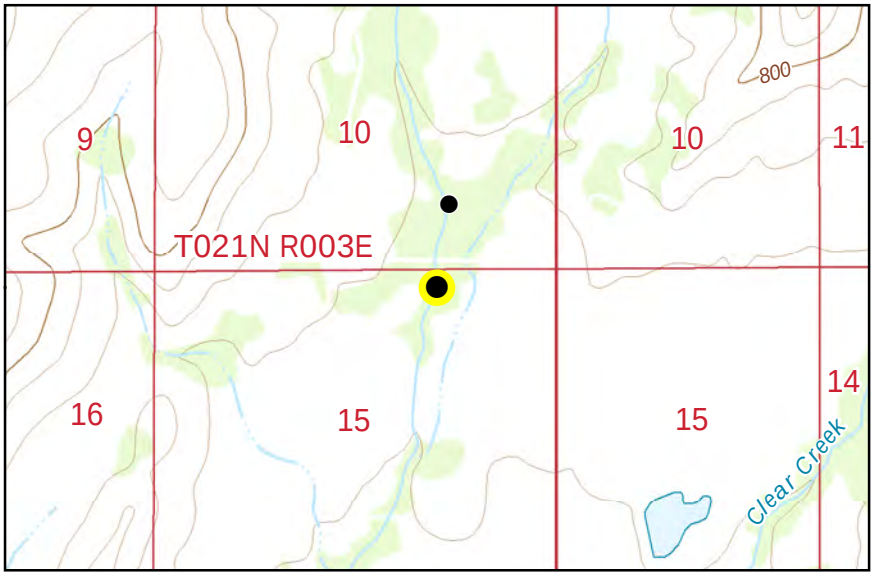


Value at Risk - Point

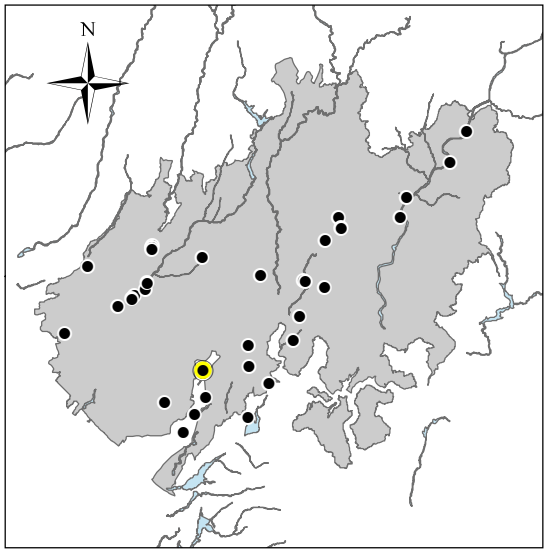
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 32
Feature: House
Feature Category: flood
Field Observation: Two garages located adjacent to channel. Structures could be at risk of flooding.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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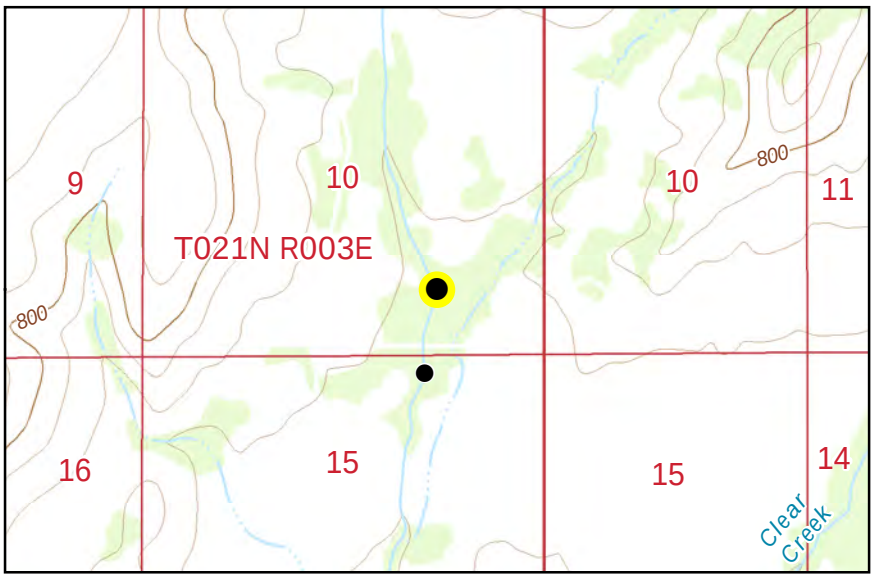


Value at Risk - Point

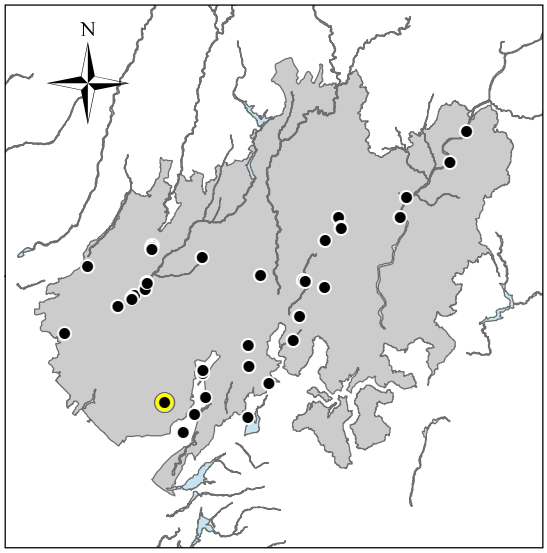
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 33
Feature: House
Feature Category: flood
Field Observation: House mapped within flood zone

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system
Protective Measures

Location



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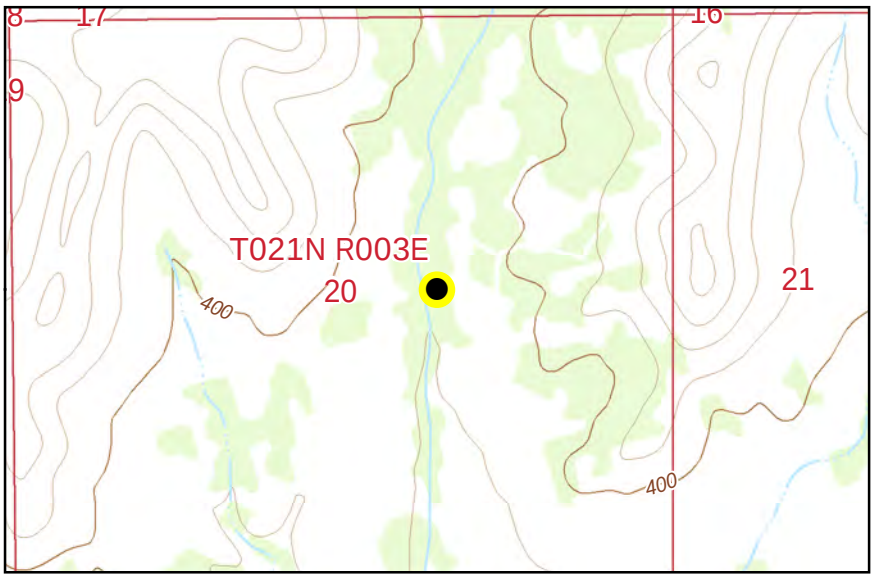


Value at Risk - Point

VALUE AT RISK DETAIL

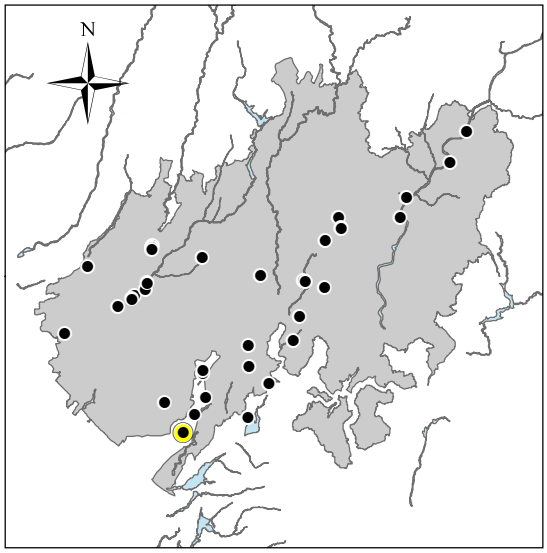
Incident Name: Camp ***Incident Number: CA-BTU-016737***

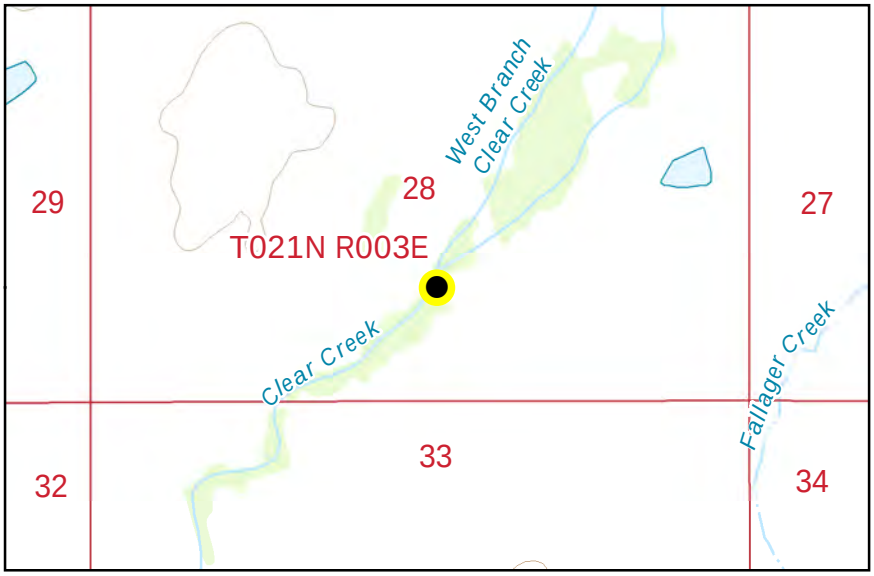
Community: **Butte Valley**
Site Number: 34
Feature: West Clear Creek Bridge
Feature Category: debris flow / flood
Field Observation: Sediment and debris could back up against bridge supports. Gas line observed across upslope side of bridge.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Storm patrol
Protective Measures

Photo ID:

Location





Value at Risk - Point

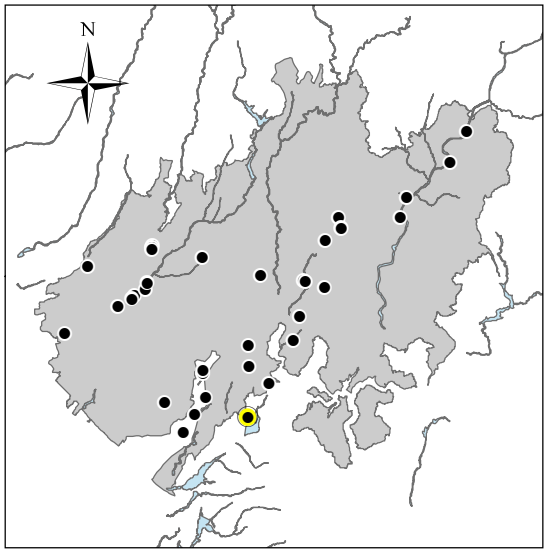
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 35
Feature: Dry Creek Bridge
Feature Category: debris flow / flood
Field Observation: Sediment and debris could back up against bridge supports.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Storm patrol
Protective Measures

Location



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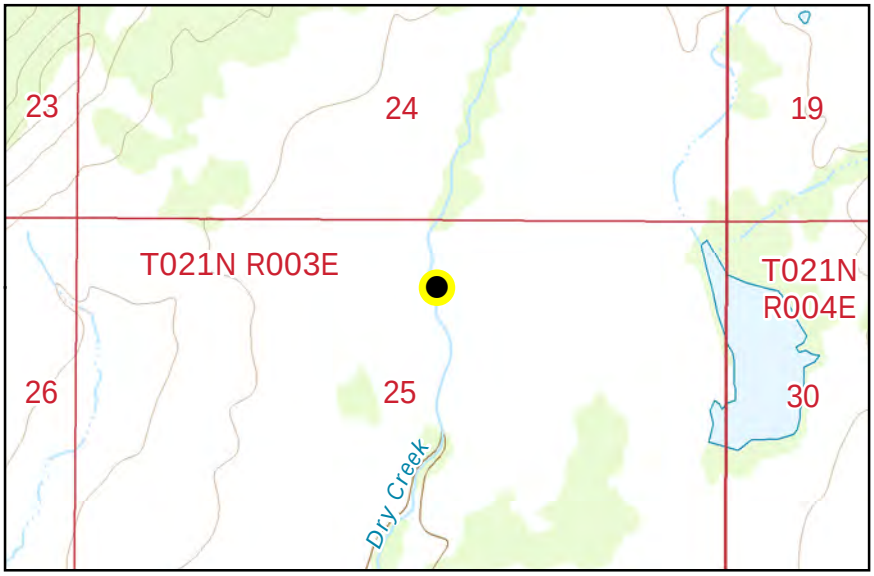


Value at Risk - Point

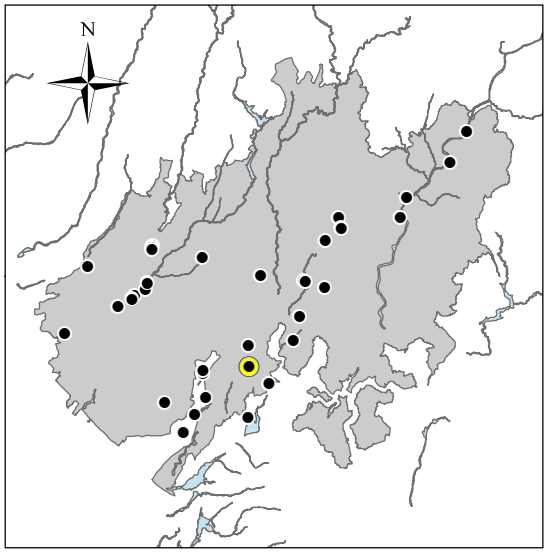
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 36
Feature: House foundation
Feature Category: flood
Field Observation: Burned houses located within flood zone, including burned bridge crossing

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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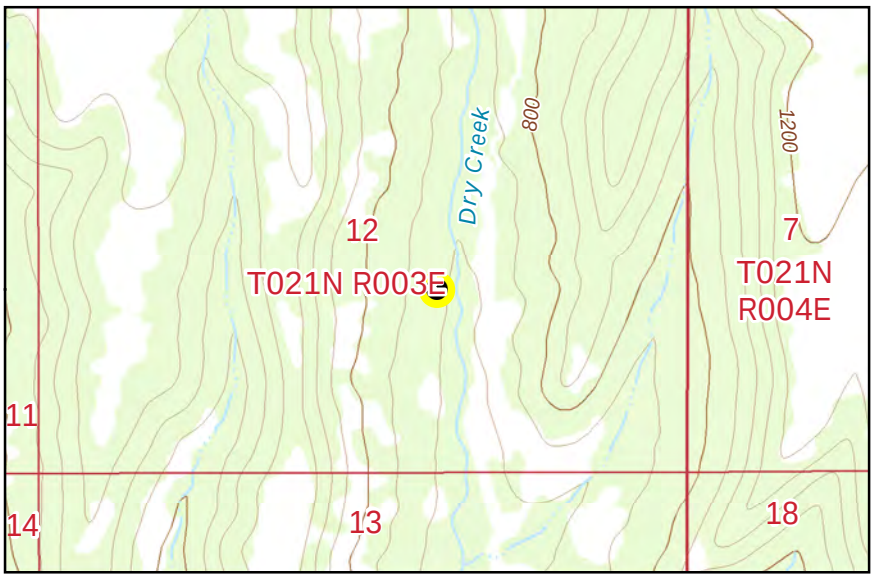


Value at Risk - Point

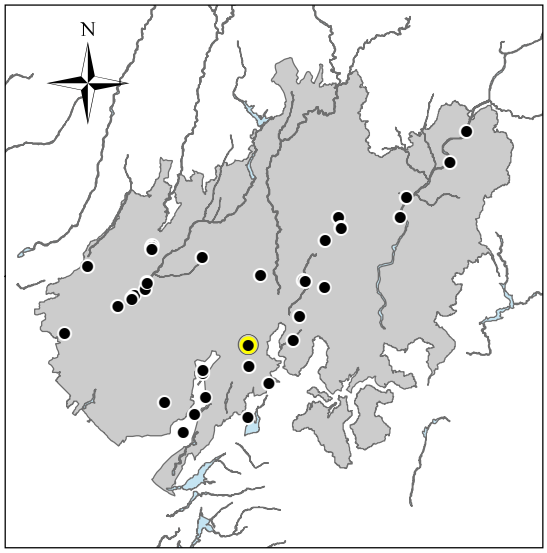
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 37
Feature: Historic dam
Feature Category: flood
Field Observation: Historic water impoundment located near top of Dry Creek. Breach in dam may exacerbate flooding downstream. Impoundment is located on a low potential debris flow segment.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency Protective Measures: Early warning system

Location



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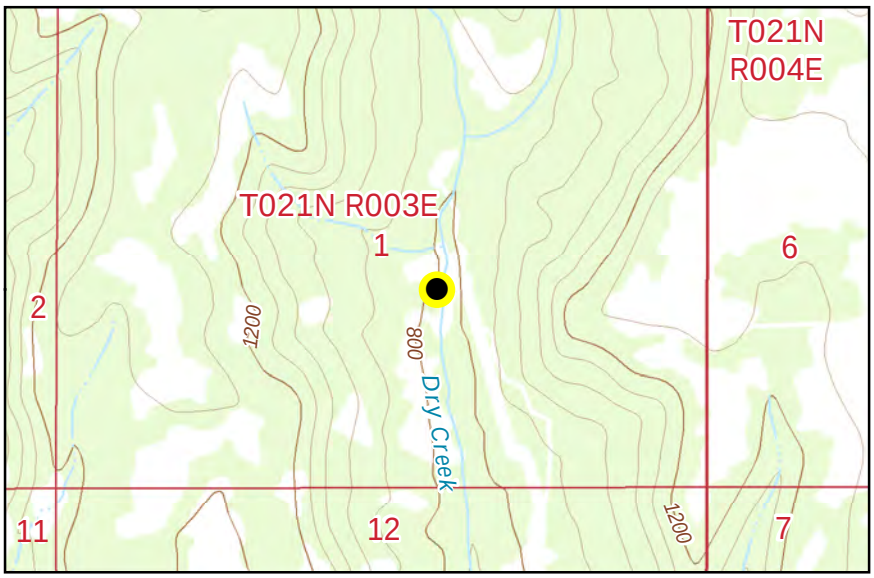


Value at Risk - Point

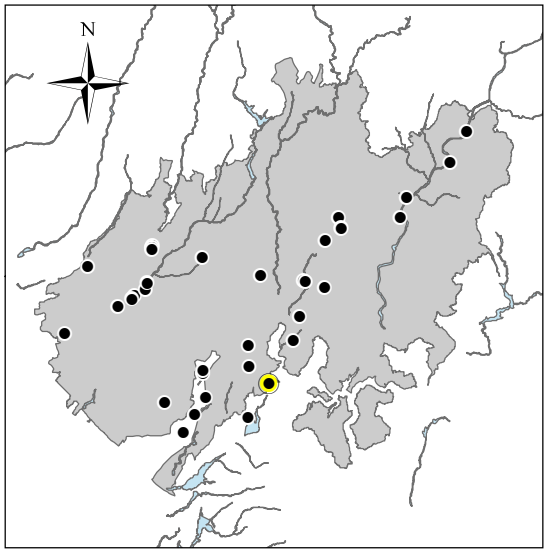
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Valley**
Site Number: 38
Feature: House
Feature Category: debris flow
Field Observation: House located on steep concave slopes and atop dormant landslide.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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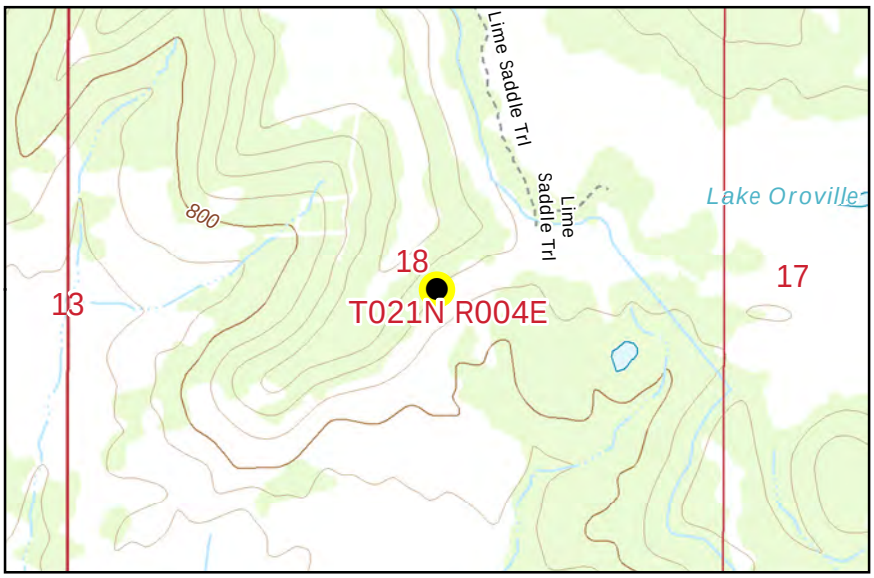


Value at Risk - Point

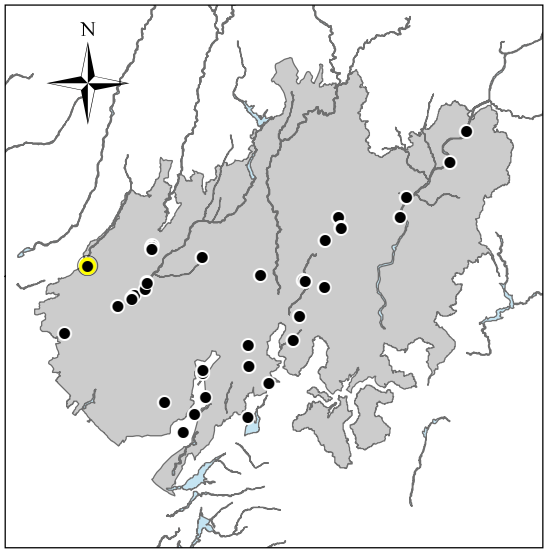
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 44
Feature: Residence
Feature Category: flood
Field Observation: Residence located within floodplain

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system
Protective Measures

Location



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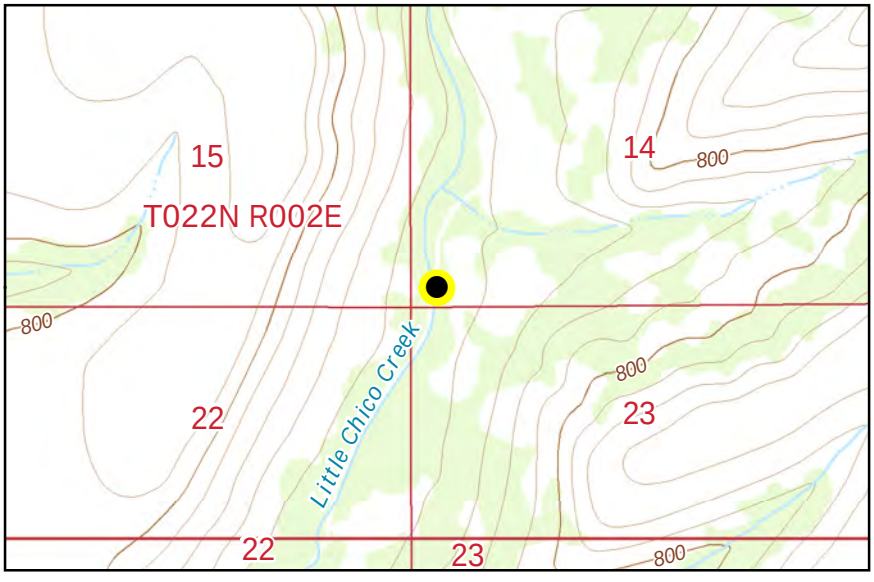


Value at Risk - Point

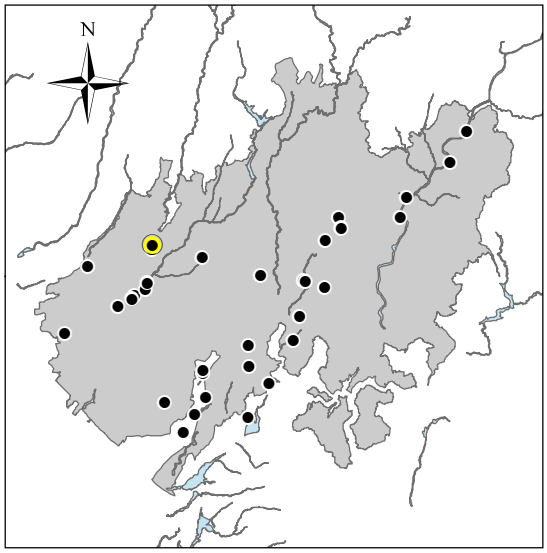
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 45
Feature: Residence
Feature Category: debris flow
Field Observation: Residence located at the bottom of steep slopes. Based on a review of topographic maps residence is located near the outlet of channel, possible debris flow deposits observed upslope of residence.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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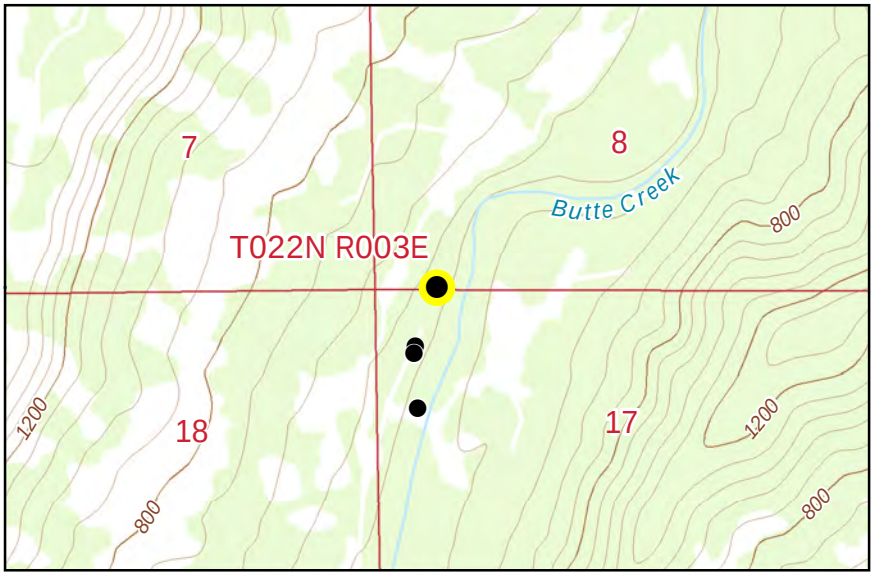


Value at Risk - Point

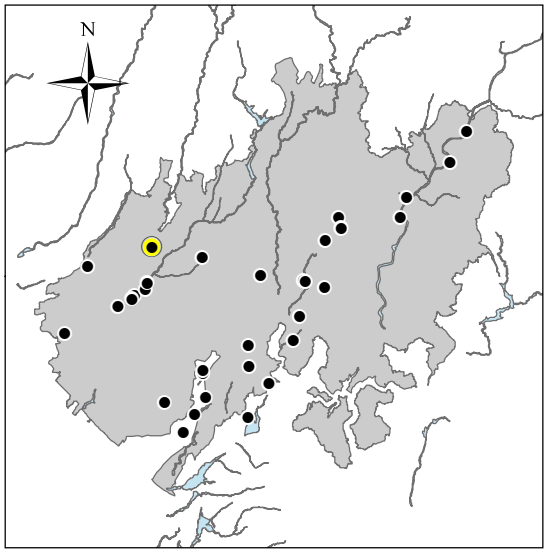
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 46
Feature: Residence
Feature Category: debris flow
Field Observation: Residence located at the bottom of steep slopes. Based on a review of topographic maps residence is located near the outlet of channel, possible debris flow deposits observed upslope of residence.

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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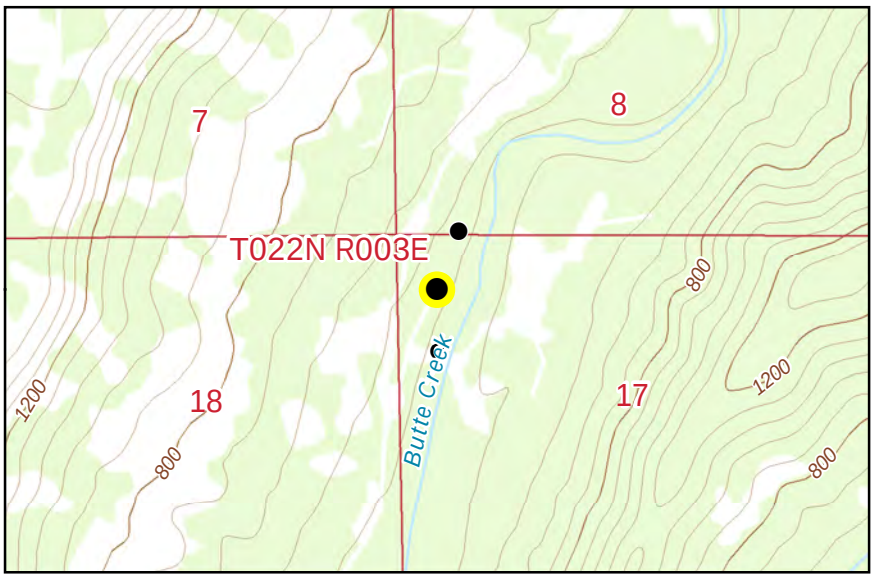


Value at Risk - Point

VALUE AT RISK DETAIL

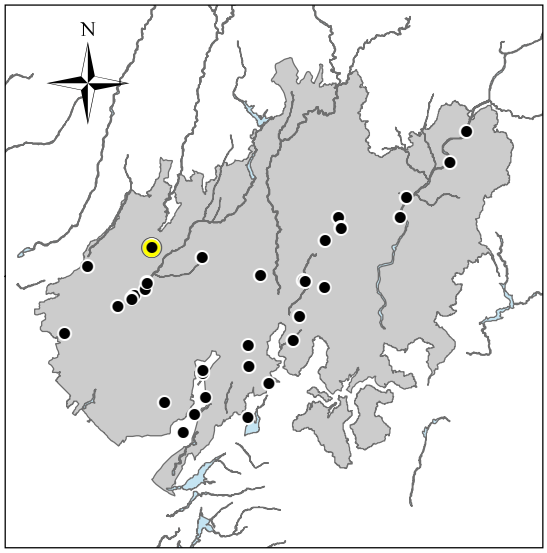
Incident Name: Camp ***Incident Number: CA-BTU-016737***

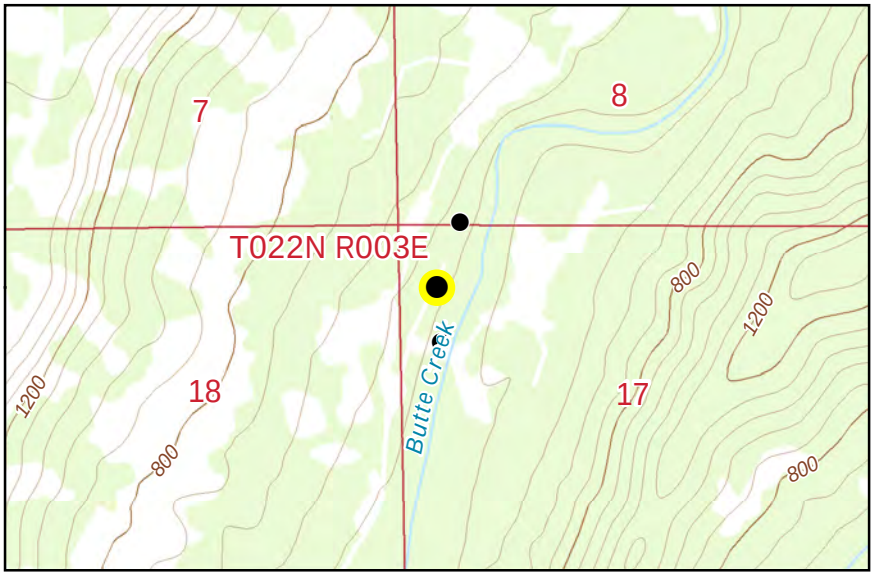
Community: **Butte Canyon**
Site Number: 47
Feature: Residence
Feature Category: debris flow
Field Observation: Residence located at the bottom of steep slopes. Possible debris flow deposits observed upslope of residence

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Photo ID:

Location





Value at Risk - Point

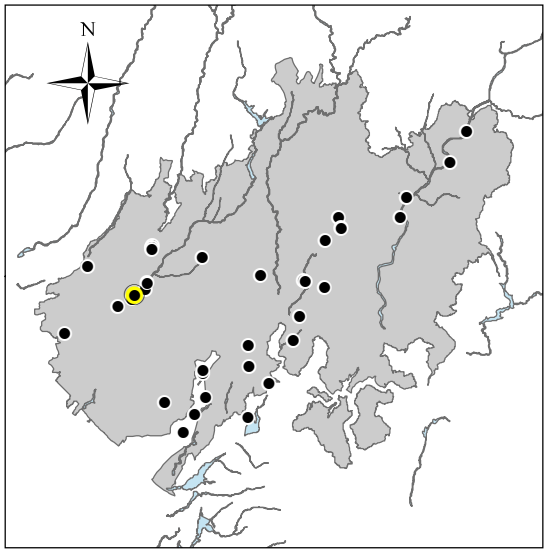
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 48
Feature: Bridge, residential access
Feature Category: other
Field Observation: Bridge does not appear to have adequate freeboard for woody debris passage

Potential Hazard to Life: low
Potential Hazard to Property: high
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Storm patrol
Protective Measures

Location



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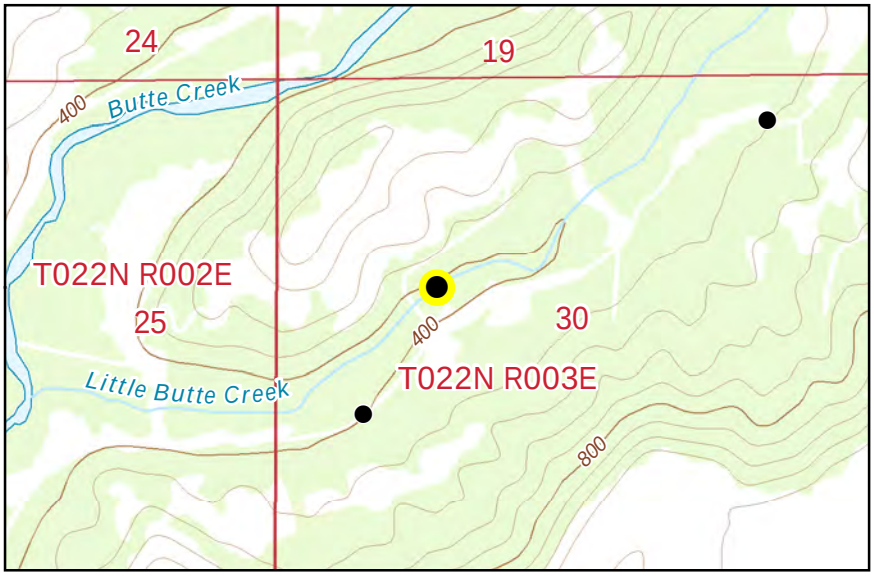


Value at Risk - Point

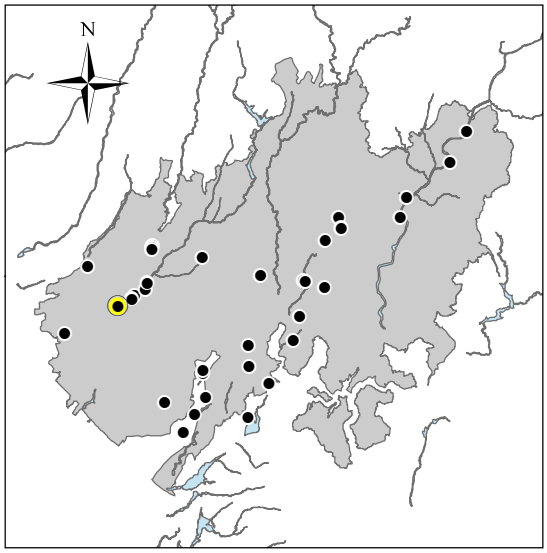
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 49
Feature: Downstream infrastructure
Feature Category: other
Field Observation: Honey Run Bridge. County removed bridge debris. Support pylons remain in channel.

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Storm patrol
Protective Measures

Location



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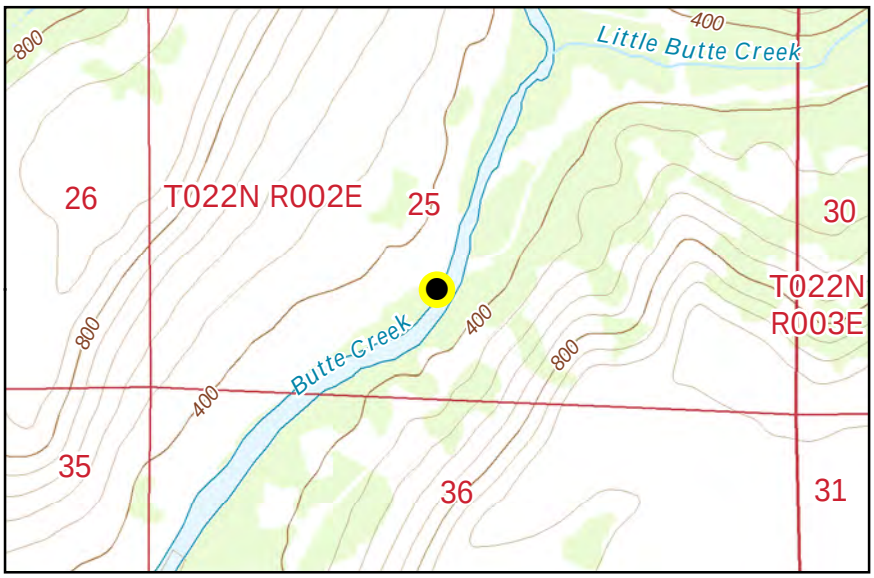


Value at Risk - Point

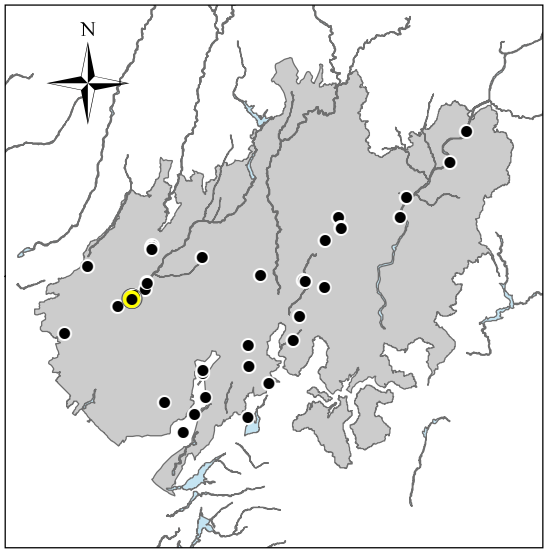
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 50
Feature: Residence
Feature Category: debris flow
Field Observation: Debris flow plugging culvert and flowing toward downslope residence

Potential Hazard to Life: low
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Location



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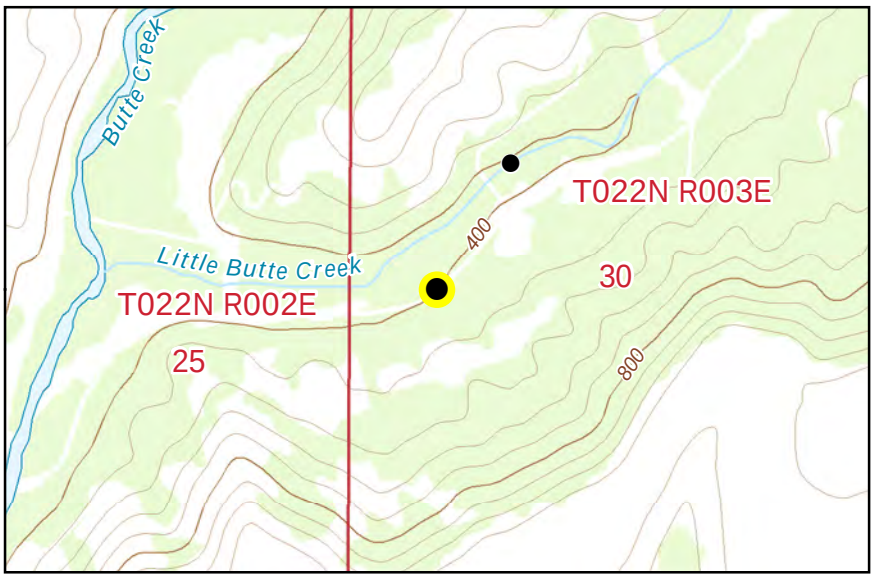


Value at Risk - Point

VALUE AT RISK DETAIL

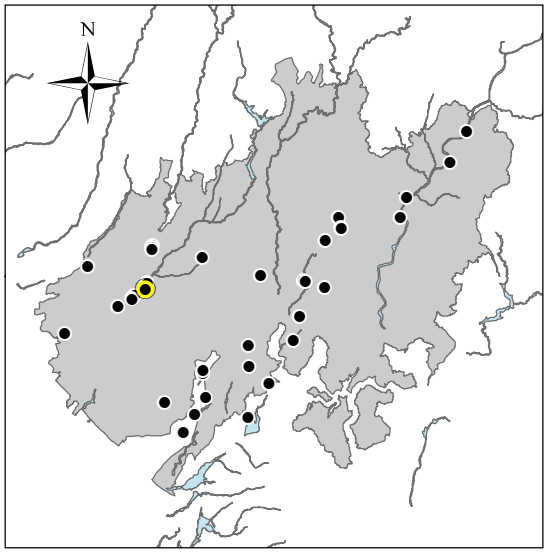
Incident Name: Camp ***Incident Number: CA-BTU-016737***

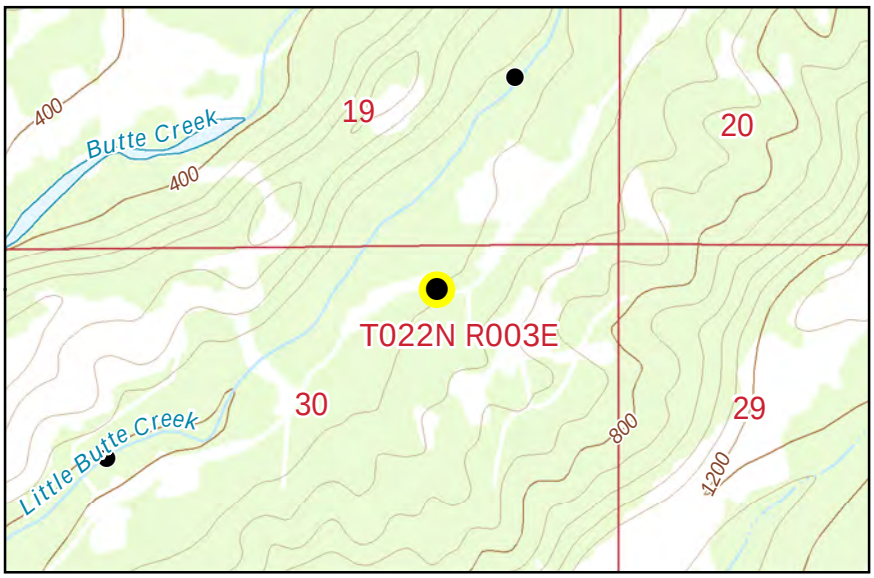
Community: **Butte Canyon**
Site Number: 51
Feature: Butte Creek Mobile Home Park
Feature Category: debris flow
Field Observation: Debris flow plugging culvert and flowing towards Butte Creek Mobile Home Park

Potential Hazard to Life: moderate
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning system
Protective Measures

Photo ID:

Location





Value at Risk - Point

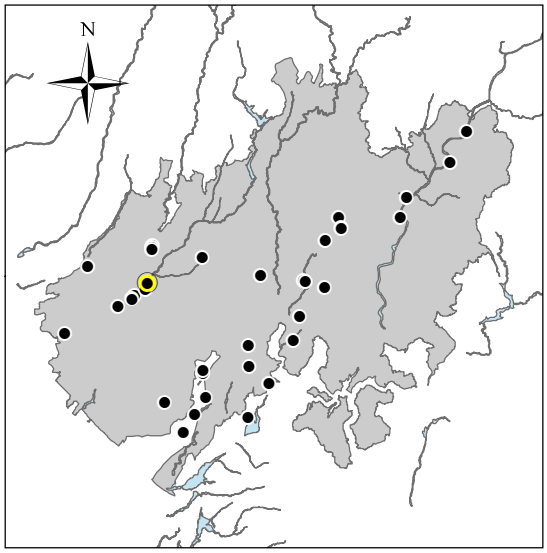
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 52
Feature: Bridge, residential access
Feature Category: flood
Field Observation: Bridges that provide residential access does not appear to have adequate freeboard for woody debris passage. Bridge may detach during high flows and impact several bridges downstream.

Potential Hazard to Life: low
Potential Hazard to Property: high
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system
Protective Measures

Location



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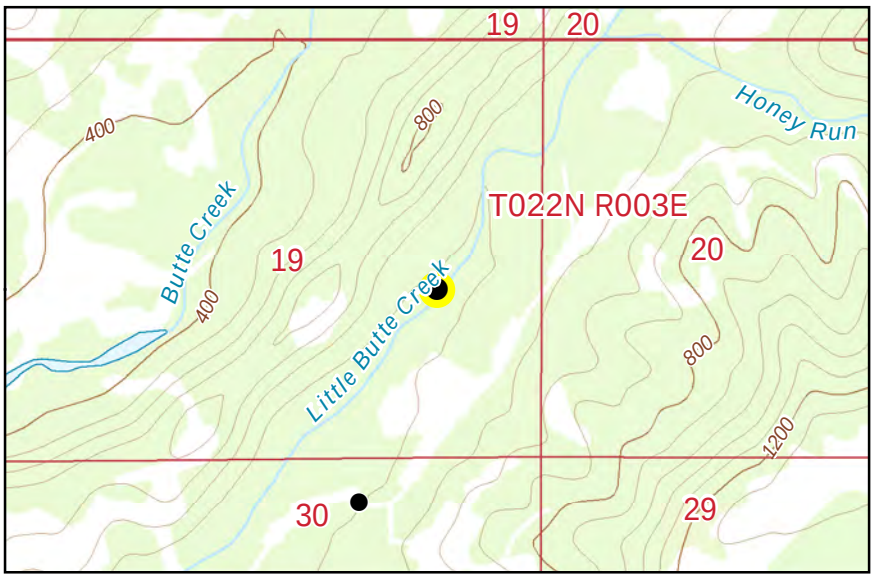


Value at Risk - Point

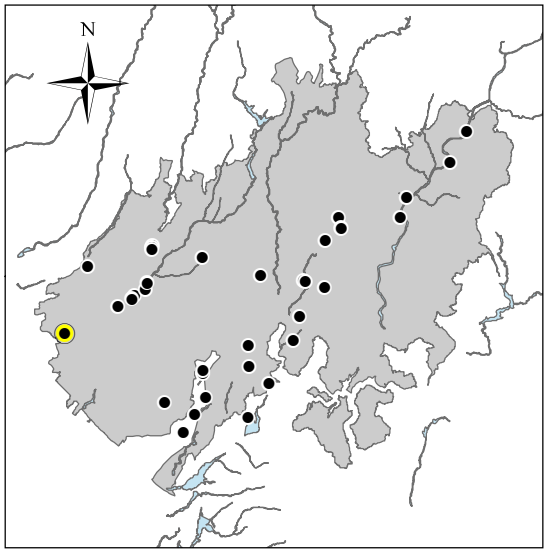
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Canyon**
Site Number: 53
Feature: Fish ladder and screen
Feature Category: flood
Field Observation: Flooding, debris racking, and sedimentation

Potential Hazard to Life: no
Potential Hazard to Property: low
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Monitor
Protective Measures

Location



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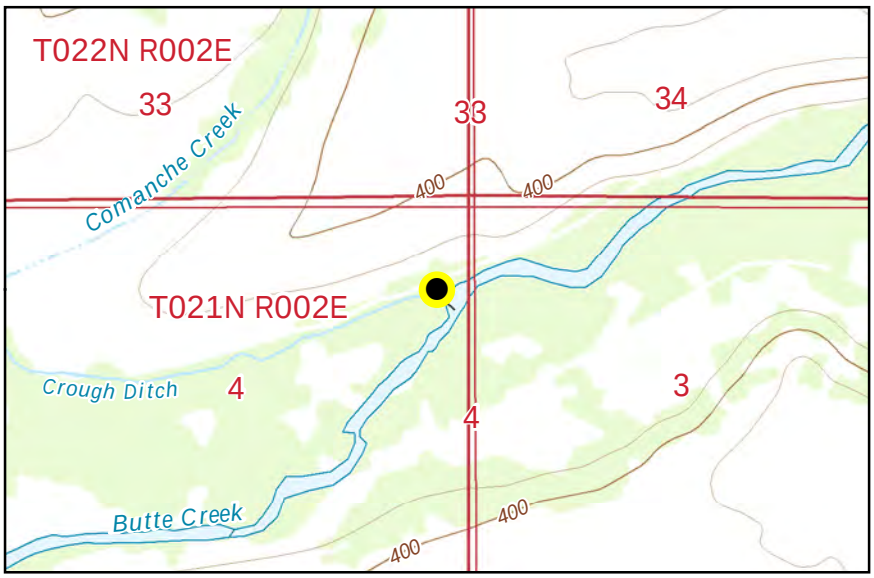


Value at Risk - Point

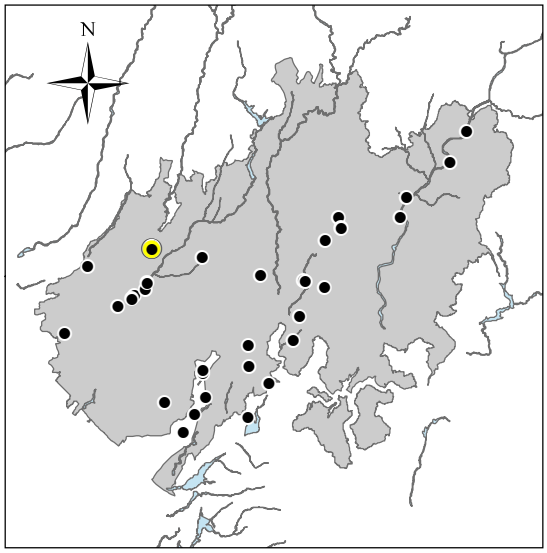
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Butte Creek**
Site Number: 054
Feature: Bridge
Feature Category: flood
Field Observation: Bridge, privately owned, could be compromised by high flows.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: yes
Preliminary Emergency: Early warning system and storm patrol
Protective Measures

Location



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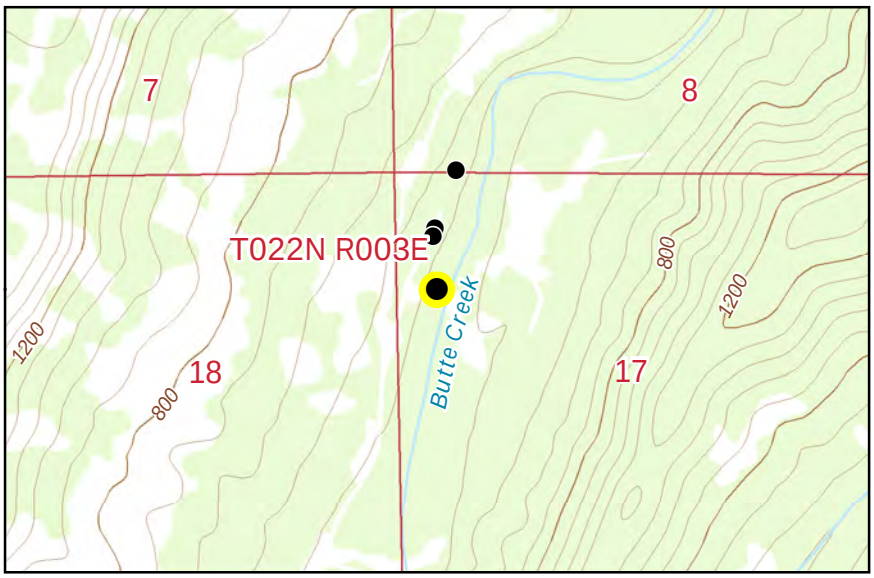


Value at Risk - Point

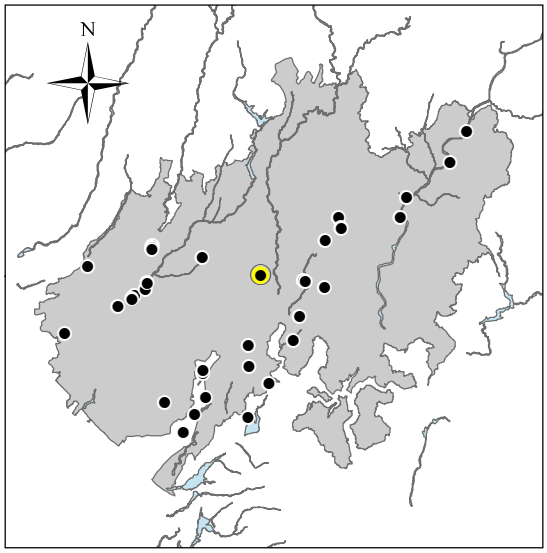
VALUE AT RISK DETAIL

Incident Name: Camp ***Incident Number: CA-BTU-016737***

Community: **Paradise**
Site Number: 056
Feature: Homesite
Feature Category: flood
Field Observation: Homesite in creek bottom/ flood risk. Evidence of erosion mitigations on lot adjacent to creek.

Potential Hazard to Life: low
Potential Hazard to Property: moderate
FEMA/DWR 100-yr Floodplain: no
Preliminary Emergency: Early warning
Protective Measures

Location



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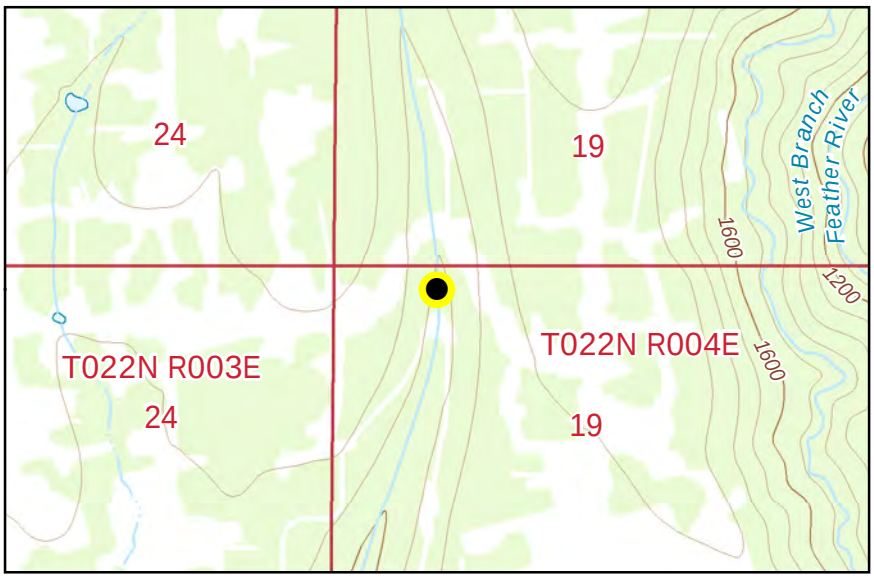

Value at Risk - Point

Camp Fire – Soils Report

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High soil burn severity in Flea Valley Creek canyon above Pulga, CA.

1.1 Soils

Soils in the burn area are typically shallow to moderately deep, developed on colluvium and residuum derived from weathered bedrock of basalt, shale, greenstone, granite, and alluvial inland-sea deposits. Four soils predominate the landscape, with four others co-dominating the landscape. The Ultic Haploxeralfs series are deep soils comprised of gravelly clay loams in volcanics. The Xerorthents series are shallow soils that are comprised of gravelly clay loams in volcanics. The Paradiso series are shallow to moderately deep soils that are composed of loam in volcanic residuum. The Luckser series are moderately deep soils that are comprised of loams in volcanic alluvium. The Griffgulch series are moderately deep gravelly loams in volcanic colluvium. The co-dominate soils are the Oroshoe series which are moderately deep gravelly loams in weathered metamorphics, the Islandbar series, deep sandy loams in igneous colluvium, and the Redtough series, moderately deep loams in volcanic colluvium. Several other soil map units are found in lower percentages within the burn area and are shown in Figure 1.

The distribution of soil map units generally correspond to their geologic parent materials. The west half of the fire is weathered volcanics whereas the east half of the fire are generally metavolcanic, metasedimentary, and igneous rocks.

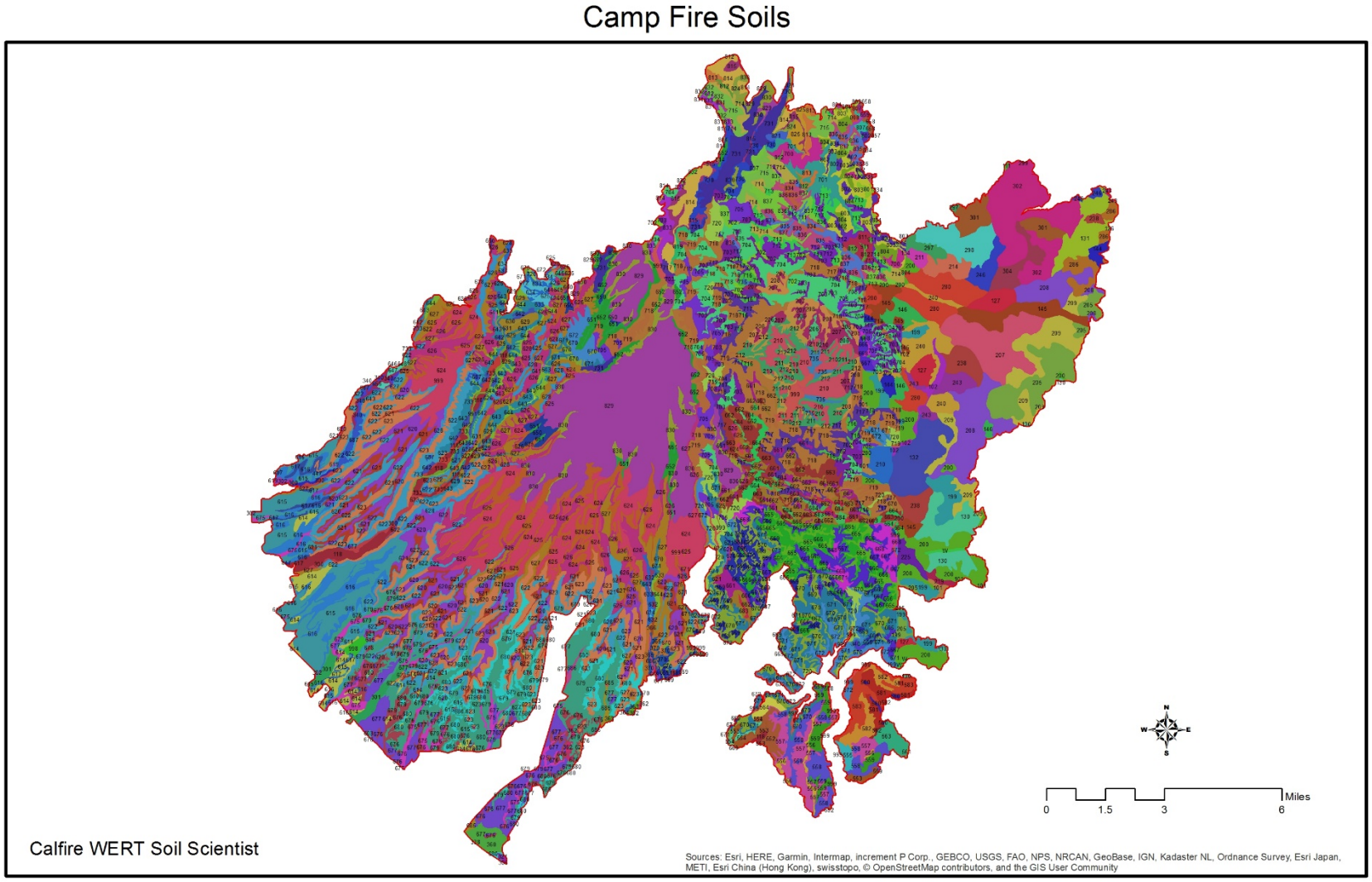

Figure 1. Soils map for the Camp Fire upper area.

1.1.1 Post-Fire Surficial Processes

The principal concern with the Camp Fire area is an increase in the potential for hillslope and in-channel erosion, increased streamflow, hyper-concentrated flows, debris torrents, and debris flows derived from erosion. The primary mechanisms for this are increases in runoff from: reductions in interception resulting from the loss of live vegetation, reductions in infiltration due to the removal of litter and duff along with deposition of soil sealing ash, the loss soil aggregate stability, and the loss of mechanical support along stream channels. Also of concern is the long-term loss of mechanical support of hillslope materials that was provided by vegetation and vegetative litter.

In areas of high and moderate soil burn severity, water repellant soils can develop where waxy substances released by plant materials during hot fires follow thermal gradients into the soil and condense onto soil particles. Along with water repellency soil, severe soil heating can cause soil organic matter destruction reducing the topsoil to a loose unconsolidated material. Additionally the headwaters of these watersheds are very steep. Dry ravel (i.e., downslope mobilization of loose bedrock, soils, and sediment wedges accumulated behind vegetation removed during the fire) was observed on very steep slopes in numerous locations in the burn area. The loose materials may become mobilized into sediment-laden runoff during heavy rains, leading to the development of debris flows and debris torrents that may flow downstream from the watershed headwater source areas. The magnitude of post-fire damage will ultimately be determined by the intensity and duration of storms that impact the burn area for several wet seasons until vegetation recovers.

3.2.3 Post-Fire Erosion and Sedimentation Modeling

Post-fire hillslope sedimentation rates were modeled by U.S. Forest Service Soil Scientists in the Camp Fire burn area using Batch ERMiT (Erosion Risk Management Tool).[1] FS-WEPP ERMiT is a web-based tool developed to predict surface erosion from post-fire hillslopes, and to evaluate the potential effectiveness of various erosion mitigation practices (Robichaud et al., 2011). Quantitative erosion and sedimentation modeling utilizing the FS-WEPP ERMiT model is fundamentally based on single hillslopes and single storm runoff events (not annual estimates). Particulars and documentation may be found at http://forest.moscowfsl.wsu.edu/fswepp/.

Three custom climates were generated for the fire area using the PRISM module integrated in ERMiT. The model was run for a range of storm-runoff recurrence intervals of 2-yr and 10-yr events. Estimates are based upon watershed area within the fire perimeter only; unburned watershed area outside the fire perimeter was not modeled. There are unburned (or very low burn severity) acres within the fire perimeter as well. ERMiT does not produce output for the unburned condition, as it was not part of the original empirical research data that went into building the model. Therefore, ERMiT values for the 5th out-year post-burn were applied to unburned acreage; this would assume that erosion returns to pre-fire levels after 5 years, which is not always the case

[1] http://forest.moscowfsl.wsu.edu/fswepp/batch/bERMiT.html

so erosion is probably over-estimated to some degree. For rapid assessment purposes, this is considered adequate, and preferable to using unrelated models or anecdotal data for a small portion of the fire area and combining results.

ERMiT requires input for climate parameters based on location, vegetation type (forest, range, chaparral), soil type (clay loam, silt loam, sandy loam, loam and rock content), topography (slope length and gradient), and soil burn severity class (low, moderate, high). This model provides probabilistic estimates of single-storm post-fire hillslope erosion by incorporating variability in rainfall characteristics, soil burn severity, and soil characteristics into each prediction (Robichaud et al., 2011).

The WERT selected ERMiT for post-fire erosion modeling over other models such as WEPP (Water Erosion Prediction Project), GeoWEPP, and AGWA (Automated Geospatial Watershed Assessment tool) due to past experience with the model and realistic results obtained using the model.

1.2 Field Methods

1.2.1 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). Soil burn severity is determined using Landsat satellite imagery-derived Burned Area Reflectance Classification (BARC) maps, followed by field verification work (see Appendix A for information on how BARC maps are created and used). (http://www.fs.fed.us/eng/rsac/baer/barc.html).

The initial BARC map was created by pre-fire image Sentinel 2 acquired on 11/10/2018 and post-fire image acquired on 11/18/2018. Sentinel use a short-wave infrared band differenced Normalize Burn Ratio for spatial resolution of 20m for mapping.

The BARC map is composed of satellite-derived data layers of post-fire vegetation conditions. The BARC map has four classes: high, moderate, low, and very flow/unburned. The Camp Fire BARC map was field-verified using methodology developed by Parsons et al. (2010). These methods included, assessments of fine root structure, soil structure, soil organic matter destruction, amount of above and ground cover, and soil hydrophobicity testing.

Soil burn severity observations were conducted at 50 sites. Soil water repellency testing took place on both the soil surface and at depth (see Figure 2 below). Surface water repellency testing was completed by scraping away the ash layer to expose bare mineral soil at the surface and then timing how long it took for a drop of water to infiltrate the soil.

Subsurface water repellency testing was completed in the same fashion as surface testing, but with excavation of the surface soil to a depth approximately ½ inch to 4 inches below the surface.

Figure 2. CAMP fire soil water repellency.

Field testing revealed that soil water repellency was not a reliable indicator for determining soil burn severity, as water repellant conditions were highly variable and occurred naturally in unburned landscapes. Parsons et al. (2010) reported that the connection between soil burn severity and soil water repellency is neither universally consistent nor well defined (i.e., it does not necessarily correlate well with burn severity).

To validate the BARC map, information on ash thickness and color, ground and canopy cover, depth of soil char showing soil structure destruction, fine root consumption, surface rock fragment percentage, pre-fire vegetation density, and soil texture along with vegetation type was collected in conjunction with soil water repellency to determine the soil burn severity for comparison with the Sentinel 2 BARC map (Parsons et al., 2010).

2.0 Results and Observations

2.1 Soil Burn Severity

In general, the WERT found the Camp Fire BARC map was good except for the need of adjustments for the break between moderate and high soil burn severity, and the break for low and very low. A universal adjustment was applied to increase high soil burn severity and to increase low burn severity from very low burn severity. Note the northeast and east sections of the North fork of the Feather River was still burning at the time of the imagery and firing operations were being conducted in the east section of the fire so inaccuracies will be evident in these areas.

We had 50 SBS verification points, among other hardcopy map notes, and adjustments got better than 90% match with the SBS points, which is good for a fire this size.

As a result, the adjusted BARC map was denoted as the soil burn severity map (Figure 3). Typically the higher the soil burn severity, the more susceptible the area is to rapid runoff and erosion. The Camp Fire soil burn severity map was used by the WERT as a guide to help identify areas of likely erosion and debris flows that may occur during storm events that could threaten impacts to downslope values at risk (structures, roads, trails, water quality, etc.). There were approximately 28,438 acres (19%) of very low/unburned soil burn severity, 95,157 acres (63%) of low soil burn severity, 24,425 acres (16%) of moderate soil burn severity, and 3,389 acres (2%) of high soil burn severity.

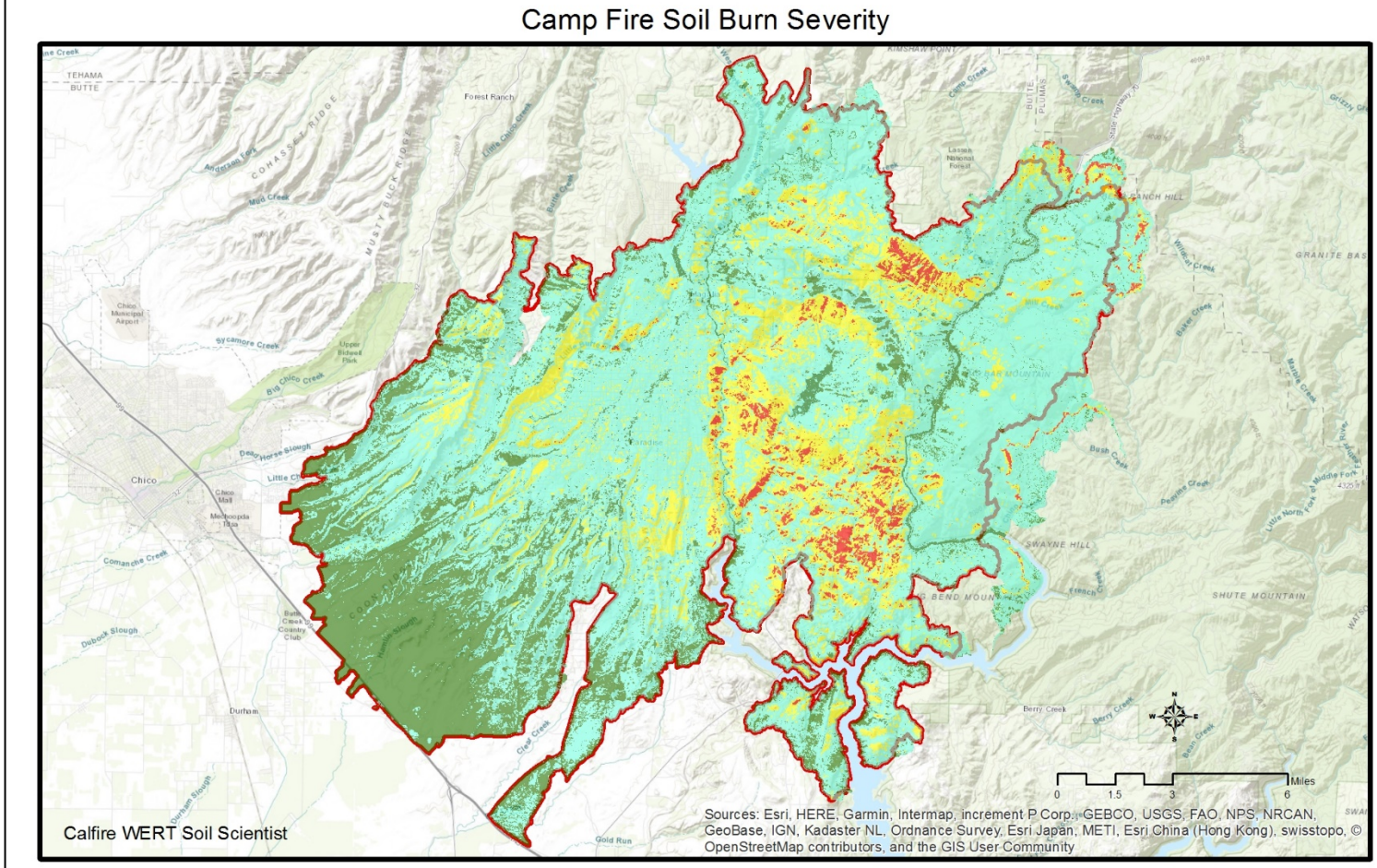

Figure 3. CAMP fire soil burn severity map.

2.2 Post-Fire Erosion and Sedimentation Results

Post-fire Batch ERMiT model predictions for the 2-year storm recurrence interval runoff event shows that surface erosion rates are estimated to range from 2 to 23 tons per acre depending on the area in the fire. These ranges take in the outliers (the very lowest to the very highest) inherent in all distribution models, but for the whole fire, it averages out to be 6 tons/acre (Figure 4). These rates have a 50 percent probability of exceedance. Hillslope erosion in these watersheds may affect downstream infrastructure, roads and drainage structures, fill stream channels with high levels of sediment, increase downstream turbidity, and bulk flood flows with higher than typical sediment loads. These areas would roughly be expected to have an 8-fold increase in sedimentation the first post-fire winter compared to pre-fire conditions.

The post-fire ERMiT model highlights areas of elevated erosion potential in the upper reaches of Butte Creek watershed (red areas in map below). This part of the fire differs from other regions of the burned area due to shallow very steep soils with hard volcanic rock below in chaparral-dominated vegetation making them more susceptible to erosion. Most of this area was in the moderate to high soil burn severity zone (see soil burn severity map above). This combination of factors makes this area stand out from the remainder of the burned area as a concern for increased sediment yield and possible debris flows.

The other area of potential concern is the metagranitic areas east of Concow Lake in the upper Concow and Flea Valley Creek watersheds. These areas shown up as red zones showing high susceptibility for erosion from an average 2-yr storm (see map below).

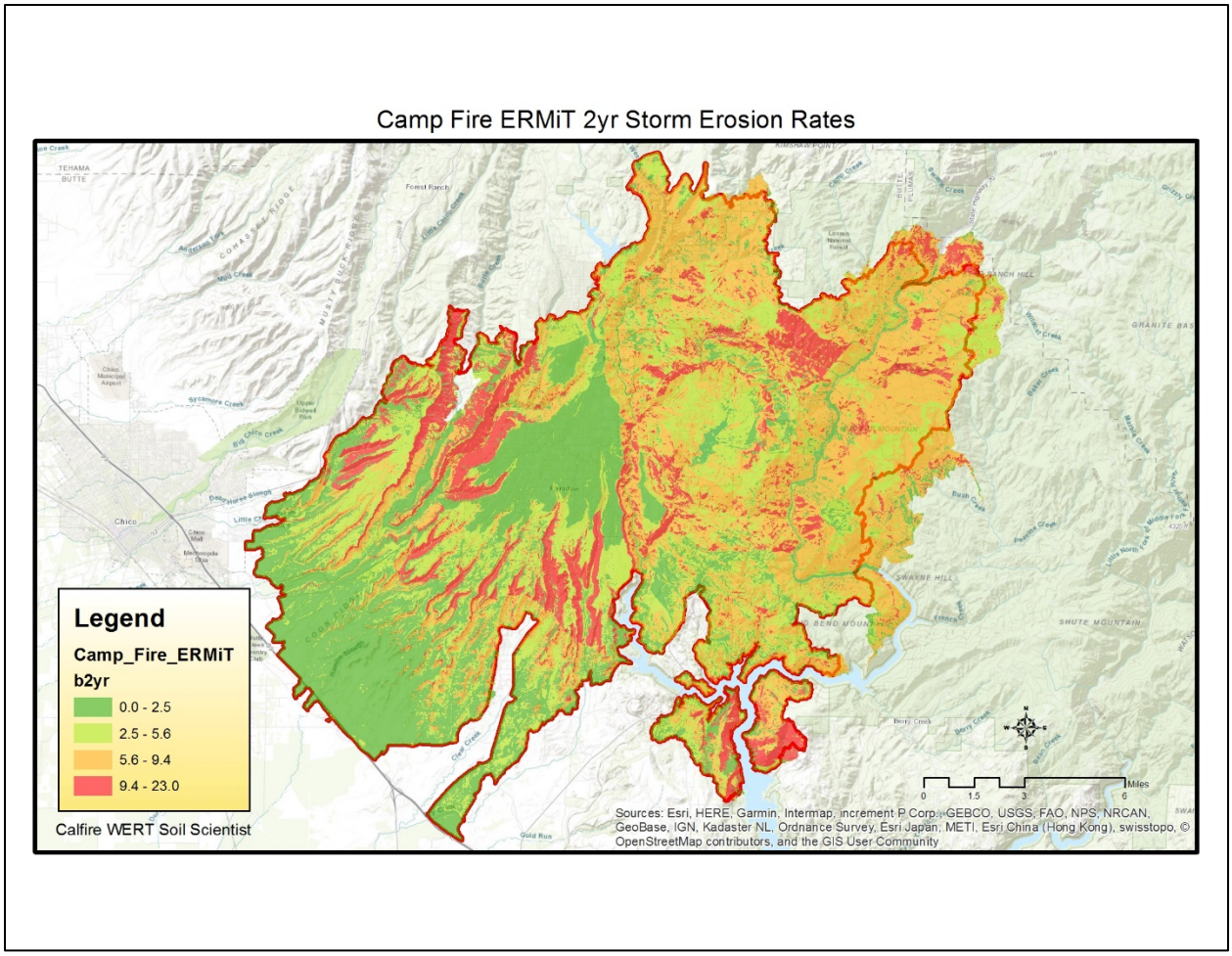

Figure 4. Batch ERMiT 2-year storm erosion rates for the Camp Fire.

Based on a 10-year storm recurrence interval, the Batch ERMiT model prediction ranges from 3 to 48 tons per acre, with a whole fire average of 13 tons per acre (see Figure 5 below).

Using the 2-year storm erosion rates in comparison to the 10-year storm erosion rates, one can observe the areas that are very sensitive that even a normal storm will trigger accelerated erosion. These areas are the upper Butte Creek watershed and the Flea Valley Creek watershed draining into the Feather River at Pulga.

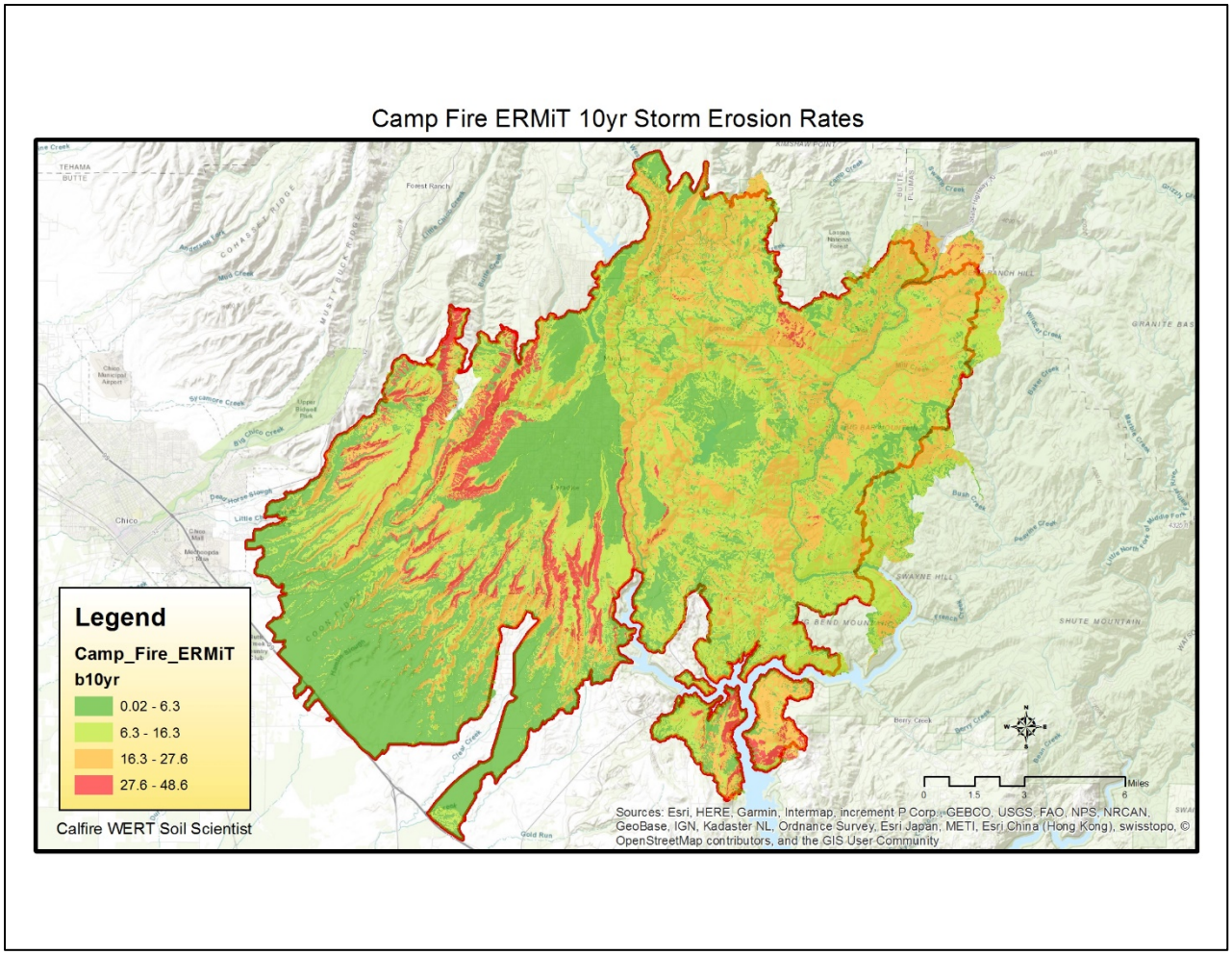

Figure 5. Batch ERMiT 10-year storm erosion rates for the Camp Fire area.

Soil Observations due to the Effects of burning:

It is very important to understand the difference between *fire intensity* or *burn severity* as discussed by fire behavior, fuels, or vegetation specialists, and *soil burn severity* as defined for watershed condition evaluation in WERT analyses. Fire intensity or burn severity as defined by fire, fuels, or vegetation specialists may consider such parameters as flame height, rate of spread, fuel loading, thermal potential, canopy consumption, tree mortality, etc. For WERT analysis, we are not mapping simply vegetation mortality or above-ground effects of the fire. Soil burn severity considers additional surface and below-ground factors that relate to soil hydrologic function, runoff and erosion potential, and vegetative recovery.

Characterization of soil burn severity is based on vegetative cover remaining (canopy and surface), depth and degree of soil char, surface ash color (white, red, gray, black), amount and size of roots destroyed by fire, and water repellency (degree and depth) Parsons et. al. 2010.

Soil texture and aggregate stability affect the expression of soil burn severity. Soil structure or aggregate stability is dependent on soil texture and organic matter. With the destruction of soil organic matter from extreme heating soil structure is reduced to single grain loose powder. Fine-textured soils have less pore space so heat cannot readily penetrate and destroy soil organic matter that affects soil structure. Whereas coarse-textured soils that have greater pore space heat can readily penetrate and destroy soil structure. Older finer-textured soils have strong aggregate stability and resist heat penetration causing the expression of soil burn to be only on the surface vs. younger coarse-textured soils have weak aggregate stability and heat penetrates into the soil causing soil char with aggregate destruction and water repellency at depth.

Pictures of soil burn severity along with explanations are shown below for the Camp Fire.

<table>
<tr><td>  </td><td>  </td></tr>
<tr><td>Very low soil burn severity soil</td><td>Very low soil burn severity</td></tr>
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<tr><td>Low soil burn severity soil effects</td><td>Low soil burn severity landscape</td></tr>
</table>

For very low soil burned severity landscapes, soils only had grass removal with black ash with no soil char or soil effects. Green grass was starting to resprout (see pictures above).

For low soil burn severity areas, there was very shallow soil char with no damage to the soil, low to moderate surface water repellency with only black ash and partial (timbered areas) to complete removal (chaparral) of cover (see pictures above).

Moderate soil burn severity soil

Moderate soil burn severity

High soil burn severity soil effects

High soil burn severity landscape

For moderate soil burned severity landscapes, soils had partial (in timbered areas) to complete removal (in chaparral areas) of cover with black to gray ash with shallow to moderate soil char destroying fine roots and soil aggregate stability. This caused a water

repellant layer to form just below the surface down to 1 to 4 inches deep. Conifers had brown frozen needles and were completely dead whereas chaparral areas had complete vegetative removal with only brush skeletons remaining.

For high soil burn severity there was moderately deep soil char with damage to soil aggregate stability and organic matter destruction rendering the soil to powdery loose dust with puffed expanded pore spaces and turning soil to a brighter red color. Strong water repellency was present down to 2 to 4 inches and complete removal of cover (see pictures above).

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Erosion Risk Management Tool (ERMiT), Robichaud, Peter R.; Elliot, William J.; Pierson, Fredrick B.; Hall, David E.; Moffet, Corey A.; Ashmun, Louise E. 2007. Erosion Risk Management Tool (ERMiT) user manual (version 2006.01.18). Gen. Tech. Rep.RMRS-GTR-188. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 24 p.

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