Geology

Rim Fire BAER
(Stanislaus NF)
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I. <u>Potential Values at Risk</u> (identified prior to the on-the-ground survey)

Debris flows and rockfalls are the primary geologic hazards associated with burned watersheds (Santi et al., 2013; Parise and Cannon, 2012). Debris flows are of particular concern due to their destructive force and the distance from their source they can travel. Commonly, debris flows from burned area are runoff-generated rather than triggered from small discrete landslides mobilizing downslope into channels (Parise and Cannon, 2012). Most of the debris flow volume results from mobilization and scour of material deposited within the channel where the debris flow is passing. On average, an additional 23% of a debris flow's volume comes from material issuing from side channels. Only an average of 3% (max. 10.5%) of a debris flow's volume comes from rills formed on adjacent slopes (Santi et al., 2008).

Debris flow activity is not uncommon within the area affected by the Rim Fire. Examples of areas where precipitation-induced debris flows have occurred include within the Clavey River area and on Pilot Ridge. Areas where conditions of geology and slope steepness are similar to those within the Rim Fire have also resulted in debris flows (De Graff, 1994; 2001). While a debris flow from Pilot Ridge impacted California Highway 120, other debris flows have impacted local roads or deposited into major streams.

Rockfall in the form of individual rocks or small groups of rocks have rolled onto roads and trails from the steep slopes within the Rim Fire area. It is recognized that rockfall activity often takes place during and immediately after a wildfire. The potential threat to the facilities at Early Intake due to wildfire-induced rockfall was identified and measures installed to reduce the risk to critical infrastructure (De Graff and Gallegos, 2012). Accumulations of small rocks can damage tires and interfere with safe driving. Rocks in motion or large rocks (1-foot diameter or larger) can damage pavement, cause accidents, damage vehicles, and cause injury or death.

Deep-seated landslides are present within the Clavey and Tuolumne drainages. A large landslide (~600 acres) was identified in the upper Granite Creek watershed (see Figure 1 – Geologic Map). Smaller (1-3 acres), active landslides were identified within the larger landslide feature. These landslides toe out on road cuts and in Granite Creek. A number of locations on Cherry Lake and Cottonwood roads are known to have moved during the past several decades. In a number of places, engineering measures were required to prevent their adversely impacting these major roads. Significant loss of forest vegetation causes a short-term (multi-

year) decrease in evapotranspiration which can cause an increase in groundwater levels. The greater shallow groundwater can trigger renewed movement on existing, deep-seated landslides. While renewed movement could be initiated after the next rainy season, there could be a time lag of up to two years and will be dependent on seasonal rainfall totals.

Therefore, roads, trails, and recreational facilities (public and private) within the burned area all constituted potential values at risk for both debris flows and rockfall. The extensive infrastructure for water conveyance and power generation operated by the City and County San Francisco was also an obvious value-at-risk given past experience with the Early Fire. Some specific potential values-at-risk associated with past wildfires which were fully or partially burned by the Rim Fire were known from the past experience on BAER teams between 1987 and 2008. Appendix A contains a spreadsheet of the potential values-at-risk (VAR).

A. Critical Values
B.

Table 1 – Geologic Hazard Value-at-Risk Summary Description

Value-at-Risk	Objective	Description	Cost
1. Road segments (see VAR table in Appendix A and Geology rockfall GIS layer)	Protect life and property	Rock accumulations impairing safe travel or blocking roads; rocks striking vehicles; rocks damaging paved surfaces	Sixty "rockfall hazard" signs to delineate 30 segments with observed increased rockfall hazard due to the fire. Recommended that rockfall hazard be included in general hazard signs posed for the burned area.
2. Rockfall deposit on 3N01 south of 1N04 junction	Protect life and property	Existing rockfall on part of road bed behind k-rails	Clear some rock and position serviceable k-rails to accommodate additional rock and install warning signs
3. Lumsden Road	Protect life and property	Rock accumulation hazard to vehicle travel or blockage; threat to motorist in vehicles from rocks	Recommend closure of the road from Ferretti Road junction area to Lumsden Bridge on the Tuolumne River. Survey of conditions on the road should occur after rock clearance to determine if rockfall activity has abated before re-opening to public.
4. Trails or segments of trails (see VAR table in Appendix A and Geology rockfall GIS layer)	Protect life and property	Threat of moving rocks to hikers on the trails and creation of unsafe trail segments due to rock accumulation	Post rockfall warning signs at the beginning of Preston, Andresen, Tuolumne River Canyon, and Indian Creek trails. Closure of Preston Trail because of early season use during storm events and overnight use is advised. Closure of other trails would be equally advisable.
5. Rainbow Pool Day Use Area access road	Protect life and property	Rockfall on access road from Hwy 120 (Buck Mdw side)	Post two rockfall hazard signs to delineate rockfall hazard segment.
6. Lumsden	Protect life	Threat of injury or	Close campground to use until

Campground	and property	fatalities due to rockfall	Lumsden Road is re-opened to public use and assessment of rockfall in campground demonstrates reduced threat.
7. Cultural resource n. of Spinning Wheel	Cultural Resource	debris flow	Pin woven filter fabric over site and hand cover with 6-inches of soil
8. Kirkwood Powerhouse and associated facilities	Property	rockfall	**No Cost to Govt:** Send notification letter to Hetch Hetchy Water & Power concerning expected rockfall hazard
9. Hetch Hetchy high-voltage Power line towers	Property	rockfall	**No Cost to Govt:** Send notification letter to Hetch Hetchy Water & Power concerning expected rockfall hazard

C. Resource Condition Assessment

a) Resource Setting - The Rim fire burned 257.000 acres within the Tuolumne River drainage in the central Sierra Nevada . While most of the area burned was within the Stanislaus National Forest, a significant area within Yosemite National Park was also burned centered around Poopenaut Valley and Hetch Hetchy Reservoir.

Geology

Within the burned area, much of the bedrock is granitic where erosion has exposed the batholiths commonly associated with the Sierra Nevada landscape. The metasedimentary bedrock which the batholiths originally intruded is still present in foothill formations and isolated roof pendants. Tertiary to Recent deposits mantle erosional surfaces and are generally of volcanic or glacial origin. Consequently, the bedrock underlying the area burned by the Rim fire (in order of oldest to youngest) is: 1) metasedimentary bedrock consists mainly of schist, argillite, quartzite, dolostone, and marble, 2) granitic (batholitic) bedrock is granitic bedrock with mafic bodies diorite and gabbro, and 3) Tertiary-aged fluvial gravels and Quaternary-aged volcanic flows and glacial deposits (see Figure 1).

Geomorphology

The Rim Fire affected the broad, westward draining slopes of the Sierra Nevada. The eroded remnants of the ancestral Sierra Nevada shaped a broad platform in the granitic batholiths. This platform is incised by the west-flowing rivers. Within these broad uplands, exposed granitic bedrock has formed domes and other characteristic landforms. The Tuolumne River and its tributaries have incised steep, inner gorge slopes due to rejuvenated downcutting after regional uplift began along the western and eastern boundary faults. Active debris slides and debris flows were observed on the inner gorge slopes forming the canyon walls of the Tuolumne River. An alluvial/debris flow fan was observed at the junction of the Tuolumne River and the South Fork Tuolumne River. The South Fork Tuolumne River is highly incised and well established within these alluvial/debris flow fan deposits. In the eastern part of the Rim Fire area, the effects of Pleistocene glacial erosion and deposition are evident. These range from the canyon below Hetch Hetchy Reservoir to area mantled by glacial till.

(b) Findings of the On-The-Ground Survey –

Debris Flow Assessment - assessing the probability and volume of debris flows draws upon empirical models developed from research in southern California and the Intermountain Western United States (De Graff et al., 2007; Cannon et al., 2010; De Graff and Gallegos, 2012). The assistance of the US Geological Survey (USGS) was obtained for assessing the debris flow hazard. Their ongoing research has developed empirical models for forecasting the probability of their occurrence and the likely volume of such an event. These are tied to a storm size consistent with the type of precipitation event which may occur within the first few years after the wildfire. The coordinates for specific locations of concern were given to USGS scientists to ensure the modeling necessary for determining the threat to particular values-at-risk were supplied by the geologic team leader. Also provided were geospatial information on the fire perimeter and the soil burn severity caused by the Rim Fire. USGS conducted a debris flow assessment and provided maps and a manuscript (Staley, 2013). The results of the debris flow assessment were analyzed for values at risk within the Rim Fire Area.

The Granite Creek watershed was assessed in detail because the Dion Holm Power House is located immediately near the Granite Creek, near the confluence with Cherry Creek (see Figure 2). . Roads and other values-at-risk were also assessed for debris flow hazards (see Table 2).

The Granite Creek watershed was evaluated at several sections in the channel and debris flow deposits were found in Granite Creek, immediately above the Dion Holm Powerhouse and below several of the tributary channels to Granite Creek. This evidence of recent debris flow deposits indicates that debris flows could occur in the Granite Creek Watershed. What is not evident is how far down Granite Creek a debris flow could flow and possibly aggrade Granite Creek at the Dion Holm Powerhouse and cause flooding because of a reduced flow capacity in Granite Creek. Considering the USGS Debris Flow Modeling, debris flow probability for the Granite Creek Watershed is 35% for a 10 year, 60 minute storm. Over a three year recovery period of the Granite Creek watershed the probability of a debris flow occurring would be 10%. In terms of the BAER Risk Assessment, the Probability of Damage or Loss is Possible; the Magnitude of Consequences is Moderate; therefore the Risk is Intermediate. Based on this risk analysis treatment is not recommended to reduce the risk any further for the Dion Holm Powerhouse.

Granite Creek is crossed by roads at three points. These roads include 1N07 and 1N96. The debris flow probability is 40-60% for a 10 year, 60 minute storm. Over a three year recovery period of the Granite Creek watershed, above the road channel crossings, the probability of a debris flow occurring would be 16%. In terms of the BAER Risk Assessment, the Probability of Damage or Loss is Possible; the Magnitude of Consequences is Moderate; therefore the Risk is Intermediate. Based on this risk analysis the recommended treatment is to install warning signs.

Rock Fall Assessment - The assessment of rockfall was guided by experience to methodically and consistently evaluate this geologic hazard within the knowledge currently available on this phenomenon (Santi et al., 2013; De Graff and Gallegos, 2012). While local specialists, especially from the engineering staff, could point out areas of chronic rockfall, there was a need to determine if the effect of the fire had increased rockfall activity at these locations or other which had not previously been a problem. The assistance of Mike Bradshaw, Forest Engineer, and Jonathan Berry, Zone Geotechnical Engineer, was invaluable (see Rim Fire BAER Geotechnical report). A map was prepared showing the road and trail segments which were downslope from areas affected by moderate or higher soil burn severity on slopes inclined more than 39% (see Figure 3). Field survey consisted traveling many of these roads and observing the size and number of rocks which had rolled onto the road during or since the fire. This information was used to establish whether the rockfall hazard was low, moderate or high. While all the designated roads could not be traveled due to the need to avoid active fire operations, blockage by trees (or rocks) or general safety considerations, the primary travel routes and many secondary ones were seen during the survey. Similarly, observations were made for may trails showing similar upslope conditions. The assessment of trails depended on the observations of rockfall at nearby roads and past BAER experience with trails in this area.

The Lumsden Road (FR1N10) has the highest rock fall hazards of all roads in the Rim Fire Area. Rock fall hazards on the Lumsden Road range from low to very high rock fall hazard. In terms of the BAER Risk Assessment, the Probability of Damage or Loss is Very Likely; the Magnitude of Consequences is High to Moderate; therefore the Risk is Very High. Based on this risk analysis the recommended treatment is to close the road until next summer and install warning signs. The rock fall hazard will be very high for at least 3 years.

(c) Consequences of the fire on values at risk – Geologic Values-at-Risk (VARs) all involve either a threat of causing injury or fatalities to people and/or substantial to moderate property damage. In some instances within the Rim Fire, the property damage potentially affected operations of hydroelectric facilities or water conveyance. VARs below slopes steeper than 39% which experienced moderate to high soil burn severity were often locations where rockfall activity was present due to loss of vegetation.

The soil burn severity was also an important element in the determining the potential for debris flow occurrence. Debris flow threat to VARs was evident from the modeled results (USGS). Like VARs initially seen as threatened by rockfall, some VARs which appeared at risk from debris flows were shown to be in locations where this threat was unlikely or only of minor consequence.

Several deep-seated landslides (including a rockfall) also were identified as potential geologic hazards. These deeper-seated landslides were likely to experience renewed movement, or more likely, movement on a part of the existing feature. This results from increased groundwater infiltrations into these features due to reduced

evapotranspiration and/or less intercepting foliage to rainfall events and snow accumulation.

II. Risk Assessment:

Summary:

D. Emergency Determination – An emergency exists for threat of life or injury to individuals using many segments of road and Preston, Andresen, Tuolumne River Canyon, and Indian Creek trails within the Rim Fire (see Geology VAR table in Appendix A for details). This threat stems from both rockfall and debris flow activity attributable to the changed conditions created by the wildfire. An emergency exists for the Kirkwood powerhouse and associated facilities near Early Intake due to rockfall hazard.

E. Treatments to Mitigate the Emergency

(a) Treatment Type – Notification and Warning Signs
(b) Treatment Objective - see Table 1
(c) Treatment Description– see Table 1
(d) Treatment Cost– see Table 1
(e) Probability of completing treatment in first year prior to damaging storms or events: The treatments for the emergencies identified for debris flows and rock falls are summarized and described in Table 1. The probability of completing the mitigating treatments prior to the damaging storm or event is 100%.
(f) Probability of treatment success: It is expected that the treatment will be 100% successful in the first year. For the second and third years, treatment may drop slightly to 95 to 90% depending on adjustments to closure timing or affected road length.

III. Discussion/Summary/Recommendations

Debris flows and rock falls are eminent in the Rim Fire Area. Rock fall hazard areas have been identified and reviewed in the field. Debris flow hazard areas have been identified with the aid of USGS Debris Flow Modeling. The debris flow modeling data was used to identify values at risk that have some potential of threats from debris flows. Treatments for debris flow and rock fall hazards include notification of the public of these hazards through warning signs and road closures.

IV. References

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V. Appendices

Table 2 – Geologic Hazard Value-at-Risk Detailed Assessment

#	GIS_ID (unique number)	Risk Type *(use dropdown)*	Risk Assessment Mag Con/Probability		Value at Risk	Potential Threat/Hazard Type *(dropdown is optional)*	Ownership *(use dropdown)*	Forest Sevice Treatment Method *(dropdown is optional)*
Forest Roads								
001	GEO_YS/DA/JD_001	Property	Mod/Unlikely	Low High	1N04 (Cottonwood Rd. @ Bear Creek)	Road failure due to colvert cloging from potential debris flows. Large rocks could move from flooding and block road pipe.	Forest Service	Treat boulders in channel to minimize risk of pipe blockage, possible blast rocks to decrease size.
002	GEO_YS/DA/JD_002	Property	Min/Unlikely	Very Low	1N04 (Cottonwood Rd. @ Jawbone Creek)	Road failure due to culvert clogging	Forest Service	
003	GEO_YS/DA/JD_003	Property	Maj/ Possible	High	1N96 (@ Granite Creek)	Road failure due to culvert clogging	Forest Service	Slope Treatment
004	GEO_YS/DA/JD_004	Property	Maj/ Possible	High	1N07 (@ Granite Creek)	Road failure due to culvert clogging	Forest Service	Slope Treatment
005	GEO_YS/DA/JD_005	Life / Property	Mod/Likely	High	3N01 North (below Rosasco Meadow)	Rock Fall	Forest Service	Rockfall hazard signs
006	GEO_YS/DA/JD_006	Life / Property	Mod/Likely	High	2N22 (Jawbone Falls Rd)	Rock Fall	Forest Service	Rockfall hazard signs
007	GEO_YS/DA/JD_007	Life / Property	Mod/Likely	High	1N04 (Cottonwood Rd)	Rock Fall	Forest Service	Rockfall hazard signs
008	GEO_YS/DA/JD_008	Life / Property	Maj/Very Likely	Very High	1N10 (Lumsden Rd.)	Rock Fall	Forest Service	Closure & Rockfall hazard signs
009	GEO_YS/DA/JD_009	Life / Property	Mod/Likely	High	1S66 & 1S13 (Pilot Ridge Roads)	Rock Fall	Forest Service	Rockfall hazard signs
010	GEO_YS/DA/JD_010	Life / Property	Mod/Likely	High	1N07 (Cherry Lake Rd.)	Rock Fall	Forest Service	Rockfall hazard signs
011	GEO_YS/DA/JD_011	Life / Property	Mod/Likely	High	1S02 (Mather Rd.) - two segments	Rock Fall	Forest Service	Rockfall hazard signs
Trails								
012	GEO_YS/DA/JD_012	Life / Property	Mod/Likely	High	Preston Trail	Rockfall	Forest Service	Trail Closure & Signs
013	GEO_YS/DA/JD_013	Life / Property	Mod/Likely	High	Andresen Trail	Rockfall	Forest Service	Rockfall hazard signs
014	GEO_YS/DA/JD_014	Life / Property	Mod/Likely	High	Golden Stairs Trail	Rockfall	Forest Service	Rockfall hazard signs
015	GEO_YS/DA/JD_015	Life / Property	Mod/Likely	High	Toulumne River Canyon Trail	Rockfall	Forest Service	Rockfall hazard signs
016	GEO_YS/DA/JD_016	Life / Property	Mod/Likely	High	Indian Creek Trail	Rockfall	Forest Service	Rockfall hazard signs
Campgrounds/Dayuse								

017	GEO_YS/DA/JD_017	Property	Min/Very Likely	Low	2 Campsites @ Sweetwater Campground	Flooding	Forest Service	None
018	GEO_YS/DA/JD_018	Life / Property	Mod/Likely	High	Rainbow Pool Day Use Area	Rockfall on access Rd.	Forest Service	Rockfall hazard signs
019	GEO_YS/DA/JD_019	Life / Property	Maj/Very Likely	Very High	Lumsden Campground	Rockfall	Forest Service	Camp Closure & Signs
USFS Misc.								
020	GEO_YS/DA/JD_020	Property	Mod/Likely	High	Access Rd. to Private Residence @ the Spinning Wheel area	Debris Flow	Private	Low water crossing
021	GEO_YS/DA/JD_021	Property	Min/Unlikely	Low	Cultural Resources at east Spinning wheel area	Erosion	Forest Service	None
022	GEO_YS/DA/JD_022	Property	Min/Unlikely	Low	Cultural Resources at west Spinning wheel area	None	Forest Service	None
023	GEO_YS/DA/JD_023	Property	Mod/Likely	High	Cultural Resources at north Spinning wheel area	Debris Flow	Forest Service	Filter Fabric
024	GEO_YS/DA/JD_024	Property	Mod/Unlikely	Low	Jawbone Station destroyed	None	Forest Service	None
025	GEO_YS/DA/JD_025	Property	Mod/Likely	High	Burnt Retaining wall @ 1N07 / 1N96	Plugged drainage i.e. culvert from slope failure	Forest Service	Rebuild Retaining wall or install k-rails & Sand bags
Downstream Lands								
026	GEO_YS/DA/JD_026	Property	Min/Unlikely	Very Low	Murphy Ranch	None	Private	None
027	GEO_YS/DA/JD_027	Property	Min/Unlikely	Very Low	River Ranch and Hacienda Campgrounds (adjacent)	None	Forest Service	None
028	GEO_YS/DA/JD_028	Property	Min/Unlikely	Very Low	Private Residence around Lee Price Camp	None	Private	None
029	GEO_YS/DA/JD_029	Property	Mod/Unlikely	Low	White Oak Creek Road	Debris Flow	Private	
030	GEO_YS/DA/JD_030	Property	Mod/Unlikely	Low	Moore Creek (Road 1S22) and Buck Loop Creek	None	Private	None
Private Lands								
031	GEO_YS/DA/JD_031	Property	(Hydro)		San Jose Family Camp structures	Flooding	Private	Notify land owner of potential flood hazard and notify NRCS

032	GEO_YS/DA/JD_032	Property	(Hydro)		Yosemite Riverside Inn Structures	Flooding	Private	Notify land owner of potential flood hazard and notify NRCS
033	GEO_YS/DA/JD_033	Property	(Hydro)		Hetch Hetchy road above Yosemite Riverside Inn	Flooding	Private	Notify land owner of potential flood hazard and notify NRCS
034	GEO_YS/DA/JD_034	Property	Maj/Very Likely	Very High	Hetch Hetchy Kirkwood Powerhouse and early intake facilities	Rock Fall	Private	Write a letter to Hetch Hetchy that recommends cleaning out existing rock fences and prepare for an increased amount of rock falls
035	GEO_YS/DA/JD_035	Property	Maj/Likely	Very High	Hetchy Hetchy Holm Powerhouse	Sedimentation / Debris flow	Private	Slope Treatment
036	GEO_YS/DA/JD_036	Property			Access Rd. to Hetch Hetchy Adit	None	Private	None
037	GEO_YS/DA/JD_037	Property	Mod/Posible	Inter.	Hetch Hetchy high-voltage Power Line Towers	Rock Fall	Private	Write a letter to Hetch Hetchy that identifies towers potentially at risk
038	GEO_YS/DA/JD_038	Property			Camp Mather	None	Private	None
039	GEO_YS/DA/JD_039	Property	(Soil Sci)		Backup Aqueduct paralleling Cherry Creek Rd	Sedimentation	Private	
040	GEO_YS/DA/JD_040	Property	Mod/Likely	High	1N07 (Cherry Lake Rd) north of 1N96	Sedimentation / Debris flow	Private	Write a letter to Hetch Hetchy that identifies potential risk & Slope Treatment. Install drop inlet snorkel, excavate basin to contain debris flow material.
041	GEO_YS/DA/JD_041	Property	Min/Unlikely	Very Low	Guinn Ranch buildings	Sedimentation / Debris flow	Private	None
042	GEO_YS/DA/JD_042	Property	Min/Unlikely	Very Low	Quinn Ranch buildings	Sedimentation / Debris flow	Private	None
043	GEO_YS/DA/JD_043	Property	Min/Unlikely	Very Low	Rogge Ranch buildings	Sedimentation / Debris flow	Private	None
044	GEO_YS/DA/JD_044	Property	Min/Unlikely	Very Low	Yosemite Lakes Campground facilities	Flooding / Debris flow	Private	None
045	GEO_YS/DA/JD_045	Property	(Hydro)		Harden Flat Mobile Home Park	Flooding	Private	None
046	GEO_YS/DA/JD_046	Property	(Hydro)		Berkeley-Tuolumne Camp	Flooding	Private	None
047	GEO_YS/DA/JD_047	Property	Min/Unlikely	Very Low	Myers Ranch	None	Private	None
048	GEO_YS/DA/JD_048	Property	Min/Unlikely	Very Low	Bull Meadow	Flooding / Debris flow	Private	None
049	GEO_YS/DA/JD_049	Property	Mod/Unlikely	Low	House at Ackerson Meadow	Flooding / Debris flow	Private	YNP is immediately above meadow.

050	GEO_YS/DA/JD_050	Property	Mod/Likely	High	Existing rockfall on 3N01 south of 1N04 junction	Rockfall	Forest Service	Clear some rock and position servicable k-rails to accommodate additional rock; warning signs
050	GEO_YS/DA/JD_050	Property	Mod/Likely	High	Existing rockfall on 3N01 south of 1N04 junction	Rockfall	Forest Service	Clear some rock and position servicable k-rails to accommodate additional rock; warning signs
051	GEO_YS/DA/JD_051	Property	Very Likely	Major	Potential debris flow across the following roads: 3N01, 1N07, 1N96, 1N10	Debris Flow Hazard	Forest Service	Install 8 debris flow and flood warning signs
052	GEO_YS/DA/JD_052	Property	Very Likely	Major	Potential debris flow across the following trails and areas: Entrance to the Spinning Wheel area; Andresen Trail – 1 at each trail head; -Small drainage just before Holm powerhouse (recommend no parking during storm events – debris flow warning); -Tuolumne River Trail – sign along a 1/3 miles section that states debris flow warning - no stopping during storm events.	Debris Flow Hazard	Forest Service	Install 8 debris flow and flood warning signs

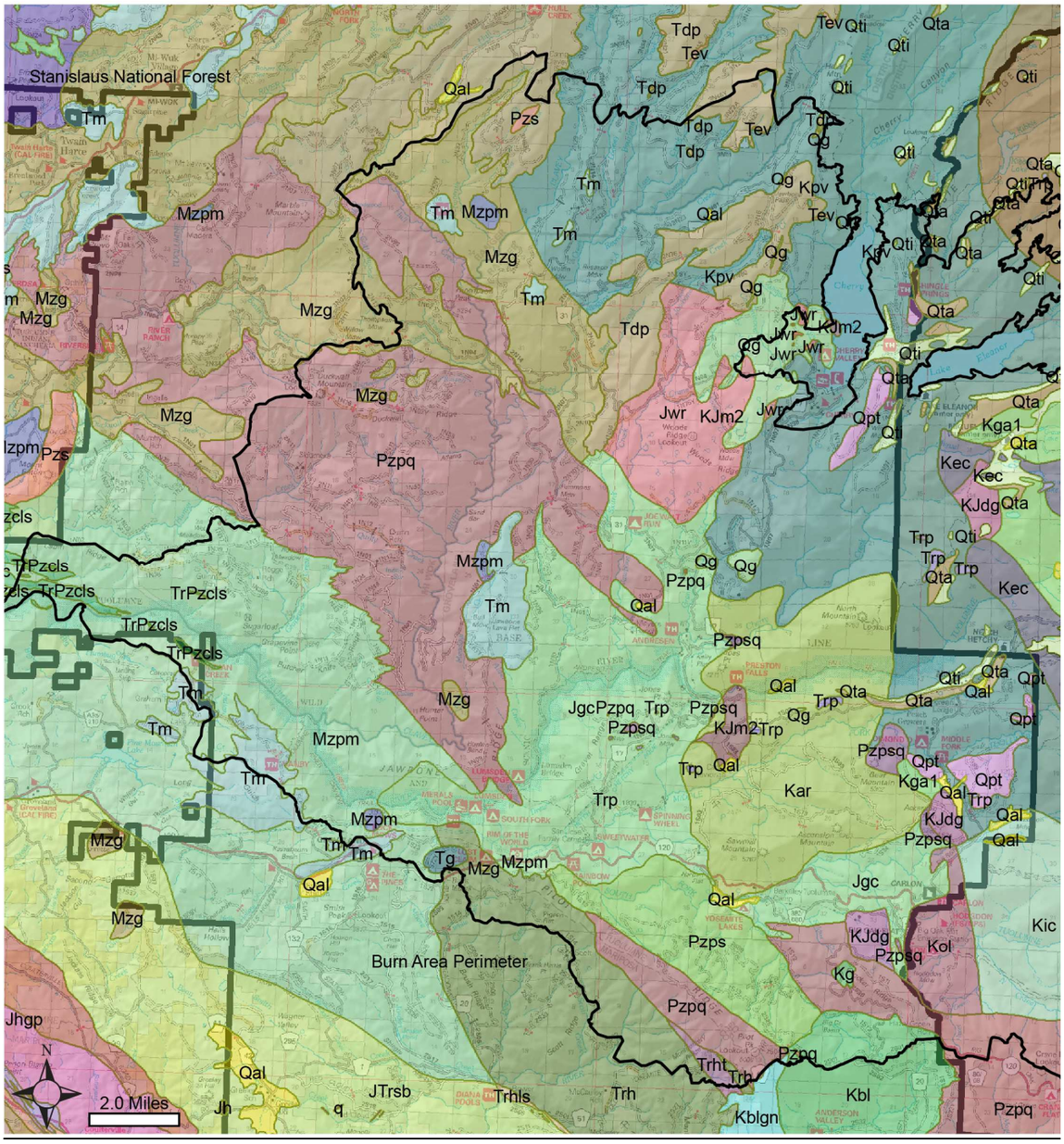

Figure 1 - Geologic map of the Rim Fire Area

Geologic Legend

- Qal - alluvium unit
- Qg - glacial unit
- Qpt - glacial, pre-Tahoe unit
- Qta - glacial, Tahoe age unit
- Qti - glacial, Tioga age unit
- Mzg - unnamed granitic plutons unit
- Mzpm - unnamed mafic plutons unit
- Tdp - Disaster Peak Formation formation
- Tev - Stanislaus Group unit, Eureka Valley Tuff u*
- Tg - unnamed alluvium unit
- Tm - Mehrten formation
- TrPzcls - Calaveras terrane
- Trh - Rhyolite Dikes
- Trht - Calaveras terrane, Hite Cove talc schist u*
- Trp - Relief Peak Formation unit
- KJdg - unnamed pluton
- KJm2 - mafic intrusive rocks unit
- Kar - Granodiorite of Arch Rock pluton
- Kbl - Granodiorite of Boundary Lake pluton
- Kec - El Capitan Granite pluton
- Kg - unnamed pluton
- Kga1 - Tonalite of the Gateway pluton
- Kic - Granodiorite of Illilouette Creek pluton
- Kol - Granodiorite of Ostrander Lake pluton
- Kpv - Granodiorite of Poopenaut Valley unit
- Jgc - Tonalite of Granite Creek pluton
- Jwr - Granite of Woods Ridge unit
- Pzpq - Pilot Ridge unit, quartzite subunit
- Pzps - Pilot Ridge unit, schist subunit
- Pzpsq - Pilot Ridge unit, schist and quartzite su*

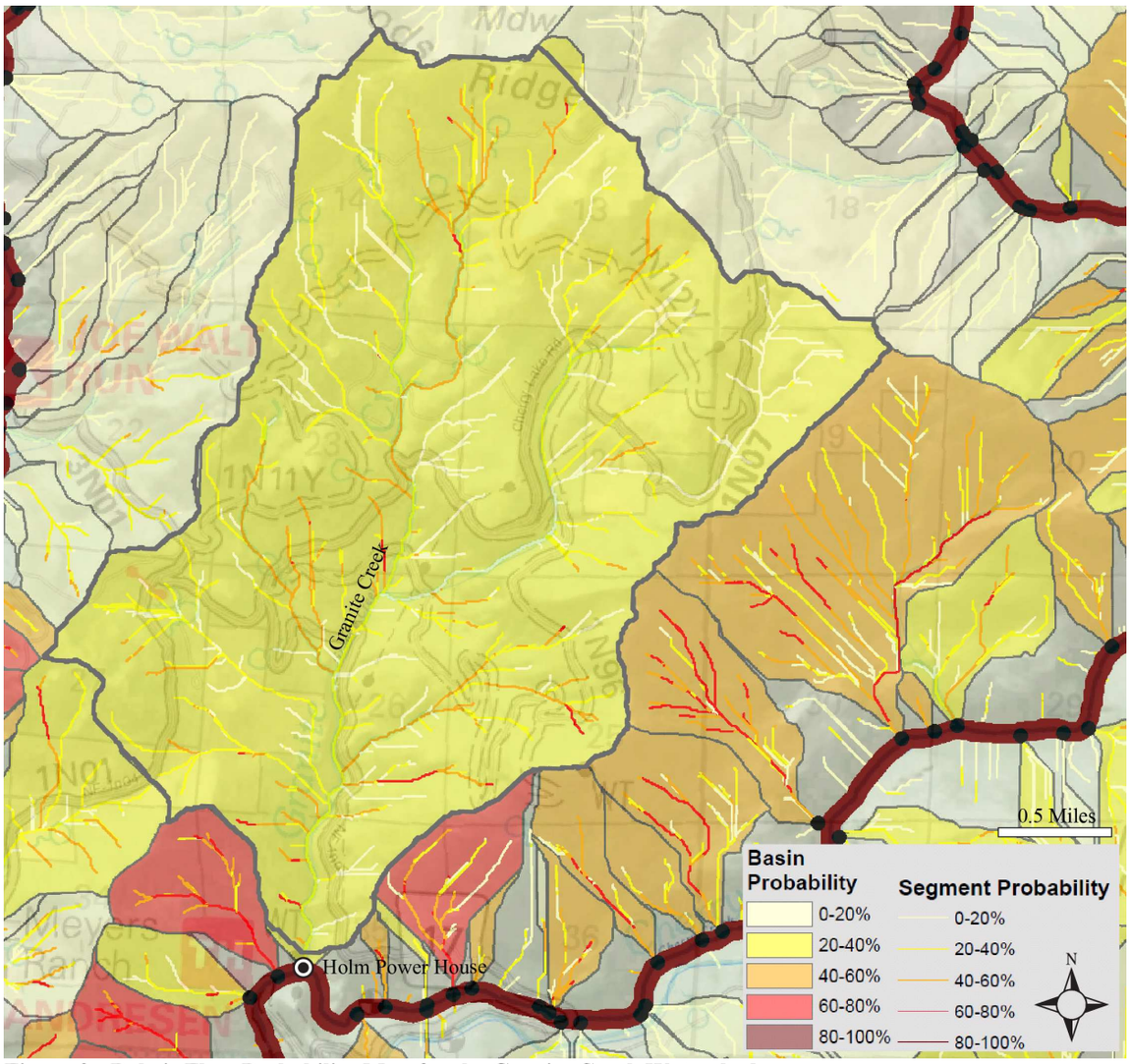

Figure 2 - Debris Flow Probability Map for the Granite Creek Watershed

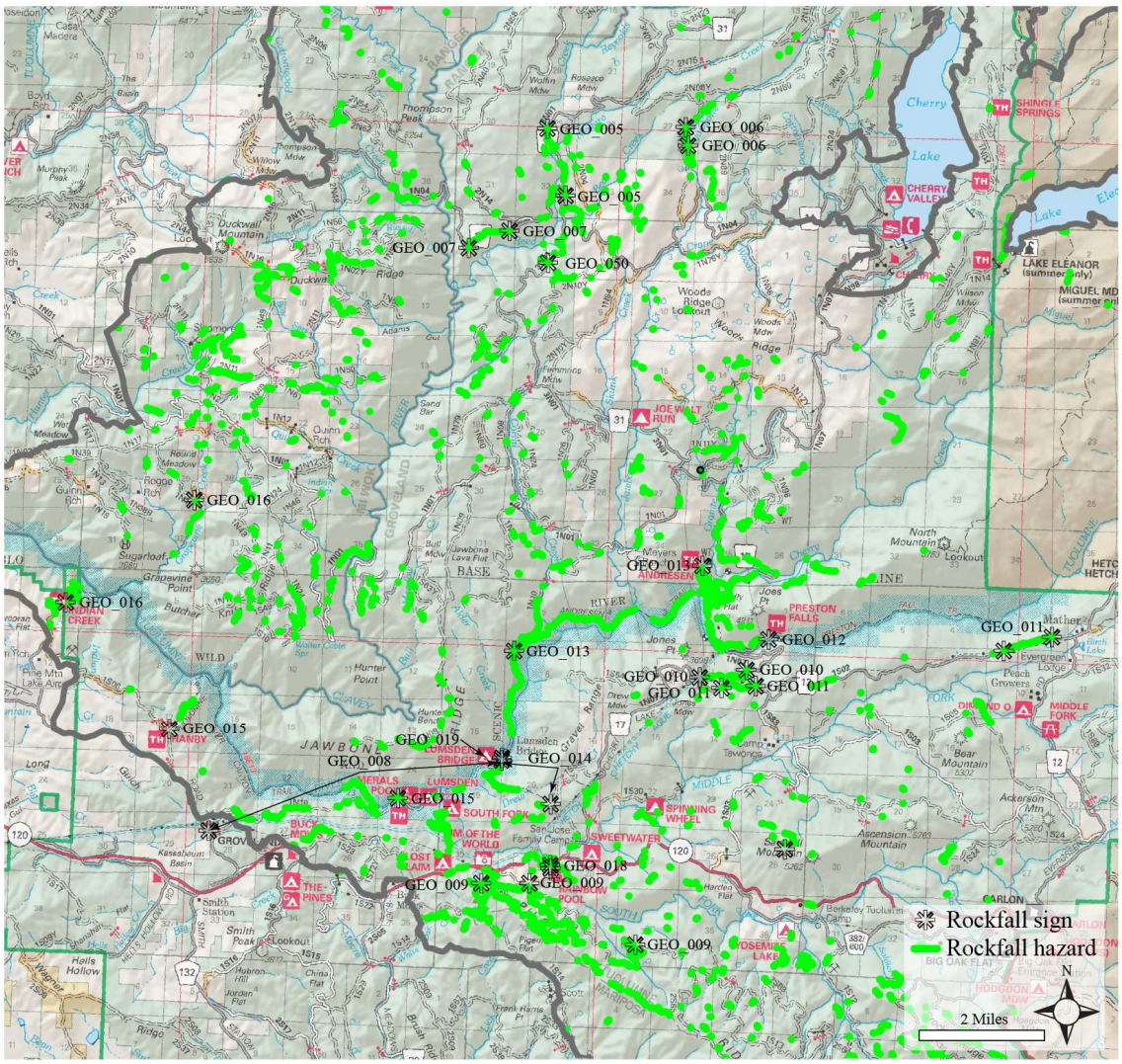

Figure 3 - Rockfall Hazards in the Rim Fire Area