Burned Area Emergency Response (BAER) Assessment
FINAL Specialist Report – GEOLOGIC HAZARDS

Erskine Fire – Sequoia N.F.

July, 2016

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Introduction

The Erskine Fire started on June 23, 2016, on the Kern River RD of the Sequoia N.F., Kern County, California. The fire burned a total of 48,019 acres, out of which 21,900 acres burned on National Forest lands, 17,370 acres burned on BLM lands, 8,620 acres burned on private lands and 97 acres burned on military lands. Out of a total of 48,019 acres, 343 acres were high soil burn severity, 20,716 acres were moderate soil burn severity, 21,556 acres were low soil burn severity and 5,405 acres were very low soil burn severity to unburned. The unburned acres refer to unburned areas within the fire parameter. This report describes and assesses the increase in risk from geologic hazards within the Erskine Fire burned area.

When evaluating Geologic Hazards, the focus of the "Geology" function on a BAER Team is on identifying the geologic conditions and geomorphic processes that have helped shape the watersheds and landscapes, and assessing the impacts from the fire on those conditions and processes that affect values at risk. Using that understanding of rock types and characteristics, geomorphic processes, and distribution of geologic hazards helps predict how the fire changed the watersheds that will be impacted during upcoming storm seasons. Within the Erskine Fire burned area, a high degree of slope failures as rock fall, rock slides and dry ravel activities have occurred in the past and will increase during future storms.

Fast moving, highly destructive debris flows triggered by intense rainfall are one of the most dangerous post-fire hazards. Protective vegetation is gone or altered and will not return to the same levels of protection for years. Soil is exposed and has become weakened, and surface rock on slopes has lost its supporting vegetation. Roads and trails are at risk from rolling rock and drainage flow out of control. Slopes will experience greatly increased erosion. Stream channels and mountainside ephemeral channels will be flushed of the sediment that in some places is loose and deep, in other places shallow. That sediment will deposit in some channels, choking flow, raising flood levels and covering roads with deep sediments. Risk to human life, infrastructure and natural resources are high in some areas.

Wildfire can significantly alter the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous debris flows, rock falls and debris slides. Debris flows and rock falls are the primary geologic hazards associated with burned watersheds (Santi et al., 2013; Parise and Cannon, 2012). Watersheds with steep slopes and significant amounts of moderate to high soil burn severity are especially likely to generate debris flows. The majority of debris flows exacerbated by wildfires usually occurs within 1-3 years after the watersheds are burned. Destructive debris flows bring side-slope materials and channel deposits racing down channel bottoms in a slurry similar to the consistency of concrete, in masses from a few hundred cubic yards to hundreds of thousands of cubic yards of saturated material.

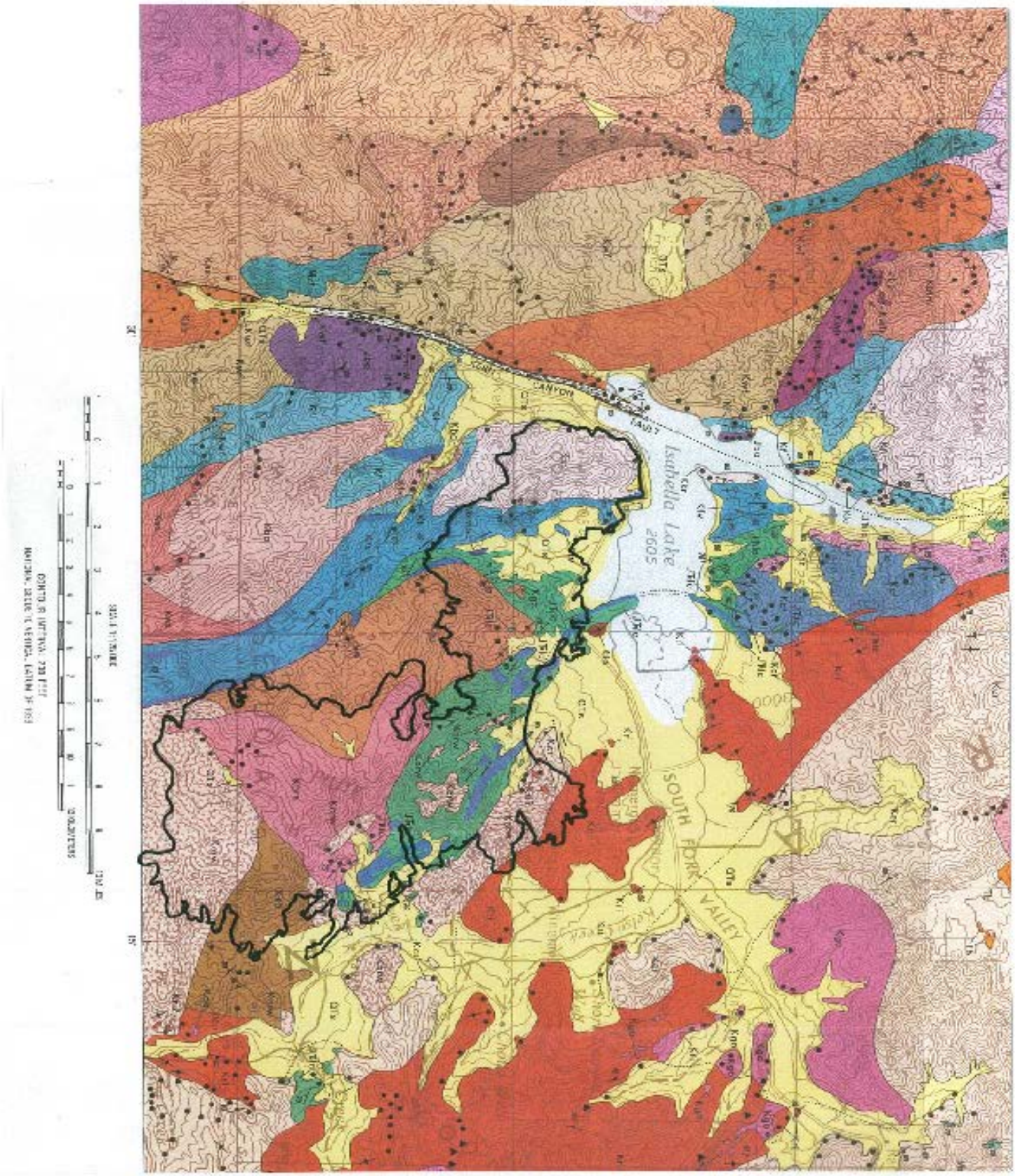
I. Resource Setting

Geology and Geomorphology: The Erskine Fire occurred in the Piute Mountains, which are part of the Southern Sierra Nevada Mountain Range. The Piute Mountains are a long, narrow mountain range with elevations ranging from 2,500 feet above sea level (Lake Isabela) to 8,400 feet above sea level at Piute Peak. The physiography of the Piute mountains is dominated by extremely steep slopes, all associated with watersheds flowing directly or indirectly into the Kern River and Lake Isabela.

The Erskine Fire is underlain by granitic and metamorphic rocks consisting of Granite of Kern River (Kkr), Granite of Bodfish Canyon (Kbo), Granite of Bob Rabbit Canyon (Kbra), Granodiorite of Goat Ranch (Kgc), Granodiorite of Rabbit Island (Kri), Granodiorite of Kelso Peak (Kkp), White rock facies Granodiorite (Kcrw), Metamorphic – Metasedimentary rocks, Long Canyon Metasedimentary rocks (Jtlc), French Gulch Meta-volcanic rocks (Kfv) and Marble lenses in several metasedimentary belts. Surficial deposits (QTs) in the burn area include surficial deposits of unconsolidated alluvial materials (Figure 1).

The Kern Canyon Fault which runs along the north-west corner of the burned area, bounds the Piute Mountains to the west.

Figure 1: Geology map



Surficial geologic rocks:

Geological map legend:

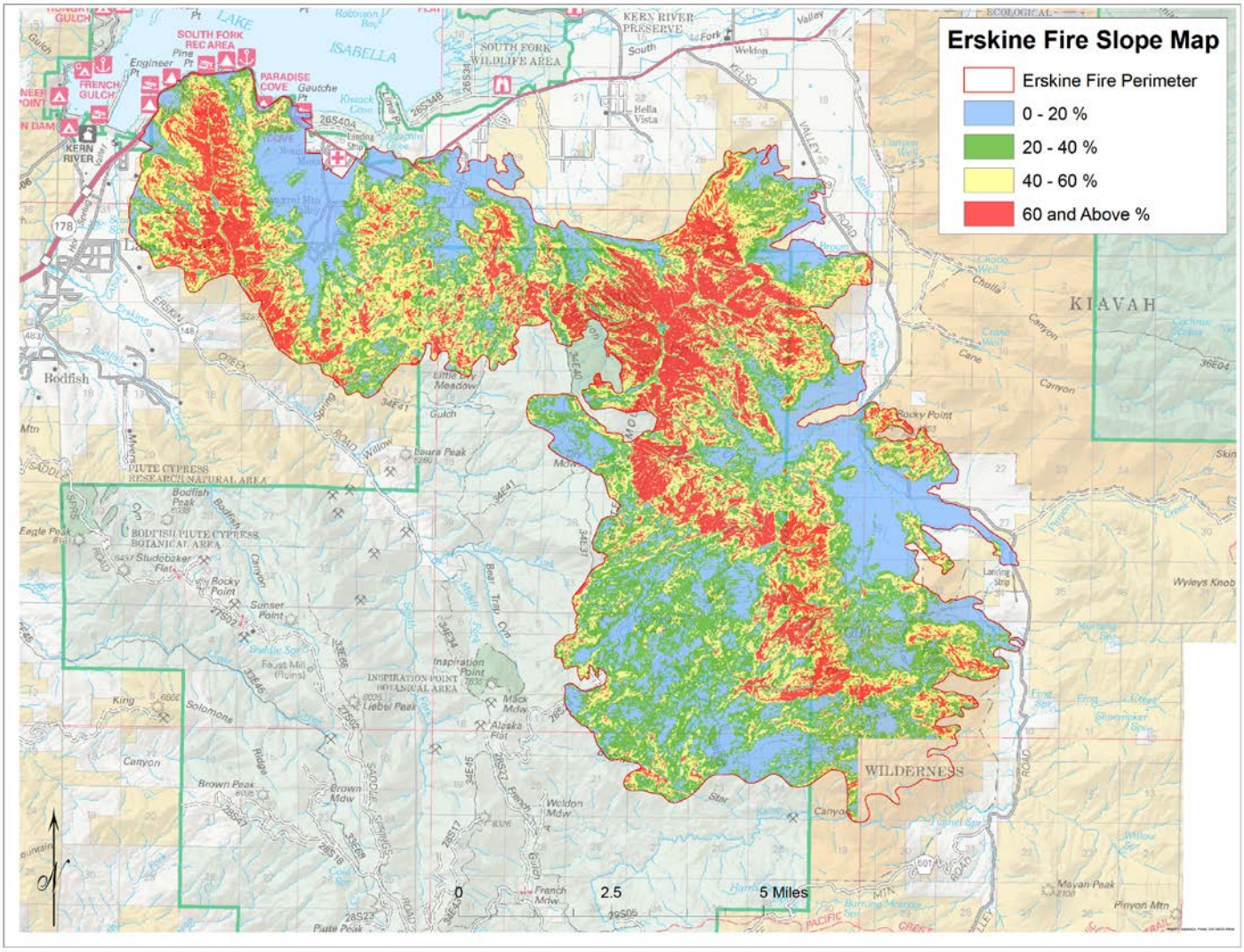
Landscape characteristics: The area of the Erskine Fire is characterized by dissected ridge lines and drainages flowing (directly or indirectly) mostly to Lake Isabella. The north drainages in the burned area flow north directly into Lake Isabela, while the majority of the other drainages in the burned area flow to the east into Kelso Creek which flows north into the South Fork of the Kern River, which in turn flows west into Lake Isabela. Elevations in the burned area range from about 2,500 feet above sea level (Lake Isabela) to over 6,900 feet above sea level (at Heald Peak) with slopes ranging from gentle (0-20%) to steep (>60%) slopes (Figure 2). The major creeks in the Erskine Fire area include: Yankee Canyon, Lynch Canyon creek, Goat Ranch Canyon creek and Long Canyon creek, all flowing directly into Lake Isabela, in addition to Dry Canyon creek, Bob Rabbit creek and Cortez creek, all flowing into Kelso creek which flows into Lake Isabela via the South Fork of Kern River. In the north-west corner of the burn area are three un-named creeks/drainages flowing from Cook Peak range west-north-west through the Lakeland Estate community of the town of Lake Isabela into the Kern River (Figure 3).

On the west facing high steep slopes of the Cook Peak range evidence of past rock-fall and debris slide is abundance. At the lower areas of these west facing slopes / mouth of the un-named drainages, massive debris flow deposits are frequent, while fluvial erosion processes have shaped the gentler valleys and ridges of other areas in the fire. Some areas show a great deal of slope dissection and slope instability, while other areas are amazingly smooth, un-dissected and devoid of instability features. Some channels were choked with rocks and sediment, while other channels were devoid of pre-fire sediment and rocks, but now are subject to filling with post-fire colluvial debris and rolling rock.

Findings / Observations

During ground surveys, a flight recon, and study of aerial photography, evidence of some past mass wasting was observed throughout parts of the burned area, while other areas reveled little to no evidence of mass wasting. From a flight recon and on-the-ground observations it is clear that some of the slopes and drainages in the burned area are loaded with unsorted, unconsolidated materials available to be transported. The majority of these slopes and drainages are in areas where the parent material is granitic rocks. In contrast to these area, other slopes and drainages in the burned area were void of any unconsolidated materials. These slopes and drainages corresponded, for the most case, to areas where the parent materials were metamorphic (meta-volcanic and meta-sedimentary) rocks.

Figure 2: Slope map



USGS Debris Flow Assessment:

In order to assess the probability and potential volumes of debris flows in the burned area the assistance of the US Geological Survey (USGS) - Landslide Hazards Program was obtained. Their ongoing research has developed empirical models for forecasting the probability and the likely volume of such debris flow events. To run their models, the USGS uses geospatial data related to basin morphometry, burn severity, soil properties, and rainfall characteristics to estimate the probability and volume of debris flows that may occur in response to a design storm (Staley, 2016). Estimates of probability, volume, and combined hazard are based upon a design storm with a peak 15-minute rainfall intensity of 12 – 40 millimeters per hour (mm/h) rate. After receiving the final Erskine Fire burn severity map, the USGS conducted a debris flow assessment of the fire area that

presented debris flow hazard classes, probability of occurrence, and volumes of materials occurring for multiple precipitation events.

We selected a design storm of a peak 15-minute rainfall intensity of 32 millimeters per hour (mm/h) rate to evaluate debris flow potential and volumes since this magnitude of storm seems likely to occur in any given year (Figures 10-12).

Debris flow probability and volume were estimated for each basin in the burned area as well as along the upstream drainage networks, where the contributing area is greater than or equal to 0.02 km^2, with the maximum basin size of 8 km^2.

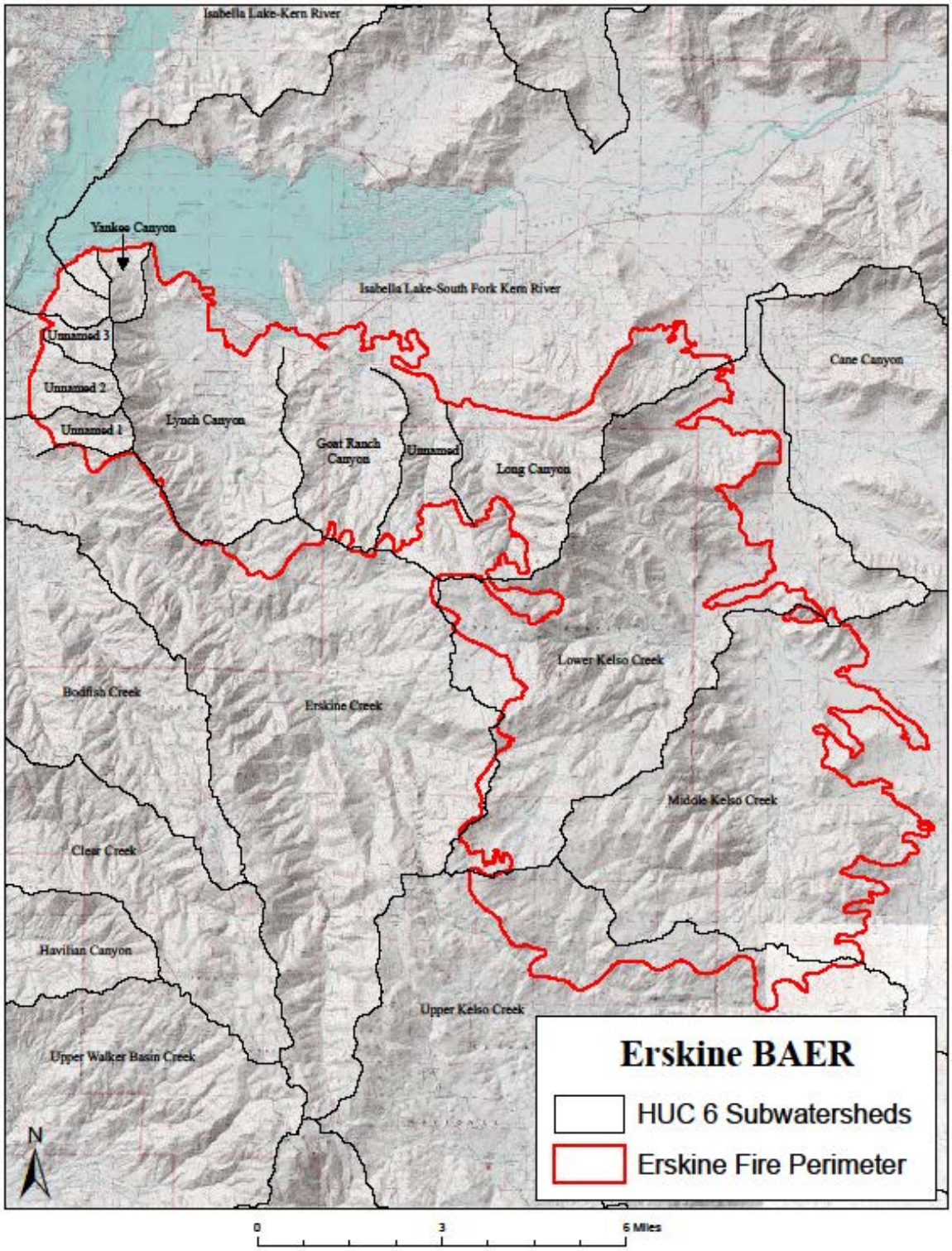
The **probability model** was designed to predict the probability of debris-flow occurrence at a point along the drainage network in response to a given storm. Probabilities predicted by the model potentially range from 0 (least likely) to 100 percent (most likely). The predicted probabilities are assigned to 1 of 5 equal (20 percent) interval classes for cartographic display.

The **volume model** was designed to estimate the volume (in m^3) of material that could issue from a point along the drainage network in response to a storm of a given rainfall magnitude and intensity. Volume estimates were classified in order of magnitude scale ranges 0–1,000 m^3; 1,000–10,000 m^3; 10,000–100,000 m^3; and greater than 100,000 m^3 for cartographic display.

Debris-flow hazards from a given basin can be considered as the combination of both probability and volume. For example, in a given setting, the most hazardous basins will show both a high probability of occurrence and a large estimated volume of material. Slightly less hazardous would be basins that show a combination of either relatively low probabilities and larger volume estimates or high probabilities and smaller volume estimates. The lowest relative hazard would be for basins that show both low probabilities and the smallest volumes.

Kean et al. (2013) and Staley et al. (2016) have identified that rainfall intensities measured over durations of 60 minutes or less are best correlated with debris-flow initiation. It is important to emphasize that local data (such as debris supply) influence both the probability and volume of debris flows. Unfortunately, locally specific data are not presently available at the spatial scale of the post-fire debris-flow hazard assessment done by the USGS. As such, local conditions that are not constrained by the model may serve to dramatically increase or decrease the probability and (or) volume of a debris flow at a basin outlet. In addition, at places were the soil burn severity was low – moderate, the model might under-estimate the potential for debris flows.

Figure 3: Watershed map



The major watersheds in the burned area (Figure 3 - following the HUC 6 Sub-watershed) include:

- An un-named watershed (Un-named drainage #1) which flows from Cook Peak Range down (west-north-west) through the Lakeland Estate community of the town of Lake Isabela and into the Kern River. This sub-watershed is part of the **Erskine Creek** watershed.
- Two un-named watersheds that flow from the Cook Peak Range down (west-north-west) to the Kern River through the Lakeland Estate community of the town of Lake Isabela, which are both part of the **Black Gulch-Kern River** watershed and include:
    - Un-named drainage #2 (middle one)
    - Un-named drainage #3 (further north)
- **Isabela Lake-South Fork Kern River** watershed, which include 5 sub-watersheds all flowing directly north into Lake Isabela. The sub-watershed include:
    - **Yankee Canyon** watershed (further west) -
    - **Lynch Canyon** watershed (second from the west) –
    - **Goat Ranch Canyon** (middle) watershed –
    - **Long Canyon** (further east) watershed –
    - And an un-named sub-watershed -
- **Lower Kelso Creek** watershed**,** which include:
    - Dry Canyon sub-watershed
    - Bob Rabbit Canyon sub-watershed
- **Middle Kelso Creek** watershed, which include:
    - **Cortez Canyon** sub-watershed

<u>The Erskine Creek watershed</u>:

The HUC 6 Erskine Creek watershed includes one un-named drainage (Un-named drainage #1) that flows from the Cook Peak range west down through the Lakeland Estate community of the town of Lake Isabella and into the Kern River. This whole watershed is underlain with granitic rocks of the Kern River formation and is loaded with unsorted, unconsolidated materials available to be transported. North facing slopes of the drainage experienced mostly moderate soil burn severity, while south facing slopes experienced mostly low and unburned soil burn severity (Figure 4). Rockfall, debris flows and occasional debris slides dominate the active slope processes and will be very active during high intensity storm events.

At the bottom of the drainage (the mouth of the drainage) is a large alluvial fan and on this fan are large elongated debris flow deposits. To the north of the alluvial fan is the current active channel (Figure 5), which based on local knowledge (residence) during winter storm flows all the way down to the road crossing, while during other times of the year has a sub-surface flow. On this alluvial fan are situated 14 houses (part of the Lakeland Estate community) which rely on private wells and are located high above the current active channel.

Based on past debris flows deposits, post fire soil burn severity, steep slopes and the amount of unconsolidated materials on the slopes and in the channels, this watershed (Un-named drainage #1) presents an eminent threat of debris flows and flooding to the Lakeland Estate neighborhood located at the mouth of this drainage.

Base on the USGS debris flow model, in an event of a design storm of a peak 15-minute rainfall intensity storm of 32 mm/h rate, the predicted probability of debris flow occurring in the main channel of un-named drainage #1 ranges from 20-60%, which potentially could initiate debris flows with volumes ranging from 1K-100K cubic meters and with a moderate debris flow hazard rating (see figures 10-12).

Black Gulch-Kern River watershed:

The Black Gulch-Kern River watershed is located at the north-west corner of the Erskine Fire and includes two un-named watersheds (Un-named #2 & #3). Both drainages flow directly from the Cook Peak range down west-north-west through the Lakeland Estate community of the town of Lake Isabella. Slopes above both drainages are extremely steep and experienced a mix of low and moderate soil burn severity. Just as with the un-named drainage (Un-Named drainage #1) of the Erskine Creek watershed (above), both un-named watersheds are underlain with granitic rocks of the Kern River formation and are loaded with unsorted, unconsolidated materials available to be transported by debris flows. Rockfall, debris flows and occasional debris slides dominate the active slope processes and will be very active during high intensity storm events.

At the bottom of both un-named drainage (the mouth of the drainages) are large alluvial fans which once again present large to very large elongated debris flow deposits (Figure 6). Based on the steep slopes above these drainages, the amount of unsorted, unconsolidated materials on the slopes and in the channels, the soil burn severity and debris flows deposits located at the bottom of these drainages, the probability of debris flows and flooding occurring in these drainages is high. Based on the location of houses and structures in both watersheds it seems that the probability of direct impact from debris flows and flooding is moderate to high.

Base on the USGS debris flow model, in an event of a design storm of a peak 15-minute rainfall intensity storm of 32 mm/h rate, the predicted probability of debris flow occurring in the main channels of un-named drainage #2 ranges from 60-80% (with some side channels ranging from 80-100%), which potentially could initiate debris flows with volumes ranging from 1K-100K cubic meters and with a high debris flow hazard rating. In comparison to un-named drainage #2, un-named drainage #3 is predicted to produce debris flows with lower probabilities and smaller volumes (see figures 10-12).

Figure 4: Soil Burn Severity map

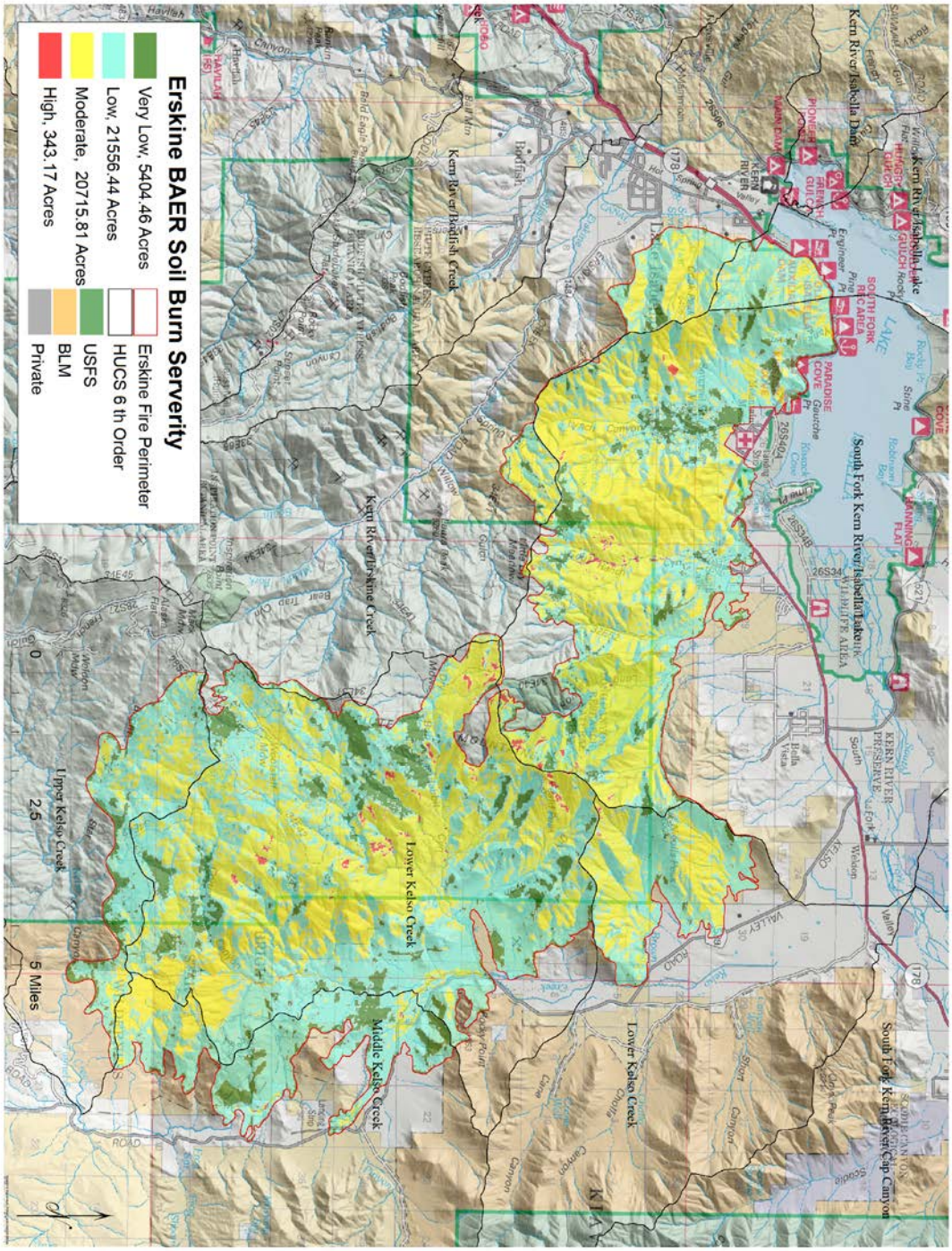


Figure 5: Active channel and debris flow deposits at the bottom of Un-named drainage #1

Figure 6: Large debris flow deposits at the bottom of Un-named drainage #2

Isabela Lake-South Fork Kern River watershed:

This watershed includes 4 sub-watersheds (all flowing directly north into Lake Isabela) is underlain by granitic and metamorphic rocks which produce very different slope and surface texture. The watershed as a whole experienced a mix of low, moderate and high soil burn severity.

The Yankee Canyon watershed is a relatively small watershed but with very steep slopes above it littered with granitic boulders of all sizes. High in this watershed is a neighborhood with about 40 houses scattered all over the watershed. A debris flow deposit is situated right in the middle of this neighborhood (Figure 7) which could very likely be the route of some post fire debris flows, potentially impacting houses and structures. In addition, an under-size culvert (24') is located under a new paved road on the main creek which could very likely get plugged and flood the road.

Base on the USGS debris flow model, in an event of a design storm of a peak 15-minute rainfall intensity storm of 32 mm/h rate, the predicted probability of debris flow occurring in the main channel of the Yankee Canyon drainage ranges from 20-40% (with some side channels ranging from 60-80%), which potentially could initiate debris flows with volumes ranging from 1K-10K cubic meters and with a moderate debris flow hazard rating (see figures 10-12).

Figure7: Debris flow deposit – Yankee Canyon

At the bottom of the Lynch Canyon watershed are located the communities of Mountain Mesa and Squirrel Mountain Valley. From these community there is a dirt road (Cook Peak road) that goes all the way up to the Cook Peak communication site. This road crosses through both granitic and metamorphic rock types, which respond very differently to roads and trails. The rocks underlain the first ¾ of the slope are meta-volcanic rocks of the French Gulch meta-volcanic formation (Kfv), while the top ¼ of the slope is underlain by the granite rocks of the Kern River formation (Kkr).

The road portions underlain by meta-volcanics are not highly erosive, but through steep side-slopes can have significant rockfall. The road tread often is solid bedrock which can wear to somewhat rocky, uneven surfaces. The road portions underlain by granitics tend to gully and rut, and are highly eroded by water flow on the surface. Increased flows from the moderate severity burn will increase damage to the road unless drainage structures are improved before winter rains. Out-sloping of sections with a grade less than 6%, rolling dips, and properly sized and armored culverts could help winterize the road as a whole and improve drainage and drivability.

Metamorphic hillslopes above and below the road appear extremely smooth with no evidence of math wasting or gully features (Figure 8), but now that vegetation along these slopes is mostly burned some excessive sedimentation from the slopes down to the creeks bellow is expected. As a result of winter storms, sediments from these burned slopes ending in the creeks bellow will eventually make their way down to road crossing which might plug culverts and cause road failure. Granitic hillslopes above and below the road produce very rocky slopes with loaded channels of unconsolidated materials.

From the top of the community of Squirrel Mountain Valley there is a dirt road system that goes up Lynch Canyon all the way to the top of the ridge. The current condition of this road and the culverts under this road are poor. Increased flows from post fire burn severity will increase damage to the road. Without appropriate maintenance and preparation of the road for winter storms some culverts will plug and portions of the road might fail.

Base on the USGS debris flow model, in an event of a design storm of a peak 15-minute rainfall intensity storm of 32 mm/h rate, the predicted probability of debris flow occurring in channels of the Lynch Canyon watershed ranges all the way from 20-80% (with some side channels ranging from 80-100%), which potentially could initiate debris flows with volumes ranging from 1K-100K cubic meters and with moderate-high debris flow hazard rating (see figures 10-12).

Figure 8: Smooth meta-volcanic slopes above and below the Cook Peak road

At the bottom of the Goat Ranch canyon watershed is located the community of South lake. On the east side of the community flows the active channel of Goat Ranch creek. A private road that is located above the main community and functions as a main access to some private properties located higher in the watershed crosses the Goat Ranch creek over a 48” culvert. The Goat Ranch creek is loaded with sediments and some unconsolidated materials (Figure 9). Due to post fire high flow conditions might plug this culvert which in turn might cause the road to fail. Beyond this specific culvert, private properties located higher up the watershed might experience some flooding and excessive sedimentation/debris on their properties due to moderate soil burn severity and steep slopes associated with post fire conditions.

Figure 9: Sediments and un-consolidated materials up Goat Ranch creek

Base on the USGS debris flow model, in an event of a design storm of a peak 15-minute rainfall intensity storm of 32 mm/h rate, the predicted probability of debris flow occurring in channels of the Goat Ranch watershed ranges all the way from 40-80% (with some side channels ranging from 80-100%), which potentially could initiate debris flows with volumes ranging from 1K-100K cubic meters and with moderate-high debris flow hazard rating (see figures 10-12).

Due to limited values at risk and limited time, Long Canyon and the un-named watershed in the Isabela Lake-South Fork Kern River watershed was not evaluated on the ground

Lower and Middle Kelso Creek watershed:

The Lower and Middle Kelso Creek watershed**,** which include the Dry Canyon sub-watershed, the Bob Rabbit Canyon sub-watershed and the Cortez creek sub-watershed are underlain by granitic and metamorphic rocks which once again, produce very different slope and surface texture. Major portions of the Kelso Creek watershed include surficial deposits of unconsolidated alluvial sedimentary rocks which includes down in the Kelso creek-bed, thick deposits of course sandy materials – product of de-composed granite. Just as other watersheds in the burn area the majority of the watershed experienced a mix of moderate to low soil burn severity.

Based on ground surveys it is clear that the majority of private houses and structures in this area of the fire are located high above the Holocene terrace or above the 100 year flood plain. In cases were private houses/structures are located below the 100 year flood plain, flooding is a concern. Other values at risk that should be of concern under these new post fire conditions include the Kelso Valley Road, especially at locations were the road crosses the Kelso Creek and other dirt roads going off the Kelso Valley creek and crossing either the Kelso creek itself or side tributes.

Base on the USGS debris flow model, in an event of a design storm of a peak 15-minute rainfall intensity storm of 32 mm/h rate, the predicted probability of debris flow occurring in channels of the Kelso Creek watershed ranges all the way from 0-40% (with some side channels ranging from 60-80%), which potentially could initiate debris flows with volumes ranging from 1K-100K cubic meters and with low - moderate debris flow hazard rating. In general, channels in the middle Kelso Creek watershed are predicted to produce debris flows with lower probability and smaller volumes in comparison to channels in the lower Kelso Creek watershed (see figures 10-12).

The three maps below displays estimates of the likelihood of debris flow (in %), potential volume of debris flow (in m3), and combined relative debris flow hazard. These predictions are made at the scale of the drainage basin, and at the scale of the individual stream segment. Estimates of probability, volume, and combined hazard are based upon a design storm with a peak 15-minute rainfall intensity of 32 millimeters per hour (mm/h).

Figure 10: Debris Flow Probability prediction based on a peak 15-minute rainfall intensity storm of 32 mm/h rate storm

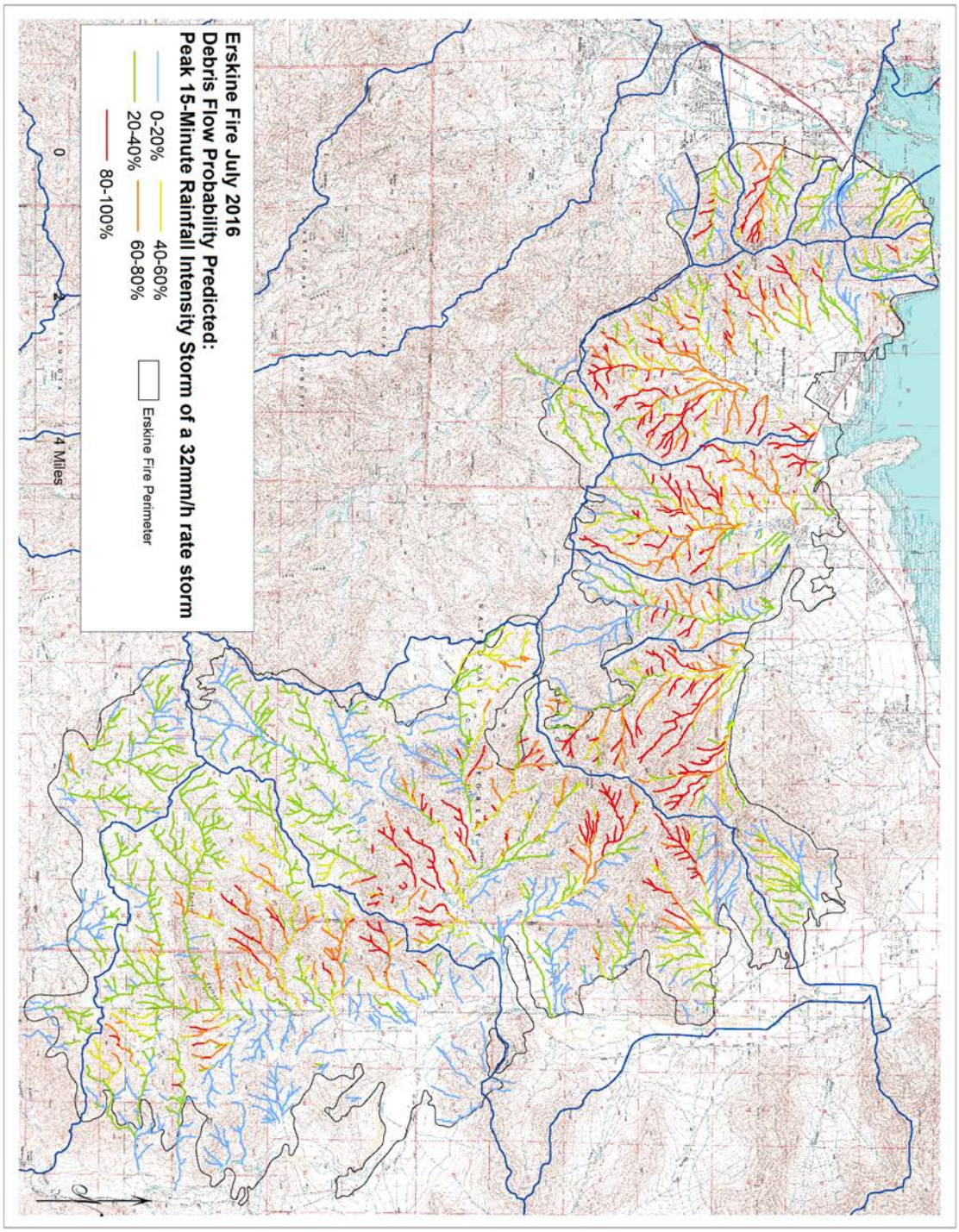


Figure 11: Debris Flow Volume prediction based on a peak 15-minute rainfall intensity storm of 32 mm/h rate storm

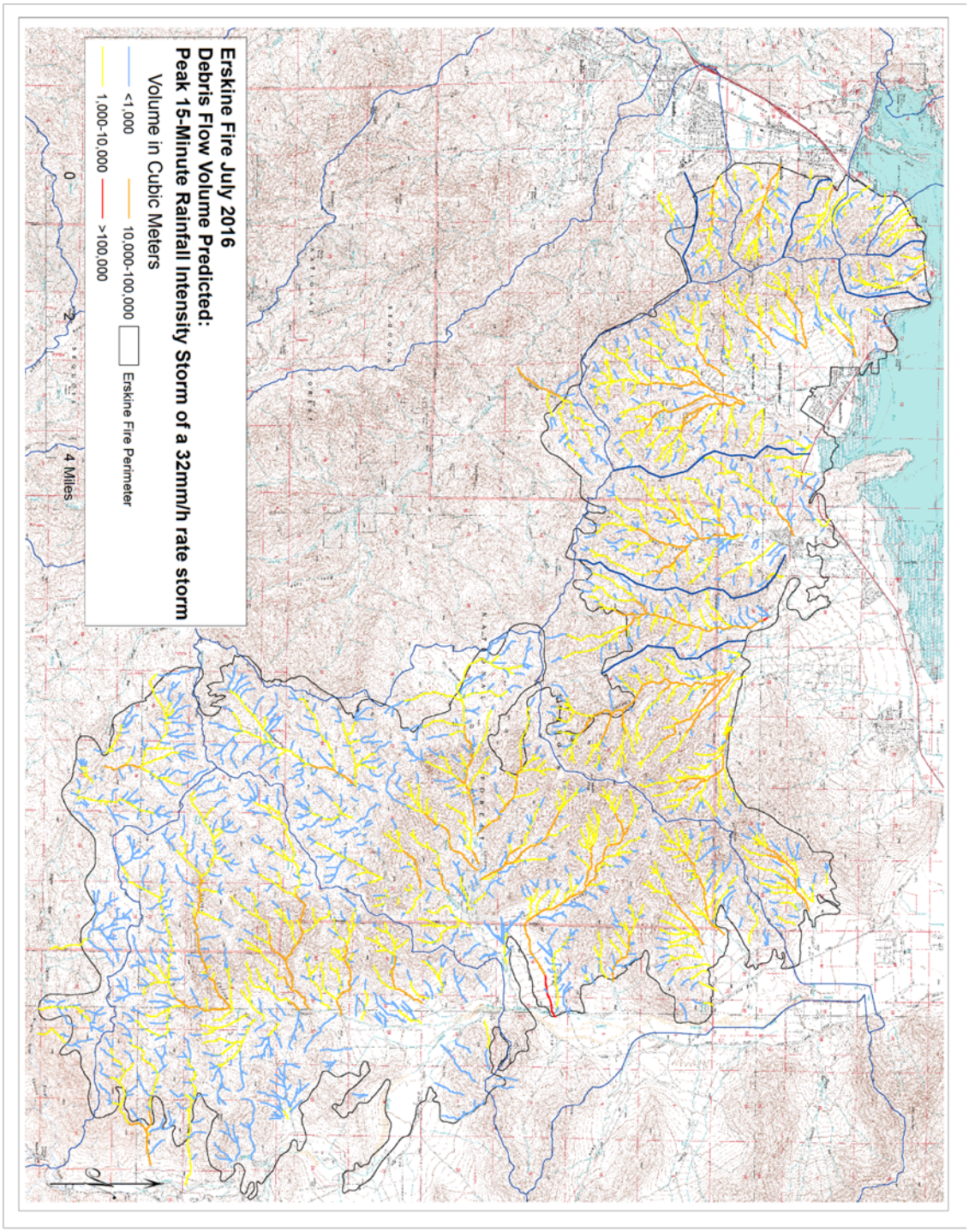
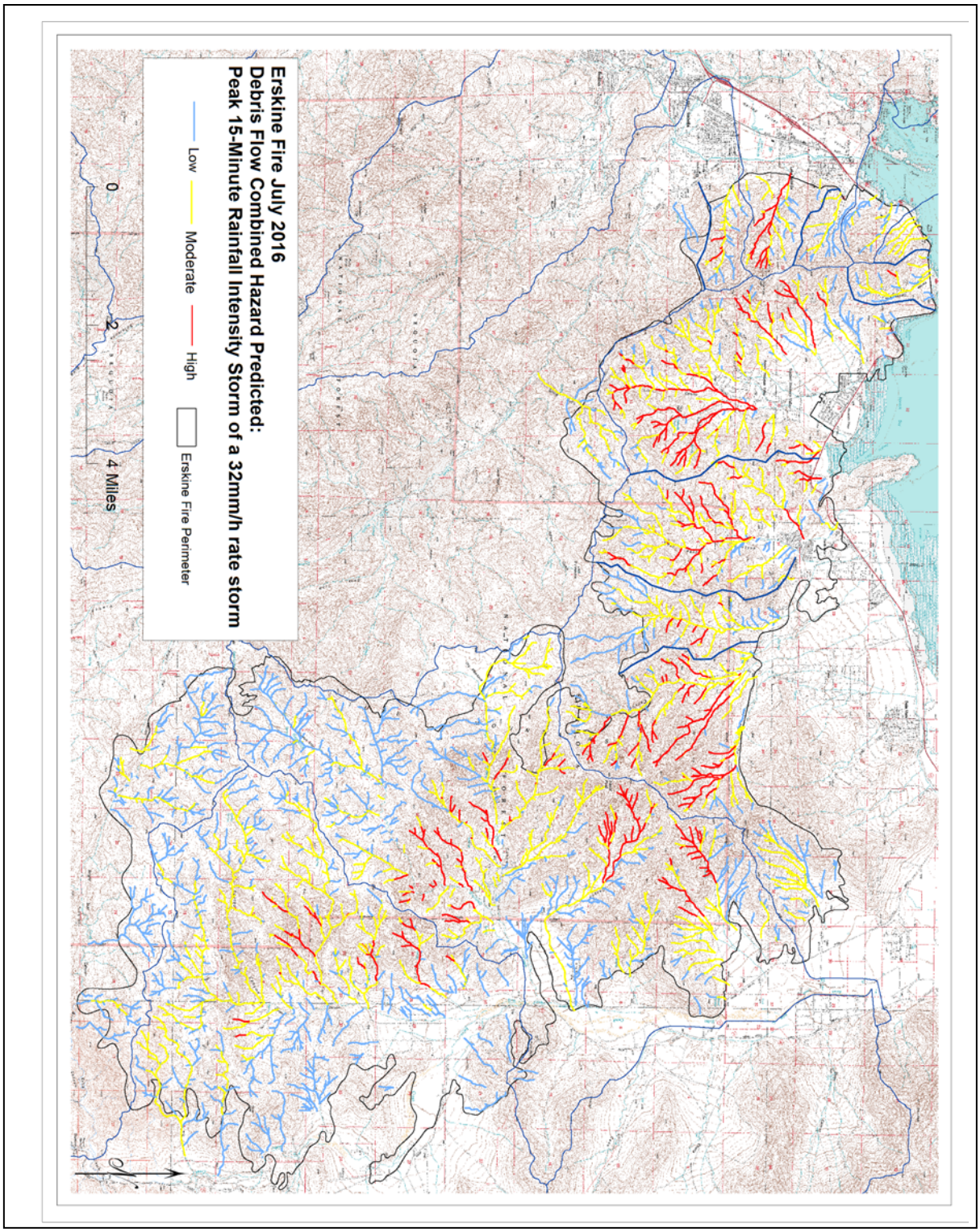


Figure 12: Debris Flow Combined Hazard prediction based on a peak 15-minute rainfall intensity storm of 32 mm/h rate storm



Resource Conditions Resulting from the Fire

Assessment of the Erskine Fire showed that susceptibility to slope instability will be associated with watersheds within the fire that have significant volumes of sediment in the channels or are likely to experience increases in sediment volume from fire-affected slopes. Sediment increases would be associated with significant areas of susceptible bedrock that were subjected to high or moderate burn severity. The basis for this assumption is a research on wildfire-generated debris flows, which can be extrapolated to other types of slope movement. Rather than being the result of infiltration-induced slope movements into the channels, wildfire-generated debris flows are a result of progressive bulking of storm flow with sediment within the channel and washed from the adjacent slopes (Cannon, 2000, 2001). As Cannon and others (2003) state:

> **"Wildfire can have profound effects on a watershed. Consumption of the rainfall-intercepting canopy and of the soil-mantling litter and duff, intensive drying of the soil, combustion of soil-binding organic matter, and the enhancement or formation of water-repellent soils can result in decreased rainfall infiltration into the soil and subsequent significantly increased overland flow and runoff in channels. Removal of obstructions to flow (e.g. live and downed timber, plant stems, etc.) by wildfire can enhance the erosive power of overland flow, resulting in accelerated stripping of material from hillslopes. Increased runoff can also erode significant volumes of material from channels. The net result of rainfall on burned basins is often the transport and deposition of large volumes of sediment, both within and down-channel from the burned area."**

II. Potential Values at Risk

The following "values at risk" (VARs) are threatened by debris slides and flows, rockfall, or flooding augmented by the effects of the fire on steep, erosive and unstable slopes and water channels.

Human Life and Safety:

- People living and or traveling through and below burned areas – Loss of life or injury could take place as a result of debris slides and flows, rockfall, or flooding in and below the burned area.

Property:

- Private properties located below Cook Peak Ridge and in other communities below the burned area, roads, trails, and drainage systems – As a result of the fire, excessive runoff and flows. In addition, stability of slopes over roads systems and trails will be compromised. Debris slides and flows, rockfall, and flooding will cause damage to

these systems and might cause damage to other private properties located below the burned area.

Natural Resources:

- Water quality, riparian sustainability and downstream uses – As a result of the fire, excessive sedimentation will adversely affect water quality in some of the creeks flowing into the Kern River and Lake Isabela Reservoir.

Specific Values At Risk (VAR's):

Specific VAR's that were identified and assessed by the BAER Team geologist include: The Lakeland community of the town of Isabela, the Yankee Canyon community and other residential properties located below and in the burned area, road and creek crossing in and below the burned area and wells and water tanks in and below the burned area.

III. Emergency Determination

The emergency to VARs from geologic hazards caused by the fire includes adverse effects to the health and safety of people, property, roads, trails and natural resources. Risk of loss of life and limb is of particular concern.

IV. Treatments to Mitigate the Emergency

The BAER Team Geologist / Geomorphologist was involved in numerous discussions with other team members about what treatments could be effective to mitigate potential impacts from the various watershed responses that endanger downstream values at risk. Most treatments are being proposed by other functions such as hydrology, soils and engineering. To conclude we would recommend that a warning system put in place to alert residences of the Lakeland Estate community, the Yankee Canyon community and other communities downstream / down slope of burned areas for potential flooding and debris flows in advance of any storm over a peak 15-minute rainfall intensity of 16 millimeters per hour (mm/h) rate.

V. Discussion / Summary / Recommendations

Rock-fall and debris slides are eminent along some steep slopes below the Cook Peak Ridge. Drainages in this same area have been identified in the field for potential debris flow hazard zones. With the aid of USGS Debris Flow Modeling, debris flow probabilities and potential volumes have been calculated.

Based on our field observations, our conclusion is that whether the primary post-fire process is rockfall, debris slides, debris flows or sediment laden flooding, the cumulative risk of various types of slope instability, sediment bulking and channel flushing is high along slopes and creeks flowing down from the Cook Peak ridge. Even though the USGS modeling presents low-moderate (20%-60%) probability of debris flows in the majority of drainages flowing down from the Cook Peak ridge, based on ground and aerial observations (quantities of rocky materials available to be transported and steepness of slopes and channels) we estimate that the majority of drainages in this area have moderate to high potential to produce debris flows. Conversely, even though other areas of the Erskine Fire present high probabilities of producing debris flows, no direct impact to Values At Risk (VAR) are expected in some of those remote drainages.

Treatments for debris flow and flooding hazards include notification of the public of these hazards through a warning system and installation of warning signs along roads in the burn area.

Following the Erskine Fire segments of the Cook Peak road will experience excessive rock-fall, potential debris flows and erosion. In order to prevent as much erosion and damage to the road surface as possible it is recommended to take some actions (storm proofing) before the first winter-storms arrive. Specific recommendations/treatments are described in the engineering report.

Conclusions from the USGS Debris Flow Assessment:

Based on USGS debris flow modeling, basins / creeks in the Erskine Fire burned area have a wide range of probability (0-100%) of producing debris flows. Similarly, predicted volumes of debris flows through-out the burned area range from 1k – 100k cubic meters. From analyzing the combined hazard maps, it is clear that even though high hazard debris flows drainages exists through-out the burned areas, the concern areas are focused on the creeks and drainages flowing down from the Cook Peak range, as well as other burned slopes and drainages located directly above existing communities and private residences. Beyond these high concern areas, other drainages that have a moderate-high probability of producing debris flows, are not expected to impact directly any Values At Risks (VAR's).

Final Thoughts:

When evaluating Geologic Hazards, the focus of the "Geology" function on a BAER Team is to identify the geologic conditions and geomorphic processes that have helped shape the watersheds and landscapes, and to identify where the effects of the fire resulted in adverse changes to geologic processes that then affect Values at Risk. Using that understanding of rock types and characteristics, geomorphic processes, and distribution of geologic hazards can help others understand the conditions and processes that affect their areas of concern and predict how the fire changed the watersheds that will be tested during upcoming storm seasons. Within the Erskine Fire area, some sub-watersheds show a great deal of past debris slide, and rockfall activity that will be increased during future storms. Other areas have little evidence of recent past slope instability, but conditions have changed due to the fire.

Protective vegetation is gone and will not return to the same levels of protection for years. Soil is exposed and has become weakened, and rock on slopes has lost its supporting vegetation. Roads and trails are at risk from rolling rock and drainage flow out of control. Slopes will experience greatly increased erosion. Stream channels and mountainside ephemeral channels will be flushed of the sediment that in some places is loose and deep, in other places shallow. That sediment will deposit in some channels, completely choking flow and raising flood levels and covering roads with deep sediment.

Much discussion occurs during BAER assignments about how specialists seldom get to return to burn areas to evaluate how their estimates of watershed response and effectiveness of treatments actually turned out. Our final recommendation is to establish an annual requirement, just as is the fire refresher and walk/pack test, that in order to be a qualified for future BAER assignments, a specialist must attend a field monitoring and assessment session, minimum of 3 days, at least once (and preferably much more often) every two years. Without this kind of learning experience, we are likely to keep making the same mistakes over and over, and not truly understand the physical processes we are trying to manage.

We recommend that the Region and local Forests support and require BAER Team specialists, especially those evaluating and making costly treatment recommendations about watershed response issues, to return as an IDT with other experts in their field, to the same burned area they evaluated, one and/or two years later to monitor and analyze the effects of winter storms and of implemented treatments. We believe that more learning will occur from this experience than from weeks of office study and training sessions.

References

Cannon, S.H., 2000, Debris-flow response of southern California watersheds recently burned by wildfire, *in* Wieczorek, G.F., and Naeser, N.D, eds., Debris-Flow Hazards Mitigation, Mechanics, Prediction, and Assessment, Proceedings of the Second International Conference on Debris-Flow Hazards Mitigation, Taipei, Taiwan, 16-18 August 2000: A.A. Balkema, Rotterdam, p. 45-52.

Cannon, S.H., 2001, Debris-Flow Generation From Recently Burned Watersheds, in Environmental & Engineering Geoscience, Vol. VII, No. 4, , pp. 321-341.

Cannon, S.H., Gartner, J.E., Rupert, M.G. and Michael, J.A., 2003, Emergency Assessment of Debris-Flow Hazards from Basins Burned by the Piru, Simi, and Verdale Fires of 2003, Southern California. U.S. Geological Survey Open-File Report OF-03-481.

Cannon, S.H., 2009, Emergency Assessment of Postfire Debris-Flow Hazards, King Fire, Southern California. U.S. Geological Survey Administrative Report, 15 p.

Gartner J.E., Cannon S.H., Santi P.M., 2014 Empirical models for predicting volumes of sediment deposited by debris flows and sediment-laden floods in the transverse ranges of southern California, Engineering Geology 176:45-56, doi:http://dx.doi.org/10.1016/j. enggeo.2014.04.008

Keller, E.A., Valentine, D.W., Gibbs, D.R., 1997, Hydrological response of small watersheds following the southern California Painted Cave Fire of June, 1990. Hydrological Processes 11, 401-414p.

King, A., 2003, Geologic Hazards of the Piru Fire, Los Padres National Forest, USDA, Unpublished Burn Area Emergency Rehab (BAER) Report, 14 p.

King, A., and Keller, G., 2003, Stabilization of Roadside Berms on Squaw Flat Road, Unpublished addendum to Piru Fire BAER Report, 2 p.

Jennings, W.C., 1975, Fault Map of California, California Division of Mines and Geology, scale 1:750,000

National Oceanics and Atmospherics Administration (NOAA), ‘NMME Probability Forecasts of Monthly Climate Anomalies For: September 2015 – March 2016’, National Weather Service Climate Prediction Center Website.

Santi, P., Cannon, S., De Graff, J. (2013) Wildfire and landscape change, In Shroder, J. (Editor in Chief), James, L.A., Harden, C.P., Clague, J.J. (eds.), Treatise on Geomorphology. Academic Press, San Diego, CA, Vol. 13, Geomorphology of Human Disturbances, Climate Change, and Natural Hazards, pp. 262–287.

Staley, Dennis M. (2013) Emergency Assessment of Post-Fire Debris-Flow Hazards for the 2013 Rim Fire, Yosemite National Park and Stanislaus National Forest, California. Open-File Report 2013-XXXX, United States Geologic Survey, Denver CO. 19 pgs.

Staley, D.M., Negri, J.A., Kean, J.W., Tillery, A.C., Youberg, A.M., 2016, Updated logistic regression equations for the calculation of post-fire debris-flow likelihood in the western United States: U.S. Geological Survey Open-File Report 2016-XXXX, 20 p., available at http:// pubs.usgs.gov/of/2016/XXXX/

Appendix 1: Geology Inputs to 2500-8

Part II – Burned Area Description:

Geologic Types: The Erskine Fire occurred in the Piute Mountains, which are part of the Southern Sierra Nevada Mountain Range. The Piute Mountains are a long, narrow mountain range with elevations ranging from 2,500 feet above sea level (Lake Isabela) to 8,400 feet above sea level at Piute Peak. The physiography of the Piute mountains is dominated by extremely steep slopes, all associated with watersheds flowing directly or indirectly into Lake Isabela.

The Erskine Fire is underlain by granitic and metamorphic rocks consisting of Granite of Kern River (Kkr), Granite of Bodfish Canyon (Kbo), Granite of Bob Rabbit Canyon (Kbra), Granodiorite of Goat Ranch (Kgc), Granodiorite of Rabbit Island (Kri), Granodiorite of Kelso Peak (Kkp), White rock facies Granodiorite (Kcrw), Metamorphic – Metasedimentary rocks, Long Canyon Metasedimentary rocks (Jtlc), French Gulch Meta-volcanic rocks (Kfv) and Marble lenses in several metasedimentary belts. Surficial geologic rocks include surficial deposits of unconsolidated alluvial sedimentary rocks.

Bounding the Piute Mountains to the west is the Kern Canyon Fault, which runs along the north-west corner of the burned area.

Part III – Watershed Conditions

Rock-fall and debris slides are eminent along some steep slopes below the Cook Peak Ridge. Drainages in this same area have been identified in the field for potential debris flow hazard zones. With the aid of USGS Debris Flow Modeling, debris flow probabilities and potential volumes have been calculated.

Based on our field observations, our conclusion is that whether the primary post-fire process is rockfall, debris slides, debris flows or sediment laden flooding, the cumulative risk of various types of slope instability, sediment bulking and channel flushing is high along slopes and creeks flowing down from the Cook Peak ridge. Even though the USGS modeling presents low-moderate (20%-60%) probability of debris flows in the majority of drainages flowing down from the Cook Peak ridge, based on ground and aerial observations (quantities of rocky materials available to be transported and steepness of slopes and channels) we estimate that the majority of drainages in this area have moderate to high potential to produce debris flows. Conversely, even though other areas of the Erskine Fire present high probabilities of producing debris flows, no direct impact to Values At Risk (VAR) are expected in some of those remote drainages.

Treatments for debris flow and flooding hazards include notification of the public of these hazards through a warning system and installation of warning signs along roads in the burn area.

Following the Erskine Fire segments of the Cook Peak road will experience excessive rock-fall, potential debris flows and erosion. In order to prevent as much erosion and damage to the road surface as possible it is recommended to take some actions (storm proofing) before the first winter-storms arrive. Specific recommendations/treatments are described in the engineering report.

Debris Flow Potential:

The US Geological Survey (USGS) - Landslide Hazards Program, has developed empirical models for forecasting the probability and the likely volume of post-fire debris flow events. To run their models, the USGS uses geospatial data related to basin morphometry, burn severity, soil properties, and rainfall characteristics to estimate the probability and volume of debris flows that may occur in response to a design storm (Staley, 2016). Estimates of probability, volume, and combined hazard are based upon a design storm with a peak 15-minute rainfall intensity of 12 – 40 millimeters per hour (mm/h) rate. We selected a design storm of a peak 15-minute rainfall intensity of 32 millimeters per hour (mm/h) rate to evaluate debris flow potential and volumes since this magnitude of storm seems likely to occur in any given year.

Based on USGS debris flow modeling, basins / creeks in the Erskine Fire burned area have a wide range of probability (0-100%) of producing debris flows. Similarly, predicted volumes of debris flows through-out the burned area range from 1k – 100k cubic meters. From analyzing the combined hazard maps, it is clear that even though high hazard debris flows drainages exists through-out the burned areas, the concern areas are focused on the creeks and drainages flowing down from the Cook Peak range, as well as other burned slopes and drainages located directly above existing communities and private residences. Beyond these high concern areas, other drainages that have a moderate-high probability of producing debris flows, are not expected to impact directly any Values At Risks (VAR's).