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

South Complex, Shasta-Trinity N.F.

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Abstract

The South Complex started on August 1, 2015, on the Hayfork RD of the Shasta-Trinity N.F., Trinity County, California, and burned a total of 29,387 acres, out of which 733 acres were high soil burn severity, 5,735 acres were moderate soil burn severity, 12,508 acres were low soil burn severity and 10,372 were low/unburn soil burn severity. This report describes and assesses the increase in risk from geologic hazards within the South Complex 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 South Complex burned area, a high degree of mass wasting as shallow slope failures, rock fall, rock slides, ravel, translational-debris slides and rotational-translational slide activity has occurred in the past and will increase during future storms. In addition, some dormant landslides are located in the burnt area which might be re-activated during future storms as a result of the fire.

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.

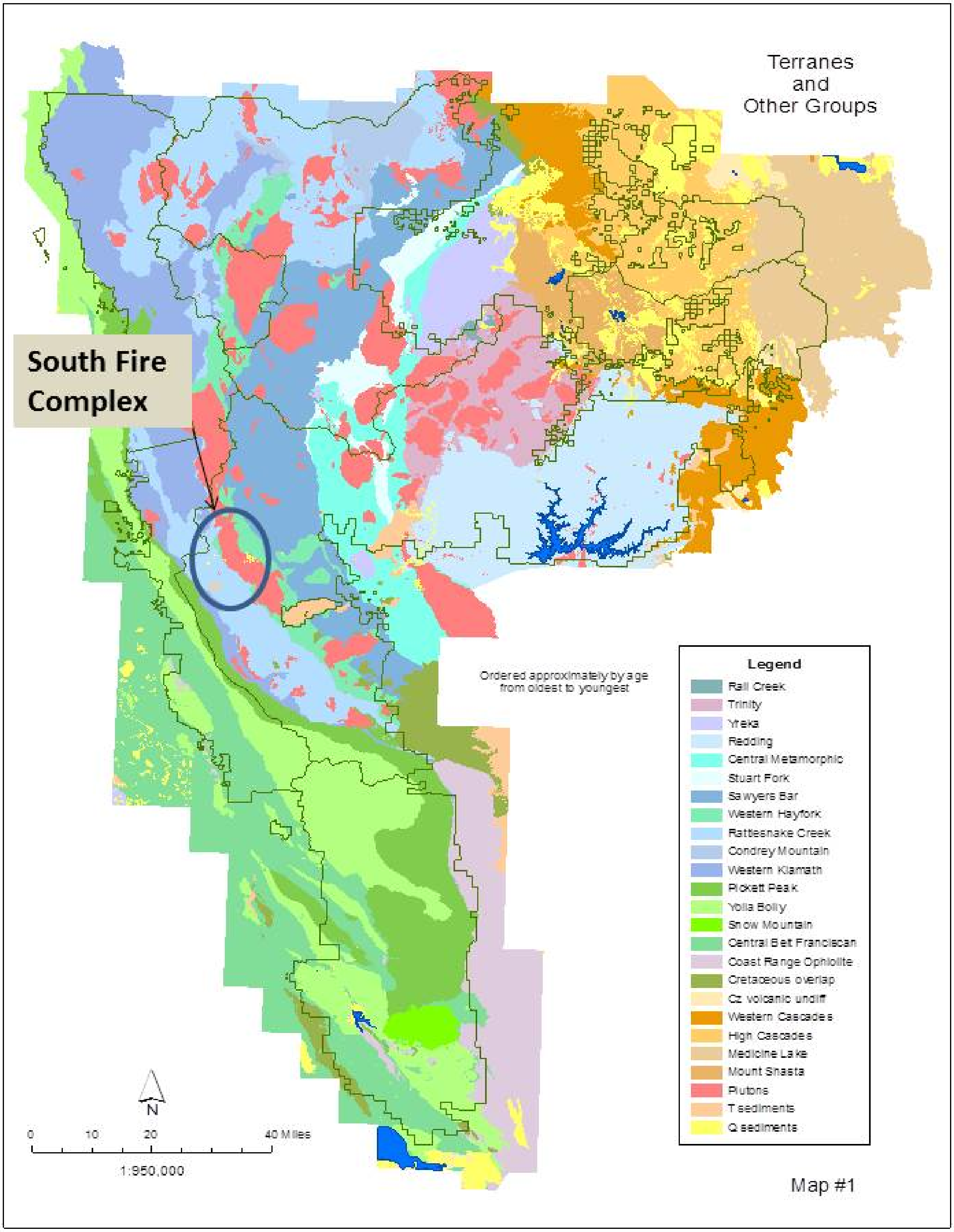
Wildfire can significantly alter the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous debris flows, rock falls and debris slides. Debris flows and rock falls are the primary geologic hazards associated with burned watersheds (Santi et al., 2013; Parise 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 South Complex lies within the Klamath Mountains Physiographic Province, and is underlain predominantly by Paleozoic and Mesozoic metavolcanic and metasedimentary rock, along with minor amounts of Tertiary and Quaternary sediments. Tectonic processes accreted numerous terranes to the western margin of North America and two of these occur within the fire area; the Western Hayfork and Rattlesnake Creek Terranes (Table 1). These Terranes were intruded by granitic plutons, the largest of which is the Ironside Mountain batholith, encompassing the eastern part of the complex. Small outcrops of sedimentary rock, represented by the Weaverville Formation and Pleistocene/Holocene colluvial deposits, occur primarily in the Hyampom Valley along with scattered patches of topographically-high relict Pleistocene alluvial land surfaces. Figure 1 displays regional distribution of terranes, with the location of the South Complex indicated.

Belt/Assemblage	Age	Terrane/Formation	Unit	Rock type
Western Pz & Tr	Paleozoic / Mesozoic	Western Hayfork	Hayfork Bally	mv plus ms Chert, Argillite, Meta-andesite, Tuff/Breccia
Western Pz & Tr	Paleozoic / Mesozoic	Rattlesnake Creek		ms, Diamictite, Serpentinite, Peridotite, Chert
Plutons	Jurassic	Western Hayfork	Ironside Mt Batholith	Intrusive igneous, Diorite, Gabbro, Pyroxenite
Weaverville Fm	Tertiary	Weaverville		Sedimentary, Fluvial, Alluvium/Lacustrine
Pleistocene Alluvial Deposits	Quaternary	Superjacent to Rattlesnake Creek		Sedimentary, Alluvium/Colluvium

Table 1: Rock Units on the South Complex



<u>Figure 1</u>: Geologic Terranes and Plutons

The **Western Hayfork Terrane** consists mainly of metavolcanic agglomerate and tuff, as well as argillite and chert. It includes the dioritic Ironside Mountain batholith as well as the Hayfork Bally meta-andesite and occupies the eastern half of the fire complex. In the NE corner of the fire, a few dormant landslides are mapped in this Terrane, and five active east-west trending earthflows on the west-facing slope east of Allen Creek are identified within the fire perimeter. The Terrane also contains small bodies of limestone which could have caves.

The **Rattlesnake Creek Terrane** occupies the western portion of the fire complex. This Terrane is an accretionary mélange consisting mostly of highly dismembered ophiolite including slabs of serpentinite and peridotite, basaltic volcanic rocks, radiolarian chert and limestone knockers. A significant proportion consists of diamictite, a weak metasedimentary rock which is prone to deep seated landslides. It contains a high density of dormant and active landslides in the western half of the fire complex (about 60% of the area within the fire perimeter is composed of this Terrane). Along the west central part of the fire complex, between the South Fork of Trinity River and Eltapom Creek to the east, a large area is mapped almost entirely as dormant landslide. Parts of this polygon do not express the hummocky bench/scarp topography typical of dormant landslides. There are, however, several active landslide areas mapped in the northwest, far west, and southernmost portions of the burn area. In general, the density of dormant and active landslide in the Rattlesnake Creek Terrane (within the fire complex) is much higher than in the Western Hayfork Terrane (<5%). Scattered bodies of serpentinite and peridotite diapirs occur within this Terrane, which could contain naturally occurring asbestos. The Rattlesnake Creek Terrane also contains small blebs of limestone which could have caves.

Plutons in the Klamath Mountains typically form sandy soils and can be particularly prone to shallow debris slides and debris flows in steeper watersheds after wildfire. Granitic lands on the Klamath Forest about 70 miles to the north of the South Complex (near Seiad Valley, CA) experienced extensive debris flows in July of 2015 after having been burned in 2014. The Ironside Mountain batholith in the far eastern edge of the fire complex area contains minor amounts of pyroxenite which could also possibly contain naturally occurring asbestos.

Deposits of the mid-Tertiary **Weaverville Formation** crop out in the vicinity of the village of Hyampom. These consist of weakly consolidated fluvial and lacustrine rocks, thinly laminated, light-colored clay and tuff, alongside coaly deposits of late Oligocene and early Miocene age. Lying predominately outside the south perimeter of the complex and just east of the floodplain of Hyampom Valley, they have low slope gradients, are poorly exposed and should not pose a significant risk of erosion or sliding.

Older alluvium (Pleistocene) deposits are composed of weakly consolidated non-marine silt, sand, and conglomerate associated with topographically high remnants of old land surfaces. Most of these deposits are at elevations of 3,000 to 4,000 feet, about 2,000 feet or more higher than that of the South Fork of Trinity River. Deposits are generally less indurated than the Weaverville Formation, and therefor are more prone to erosion after wildfire.

Geomorphology:

Most of the geologic terranes of the Klamath Mountains are weak and prone to landslides. Rapid uplift, high precipitation, and seismic activity to the west have created a landscape with abundant deep seated landslides, many of which occupy several square miles. Most of these larger complexes are dormant under present climatic and seismic conditions though some from tens to hundreds of acres in size are known to be active. Both the dormant and active landslides are very important parts of the landscape because they are often the source of debris slides during wet winters, and the debris slides in turn generate debris flows. Post-fire summer debris flows triggered by the rapid influx of sediment from rills and gullies typical of places like southern California and the Rockies are less common in this region, most likely because intense summer storms occur less frequently. The geomorphic map (Figure 1, (Yonni has it)) is a derivative map produced by overlaying the geomorphic coverage with slope and bedrock.

Some of the large active slides near the South Fork Trinity River, and specifically the ones mapped just north of Hyampom, have experienced high to moderate burn severity. The largest area with high burn severity is the eastern slope of Underwood Mountain and the adjacent areas on both sides of Buckhorn Creek in the northern part of the complex. This spot is situated within the Rattlesnake Creek Terrane (as described above), generally with slopes of less than 65% and a small number of dormant landslides located within it. The high burn severity coupled with the high probability of heavy winter rains (NOAA, Sep. 2015), suggests the possibility of reactivating these dormant slides or even the creation of new ones.

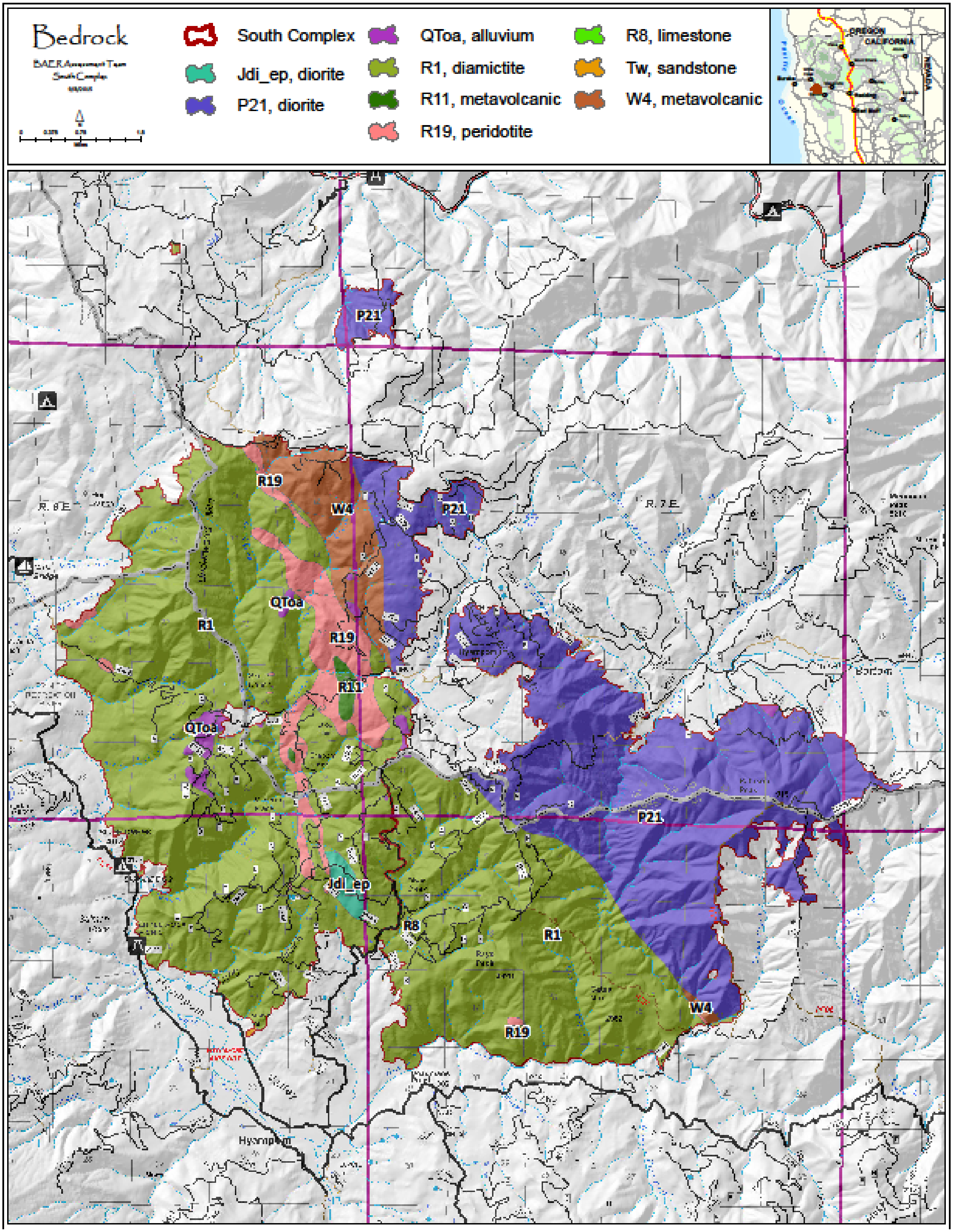


Figure 2: Bedrock map of the South Complex area

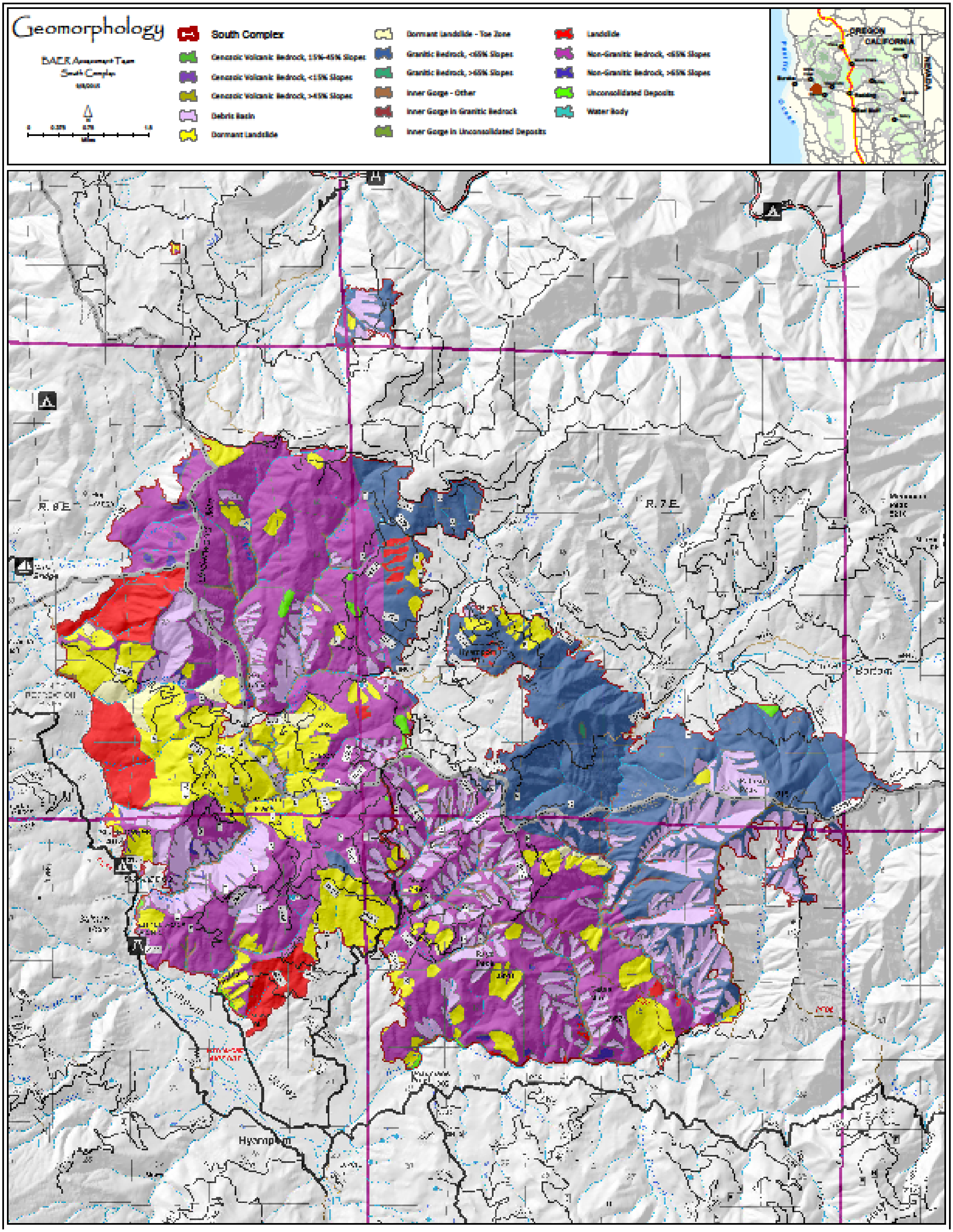


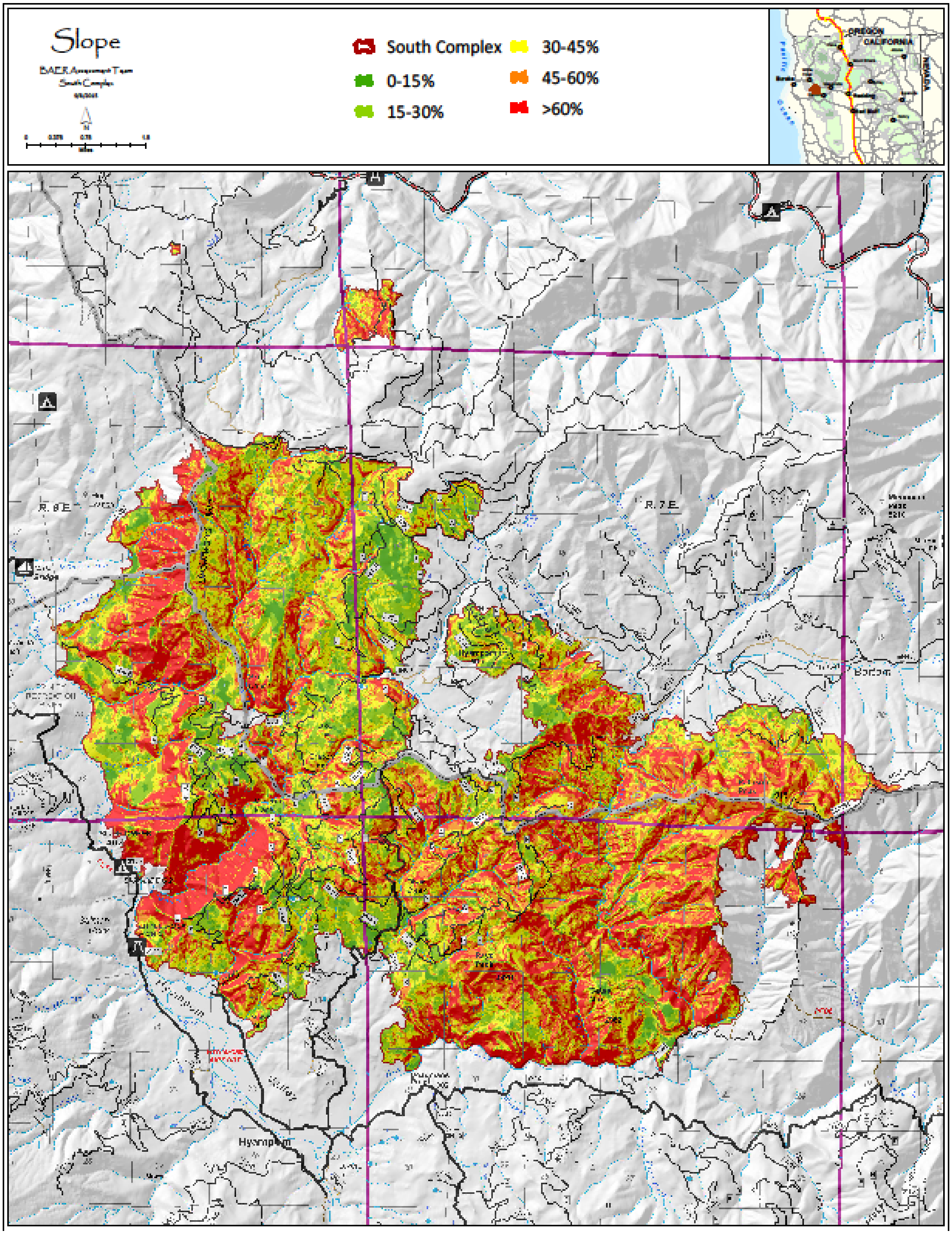
Figure 3: Geomorphology map of the South Complex area

Faults:
Some faults traverse the fire complex, including numerous thrust faults separating geologic terranes. However, these faults have not exhibited recent movement. The nearest Quaternary faults lie about 7 miles to the west and are associated with the Coast Ranges.

Landscape characteristics: The area is characterized by dissected ridge lines in a south – north direction and slopes ranging from gentle (0-15%) to steep (>60%) slopes (see Figure 4). The major creeks draining the fire area include: Eltapom Creek, Buckhorn Creek, Allen Creek, Young Gulch, Olsen Creek, and Coral Creek all tributes of the South Fork of the Trinity River which is a tribute of the Trinity River, which is in turn a tribute of the Klamath River.

Slope in-stability features such as recent pre-fire debris slides, rock-falls, channels and gullies frequent the steep inner gorge slopes, while fluvial erosion processes have shaped the gentler valleys and ridges. Areas of active mass wasting are typically void of vegetation (see photo 1). 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 sediment that will mobilize during flood events and add significant bulk to flowing water. Other channels, especially on steep hillsides, were relatively devoid of pre-fire sediment, but now are subject to filling with post-fire colluvial debris and rolling rock.

Photo 1: Active mass wasting – Rays Peak, Pattison fire



<u>Figure 4</u>: Slope Map – South Complex

Findings / Observations

Through ground surveys, flight recons and study of geomorphic maps evidence of past mass wasting was observed throughout much of the South Complex burnt area. From on-the-ground observations it is clear that some of the headwaters of the Eltapom creek, the Buckhorn creek and others are loaded with unsorted, unconsolidated materials available to be transported.

Castle Fire:

The Castle fire area includes two major watersheds: The Eltapom Creek and the South Fork Trinity River. The few sub-watersheds that flow directly into the South Fork Trinity River and are part of the South Fork Trinity River watershed can be divided into two major areas. The north-west corner of the fire, which includes sub-watersheds/creeks that all flow from Underwood mountain west directly into the South Fork Trinity River and the Young Gulch sub-watershed/creek that flows directly into the South Fork Trinity River and drains the whole south-west corner of the fire. Out of these two areas, the sub-watersheds/creeks to the north-west burned for the most case with a very low-unburn soil burn severity. In contrast, the Young Gulch watershed experienced a whole range of burn severity from very low-unburn to high soil burn severity. Out of the whole South fire Complex, the watershed that exhibits the highest concentrations of moderate-high soil burn severity is the Eltapom Creek watershed (see photo 2).

With an unstable lithology that is weak and prone to landslides, many dormant and active landslides, slopes that are in some cases over 75% steep and upper slopes/channels that are loaded with unconsolidated materials available to be transported (see photo 3) the Eltapom watershed under these new (burn) conditions is expected to activate some dormant debris slides, initiate some new debris slides and potentially produce some debris flows. Beyond some level 1 & 2 FS roads that might experience some excessive rock falls, dry ravel and erosion, other concerns/Values At Risk (VAR) in this area include: negative effects on water quality and fish habitat, soil productivity and threat to ingress - egress of private properties. Along segments of FS roads (4N24, 4N09, 4N04) that might experience some excessive rock-fall and erosion, it is recommended to keep the basins at the creek crossings as clear as possible and have storm patrols after every major rain storm. It is also recommended to install rises on some of the culverts crossing these roads, as well as installation of rolling dips to channel plugged culverts off the roadway.

As mentioned above, the Eltapom watershed exhibits the highest concentration of moderate to high soil burn severity in the fire area. A major sub-watershed in the Eltapom watershed is the Buckhorn watershed and its tributes. In an event of a 10-year storm, segments of the Buckhorn and its tributes are predicted to produce debris flows ranging from less than 1K to 100K cubic meters with a probability ranging from 0-20% all the way up to 60-80% depending by the specific segment. For a 10-year storm, the combined hazard rating in this area is for the most case moderate hazard rating.

Photo 2: Moderate-High soil burn severity at the headwaters of the Buckhorn Creek, sub-watershed of the Eltapom watershed

Photo 3: Steep mountainside ephemeral channels loaded with unconsolidated materials available to be transported, Eltapom Creek

Pattison Fire:

The Pattison fire burnt area includes two major watersheds: The Corral Creek watershed to the north and east of the fire and the Olsen Creek-Hayfork Creek watershed to the south-west of the fire. In general, the majority of the Pattison Fire had low and very low/unburned soil burn severity. Some very small patchy areas (around Rays Peak, Gates Mountain and Pattison Peak) exhibit moderate to high soil burn severity (see photo 4), mostly in the Olsen Creek-Hayfork Creek watershed.

In both major watersheds that constitute the Pattison Fire very few Values At Risk (VAR's) were identified. The few VAR's that were identified for this fire include: a few level 1 & 2 FS roads that might experience some excessive rock fall, dry ravel and erosion and two trails that might be prone to some erosion. Along these few of FS roads, it is recommended to keep the basins at the creek crossings as clear as possible and have storm patrols after every major rain storm. It is also recommended to install rises on some of the culverts crossing these roads, as well as installation of rolling dips to channel plugged culverts off the roadway.

Photo 4: Mass wasting and patchy moderate burn severity near Pattison Peak – Pattison fire

Through ground surveys, flight recons and study of geomorphic maps it is evident that that mass wasting takes place throughout much of the Pattison Fire burnt area. For the most case, this mass wasting includes inner gorge debris basins, dormant landslides and a few active landslides (see photo 5).

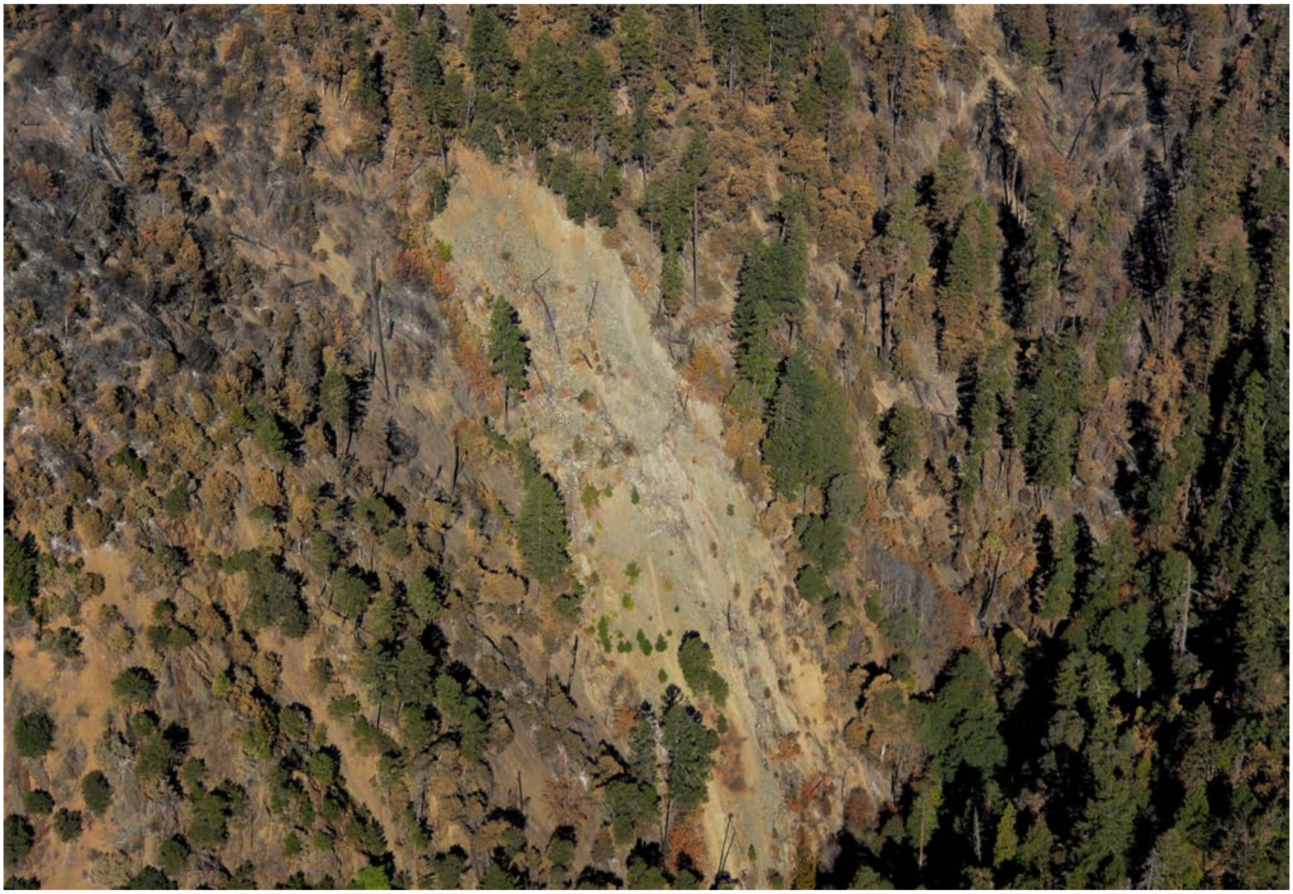


Photo 5: Active landslide, lower Corral Creek, Pattison Fire

In an event of a 10-year storm in the Pattison Fire area the probability of debris flow is for the most case low (0-20%) with very few and short segments of creeks presenting higher probabilities of 40-60% or 60-80%.

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) 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, 2013). After receiving the final South Complex fire burn severity map (Figure 5), 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 including 2, 5, 10, 25, 50 and 100 year storms. We selected the 10 year design storm which has a magnitude of 0.789” of rain in a 1-hour duration, referred to as a 10-year storm (a 10% chance of occurrence in any given year) to evaluate debris flow potential and volumes since this magnitude of storm seems likely to occur in any given year (Figures 6 - 8). Below is the magnitude of the recurrence interval rainstorm for the area of the South Complex associated with a 1-hour duration rainstorm.

Design storm (x” of rain / 1-hour duration):

Recurrence interval rainstorm	2- years	5- years	10- years	25- years	50- years	100- years
60 min duration	0.521”	0.665”	0.789”	1.966”	1.11”	1.26”

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 km².

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. (2013) 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.

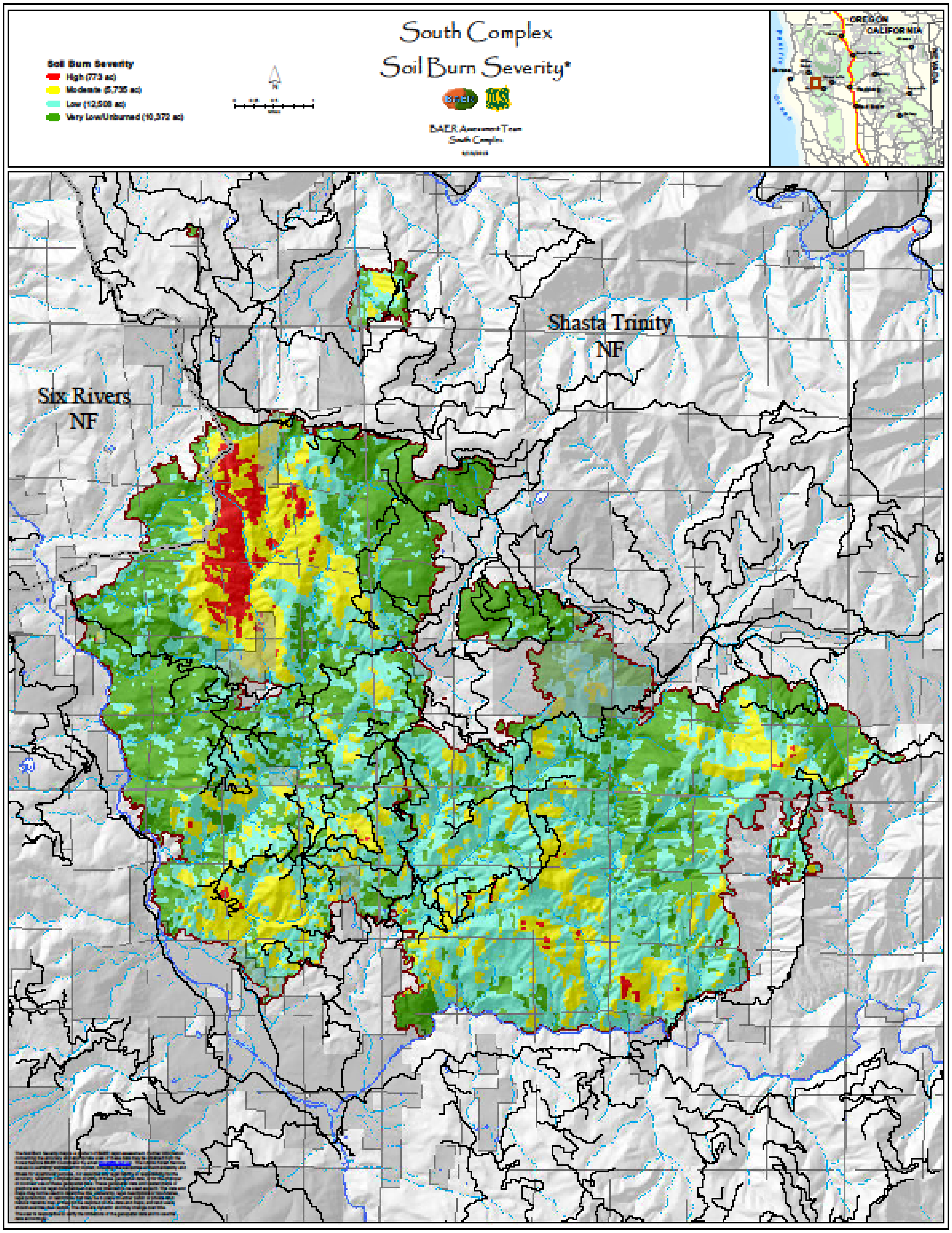
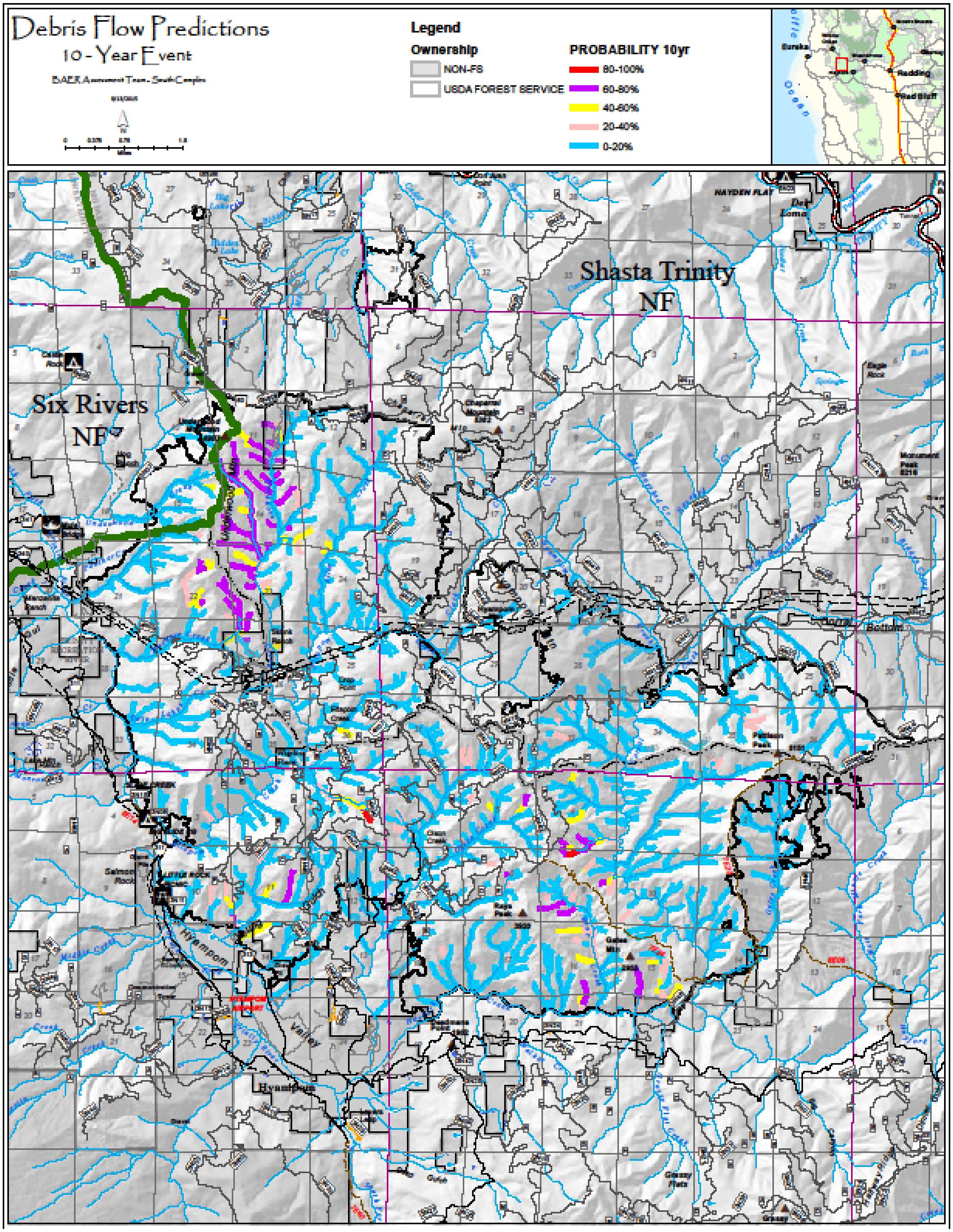


Figure 5: Soil Burn Severity map – Fork Complex



<u>Figure 6</u>: Predicted debris flow PROBABILITY map for the South Complex Fire – 10 year storm

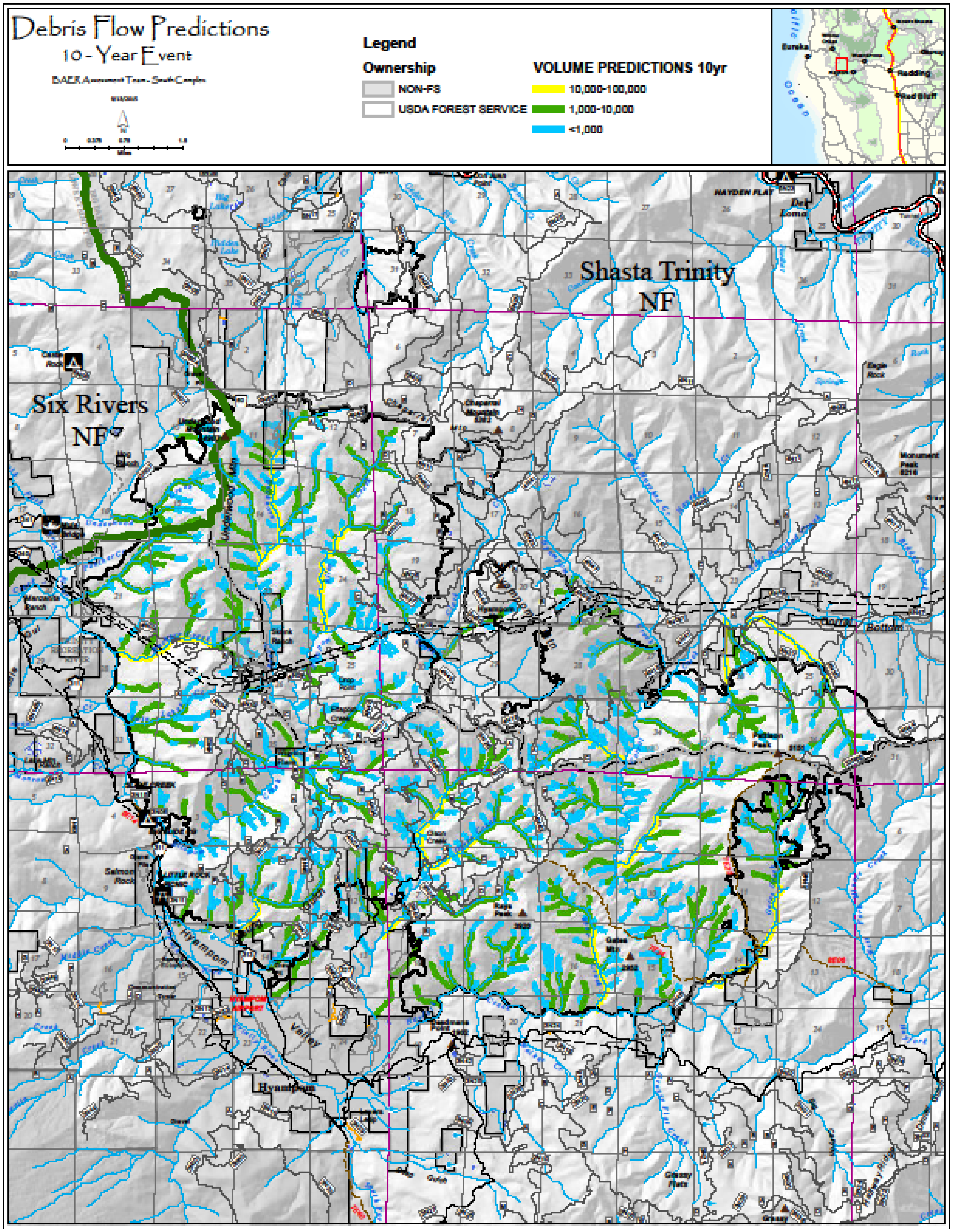


Figure 7: Predicted debris flow VOLUME map for the South Complex Fire – 10 year storm

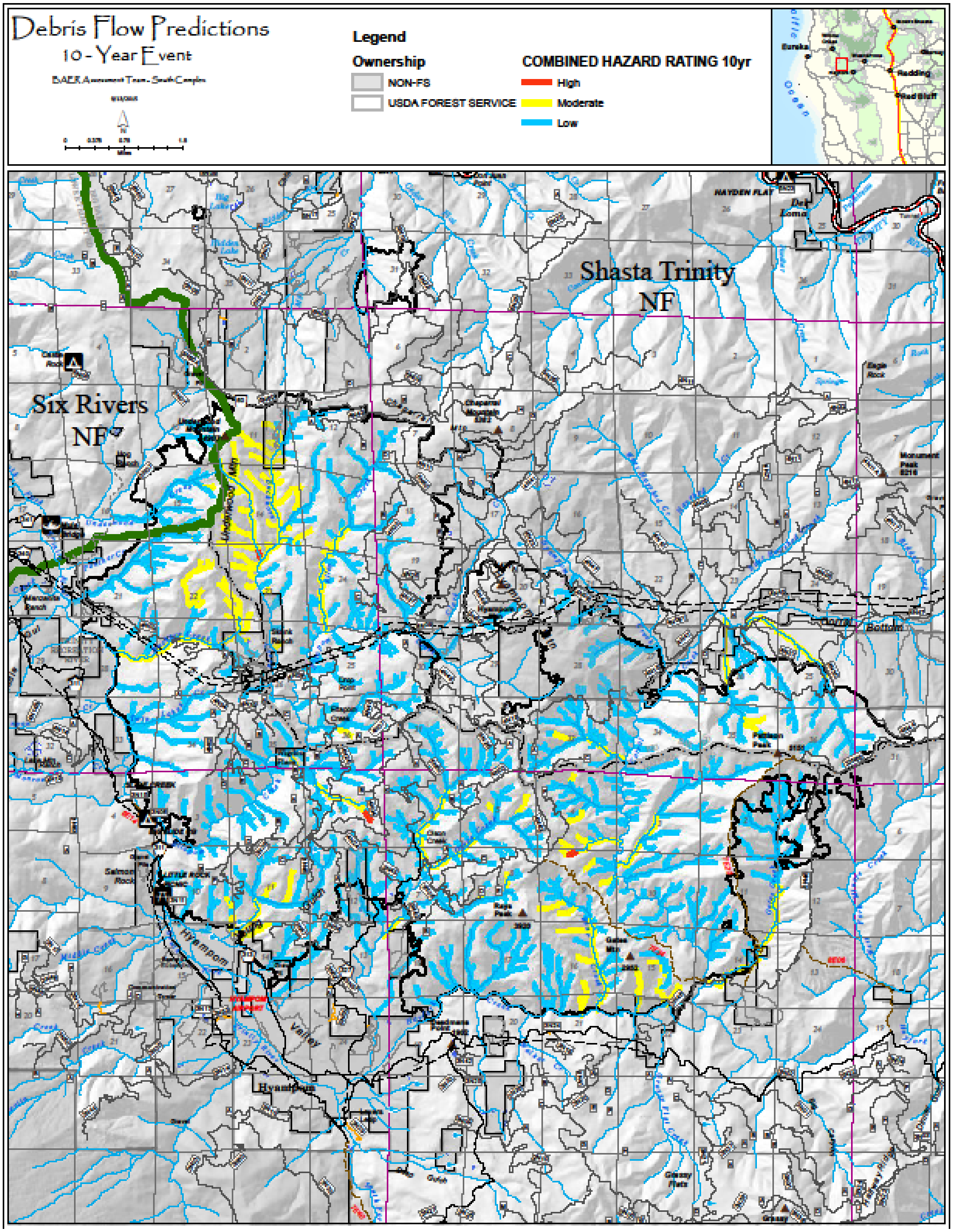


Figure 8: Predicted debris flow COMBINED HAZARD CLASS map for the South Complex Fire – 10 year storm

Resource Conditions Resulting from the Fire

Assessment of the South Complex 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 recent 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 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.

Property:

- Forest roads, trails, and drainage systems – As a result of the fire, excessive runoff and flows, stability of slopes over Forest roads and trails will be compromised. Debris slides and flows, rockfall, and flooding will cause damage to these systems.

- Private property, including homes, roads and facilities, both within and outside the Forest boundary, downstream and downslope from the burned area, is at risk.

Natural Resources:

- Water quality for Coho Salmon, riparian sustainability and downstream uses – As a result of the fire excessive sedimentation will adversely affect water quality in some of the creeks.

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, conveyance capacity of stream channels and other facilities within and downstream from the wildfire area. Risk of loss of life and limb is of particular concern.

IV. Treatments to Mitigate the Emergency

The Geology Team 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 and engineering.

ROADS: <u>Inside ditches, culverts, risers, rolling dips, downdrains, and outsloping</u>

A. Treatment Type and Proposed Location: Inside ditches, etc. located along all roadways. Create outsloped road prisms and rolling dips to improve road drainage where berms are removed, gradients are gentle enough, and inside ditches are not needed, to reduce concentration of drainage and disperse overland flow.
B. Treatment Objective: To improve water flow along and below roadways to keep roads from being washed out where drainage becomes overwhelmed during peak flows, or is impacted by increased flows resulting from burn severity. To decrease resource damage.
C. Treatment Description: Fix ditch sloughing, sizing, install or repair culverts, many of which are undersized or damaged, enlarge, add risers and drop inlets as needed; install or repair engineered dips and fords, install or repair downdrains, etc. Install outsloped road prisms with rolling dips and downdrains long enough to insure gullying does not create future threats to the road.
D. Treatment Costs: See engineering contracts and specs.

E. Monitoring needs: If drainage devices plug or otherwise fail, severe damage can be done to roads, fills and drainage structures. Monitoring, especially during storm events is necessary.

ROADS: <u>Debris clearing, sidecasting and waste disposal sites</u>,

A. Treatment Type and Proposed Location: Debris clearing, where large deposits of debris threaten drainage systems, especially culverts; locations scattered throughout burned area. Include channel clearing to aid unobstructed flow. Work with both in-house and private contractors to stop sidecasting and improve ditch and dip maintenance practices, throughout the road system. Identify specific locations where changes in practices are most needed. Since the area has no approved disposal sites, and waste disposal is continually contributing to resource damage, and that damage will increase as a result of the fire, waste disposal sites that are on stable and otherwise approved land are an urgent need, to reduce resource damage.
B. Treatment Objective: To remove unconsolidated debris threatening drainage structures. To prevent slide and debris cleanout material from being sidecast or disposed of in inappropriate locations, especially once watersheds begin to recover.
C. Treatment Description: Use backhoe or excavator to remove loose material, end-haul, and dispose in approved disposal site. Document improvements and continuing problems. Locate and design and get all necessary approvals for disposal sites, strategically located so as to reduce haul costs and resource damage.
D. Treatment Costs: See engineering contracts and specs.
E. Monitoring needs: Continue identifying debris deposits, including new ones that may form during subsequent storms that threaten drainage structures. Monitor to assure sites are well drained and functioning properly.

ROADS: <u>Install warning signs</u>

A. Treatment Type and Proposed Location: Install approved warning signs regarding flood and landslide/rockfall potential during storm events, at major road intersections and as needed.
B. Treatment Objective: to improve safety from landslide/rockfall and flood events for workers and Forest visitors.
C. Treatment Description: Install approved signs at key access points.
D. Treatment Costs: See engineering prescriptions.
E. Monitoring Needs: Monitor continued existence of signs for next 3 years, and replace as needed.

V. Discussion / Summary / Recommendations

Debris flows and rock falls are eminent in some areas of the South Complex Fire. Rock fall and debris flow hazard areas have been identified and reviewed in the field. In addition, with the aid of USGS Debris Flow Modeling, debris flow probabilities and potential volumes have been calculated.

The conclusion of our field observations is that whether the primary post-fire process is debris flows, rockfall, debris slides, rotational landslides, or sediment laden flooding, the cumulative risk of various types of slope instability, sediment bulking, and channel flushing and deposition is moderate - high following the South Complex Fire.

Treatments for debris flow and rock fall hazards include notification of the public of these hazards through warning signs and road closures; clearing and improvement of catch basins and ditches along the road; maintenance and up-grade of drainage structures; construction of rolling dips in critical locations along the road.

Conclusions from the USGS Debris Flow Assessment:

As expected, USGS debris flow modeling estimates that the area of the Eltapom upper watershed, east of Underwood Mountain (Buckhorn Creek watershed) exhibits the highest concentration of creeks predicted to produce debris flows with 60-80% probability. In this same area the creeks are predicted to produce debris flows with volumes ranging all the way from less of 1000 cubic meters in some segments to 100,000 cubic meters in other segments (see Figures 6, 7 & 8). Beyond very few and very short creek segments, the entire rest of the South Complex area has for the most case very low probability (0-20%) of producing any debris flows. Based on field observations (steepness of slopes and unconsolidated available materials) it seems that segments of the Buckhorn creek and some of it tributes might even have a higher probability of producing debris flows than estimated by the USGS modeling, obviously all depending on the right rain storm conditions.

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 Fork Complex 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.

VI. References

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Appendix 1: Geology Inputs to 2500-8

Part II – Burned Area Description:

Geologic Types: Bedrock within the boundaries of the South Complex is underlain predominantly by Paleozoic and Mesozoic metavolcanic and metasedimentary rock, along with minor amounts of Tertiary and Quaternary sediments. In the fire complex area some intrusions of granitic plutons exisist, the largest of which is the Ironside Mountain batholith, encompassing the eastern part of the complex. Small outcrops of sedimentary rock, represented by the Weaverville Formation and Pleistocene/Holocene colluvial deposits, occur primarily in the Hyampom Valley.

Part III – Watershed Conditions

Within the South Complex burned area, some watersheds show a great deal of past mass wasting as debris slide/rockfall activity that will be increased during future storms. Other areas have little evidence of recent past slope instability, but as conditions have changed due to the fire, new mass wasting might be initiated.

As a result of the removal of vegetation by the fire, excessive sediment and available transported material in channels and potential high runoff as a result of moderate to high rainstorms, debris-flow probabilities are moderate-high along some creek segments. Soils are exposed and have become weakened, and rocks on slopes have lost their supporting vegetation. Roads are at risk from rolling rock, plugged culverts, debris slides and debris flows. 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, then covering roads or eroding road prisms. Risks to human life, roads, trails and natural resources is moderate to high in some areas of the South Complex.

Field and aerial observations in the Buckhorn drainage area showed numerous channels loaded with large deposits of rock and soil, and many slopes burned at moderate and high soil burn severity at risk for contributing large quantities of soil, rock and organic debris to the main channel. USGS debris flow modeling estimates that within the Buckhorn watershed area some creeks present potential debris flows with volumes ranging from 1,000 to 100,000 cubic meters with probability ranging from 0-20% in some segments to 60-80% in other segments. Beyond the upper watershed of the Eltapom Creek (including the Buckhorn watershed) the entire rest of the South Complex presents for the most case, low probability (0-20%) of debris flow initiation.

Treatments for debris flow and rock fall hazards include notification of the public of these hazards through warning signs and road closures; clearing and improvement of catch basins and ditches along the road; maintenance and up-grade of drainage structures; construction of rolling dips in critical locations along the road.