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

River Complex, Shasta-Trinity National Forest
September 28, 2015

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Pre-fire Debris slide below Road 7N53, Quinby Creek watershed Photo #6595 9-21-15;

SUMMARY

Primary geologic hazards affected by the River Complex consist of rock fall, debris slides (shallow rapid landslides), debris flows, and to a lesser degree, deep landslides such as slumps and earthflows. Several areas of fire-initiated rockfall were observed along Road 7N26 and County Road 402, on the west side of New River. Rock fall is facilitated by the burning out of woody material holding rock on a hillslope, and will continue at an elevated rate through the first winter after the fire, with spikes during the first significant storms. The potential for rock fall will likely return to pre-fire levels within a few years. Two distinct triggers are at play following the fire which can initiate landslides and debris flows. One is high intensity convective storms which typically occur in summer, and the other is long duration winter storms in winter which often involve snow melt. The summer storms produce rapid runoff due in part to fire-related water repellency in soils, and this generates debris flows, but few landslides of other types. The most likely settings for this to occur are where high and moderate severity fire occurs on headwall basins, old debris slide scars, or other types of steep hillslopes (>65%). Potential for such events typically recovers to pre-fire levels in less than five years. Winter storms saturate the soil and underlying bedrock, and can initiate debris slides along with slumps and earthflows. By removing vegetation, the fire reduces evapotranspiration and root support, and both of these effects can increase landslide potential. Areas at greatest risk for this are where high and moderate severity fire occur on dormant landslides or earthflows, such as on Jim Jam Ridge or in the vicinity of Caraway Creek, but also in headwall basins, old debris slide scars, or other types of steep hillslopes (>65%), such as those which occupy much of Devils Canyon. This increase in landslide potential can last for tens of years, until vegetation becomes reestablished.

As a result of the removal of vegetation by the fire, channels will likely receive sediment by dry ravel and other processes, and this material will be available for transport during high runoff, facilitated by fire effects. Soils are exposed, 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 ephemeral channels will be flushed of the sediment when high flows eventually occur.

Since rock fall has already occurred along parts of the road system, and will continue to occur at an elevated rate at least through the first winter, the probability of damage or loss to people or vehicles traveling the roads from rock fall is estimated to be “possible” on the BAER Risk Matrix. The magnitude of consequences of such an event would be “major”, and this translates to a risk of “high” on the BAER Risk Matrix. Debris flows and landslides are less likely to occur than rock fall, and the potential for damage or loss is “possible”. The size of the events could be larger rock falls, and the consequences would be “major”, yielding a risk rating of “high”.

Treatments for debris flow and rock fall hazards include notification of the public of these hazards through warning signs and road closures, notification of the public and other agencies,

clearing and improvement of catch basins and ditches along roads, maintenance and up-grade of drainage structures, and construction of rolling dips in critical locations along roads.

METHODS

The field data collected for this project was recorded from personal observations taken primarily adjacent to county and Forest Service roads, along with a few cross country traverses. A total of five person days were spent in the field, and one person day was devoted to validating the debris flow model outputs. Notes, maps, and photographs documenting field observations are filed with the project record. The Forest GIS coverages for bedrock and geomorphology were examined on-screen with fire severities superimposed to identify areas where unstable land was severely burned. Historical air photos from 1982 and 2006, along with Google Earth images from 1993-2012 of the fire area were examined to get a sense for the effects of previous fires, and to look for recent landslides which may have been missed by the Forest active landslide GIS coverage. The US Geological Survey graciously ran their debris flow model on the River Fire Complex and provided results to the BAER team. The BAER team then independently ran the model and validated their results.

RESOURCE SETTING

Geology and Geomorphology: The River Complex lies within the Klamath Mountains Physiographic Province, and is underlain predominantly by Paleozoic and Mesozoic metavolcanic and metasedimentary rock, along with minor amounts 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 Eastern Hayfork Subterranes, members of the Hayfork Terrane (Table 1). These Terranes were intruded by

Belt/Assemblage	Age	Terrane/Formation	Unit	Rock type
Western Paleozoic & Triassic	Jurassic	Western Hayfork	Hayfork Bally	mv plus ms, Quartzite Chert, Argillite, Meta-andesite
Western Paleozoic & Triassic	Triassic	Eastern Hayfork		mv plus ms, Diamictite, Chert, Serpentinite, Amphibolite
Plutons	Jurassic	Intrudes the Western Hayfork	Ironside Mt Batholith	Intrusive igneous, Diorite, Gabbro, Pyroxenite
Pleistocene / Holocene Alluvial Deposits	Quaternary	Superjacent to Western & Eastern Hayfork		Sedimentary, Fluvial, Alluvium/Colluvium

Table 1: Rock Units on the River Complex

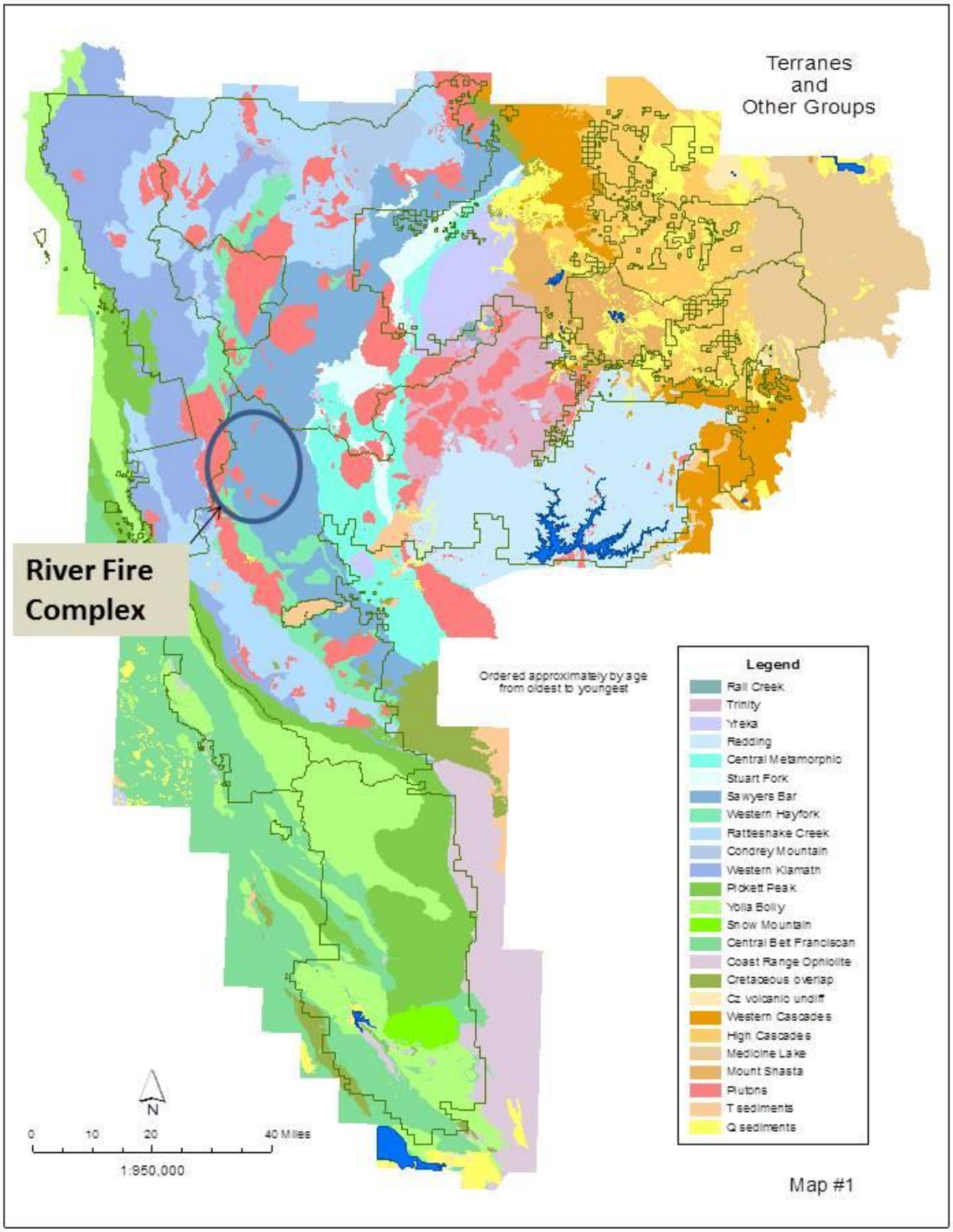
granitic plutons, the largest of which is the Ironside Mountain batholith, encompassing the western part of the complex. Small outcrops of sedimentary rock, represented by Pleistocene/Holocene fluvial and colluvial deposits, occur primarily in the New River Valley along with scattered patches of topographically-high relict Pleistocene alluvial land surfaces. Figure 1 displays the regional distribution of terranes, with the location of the South Complex indicated. Figure 2 illustrates the bedrock specific to the Complex.

The **Western Hayfork Subterrane** 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 western third of the fire complex. In the west-central and southwest sections of the fire, a few dormant landslides are mapped in this Subterrane, and two active landslides are identified along the New River. The Subterrane also contains small bodies of limestone which could have caves.

The **Eastern Hayfork Subterrane** occupies the eastern portion of the fire complex. This Subterrane is an accretionary mélange consisting mostly of diamictite, thin-bedded chert, and exotic oceanic rocks including mafic metavolcanic and metasedimentary rocks, limestone lenses, and scattered blocks of schist including lenses of serpentinite. The NW portion of the burn area contains a high density of dormant landslides, and there are a few active landslide areas mapped in the far north in the Quinby Creek and Fawn Creek subdrainages. In general, the density of dormant and active landslide in the Eastern Hayfork Subterrane (within the fire complex) is much higher than in the Western Hayfork Subterrane (<10%). Scattered bodies of serpentinite and peridotite diapirs occur within this Terrane, which could contain naturally occurring asbestos. The Eastern Hayfork Subterrane also contains small lenses of limestone which could have caves.

Plutons in the Klamath Mountains typically form sandy granitic 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 65 miles to the north of the River 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 western edge of the fire complex and a mapped gabbro body in the Big Mountain area contain minor amounts of pyroxenite which could possibly contain naturally occurring asbestos.

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 poorly indurated and therefor are more prone to erosion after wildfire.



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

Faults:

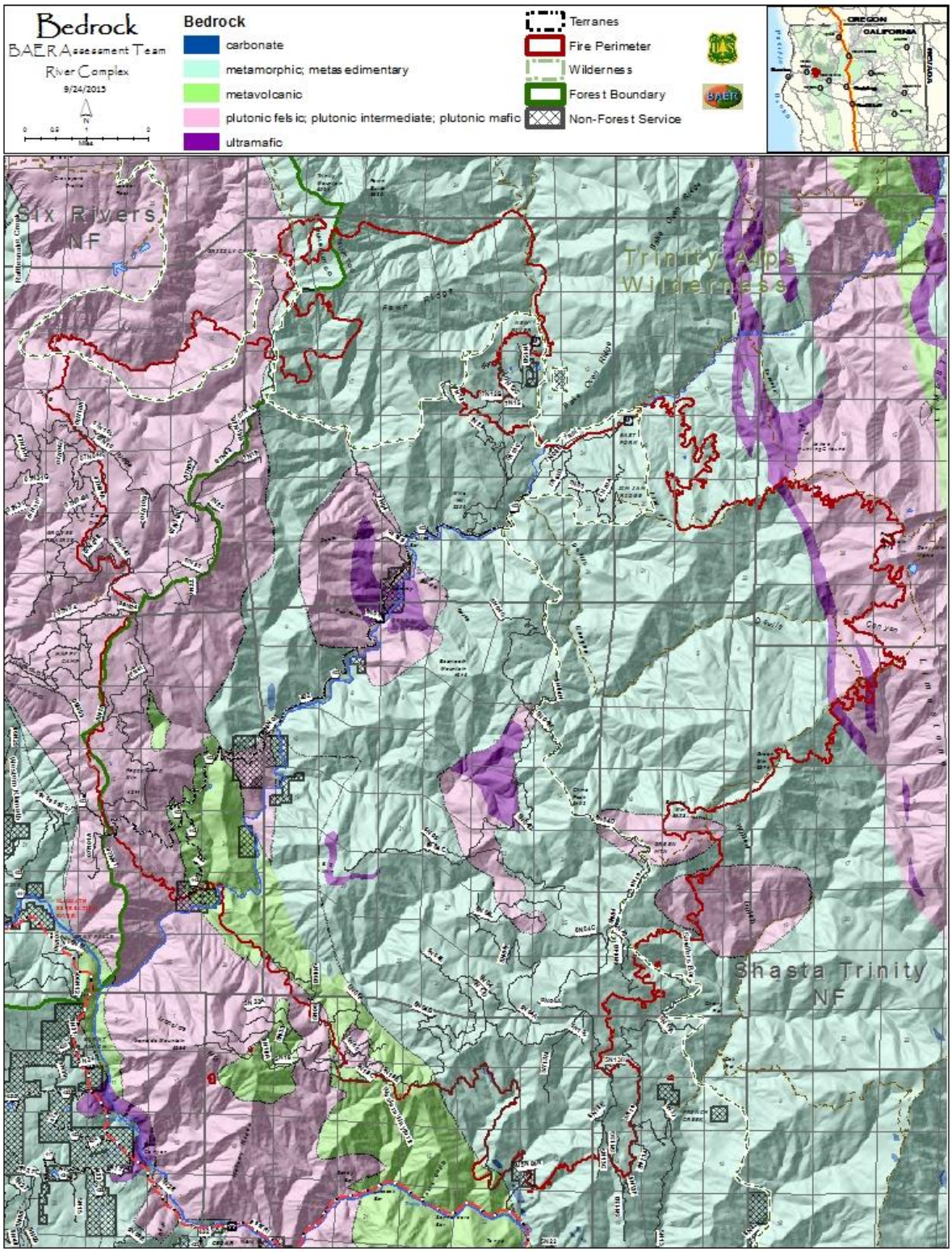
There are two main east-dipping, N/S-trending, low angle thrust faults within the Complex: the Twin Sisters fault near the eastern edge and another unnamed fault near the western edge of the fire. These faults bracket the Eastern and Western Hayfork Subterranes, respectively, but neither of these faults has shown any recent movement or seismicity (USGS 2010).

There is a cluster of east-dipping, NW/SE trending thrust faults in the Blue Lake and Arcata area, the closest of which are the Blue Lake and Trinidad faults. Both of these faults have shown activity within the Holocene period and are situated approximately 40 miles to the west (USGS 2010).

The closest active fault (within the past 200 years) is the King Range fault (synthetic to San Andreas Fault Zone) 70 miles to the southwest at the town of Shelter Cove; this fault showed activity in 1906 (USGS 2010).

Recent Seismic Activity:

There have been five recorded earthquakes from magnitude 2.8 to 3.9 on the Richter Scale within the Complex since 1984. The largest concentration of seismic activity emanates from the Mendocino Triple Junction, the most recent occurring on 9-23-2015 and the largest (since 1960) was a magnitude 7.2 earthquake which happened on 4-25-1992 (USGS 2015). The Mendocino Triple Junction is approximately 75 miles west of the burn area and 15 miles northwest offshore from Point Mendocino (USGS 2015). Generally any earthquake above magnitude 2.0 can be enough to start a small debris slide or rockfall.



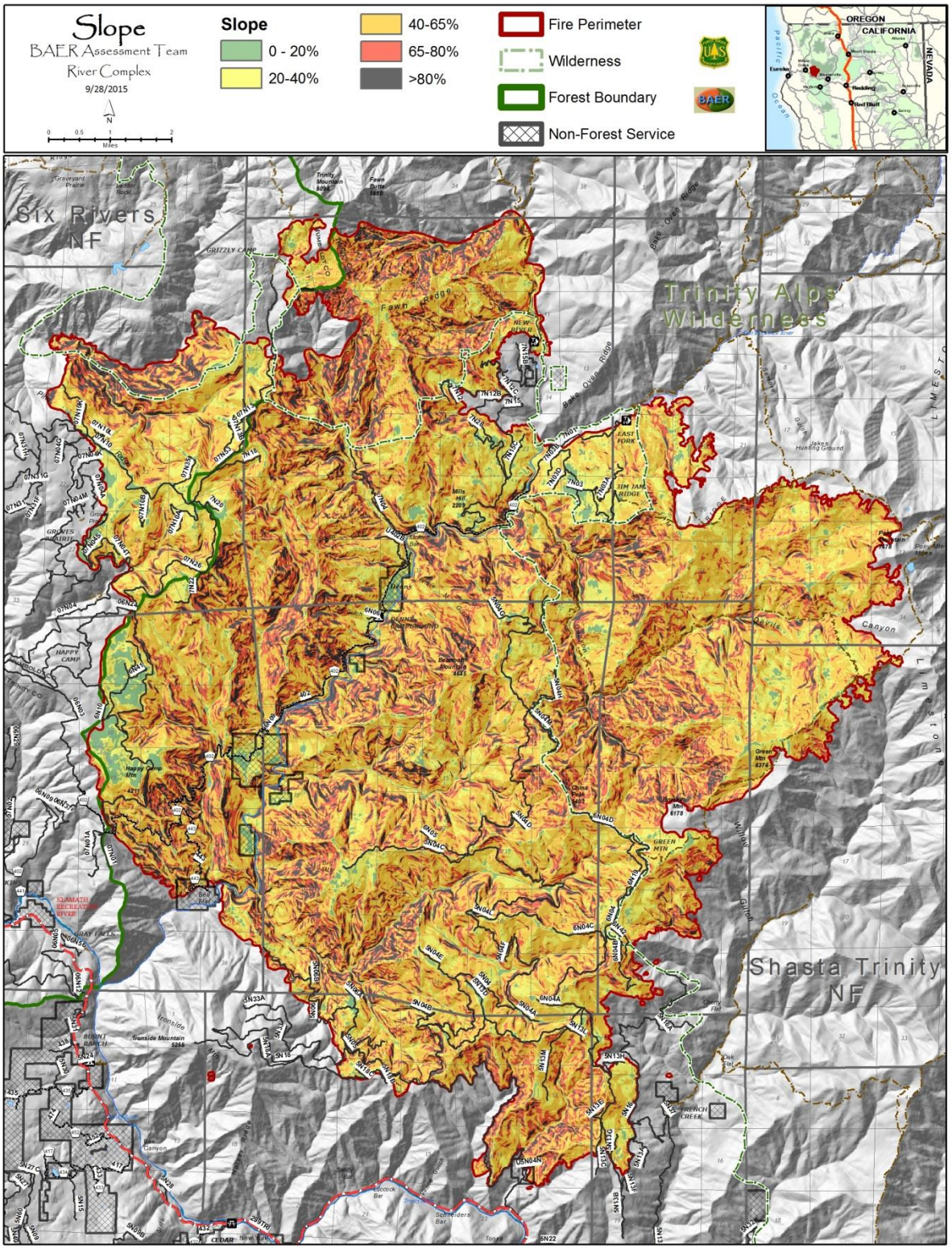
<u>Figure 2:</u> Bedrock Map

Geomorphology:

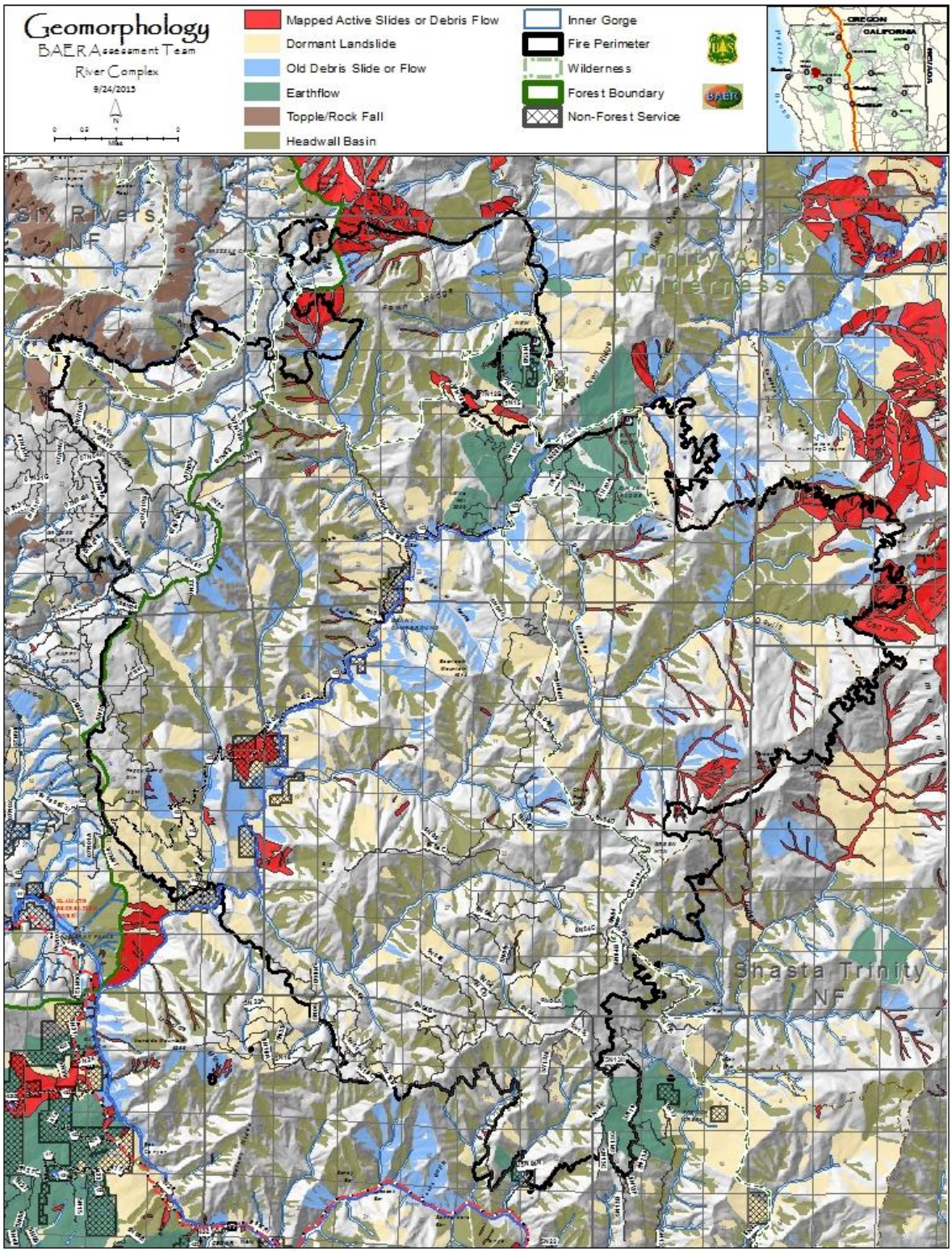
Most of the geologic terranes of the Klamath Mountains are weak and prone to landslides. Rapid uplift, high precipitation, and seismic activity to the west have created a landscape with abundant deep seated landslides, many of which occupy several square miles. Most of these larger complexes are dormant 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. Much of the terrain in the fire area is very steep, with 31% of the area having a slope gradient of >65% slopes. Gentler terrain is typically formed by dormant landslides, such as in the Jim Jam Ridge area, or near ridge crests such as around Happy Camp Mountain. Table 2 shows the area occupied by each slope class, and the Slope Map (Figure 3) displays the geographic distribution.

SLOPE CLASSES		
Class	**Acres**	**%**
0-20%	3,473	4
20-40%	13,657	18
40-65%	36,074	46
65-80%	16,653	21
>80%	7,949	10
Total	**69,857**	100

Table 2: Area (acres) and percent of the fire area



<u>Figure 3:</u> Slope Map



<u>Figure 4</u>: Geomorphology Map

Several features mapped as active landslides in the Forest Geomorphology layer burned in the fire (see active landslides shown on Figure 4). The severity of the burn on these features, and interpreted response to the fire is described below.

Hoboken- This site is located about a half mile SE of Hoboken on the east side of New River, and is identified as a debris slide. Part of the landslide drains directly into New River, and burned at lower severity, except for the uppermost part. Little increase in debris slide potential is anticipated for this part. The SE part of the landslide drains into an unnamed tributary to New River, and burned at high and moderate severity. As a result, the potential for shallow debris slides in this area is interpreted to increase considerably.

Dailey- This site is located on the west side of New River at Dailey, and is mapped as an earthflow. This landslide burned at lower severity, and little effect from the fire is anticipated.

Devils Canyon/Green Mountain- A west-trending feature mapped as an active debris slide occurs on the west flank of Green Mountain in Devils Canyon, along the east central margin. Much of this landslide burned at higher severity, and a considerable increase in debris slide potential is anticipated.

Jakes Hunting Ground- Several large features mapped as active debris slides burned at higher severities south and west of Jakes Upper Camp at the east edge of the fire. Two separate polygons are mapped, one trending westward, and another trending southward, into a separate tributary of Devils Canyon. These were sparsely vegetated headwall areas and a moderate increase in debris slide potential is anticipated.

Fawn Creek- Some east trending features are mapped as large active debris slides in the headwaters of Fawn Creek, at the northern margin of the fire burned in the fire. One of these burned at higher severity, and pre-fire imagery shows that these areas were de-vegetated by previous fires over the past 50 years. A small debris slide is visible on NAIP imagery (see below) a short distance north of the fire boundary in an older burn area which is identified as a 1999 fire in the Hydrology BAER Report for the River Complex. Examination of Google Earth time sequence imagery brackets the landslide as having occurred after August 12, 1998 and before June 30, 2004, suggesting that it likely occurred 1-5 years after the fire. However, due to the dates of the bracketing images, there is a possibility that the event actually occurred before the fire. This landslide is the type and size of feature which is likely to occur in similar settings within the River Complex with sufficient rainfall. The slide is a maximum of about 100 feet wide, 200 feet long and appears to be less than 20 feet deep. The debris flow track below is about ¼ mile long, and ends abruptly without altering the channel below. These observations suggest an increased potential for debris sliding in the more severely burned part of the mapped active debris slides in this area.

2008 NAIP Image: Shows a debris slide in a 1999 burn about ¼ mile north of the River Complex fire perimeter

The cover page to this report shows a similar debris slide (about 100' wide and 200' long) of similar age within the 1999 fire, but this landslide actually predates the 1999 fire (it is visible on on the 6-23-93 Google Earth image).

Caraway Creek- Two SE trending features along Caraway Creek mapped as active earthflows were affected by the fire. They are located on the NE margin of the fire area about a mile south of Miller Ranch. The two features are probably part of the same landslide, and the lower one is outside the fire perimeter, while about 15% of the area draining into the upper feature burned at high to moderate severity. The associated reduction in transpiration within the watershed of the earthflow will likely increase the potential for movement on the feature.

Quinby Creek- Several south trending active debris slides are mapped the headwaters of Quinby Creek at the northern fire boundary. The uppermost part of one of these burned at higher severity, and appears to be part of a re-burn of recent fires. As a result, the potential for future debris slides is interpreted to be increased by a moderate amount.

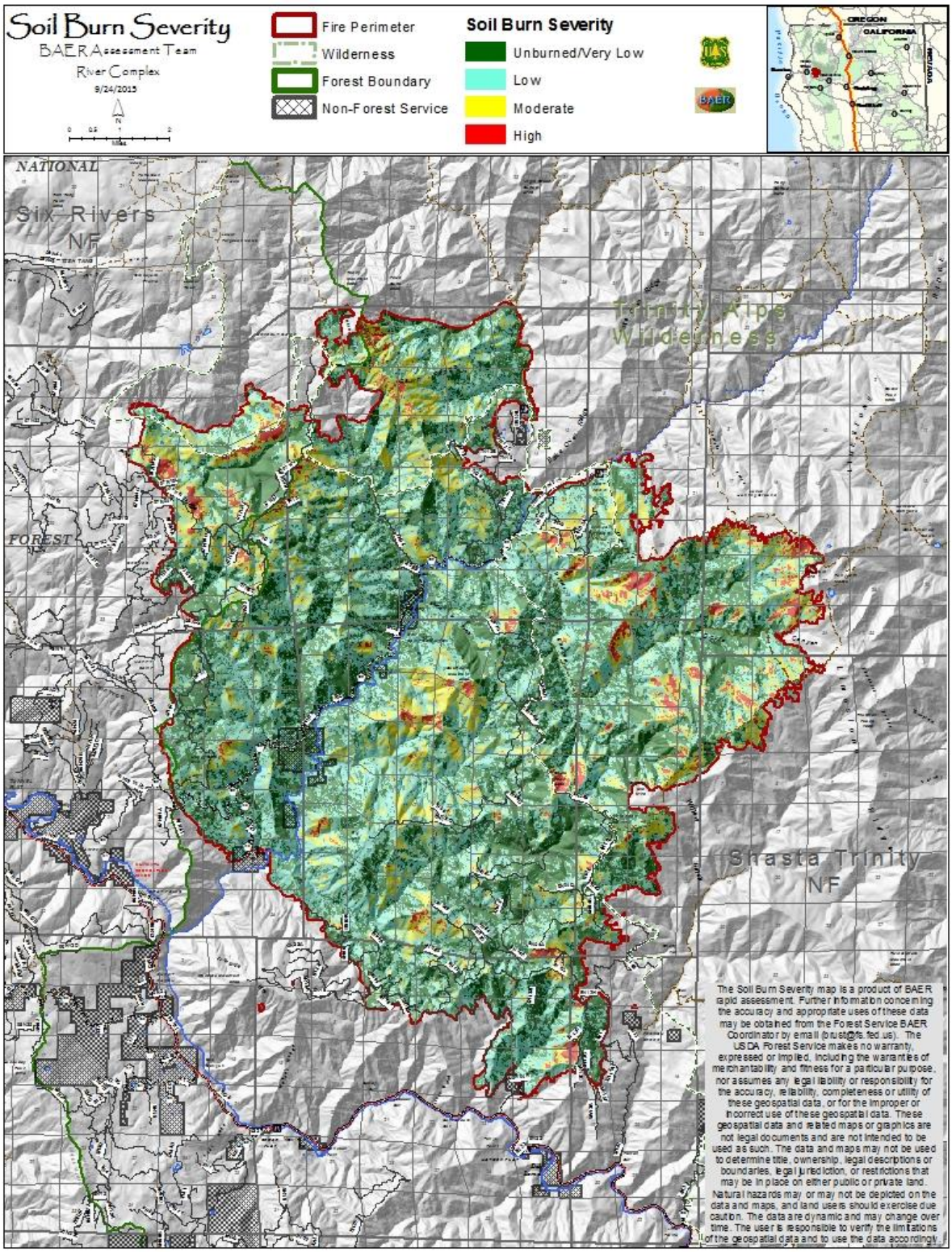
Horse Linto Creek- A large raw debris slide on a NW-trending unnamed tributary to Horse Linto Creek was partially burned by the fire. It is located on the NE margin of the fire area, about a mile SW of the junction of the East Fork of Horse Linto Creek with the main creek. The Active Feature coverage indicates that the landslide first appeared on 1944 air photos. The fire overlapped the NE margin of the landslide, and burned at lower severities. A small area draining into the landslide from the NE burned at higher severity. Higher severity area affected roughly 20% of the area draining into the landslide and into some smaller mapped debris slides to the NE of the main slide polygon. These effects are interpreted to increase the potential for enlargement of this landslide by a small to moderate amount.

The Fire

Soil burn severities were relatively low compared to other fires on the Forest in 2015, with about 18% of the area in the high/moderate category. Table 3 lists area by burn severity.

SOIL BURN SEVERITY		
Severity	**Acres**	**%**
High	2373	3
Moderate	11917	15
Low	34244	44
Unburned	29271	38
Total	77805	100

Table 3: Soil Burn Severity



<u>Figure 5:</u> Soil Burn Severity Map

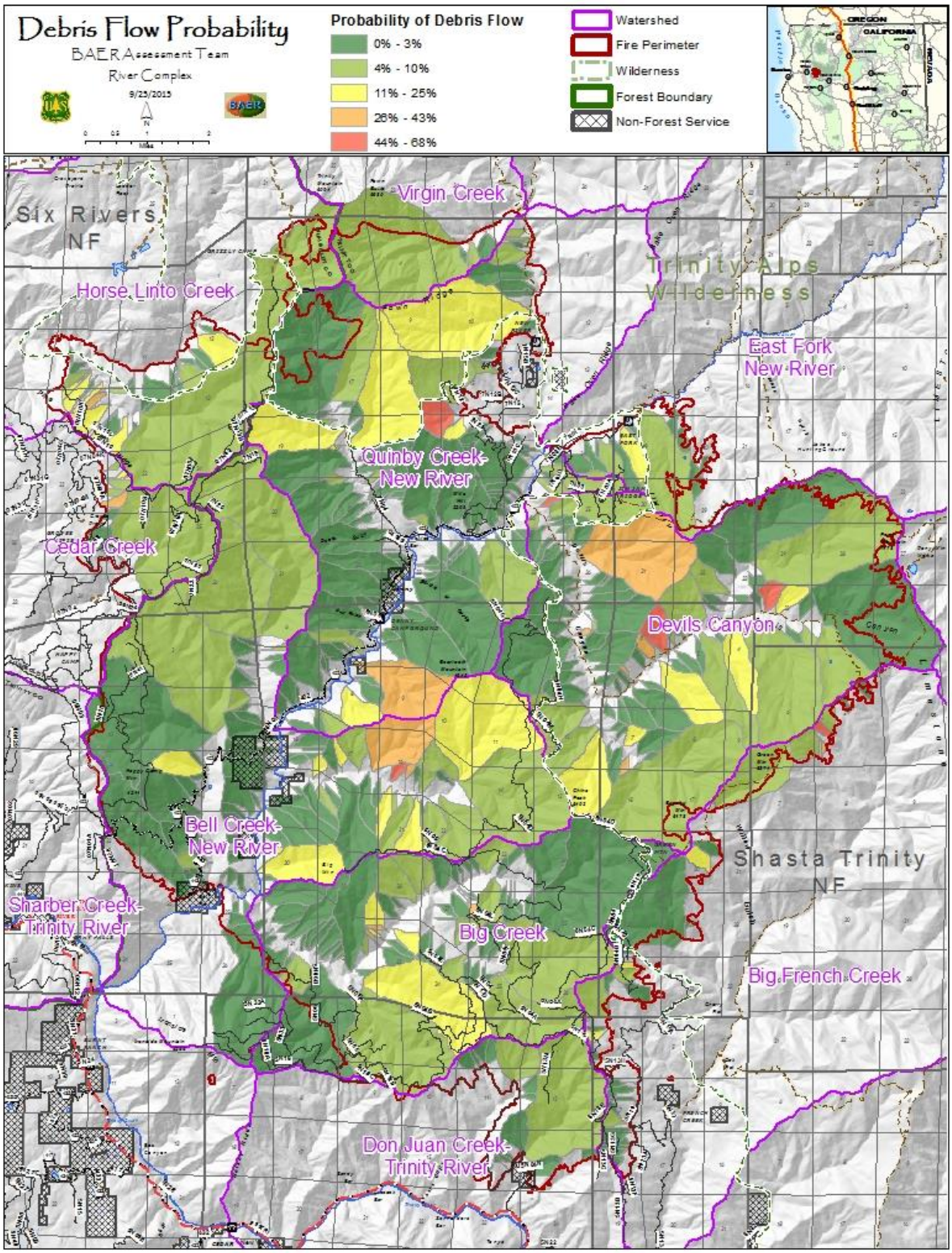
Much of the fire burned areas already affected by multiple fires within the past 50 years. As such, soils in areas burned at high and moderate severity in the River Complex will experience extremely low levels of root support since the roots in such areas are quite young and will decay much more rapidly than older, thicker roots associated with mature trees, thereby increasing vulnerability to landslides until vegetation is reestablished. Effects of such multiple burns on water repellency is not well understood, and it is unclear how this will affect debris flow potential.

FIRE EFFECTS

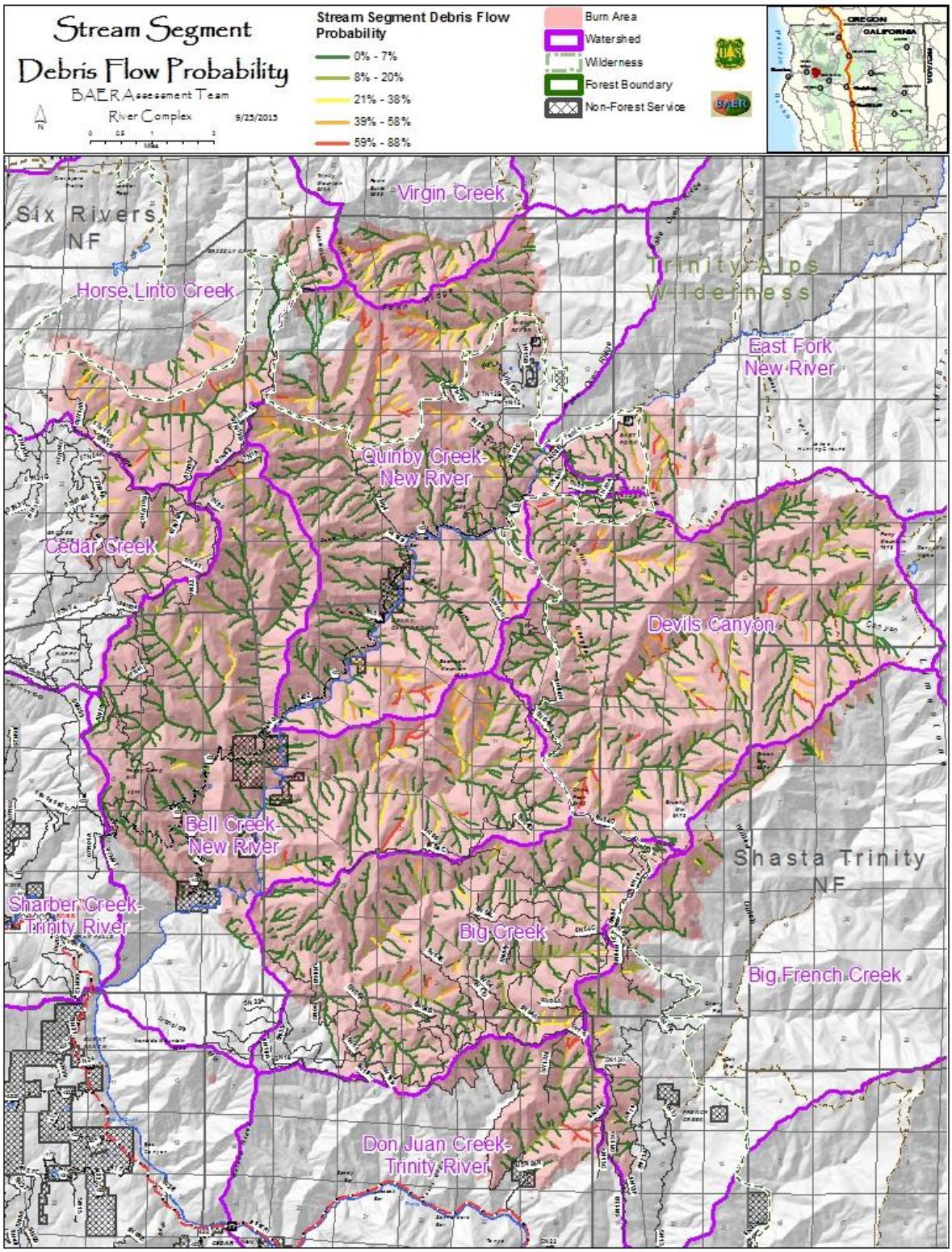
Post-fire summer debris flows triggered by the rapid influx of sediment from rills and gullies typical of places like southern California and the Rockies are less common in this region, most likely because intense summer storms occur less frequently. Discussions with Forest personnel with long tenure in the New River area revealed that debris flows and landslides following previous fires in this area were extremely rare (Eric Wiseman, personal communication 2015). Some of the large active slides mapped in the New River canyon have experienced high to moderate burn severity. The east-facing slopes of the East Fork Horse Linto Creek and Panther Creek subwatersheds in the northwestern part of the complex have the highest concentration of land with high burn severity. This area is situated within the Western Hayfork Subterrane (as described above), generally having slopes with an average of 50-60% and a small number of dormant landslides located within it. If predictions of heavy winter rains in 2015-2016 are correct (NOAA), some dormant slides could be reactivated, or new ones created in areas which burned at high and moderate severity.

OUTPUTS OF THE USGS DEBRIS FLOW MODEL

Debris flow probabilities for a 25 year 1-hour storm from the USGS debris flow model suggest that most watersheds have a debris flow potential of 0-10%, some are in the range of 11%-43%, and a few very small watersheds have a debris flow potential of 44-68% (refer to Figure 6, Debris Flow Probability Map). One watershed about a mile south of Denny Campground which enters New River from the east has a potential of 25%-43%, and there is a private cabin on a terrace adjacent to the stream. Observations from County Road 402 road across New River suggest that the cabin is outside the threat zone, but a field inspection would be necessary to verify this. Another watershed on the east flank of Happy Camp Mountain has a potential of 11%-25%, and a debris flow there would threaten County Road 402, where it crosses the stream on the west side of New River. Some, very small basins on the north side of Devils Canyon have probabilities of 44%-68%, and debris flows there would cross Trail 12W13. The Stream Segment Debris Flow Probability Map (Figure 7) allows a closer look at individual watersheds to see which parts of the stream network in that watershed are most likely to experience debris flows.



<u>Figure 6:</u> Watershed Debris Flow Probability Map



<u>Figure 7:</u> Stream Segment Debris Flow Probability Map

It should be noted that the USGS debris flow model is designed to address relatively short duration, high intensity storms, and not the longer duration storms that typically occur in winter in NW California. Additionally, it is not yet calibrated for the Klamath Mountains, and does not take into consideration geomorphic features such as the presence of dormant or active landslides. As such, it should be viewed as an indicator of debris flow potential, rather than as an absolute predictor. The model also produces estimates of debris flow volumes for the analysis watersheds, and debris flow hazard, which is a combination of debris flow probability and debris flow volume. These maps are available for review in the BAER project record for the River Complex, and also on the USGS web site listed below:

http://landslides.usgs.gov/hazards/postfire_debrisflow/2015/20150730river/

POTENTIAL VALUES AT RISK

Human Life and Safety-

Property-

Private Property-

Natural Resources-

EMERGENCY DETERMINATION

Values at Risk

Public Safety

Infrastructure- Roads, bridges, structures

Other resources and features including trails, adjacent streams and aquatic habitat

Emergency repairs involving road repairs or earthwork in areas underlain by ultramafic rock could introduce natural asbestos fibers into the air;

TREATMENTS TO MITIGATE THE EMERGENCY

Risk Matrix- Incorporated into the 2500-8 (River Complex Fire BAER Assessment)

SUMMARY/RECOMMENDATIONS

Area Closures

Close roads as appropriate, and post road closure signs.

Install berms and gates

Warning Signs

Install signs warning of rock fall, debris flows and landslides

Notification of individuals and Agencies

Notify private citizens and other agencies of potential threats posed by rock fall, landslides, and debris flows. Provide maps to all interested parties of ultramafic rock which could contain natural asbestos, and apply mitigation measures to limit dust production and human exposure in such areas.

Road Repairs/Storm Proofing

See Road Hazard Assessment report

View of New River Valley from Ironside Mountain Lookout (9-20-15)

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US Geological Survey web site for Debris Flow Model
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