Rough BAER North Zone

Sierra National Forest

Soil Resource Assessment Report

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Figure 1: Moderate soil burn severity off of the Spanish OHV Trail

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Soil Resource Setting

Due to changing fire conditions the Rough Fire was broken up into two different phases. Phase one was only conducted on 30,822 acres of the Sierra National Forest and phase two will be conducted for the Sequoia National Forest and those areas not previously analyzed during phase one at a later date. Field surveys were conducted to verify soil map units, but also to assess other factors affecting soil hydrologic function, productivity, erosion potential, and fire effects. Such factors include vegetative burn intensity, aspect, slope gradient, soil cover, duff consumption, soil heating and char, soil structure and aggregate stability, organic matter, fine root condition, and water repellency. These more detailed and GPS-located survey points were supplemented with numerous additional spot checks between too quickly assess water repellency and soil heating characteristics in more locations along travel routes.

Overall the fire area consisted of 5,039 acres of unburned/very low, 15,703 acres of low, 8,243 acres of moderate, and 1,837 acres of high soil burn severities, see Table 1. The largest concentration of high soil burn severity occurs on the southern flank of Rodgers Ridge, south of FS road 11S07 within the Spring Creek drainage. See Figure 6 for a map of the soil burn severity for the North Zone analysis area.

Table 1: Soil burn severity for the Rough BAER North Zone analysis area

Soil Burn Severity	Acres	Percent of Fire Area
Unburned/Very Low	5,039	16%
Low	15,703	51%
Moderate	8,243	27%
High	1,837	6%
Total Acres:	30,822	

The Sierra National Forest (CA750) and the High Sierra (CA740) Soil Resource Inventories were used for assessment purposes. There are forty-one soil map units (SMUs) present within the analysis area, see Table 7 for the complete list of the SMUs and Figure 7 for a map of the SMUs present within the analysis area. Corresponding map unit data and interpretations were obtained for further analyses. This provided the basic soil information for making interpretations of fire effects upon the various soils, particularly as many areas were not field visited due to access and time constraints.

The top five dominant soil families within the burned area included the Coarsegold, Holland, Chawanakee, Entic Xerumbrepts, and Auberry soil families, see Table 2. For the complete list of soil families present within the analysis area see Table 8. Soil map unit data was combined with field data and site-specific observations to generate interpretations of fire effects upon known (visited) soils, and extrapolate interpretations for unvisited areas. Subsequent erosion hazard ratings and erosion modeling estimates were based in part upon soil survey information and modified using field-calibrated data where appropriate.

Table 2: Top five dominant soil families within the Rough BAER North Zone analysis area

Soil Family	Acres	%
Coarsegold	7,485	24%
Holland	4,404	14%
Chawanakee	2,992	10%

Soil Family	Acres	%
Entic Xerumbrepts	2,673	9%
Auberry	2,165	7%

In order to assess the potential risk of a given soil to erode, an erosion hazard rating (EHR) system was developed in R-5 (FSH 2505.22). The EHR system is designed to assess the relative risk of accelerated sheet and rill erosion processes only, and was developed primarily for land use activities such as agriculture or logging. The rating system is based on soil texture, depth, clay content, infiltration, amount of rock fragments, effective surface cover, slope gradient, and climate (USDA Forest Service 1990). Risk ratings range from low to very high, with low ratings meaning low probability of surface erosion occurring. Moderate ratings mean that accelerated erosion is likely to occur in most years and water quality impacts may occur for the upper part of the moderate numerical range. High to very high EHR ratings mean that accelerated erosion is likely to occur in most years and that erosion control measures should be evaluated. For BAER purposes, fire induced changes to soil infiltration, ground cover, and runoff from adjacent areas can be factored in to determine changes in erosion hazard by soil burn severity classes, to produce a customized "post-fire EHR" map displaying erosion hazards on a relative basis.

For EHR purposes, soil map units were evaluated using information for texture, rock content, slope gradient, and characteristics relating to infiltration, permeability, and depth of the soil. EHR ratings were calculated for each soil with soil burn severity characteristics also factored in. Ratings thus represent a summary of soil physical characteristics, slope gradient, soil cover present, and level of hydrophobicity (water repellency) as observed in the field. Fire has altered the erosion hazard rating of the soils and the altered EHR ratings were 2,080 acres of none, 3,773 acres of low, 13,524 acres of moderate, 11,099 acres of high, and 346 acres of very high. See Table 3 for the EHR ratings and Figure 8 for a map of the EHRs present within the analysis area.

Table 3: Rough BAER North Zone soil erosion hazard ratings (EHRs)

Soil Erosion Hazard Rating	Acres	%
None	2,080	7%
Low	3,773	12%
Moderate	13,524	44%
High	11,099	36%
Very High	346	1%

Hydrologic soil groups are a standard soil-survey index of potential for runoff generation and subsequent erosion, regardless of fire effects of soil burn severity or water repellency. Soil hydrologic groups include 4,860 acres of A, 10,090 acres of B, 8,479 acres of C, 5,314 of D, and 2,079 acres of no ratings (see Table 4). Additional effects of the fire will cause more runoff, accelerated sheet and rill erosion throughout the fire areas.

Table 4: Rough BAER North Zone soil hydrologic groups

Soil Hydrologic Group	Acres	%
A	4,860	16%
B	10,090	33%

Soil Hydrologic Group	Acres	%
C	8,479	28%
D	5,314	17%
None	2,079	7%

Post-Fire Condition Assessment

Rapid assessment and mapping of areas in soil burn severity (SBS) classes is necessary for incorporation with other site factors such as soil type, slope, hydrologic characteristics, and biological or human resource issues to identify source areas of potential flooding and erosion, and areas where critical ecosystem values may be degraded.

Figure 2: Strong soil water repellency

It should be understood that **soil burn severity is NOT vegetative burn severity or mortality**. Vegetative burn severity is but one component taken into consideration – soil burn severity goes beyond aboveground vegetation impacts to belowground soil heating effects and associated impacts to soil hydrologic function, runoff and erosion potential, and vegetative recovery. Such additional factors include amount and condition of residual ground cover, viability of native seed banks, condition of residual fine roots, degree of fire-induced water-repellency, soil physical factors (texture, structural stability, porosity, restricted drainage), soil chemical factors (oxidation, altered nutrient status), and topography (slope gradient, length, and profile). While above-ground burn severity is more related to peak temperatures and fire behavior during the fire, below-ground soil burn severity is related strongly to the length of time that heat is in contact with the soil (residence time).

Understanding these differences is crucial to meeting the objectives of the BAER assessment. A high intensity fire (high flame lengths, rapid rate of spread, crown fire, etc.) in a stand-replacement event can result in a moderate (or even low) soil burn severity, if the residence time is short and soil characteristics are not altered significantly. Conversely, a slow-moving fire with complete consumption of accumulated surface fuels can leave trees alive, but heat the soil severely with predictable negative consequences to soils and streams. Soil burn severity, used in this context, is a much better index of soil damage, watershed response, and potential for natural vegetative recovery after the fire. Residual soil cover post-fire is the most crucial aspect of aboveground fire effects for potential erosion, but there is a tendency for some to consider only cover at the expense of belowground soil conditions.

Soil Burn Severity Indicators (Parsons et al 2010) used to characterize the soil burn severity at field data points:

- **Low soil burn severity**: Surface organic layers are not completely consumed and are still recognizable. Structural aggregate stability is not changed from its unburned condition, and roots are generally unchanged because the heat pulse below the soil surface was not great enough to consume or char any underlying organics. The ground surface, including any exposed mineral soil, may appear brown or black (lightly charred), and the canopy and understory vegetation will likely appear "green."

- **Moderate soil burn severity:** Up to 80 percent of the pre-fire ground cover (litter and ground fuels) may be consumed but generally not all of it. Fine roots (~0.1 inch or 0.25 cm diameter) may be scorched but are rarely completely consumed over much of the area. The color of the ash on the surface is generally blackened with possible gray patches. There may be potential for recruitment of effective ground cover from scorched needles or leaves remaining in the canopy that will soon fall to the ground. The prevailing color of the site is often "brown" due to canopy needle and other vegetation scorch. Soil structure is generally unchanged.

- **High soil burn severity**: All or nearly all of the pre-fire ground cover and surface organic matter (litter, duff, and fine roots) is generally consumed, and charring may be visible on larger roots. The prevailing color of the site is often "black" due to extensive charring. Bare soil or ash is exposed and susceptible to erosion, and aggregate structure may be less stable. White or gray ash (up to several centimeters in depth) indicates that considerable ground cover or fuels were consumed. Sometimes very large tree roots (> 3 inches or 8 cm diameter) are entirely burned extending from a charred stump hole. Soil is often gray, orange, or reddish at the ground surface where large fuels were concentrated and consumed.

Field sites were evaluated to validate the soil burn severity map and to determine the degree of water repellency present within the top soil. Commonly within the areas identified as high soil burn severity (6% of the fire area) a moderate to high soil burn severity was observed. The depth of soil charring was discovered to around 1" to 1.5" with the some of the fine roots consumed and charring of the coarser roots was observed. Soil structure was never completely destroyed resulting in a granular soil structure. The presence of non-consumed organic matter within the surface soil caused the soil structure to vary between slightly and moderately altered, as the soil structure became more altered as the soil aggregates became weaker and weaker. An increased fuel load within some areas has increased the fire residence time increasing the burn severity on the soils below. Soil water repellency (hydrophobicity) was variable down to three inches; included were areas of moderately (10-40 seconds) to strongly (>40 seconds) hydrophobic soils. See Figure 3 for a visual representation of high soil burn severity. The canopy was typically consumed and minimal recruitment of additional soil cover will occur in these areas resulting in a higher likelihood of hillslope erosion occurring.

Figure 3: High soil burn severity

Within the areas identified with a moderate SBS (27% of the area) the ground conditions were representative of moderate SBS. In these areas minimal soil charring was observed and commonly only occurred to ¼ of an inch. Fine roots were frequently present but charred within this same depth range and soil structure was only slightly altered. Soil water repellency (hydrophobicity) was very patchy and included areas of weak (<10 second) too strongly (>40 seconds) hydrophobic soils. Ground cover was partially recognizable with 20% to 80% consumption and the canopy was partially to completely intact. See Figure 4 for a visual example of a soil within moderate SBS. With an intact brown canopy providing needle cast for ground cover in addition to present ground cover, a less intense watershed response is expected. Infiltration of storm precipitation will vary depending on storm intensity and duration, possibly resembling a high watershed response similar to high SBS areas in the event of a severe storm. In general areas with a

moderate SBS will have higher infiltration capacity and greater soil cover retention when compared to areas with a high SBS, resulting in a lesser erosion risk.

Figure 4: Moderate soil burn severity

The remaining 51% of the burned area contains low soil burn severity. Very little evidence of significant soil heating was observed; no changes in soil color, structure, organic matter or fine root combustion occurred within these soils. Water repellency is hit-or-miss, from slight to severe, and is attributed as natural, not fire-exacerbated. The seed source within these areas would still be present in most topsoils and natural understory revegetation is expected to progress without delay. Ground cover was recognizable and less than 20% consumption was observed. These areas currently have 50 to 100% soil cover and should produce little accelerated runoff or erosion above natural "background" rates. See Figure 5 for a visual representation of low soil burn severity.

Figure 5: Low soil burn severity

Quantitative erosion figures were estimated using the ERMiT batch model. ERMiT (Erosion Risk Management Tool) is a WEPP-based application developed by USFS Rocky Mountain Research Station (USFS, RMRS-GTR-188, 2007) specifically for use with post-fire erosion modeling. The model estimates only sheet and rill erosion, which occurs when rainfall exceeds infiltration rates, and surface runoff entrains surface soil particles. The model does not account for shallow landsliding or gullying, stream-bank erosion, road effects, or fire-line erosion and gullying, which could present large additional sources of sediment entering the fluvial systems.

ERMiT models erosion potential based on single hillslopes, single-storm "runoff events," and post-fire soil burn severity. Hillslopes include soil and topography inputs. Soil inputs include texture and matrix rock content, which was based upon soil map unit information and field verified in many areas of the fire as part of the assessment. Generalized hillslope gradients and profiles were developed in GIS by soil map unit, and soil burn severity class to account for fairly site specific differences in topography. Three hundred and sixty-six hillslopes were modeled within the analysis area. One batch run was completed for the entire analysis area and four individual runs for each of the HUC12 watersheds within the same area. See Table 5 and Table 6 for the burned and unburned ERMiT batch results. See Figure 9 for a fire wide erosion potential map. As input for storm events, ERMiT uses the PRISM module to generate climatic input parameters; a customized climate interpolated from Grant Grove, CA was generated for this area to refine erosion estimates. Various storm runoff-event magnitudes may be chosen in ERMiT for erosion response estimates; 2-year, 5-year, and 10-year events were run for this analysis.

Soil erosion estimates are based upon watershed areas within the fire perimeter only; unburned watershed areas outside the fire area were not modeled. As an interpretive visual, tons/ac is roughly equivalent to that many sheets of paper stacked being removed from the soil surface, and 1000 tons of sediment would fill about 120 standard 10-yard dump trucks. A 5-Year storm was modeled in ERMiT to determine if the estimated soil erosion for the fire area would affect soil productivity. For the 5-year event (20% probability); an estimated average 766,529 tons of sediment may be produced (20.6 tons/acre), equivalent to 11,790 cubic yards per square mile (using a conversion factor of 1.35 tons per cubic yard). Increased hillslope erosion is expected to occur throughout the fire area, especially within those areas in the high soil burn severity. Unburned, pre-fire conditions estimated an average 17,484 tons of sediment could be produced (0.48 tons/acre) for a 5-year event (20% probability). Stated model accuracy is +/- 50%.

Table 5: Burned ERMiT batch results

Burned						
Area	**50% (2 Year)**		**20% (5 Year)**		**10% (10 Year)**	
	Tons/Acre	**Tons**	**Tons/Acre**	**Tons**	**Tons/Acre**	**Tons**
Rough Fire	7.47	282,943	20.60	766,529	37.05	1,444,743
Converse Creek-Kings River	8.92	106,591	24.52	308,126	42.91	539,126
Patterson Creek-North Fork Kings River	9.24	59,986	26.25	164,376	47.21	310,145
Rancheria Creek-North Fork Kings River	4.87	35,449	15.23	109,281	27.37	202,134
Verplank Creek-Kings River	9.98	101,193	25.94	256,864	46.76	457,336

Table 6: Unburned ERMiT batch results

Unburned						
Area	**50% (2 Year)**		**20% (5 Year)**		**10% (10 Year)**	
	Tons/Acre	**Tons**	**Tons/Acre**	**Tons**	**Tons/Acre**	**Tons**
Rough Fire	0.08	3,264	0.48	17,484	1.98	43,712
Converse Creek-Kings River	0.06	351	0.36	2,780	1.40	12,275
Patterson Creek-North Fork Kings River	0.12	298	0.70	2,195	2.40	5,068
Rancheria Creek-North Fork Kings River	0.03	17	0.19	227	1.24	942
Verplank Creek-Kings River	0.14	2,592	0.82	12,250	2.82	22,869

Values at Risk – Threats to Life, Property, and Cultural & Natural Resources

In one sense, fire and post-fire erosion are integral parts of the local disturbance regime; however many of the BAER critical values we are concerned with did not naturally occur in the fire area prior to historic times. Soil quality and hydrologic function throughout the fire was assessed by determining soil burn severity, soil erosion hazard, and evaluating potential on- and off-site effects of topsoil loss and sediment production. The combination of soil types, steep slopes, and lack of soil cover will create watershed responses with elevated erosion and sedimentation, the degree depending upon the severity of the coming winters over the next 3-5 years at least. Potential impacts can be categorized into both on-site and off-site effects. On-site effects include the physical, chemical, and biological

response of the soils to the fires, and likely recovery rates. Off-site effects due to sedimentation and stream bulking are downstream; these in a general sense include potential adverse effects to life and facilities (roads, buildings, reservoirs), water quality deterioration for sensitive aquatics species and human use, and risk to human life and property from potential flooding, mudslides, and debris flows, both on and off of Forest Service lands.

Erosion and sedimentation would contribute to debris flows and mudflows IF they were to occur, which would have a high potential to threaten life and property, as well as water quality for beneficial uses. Natural hillslope erosion rates are rather low (< 1 ton/acre) when vegetated and covered with duff; vegetation mortality and lack of cover in moderate SBS areas will certainly accelerate runoff and erosion processes in the post-fire environment, the degree depending on the magnitude and intensity of coming storm events. While this may or may not pose an unacceptable risk to on-site soil resources, it would contribute to downstream hazards, particularly if larger storm events occur in the first several winters.

Emergency Determination

Specific to soil productivity, modeled erosion rates (20.6 tons/acre) are low and are not likely impact to soil productivity. Soil families within the analysis area consisted of moderately deep to deep soil profiles, with a few shallow profiles as well. Water repellency was observed in all of the soil burn severities and is patchy and discontinuous where it occurs. Risk rating for soils varies according to the likelihood of major soil loss: there is a <u>possible</u> probability of damage or loss with a <u>low</u> magnitude of consequences resulting in a <u>low</u> risk to soil productivity. While soil erosion is always irreversible (major magnitude of consequences), the damage to soil productivity is considered recoverable in most cases, as forest soils are generally resilient and post-fire pulse erosion is a very natural geomorphic process.

References

Giger, D. 1993. Soil Survey of Sierra National Forest Area, California. U.S. Department of Agriculture, Forest Service. Open File Report, Clovis, CA.

Parsons, A., P.R. Robichaud, S.A. Lewis, C. Napper, J.T. Clark, 2010. Field Guide for Mapping Post-Fire Soil Burn Severity. USDA Forest Service General Technical Report RMRS-GTR-243, 2010.

Taskey, Ronald D. 1995. Soil Survey of High Sierra Area, California. U.S. Department of Agriculture, Forest Service. Open File Report, Clovis, CA.

USDA Forest Service. 1990. Soil erosion hazard rating. Soil and Water Conservation Handbook

Table 7: Soil map units and acreages

Soil Map Unit - Soil Survey - Soil Map Unit Name	Acres
103 - SNF - Ahwahnee family-Rock outcrop complex, 35 to 75 percent slopes	950
106 - SNF - Auberry family, 35 to 65 percent slopes	512
108 - SNF - Auberry-Ahwahnee families association, 35 to 65 percent slopes	67
109 - SNF - Auberry family-Rock outcrop complex, 35 to 75 percent slopes	364
110 - SNF - Auberry-Tollhouse families-Rock outcrop association, 25 to 65 percent slopes	1,221
111 - SNF - Cagwin family, 25 to 60 percent slopes	759
112 - SNF - Cagwin-Cannell families complex, 2 to 25 percent slopes	177
113 - SNF - Cagwin family-Lithic Xeropsamments-Rock outcrop complex, 15 to 45 percent slopes	100
116 - SNF - Cagwin family-Rock outcrop complex, 35 to 65 percent slopes	240
126 - SNF - Chawanakee family-Rock outcrop complex, 35 to 65 percent slopes	2,992
127 - SNF - Coarsegold-Auberry families association, 35 to 65 percent slopes	4,660
128 - SNF - Coarsegold-Auberry families-Rock outcrop association, 35 to 85 percent slopes	2,825
128 - HS - Typic Xerorthents-Entic Haploxerolls-Typic Xerochrepts complex, 35 to 75 percent slopes	278
131 - SNF - Dystric Xerochrepts and Typic Xerumbrepts, 20 to 50 percent slopes	87
135 - SNF - Gerle-Cagwin families association, 35 to 55 percent slopes	1,659
137 - SNF - Holland family, 35 to 65 percent slopes	2,248
139 - SNF - Holland-Chaix families complex, 35 to 65 percent slopes	1,672
139 - HS - Typic Cryumbrepts-Typic Cryorthents-Rock outcrop complex, 0 to 30 percent slopes	3
140 - SNF - Holland-Chawanakee families complex, 35 to 65 percent slopes	485
142 - SNF - Entic Xerumbrepts-Dystric Xerorthents-Rock outcrop association, 40 to 85 percent slopes	2,673
147 - SNF - Rock outcrop	227
147 - HS - Rock outcrop-Typic Cryorthents complex, 0 to 45 percent slopes	6
148 - SNF - Rock outcrop-Chawanakee family association, 35 to 65 percent slopes	1,183
149 - SNF - Rock outcrop-Cryorthents complex, 5 to 50 percent slopes	22
152 - SNF - Rock outcrop-Lithic Xeropsamments complex, 15 to 45 percent slopes	233
153 - SNF - Rock outcrop-Lithic Xeropsamments complex, 45 to 85 percent slopes	410
158 - SNF - Sirretta family, 25 to 50 percent slopes	482
159 - SNF - Sirretta family-Rock outcrop complex, 15 to 45 percent slopes	201
160 - SNF - Sirretta family-Rock outcrop complex, 45 to 65 percent slopes	484
161 - SNF - Sirretta family and Umpa family, wet, 2 to 25 percent slopes	317
162 - SNF - Stecum family, 3 to 35 percent slopes	166
163 - SNF - Stecum family-Aquic Cryumbrepts association, 1 to 25 percent slopes	38
164 - SNF - Stecum family-Rock outcrop complex, 5 to 45 percent slopes	100
166 - SNF - Tollhouse family-Rock outcrop complex, 30 to 60 percent slopes	593
167 - SNF - Tollhouse family-Rock outcrop association, 60 to 85 percent slopes	510
168 - SNF - Typic Argixerolls, 15 to 50 percent slopes	6
169 - SNF - Typic Argixerolls-Coarsegold family association, 35 to 65 percent slopes	50
170 - SNF - Typic Xerumbrepts, 5 to 20 percent slopes	310
171 - SNF - Ultic Haploxeralfs, deep, 15 to 50 percent slopes	308

174 - SNF - Umpa family, 5 to 35 percent slopes	932
175 - SNF - Umpa family, 35 to 55 percent slopes	272

Table 8: Rough BAER North Zone soil families

Soil Family	Acres	%
Coarsegold	7,485	24%
Holland	4,404	14%
Chawanakee	2,992	10%
Entic Xerumbrepts	2,673	9%
Auberry	2,165	7%
Rock Outcrop	2,080	7%
Gerle	1,659	5%
Sirretta	1,485	5%
Cagwin	1,277	4%
Umpa	1,204	4%
Tollhouse	1,102	4%
Ahwahnee	950	3%
Typic Xerumbrepts	310	1%
Ultic Haploxeralfs	308	1%
Stecum	304	1%
Typic Xerorthents	278	1%
Dystric Xerochrepts	87	0%
Typic Argixerolls	56	0%
Typic Cryumbrepts	3	0%
Total:	30,822	

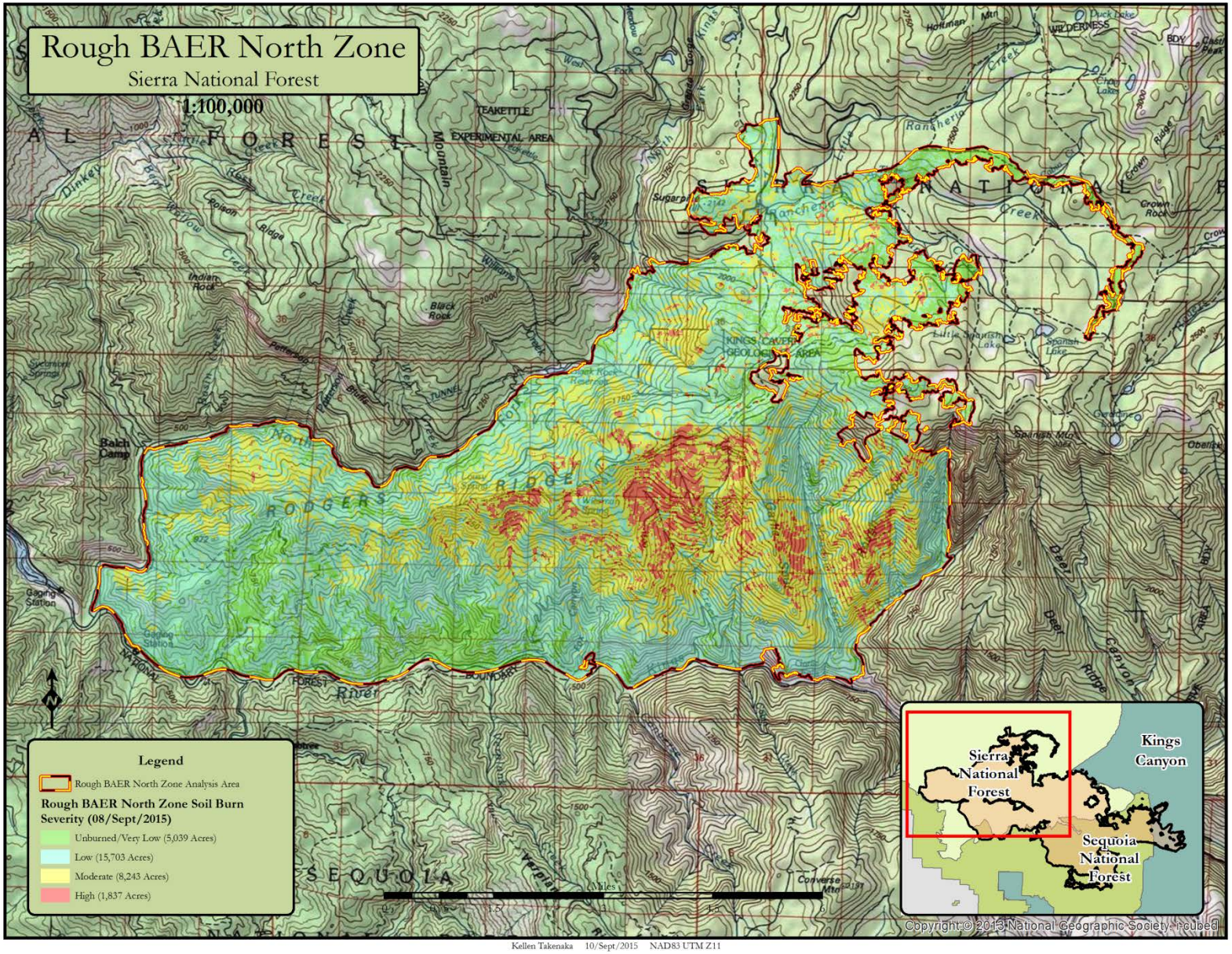

Figure 6: Rough BAER North Zone soil burn severity map

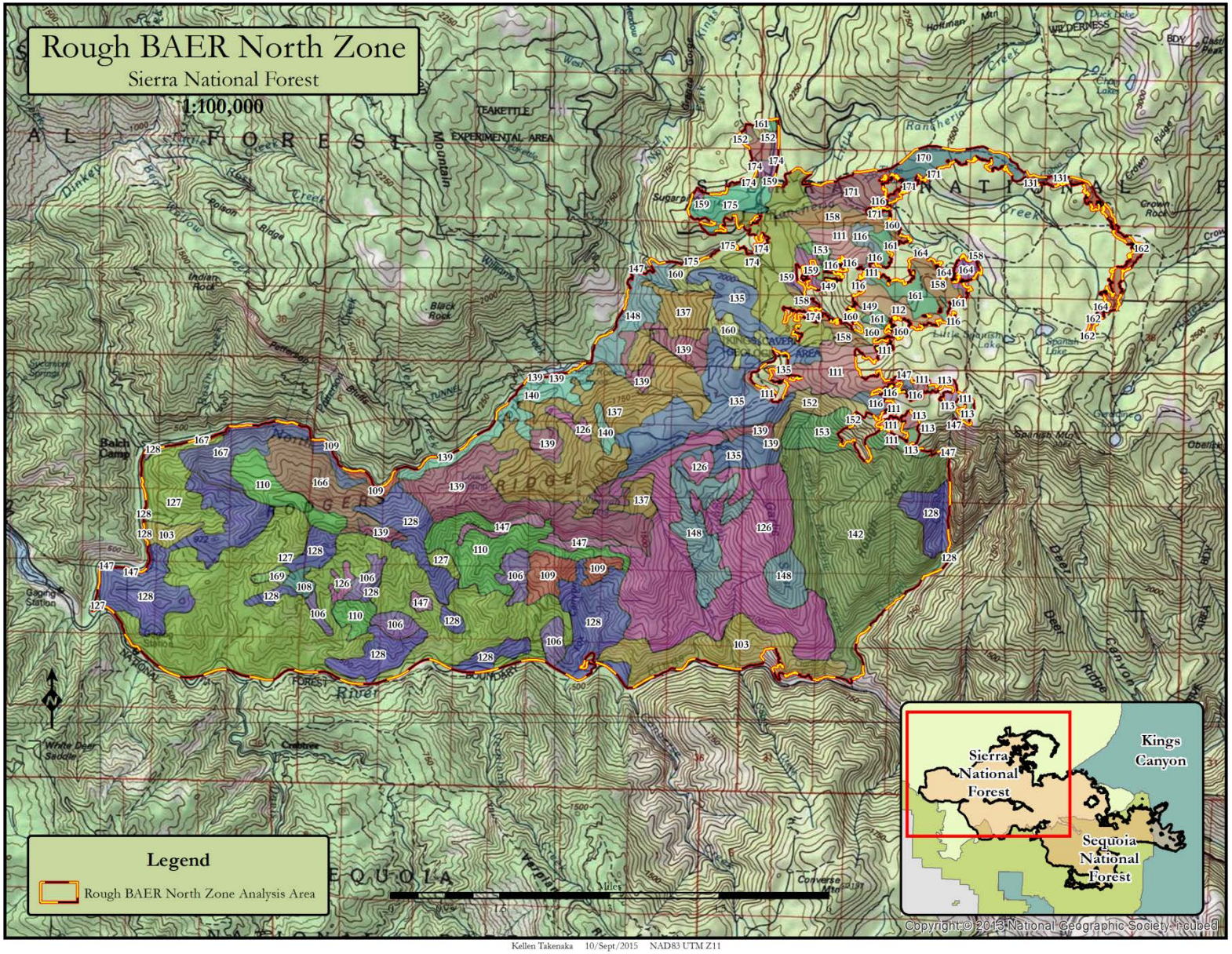

Figure 7: Rough BAER North Zone soil map units (SMUs)

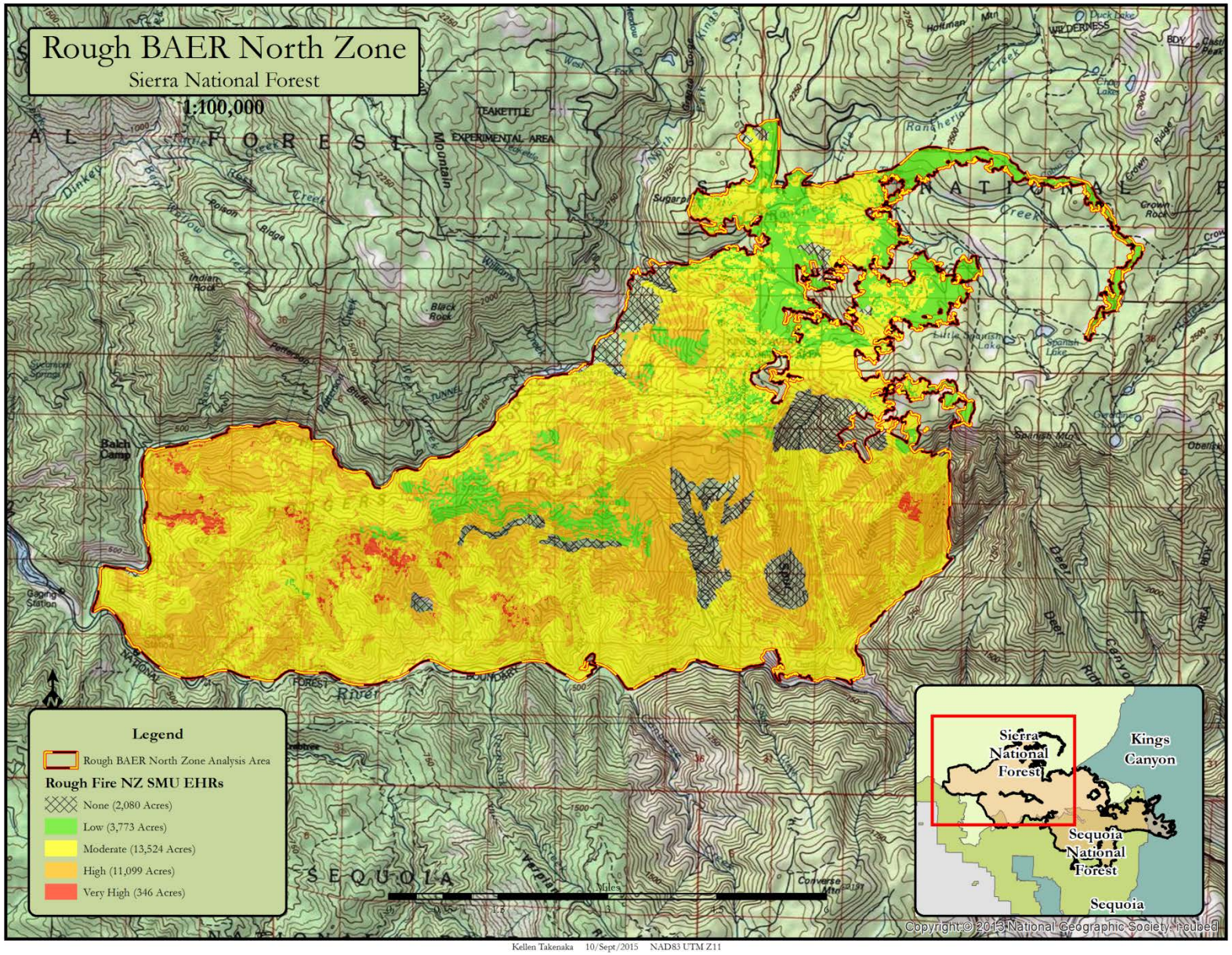

Figure 8: Rough BAER North Zone erosion hazard ratings (EHRs)

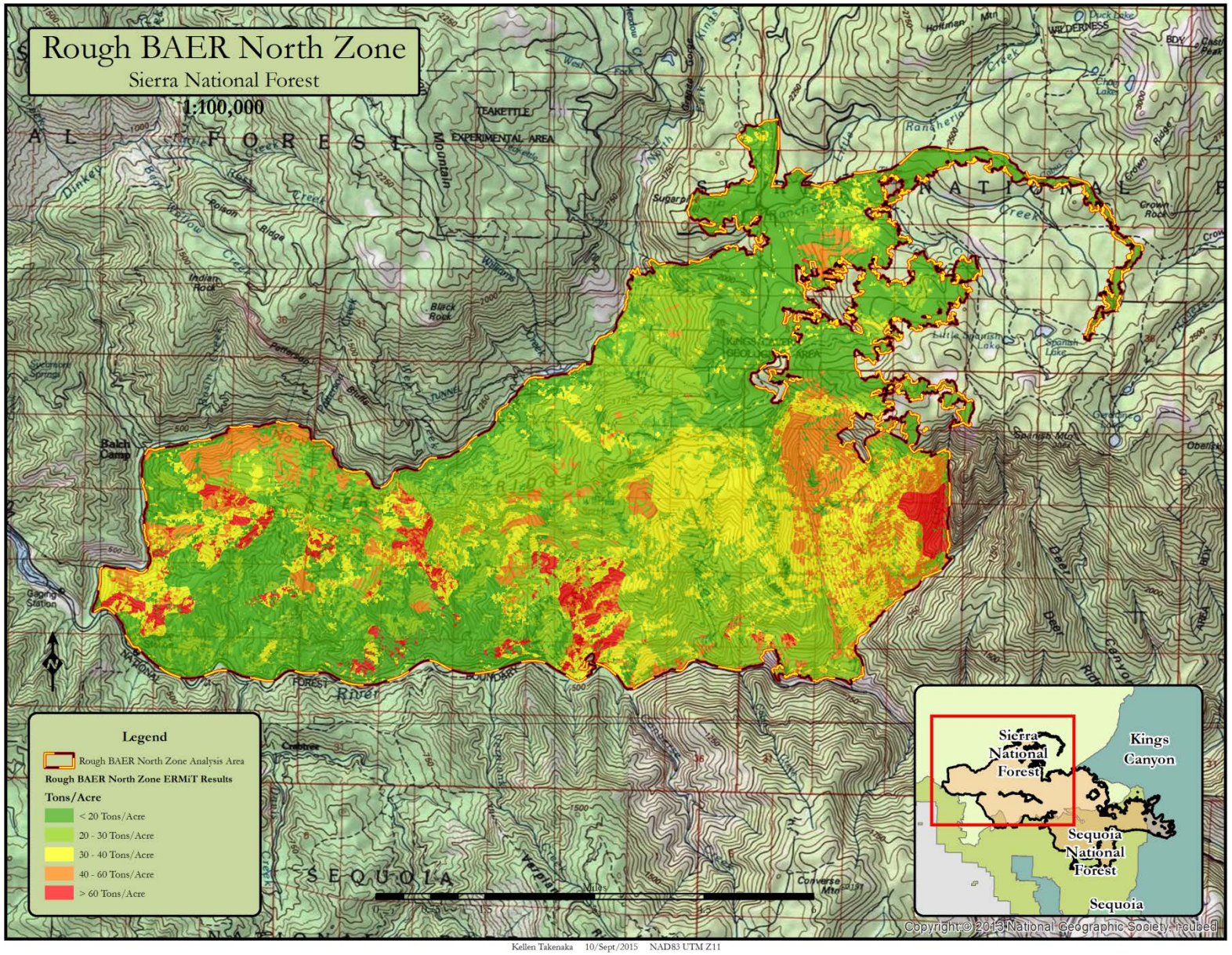

Figure 9: Rough BAER North Zone ERMiT batch results fire wide