Pacific Southwest Region | February 2025

Burned Area Emergency Response Assessment (BAER) Technical Report Eaton Fire (CA-LAC-009087)

February 7, 2025

Eaton Fire (USDA FS)

Jonathan Schwartz, Geologist, Los Padres National Forest
Eric Nicita, Soil Scientist, El Dorado National Forest
Nathan Clark, Soil Scientist, Humbolt-Toiyabe National Forest
Hilda Kwan, Hydrologist, Mendocino National Forest
Todd Ellsworth, Post-Fire Recovery Specialist, Pacific Southwest Regional Office
Kyle Wright, Hydrologist, Deschutes National Forest

This report and mapping are products of BAER rapid assessment completed by the USFS. Further information concerning the accuracy and appropriate uses of geospatial data as displayed may be obtained from the various sources. The USDA Forest Service makes no warranty, expressed or implied, including the warranties of merchantability and fitness for a particular purpose, nor assumes any legal liability or responsibility for the accuracy, reliability, completeness, or utility of these geospatial data, or for the improper or incorrect use of these geospatial data. These geospatial data and related maps or graphics are not legal documents and are not intended to be used as such. The data and maps may not be used to determine title, ownership, legal descriptions, boundaries, legal jurisdiction, or restrictions that may be in place on either public or private land. Natural hazards may or may not be depicted on the data and maps, and land users should exercise due caution. The data is dynamic and may change over time. The user is responsible to verify the limitations of the geospatial data and to use the data accordingly.

Overview and Process

The Eaton Fire ignited in the hills of Eaton Canyon, near Altadena, California on the evening of January 7, 2025. By 10:30 a.m. the next day, the fire had quickly grown to cover more than 10,000 acres (40 square kilometers), according to CAL FIRE. By January 11, it had expanded to approximately 14,000 acres (57 square kilometers). The fire started during a "Particularly Dangerous Situation" red flag warning; it was wind-driven with Santa Ana winds up to 100 mph. The previous 3-month period from October to January is the driest on record. As of January 28, 2025, the fire was considered 99% contained. The fire perimeter encompassed roughly 14,200 acres. Approximately 55% of the burned area are on National Forest System (NFS) lands, all on the Angeles National Forest (NF). Roughly 6,400 acres (45%) within the fire perimeter were on non-NFS (mostly private) land.

The Eaton Fire burn scar extends from Occidental Peak and Mount Wilson at the north (north-east) end of the fire, to neighborhoods of Altadena, Pasadena and Sierra Madre, at the southern (bottom) end of the fire. The west end of the fire included parts of the Millard Canyon watershed (on the Angeles NF) and down along Lincoln Ave in Altadena and Pasadena. At the east end of the fire, the burn scar extended nearly to the Santa Anita Dam, and Santa Anita Avenue, in the town of Sierra Madre. The physiography of the burn area is dominated by steep slopes and rugged canyons largely draining to the south-east, south and south-west, and include the Eaton Canyon watershed, the Little Santa Anita watershed, and other smaller watershed flowing south directly into the communities of Altadena and Sierra Madre. The average slope gradient in the San Gabriel Mountains is over 65 percent which leads to high erosion rates in both dry and wet periods (Krames, 1963). Elevation ranges from approximately 1,100 feet above sea level (asl) at, the lower neighborhoods, to about 5,700 feet (asl) at Mount Wilson.

A Burned Area Emergency Response (BAER) assessment team began field reconnaissance of the burned area on January 14, 2025, to complete soil burn severity mapping, characterize soil, hydrologic, geologic response, and other post-fire threats, and to identify BAER Critical Values.

This BAER assessment was a coordinated, shared response, including close coordination with the California Watershed Emergency Response Team (CAL WERT) and Los Angeles and San Bernardino Public Works. The BAER team reached out to many non-Forest Service entities (*e.g.*, USGS, CAL-OES, CAL FIRE, National Weather Service (NWS), Natural Resources Conservation Service (NRCS), etc.) to ensure cross boundary coordination and information sharing during the BAER assessment. Many non-forest entities, and partners have infrastructure in and adjacent to the fire area and are actively repairing damaged infrastructure and/or implementing mitigations to reduce post-fire runoff damage. The BAER team continues to share results and findings with non-forest entities so that they can develop appropriate response plans to properly inform public safety, protect/prepare infrastructure, and critical natural resources from anticipated post-fire watershed response events.

***Picture 1**: Burned landscape on Eaton Fire.*

The BAER team participated in Los Angeles County led interagency “Debris Flow Task Force” meetings. The Angeles NF is a key partner to prepare for winter runoff events. Currently, meetings are held weekly and will continue into the rainy season. The BAER team also organized and attended an Interagency field trip led by CAL WERT which was also attended by Los Angeles County Public Works to discuss assessment and potential post-fire response in the built urban environment.

Burned area emergency assessments are rapid evaluations done to determine if critical values are at risk due to imminent post-fire threats and to develop appropriate actions to manage unacceptable risks. Critical values identified by the BAER team included human life and safety, recreation and transportation infrastructure, cultural and heritage sites, critical aquatic and wildlife habitat, and other natural resource values. These assessments are not intended to provide a comprehensive evaluation of all fire or fire-suppression damages, nor to identify long-term rehabilitation or restoration needs.

The first step in a burned area assessment is to identify specific values that are potentially at risk from post-fire events. Once these critical values have been identified, each is assessed for potential threats from post-fire conditions. To characterize post-fire threats, the BAER team makes field observations of soil and watershed conditions that are used in conjunction with analysis methods to estimate anticipated levels of post-fire damage from erosion, flooding, and geologic hazards. A post-fire emergency is identified when a critical value found to be at unacceptable risk of damage due to post-fire conditions. After defining the post-fire emergency, a response strategy that considers natural recovery is developed to mitigate the risk.

General Resource Setting

Geology and Soils

The Eaton Fire burn footprint occurred on the south slopes of the central San Gabriel Mountains rock assemblage, a group of rocks that form part of the east-west oriented Transverse Ranges of Southern California. The Transverse Ranges resulted from complex tectonic interaction between the Pacific and North American plates along the right-lateral, strike-slip San Andreas Fault. During the early Miocene (from about 23.03 to 5.33 million years ago) increased friction between the Pacific and North American plates caused a left restraining bend in the San Andreas Fault, rotating and uplifting the mountains in a clockwise east-west orientation (Crowell, 1982). While the relative motions of the plates remain the same, this "big bend" section allowed for a mix of strike-slip and thrust faulting that further uplifted the San Gabriel Mountains about 7 million years ago (Moulin, A. & Cowgill, E., 2023). This tectonic activity continues today and contributes to the faster than average uplift rate relative to other mountain ranges in the United States. Large fault networks occur near or within the burn perimeter and include the San Gabriel Fault to the north, the Sierran Madre Fault Zone to the south and southwest and the Vincent Thrust to the west.

The northern part of the burn area consists of undifferentiated Mesozoic granite (Mount Lowe Granodiorite and Parker Quartz Diorite) juxtaposed with undifferentiated Precambrian metamorphic rocks consisting of quartz-plagioclase gneiss with ferromagnesium minerals. Moving south, the central part of the burn area is characterized by undifferentiated Precambrian granite (Echo Granite), which is described as orange to pinkish-gray, locally foliated, quartz-rich granitic rock; the Precambrian suite also includes Syenite phase of the San Gabriel anorthosite complex (Mint Canyon area); Gabbroic and noritic rocks; altered rocks (anorthosite), ilmenite-magnetite gabbro and massive ilmenite-magnetite. Southeast of the Precambrian metamorphic and granitic rocks lies Mesozoic granitic rocks consisting of tonalite and unnamed quartz diorites and diorite. The southern part of the burn area is comprised of Mesozoic granitic rocks including adamellite, granite, alaskite, and quartz monzonite. Where the San Gabriel Mountains give way to the San Gabriel Valley, Pleistocene nonmarine sedimentary rocks dominate and consist of interbedded gravel, sand, silt, and gypsiferous clay, with "older" alluvium consisting of gravel, sand, silt and clay.

Due to the steep slopes, semi-arid climate and active tectonics, the soils across the Eaton fire are typically shallow, poorly developed and coarse textured. There is also significant coverage of rock outcrop and urban lands. The soil survey information is aggregated for specific map units, which are areas on the landscape that have consistent repeating soil patterns. The specific information within these map units is generally aggregated by the dominant condition for that area. The table below displays the dominant condition for the map units across the fire perimeter. Entisols and inceptisols are the taxonomic soil orders defined by minimal soil development.

With the preponderance of soils being weakly developed, they do not have the robust chemical and biological binding mechanisms to stabilize soil particles. The fire impacted soil and vegetative qualities that stabilize the soil from impacts such as rain, wind and gravity, consequently, the 80-100 mph winds stripped off the affected organic and mineral surface layers where most of the seed bank and nutrients are stored. This will have a noticeable effect to soil productivity. These impacts are primarily occurring in the lower 1/3 in elevation of the fire. The upper elevations did experience less impacts but will soil effects are noticeable.

Hydrology

The temperature and precipitation in the burn scar varies with elevation. Overall, the area experiences a Mediterranean climate, with warm, dry summers and mild, wet winters. The rainy season extends from November to April, and the most precipitation for the season falls between December and February. At lower elevations annual precipitation ranges from 20-24 inches a year, while at higher elevations, precipitation increases to about 33 inches a year at the Mount Wilson area. During cold fronts/winter storms, snow typically falls at elevations of 5,000 feet and above. While summers are generally dry, moisture from the Gulf of California occasionally reaches the San Gabriel Mountains to bring scattered monsoonal thunderstorms in July and August. Most of the fire burn scar is dominated by typical chapparal shrub, while north facing slopes and high elevations areas are characterized by mixed coniferous vegetation.

In general, these drainages are steep and rugged with deep finger-canyons indicative of debris flow potential. As shown in the Soil Burn Severity (SBS) map (Maps 1 and 2 at end of document), the landscape has large continuous areas of moderate SBS, which will affect watershed response.

Eaton Canyon is the largest watershed affected by the Eaton Fire and has a long history of use by native Americans, Spanish settlers, and modern populations. This perennial stream is laden with evidence of past debris flows, as the BAER team saw during our hike to Eaton Canyon Falls. Additionally, walls of the Canyon are steep with limited access. Although not many roads traverse this canyon, there are numerous trails and several recreational sites within the watershed including the highly visited Eaton Canyon Falls. Extensive dry ravel and rock fall was noted while driving around the burn area.

Little Santa Anita Canyon, though smaller, has similar features as Eaton Canyon. There is a catchment dam at the mouth of this canyon, as there are homes just downstream. The Mt. Wilson trail runs parallel to the Canyon (well above the high watermark) and already has ample dry ravel on the trail bed when the BAER team hiked the trail.

Analysis and Results – Post-Fire Conditions

Soil Burn Severity

Assessment of soil burn severity (SBS) is one of the first steps in the USDA Forest Service (FS) BAER process. Post-fire soil burn severity is often mapped with the intention of identifying the degree to which the fire has affected soil characteristics that impact soil health and hydrologic function, and hence erosion rate and runoff potential. Soil burn severity is not a simple assessment of vegetation consumption, but rather an integration of vegetation loss, changes in soil structure and infiltration capacity, remaining vegetation and duff layers, ash, and soil color, all of which may indicate relative degrees of soil heating. From the soil burn severity map, geologists can predict debris flow hazards, hydrologists can predict changes to runoff and flood flows, and soil scientists can predict erosion potential.

Picture 2. View looking up Eaton Canyon towards Mount Wilson displaying wind eroded tan foreground and darker un-eroded background. (USDA FS)

The final soil burn severity maps were developed with *ESRI ArcGIS* software using satellite-imagery-derived Burned Area Reflectance Classification (BARC) and field survey data collected in collaboration with the California Geological Survey Watershed Emergency Response Team (CAL WERT). Field work to document and confirm soil burn severity was completed from January 15 to 18, 2025. Field work included assessment of ash characteristics, ground cover, roots, soil structure, soil water-repellency, and vegetation burn severity as described in the *Field Guide for Mapping Post-fire Soil Burn Severity* (Parsons et al. 2010*)*. The BAER team modified the original BARC map in several zones to better match the field collected SBS data. These adjustments included a small reduction in high SBS, a large increase in moderate SBS, a large reduction of low SBS and a mask for the urban area. Soil burn severity was developed for natural landscapes and is therefore an inappropriate tool for urban environments. To mitigate this, the assessment area was clipped where the built environment became the majority land cover.

The field surveys indicated that the low SBS was vastly over-mapped. This was likely due to the wind-driven loss of the black ash and char layer during the fire. Since this black colored layer was gone when the satellite imagery was taken, it did not indicate as large of a change in reflectance.

It must be understood that **soil burn severity is NOT vegetative burn severity or mortality** as illustrated in Figure 1 below. 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 (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 the heat is in contact with the soil (residence time).

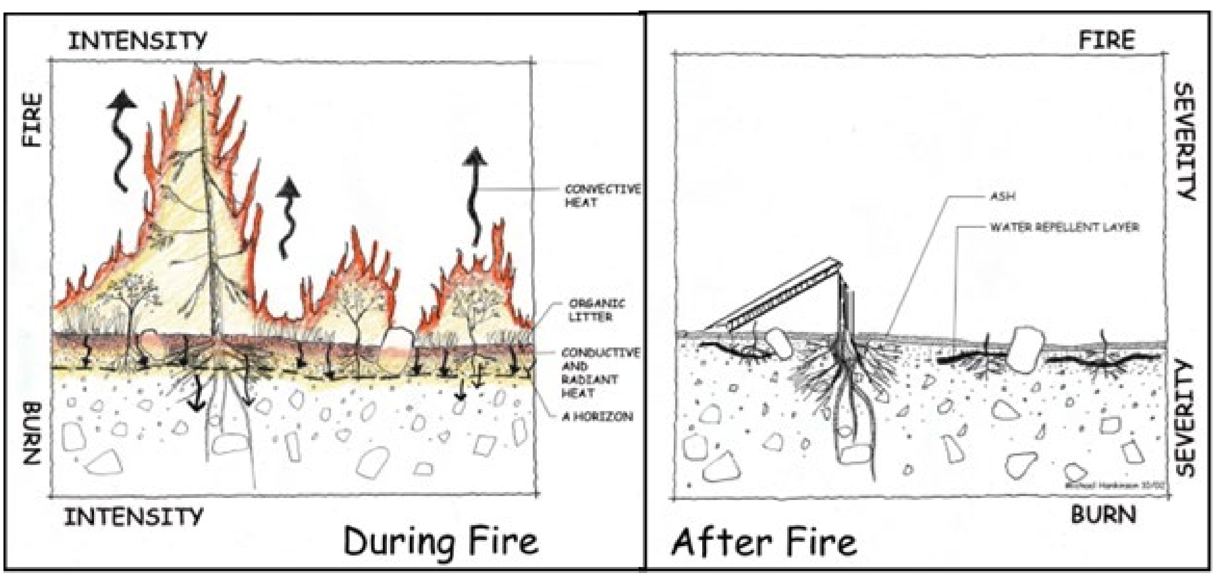


Figure 1*. A graphical representation of burn severity vs. fire intensity. Residence time is not represented in the drawing but is a key factor in resulting severity (Effects of Fire-GTR WO-7).*

Soil Burn Severity Indicators used for the Eaton Fire are generalized best in Parsons et al., 2010:

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 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. Figure 2 are visual examples of different soil burn severities.

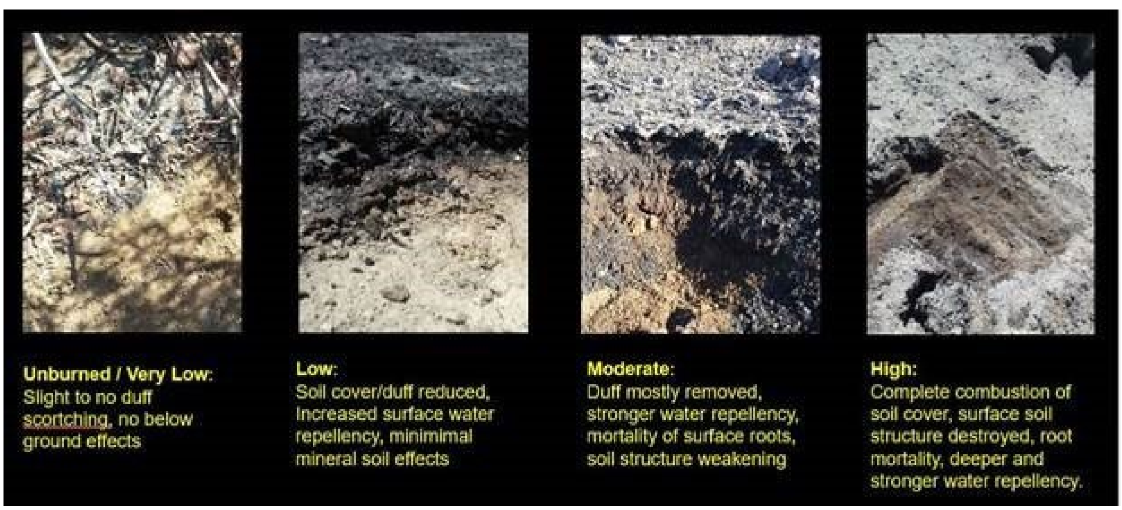


Figure 2. *Visual examples of different soil burn severities*

This fire produced a large amount of moderate SBS due to the fire’s rapid movement through the chaparral-dominated landscape. SBS was assessed for the entire fire perimeter excluding the urban landscape. The SBS breakdown is as follows: 535 acres (5%) unburned/very low, 1,959 acres (17%) low, 8,490 acres (74%) moderate and 448 acres (4%) high. Soil water repellency was very strong and widespread across the burn perimeter, with an estimated 90% of moderate and high SBS areas exhibiting strong water repellency.

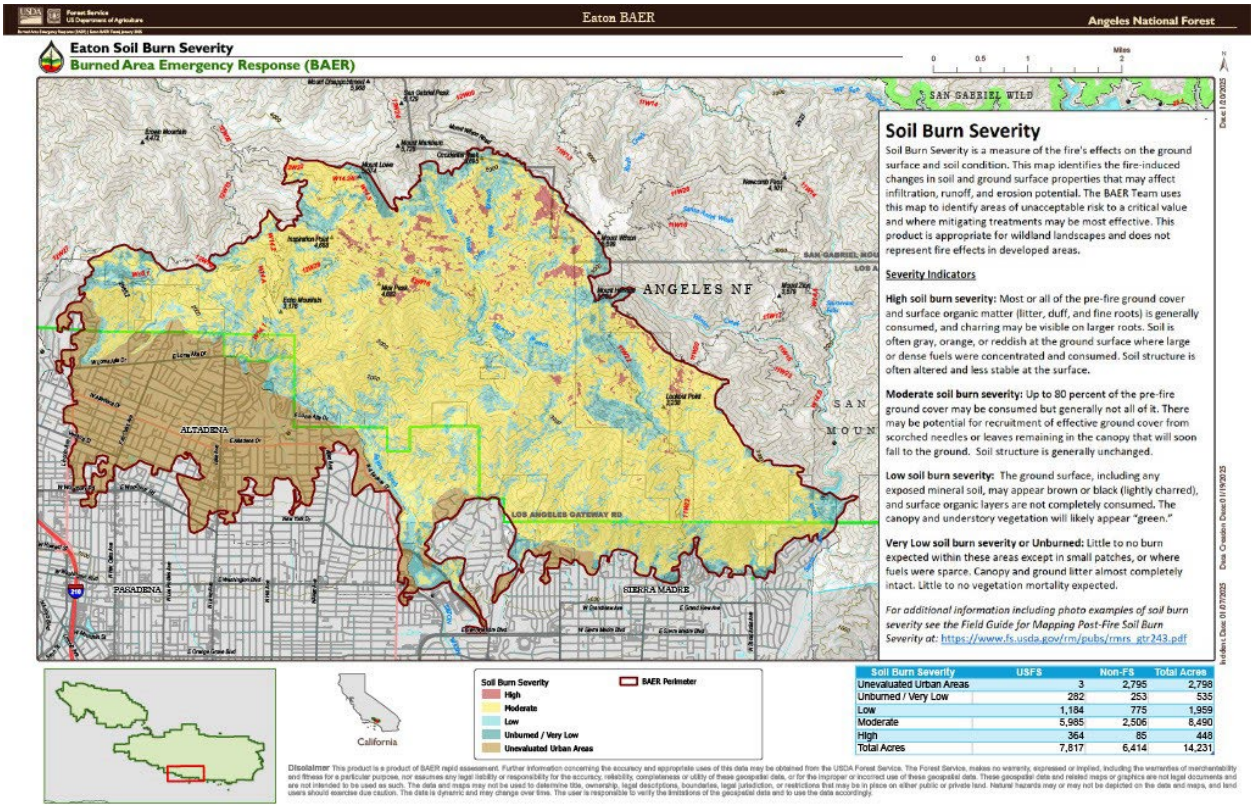


__Figure 3__. Soil burn severity map for the Eaton Fire.

Soil Erosion

Many areas of moderate SBS had signs of significant wind erosion, especially in the lower half of the fire. This was observed as exposed, tan-colored subsurface soil and by exposed roots that were not consistently charred. This was likely caused by the extreme Santa Ana winds. The wind erosion removed much of the ash layer and the loose surface soil once the structure was lost. Further surface sediment was lost through dry-ravel processes. Indicators of erosion such as exposed unburned roots and shrub collars along with weathering rinds indicates erosion depths of 4-8 cm. The loss of these materials could reduce the ash loads being deposited in the drainages during the initial rain events, but also reduces the soil's water holding capacity and fertility. This reduction in water holding capacity along with strong water repellency will expedite runoff during the onset of precipitation events. This loss of the surface "A" horizon will also significantly reduce the soil productivity in these areas. These areas have long-term soil damage, and natural recovery will be slow particularly in the areas that lost much of the surface horizon. It must be emphasized the importance of crown cover to intercept wind-blown soil to accrete surface soil material to maintain a soil seed bank and water holding capacity.

The pictures below show the clear evidence of the extreme wind erosion that occurred during the 80 mph winds that drove the fire behavior.


Picture 4: *Exposed graminoids following loss of surface soil horizon*.

Picture 5: *Exposed shrub root system following loss of surface soil horizon*.

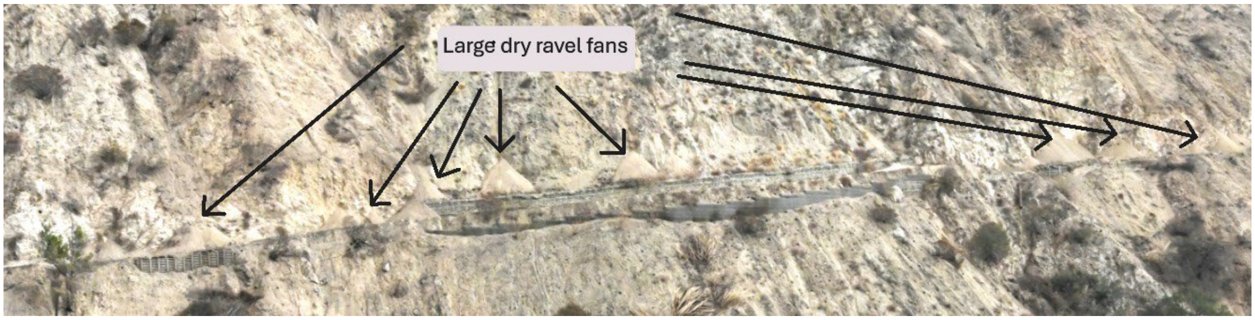
Picture 5 shows the exposure of the root mass of a chaparral shrub. In the lower country, the soils are shallow, and roots tend to establish on top of the rock or consolidated soil. According to Esther Lewis, the BAER team botanist, we are not likely to see resprouting due to the roots being exposed and overheating. Shrub roots experiencing this excessive wind erosion and exposure are likely to perish.

Picture 4 similarly shows the exposure of that portion of graminoid species that were insulated by soil during the soil and subsequently exposed when soil properties that stabilize soils are removed by wind.

The figures below demonstrate the extreme dry ravel that can clearly be seen on the Wilson Toll Road. Similar deposits are common in channels throughout the fire area. These dry ravel deposits will immediately mobilize during a hydrologic event dramatically increasing bulk flow. This bulk flow will increase flow elevation and buoyancy that will help mobilize large rock in debris flows.

Picture 6: *Large dry-ravel deposits observed on Mt. Wilson toll road*

Picture 7 (below): *Dry-ravel deposits on Mt. Wilson toll road*.



Picture 8*: Evidence of exposed bedrock following loss of mineral surface soil due to wind erosion.*

Lastly, the wind erosion was so extreme that weathered bedrock was exposed in areas. These areas likely supported shrubs, forbs and grasses and will not support this vegetation in the foreseeable future. This represents a significant loss in soil productivity and will not recover if the shrub canopy does not recover. A 4-8 cm of soil loss represents approximately a 2 cm loss of water holding capacity and a significant increase in hydrologic response. The black polygons in Figure 8 delineate areas where igneous bedrock has been exposed by surface mineral soil removal.

The ERMiT (Erosion Risk Management Tool) model was used to predict the storm-driven erosion rates from a 2-year rainfall event and spatially display erosion source areas (USFS, RMRS-GTR-188, 2007). The spatial distribution of erosion is displayed in Appendix A.

On this fire, erosion rates are determined primarily by the topography with the highest erosion rates occurring on the steeper slopes.

In the high and moderate SBS areas in the southern half of the fire, we expect sediment delivery to be less that indicated. Since these areas already lost much of the topsoil from wind erosion during the burn, the easily erodible soil available for transport will be low.

The table below summarizes the SBS and erosion rates for several drainage basins of interest. These basins correlate with Forest Service critical values. Reference the hydrology section for additional discussion of these “pour points”.

Watershed	Average Erosion (tons/ac)	Area (ac)
Eaton Canyon	17.6	4133.2
Mt Lowe CG	21.2	53.2
Idlehour CG	16.6	2,924.70
Crossing Near Millard	18.8	13.8
Little Santa Anita	15.8	1583
Entire Fire Drainage Area	16.5	11,740.40

Table 1

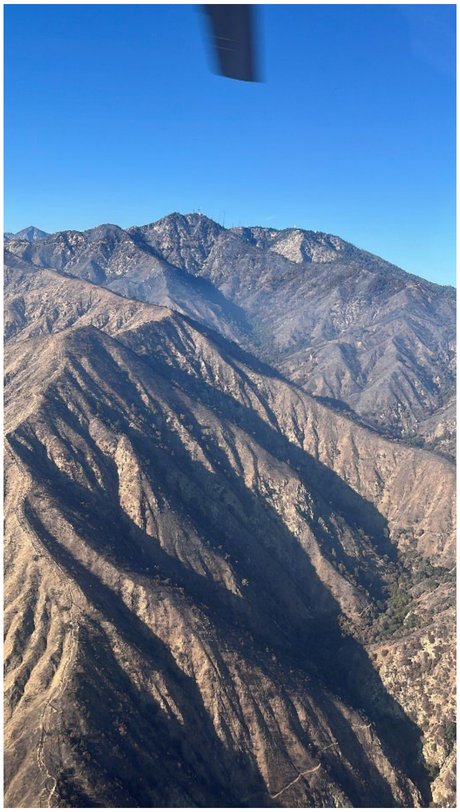
Hydrology

Hydrologic function is connected to vegetation (type, density, litter and organic matter accumulation) and soil types. Fire causes impacts to several hydrologic processes including reduction in interception, transpiration, and infiltration, and the rate of runoff (due to lack of litter and decreased surface roughness). Removal of vegetation and changes to soil (such as increases in hydrophobicity, changes in soil structure, and removal of duff and organic matter) alters these processes and ultimately lead to increases in runoff, peak flows and erosion. These alterations are typical of soils classified as having incurred moderate to high soil burn severity. Trees with remaining overstory contribute to post-fire cover through needle cast. Needles remaining in trees intercept rainfall and once needles fall to the ground, offer protective cover to damaged soils, reducing erosion and providing surface roughness. Given the large percentage of moderate and high soil burn severity, widespread hydrophobicity and vegetation mortality, watershed response is expected to be significant

The analysis below (hydrologic modeling) was driven by the location of Forest Service critical values. While storms are necessary to generate floods, flooding typically associated only with large storms flows may occur from smaller storms given the fire impacts to soils, vegetation, and hydrologic function. In places, fire effects to soils, vegetation, and hydrologic processes will also exacerbate slope and channel instability. Locations (downstream or within the burn area) prone to flooding in pre-fire conditions are very likely to flood from post-fire flows.

As shown in the Soil Burn Severity (SBS) map (Appendix A), the landscape has large continuous areas of moderate SBS, which will affect watershed response (Pictures 9 and 10).

Picture 9 Eaton Canyon



Picture 10. (left) Little Santa Anita Canyon (Mt. Wilson Trail near bottom)

Hydrologic Modeling

Flood potential will decrease as vegetation reestablishes, providing ground cover, increasing surface roughness, and stabilizing and improving the infiltration capacity of soils. Modeling for post-fire flooding was conducted on selected pour points that were associated with specific critical values and/or that might be representative of watershed response in a general area, see Map 2 (end of report). Pour points are points on the landscape through which all water upslope of the point passes through.

Due to the wide variability of factors that are hard to account for (e.g., what storms may happen in the future) and approximate nature of the modeling tools, it must be noted that any results from modeling performed should be cautiously used, and that these values are giving us a broad look at how the watershed *may* respond. Wheelock et.al (2024) attempts to review various post-fire discharge modeling methods and identify limitations for each.

Because of the lack of unregulated stream gages and size of the impacted watersheds, the USGS regression equations for South Coast (Region 5) were selected to estimate pre- and post-fire flows (Gotvald, et al., 2012).

USGS Regression Equations: Regional regression equations were developed to estimate magnitude and frequency of flows in ungaged watersheds based on analysis of discharge at gaged sites and relationship with significant basin characteristics. The South Coast (Region 5) is applicable to the burn area. South Coast regional regression equation (Gotvald, et al, 2012) uses inputs of drainage area, elevation and mean annual precipitation to estimate peak discharge for different return intervals.

Estimates of post-fire flooding are related to the acres of soil burn severity within a pour point watershed. To determine pre-fire discharge using regression equations, no adjustments are made to calculated flows at a given pour point for the selected peak flow (Q2 for this analysis). For estimates of post-fire discharge at the same pour point, percentage of high SBS, moderate SBS, low SBS, and unburned acres is calculated from the soil burn severity map. The addition of a category for moderate soil burn severity without future needle cast potential was also added. For this analysis, runoff from unburned soil burn severity areas are assumed to be unchanged (Q2); runoff from low soil burn severity areas are assumed to respond similar to a five-year discharge (Q5); runoff from moderate soil burn severity areas are assumed to respond similar to an average of the ten-year discharge (Q10) and twenty-five year discharge (Q25) ; and runoff from high soil burn severity areas and moderate soil burn severity areas with no needle cast potential are assumed to respond similar to a twenty-five year discharge (Q25). Applicable regression equations for Q2, Q5, Q10, and Q25 are applied to each category. The sum of the flows at these various recurrence intervals estimates the response of the newly burned landscape from an event that would typically generate a 2-year peak flow.

The analysis for pre- and post- fire hydrologic response and probability of flows is based on the probability of a 2-year storm occurring in the fire area (assuming a 2-year storm event will produce a 2-year runoff event). The 2-year, 24-hour duration storm for the burn area ranges approximately between 4.11 to 6.32 inches based on NOAA precipitation tables (NOAA website, 2025). The storms expected to occur within the fire burned area that could produce damaging post-fire effects is a short duration, high intensity rainstorm (likely to cause localized effects), a longer duration rainstorm associated with an atmospheric river (causing flooding in large mainstems), or a rain-on-snow event (causing flooding in large mainstems). Intensity within a storm and antecedent soil moisture are both spatially variable. Ultimately, when precipitation intensity is greater than infiltration rates or exceeds infiltration capacity, runoff initiates and erosion potential increases.

The 2-year design storm has a 50% chance of occurring in any given year, and a 97% chance of occurring in the next five years. Conversely, there is a less than 0.1% chance that the 2-year storm event will not occur in the next 10 years (during the recovery period). The risk or probability (R) that a certain return interval storm (T) will occur over different time periods (n) was calculated by the following equation:

Table 2. Comparison of pre- and post-fire peak flow related to the 2-year return interval.

Critical Values Pour Point Watersheds	Drainage size (acres)	% Mod + High SBS	Pre-Fire Discharge (cfs) Q2	Post-Fire Discharge, Bulked (cfs)	Magnitude of Post-Fire streamflow increase w/bulking
Eaton Canyon near Falls	4,133	74%	187	2346	12.52
Idlehour CG	2,925	68%	155	1857	12.01
Crossing near Millard CG	14	71%	3	17	5.04
Mt.Lowe Rec Site	53	70%	10	70	6.87
Little Santa Anita Canyon	1,583	79%	92	986	10.71
Millard Crossing at Arroyo Seco	1,768	19%	95	426	4.51

Bulking factor: Post-fire flows will be bulked with sediment and woody debris, increasing the volume of runoff, which could negatively impact culverts, constructed channel ways, and other infrastructure designed to pass “normal” flows. Many steeper slopes of the fire coincide with evidence of historic debris flows, especially in the Eaton Canyon and Little Santa Anita drainages. These areas contain stored sediment and will possibly be mobilized in post-fire storm events. Bulking and increased flows may cause channels to flood, divert, or migrate to areas that do not usually flood. A bulking factor of 1.25 was applied to post-fire estimates (Foltz, et al. 2009).

Modeling Results: Post-fire bulked flows are expected to be 4.5 to over 12 times that of non-bulked, pre-fire peak flows. Some of these values represent significant increases in runoff justifying the need for emergency response treatments. Post-fire modeling results are most applicable during the first year of recovery; hydrologic response will decrease in subsequent years. Most of the results hover at or just below the normal 25-year flood event. That is, in the post fire environment with a 2-year winter storm, flows will act like a 25-year flood. A storm greater than the 2-year will produce an even higher flood event.

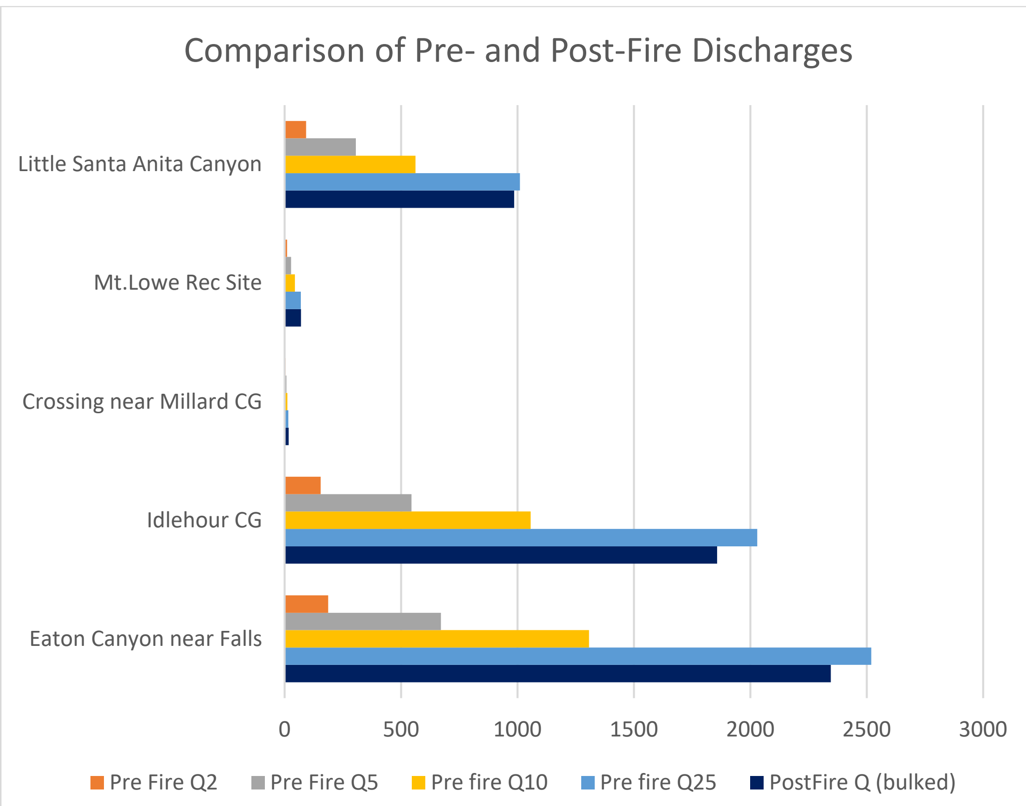


Figure 4. *Post fire discharges in relation pre-fire return intervals for Eaton Fire*.

Geologic Hazards

Geologic hazards commonly exacerbated by fire are debris flow and rockfall. Rockfall is most common on steeper slopes, especially along stream banks and roadcuts. Under post-fire conditions, burned watersheds with steep slopes and first-order channels that contain significant volumes of stored sediment are likely to experience increases in runoff and erosion from a lack of protective vegetation cover, soil hydrophobicity, and loss in cohesive root strength, which provide the potential to generate debris flows (Kean et al., 2011; Parise and Cannon, 2012; and Kean et al., 2019). Post-fire debris flows initiate as result of progressive bulking or accumulation of slurry in stream channels (Cannon, 2000, 2001; Cannon et al., 2001a). Runoff generated slurry typically has high sediment concentrations (40–65 percent) and can scour colluvial and fluvial stream deposits. The flow can then progressively grow in size as it moves downstream by recruiting boulders and woody debris, resulting in destructive debris flows (Iverson, 1997). Hydrologic processes such as debris flows and hyper-concentrated flows threaten life, property, and infrastructure. They can destroy houses, block, or erode roads and cause transportation impacts, sever pipelines, damage utilities and add large quantities of sediment to stream channels that impact water resources (Schwartz et al., 2021).

Picture 10: *Extension of the Eaton Fire, from Mount Wilson down to neighborhoods of Altadena*

The two major watersheds that were burned by the Eaton Fire are the Eaton Canyon and Little Santa Anita canyon watersheds. In addition to these two major watersheds, numerous smaller, named and un-named watersheds were burned, which include (from west to east): Millard Canyon, Chiquita Canyon, Las Flores Canyon, Rubio Canyon, Pasadena Glen, Hastings Canyon, and Bailey Canyon. Most of these drainages flow directly into neighborhoods and private back-yard properties.

Within the Eaton Fire burn scar, ground surveys and an aerial reconnaissance flight, revealed evident of widespread pre-fire mass wasting as rock-fall, shallow landslides, and old debris flow deposits. Throughout the Eaton Fire burn scar many slopes and drainages are loaded with unsorted, unconsolidated materials comprised of rocks of all sizes including boulders, cobbles, gravels, and fine sediments, available to be transported. Evidence of past mass wasting is related to the type of parent materials, the steep slopes and continues gravitational and hydrological mobilization of rocks and sediments down slopes and drainages. In some of the smaller watersheds, larger rocky materials are absent, but large amounts of fine sediments are available to be mobilized. In most of these watersheds, in addition to the fact that large amounts of sediments are present and available to be transported, major portions of these watersheds experienced moderate to high soil burn severity. From ground surveys and aerial reconnaissance, it is evident that large amounts of ash and topsoil were blown off during the fire event, due to extremely strong (80-100 miles/hour) Santa Ana winds, which propagated this fire. Currently large portions of the burn scar are lacking ash and 2-3” of topsoil and are exposed to minerals. From hydrophobicity testing that were done in points throughout the burn scar, it is apparent that high hydrophobicity extends throughout the burn area. In addition, about 25 points were tested for infiltration at 3 different elevations. The testing was done by mini disk infiltrometer and once again revealed very low infiltration rates.

***Picture 11**: Lateral bank erosion, exposing unsorted, non-stratified, matrix-supported, paleo debris flow deposits – Eaton Canyon*

As a result of the fire and the removal of supportive vegetation, post-fire dry ravel is prevalent throughout the burn scar (Pictures 9 & 10). In Southern California in general, and the San Gabriel Mountain range in specific, dry ravel has been documented as a dominant hillslope erosion mechanism following wildfire in chaparral environments (Moody et al., 2013; Florsheim, et al., 2016; DiBiase & Lamb, 2020). Dry ravel is an important 'ingredient' of a post-fire debris flow slurry.

Geologic hazards commonly exacerbated by fire are rockfall and debris flow. Rockfall is most common on steeper slopes, especially along stream banks and roadcuts. On slopes loaded with rocks, rockfall was observed, impacting roads, and further loading channels with fine sediments and rocks. In addition to the fact that many of these drainages impacted by the fire experienced a moderate to high soil burn severity, most of the slopes in the burn area are very steep (60+%) slopes.

USGS Debris Flow Assessment

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. Using data and conclusions from their ongoing debris flow research, geologists at the USGS have developed empirical models for forecasting the probability and estimating the likely volume of debris flow events in a particular watershed. To run their models, the USGS uses geospatial data related to basin morphometry, burn severity, soil properties, and rainfall to estimate the probability and volume of debris flows that may occur in response to a design storm (Staley, 2013). Estimates of probability, volume, and combined hazard are based upon a design storm with a peak 15-minute rainfall intensity of 12 to 40 millimeters per hour (mm/h) rate.

After receiving the final Eaton Fire soil 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 40 millimeters per hour (1.57 inch/hr.) rate to evaluate debris flow potential and volumes, since based on the NOAA Atlas 14 Point Precipitation Frequency Estimates, in this area this magnitude of storm seems likely to occur in any given year.

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. Within the analysis area, streams that exceed an upslope area of 8 square kilometers were added as Watch-streams features, representing streams susceptible to flood and possibly debris-flow hazards.

Summary of Post-fire Watershed Response

- Soil burn severity was moderate to high across roughly 60% of the burned area.
- Erosion will be elevated in most of the burned areas, and substantially elevated on and near areas of moderate and high soil burn severity on roughly the southern third of the fire.
- Ash and fine sediment will likely be transported to stream channels and washed downstream during the first fall rainstorms.
- Mobile woody debris in many of the stream channels throughout the burned areas will likely be entrained in flood flows.
- Water quality in streams and the nearshore environment will be impaired by ash, fine sediment, nutrients, and dissolved organic carbon during and following rainfall on the burned areas.
- The probability of debris flows was predicted by USGS models to be high for many of the small watersheds within the burned area with a 15-minute rainfall intensity of 32 mm/hour (about 0.3 inches in 15 minutes), a storm intensity that is likely to occur at least once annually.
- Debris flows in headwater draws and canyons will add material to floodwaters in the larger streams draining the burned area, and have the potential to temporarily dam larger streams, causing backwater effects as well as flood surges when the temporary dams fail.
- Debris-laden flood waters and debris flows threaten anyone in or near streams and rivers within and downstream of the burned area.
- The threat of damage from flooding and debris flows extends to in-channel structures such as culverts, bridges, and diversions, as well as any structures or improvements located on existing debris fans, runout zones, and other flood-prone areas. Areas of concern include the communities of Mount Baldy and Wrightwood, permitted developments on NFS land (recreation residences, organizational camps, ski areas, and others), and state and county roads.
- Rockfall and hillslope instability on steeper slopes throughout the burned area are threats to life and safety as well as infrastructure.
- Debris-laden floodwaters and debris flows threaten critical habitat for the ESA-listed mountain yellow legged frog and Santa Ana sucker.

Recommendations for post-fire emergency stabilization

- Road and Trail Stabilization

- Signage, Barriers and Gates
- Hazardous Material stabilization
- Invasive and noxious weed detection and eradication
- Continue Interagency Coordination

Capacity and Collaboration

Continuous dialogue and close coordination are needed to address stabilization/containment and cleanup of burned Recreation residences, in addition to developing a response plan for post-fire flood risks to burned and remaining cabins.

Picture 12. Interagency field day along Santa Anita County Road (USDA FS)

Monitoring

Monitoring burned area conditions and recovery can assist managers in planning for public safety as of watershed conditions recover. We recommend recurring evaluation of recovery over time in conjunction with monitoring of runoff response to rainstorms and snowmelt, especially after heavy rainstorms.

References

Foltz, R.B., Robichaud, P. R., and Rhee, H. 2009. A synthesis of post-fire road treatments for BAER teams: methods, treatment effectiveness, and decision making tools for rehabilitation. Gen. Tech. Rep RMRS-GTR-228 Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 152 p.

Foltz, R.B., and Wagenbrenner, N.S. 2010. An evaluation of three wood shred blends for post-fire erosion control using indoor simulated rain events on small plots. Catena 80, 86-94.

Fortini, L.B., Kaiser, L.R., Perkins, K.S., Xue, L., and Wang, Y., 2023. Estimating the Impact of Climate and Vegetation Changes on Runoff Risk across the Hawaiian Landscape. Conservation 2023, 3 291-302. https://doi.org/10.3390/conservation3020020

Parsons, A., Robichaud, P., Lewis, S., Napper, C., Clark, J., and Jain, T. 2010 Field Guide for Mapping Post-Fire Soil Burn Severity. Gen. Tech. Rep. RMRS-GTR-243. Moscow, ID: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

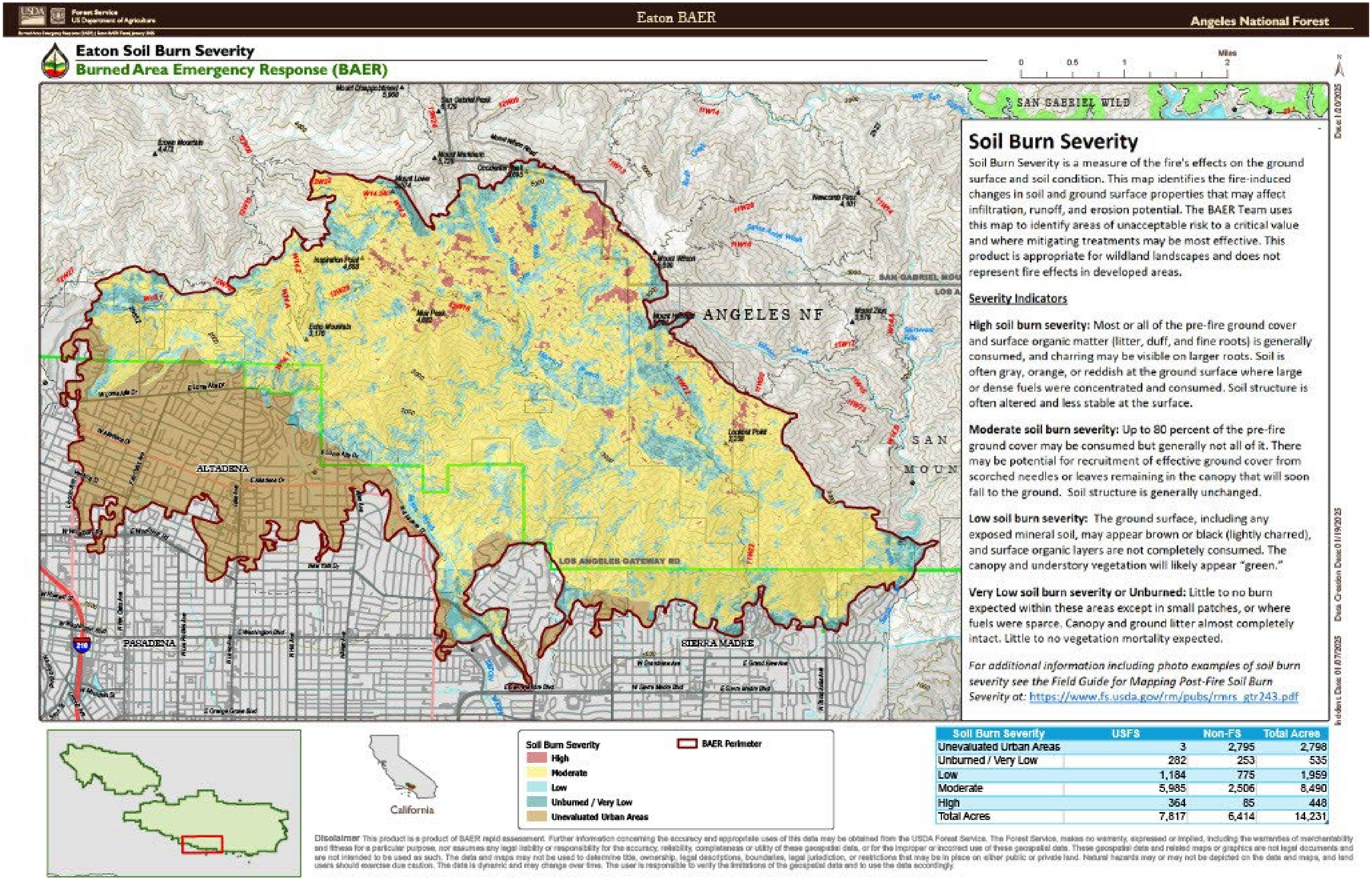
Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, Charles,2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl.

Robichaud, P. R., Ashmun, L.E., Foltz, R.B., Showers, C.G., and Groenier, J.S. 2013. Production and aerial application of wood shreds as a post-fire hillslope erosion mitigation treatment. General Technical Report RMRS-GTR-307, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

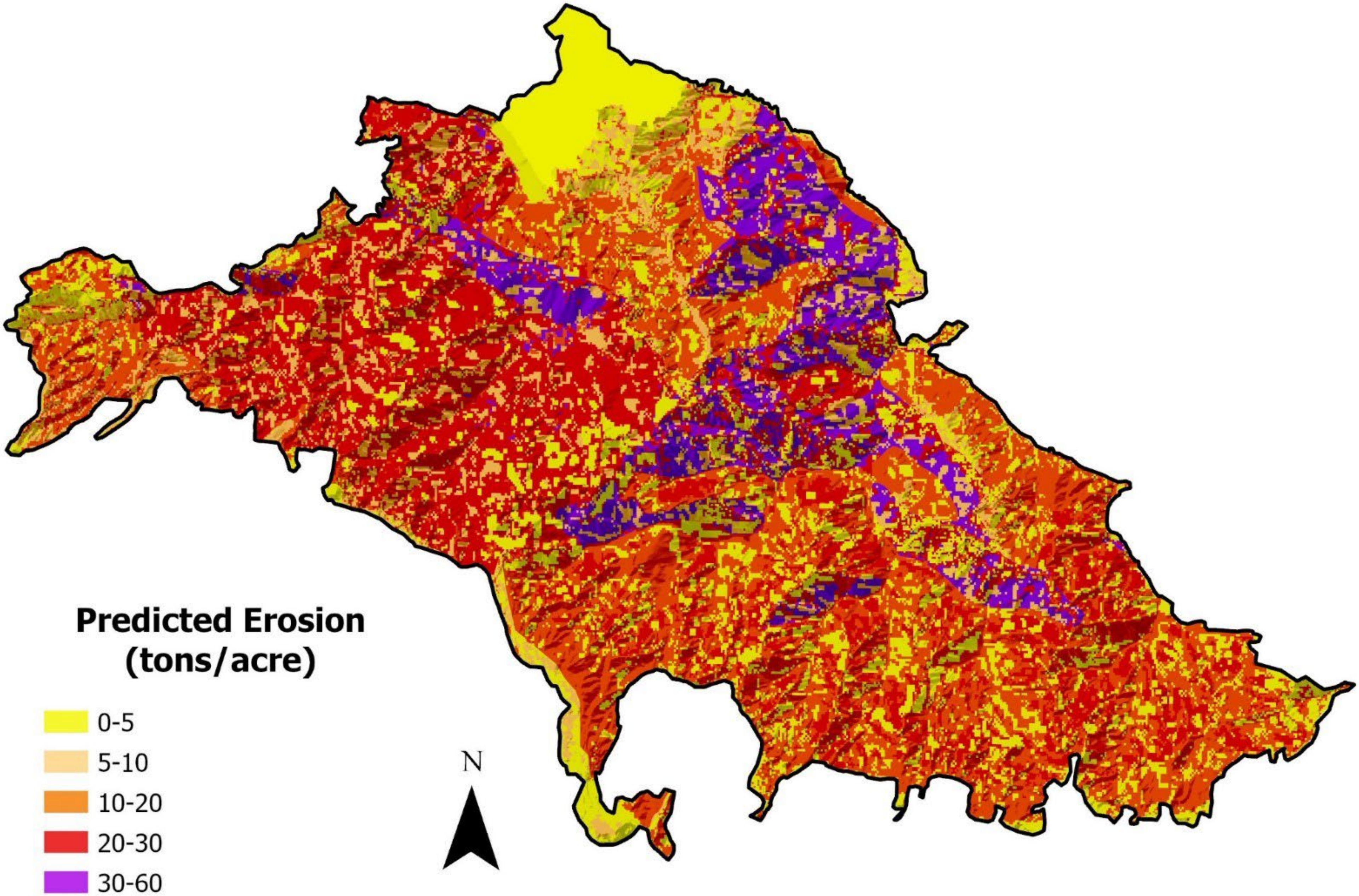
Robichaud, P.R., Elliot, W.J., Pierson, F.B., Hall, D.E., Moffet, C.A., and Ashmun, L.E. 2007. Erosion Risk Management Tool (ERMiT) user manual (version 2006.01.18). Gen. Tech. Rep. RMRS-GTR-188. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 24 pages. https://forest.moscowfsl.wsu.edu/fswepp/

United States Department of Agriculture, Soil Conservation Service, 1973. *Engineer Field Manual for Conservation Practices.* Chapter 2: Peak Rates of Discharge for Small Watersheds.

Appendix A. Eaton Fire BAER Map Products

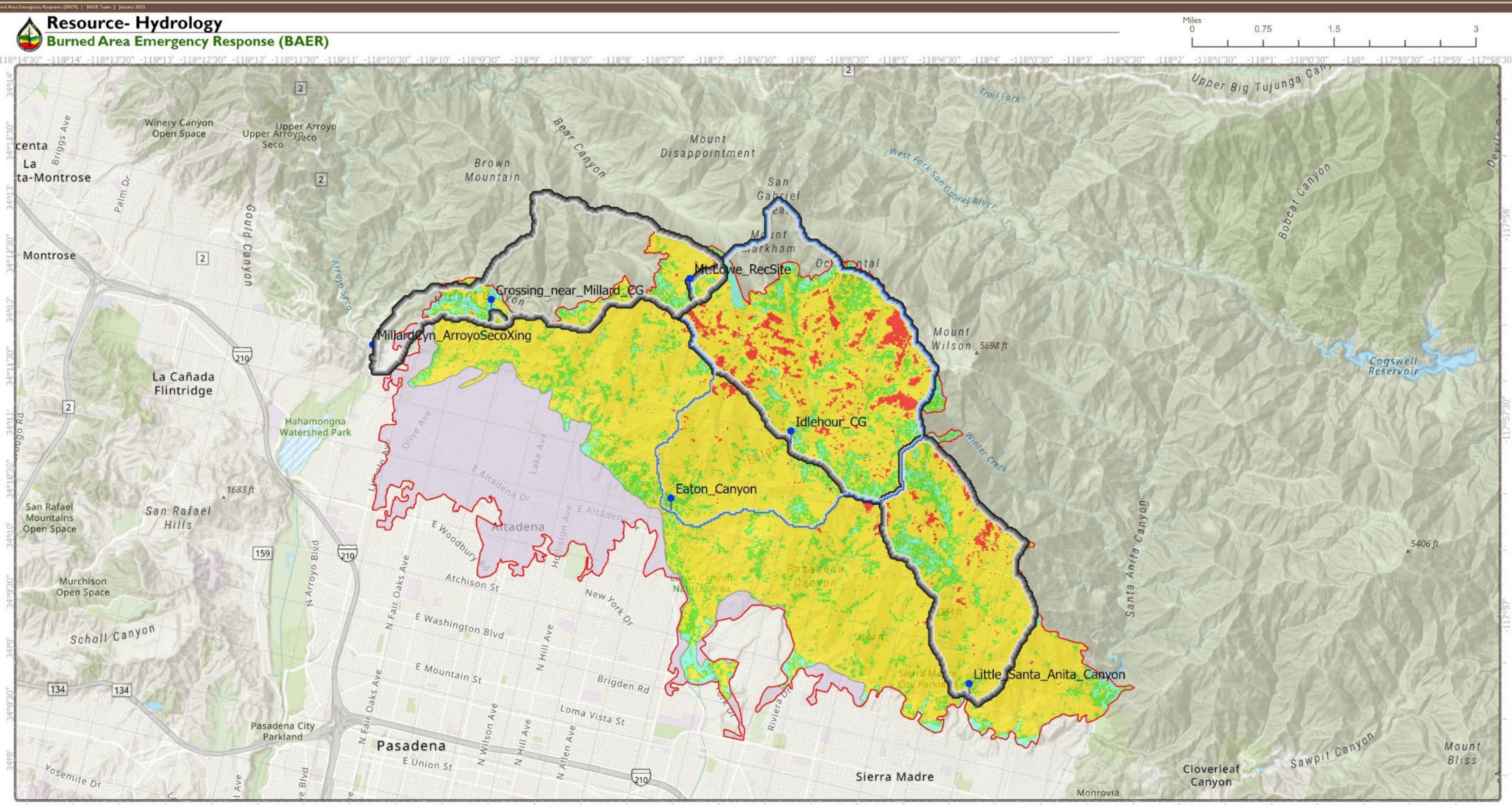


Soil Burn Severity	USFS	Non-FS	Total Acres
Unevaluated Urban Areas	3	2,795	2,798
Unburned / Very Low	282	253	535
Low	1,184	775	1,959
Moderate	5,985	2,506	8,490
High	364	85	448
Total Acres	7,817	6,414	14,231


Predicted Erosion
(tons/acre)
0-5
5-10
10-20
20-30
30-60
N

Resource- Hydrology

Burned Area Emergency Response (BAER)



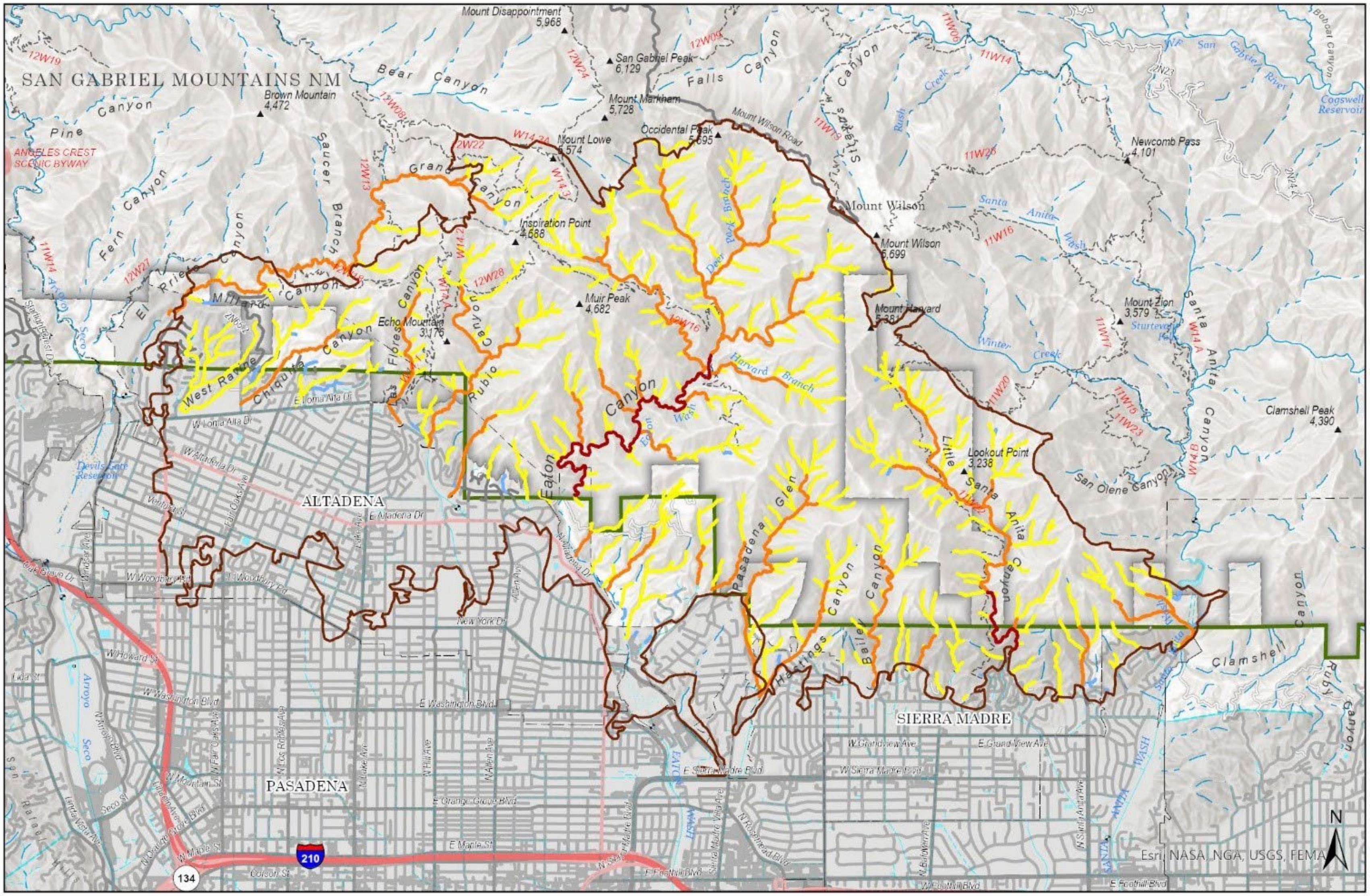
Eaton Fire (2025 ANF)

Eaton_Final_SBS

SBS

- High
- Low
- Moderate
- Unburned / Very Low
- Unevaluated Urban Areas
- <all other values>
- EatonFire_Pourpoints_M
- Eaton_BARC_Perimeter
- Eaton Canyon
- Smaller Pourtsheds

Disclaimer This product is a product of BAER rapid assessment. Further information concerning the accuracy and appropriate uses of this data may be obtained from the USDA Forest Service. The Forest Service, makes no warranty, expressed or implied, including the warranties of merchantability and fitness for a particular purpose, nor assumes any legal liability or responsibility for the accuracy, reliability, completeness or utility of these geospatial data, or for the improper or incorrect use of these geospatial data. These geospatial data and related maps or graphics are not legal documents and are not intended to be used as such. The data and maps may not be used to determine title, ownership, legal descriptions, boundaries, legal jurisdiction, or restrictions that may be in place on either public or private land. Natural hazards may or may not be depicted on the data and maps, and land users should exercise due caution. The data is dynamic and may change over time. The user is responsible to verify the limitations of the geospatial data and to use the data accordingly.



Debris Flow Volume Prediction
Eaton Fire - Angeles National Forest
January 2025

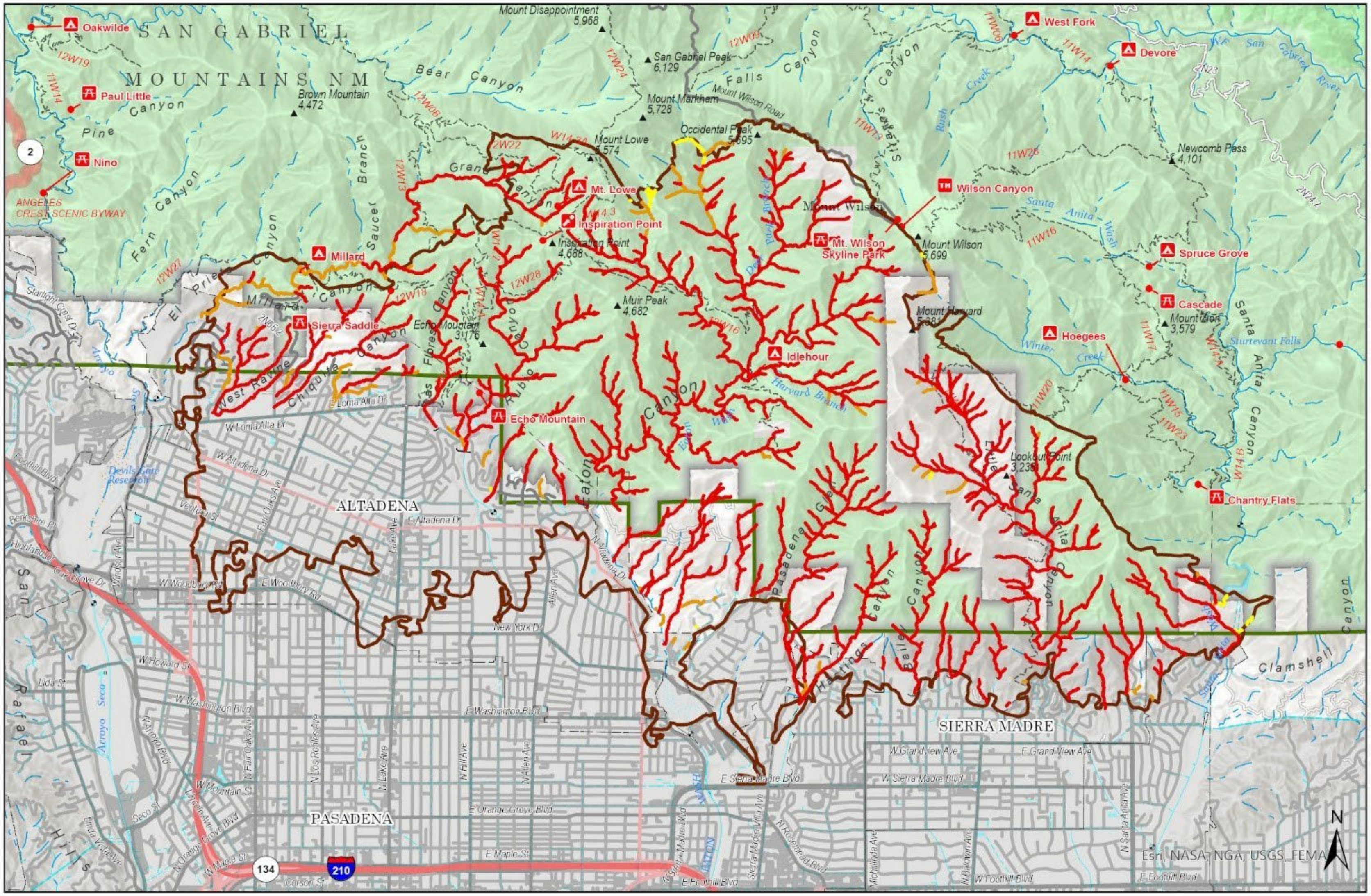
Peak 15 Minute Rainfall Intensity 40 mm/h rate

Burned Area Emergency Response (BAER)

Debris Flow Estimated Volume (cubic meters)

- <1,000
- 1,000-10,000
- 10,000-100,000
- >100,000
- BAER Perimeter

0 ½ 1 Miles



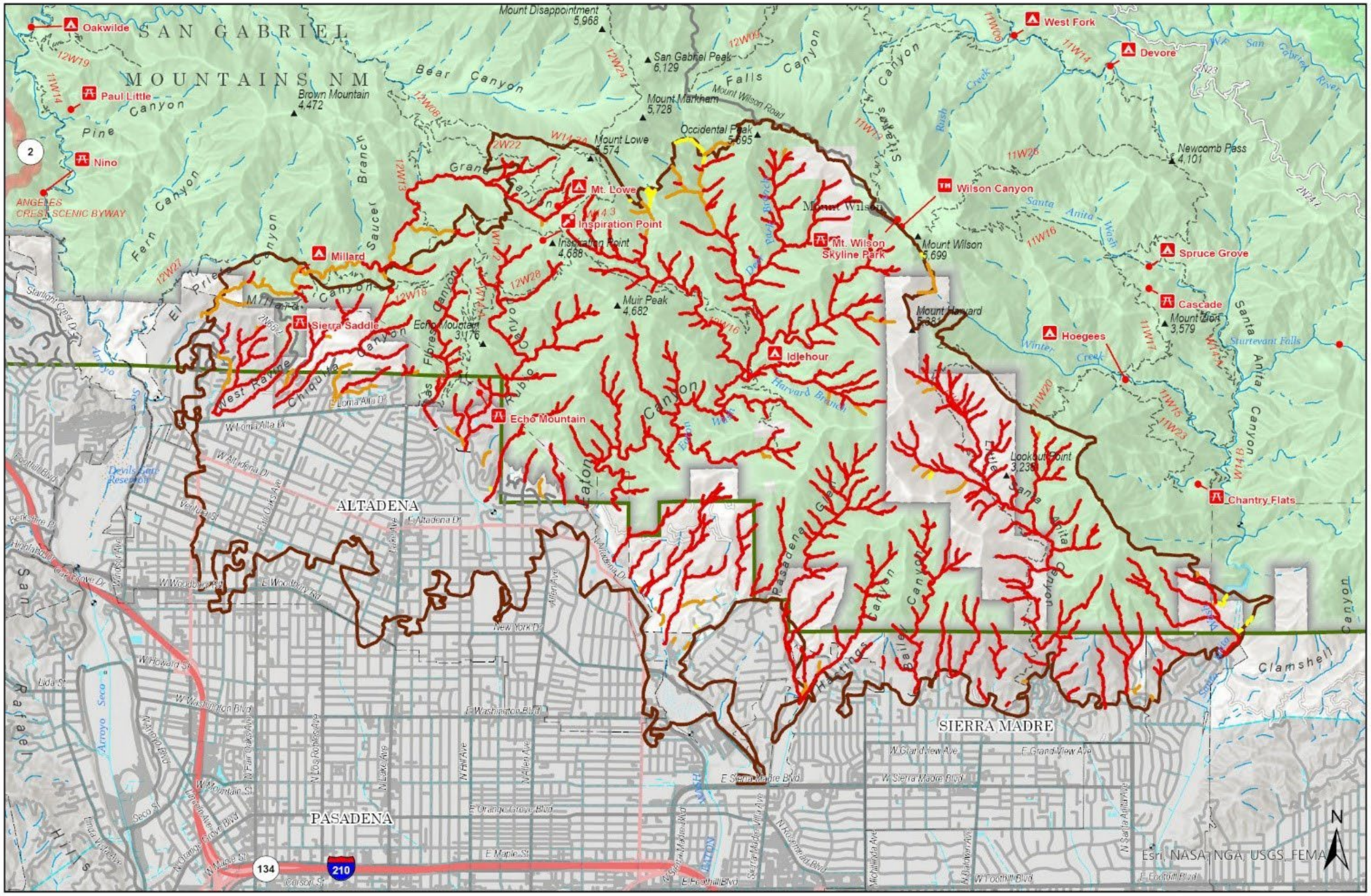
Debris Flow Combined Hazard
Eaton Fire - Angeles National Forest
January 2025

Peak 15 Minute Rainfall Intensity 40 mm/h rate

Burned Area Emergency Response (BAER)

Debris Flow Combined Hazard
- Low
- Moderate
- High
- BAER Perimeter

0 ½ 1 Miles



Debris Flow Combined Hazard
Eaton Fire - Angeles National Forest
January 2025

Peak 15 Minute Rainfall Intensity 40 mm/h rate

Burned Area Emergency Response (BAER)

Debris Flow Combined Hazard
- Low
- Moderate
- High
- BAER Perimeter