Museum Fire Burned Area Emergency Response (BAER) Executive Summary

Coconino National Forest, Flagstaff, Arizona.
Prepared by Museum Fire BAER Team
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Fire Background

The Museum Fire started on July 21, 2019, in the Dry Lake Hills area approximately one mile north of Flagstaff, Arizona. As of August 4th, the fire perimeter encompassed 1,961 acres with approximately 74 acres of tribal land and 1,887 acres on the Coconino National Forest (CNF). Rugged, steep terrain hindered firefighting efforts, and soon after the fire began about two dozen homes were under mandatory evacuation orders with hundreds more placed on standby. The Southwest Type 1 Incident Management Team (IMT) assumed management of the response on July 22nd. The Type 1 IMT demobilized and a local Type 3 team assumed management of the fire on July 30th. As of the writing of this report, the fire is at 96% containment.

BAER Assessment

Due to anticipated risk to Forest and public values (including the potential for severe flooding and debris flows in Flagstaff), a BAER team was assembled on July 26th to identify critical values on USFS lands and associated risk. BAER is an emergency program for stabilization work that involves time-critical activities that must be completed before the first damaging storm event to meet program objectives. The BAER team uses science-based models to rapidly evaluate and assess the burned area.

BAER team assessments consist of rapid evaluations of post-fire conditions of the burned landscape to determine the level of risk from potential flooding and debris flow to values on National Forest System (NFS) lands. The team identifies 'Critical Values' such as human life and safety, infrastructure, private property, and critical natural and cultural resources. The BAER assessment focuses on determining where post-fire precipitation events could increase runoff, flooding, erosion and sediment delivery, where post-fire effects could impact critical threatened and endangered wildlife habitat, and where high-risk areas exist for the spread of invasive weeds. BAER teams analyze both satellite reflectance images and data collected during field surveys to produce a Soil Burn Severity (SBS) map (Figure 1), which categorizes the burned area as High, Moderate, Low, or Very Low soil burn severity (Figure 2).

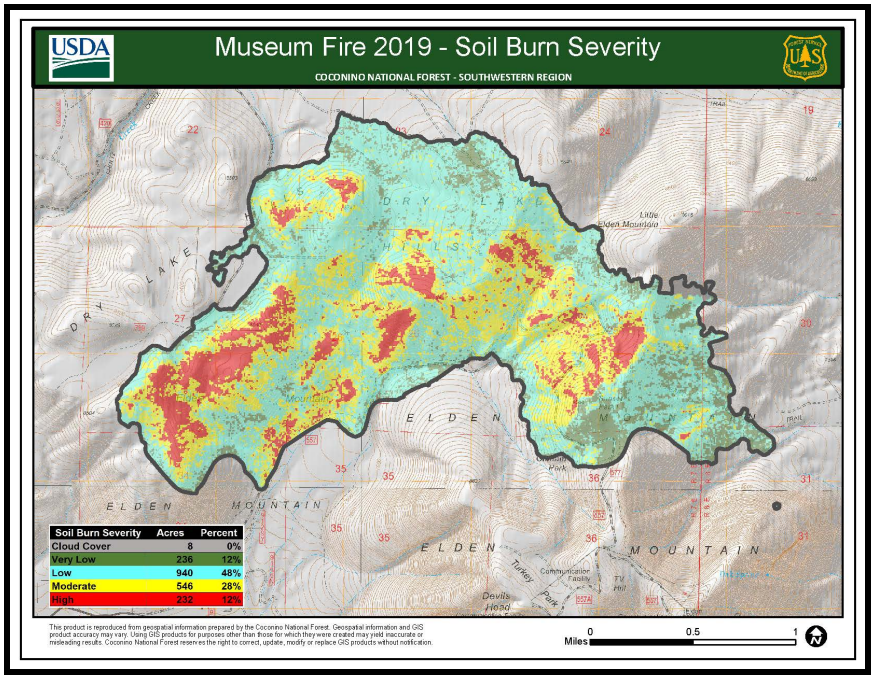

Figure 1. Museum Fire Soil Burn Severity.

Figure 2. Examples of high (left) and moderate (right) soil burn severities.

Fire-damaged soils are at higher risk for erosion and increased water runoff, and the final SBS map is used to document the degree to which soil properties changed within the burned area. If unacceptable risks, as identified with the BAER Risk Assessment (Table 1) are determined to exist to critical values, these values become *values at risk* (VAR) and the team may recommend appropriate and proven effective emergency stabilization measures to reduce the risks to NFS and forest values. Treatment actions must be evaluated based on (1) the ability to be implemented in a timely manner, (2) effectiveness in reducing risk, (3) practical and technical feasibility, and (4) cost.

Table 1: BAER Risk Assessment

	Magnitude	**of**	**Consequences**
	Major	Moderate	Minor
Probability of Damage or Loss	**RISK**		
Very Likely	**Very High**	**Very High**	**Low**
Likely	**Very High**	**High**	**Low**
Possible	**High**	**Intermediate**	**Low**
Unlikely	**Intermediate**	**Low**	**Very Low**

The Museum Fire BAER team consisted of scientists and specialists covering a variety of fields including soil science, hydrology, engineering, geographic information systems (GIS), wildlife, archaeology, botany, recreation, and geology. These specialists work together to survey the burned area, analyze field data and model results, and present findings along with recommended proven, and effective emergency BAER treatments to the Forest Supervisor.

BAER assessment information is also shared with interagency cooperators who work with downstream private home and landowners to prepare for potential post-fire flooding and sediment flow impacts. Cooperators involved in the BAER process include the Natural Resource Conservation Service (NRCS), United States Geological Survey (USGS), National Weather Service (NWS), state, local, and county entities, and associated contractors.

Analysis Overview

Despite cloud cover over much of the burned area for several days post-fire, the US Forest Service Geospatial Technology and Applications Center (GTAC) provided the BAER team with an initial burned area reflectance classification (BARC) map derived from satellite imagery that compares pre- and post-fire images. The team conducted field surveys from July 26th to July 30th to verify BARC data, assess threats to critical values and create a final SBS map.

Hydrology Report Summary

The Museum fire occurred in the steep western slopes of Elden Mountain in mixed conifer and ponderosa pine forest ecological response units. Recent thinning within the Flagstaff Watershed Protection Project (FWPP) had reduced forest density and structure in portions of the fire perimeter but did not necessarily reduce on-the-ground fuel loadings. At the time of the Museum fire, Phase 2 operations of the FWPP were less than 50% complete, as a result, some areas had high fuel loads remaining. Most of the fire occurred within a roughly 3,100-acre catchment that drains through an urbanized portion of the City of Flagstaff. A USGS estimate of the largest peak discharge from this catchment for an unspecified precipitation event during an 11 year period of observation was less than 5 cubic feet per second (cfs).

The BAER team hydrologists modeled the post-fire hydrologic response from a one-inch one-hour duration rain event (roughly equating to a 2-year monsoonal storm event) over the Spruce Avenue Wash watershed. Expected post-fire peak flows are approximately 100 times higher than pre-fire flows. The drainage for this catchment enters a highly urbanized portion of the City of Flagstaff. Given the distribution of high and moderate soil burn severities, steep slopes of the catchment, high percentage of the catchment impacted by fire, and the intense nature of rain events associated with the North American Monsoon, widespread channel incision is very likely with headward extension of drainages into hillslopes. Areas that currently store sediment, such as broad alluvial portions of Spruce Avenue Wash at the base of Elden Mountain, will likely transition to sediment sources.

Soil and Watershed Report Summary

Overall, about 40% of the fire burned in moderate and high soil burn severity classes. Post-wildfire storm events in the moderate and high soil burn severity classes on slopes greater than about 15 percent, are very likely to result in accelerated water runoff and erosion exceeding soil loss tolerance thresholds. Soil loss tolerance thresholds are expected to be exceeded by an order of four to six times until watershed recovery occurs. Soil loss tolerance thresholds directly relate to annual productivity of a site. Once these thresholds are exceeded, accelerated soil erosion occurs and degradation and loss of soil productivity are likely to occur. Overall, the watershed is in poor or fair condition in areas of moderate or high soil burn severity but is expected to improve as recovery occurs. Recovery is likely to occur faster where hillslope and road treatments are implemented. Heli-mulching wood shred mulch on areas described above is recommended to minimize risks to soil productivity. However, if recommended emergency treatments are not implemented immediately, accelerated erosion and sediment delivery, and high water runoff are expected to occur following post-wildfire storm events posing risk to life and property, soil productivity, and trail and road infrastructure downstream of the burn area. Therefore, emergency treatments recommended by the BAER team (aerial mulching with wood shred mulch on areas that would exceed soil loss tolerance thresholds if not treated) are essential to minimize risks to critical values.

Figure 3. Example of water repellency occurring in the post fire setting.

Debris-flow Report Summary

Research efforts over the last few decades have significantly contributed to our understanding of how post-fire debris flows are generated. Wildfires alter watershed hydrologic function by consuming above and below-ground organic matter, thus reducing rainfall interception and altering soil hydrologic properties such that infiltration is decreased, and water runoff volumes and velocities are increased. Fire intensity and soil burn severity strongly influence the magnitude of these changes. Post-wildfire debris flows are generated when high-intensity precipitation falls onto steep slopes with enough area of moderate and high soil burn severity. Increased surface runoff erodes hillslopes with enough energy to trigger hillslope debris flows (HDF) which transports sediment into channels and accumulates. Concentrated channel flow breaches the accumulated sediment pile, similar to a dam break, mobilizing large amounts of sediment, boulders and large woody debris as a more destructive in-channel debris flow. Debris flows can be destructive and pose a significant threat to human life and safety, roads, trails, and cultural and natural resources. Thus, it is critical to slow hillslope runoff to reduce hillslope erosion and reduce the risk of debris flows.

Based on the data available for this hazard assessment, it is very likely that debris flows will occur in the Museum Fire burn scar, particularly if intense rainfall occurs before treatments can be fully implemented. Indeed, one debris flow has already occurred (Figure 4). The consequence of debris flows to critical BAER resources are moderate to major.

The upper sections of FSR 557 are particularly threatened by post-fire debris flows and their associated scouring and erosion. Soil and hydrologic resources are also at risk from erosion and post-fire hillslope

and channel debris flows. Recommended treatments include wood shred mulch on slopes from 15% to 65%, and several road treatments, including removing culverts, creating rolling dips and drainage structure reinforcement. The risk to structural reinforcement is from scour and not weight loads, so scour protection should be included with the drainage structure reinforcements. Treatments will help reduce surface runoff which in turn will help reduce risks from post-fire debris flows.

Figure 4. Debris-flow deposit on Upper Oldham Trail from the July 23rd storm.

Heritage Resources Report Summary

Cultural resources or historic properties consist of archaeological sites, historic buildings, and traditional cultural properties. The Coconino National Forest had previously surveyed approximately 589 acres (30%) of the burned area. There is one known site within the burned area and five sites were considered at risk of erosion effects due to their location in the watershed. These six archaeological sites were assessed post-fire to determine fire effects and potential post-fire treatment needs.

The site within the fire perimeter is considered Not Eligible to the National Register of Historic Places, and no treatment is recommended. The risk to heritage resources due to post-fire environmental conditions are very low. Accordingly, no sites are recommended for BAER treatment.

Engineering Report Summary

Watersheds that burned in the Museum Fire will experience increased runoff, sediment/ash-laden flows, and debris flows creating a future concern for roads, culverts, and channels along the drainage paths of the burned watersheds. Increased flows may cause the capacity of drainage features to be exceeded and transported sediment and debris may cause culverts and other drainage features to become overwhelmed and ultimately fail. These impacts may cause the uncontrolled flow to overtop the road and damage the road prism with the potential for structural failure of roads. Emergency ingress and egress on roads within the fire perimeter are also at risk. Forest Service Road (FSR) 557 provides the sole access to Elden Mountain fire lookout tower, Elden Mountain dispatch repeater and Elden

Mountain remote fire sensing camera equipment. This repeater provides radio communication sightlines for the majority of the north and eastern sides of the Coconino National Forest. Three roads (557 for 5.38 miles, 789 for 1.9 miles, and 6353 for 2 miles) were analyzed for possible post-fire impacts.

The reconnaissance of the roads and upstream drainages during the field investigations identified issues pertaining to road stabilization and public safety. A considerable threat exists to FSR 557. The hydrologic and debris flow modeling predicts significantly higher runoff and debris flows than pre-fire conditions which could result in the erosion of the road prism, overwhelming culverts and drainage features causing failure, uncontrolled flow on the road prism and potentially complete embankment failure. Recommended emergency stabilization treatments include: 1) Road Hardening; 2) Storm proofing, Rolling & Critical Dip Installation; 3) Storm Inspection and Response; 4) Energy Dissipation – Log Structures and Riprap Placement; 5) Culvert Removal; 6) Warning Signs; and 7) Closure of Hazardous Areas. Emergency stabilization treatments should be implemented as quickly as possible to protect human life and safety and minimize the negative impacts of other critical values.

Wildlife Report Summary

Mexican Spotted Owls (MSO, Threatened species) are present within the Museum Fire perimeter. Approximately 993 acres (52%) of protected habitat acreage was within the Museum Fire perimeter affecting three PACs: Mt. Elden, Oldham and Weatherford2. Of the total acreage, 122 acres (12%) experienced high severity burn and 365 acres (37%) experienced moderate severity. The entire Mt Elden PAC was within the fire perimeter and experienced a combined 314 acres (51%) of high and moderate severity. The Oldham PAC had 231 acres (44%) within the fire perimeter, and 126 acres (24% of the PAC) experienced high to moderate burn severity. The Weatherford2 PAC had 141 acres (21% of the PAC) within the fire perimeter and 47% (7% of the PAC) experienced high to moderate burn severity.

There are 195 acres of MSO Recovery Habitat within the fire perimeter. Of this, 181 acres are in mixed conifer cover type and 14 acres are in Ponderosa pine recovery habitat with only 23 acres burned at high and moderate severity. As a result, most of the recovery habitat in the fire perimeter will continue to provide foraging and nest/roost opportunities into the future.

There are 1,711 acres of MSO Critical Habitat within the fire perimeter. Critical habitat is designated by U.S. Fish and Wildlife Service (FWS) to provide for the survival and recovery of listed species. For the MSO, critical habitat includes areas within mapped boundaries that are protected or recovery habitat and include one or more of the primary constituent elements as listed in the Federal Register (USDI 2004). The CH in the fire perimeter experienced 761 acres (44% of the CH burned) of high and moderate burn severity.

Post-fire flooding could alter or destroy critical environmental features of MSO habitat. Wood shred mulch application sourced from local material would reduce soil erosion and hasten recovery of native vegetation communities, thereby protecting MSO habitat.

Recreation Report Summary

Two recreation sites (Brookbank Trailhead and Lower Oldham/Rocky Ridge Trailhead) and 8.75 miles of Forest System Trails are located within the Museum Fire burned area. Approximately 22.4% (2 miles) of trail burned in Moderate or High Soil Burn Severity (SBS) and all of this was through steep terrain above 15%. Soil and hydrologic models showed post-fire storm events are likely to cause accelerated runoff

and soil erosion exceeding soil loss thresholds in these areas. Trail infrastructure such as trail tread is expected to be damaged or lost after storm events with increased flows, erosion, and debris flows. Trails will carry increased flows also affecting trail segments in Low or Unburned SBS as well as serving as a conduit for debris and flood transport, affecting other resources.
The segments of trails recommended for treatment are segments that would have a high probability of success for storm-proofing and affective trail tread stabilization. Prescribed work would include trail stabilization and storm-proofing, including installation and improvement of drainage structures (drain construction, rolling dips, outsloping, and retaining walls) focused on trail segments in High and Moderate SBS. Trails identified for treatments are Lower Oldham, Brookbank, Sunset, Heart, Upper Oldham, and Rocky Ridge.

Invasive Species Report Summary

The area within the fire is comprised of ponderosa pine and mixed conifer forests with moderately dense to dense forest cover. The dense overstory and presence of needle cast limited the extent, health, and vigor of the native plant community. Portions of the forest had been recently thinned as part of the Flagstaff Watershed Protection Project (FWPP). One result of the fire was a removal of the litter and existing plant cover in large areas where needle cast and native plants previously existed, resulting in large areas of bare ground within the fire area. Dalmatian toadflax (*Linaria dalmatica*) is a non-native invasive plant that is difficult to control. It is a perennial species that reproduces by seeds and by creeping rhizomes. It responds well to wildfire and can persist at the expense of the native plant community. Recommended treatment for invasive and noxious weeds is early detection and rapid response (EDRR) for Dalmatian toadflax and other species such as diffuse knapweed (*Centaurea diffusa*) and Scotch thistle (*Onopordum acanthium*). These species are known to exist along the roadways used to access the fire area and could have inadvertently been introduced into the burned area during the emergency actions needed to suppress the fire.

Identified Values at Risk

The BAER team assessed Critical Values using the BAER Risk Assessment which identified critical values at risk from post-wildfire effects including human life and safety, MSO critical habitat, soil productivity, hydrologic function, native plant communities, FSR 557 and 789, and Brookbank, Lower Oldham, Sunset, and Rocky Ridge trails. Treatment methods were identified and recommended to the Coconino National Forest supervisor.

Partner Efforts

In addition to identifying and recommending treatments to reduce post-wildfire effects to VARs on NFS lands, partners with the City of Flagstaff, Coconino County, and local consultants were embedded with the BAER team during post-fire assessments on NFS lands with the intent of informing off-Forest risks to the local community, including Elden Mountain Lookout Estates, Paradise Road, Grandview Drive, and Sunnyside neighborhood. With their assistance, some additional needs were identified on NFS lands that are outside of the scope of the Forest Service BAER program, but are critical to protecting the community through advanced warning of flood risk and protection of stream channel morphology and alluvial deposits from changes that would increase risks to these neighborhoods through flooding and sediment delivery. Installation of three precipitation-monitoring stations and a water-flow monitoring station was recommended by our partners to provide advanced warning of rain high in the watershed above the City of Flagstaff and potential flooding. Additionally, our partners recommended the

installation of several cross-vein weirs (stream channel grade control structures) to prevent stream channel incision or degradation which would increase sediment transport into the local community. The City of Flagstaff and Coconino County recommended the installation of these structures to prevent conditions that would lead to increased flooding in these neighborhoods. In combination with County diversion structures and local sandbagging efforts, BAER treatments will play a critical role in reducing the impact on the local community.

Conclusion

The BAER team has identified threats to Values at Risk on National Forest System lands based on a rapid assessment of the area burned by the Museum fire. The BAER team has recommended emergency treatments for reducing post-fire impacts to VARs, but because much of this fire included steep slopes that burned at moderate and high severity there are likely to be unavoidable impacts. Aerial mulching using wood shred mulch has been proven to be an effective treatment to reduce post-fire erosion, and sediment delivery (pollution) to stream channels. FSR 557, which serves as the only road access to critical USFS and private infrastructure, is also threatened and requires treatment to reduce impacts.