2015 Rough Fire
Sierra and Sequoia National Forests and
Kings Canyon National Park

Fire Behavior Assessment Team Summary Report

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Pre-fire Plot 14 (Transect 2)

Fire entering Plot 14 from down/side canyon

Post-fire Plot 14 (Transect 2)

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Introduction

Wildland fire management relies on quality fire behavior and resource effects predictions. Existing prediction models are based upon limited field data from wildfires, especially quantitative data. The Fire Behavior Assessment Team (FBAT) collects data to improve our ability to predict fire behavior and resource effects in the long-term and provides short-term intelligence to wildland fire managers and incident management teams on fire behavior, fuels, and effects relationships. Increasing our knowledge of fire behavior is also important to firefighter safety; so we can mitigate hazards and prevent accidents. FBAT has seen their data used for a variety of purposes (see Appendix C) and is working to facilitate further applications to safety zone research, fire and fire effects model evaluation, and fuel treatment effectiveness assessments. This report contains the results of a two week assessment of fire behavior, vegetation and fuel loading, consumption, and fire effects for the 2015 Rough Fire.

The lightning-caused Rough Fire and started on July 31st, 2015 on the north side of the Kings river, at about 5 miles North of Hume Lake and 2.5 miles to the southwest of Spanish Mountain, in a difficult to access area on Sierra National Forest in California. Over the course of the few weeks the fire spread rapidly upslope in response to the warm, dry and windy weather, and "jumped" south over the Kings River on Aug. 18th. The steep, rugged terrain and lack of roads made access and management of the fire difficult. On Sept. 11th the Rough Fire had grown to an approximate size of 129,754 acres (Figure 2) with major portions of the perimeter effectively contained. Eventually, the 151,643 acre Rough Fire burned within the Sierra National Forest (58,541 ac), the Sequoia National Forest and Giant Sequoia National Monument (82,573 ac), Kings Canyon National Park (9,413 ac), CA state and private lands (1,096 ac), and was categorized as contained on Nov. 6th.

Fuels in the Rough Fire Area consisted primarily of pine and mature mixed shrub below 4500 feet elevation, with mixed conifer and montane shrub above 4500 feet elevation. The southern half of the Rough Fire burned towards the footprint of the 2010 Sheep Fire, and west into Converse Basin, Mill Creek, and Grant Grove. Live fuel loadings in this area were generally lighter with dead fuel loadings and snag occurrence generally higher.

Fuels and vegetation plots and fire behavior equipment were installed at 19 locations in the vicinity of the Rough Fire, with 12 plots burned by the fire, and a couple remained in unburned islands within the fire's perimeter. FBAT installed plots between the dates of Aug. 17 to 30th. Plots were burned starting Aug. 19th and over the next couple of weeks due to varying fire behavior, terrain conditions, management strategies, and geographic spread of the fire and our plots (Figure 2).

Objectives

Our objectives were to:

1. Characterize fire behavior and quantify fuels for a variety of fuel conditions, especially fuel treatment areas. Safety considerations, access, and current fire conditions restrict which areas can be measured.
2. Gather energy transport data during actively burning fires, in conjunction with site characteristics, for the Missoula Fire Lab's safety zone research.
3. Assess and measure representative vegetation to support smoke emission and fire behavior modeling.
4. Assess fire severity and effects based on immediate post-fire measurements.
5. Share the information the FBAT module gathered at the fire. Test out upgraded equipment and protocol.

See this report, and updated versions at: http://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php
See the plot level in-fire videos at: http://www.fs.fed.us/adaptivemanagement/amset_videos.php

Approach/Methods

FBAT selects study sites to represent a variety of fire behavior and vegetation/fuel conditions. Plot selection priorities are also based on safe access and areas that would most likely be burned over within the timeframe that FBAT could be at the incident. Within each plot both fuels and fire behavior data are gathered; a graphic of a plot set up is shown below (Figure 1), though the plot layout changes based on terrain, fuels, and additional objectives (radiant and convective heat for safety zone dataset). The map (Figure 2) displays daily fire progression and approximate plot locations.

Figure 1: Schematic of FBAT fuels and fire behavior study site.

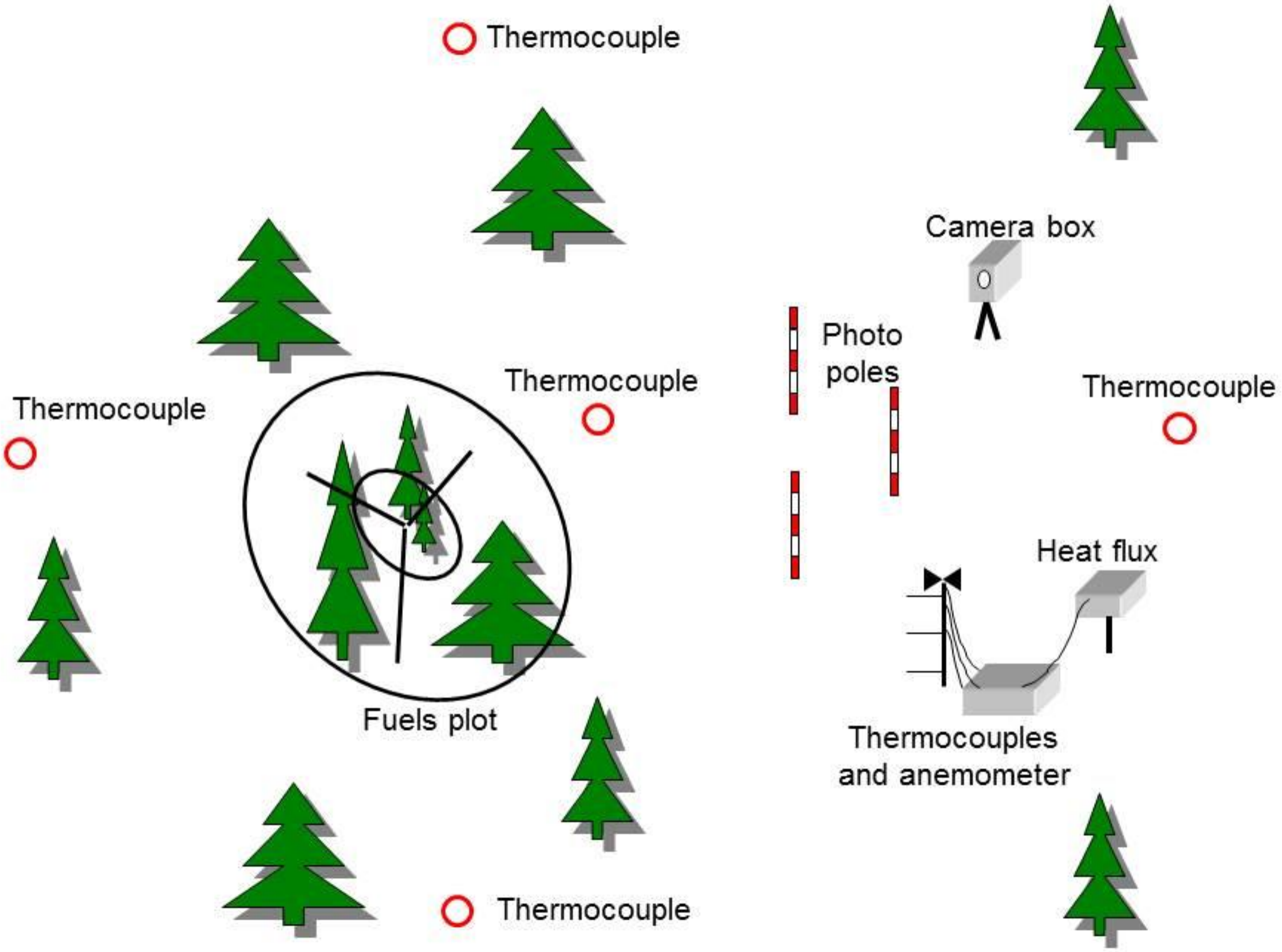
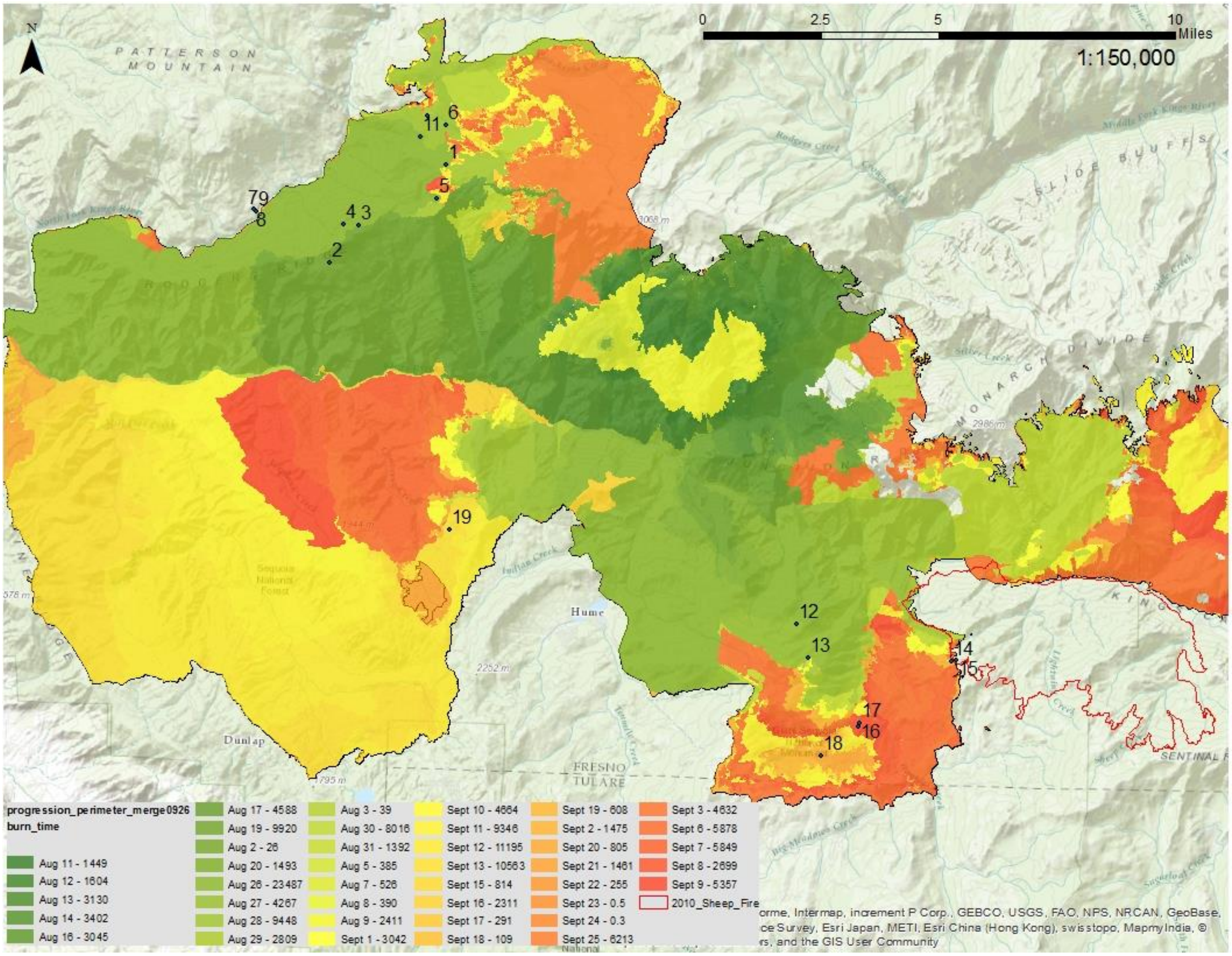


Figure 2: Fire progression as of Sept. 11th and location of FBAT fuels and fire behavior plots in the Rough Fire. Note the progression date does not always match the date fire behavior was captured due to green islands burning and the time of day of infra-red mapping.



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Vegetation and Fuel Measurements

Vegetation and fuels were inventoried both before the fire reached each plot and then again after the fire at plots. Plots were marked with rebar to provide options for long term monitoring (Figure 3).

Overstory Vegetation Structure and Crown Fuels

Variable radius sub-plots were used to characterize crown fuels and overstory vegetation structure. A relescope (slope-correcting tree prism) was used to create individual plots for both pole (>2.5 to 5.9 in diameter at breast height (DBH)) and overstory (>6 in DBH) trees. When possible a basal area prism factor was selected to include between 5 and 10 trees for each classification. Tree species, status (alive or dead), DBH, height, canopy base height (canopy fuel height at bottom of the tree), and crown classification (dominant, co-dominant, intermediate or suppressed) was collected for each tree before the fire. Tree height measurements were completed with a laser rangefinder; DBH was measured with a diameter tape.

After the fire, maximum bole char, crown scorch, torch heights and percentages of scorch and torch were recorded for each tree. Post-fire trees were assumed to be alive if any green needles were present. Changes in canopy base height were estimated from heights of scorch and torch on tree branches, or if necessary from percent of scorch rather than the maximum heights because uneven scorch values occurred sometimes due to trees affected by slope and alignment with heat. Because of smoke and poor lighting, visibility of the full crown is sometimes difficult. If a more accurate assessment of tree survivorship in the plots is desired we recommend another plot visit next year.

The Forest Vegetation Simulator program (FVS, Crookston and Dixon 2005) and its Fire and Fuels Extension (FFE-FVS, Rebain 2010) was used to calculate canopy bulk density, canopy base height, tree density, and basal area both pre- and post-fire for all tree species. FVS/FFE-FVS is stand level growth and yield program used throughout the United States. The Western Sierra variant was used for all calculations.

Understory Vegetation Structure and Loading

Understory vegetation was measured in a one meter wide belt along three 50-foot transects before and after the fire. The fuel and vegetation transects were always in view of the video camera (which will be described below in the “Fire Behavior Measurements and Observations” section). Species, average height and percent cover (based on an ocular estimation) were recorded for all understory shrubs, grasses and herbaceous plants. Biomass of live woody fuels (shrubs and seedlings) and live herbaceous fuels (grasses, herbs, subshrubs) were estimated using coefficients developed for the Behave Fuel Subsystem (Burgan and Rothermel 1984), but calculations were done on a spreadsheet (Scott 2005).

Surface and Ground Fuel Loading

Surface and ground fuels were measured along the same three 50-foot transects as the understory vegetation at each plot. Surface fuel loadings (litter, 1-hr, 10-hr, 100-hr and 1000-hr time lag fuel classes and fuel height) were measured using the line intercept method (Brown 1974, Van Wagner 1968). One and 10-hr fuels were tallied from 0 to 6 ft, 100-hr from 0 to 12 ft and 1000-hr from 0 to 50 ft. Maximum fuel height was recorded from 0 to 6 ft, 6 to 12 ft and 12 to 18 ft. Litter and duff depths were measured at 1 and 6 ft. All measurements were taken both pre- and post-fire. The measurements were used to calculate surface and ground fuel loading with basal area weighted species specific coefficients (van Wagtendonk *et al.* 1996; 1998); and ultimately percent fuel consumption.

Burn Severity

A rapid assessment of burn severity was completed along each transect and for the entire plot area to document the effects of fire on the surface and ground (USDI National Park Service 2003). The National Park Service (NPS) uses fire severity ratings from 1 to 5 when evaluating fire severity. In this rating system 1 represents unburned areas, and 5 represents areas with high fire severity (Appendix B).

Fire Behavior Measurements and Observations

At each plot, multiple sensors (thermocouples, heat flux sensors, and anemometers) and a video camera were set up to gather information on fire behavior (Figure 3). The thermocouples arrayed across the plot have the capability to capture date and time of temperatures from which rate of spread can be calculated. The heat flux sensors capture total, radiant, and convective heat flux from the flame front while the associated anemometers capture wind speed. The video camera is used to determine fire type, flame length, variability and direction of rate of spread, flame duration, wind direction and the direction of fire spread in relation to slope and wind. The sensors are described in more detail below.

Figure 3: Examples of fire behavior equipment set up at the Rough Fire at plot 18, in the Boulder Creek giant sequoia grove. Equipment from left to right next to the workers are the heat flux sensor and anemometer, the video reference poles (to estimate flame lengths and spread rate), and in the distance is the video camera box.

Rate of Spread and Temperature

Rate of spread was determined both by estimating rate of spread from video analysis and by calculating rate of spread with time stamps from sensors (data loggers with a thermocouple attached). The data loggers are buried underground with the thermocouple at the surface of the fuel bed. The thermocouple is able to record temperature up to six days or until the thermocouple and/or data logger is damaged by heat. The distances and azimuths among thermocouples were measured and these geometrical data and time of fire arrival were used to estimate rate of spread from Simard *et al.* (1984).

Fire Type

Fire type is classified as surface fire (low, moderate or high intensity) or crown fire. Crown fire can be defined as either passive (single or group torching) or active (tree to tree crowning). Fire type was determined from video as well as post-fire effects at each plot. For example, plots where there was complete consumption of tree canopy needles indicate at least torching or passive crown fire.

Flame Length and Flaming Duration

Flame length was primarily determined from video footage. Flaming duration was based on direct video observation and/or when temperature was measured, from those sensors as well.

Energy Transport

Energy transport data are collected with a heat flux sensor, where flux refers to the rate of energy transfer onto the surface of the sensor measured in units of kW/m^2. As with other recent work (e.g., Frankman *et al.* 2012, Butler *et al.* 2014), we use a Medtherm® Dual Sensor Heat Flux sensor (Model 64-20T), along with calibration relationships derived from laboratory measurements and theory, to provide incident total and radiant heat flux.

Radiant flux is detected behind a sapphire window while total flux is detected underneath a blackened surface on the face of the copper plug that houses the detectors. The difference between total and radiant flux is an estimate of convective flux to the sensor (e.g., Frankman *et al.* 2012). Though safety zone guidelines are based on radiant flux alone, Butler (2014) recommends a consideration of total heat flux. The maximum incident heat flux tolerable by firefighters (wearing nomex and protective head and neck equipment) was described as 7 kW/m^2 by Butler and Cohen (1998) in their work on safety zone guidelines. Apart from firefighter safety, heat flux data are useful in developing a fundamental understanding of wildland fire spread and fire effects on trees and soils. Orientation of the sensor relative to the oncoming fire is critical. The sensors have a full-angle field of view of approximately 160 degrees (Frankman *et al.* 2012). A successful data collection requires that the flame front approach the sensor within less than approximately +/- 30 degrees of the sensor face (where the sensor face is 0 degrees). The sensor is placed at 1 m above the ground surface and, for small flames, may not be impacted directly by flames, resulting in low heat flux at the sensor. Data summary follows the methods used by the Missoula Fire Laboratory.

Plot Wind Speed

Wind data collected with cup anemometers placed 5-feet above ground at the locations of the heat flux sensors gives an indication of the wind experienced at each plot as the fire passed through. Wind data on plots with intense fire are only valid only up until the plastic anemometer melts or otherwise is compromised. Wind data were recorded at 1 second intervals and averaged over 10-seconds. Average winds were calculated over the 20 minutes prior to fire detection at the heat flux sensor.

Findings/Results

Pre-fire data were collected at all 19 plots that we established on the Rough Fire, however post-fire fuels and fire behavior data were only collected at the 13 plots which burned. The plots represented different forest/vegetation types and management activities (Table 1). Paired photographs of plots with fuels data are available in Appendix A. Video cameras and rate of spread sensors functioned properly on burned plots. As of Jan. 2016 wind speed data on 8 plots and heat flux measurements on 2 plots have been obtained. Due to fire intensity damage and/or mechanical equipment failure other data was not recovered/collected, however we remain hopeful that video footage recovery from the SD cards will still occur on plot 1 and 17.

Table 1: Site description of the 19 plots.

Site	Forest/Vegetation Type	FACTS[1] History (last 10 years)	Slope %	Aspect (deg.)	Elevation (feet)*
North Zone of Fire					
1	red and white fir		45	320	7159
2	mixed conifer		13	162	6118
3	mixed conifer (white fir)		10	324	6860
4	shrubland (Prunus and Ceanothus sp.)		27	194	6849
5	red and white fir		24	324	7036
6	mixed conifer (white fir, sugar pine)		18	352	6727
7	oak woodland and mixed conifer		14	166*	4016
8	shrubland (manzanita)		33*	156*	4064
9	oakland and mixed conifer		26	165	4005
10	ponderosa pine plantation	mechanical treatment	10	334	6584
11	ponderosa pine plantation	mechanical treatment	42	248	6766
South Zone of Fire					
12	mixed conifer: (sequoia, white fir, sugar pine)	planning done, not implemented2	40	248	6754
13	mixed conifer (sequoia, white fir, sugar pine)	planning done, not implemented, heritage area2	28	60	6907
14	mixed conifer (white & red fir, Jeffrey pine)	just outside/west of Sheep Fire, planning done, not implemented2	45	264	8122
15	red and white fir	inside western edge of Sheep Fire perimeter (burned in Sheep fire)	35	320	8203
16	mixed conifer with sequoia	planning done, not implemented2	45	336	6630
17	mixed conifer with sequoia	planning done, not implemented2	40	326	6548
18	mixed conifer with sequoia	planning done, not implemented2	5	360	6745
19	mixed conifer with sequoia and meadow ecotone	heritage area	5	360	6072

* Plot information based on GIS, not field data.

[1] FACTS is the acronym for **F**orest Service **Ac**tivity **T**racking **S**ystem.

[2] Part of Sequoia NF’s Boulder Creek treatment project, but mostly not implemented prior to Rough Fire.

Pre- and Post-Fire Vegetation and Fuel Measurements

Overstory Vegetation Structure and Crown Fuels

Canopy base height, canopy bulk density, and canopy continuity are key characteristics of forest structure that affect the initiation and propagation of crown fire (Albini 1976, Rothermel 1991). Canopy base height (CBH), or the bottom of the tree canopy fuels, is important because it affects crown fire initiation. As stated in Scott and Reinhardt (2001), "Defined in terms of its consequences to crown fire initiation, CBH is the *lowest* height above the ground at which there is sufficient canopy fuel to propagate fire vertically through the canopy." Canopy Bulk Density (CBD), is the mass of canopy fuel available per unit canopy volume (Scott and Reinhardt 2001).

Forest treatments that target canopy base height and canopy bulk density can be implemented to reduce the probability of crown fire (Graham *et al.* 2004). Canopy bulk density varies considerably within the stands measured on the Rough fire (Table 2), and CBD was calculated at maximum value of 0.35 kg/m^3 at untreated areas represented by plots 2 and 3, a minimum value of 0.017 kg/ m^3 at plots 14 and 18 prior to the Rough fire, which had more open canopy, large dominant trees compared to other areas. Note plots 4 and 8 were shrub dominated, and are not considered part of the canopy fuel discussion.

Thinning to reduce canopy bulk density to less than 0.10 kg/m^3 is generally recommended to minimize crown fire hazard (Agee 1996, Graham *et al*. 1999), and for the most part below this point, active crown fire is very unlikely (Scott and Reinhardt 2001). Canopy bulk densities (Table 2) were below this threshold before the fire for plots 1, 6, 10-11(plantation areas with mechanical treatments), 14, 16, and 18. Based on post-fire site visits, plots 2, 4, 10, and 11 have probably all dead trees in the measured plot areas. Only plots 10 and 11 (plantation sites) with low CBD had obvious crown fire behavior (probably torching trees), as well as plot 17 which had higher CBD of 0.127 kg/m^3. Tree mortality and canopy fuel changes cannot be determined with certainty until one or more years post-fire due to delayed mortality effects and tree recovery rates. Based on immediate post-fire data, the CBD *did not change* post fire on plots12 or 13, potentially because surface fire did not prune the canopy height or basal area and few differences were observed in overstory trees/canopy fuels. Plots 3, 14, 16 and 17 had clear changes in canopy metrics during post-fire measurements. Using FVS-FFE analysis, trees that were estimated as dead post-fire are not included in outputs, but we adjusted the parameters to include hardwood trees.

Table 2: Pre- and post-fire overstory vegetation and crown fuel data by site estimated by FVS-FFE. FVS was programmed to include hardwood species in below estimates. QMD is the quadratic mean diameter based on tree data collected at the site scale. Green colored areas are pre-burn data and/or were unburned by the Rough Fire.

Site	Overstory (>6 in DBH) trees/acre		Pole-size (<6 in DBH) trees/acre[2]		QMD (in)		Basal Area (ft²/acre)		Canopy Cover (%)[3]	Canopy Height (ft)		Canopy Base Height (ft)		CBD (kg/m³)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Pre	Post	Pre	Post	Pre	Post
1	45	45	0	0	42	42	433	433	80	149	149	27	20	0.067	0.071
2	334	~	47	~	10	~	205	~	<204	47	~	6	~	0.350	~
3	245	142	86	0	17	22	492	361	604	97	97	3	31	0.350	0.285
4	10	~	0	~	19	~	19	~	0	46	~	12	~	0.015	~
5	123		75		19		405		60	135		5		0.130	
6	100	100	34	34	20	20	296	296	70	132	132	13	13	0.092	0.094
7	467		1081		5		220		90	42		6		0.230	
9	402		179		7		170		30	30		7		0.217	
10	96	~	0	~	15	~	122	~	50	46	~	20	~	0.068	~
11	79	~	0	~	8	~	35	~	0	26	~	5	~	0.055	~
12	139	139	30	30	21	21	389	389	83	120	120	7	7	0.153	0.153
13	148	148	0	0	30	30	726	726	92	162	162	34	34	0.174	0.174
14	12	12	0	0	39	39	100	100	25	119	119	27	40	0.017	0.022
15	41		0		27		161		25	99		30		0.106	
16	33	33	0	0	30	30	162	162	58	76	76	6	38	0.043	0.030
17	92	25	98	28	11	13	115	45	60	62	52	1	21	0.127	0.085
18	16		0		73		469		50	172		45		0.017	
19	59	59	0	0	19	19	118	118		54	54	2	6	0.069	0.057

[1] Plot 4 was shrub dominated and only 1 tree was on the plot. Plot 8 did not have any trees and was manzanita dominated.

[2] Note that a "~" symbol in post-fire data where pre-fire data was greater than zero indicate all trees were scorched or torched and appeared dead at the time of post-fire sampling. FVS-FFE does not calculate canopy characteristics for dead trees.

[3] Canopy cover was based on field data with densitometer, not FVS outputs.

[4] Canopy cover was only ocular estimate; no time for field data with densitometer.

Fire Effects: Tree Canopy Scorch, Torch, and Bole Char

A few days after the fire burned through each plot (allowing for smoldering combustion to complete and some fire-weakened trees to fall) additional measurements were gathered (char height, maximum heights and percentage of crown scorch and torch) to better assess the fire effects at each plot. Percentage values were determined using ocular estimations, and heights were measured with a laser rangefinder. Severity or fire effects can be accessed from the percentage of scorch and torch for each study plot (Figures 4 and 5). Plots 1, 6, 12 and 13 had minimal scorched (browned or heated) portions of tree canopies, with the majority of tree canopies remained green. In and plots 2, 4, 10 and 11, the canopies had large amounts of scorched and torched (foliage consumed) branches. The average bole char height varied from less than 5 feet in plot 6 to about 45 feet in plot 10. Plot 13 and 1 had the tallest trees, followed by plots 6 and 14. Plot 2, 4, 10 and 11 appear to have levels of scorch and torch which could lead to mortality, but that might change as second order effects occur.

Figure 4. Average percentage of scorch and torch of tree crowns per plot. The portion of tree crown which still appears as live (not scorched or torched) during the immediate post-fire site visit is labeled "green."

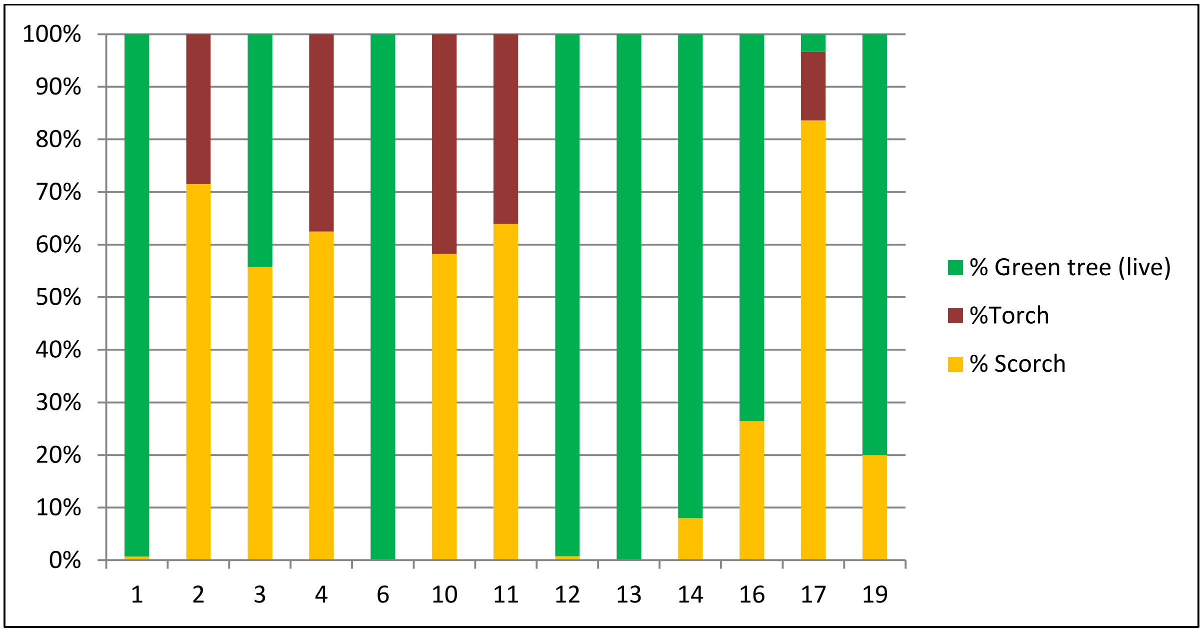
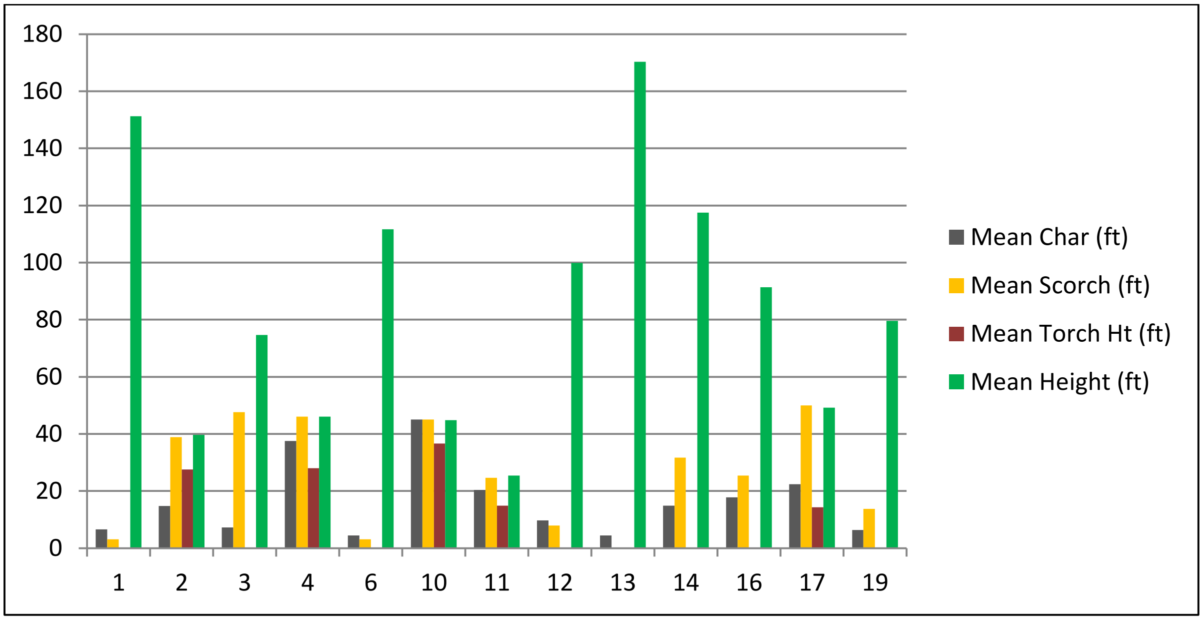


Figure 5. Average height (feet) of tree bole char, scorch, torch, and tree heights per burned site.



Understory Vegetation Loading and Consumption

The understory vegetation varied by forest type and treatment/fire history, but there were very low levels of herbaceous fuels in all plots of 0.02 ton/ac or less, but nearly full consumption of the above ground portion of this layer (Tables 3 and 4). The shrub/seedling fuels had higher loading than herbaceous, but variable amounts between the plots. Plot 4 had a large shrub component, with a total shrub loading to 9.1 ton/ac. Plots 8, 9 and 10, which did not burn, were shrub and oak dominated. The areas around Plots 10 and 11 had mechanical treatment within the past 10 years, and plot 11 had fairly high shrub fuels. Plot 15 was within the perimeter of the Sheep Fire and had low herbaceous and shrub fuels. Understory vegetation consumption percentage in burned plots was moderate to high percentages (Table 4). Plots 6 and 12 had unburned patches which accounts for the lower consumption percentage. The paired photographs in Appendix A show a sample of the distribution and density of understory flora for each plot, as well as illustrate the change post-burn.

Table 3: Average (three transects per plot) for understory vegetation fuel loading pre-fire, and post-fire for burned plots.

Site	Average Grass/Herb (ton/ac)						Average Shrub/Seedling (ton/ac)					
	Pre-Fire			Post-Fire			Pre-Fire			Post-Fire		
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total
1	0.003	0.002	0.004	0	0	0	0.110	0.033	0.143	0	0.015	0.015
2*	0	0	0	0	0	0	4.754	1.141	5.896	0.023	0.609	0.632
3	<0.000	<0.000	<0.000	0	0	0	0.021	0.003	0.024	0.002	0.001	0.003
4*	0	0	0	0	0	0	5.826	3.268	9.094	0	0.110	0.110
5	0	0	0				0.132	0.015	0.148			
6	0.012	0.003	0.015	<0.000	<0.000	<0.000	0.017	0.015	0.027	0.002	0.002	0.027
7	0	0	0				1.706	1.764	3.470			
8	0.001	0.015	0.017				15.499	11.559	27.057			
9	0	0	0				2.020	2.873	4.893			
10	0.020	0.006	0.026	0	0	0	0.736	0.235	0.971	0	0.008	0.008
11	0	0	0	0	0	0	3.743	0.289	4.032	0	0.005	0.005
12	0.002	<0.000	0.002	0.001	<0.000	0.002	0.018	0	0.019	0.014	0.004	0.018
13	<0.000	0	0.000	0	0	0	0.001	0	0.001	0	0	0
14	0.002	0	0.002	<0.000	<0.000	0.001	0.080	0.001	0.081	0.009	0.023	0.023
15	<0.000	0	0.000				0.011	0	0.011			
16	<0.000	0	0.000	0	0	0	1.625	0.069	1.694	0.271	0.474	0.474
17	<0.000	0.001	0.001	0	0	0	0.010	0	0.010	0	0	0
18	0.006	0.001	0.007				0.126	0.003	0.129			
19	0.067	0.197	0.265	0.002	0.015	0.017	0.194	0.217	0.412	0	0	0

* Due to limited time/safety windows, plot 2 had two understory transects, and plot 4 had one understory transect.

Table 4: Average (three transects per plot) total understory vegetation consumption percentage for burned plots based on values in above table. Note plots 5, 7, 8, 9, 15, and 18 did not burn. Plots 2, 4, and 11 did not have grass or herbs located on the understory transect(s).

Site	Understory Percent Consumption	
	Grass/Herb	Shrub/Seedling
1	100%	89%
2*	n/a	89%
3	100%	89%
4*	n/a	99%
6	98%	0%
10	100%	99%
11	n/a	100%
12	29%	5%
13	100%	100%
14	74%	72%
16	100%	72%
17	100%	100%
19	94%	100%

* Due to limited time/safety windows, plot 2 had two understory transects, and plot 4 had one understory transect.

Surface and Ground Fuel Loading

As considered normal in forested ecosystems, the predominant fuel layer making up the bulk of the total surface and ground fuel loadings was duff, followed by litter (Table 5). Plot 4 is an exception to this, where more litter was measured than duff, probably due to the confusing differentiation of material in these strata. Loading at the unburned plot 15 was very low, due to previous fuel reduction from the Sheep fire. Ground and surface fuels were very high in plot 13, which was in an area where treatment was planned, but not implemented yet. One- and 10-hour fuels contributed only slightly to total fuel loads. Hundred- and 1000-hour fuels were present, but not abundant, except for several plots, namely plots 2, 6, 13, 14, 17 and 19, which had over 10 tons/acre of 1000-hour fuels. Plots 6, 13, 14, 17 and 19 had greater than 20 tons/acre of 1000-hour fuels, and also greater than 50% consumption of 1000-hour fuels. Consumption of surface and ground fuels was never less than 50%, and was often 98% or greater (Table 5). Plot 18 was reported to have burned after the FBAT module left the fire area.

Table 5: Average fuel loading and fuel bed depth based on 3 transects per plot, and post-fire data for burned plots. Plots highlighted in green did not burn during FBAT's time at the fire.

Plot	Status	Duff	Litter	1 hr	10 hr	100 hr	1000 hr	Total
		ton/acre						
1	Pre	53.3	23.5	0.3	0.9	2.6	4.0	84.6
	Post	0.0	1.4	0.0	0.2	0.0	0.0	1.6
	Consumption	100%	94%	88%	79%	100%	100%	98%
2	Pre	12.8	12.8	0.0	0.4	2.0	16.0	44.0
	Post	0.0	9.5	0.0	0.0	0.0	4.2	13.7
	Consumption	100%	26%	100%	100%	100%	74%	69%
3	Pre	32.0	10.3	0.6	1.2	0.5	7.6	52.3
	Post	1.4	2.8	0.2	0.3	0.3	3.2	8.1
	Consumption	96%	73%	72%	76%	50%	58%	84%
4	Pre	9.5	79.5	0.7	1.5	1.4	0.0	92.7
	Post	0.0	0.0	0.0	0.3	0.0	0.0	0.4
	Consumption	100%	100%	95%	78%	100%	N/A	100%
5	Pre	44.2	16.1	0.3	0.9	2.5	6.7	70.6
6	Pre	13.7	12.2	0.2	1.1	1.7	31.8	60.6
	Post	0.0	2.0	0.0	0.3	0.0	0.0	2.3
	Consumption	100%	83%	87%	76%	100%	100%	96%
7	Pre	29.7	11.0	0.3	0.8	5.2	1.1	48.1
8	Pre	0.0	5.8	0.1	0.1	0.6	0.3	7.1
9	Pre	24.8	7.5	0.5	0.8	2.5	1.8	37.9
10	Pre	37.1	22.9	2.6	3.4	5.5	7.0	78.6
	Post	19.9	0.0	0.0	0.4	0.0	0.0	20.3
	Consumption	46%	100%	98%	88%	100%	100%	74%
11	Pre	29.5	8.3	1.3	4.2	5.0	2.4	50.7
	Post	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Consumption	100%	100%	100%	100%	100%	100%	100%
12	Pre	55.0	12.3	0.5	1.0	1.0	0.3	70.1
	Post	27.5	3.4	0.2	0.2	0.3	0.0	31.7
	Consumption	50%	72%	64%	75%	67%	100%	55%

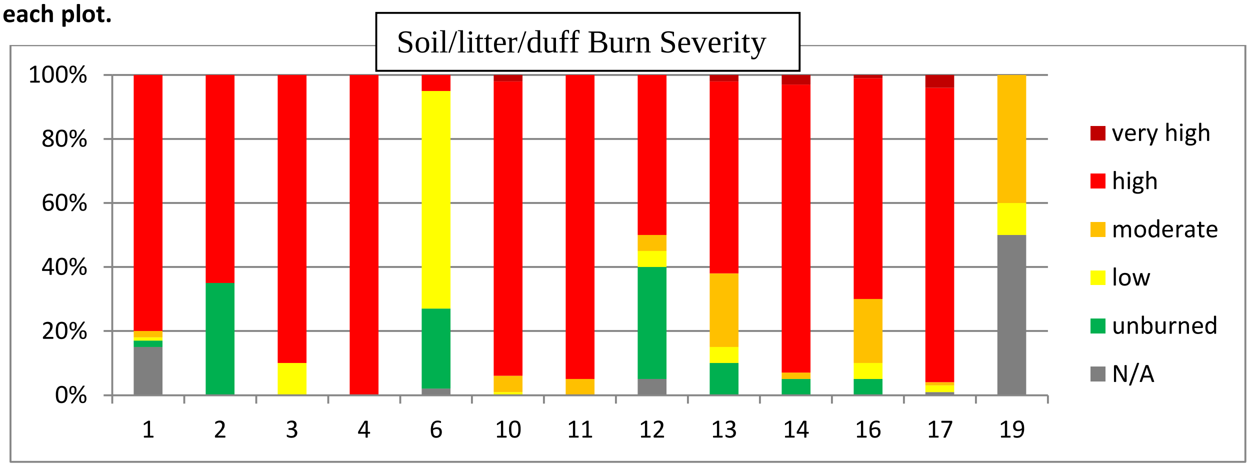
	Status	Duff	Litter	1 hr	10 hr	100 hr	1000 hr	Total
13	Pre	72.9	13.3	0.7	0.7	2.4	58.8	148.8
	Post	0.0	0.9	0.0	0.1	0.0	25.8	26.8
	Consumption	100%	94%	95%	82%	100%	56%	82%
14	Pre	36.3	10.8	0.3	0.6	0.9	53.6	102.6
	Post	6.0	3.4	0.1	0.1	0.0	3.9	13.5
	Consumption	83%	69%	63%	91%	100%	93%	87%
15	Pre	0.0	2.2	0.4	1.2	3.6	0.0	7.33
16	Pre	17.5	8.7	0.3	0.4	0.0	6.3	33.0
	Post	4.4	1.7	0.1	0.1	0.0	0.0	6.3
	Consumption	75%	80%	74%	67%	N/A	100%	81%
17	Pre	47.5	20.2	0.8	4.1	4.0	28.9	105.5
	Post	0.0	0.0	0.0	0.2	0.0	0.5	0.8
	Consumption	100%	100%	100%	94%	100%	98%	99%
18	Pre	63.0	15.1	0.9	3.9	3.3	7.1	93.3
19	Pre	3.0	10.0	0.2	0.7	1.9	142.9	158.8
	Post	0.0	1.0	0.0	0.0	4.4*	30.6	36.0
	Consumption	100%	90%	94%	100%	-126%*	79%	77%

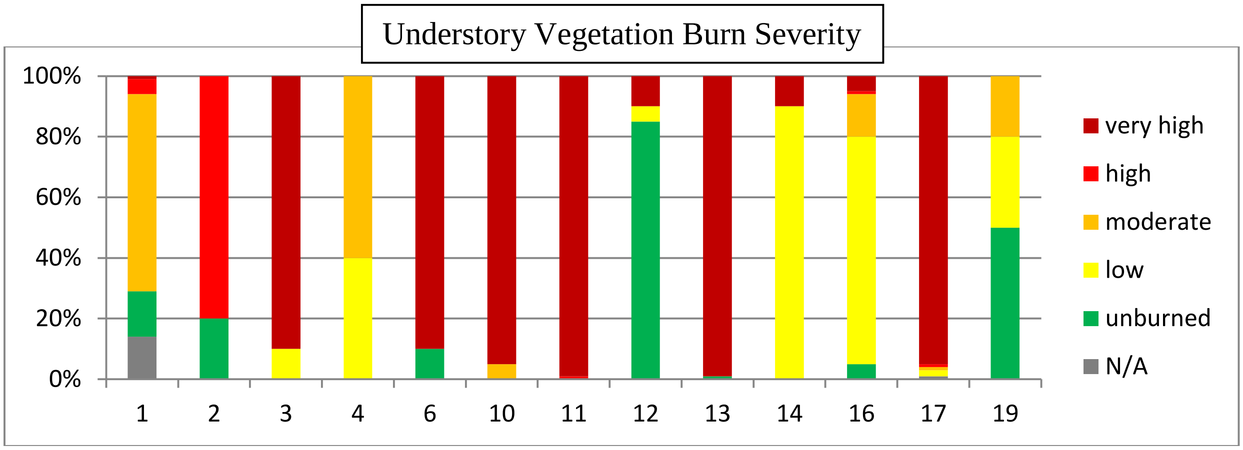
*Amount of 100-hour is higher than pre-burn because this material had been categorized as 1000-hour size class pre-burn, which only partially consumed, and remaining woody debris was categorized as a reduced size class post-fire.

Soil and Understory Vegetation Burn Severity

The National Park Service's severity categories were used to assess post-burn soil/substrate and understory vegetation severity along each transect and for the entire plot. Vegetation burn severity is only based on the vegetation that was documented pre-burn. For full descriptions of the categories, please see Appendix B. Substrate severity was generally high, with the exceptions being plots 2, 6, 12 and 19 which had large unburned soil patches (Figure 6). Understory vegetation severity was variable (Figure 6). Plots 3, 6, 10 and 11 showed the highest vegetation severity. Plots 12 and 19 had large patches of unburned vegetation and plots 14 and 16 had large patches of low vegetation severity.

Figure 6: Average post-fire surface soil/substrate (top graphic) and understory vegetation severity rating (bottom graphic) for each plot.





Fire Behavior Observations and Measurements

The narratives below describe fuels and the fire behavior movement through the plot. The metal poles in the video camera's field of view are marked in 1-foot increments; however, often it is difficult to determine how close the flame is to these poles, making flame length estimates approximate. Rate of spread was estimated from the video when possible, by timing the fire progress through a visually-estimated distance. However, fire spread is rarely a simple heading fire, and varies with wind gusts and terrain, as sometimes captured by the video. Five plots had easy video data recovery and quality video footage. Many of the other plots had video camera or camera trigger problems, as we tested a new equipment configurations. The video camera boxes at Plots 1 and 17 received more heat than anticipated, and that video data is at a recovery service. Plot 18 was reported to have burned by Oct. 1 (Caprio Pers. Com. 2016), but after that was after the FBAT module had left the fire area. Below the burned study sites are listed, some only with partial data due to above reasons.

Video Observations at North Zone of Rough Fire

Plot 1, Mixed conifer Forest, below 11S07 Rd

The video data (SD card) is still at data recovery services. Damage was probably due to heat residence time at video site. This site appeared to have a surface fire (Figure 7). More paired photos of this site are in Append. A.

Figure 7. Plot 1, Transect 1 before and after the fire. Another pair of photos is in Appendix A.

Plot 2, Mixed conifer Forest, understory treated by incident operations for suppression area, then burnout

Plot 2 was installed quickly in an unburned area that had been prepared for burnout operations near Drop Point 3 on the east side 11S007 Road. No mechanical video trigger was necessary, as this unburned area was strategically burned by drip torch after we left as part of the containment plan. It had patchy tree canopy cover with manzanita and bear clover understory. Spread rate is very slow (about 0.25 chains/hour). Flame lengths are 2 to 10 feet (based on video reference poles and observed firefighters), with occasional single tree and snag torching, and slash (or limbed material) piles are burning (Figure 8). Active consumption is observed up until the end of the video approximately 2.5 hours later.

Figure 8. Plot 2 burning, photo captured from video. All three four-foot reference poles are visible in center of the photo, and the heat flux sensor in the background (just right of center). The day the site burned is captured on the video.

Plot 4, shrub (whitethorn or Ceanothus species and Prunus species) area, near conifer edge

Plot 4 was in a ceanothus/whitethorn dominated area, which had a large amount of *Prunus* species (choke cherry) as a taller shrub/sapling size live fuel, on the west side of the 11S07 Road. Access and foot travel were difficult. This was near Drop Point 2 (also called Drop Point 2 ½ locally). After the fire, the entire shrub field appeared burned and only thicker branches remained, with hardly any scorched foliage remaining; but some trees and vegetation in surrounding areas was intact or largely unburned (Figure 9). The video data was not functional or recovered, and it might have been due to the amount of heat and FBAT program testing new protocol and video equipment.

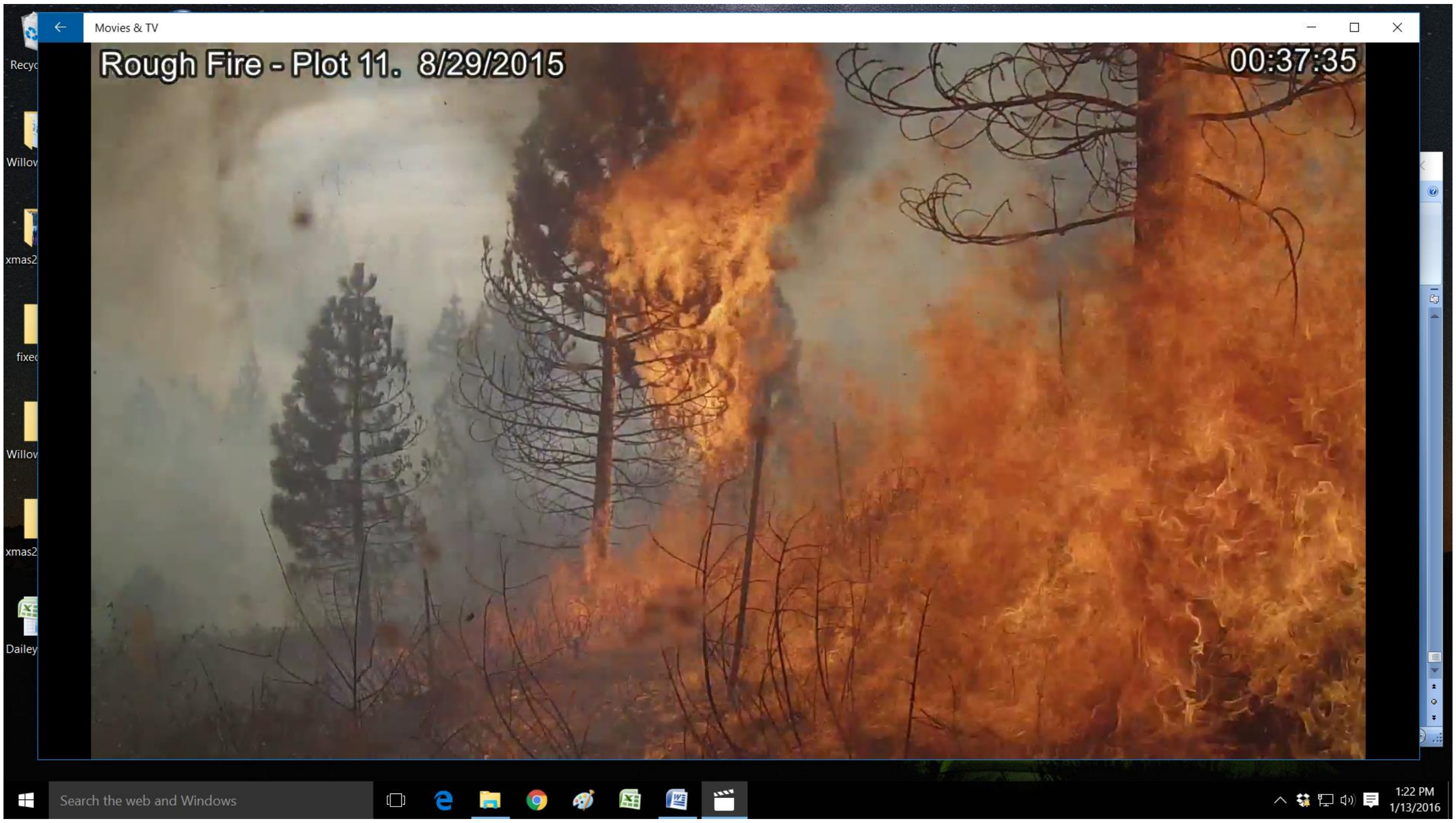
Figure 9. Plot 4, overview of the area after the fire. The plot location is circled in red, where workers are there re-visiting the site. Another pair of photos is in Appendix A.

Plot 11, Plantation open canopy area with mechanical treatment top of knoll near Smith Meadow

Plot 11 was located on the upslope side of the 11S44 Road on a knoll overlooking Smith Meadow, above the junction of the 11S44B and C roads. This area had received mechanical treatments a few years ago, including mastication, but understory was already three feet tall across much of the area. Fire progression appears mostly uphill, with some flanking spread. Video shows quick progression, and is short due to video camera's heat sensitivity problems. Multiple trees were captured torching in quick succession (Figure 10). Wind increase is observed, with debris and embers flying, and flame lengths of 10 to 15 ft. It takes approximately 7 hours for the fire to travel a very roughly estimated 200 meters (about 1.5 chains/hour). During the last 4 minutes of the video, the fire travels approximately 10 meters (about 7.5 chains/hr). Active consumption is observed up until the end of the video at approximately 38 minutes

This video was shared with incident PIO group and CBS news at: insert http://www.cbsnews.com/videos/how-cameras-help-firefighters-stay-ahead-of-wildfires/

Figure 10. Fire in plot 11 in an open plantation as the fuels there are fully engaged in active flaming. A four-foot reference pole is mostly visible center screen, but the other poles and sensors are obscured.

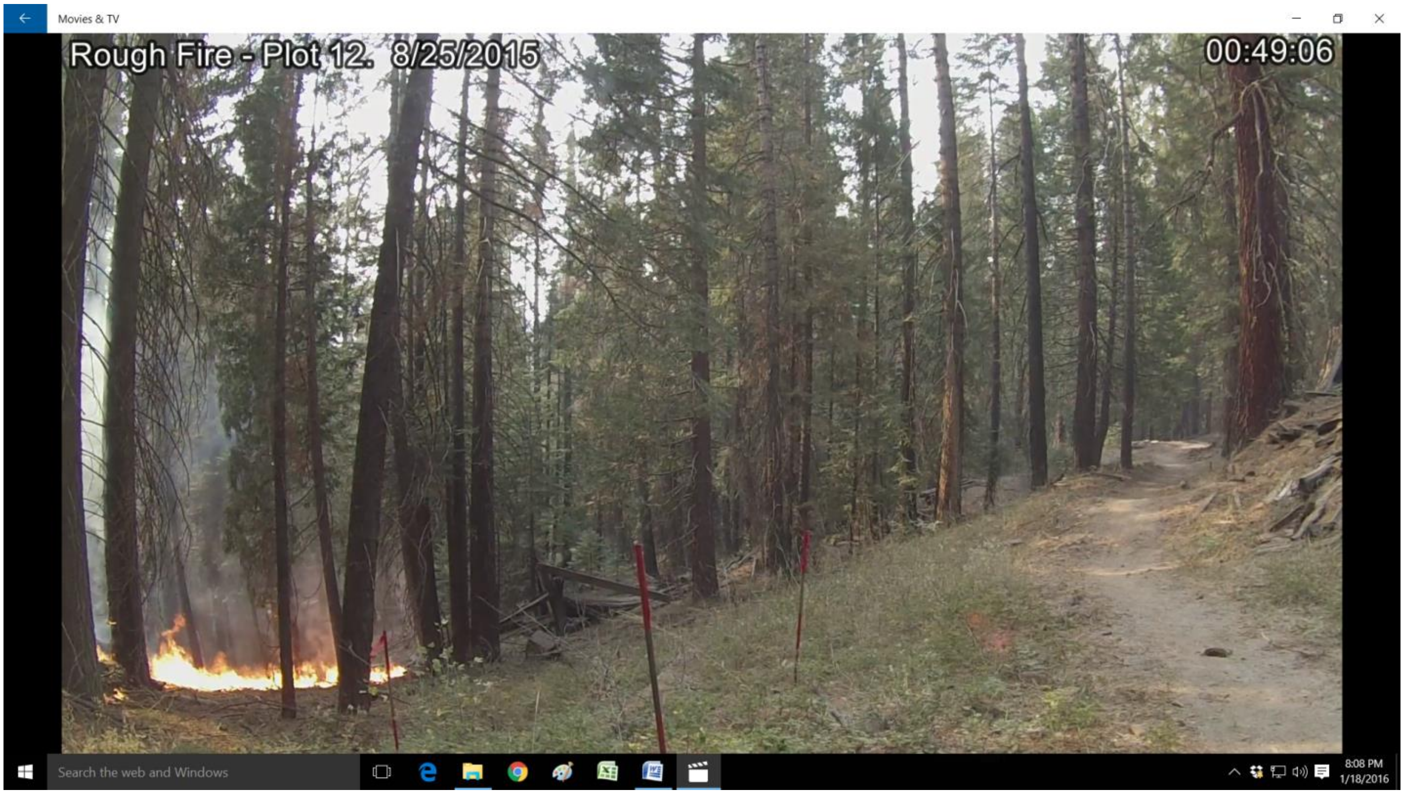


Video Observations at South Zone of Rough Fire

Plot 12, Mixed Conifer Forest, Evans Complex (Boulder Creek) Grove, Heritage Site (old trestle)

Plot 12 was located on the downslope side of the old road or trail on the N. side of Evans Creek off the 13S05 Road. Fire progression was captured as a slow progression uphill, and consumed much of the fallen-apart trestle, support beams, and material on the structural rock pile area (Figure 11). The fire burns in the understory, with fire creeping up tree boles, but no torching out is observed. ROS is slow about 0.5 chain/hour. Flame lengths are mostly 1 to 3ft, but increases to approx. 8ft or so for brief periods. Residence time is high; active consumption is observed up until the end of the video at about 3.75 hours later. The area had a patchy burn pattern, but the trail and previous prescribed burn preparations seemed at act as a barrier or slowing mechanism in some areas based on post-fire observations.

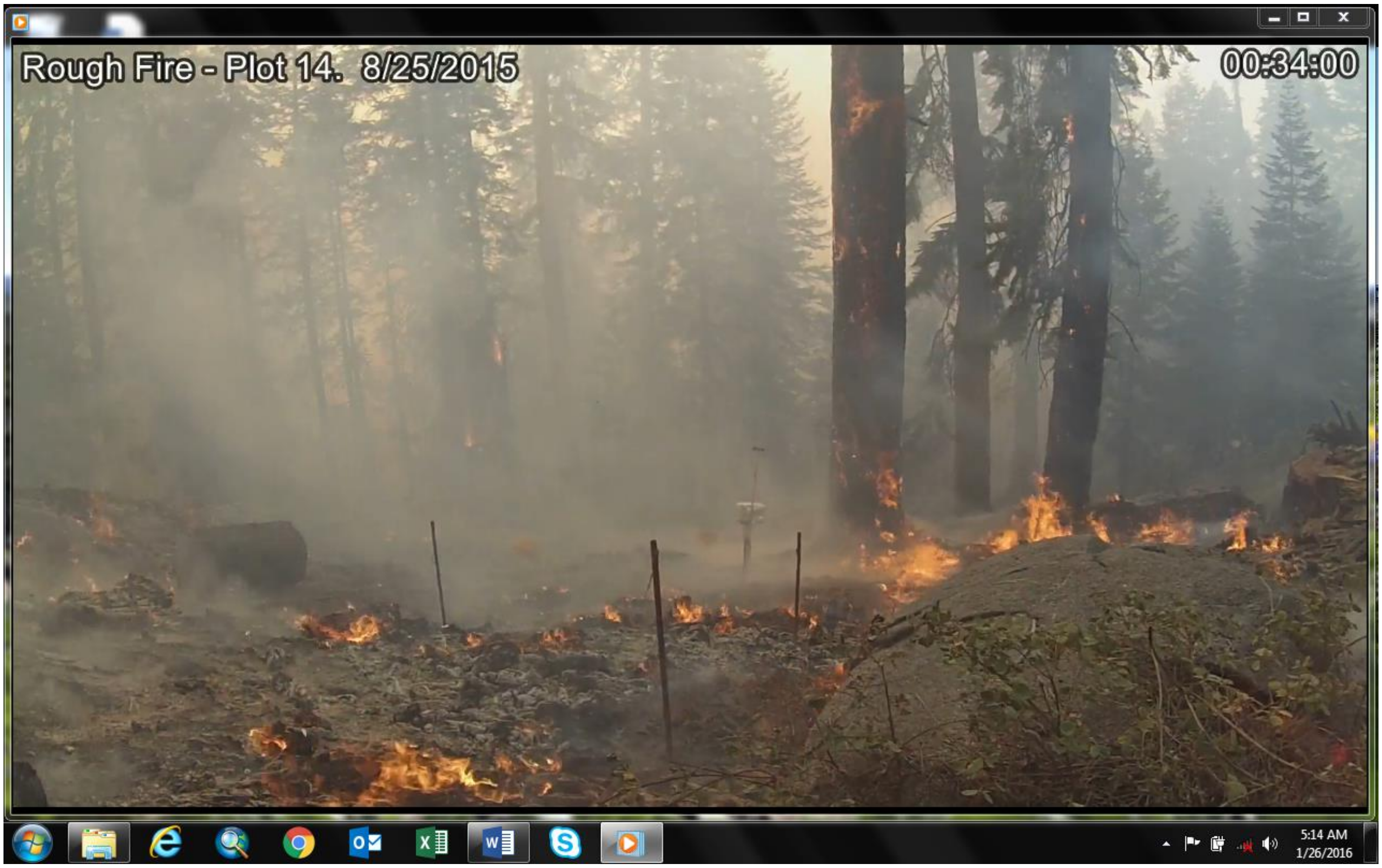
Figure 11. Fire in Plot 12 in a mixed conifer (with sequoia tree) area and heritage site. All three of the four-foot reference poles are visible at center screen, as the fire slowly spread and consumed the available fuel.



Plot 14, Mixed Conifer Forest, in Boulder Creek planned prescribed burn area, outside western edge of 2010 Sheep Fire

Plot 14 was located on the downslope side of the Deer Meadow Trail, reached from the Deer Meadow Trailhead (leading to the Monarch Wilderness and western edge of the Sheep Fire). Area had sparse to patchy live understory fuels. The video begins with fire already established in the plot, just having passed the first of three reference poles (Figure 12 center). More photos of this site are on this report's cover page and in Appendix A. Fire progression was captured as a slow progression uphill/sidehill. Fire creeps up tree boles, but no torching is observed. Fire intensity appears to be mostly low, but heat intensity appears high when the fire gets into isolated patches of thick/heavy woody material. Residence time is long duration; active consumption is observed up until the end of the video 43 minutes later. Flame length (estimated by known photo pole heights) is mostly 1-3ft, but increases to 2-4ft with brief wind gusts, and/or when the fire burns into patches of heavier fuel. The area had a patchy burn pattern, but most of the plot area had signs of surface fuel consumption.

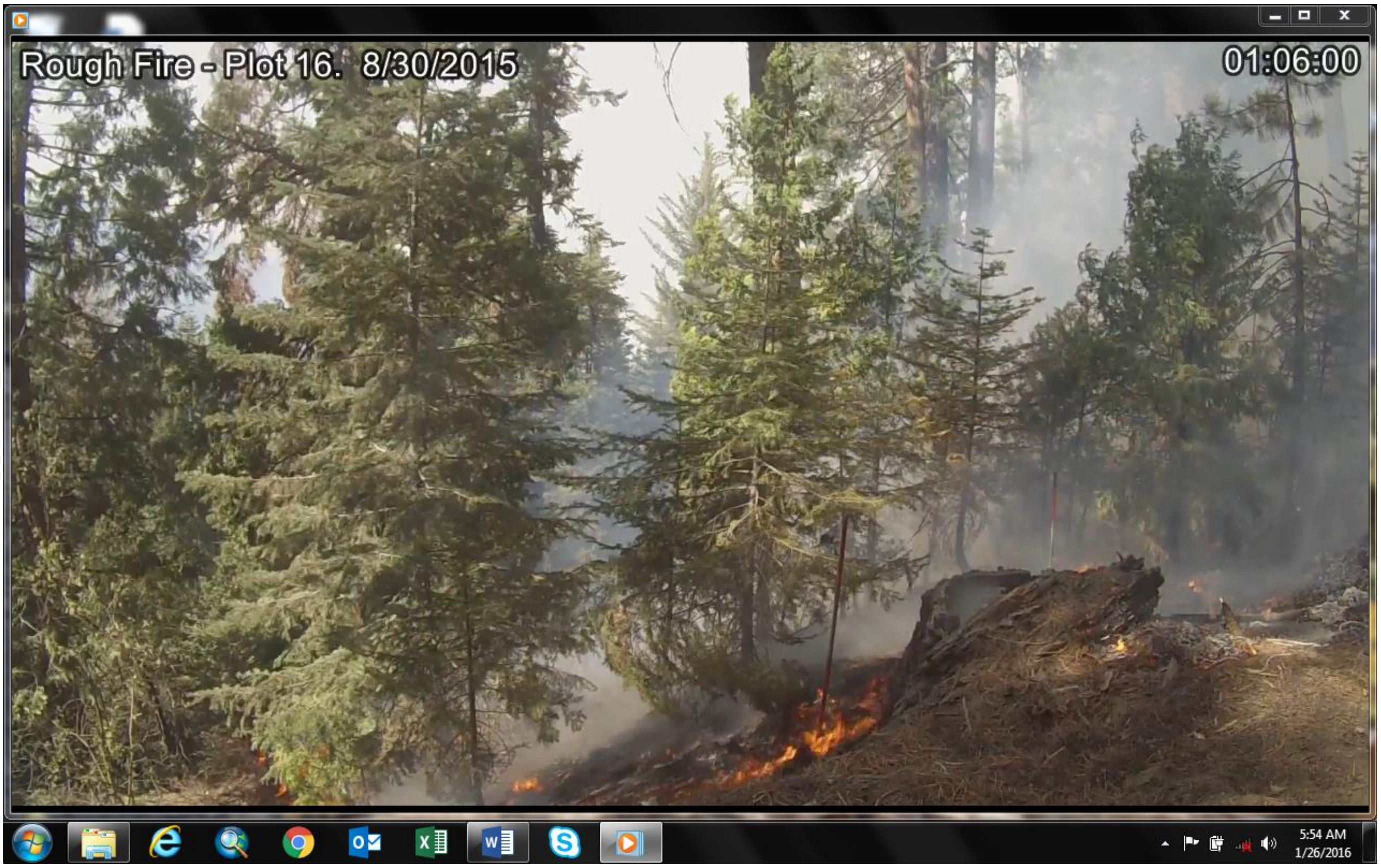
Figure 12. Fire in plot 14 in a mixed conifer forest below Deer Meadow Trail. All three of the four-foot reference poles are visible at center screen as well as heat flux sensor and anemometer, as the fire slowly spread and consumed the available fuel.



Plot 16, Mixed Conifer Forest, Evans Complex (Boulder Creek) Grove

Plot 16 was located on the upslope side of the Little Boulder Grove trail (just west of the east side trailhead), reached from the 13S23 road and only about 200 yards west of plot 17. Area had medium to thick understory fuels and sapling trees, with a maintained trail (old road) below it, and an unmaintained old road in the upper half the plot. Fire intensity is mostly low. Flame length is mostly 6in to 1ft, but 1-2ft at times. The leading edge of the fire approaching the camera is a flanking section of the fire; overall progression was slow as either backing downslope or side hill (flanking) orientation. Fire creeps up tree boles, but very minimal low branch torching on *small* trees is observed (Figure 13, with 2 reference poles visible at center). Active consumption is observed up until the end of the video approximately 1.5 hours later. Flame length (estimated by known photo pole heights) ranges from 6 inches to 1ft mostly, with isolated increases to 2 feet, and a spread rate of less than 1 ch/hr. The area had a patchy burn pattern, but over half of the plot area had signs of surface fuel consumption.

Figure 13. Fire in plot 16 in a mixed conifer forest above Little Boulder Grove trail. All three of the four-foot reference poles are visible at center screen as well as heat flux sensor and anemometer, as the fire slowly spread and consumed the available fuel.



Plot 17, Mixed conifer Forest, bordering Evans Complex (Boulder Creek) Grove

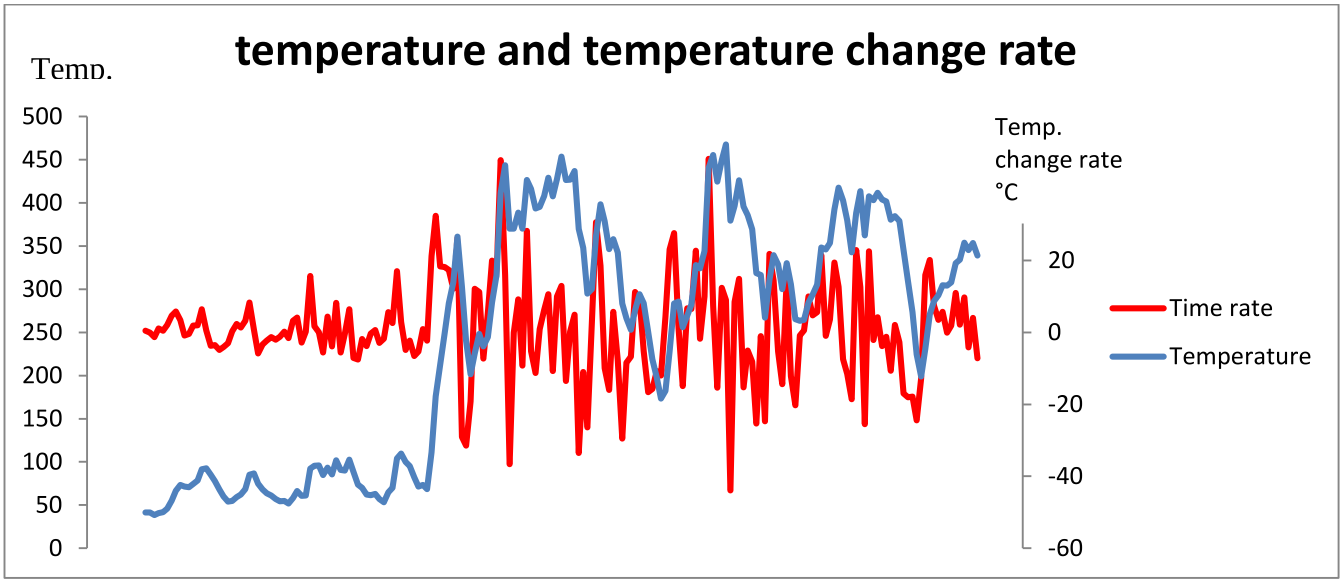
Plot 17 was in mixed conifer forest below the 13S23 Road at the tight bend in the road near the Little Boulder Grove trailhead (east side). It is only about and only about 200 yards east of plot 16. Video data (SD card) at data recovery services, probably due to heat residence time at video site. This appeared to be a more intense, higher severity area compared to other plots in this part of the fire (Figure 14). More paired photos of this site are in Appendix A.

Figure 14. Paired pictures at plot 17 in a mixed conifer forest below the 13S23 Rd (near the Little Boulder Grove trailhead east). The 50-foot survey tape is in the photo for reference, which is centered on the surface/ground fuels planar transect and understory vegetation belt (1 meter wide) transect. This was transect 3, which probably had the highest dead fuel loading of the three transects at this plot.

Rate of Spread and Temperature

Rate of spread and thermocouple temperature data were gathered using five heat resistant data loggers, or sensors, at each plot. One rate of spread calculation can be performed for each triangle formed by three sensors, and rate of spread was calculated for the larger triangles when quality data was recorded and recovered. If more than one triangle of sensors burned, the range of spread rates was reported (Table 6). The temperature sensors logged temperature at 2 second intervals. One temperature sensor for plot 6 below shows a sharp increase in temperature, which marks fire arrival, with a few temperature spikes over a couple of minutes, and then a temperature decay through time (Figure 15). The peak in Figure 15 that is followed by a slow decay in temperature as fuels smolder is typical of most wildfire temperature data.

Figure 15: Thermocouple temperature graph for north sensor at Plot 6.



Fire Type, Flame Length and Duration

In addition to the sensors, fire behavior data can be obtained from the video footage. Table 6 below lists the fire type, flame length, flame angle, and rate of spread (ROS) determined video analysis and the rate of spread sensors.

Differences between fire behavior measurements obtained from video footage and rate of spread sensors were small. The ROS estimate from video is based on what is visible in the camera frame and uses the metal reference poles and anemometer pole, but may not describe the overall rate of spread within the plot area as recorded by the temperature sensors. Further data analysis could compare the amount of spread rate differences determined by the two methods.

Table 6: Fire behavior data based on the video camera footage and from sensors.

Plot	Fire Type	Flame Length (feet)	Flame Angle[1] (degrees)	ROS (ch/hr) camera	ROS (ch/hr) sensors[2,3]	Date & Approximate Arrival Time[2]	End of Active Consumption
1	surface fire (assumed)				(user error)		(video data compromised due to heat exposure)
2	surface fire, with torching near piles	1-2 ft, 10 ft when torching	80-90	0.25	(no ROS sensors used)	Aug. 18; 1330	still active consumption at video end; 1433
4	surface to crown fire (shrub crown fire)			(too dark or distant behavior)	approx. 1 ch/hr[4]		(video captured mostly darkness, fire backing in distance)
6	surface fire (assumed)			(camera failure)	0.1 (based on 2 triangles)		(video camera failure)
10	higher intensity fire (assumed)			(camera trigger failure)	5.2, 5.5,10.9		(camera trigger failure)
11	surface fire with torching	1 – 10 ft	90 during first 35 min., then 45, then 0	1.5 at first, then 7.5	1.1, 1.2, 1.9,4.9	Aug. 29; 1600, fire pulled uphill at 0037	active consumption at video end; 00:38
12	low intensity surface fire, with moderate intensity surface fire in isolated pockets of 1000-hr fuels	1-3 ft, 2-4 ft in 1000-hr pockets	95	0.5	(no ROS sensors used)	August 25, 1600	active consumption at video end; 0348
14	low intensity surface fire	1-3 ft, but 2-4 ft during gusts	90, 45 during gusts	1	sensors triggered separately over 24 hours	Aug. 26; unknown time of day	active consumption at video end; 43-minute video
16	low intensity surface fire	6 inches to 2 feet	90	0.75	<0.1, 0.2	Aug. 30; approx. 1500	Active consumption until end of1.5-hour video
17	higher intensity fire (assumed)				0.9 (based on 3 triangles)		(video data compromised due to heat exposure)

[1] Approximate angle from the line between flame tip to center of flame base then to ground surface.

[2] Time is local. Year is 2015. Plot 3 video triggered in darkness and no ROS sensors used. Plot 13 video only captured smoke activity (patchy fire area in riparian area), and no ROS sensors used. Plot 19 video was too smoky and fire was too distant/spotty and too few temperature sensors recorded data to calculate spread rates.

[3] Multiple rates of spread are displayed if more than 3 sensors burned.

[4] At plot 4 rate of spread is approximate due to shrub fuels making distance measurements difficult.

Energy Transport

With limited video availability, we were able to confirm that the flame front spread sufficiently towards the heat flux sensor on plot 11 for the heat flux data to be considered a successful collection (Table 7). A successful collection occurs when flames spread towards the heat flux sensor. Convective heat flux to the sensor is approximately the difference between total and radiant. Plot 11 showed relatively high wind speeds with a substantial increase as the fire arrived at the sensor (Figure 16). The increased winds were also associated with a wind shift from about 45 degrees to the right of perpendicular relative to the sensor's face to straight towards the heat flux sensor. The high total energy experienced in plot 16 is a result of long-term exposure to low convective heat fluxes from smoke flowing up a steep slope (Figure 17).

Table 7. Summary of heat flux and energy transport to the heat flux sensors in plots 11 and 16. The percentage of peak total heat flux accounted for by convection is listed. The high total energy experienced in plot 16 is a result of long-term exposure to low convective heat fluxes from smoke flowing up a steep slope.

Peak heat flux (kW/m2)					Energy (kJ/m2)		
Plot	Radiant	Total	Convective	Percent convective	Radiant	Total	Comment
11	45	67	22	33	1480	3144	Strong and shifting winds as fire passed sensor
16	0.5	8	7.5	94	0	5567	Creeping flames on steep slope, long exposure to smoke

Figure 16: Radiant and total heat flux and 10-second average wind for Plot 11 on the Rough Fire. The wind velocity increase was associated with a shift in the wind to more directly towards the sensor. The anemometer was compromised part way through the exposure as indicated by wind speeds falling to zero.

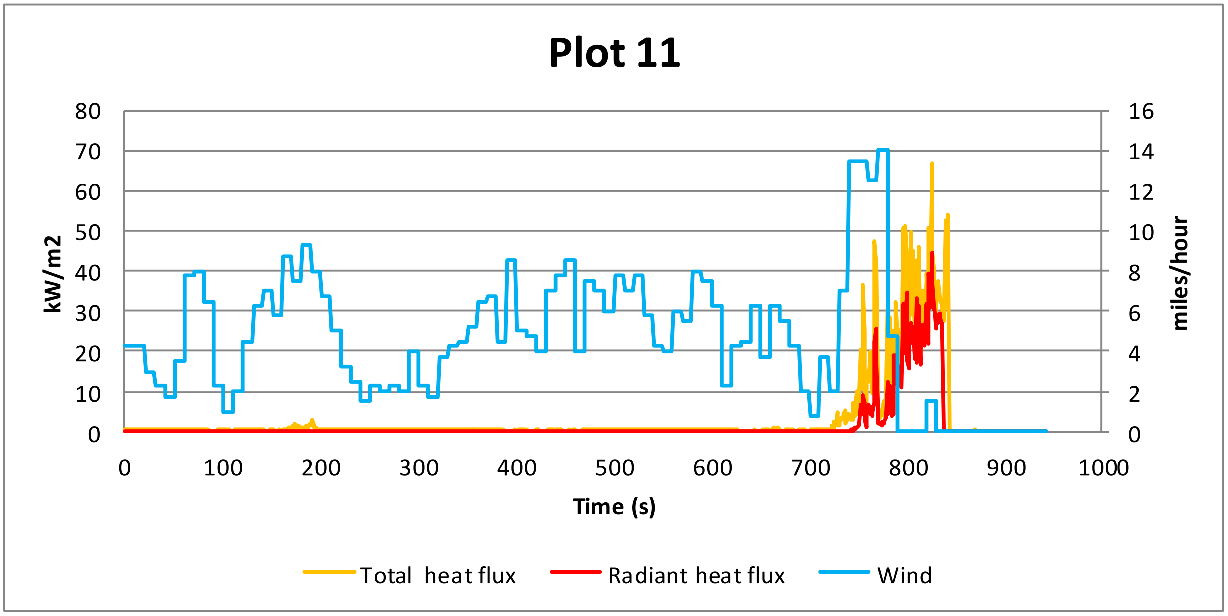
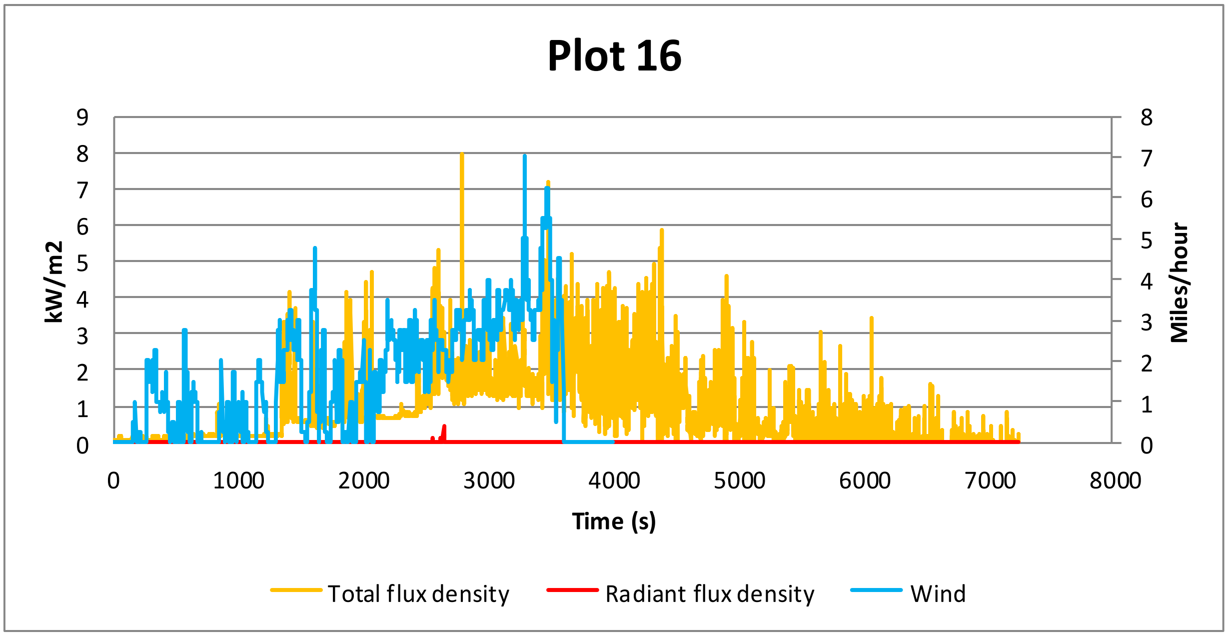


Figure 17: Radiant and total heat flux and 10-second average wind for Plot 16 on the Rough Fire. Creeping flames resulted in low radiant fluxes. Total heat fluxes were low (compare with Figure 17) but because the plot was on a steep slope, and was exposed to hot smoke over a long period, total energy was large (Table 8). The anemometer was compromised part way through the exposure as indicated by wind speeds falling to zero.



Plot Wind Speed

Average and peak wind speeds for 20 minutes before fire arrival at the heat flux sensors are listed in Table 7. Winds on plot 11 (Figure 16) were stronger than for other plots at the time of fire arrival. Upslope winds on plot 16 were low. In general, caveats to the data are that winds are at 5 feet (which would approximate mid-flame wind speeds for intense surface fires) and are sheltered by any canopy that is present. Winds leading up to fire arrival at the heat flux sensor and while flames were spreading around the sensor are listed for plot 11 (Figures 16).

Table 7: Winds over 20 minutes prior to fire arriving at heat flux sensor and associated anemometer (top of table). The table is sorted by average wind speed. Peak wind speed is from the 10 second moving average.

	Wind speed (miles/hour)	
Plot	20 minute average	Peak over 20 minutes
10	0.0	0.3
4	0.3	2.3
16	0.4	2.8
19	0.5	3.0
2	0.5	5.0
6	3.7	5.0
1	4.3	6.5
11	4.7	14.0

Summary

Our objectives were to:

1. Characterize fire behavior and quantify fuels for a variety of fuel conditions, especially in areas with treated fuels. Safety considerations, access, and current fire conditions restrict which areas can be measured and amount of sensors.
2. Gather energy transport data during active burning fires, in conjunction with site characteristics, for the Missoula Fire Lab's safety zone research.
3. Gather and measure representative vegetation to support smoke emission and fire behavior modeling.
4. Assess fire severity and effects based on immediate post-fire measurements.
5. Share the information the FBAT module gathered at the fire. Test out upgraded equipment and protocol.

The FBAT program met its objectives on this incident. We installed and re-visited plots safely, mitigating for risks associated with data collection on active fires. The 13 plots that burned captured the fuel characteristics and effects of areas with no recorded vegetation treatments, as well as a few areas that had mechanical treatments and a previous wildfire (2010 Sheep Fire). Some of the data were used immediately, and some will be used over the course of the next couple years. FBAT also gathered heat flux data with newly calibrated equipment which will form part of a growing dataset used to develop improved firefighter safety zone guidelines. FBAT also beta-tested a new video camera trigger system that was adapted to work with new video cameras. We had mixed results with this, and some cameras that received unexpected heat had data sent for recovery, and we are creating solutions for equipment to be more heat resistant. Soil samples to build the pilot dataset went to collaborators at Michigan State University for analysis; this continues steps in integrating soil nutrient and black carbon effects into FBAT protocols. FBAT also collected integrated fuels, consumption, fire effects and fire behavior data which will be used along with data from other fires to evaluate and possibly calibrate fire behavior or fire effects models.

The Rough fire burned during drought conditions resulting in high fuel consumption and some areas of intense fire behavior. The data collected by FBAT will be used to improve understanding of fires burning under different conditions.

The information that the FBAT module gathered at the Rough fire is available to all.
See this report at: http://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php
See the video at: http://www.fs.fed.us/adaptivemanagement/amset_videos.php

During the Rough fire we were involved with the Public Information Officer and their staff and had some media coverage about the FBAT program. Here's some samples from those efforts:
http://inciweb.nwcg.gov/incident/article/4456/28285/
http://www.cbsnews.com/videos/how-cameras-help-firefighters-stay-ahead-of-wildfires/
http://www.fresnobee.com/news/local/article32600712.html

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In Remembrance

A good friend and leader of the FBAT program, **Mike Campbell** (pictured on the right below at 2008 Clover Fire), went to heaven this summer after a bumpy ride with cancer. He was admired and respected in the wildfire community and beloved on the Tahoe NF. In 2012 he turned 57 and retired from the Tahoe after making a **career out of leading by example**. This year's FBAT summary reports are *dedicated to Mike and in remembrance of all he gave to the FBAT program* (making it more operational) and to the fire and USFS communities. ***Enjoy the beach Mike! We miss you.***

Appendix A: Representative Paired Photographs

Below are representative pre- and post-fire vegetation and fuel plots paired photographs for the 2015 Rough Fire. More photos are available upon request.

Plot 1, Transect 2, 0-50ft, pre-fire

Plot 1, Transect 2, 0-50ft, post-fire

Plot 2, Transect 1, 50-0ft, pre-fire

Plot 2, Transect 1, 50-0ft post-fire


Plot 3, Transect 3, 0-50ft, pre-fire

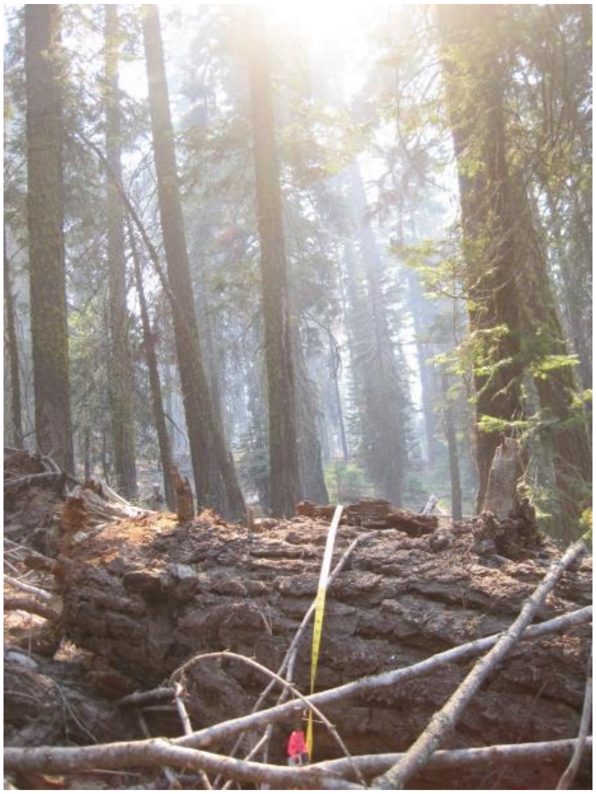

Plot 3, Transect 3, 0-50ft, post-fire


Plot 4, Transect 1, 0-50ft, pre-fire


Plot 4, Transect 1, 0-50ft, post-fire

Plot 5, Transect 2, 0-50ft, **unburned**

Plot 5, Transect 2, 50-0ft, **unburned**

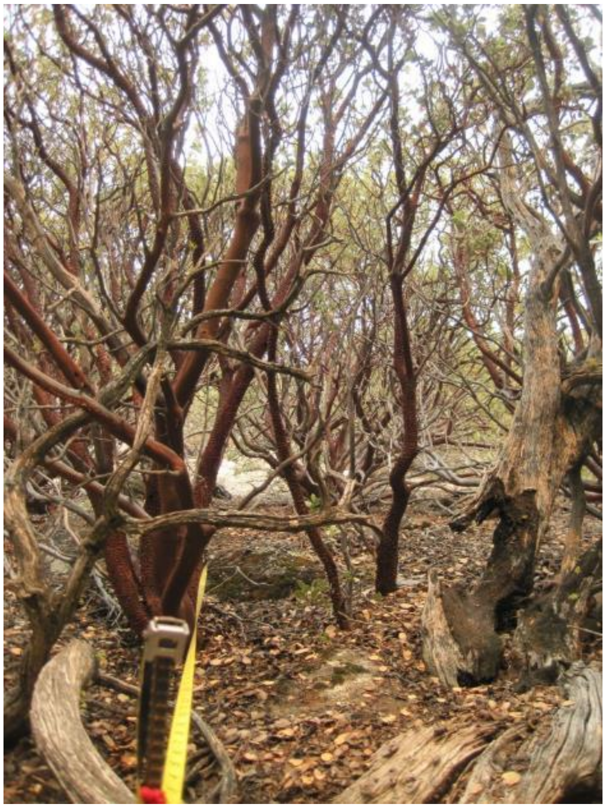


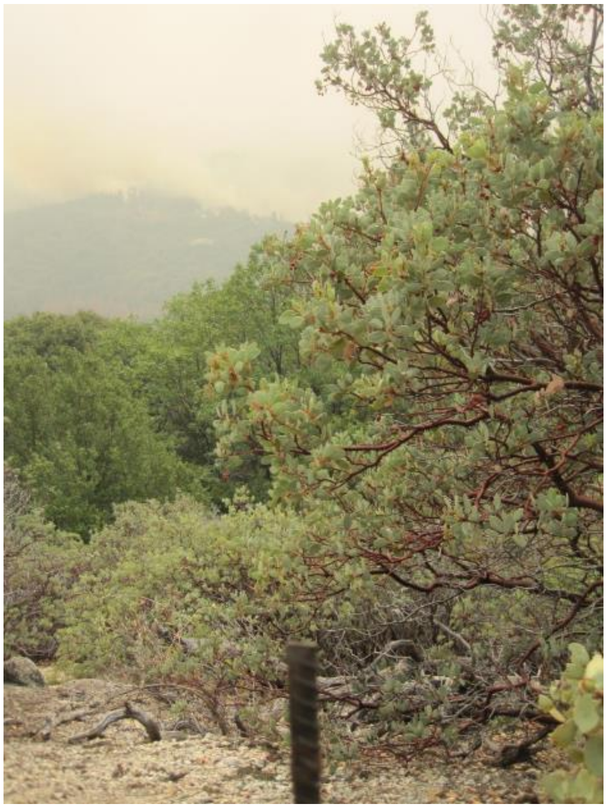
Plot 6, Transect 1, 0-50ft, pre-fire

Plot 6, Transect 1, 0-50ft, post-fire


Plot 7, Transect 2, 0-50ft, **unburned**


Plot 7, Transect 2, 50-0ft, **unburned**


Plot 8, Transect 2, 0-50ft, **unburned**

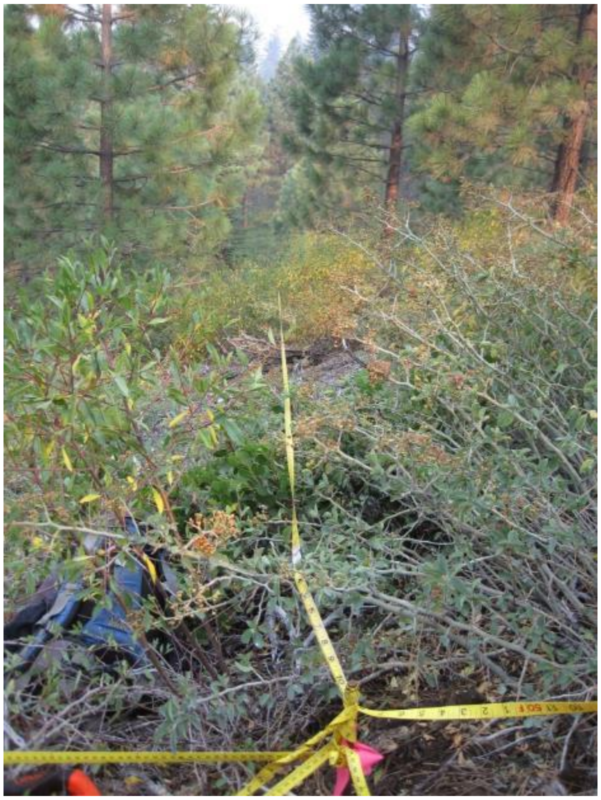

Plot 8, Transect 2, 50-0ft, **unburned**


Plot 9, Transect 1, 0-50ft, **unburned**


Plot 9, Transect 1, 50-0ft, **unburned**


Plot 10, Transect 2, 50-0ft, pre-fire

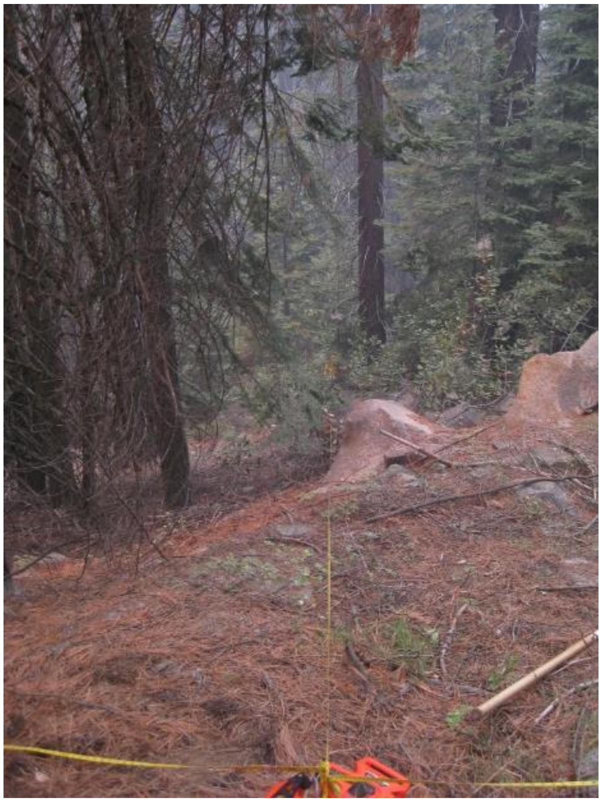
Plot 10, Transect 2, 50-0ft, post-fire



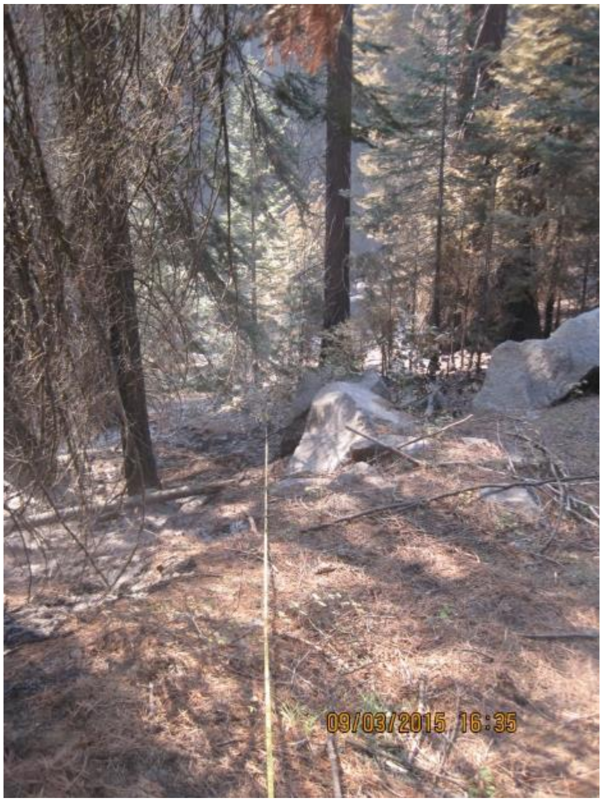
Plot 11, Transect 3, 50-0ft, pre-fire

08/31/2015 15:59

Plot 11, Transect 3, 50-0ft, post-fire



Plot 12, Transect 3, 50-0ft, pre-fire



09/03/2015 16:35

Plot 12, Transect 3, 50-0ft, post-fire

Plot 13, Transect 3, 0-50ft, pre-fire

Plot 13, Transect 3, 0-50ft, post-fire

Plot 14, Transect 3, 0-50ft, pre-fire

Plot 14, Transect 3, 0-50ft, post-fire


Plot 15, Transect 3, 0-50ft, **unburned**


Plot 15, Transect 3, 50-0ft, **unburned**


Plot 16, Transect 3, 0-50ft, pre-fire

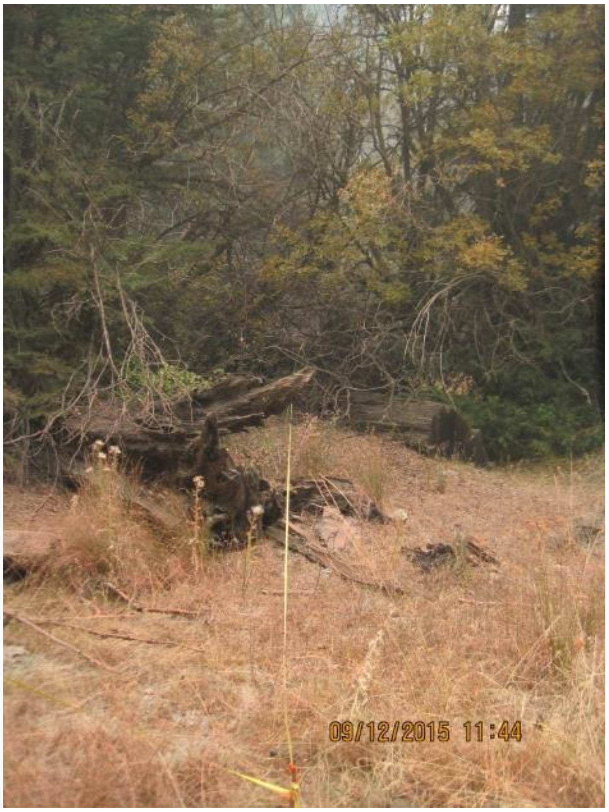

Plot 16, Transect 3, 0-50ft, post-fire

Plot 17, Transect 2, 50-0ft, pre-fire

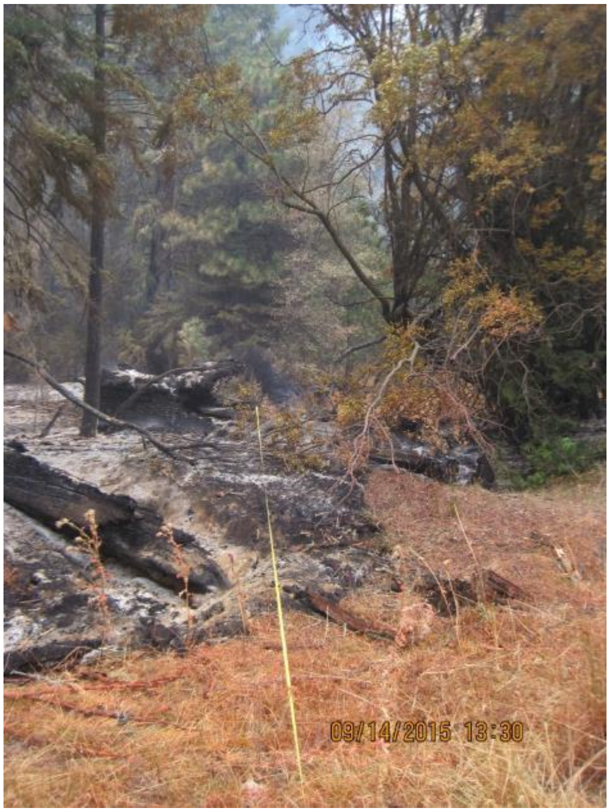
Plot 17, Transect 2, 50-0ft, post-fire

Plot 18, Transect 3, 0-50ft, **burned later**

Plot 18, Transect 3, 50-0ft, **burned later**



Plot 19, Transect 2, 50-0ft, pre-fire



Plot 19, Transect 2, 50-0ft, post-fire

Appendix B: Burn severity coding matrix from the National Park Service

Table B1. Burn severity coding matrix from the National Park Service (USDI 2003).

Code	Forests		Shrublands	
	Substrate	**Vegetation**	**Substrate**	**Vegetation**
Unburned (1)	not burned	not burned	not burned	not burned
Scorched (2)	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	foliage scorched and attached to supporting twigs
Lightly Burned (3)	litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned	foliage and smaller twigs partially to completely consumed; branches mostly intact	litter charred to partially consumed, some leaf structure undamaged; surface is predominately black; some gray ash may be present immediately after burn; charring may extend slightly into soil surface where litter is sparse otherwise soil is not altered	foliage and smaller twigs partially to completely consumed; branches mostly intact; less than 60% of the shrub canopy is commonly consumed
Moderately Burned (4)	litter mostly to entirely consumed, leaving course, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches still present	leaf litter consumed, leaving course, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches (0.25-0.50 inch in diameter) still present; 40-80% of the shrub canopy is commonly consumed.
Heavily Burned (5)	litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas	all plant parts consumed, leaving some or no major stems or trunks; any left are deeply charred	leaf litter completely consumed, leaving a fluffy fine white ash; all organic material is consumed in mineral soil to a depth of 0.5-1 in, this is underlain by a zone of black organic material; colloidal structure of the surface mineral soil may be altered	all plant parts consumed leaving only stubs greater than 0.5 in diameter
Not Applicable (0)	inorganic pre-burn	none present pre-burn	inorganic pre-burn	none present pre-burn

Appendix C: About the Fire Behavior Assessment Team (FBAT)

The Fire Behavior Assessment Team (FBAT) operates under the management of the Adaptive Management Services Enterprise Team (AMSET) of the USFS. We specialize in measuring fire behavior and fuels on active wildland and prescribed fires. We utilize fire-resistant sensors and video cameras to measure direction and variation in rate of spread, fire type (e.g. surface, passive or active crown fire behavior), onsite weather, and couple this with measurements of fire effects, topography, and fuel loading and moisture. We measure fuel load changes from fire consumption and compare the effectiveness of past fuel treatments or fires in terms of fire behavior and effects. We are prepared to process and report some data while on the incident, which makes the information immediately applicable for verifying LTAN or FBAN fire behavior prediction assumptions. In addition, the video and data are useful for conveying specific information to the public, line officers and others. We can also collect and analyze data to meet longer term management needs, such as calibrating fire behavior modeling assumptions for fire management plans, unit resource management plans, or project plans.

Since 2003, the FBAT program has built a rich dataset and library of products for fire and fuels managers; fire training and safety; and fuel, fire, and smoke scientific communities. FBAT video has been utilized by the Wildland Firefighter Apprenticeship Program and USFS PSW ecological restoration video series; and FBAT data and program information were shared with the **JFSP crown fire behavior knowledge synthesis project** (p. 41) and a **PSW Research Station project** that estimated carbon stocks and emissions in CA and evaluated FOFEM. Other collaborations to collect and utilize FBAT data are in progress including: supplying data to support fire safety zone research at the Missoula Fire Sciences Lab, and testing sampling methods and pilot dataset for black carbon measurements with Dr. Miesel at Michigan State.

FBAT is a module of fireline qualified technical specialists and experienced fire overhead. The overhead personnel include a minimum of crew boss qualification, and more often one or more division supervisor qualified firefighters. The team can vary in size, depending upon availability and needs of order, from 5 to 12 persons. We have extensive experience in fire behavior measurements during wildland and prescribed fires. We have worked safely and effectively with over 17 incident management teams. We are comprised of a few AMSET FBAT core members and other on-call firefighters from the USFS and other agencies. We are available to train other interested and motivated firefighters while on fire incidences, as time allows.

We can be ordered from ROSS; we are described as the “Fire Behavior Assessment Team”, and are in the CA Mobilization Guide (near the BAER Teams). We can be name requested, and we’ll request additional personal to join our team, like a Wildland Fire Module, based on availability. Please contact us directly by phone to notify us that you are placing an order, which will speed up the process. You can reach Alicia Reiner at 530-559-4860 (cell) or Carol Ewell at 530-559-0070 (cell) or via the Stanislaus NF dispatch (209-532-3671 x212). We may be available if you call dispatch and we are already assigned to a fire. We can work more than one fire simultaneously and may be ready for remobilization. This is the FBAT web page, which has links to most FBAT Incident Summary Reports:
http://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php