Appendix 3

Wildfire Simulation Methods

for

The Rogue Basin Cohesive Forest Restoration Strategy

Prepared by:
Don Helmbrecht – Wildland Fire Analyst, TEAMS Enterprise Unit, USDA Forest Service

Prepared for:
Kerry Metlen, Ecologist
The Nature Conservancy
Medford, OR

October 2016

Contents

Tables

Figures[1]

[1] The source of base map data in figures is the World Topographic Base map data available in ESRI ArcGIS 10.2.2 software.

1 Data preparation

1.1 Fuelscapes

1.1.1 Data Acquisition

The LANDFIRE Program (www.landfire.gov) produces and maintains, for the extent of the United States, the geospatial data required for spatial fire behavior modeling (Ryan and Opperman 2013). We acquired version 1.3 (also referred to as LANDFIRE 2012) of these data for the 12.8 million-acre wildfire simulation area (Figure 1). Although designed for national to regional applications, LANDFIRE data may be appropriately applied at more local scales given proper review and adjustment where necessary (Rollins 2009; Helmbrecht and Blankenship 2016). Data applicability may vary by location and specific use.

Updates to the LANDFIRE 2012 data were required to account for disturbances that occurred in 2013 and 2014. First, we acquired geospatial burn severity data for nine wildfires from the USFS Rapid Assessment of Vegetation Condition after Wildfire program (RAVG; http://www.fs.fed.us/postfirevegcondition/index.shtml). These data include a raster data layer of post-fire canopy cover reduction. We used this data layer directly to reduce forest canopy cover, and classified it into low, moderate, and high severity classes to assist in assigning post-fire, fire behavior fuel model (see Section 1.1.2).

Geospatial burn severity data for three large wildfires, not available from the RAVG website at the time of acquisition, were acquired from BLM Fire Ecologist, Jena Volpe. Of these three fires, the Douglas Complex data were a RAVG product and therefore included the canopy cover reduction layer. The Oregon Gulch and Big Windy burn severity data were only available as pre-classified severity data.

The mapping methodology of the disturbance data varied by source. RAVG burn severity data use the relative delta normalized burn ratio (RdNBR) methodology (Miller and Thode 2007; Miller et al. 2009). The Oregon Gulch burn severity data were classified, using the burned area reflectance classification (BARC; http://www.fs.fed.us/eng/rsac/baer/barc.html). The BARC methodology classifies absolute dNBR values into four severity classes (see Miller et al. 2009 for a comparison of absolute dNBR and RdNBR) that are more geared towards soil severity than vegetation severity. The Big Windy burn severity data were also pre-classified but used the six-class thematic classification from the Monitoring Burn Severity Program (http://www.mtbs.gov/), which also applies the dNBR severity mapping methodology but is calibrated with RdNBR and geared towards vegetation severity. Additional 2013-2015 disturbance data for smaller wildfires, prescribed burns, and management activities were collected from Jena Volpe (BLM Fire Ecologist), Jon Lamb (Rogue River-Siskiyou National Forest Fire/Fuels Planner), and Derek Olson (The Nature Conservancy Spatial Analyst). These data were in vector format with no severity attribution. Disturbance polygons were therefore assigned an “average” severity for their full extent by those providing the data.

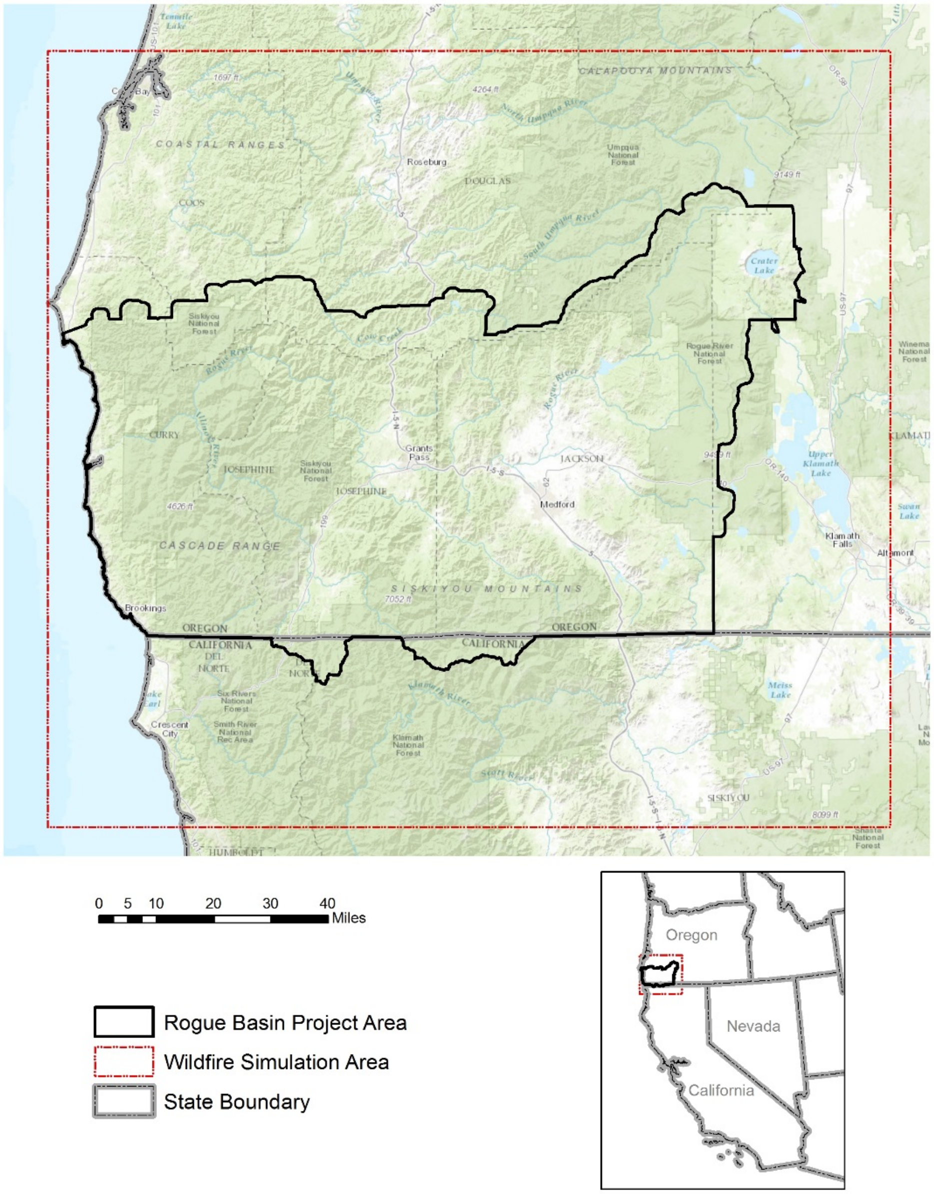

Figure 1: Rogue Basin project area and wildfire simulation area.

1.1.2 Data Processing

A field visit and fuel data calibration workshop with local fire and fuel specialists were conducted to further validate the LANDFIRE data for use in this analysis. The findings of our data critique are summarized as follows:

- Oak woodland vegetation is underrepresented in the LANDFIRE existing vegetation type (EVT) data for the project area.
- Some disturbance type map unit assignments are inaccurate in the LANDFIRE fuel disturbance (FDist) data due to generalization of treatment types at the national scale and/or incorrect accounting of cumulative treatment effects.

- Mastication treatments are grouped with other mechanical treatment types in the FDist data that don't reflect the unique nature of masticated fuel on fire behavior.
- Data is not current through the project year (2014).
- The analysis area intersects multiple LANDFIRE map zones.

Oak Woodlands

Field reconnaissance and spatial data review indicated that oak woodland vegetation was underrepresented in the LANDFIRE existing vegetation data for LANDFIRE map zones 3 and 7. To mitigate this issue we acquired ancillary vegetation data developed by the Landscape Ecology, Modeling, Mapping, and Analysis team (LEMMA). We extracted the oak woodland vegetation cover types from this data to augment the LANDFIRE EVT data layer for map zones 3 and 7 only. LEMMA also provides spatial data of canopy cover and canopy height. To ensure consistency across layers, we also updated the LANDFIRE existing vegetation cover (EVC) and existing vegetation height (EVH) with LEMMA data wherever the EVT had been updated.

Disturbance Type

Participants at the fuel data calibration workshop identified two map unit accuracy issues in the FDist data. First, the LANDFIRE FDist mapping process assumes that all silvicultural treatments are followed by a fuel treatment that removes activity fuels and assigns a *mechanical remove* disturbance type to indicate this. However, participants noted that harvest activities were not always accompanied by activity-fuel treatments, such as hand-pile burning or biomass extraction, and therefore the disturbance should be classified as a *mechanical add* disturbance type to account for the activity fuel left on site. If harvested areas did receive follow-up activity-fuel treatments, this would be reflected with an overlapping *mechanical remove* treatment polygon. Similarly, participants felt that some activities assigned to the 'other mechanical' event type and classified as a *mechanical add* disturbance should be classified as *mechanical remove*. In addition, participants felt that local mastication treatments resulted in a unique fuel structure that could not be grouped into either of the LANDFIRE mechanical treatment types—*mechanical add* or *mechanical remove*.

A second map unit accuracy issue is in relation to how cumulative treatments were being handled. By default, LANDFIRE does not account for the cumulative effect of multiple treatments in the same location during a single update period. If two or more treatments are mapped to the same location, the last treatment type and severity is assigned to the pixel (unless one of the treatments is fire, in which case the pixel is classified as fire). This can result in inaccurate map unit assignments.

To mitigate these inaccuracies in disturbance type we analyzed the LANDFIRE yearly disturbance grids, which classify disturbances by the thematically finer-scale, *event type* classes. We identified four unique situations and made adjustments based on local resource specialist input (Table 1).

Table 1: Adjustments made to mechanical disturbance type based on local input.

Criteria	Acres	Adjustment
Silvicultural treatments only	200,039	Disturbance type was changed from mechanical remove to mechanical add.
Mastication treatments only	9,188	Created a mask of mastication only pixels and changed the final fuel model values to a "post-mastication" fuel model within the mask during post-processing.
'Other mechanical' treatments only	75,936	Modified disturbance type only if local resource specialists felt the cumulative effect of the treatments was incorrectly assigned.

Combination of mechanical treatment types	289,248	Typically a combination of “other mechanical” and silvicultural treatment. Modified disturbance type only if local resource specialists felt the cumulative effect of the treatments was incorrectly assigned.

Data Currency

As discussed in Section 1.1.1, spatial data for disturbances that occurred in 2013 and 2014 we acquired. These data were used to update the LANDFIRE FDist data layer. The FDist layer uses a three-digit numeric code to represent the type, severity, and time since disturbances have occurred. We first updated time-since-disturbance value of this layer to reflect the two years that had passed since the data’s currency date of 2012. Next, we added the new 2013 and 2014 disturbances. For the RAVG data, we classified the post-fire canopy cover reduction into LANDFIRE’s three severity classes:

- Low: < 25% canopy cover reduction
- Moderate: 25% - 50% canopy cover reduction
- High: > 75% canopy cover reduction

For the non-RAVG burn severity and management activity disturbance data we reclassified the severity values into the appropriate LANDFIRE three-digit code.

Next, we reduced forest canopy cover to reflect post-disturbance effects. We accomplished this by reducing the midpoint canopy cover value for forested canopy cover classes in the LANDFIRE EVC data layer by the post-fire canopy cover reduction. For the non-RAVG burn severity and other disturbances data we used the following reduction values based on severity class:

- Low: 12.5% canopy cover reduction
- Moderate: 50% canopy cover reduction
- High: 87.5% canopy cover reduction

Map Zones

The Rogue Basin fire modeling area intersects three LANDFIRE map zones—2, 3, and 7—with the majority of the 4.6 million-acre project area in zone 2 (Figure 2). Although LANDFIRE mapping methodologies are consistent across the United States, products are produced on a map zone-by-map zone basis. Differences may occur at map zone boundaries due to inconsistencies in, or the amount of, source data (e.g., field plots, remotely sensed imagery), and/or differences in expert-opinion based mapping rules, such as those used for mapping fire behavior fuel model. To mitigate potential map zone boundary issues we used the LANDFIRE Total Fuel Change Tool (LFTFCT 2011) to assign consistent fire behavior fuel model mapping rules across the fire modeling extent. We accomplished this by first importing the mapping rules for LANDFIRE map zone 7, as it comprised the most area within the fire modeling extent. Fire behavior fuel model mapping rules are stratified by EVT classes. For EVTs, not present in map zone 7, we imported mapping rules from the map zone with the most acres of the EVT in the project area. The LFTFCT was then used to map fire behavior fuel model and canopy fuel characteristics across the full fire modeling area.

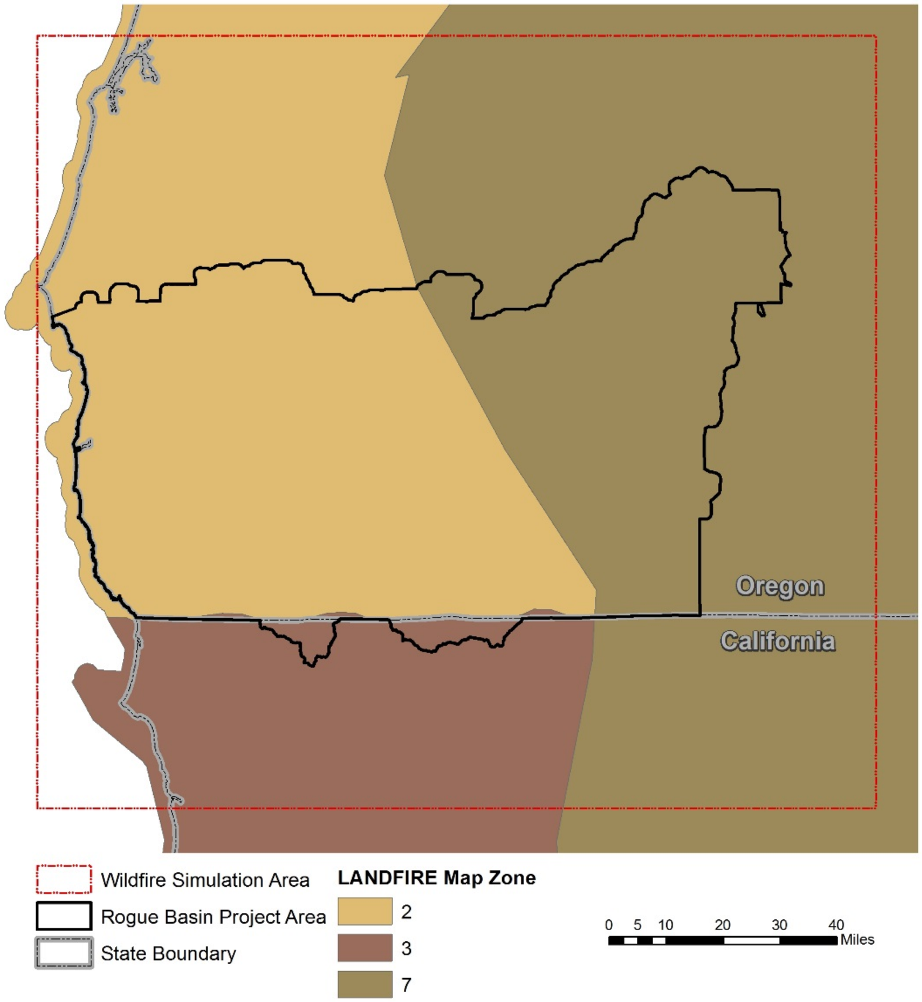

Figure 2: LANDFIRE map zones in the wildfire simulation area.

1.1.3 Fuel Critique

With the above data processing complete, workshop participants critiqued the LANDFIRE fuel mapping rules for the major EVTs in the fire modeling area using the LFTFCT. Adjustments were made if workshop participants felt the specified standard fire behavior fuel model (Scott and Burgan 2005) didn't represent the expected surface fire behavior or if the spatial distribution of fuel mapping didn't reflect on-the-ground conditions. Default canopy base height values were also assessed for non-disturbed, and low- and moderate-severity fire disturbances (default post-disturbance canopy base height assignments for mechanical disturbances were not reviewed or modified). Canopy base height values were "hardcoded" in the fuel rules if workshop participants felt that simulated crown-fire initiation didn't accurately represent expected crown-fire initiation under a range of fire weather variables. Default canopy bulk density mapping rules were not reviewed or modified.

EVT and EVH data were not modified to reflect high-severity fire effects. Since we were only concerned with post-disturbance effects on surface and canopy fuels, we were able to omit this step and rely on our updates to EVT, EVC, and the *canopy guide* feature of the LFTFCT to correctly assign post-disturbance fuel attributes. We set the canopy guide value to 2 for all high-severity fire disturbances. This technique allows for the standing dead trees (15% post-high-severity disturbance canopy cover and pre-disturbance canopy height) to still have some, albeit minimal, influence on dead fuel moisture content and wind reduction, but eliminates crown fire and spotting from being modeled in the post-high-severity areas.

Finally, the LFTFCT was used to create the circa-2015, locally calibrated, vegetation and fuel geospatial data layers for the full fire modeling extent. Together with geospatial data of elevation, aspect, and slope, these data were used to create the fire modeling landscape file (.LCP) used in the wildfire simulations.

1.2 Historical wildfire occurrence

Fire occurrence data were acquired from the Short (2014) national Fire Occurrence Database (FOD), which contains 22 years of fire occurrence data for the period of 1992-2013. The start location, start date, and final fire size information from these data are used to run and calibrate the large fire simulator (FSim; Finney et al. 2011).

Fire Occurrence Areas (FOAs) are used to represent geographic areas of relatively uniform historical fire occurrence. We split the fire modeling area into two FOAs to account for climate-influenced differences in fire occurrence. The FOA boundaries (Figure 3) were created by Derek Olson (TNC Spatial Analyst) and Steve Ziel (retired USFS, Fire Behavior Analyst). The western FOA (hereafter, coastal) represents the portion of the fire modeling area most influenced by coastal weather patterns. The eastern FOA (hereafter, inland) represents the portion of the fire modeling area where coastal weather patterns are much less influential[2].

We summarized the FOD data by each FOA and calculated a historical (i.e., past 22 years) large-fire size threshold of 35 acres for the coastal FOA and 36 acres for the inland FOA, using the 'balanced fires-acres' approach from Scott (2014). We then calculated the mean large-fire size, mean annual number of large fires, and mean annual large-fire area burned. These variables would later be used as calibration targets to compare with simulated fire occurrence results.

The use of a large-fire size threshold does not imply that small wildfires are unimportant to fire management in general. On the contrary, fire management activities resulting in successful initial attack keep most wildfires small. FSim, the "large-fire" simulation system, focuses on the relatively small fraction of wildfires that escape initial attack but are responsible for nearly all the area burned. It is because of this unequal fire-size distribution that we use a large-fire size threshold.

Historical large-fire occurrence also varied spatially across the fire modeling area, with large fires more likely to occur in some portions of the landscape than others. To incorporate this spatial variability, we used the FOD to build an ignition density grid (IDG; Figure 4). The IDG informs the placement of randomly located large-fire ignitions in FSim. We built the IDG for fires greater than or equal to the large-fire size threshold for each FOA using the kernel density tool in ArcGIS. We built the IDG at a 30m spatial resolution using a 50km search radius. We then resampled this IDG to 270m resolution and scaled it between 0 and 1 to create the final IDG. Two IDGs, one for each FOA, were extracted for the simulations by masking out the adjacent FOA, thereby limiting simulated ignitions to occurring only within the designated FOA area, however, allowing for fire spread out of the FOA.

[2] The original coastal FOA, clipped to the fire modeling extent, did not contain enough fires to provide reliable calibration targets. We extended the coastal FOA into California to acquire a larger sample of contemporary, historical fires. The results of the original (smaller) FOA are not presented in this report.

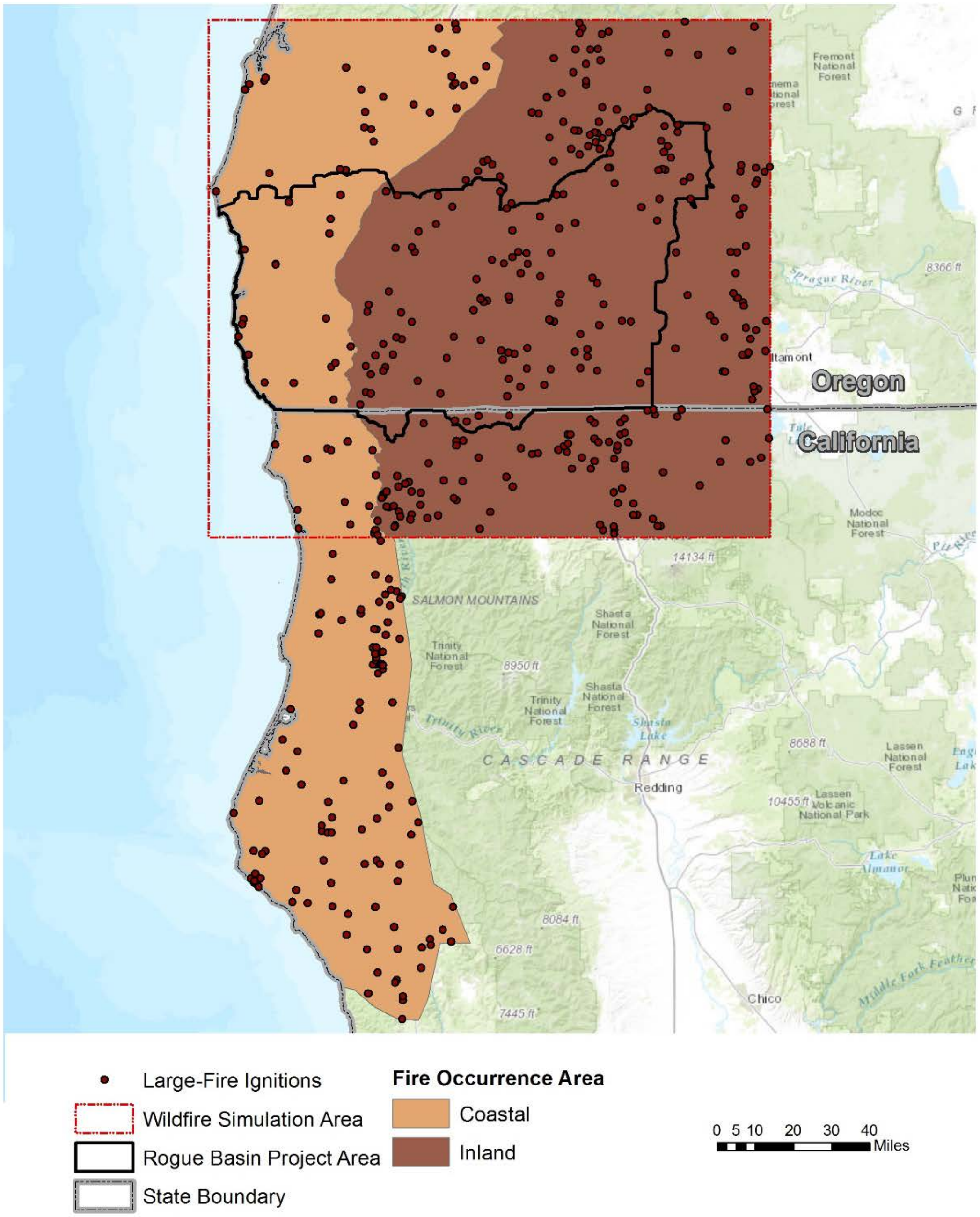

Figure 3: Fire occurrence areas and large-fire ignition locations.

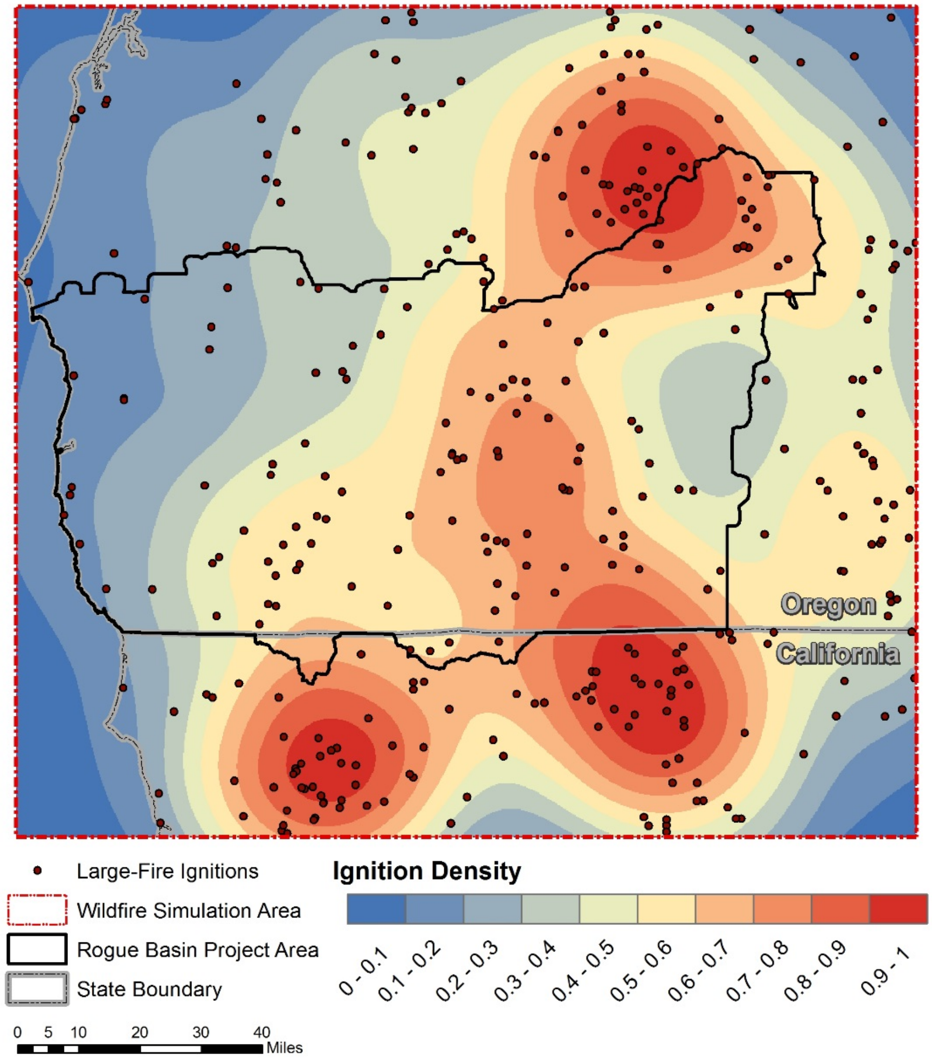

Figure 4: Large-fire ignition density.

1.3 Historical weather

Remote Automated Weather Stations (RAWS) were used to acquire historical Energy Release Component (ERC)[3] and wind speed and direction inputs for running FSim. RAWS were selected based on the completeness of their data record, their location within the FOAs, and wind exposure, taking care to avoid RAWS that were influenced by topographic or vegetation features and strong bi-directional trends (e.g., valley locations). Jena Volpe (BLM Fire Ecologist), Jon Lamb (Rogue River-Siskiyou National Forest Fire/Fuels Planner), and Steve Ziel (retired USFS, Fire Behavior Analyst) assisted in the selection of the RAWS to be used for this assessment. For the coastal FOA data were acquired from the Bald2 RAWS (NWS ID# 352813); for the inland FOA data were acquired from the Onion2 RAWS (NWS ID# 353114).

ERC and wind data were acquired for the period 1992-2012. For wind speed and direction inputs the hourly 10-minute average values recorded from the time period 1000 to 1800 hours were used. FireFamilyPlus v 4.1 software was used to create the required fire risk (i.e., .frisk) input files of seasonal

[3] FSim uses the ERC index for National Fire Danger Rating System fuel model “G” because it contains parameters for all fuel components and size classes (1, 10, 100, 1000 h, live herbaceous, and live woody; Finney et al. 2011)

trend in mean and standard deviation in ERC and mean monthly wind speed/direction distribution for each RAWS.

FSim uses three fuel moisture scenario files (FMS)—one for each of three ERC bins—in its simulations. These files identify the 1, 10, and 100-hr dead; live herbaceous; and live woody fuel moisture values for all fuel models represented on the landscape. FSim does not have a mechanism to account for the effect of topography or canopy shading on fuel moisture. We built customized FMS files by running the dead fuel moisture conditioning module in FlamMap5 to account for topographic and vegetation influences on the 1-hr dead fuel moisture. Specifically, FireFamilyPlus software was used to identify the mean minimum and maximum temperature and relative humidity values after five rain-free days for the mid-point ERC value of each ERC bin. These average values were used to create the weather files (WTR) required by the FlamMap5 fuel moisture conditioning module for each FOA. We then exported the conditioned 1-hr fuel moisture raster and applied the zonal stats function in ArcGIS to determine the mean fuel moisture value within each fuel model. We approximated the 10-hr and 100-hr values by adding one and two percentage points, respectively, to the mean 1-hr value. Live fuel moisture values were assigned to each fuel model in the FMS file through consultation with Jena Volpe (BLM Fire Ecologist), Jon Lamb (Rogue River-Siskiyou National Forest Fire/Fuels Planner), and Steve Ziel (retired USFS, Fire Behavior Analyst).

The fire-day distribution file (FDist) required by FSim integrates weather and wildfire occurrence data to calculate the logistic regression coefficients describing the relationship between the probability of a large-fire day to ERC and the number of large fires per large-fire day. We used FireFamilyPlus software to create the FDist file for each FOA.

2 Wildfire Simulation

2.1 Model Calibration

FSim simulations were calibrated to the historical mean large-fire size, mean annual number of large fires, and mean annual area burned for each FOA. The mean large-fire size provides a useful metric for determining whether simulated wildfires need to be larger or smaller on average. The mean number of large-fires metric is used to determine whether the annual frequency of simulated fires is similar to the historical record.

Adjustments were made to two FSim input parameters, over multiple calibration runs, to align simulated results with the historical large-fire calibration targets. The AcreFract input, originally designed to account for differences between the fire modeling extent and the extent of fire occurrence data, was used to align the simulated and historical mean annual number of large fires. Mean large-fire size, a function of fire spread across varied fuels and terrain, was addressed in part during the fuel calibration workshop (Section 1.1.3) by critiquing modeled fire intensity (i.e. flame length) and rate of spread with local subject matter experts. The FSim suppression factor parameter provides an additional method for fine-tuning fire size by affecting the rate at which the flanks of a wildfire are expected to be contained under typical suppression scenarios—this also influences fire shape. Adjustments to the suppression factor were used to further align simulated and historical mean large-fire size. The final calibration run, at 270 meter spatial resolution, revealed that some burnable areas of the landscape were not burning in the 10,000 simulations—burn probability equaled zero. Further review indicated that fuel model and canopy base height values were such that the torching index (20-ft wind speed at which individual or group tree torching can occur) in these areas was for wind speed values that never, or very rarely, occurred in the historical record. This occurred primarily in existing vegetation types that were not evaluated in the fuel calibration workshop. To mitigate this issue we lowered the canopy base height value for the existing vegetation types for which this was occurring to allow for more fire spread in these areas. The historical and final calibrated simulations are summarized in Table 2.

Table 2: Comparison of historical and final, calibrated FSim results for each FOA.

	Historical			Simulated		
Fire Occurrence Area	**Mean Annual Number of Large Fires**	**Mean Large-Fire Size (Ac)**	**Mean Annual Area Burned (Ac)**	**Mean Annual Number of Large Fires**	**Mean Large-Fire Size (Ac)**	**Mean Annual Area Burned (Ac)**
Coastal	7.9	3,663	28,957	8.5	3,257	27,507
Inland	14.3	1,838	26,345	11.42	3,933	44,897

2.2 Wildfire Hazard

Each FOA was run using the calibrated model parameters and fuelscape for 10,000 simulations at 270-meter resolution[4]. Because the large-fire logistic regression coefficients and calibration targets were created at the FOA level, simulated wildfires were only allowed to start within the FOA but could spread outside its boundary. The burn probability, flame-length probabilities at each of the six flame-length classes, and fire perimeter polygons were combined into single, landscape-wide results. This was done by summing burn probability results and merging perimeter shapefiles in ArcGIS. Flame-length probabilities were weighted by their FOA burn probability and summed as follows (Thompson et al. 2013):

$$((\text{"coast\_bp"} * \text{"coast\_filX"}) + (\text{"inland\_bp"} * \text{"inland\_filX"})) / \text{"rogue\_bp"}$$

Where; “coast_bp” and “inland_bp” are the annual burn probability for the respective FOA, “rogue_bp” is the annual burn probability of each FOA summed, and “coast_filX” and “inland_filX” are the flame-length probabilities at fire intensity level X (1-6) for the respective FOA.

Burn probabilities vary widely across the wildfire simulation area (Figure 5) with a minimum of 0.0002 (1-in-5,000 chance of burning) to 0.061 (1-in-16.4 chance of burning). The mean burn probability for the simulation landscape is approximately 0.006 or a 1-in-167 chance of burning.

A total of 83,483 acres burned in the wildfire simulation area during the 2015 fire season (source: RAVG fire perimeters). An additional 33,720 acres burned in the Gap Fire in August 2016 for a total of 117,203 acres in seven wildfires at the time of this writing. Since the fuelscape data within the wildfire simulation area is updated for disturbances through 2014, we overlaid the 2015-2016 fire perimeters with the simulated burn probability data and performed a zonal statistics calculation using ArcGIS as a thumbnail validation of the burn probability results. Five of the seven wildfires burned in portions of the landscape with higher than average burn probability (Figure 5), indicating the fire modeling and LCP data appropriately captured areas on the landscape with high potential for future fires.

[4] Final simulations at a finer spatial resolution were not done due to project timeline constraints.

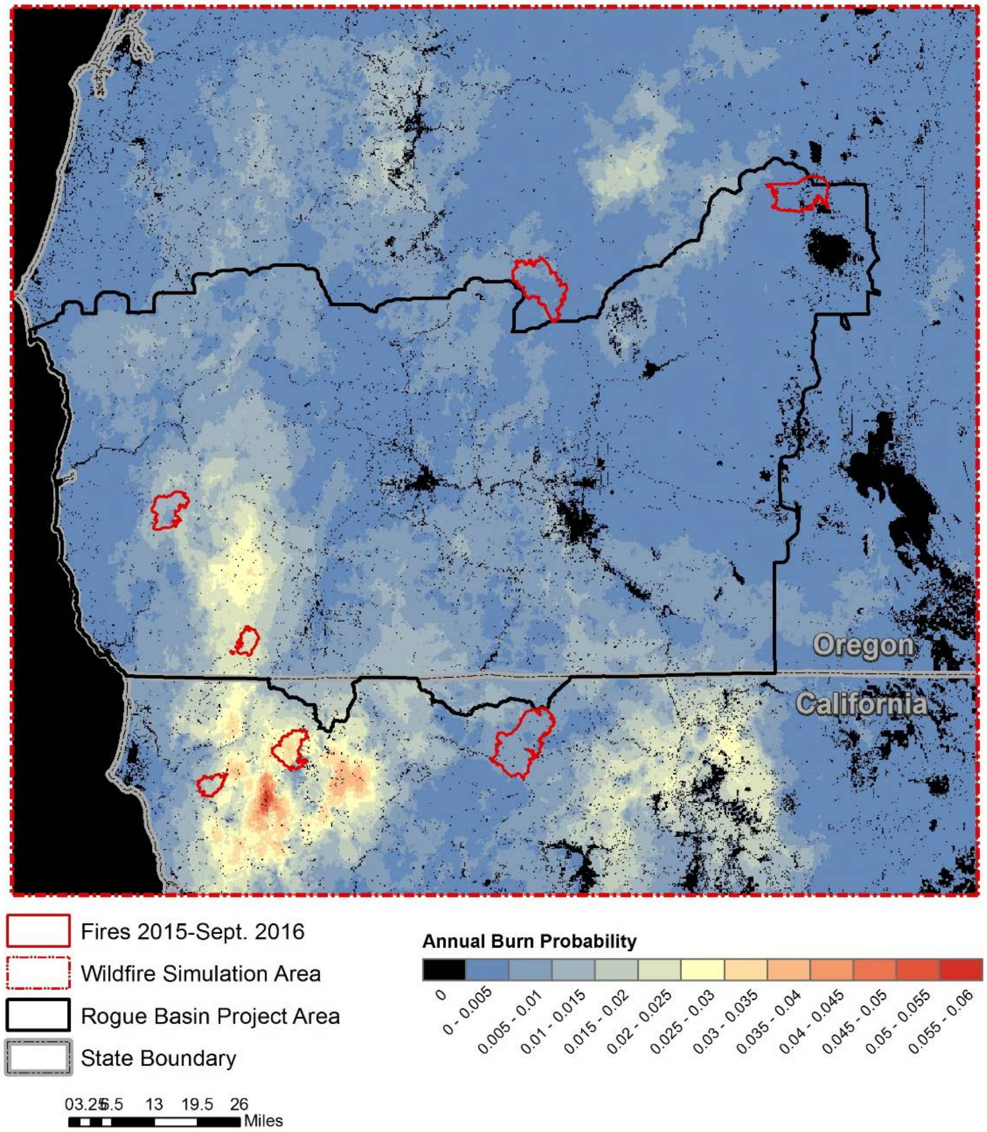

Figure 5: Simulated annual burn probability with recent wildfire perimeters overlay.

3 References

Finney, M. A.; McHugh, C. W.; Grenfell, I. C.; Riley, K. L.; Short, K. C. 2011. A simulation of probabilistic wildfire risk components for the continental United States. Stochastic Environmental Research and Risk Assessment. 25: 973-1000.

Helmbrecht, Donald J. and Kori Blankenship. 2016. Modifying LANDFIRE Geospatial Data for Local Applications. Available: http://www.conservationgateway.org/ConservationPractices/FireLandscapes/LANDFIRE/Pages/landfire.aspx.

[LFTFCT] LANDFIRE Total Fuel Change Tool (ToFu Δ) for ArcGIS 10 (v. 0.12). 2011. National Interagency Fuels Technology Transfer; U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station; LANDFIRE Fuels Development Team, SGT, Inc.; and U.S. Geological Survey. Available: http://www.landfire.gov/download_lfdat.php

Miller, J. D. & Thode, A. E. 2007. Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). Remote Sensing of Environment, 109, 66–80.

Miller, J. D.; Knapp, E. E.; Key, C. H.; Skinner, C. N.; Isbell, C. J.; Creasy, M. R.; Sherlock, J. W. 2009. Calibration and validation of the relative differenced Normalized Burn Ratio (RdNBR) to three measures of fire severity in the Sierra Nevada and Klamath Mountains, California, USA. Remote Sensing of Environment, 113, 645–656.

Rollins, M. G. 2009. LANDFIRE: a nationally consistent vegetation, wildland fire, and fuel assessment. International Journal of Wildland Fire, 18(3), 235-249.

Ryan, K. C., & T. S. Opperman 2013. LANDFIRE- A national vegetation/fuels data base for use in fuels treatment, restoration, and suppression planning, Forest Ecology and Management, 294, 208-216.

Scott, Joe H. 2014. Summarizing contemporary large-fire occurrence for land and resource management planning. Draft Report for Elizabeth Reinhardt, Assistant Director, Fuel and Fire Ecology, USDA Forest Service, Washington Office. 21 p.

Scott, J. H., & Burgan, R. E. 2005. Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

Short, Karen C. 2014. Spatial wildfire occurrence data for the United States, 1992-2012 [FPA_FOD_20140428]. 2nd Edition. Fort Collins, CO: Forest Service Research Data Archive. http://dx.doi.org/10.2737/RDS-2013-0009.2

Thompson, M. P., Scott, J., Langowski, P. G., Gilbertson-Day, J. W., Haas, J. R., & Bowne, E. M. 2013. Assessing watershed-wildfire risks on national forest system lands in the rocky mountain region of the United States. Water, 5(3), 945-971.