Appendix D – Modeling Large Stochastic Wildfires and Fire Severity within the Range of the Northern Spotted Owl

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Introduction
Wildfire is a natural process within the identified range for the northern spotted owl (*Strix occidentalis caurina*), especially in the southern and eastern portions of the range. While the bird has adapted to wildfire and its effects in an intact landscape, human development and land use have reduced and fragmented habitat and populations in large portions of the region (Davis and Lint 2005, Davis *et al*. 2011). One result has been an increase in the potential for adverse effects of large, high severity wildfires on remnant northern spotted owl habitats and populations. Over the past two decades, large wildfires have accounted for the majority of northern spotted owl nesting and roosting habitat losses on federally managed forests (Davis *et al*. 2011). In addition, fire suppression, inadequate levels of natural or prescribed fire, and climate change are believed to have created conditions considered more favorable for frequent, higher severity, and larger wildfires (Westerling *et al*. 2006, Littell *et al*. 2009, Dillon *et al*. 2011a, Miller *et al*. 2012).

In 2008, the Bureau of Land Management (BLM) attempted to revise six resource management plans in western Oregon, but subsequently withdrew the decisions. A scientific review of that effort noted that one significant weakness was the failure to account for the potential effects of high severity wildfire on habitat for the northern spotted owl, a threatened species under the Endangered Species Act. Specifically, the review stated that the models overestimated amounts of owl habitat and did not assume that any would be lost to high severity wildfire during the projected modeling timeline (Drake *et al*. 2008). To address that weakness under the current planning effort, BLM assembled a team of northern spotted owl experts, fire ecologists, silviculturists, and modelers to develop an approach to model and analyze the potential effects on northern spotted owl habitat and populations from large wildfires.29 For this analysis, the BLM predicted future wildfire effects based upon historic fire frequency, size, and severity.

This effort also supports a U.S. Fish and Wildlife Service request for the BLM to evaluate whether the resulting plan would provide sufficient habitat to assure persistence of the northern spotted owl for the next 50 years. This estimation of the quantity of habitat affected by fire over the next five decades better informs the development of land management strategies for the BLM-administered lands in western Oregon. This report describes the methods used to determine potential burned area and fire severity, and the results of that analysis. Subsequent modeling will evaluate the potential results on habitat availability.

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for the northern spotted owl. Since the BLM conducted this analysis in direct support of the analysis of environmental effects in conjunction with an environmental impact statement, model parameters are constrained by the ‘reasonably foreseeable’ criteria in BLM’s planning regulations.

**Analysis Area**

The range of the northern spotted owl used in this analysis extends from the Canadian border through northern California and from the west coast to the eastern foothills of the Cascade and Klamath Mountain ranges. The BLM used the entire range of the northern spotted owl for the analysis area to maintain consistency with the previous fire analyses conducted within the range of the northern spotted owl. The BLM planning area for western Oregon comprises 19,647,000 acres, or approximately 34 percent, of the lands within this range and is located within the core of that range, divided among six Districts (Salem, Eugene, Roseburg, Coos Bay, Medford, and Lakeview) (Figure D-1). The majority of BLM-administered lands consist of a so-called ‘checkerboard’ pattern (alternating square mile sections), largely intermingled with privately owned industrial and non-industrial forests, along with state-owned lands, and a limited amount of U.S. Forest Service National Forest System lands and Tribal lands. Large contiguous blocks of BLM-administered lands are rare within the range of the northern spotted owl. The largest concentration of BLM-administered lands in western Oregon occurs on the Medford and Roseburg Districts in southwestern Oregon.
Forest types within the analysis area range from dry mixed evergreen forests in California and southwestern Oregon to temperate rainforests along the coast and in much of western Washington. The climate ranges from maritime in western Washington, northwestern Oregon, and the coast; to Mediterranean in southwestern Oregon and northern California. Soils are highly variable in texture, depth, and other characteristics, and derive primarily from volcanic parent materials with ultramafic soils common in southwestern Oregon.

**Methods**

The BLM used the entire range of the northern spotted owl as the analytical framework to provide sufficient data to capture the potential range of annual area burned and fire severity proportions. This more accurately reflects impacts to northern spotted owl habitat, unaffected by arbitrary divisions along biologically irrelevant lines such as state, ownership, and administrative boundaries. The modeling regions used in this analysis were similar to those used by the U.S. Fish and Wildlife Service for the revised Northern Spotted Owl Recovery Plan and designation of critical habitat (USDI FWS 2011 and 2012).
The median northern spotted owl territory size ranges from 1,300 to 11,800 acres, depending on geographic location (Appendix B in Davis et al. 2011), thus it takes a rather large wildfire to have a substantial effect on one owl territory (Davis and Lint 2005). As such, this analysis evaluates larger wildfires in identifying effects to northern spotted owls using the large wildfire suitability model (LWSM). Developed as part of the 15-year monitoring report for the Northwest Forest Plan (Chapter 4, in Davis et al. 2011), the LWSM model is based on large wildfires (≥ 1,000 acres) from 1970 through 2002, and validated against large wildfires that occurred from 2003 through 2009. The LWSM represents a relative probability surface for large wildfire occurrence within the range of the northern spotted owl that has continued to predict the locations of nearly all large wildfires that have occurred since 2009.

Using the regional wildfire history from 1970 through 2013 (4.4 decades), the BLM modeled large wildfires five decades into the future using a three-step process to determine wildfire: 1) number and location, 2) size distribution, and 3) severity.

**Step 1 - Estimating Number and Location of Future Large Wildfires**

Records for large wildfire occurrence from 1970 through 2013 show a marked increase in the occurrence of large wildfires in the last decade of this timeframe (Figure D-2). While the decadal totals suggest the number of large wildfires is increasing, the short period of record and the influence of the phase and annual sign of the Pacific Decadal Oscillation are confounding factors in identifying a definite trend. As such, this analysis used the decadal average of 100 large wildfires to generate 500 potential large wildfires over the next 5 decades. To do this, the BLM used the ‘Generate Random Points’ tool in Geospatial Modeling Environment (GME version 0.7.2.1) software (Beyer 2012) to produce five sets of randomly placed points (n=100) for each decade, using the LWSM as a relative probability surface for point placement. Points could occur anywhere, but were more likely to occur where the probability of a large wildfire (i.e., wildfire suitability) was higher (Figure D-3).
Figure D-2. Annual and decadal numbers of large wildfires (≥ 1,000 acres) in the analysis area (1970–2013)
Figure D-3. Comparison of three decades of observed large wildfire history from Monitoring Trends in Burn Severity fire occurrence data (left) with the first three decades of randomly generated fire locations (right)
Reburning has been observed within the analysis area on several occasions. For example, the Biscuit Fire in 2002 reburned nearly all of the 1987 Silver Fire, and a portion of this area burned again in 2013. Portions of the 1933 Tillamook Fire area reburned as many as five times before 1960. To account for reburns, the BLM calibrated the model by comparing the area burned by projected large wildfires to the actual area burned by past large wildfires. Initially, the model projected much more reburning than has been observed. To correct for this over-prediction, the BLM added a decadal constraint parameter on reburning by preventing the placement of random points within 5 km of fire ‘perimeter’ locations from the prior decade. In subsequent decades, and consistent with historical observations, random points could occur within or adjacent to previous modeled fire perimeters. Subsequent model runs produced similar levels of acres burned, and proportion of area reburned, as the observed record.

**Step 2 - Estimating Size of Future Large Wildfires**

The LWSM generates an estimate of the number and location of future large wildfires, but does not generate sizes of these future wildfires. To determine acres of future large wildfires, the BLM applied the historical trends in fire size to predict future large wildfire sizes (1970–2013). In the analysis area, the majority (85 percent) of large wildfires burned less than 15,000 acres, and only 1 percent of them exceeded 100,000 acres in size (Figure D-4). Using this information, the BLM created eight large wildfire size class bins to represent the occurrence of future large wildfires (Figure D-4).

![Figure D-4](image)

**Figure D-4.** Historical (1970–2013) wildfire distribution by fire size within the range of the northern spotted owl

Because this analysis was more concerned with the overall potential loss of habitat than with accurately representing fire shapes, modeling simply represented wildfires as circles associated with the median sizes. The BLM used the median fire size for each size-class bin to determine the appropriate radius for creating a circular fire perimeter for modeling (Table D-1).
Table D-1. Parameters used to assign random points a wildfire size by buffering the point location

<table>
<thead>
<tr>
<th>Simulated Wildfire Size (Acres)</th>
<th>Fire Perimeter Radius (Miles)</th>
<th>Simulated Decadal Number of Future Large Wildfires (Random Points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,250</td>
<td>0.79</td>
<td>41</td>
</tr>
<tr>
<td>3,750</td>
<td>1.37</td>
<td>20</td>
</tr>
<tr>
<td>7,500</td>
<td>1.93</td>
<td>15</td>
</tr>
<tr>
<td>12,500</td>
<td>2.55</td>
<td>9</td>
</tr>
<tr>
<td>20,000</td>
<td>3.15</td>
<td>7</td>
</tr>
<tr>
<td>37,500</td>
<td>4.32</td>
<td>5</td>
</tr>
<tr>
<td>75,000</td>
<td>6.11</td>
<td>2</td>
</tr>
<tr>
<td>100,000</td>
<td>7.05</td>
<td>1</td>
</tr>
</tbody>
</table>

The BLM then used the underlying LWSM probability layer to apply a fire size to the random points generated by the GME software. The higher the underlying LWSM probability value, the more likely a random point would ‘burn’ more acres, although smaller fires could also occur in the higher probability areas. Beginning with random points having the lowest wildfire suitability value, the BLM assigned the smallest radius to each point; ending with assignment of the largest radius to the last random point of the highest wildfire suitability score (Table D-1). To establish the hypothetical fire perimeters, the BLM buffered each random point by the assigned radii. The resulting individual and overlapping circles represented that decade’s ‘footprint’ of large wildfires. The BLM repeated this process for each decade.

**Step 3 - Estimating Fire Severity of Future Large Wildfires**

After determining potential future wildfire locations and sizes, the BLM estimated fire severities within their perimeters. Analysis relied on data from the Severe Fire Potential Map (Dillon et al. 2011a and 2011b, Dillon et al. 2012) portion of the Fire Severity Mapping Tools (FIRESEV) project (Keane et al. 2013) to assign fire severities within each decadal wildfire footprint. The FIRESEV data reflect spatial predictions of the conditional likelihood of high severity fire. The FIRESEV project based these projections on statistical models relating topographic, vegetation, and fire weather variables to empirical satellite-derived wildfire severity from 1984 to 2007 as mapped by the Monitoring Trends in Burn Severity (MTBS) program (Eidenshink et al. 2007). The FIRESEV model’s spatial predictions use 90th percentile fuel moisture conditions for dryness, although actual fuel moistures often varied over the spatial and temporal extent of any given large fire (Dillon et al. 2011a and 2011b, Miller et al. 2012).

Since the FIRESEV only estimated the probability for high severity fire, the BLM classified this probability into three quantile classes. The BLM assumed that lower severity fires would occur in areas modeled as having a lower probability for high severity fire and that high severity fires would most likely occur in areas modeled as high probability. These three quantile classes served as our low, moderate, and high severity map classification for assignment of fire severity to the fire footprints created in Step 2. To test this assumption, the BLM compared relative proportions of observed wildfire severity (based on MTBS severity mapping from 1986–2011) to the classified FIRESEV model from the five decadal maps. Comparisons found similar proportions between observed and modeled wildfire severities indicating that the assumption was a valid one and would produce proportions of area burned by low to high severity that were similar to the observed record (Figure D-5).
Finally, the BLM also examined the MTBS data for any obvious temporal trends in wildfire severity, but did not detect a strong signal (Figure D-6). Over the course of 25 years, there appears to be a slight increase in the percentage of area burned by low and moderate severity wildfire, and a slight decrease in the percent of area burned in high severity wildfire, although these trends are not statistically significant. Analysis also noted that the variability for area burned in the different severity classes has declined since about 2002, but it is not certain why this apparent smoothing has occurred. Given the non-significance of the observed trends and the uncertainty over whether these slight trends will continue into the future, the BLM did not attempt to model any fire severity trends in our framework.

Figure D-5. Comparison of annual proportion of area burned by mapped fire severity from MTBS data from 1986 to 2011 with modeled severity based on a three quantile classification of the FIRESEV map for the five decadal models. Note: Labels show modeled estimates of proportion of area burned by severity class.
Figure D-6. Trends in area burned by fire severity class
Results

The analysis resulted in five decadal maps of potential large wildfire ‘footprints’, including potential wildfire severities, over the entire range of the northern spotted owl. Given an average of 100 large wildfires per decade, the model estimated that approximately 4.4 million acres would burn within the range of the northern spotted owl over the next 50 years, with 10 percent of the area burning twice and 0.2 percent burning three times. On BLM-administered lands only, the model estimated that approximately 192,000 acres would burn, with 10 percent burning twice and no areas burning three times. In comparison, approximately 4.4 million acres have burned within the range of the northern spotted owl over the past 44 years (1970–2013), with 16 percent of the area burning twice and 1.6 percent burning three times. In that same time span, approximately 153,500 acres burned on BLM-administered lands, with 16 percent burning twice. Both spatially (Figure D-7) and from the burned area comparisons above, the model produced a plausible scenario based on recent observed wildfire history for potential future large wildfires both rangewide and on BLM-administered lands in western Oregon over the next five decades.

Figure D-7. Comparison of actual area burned (black shading) by large wildfires from 1970 to 2013 (left) with modeled large wildfires over 5 decades (right)
Discussion
For the given analysis period (5 decades), the model projected relatively minor changes in potential
burned area within the range of the northern spotted owl generally and on Oregon BLM-administered
lands within that range. While the observed decadal trends suggest an increasing trend in the number
of large fires over time (Figure D-2), it is not clear that this increasing trend will continue. The observed
large wildfire history records contain a small number of anomalous years that may distort the data.
Particular stand-out years are 1987, 2002, and 2008. The 1987 fire season was particularly severe in
southwest Oregon and northwest California, while 2002 was particularly severe in southwest Oregon, and
2008 particularly severe in northwest California. An unusually high number of wildfire starts
characterized all three years, and an unusually high number of acres burned. Miller et al. (2012) did find
an trend of increasing numbers of large fires in the Klamath Mountains of northwestern California, but
this same trend is not apparent in the analysis area as a whole (Littell et al. 2009, supplemental
information). The BLM notes that the current decade (2010–2020) is not quite half over, yet 67 large
wildfires have burned as of 2013. It is possible that future decades might incur more than the 100 large
wildfires per decade used in this analysis; however, selection of a higher number would be speculative
and the BLM instead based the analysis on observations from recent decades.

While several studies have indicated that high severity fires are increasing across the western United
States (e.g., Westerling et al. 2006, Dillon et al. 2011a, Miller et al. 2012), no such trends were apparent
in the observed record within the range of the northern spotted owl (Figure D-6). The observed trends in
increasing fire severity in various studies appear to be scale-dependent in that these trends were typically
for the western United States as a whole. Much of the observed change is either occurring in areas not
encompassed by the range of the northern spotted owl or becomes apparent only when analyzing a larger
area that provides a much larger sample size. In such cases, many small changes that are difficult to detect
at finer scales can add up to larger, detectable changes for the aggregate area, reflective of how the
aggregate number of small emissions of greenhouse gases cumulatively are affecting global climate. In
part, trends for area burned as high severity is a function of total area burned – the more area burned, the
greater the amount of high severity fire (Dillon et al. 2011a, Miller et al. 2012). In the absence of any
clear trends, The 50-year projection, presented here, falls within a range of reasonably expected
outcomes.

Given the uncertainty surrounding trends in frequency, size, and severity, model results may prove, with
time, to either underestimate or overestimate potential fire sizes and severity because of several
confounding factors not included in the model, such as extreme weather events and interactions with
insect outbreaks, management affects to vegetation composition and structure, and climate change. Forest
management in particular has potential to alter the outcomes of wildfires (Pollet and Omi 2002, Prichard
it is less clear if forest management can effectively alter the size distribution of large fires (Cochrane et al.
2012). Historically, extremely large wildfires have occurred outside of the areas modeled as highly
suitable for large wildfires, consistently associated with either extreme weather events, such as the severe
drought and east wind event that preceded the initial Tillamook Burn in 1933, or with heavy, continuous,
dry fuels, such as following an insect outbreak (McClure 2005, Morris 1935). The large wildfires that do
occur in areas of low suitability west of the Cascade crest tend to be infrequent, but extremely large and
severe and typically associated severe drought and high winds (Agee 1993, Littell et al. 2009, Davis et al.
2011). The above management affects to vegetation, stochastic disturbance other than wildfire, extreme
environmental variables, and fire occurrence datasets reflective of long fire return interval timelines were
not included in this modeling effort.

It was far less clear how to incorporate projected climate changes into the model. The BLM can estimate
how the large wildfire suitability area may change as climate changes (Figure D-8), based on ensemble
climate model results, since LWSMs include climate parameters. However, to what extent these changes may influence the frequency of large wildfires is uncertain. Additionally, large wildfires, particularly in moist forests, in the Pacific Northwest, are at least modestly associated with the phase of the Pacific Decadal Oscillation (PDO) and not associated with the phase of El Niño-Southern Oscillation (ENSO) (Hessl et al. 2004, Gedalof et al. 2005). Interannual variability within a given PDO phase appears to have a stronger influence than the interdecadal variability, as well (Gedalof et al. 2005). Hessl et al. (2004) also found about a 5-year lag between PDO and regional fire years in eastern Washington. The period of record used for this large wildfire analysis includes the latter stages of a cool phase PDO that ended in about 1977 and a warm phase that began in 1977 and appears to have ended around 2005 with considerable interannual variability between circa 1998 and 2005 (Gedalof et al. 2005, http://www.jisao.washington.edu/pdo/). Given that PDO has apparently entered a cool phase, the number of fires and acres burned should be lower for one or two decades unless the current climate forcing from greenhouse gas emissions ‘over-rides’ the PDO signal. The apparent increase in number of fires and acres burned may be more a reflection of the combined influences of increasing fuel loadings due to land use changes, the PDO phase, and the sign of PDO in a given year than of a trend useful for predicting future losses of northern spotted owl habitat from wildfire.

Figure D-8. Comparison of a large wildfire suitability model based on the current climate normal (left) with same model based on projected climate normal changes in temperature and precipitation by 2060 (right) (from Yang et al. in prep.)
Most climate change projections that discuss wildfire indicate that fires are expected to get larger and more severe. Several studies have found that as the climate warms in forested ecosystems, burned area increases (Westerling et al. 2006, Halofsky et al. 2011, Loudermilk et al. 2013) with large increases projected by mid-century within the range of the northern spotted owl (McKenzie et al. 2004, Spracklen et al. 2009, Littell et al. 2009 and 2010, Rogers et al. 2011). Many of these same studies indicate an increase in overall fire severity as well. However, projections in burned area do not inform how to adjust the potential number of fires, the relative distribution of the size classes, or the proportion burned in the different severity classes over time. If these projections are accurate, model results could underestimate the potential of adversely affected northern spotted owl habitat, particularly towards the end of the analysis period.

Lastly, climate change is not linear. Natural variability in the climate system is still an important factor. Thus, overall changes in burned area until mid-century would also not be linear. Experts expect to continue to experience considerable variability in fire season severity (number of fires, acres burned, and extent of high severity fire). Despite the inability to include these confounding factors, the model successfully predicted the locations of many of the large wildfires that occurred in 2013, which were included in the final analysis.

**Conclusions**

Over the next 50 years, large wildfires will continue to affect suitable northern spotted owl nesting/roosting habitat on BLM-administered lands. However, wildfires do not always remove nesting/roosting habitat; often low to moderate severity wildfire alters habitat such that it may still be suitable for nesting and roosting. Some spotted owl studies show that low to moderate severity wildfire may actually benefit the owl, perhaps due to changes in prey species habitat (Bond et al. 2002, Ganey et al. 2014). However, extensive high severity wildfire usually removes nesting/roosting habitats, decreasing survival and occupancy rates related to loss and fragmentation of suitable nesting and roosting habitat (Clark et al. 2011 and 2013, Tempel et al. 2014).

Although the relationship between large wildfire frequency and severity on owl demography is not fully understood, habitat loss was the primary reason for the bird’s decline and subsequent listing as threatened under the Endangered Species Act (USDI FWS 1990). The BLM used the underlying data for the maps produced from this modeling effort as input into the vegetation modeling process (Appendix C) to inform the effects of disturbance on habitat loss and recruitment over the next 5 decades. The BLM used the results of the vegetation modeling efforts in the northern spotted owl population analysis for these RMP revisions, which will inform management decisions on lands administered by the BLM in western Oregon.
References


